presented in Table 2-3 (SI units) and Table 2-4 (English units).[2]

Hospital waste can vary considerably in composition and consequently in heat content, moisture content, and bulk density. Hospital waste can vary in Btu content from a low value of about 3,400 kJ/kg (1,500 Btu/lb) (primarily low-Btu, high-moisture anatomical waste) to 45,000 kJ/kg (20,000 Btu/lb) (low-moisture, high-heat content plastics such as polyethylene). Because of the potential for a wide range in waste characteristics and the impact of varying waste characteristics on incinerator performance, large volumes of wastes with unusually high or low Btu or moisture contents should be identified so that charging procedures and rates to the incinerator can be adjusted accordingly as described in Chapter 4.

The chemical composition of the waste materials also may affect pollutant emissions. Wastes containing metals and plastics are of particular concern. Metals which vaporize at the primary combustion chamber temperature (e.g., mercury) may become metal oxides with particle size distributions primarily in the size range of 1 µm or less. These small particles may become easily entrained and exhausted with the combustion gases with limited capture by conventional air pollution control equipment. Halogenated plastics, such as polyvinyl chloride, will produce acid gases such as HCl. The presence of the chlorinated waste also may contribute to the formation of toxic polycyclic organic material such as dioxins and furans under poor operating conditions.

Some plastics such as polyethylene and polystyrene do not contain significant amounts of halogens and can be incinerated efficiently without major concern for acid gas or toxic pollutant formation. However, the high heating value of these and other plastic materials can cause excessively high temperatures in the primary combustion chamber. The potential for refractory damage, slagging, and clinker formation increases unless charging rates are adjusted or the plastics are mixed with other wastes of lower heat content.

2.4 Types of Hospital Waste Incinerator Systems

2.4.1 Introduction[7,11,12]

The terminology used to describe hospital waste incinerators that has evolved over the years is quite varied. Multiple names have been used for the same basic types of incinerators, and much of the terminology does not enhance precise definitions that can be used to define good O&M practices. However, most incinerators have been grouped historically into one of three types – "multiple-chamber," "controlled-air," and "rotary kiln."

Most incineration systems installed before the early 1960's were "multiple-chamber" systems designed and constructed according to Incinerator Institute of America (IIA) standards. The multiple-chamber incinerator has two or more combustion chambers. These "multiple-chamber" systems are designed to operate at high excess-air levels and, hence, are often referred to as "excess-air" incinerators. Multiple-chamber, excess-air incinerators are still found at many hospitals. Many of the multiple-chamber incinerators were designed specifically for pathological wastes and are still being used for that purpose. Note that although the term "multiple-chamber" incinerator typically is used to describe this type of excess-air incinerator, the typical controlled-air and rotary kiln units also contain multiple chambers.

The incineration technology that has been installed most extensively for hospital wastes over the last 15 years generally has been "controlled-air" incineration. This technology is also called "starved-air" combustion, "modular" combustion, and "pyrolytic" combustion. The systems are called "controlled-air" or "starved-air" because they operate with two chambers in series and the first chamber operates at substoichiometric conditions. Similar modular "controlled-air" units which operate with excess-air levels in the primary chamber are also manufactured and sold for combustion of municipal solid waste (MSW); however, these units apparently are not widely used for hospital waste incineration.

Rotary kiln-type incineration systems have been widely used for hazardous waste incineration in the U.S. The rotary kiln has two combustion chambers. The primary chamber is a horizontal rotating kiln that typically operates with excess air. However, some manufacturers now have rotary kilns designed to operate with a substoichiometric atmosphere in the kiln; these kilns use special seals and air injection schemes.[13] The exhaust gases exit the kiln to a fixed secondary chamber. Rotary kiln incineration technology is being applied to hospital waste incineration at a few locations in the U.S. and Canada.[11]

This historical grouping of incineration types is of some assistance in characterizing how hospital waste incinerators operate, but it is limited because it does not address the complete combustion "system" and how the incinerator is operated. Three important factors which help to characterize the hospital waste incinerator system and its operation are (1) the air distribution to the combustion chambers, (2) the mode of operation and method of moving waste through the system, and (3) the method of ash removal. For hospital waste incinerators, air distribution can be classified based on whether the primary chamber operates under substoichiometric (starved) or excess-air conditions. The mode of

Table 2-3. **Characterization of Hospital Waste[2] (Metric)**

Component description	HHV dry basis, kJ/kg	Bulk density as fired, kg/m³	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 2-4. **Characterization of Hospital Waste[2] (English)**

Component description	HHV dry basis, Btu/lb	Bulk density as fired, lb/ft³	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	46-62	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

operation can be single batch, intermittent duty, or continuous duty. Ash is removed on a batch or a semicontinuous basis. Characteristics of the major types of incinerators that are likely to be found at U.S. hospitals with respect to these three factors described above are listed in Table 2-5. The remainder of this section describes the types of incinerators as classified in Table 2-5.

2.4.2 Multiple-Chamber Incinerators[14]

Two traditional designs that are used for multiple chamber incinerators are the "in-line hearth" and "retort" hearth. The in-line hearth design is depicted in Figure 2-3. For in-line hearth incinerators, combustion gases flow straight through the incinerator, with turns in the vertical direction only (as depicted by the arrows in Figure 2-3). Depicted in Figure 2-4 is the retort hearth multiple-chamber incinerator. In the retort hearth design, the combustion gases turn in the vertical direction (upward and downward) as in the in-line incinerator, but also turn sideways as they flow through the incinerator. Because the secondary chamber is adjacent to the primary chamber (they share a wall) and the gases turn in the shape of a U, the design of the incinerator is more compact. In-line incinerators perform better at capacities greater than 750 lb/h. The retort design performs more efficiently than the in-line design at capacities less than 750 lb/h. The retort design is the most common design used in hospital waste applications.

Multiple-chamber incinerators may have fixed hearths or grates or a combination of the two in the primary chamber. The use of grates for a system incinerating infectious waste is not recommended because liquids, sharps, and small, partially

Table 2-5. Classification of Hospital Incinerators

Type of incinerator	Air supply[a]	Waste feed	Ash removal
Multiple chamber	Excess	Manual or mechanical batch feed; single or multiple batches per burn	Batch at end of burn
Batch/controlled air	Starved	Batch (manual or mechanical); 1 batch per burn	Batch at end of burn
Intermittent duty controlled air	Starved	Manual or mechanical batch feed; multiple batches per burn	Batch at end of burn
Continuous duty controlled air	Starved	Mechanical continuous or multiple batch feed	Intermittently or continuously during burn
Rotary kiln	Excess	Mechanical semicontinuous or continuous feed	Continuous

[a] Indicates whether primary chamber operates at below (starved) or above (excess) stoichiometric air levels.

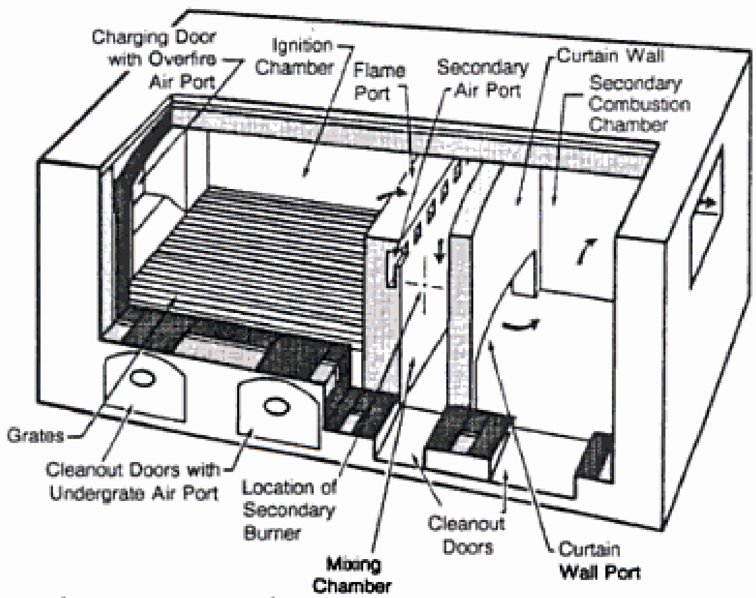


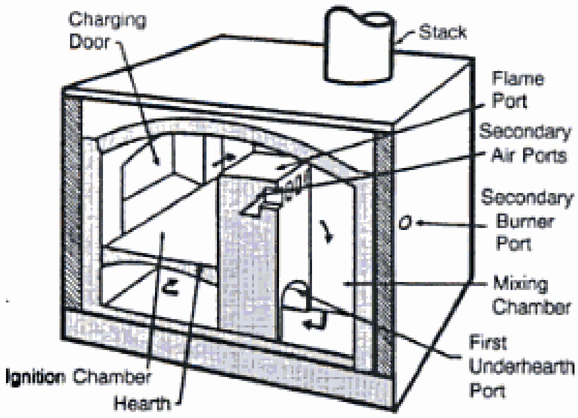
Figure 2-3. In-line multiple-chamber incinerator with grate.[14]

combusted items can fall through the grates prior to complete combustion or sterilization.

Multiple-chamber incinerators frequently are designed and used specifically for incinerating pathological ("Type 4" anatomical) wastes. Pathological waste has a high moisture content and may contain liquids; consequently, a pathological incinerator always will be designed with a fixed hearth. A raised "lip" at the door often is designed into the hearth to prevent liquids from spilling out the door during charging. Because the heating value of pathological waste is low and is not sufficient to sustain combustion, the auxiliary burner(s) provided in the primary chamber of pathological incinerators are designed for continuous operation and with sufficient capacity to provide the total heat input required.

2.4.2.1 Principle of Combustion and Air Distribution

Combustion in the multiple-chamber incinerator occurs in two (or more) combustion chambers. Both chambers are operated with excess air (thus these units often are referred to as "excess-air" incinerators). Ignition of the waste, volatilization of moisture, vaporization of volatile matter, and combustion of the fixed carbon (solid-phase combustion) occur in the primary chamber. The combustion gases containing the volatiles exit the primary chamber through a flame port into a mixing



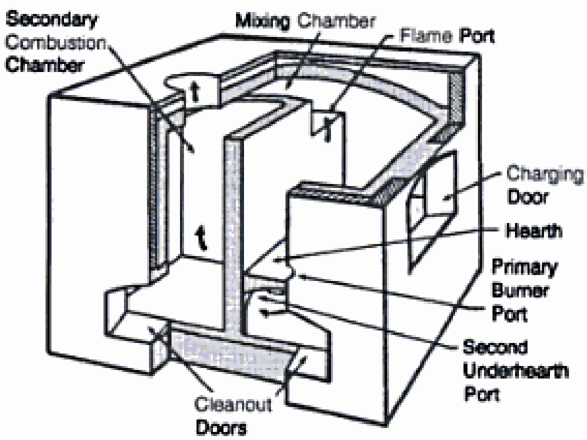


Figure 2-4. Retort multiple-chamber incinerator for pathological wastes.[14]

chamber and then pass into the secondary combustion chamber. Secondary air is added into the flame port and is 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.

The incinerator is designed for surface combustion of the waste which is achieved by predominant use of overfire combustion air and limiting the amount of underfire air in the primary chamber. Multiple-chamber, excess-air incinerators operate with an overall excess-air range of 300 to 600 percent.[14] In older units, combustion air typically was provided by natural draft via manually adjusted dampers and air in-leakage through doors. Newer multiple-chamber incinerators often use forced-draft combustion air blowers to provide the combustion air to the combustion chambers.[15]

2.4.2.2 *Mode of Operation*

Multiple-chamber incinerators typically are designed for single batch or intermittent-duty operation. That is, this type of incinerator typically does not have an automatic, continuous ash removal system which would make continuous operation possible. Consequently, the incinerator must be shut down at routine intervals (for example, daily) for ash removal, and the incinerator is operated "intermittently."

2.4.2.3 *Waste Feed Charging Systems*

Waste feed charging to multiple-chamber units is typically done manually. The waste is loaded into the primary chamber through the open charging door. Mechanical charging systems, such as hopper/ram-feed systems also may be used.[15] (Hopper/ram-feed systems are discussed in the next section.)

2.4.2.4 *Ash Removal Systems*

For the typical multiple-chamber incinerator, ash is removed manually after the incinerator is shut down. The charging and/or ash cleanout doors are opened, and either a rake or shovel is used to remove the ash.

2.4.2.5 *Use of Multiple-Chamber Incinerators for Incinerating Hospital Wastes*

The use of multiple-chamber, excess-air incinerators for incineration of redbag wastes has several drawbacks. First, operating in the surface-combustion excess-air mode in the primary chamber results in entrainment of flyash which can cause excessive particulate matter emissions. Second, since the incinerator is designed to operate with the primary chamber in an excess-air mode, the combustion air levels and the combustion rate within the primary chamber are not easily controlled. Consequently, the incinerator control system may not provide a sufficient level of control to assure complete combustion when waste composition and volatile content of the waste fluctuates over a wide range. Red bag wastes are not homogeneous and may vary widely in volatile content and moisture content. Third, operating with high levels of excess air is less energy efficient because it requires auxiliary fuel usage to maintain secondary combustion chamber temperatures.

Multiple-chamber, excess-air incinerators are better suited to incineration of pathological wastes than red bag wastes because the consequences of the above-mentioned drawbacks are not as severe for pathological wastes.[2] 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 steady, consistent combustion air input and excess-air level.

In some cases, older multiple-chamber incinerators may be upgraded to include more modern technology. Recently, some older multiple-chamber units have been retrofitted so that the incinerator operates with substoichiometric air levels in the primary chamber; in essence, these units have been converted into the controlled-air units discussed in the next section.[15]

2.4.3 Controlled-Air Incinerators

2.4.3.1 Principle of Controlled-Air Incineration[16]

The principle of controlled-air incineration involves sequential combustion operations carried out in two separate chambers. Figure 2-5 is a simplified schematic of an incinerator that operates on the controlled-air principle. The primary chamber (sometimes referred to as the ignition chamber) accepts the waste, and the combustion process is begun in a below stoichiometric oxygen atmosphere. The amount of combustion air to the primary chamber is strictly regulated (controlled). The combustion air usually is fed to the system as underfire air. Three processes occur in the primary chamber. First, the moisture in the waste is volatilized. Second, the volatile fraction of the waste is vaporized, and the volatile gases are directed to the secondary chamber. Third, the fixed carbon remaining in the waste is combusted. The combustion gases containing the volatile combustible materials from the primary chamber are directed to the secondary chamber (sometimes referred to as the "combustion chamber"). There, the combustion air is regulated to provide an excess-air combustion condition and is introduced to the chamber in such a manner as to produce turbulence and promote good mixing of the combustion gases and combustion air. This gas/air mixture is burned, usually at high temperatures. The burning of the combustion gases under conditions of high temperature, excess oxygen, and turbulence promotes complete combustion.

Combustion control for a controlled-air incinerator is usually based on the temperature of the primary (ignition) and secondary (combustion) chambers. Thermocouples within each chamber are used to monitor temperatures continuously; the combustion air rate to each chamber is adjusted to maintain the desired temperatures. Systems operating under controlled-air principles have varied degrees of combustion air control. In many systems, the primary and secondary combustion air systems are automatically and continuously regulated or "modulated" to maintain the desired combustion chamber temperatures despite varying waste composition and characteristics (e.g., moisture content, volatile content, Btu value).[11] In other systems (particularly batch or intermittent-duty systems), the combustion air level control is simplified and consists of switching the combustion air rate from a "high" to a "low" level setting when temperature setpoints are reached or at preset time intervals.

The controlled-air technique has several advantages. Limiting air in the primary chamber to below stoichiometric conditions prevents rapid combustion and allows a quiescent condition to exist within the chamber. This quiescent condition minimizes the entrainment of particulate matter in the combustion gases, which ultimately are emitted to the atmosphere. High temperatures can be maintained in a turbulent condition with excess oxygen in the secondary chamber to assure complete combustion of the volatilized gases emitted from the primary chamber. The temperature of the secondary chamber can be maintained in the desired range (hot enough for complete combustion but not hot enough to cause refractory damage) by separately controlling the excess-air level in the secondary chamber; as the excess-air level is increased, the temperature decreases. Second, control of the primary chamber combustion air to below stoichiometric levels maintains primary chamber temperatures below the melting and fusion temperatures of most metals, glass, and other noncombustibles, thereby minimizing slagging and clinker formation.

For the controlled-air incinerator, the capacity of the secondary combustion chamber dictates (i.e., limits) the burning rate; the combustion chamber 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.

2.4.3.2 Batch/Controlled-Air Incinerators[11]

In this type of unit, the incinerator is charged with a single "batch" of waste, the waste is incinerated, the incinerator is cooled, and the ash residue is removed; the cycle is then repeated. Incinerators designed for this type of operation range in capacity from about 50 to 500 lb/h. In the smaller sizes, the combustion chambers are often vertically oriented with the primary and secondary chambers combined within a single casing. Figure 2-6 is a schematic of a controlled-air incinerator intended for batch operation.[17] This unit's combustion chambers are rectangular in design and are contained within the same casing.

Batch/controlled-air units can be loaded manually or mechanically. For the smaller units up to about 300 lb/h, manual waste feed charging typically is used.

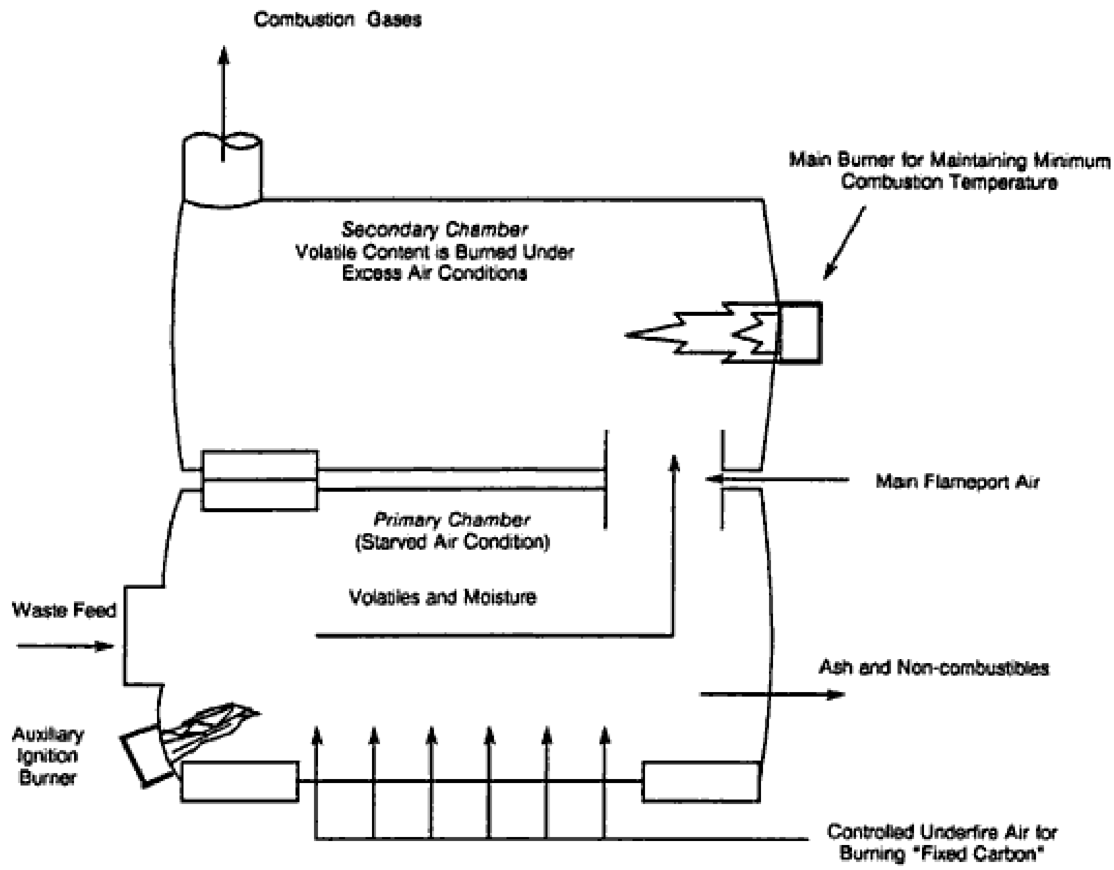


Figure 2-5. Schematic of a controlled-air incinerator.[16]

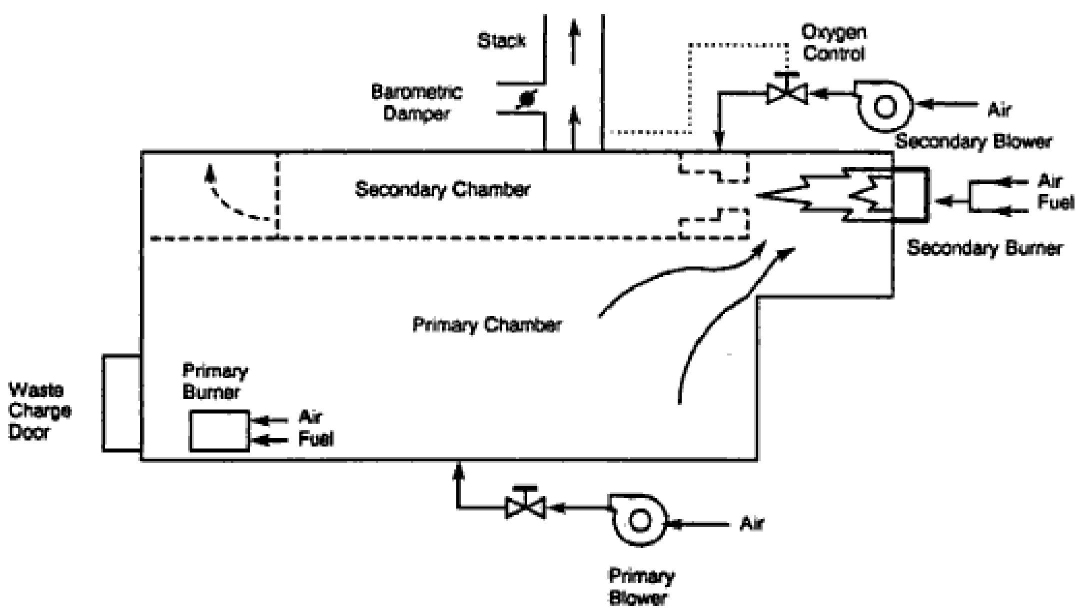


Figure 2-6. Schematic of a single batch controlled-air incinerator.[17]

Manual loading involves having the operator load the waste directly to the primary chamber without any mechanical assistance. For a batch-type unit, one loading cycle per day is used. The incinerator is manually loaded; the incinerator is sealed; and the incineration cycle is then continued through burndown, cooldown, and ash removal without any additional charging. Ash is removed manually at the end of the cycle by raking or shoveling the ash from the primary chamber.

2.4.3.3 *Intermittent-Duty, Controlled-Air Incinerators*

The charging procedures of an incinerator that could operate in single batch mode often are varied to include multiple charges (batches) during the 12- to 14-hour operating period before final burndown is initiated. These intermittent-duty units typically operate in the 50 to 1,000 lb/h range. The intermittent charging procedure allows the daily charge to the incinerator to be divided into a number of smaller charges that can be introduced over the combustion cycle. Consequently, a more uniform gas stream is fed to the secondary chamber. Figure 2-7 is a schematic of a controlled-air incinerator which is intended for intermittent-duty operation. This unit has a vertically oriented primary chamber followed by a horizontal combustion chamber. This unit, although not shown with a mechanical feeder, can be fitted with a hopper/ram assembly.

A typical daily operating cycle for a controlled-air, intermittent- duty-type incinerator is as follows:

	Operating step	Typical duration
1.	Cleanout of ash from previous day 15 to 30 minutes	15 to 30 minutes
2.	Preheat of incinerator 15 to 60 minutes	15 to 60 minutes
3.	Burndown	2 to 4 hours
4.	Cooldown	5 to 8 hours

For intermittent-duty operation, the daily waste loading cycle of the incinerator is limited to about an 8- to 14-hour period. The waste loading period is limited by the amount of ash the primary chamber can physically hold prior to shutting down the unit for ash removal. The remainder of the 24-hour period is required for burndown of the ash, cooldown, ash cleanout, and preheat.

For smaller units, the waste often is fed manually. For units in the 300 to 500 lb/h range, mechanical waste feed systems often are employed, and for units

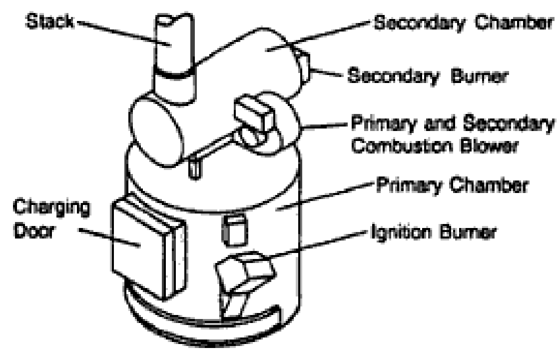


Figure 2-7. Example intermittent-duty, controlled-air incinerator.[18]

above 500 lb/h, mechanical waste feed systems typically are employed. The typical mechanical waste feed system is a hopper ram assembly. Figure 2-8 is a schematic of a typical hopper ram assembly.[20] In a mechanical hopper/ram feed 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 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 to quench the ram face as it retracts typically is provided. The entire charging sequence normally is timed and controlled by an automatic sequence. The cycle can be started manually by the operator or, in some systems, the cycle is automatically started on a predetermined basis.

Mechanical loading systems have several advantages. First, they provide added safety to the operating personnel by preventing heat, flames, and combustion products from escaping the incinerator during charging. Second, they limit ambient air infiltration into the incinerator. This assists in controlling the combustion rate by strictly controlling the quantity of available combustion air. Third, they facilitate charging the incinerator with smaller batches of waste at regulated time intervals.[11]

With intermittent-duty incinerators, ash removal is a limiting factor for the incinerator operations. As with the single batch-operated units, the ash is removed at regular intervals (typically daily) after the incinerator has gone through a cooldown cycle. The ash usually is manually removed by raking and/or shoveling from the primary chamber.

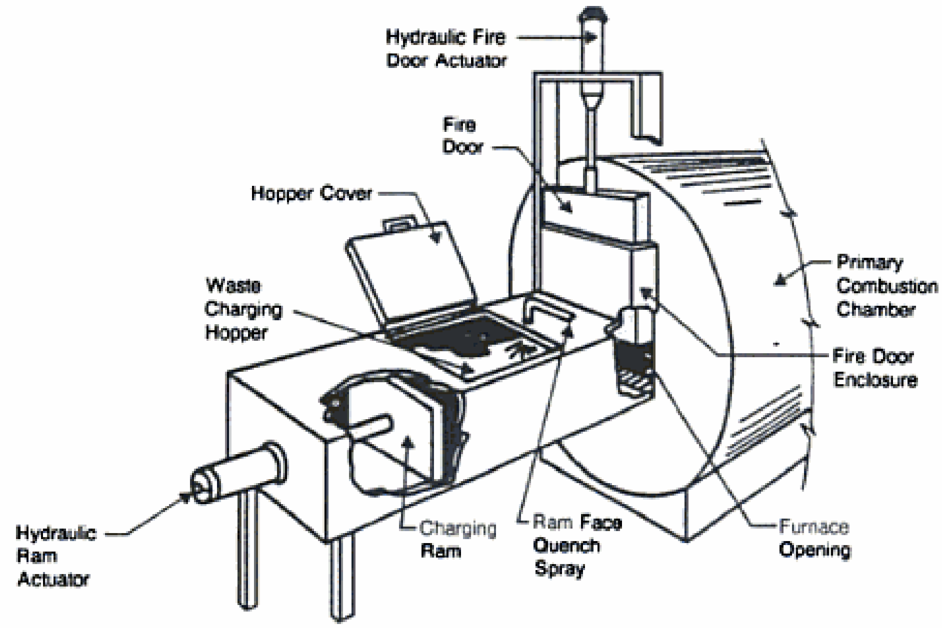


Figure 2-8. Hopper/ram mechanical waste feed system.[21]

2.4.3.4 Continuous-Duty, Controlled-Air Incinerators.

Controlled-air units intended for continuous operation are available in the 500 to 3,000 lb/h operating range. Continuous-duty, controlled-air units operate according to the controlled-air principles of the systems described earlier. However, continuous operation requires a mechanism for automatically removing ash from the incinerator hearth. The ash must be moved across the hearth, collected, and removed from the combustion chamber.

Continuous-duty units typically have mechanical waste feeding systems. For large continuous-duty units, the charging sequence may be fully automatic. The incinerator can be automatically charged with relatively small batches (in relation to the primary chamber capacity) at frequent, regulated time intervals. The use of frequent, small charges promotes relatively stable combustion conditions and approximates steady-state operation. For large systems, the mechanical charging system may include waste loading devices such as cart dumpers, which automatically lift and dump the contents of carts that are used to collect and contain the waste, into the charge hoppers. Use of these loading devices reduces the operator's need to handle infectious waste and, consequently, further improves worker safety.

For smaller units, the mechanical waste feed charging ram is sometimes used to move the ash across the hearth. As a new load is pushed into the incinerator, the previous load is pushed forward. Each subsequent load has the same effect of moving the waste across the hearth. The waste should be fully reduced to ash by the time it reaches the end of the hearth. For larger systems, one or more special transfer rams are provided to move the waste across the hearth. A continuous-duty, controlled-air incinerator with a stepped hearth and multiple ash transfer rams is depicted in Figure 2-9.[21] The use of the stepped hearth promotes "mixing" the ash bed as the ash is moved from hearth to hearth and, consequently, promotes improved solid-phase combustion.

Typically, when the ash reaches the end of the hearth, it drops off the end of the hearth into a discharge chute. One of two methods for collecting ash is usually used. The ash can discharge directly into an ash container positioned within an air-sealed chamber or sealed directly to the discharge chute. When the container is full, it is removed from the chamber and replaced with an empty ash container. The second method is for the ash to discharge 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, is used to remove 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.[11]

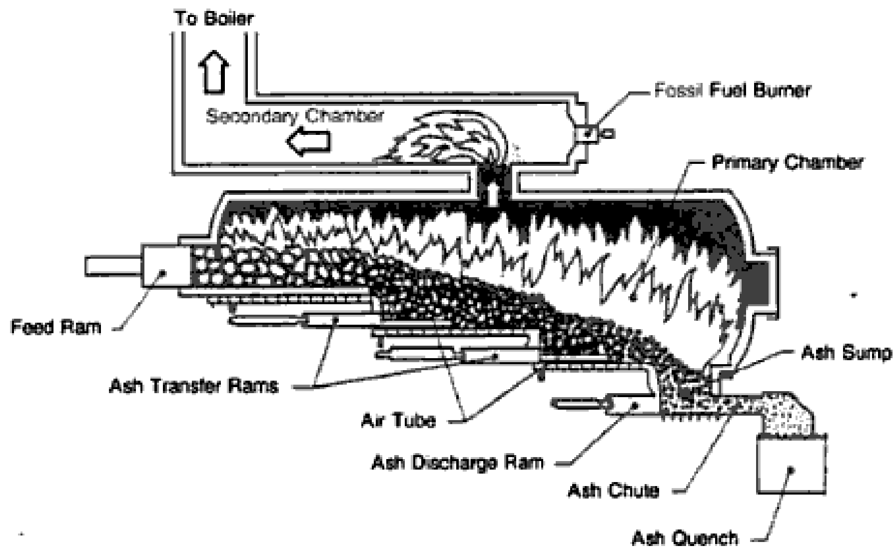


Figure 2-9. Incinerator with step hearths and automatic ash removal.[20]

2.4.4 Rotary Kilns

A rotary kiln also utilizes two-stage combustion and has two combustion chambers. Figure 2-10 is a simplified schematic of a rotary kiln. The primary combustion chamber is a rotating cylindrical chamber which is slightly inclined from the horizontal plane; hence, the name "rotary kiln." The secondary chamber often is cylindrical in shape and oriented horizontally much like the secondary chambers described for controlled-air incinerators, or it may be box-like as depicted in Figure 2-10.

2.4.4.1 Principle of Operation.

The rotating kiln is inclined at an angle determined during design of the system. Waste is fed to the higher end of the kiln by a mechanical feed system. Typically, combustion air is provided to the kiln such that an excess-air atmosphere exists. However, some manufacturers now have rotary kilns designed to operate with a substoichiometric atmosphere in the kiln; these kilns use special seals and air injection schemes. Running the kiln substoichiometrically decreases kiln sizes required and reduces auxiliary fuel usage in the secondary chamber. Inside the kiln, moisture and volatiles are vaporized from the waste, and the waste is ignited. An auxiliary burner provided in the kiln maintains the desired combustion temperature if sufficient heat input is not available from the waste. As the kiln rotates, the solids are tumbled within the kiln and slowly move down the incline toward the discharge end. The turbulence of the waste within the kiln provides exposure of the solid waste to the combustion air. Combustion of the solids occurs within the kiln, and the residue ash is discharged from the end of the kiln into an ash removal system.

The volatile gases pass into the secondary chamber where combustion of the gases is completed. A secondary burner is used to maintain the secondary chamber temperature, and secondary combustion air is added to the chamber as necessary to maintain the desired excess-air level.

2.4.4.2 Mode of Operation.

Since the solid waste continuously moves down the length of the rotating kiln, the incineration system is designed to operate in a continuous mode with a semicontinuous or continuous waste feed input. Consequently, a rotary kiln typically has a mechanical waste feed system and a system for continuous ash removal.

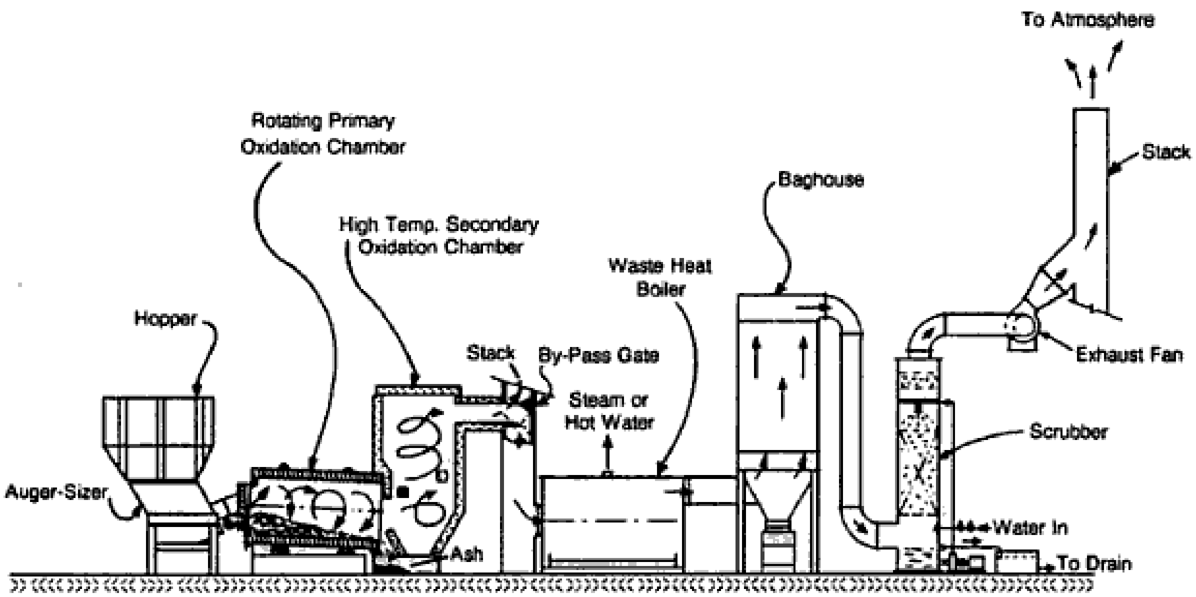


Figure 2-10. Rotary kiln with auger feed.[21]

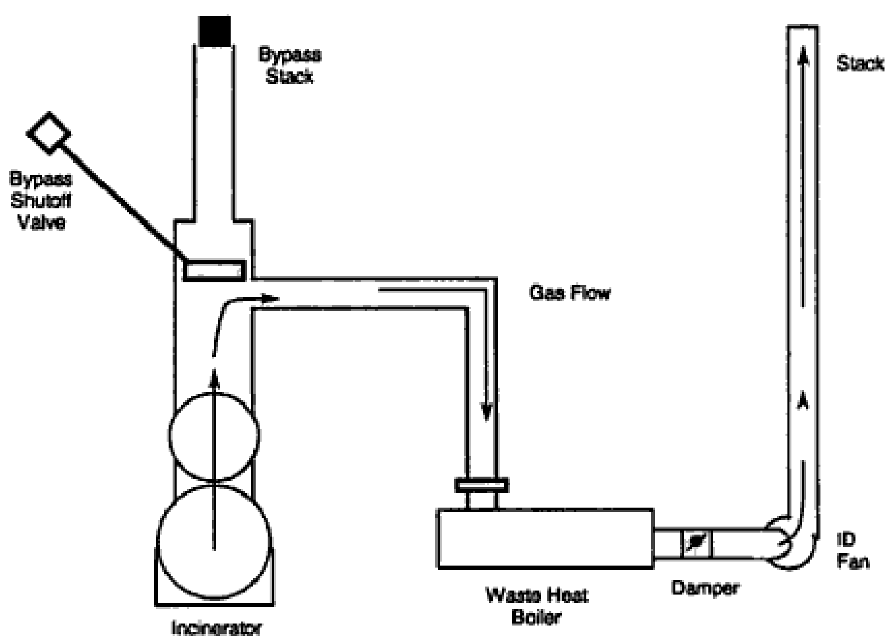


Figure 2-11. Incinerator with waste heat boiler and bypass stack.

2.4.4.3 *Charging System.*

The waste feed system must provide waste to the kiln in a continuous or semicontinuous manner. One manufacturer that provides rotary kiln incinerators for hospital waste applications uses an auger-feeder system to feed the waste continuously to the kiln.[22] Waste is fed to the feed hopper, and the auger-feeder continuously discharges the waste from the bottom of the hopper to the kiln.

The hopper/ram feed system of the type previously described also has been used for feeding rotary kilns (particularly in hazardous waste incineration applications).

2.4.4.4 *Ash Removal.*

As the kiln rotates, the ash is continuously discharged from the end of the kiln. A system for collecting the ash and continuously or semicontinuously removing the ash is required. Automated ash removal systems such as those previously described for the continuous-duty, controlled-air incinerators are used.

2.4.5 Auxiliary Equipment

2.4.5.1 *Waste Heat Boilers.*

Incinerator manufacturers often provide waste heat boilers as an option to their incineration units. Waste heat boilers are used in conjunction with a hospital waste incinerator to generate steam or hot water for use in the hospital. The combustion gases from the incinerator pass through the waste heat boiler prior to being emitted to the atmosphere via the stack. Use of a waste heat boiler requires that an induced draft fan be added to the system. Furthermore, incinerators equipped with waste heat boilers have a system for diverting the combustion gases directly to the atmosphere and bypassing the boiler. This bypass system is required for safety (for example, to avoid excessive pressures in the incinerator should the fan cease operation) and for normal operation if demand for waste heat is low (so the boiler can be taken off line). Typical systems include either a second "bypass" stack before the waste heat boiler or a breeching directly connecting the incinerator to the stack and bypassing the boiler. Figure 2-11 is a schematic of a controlled-air unit with waste heat recovery.[16]

2.4.5.2 *Auxiliary Waste Liquid Injection.*

Incinerators also may include the capability to inject liquid wastes into the primary chamber. Generally liquid waste incineration is accomplished through either an atomizing nozzle or burner assembly in the primary chamber. Wastes such as used solvents can be readily incinerated via liquid injection.

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