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Medical Waste Incinerators - Background Information for Proposed Standards and Guidelines:

Process Description Report for New and Existing Facilities

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U. S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina

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ABBREVIATIONS USED IN THIS REPORT

Btu	British thermal unit
°C	degrees centigrade
Cd	cadmium
CDD's	total dibenzo-p-dioxins (the sum of all isomers)
CDF's	total dibenzofurans (the sum of all isomers)
CO	carbon monoxide
CO_2	carbon dioxide
dscf	dry standard cubic foot
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
ft^3	cubic feet
g	gram
Hg	mercury
hr	hour
HCl	hydrogen chloride
H_2O	water
kg	kilogram
kJ	kilojoule
lb	pound
m^3	cubic meter
MWI	medical waste incinerator
MWTA	Medical Waste Tracking Act
N_2	(free) nitrogen
NO_x	nitrogen oxides
NSPS	New Source Performance Standards
OSW	Office of Solid Waste
Pb	lead
PM	particulate matter
ppmdv	parts per million (dry volume)
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
sec	second
SO_2	sulfur dioxide

MEDICAL WASTE INCINERATOR FACILITY
PROCESS DESCRIPTION

1.0 INTRODUCTION

1.1 REPORT DESCRIPTION

This report describes the medical waste incineration process starting from the point of generation of the waste and continuing through the handling and transportation of the waste, the combustion process, and the disposal of the ash. This document is one of a series of reports written to provide background information on the medical waste incineration industry, the process description, emissions, emission control technology, emission control costs, model plants, and environmental and energy impacts for the medical waste incineration process.

1.2 PURPOSE OF THE REPORT

This report is designed to provide an overview of the medical waste incineration process, describe the types of medical waste incinerators (MWI's) and their components, and to discuss the combustion process as it relates to MWI's. The report is also intended to describe current practices associated with medical waste generation, segregation, handling, and transportation. Other specific purposes of the report include identifying and characterizing the pollutants, as well as describing the sources of emissions of these pollutants and the factors that affect emissions of specific pollutants. The report presents emission test data and existing State emission rate limitations.

1.3 ORGANIZATION OF THE REPORT

Section 2.0 provides an overview of the incineration process for MWI's and includes a description of the generic composition of medical waste, as well as a brief discussion of what happens during the combustion process. The physical and chemical properties of medical waste and a description of how the waste is segregated, stored, and transported are presented in Section 3.0. The different types of MWI's and their associated components are described in Section 4.0. Included in this section is a discussion of the variations in MWI components. The characterization of stack and fugitive emissions is presented in Section 5.0. This section includes discussions of sources of emissions, factors that affect these emissions, and existing emission limits (based on existing State requirements for MWI's).

2.0 OVERVIEW OF THE INCINERATION PROCESS FOR MWI'S

Medical waste includes infectious and noninfectious wastes generated by facilities such as hospitals, clinics, doctors' and dentists' offices, nursing homes, veterinary establishments, medical and research laboratories, and funeral homes.

The Resource Conservation and Recovery Act (RCRA), 1976, as amended by the Medical Waste Tracking Act (MWTA), defines medical waste as ". . . any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in production or testing of biologicals." ("Biologicals" refers to preparations, such as vaccines, that are made from living organisms.) Medical waste is, in fact, a heterogeneous mixture of general refuse, laboratory and pharmaceutical chemicals and containers, and pathological waste. General refuse includes plastic materials, paper products, glass, food wastes, and metal containers. These materials may originate in administrative offices or cafeterias, as well as in laboratories, hospital wards, or operating rooms. Examples of laboratory and pharmaceutical chemical wastes include alcohols, disinfectants, antineoplastic (chemotherapeutic) agents, and materials containing heavy metals. Pathological wastes include tissues, organs, body parts, blood, and body fluids removed during surgery, autopsy, and biopsy.

Medical waste includes cultures and stocks of infectious agents and associated biologicals, human blood and blood products, pathological wastes, sharps, animal carcasses and bedding, and waste from patients with highly communicable diseases.[1] The U.S. Environmental Protection Agency (EPA) Office of Solid Waste (OSW) uses the term "regulated medical waste" to denote the infectious component of medical waste. The categories of regulated medical waste, as defined by OSW, are presented in

Table 1. Other terms commonly used for the infectious component of medical waste include biological, biomedical, biohazardous, contaminated, red bag, pathological, and pathogenic waste. In the United States, infectious wastes are required to be placed in orange or red plastic bags or containers for handling. Often these "red bag" wastes may contain noncontaminated general refuse that has been combined with the infectious wastes.

Treatment by incineration, and disposal of the resultant ash by landfilling, is an attractive option for managing medical waste. A major benefit of incineration is the destruction of pathogens (disease-causing agents), which occurs as a result of the high temperatures achieved in MWI's. Another benefit is the significant reduction of the weight and volume of waste material to be landfilled; MWI's typically achieve better than 90 percent burndown. In addition, converting waste to ash results in a more aesthetically acceptable material. One of the major objectives of incineration is to generate acceptable ash for land disposal. (Acceptable ash is characterized by pathogen destruction, low volatile metals content, and a low percentage of organic matter.) In some cases, incineration may provide economic benefits through waste heat recovery.

Medical waste is burned in incineration units under controlled conditions to yield ash and combustion gases. The combustion process is a complex combination of chemical reactions that involve the rapid oxidation of organic substances in the waste and in auxiliary fuels. The goal of the process is to achieve complete combustion of the organic materials and destruction of pathogens in the waste while minimizing the formation and release of undesirable pollutants. How well the process approaches complete combustion is determined by temperature, time, turbulence, and mixing with oxygen.

Each organic substance in medical waste has a characteristic minimum ignition temperature that must be attained or exceeded, in the presence of oxygen, for combustion to occur. Above that ignition temperature, heat is generated at a sufficient rate to sustain combustion. Wastes containing high levels of moisture,

TABLE 1. REGULATED MEDICAL WASTES[2]

Waste class	Description
1. Cultures and stocks	Cultures and stocks of infectious agents and associated biologicals, including: cultures from medical and pathological laboratories; cultures and stocks of infectious agents from research and industrial laboratories; wastes from the production of biologicals; discarded live and attenuated vaccines; and culture dishes and devices used to transfer, inoculate, and mix cultures.
2. Pathological wastes	Human pathological wastes, including tissues, organs, and body parts and body fluids that are removed during surgery or autopsy or other medical procedures and specimens of body fluids and their containers.
3. Human blood and blood products	(a) Human blood; liquid waste; (b) products of blood; (c) items saturated and/or dripping with human blood; or (d) items that were saturated and/or dripping with human blood that are now caked with dried human blood, including serum, plasma, and other blood components and their containers, which were used or intended for use in patient care, testing and laboratory analysis, or the development of pharmaceuticals. Intravenous bags are also included in this category.
4. Sharps	Sharps that have been used in animal or human patient care or treatment or in medical, research, or industrial laboratories, including hypodermic needles, syringes (with or without the attached needle), Pasteur pipettes, scalpel blades, blood vials, needles with attached tubing, and culture dishes (regardless of presence of infectious agents). Also included are other types of broken or unbroken glassware that were in contact with infectious agents, such as used slides and cover slips.
5. Animal wastes	Contaminated animal carcasses, body parts, and bedding of animals that were known to have been exposed to infectious agents during research (including research in veterinary hospitals), production of biologicals, or testing of pharmaceuticals.
6. Isolation wastes	Biological waste and discarded materials contaminated with blood, excretion, exudates, or secretions from humans who are isolated to protect others from certain highly communicable diseases or from isolated animals known to be infected with highly communicable diseases.
7. Unused sharps	The following unused, discarded sharps: hypodermic needles, suture needles, syringes, and scalpel blades.

however, require additional supplemental heat input. A waste constituent should reside in the high-temperature region of the MWI for a time period that exceeds the time required for it to completely combust. Because the combustion reaction rate increases with increasing temperature, a shorter residence time is required for combustion at higher temperatures (assuming the presence of good combustion conditions). Adequate oxygen supplies and turbulence sufficient to promote the mixing of organic materials and oxygen are also essential for efficient combustion. Inadequate mixing of combustible gases and air can result in emissions of incomplete combustion products. Turbulence within the primary chamber helps to break down the ash layer formed around burning particles of waste and expose the waste material to the high temperatures and combustion air. Bed turbulence is needed to maintain the combustion process and the elevated temperatures throughout the bed.

Throughout this report, unless otherwise indicated, discussions focus on dual-chambered MWI's because of their prevalence in the industry. In these units, sequential combustion operations are carried out in two separate chambers. The primary chamber accepts the waste, and the combustion process is begun. Three processes occur in the primary chamber. First, the moisture in the waste is evaporated. Second, the volatile fraction of the waste is volatilized, and the volatilized gases are directed to the secondary chamber. Third, the nonvolatile combustible portion (fixed carbon) of the waste is burned. The typical operating temperature range for primary chambers is 650° to 760°C (1200° to 1400°F), but the temperatures can range from 400° to 980°C (750° to 1800°F).[3-5] Combustion gases containing the volatile combustible materials from the primary chamber are directed to the secondary chamber. Here the gases are burned with excess air, and at least one auxiliary fuel burner is used, as necessary, to maintain temperatures. According to most manufacturers, typical operating temperatures for secondary chambers range from 870° to 1100°C (1600° to 2000°F). The combustion gases from the secondary chamber are then vented through the stack to the atmosphere.

Medical waste incinerators have the potential to emit a variety of air pollutants. The pollutants from MWI's either exist in the waste feed material and are released unchanged during combustion, or they are generated as a result of the combustion process itself. These pollutants include particulate matter (PM); toxic metals; toxic organics; carbon monoxide (CO); and the acid gases hydrogen chloride (HCl), sulfur dioxide (SO_2), and nitrogen oxides (NO_x). In addition to emissions of pollutants through the combustion air stack, there is the potential for fugitive emissions in the medical waste incineration process. These emissions occur while charging the waste, handling the ash, and handling and transporting the catch or residue from air pollution control devices (e.g., fabric filters).

3.0 MEDICAL WASTE CHARACTERISTICS, SEGREGATION, STORAGE, AND TRANSPORTATION

The characteristics of medical waste, in terms of its physical and chemical properties, are described in Section 3.1. Section 3.2 describes current medical waste segregation and storage practices. Transportation practices are discussed in Section 3.3.

3.1 CHARACTERISTICS OF MEDICAL WASTE COMPONENTS

Medical waste is characteristically heterogeneous, consisting of items composed of many different materials. The composition of the wastes depends on the type of generator and the source of the waste within the generator facility. Activities and procedures within the facility can vary significantly from day to day, making it difficult to predict the composition of the waste. Therefore, no data are available from which a representative characterization of medical waste can be formulated, and only the <u>components</u> of the waste can be characterized. The chemical and physical properties of the components of wastes treated in MWI's vary considerably--not only from charge to charge, but within each charge to the incinerator.

The waste characteristics are important because they may affect combustion efficiency and emission characteristics. A study of hospitals in Ontario provided information on the heating value, bulk density, and moisture content of different medical waste materials. The results from this study are presented in Tables 2a (metric units) and 2b (English units).[3] As shown in these tables, the heating values (as fired) range from about 2,330 kilojoules per gram (kJ/g) (1,000 British thermal units per pound [Btu/lb]) for high-moisture, low-heat-content anatomical waste to 46,500 kJ/g (20,000 Btu/lb) for low-moisture, high-heat-content plastics such as polyethylene. Bulk densities ranged from 80 kilograms per cubic meter (kg/m^3) (5 pounds per cubic foot [lb/ft^3]) to 8,000 kg/m^3 (500 lb/ft^3). Moisture contents varied from zero to 100 percent.

The chemical composition of the medical wastes, particularly the metals and plastics, are also of concern because of their impact on air pollutant emissions. Metals and metal compounds that vaporize at the hearth temperatures encountered in the primary combustion chamber may be emitted as metal oxides. Halogenated plastics such as polyvinyl chloride (PVC) produce acid gases (e.g., HCl). The presence of the chlorinated wastes may also contribute to the formation of toxic organic pollutants such as dioxins (CDD's) and furans (CDF's).

3.2 MEDICAL WASTE SEGREGATION AND STORAGE PRACTICES

The degree to which medical waste is segregated is typically a function of the size of the generator and the economics of disposal options. If a large incinerator is available or if unsegregated wastes may be hauled to a local landfill, a generator may combine most or all medical wastes in preparation for disposal. However, a generator might tend to segregate medical waste more carefully in cases where only a small incinerator is available or when the waste hauling charges are significant, and the added costs of special handling would apply to the noninfectious component of medical waste as well.

During the segregation process, efforts are generally made to exclude from the medical wastes certain materials that may

TABLE 2a. PHYSICAL CHARACTERISTICS OF MEDICAL WASTE COMPONENTS[1]
(Metric Units)

Component description	HHV dry basis, kJ/g	Bulk density as fired, kg/m^3	Moisture content of component, weight %	Heat value as fired, kJ/g
Human anatomical	18,600-27,900	800-1,200	70-90	1,860-8,370
Plastics	32,500-46,500	80-2,300	0-1	32,300-46,500
Swabs, absorbants	18,600-27,900	80-1,000	0-30	13,000-27,900
Alcohol, disinfectants	25,500-32,500	800-1,000	0-0.2	25,500-32,500
Animal-infected anatomical	20,900-37,100	500-1,300	60-90	2,090-14,900
Glass	0	2,800-3,600	0	0
Beddings, shavings, paper, fecal matter	18,600-20,900	320-730	10-50	9,300-18,800
Gauze, pads, swabs, garments, paper, cellulose	18,600-27,900	80-1,000	0-30	13,000-27,900
Plastics, PVC, syringes	22,500-46,500	80-2,300	0-1	22,300-46,500
Sharps, needles	140	7,200-8,000	0-1	140
Fluids, residuals	0-23,200	990-1,010	80-100	0-4,640

TABLE 2b. PHYSICAL CHARACTERISTICS OF MEDICAL WASTE COMPONENTS[3]
(English Units)

Component description	HHV dry basis, Btu/lb	Bulk density as fired, lb/ft^3	Moisture content of component, weight %	Heat value as fired, Btu/lb
Human anatomical	8,000-12,000	50-75	70-90	800-3,600
Plastics	14,000-20,000	5-144	0-1	13,900-20,000
Swabs, absorbants	8,000-12,000	5-62	0-30	5,600-12,000
Alcohol, disinfectants	11,000-14,000	48-62	0-0.2	11,000-14,000
Animal-infected anatomical	9,000-16,000	30-80	60-90	900-6,400
Glass	0	175-225	0	0
Beddings, shavings, paper, fecal matter	8,000-9,000	20-45	10-50	4,000-8,100
Gauze, pads, swabs, garments, paper, cellulose	8,000-12,000	5-62	0-30	5,600-12,000
Plastics, PVC, syringes	9,700-20,000	5-144	0-1	9,600-20,000
Sharps, needles	60	450-500	0-1	60
Fluids, residuals	0-10,000	62-63	80-100	0-2,000

create special problems in the combustion process, adversely impact the composition of the effluents or residues from the process, or unnecessarily contribute to the volume of wastes to be incinerated. For example, the presence of batteries or radiological materials in the waste feed may account for high concentrations of heavy metals (e.g., lead, mercury, and cadmium) in incinerator ash, and so these items are often segregated from the wastes to be combusted. While paper plates, polystyrene cups, and other "dry" hospital cafeteria wastes may be included with medical wastes, cafeteria food wastes are often excluded from the medical wastes to be incinerated because of their high moisture content. Metal cans from cafeterias also are generally excluded. Large stacks of computer paper are usually segregated from medical wastes unless they are shredded prior to incineration. Bulky cardboard is often compacted and recycled rather than incinerated.

In addition to the above examples of waste segregation, other wastes are appropriately excluded from medical waste intended for incineration. While the Nuclear Regulatory Commission (NRC) permits the incineration of certain wastes containing low-level radioactive materials (e.g., scintillation vials, research animal carcasses, and certain chemotherapy wastes with radioactive concentrations below a specified level), special permits are required to treat other radioactive wastes. In most cases, it is inappropriate to use MWI's to dispose of some radioactive wastes and certain hazardous wastes regulated under RCRA. However, there are a few incineration facilities designed primarily as MWI's that have obtained permits to treat wastes regulated under RCRA.

Color-coded bags (usually polyethylene) and containers are frequently used to help segregate and identify medical waste. Most often, red or red-orange bags are used for infectious wastes, and these wastes are usually double-bagged. For aesthetic reasons, opaque bags are generally used for certain types of wastes (e.g., pathological). Other colored containers may be used based on the protocol of the particular generator.

For example, generators might use blue bags for body fluid wastes, orange bags for chemotherapy wastes, and brown bags for general waste. Plastic bags containing medical wastes are sometimes placed in plastic-lined, corrugated cartons or fiber drums, which are then appropriately labelled. Sharps, such as needles, scalpels, and pipettes, are commonly placed in rigid, colored, puncture-proof plastic containers. Capped or tightly stoppered bottles or flasks may be used for liquid wastes, as may tanks. Use of the biological hazard symbol on appropriate packaging is recommended. Regardless of the type of containers used, the integrity of the packaging must be preserved throughout handling, storage, and transportation.

The storage of medical wastes prior to onsite treatment or offsite disposal is typically kept to a minimum. Some States regulate storage times. For example, Massachusetts allows infectious waste to be stored for 24 hours at room temperature (18° to 25°C [64° to 77°F]) or for 72 hours at refrigerated temperatures (1° to 7°C [34° to 45°F]).[1] Wastes stored without refrigeration for several days are prone to increased rates of microbial growth and putrefaction. Ideally, wastes are stored in areas with refrigeration and provisions for regular disinfection to avoid the spread of disease by rodents and vermin. Storage areas typically are secured from public access. These areas generally display the biological hazard symbol.

3.3 MEDICAL WASTE TRANSPORTATION

3.3.1 Transportation Within the Facility

Medical wastes are transported within the generating facility using chutes and wheeled containers. (Chutes are not recommended for transporting infectious wastes.) Plastic bags and other containers described in the previous section may be placed in rigid, leakproof containers with wheels to be transported to storage or treatment areas. When mechanical loading devices are used, care must be taken to avoid rupturing the packaged wastes.

3.3.2 Transportation of Untreated Medical Waste to Offsite Locations

Medical waste intended for offsite treatment generally is transported in closed and leakproof dumpsters or trucks to prevent the waste from scattering, spilling, and leaking during transport. Because the truck is not considered to be a rigid containment system, medical wastes typically are placed in rigid or semi-rigid, leakproof containers before being loaded into a truck.

When medical waste is transported offsite, specific packaging requirements are generally imposed by State or Federal regulations. These regulations typically require that infectious waste be placed in double (plastic) bags, with each bag tied or taped and the bags placed in plastic-lined, rigid, corrugated cartons or fiber drums, which are then sealed or taped. The containers are generally required to be marked with the universal biohazard symbol or the words "infectious waste," and if chemotherapy wastes are included, the containers must be so marked. Other labeling of the containers, as well as manifesting procedures, must conform with the statutory requirements of the generator's State. Classifications of medical, and specifically infectious, wastes vary among the States. Drivers or warehousemen at the disposal site may inspect each shipment of medical waste (e.g., for structural integrity of the containers or for the presence of radiation hazards). The disposal company may reserve the right to refuse any "off-spec" packages.

Carts and other reusable transport mechanisms should be disinfected frequently and, when used to transport infectious wastes, should not be used to transport other materials prior to decontamination.

Should storage of medical waste during transport or at the offsite facility be required, procedures are the same as those discussed in Section 3.2.

As discussed in Section 3.2, the degree of segregation of medical wastes (i.e., infectious vs. noninfectious or regulated vs. nonregulated) is likely to be greater when the waste is to be shipped offsite for treatment. Therefore, the characteristics of the waste may be considerably different from those of medical waste treated onsite. Because of the requirements of the disposal facility and the special handling costs and regulatory requirements associated with hauling medical wastes, waste shipped offsite is more likely to be composed primarily of materials defined as infectious.

4.0 MEDICAL WASTE INCINERATION PROCESSES AND PROCESS COMPONENTS

The medical waste incineration process can be described in terms of the following steps: waste charging, primary chamber combustion, solids movement though the primary chamber, secondary chamber combustion, combustion gas handling, and ash removal. Figure 1 is a process flow diagram that illustrates how these steps relate to each other in the incineration system.

The important factors that help to characterize an MWI system and its operation are the mode of operation, the method of waste feed charging, the method of ash removal, and the air distribution to the combustion chambers. The basic types of MWI's can be classified by mode of operation as continuous-duty, intermittent-duty, and batch-duty systems. All MWI's, regardless of the type of waste burned, fit into one of these MWI types. However, MWI's burning pathological waste, while they fall under the intermittent-duty category, operate significantly differently and have significantly different emission characteristics from other intermittent-duty MWI's. Therefore, pathological MWI's are treated as a separate subcategory of MWI's. In each of these systems, sequential combustion operations typically are carried out in two separate chambers (primary and secondary). Table 3 characterizes the major types of MWI's with respect to these factors.

Waste charging to the primary chamber is accomplished either manually or mechanically. Typically, manual waste feed charging is used on batch-duty units and those intermittent-duty MWI's with capacities less than 180 kilograms per hour (kg/hr) (400 pounds per hour [lb/hr]). Intermittent-duty units larger than 180 kg/hr (400 lb/hr) and continuous-duty MWI's generally

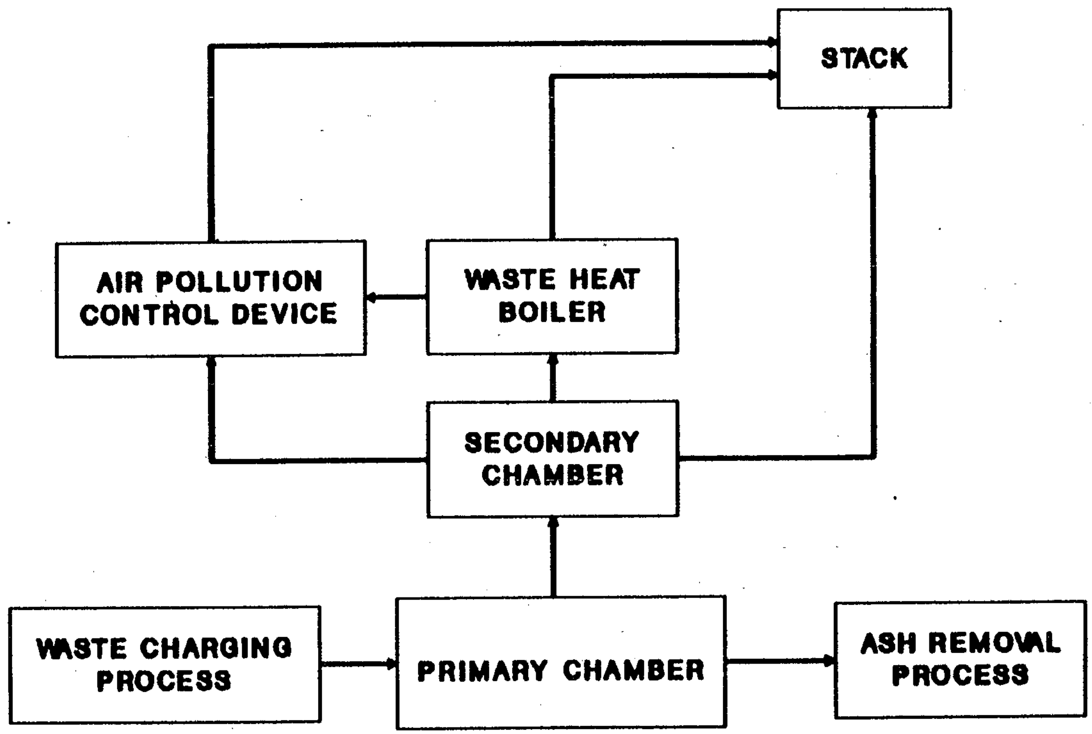

Figure 1. Medical waste incinerator process flow diagram.

TABLE 3. CHARACTERISTICS OF THE BASIC TYPES OF MWI's

Type of incinerator	Mode of operation	Primary chamber combustion air	Waste feed	Ash removal
1. Continuous-duty	Continuous	Substoichiometric	Mechanical continuous or multiple charges	Periodic or continuous ash removal during burn
2. Intermittent-duty	Intermittent	Substoichiometric	Manual or mechanical charges; multiple charges per burn	Ash removal at end of burn
3. Batch-duty	Single batch	Substoichiometric	Manual batch; one batch per burn	Ash removal at end of burn
4. Pathological	Intermittent	Excess	Manual or mechanical charges	Ash removal at end of burn

have a mechanical waste feed charging system. Continuous-duty units have a means of moving the waste/ash bed from the charging end to the ash-discharge end, while intermittent- and batch-duty units utilizing manual charging have no means of solids transfer in the primary chamber.

Ash is removed either periodically or continuously, depending upon the operating mode of the MWI (see Table 3). Continuous ash removal, used for continuous-duty MWI's, takes place while the incinerator is operating. Periodic ash removal is performed either manually or mechanically (typically on the morning after a burn) in units without continuous ash removal systems.

The stoichiometric amount of combustion air is the quantity of air needed to provide exactly the theoretical amount of oxygen needed for the carbon and hydrogen in the waste to completely combust. For MWI's, air distribution can be classified based on whether the primary chamber operates under starved (substoichiometric) or excess-air (an amount above stoichiometric) conditions. In most MWI's, the combustion process in the primary chamber proceeds in a substoichiometric oxygen atmosphere. However, pathological systems operate with excess air in the primary chamber.

With the exception of pathological MWI's, the continuous-duty, intermittent-duty, and batch-duty MWI's are designed to burn general medical waste (including pathological waste) that typically has a heating value of 1.98×10^7 Joule/kg (8,500 Btu/lb). Pathological MWI's are designed to burn only pathological waste, typically having a heating value of 2.3×10^6 Joule/kg (1,000 Btu/lb). However, there is a pathological "dual mode" system that operates under substoichiometric conditions when burning nonpathological wastes and under excess-air conditions when treating only pathological wastes.

The design capacities of MWI's are presented in Table 4. These capacities range from 20 kg/hr (50 lb/hr) for intermittent-duty, pathological and nonpathological systems to 2,830 kg/hr (6,250 lb/hr) for continuous-duty systems. For batch units, the

TABLE 4. DESIGN CAPACITIES OF MWI's

Type of incinerator	Design capacities	
	Metric units	English units
Continuous-duty[a]	160 to 3,000 kg/hr	350 to 6,590 lb/hr
Intermittent-duty[b]	20 to 1000 kg/hr	50 to >2,200 lb/hr
Batch-duty[c]	70 to 1,720 kg/batch	150 to 3,800 lb/batch
Pathological[d]	20 to 910 kg/hr	50 to 2,000 lb/hr

[a]References 6-19 and 22.
[b]References 6-10, 16, 20, and 21.
[c]Reference 11.
[d]References 9, 16, 20, and 21.

capacities range from 70 kg/batch (150 lb/batch) to 1,720 kg/batch (3,800 lb/batch).

Each of the basic types of MWI's, along with the variations in their process components, are discussed in greater detail in the following sections. Sections 4.1, 4.2, and 4.3 describe continuous-duty, intermittent-duty, and batch-duty MWI's, respectively, with respect to the combustion of general medical waste. Section 4.4 describes pathological MWI's (also intermittent-duty MWI's) with respect to the combustion of pathological waste and also includes a description of retort hearth MWI's. Section 4.5 describes the variations in process components among the basic MWI types.

4.1 CONTINUOUS-DUTY SYSTEMS

This section first provides a brief overview of the general medical waste combustion process occurring in the MWI, describes the flow of combustion air and exhaust gases through the system, and discusses the control of combustion air to the primary and secondary chambers. Secondly, this section describes the unique features of continuous-duty systems.

Figure 2 is a schematic of an MWI. The waste enters the primary chamber, where it is ignited. The moisture in the waste is evaporated, the volatile fraction is vaporized, and the fixed carbon remaining in the waste is combusted. The combustion air flow to the primary chamber may be set at a fixed rate or it may be varied based on primary chamber exit gas temperature to maintain a substoichiometric oxygen condition. The gases containing the volatile combustible materials from the primary chamber are directed to the secondary chamber. In the secondary chamber, the combustion air is regulated to provide an excess-air combustion condition and is introduced to the chamber in a manner that produces turbulence and promotes mixing of the combustion gases and combustion air. Combustion air is regulated using modulating combustion air dampers or fans that are activated based on the secondary chamber exit gas temperatures. Burning the combustion gases under conditions of high temperature, excess oxygen, and turbulence promotes complete combustion.

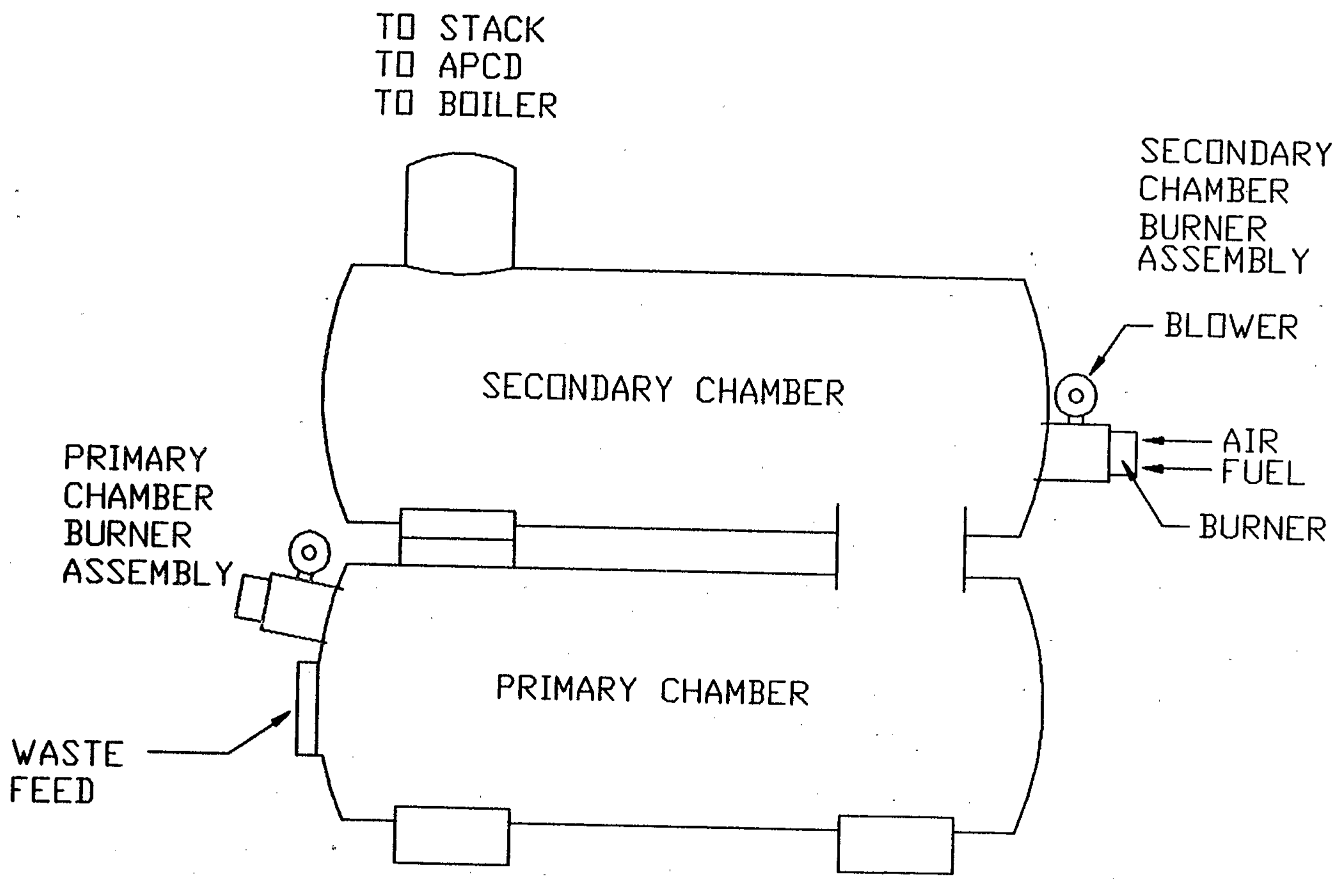

Figure 2. Schematic of a controlled-air incinerator.

Limiting air to substoichiometric conditions in the primary chamber prevents rapid combustion and favors the quiescent conditions that minimize entrainment of PM in the combustion gases. Also, control of the distribution and amount of combustion air allows the primary chamber temperatures to be maintained below the melting and fusion points of most metals, glass, and other noncombustibles, thereby minimizing slagging and clinker formation. On the other hand, sufficiently high temperatures can be maintained in a turbulent condition with excess oxygen in the secondary chamber to ensure complete combustion of the combustion gases, while at the same time avoiding temperatures that are hot enough to cause refractory damage.

The continuous-duty MWI has an operating cycle that can accommodate waste charging for an unrestricted length of time because ash is automatically discharged from the incinerator on a continuous basis. The unit can be automatically charged with relatively small charges at frequent, regulated time intervals. Available information indicates that nearly all of these units are used by commercial facilities, hospitals, and laboratories.[6-15] These end-users tend to be facilities whose medical waste incineration requirements are continuous and do not allow for periodic shutdown of the units for ash removal.

The primary chamber of continuous-duty MWI's may comprise either a fixed-hearth, a rotary kiln, or a moving hearth such as a Pulse Hearth™ or a stoker. Currently, fixed-hearth systems are significantly more prevalent than the other types. Because of their size and because of the need to move waste through the system effectively, most continuous-duty, fixed-hearth MWI's utilize stepped hearths. Figure 3 depicts a continuous-duty, stepped-hearth MWI with internal ash transfer rams.

Figure 4 is a simplified schematic of a rotary kiln. The primary chamber is a rotating cylindrical chamber that is slightly inclined from the horizontal plane. Waste is fed at the higher end of the rotating chamber. For wastes other than medical wastes, combustion air provided to the primary chamber

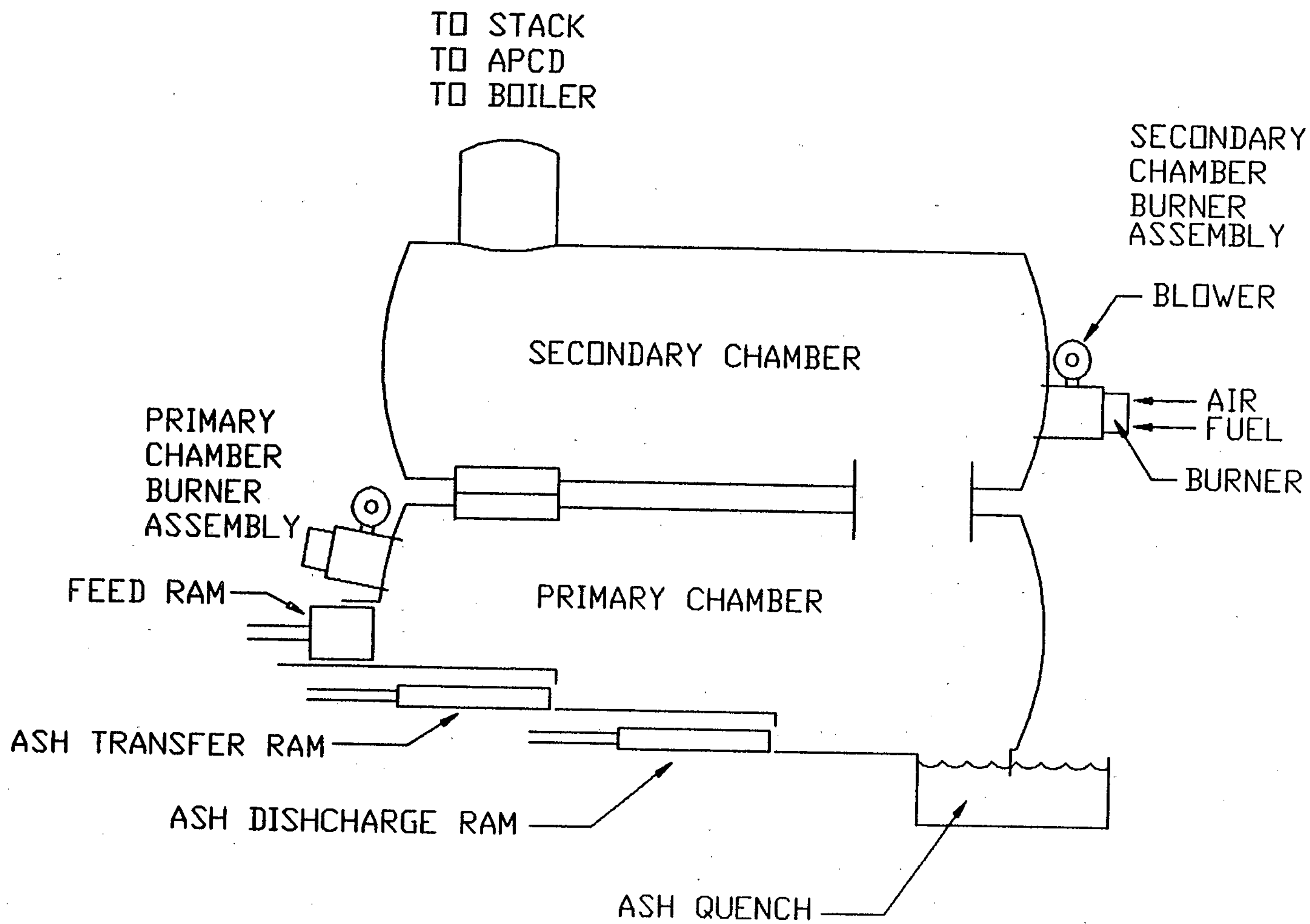

Figure 3. Schematic of a continuous-duty medical waste incinerator with stepped hearth and automatic ash removal.

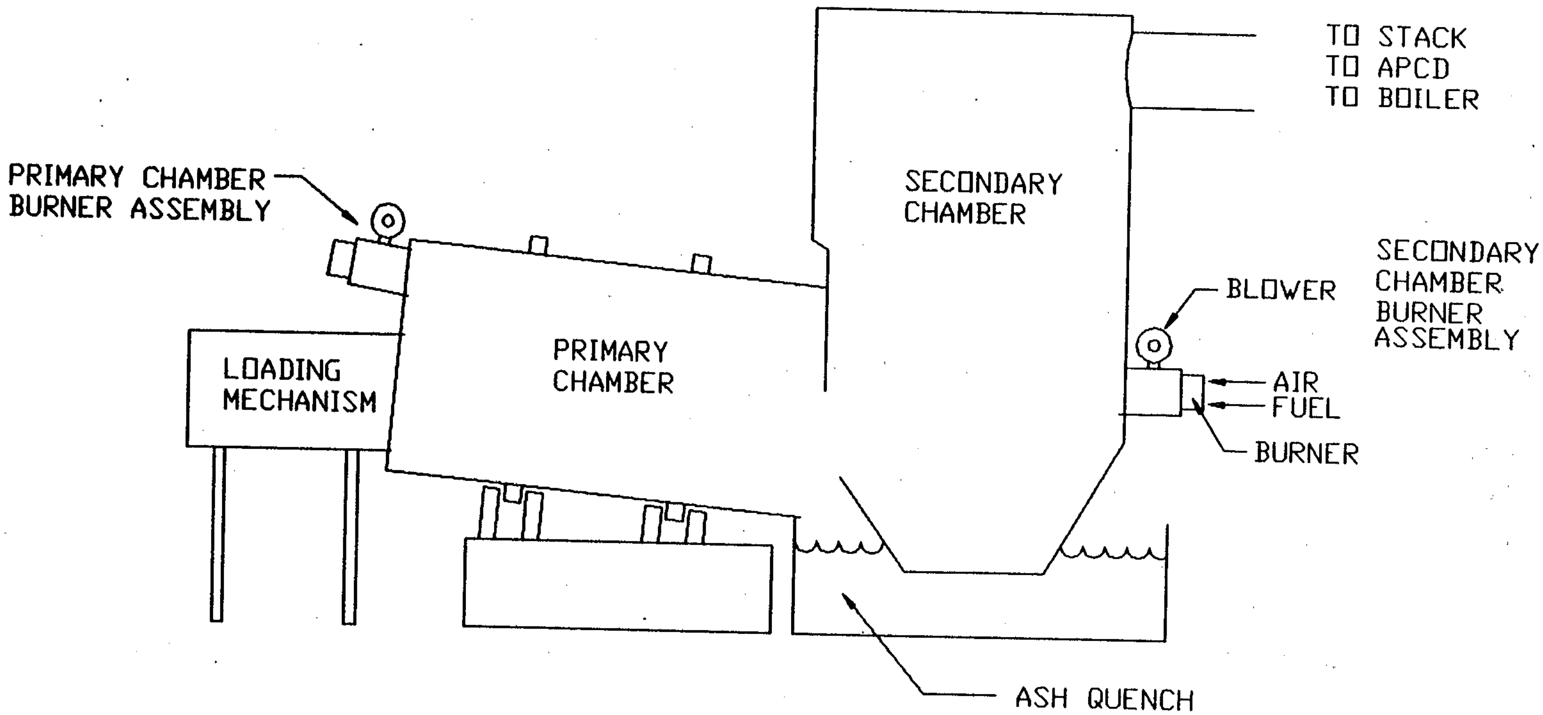

Figure 4. Schematic of a rotary kiln medical waste incinerator.

typically creates an excess-air atmosphere. However, a major manufacturer of rotary kilns used as MWI's reports that the airflow to the primary chamber in these kilns is substoichiometric.[22] Operating the kiln under these conditions reduces kiln size and decreases auxiliary fuel usage in the secondary chamber. Inside the rotating chamber, moisture and volatiles are vaporized from the waste, and the waste is ignited. As the chamber rotates, the solids tumble within the chamber and slowly move down the incline toward the discharge end. The turbulence of the waste provides exposure of the solids to the combustion air. Combustion of the solids occurs within the rotating chamber, and the residue ash is discharged from the end of the kiln into an ash removal system. The volatile gases pass from the primary chamber into the secondary chamber, where combustion of the gases is completed.

Because the waste continuously moves down the length of the rotating chamber and ash is removed continuously, the incineration system is designed to operate with continuous waste feed input. Available information indicates that relatively few rotary kilns are being used as MWI's, and most of these are used at hospitals.[10, 16-19]

Pulse Hearth™ and stoker systems are used to a lesser extent than fixed-hearth and rotary kiln MWI's and are described in Section 4.5.2.2.

4.2 INTERMITTENT-DUTY SYSTEMS

An intermittent-duty MWI typically has an operating cycle of less than 24 hours. The unit is designed to accept waste charges for durations of 8 to 16 hours, depending upon its size. Once ash builds up to a level that interferes with normal charging of the unit, the unit must be shut down and the ash removed. The intermittent charging procedure allows the daily charge to the MWI to be divided into a number of smaller charges that can be introduced over the combustion cycle. Waste is generally charged every 6 to 15 minutes. The following is a typical daily operating cycle for an intermittent-duty MWI.

1.	Cleanout of ash from previous day	15 to 30 minutes
2.	Preheat of incinerator	30 to 60 minutes
3.	Charging of waste	Varies (up to 16 hours)
4.	Burndown	2 to 4 hours
5.	Cooldown	5 to 8 hours

The burndown step indicates the period of time in the cycle during which no additional waste is charged to the incinerator, and the solid phase combustion of the waste bed is taking place in the primary chamber. The cooldown step, the period during which the MWI is allowed to cool, occurs at the end of the operating cycle, after the burndown step and may or may not use forced air.

A schematic of an intermittent-duty MWI is presented in Figure 5. This unit has a vertically oriented primary chamber followed by a horizontal secondary chamber. Intermittent-duty MWI's are used in hospitals, laboratories and research facilities, nursing homes, and veterinaries.[6-10,16,20,21]

4.3 BATCH-DUTY SYSTEMS

In this type of system, the incinerator is charged with a single "batch" of waste, the waste is combusted, the incinerator is cooled, and the ash residue is removed; the cycle is then repeated. When the unit is loaded, the incinerator is sealed, and the incineration cycle then continues through burndown, cooldown, and ash removal without any additional charging. Depending on the size of the batch MWI, batch units may operate on a 1- or 2-day cycle. Ash is removed either one day or two days after the initial batch charge of waste. In these units, the primary and secondary chambers are often vertically oriented and combined within a single casing. Figure 6 is a schematic of a batch-duty MWI. This unit's combustion chambers are rectangular in design and are contained within the same casing. According to information obtained on batch-duty MWI's, nearly all these units are used at hospitals.[11]

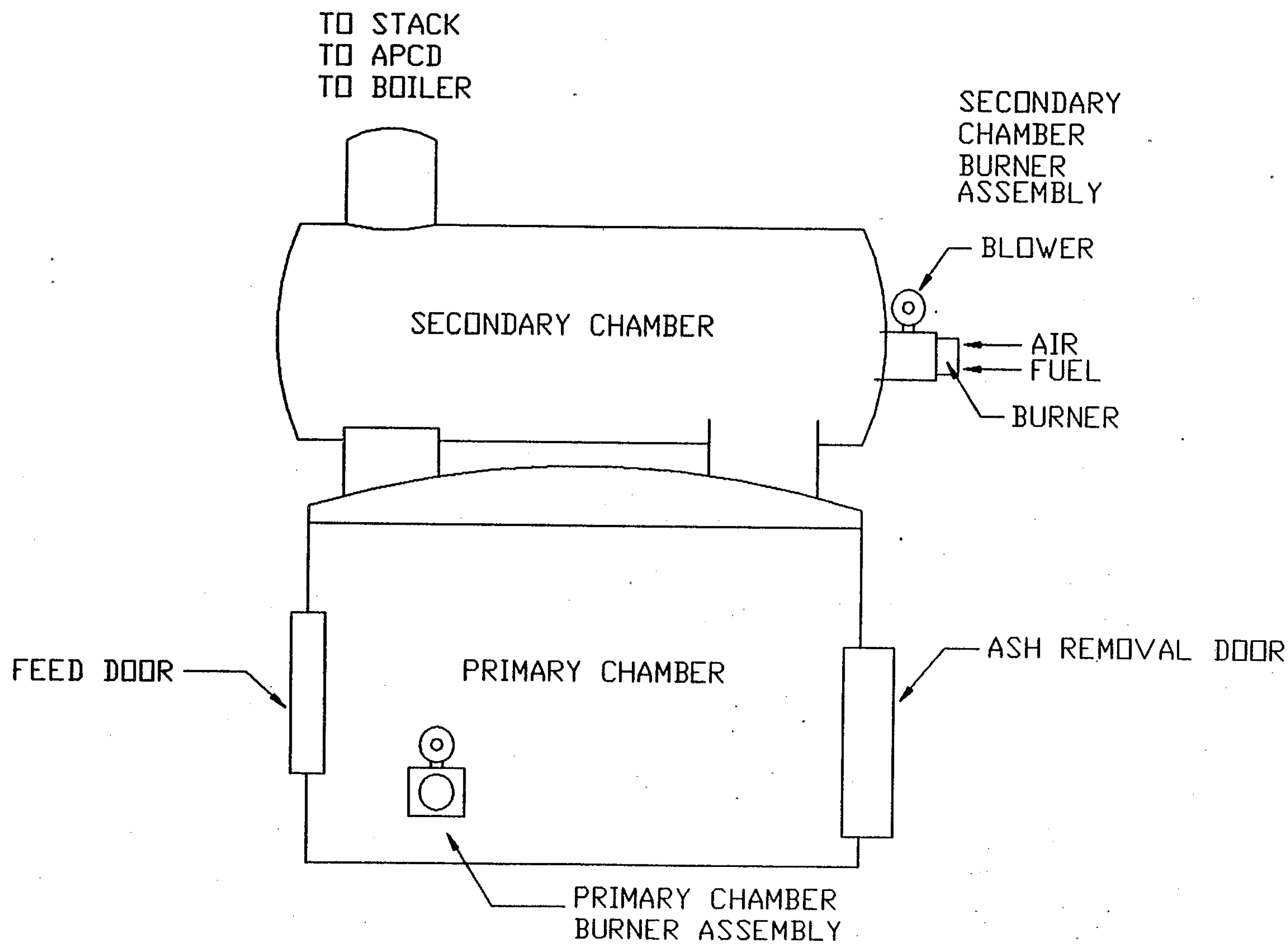

Figure 5. Schematic of an intermittent-duty medical waste incinerator.

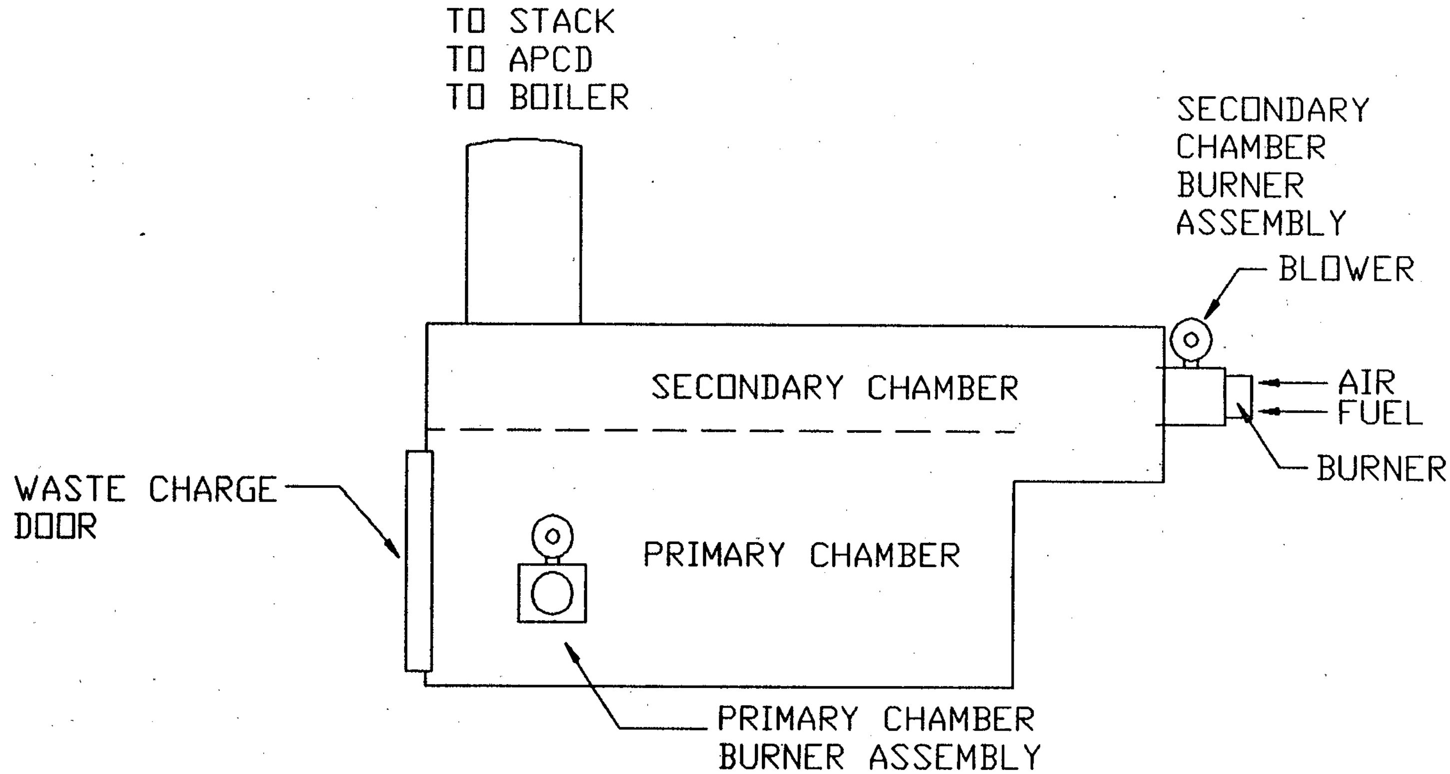

Figure 6. Schematic of a single batch-duty medical waste incinerator.

4.4 PATHOLOGICAL SYSTEMS

Incinerators that burn only pathological wastes operate under excess-air conditions. Excess-air systems are better suited to the incineration of pathological wastes than red bag wastes because the volatile content of pathological waste is low, and, in general, the waste composition is not highly variable. The primary burner provides most of the heat input, and the incinerator operates in a steady, constant mode with a regular, consistent combustion air input and excess-air level.

There is a "dual mode" system that is designed to burn either pathological or nonpathological (general medical) wastes. The dual mode feature is achieved through the use of a switch that controls the operation of the primary chamber burners and the combustion air blowers. In the pathological mode, the primary chamber burner(s) cycle(s) on and off more frequently (or remains on) to accommodate the combustion requirements of the pathological wastes with their lower Btu values. Because of the high moisture content of the pathological wastes, combustion cannot be sustained without using auxiliary fuel. The air supply required to operate the burner and the relatively small amount of combustible gases generated from the waste result in an excess-air condition in the primary chamber. When the unit is operated in the nonpathological mode, the primary burner is turned off because the waste provides its own fuel. In this mode the underfire combustion air levels are set to maintain a substoichiometric condition in the primary chamber.[23]

Pathological MWI's are typically designed for intermittent-duty operation--i.e., these units generally do not have automatic, continuous ash removal systems. Consequently, the incinerator must be shut down at routine intervals (e.g., daily) for ash removal. Pathological systems are used at hospitals, nursing homes, research laboratories, and veterinaries.[16,20,21]

A traditional design that has been used to burn medical waste in the past is the retort hearth system. This system is being used to a limited extent only and can be characterized as an older, existing hospital incinerator. The principal design configuration for the unit is shown in Figure 7.

The system operates under excess-air conditions in the primary and secondary chambers. Combustion of the waste begins in the primary chamber. The waste is dried, ignited, and combusted by heat provided by a primary chamber burner, as well as by hot chamber walls and hearth that are heated by the flue gases. The combustion gases containing the volatiles pass out of the primary chamber through a flame port into a mixing chamber and then pass into the secondary chamber. Secondary air is added through the flame port and mixed with the combustion gas in the mixing chamber. A secondary burner is provided in the mixing chamber to maintain adequate temperatures for complete combustion as the gases pass into and through the secondary combustion chamber. Waste is fed manually or mechanically with single or multiple batches per burn. Ash is removed on a batch basis at the end of the burn. The retort design accommodates capacities under 230 kg/hr (500 lb/hr).[24]

The retort hearth system is best suited to burn pathological wastes. There are drawbacks to using these units to incinerate general medical wastes. Retort units employ overfire combustion air predominantly to promote surface combustion. This excess, overfire air in the primary chamber results in entrainment of fly ash, which can cause excessive PM emissions. Also, because the primary chamber is in an excess-air mode and these older units lack controls, the combustion air levels and the combustion rate within the primary chamber are not easily controlled. Consequently, there may be no assurance of complete combustion when waste composition and volatile content of the waste fluctuate over a wide range. Because true pathological waste does not exhibit the variation in composition found in other medical wastes, and it has a lower volatile content, these units are better suited to incinerate pathological wastes than general hospital wastes.

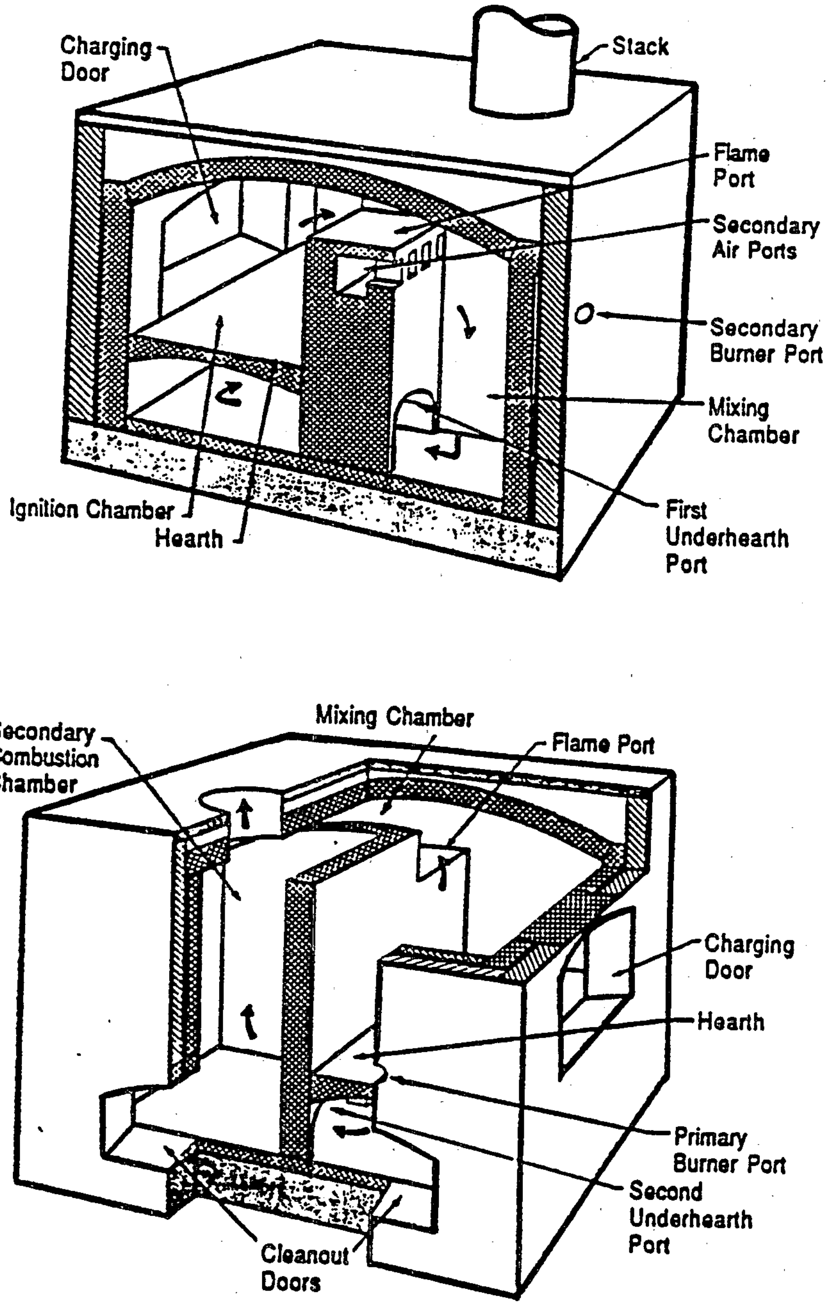

Figure 7. Retort hearth incinerator.

4.5 VARIATIONS IN MWI PROCESS COMPONENTS

Several process components are integral parts of each of the medical waste incineration processes. These include waste feed mechanisms, primary and secondary chamber configurations, solids transfer mechanisms, air supply and handling systems, auxiliary burners, ash removal and handling processes, energy recovery options, and stack bypass systems. The variations in these components among the basic MWI processes are described in this section.

4.5.1 Waste Loading and Feeding Mechanisms

Two basic types of systems are used to charge waste into MWI's: manual and mechanical. Manual charging involves feeding the waste directly into the primary chamber without any mechanical assistance. This charging system is generally used for batch-fed and small, intermittent-duty MWI's, including pathological systems.

Automatic, or mechanical, equipment for charging the waste is used for all continuous-duty models, including rotary kilns, and for most intermittent-duty MWI's with capacities larger than about 90 to 140 kg/hr (200 to 300 lb/hr), including pathological systems. One mechanical system for charging wastes into the MWI is the hopper/ram. Some pathological MWI's are fed through top-loading mechanisms. Veterinary facilities, for instance, sometimes use this method of waste feeding when very large animal carcasses are involved.

Figure 8 is a schematic of a commonly used hopper/ram assembly. In this system, waste is manually placed into a charging hopper, and the hopper cover is closed. A fire door isolating the hopper from the incinerator opens, and the ram moves forward to push the waste into the incinerator. The ram then reverses to a location behind the fire door. After the fire door closes, the ram retracts to the starting position and is ready to accept another charge. A water spray is typically provided to quench the ram face as it retracts. The entire charging sequence is usually timed and automatically controlled. The cycle can be started manually by the operator, or, in some

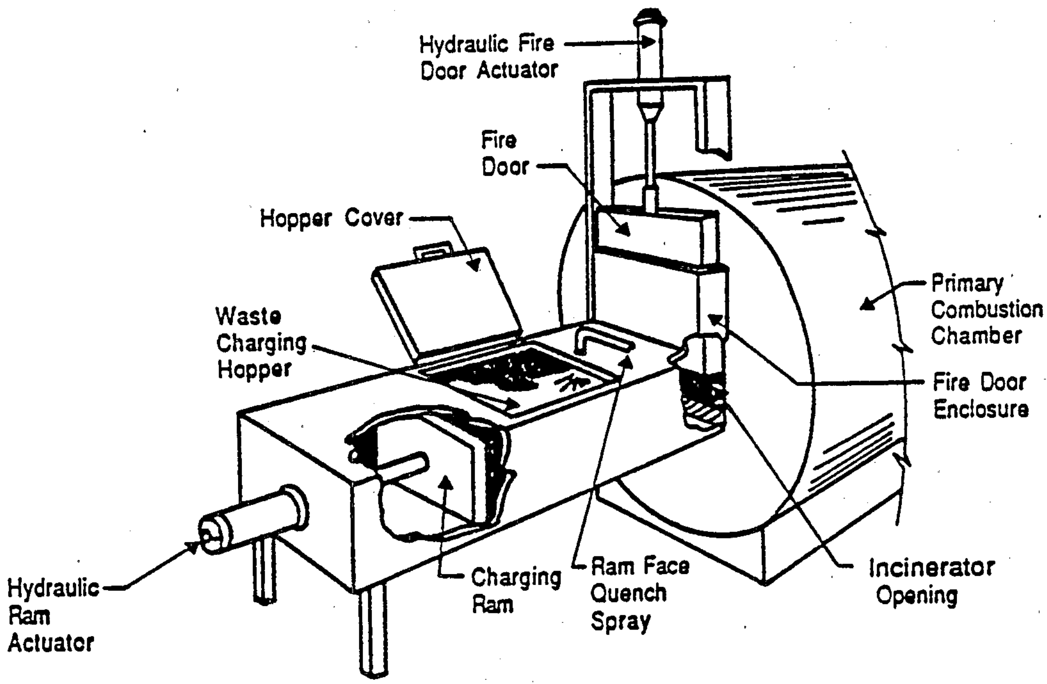

Figure 8. Hopper/ram mechanical waste feed system.[25]

systems, the cycle starts automatically on a predetermined basis. The charging frequency can be changed by adjusting the length of time between charges in the automatic sequence. The size of the hopper limits the volume of waste that can be fed in each charge; therefore, the size of the charge may be decreased by not filling the hopper to capacity.

In some facilities, mechanical loading equipment is used to deposit the waste material into the waste feeding systems. Waste containers may be lifted and dumped into the MWI charging hopper with no handling of the waste by the MWI operator. In fully automated, computer-controlled systems, the waste container is conveyed to a weighing platform. After the weight of the waste is recorded, the container is automatically emptied into the feed chute. Controlled amounts of wastes are conveyed from the end of the feed chute to the ram hopper. The door isolating the hopper from the primary chamber is automatically opened at preset intervals, and the wastes are fed into the chamber. During the early stages of the automatic cycle, prior to charging, the wastes may be subjected to screening sensors to check for radioactivity levels in the waste.

4.5.2 Primary Chamber Variations

4.5.2.1 Primary Chamber Configuration. The sizes and shapes of the primary chambers for each of the basic MWI systems vary. The primary chamber of the continuous-duty, rotary kiln is cylindrical in shape and is slightly inclined from the horizontal plane. The primary chamber on other MWI's may be cylindrical, square, or rectangular in shape and may be vertically or horizontally oriented. In all units, the chamber size is designed for a specified volume of waste with a particular Btu content. In intermittent-duty systems, the size of the primary chamber determines the total amount of waste that can be loaded and the amount of ash that can be accumulated without restricting the overall process. For continuous-duty units, the size of the primary chamber will impact the rate of charging and the quality of burnout. Some continuous-duty systems are designed with larger primary chambers to accommodate longer solids retention times and more complete combustion of the fixed carbon.

4.5.2.2 Solids Transfer Systems in the Primary Chamber. Small MWI's utilizing manual charging and some small MWI's with mechanical charging systems have no means of solids transfer, or agitation. Waste is charged into the unit until the ash builds up to the point where no more waste can safely be charged. Many MWI's with a single hearth and a waste feed charge ram use the ram to move burning waste and ash across the hearth. As a new load is pushed into the primary chamber, the previous load is pushed forward. Each subsequent load has the same effect of moving the waste across the hearth. Some single-hearth systems also may have an ash ram located below the charge ram at the hearth level. This ram is used both to stoke the burning waste (i.e., agitate the waste bed to expose all surfaces to heat and air) and to move the waste and ash toward the discharge end of the chamber. Stoking may be automatic or manual. Figure 9 is a schematic of a single-hearth, intermittent-duty MWI equipped with an ash ram.

Large, continuous-duty MWI's often have multiple hearths arranged in a stepped fashion. This type of system is shown in Figure 3. The face of each step is that of an internal ash transfer ram. These internal rams are automatically controlled to operate in sequence to clear off space on each step for the ash pushed off from the previous (higher) step. The ash discharge ram operates first by pushing ash into the ash pit (dry or containing water as a quench). Then the ash transfer ram for the step behind the ash discharge ram pushes ash from its step onto the ash discharge step. The process of clearing space is repeated back to the waste feed ram, which pushes waste onto the top step, thereby pushing the previous charges onto the space cleared by the ash transfer ram for the next step. This system causes agitation of the waste, as the ash is moved from hearth to hearth, thereby improving solid-phase combustion.

At least one manufacturer provides a stoker to move waste through the primary chamber.[26] The stoker consists of a double

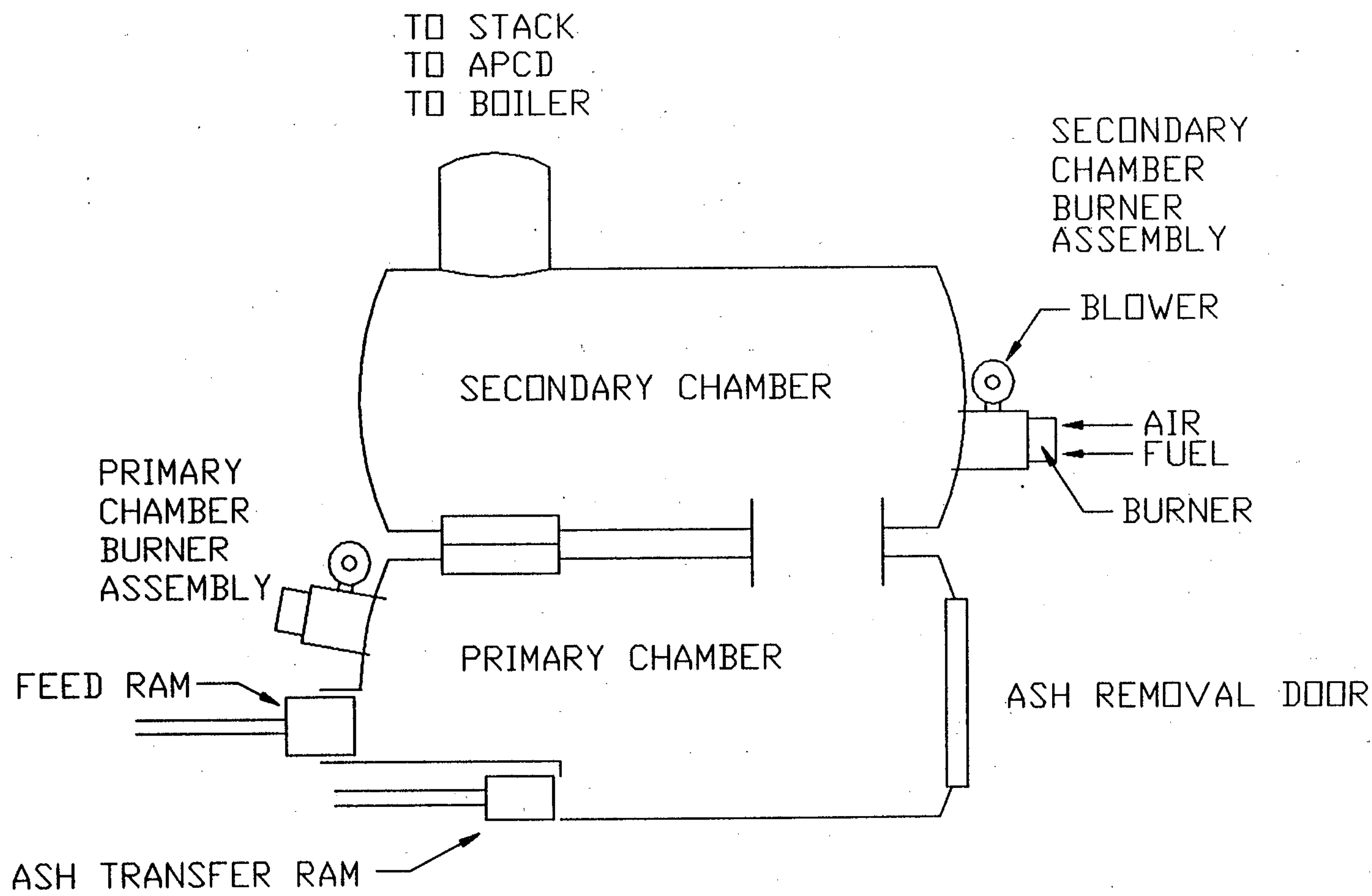

Figure 9. Schematic of a single hearth, intermittent-duty incinerator equipped with an ash ram.

reciprocating grate that mixes the waste and constantly exposes it to heat and oxygen. The stoker comprises a series of overlapping, alternating stationary and movable grates. While a movable grate positioned over a stationary grate is advancing, a movable grate positioned under that stationary grate retracts to form a step 15 inches high. This action causes waste to fall and mix as it moves across the length of the stoker.

One manufacturer offers a Pulse Hearth™ in the primary chamber.[27] The entire floor of the chamber consists of the pulse hearth, a refractory-lined, stepped hearth suspended on the outside of the primary chamber at four points by steel cables. The hearth is pulsed forward and upward by an external pneumatic system. This pulsing action moves the waste forward from the charge end of the primary chamber to the ash removal end.

Rotary kilns mix and transfer solids through the rotation of the cylindrical primary chamber, which is slightly inclined from the horizontal plane. The solids are tumbled within the kiln and slowly move down the incline toward the discharge end of the chamber.

4.5.2.3 Auxiliary Burners. In the primary chamber, with the exception of pathological MWI's, auxiliary burners are used only to ignite the waste. Once the waste has started to burn, the primary chamber auxiliary burners are rarely, if ever, needed again. Typically, the setpoint for these burners is about 430°C (800°F), so that if the chamber temperature falls below the setpoint, the burner comes on. The temperatures in the primary chamber are typically above 538°C (1000°F), assuming the MWI is being properly charged with waste. In pathological MWI's, the auxiliary burner usually stays on because the heating value of the pathological waste (2,330 kJ/g [1,000 Btu/lb]) is not high enough to sustain combustion and, therefore, requires additional heat from the burner for combustion.

4.5.2.4 Air Supply and Handling. Air is supplied to the primary chambers of MWI's primarily as underfire air through air ports by a single forced-draft blower. The air supply can be reduced or increased by adjusting control dampers or by adjusting the speed of the fan. In fixed-hearth systems, the air ports typically consist of small holes, arranged at regular intervals, built into the floor of the hearth. If the hearth is rectangular or square, the ports typically will be arranged in a regular grid equally spaced or in a series of rows across the hearth. If the hearth is circular, the ports may be arranged in concentric circles or, if the unit is very small, in one circle.

Several methods are currently in use on MWI's to control the amount of combustion air to the primary chamber so as to maintain substoichiometric oxygen levels. Because of the relationship between the stoichiometry of the combustion air and temperature, temperature can be used as an indicator of combustion air levels in the chamber. Maximum combustion temperatures are attained at stoichiometric conditions. As the amount of excess air increases above the stoichiometric point, the combustion temperature decreases because of the energy needed to heat the combustion air. However, while in the substoichiometric region, increasing the amount of air towards the stoichiometric point increases temperature as more oxygen becomes available for combustion. A graphical representation of the relationship between combustion temperature and combustion air levels is presented in Figure 10.

In many systems, the primary chamber air systems are automatically, continuously controlled by regulating (or "modulating") the amount of air supplied in order to maintain the desired combustion chamber temperatures, regardless of the variations in waste characteristics (e.g., moisture content, heating value). One or more thermocouples measure the temperature in the primary chamber. If the temperature is above the setpoint, the control feedback loop automatically adjusts (closes) the damper, limiting the air supply into the chamber, thereby reducing the rate of combustion and the thermal heat output. Conversely, if the temperature is below the setpoint, the damper is automatically adjusted (opened) to allow more air in to increase the temperature. In other systems, particularly batch or intermittent-duty systems, the combustion air level control is simplified and may consist of the automatic switching

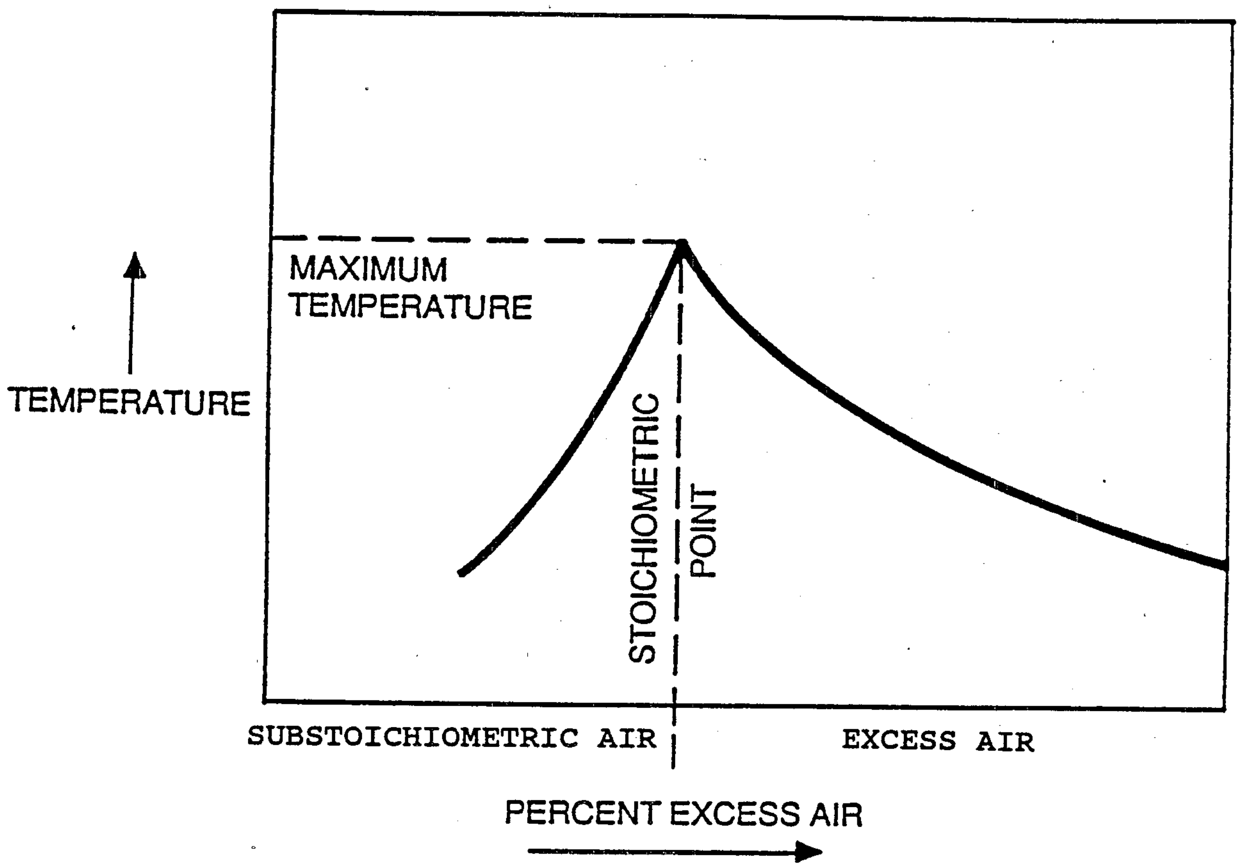

Figure 10. Relationship between temperature and combustion air levels.

of the combustion air rate from a high to a low setting (adjusting damper position or blower speed) when temperature setpoints are reached or at preset time intervals.

In rotary kilns, forced draft is used to introduce combustion air into the kiln through the fixed endplate. Because of the physical orientation of the kiln, the air enters the chamber as overfire air. The air supply is controlled in the same manner as in the intermittent- or continuous-duty systems described above.

Pathological MWI's are designed for surface combustion of the waste, which is achieved predominantly by using a burner and limiting the amount of "underfire air" in the primary chamber. In some systems, combustion air ports may be built into the side walls of the chamber. While in all pathological units combustion air comes in through the burner flame port(s), in some units additional excess air ("underfire air") may be introduced through the side wall ports. When burning pathological waste, both air and direct heat are required--first to vaporize the moisture in the layer of tissue and, subsequently, to burn the dried layer. This combustion occurs layer by layer, and, because of its low heating value (2,330 kJ/g [1,000 Btu/lb]), pathological waste requires direct contact by the flame of the primary chamber auxiliary fuel burners.

4.5.2.5 Other Features. In some MWI systems, the primary chamber is equipped with a thermocouple to govern the activation of a water spray when the chamber temperature exceeds a preset value. Some systems use steam injection through underfire air ports to keep the temperature of the ash bed down and to facilitate burnout of fixed carbon in the ash bed. Because steam injection helps to maintain ash bed temperatures below the melting and fusion points of most combustibles, this procedure also helps to prevent clinker buildup and slagging that could plug the underfire air ports.[28]

4.5.3 Secondary Chamber Variations

4.5.3.1 Secondary Chamber Configuration. There are several variations in the configuration of secondary chambers. As with primary chambers, secondary chambers may be cylindrical, square, or rectangular, and they may be vertically or horizontally oriented. Although the secondary chamber of the rotary kiln is sometimes oriented horizontally, it is often vertically oriented to reduce carryover of entrained particulates. The chamber is usually cylindrical, but it can also have a box-like shape.

All secondary chambers must have adequate volume to accept and completely oxidize all the volatile gases generated in the primary chamber and to maintain sufficient combustion air so that excess oxygen is available.

The volume of the secondary chamber is the key parameter influencing the residence time of the combustion gases. If the incinerator is designed for a specified residence time and volumetric flow rate, the secondary chamber is sized accordingly. Some MWI's have a tertiary chamber that serves to increase the residence time of the combustion gases at high temperatures. Thus, the tertiary chamber can be regarded as an extended secondary chamber.

4.5.3.2 Auxiliary Burners. The auxiliary fuel burner(s) are designed to maintain setpoint temperatures, and they operate in conjunction with modulating air controls to maintain these temperatures in the secondary chamber. The burners either modulate on and off or are equipped with high and low settings. In some units, fully modulating burners are used.

4.5.3.3 Air Supply and Handling. All secondary chambers operate in an excess-air mode. The excess air typically is introduced into the secondary chamber through a flame port at right angles (or tangentially) to the incoming combustion gases from the primary chamber, thereby creating a turbulent zone that promotes mixing of the air and combustion gases. In some applications, combustion air is supplied to the secondary chamber in multiple locations.

Typically, air is supplied to the secondary chamber through a port by a forced-draft blower. This air supply is controlled as described for primary chambers in Section 4.5.2.4. Some systems, particularly batch- or intermittent-duty units, simply control the combustion air level with automatic switching of the combustion air rate from high to low to rectify deviations from the setpoints.

As discussed in Section 4.5.2.4, the relationship between combustion air stoichiometry and temperature is such that temperature can be used as a control to maintain the appropriate combustion air level. A control feedback loop, based on temperature measured by the secondary chamber thermocouple(s), can be used. This system operates in a manner similar to that described for the primary chamber air supply (see Section 4.5.2.4). However, because the secondary chamber has an excess-air environment, when the temperature is too high (above the setpoint), the damper is opened to admit more air, and when it is too low (below the setpoint), the damper is shut to limit the air supply.

4.5.4 Ash Removal and Handling

Ash removal and handling systems may be classified as continuous or periodic. Continuous ash removal systems are used on continuous-duty MWI's, including rotary kiln MWI's. These continuous ash removal systems may be dry or wet processes. In either system, ash falls off the end of the hearth or kiln into an ash discharge chute. In the dry system, the ash discharges directly into an ash container positioned within an air-sealed chamber. When the container is full, it is removed from the chamber and replaced with an empty ash container. In the wet process, the ash is discharged into a water pit. The water bath quenches the ash, and it also forms an air seal with the incinerator. A mechanical device, either a rake or a conveyor, removes the ash from the quench pit intermittently or continuously. The excess water is allowed to drain from the ash as it is removed from the pit, and the wetted ash is discharged into a collection container.

Manual ash removal typically involves removing ash by raking and shoveling the ash into metal containers. Generally, this removal occurs the morning after the burn, once the MWI has cooled, and it is safe to remove the ash. Manual ash removal is practiced on almost all MWI's without a continuous ash removal system. Some systems include an ash ram that pushes some of the ash from the incinerator. However, manual removal of the remaining ash is still required in these units.

4.5.5 Energy Recovery

The heat generated during incineration can be recovered and used to generate hot water or steam. The facilities that most often recover heat from the stack gases are those with larger MWI systems. Most often, a waste heat recovery boiler is installed and used to generate steam and/or hot water. However, heat exchangers are also used to recover heat.

Incinerator manufacturers often provide waste heat boilers as an option with their incineration units. Figure 11 is a schematic of an MWI with a waste heat recovery boiler. The combustion gases from the incinerator pass through the waste heat boiler prior to being emitted to the atmosphere. When a waste heat boiler is used, an induced draft fan must be added to move air through the system.

Heat exchangers are sometimes used to cool the hot secondary chamber exhaust gases before they enter an air pollution control system. These systems are used for situations in which space limitations and/or economics prevent the installation of a waste heat boiler for energy-recovery purposes.

4.5.6 Bypass Stack

An emergency bypass stack is typically added to an MWI when a waste heat boiler (or an air pollution control system) is included as part of the system. Because a waste heat boiler causes a resistance (blockage to airflow) in the system if the induced draft fan stops, pressure can build up in the incinerator if the hot gases cannot escape quickly enough. The bypass stack is added to allow a route for the hot gases to escape should the fan fail. In other words, it allows the incinerator to go back

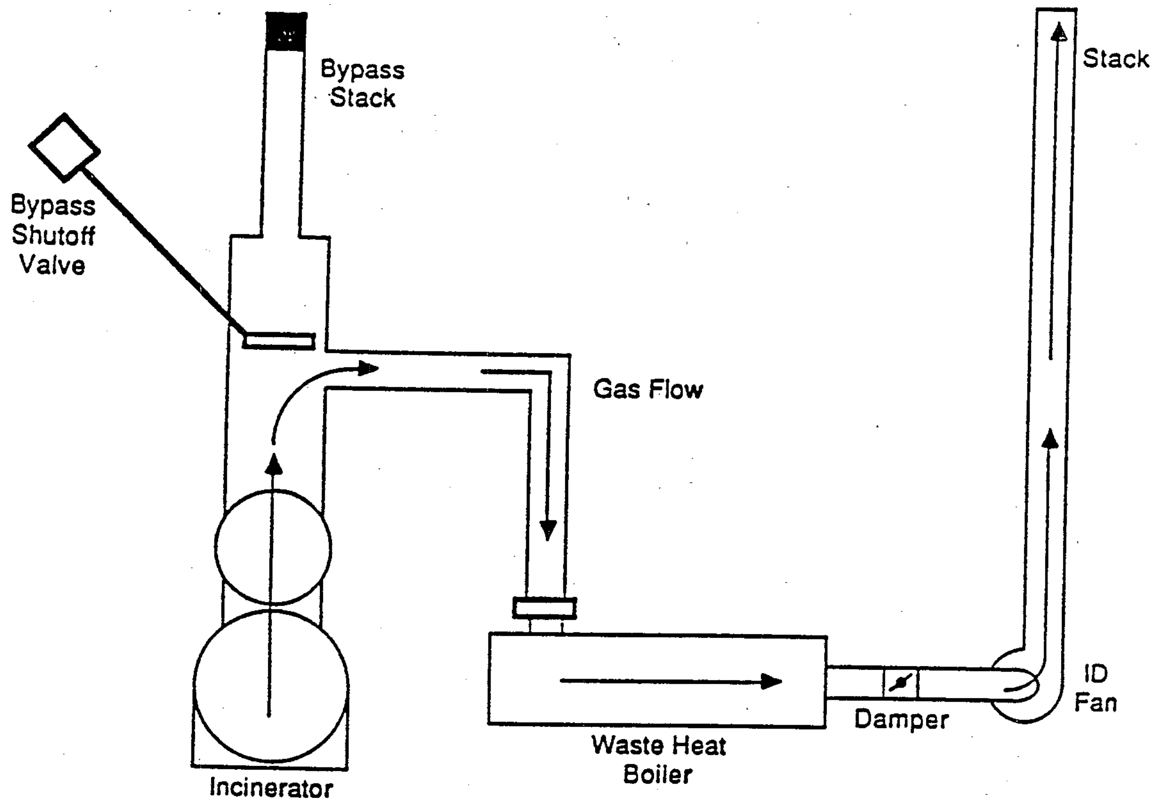

Figure 11. MWI with a waste heat recovery boiler and bypass stack.

to a natural draft system. The bypass stack is also used in cases where the boiler must be bypassed for safety reasons or operational upset conditions (e.g., loss of water flow to the boiler, causing heat buildup). Another purpose of the bypass stack is to protect the air pollution control device when a system malfunction could result in damage to the device. The combustion gases can be routed through the bypass stack to avoid contact with the control device in these cases.

The bypass stack usually contains a damper valve to control direction of the gas flow or a cap on top of the stack to prevent air from being pulled into the system when the fan is operating. If the bypass must be activated, the damper or cap is opened automatically by some type of sensor; for example, if the fan speed falls below a preset level, the bypass opens. Figure 11, the schematic of an MWI with a waste heat boiler, illustrates a typical position of the bypass stack in the duct between the outlet of the secondary chamber and the waste heat boiler.

5.0 CHARACTERIZATION OF EMISSIONS

The pollutants emitted from MWI's include PM; metals; organics, including CDD's and CDF's; CO; and the acid gases HCl, SO_2, and NO_x. These pollutants exist in the waste feed material or are formed in the combustion process, but the primary point of emissions release is the combustion stack (i.e., combustion gases from the secondary chamber). Because of the high temperatures typically encountered and because of the turbulent conditions and adequate residence time in MWI's, pathogens are expected to be completely destroyed in the combustion process. In addition to stack emissions, there are potential sources of fugitive emissions of these pollutants in the MWI process. Section 5.1 discusses the generation and emission of the pollutants from the combustion process and from fugitive emission sources. The various factors that affect emissions are discussed in Section 5.2. Section 5.3 presents emission test data. Section 5.4 presents existing emission limits (based on existing requirements for MWI's).

5.1 SOURCES OF EMISSIONS

5.1.1 Combustion Stack

Pollutants in the combustion gas stream from the secondary chamber are emitted with the gases through the stack. The pollutants that are likely to be emitted through the stack as a result of the combustion process are discussed in this section.

There are two types of PM: inerts (ash) and products of incomplete combustion (soot). The noncombustible portion of the waste feed represents those materials that will not burn under any conditions in the incinerator. Emissions of noncombustible materials result from the suspension or entrainment of ash by the combustion air added to the primary chamber of the incinerator. The more air added, the more likely that noncombustibles will become entrained in the primary chamber and be emitted with the flue gas. While entrainment is the primary mechanism for ash PM emissions, soot formation also plays a role in PM emissions. Soot, which is primarily elemental carbon, is a product of incomplete combustion.

Metal emissions depend upon the characteristics of the feed material. Metals may exist in the waste as parts of discarded instruments or utensils; in plastics, paper, pigments, and inks; or as discarded heavy metals used in laboratories. Trace metals present in medical waste materials include lead, cadmium, mercury, chromium, antimony, arsenic, barium, beryllium, nickel, silver, and thallium. Emissions of these metals are generated during the combustion process as a consequence of entrainment or volatilization. Unlike organic constituents, metals are not "destroyed" during the combustion process. Rather, they are distributed or partitioned among the incinerator effluent streams. As a result of this partitioning effect, metal constituents can leave the primary chamber as bottom ash or in the combustion gas. The relative distribution of the metals between these streams is based on such factors as the chemical form of the metals charged to the combustor, the localized reaction atmosphere in the primary chamber, localized chamber temperatures, and localized airflows. Many metals are converted to oxides or chlorides during combustion and are emitted primarily as entrained submicron- to micron-sized particles. Metals that volatilize at primary combustion chamber temperatures may exit the system as a gaseous component of the air stream or may selectively condense on small particles in the incinerator combustion gas. Of the metals known to be present in medical waste ash, the following are generally thought to exhibit such fine-particle enrichment: arsenic, cadmium, chromium, nickel, lead, and antimony.[29]

Complete combustion of organic materials results in the formation of water (H_2O) and carbon dioxide (CO_2). The concentration of CO in the incinerator exhaust gas stream is an indicator of the combustion efficiency of the unit and is primarily related to gas-phase combustion conditions in the secondary chamber. Carbon monoxide is an intermediate product of the reaction between carbonaceous fuels and oxygen. Combustion conditions that result in incomplete combustion produce elevated levels of CO, as well as PM and organics.

Inadequate gas-phase combustion conditions in the secondary chamber also favor increased organic emissions. While these emissions can originate directly from the vaporization of organic material present in the waste, new organic species can be formed during combustion as a result of the complex chemical reactions occurring during the combustion process. When chlorine is available (for example, from PVC or other chlorinated plastics), the organics generated can include highly toxic chlorinated organics, such as CDD's and CDF's.

Nitrogen enters the MWI as a constituent of auxiliary fuels, as the chemical compounds found in the waste material, and as N_2 in the combustion air. Nitrogen oxides are primarily formed from the reaction of the N_2 in the combustion air with oxygen or oxygenated species, and the resultant product is referred to as thermal NO_x.

The principal acid gas from MWI's is HCl. The determining factor in HCl formation and emissions is the availability of chlorine in the feed material. In the presence of available hydrogen, as would occur in medical waste materials with high organic contents, most of the available chlorine is converted to HCl; however, low levels of elemental chlorine do exist in the exhaust gas. Most of the sulfur in the medical wastes is converted to SO_2 during combustion, regardless of incinerator design or operation.

5.1.2 Fugitive Emissions

There are three types of fugitive emissions: combustion gases (including unburned volatile materials), PM, and pathogens. Emissions of combustion gases can occur when charging wastes into the incinerator and from leakage through improperly sealed doors. Fugitive emissions of combustion gases may also accumulate in poorly ventilated areas around the primary chamber. Fugitive emissions of PM can occur when handling incinerator ash and when handling and transporting the residue from air pollution control devices (e.g., fabric filters). A potential source of fugitive pathogen emissions is handling unburned medical waste. However, careful handling of medical waste, not overfilling the plastic bags containing the waste, the use of containers on wheels with structural integrity to transport waste, and the use of automated waste charging systems should reduce fugitive pathogen emissions to negligible levels.

Fugitive emissions from the operation of an MWI are usually the result of poor design, operation, or maintenance. Manually fed MWI's are considered to be poor designs from an emissions standpoint because the charging door must be opened to the atmosphere during charging. The "air-lock" feature of ram-fed MWI's helps to alleviate the fugitive emissions problem by eliminating the need to have the primary chamber open directly to the atmosphere. Proper precautions when handling waste and ash reduce the potential for fugitive emissions. For example, wetting or covering the ash or control device catch before transporting can minimize the possibility of windblown fugitives. Adequate maintenance of door seals, flanges, and auxiliary burner housings also help reduce the possibility of leakage of gaseous emissions to the atmosphere.

5.2 FACTORS THAT AFFECT EMISSIONS

The formation, generation, and emissions of all of the pollutants discussed in Section 5.1 depend upon either the availability of certain materials in the waste feed (i.e., waste characteristics) or on the efficiency of the combustion process. Factors involved in combustion process efficiency include MWI system design, operating parameters, startup and shutdown procedures, proper training of the operators, and how well the system has been maintained. These factors are discussed in this section.

5.2.1 Waste Characteristics

As discussed in Section 3.1, medical waste varies considerably in composition and, therefore, in chemical and physical characteristics. Waste characteristics can affect combustion efficiency and pollutant formation. The chemical composition of the waste materials is an important factor in generating emissions. The presence of metals, halogenated materials, and sulfur in the waste feed increases the potential for emissions of PM, metals, organics, SO_2, and HCl. Medical waste incinerators are designed to operate under certain conditions, including specific physical attributes of the waste feed. These attributes (e.g., heat content, moisture content, and bulk density) influence MWI feed rates, temperatures, air flow conditions, and residence times - all of which affect emissions of PM, metals, organics, CO, and NO_x. If the physical attributes of the waste vary from the design specifications, then the potential for emissions can be affected.

5.2.2 Incinerator Operating Characteristics

Complete combustion of combustible material requires proper control of feed charging procedures, temperatures, excess air, turbulence, mixing, and residence time. Because of the variability of the physical properties of medical wastes, incinerator operating parameters need to be adjusted to match the composition of the waste in order to maximize combustion efficiency. In general, increased temperatures and excess air rates, good mixing, and longer residence times in the secondary chamber result in improved combustion efficiency and lower emissions of PM, toxic organics, and CO. However, incinerator operating parameters have little or no effect on emissions of HCl and SO_2. (It should be noted that although the MWI operator can control feed charging, temperatures, and excess air rates, an operator has only indirect control over turbulence, mixing, and residence times.)

Waste handling and charging procedures may account, in part, for fugitive emission sources. For example, emptying medical waste from its container into the incinerator (instead of leaving it in a disposable container that can be loaded into the incinerator) may result in spillage. Waste charging activities often include segregating wastes and, therefore, can influence the composition of the feed material, incinerator operating conditions, and subsequent stack and fugitive emission characteristics. Systems with automatic feeders usually have controls to prevent overfeeding, but in manually fed and batch units, overfeeding can occur. Overfeeding the primary chamber can result in blockage of the air port to the secondary chamber, premature ignition of the waste, and excessive emissions because the rapid generation of volatiles can exceed the capacity of the secondary chamber. Feed volumes and frequency (determined by the waste composition) are responsible for variations in chamber temperatures, which, in turn, affect combustion efficiency and emission profiles.

Temperatures in the primary chamber must be high enough to sustain combustion and to generate sufficient volatile combustion gases. Inadequate temperatures may result in increased emissions of PM, CO, and organics. Temperature also plays a role in the volatilization of metals and the subsequent emission of these as gaseous components of the air stream. Temperatures must be high enough to destroy pathogens and combust fixed carbon. Adjustments that increase combustion temperatures may, however, increase emissions of NO_x and trace metals.

The quantity and distribution of combustion air is another operating characteristic that affects emissions. The rate of entrainment of ash in the combustion air added to the primary chamber is likely to increase as more air is added, resulting in a higher rate of PM-entrained trace metal emissions. On the other hand, low excess-air conditions in the secondary chamber can result in soot emissions. Oxygen concentration and the degree of mixing of the air with the fuel has a direct impact on CO formation. Emissions of organics increase with poor air distribution in the waste bed and inadequate combustion air conditions in the secondary chamber. As airflow rates increase, the residence times in the secondary chamber decrease.

Residence times in the secondary chamber have an impact on emissions. Organic materials present in the medical waste material must be exposed to optimum temperatures long enough to ensure their complete combustion. Emissions of organic species formed as by-products of combustion (e.g., CDD's and CDF's) are affected by the residence times in the secondary chamber if they have already been formed.

5.2.3 System Design

Manual control of air modulation and primary and secondary chamber burner modulation does not always result in effective control of the combustion process. Because proper combustion air rate and chamber temperatures are critical to combustion efficiency, the inability to closely monitor and control these key parameters can result in higher pollutant emissions.

Residence time requirements establish constraints on the size and shape of the secondary chamber. The secondary chamber is sized to provide the desired residence time based on the flow rate for which the unit is designed. Using a unit with a secondary chamber whose volume is insufficient to accept and completely oxidize all volatile gases generated in the primary chamber can contribute to pollutant emissions. As discussed in Section 5.2.2, residence times in the secondary chamber play a critical role in the reduction of emissions of PM, CO, and organics.

For MWI's, the distribution of combustion air between the primary and secondary chambers is a key operating consideration.

Air distribution affects the amount of oxygen that is available for reaction in each chamber and, therefore, influences combustion efficiency and subsequent air emissions.

When MWI's are not designed to include effective mechanisms for promoting the mixing of solids in the primary chamber, burnout may not be complete. Mechanical turbulence of the bed may be used to expose all of the solid waste to oxygen, thereby enhancing the degree of burnout. Various hearth designs and ram systems are used to accomplish mechanical turbulence. While effective mixing of solids maximizes combustion efficiency, increased emissions of PM may occur as a result of the turbulence.

The size of burners specified for MWI's also affects emissions. The burners provide the heat required to initially ignite the waste, to sustain combustion of the charged waste, and to complete the vapor-phase combustion. Burners are designed to provide a rated heat input expressed in kJ/hr (Btu/hr). Specifying improper burner sizes can result in incomplete combustion and a consequent increase in emissions.

For MWI systems that are designed without automated ash removal and handling systems, the repeated manual opening and closing of the ash cleanout door and tightening of the door clamps may damage the seal gasket, which can allow infiltration of outside air around the door face. This infiltration may result in decreased combustion efficiency and a subsequent increase in emissions.

5.2.4 Startup and Shutdown Procedures

Startup and shutdown of a MWI involves special procedures that vary depending upon the type of unit. Included in the startup procedures are charging the waste, preheating the secondary chamber, and activating the combustion air blowers. Startup procedures for batch-feed units also include removing the ash from the previous cycle and sealing the charge door. Shutdown of a continuous-duty incinerator involves stopping the charging process and maintaining temperatures in the secondary chamber until the remaining waste burns down to ash and is discharged from the system. For intermittent-duty and batch-feed units, shutdown procedures include increasing the combustion air level in the primary chamber and maintaining the temperature in that chamber at a minimum setting for a predetermined length of time to ensure that the fixed carbon is combusted. In addition, the secondary chamber temperature is maintained at a level sufficient to complete the vapor phase combustion of material exiting the primary chamber. When this burndown period is complete, the cooldown period is initiated. If not conducted properly, any of these startup or shutdown procedures may result in increased emissions. These emissions could occur as a direct result of the procedure (e.g., removing ash or charging the waste) or as an indirect result, i.e., reduced combustion efficiency.

5.2.5 Operator Training

The success of incineration as a technique for treating medical waste depends on the proper operation of the incinerator. The operator is in control of many of the factors that affect the performance of an MWI, including: (1) waste charging procedures, (2) incinerator startup and shutdown, (3) monitoring and adjusting operating parameters, and (4) ash handling. An operator without adequate training will probably not be sufficiently aware of the relationship between MWI process components and potential air pollution problems to be able to avoid or minimize these problems.

5.2.6 Preventive Maintenance

Without an effective MWI preventive maintenance program, the frequency of inefficient operation conditions, upset situations, and air pollution episodes increases. Observations made during the EPA emissions testing program illustrate the importance of an effective maintenance program. At one facility, the lack of routine maintenance was reflected in inoperative burners, malfunctioning relays, clogged air ports, cross-wired lead wires in the control box, improperly wired thermocouple assemblies with chipped insulation, and several other conditions that resulted in a poorly operated unit. These conditions contributed to the unit's severely limited burning capacity, very poor burnout of waste, and a greater amount of visible emissions than would normally be expected. At another site, maintenance-related problems included malfunctioning hydraulic cylinders and pumps in the automatic ram system and a problem with the switch on the gate in that system. These problems caused the gate to remain open after the ram cycle was completed and, because of the disruption of airflow, increased visible stack emissions. Problems at a third site involved a disabled primary chamber underfire control damper, a nonfunctional control arm on a secondary chamber air blower modulation damper, and seals in need of replacement. Additional maintenance-related conditions included an improperly programmed process control loop, which caused the hopper lid to open too soon after the charging ram retracted. Each of these circumstances contributed to substandard operating conditions and, therefore, resulted in increased emissions.

5.3 EMISSION RATES

During the development of background information on MWI's, numerous emissions test reports and test report summaries were obtained. Approximately 25 of these reports and report summaries provide emission test data. For test data to be most useful, certain information on the MWI process design and operating conditions, as well as details on the test methods used for testing, must also be available. In almost every case, the test reports obtained were incomplete, in that information on the design and operation of the MWI during testing was not provided. Table 5 presents the post-combustion emission rates (i.e., in the stack for facilities without an pollution control device and between the incinerator and air pollution control device at other sites) for eight tests that were performed at seven test sites as part of EPA's MWI test program. The emission rates are presented in three different formats: Table 5a is presented in metric units; Table 5b is presented in English units; and Table 5c is presented in pounds of emissions per year.

TABLE 5a. POST-COMBUSTION EMISSION RATES FOR MEDICAL WASTE INCINERATORS
(Metric Units)

Pollutant, at 7 percent O_2	A	B	C	D	E	F	G	H
PM, mg/dscm	358	593	1,030	227	230	105	35	1,125
CO, ppmv	297	529	1,213	14	26	108	10	11.7
2,3,7,8-TCDD, ng/dscm	3.58	15.3	29.4	0.2	0.27	0.85	0.46	0.02
Total CDD, ng/dscm	717	2,843	5,050	94	319	226	137	24
2,3,7,8-TCDF, ng/dscm	13.8	66.9	80.1	0.91	0.88	4.2	2.3	0.633
Total CDF, ng/dscm	3,741	14,598	19,700	343	1,133	520	487	171
Total CDD + CDF, ng/dscm	4,458	17,440	24,700	437	1,451	745	623	195
HCl, ppmv	1,308	1,470	1,537	1,714	NM	117	198	950
SO_2, ppmv	23	13	42.8	8	1.5	114	17	14
NO_x, ppmv	83	86	182	180	72	354	85	84
Antimony, µg/dscm	1,578	1,089	612	NM	NM	101	63	662
Arsenic, µg/dscm	17.9	13.1	11.1	14.4	28	63.6	2.6	10.6
Barium, µg/dscm	384.7	143.8	86.2	NM	NM	26.8	43.5	2,825
Beryllium, µg/dscm	0.22	0.12	1.11	NM	NM	0.21	0.10	1.56
Cadmium, µg/dscm	416	261	55	298	385	140	118	482
Chromium, µg/dscm	31.3	41.5	36.3	19	53.0	108	19.7	141
Iron, µg/dscm	NM	NM	NM	434	1,497	NM	NM	NM
Lead, µg/dscm	5,420	2,774	1,878	4,643	3,317	485	3,174	4,000
Manganese, µg/dscm	NM	NM	NM	103	191	NM	NM	NM
Mercury, µg/dscm	1,111	861	7.96	6,024	366	121	2,326	2,609
Nickel, µg/dscm	10	32	25.8	10	39	164	11	114
Silver, µg/dscm	12.2	7.4	14.2	NM	NM	3.4	2.8	3.7
Thallium, µg/dscm	198	3.3	5.4	NM	NM	5.8	1.0	16.1

NM = Not Measured

A: 140 Kg/hr; general medical waste; intermittent, ram-fed; 1-sec residence time in secondary (average of nine test runs).
B: 140 Kg/hr; general medical waste; intermittent, ram-fed; 0.33-sec residence time in secondary (average of nine test runs).
C: 110 Kg/hr; general medical waste; intermittent, manually-fed; 0.2-sec residence time in secondary (average of three test runs).
D: 330 Kg/hr; general medical waste; intermittent, ram-fed; 1.6-sec residence time in secondary (average of 21 test runs).
E: 680 Kg/hr; general medical waste; continuous, ram-fed; 2-sec residence time in secondary (average of three test runs).
F: 80 Kg/hr; pathological waste; intermittent, manually-fed; 0.2-sec residence time in secondary (average of six test runs).
G: 340 Kg/batch; general medical waste; batch-feed; 1.75-sec residence time in secondary chamber (average of six test runs).
H: 365 Kg/hr; general medical waste; continuous, ram-fed; 2.2-sec residence time in secondary chamber (average of six test runs).

TABLE 5b. POST-COMBUSTION EMISSION RATES FOR MEDICAL WASTE INCINERATORS
(English Units)

Pollutant, at 7 percent O_2	A	B	C	D	E	F	G	H
PM, gr/dscf	0.157	0.259	0.451	0.099	0.100	0.046	0.015	0.490
CO, ppmv	297	529	1,213	14	26	108	10	11.7
2,3,7,8-TCDD, gr/dscf (10^{-9})	1.56	6.67	12.8	0.09	0.12	0.35	0.20	0.01
Total CDD, gr/dscf (10^{-9})	3.13	1,242	2,207	41	139	99	60	11
2,3,7,8-TCDF, gr/dscf (10^{-9})	6.03	29.25	35	0.40	0.39	1.7	1.01	0.28
Total CDF, gr/dscf (10^{-9})	1,635	6,379	8,610	150	495	227	213	75
Total CDD + CDF, gr/dscf (10^{-9})	1,948	7,621	10,800	191	634	326	272	85
HCl, ppmv	1,308	1,470	1,537	1,714	NM	117	198	950
SO_2, ppmv	23.1	12.6	42.8	7.5	1.5	114	16.9	14
NO_x, ppmv	83	86	182	180	72	354	85	84
Antimony, gr/dscf (10^{-6})	690	476	270	NM	NM	45	28	289
Arsenic, gr/dscf (10^{-6})	7.8	5.7	4.9	6.3	12.3	28	1.1	4.6
Barium, gr/dscf (10^{-6})	168	63	38	NM	NM	12	19	1,234
Beryllium, gr/dscf (10^{-6})	0.09	0.05	0.5	NM	NM	0.09	0.04	0.68
Cadmium, gr/dscf (10^{-6})	182	114	24	130	168	62	52	210
Chromium, gr/dscf (10^{-6})	13.7	18.1	16	8.3	23.1	48	8.6	62
Iron, gr/dscf (10^{-6})	NM	NM	NM	190	654	NM	NM	NM
Lead, gr/dscf (10^{-6})	2,368	1,212	820	2,029	1,449	210	1,387	1,748
Manganese, gr/dscf (10^{-6})	NM	NM	NM	44.9	83.5	NM	NM	NM
Mercury, gr/dscf (10^{-6})	485	376	3.5	2,632	160	53	1,016	1,140
Nickel, gr/dscf (10^{-6})	4.5	14.1	11.3	4.5	16.8	72	4.9	50
Silver, gr/dscf (10^{-6})	5.3	3.2	6.2	NM	NM	1.5	1.2	1.6
Thallium, gr/dscf (10^{-6})	86.7	1.43	2.4	NM	NM	2.6	0.43	7.04

NM = Not Measured

A: 300 lb/hr; general medical waste; intermittent, ram-fed; 1-sec residence time in secondary (average of nine test runs).
B: 300 lb/hr; general medical waste; intermittent, ram-fed; 0.33-sec residence time in secondary (average of nine test runs).
C: 250 lb/hr; general medical waste; intermittent, manually-fed; 0.2-sec residence time in secondary (average of three test runs).
D: 720 lb/hr; gemeral medical waste; intermittent, ram-fed; 1.6-sec residence time in secondary (average of 21 test runs).
E: 1,500 lb/hr; general medical waste; continuous, ram-fed; 2-sec residence time in secondary (average of three test runs).
F: 175 lb/hr; pathological waste; intermittent, manually-fed; 0.2-sec residence time in secondary (average of six test runs).
G: 750 lb/batch; general medical waste; batch-feed; 1.75-sec residence time in secondary chamber (average of six test runs).
H: 800 lb/hr; general medical waste; continuous, ram-fed; 2.2-sec residence time in secondary chamber (average of six test runs).

TABLE 5c. POST-COMBUSTION EMISSION RATES FOR MEDICAL WASTE INCINERATORS (Pounds Per Year)

Pollutant	A	B	C	D	E	F	G	H
PM	1,270	2,200	3,650	3,000	4,940	375	108	40,095
CO	1,200	2,100	4,900	220	610	435	35	576
2,3,7,8-TCDD, (10^{-3})	0.015	0.05	0.1	<0.01	0.09	<0.01	<0.01	0.0007
Total CDD, (10^{-3})	2.5	10	18	1.2	7	0.8	0.4	0.8
2,3,7,8-TCDF, (10^{-3})	0.05	0.2	0.3	<0.01	0.02	0.02	<0.01	0.02
Total CDF, (10^{-3})	13	52	70	5.2	29	1.8	1.5	5.7
Total CDD + CDF, (10^{-3})	16	62	90	6.4	36	2.6	1.9	6.6
HCl	6,800	8,000	8,000	32,230	NM	600	890	804
SO_2	215	120	395	270	85	1,050	138	1,575
NO_x	550	580	1,200	4,400	3,150	2,350	477	4,428
Antimony	6	3.8	2.2	NM	NM	0.35	0.2	23.8
Arsenic	0.07	0.05	0.04	0.18	0.6	0.23	<0.01	0.38
Barium	1.4	0.5	0.31	NM	NM	0.09	0.14	101
Beryllium	<0.01	<0.01	<0.01	NM	NM	<0.01	<0.01	0.06
Cadmium	1.5	0.9	0.2	4.0	8.0	0.5	0.4	17.3
Chromium	0.12	0.14	0.13	0.26	1.2	0.38	0.06	5.08
Lead	20	9.5	6.5	59	70	1.8	10	144
Mercury	4.0	3.1	0.03	77	8.3	0.43	7.3	95
Nickel	0.04	0.1	0.1	0.13	0.9	0.6	0.04	4.12
Silver	0.05	0.05	0.05	NM	NM	0.01	<0.01	0.13
Thallium	0.7	0.01	0.02	NM	NM	0.02	<0.01	0.56

NM = Not Measured

A: 300 lb/hr; general medical waste; intermittent, ram-fed; 1-sec residence time in secondary (average of nine test runs).
B: 300 lb/hr; general medical waste; intermittent, ram-fed; 0.33-sec residence time in secondary (average of nine test runs).
C: 250 lb/hr; general medical waste; intermittent, manually-fed; 0.2-sec residence time in secondary (average of three test runs).
D: 720 lb/hr; general medical waste; intermittent, ram-fed; 1.6-sec residence time in secondary (average of 21 test runs).
E: 1,500 lb/hr; general medical waste; continuous, ram-fed; 2-sec residence time in secondary (average of three test runs).
F: 175 lb/hr; pathological waste; intermittent, manually-fed; 0.2-sec residence time in secondary (average of six test runs).
G: 750 lb/batch; general medical waste; batch-feed; 1.75-sec residence time in secondary chamber (average of six test runs).
H: 800 lb/hr; general medical waste; continuous, ram-fed; 2.2-sec residence time in secondary chamber (average of six test runs).

The MWI's tested as part of the EPA test program range in size from about 110 kg/hr (250 lb/hr) to about 680 kg/hr (1,500 lb/hr). One unit is a batch-feed MWI with a capacity of about 340 kg/batch (750 lb/batch). The smallest unit is a manually-fed, intermittent-duty MWI that can incinerate nonpathological (general medical) waste or pathological waste, and the largest unit is a continuous-duty MWI with automatic feeding. The secondary chamber residence times range from about 0.2 sec to 2.0 sec. Five different MWI manufacturers' products were tested during the test program. Units A, B, and D were tested over a wide range of waste feed charging conditions.

As can be seen in Table 5, the degree of variation in emissions from unit to unit is much greater for some pollutants than for others. For the pollutants that are directly impacted by the secondary chamber designs (PM, CO, and CDD + CDF), units D, E, and G show a significant improvement over units B and C. The secondary chamber residence time for units D, E, and G is about 1.6 to 2.0 sec, whereas for units B and C, the time averages about 0.2 sec. Emissions from unit A, with a 1.0 sec residence time, are between the averages for the other units.

Emission rates for pollutants that are largely unaffected by secondary chamber conditions (HCl, SO_2, NO_x, and metals) are dependent on the characteristics of the waste. Pollutants such as arsenic, chromium, lead, and nickel vary only slightly among the six MWI's burning general medical waste. Some other pollutants such as mercury, cadmium, and thallium show significant variations from site to site. These variations are apparently a function of the practices of the hospitals with respect to purchase and disposal of items that contain these pollutants.

Average post combustion emission rates were calculated based on the measured emission rates from the eight EPA tests to present the reader with an understanding of the magnitude of emission rates from MWI's. These averages are presented in Tables 6a (Metric units) and 6b (English units).

TABLE 6a. AVERAGE POST-COMBUSTION EMISSION RATES FOR MEDICAL WASTE INCINERATORS
(METRIC UNITS, @ 7 PERCENT O_2)

	Range	Average
PM, mg/dscm	35-1,125	463
CO, ppmv	10-1,210	276
2,3,7,8-TCDD, ng/dscm	0.02-29.4	6.17
Total CDD, ng/dscm	24-5,050	1,176
2,3,7,8 -TCDF, ng/dscm	0.63-80.1	21.3
Total CDF, ng/dscm	171-19,700	5,087
Total CDD + CDF, ng/dscm	195-24,700	6,256
HCl, ppmv	117-1,714	1,044
SO_2, ppmv	1.5-114	29.1
NO_x, ppmv	72-354	141
Antimony, μg/dscm	63-1,580	686
Arsenic, μg/dscm	2.6-63.6	20.1
Barium, μg/dscm	26.8-2,825	473
Berylium, μg/dscm	0.10-1.56	0.50
Cadmium, μg/dscm	55-482	269
Chromium, μg/dscm	19.0-141	56.2
Iron, μg/dscm	434-1,500	966
Lead, μg/dscm	485-5,420	3,212
Manganese, μg/dscm	103-191	147
Mercury, μg/dscm	7.96-6,024	1,678
Nickel, μg/dscm	10-164	50.7
Silver, μg/dscm	2.8-14.2	7.5
Thallium, μg/dscm	1.0-198	39.4

TABLE 6b. AVERAGE POST-COMBUSTION EMISSION RATES FOR MEDICAL WASTE INCINERATORS
(ENGLISH UNITS, @ 7 PERCENT O_2)

	Range	Average
PM, gr/dscf	0.015-0.482	0.20
CO, ppmv	10-1,210	276
2,3,7,8-TCDD, gr/dscf (10^{-9})	0.009-12.8	2.72
Total CDD, gr/dscf (10^{-9})	0.80-2,210	474
2,3,7,8 -TCDF, gr/dscf (10^{-9})	0.28-35.0	9.2
Total CDF, gr/dscf (10^{-9})	75-8,610	2,223
Total CDD + CDF, gr/dscf (10^{-9})	85-10,800	2,735
HC1, ppmv	117-1,714	1,044
SO_2, ppmv	1.5-114	29.1
NO_x, ppmv	72-354	141
Antimony, gr/dscf (10^{-6})	28-690	300
Arsenic, gr/dscf (10^{-6})	1.1-28	8.82
Barium, gr/dscf (10^{-6})	12-1,332	206
Berylium, gr/dscf (10^{-6})	0.04-0.7	0.22
Cadmium, gr/dscf (10^{-6})	24-210	118
Chromium, gr/dscf (10^{-6})	8.6-62	24.7
Iron, gr/dscf (10^{-6})	190-654	422
Lead, gr/dscf (10^{-6})	210-2,370	1,403
Manganese, gr/dscf (10^{-6})	44.9-83.5	64.2
Mercury, gr/dscf (10^{-6})	3.5-2,630	733
Nickel, gr/dscf (10^{-6})	4.5-72	22.2
Silver, gr/dscf (10^{-6})	1.2-6.2	3.26
Thallium, gr/dscf (10^{-6})	0.43-86.7	17.2

5.4 EXISTING EMISSION LIMITS

The majority of the States have promulgated or are proposing regulations or permit guidelines specific to MWI's. Tables 7 and 8 summarize this regulatory activity for new and existing units, respectively. Proposed and final regulations, as well as applicable guidelines, have been included.

The State regulations are generally very complex, and many are in the process of being revised. There is a wide variability in the requirements from State to State. This variability extends to regulatory format, pollutants addressed, emission limits, affected facility definition, size cutoffs, and operating parameters. For example, some State limits are expressed in terms of pounds of PM per pound of waste charged to the incinerator (lb/lb), while others are expressed in terms of grains of PM per dry standard cubic foot (gr/dscf) of stack gas. Some States use permit conditions rather than formal regulations, and even these may vary from site to site.

While the most frequently regulated pollutants are PM and HCl, the range of the emission limits is very wide. For PM, the range covers an order of magnitude. In the case of HCl, not only is there a wide range of requirements for emission reduction, but the emission limits are expressed in many different formats, including percent reduction, lb/hr, and parts per million dry volume (ppmdv).

Frequently, States have different emission limits for different sizes or capacities of incinerators. Two- and three-tiered regulations are not uncommon. In many States the emission limits on some or all MWI's can be achieved without add-on controls. The levels at which size cutoffs are established are not consistent among the States. Furthermore, an incinerator may be subject to different regulations depending on the age of the unit and the type of waste burned.

The States have established a wide variety of equipment and operating standards for MWI's to ensure proper operation. These standards include various minimum secondary chamber temperatures and gas residence times, minimum primary chamber temperatures,

TABLE 7. STATE REQUIREMENTS FOR NEW MEDICAL WASTE INCINERATORS.

New Sources (STATEREQ.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SO2/NOx Emissions	HCl Emissions(b)	Dioxin/Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/Recordkeeping(f)	Operator Training Requirements(f)
AL	30	after 1/1/92	<100 lb/hr	.08 gr/dscf @7% O2	N/R	N/R	4 lb/hr or 90% reduction	N/R	100 ppm	10%	all: 2-sec resid. @1800 F	record final chamber temp.	training required
			100-1000 hr	.05 gr/dscf @7% 02			4 lb/hr or 90% reduction		100 ppm	5%			
			>1000 lb/hr	.02 gr/dscf @7% 02			4 lb/hr or 90% reduction		100 ppm	5%			
AK	31	1993	1000-2000 lb/hr	0.15 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20% except 3 min/hr	N/R	*	N/R
			>2000 lb/hr	.08 gr/dscf @12% CO2						20% except 3 min/hr			
AZ	32	1993	all	0.08 gr/dscf (12% CO2)	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
AR	31,33	*	all	0.1 gr/dscf @12% CO2	N/R	N/R	N/R		N/R	5%	all: Install continuous temp. monitors/w recorders 1 sec resid. @1800 F	record-chamber temp. continuously	N/R
CA	34	proposed 7/13/91	>25 tpy	85-99% reduction (reasonable BACT)	37-99% cadmium reduction (reasonable BACT)	N/R	85-99% reduction (reasonable BACT)	10 ng/dscm @7% O2 or 99% red.	N/R	N/R	single chamber temp. @1800 F mult. chamber 1-sec resid. @1400/1800 F exit temp. =<300 F	report-upsets record-charge rate/weight, control/monitoring equipment calibration	training required (ASME)
CO	35	6/30/89	<200 lb/hr	.08 gr/dscf @7% O2	N/R	N/R	4 lb/hr/90% reduction	N/R	100 ppm	10%	1-sec resid. @1800 F	record-monthly burning rates, hrs of operation report-quarterly-CEM data, excess emissions, daily charge rates	training required
			>=200 lb/hr	.03 gr/dscf @7% O2			50 ppm/90% reduction		100 ppm	10%	2-sec resid. @1800 F exit temp. =<300 F		
			>=1000 lb/hr	.015 gr/dscf @7% O2			50 ppm/90% reduction		100 ppm	10%	2-sec resid. @1800 F exit temp. =<300 F		
CT	31	2/1/89	all	.015 gr/dscf @12% CO2	N/R	N/R	90% red. or 4 lb/hr whichever is less	N/R	100 ppmdv @7% O2 (1h)	10%	2-sec resid. @1800/2000	*	N/R
DE	31	1989	<1000 lb/hr	.08 gr/dscf @7% O2	N/R	N/R	90%, 50 ppm @ 7% O2 or <4 lb/hr	N/R	100 ppmdv @7% O2	10%	all: 1-sec resid. @1600/2000 F	*	N/R
			>1000 lb/hr	.03 gr/dscf @7% O2			90%, 50 ppm @ 7% O2 or <4 lb/hr		100 ppmdv @7% O2	10%			
DC	38	7/7/72	all	.03 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	N/R	multiple chambers	*	N/R

TABLE 7. (continued)

New Sources (STATEREQ.WQ1)

State	Reference	Effective Date (a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions (b)	Dioxin/ Furan Emissions	CO Emissions (b)	Opacity	Operation Requirements (c) (d) (e)	Reporting/ Recordkeeping (f)	Operator Training Requirements (f)
FL	31	1990	<=500 lb/hr 501-2000 lb/hr >2000 lb/hr	0.1 gr/dscf @7% O2 .03 gr/dscf @7% O2 .02 gr/dscf @7% O2	N/R	N/R	4 lb/hr 4 lb/hr or 90% (hr) 50 ppmdv @7% O2 (3hr) or 90% (hr)	N/R	all: 100 ppmdv @7% O2	5%, up to 20% for 3 min/hr 5%, up to 20% for 3 min/hr 5%, up to 20% for 3 min/hr	all: 1-sec resid. @1800 F	*	N/R
GA	31,37	1991	<=500 lb/hr >500 lb/hr	1.0 lb/hr 0.2 lb/100 lb refuse charged	N/R	N/R	N/R	N/R	N/R	all: 20%, up to 27% for 6 min/hr	all: @800/1500 F	*	N/R
HI	31	*	all	case-dependent	case-dependent	case-dependent	case-dependent	case-dependent	case-dependent	case-dependent	N/R	*	N/R
ID	38	8/21/92 amended	all	0.2 lb/100 lb refuse charged	N/R	N/R	N/R	N/R	N/R	20% (except 3 min/hr)	multiple chambers	*	N/R
IL	39	12/89	<=2000 lb/hr 2,001-60,000 lb/hr >60,000 lb/hr	0.1 gr/dscf @12% CO2 .08 gr/dscf @12% CO2 .05 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	500 ppm (50% ex. air) 500 ppm (50% ex. air) 500 ppm (50% ex. air)	all: 30%, up to 60% 8 min/hr	N/R	*	N/R
IN	31,40	1988	<200 lb/hr >200 lb/hr	0.3 lb/1000 lb dry exhaust 0.5 lb/1000 lb dry exhaust	N/R	N/R	N/R	N/R	N/R	40% 40%	1 sec resid. @1600 F, if anti-neoplastic agents 1.5 sec resid.	*	N/R
IO	41	7/21/78	<1000 lb/hr >=1,000 lb/hr	0.35 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	40%, up to 60% 3min/hr 40%, up to 60% 3min/hr	N/R	*	N/R
KS	42	6/8/92 amended	<200 lb/hr 200-20,000 lb/hr > 20,000 lb/hr	0.3 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2 0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20% 20% 20%	multiple chambers	*	N/R
KY	43	2/2/91 amended	<=500 lb/hr 501 lb/hr-250 tpd >250 tpd	.08 gr/dscf @7% O2 .015 gr/dscf @7% O2 .015 gr/dscf @7% O2	N/R	- - NOx: 120 ppm @7% O2	- less stringent: 25 ppmdv @7% O2 or 90% (hr) less stringent: 25 ppmdv @7% O2 or 95% (hr)	N/R	100 ppmdv @7% O2 100 ppmdv @7% O2 100 ppmdv @7% O2	10% 10% 10%	all: 1-sec resid. @1800 F PM inlet APCD temp. (g)	record-perf. test, and operating parameters report quarterly compliance reports	training required

TABLE 7. (continued)

New Sources (STATEREQ.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
LA	44	1992	<500 lb/hr >=500 lb/hr	.08 gr/dscf @7% O2 .04 gr/dscf @7% O2	N/R	all: SO2; 100 ppmv @7% O2 or 70% red. NOx; 250 ppmv @7% O2	4 lb/hr or 98% reduction 4 lb/hr or 98% reduction	N/R	100 ppmv @7% O2 100 ppmv @7% O2	10% 10%	all: onsite: 1.5-sec resid. @1500/2000 F offsite: 2-sec resid. @1500/2000 F	record-hrs of operation, amount of waste charged report-monthly amount of waste charged and hrs of operation	N/R
ME	31	1989	=<50 lb/hr >50 lb/hr	0.1 gr/dscf @7% O2 .02 gr/dscf @7% O2	N/R	N/R	- 90% red. or 30 ppmdv	N/R	N/R	10% 10%	all: 1-sec resid. @1600/1800 F 2000/2000 F/w chemo. waste or cytotoxic drugs	*	N/R
MD	45	7/1/88	all prior to 1/17/72	0.03 gr/dscf @12% CO2	under PM limit	N/R	50 ppmv @7% O2 or 90% reduction	N/R	N/R	5%	N/R	*	training and certification required
MA	46	10/27/90	all	TOP-DOWN BACT .02 gr/dscf @12% CO2 (reasonable)	N/R	N/R	TOP-DOWN BACT 50 ppmv @ 12% CO2 or 97% reduction (reasonable)	N/R	N/R	10%	all: 1-sec resid. @1800 F yearly checkups	*	operator training
MI	31	1989	all	0.2 lb/1000 lb flue gas with 50% ex. air	N/R	N/R	N/R	N/R	N/R	N/R	N/R	*	N/R
MN	47	8/26/93 proposed	<350 lb/hr >350 lb/hr	0.08 gr/drscf @ 7 O2 0.035 gr/drscf @ 7% O2	N/R	N/R	N/R	- 200 ng/dscm	50 ppm @ 7% O2 50 ppm @ 7% O2	20% 20%	all: 1-sec resid. @1800 F PM APCD inlet temp.(h) Hg feed rate	report-exceedances upon occurance, daily records of hrs of operation, amount of waste burned, emissions data and Hg feed rate	training and certification required
MS	31,48	10/6/92 updated	all	.08 gr/dscf @12% CO2	N/R	N/R	evaluate ambient impact by 1% TLV	N/R	N/R	10%	1-sec resid. @1800 F	record-times of operation, amounts charged, secondary chamber temp.	N/R
MO	31,49	after 6/10/91	<2.0 MMBtu/hr 2.0-12 MMBtu/hr >12.0 MMBtu/hr	.09 gr/dscf @7% O2 .03 gr/dscf @7% O2 .015 gr/dscf @7% O2	- - Hg: 50 ug/dscm @7% O2	N/R	- 50 ppmv @7% O2 50 ppmv @7% O2	- - 25 ng/dscm @ 7% O2	N/R	10% 10% 10%	1-sec resid. @1650/1800 F 1-sec resid. @1650/1800 F 2-sec resid. @1650/1800 F	record-testing data, maintenance, chamber temp., type and amount of waste charged	training and certification required (ASME or MWI manufacturer)
MT	50	12/14/92 amended	all	0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	10%	N/R	*	N/R
NB	51	2/20/91 amended	> 50 tpd	40 CFR 60 Subpart E	N/R	N/R	N/R	N/R	N/R	N/R	N/R	*	N/R

TABLE 7. (continued)

New Sources (STATEREQ.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
NV	31,52	12/28/91 amended	<2,000 lb/hr >=2000 lb/hr	1.8 lb/ton dry waste charged =0.6(40.7 x 10EE-6 x C) C=dry waste charged lb/hr	N/R	N/R	N/R	N/R	N/R	N/R	all 0.3-sec resid. @1400 F	•	N/R
NH	31,53	after 4/15/70	<200 lb/hr 200-4000 lb/hr >4,000 lb/hr	0.3 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2 .08 gr/dscf @12% CO2	N/R	N/R	• • 50 ppmdv @7% O2 or 90% red.	N/R	N/R	N/R	N/R	•	owner is responsible for training
NJ	31,54	7/14/78	all	.015 gr/dscf @7% O2	No Be waste burned	SO2: 50 ppmdv @7% O2 or 80% red.	50 ppmdv @7% O2 or 90% red.	N/R	100 ppmv @7% O2	10%	1-sec resid. @1200/1800 F	•	N/R
NM	55	5/13/92	<200 lb/hr 200-999 lb/hr >=1,000 lb/hr	.08 gr/dscf @12% CO2 .03 gr/dscf @12% CO2 .015 gr/dscf @12% CO2	• As,Be,Cd, Cr,& Pb (90%) Hg: 90% As,Be,Cd, Cr,& Pb (90%) Hg: 90%	• SO2: 80 mg/dscm NOx: 235 mg/dscm both @7%O2 SO2: 80 mg/dscm NOx: 235 mg/dscm both @7%O2	4 lb/hr or 90% reduction 40 mg/dscm @7% O2 40 mg/dscm @7% O2	500 ng/dscm @7% O2 5 ng/dscm @7% O2 5 ng/dscm @7% O2	80 mg/dscm @7% O2 80 mg/dscm @7% O2 80 mg/dscm @7% O2	10% 10% 10%	all: 1-sec resid. @1400/1800 F, exit temp. =<300 F	report-quarterly operating parameters excess emissions record-all parameters and quarterly reports	training required
NY	31,56	2/3/89	new onsite modified onsite commercial	.015 gr/dscf @7% O2 .03 gr/dscf @7% O2 .015 gr/dscf @7% O2	N/R	N/R	All: 90% red. or 50 ppmdv @7% O2 OR uncont. <4 lb/hr and <500 lb/hr charged	N/R	150 ppmdv @7% O2 150 ppmdv @7% O2 150 ppmdv @7% O2	10% 10% 10%	all: 1-sec resid. @1400/1800 F, exit temp. <300 F, annual inspection	report-annual inspection	training and certification required
NC	57	9/30/91	<100 lb/hr 101-2,000 lb/hr >2,000 lb/hr	0.2 lb/hr or 0.08 gr/dscf lb/hr = 0.002P or 0.08 gr/dscf 4.0 lb/hr or .08 gr/dscf @12% CO2 or P=Charge rate (lb/hr)	Hg=.032 lb/hr Hg=.032 lb/hr Hg=.032 lb/hr	SO2: 2.3 lb/MMBtu SO2: 2.3 lb/MMBtu SO2: 2.3 lb/MMBtu	4 lb/hr or 90% or 50 ppmdv @7% O2 4 lb/hr or 90% or 50 ppmdv @7% O2 4 lb/hr or 90% or 50 ppmdv @7% O2	N/R	N/R	20% 20% 20%	all: 1-sec resid. @1200/1800 F	record-primary and secondary chamber temp., any continuous monitoring data	N/R
ND	31	after 8/17/71	all	.015 gr/dscf @7% O2	N/R	N/R	90% red. or 25 ppmdv @7% O2	N/R	100 ppmdv @7% O2	10%, up to 20% for 6 min /hr	1-sec resid. @1800 F	•	N/R

TABLE 7. (continued)

New Sources (STATEREQ.WQ1) State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
OH	31,58	7/9/91	<100 lb/hr 100-1,800 lb/hr >1,800 lb/hr	0.2 lb/100 lb waste charged 0.1 lb/100 lb waste charged .06 lb/100 lb waste charged	All: (lb/hr) As=.0042 Be=.0076 Cd=.010 Cr=.0015 Pb=.068 Hg=.011 Ni=.0076	N/R	4 lb/hr or 90% red. by wt 4 lb/hr or 90% red. by wt 4 lb/hr or 90% red. by wt	N/R	100 ppmdv @7% O2(hr) - -	5%, up to 10% 1 min/hr 5%, up to 10% 1 min/hr 5%, up to 10% 1 min/hr	intermittent and batch: 1200/1800 F continuous: 1-sec resid. @1400/1400 all after 1/1/91: 2-sec resid. 1400/1800 F	report-performance test, quarterly excess emissions record-charging rates	training required
OK	31	1992	<250 lb/hr 250-999 >1000 lb/hr	0.08 gr/dscf @12% CO2 0.03 gr/dscf @12% CO2 0.015-0.03 gr/dscf @12% CO2	N/R	NOx: 0.5 lb/hr NOx: 0.5 lb/hr SO2: 35 ppmdv @7% O2 and 70% red. NOx: 300 ppmdv	4 lb/hr 4 lb/hr 4 lb/hr and 95% red. by weight	- - 20 ng/dscm @7% O2	100 ppmdv @ 7% O2(15min) 50 ppmdv @ 7% O2(15min) 50 ppmdv @ 7% O2(15min) or 100 ppmdv @7% O2(inst)	20% 20% 20%	all: 2-sec resid. @1400/2000 F exit temp =<350 F	*	N/R
OR	31	1990	all	.015 gr/dscf @7% O2	N/R	SO2: 50 ppmdv @ 7% O2 or 70% (3-hr) NOx: 200 ppmdv @7% O2	50 ppmdv @ 7% O2 (hr) or 90% red.	N/R	100 ppmdv @ 7% O2 (8-hr)	10%	1-sec resid. @1400/1800 F, exit temp. =<350 F	*	N/R
PA	31	1989	<=300 lb/hr 301-2,000 lb/hr >2,000 lb/hr	.08 gr/dscf @7% O2 .03 gr/dscf @7% O2 .015 gr/dscf @7% O2	N/R	- SO2: 30 ppmdv @ 7% O2 or 75% (8hr) SO2: 30 ppmdv @ 7% O2 or 75% (8hr)	4 lb/hr @ 7% O2 or 90% (hr) 30 ppmdv @7% O2 or 90% (hr) 30 ppmdv @7% O2 or 90% (hr)	N/R	100 ppmdv @ 7% O2 (hr) 100 ppmdv @ 7% O2 (hr) 100 ppmdv @ 7% O2 (hr)	10%, up to 30% 3 m/hr 10%, up to 30% 3 m/hr 10%, up to 30% 3 m/hr	all: 2-sec resid. @1800 F	*	N/R
PR	59	12/27/80 amended	<50 tpd	0.5 lb/100 lb waste charged	N/R	N/R	N/R	N/R	N/R	20%, up to 60% for 4 min/30min	multiple chambers	*	N/R
RI	31	1989	< 500 lb/hr 500-2,000 lb/hr > 2,000 lb/hr	.04 gr/dscf @12% CO2 .02 gr/dscf @12% CO2 .01 gr/dscf @12% CO2	N/R	N/R	4 lb/hr or 90% 4 lb/hr or 90% 90% or 50 ppmdv @12% CO2	N/R	- - 100 ppmdv @7% O2 (1hr)	10% 10% 10%	all: 2-sec resid. @1800 F, exit temp. =<300 F	*	N/R
SC	31,60	6/28/92	<500 lb/hr 500-2,000 lb/hr >2,000 lb/hr	0.1 gr/dscf @7% O2 .08 gr/dscf @7% O2 .03 gr/dscf @7% O2	N/R	- - SO2: 30 ppmdv @7% O2 (hrly) or 75% red. by weight (8hr)	4 lb/hr or 90% (hr) 30 ppmdv @7% O2 or 90% (hr) 30 ppmdv @7% O2 or 90% (hr)	N/R	100 ppmdv @ 7% O2 (hr) 100 ppmdv @ 7% O2 (hr) 100 ppmdv @ 7% O2 (hr)	10%, 30% max anytime 10%, 30% max anytime 10%, 30% max anytime	0.5-sec resid. @1800 F 0.5-sec resid. @1800 F 1-sec resid. @1800 F	record-CEMS data, peformance testing report-quarterly exceedances	training and certification required

TABLE 7. (continued)

New Sources (STATEREQ.WQ1)

State	Reference	Effective Date(s)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
SD	61	4/3/81	=<200 lb/hr >200 lb/hr > 500 lb/hr	- 0.04 gr/dscf @7% O2 (w/condensables) 0.04 gr/dscf @7% O2 (w/condensables)	N/R	- SO2:30 ppmdv @7% O2 (1hr) SO2:30 ppmdv @7% O2 (1hr)	- 90% or 50 ppmdv @7% O2 (1hr) 90% or 50 ppmdv @7% O2 (1hr)	- - 60 gr/BBdscf @ 7% O2	- 100 ppmdv @7% O2 (1 hr) 100 ppmdv @7% O2 (1 hr)	- 10% (6min) 10% (6min)	1-sec resid. @1800 F 2-sec resid. @1800 F 2-sec resid. @1800 F	record-quarterly charge rates, hours of operation, monitoring data, excess emissions	
TN	31,62	1990	all	0.1 gr/dscf @ 12% CO2	N/R	N/R	RACT and Ambient Air Quality Impact Standard of 70 ug/m3	N/R	N/R	10%	before 11/8/88: primary chamber 1800 F and zero percent opacity after 11/8/88: 1-sec resid. @1800 F	•	N/R
TX	31,63	1991	<100 lb/hr 100-225 lb/hr >225 lb/hr	.08 gr/dscf @ 7% O2 (front half only) .08 gr/dscf @ 7% O2 (front half only) .03 gr/dscf @ 7% O2 (front half only)	N/R	N/R	• • 4 lb/hr or 95% red.	N/R	- • 100 ppmdv @7% O2	5% 5% 5%	onsite: 1400 F 1-sec resid. @1800 F 1-sec resid. @1800 F all: minimum carbon flow rate	•	N/R
UT	64	3/8/91 updated	all	Use of source specific BACT to ensure NAAQS	N/R	N/R	N/R	N/R	N/R	20%	N/R	•	N/R
	65		Typical permit limits	0.02 gr/dscf		NOx: 150 ppmdv SOx: 250 ppmdv		1 ppm	100 ppmdv	10%	3-sec resid.(i) @1500/1800 F		
VT	66	after 4/30/70	<50 tpd >50 tpd	0.1 lb/100 lb waste .08 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20% 20%	N/R	•	N/R
VA	67	1/1/93	<500 lb/hr 500-1000 lb/hr >=1000 lb/hr	0.10 gr/dscf @7% O2 0.03 gr/dscf @7% O2 0.01 gr/dscf @7% O2	N/R	N/R	20 ppmdv @7% O2 20 ppmdv @7% O2	- 8 gr/BBdscf @7% O2 8 gr/BBdscf @7% O2	- 50 ppmdv @7% O2 25 ppmdv @7% O2 25 ppmdv @7% O2	5% 5% 5%	all: 2-sec resid. @1400/2000 F exit temp. =<300 and PM APCD inlet temp.(f) exit temp. =<300 and PM APCD inlet temp.(f)	report-performance test data, quarterly annual perf. test, excess emissions, compliance data record-emissions rates, operating parameters, exceedances	training and certification required
WA	68,69	1/1/85	<12 tpd 12-250 tpd >250 tpd	0.1 gr/dscf @7% O2 .03 gr/dscf @7% O2 .02 gr/dscf @7% O2	N/R	SO2: 1,000 ppmdv @7% O2 SO2 80% red. or 50 ppmdv @7% O2 or BACT SO2 80% red. or 50 ppmdv @7% O2 or BACT	80 % red. or 50 ppmdv @7% O2 (1hr) or BACT 80 % red. or 50 ppmdv @7% O2 (1hr) or BACT	N/R	N/R	20% 5% 5%	all: 1-sec resid. @1800 F, PM APCD inlet temp.(j), and operation and maintenance plan	report-performance test data, quarterly pollutant conc., exceedances, and monitoring down-times	training and certification required

TABLE 7. (continued)

New Sources (STATEREQ.WQ1)													
State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
WV	70	5/6/91 amended	<=200 lb/hr	lb/hr = (6.25)(C)	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
			>200 lb/hr	lb/hr = (5.43)(C) C = Incinerator capacity (ton/hr)						20%			
WI	71	10/1/88	<200 lb/hr	.08 gr/dscf @7% O2	N/R	N/R	case-dependent	case-dependent	75 ppmdv @7% O2(3 hr)	20%	all: 2-sec resid. @1800 F and PM APCD inlet temp.(k)	record-weight of each charge, CEM data	training and 3 levels of certification required
			200-999 lb/hr	.03 gr/dscf @7% O2			50 ppmdv @7% O2	case-dependent	75 ppmdv @7% O2(3 hr)	5%			
			1,000 lb/hr to 50 tpd	.015 gr/dscf @7% O2 (including condensible)			50 ppmdv @7% O2	.02 ng 2,3,7,8-TCDD/dscm @7% O2	75 ppmdv @7% O2(3 hr)	5%			
			>=50 tpd	0.015 gr/dscf @7% O2			25 ppmdv or 95% reduction	.02 ng 2,3,7,8-TCDD/dscm @7% O2	50 ppmdv @7% O2(3 hr)	5%			
WY	72	10/20/90 amended	all	0.2 lb/100 lb of waste charged	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
	65		Typical permit limits	0.04 gr/dscf @7% O2						10%	1-sec resid. @1800 F		

\- Requirment not applicable for particular size.
* No information presently available.
N/R Not regulated.
(a) If the effective date of the regulation was unknown the date of amendment or update in the Environmental Reporter was cited, if available.
(b) Times in parenthesis indicate averaging times.
(c) All residence times and temperatures are minimum requirements for secondary chambers unless otherwise indicated.
(d) Temperatures seperated by a slash indicate minimum temperatures for the primary and secondary chambers respectively.
(e) Exit temperatures indicate a maximum temperature from the final APCD.
(f) Reporting/Recordkeeping and training requirements apply to all sizes, unless otherwise indicated.
(g) The inlet temperature to the most efficient PM control device must be less than or equal to 300 F, except for wet scrubbers.
(h) The inlet gas stream temperature to the most efficient PM control device must have a temperature of no greater than 30 F above the mean temperature measured for this gas stream during the most resent performance test for dioxins/furans.
(i) The 3-sec minimum residence time was only specified in one permit.
(j) The inlet temperature of the primary PM APCD may not exceed 350 F.
(k) The temperature of any exhaust gas stream entering a baghouse or electrostatic precipitator may not exceed 300 F.

TABLE 8. STATE REQUIREMENTS FOR EXISTING MEDICAL WASTE INCINERATORS

Existing Sources (STATEREQ.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
AL	30	on or before 1/1/82	<600 lb/hr	0.2 lb/100 lb	N/R	N/R	-	N/R	-	10%	-	report if >15,000 lb/wk charged	training required
			600-1150 lb/hr	.08 gr/dscf @7% O2			-		100 ppm	10%	1-sec resid. @1800 F	>40,000 lb/wk charged	
			>1150 lb/hr	.02 gr/dscf @7% 02			4 lb/hr or 90% reduction		100 ppm	5%	2-sec resid. @1800 F		
AK	•	•	•	•	•	•	•	•	•	•	•	•	•
AZ	32	•	all	0.1 gr/dscf (12% CO2)	N/R	N/R	N/R	N/R	N/R	20%	N/R	•	N/R
AR	33	•	all	0.2 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	5%	all: install continuous temp. monitors/w recorders	record-chamber temp. continuously	N/R
CA	34	proposed 7/13/91	>25 tpy	85-99% reduction (reasonable BACT)	37-99% cadmium reduction (reasonable BACT)	N/R	85-99% reduction (reasonable BACT)	10 ng/dscm @7% O2 or 99% red.	N/R	N/R	single chamber temp. 1800 F mult. chamber 1-sec resid. @1400/1800 F exit temp. = <300 F	report-upsets record-charge rate/weight, control/monitoring equipment calibration	training required (ASME)
CO	73	after 1/30/79	<= 50 tpd	.10 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20%	N/R	•	training required
			>50 tpd	.08 gr/dscf @12% CO2						20%			
CT	74	before 2/1/89	all	4/10 lb/1000 lb flue gas, 50% excess air.	N/R	N/R	N/R	N/R	N/R	20%, except to 40% 5min/hr	N/R	•	N/R
		after 2/1/89		.08 gr/dscf @12% CO2						20%, except to 40% 5min/hr			
DE	•	•	•	•	•	•	•	•	•	•	•	•	•
DC	36	on or before 7/7/72	all	.08 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	N/R	multiple chambers	•	N/R

TABLE 8. (continued)

Existing Sources (STATEREQ.WQ1)													
State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
FL	31	1990	<=500 lb/hr 501-2000 lb/hr >2000 lb/hr	0.1 gr/dscf @7% O2 .03 gr/dscf @7% O2 .02 gr/dscf @7% O2	N/R	N/R	4 lb/hr 4 lb/hr or 90% (hr) 50 ppmdv @7% O2 (3hr) or 90% (hr)	N/R	all: 100 ppmdv @7% O2	5%, up to 20% 3 min/hr 5%, up to 20% 3 min/hr 5%, up to 20% 3 min/hr	all: 1-sec resid. @1800 F	*	N/R
GA	37	*	<=500 lb/hr >500 lb/hr	1.0 lb/hr 0.2 lb/100 lb waste charged	N/R	N/R	N/R	N/R	N/R	all: 20%, up to 27% for 6 min/hr	all: 800/1500 F	*	N/R
HI	75	*	all	0.2 lb/100 lb refuse charged	N/R	N/R	N/R	N/R	N/R	40 %, prior to 3/21/72 20%, after 3/21/72	N/R	*	N/R
ID	38	8/21/92 amended	all	0.2 lb/100 lb refuse charged	N/R	N/R	N/R	N/R	N/R	20% (except 3 min/hr)	multiple chambers	*	N/R
IL	39	12/89	<=2000 lb/hr 2,001-60,000 lb/hr >60,000 lb/hr	0.2 gr/dscf @12% CO2 .08 gr/dscf @12% CO2 .05 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	500 ppm (50% ex. air) 500 ppm (50% ex. air) 500 ppm (50% ex. air)	all: 30%, up to 60% 8 min/hr	N/R	*	N/R
IN	40	1988	<200 lb/hr >200 lb/hr	0.3 lb/1000 lb dry exhaust 0.5 lb/1000 lb dry exhaust	N/R	N/R	N/R	N/R	N/R	40% 40%	N/R	*	N/R
IO	41	7/21/78	<1000 lb/hr >=1,000 lb/hr	0.35 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	40%, up to 60% 3min/hr 40%, up to 60% 3min/hr	N/R	*	N/R
KS	42	6/8/92 amended	<200 lb/hr 200-20,000 lb/hr > 20,000 lb/hr	0.3 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2 0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20% 20% 20%	multiple chambers	*	N/R
KY	78	2/2/91 amended	<=500 lb/hr 501 lb/hr-250 tpd >250 tpd	0.1 gr/dscf @7% O2 .08 gr/dscf @7% O2 .08 gr/dscf @7% O2	N/R	N/R	less stringent: 25 ppmdv @7% O2 or 85% (hr)	N/R	100 ppmdv @7% O2 100 ppmdv @7% O2 100 ppmdv @7% O2	10% 10% 10%	all: 1-sec resid. @1800 F PM APCD inlet temp.(g)	record-performance test, and operating parameters report quarterly compliance reports	training required

TABLE 8. (continued)

Existing Sources (STATERED.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
LA	44	1992	<500 lb/hr >=500 lb/hr	.03 gr/dscf @7% O2 .04 gr/dscf @7% O2	N/R	all: SO2; 100 ppmv @7% O2 or 70% red. NOx; 250 ppmv @7% O2	4 lb/hr or 98% reduction 4 lb/hr or 98% reduction	N/R	100 ppmv @7% O2 100 ppmv @7% O2	10% 10%	all onsite: 1.5-sec resid. @1500/2000 F all offsite: 2-sec resid. @1500/2000 F	record-hrs of operation, amount of of waste charged report-monthly amount of waste charged and hrs of operation	N/R
ME	31	1989	<=50 tpd >50 tpd	0.2 gr/dscf @12% CO2 .08 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	10% 10%	all: 1-sec resid. @1800/1800 F 2000/2000 F/w chemo. waste or cytotoxic drugs	*	N/R
MD	77	prior to 1/17/72 after 1/17/72	<200 lb/hr =>200 lb/hr all after 1/17/72	0.3 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2 0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20% 20% 20%	N/R	*	training and certification required
MA	45	10/27/90	all	0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	40%	N/R	*	training required
MI	31	1989	all	0.2 lb/1000 lb flue gas with 50% exc. air	N/R	N/R	N/R	N/R	N/R	N/R	N/R	*	N/R
MN	78	prior to 1976 after 1976	all prior to '76 all after '76	0.3 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	training and certification required
MS	79	*	all	0.2 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	40%	multiple chambers	*	N/R
MO	49	6/10/93 6/10/98 for CDD/CDF HCl, and Hg	<2.0 MMBtu/hr 2.0-12 MMBtu/hr >12.0 MMBtu/hr	.09 gr/dscf @7% O2 .09 gr/dscf @7% O2 .03 gr/dscf @7% O2	- - Hg: 50 ug/dscm @7% O2	N/R	- 50 ppmv @7% O2 50 ppmv @7% O2	- - 25 ng/dscm @ 7% O2	N/R	10% 10% 10%	1-sec resid. @1650/1600 F 1-sec resid. @1650/1600 F 2-sec resid. @1650/1600 F	record-testing, maintenance, chamber temp., type and amount of waste charged	training and certification required (ASME or manufacturer)
MT	50	12/14/92 amended	all	0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	10%	N/R	*	N/R
NB	51	2/20/91 amended	all	0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	*	N/R

TABLE 8. (continued)

Existing Sources (STATEREQ.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
NV	52	12/28/91 amended	<2,000 lb/hr >=2000 lb/hr	1.8 lb/ton dry waste charged =0.6(40.7 x 10EE-5 x C) C=dry waste charged lb/hr	N/R	N/R	N/R	N/R	N/R	N/R	all: 0.3-sec resid. @1400 F	•	N/R
NH	53	on or before 4/15/70	<200 lb/hr >200 lb/hr	0.3 gr/dscf @12% CO2 0.2 gr/dscf @12% CO2	N/R	N/R	- 50 ppmdv @7% O2 or 90% red.	N/R	N/R	N/R	N/R	•	owner is responsible for training
NJ	54	3/14/78	<800 lb/hr >800 lb/hr	0.2 gr/dscf @12% CO2 0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	N/R	multiple chambers	•	N/R
NM	55	5/13/92	<200 lb/hr 200-999 lb/hr >=1,000 lb/hr	.08 gr/dscf @12% CO2 .03 gr/dscf @12% CO2 .015 gr/dscf @12% CO2	- As,Be,Cd, Cr,& Pb (99%) Hg: 90% As,Be,Cd, Cr,& Pb (99%) Hg: 90%	- SO2: 80 mg/dscm NOx: 235 mg/dscm both @7%O2 SO2: 80 mg/dscm NOx: 235 mg/dscm both @7%O2	4 lb/hr or 98% reduction 40 mg/dscm @7% O2 40 mg/dscm @7% O2	500 ng/dscm @7% O2 5 ng/dscm @7% O2 5 ng/dscm @7% O2	80 mg/dscm @7% O2 80 mg/dscm @7% O2 80 mg/dscm @7% O2	10% 10% 10%	all: 1-sec resid. @1400/1800 F, exit temp. =<300 F	report-quarterly operating parameters excess emissions record-all parameters and quarterly reports	training required
NY	56	5/26/92 amended	onsite commercial	.03 gr/sdcf @7% O2 .015 gr/dscf @7% O2	N/R	N/R	All: 90% red. or 50 ppmdv @7% O2 OR uncont. <4 lb/hr and <500 lb/hr charged	N/R	150 ppmdv @7% O2 150 ppmdv @7% O2	10% 10%	all: 1-sec resid. @1400/1800 F exit temp. <300 F, annual inspection	report-annual inspection	training and certification required
NC	57	9/30/91	<100 lb/hr 101-2,000 lb/hr >2,000 lb/hr	0.2 lb/hr or 0.08 gr/dscf lb/hr = 0.002P or 0.08 gr/dscf 4.0 lb/hr or .08 gr/dscf @12% CO2 P=Charge rate (lb/hr)	N/R	SO2: 2.3 lb/MMBtu SO2: 2.3 lb/MMBtu SO2: 2.3 lb/MMBtu	N/R	N/R	N/R	20% 20% 20%	all: 1-sec resid. @1200/1800 F	record-primary and secondary chamber temp., any continuous monitoring data	N/R
ND	60	10/1/87	<=1,000 lb/hr >1,000 lb/hr	lb/hr=0.00515(R^0.9) lb/hr=0.0252(R^0.67) R=lb/hr charged	N/R	N/R	N/R	N/R	N/R	20%, up to 40% for 6 min/hr 20%, <40% for 6 min /hr	all: 0.3-sec resid. @1500 F	•	N/R

TABLE 8. (continued)

Existing Sources (STATEREQ.WQ1)													
State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
OH	58	7/9/91	<100 lb/hr 100-1,800 lb/hr >1,800 lb/hr	0.2 lb/100 lb waste charged 0.1 lb/100 lb waste charged 0.08 lb/100 lb waste charged	All: (lb/hr) As=.0042 Be=.0076 Cd=.010 Cr=.0015 Pb=.068 Hg=.011 Ni=.0076	N/R	4 lb/hr or 90% red. by wt 4 lb/hr or 90% red. by wt 4 lb/hr or 90% red. by wt	N/R	100 ppmdv @7% O2(hr) 100 ppmdv @7% O2(hr) 100 ppmdv @7% O2(hr)	5%, up to 10% 1 min/hr 5%, up to 10% 1 min/hr 5%, up to 10% 1 min/hr	Intermittent and batch: 1200/1800 F continuous: 1-sec resid. all: after 1/1/91 2-sec resid. 1400/1800 F	report-performace test, quarterly excess emissions record-charging rates	training required
OK	61	7/21/71	all	Y=(0.01221)(X^0.7577) Y=lb/hr X=charge rate (lb/hr)	N/R	N/R	N/R	N/R	N/R	20% 20% 20%	600 F primary chamber temp.	*	N/R
OR	62	11/8/91 amended	all	.03 gr/dscf @7% O2	N/R	SO2: 50 ppmdv @ 7% O2 or 70% (3-hr) NOx: 200 ppmdv @7% O2	50 ppmdv @ 7% O2 (hr) or 90% red.	N/R	100 ppmdv @ 7% O2 (8-hr)	10%	N/R	*	N/R
PA	63	10/11/71	all	0.1 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
PR	59	12/27/80 amended	< 50 tpd	0.5 lb/100 lb waste charged	N/R	N/R	N/R	N/R	N/R	20%, up to 60% 4 min/30min	multiple chambers	*	N/R
RI	64	6/8/90	Pathological <2000 lb/hr >=2000 lb/hr	.08 gr/dscf @12% CO2 .16 gr/dscf @12% CO2 .08 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20%, except 3-min/hr 20%, except 3-min/hr 20%, except 3-min/hr		*	N/R
SC	65	6/28/92	<500 lb/hr 500-2,000 lb/hr >2,000 lb/hr	0.15 gr/dscf @7% O2 0.1 gr/dscf @7% O2 .08 gr/dscf @7% O2	N/R	N/R	RACT and Ambient Air Quali Impact Standard of 70 ug/m3 30 ppmdv @7% O2 or 90% (hr)	N/R	- 100 ppmdv @ 7% O2 (hr) 100 ppmdv @ 7% O2 (hr)	10%- 30% max anytime 10%- 30% max anytime 10%- 30% max anytime	0.5-sec resid. @1800 F 0.5-sec resid. @1800 F 1-sec resid. @1800 F	record-CEMS data, performace testing report-quarterly exceedances	training and certification required

TABLE 8. (continued)

Existing Sources (STATEREQ.WQ1)

State	Reference	Effective Date(a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions(b)	Dioxin/ Furan Emissions	CO Emissions(b)	Opacity	Operation Requirements(c)(d)(e)	Reporting/ Recordkeeping(f)	Operator Training Requirements(f)
SD	86	*	all	N/R	N/R	N/R	N/R	N/R	N/R	20% 20%	N/R	*	N/R
TN	62	11/15/91 update	all	0.1 gr/dscf @ 12% CO2	N/R	N/R	RACT and Ambient Air Quali Impact Standard of 70 ug/m3	N/R	N/R	10%	before 11/6/88: primary chamber 1600 F and zero percent opacity after 11/6/88: 1-sec resid. @1600 F	*	N/R
TX	63	10/23/92 amended	<100 lb/hr (12/31/91) 100-225 lb/hr (7/31/92) >225 lb/hr (7/31/92 onsite 7/31/90 commercial	.08 gr/dscf @ 7% O2 .08 gr/dscf @ 7% O2 .08 gr/dscf @ 7% O2 (front half only) .03 gr/dscf @ 7% O2 (front half only)	N/R	N/R	4 lb/hr or 95% red.	N/R	100 ppmdv @7% O2	5% 5% 5%	N/R	*	N/R
UT	87	3/8/91	all	N/R	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
	65		Typical permit limits								3-sec resid.(h) @1500/1800 F		
VT	66	on or before 4/30/70	<50 tpd >50 tpd	0.1 lb/100 lb waste .08 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	40% 40%	N/R	*	N/R
VA	88	3/17/72	all	0.14 gr/dscf @12% CO2	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	training and certification required
WA	68,69	1/1/85	<12 tpd 12-250 tpd >250 tpd	0.1 gr/dscf @7% O2 .03 gr/dscf @7% O2 .02 gr/dscf @7% O2	N/R	SO2: 1,000 ppmdv @7% O2 SO2 80% red. or 50 ppmdv @7% O2 or BACT SO2 80% red. or 50 ppmdv @7% O2 or BACT	80 % red. or 50 ppmdv @7% O2 (1hr) or BACT 80 % red. or 50 ppmdv @7% O2 (1hr) or BACT	N/R	N/R	20% 5% 5%	all: 1-sec resid. @1800 F, PM APCD inlet temp.(j), and operation and maintenance plan	report-performance test data, quarterly pollutant conc., exceedances, and monitoring down-times	training and certification required

TABLE 8. (continued)

Existing Sources (STATEREQ.WQ1)

State	Reference	Effective Date (a)	Size	PM Emissions	Metals Emissions	SOx/NOx Emissions	HCl Emissions (b)	Dioxin/ Furan Emissions	CO Emissions (b)	Opacity	Operation Requirements (c) (d) (e)	Reporting/ Recordkeeping (f)	Operator Training Requirements (f)
WV	70	5/8/91 amended	<=200 lb/hr	lb/hr = (1.25)(C)	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
			>200 lb/hr	lb/hr = (5.43)(C) C = incinerator capacity (ton/hr)						20%			
WI	71	10/1/88	<200 lb/hr	.08 gr/dscf @7% O2	N/R	N/R	case-dependent	case-dependent	75 ppmdv @7% O2(3 hr)	20%	all: 2-sec resid. @1800 F and PM APCD inlet temp. (j)	record-weight of each charge, CEM data	training and 3 levels of certification required
			200-999 lb/hr	.03 gr/dscf @7% O2			50 ppmdv @7% O2	case-dependent	75 ppmdv @7% O2(3 hr)	5%			
			1,000 lb/hr to 50 tpd	.015 gr/dscf @7% O2 (including condensible)			50 ppmdv @7% O2	.02 ng 2,3,7,8-TCDD/dscm @7% O2	75 ppmdv @7% O2(3 hr)	5%			
			>=50 tpd	0.015 gr/dscf @7% O2			25 ppmdv or 95% reduction	.02 ng 2,3,7,8-TCDD/dscm @7% O2	50 ppmdv @7% O2(3 hr)	5%			
WY	72	10/20/90 amended	all	0.2 lb/100 lb of waste charged	N/R	N/R	N/R	N/R	N/R	20%	N/R	*	N/R
	65		Typical permit limits	0.04 gr/dscf @7% O2						10%	1-sec resid. @1800 F		

- Requirment not applicable for particular size.
* No information presently available.
N/R Not regulated.
(a) If the effective date of the regulation is unknown the date of amendment or update in the Environmenal Reporter is cited, if available.
(b) Times in parenthesis inidcate averaging times.
(c) All residance times and temperatures are minimum requirements for secondary chambers unless otherwise indicated.
(d) Temperatures seperated by a slash indicate minimum temperatues for the primary and secondary chambers respectively.
(e) Exit temperatures indicate a maximum temperature from the final APCD.
(f) Reporting/Recordkeeping and training requirements apply to all sizes, unless otherwise indicated.
(g) The inlet temperature to the most efficient PM control device must be less than or equal to 300 F, except for wet scrubbers.
(h) The 3-sec minimum residance time was only specified in one permit.
(i) The inlet temperature of the primary PM APCD may not exceed 350 F.
(j) The temperature of any exhaust gas stream entering a baghouse or electrostatic precipitator may not exceed 300 F.

and required interlock systems to prevent waste charging when the chamber temperature is below a specified value. These standards vary from State to State and may be tiered for different incinerator sizes. Several states also have requirements for operator training programs.

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16. ABSTRACT

This report provides an overview of the medical waste incineration process, describes the types of medical waste incinerators (MWI's) and their components, and discusses the combustion process as it relates to MWI's. The report also describes current practices associated with medical waste generation, segregation, handling, and transportation. This is one in a series of reports used as background information in developing air emission standards and guidelines for new and existing MWI's.

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