2.1 Refuse Combustion

Refuse combustion involves the burning of garbage and other nonhazardous solids, commonly called municipal solid waste (MSW). Types of combustion devices used to burn refuse include single chamber units, multiple chamber units, and trench incinerators.

2.1.1 General[1-3]

As of January 1992, there were over 160 municipal waste combustor (MWC) plants operating in the United States with capacities greater than 36 megagrams per day (Mg/day) (40 tons per day [tpd]), with a total capacity of approximately 100,000 Mg/day (110,000 tpd of MSW).[1] It is projected that by 1997, the total MWC capacity will approach 150,000 Mg/day (165,000 tpd), which represents approximately 28 percent of the estimated total amount of MSW generated in the United States by the year 2000.

Federal regulations for MWCs are currently under 3 subparts of 40 CFR Part 60. Subpart E covers MWC units that began construction after 1971 and have capacities to combust over 45 Mg/day (50 tpd) of MSW. Subpart Ea establishes new source performance standards (NSPS) for MWC units which began construction or modification after December 20, 1989 and have capacities over 225 Mg/day (250 tpd). An emission guideline (EG) was established under Subpart Ca covering MWC units which began construction or modification prior to December 20, 1989 and have capacities of greater than 225 Mg/day (250 tpd). The Subpart Ea and Ca regulations were promulgated on February 11, 1991.

Subpart E includes a standard for particulate matter (PM). Subparts Ca and Ea currently establish standards for PM, tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans (CDD/CDF), hydrogen chloride (HCl), sulfur dioxide (SO_2), nitrogen oxides (NO_x) (Subpart Ea only), and carbon monoxide (CO). Additionally, standards for mercury (Hg), lead (Pb), cadmium (Cd), and NO_x (for Subpart Ca) are currently being considered for new and existing facilities, as required by Section 129 of the Clean Air Act Amendments (CAAA) of 1990.

In addition to requiring revisions of the Subpart Ca and Ea regulations to include these additional pollutants, Section 129 also requires the EPA to review the standards and guidelines for the pollutants currently covered under these subparts. It is likely that the revised regulations will be more stringent. The regulations are also being expanded to cover new and existing MWC facilities with capacities of 225 Mg/day (250 tpd) or less. The revised regulations will likely cover facilities with capacities as low as 18 to 45 Mg/day (20 to 50 tpd). These facilities are currently subject only to State regulations.

2.1.1.1 Combustor Technology -

There are 3 main classes of technologies used to combust MSW: mass burn, refuse-derived fuel (RDF), and modular combustors. This section provides a general description of these 3 classes of combustors. Section 2.1.2 provides more details regarding design and operation of each combustor class.

With mass burn units, the MSW is combusted without any preprocessing other than removal of items too large to go through the feed system. In a typical mass burn combustor, refuse is placed on a grate that moves through the combustor. Combustion air in excess of stoichiometric amounts is supplied both below (underfire air) and above (overfire air) the grate. Mass burn combustors are usually erected at the site (as opposed to being prefabricated at another location), and range in size from 46 to 900 Mg/day (50 to 1,000 tpd) of MSW throughput per unit. The mass burn combustor category can be divided into mass burn waterwall (MB/WW), mass burn rotary waterwall combustor (MB/RC), and mass burn refractory wall (MB/REF) designs. Mass burn waterwall designs have water-filled tubes in the furnace walls that are used to recover heat for production of steam and/or electricity. Mass burn rotary waterwall combustors use a rotary combustion chamber constructed of water-filled tubes followed by a waterwall furnace. Mass burn refractory designs are older and typically do not include any heat recovery. Process diagrams for a typical MB/WW combustor, a MB/RC combustor, and one type of MB/REF combustor are presented in Figure 2.1-1, Figure 2.1-2, and Figure 2.1-3, respectively.

Refuse-derived fuel combustors burn processed waste that varies from shredded waste to finely divided fuel suitable for co-firing with pulverized coal. Combustor sizes range from 290 to 1,300 Mg/day (320 to 1,400 tpd). A process diagram for a typical RDF combustor is shown in Figure 2.1-4. Waste processing usually consists of removing noncombustibles and shredding, which generally raises the heating value and provides a more uniform fuel. The type of RDF used depends on the boiler design. Most boilers designed to burn RDF use spreader stokers and fire fluff RDF in a semi-suspension mode. A subset of the RDF technology is fluidized bed combustors (FBC).

Modular combustors are similar to mass burn combustors in that they burn waste that has not been pre-processed, but they are typically shop fabricated and generally range in size from 4 to 130 Mg/day (5 to 140 tpd) of MSW throughput. One of the most common types of modular combustors is the starved air or controlled air type, which incorporates two combustion chambers. A process diagram of a typical modular starved-air (MOD/SA) combustor is presented in Figure 2.1-5. Air is supplied to the primary chamber at sub-stoichiometric levels. The incomplete combustion products (CO and organic compounds) pass into the secondary combustion chamber where additional air is added and combustion is completed. Another type of modular combustor design is the modular excess air (MOD/EA) combustor which consists of 2 chambers as with MOD/SA units, but is functionally similar to mass burn units in that it uses excess air in the primary chamber.

2.1.2 Process Description[4]

Types of combustors described in this section include:

- Mass burn waterwall,
- Mass burn rotary waterwall,
- Mass burn refractory wall,
- Refuse-derived fuel-fired,
- Fluidized bed,
- Modular starved air, and
- Modular excess air.

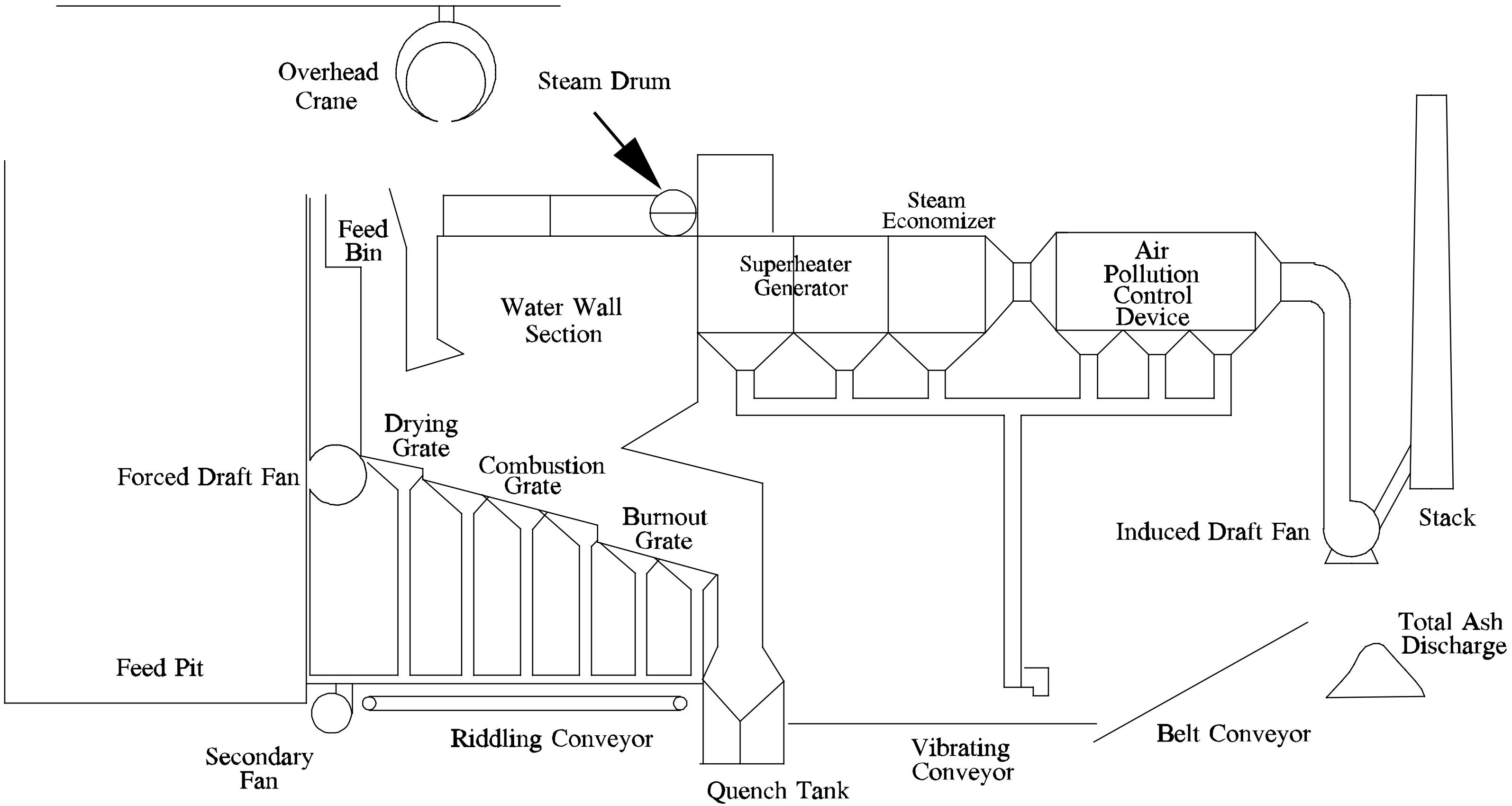

Figure 2.1-1. Typical mass burn waterfall combustor.

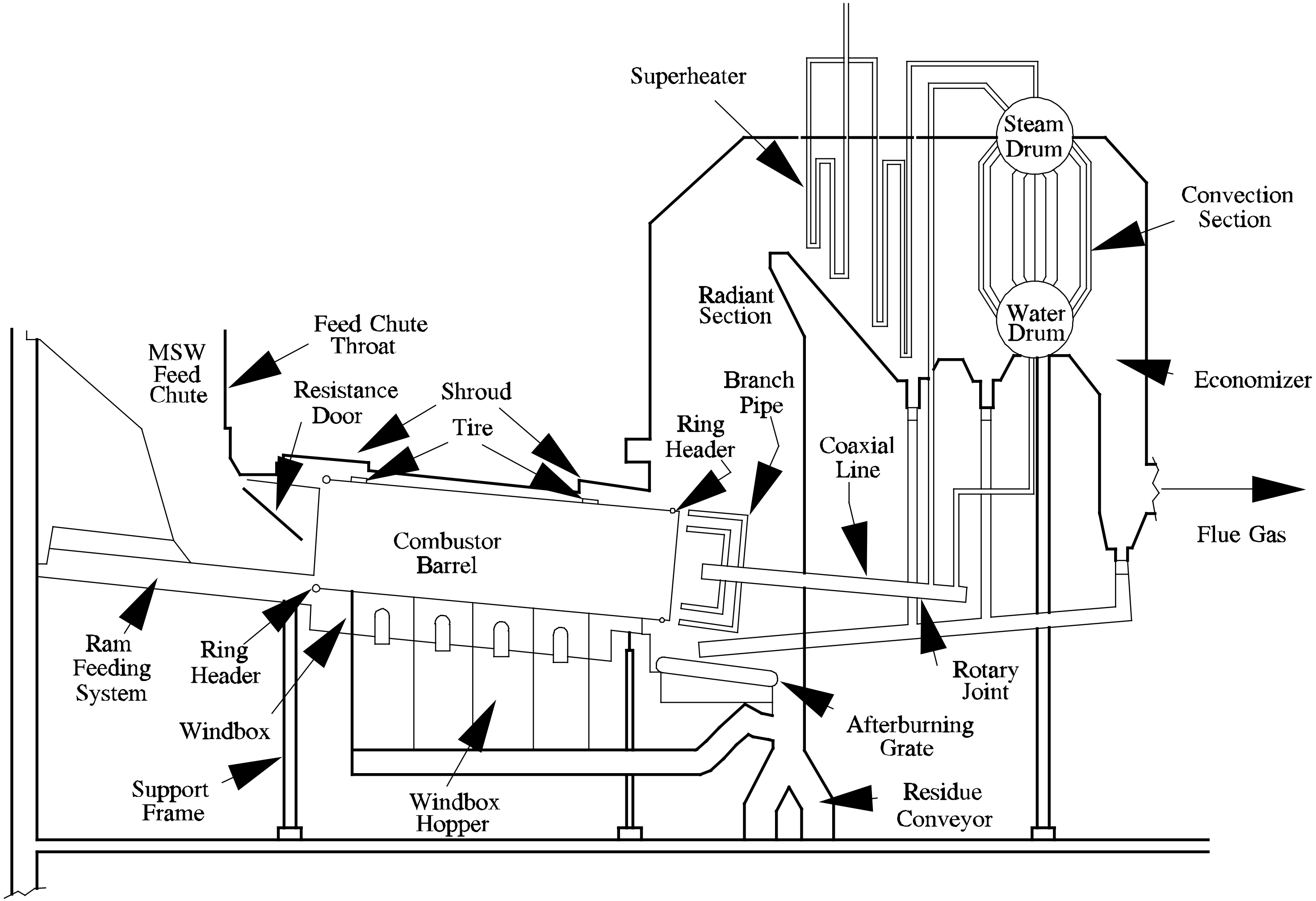

Figure 2.1-2. Simplified process flow diagram for a rotary waterwall combustor.

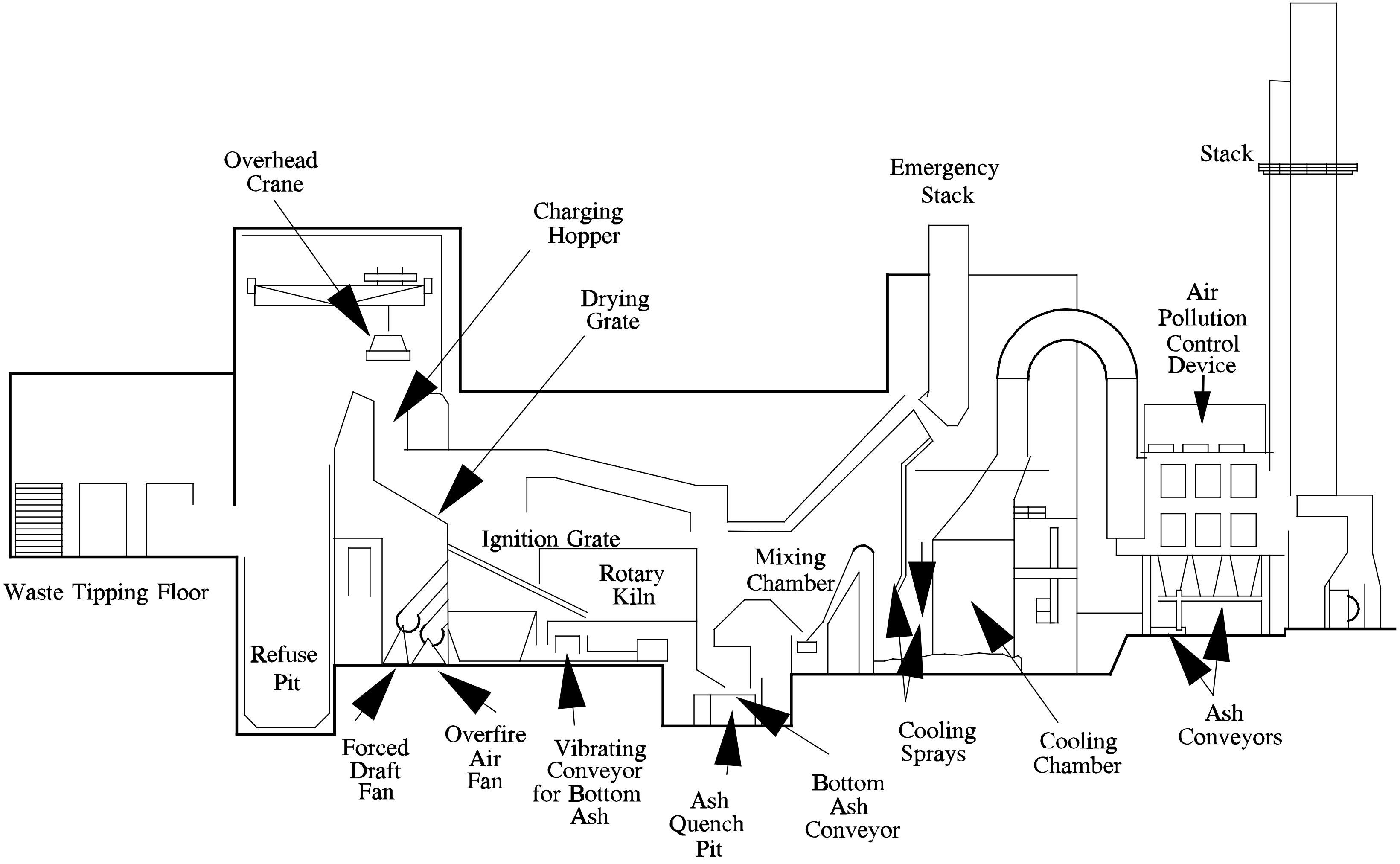

Figure 2.1-3. Mass burn refractory wall combustor with grate/rotary kiln.

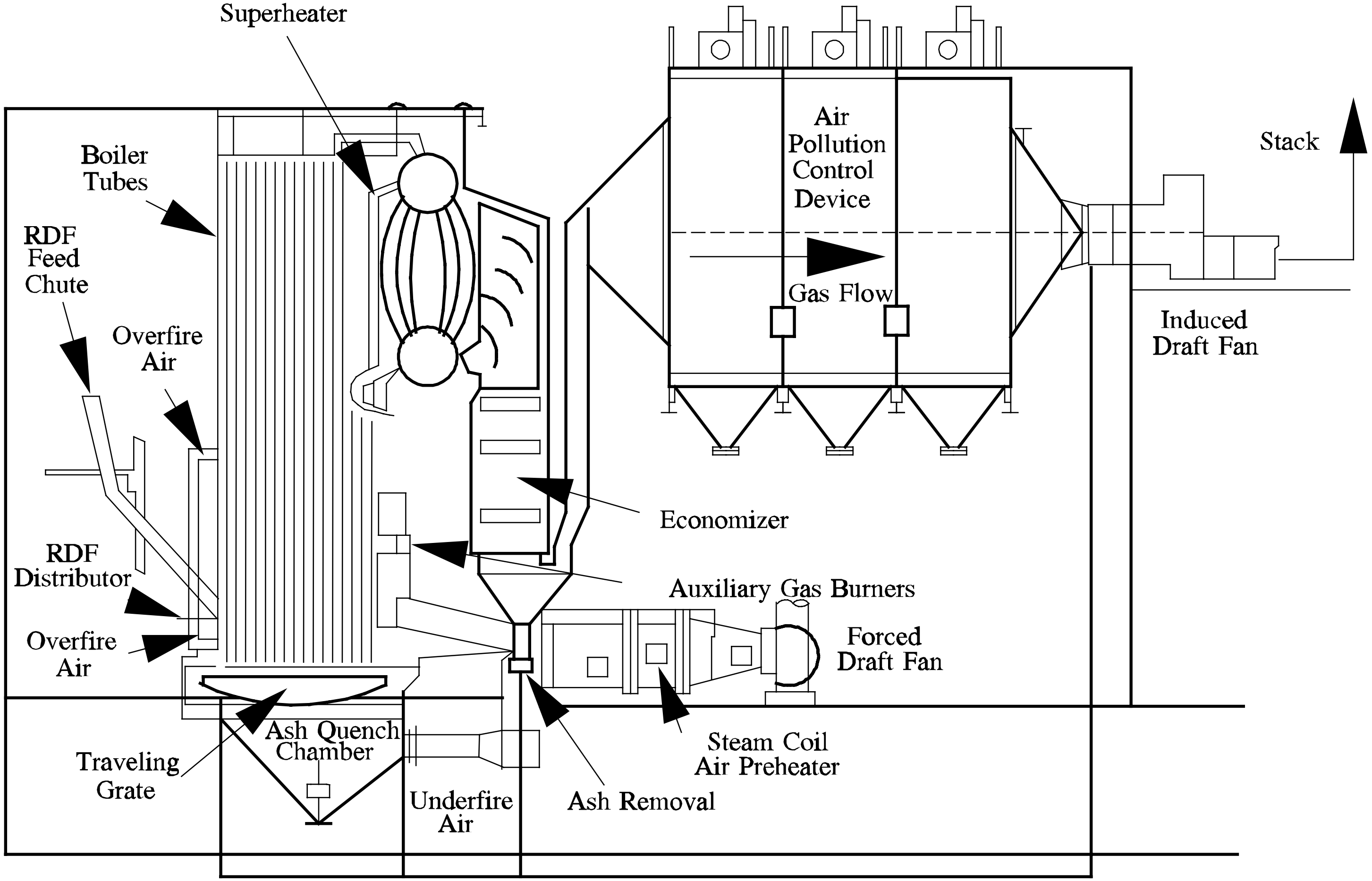

Figure 2.1-4. Typical RDF-fired spreader stoker boiler.

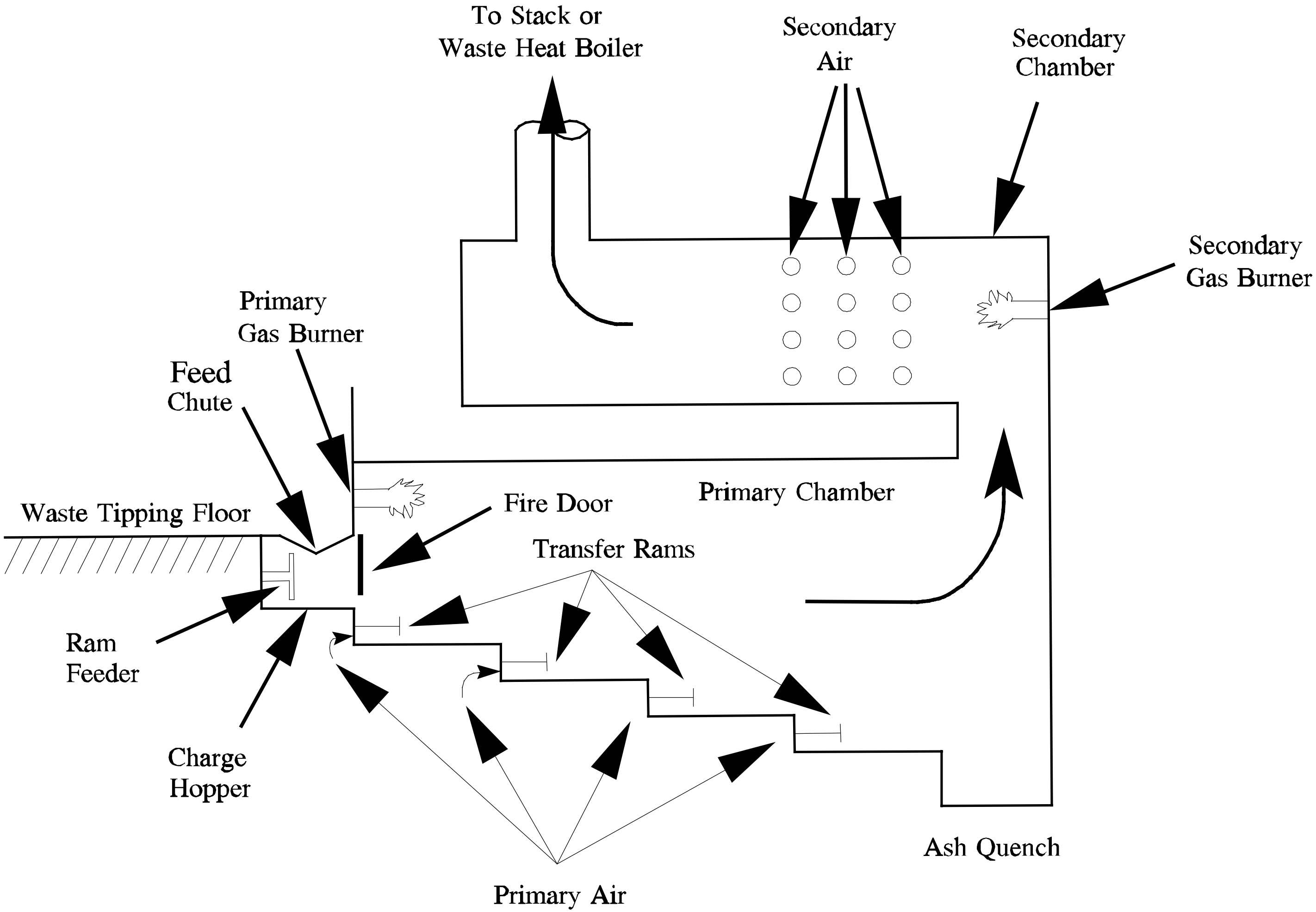

Figure 2.1-5. Typical modular starved-air combustor with transfer rams.

2.1.2.1 Mass Burn Waterwall Combustors -

The MB/WW design represents the predominant technology in the existing population of large MWCs, and it is expected that over 50 percent of new units will be MB/WW designs. In MB/WW units, the combustor walls are constructed of metal tubes that contain circulating pressurized water used to recover heat from the combustion chamber. In the lower actively burning region of the chamber where corrosive conditions may exist, the walls are generally lined with castable refractory. Heat is also recovered in the convective sections (i. e., superheater, economizer) of the combustor.

With this type of system, unprocessed waste (after removal of large, bulky items) is delivered by an overhead crane to a feed hopper, which conveys the waste into the combustion chamber. Earlier MB/WW designs utilized gravity feeders, but it is now more typical to feed by means of single or dual hydraulic rams.

Nearly all modern MB/WW facilities utilize reciprocating grates or roller grates to move the waste through the combustion chamber. The grates typically include 3 sections. On the initial grate section, referred to as the drying grate, the moisture content of the waste is reduced prior to ignition. The second grate section, referred to as the burning grate, is where the majority of active burning takes place. The third grate section, referred to as the burnout or finishing grate, is where remaining combustibles in the waste are burned. Smaller units may have only 2 individual grate sections. Bottom ash is discharged from the finishing grate into a water-filled ash quench pit or ram discharger. From there, the moist ash is discharged to a conveyor system and transported to an ash load-out or storage area prior to disposal. Dry ash systems have been used in some designs, but their use is not widespread.

Combustion air is added from beneath the grate by way of underfire air plenums. The majority of MB/WW systems supply underfire air to the individual grate sections through multiple plenums, which enhance the ability to control burning and heat release from the waste bed. Overfire air is injected through rows of high-pressure nozzles located in the side walls of the combustor to oxidize fuel-rich gases evolved from the bed and complete the combustion process. Properly designed and operated overfire air systems are essential for good mixing and burnout of organics in the flue gas. Typically, MB/WW MWCs are operated with 80 to 100 percent excess air.

The flue gas exits the combustor and passes through additional heat recovery sections to one or more air pollution control devices (APCD). The types of APCDs that may be used are discussed in Section 2.1.4.

2.1.2.2 Mass Burn Rotary Waterwall Combustors -

A more unique mass burn design is the MB/RC. Plants of this design range in size from 180 to 2,400 Mg/day (200 to 2,700 tpd), with typically 2 or 3 units per plant. This type of system uses a rotary combustion chamber. Following pre-sorting of objects too large to fit in the combustor, the waste is ram fed to the inclined rotary combustion chamber, which rotates slowly, causing the waste to advance and tumble as it burns. Underfire air is injected through the waste bed, and overfire air is provided above the waste bed. Bottom ash is discharged from the rotary combustor to an afterburner grate and then into a wet quench pit. From there, the moist ash is conveyed to an ash load-out or storage area prior to disposal.

Approximately 80 percent of the combustion air is provided along the rotary combustion chamber length, with most of the air provided in the first half of the chamber. The rest of the combustion air is supplied to the afterburner grate and above the rotary combustor outlet in the boiler. The MB/RC operates at about 50 percent excess air, compared with 80 to 100 percent for typical MB/WW firing systems. Water flowing through the tubes in the rotary chamber recovers heat from combustion. Additional heat recovery occurs in the boiler waterwall, superheater, and economizer. From the economizer, the flue gas is typically routed to APCDs.

2.1.2.3 Mass Burn Refractory Wall Combustors -

Prior to 1970 there were numerous MB/REF MWCs in operation. The purpose of these plants was to achieve waste reduction; energy recovery was generally not incorporated in their design. Most of the roughly 25 MB/REF plants that still operate or that were built in the 1970s and 1980s use electrostatic precipitators (ESPs) to reduce PM emissions, and several have heat recovery boilers. Most MB/REF combustors have unit sizes of 90 to 270 Mg/day (100 to 300 tpd). It is not expected that additional plants of this design will be built in the United States.

The MB/REF combustors comprise several designs. One design involves a batch-fed upright combustor, which may be cylindrical or rectangular in shape. A second design is based on a rectangular combustion chamber with a traveling, rocking, or reciprocating grate. This type of combustor is continuously fed and operates in an excess air mode. If the waste is moved on a traveling grate, it is not sufficiently aerated as it advances through the combustor. As a result, waste burnout or complete combustion is inhibited by fuel bed thickness, and there is considerable potential for unburned waste to be discharged into the bottom ash pit. Rocking and reciprocating grate systems stir and aerate the waste bed as it advances through the combustion chamber, thereby improving contact between the waste and combustion air and increasing the burnout of combustibles. The system generally discharges the ash at the end of the grate to a water quench pit for collection and disposal in a landfill.

Because MB/REF combustors do not contain a heat transfer medium (such as the waterwalls that are present in modern energy recovery units), they typically operate at higher excess air rates (150 to 300 percent) than MB/WW combustors (80 to 100 percent). The higher excess air levels are required to prevent excessive temperatures, which can result in refractory damage, slagging, fouling, and corrosion problems. One adverse effect of higher excess air levels is the potential for increased carryover of PM from the combustion chamber and, ultimately, increased stack emission rates. High PM carryover may also contribute to increased CDD/CDF emissions by providing increased surface area for downstream catalytic formation to take place. A second problem is the potential for high excess air levels to quench (cool) the combustion reactions, preventing thermal destruction of organic species.

An alternate, newer MB/REF combustor is the Volund design (Figure 2.1-3 presents this MB/REF design). This design minimizes some of the problems of other MB/REF systems. A refractory arch is installed above the combustion zone to reduce radiant heat losses and improve solids burnout. The refractory arch also routes part of the rising gases from the drying and combustion grates through a gas by-pass duct to the mixing chamber. There the gas is mixed with gas from the burnout grate or kiln. Bottom ash is conveyed to an ash quench pit. Volund MB/REF combustors operate with 80 to 120 percent excess air, which is more in line with excess air levels in the MB/WW designs. As a result, lower CO levels and better organics destruction are achievable, as compared to other MB/REF combustors.

2.1.2.4 Refuse-derived Fuel Combustors -

Refuse-derived fuel combustors burn MSW that has been processed to varying degrees, from simple removal of bulky and noncombustible items accompanied by shredding, to extensive processing to produce a finely divided fuel suitable for co-firing in pulverized coal-fired boilers. Processing MSW to RDF generally raises the heating value of the waste because many of the noncombustible items are removed.

A set of standards for classifying RDF types has been established by the American Society for Testing and Materials. The type of RDF used is dependent on the boiler design. Boilers that are designed to burn RDF as the primary fuel usually utilize spreader stokers and fire fluff RDF in a semi-suspension mode. This mode of feeding is accomplished by using an air swept distributor, which allows a portion of the RDF to burn in suspension and the remainder to be burned out after falling on a horizontal traveling grate. The number of RDF distributors in a single unit varies directly with unit capacity. The distributors are normally adjustable so that the trajectory of the waste feed can be varied. Because the traveling grate moves from the rear to the front of the furnace, distributor settings are adjusted so that most of the waste lands on the rear two-thirds of the grate. This allows more time for combustion to be completed on the grate. Bottom ash drops into a water-filled quench chamber. Some traveling grates operate at a single speed, but most can be manually adjusted to accommodate variations in burning conditions. Underfire air is normally preheated and introduced beneath the grate by a single plenum. Overfire air is injected through rows of high-pressure nozzles, providing a zone for mixing and completion of the combustion process. These combustors typically operate at 80 to 100 percent excess air.

Due to the basic design of the semi-suspension feeding systems, PM levels at the inlet to the pollution control device are typically double those of mass burn systems and more than an order of magnitude higher than MOD/SA combustors. The higher particulate loadings may contribute to the catalytic formation of CDD/CDF. However, controlled Hg emissions from these plants are considerably lower than from mass burn plants as a result of the higher levels of carbon present in the PM carryover, as Hg adsorbs onto the carbon and can be subsequently captured by the PM control device.

Pulverized coal (PC)-fired boilers can co-fire fluff RDF or powdered RDF. In a PC-fired boiler that co-fires fluff with pulverized coal, the RDF is introduced into the combustor by air transport injectors that are located above or even with the coal nozzles. Due to its high moisture content and large particle size, RDF requires a longer burnout time than coal. A significant portion of the larger, partially burned particles disengage from the gas flow and fall onto stationary drop grates at the bottom of the furnace where combustion is completed. Ash that accumulates on the grate is periodically dumped into the ash hopper below the grate. Refuse-derived fuel can also be co-fired with coal in stoker-fired boilers.

2.1.2.5 Fluidized Bed Combustors -

In an FBC, fluff or pelletized RDF is combusted on a turbulent bed of noncombustible material such as limestone, sand, or silica. In its simplest form, an FBC consists of a combustor vessel equipped with a gas distribution plate and underfire air windbox at the bottom. The combustion bed overlies the gas distribution plate. The combustion bed is suspended or "fluidized" through the introduction of underfire air at a high flow rate. The RDF may be injected into or above the bed through ports in the combustor wall. Other wastes and supplemental fuel may be blended with the RDF outside the combustor or added into the combustor through separate openings. Overfire air is used to complete the combustion process.

There are 2 basic types of FBC systems: bubbling bed and circulating bed. With bubbling bed combustors, most of the fluidized solids are maintained near the bottom of the combustor by using relatively low air fluidization velocities. This helps reduce the entrainment of solids from the bed into the flue gas, minimizing recirculation or reinjection of bed particles. In contrast, circulating bed combustors operate at relatively high fluidization velocities to promote carryover 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. Some of the ash is removed from the cyclone with the solids from the bed.

Good mixing is inherent in the FBC design. Fluidized bed combustors have very uniform gas temperatures and mass compositions in both the bed and in the upper region of the combustor. This allows the FBCs to operate at lower excess air and temperature levels than conventional combustion systems. Waste-fired FBCs typically operate at excess air levels between 30 and 100 percent and at bed temperatures around 815°C (1,500°F). Low temperatures are necessary for waste-firing FBCs because higher temperatures lead to bed agglomeration.

2.1.2.6 Modular Starved-air (Controlled-air) Combustors -

In terms of number of facilities, MOD/SA combustors represent a large segment of the existing MWC population. However, because of their small sizes, they account for only a small percent of the total capacity. The basic design of a MOD/SA combustor consists of 2 separate combustion chambers, referred to as the "primary" and "secondary" chambers. Waste is batch-fed to the primary chamber by a hydraulically activated ram. The charging bin is filled by a front end loader or other means. Waste is fed automatically on a set frequency, with generally 6 to 10 minutes between charges.

Waste is moved through the primary combustion chamber by either hydraulic transfer rams or reciprocating grates. Combustors using transfer rams have individual hearths upon which combustion takes place. Grate systems generally include 2 separate grate sections. In either case, waste retention times in the primary chamber are long, lasting up to 12 hours. Bottom ash is usually discharged to a wet quench pit.

The quantity of air introduced into the primary chamber defines the rate at which waste burns. Combustion air is introduced in the primary chamber at sub-stoichiometric levels, resulting in a flue gas rich in unburned hydrocarbons. The combustion air flow rate to the primary chamber is controlled to maintain an exhaust gas temperature set point, generally 650 to 980°C (1,200 to 1,800°F), which corresponds to about 40 to 60 percent theoretical air.

As the hot, fuel-rich flue gases flow to the secondary chamber, they are mixed with additional air to complete the burning process. Because the temperature of the exhaust gases from the primary chamber is above the autoignition point, completing combustion is simply a matter of introducing air into the fuel-rich gases. The amount of air added to the secondary chamber is controlled to maintain a desired flue gas exit temperature, typically 980 to 1,200°C (1,800 to 2,200°F). Approximately 80 percent of the total combustion air is introduced as secondary air. Typical excess air levels vary from 80 to 150 percent.

The walls of both combustion chambers are refractory lined. Early MOD/SA combustors did not include energy recovery, but a waste heat boiler is common in newer installations, with 2 or more combustion modules manifolded to a single boiler. Combustors with energy recovery capabilities also maintain dump stacks for use in an emergency, or when the boiler and/or air pollution control equipment are not in operation.

Most MOD/SA MWCs are equipped with auxiliary fuel burners located in both the primary and secondary combustion chambers. Auxiliary fuel can be used during startup (many modular units do not operate continuously) or when problems are experienced maintaining desired combustion temperatures. In general, the combustion process is self-sustaining through control of air flow and feed rate, so that continuous co-firing of auxiliary fuel is normally not necessary.

The high combustion temperatures and proper mixing of flue gas with air in the secondary combustion chamber provide good combustion, resulting in relatively low CO and trace organic emissions. Because of the limited amount of combustion air introduced through the primary chamber, gas velocities in the primary chamber and the amount of entrained PM are low. As a result, PM emissions of air pollutants from MOD/SA MWCs are relatively low. Many existing modular systems do not have air pollution controls. This is especially true of the smaller starved-air facilities. A few of the newer MOD/SA MWCs have acid gas/PM controls.

2.1.2.7 Modular Excess Air Combustors -

There are fewer MOD/EA MWCs than MOD/SA MWCs. The design of MOD/EA units is similar to that of MOD/SA units, including the presence of primary and secondary combustion chambers. Waste is batch-fed to the primary chamber, which is refractory-lined. The waste is moved through the primary chamber by hydraulic transfer rams, oscillating grates, or a revolving hearth. Bottom ash is discharged to a wet quench pit. Additional flue gas residence time for fuel/carbon burnout is provided in the secondary chamber, which is also refractory-lined. Energy is typically recovered in a waste heat boiler. Facilities with multiple combustors may have a tertiary chamber where flue gases from each combustor are mixed prior to entering the energy recovery boiler.

Unlike the MOD/SA combustors but similar to MB/REF units, a MOD/EA combustor typically operates at about 100 percent excess air in the primary chamber, but may vary between 50 and 250 percent excess air. The MOD/EA combustors also use recirculated flue gas for combustion air to maintain desired temperatures in the primary and secondary chambers. Due to higher air velocities, PM emissions from MOD/EA combustors are higher than those from MOD/SA combustors and are more similar in concentration to PM emissions from mass burn units. However, NO_x emissions from MOD/EA combustors appear to be lower than from either MOD/SA or mass burn units.

2.1.3 Emissions[4-7]

Depending on the characteristics of the MSW and combustion conditions in the MWC, the following pollutants can be emitted:

- PM,
- Metals (in solid form on PM, except for Hg),
- Acid gases (HCl, SO_2),
- CO,
- NO_x, and
- Toxic organics (most notably CDD/CDF).

A brief discussion on each of the pollutants is provided below, along with discussions on controls used to reduce emissions of these pollutants to the atmosphere.

2.1.3.1 Particulate Matter -

The amount of PM exiting the furnace of an MWC depends on the waste characteristics, the physical nature of the combustor design, and the combustor's operation. Under normal combustion conditions, solid fly ash particulates formed from inorganic, noncombustible constituents in MSW are released into the flue gas. Most of this particulate is captured by the facility's APCD and are not emitted to the atmosphere.

Particulate matter can vary greatly in size with diameters ranging from less than 1 micrometer to hundreds of micrometers (µm). Fine particulates, having diameters less than 10µm (known as PM-10), are of increased concern because a greater potential for inhalation and passage into the pulmonary region exists. Further, acid gases, metals, and toxic organics may preferentially adsorb onto particulates in this size range. The NSPS and EG for MWCs regulate total PM, while PM-10 is of interest for State Implementation Plans and when dealing with ambient PM concentrations. In this chapter, "PM" refers to total PM as measured by EPA Reference Method 5.

The level of PM emissions at the inlet of the APCD will vary according the combustor design, air distribution, and waste characteristics. For example, facilities that operate with high underfire/overfire air ratios or relatively high excess air levels may entrain greater quantities of PM and have high PM levels at the APCD inlet. For combustors with multiple-pass boilers that change the direction of the flue gas flow, part of the PM may be removed prior to the APCD. Lastly, the physical properties of the waste being fed and the method of feeding influences PM levels in the flue gas. Typically, RDF units have higher PM carryover from the furnace due to the suspension-feeding of the RDF. However, controlled PM emissions from RDF plants do not vary substantially from other MWCs (i. e., MB/WW), because the PM is efficiently collected in the APCD.

2.1.3.2 Metals -

Metals are present in a variety of MSW streams, including paper, newsprint, yard wastes, wood, batteries, and metal cans. The metals present in MSW are emitted from MWCs in association with PM (e. g., arsenic [As], Cd, chromium [Cr], and Pb) and as vapors, such as Hg. Due to the variability in MSW composition, metal concentrations are highly variable and are essentially independent of combustor type. If the vapor pressure of a metal is such that condensation onto particulates in the flue gas is possible, the metal can be effectively removed by the PM control device. With the exception of Hg, most metals have sufficiently low vapor pressures to result in almost all of the metals being condensed. Therefore, removal in the PM control device for these metals is generally greater than 98 percent. Mercury, on the other hand, has a high vapor pressure at typical APCD operating temperatures, and capture by the PM control device is highly variable. The level of carbon in the fly ash appears to affect the level of Hg control. A high level of carbon in the fly ash can enhance Hg adsorption onto particles removed by the PM control device.

2.1.3.3 Acid Gases -

The chief acid gases of concern from the combustion of MSW are HCl and SO_2. Hydrogen fluoride (HF), hydrogen bromide (HBr), and sulfur trioxide (SO_3) are also generally present, but at much lower concentrations. Concentrations of HCl and SO_2 in MWC flue gases directly relate to the chlorine and sulfur content in the waste. The chlorine and sulfur content vary considerably based on seasonal and local waste variations. Emissions of SO_2 and HCl from MWCs depend on the chemical form of sulfur and chlorine in the waste, the availability of alkali materials in combustion-generated fly ash that act as sorbents, and the type of emission control system used. Acid gas concentrations are considered to be independent of combustion conditions. The major sources of chlorine in MSW are paper and plastics. Sulfur is contained in many constituents of MSW, such as asphalt shingles, gypsum wallboard, and tires. Because RDF processing does not generally impact the distribution of combustible materials in the waste fuel, HCl and SO_2 concentrations for mass burn and RDF units are similar.

2.1.3.4 Carbon Monoxide -

Carbon monoxide emissions result when all of the carbon in the waste is not oxidized to carbon dioxide (CO_2). High levels of CO indicate that the combustion gases were not held at a sufficiently high temperature in the presence of oxygen (O_2) for a long enough time to convert CO to CO_2. As waste burns in a fuel bed, it releases CO, hydrogen (H_2), and unburned hydrocarbons. Additional air then reacts with the gases escaping from the fuel bed to convert CO and H_2 to CO_2 and H_2O. Adding too much air to the combustion zone will lower the local gas temperature and quench (retard) the oxidation reactions. If too little air is added, the probability of incomplete mixing increases, allowing greater quantities of unburned hydrocarbons to escape the furnace. Both of the conditions would result in increased emissions of CO.

Because O_2 levels and air distributions vary among combustor types, CO levels also vary among combustor types. For example, semi-suspension-fired RDF units generally have higher CO levels than mass burn units, due to the effects of carryover of incompletely combusted materials into low temperature portions of the combustor, and, in some cases, due to instabilities that result from fuel feed characteristics.

Carbon monoxide concentration is a good indicator of combustion efficiency, and is an important criterion for indicating instabilities and nonuniformities in the combustion process. It is during unstable combustion conditions that more carbonaceous material is available and higher CDD/CDF and organic hazardous air pollutant levels occur. The relationship between emissions of CDD/CDF and CO indicates that high levels of CO (several hundred parts per million by volume [ppmv]), corresponding to poor combustion conditions, frequently correlate with high CDD/CDF emissions. When CO levels are low, however, correlations between CO and CDDs/CDFs are not well defined (due to the fact that many mechanisms may contribute to CDD/CDF formation), but CDD/CDF emissions are generally lower.

2.1.3.5 Nitrogen Oxides -

Nitrogen oxides are products of all fuel/air combustion processes. Nitric oxide (NO) is the primary component of NO_x; however, nitrogen dioxide (NO_2) and nitrous oxide (N_2O) are also formed in smaller amounts. The combination of the compounds is referred to as NO_x. Nitrogen oxides are formed during combustion through (1) oxidation of nitrogen in the waste, and (2) fixation of atmospheric nitrogen. Conversion of nitrogen in the waste occurs at relatively low temperatures (less than 1,090°C [2,000°F]), while fixation of atmospheric nitrogen occurs at higher temperatures. Because of the relatively low temperatures at which MWC furnaces operate, 70 to 80 percent of NO_x formed in MWCs is associated with nitrogen in the waste.

2.1.3.6 Organic Compounds -

A variety of organic compounds, including CDDs/CDFs, chlorobenzene (CB), polychlorinated biphenyls (PCBs), chlorophenols (CPs), and polyaromatic hydrocarbons (PAHs), are present in MSW or can be formed during the combustion and post-combination processes. Organics in the flue gas can exist in the vapor phase or can be condensed or absorbed on fine particulates. Control of organics is accomplished through proper design and operation of both the combustor and the APCDs.

Based on potential health effects, CDD/CDF has been a focus of many research and regulatory activities. Due to toxicity levels, attention is most often placed on levels of CDDs/CDFs in the tetra-through octa- homolog groups and specific isomers within those groups that have chlorine substituted in the 2, 3, 7, and 8 positions. As noted earlier, the NSPS and EG for MWCs regulate the total tetra-through octa-CDDs/CDFs.

2.1.4 Controls[8-10]

A wide variety of control technologies are used to control emissions from MWCs. The control of PM, along with metals that have adsorbed onto the PM, is most frequently accomplished through the use of an ESP or fabric filter (FF). Although other PM control technologies (e. g., cyclones, electrified gravel beds, and venturi scrubbers) are available, they are seldom used on existing systems, and it is anticipated that they will not be frequently used in future MWC systems. The control of acid gas emissions (i. e., SO_2 and HCl) is most frequently accomplished through the application of acid gas control technologies such as spray drying or dry sorbent injection, followed by a high-efficiency PM control device. Some facilities use a wet scrubber to control acid gases. It is anticipated that dry systems (spray drying and dry sorbent injection) will be more widely used than wet scrubbers on future U. S. MWC systems. Each of these technologies is discussed in more detail below.

2.1.4.1 Electrostatic Precipitators -

Electrostatic precipitators consist of a series of high-voltage (20 to 100 kilojoules per coulomb [20 to 100 kilovolts]) discharge electrodes and grounded metal plates through which PM-laden flue gas flows. 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, and be collected on, the grounded plates. 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.

As a general rule, the greater the amount of collection plate area, the greater the ESP’s PM collection efficiency. 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 re-entrained in the flue gas. To ensure 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 re-entrained when the dust layer is removed from one field can be recollected in a downstream field. Because of this phenomena, increasing the number of fields generally improves PM removal efficiency.

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 smaller than 1 µm. As compared to pulverized coal fired combustors, in which only 1 to 3 percent of the fly ash is generally smaller than 1 µm, 20 to 70 percent of the fly ash at the inlet of the PM control device for MWCs is reported to be smaller than 1 µm. As a result, effective collection of PM from MWCs requires greater collection areas and lower flue gas velocities than many other combustion types.

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 flue gas flow rate and is expressed as square meters per 304.8 cubic meters per minute (square feet per 1000 cubic feet per minute) of flue gas. In general, the higher the SCA, the higher the collection efficiency. Most ESPs at newer MWCs have SCAs in the range of 400 to 600. When estimating emissions from ESP-equipped MWCs, the SCA of the ESP should be taken into consideration. Not all ESPs are designed equally and performance of different ESPs will vary.

2.1.4.2 Fabric Filters -

Fabric filters are also used for PM and metals control, particularly in combination with acid gas control and flue gas cooling. Fabric filters (also known as "baghouses") remove PM by passing flue gas through a porous fabric that has been sewn into a cylindrical bag. Multiple individual filter bags are mounted in an arranged compartment. A complete FF, in turn, consists of 4 to 16 individual compartments that can be independently operated.

As the flue gas flows through the filter bags, particulate is collected on the filter surface, mainly through inertial impaction. The collected particulate builds up on the bag, forming a filter cake. As the thickness of the filter cake increases, the pressure drop across the bag also increases. Once pressure drop across the bags in a given compartment becomes excessive, that compartment is generally taken off-line, mechanically cleaned, and then placed back on-line.

Fabric filters are generally differentiated by cleaning mechanisms. Two main filter cleaning mechanisms are used: reverse-air and pulse-jet. In a reverse-air FF, flue gas flows through unsupported filter bags, leaving the particulate on the inside of the bags. The particulate builds up to form a particulate filter cake. Once excessive pressure drop across the filter cake is reached, air is blown through the filter in the opposite direction, the filter bag collapses, and the filter cake falls off and is collected. In a pulse-jet FF, flue gas flows through supported filter bags leaving particulate on the outside of the bags. To remove the particulate filter cake, compressed air is pulsed through the inside of the filter bag, the filter bag expands and collapses to its pre-pulsed shape, and the filter cake falls off and is collected.

2.1.4.3 Spray Drying -

Spray dryers (SD) are the most frequently used acid gas control technology for MWCs in the United States. When used in combination with an ESP or FF, the system can control CDD/CDF, PM (and metals), SO_2, and HCl emissions from MWCs. Spray dryer/fabric filter systems are more common than SD/ESP systems and are used mostly on new, large MWCs. In the spray drying process, lime slurry is injected into the SD through either a rotary atomizer or dual-fluid nozzles. The water in the slurry evaporates to cool the flue gas, and the lime reacts with acid gases to form calcium salts that can be removed by a PM control device. The SD is designed to provide sufficient contact and residence time to produce a dry product before leaving the SD adsorber vessel. The residence time in the adsorber vessel is typically 10 to 15 seconds. The particulate leaving the SD contains fly ash plus calcium salts, water, and unreacted hydrated 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 approach to saturation temperature is controlled by the amount of water in the slurry. More effective acid gas removal occurs at lower approach to saturation temperatures, but the temperature must be 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 115°C (240°F) is required to control agglomeration of PM and sorbent by calcium chloride. Outlet gas temperature from the SD is usually around 140°C (285°F).

The stoichiometric ratio is the molar ratio of calcium in the lime slurry fed to the SD divided by the theoretical amount of calcium required to completely react with the inlet HCl and SO_2 in the flue gas. At a ratio of 1.0, the moles of calcium are equal to the moles of incoming HCl and SO_2. However, because of mass transfer limitations, incomplete mixing, and differing rates of reaction (SO_2 reacts more slowly than HCl), more than the theoretical amount of lime is generally fed to the SD. The stoichiometric ratio used in SD systems varies depending on the level of acid gas reduction required, the temperature of the flue gas at the SD exit, and the type of PM control device used.

Lime is fed in quantities sufficient to react with the peak acid gas concentrations expected without severely decreasing performance. The lime content in the slurry is generally about 10 percent by weight, but cannot exceed approximately 30 percent by weight without clogging of the lime slurry feed system and spray nozzles.

2.1.4.4 Dry Sorbent Injection -

This type of technology has been developed primarily to control acid gas emissions. However, when combined with flue gas cooling and either an ESP or FF, sorbent injection processes may also control CDD/CDF and PM emissions from MWCs. Two primary subsets of dry sorbent injection technologies exist. The more widely used of these approaches, referred to as duct sorbent injection (DSI), involves injecting dry alkali sorbents into flue gas downstream of the combustor outlet and upstream of the PM 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 or quench tower. Alkali in the sorbent (generally calcium or sodium) reacts with HCl, HF, and SO_2 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 the potential for acid corrosion of equipment. Solid reaction products, fly ash, and unreacted sorbent are collected with either an ESP or FF.

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. Not all DSI systems are of the same design, and performance of the systems will vary. Flue gas temperature at the point of sorbent injection can range from about 150 to 320°C (300 to 600°F) 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 (Na_2CO_3), and sodium bicarbonate ($NaHCO_3$). Based on published data for hydrated lime, some DSI systems can achieve removal efficiencies comparable to SD systems; however, performance is generally lower.

By combining flue gas cooling with DSI, it may be possible to increase CDD/CDF removal 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., cubic meters per minute) and reducing the resistivity of individual particles.

Furnace sorbent injection involves the injection of powdered alkali sorbent (either lime or limestone) 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, fly ash, and unreacted sorbent are collected using an ESP or FF.

The basic chemistry of FSI is similar to DSI. Both use a reaction of sorbent with acid gases to form alkali salts. However, several key differences exist in these 2 approaches. First, by injecting sorbent directly into the furnace (at temperatures of 870 to 1,200°C [1,600 to 2,200°F]) limestone can be calcined in the combustor to form more reactive lime, thereby allowing use of less expensive limestone as a sorbent. 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. Fourth, if a significant portion of the HCl is removed before the flue gas exits the combustor, it may be possible to reduce the formation of

CDD/CDF in latter sections of the flue gas ducting. However, HCl and lime do not react with each other at temperatures above 760°C (1,400°F). This is the flue gas temperature that exists in the convective sections of the combustor. Therefore, HCl removal may be lower than with DSI. Potential disadvantages of FSI include fouling and erosion of convective heat transfer surfaces by the injected sorbent.

2.1.4.5 Wet Scrubbers -

Many types of wet scrubbers have been used for controlling acid gas emissions from MWCs. These include spray towers, centrifugal scrubbers, and venturi scrubbers. Wet scrubbing technology has primarily been used in Japan and Europe. Currently, it is not anticipated that many new MWCs being built in the United States will use this type of acid gas control system. Wet scrubbing normally involves passing the flue gas through an ESP to reduce PM, followed by a 1- or 2-stage absorber system. With single-stage scrubbers, the flue gas reacts with an alkaline scrubber liquid to simultaneously remove HCl and SO_2. With two-stage scrubbers, a low-pH water scrubber for HCl removal is installed upstream of the alkaline SO_2 scrubber. 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 disposed.

2.1.4.6 Nitrogen Oxides Control Techniques -

The control of NO_x emissions can be accomplished through either combustion controls or add-on controls. Combustion controls include staged combustion, low excess air (LEA), and flue gas recirculation (FGR). Add-on controls which have been tested on MWCs include selective noncatalytic reduction (SNCR), selective catalytic reduction (SCR), and natural gas reburning.

Combustion controls involve the control of temperature or O_2 to reduce NO_x formation. With LEA, less air is supplied, which lowers the supply of O_2 that is available to react with N_2 in the combustion air. In staged combustion, the amount of underfire air is reduced, which generates a starved-air region. In FGR, cooled flue gas and ambient air are mixed to become the combustion air. This mixing reduces the O_2 content of the combustion air supply and lowers combustion temperatures. Due to the lower combustion temperatures present in MWCs, most NO_x is produced from the oxidation of nitrogen present in the fuel. As a result, combustion modifications at MWCs have generally shown small to moderate reductions in NO_x emissions as compared to higher temperature combustion devices (i. e., fossil fuel-fired boilers).

With SNCR, ammonia (NH_3) or urea is injected into the furnace along with chemical additives to reduce NO_x to N_2 without the use of catalysts. Based on analyses of data from U. S. MWCs equipped with SNCR, NO_x reductions of 45 percent are achievable.

With SCR, NH_3 is injected into the flue gas downstream of the boiler where it mixes with NO_x in the flue gas and passes through a catalyst bed, where NO_x is reduced to N_2 by a reaction with NH_3. This technique has not been applied to U. S. MWCs, but has been used on MWCs in Japan and Germany. Reductions of up to 80 percent have been observed, but problems with catalyst poisoning and deactivation may reduce performance over time.

Natural gas reburning involves limiting combustion air to produce an LEA zone. Recirculated flue gas and natural gas are then added to this LEA zone to produce a fuel-rich zone that inhibits NO_x formation and promotes reduction of NO_x to N_2. Natural gas reburning has been evaluated on both pilot- and full-scale applications and achieved NO_x reductions of 50 to 60 percent.

2.1.5 Mercury Controls[11-14]

Unlike other metals, Hg exists in vapor form at typical APCD operating temperatures. As a result, collection of Hg in the APCD is highly variable. Factors that affect Hg control are good PM control, low temperatures in the APCD system, and a sufficient level of carbon in the fly ash. Higher levels of carbon in the fly ash enhance Hg adsorption onto the PM, which is removed by the PM control device. To keep the Hg from volatilizing, it is important to operate the control systems at low temperatures, generally less than about 300 to 400°F.

Several mercury control technologies have been used on waste combustors in the United States, Canada, Europe, and Japan. These control technologies include the injection of activated carbon or sodium sulfide (Na_2S) into the flue gas prior to the DSI- or SD-based acid gas control system, or the use of activated carbon filters.

With activated carbon injection, Hg is adsorbed onto the carbon particle, which is then captured in the PM control device. Test programs using activated carbon injection on MWCs in the United States have shown Hg removal efficiencies of 50 to over 95 percent, depending on the carbon feed rate.

Sodium sulfide injection involves spraying Na_2S solution into cooled flue gas prior to the acid gas control device. Solid mercuric sulfide is precipitated from the reaction of Na_2S and Hg and can be collected in the PM control device. Results from tests on European and Canadian MWCs have shown removal efficiencies of 50 to over 90 percent. Testings on a U. S. MWC, however, raised questions on the effectiveness of this technology due to possible oversights in the analytical procedure used in Europe and Canada.

Fixed bed activated carbon filters are another Hg control technology being used in Europe. With this technology, the flue gas is passed through a fixed bed of granular activated carbon where the Hg is adsorbed. Segments of the bed are periodically replaced as system pressure drop increases.

2.1.6 Emissions[15-121]

Tables 2.1-1, 2.1-2, 2.1-3, 2.1-4, 2.1-5, 2.1-6, 2.1-7, 2.1-8, and 2.1-9 present emission factors for MWCs. The tables are for distinct combustor types (i. e., MB/WW, RDF), and include emission factors for uncontrolled (prior to any pollution control device) levels and for controlled levels based on various APCD types (i. e., ESP, SD/FF). There is a large amount of data available for this source category and, as a result of this, many of the emission factors have high quality ratings. However, for some categories there were only limited data, and the ratings are low. In these cases, one should refer to the EPA Background Information Documents (BIDs) developed for the NSPS and EG, which more thoroughly analyze the data than does AP-42, as well as discuss performance capabilities of the control technologies and expected emission levels. Also, when using the MWC emission factors, it should be kept in mind that these are average values, and emissions from MWCs are greatly affected by the composition of the waste and may vary for different facilities due to seasonal and regional differences. The AP-42 background report for this section includes data for individual facilities that represent the range for a combustor/control technology category.

Table 2.1-1 (Metric Units). PARTICULATE MATTER, METALS, AND ACID GAS EMISSION FACTORS FOR MASS BURN AND MODULAR EXCESS AIR COMBUSTORS[a,b]

Pollutant	Uncontrolled		ESP[c]		DSI/ESP[d]		SD/ESP[e]		DSI/FF[f]		SD/FF[g]	
	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING
PM[h]	1.26 E+01	A	1.05 E-01	A	2.95 E-02	E	3.52 E-02	A	8.95 E-02	A	3.11 E-02	A
As[j]	2.14 E-03	A	1.09 E-05	A	ND[k]	E	6.85 E-06	A	5.15 E-06	C	2.12 E-05	A
Cd[j]	5.45 E-03	A	3.23 E-04	B	4.44 E-05	E	3.76 E-06	A	1.17 E-05	C	1.36 E-05	A
Cr[j]	4.49 E-03	A	5.65 E-05	B	1.55 E-05	E	1.30 E-04	A	1.00 E-04	C	1.50 E-05	A
Hg[j]	2.8 E-03	A	2.8 E-03	A	1.98 E-03	E	1.63 E-03	A	1.10 E-03	C	1.10 E-03	A
Ni[j]	3.93 E-03	A	5.60 E-05	B	1.61 E-03	E	1.35 E-04	A	7.15 E-05	C	2.58 E-05	A
Pb[j]	1.07 E-01	A	1.50 E-03	A	1.45 E-03	E	4.58 E-04	A	1.49 E-04	C	1.31 E-04	A
SO_2	1.73 E+00	A	ND	NA	4.76 E-01	C	3.27 E-01[m]	A	7.15 E-01	C	2.77 E-01[m]	A
HCl[j]	3.20 E+00	A	ND	NA	1.39 E-01	C	7.90 E-02[m]	A	3.19 E-01	C	1.06 E-01[m]	A

[a] All factors in kg/Mg refuse combusted. Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/joule (J) and a heating value of 10,466 J/g. Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g. Source Classification Codes 5-01-001-04, 5-01-001-05, 5-01-001-06, 5-01-001-07, 5-03-001-11, 5-03-001-12, 5-03-001-13, 5-03-001-15. ND = no data. NA = not applicable.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., SO_2).

[c] ESP = Electrostatic Precipitator

[d] DSI/ESP = Duct Sorbent Injection/Electrostatic Precipitator

[e] SD/ESP = Spray Dryer/Electrostatic Precipitator

[f] DSI/FF = Duct Sorbent Injection/Fabric Filter

[g] SD/FF = Spray Dryer/Fabric Filter

[h] PM = Filterable particulate matter, as measured with EPA Reference Method 5.

[j] Hazardous air pollutants listed in the *Clean Air Act*.

[k] No data available at levels greater than detection limits.

[m] Acid gas emissions from SD/ESP- and SD/FF-equipped MWCs are essentially the same. Any differences are due to scatter in the data.

Table 2.1-2 (English Units). PARTICULATE MATTER, METALS, AND ACID GAS EMISSION FACTORS FOR MASS BURN AND MODULAR EXCESS AIR COMBUSTORS[a,b]

	Uncontrolled		ESP[c]		DSI/ESP[d]		SD/ESP[e]		DSI/FF[f]		SD/FF[g]	
Pollutant	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING
PM[h]	2.51 E+01	A	2.10 E-01	A	5.90 E-02	E	7.03 E-02	A	1.79 E-01	A	6.20 E-02	A
As[j]	4.37 E-03	A	2.17 E-05	A	ND[k]	E	1.37 E-05	A	1.03 E-05	C	4.23 E-06	A
Cd[j]	1.09 E-02	A	6.46 E-04	B	8.87 E-05	E	7.51 E-05	A	2.34 E-05	C	2.71 E-05	A
Cr[j]	8.97 E-03	A	1.13 E-04	B	3.09 E-05	E	2.59 E-04	A	2.00 E-04	C	3.00 E-05	A
Hg[j]	5.6 E-03	A	5.6 E-03	A	3.96 E-03	E	3.26 E-03	A	2.20 E-03	C	2.20 E-03	A
Ni[j]	7.85 E-03	A	1.12 E-04	B	3.22 E-05	E	2.70 E-04	A	1.43 E-04	C	5.16 E-05	A
Pb[j]	2.13 E-01	A	3.00 E-03	A	2.90 E-03	E	9.15 E-04	A	2.97 E-04	C	2.61 E-04	A
SO_2	3.46 E+00	A	ND	NA	9.51 E-01	C	6.53 E-01[m]	A	1.43 E-00	C	5.54 E-01[m]	A
HCl[j]	6.40 E+00	A	ND	NA	2.78 E-01	C	4.58 E-01[m]	A	6.36 E-01	C	2.11 E-01[m]	A

[a] All factors in lb/ton refuse combusted. Emission factors were calculated from concentrations using an F-factor of 9,570 dscf/MBtu and a heating value of 4,500 Btu/lb. Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 4,500 Btu/lb. Source Classification Codes 5-01-001-04, 5-01-001-05, 5-01-001-06, 5-01-001-07, 5-03-001-11, 5-03-001-12, 5-03-001-13, 5-03-001-15. ND = no data. NA = not applicable.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., SO_2).

[c] ESP = Electrostatic Precipitator

[d] DSI/ESP = Duct Sorbent Injection/Electrostatic Precipitator

[e] SD/ESP = Spray Dryer/Electrostatic Precipitator

[f] DSI/FF = Duct Sorbent Injection/Fabric Filter

[g] SD/FF = Spray Dryer/Fabric Filter

[h] PM = Filterable particulate matter, as measured with EPA Reference Method 5.

[j] Hazardous air pollutants listed in the *Clean Air Act*.

[k] No data available at levels greater than detection limits.

[m] Acid gas emissions from SD/ESP- and SD/FF-equipped MWCs are essentially the same. Any differences are due to scatter in the data.

Table 2.1-3 (Metric Units). ORGANIC, NITROGEN OXIDES, CARBON MONOXIDE, AND CARBON DIOXIDE EMISSION FACTORS FOR MASS BURN WATERWALL COMBUSTORS[a,b]

	Uncontrolled		ESP[c]		SD/ESP[d]		DSI/FF[e]		SD/FF[f]	
Pollutant	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING	kg/Mg	EMISSION FACTOR RATING
CDD/CDF[g]	8.35 E-07	A	5.85 E-07	A	3.11 E-07	A	8.0 E-08	C	3.31 E-08	A
NO_x[h]	1.83 E+00	A	*		*		*		*	
CO[h]	2.32 E-01	A	*		*		*		*	
CO2[j]	9.85 E+02	D	*		*		*		*	

[a] All factors in kg/Mg refuse combusted. Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J and a heating value of 10,466 J/g. Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g. Source Classification Codes 5-01-001-05, 5-03-001-12. * = Same as "uncontrolled" for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., CO, NO_x).

[c] ESP = Electrostatic Precipitator

[d] SD/ESP = Spray Dryer/Electrostatic Precipitator

[e] DSI/FF = Duct Sorbent Injection/Fabric Filter

[f] SD/FF = Spray Dryer/Fabric Filter

[g] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in 1990 *Clean Air Act*.

[h] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[j] Calculated assuming a dry carbon content of 26.8% for feed refuse.[126,135] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

Table 2.1-4 (English Units). ORGANIC, NITROGEN OXIDES, CARBON MONOXIDE, AND CARBON DIOXIDE EMISSION FACTORS FOR MASS BURN WATERWALL COMBUSTORS[a,b]

	Uncontrolled		ESP[c]		SD/ESP[d]		DSI/FF[e]		SD/FF[f]	
Pollutant	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING	lb/ton	EMISSION FACTOR RATING
CDD/CDF[g]	1.67 E-06	A	1.17 E-06	A	6.21 E-07	A	1.60 E-07	C	6.61 E-08	A
NO_x[h]	3.56 E+00	A	*		*		*		*	
CO[h]	4.63 E-01	A	*		*		*		*	
CO_2[j]	1.97 E+03	D	*		*		*		*	

[a] All factors in lb/ton refuse combusted. Emission factors were calculated from concentrations using an F-factor of 9,570 dscf/MBtu and a heating value of 4,500 Btu/lb. Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 4,500 Btu/lb. Source Classification Codes 5-01-001-05, 5-03-001-12. * = Same as "uncontrolled" for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., CO, NO_x).

[c] ESP = Electrostatic Precipitator

[d] SD/ESP = Spray Dryer/Electrostatic Precipitator

[e] DSI/FF = Duct Sorbent Injection/Fabric Filter

[f] SD/FF = Spray Dryer/Fabric Filter

[g] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the 1990 *Clean Air Act*.

[h] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[j] Calculated assuming a dry carbon content of 26.8% for feed refuse.[126,135] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

Table 2.1-5 (Metric And English Units). ORGANIC, NITROGEN OXIDES, CARBON MONOXIDE, AND CARBON DIOXIDE EMISSION FACTORS FOR MASS BURN ROTARY WATERWALL COMBUSTORS[a,b]

	Uncontrolled			ESP[c]			DSI/FF[d]			SD/FF[e]		
Pollutant	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING
CDD/CDF[f]	ND	ND	NA	ND	ND	NA	4.58 E-08	9.16 E-08	D	2.66 E-08	5.31E-08	B
NO_x[g]	1.13 E+00	2.25 E+00	E	*	*		*	*		*	*	
CO[g]	3.83 E-01	7.66 E-01	C	*	*		*	*		*	*	
CO_2[h]	9.85 E+02	1.97 E+03	D	*	*		*	*		*	*	

[a] Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J (9,570 dscf/MBtu) and a heating value of 10,466 J/g (4,500 Btu/lb). Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g (4,500 Btu/lb). Source Classification Codes 5-01-001-06, 5-03-001-13. ND = no data. NA = not applicable. * = Same as "uncontrolled" for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., CO, NO_x).

[c] ESP = Electrostatic Precipitator

[d] DSI/FF = Duct Sorbent Injection/Fabric Filter

[e] SD/FF = Spray Dryer/Fabric Filter

[f] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the *Clean Air Act*.

[g] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[h] Calculated assuming a dry carbon content of 26.8% for feed refuse.[126,135] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

Table 2.1-6 (Metric And English Units). ORGANIC, NITROGEN OXIDES, CARBON MONOXIDE, AND CARBON DIOXIDE EMISSION FACTORS FOR MASS BURN REFRACTORY WALL COMBUSTORS[a,b]

	Uncontrolled			ESP[c]			DSI/ESP[d]		
Pollutant	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING
CDD/CDF[e]	7.50 E-06	1.50 E-05	D	3.63 E-05	7.25 E-05	D	2.31 E-07	4.61 E-07	E
NO_x[f]	1.23 E+00	2.46 E+00	A	*	*		*	*	
CO[f]	6.85 E-01	1.37 E+00	C	*	*		*	*	
CO_2[g]	9.85 E+02	1.97 E+03	D	*	*		*	*	

[a] Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J (9,570 dscf/MBtu) and a heating value of 10,466 J/g (4,500 Btu/lb). Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g (4,500 Btu/lb). Source Classification Codes 5-01-001-04, 5-03-001-11. * = Same as "uncontrolled" for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., CO, NO_X).

[c] ESP = Electrostatic Precipitator

[d] DSI/ESP = Duct Sorbent Injection/Electrostatic Precipitator

[e] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the *Clean Air Act*.

[f] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[g] Calculated assuming a dry carbon content of 26.8% for feed refuse.[126,135] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

Table 2.1-7 (Metric And English Units). ORGANIC, NITROGEN OXIDES, CARBON MONOXIDE, AND CARBON DIOXIDE EMISSION FACTORS FOR MODULAR EXCESS AIR COMBUSTORS[a,b]

Pollutant	Uncontrolled			ESP[c]			DSI/FF[d]		
	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING
CDD/CDF[e]	ND	ND	NA	1.11 E-06	2.22 E-06	C	3.12 E-08	6.23 E-08	E
NO_x[f]	1.24 E+00	2.47 E+00	A	*	*		*	*	
CO[f]	ND	ND	NA	*	*		*	*	
CO_2[g]	9.85 E+02	1.97 E+03	D	*	*		*	*	

[a] Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J (9,570 dscf/MBtu) and a heating value of 10,466 J/g (4,500 Btu/lb). Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g (4,500 Btu/lb). Source Classification Codes 5-01-001-07, 5-03-001-15. ND = no data. NA = not applicable. * = Same as "uncontrolled" for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., CO, NO_x).

[c] ESP = Electrostatic Precipitator

[d] DSI/FF = Duct Sorbent Injection/Fabric Filter

[e] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the *Clean Air Act*.

[f] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[g] Calculated assuming a dry carbon content of 26.8% for feed refuse[126,135] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

Table 2.1-8 (Metric And English Units). EMISSION FACTORS FOR REFUSE-DERIVED FUEL-FIRED COMBUSTORS[a,b]

Pollutant	Uncontrolled			ESP[c]			SD/ESP[d]			SD/FF[e]		
	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING
PM[f]	3.48 E+01	6.96 E+01	A	5.17 E-01	1.04 E+00	A	4.82 E-02	9.65 E-02	B	6.64 E-02	1.33 E-01	B
As[g]	2.97 E-03	5.94 E-03	B	6.70 E-05	1.34 E-04	D	5.41 E-06	1.08 E-05	D	2.59 E-06[h]	5.17 E-06[h]	A
Cd[g]	4.37 E-03	8.75 E-03	C	1.10 E-04	2.20 E-04	C	4.18 E-05	8.37 E-05	D	1.66 E-05[h]	3.32 E-05[h]	A
Cr[g]	6.99 E-03	1.40 E-02	B	2.34 E-04	4.68 E-04	D	5.44 E-05	1.09 E-04	D	2.04 E-05	4.07 E-05	D
Hg[g]	2.8 E-03	5.5 E-03	D	2.8 E-03	5.5 E-03	D	2.10 E-04	4.20 E-04	B	1.46 E-04	2.92 E-04	D
Ni[g]	2.18 E-03	4.36 E-03	C	9.05 E-03	1.81 E-02	D	9.64 E-05	1.93 E-04	D	3.15 E-05[j]	6.30 E-05[j]	A
Pb[g]	1.00 E-01	2.01 E-01	C	1.84 E-03[h]	3.66 E-03[h]	A	5.77 E-04	1.16 E-03	B	5.19 E-04	1.04 E-03	D
SO_2	1.95 E+00	3.90 E+00	C	ND	ND	NA	7.99 E-01	1.60E+00	D	2.21 E-01	4.41 E-01	D
HCl[g]	3.49 E+00	6.97 E+00	E	*	*		ND	ND	NA	2.64 E-02	5.28 E-02	C
NO_x[k]	2.51 E+00	5.02 E+00	A	*	*		*	*		*	*	
CO[k]	9.60 E-01	1.92 E+00	A	*	*		*	*		*	*	
CO_2[m]	1.34 E+03	2.68 E+03	E	*	*		*	*		*	*	
CDD/CDF[n]	4.73 E-06	9.47 E-06	D	8.46 E-06	1.69 E-05	B	5.31 E-08	1.06 E-07	D	1.22 E-08	2.44 E-08	E

[a] Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J (9,570 dscf/MBtu) and a heating value of 12,792 J/g (5,500 Btu/lb). Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 12,792 J/g (5,500 Btu/lb). Source Classification Code 5-01-001-03. ND = no data. NA = not applicable. * = Same as uncontrolled for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (SO_2, NO_x, CO).

[c] ESP = Electrostatic Precipitator

[d] SD/ESP = Spray Dryer/Electrostatic Precipitator

[e] SD/FF = Spray Dryer/Fabric Filter

[f] PM = total particulate matter, as measured with EPA Reference Method 5.

[g] Hazardous air pollutants listed in the *Clean Air Act*.

[h] Levels were measured at non-detect levels, where the detection limit was higher than levels measured at other similarly equipped MWCs. Emission factors shown are based on emission levels from similarly equipped mass burn and MOD/EA combustors.

[j] No data available. Values shown are based on emission levels from SD/FF-equipped mass burn combustors.

[k] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[m] Based on source tests from a single facility.[120] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

[n] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the *Clean Air Act*.

Table 2.1-9 (Metric And English Units). EMISSION FACTORS FOR MODULAR STARVED-AIR COMBUSTORS[a,b]

Pollutant	Uncontrolled			ESP[c]		
	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING
PM[d]	1.72 E+00	3.43 E+00	B	1.74 E-01	3.48 E-01	B
As[e]	3.34 E-04	6.69 E-04	C	5.25 E-05	1.05 E-04	D
Cd[e]	1.20 E-03	2.41 E-03	D	2.30 E-04	4.59 E-04	D
Cr[e]	1.65 E-03	3.31 E-03	C	3.08 E-04	6.16 E-04	D
Hg[e,f]	2.8 E-03	5.6 E-03	A	2.8 E-03	5.6 E-03	A
Ni[e]	2.76 E-03	5.52 E-03	D	5.04 E-04	1.01 E-03	E
Pb[e]	ND	ND	NA	1.41 E-03	2.82 E-03	C
SO_2	1.61 E+00	3.23 E+00	E	*	*	
HCl[e]	1.08 E+00	2.15 E+00	D	*	*	
NO_x[g]	1.58 E+00	3.16 E+00	B	*	*	
CO[g]	1.50 E-01	2.99 E-01	B	*	*	
CO_2[h]	9.85 E+02	1.97 E+03	D	*	*	
CDD/CDF[j]	1.47 E-06	2.94 E-06	D	1.88 E-06	3.76 E-06	C

[a] Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J (9,570 dscf/MBtu) and a heating value of 10,466 J/g (4,500 Btu/lb). Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g (4,500 Btu/lb). Source Classification Codes 5-01-001-01, 5-03-001-14. ND = no data. NA = not applicable. * = Same as "uncontrolled" for these pollutants.

[b] Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e. g., CO, NO_x).

[c] ESP = Electrostatic Precipitator

[d] PM = total particulate matter, as measured with EPA Reference Method 5.

[e] Hazardous air pollutants listed in the *Clean Air Act*.

[f] Mercury levels based on emission levels measured at mass burn, MOD/EA, and MOD/SA combustors.

[g] Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

[h] Calculated assuming a dry carbon content of 26.8% for feed refuse.[126,135] CO_2 emitted from this source may not increase total atmospheric CO_2 because emissions may be offset by the uptake of CO_2 by regrowing biomass.

[j] CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the *Clean Air Act.*

Another point to keep in mind when using emission factors is that certain control technologies, specifically ESPs and DSI systems, are not all designed with equal performance capabilities. The ESP and DSI-based emission factors are based on data from a variety of facilities and represent average emission levels for MWCs equipped with these control technologies. To estimate emissions for a specific ESP or DSI system, refer to either the AP-42 background report for this section or the NSPS and EG BIDs to obtain actual emissions data for these facilities. These documents should also be used when conducting risk assessments, as well as for determining removal efficiencies. Since the AP-42 emission factors represent averages from numerous facilities, the uncontrolled and controlled levels frequently do not correspond to simultaneous testing and should not be used to calculate removal efficiencies.

Emission factors for MWCs were calculated from flue gas concentrations using an F-factor of 0.26 dry standard cubic meters per joule (dscm/J) (9,570 dry standard cubic feet per million British thermal units [Btu]) and an assumed heating value of the waste of 10,466 J/g (4,500 Btu per pound [Btu/lb]) for all combustors except RDF, for which a 12,792 J/g (5,500 Btu/lb) heating value was assumed. These are average values for MWCs; however, a particular facility may have a different heating value for the waste. In such a case, the emission factors shown in the tables can be adjusted by multiplying the emission factor by the actual facility heating value and dividing by the assumed heating value (4,500 or 5,500 Btu/lb, depending on the combustor type). Also, conversion factors to obtain concentrations, which can be used for developing more specific emission factors or making comparisons to regulatory limits, are provided in Tables 2.1-10 and 2.1-11 for all combustor types (except RDF) and RDF combustors, respectively.

Also note that the values shown in the tables for PM are for total PM, and the CDD/CDF data represent total tetra- through octa-CDD/CDF. For SO_2, NO_x, and CO, the data presented in the tables represent long-term averages, and should not be used to estimate short-term emissions. Refer to the EPA BIDs which discuss achievable emission levels of SO_2, NO_x, and CO for different averaging times based on analysis of continuous emission monitoring data. Lastly, for PM and metals, levels for MB/WW, MB/RC, MB/REF, and MOD/EA were combined to determine the emission factors, since these emissions should be the same for these types of combustors. For controlled levels, data were combined within each control technology type (e. g., SD/FF data, ESP data). For Hg, MOD/SA data were also combined with the mass burn and MOD/EA data.

2.1.7 Other Types Of Combustors[122-134]

2.1.7.1 Industrial/Commercial Combustors -

The capacities of these units cover a wide range, generally between 23 and 1,800 kilograms (50 and 4,000 pounds) per hour. Of either single- or multiple-chamber design, these units are often manually charged and intermittently operated. Some industrial combustors are similar to municipal combustors in size and design. Emission control systems include gas-fired afterburners, scrubbers, or both. Under Section 129 of the CAAA, these types of combustors will be required to meet emission limits for the same list of pollutants as for MWCs. The EPA has not yet established these limits.

2.1.7.2 Trench Combustors -

Trench combustors, also called air curtain incinerators, forcefully project a curtain of air across a pit in which open burning occurs. The air curtain is intended to increase combustion efficiency and reduce smoke and PM emissions. Underfire air is also used to increase combustion efficiency.

Table 2.1-10. CONVERSION FACTORS FOR ALL COMBUSTOR TYPES EXCEPT RDF

Divide	By	To Obtain[a]
For As, Cd, Cr, Hg, Ni, Pb, and CDD/CDF:		
kg/Mg refuse	4.03×10^{-6}	µg/dscm
lb/ton refuse	8.06×10^{-6}	
For PM:		
kg/Mg refuse	4.03×10^{-3}	mg/dscm
lb/ton refuse	8.06×10^{-3}	
For HCl:		
kg/Mg refuse	6.15×10^{-3}	ppmv
lb/ton refuse	1.23×10^{-2}	
For SO^2:		
kg/Mg refuse	1.07×10^{-2}	ppmv
lb/ton refuse	2.15×10^{-2}	
For NO_x:		
kg/Mg refuse	7.70×10^{-3}	ppmv
lb/ton refuse	1.54×10^{-2}	
For CO:		
kg/Mg refuse	4.69×10^{-3}	ppmv
lb/ton refuse	9.4×10^{-3}	
For CO_2:		
kg/Mg refuse	7.35×10^{-3}	ppmv
lb/ton refuse	1.47×10^{-2}	

[a] At 7% O_2.

Table 2.1-11. CONVERSION FACTORS FOR REFUSE-DERIVED FUEL COMBUSTORS

Divide	By	To Obtain[a]
For As, Cd, Cr, Hg, Ni, Pb, and CDD/CDF:		
kg/Mg refuse	4.92×10^{-6}	µg/dscm
lb/ton refuse	9.85×10^{-6}	
For PM:		
kg/Mg refuse	4.92×10^{-3}	mg/dscm
lb/ton refuse	9.85×10^{-3}	
For HCl:		
kg/Mg refuse	7.5×10^{-3}	ppmv
lb/ton refuse	1.5×10^{-2}	
For SO_2:		
kg/Mg refuse	1.31×10^{-2}	ppmv
lb/ton refuse	2.62×10^{-2}	
For NO_x:		
kg/Mg refuse	9.45×10^{-3}	ppmv
lb/ton refuse	1.89×10^{-2}	
For CO:		
kg/Mg refuse	5.75×10^{-3}	ppmv
lb/ton refuse	1.15×10^{-2}	
For CO_2:		
kg/Mg refuse	9.05×10^{-3}	ppmv
lb/ton refuse	1.81×10^{-2}	

[a] At 7% O_2.

Trench combustors can be built either above- or below-ground. They have refractory walls and floors and are normally 8-feet wide and 10-feet deep. Length varies from 8 to 16 feet. Some units have mesh screens to contain larger particles of fly ash, but other add-on pollution controls are normally not used.

Trench combustors burning wood wastes, yard wastes, and clean lumber are exempt from Section 129, provided they comply with opacity limitations established by the Administrator. The primary use of air curtain incinerators is the disposal of these types of wastes; however, some of these combustors are used to burn MSW or construction and demolition debris.

In some states, trench combustors are often viewed as a version of open burning and the use of these types of units has been discontinued in some States.

2.1.7.3 Domestic Combustors -

This category includes combustors marketed for residential use. These types of units are typically located at apartment complexes, residential buildings, or other multiple family dwellings, and are generally found in urban areas. Fairly simple in design, they may have single or multiple refractory-lined chambers and usually are equipped with an auxiliary burner to aid combustion. Due to their small size, these types of units are not currently covered by the MWC regulations.

2.1.7.4 Flue-fed Combustors -

These units, commonly found in large apartment houses or other multiple family dwellings, are characterized by the charging method of dropping refuse down the combustor flue and into the combustion chamber. Modified flue-fed incinerators utilize afterburners and draft controls to improve combustion efficiency and reduce emissions. Due to their small size, these types of units are not currently covered by the MWC regulations.

Emission factors for industrial/commercial, trench, domestic, and flue-fed combustors are presented in Table 2.1-12.

Table 2.1-12 (Metric And English Units). UNCONTROLLED EMISSION FACTORS FOR REFUSE COMBUSTORS OTHER THAN MUNICIPAL WASTE[a]

EMISSION FACTOR RATING: D

Combustor Type	PM		SO_2		CO		Total Organic Compounds[b]		NO_x	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Industrial/commercial										
Multiple chamber	3.50 E+00	7.00 E+00	1.25 E+00	2.50 E+00	5.00 E+00	1.00 E+01	1.50 E+00	3.00 E+00	1.50 E+00	3.00 E+00
Single chamber	7.50 E+00	1.50 E+01	1.25 E+00	2.50 E+00	1.00 E+01	2.00 E+01	7.50 E+01	1.50 E+01	1.00 E+00	2.00 E+00
Trench										
Wood (SCC 5-01-005-10, 5-03-001-06)	6.50 E+00	1.30 E+01	5.00 E-02	1.00 E-01	ND	ND	ND	ND	2.00 E+00	4.00 E+00
Rubber tires (SCC 5-01-005-11, 5-03-001-07)	6.90 E+01	1.38 E+02	ND	ND	ND	ND	ND	ND	ND	ND
Municipal refuse (SCC 5-01-005-12, 5-03-001-09)	1.85 E+01	3.70 E+01	1.25 E+00	2.50 E+00	ND	ND	ND	ND	ND	ND
Flue-fed single chamber	1.50 E+01	3.00 E+01	2.50 E-01	5.00 E-01	1.00 E+01	2.00 E+01	7.50 E+00	1.50 E+01	1.50 E+00	3.00 E+00
Flue-fed (modified)	3.00 E+00	6.00 E+00	2.50 E-01	5.00 E-01	5.00 E+00	1.00 E+01	1.50 E+00	3.00 E+00	5.00 E+00	1.00 E+01
Domestic single chamber (no SCC)										
Without primary burner	1.75 E+01	3.50 E+01	2.50 E-01	5.00 E-01	1.50 E+02	3.00 E+02	5.00 E+01	1.00 E+02	5.00 E-01	1.00 E+00
With primary burner	3.50 E+00	7.00 E+00	2.50 E-01	5.00 E-01	Neg	Neg	1.00 E+00	2.00 E+00	1.00 E+00	2.00 E+00

[a] References 116-123. ND = no data. SCC = Source Classification Code. Neg = negligible.

[b] Expressed as methane.

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