Chapter 5

Current Land-Based Incineration Technologies

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Current Land-Based Incineration Technologies

A variety of technologies are used to thermally destroy hazardous wastes. In its strictest sense, incineration means the high-temperature destruction of wastes carried out in the presence of oxygen. For practical purposes, however, certain other thermal destruction technologies that destroy wastes using little or no oxygen (i.e., pyrolysis and starved air incineration) can be be grouped with incineration technologies. [1] This section briefly describes the distinctive features of the various processes that thermally destroy hazardous wastes.

All waste incinerators have several common components: a waste feed system, a combustion air or oxygen system, a combustion chamber, combustion monitoring systems, and (where required) an air pollution control and ash removal system. The actual applications of the various components vary somewhat in different designs. The following brief description of available incineration technologies discusses each of these features.

[1]The destruction of hazardous wastes in boilers and furnaces (see ch. 4) is a common practice that is only beginning to come under regulation; however, under current regulations (46 FR 7666, Jan. 23, 1981), these practices are distinguished from incineration because wastes are burned in boilers and furnaces for the *primary* purpose of recovering their energy content, not for the purpose of destroying the wastes. EPA estimated that, in 1981, almost twice as much hazardous waste was burned in boilers and furnaces than was burned in incinerators (4).

TRADITIONAL INCINERATION TECHNOLOGIES

Liquid Injection Incineration

Liquid injection incineration is, by far, the most common incineration technology used on land (primarily onsite), and is the only technology being used or considered for ocean incineration, As the name implies, liquid injection incineration can accommodate only freely flowing (pumpable) liquid or slurry wastes. When coupled with other types of incinerator designs, this technology serves as a secondary chamber (afterburner) for volatilized constituents produced by the primary incinerator.

Liquid injection incinerators are designed with almost no moving parts and are almost exclusively single-chamber units. (Figure 3 depicts in schematic form a typical liquid injection incinerator.) Wastes are typically injected into the combustion chamber after being atomized (i.e., broken up into very fine droplets) by passage through a nozzle or rotating cup located in or near the burner. A forced air draft system supplies the oxygen required for combustion and also provides turbulence to aid in mixing. The combustion chamber itself is typically a refractory-lined (heat-resistant) cylinder, which can be mounted either vertically or horizontally.

Combustion gases are vented directly to the atmosphere, if they comply with air pollution regulations for incinerators. If halogenated wastes are burned, scrubbers capable of removing acid gases may be required. Incineration of liquids usually results only in very low particulate emissions and, therefore, does not usually require particulate removal equipment.

Rotary Kiln Incineration

Rotary kiln incineration is the technology most commonly used by major commercial land-based facilities and is the third most common incinerator design in the United States. Rotary kilns can accommodate a wide range of solid and sludge wastes, including dry flowable granular wastes, containerized wastes, nonpumpable slurries, and semisolids. Rotary kilns are generally equipped with sec-

Photo credit: E.T. Oppelt, Hazardous Waste Engineering Laboratory, US. Environmental Protection Agency

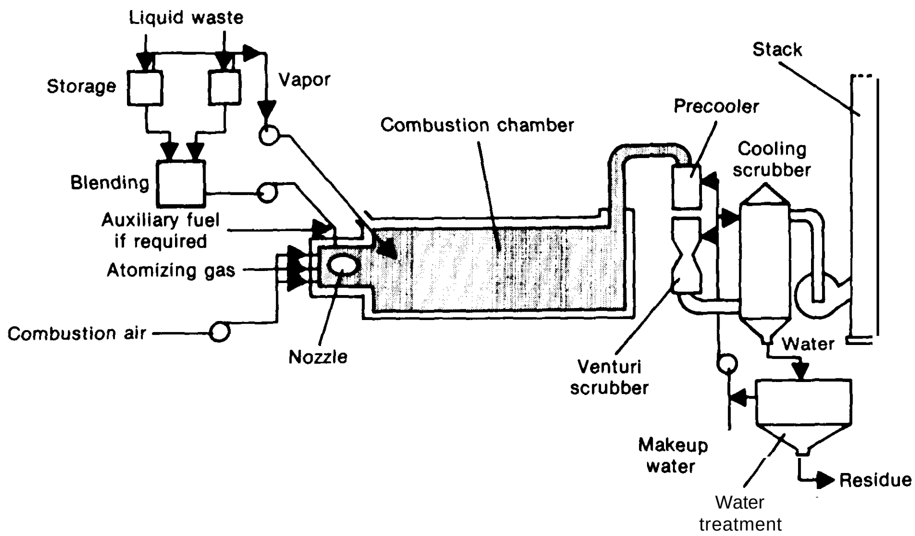
Liquid injection incineration, the most common incineration technology in the United States, is typically used by waste generators to destroy their own liquid wastes onsite. It is the only technology being used or considered at this time for ocean incineration.

ondary combustion chambers (afterburners) to increase the length of time during which wastes are subjected to the high temperatures necessary to ensure complete destruction.

The major commercial facilities operate large rotary kilns, coupled with liquid injection units to accommodate liquid wastes. Rotary kiln technology is not currently applicable to at-sea operation, nor is it likely to be in the foreseeable future, because of design and spatial constraints. The capital costs of rotary kiln technology are significantly higher than those of liquid injection systems.

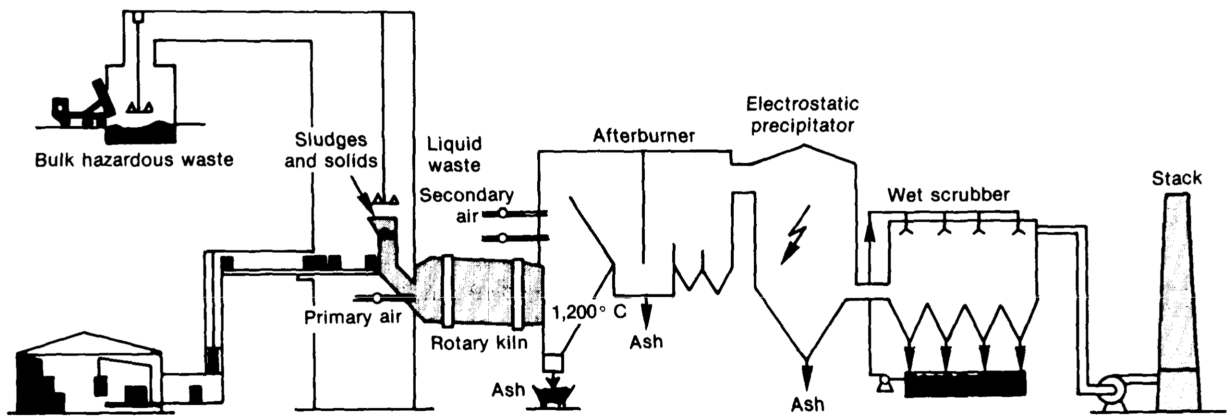
The combustion chamber of a rotary kiln incinerator consists of a slowly rotating, refractory-lined cylinder mounted at a slight incline to aid gravity feed of wastes. (Figure 4 is a schematic representation of a typical rotary kiln incinerator.) Solid and sludge wastes enter at its high end, and liquid wastes or auxiliary fuel are introduced as needed through nozzles. Ash moves to the low end of the

Figure 3.—Liquid Injection Incineration Technology



SOURCE: Arthur D. Little, Inc., *Overview of Ocean Incineration,* prepared by J.R. Ehrenfeld, D. Shooter, F. Ianazzi, and A. Glazer for the Office of Technology Assessment (Cambridge, MA: May 1986).

Figure 4.-Rotary Kiln Incineration Technology



SOURCE: Arthur D. Little, Inc., *Overview of Ocean Incineration,* prepared by J.R. Ehrenfeld, D. Shooter, F. Ianazzi, and A. Glazer for the Office of Technology Assessment (Cambridge, MA: May 1986).

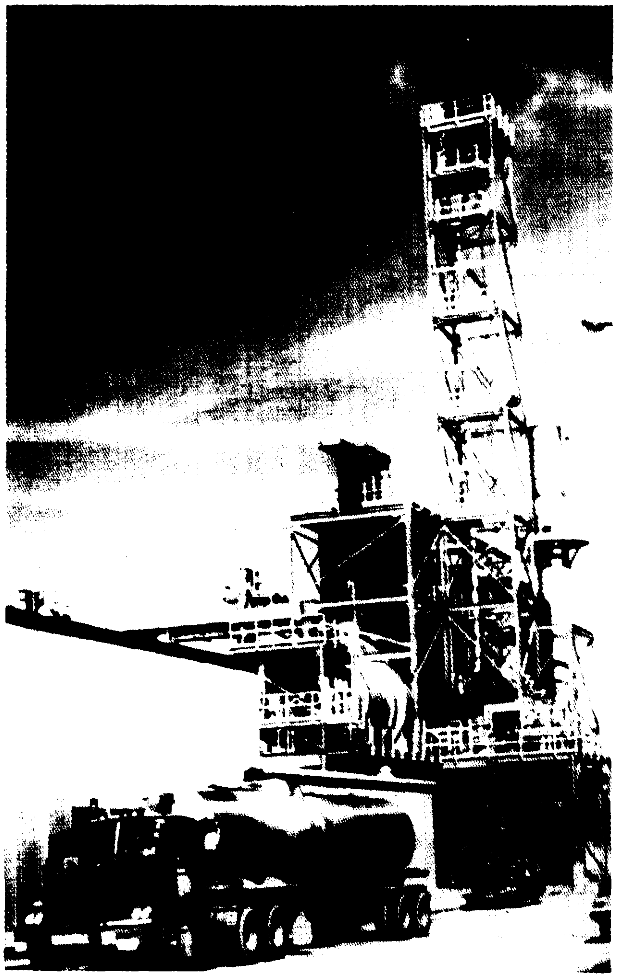


Photo credit: E.T. Oppelt, Hazardous Waste Engineering Laboratory, EPA

Rotary kiln incineration can destroy a wide range of hazardous wastes—solids, sludges, and liquids—and is the technology most frequently used at commercial facilities.

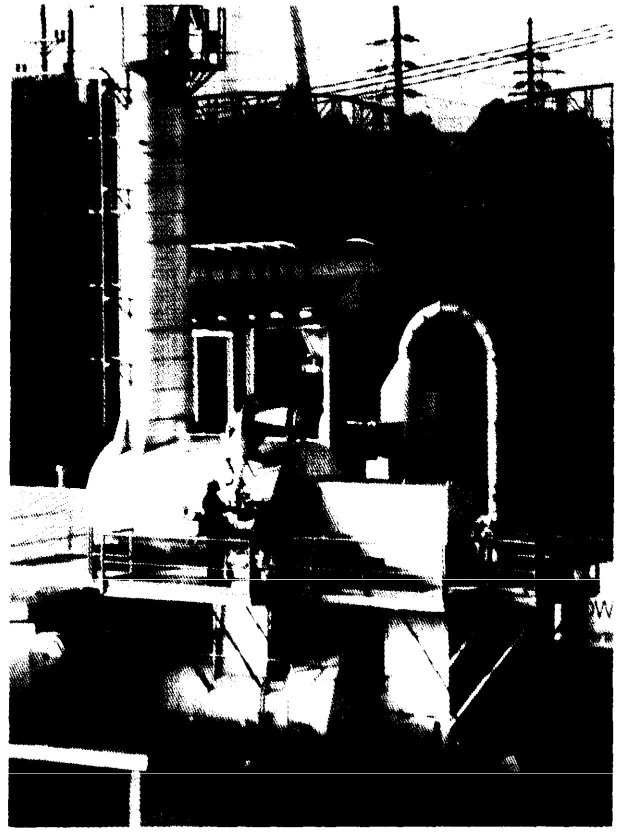


Photo credit: Trade Waste Incineration/Air Pollution Control Association

Fixed hearth incinerators are commonly used to burn solids and sludges at the site of generation. This particular facility has been equipped with liquid injection equipment to allow the incineration of liquid hazardous wastes as well.

kiln, where it can be removed for disposal. After being volatilized and partially destroyed in the primary chamber, gases are directed to the secondary chamber to complete the destruction process.

Incinerating solid wastes creates appreciable ash residues and particulate, so rotary kilns are typically equipped with stack scrubbers to clean flue gases.

Hearth Incineration

Hearth incineration, which is the second most common design in the United States, is employed primarily to burn wastes onsite. Hearth incinerators are designed to burn waste in solid and sludge form, but they can also be equipped with liquid injection capability.

Wastes are introduced onto a platform (hearth) in the bottom of the combustion chamber. Both fixed- and multiple-hearth designs are in use. Multiple-hearth designs, in which wastes are conveyed from chamber to chamber, are especially useful for burning complex wastes that need to be exposed to high temperatures for long periods. Incineration in fixed hearth units can occur under conditions of excess air or starved air (pyrolytic) conditions. Pyrolytic systems are generally accompanied by excess-air afterburners.

Although air flow over the waste mass can be controlled to limit the amount of particulate matter in the exhaust gases, scrubbers are often necessary to comply with air pollution regulations.

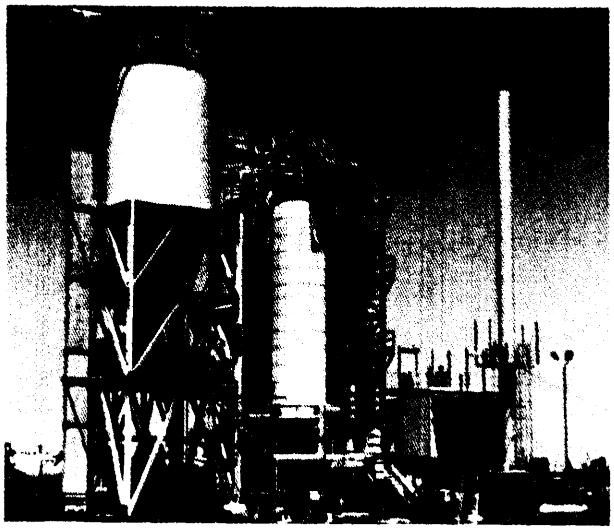


Photo credit: GA Technologies, Inc.

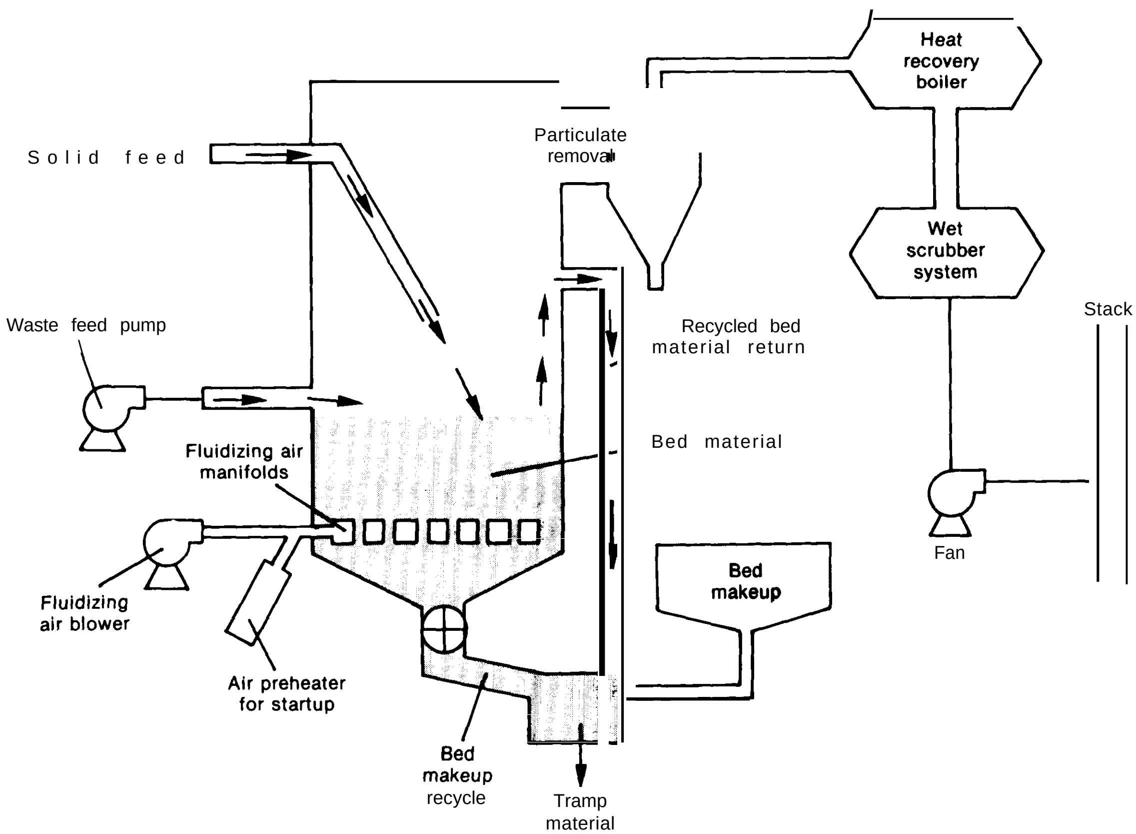
Fluidized bed incinerators can destroy liquids and sludges that are not easily handled by more conventional incinerator technologies,

Fluidized Bed Incineration

Fluidized bed incineration uses a layer of small particles (e. g., sand) suspended in an upward flowing stream of air. (Figure 5 schematically illustrates a fluidized bed incinerator.) The particles behave much like a fluid (hence, the name). Wastes (and auxiliary fuel, if needed) are mixed into the suspended bed and combusted. Fluidized bed incinerators were developed primarily to accommodate highly viscous liquids and sludges not easily burned in more conventional types of incinerators.

Combustion gases from this type of incineration typically contain high levels of particulate and, therefore, must be scrubbed before release to the atmosphere.

Figure 5.— Fluidized Bed Incineration Technology



SOURCE: Arthur D. Little, Inc., *Overview of Ocean Incineration,* prepared by J.R. Ehrenfeld, D. Shooter, F. Ianazzi, and A. Glazer for the Office of Technology Assessment (Cambridge, MA: May 19S6).

Several other incinerator designs are currently in operation. These include fume incinerators (typically with liquid waste incineration capability) for burning gaseous wastes, incinerators for destroying ammunition and explosives, drum burners, and combination systems (e. g., a hearth connected to a liquid injection unit).

OTHER INCINERATION-LIKE TECHNOLOGIES

In addition to the traditional incineration technologies, two incineration-like technologies for destroying wastes are currently in use.

Pyrolysis

Pyrolysis refers to technologies that accomplish thermal destruction in an oxygen-deficient atmosphere. Pyrolysis equipment is similar to conventional incineration technologies, with the obvious exception that it lacks a system for introducing air into the combustion chamber. Organic waste compounds are volatilized and partially decomposed by thermal reactions alone. Gases from the pyrolytic chamber then pass into a conventional chamber where they are combusted in the presence of excess air. One advantage of pyrolytic technologies is that emissions of particulate tend to be lower than do those from more traditional incinerators (8).

Three pyrolysis units are currently operating in the United States, and several others are planned (l).

Wet Air Oxidation

Wet air oxidation is a thermal destruction technology that oxidizes organic contaminants in water. The water modifies oxidation reactions so that they can occur at relatively low temperatures (3500 to 650° F). Air is bubbled through the liquid phase, and the reactor vessel is maintained at a pressure high enough to prevent excessive evaporation (8).

Wet air oxidation is primarily applicable to aqueous waste contaminated with dissolved or suspended organic material. The organic content of wastes suitable for wet air oxidation is generally too low to make traditional incineration economical, but sufficiently high to sustain the reaction temperatures needed for oxidation. The technology has been used successfully to treat a variety of aqueous wastes contaminated with nonhalogenated organic compounds, but it has been much less successful with halogenated compounds. Moreover, a secondary process is typically needed, because detoxification is incomplete (40 to 95 percent).

Figure 6 depicts a typical wet air oxidation system. Several units are currently operating in the United States.

USE OF AIR POLLUTION CONTROL AND HEAT RECOVERY EQUIPMENT

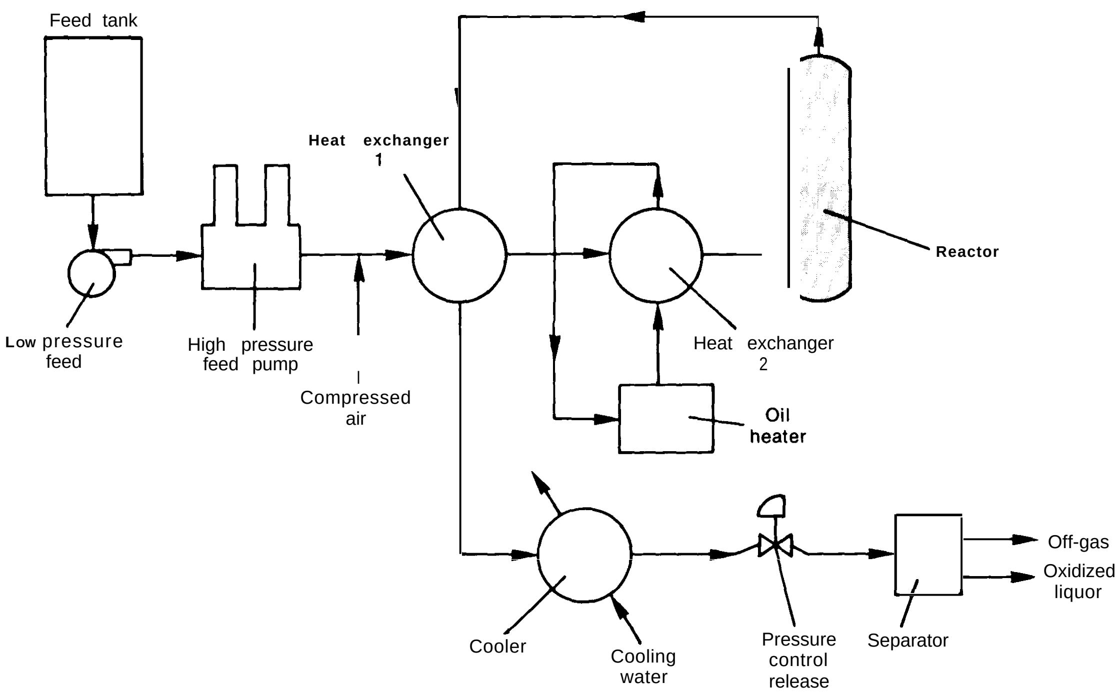
Equipment serving either of two additional functions can be (or is required to be) added to the basic systems described above. Such equipment includes devices to control the emission of air pollutants and devices to recover and use a portion of the energy released through incineration. [2]

'This discussion is drawn primarily from refs. 1 and 3; these sources should be consulted for additional information,

Air Pollution Control Equipment

Air pollution control equipment is often required for land-based incinerators, particularly if wastes with significant ash or halogen content are to be incinerated. Such equipment consists of two components. The first is a quench chamber or heat exchanger to cool the gases leaving the combustion chamber. The cooling is necessary for efficient operation of air pollution controls located downstream.

Figure 6.—Wet Air Oxidation



SOURCE: Arthur D. Little, Inc., *Overview of Ocean Incineration*, prepared by J.R. Ehrenfeld, D. Shooter, F. Ianazzi, and A. Glazer for the Office of Technology Assessment (Cambridge, MA: May 1986).

The second component includes one or more scrubbers for actually cleaning the gases. Major commercial incineration facilities typically remove particulate by using wet or dry electrostatic precipitators, venturi scrubbers, or, less commonly, fabric filters. Removal of gaseous pollutants, including corrosive acid gases, usually requires a wet scrubber, which neutralizes gases through contact with an alkaline liquid reagent. Operation of a wet scrubber requires installation of a mist eliminator downstream, to separate the flue gases from water droplets containing contaminants. (For a fuller discussion of scrubbers, see app. B in ref. 6.)

Both particulate and gaseous pollutant removal systems generate waste sludges that, along with ash residues, are typically handled as hazardous wastes and disposed of in hazardous waste landfills.

Energy Recovery Equipment

Energy recovery equipment is not required under current regulations but is sometimes installed on hazardous waste incinerators if it is deemed economically feasible and advantageous. Such equipment generally can only be installed *upstream* from air pollution control equipment, that is, prior to removal of corrosive gases or particulate. Incineration of wastes generating these products may damage or interfere with the operation of energy recovery equipment and, therefore, often precludes its use. Certain modifications have recently been introduced to partially alleviate these design restrictions.

Energy is generally recovered through the production of steam, which can be used to generate electricity, to drive machinery, or to provide heat. Alternatively, energy can be used to heat the air fed to the incinerator, thereby increasing combustion efficiency and reducing the need for auxiliary fuel.

Typical energy recovery equipment consists of watertube or firetube boilers capable of recovering 60 to 80 percent of the heat content of combustion gases.

PROFILE OF EXISTING HAZARDOUS WASTE INCINERATORS

This section, which is drawn largely from EPA documents, summarizes available information on the number, capacity, and characteristics of existing land-based hazardous waste incinerators. OTA has found that these data are incomplete and only provide rough estimates, even of seemingly straightforward statistics, such as the number of permitted hazardous waste incineration facilities currently operating in the United States. No reliable national database containing such information currently exists. Moreover, the number and permit status of incineration facilities is constantly changing, as permits are processed or facilities open or shut down in response to various regulatory or economic, factors.

Despite these deficiencies, data derived from several sources can be used to develop a profile of existing facilities.

Number of Incineration Facilities

EPA has estimated that about 240 to 275 operating hazardous waste incineration facilities exist in the United States.[3] This estimate emerged from several independent studies, including those based on the Westat national survey (10), interviews with incineration manufacturers, a survey of RCRA Part A permit applicants listed in the EPA Hazardous Waste Data Management System, and data from EPA Regional Office permit files.

As of July 1982, EPA had identified 271 hazardous waste incineration facilities using 352 operational incineration units (3). Based on 1985 permit data, however, this estimate was revised downward, to about 240 facilities using about 310 incineration units (5). The reduction in part reflected the fact that some facilities ceased operations instead of securing final Part B RCRA permits.[4]

Table 9 presents two estimates of the number of incinerators of each design that were in use in 1981 (3). One estimate (shown in column A) was derived from interviews with incinerator manufacturers regarding the number and type of units sold in the United States. The other (column B) was extrapolated from partial data obtained from applications for RCRA Part A permits. These estimates generally agree regarding liquid injection and hearth in-

‘This estimate excludes industrial boilers and furnaces, which are not considered incinerators under current regulations. These facilities are numerous in the United States, and they currently account for the destmction of substantially more hazardous waste than do incinerators (see ch. 4).

*Complicating matters further, OTA recently obtained a computer printout from the Hazardous Waste Data Management System of incinerator facilities that had submitted permit applications as of May 1986. This source listed a total of 274 incineration facilities with pending applications, but it did not provide any information concerning incinerator design or commercial status. In this discussion, the data from this source will be used as the most current available data.

Table 9.—Two Estimates of the Number of Land-Based incineration Units Operating in the United States

	Estimate A[a]		Estimate B[b]	
	Number of units	Percent of total	Number of units	Percent of total
Liquid injection	219	650/o	213	61 %
Hearth (total)	70	21	75	21
Hearth (with liquid capacity)	—	—	(44)	–
Hearth (solids only)	–	—	(31)	–
Rotary kiln (total)	37	11	17	
Rotary kiln (with liquid capacity)	–	—	(15)	5
Rotary kiln (solids only)		—	(2)	–
Fluidized bed	9	3	5	1
Other or unspecified	—	—	42	12
Total	335		352	

[a]Estimate A is derived from interviews with incinerator manufacturers regarding the number and type of units sold in the United States.
[b]Estimate B is based on extrapolation from partial data obtained from RCRA Part A Permit applicant.

SOURCE: E. Keitz, G. Vogel, R. Holberger, et al., A *Profile of Existing Hazardous Waste Incineration FacH/ties and Manufacturers in the United States,* EPA No. S00/2-84452, prepared for the U.S. Environmental Protection Agency, Office of Research and Development (Washington, DC: 19S4).

cinerators but differ significantly regarding rotary kilns. (Note that these estimates were derived from 1981 data; the total number of units has changed since 1981, but revised data for the distribution among different designs are not available.)

The data from Estimate B in table 9 indicate that almost 80 percent of hazardous waste incinerators have some capacity for burning liquid wastes.

Data on the use and nature of air pollution control equipment on land-based incinerators are scant. Based on data obtained from applicants for RCRA Part A permits, EPA (3) estimated that about 45 percent of existing incinerators have some form of air pollution control equipment. About 37 percent of existing units use some type of scrubber. Large incinerators and those employing higher temperatures and longer residence times were more likely to have air pollution control equipment.

EPA (3) also found that only about 22 percent of existing incinerators used energy recovery equipment. Energy recovery equipment is more commonly found on incinerators burning liquids, on larger incinerators, and on incinerators operating on a continuous basis.

Only six incineration facilities are currently permitted to incinerate PCBs, as provided under the Toxic Substances Control Act. See box B in chapter 3 for a more detailed discussion of PCB incineration.

Location of Incineration Facilities

This section considers both the regional distribution and the commercial status (i.e., onsite versus offsite) of existing incineration facilities. For the 274 facilities for which data were available, figure 7 indicates the number of facilities located in each State and EPA Region. Table 10 presents the commercial status of the 227 facilities whose status was indicated in reference 3.

Several conclusions can be drawn from these data on regional distribution. First, as was true for incinerable waste generation, the distribution of hazardous waste incinerators is concentrated in particular States and regions. (For example, as shown in figure 7, EPA Regions V and VI each contain about one-fifth of all facilities. Texas alone accounts for almost one-eighth of all facilities.) Second, the Northwestern United States, in general, contains few incineration facilities, and EPA Region VIII contains no *commercial* facilities. Finally, the great majority (80 percent) of existing hazardous waste incinerators are private facilities located onsite. No correlation is apparent between onsite or offsite incineration and regional distribution.

EPA also examined the sources of waste burned by the incinerators covered in its survey. Of the respondents, 77 percent identified waste they incinerated as having been generated onsite. Of the 23 percent that reported handling waste generated offsite, 90 percent were commercial incinerators (3).

Incinerator Capacities and Operating Characteristics

Existing incinerators have been further characterized with respect to their capacity for liquid and solid wastes and the temperatures and residence times attained under typical operating conditions.

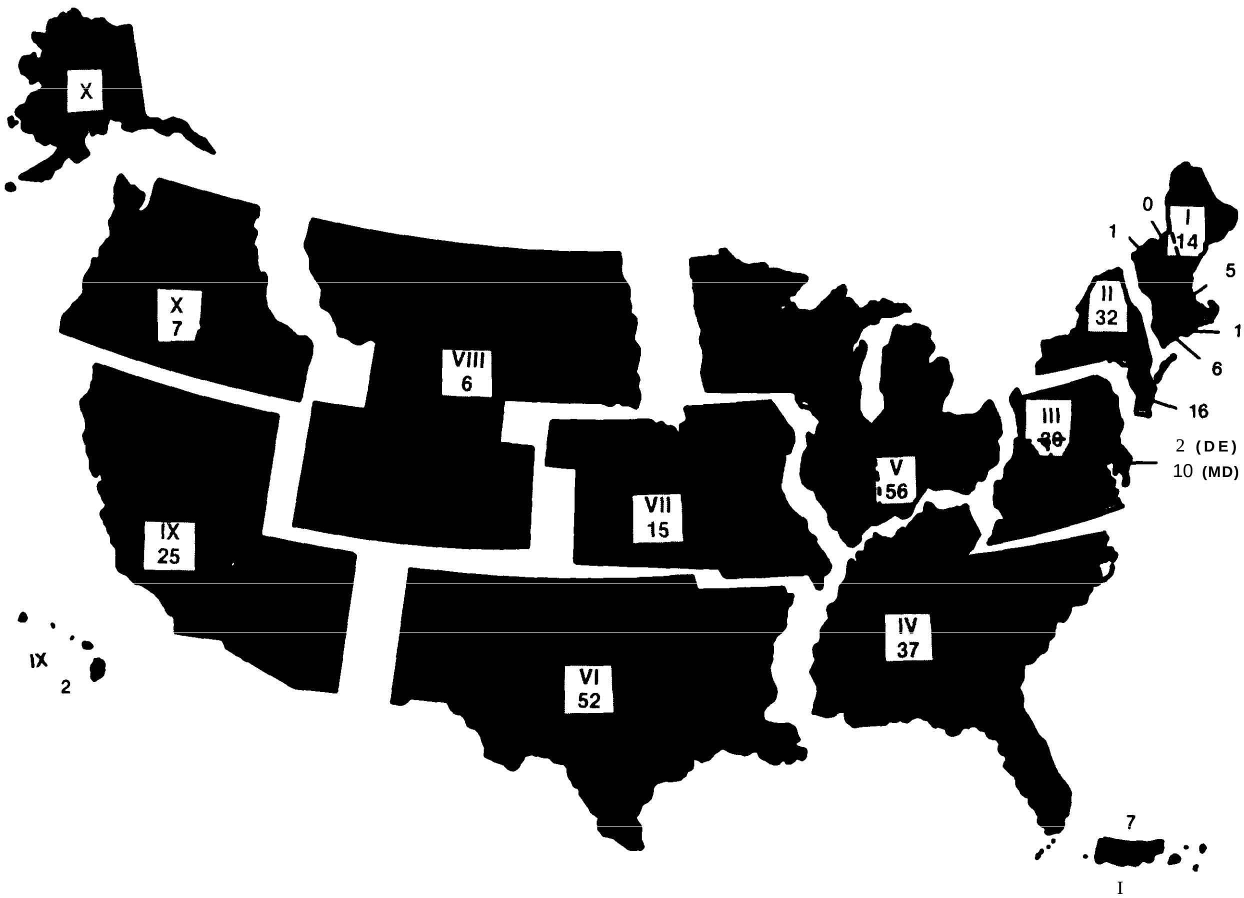
Capacity

For 180 of the incinerators surveyed by EPA (3), capacity for liquid wastes was specified. Figure 8 shows the range of capacities.

According to these data, the capacities of two-thirds of existing incinerators for liquid wastes are below 300 gal/hr (2,500 lbs/hr). The median capacity for liquid wastes is 150 gal/hr (1 ,250 lbs/hr). Similar data for incinerators burning solid wastes revealed a median capacity of less than 80 gal/hr (650 lbs/hr), or about half of the median for liquids. Assuming that the facilities were operated at an average of 55 percent capacity, as estimated by EPA (9), the median capacities would translate into *annual* throughputs of about 1,400 metric tons for solid wastes and 3,000 metric tons for liquids.

These data can be compared to the burning rate for liquid wastes incinerated at sea. Each of the incinerators on the Vulcanus ships has a capacity of about 1,650 gal/hr, or about 11 times the median for land-based incinerators. The Apollo ships are designed to have an even greater capacity, about 2,750 gal/hr per incinerator (7). Only 2 percent of all land-based incinerators have a reported capacity greater than 2,000 gal/hr, and about 4 percent have capacity greater than 1,000 gal/hr.

Figure 7.—A Regional Profile of Land-Based Hazardous Waste Incineration Facilities: Number of Facilities Located in Each State and EPA Region (Total of 274 facilities)



SOURCE: Data based on a computer printout from the Hazardous Waste Data Management System of incinerator facilities that had submitted permit applications as of May 19S6.

The large commercial rotary kiln incinerators in use today have annual throughputs of about 20,000 to 35,000 metric tons of mixed wastes,[5] whereas existing ocean incineration vessels could each burn 50,000 to 100,000 metric tons of liquid wastes annually (refs. 2,9; and data from incineration vessel owners).

Combustion Zone Temperature and Residence Time

According to EPA (3), the average combustion zone temperature in those incinerators for which data were available was 1,820 + 2250 F (993 + 1070 C). For liquid injection incinerators, the average was slightly higher, 1,857 + 224° F (1 ,014 + 1070 C). In both cases, the median temperature was about 1,8000 F. Liquid injection incinerators generally operate at higher temperatures than do rotary kilns, because the former do not require as much excess air to atomize and combust liquid wastes.

With respect to residence time, EPA data indicate that about half of the incinerators for which data were provided had residence times of 2 seconds or longer, and only about 15 percent had residence times under 1 second, Liquid injection incinerators had a similar distribution.

[5]If these incinerators were to burn only liquid wastes, the capacity would be considerably higher.