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A Review of Standards of Performance for New Stationary Sources - Sewage Sludge Incinerators

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A Review of Standards of Performance for New Stationary Sources - Sewage Sludge Incinerators

by

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ABSTRACT

This report reviews the current Standards of Performance for New Stationary Sources: Subpart O - Sewage Sludge Incinerators. It includes a summary of the current standards, the status of applicable control technology, and the ability of sewage sludge incinerators to meet current standards. Compliance test results are analyzed and a recommendation made to retain the current standard. Information used in this report is based upon data available as of November 1978.

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1.0 EXECUTIVE SUMMARY

The objective of this report is to review the particulate matter New Source Performance Standard (NSPS) of 0.65 kg/Mg (1.3 lb/ton) dry sludge input and the opacity standard of 20 percent for the incineration of sewage sludge (Subpart O, 40 CFR 60). This review is given in terms of developments in technology and issues that have developed since the standard was proposed in 1973. Possible revisions to the standard are discussed in the light of compliance test data available since that time. The following paragraphs summarize the results of the analysis as well as recommendations for future action.

1.1 Best Demonstrated Control Technology

Particulate matter from the inert material in sludge is present in the flue gas of sewage sludge incinerators. Uncontrolled emissions may vary from as low as 4 kg/Mg (8 lb/ton) dry sludge input to as high as 110 kg/Mg (220 lb/ton) dry sludge input depending upon the incinerator type and the sludge composition (e.g., percent volatile solids, percent moisture, and source treatment). While some type of scrubber is universally used to control emissions, the analysis of test results does not show a clear-cut relationship between a particular technology (e.g., venturi scrubber) and the ability to comply with the standard. Rather, both the facility type and input sludge composition are equally important considerations as the large range in uncontrolled emissions factors indicates. The pressure drops in various successful scrubber configurations range from 7 to 35 in.

WG with a mean of 20 in. WG. These configurations included three-stage perforated plate impingement scrubbers operating at 6 to 9 in. WG and venturi scrubbers, or venturi scrubbers in series with various impingement plate scrubbers operating in the 10 to 35 in. WG range.

1.2 Current Particulate Matter Levels Achievable with Best Demonstrated Control Technology

Test results since 1974 for 26 facilities indicate that scrubber controlled incinerators can comply with the NSPS. The average emission from all tests was 0.6 ± 0.35 kg/Mg (1.2 ± 0.70 lb/ton) dry sludge input. When one obviously underdesigned facility and three known non-NSPS tests were deleted the average emission were 0.45 ± 0.17 kg/Mg (0.91 ± 0.33 lb/ton) dry sludge input or about 25 percent below the standard.

Experimental data and some of the tested units indicate that incinerators burning sludge below 20 percent solids may have difficulty complying with the NSPS. Because combustion air requirements per unit of dry sludge increase with increasing sludge moisture, stack concentrations of 0.02 grams/dscm (0.01 grains/dscf) or less may be needed. For this reason, and because of the wide variations encountered in sludge and incinerator characteristics, it is recommended that the NSPS level for particulate emissions not be changed.

1.3 Opacity Standard

Opacity levels from successful emissions tests never exceeded 15 percent and were most often either 0 or 5 percent. These results are similar to those found when the standard was first proposed as a 10 percent value with exceptions allowed during 2 min. of a 60 min. test cycle. This standard was changed to 20 percent with no exemptions except during startup, shutdown, or malfunctions. The current data indicate that the rationale used to arrive at the 20 percent opacity level still applies.

1.4 Coincineration with Municipal Refuse

Various possibilities exist for incinerating municipal solid waste and sewage sludge. There is currently no explicit statement in either Subpart O or Subpart E (Standards of Performance for Incinerators) that covers the appropriate standard to be used for incinerators jointly burning both types of waste. It is suggested that consideration be given to revising both Subparts E and O to cover this situation.

2.0 INTRODUCTION

In Section 111 of the Clean Air Act, "Standards of Performance for New Stationary Sources," a provision is set forth which requires that "The Administrator shall, at least every four years, review and, if appropriate, revise such standards following the procedure required by this subsection for promulgation of such standards." Pursuant to this requirement, the MITRE Corporation, under EPA Contract No. 68-02-2526, is to review 10 of the promulgated NSPS including Subpart O, Standards of Performance for Sewage Treatment Plants.

The main purpose of this report is to review the current sewage sludge incineration particulate matter and opacity standard and to assess the need for revision on the basis of developments that have occurred or are expected to occur in the near future. This report addresses the following issues:

1. A review of the definition of the present standard.
2. A discussion of the status of sewage sludge incineration and the status of applicable control technology.
3. An analysis of particulate matter and opacity test results and review of level of performance of best demonstrated control technology for emission control.

Based on the information contained in this report, conclusions are presented and specific recommendations are made with respect to changes in the NSPS.

3.0 CURRENT STANDARDS FOR SEWAGE SLUDGE INCINERATORS

3.1 Background Information

Prior to the promulgation of the NSPS in 1974, most sewage sludge incinerators (SSI) utilized low pressure scrubbers (2 to 8 in. WG) to reduce emissions to the atmosphere (Balakrishman, et al., 1970). These scrubbers were designed to meet state and local standards that were on the order of 0.2 to 0.9 grams/dry standard cubic meter (dscm) or 0.1 to 0.4 grains/dry standard cubic foot (dscf) at 50 percent excess air. Incineration standards, for the most part, reflected general incineration of all types with emphasis on municipal solid waste. A separate standard for sewage sludge incineration emissions was unusual. Control efficiencies, based on an uncontrolled rate of 2.1 grams/dscm (0.9 grains/dscf) were between 50 and 90 percent (EPA, 1973).

Testing was performed at three relatively well controlled multiple-hearth incinerators and two fluidized bed reactors prior to proposal of the standard in 1973 (EPA, 1973). One of the fluidized-bed reactors was controlled by a venturi scrubber operating at 18 in. WG, while the other incinerators were controlled by low pressure impingement type scrubbers. Based upon these test results the standard was proposed and promulgated, as discussed in the following paragraphs.

3.2 Facilities Affected

The NSPS promulgated as Subpart O, Standards of Performance for Sewage Treatment Plants, applies to incinerators built or modified after June 11, 1973. The Standard, as amended November 10, 1977, defines an affected facility as any incinerator that burns wastes containing more than 10 percent sewage sludge (dry basis) produced by municipal sewage treatment plants or charges more than 1000 kg (2205 lb)/day municipal sewage sludge (dry basis) (42 FR 58520). If a question exists, the owner/operator of a sewage sludge incinerator may apply to the Administrator of EPA for a determination of whether or not his facility is an affected facility.

A facility is considered to have commenced construction or modification on the date that the owner or operator has undertaken a continuous program of construction. This definition includes the time that a contractual agreement has been signed to undertake and complete, within a reasonable time, a continuous program of construction or modification. An existing facility modification includes any changes in the physical plant or operations that will increase the quantity of particulate matter emitted.

3.3 Pollutants Controlled

The NSPS for sewage sludge prohibits the discharge of particulate matter at a rate greater than 0.65 grams/kg of dry sludge input (1.30 lb/ton) and prohibits the discharge of any gases exhibiting 20 percent opacity or greater.

This is a change from the original proposed standards of 0.07 grams/dscm (0.031 grains/dscf) and less than 10 percent opacity. The proposed standard was changed from a concentration to a mass basis because EPA felt that the determination of combustion air as opposed to dilution air is particularly difficult due to the variable center shaft and rabble arm cooling air designed into multiple hearth incinerators and could lead to unacceptable degrees of error (EPA, 1974). The proposed opacity standard was changed from 10 to 20 percent because: (1) 10 percent was too restrictive, (2) new regulations provided exemptions during startup, shutdown, and malfunction, and (3) 10 percent opacity was not consistent with the new mass emission limit (EPA, 1974). A proposed opacity exemption of 2 min in any 1 hr was also deleted in the promulgated standard because reevaluation of data and analysis of new data indicated there was no basis for additional time exemptions.

3.4 Monitoring and Testing Requirements

A flow measuring device must be installed, calibrated, maintained, and operated at all affected facilities. The purpose of this device is to determine the mass or volume of sludge charged to the incinerator. The NSPS requires that the flow measuring device have an accuracy of ±5 percent over its operating range. If municipal solid waste is incinerated with sewage sludge, a weighing device for the solid waste is required with a similar ±5 percent accuracy.

In addition to the flow measuring device, the owner or operator of a sludge incinerator is required to provide access to the sludge charged so that a well-mixed representative grab sample can be obtained. The grab sample is used to determine the dry sludge content (total solids residue).

The following EPA reference test methods are then used to determine compliance:

- Method 1 - sample and velocity traverses
- Method 2 - volumetric flow rate
- Method 3 - gas analysis
- Method 5 - concentraction of particulate matter and associated moisture content

Additional procedures for reference method 5 require that the sampling time for each run be at least 60 min and the sampling rate be at least 0.015 dscm/min (0.53 dscf/min).

The dry sludge charging rate is determined from a grab sample and data from the flow measuring device. The dry sludge content (total solids residue) is determined in accordance with "224G Method for Solid and Semisolid Samples" (American Public Health Association, 1971) with the following exceptions:

1. Evaporating dishes are ignited to at least 103' rather than 550
2. The determination of volatile residue may be deleted
3. The quantity of dry sludge per unit sludge charged is determined in terms of either milligrams dry sludge/liter sludge charged (pounds/cubic feet) or milligrams dry sludge/milligrams sludge charged (pounds/pound).

Compliance or noncompliance with the standard is then determined by calculations presented in 40 CFR 60.154.

3.5 Applicability of NSPS to Coincineration of Municipal Solid Waste with Municipal Sewage Sludge

The coincineration of municipal solid waste and sewage sludge has been practiced in Europe for several years, and on a limited scale in the U.S. (Sussman and Gershman, 1978). Where energy resources are scarce and land disposal is economically or technically unfeasible, the recovery of the heat content of dewatered sludge as an energy source will become more desirable. Due to the institutional commonality of these wastes and advances in the preincineration processing of municipal refuse to a waste fuel, many communities may find joint incineration in energy recovery incinerators an economically attractive alternative to their waste disposal problems.

Coincineration of municipal solid waste and sewage sludge, as described above, is not currently explicitly covered in 40 CFR 60. The particulate standard for municipal solid waste described in Subpart E (0.18 grams/dscm or 0.08 grains/dscf at 12 percent CO_2 applies to the incineration of municipal solid waste in furnaces with a capacity of at least 45 Mg/day (50 tons/day). Subpart O, the particulate standard for sewage sludge incineration (0.65 grams/kg dry sludge input or 1.3 lb/ton dry sludge), applies to any incinerator that burns sewage sludge, with the exception of small communities practicing coincineration.*

To clarify the situation when coincineration is involved, the EPA Division of Stationary Source Enforcement determined that when an incinerator with a capacity of at least 45 Mg/day (50 tons/day) burns

*Special rules apply to communities of less than approximately 9000 persons. See the Federal Register (1977).

at least 50 percent municipal solid waste, then the Subpart E applies regardless of the amount of sewage sludge burned. When more than 50 percent sewage sludge and more than 45 Mg/day (50 tons) is incinerated, the standard is based upon Subpart O or, alternatively, a proration between Subparts O and E. Table 3-1 summarizes the current rules that apply to solid waste and sewage sludge incineration (Farmer, 1978).

The alternative for prorating the Subparts E and O is not straightforward, since the two standards are stated in different units. The proration scheme requires a transformation of the municipal incineration standard of Subpart E from grams per dry standard cubic meters (grains per dry standard cubic foot) at 12 percent CO_2 to grams per kilograms (pounds per ton) refuse input, or a transformation of the sewage sludge standard (Subpart O) from grams per dry kilograms (pounds per dry ton) input to grams per dry standard cubic meter at 12 percent CO_2. Such transformations are dependent on the percent CO_2 in the flue gas stream, the stoichiometric air requirements, excess air, the volume of combustion products to required air, and the percent moisture and the heat content of the sludge and solid waste.

As shown in Figure 3-1, the proration scheme, as currently determined has a discontinuity when a municipal incinerator burns 50 percent solid waste. Nominal equivalent values for sludge and refuse emissions appear on the vertical axis for each standard.

TABLE 3-1

APPLICABILITY OF 40 CFR 60 FOR
COINCINERATION WITH SEWAGE SLUDGE

Sewage Sludge (percent)	Municipal Refuse (percent)	Incinerator Charging Rate	Applicable Subpart (40 CFR 60)
51-100	0-49	>50 Tons/Day Total Waste	Subpart O or Proration of O and E
0-50	50-100	>50 Tons/Day Total Waste	Subpart E
0	100	≤50 Tons/Day Municipal Refuse	None
100	0	Any Rate	Subpart O
1-99	1-99	≤50 Tons/Day Total Wastes, >1.1 Dry Tons/Day Sewage Sludge	Subpart O
11-99	1-89	≤50 Tons/Day Total Wastes, ≤1.1 Dry Tons/Day Sewage Sludge	Subpart O
0-10	90-100	≤50 Tons/Day Total Wastes ≤1.1 Dry Tons/Day Sewage Sludge	None

Source: Farmer, 1978.

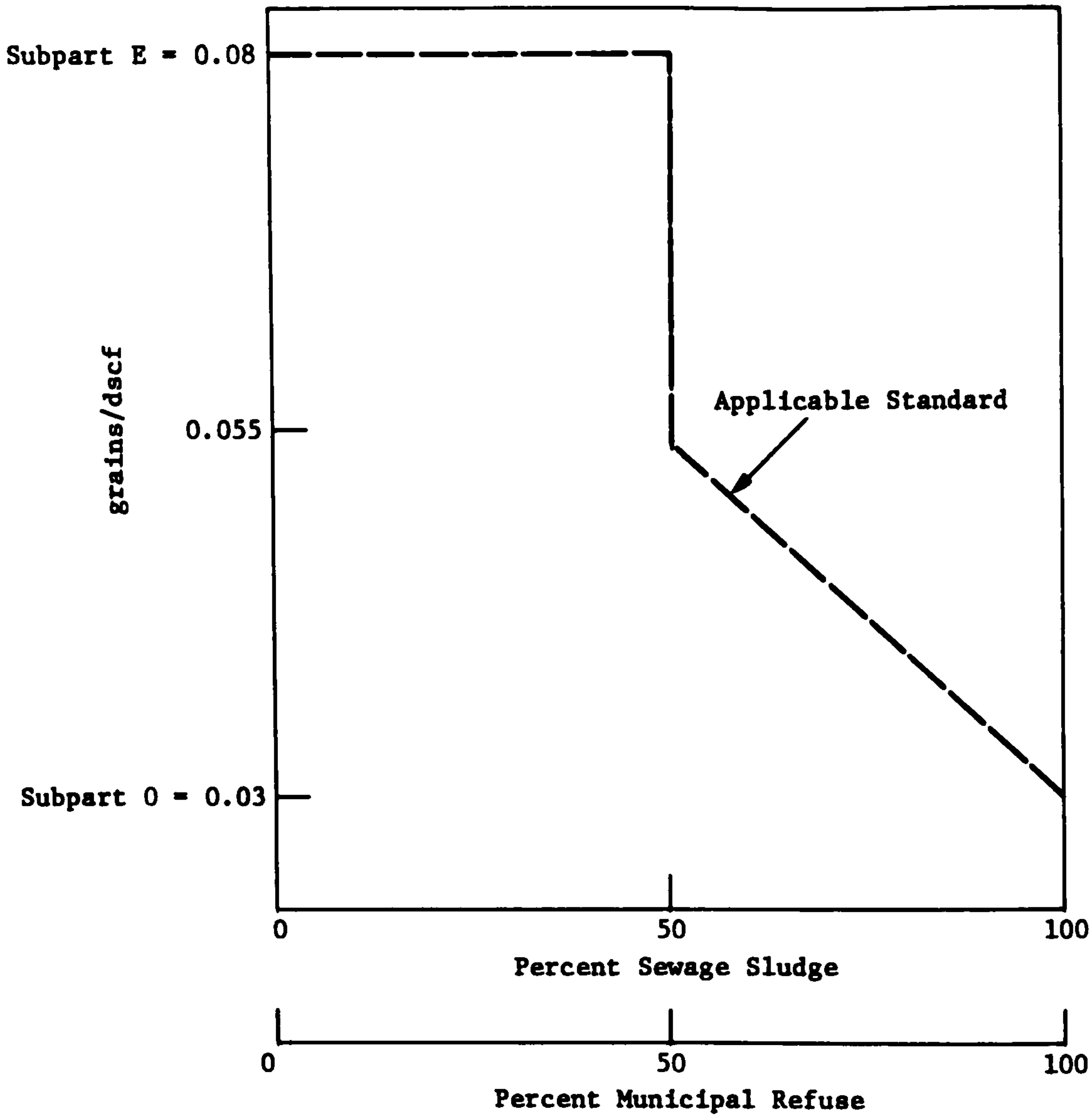


FIGURE 3-1
INTERPRETATION OF COINCINERATION STANDARD
WHEN TOTAL WASTE IS GREATER THAN 50 TONS/ DAYS

3.6 State Regulations

A survey of current state air quality control regulations was performed to identify differences between the Federal NSPS for sewage sludge incinerators and state regulations (Environmental Reporter, 1978). Of particular interest were the control levels specified by the states as compared with the current NSPS of 0.65 grams/kg (1.3 lb/ton) dry sludge input. The survey results are summarized as follows:

- Of the 22 states explicitly referencing NSPS for sewage sludge incinerators, none differ from the Federal standard. Maryland's NSPS for particulate emissions of 0.03 grains/dscf at 12 percent CO_2 may be more stringent than the 1.3 lb/dry ton input standard. The remaining states either have standards less strict for new sewage sludge incinerators or have general incineration standards that do not explicitly reference sewage sludge. None of the states have explicit standards for existing SSIs.

- Of those states having general incineration standards, the standard level, wording and description of the testing procedures indicate that the standards apply mainly to characteristics associated with municipal incineration of solid waste and not to the special case of SSIs.

- No state has a standard for the joint incineration of municipal sewage sludge and solid waste.

- Many states use the categorization of waste given in Table 3-2 as adopted from the National Solid Wastes Management Association (NSWMA) as a basis for emission standards for each waste category. This categorization is incomplete in that the sludge from municipal wastewater treatment is not described in the NSWMA categorizations. It is, therefore, difficult to identify what emission standard would be applied to operating an SSI within the state.

- Many states have incinerator standards that require new incinerators to be multichambered, operate at minimum temperatures ranging from 1200°F to 1600°F, and have minimum retention times of 0.3 seconds or greater. These standards

TABLE 3-2

CLASSIFICATION OF INCINERATOR WASTE

Type 0 (Trash)	A mixture of highly combustible waste such as paper, cardboard, cartons, wood boxes and combustible floor sweepings from commercial and industrial activities. The mixture may contain up to 10 percent by weight of plastic bags, coated paper, laminated paper, treated corrugated cardboard, oily rags and plastic or rubber scraps. This type of waste contains approximately 10 percent moisture and 5 percent incombustible solids and has a heating value of approximately 8500 Btu/lb as fired.
Type 1 (Rubbish)	A mixture of combustible waste such as paper, cardboard, wood scrap, foliage and combustible floor sweepings, from domestic commercial and industrial activities. The mixture may contain up to 20 percent by weight of restaurant or cafeteria waste, but contains little or no treated paper, plastic or rubber wastes. This type of waste contains approximately 25 percent moisture and 10 percent incombustible solids and has a heating value of approximately 6500 Btu/lb as fired.
Type 2 (Refuse)	An approximately even mixture of rubbish and garbage by weight. This type of waste is common to apartments and residential homes. It consists of up to 50 percent moisture and approximately 7 percent incombustible solids and has a heating value of approximately 4300 Btu/lb as fired.
Type 3 (Garbage)	Animal and vegetable wastes from restaurants, cafeterias, hotels, hospitals, markets and the like. This type of waste contains up to 70 percent moisture, up to 5 percent incombustible solids and has a heating value of approximately 2500 Btu/lb as fired.
Type 4 (Human and Animal Remains)	Carcasses, organs and solid organic wastes from hospitals, laboratories, abatoirs, animal pounds and similar sources, consisting of up to 85 percent incombustible solids and having a heating value of approximately 1000 Btu/lb as fired.
Type 5 (By-Product Waste)	Gaseous, liquid or semiliquid waste, such as tar, paints, solvents, sludge, and fumes from industrial operations.
Type 6 (Solid By-Product Waste)	Rubber, plastics and wood waste from industrial operations and all salvage operations.

appear to be written for municipal solid waste disposal incinerators but, as discussed above, may also apply to SSIs.

- Every state but Illinois and Indiana has an opacity standard of 20 percent for new sewage sludge incinerators. The Illinois standard is 30 percent and the Indiana standard is 40 percent.

In summary, only Maryland has a standard for sewage sludge incinerators that is more stringent than the NSPS. Many states do not have standards that explicitly recognize SSI as a different source capacity from other incineration processes. A number of states have equipment and minimum temperature standards that apply to general incineration processes including sewage sludge. It also appears that several states depend on the NSWMA waste categorization for application of incineration emission standards, and municipal sludge is not included in the NSWMA categories.

4.0 STATUS OF CONTROL TECHNOLOGY

4.1 Status of Municipal Sludge Incinerators

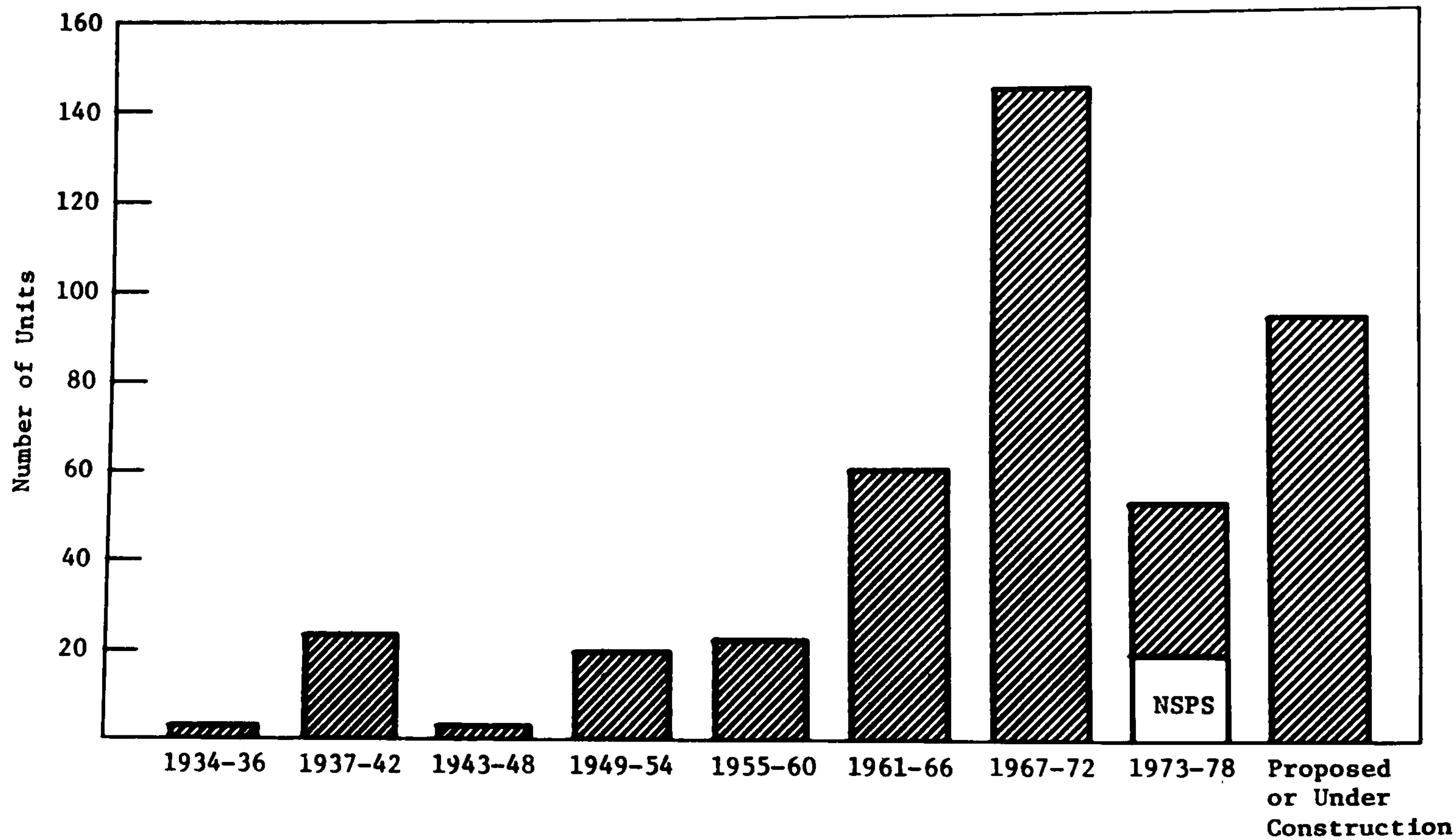
4.1.1 Number and Geographic Distribution

Since 1934 approximately 400 municipal sludge incinerator units* have been built, are under construction, or have been proposed. Figure 4-1 indicates that the large growth of Municipal Sewage Sludge Incinerators (MSSIs) occurred in the 1967-1972 period and that interest in this sludge reduction technique has continued today.

A recent survey of sludge incinerators indicates that about half of those installed before 1950, 70 percent of those installed between 1950 and 1969, and 85 percent of those installed between 1970 and the present are still in service (Gordian Associates, 1978). Using these proportions with the distribution shown in Figure 4-1 gives an estimate of approximately 240 MSSIs presently in operation. A compilation of incinerator units subject to the construction grants program indicated that 92 new units were either in the construction or planning stages in mid-1977 (EPA, 1977). A total of 23 MSSIs have been identified as candidates for NSPS testing within the 1973-1978 timeframe.

The majority of units in place are multiple hearth incinerators (approximately 80 percent) with the remainder mostly fluidized bed reactors. Fluidized bed reactors are relatively new with the first

*A unit is equivalent to a facility as defined in the NSPS. Many municipalities have more than one facility (unit) at a single location.



Sources: Gordian Associates, 1978;
EPA, 1977

FIGURE 4-1
SEWAGE SLUDGE INCINERATOR UNITS

reactor becoming operational in 1962. A very new sewage sludge incineration technique involving electric (infrared) furnaces has been demonstrated in two locations during the past 2 years. At least eight more of these furnaces are planned or under construction.

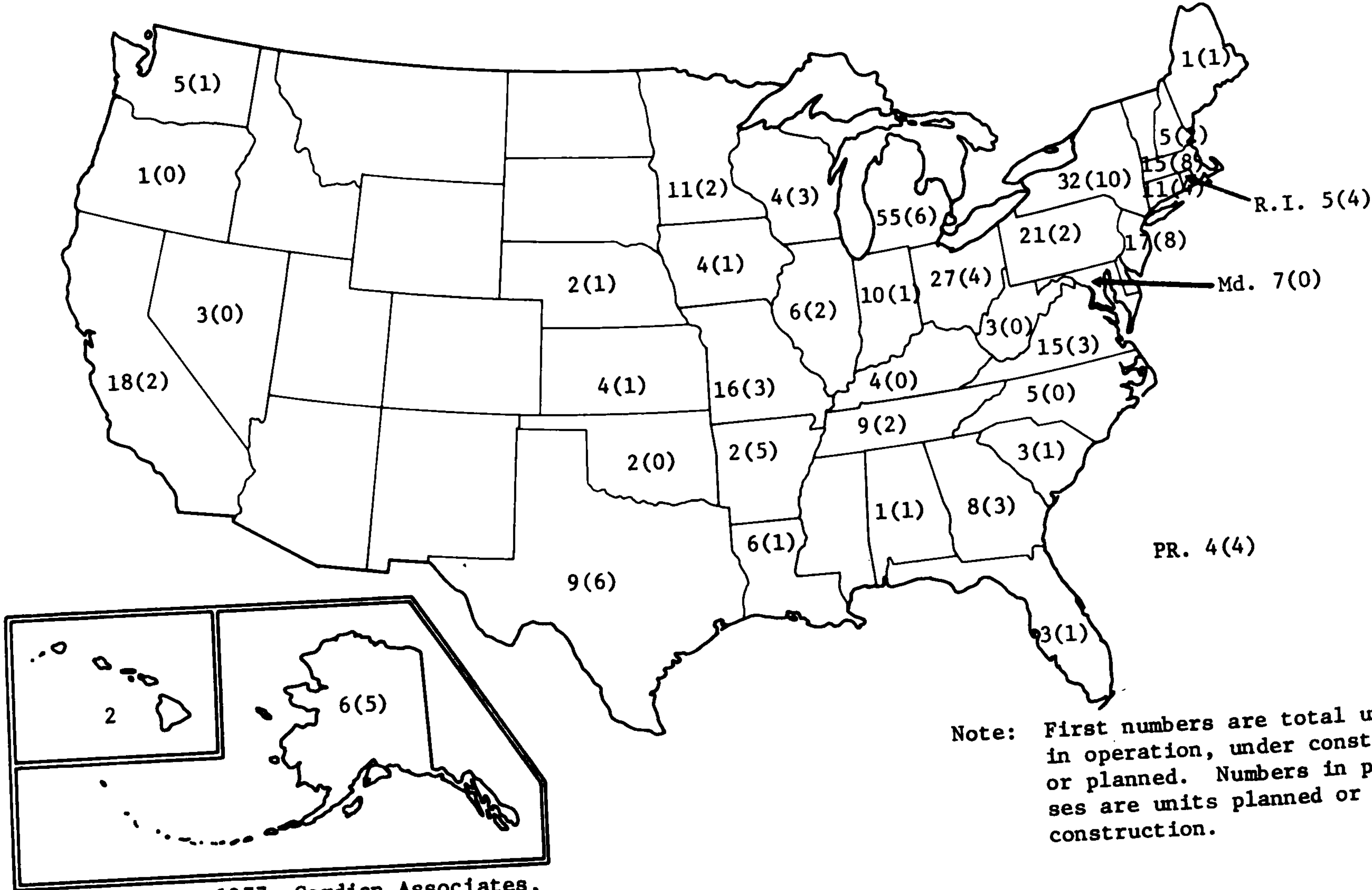
The geographic distribution of sewage sludge incinerators is shown in Figure 4-2. The major concentration of units is found in the Northeast and upper Midwest states, although 38 states have, or are planning, at least one facility.

4.1.2 National Emissions Summary and Projections

It is estimated that approximately 5 million Mg (5.5 million tons) dry sludge/year are generated by municipal wastewater treatment plants (EPA, 1978). About 2.3 million Mg (2.5 million tons) of this sludge are incinerated, or approximately 45 percent of the total (Gordian Associates, 1978). The resultant controlled particulate emissions from municipal sludge incineration are estimated to be 3800 Mg (4200 tons)/year or approximately 0.03 percent of total nationwide particulates emitted annually.*

Projections have indicated that the generation of sludge from municipal wastewater treatment plants may double in the next 10 years due to environmental legislation calling for higher quality effluents from wastewater treatment (EPA, 1978). If the proportion of this

*This is based on an emission factor of 1.5 kg/Mg (3 lb/ton) dry sludge input in AP-42 (EPA, 1977) and national particulate emissions of 12.5×10^6 Mg/yr (13.8×10^6 tons/yr) given in the EPA National Emissions Inventory (EPA, 1978a).



Note: First numbers are total units in operation, under construction, or planned. Numbers in parentheses are units planned or under construction.

Sources: EPA, 1977; Gordian Associates, 1977; MITRE, 1978.

FIGURE 4-2
GEOGRAPHIC DISTRIBUTION OF SEWAGE SLUDGE INCINERATORS PROPOSED, UNDER CONSTRUCTION, OR IN OPERATION

sludge that is incinerated remains the same (45 percent), and if the additional sludge were incinerated in facilities subject to the current NSPS, there would be an increase to about 5500 Mg (6000 tons) of particulate matter emitted per year.

4.1.3 Municipal Sludge Incineration Trends

In mid-1973 EPA predicted that:

> Over the next few years, it is estimated that 70 new municipal sewage sludge incinerators will be constructed annually in the United States. Factors such as the availability of alternative methods of sludge disposal will have a significant effect on the actual rate of construction....(EPA, 1973)

This prediction was made just prior to the oil embargo and the subsequent increase in fuel oil costs and the growing national emphasis on energy conservation. The data indicate that many communities switched sludge disposal strategies away from incineration due to the energy crises, since a total of about 110 units have been identified as being built, under construction, or planned in the 5-year period since that time.

As a result of several interacting factors such as energy, land, equipment costs and the increasing amounts of sludge being generated due to improved wastewater treatment facilities, the most economical sludge disposal technique has become difficult to determine. As a competing alternative, sludge incineration has undergone significant changes, the most notable being the recovery and use of waste heat generated in the incinerator. The use of waste heat to produce steam for in-plant use, preheating combustion air, or heat treating sludge to improve dewatering characteristics is becoming common in almost all designs suggested by manufacturers of incineration equipment. In addition, the cost of fuel has increased the desirability of autogeneous (self-sustaining) incineration which, in turn, has given emphasis to improved sludge dewatering techniques that are necessary to raise the relative energy content of the input sludge to a self-sustaining level. Although relatively new in the United States, the concept of using the refuse derived fuel from a solid waste resource recovery facility as the fuel for sludge incineration has been tested and is about to be implemented on a large scale basis in at least one community (Duluth, Minnesota).

As a result of the above improvements in design, and the economic or technical problems associated with land disposal in certain locations, incineration has remained a viable technique for sludge volume reduction as is indicated by the 92 units identified by EPA as proposed or under construction.

4.2 Sludge Incineration Process*

The basic elements of sludge incinceration are shown schematically in Figure 4-3. An incinerator is usually part of a sludge treatment system which includes sludge thickening, a dewater conditioning system, a dewatering device (such as a vacuum filter, centrifuge, or filter press), an incinerator feed system, air pollution

*Much of this section was extracted from "Process Design Manual for Sludge Treatment and Disposal" (EPA, 1974a).

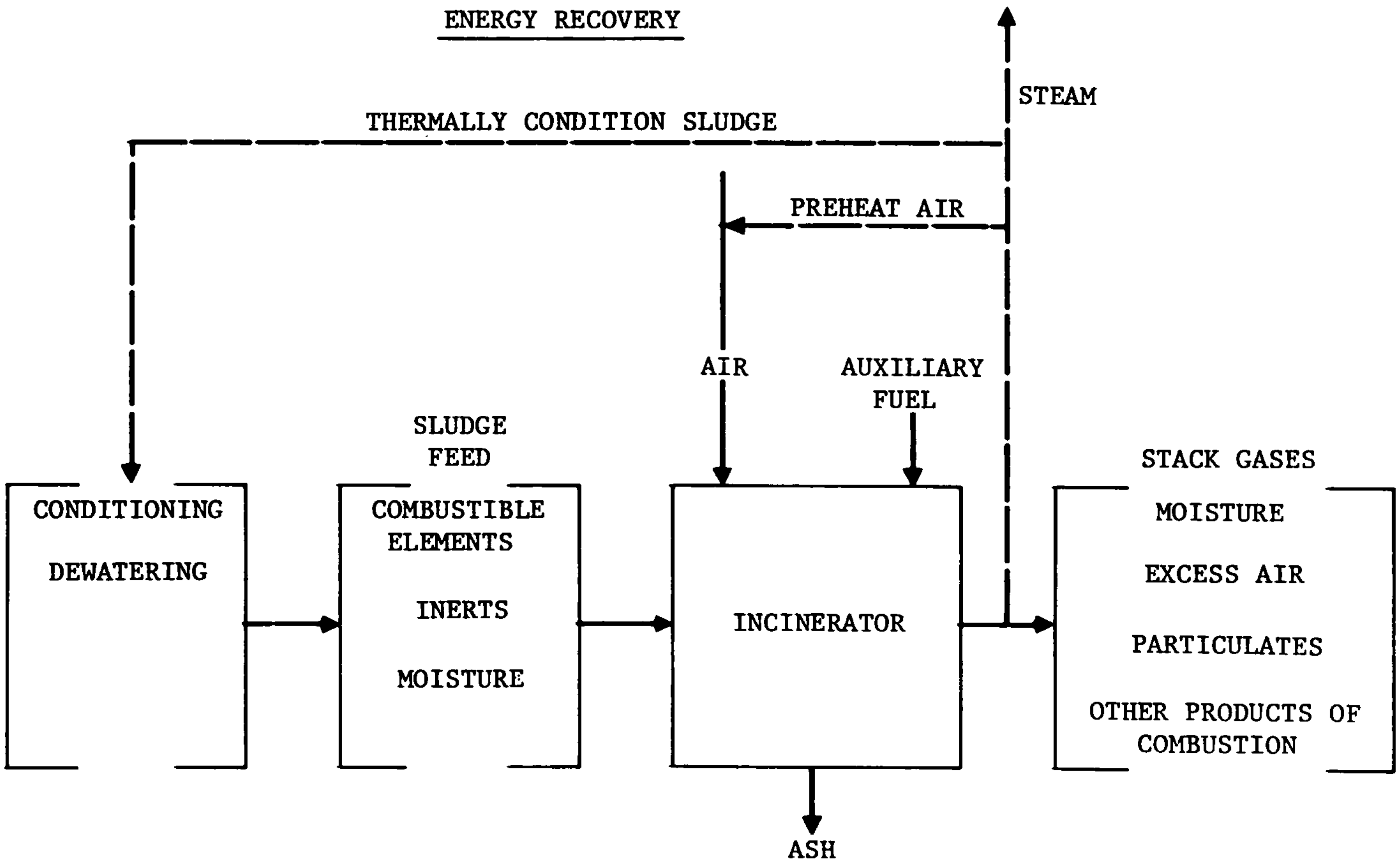


FIGURE 4-3
GENERIC SLUDGE INCINERATION SYSTEM DESCRIPTION

control devices, ash handling facilities, and the related automatic controls.

A primary consideration in the cost-effectiveness of sludge incineration is the effect of sludge feed composition on auxiliary fuel requirements. Other variables of importance are the type of incinerator employed, excess air requirements, operating temperatures necessary for odor control and other air pollution constraints. A recent addition to the sludge incineration system is the capability for energy recovery when a net heat gain is available.

Processed sludge (e.g., anaerobic digestion) and heat treatment processes reduce the volatile content and increase the inert noncombustible content with resultant lower fuel value for a sludge. As a result, auxiliary fuel is required to sustain combustion in many SSIs. Pretreatment methods such as chemical conditioning and dewatering do result in substantial reduction of incineration fuel requirements, but frequently they do so by creating increased energy demands on other unit processes. Figure 4-4 indicates the general relationship between auxiliary fuel requirements (in this case natural gas), moisture content, and volatile solid contents for a 10,000 Btu/lb volatile solids sludge. The use of a relatively wet sludge (e.g., 80 percent moisture) can greatly increase fuel requirements and the amount of air requiring cleaning.

4.2.1 Multiple Hearth Incineration

The multiple hearth furnace is the most widely used wastewater sludge incinerator in the U.S. today, because it is simple, durable,

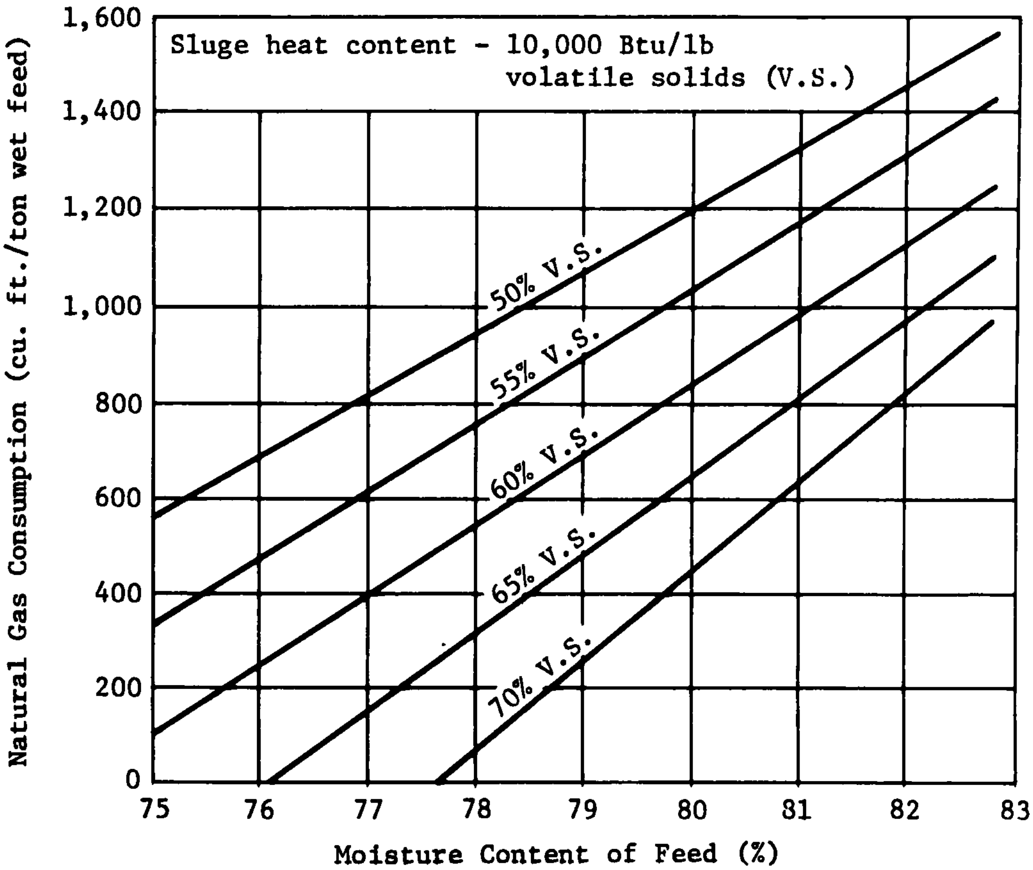


FIGURE 4-4
AUXILIARY ENERGY REQUIREMENTS AS A FUNCTION OF MOISTURE AND VOLATILE MATTER

and has the flexibility of burning a wide variety of materials even with fluctuations in the feed rate. A typical multiple hearth furnace is shown in Figure 4-5. It consists of a circular steel shell surrounding a number of solid refractory hearths and a central rotating shaft to which rabble arms are attached. Capacities of multiple hearth furnaces vary from 91 to 3600 Kg/hr (200 to 8000 lb/hr) of dry sludge with operating temperatures ranging from 700°C to 1100°C (1300°F to 2000°F). The dewatered sludge enters at the top through a flapgate and proceeds downward through the furnace from the hearth through the rotary action of the rabble arms. Since the furnace may operate at temperatures up to 1100°C (2000°F), the central shaft and rabble arms are effectively cooled by air supplied in regulated quantity and pressure from a blower which discharges air into a housing at the bottom of the shaft. The air may be discharged to the atmosphere or returned to the bottom hearth of the furnace as preheated air for combustion purposes.

The rabble arms provide mixing action as well as rotary and downward movement of the sludge. The flow of combustion air is countercurrent to that of the sludge. Gas or oil burners are provided on some of the hearths for furnishing heat for startup or supplemental use as required. As shown in Figure 4-6, a multiple hearth sludge furnace may generate gas temperatures exceeding 760°C (1500°F) in the combustion zone. These gases sweep over the wet, cold sludge in the drying zone and perform useful work by giving up a considerable

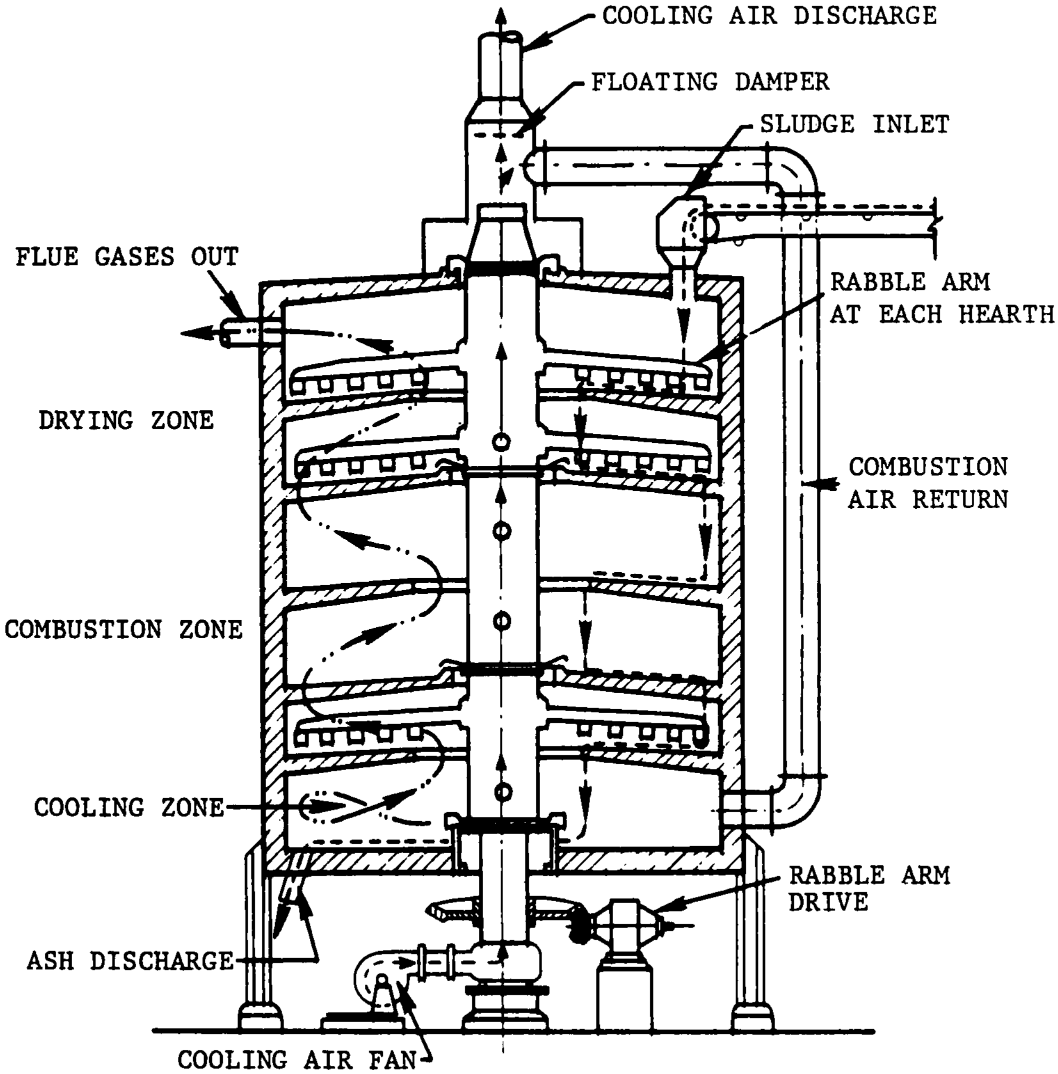


FIGURE 4-5
CROSS SECTION OF A TYPICAL MULTIPLE HEARTH INCINERATOR

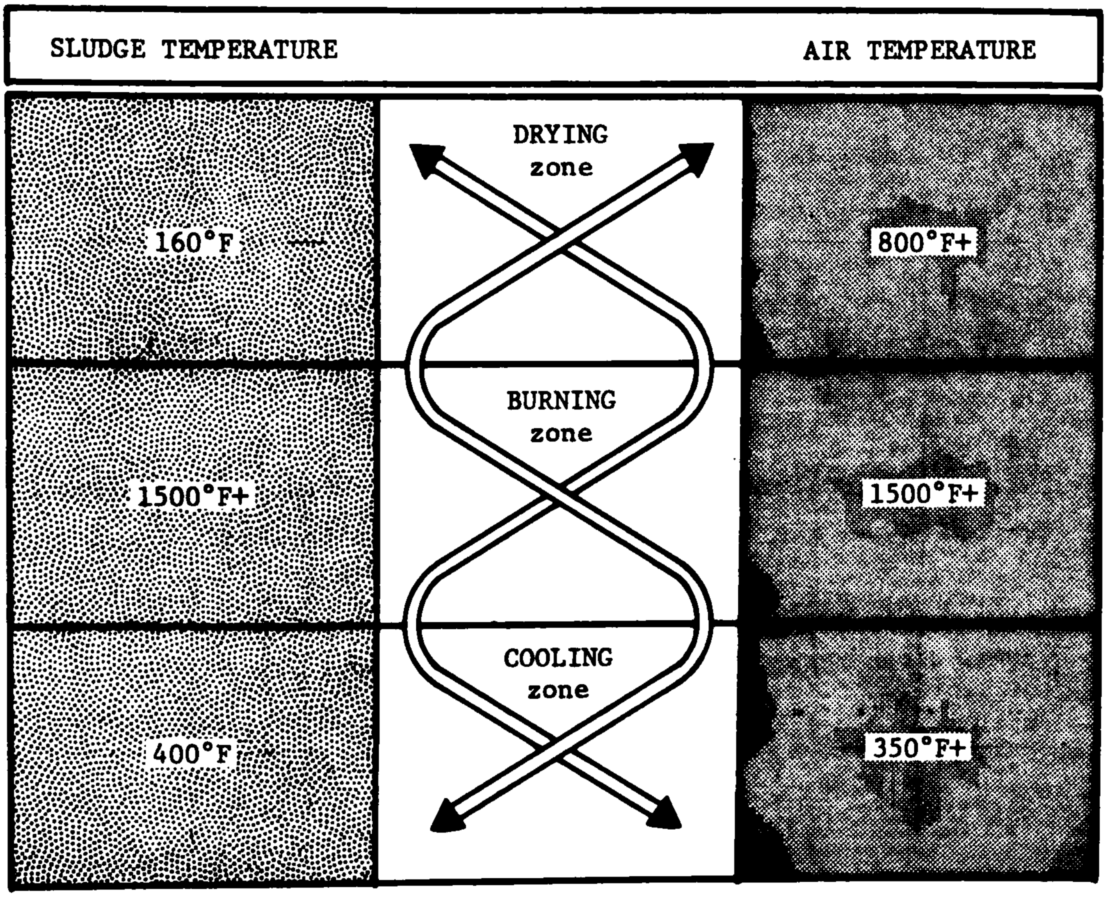


FIGURE 4-6
MULTIPLE HEARTH PROCESS ZONES

portion of their heat for evaporation of moisture. In this heat exchange, the gas temperature may drop to as low as 260°C (500°F) at the gas outlet. But while this exchange of heat evaporates an important percentage of sludge moisture, it does not raise the sludge temperature higher than about 71°C (160°F) because the evaporation of water cools the mass it leaves. When properly operating (e.g., hearth temperatures are properly maintained) no significant quantity of odoriferous matter is distilled, and exhaust gases need not be raised in temperature in an afterburner to destroy odors. Distillation of odoriferous material from sludge containing 75 percent moisture should not occur until 80 to 90 percent of the water has been driven off and by this time, the sludge is down far enough in the incinerator to encounter gases hot enough to burn much of the odoriferous materials.

To protect against odors during nonoptimum operation, some states require incinerator installations to provide high temperature afterburning of the stack gases. Gases are conveyed to a chamber where the temperature is raised by burning auxiliary fuel in direct contact with the gases before venting to the atmosphere.

4.2.2 Fluidized Bed Combustion

Fluidized bed combustion is a second technique for incinerating municipal sludge. A typical section of a fluid bed reactor used for combustion of wastewater sludges is shown in Figure 4-7. The fluidized bed incinerator is a vertical cylindrical vessel with a grid in

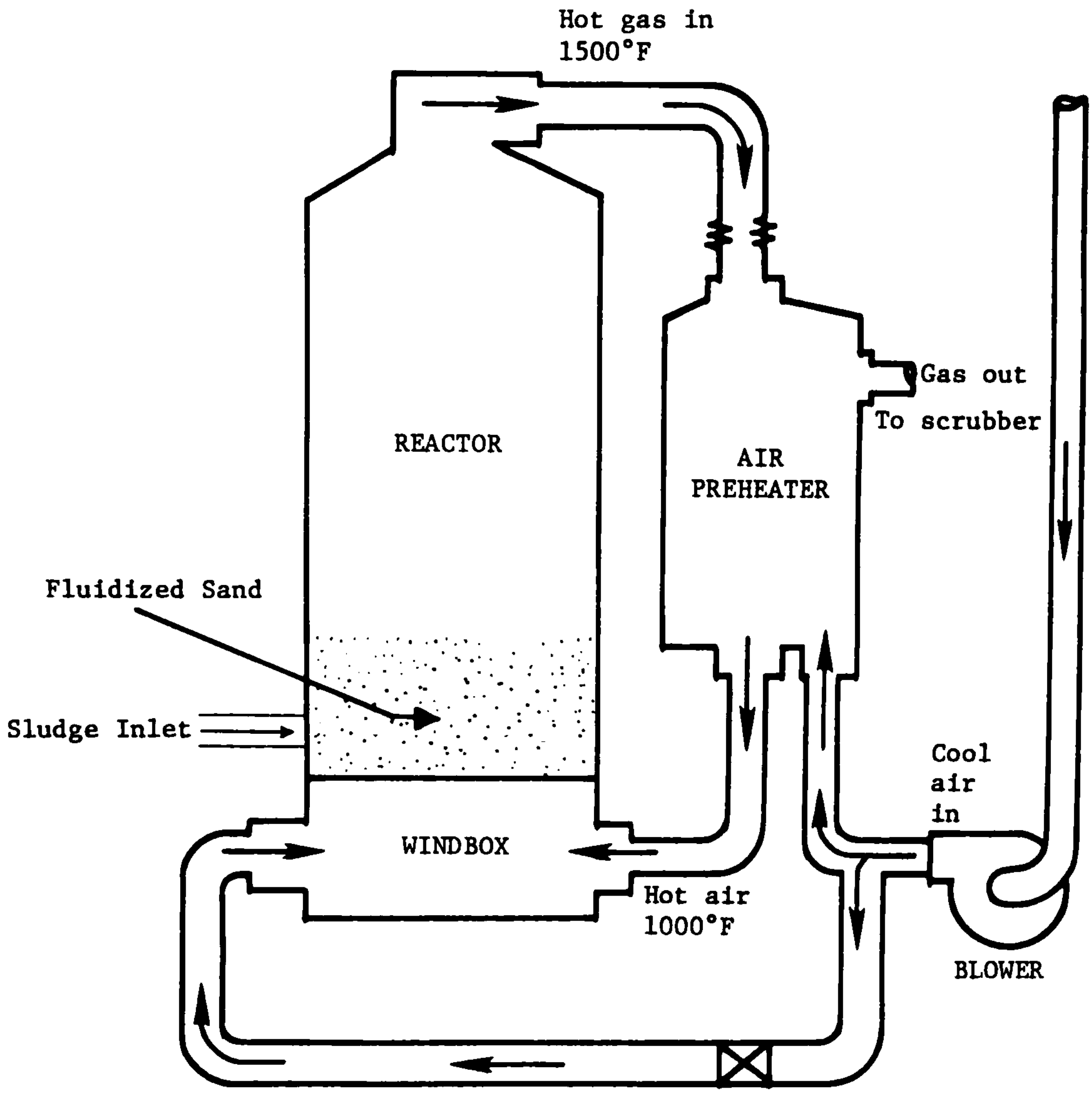


FIGURE 4-7
FLUIDIZED BED SYSTEM WITH AIR PREHEATER

the lower section to support a sandbed. Dewatered sludge is injected above the grid and combustion air flows upward and fluidizes the mixture of hot sand and sludge resulting in fine mixing of sludge and air. Supplemental fuel can be supplied by burners above or below the grid and preheating of the combustion air is often performed. In essence, the reactor is a single chamber unit where both moisture evaporation and combustion occur at 1400° to 1500°F in either the dense or dilute phases of the sandbed. All the combusion gases pass through the combustion zone with residence times of several seconds. All the resulting ash is carried out of the top with combustion exhaust and is removed by air pollution control devices. Excess air requirements, uusally between 20 and 50 percent, are less than those of the multiple hearth incinerator which operates with 50 to 75 percent excess air.

The heat reservoir provided by the sandbed also enables reduced startup times when the unit is shut down for relatively short periods (overnight). This is advantageous to facilities with intermittent incineration requirements. The cool-down time for some maintenance activities is also shorter in fluidized bed incinerators than in multiple hearths.

4.2.3 Other Incinerator Processes

Several other incinerator processes are in limited use, including flash drying/incineration, cyclonic reactors, the rotary kiln, and the wet oxidation method (this process does not produce flyash since relatively slow, low temperature, high pressure oxidation of material is involved). The electric infrared furnace is a new process that has been tested under the NSPS. The results of two tests using this process are given in Section 5.1.

4.3 Emissions From Sewage Sludge Incinerators

4.3.1 Particulate Matter

Uncontrolled particulate emission rates from sludge incinerators can vary considerably depending on the volatile solids and moisture contents of the input sludge and the type of facility being used. Fluidized bed reactors are designed to burn sludge in suspension with much of the ash to be carried out with the exhaust gas. Multiple hearth incinerators have an 80 to 90 percent retention rate of ash, although uncontrolled emissions are still higher than conventional solid waste incinerators. Infrared incineration systems that were recently tested had relatively low uncontrolled emission rates when compared with the first two techniques.*

Table 4-1 summarizes the limited data available on uncontrolled particulate emissions. The fluidized bed emissions were from a primary sludge with high volatile solid content. It is likely that sludge resulting from anerobic treatment would tend to have more inert matter than was indicated in the referenced study and therefore would produce a higher emission factor.

*Indirect emissions resulting from the generation of electrical power required to incinerate the sludge were not included in the emission rates.

TABLE 4-1

UNCONTROLLED EMISSION FACTORS FROM SLUDGE INCINERATION

Source	Incinerator Type	Sludge Characteristics		Uncontrolled Emissions		
		% Moisture	% Solids (% Ash/% Volatiles)	Low kg/Mg(lb/ton)	Average kg/Mg(lb/ton)	High kg/Mg(lb/ton)
EPA, 1976	All	N.G.	N.G.	N.G.	50(100)	N.G.
EPA, 1975	Multiple Hearth	N.G.	N.G.	N.G.	17(33)	N.G.
	Fluidized Bed	N.G.	N.G.	N.G.	23(45)	N.G.
Petura, 1976	Multiple Hearth	67	33 (45/55)	45(90)	75(150)	110(220)
Liao & Pilat, 1972	Fluidized Bed	75	25 (15/85)	9(18)[a]	47(94)[a]	171(342)[a]
Shirco, 1978	Electric(Infrared)	85	15 (50/50)	N.G.	9(17)	N.G.
Kroneberger, 1978	Multiple Hearth	80	15 (20/80)	N.G.	61(122)	N.G.
			20 (20/80)	N.G.	52(103)	N.G.
			25 (20/80)	N.G.	41(82)	N.G.

[a]Values Corrected to 12% CO_2 from approximately 8% CO_2.

N.G.: Not Given.

The EPA Sludge Design Manual estimates a value of 17 kg/Mg (33 lb/ton) of dry sludge input in a multiple hearth furnace and 23 kg/Mg (45 lb/ton) of dry sludge input in a fludized bed incinerator (EPA, 1974). The document also states:

> Particulate collection efficiencies of 96 to 97 percent will be required to meet the standard, based on the above uncontrolled emissions rate ....

The uncontrolled emission values in the design manual appear to be low if the basis is tons of dry sludge burned. Based upon the results in Table 4-1, uncontrolled emissions from multiple hearth incinerators are three to four times those given in the design manual. Control efficiences of 98.5 to 99.5 percent would be required to comply with the NSPS as shown by the equation:

$$\text{Eff} = 1 - \frac{\text{1.3 lb particulate/dry ton sludge}}{\text{80 to 220 lb particulate/dry ton sludge}}$$

4.3.1.1 Particle Size Distributions. Little experimental data are available in the literature with respect to the particle size distribution of uncontrolled emissions entering control devices of sewage sludge incinerators. In a fluidized bed reactor more than 85 to 95 percent of the particles by weight were greater than 30 microns (Liao and Pilat, 1972). These particles are relatively easy to control with low pressure drop scrubbers. With the NSPS requirement of 65 kg/Mg (1.3 lb/ton) of dry sludge input, emission volume densities of 0.009 to 0.071 grams/dscm (0.004 to 0.03 grains/dscf) have been observed after the gases have been passed through scrubbers operating at 10 to 35 in. WG pressure drop (See Table 5-1). Based on these results it is likely that at least 1 to 5 percent of the uncontrolled particulate matter entering a scrubber from a sludge incinerator is in the low micron and submicron range.

4.3.1.2 NSPS Control Techniques. Sludge incinerator controls have historically involved the use of scrubber equipment. The most obvious reasons for this are the readily available scrubber water treatment facility (e.g., the sewage treatment plant) and the apparent success to date of meeting the increasingly stringent standards through scrubbing techniques. As removal requirements have increased in stringency from 50 percent in the mid 1960s to the current levels of 99 percent, the sophistication of the scrubbers has increased. Common configurations used today include variable throat venturi scrubbers in series with cyclonic mist eliminators, venturi scrubbers in series with perforated-plate impingement type scrubbers, or multiple series of perforated plate impingement scrubbers. Pressure drops in these devices may range from 6 in. WG to as high as 35 in. WG. To overcome pressure losses draft fans are employed which are sized to handle the designed pressure drops. There are no plants operating in the U.S. at this time that employ baghouse or electrostatic precipitators for control purposes.

4.3.2 Other Pollutants

Mercury emissions from sewage sludge incinerators are explicitly controlled under the National Emissions Standards for Hazardous

Pollutants (NESHAPS) section of the Code of Federal Regulations (40 CFR 61.5). Mercury emissions are not to exceed 3200 grams/day. This limit is based on maintaining a maximum average ambient mercury concentration of 1 μ grams/m^3 over a 30-day period. As indicated in Section 5.2, limited test data show that no facility approaches the emission level of 3200 gram/day. Measurements taken by EPA's Office of Air Programs to support a mercury emissions standard showed that 68 to 96 percent of the mercury was removed from the exhaust gases (EPA, 1974). This high removal rate was verified independently in another study that showed only 2 percent of the mercury in the incoming sludge appeared in the flue gases based on a complete mass balance around a multiple hearth incinerator (Whitmore and Durfee, 1974).

EPA studies have shown that less than 15 percent of the lead in input sludge appears in flue gases, while other field tests have shown less than 1 percent of the input lead in the flue gases (Kalinski, et al., 1975). However, in a recently reported result from a set of four multiple hearth sludge incinerators with relatively low pressure drop wet scrubbers (6 to 7 in. WG), as high as 30 percent of the lead and cadmium fed to the incinerators was discharged in the form of fine particulate matter after scrubbing (Farrell et al., 1978). The report goes on to suggest that higher scrubber pressure drops will likely achieve reductions in lead emissions but may not reduce cadmium emissions sufficiently to prevent excessive ground level concentrations.

It has been generally recognized that the high temperatures existing in incinerators could be utilized to destroy excess quantities of unwanted pesticides (EPA, 1975a). As an extension of this concept, the Office of Solid Waste Management at EPA funded a study to see if stocks of excess pesticides, such as DDT and 2,4,5-T, could be destroyed by coincineration with sewage sludge in a multiple hearth sludge incinerator at pesticide preparation concentrations of 2 to 5 percent (based on dry sludge weight). Very high destruction efficiencies were verified in this study--99.97 percent or higher in the case of 2,4,5-T (Whitmore and Durfee, 1975).

The present EPA position with respect to polychlorinated biphenyls (PCBs) does not require any particular test for sludges with less than 25 ppm of PCBs and a performance test showing 95 percent destruction when the PCB concentration is over 25 ppm (FR57420, 1977). Such destruction rates have been measured in tests sponsored by EPA where the sewage sludge was "doped" by adding 50 ppm of an easily identifiable PCB into the sludge; however, most municipal sludges contain significantly less than 25 ppm of PCBs (Whitmore, 1977; Furr, 1976).

Measurements of the emissions of hydrocarbons and carbonyls from sludge incineration have been made on two sludge incinerators in the San Francisco Bay Area to assure compliance with stringent emission limits of 25 ppm for both classes of organic compounds.

Results showed emission levels significantly less than the 25 ppm standards; 0.4 to 2.2 ppm for the hydrocarbons and 3.4 to 7.6 ppm for the carbonyls (EPA, 1975a).

5.0 INDICATIONS FROM TEST RESULTS

A survey of the literature and polls of EPA regional offices, state agencies, and local facilities were performed to obtain test data from new sewage sludge incinerators. In certain cases the incinerators were put into operation after the date of the standard proposal but construction was begun before the date of proposal. Test data were included if the state or local standard was relatively stringent and/or if the control level achieved was sufficient for meeting the NSPS. In at least one instance a wastewater treatment facility with an incinerator constructed after the standard proposal date was given a permit to construct prior to the proposal date. This facility was designed and is operating at a less stringent level of control which is equivalent to the state regulation (Schmidt, 1978).

In several instances only partial test results were available. In these cases an attempt was made to estimate missing parameters based upon known information in the test report and design data obtained from manufacturers. These cases are indicated by an E prefix in Table 5-1.

5.1 Analysis of NSPS Test Results

The results of tests at 26 incinerators are summarized in Table 5-1. As is evident from the data most facilities are meeting the standard. The average of all tests results is 0.55 Kg/Mg (1.1 lb/ton) dry sludge input with a standard deviation of 0.35 Kg/Mg

TABLE 5-1

SLUDGE INCINERATOR TEST RESULTS

Type	Location	Date	Input (dry tons/ hour)	Percent Solids	Device Type (P in. WG)	P pounds/dry ton input	C Concentration (grains/dscf)	Calculated grains/dscf Concentration Equivalent to 1.3 lb/dry ton = 1.3 x $\frac{C}{P}$	Source
MH[a]	Chicopee, Mass. #1	2/78	0.3	21	VS/IS(25)[b]	1.17	0.009[c]	0.013	Rice, 1978
MH	Chicopee, Mass. #2	6/78	0.4	26	VS/IS(25)	0.92	N.G.[d]	N/A	Rice, 1978
MH	East Fitchburg, Mass.	2/76	1.3	15-18	IS(3)	3.50	0.250	0.094	Rice, 1978
MH	Manchester, N.H. #1	3/77	0.6	15	VS(N.G.)	0.39	0.007	0.024	Rice, 1978
MH	Manchester, N.H. #2	3/77	0.6	15	VS(N.G.)	0.60	0.010	0.022	Rice, 1978
MH	Merrimack, N.H. #1	3/78	1.1	16	VS/IS(30)	1.25	0.009[c]	0.012[e]	Rice, 1978
MH	Merrimack, N.H. #2	3/78	1.0	16	VS/IS(30)	1.34	0.010[c]	0.013[e]	Rice, 1978
MH	Upper Blackstone, Mass. #1	6/77	1.9	26	VS/IS(27)	0.98	0.018[c]	0.032[e]	Rice, 1978
MH	Upper Blackstone, Mass. #2	6/77	1.9	26	VS/IS(32)	0.79	0.015[c]	0.032[e]	Rice, 1978
MH	Upper Blackstone, Mass. #3	6/77	2.0	26	VS/IS(25)	1.50	0.029[c]	0.032[e]	Rice, 1978
MH	Erie, Pa. #1[f]	11/75	2.0[e]	20	N.G.	3.00[e]	0.046 (-12% CO_2)	0.015[e]	Story, 1976
MH	Erie, Pa. #2[f]	11/75	2.0[e]	20	N.G.	2.80[e]	0.042 (-12% CO_2)	0.015[e]	Story, 1976
MH	Morrisville, Pa.[f]	2/77	0.8	29	VS/IS(18)	1.61[e]	0.015	0.012[e]	Cook, 1977
FB[g]	Tyrone, Pa.	3/77	1.0	23	VS(22)	0.20	0.010 (-12% CO_2)	0.066	Jacobson, 1977
MH	Hopewell, Va.	8/78	3.2	50	N.G.	0.91	N.G.	N/A	Van Natter, 1978
MH	Maryville, Tenn.	12/77	0.4	19	VS/IS(20)	0.64	0.004	0.008	Lyttle, 1978
MH	Granite City, Ill.	1/77	2.3[e]	22	N.G.	0.67[e]	0.020	0.039[e]	Ullrich, 1977
MH	Cincinnati, Ohio #1	N.G.(76)	2.9	34	3IS(7)	1.01	0.024	0.031	Petura, 1976
MH	Cincinnati, Ohio #2	N.G.(76)	2.8	33	3IS(8)	0.56	0.014	0.033	Petura, 1976
MH	Cincinnati, Ohio #3	N.G.(76)	2.4	32	3IS(8)	0.77	0.015	0.026	Petura, 1976 .
MH	Lawton, Okla.	8/78	0.6	21	N.G.	0.90	0.010	0.015	Spruiell, 1978
MH	Mission, Kans. #2	2/77	0.8[e]	20	VS/IS(18)	0.99	N.G.	N/A	Langston Lab., 1977
EL[h]	Plano, Tex. #1	5/78	0.2	N.G.	VS/IS(9)	0.92	0.008	0.011	Mullins, 1978
EL	Plano, Tex. #2	5/78	0.2	N.G.	VS/IS(9)	1.27	0.036	0.037	Mullins, 1978
EL	Richardson, Tex.	2/77	N.G.	N.G.	N.G.	1.30	0.009	0.009	Ecology Audits, 1977
FB	Longview, Wash.	2/77	1.1	30-70	VS(30)	N.G.	0.004	N/A	Strandy, 1978
	Average ± Std. Dev.		1.4±.9	24±8	20±9	1.20±0.80 0.91±0.33[i]	0.014±0.008	0.027±0.020 0.022±0.010[i]	

[a]MH: Multiple hearth incinerator.
[b]VS/IS: Venturi scrubber/impingement scrubber.
[c]Grains/actual cubic foot.
[d]N.G.: Not given.
[e]Estimate.
[f]Compliance to 0.08 grains/dscf at 12% CO_2.
[g]FB: Fluidized bed incinerator.
[h]EL: Electric incinerator.
[i]Excludes E. Fitchburg, Erie and Morrisville.

(0.69 lb/ton) or 0.55 + 0.35 Kg/Mg (1.1 ± 0.69 lb/ton) dry sludge input. If the East Fitchburg incinerator and non-NSPS tests at Erie #1 and #2 and Morrisville are deleted, the mean is 0.46 Kg/Mg (0.91 lb/ton) dry sludge input with a standard deviation of 0.17 Kg/Mg (0.33 lb/ton) or 0.46 ± 0.17 Kg/Mg (0.91 ± 0.33 lb/ton) dry sludge input.

5.1.1 Scrubber Pressure Drop Versus Emissions

Where possible, information was collected on the type of scrubber and the pressure drop used during the test as well as the percent of solids present in the sludge. (The percent of volatile solids was not readily available when the information was compiled.) Pressure drops ranged from 3 to 32 in. WG, while sludge solids ranged from 15 to 50 percent with the majority in the 20 to 35 percent range.

There does not appear to be a consistent relationship between pressure drop in the scrubbers and emissions values. In Figure 5-1, the results are plotted as a function of scrubber pressure drop and associated emissions on a mass basis. The East Fitchburg result stands by itself and is unique in that a very low pressure plate scrubber was used with apparently poor results. The cluster of tests at about 8 in. WG are from the three incinerators in Cincinatti and the two electric incinerators in Texas. With the

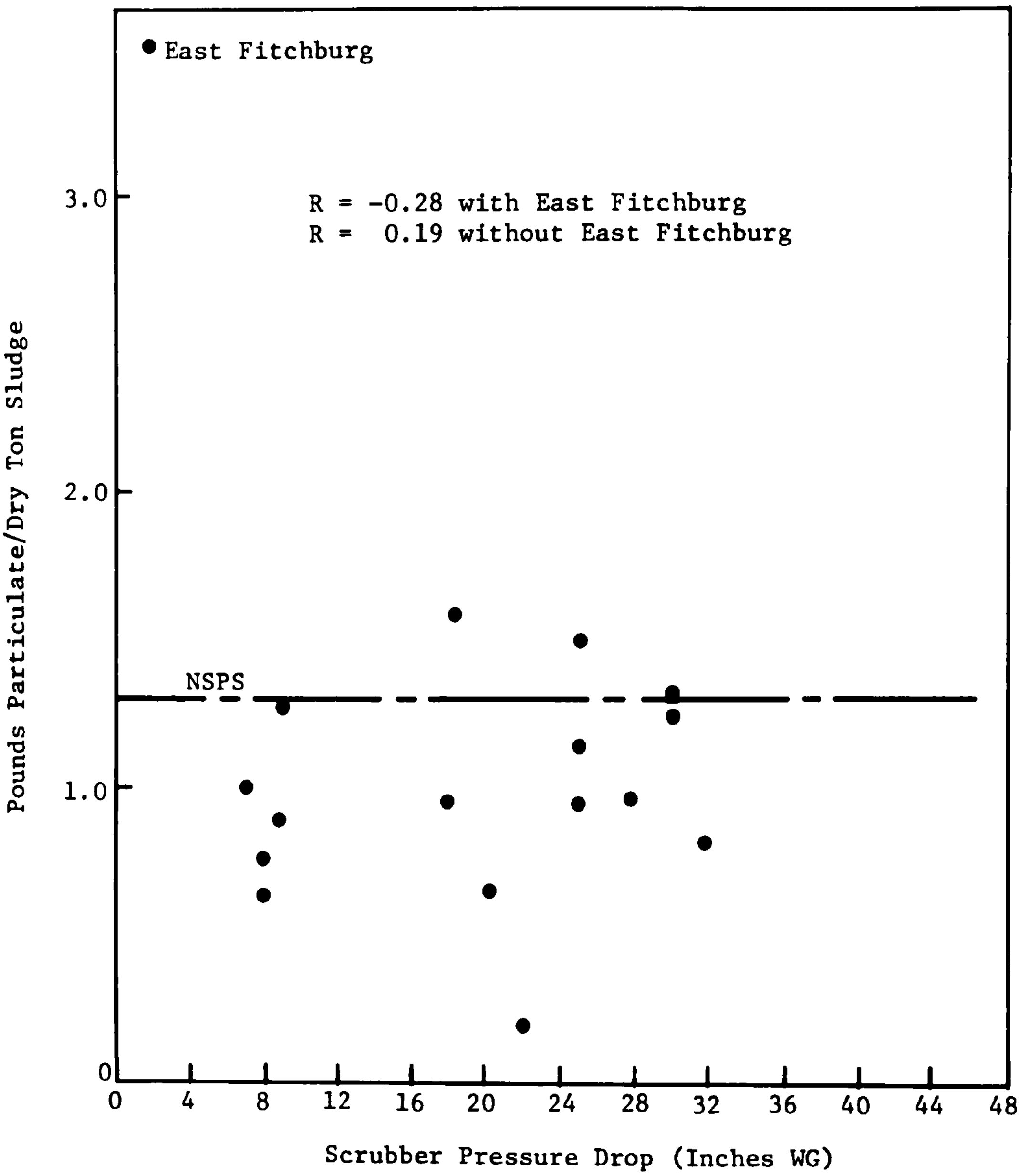


FIGURE 5-1
EMISSIONS VERSUS SCRUBBER PRESSURE DROP

East Fitchburg incinerator included, the correlation coefficient* is a poor -0.28 and, with that data point deleted, a poorer 0.19. While the correlation between pressure drop and emission is poor, the overall affect of the NSPS on control technology can readily be seen by the average pressure drop of 20 in. WG. This is in contrast to the facilities tested in 1974 when only one was found with a venturi scrubber operating at 18 in. WG and the other facilities had various plate scrubbers operating at 6 in. WG or less.

One set of test results indicates that, beyond a point, increasing venturi scrubber pressure drops does not necessarily reduce particulate emissions on a mass basis. These test results, illustrated in Figure 5-2, are from one multiple hearth incinerator operating on nominal 30 percent sludge solids with pressure drops in a venturi/impingement combination scrubber ranging from 22 to 35 in. WG (Kroneberger, 1978). The sample correlation coefficient was -0.395, a weak result at best. It should be pointed out, however, that the correlation applies only to the pressure drop range of 22 to 35 in. WG and would likely be much stronger if data covering pressure drops of 0 to 36 in. WG were included in the calculation.

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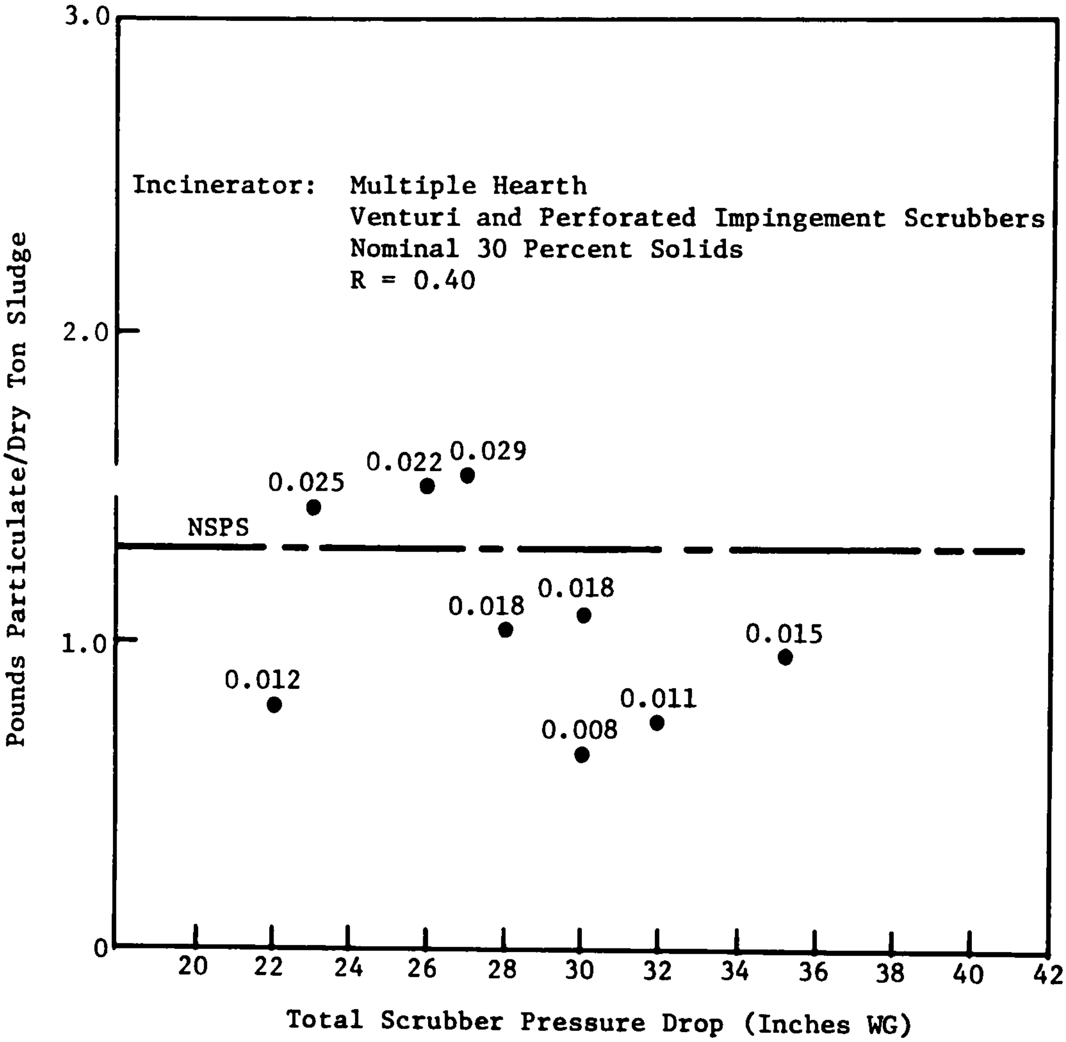
*The sample correlation coefficient is a useful statistical measure of the relationship between two variables from sample data. Values close to 1 or -1 indicate high positive or negative correlations, respectively, while values near 0 indicate poor correlation.



Note: Values above data points are grains/dscf

Source: Kroneberger, 1978

FIGURE 5-2
EMISSIONS VERSUS SCRUBBER PRESSURE DROP IN A MULTIPLE HEARTH INCINERATOR

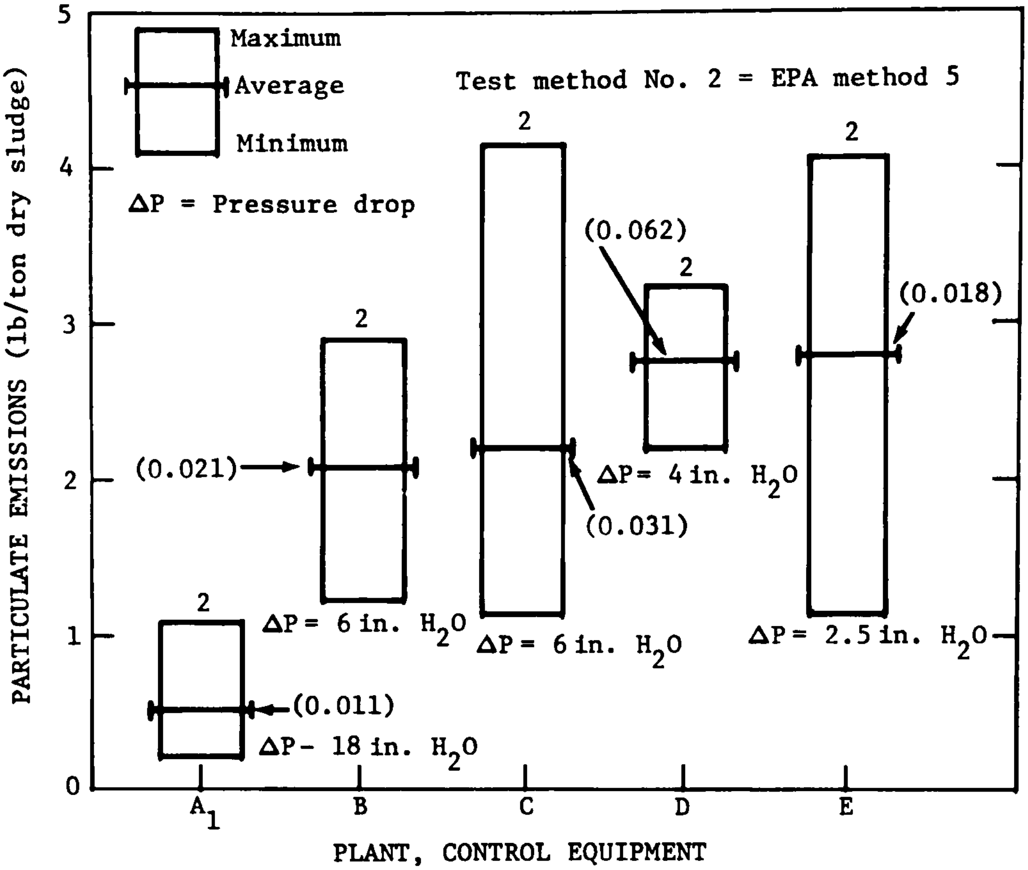
5.1.2 Emissions on a Volume Versus Mass Basis

As discussed in Section 3.3, the NSPS was first proposed as a volume concentration standard equal to 0.071 grams/dscm (0.031 grains/dscf) based upon the analysis of emissions from three multiple hearth incinerators and two fluidized bed reactors. The test results used at the time are summarized in Figure 5-3 (EPA, 1974). Due to comments concerning the relative use of dilution air for cooling the rabble arms in multiple hearth incinerators and the difficulties involved in measuring and calculating corrections for this factor, the standard was changed to particulate emissions per weight of dry sludge burned. The equation used to make this conversion was:

$$\text{New Standard} = \frac{\text{(lb/ton dry sludge Facility A)}}{\text{grains/dscf Facility A}} \times 0.031 \text{ grains/dscf}$$

$$= \frac{0.481}{0.011} \times 0.031 = 1.3 \text{ lb/ton dry sludge}$$

Critical to this calculation is the validity of the equivalence of the emissions on a mass basis to the emission volume concentration. In Table 5-1, the ratio of volume concentration to the emissions on a mass basis is calculated for each facility and then normalized to 0.65 Kg/Mg (1.3 lb/ton) dry sludge input. The average from all tests shows an equivalent volume concentration of 0.062 $\pm$ 0.046 grams/dscm (0.027 $\pm$ 0.02 grams/dscf). If the results from East Fitchburg, 0.216 grams/dscm (0.094 grains/dscf), the fluidized



Note: Numbers in parentheses are grains/dscf

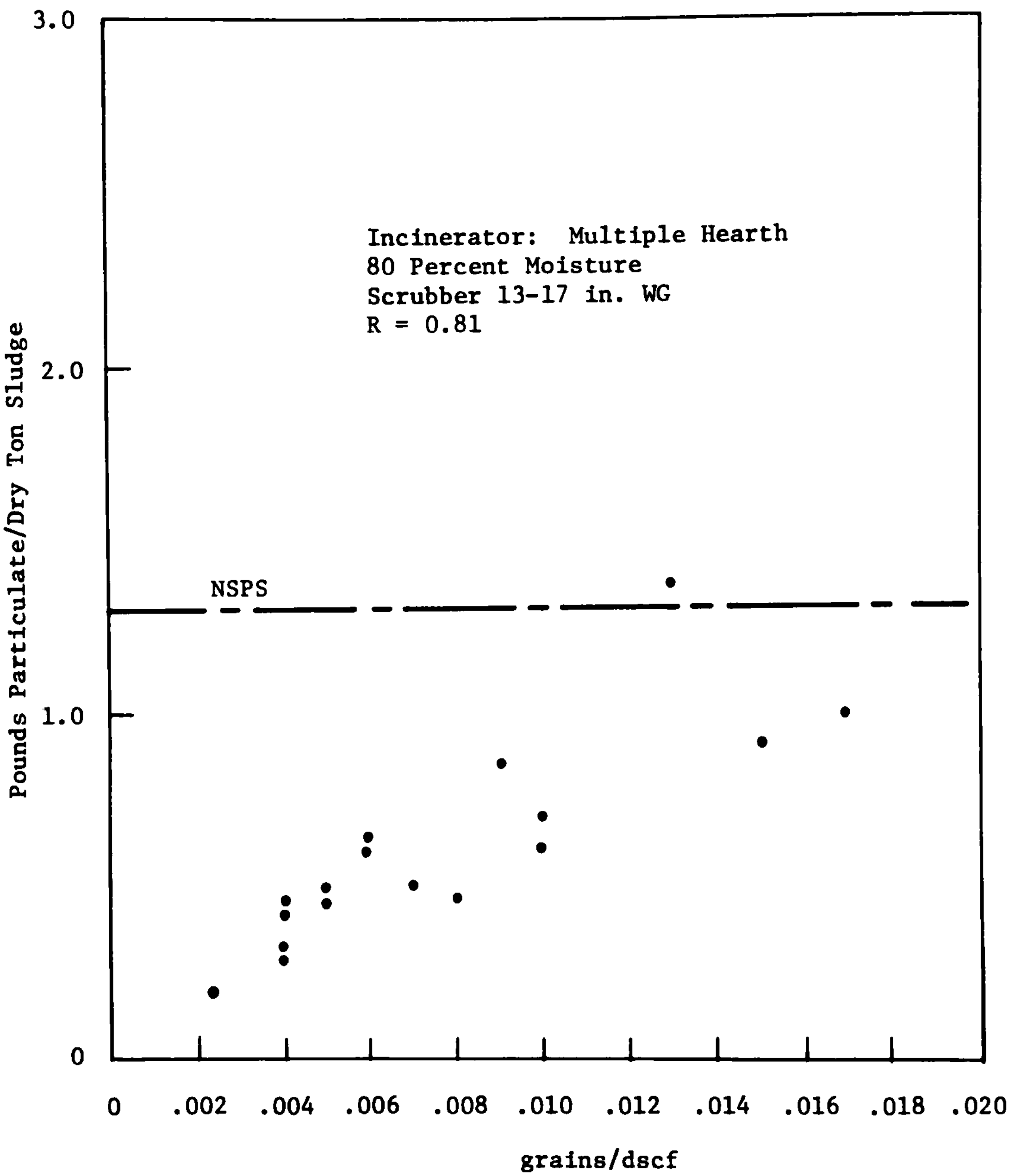
Source: EPA, 1974.

FIGURE 5-3
SUMMARY OF 1973 TEST RESULTS
USED FOR SETTING NSPS

bed reactor at Tyrone, Pennsylvania, 0.151 grams/dscm (0.066 grains/dscf), and the electric furnaces in Texas are deleted, multiple hearth furnaces have an equivalent volume concentration of 0.050 ± 0.023 grams/dscm (0.022 ± 0.010 grains/dscf). If equivalent to 0.071 grams/dscm (0.031 grains/dscf), the resulting mass concentration would be 0.9 Kg/Mg (1.8 lb/ton) dry sludge input.

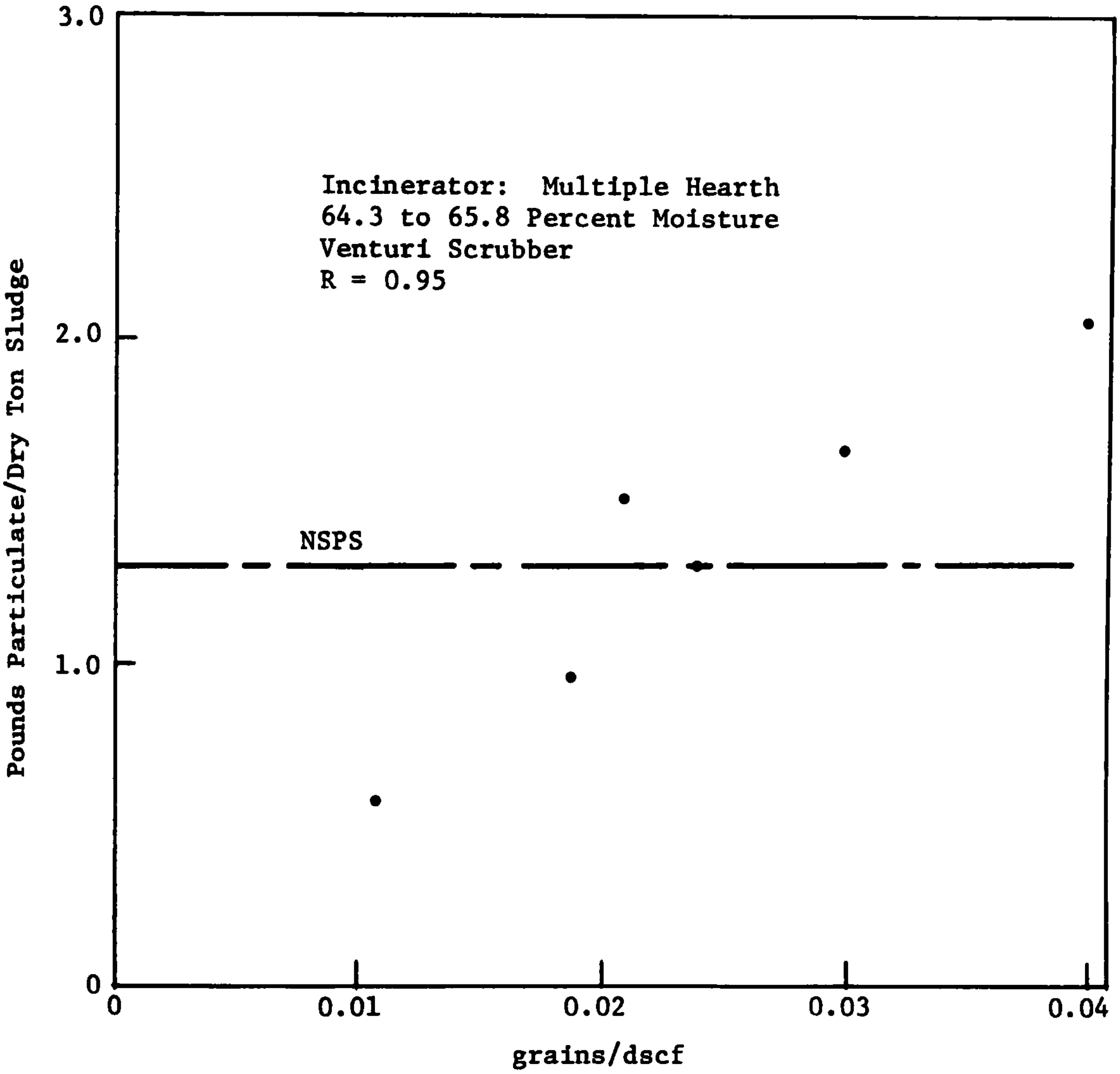
Test data furnished to MITRE by an incinerator manufacturer indicate a similar result (Kroneberger, 1978). Figure 5-4 is a plot of grains/dry standard cubic foot versus pounds/dry ton of sludge at a facility operating on 20 percent solids sludge with a venturi scrubber at 13 to 17 in. WG. The correlation coefficient for these data is 0.81. A nominal equivalence to 0.65 Kg/Mg (1.3 lb/ton) dry sludge input would occur at about 0.041 grams/dscm (0.018 grains/dscf). In Figure 5-5, another incinerator with higher sludge solids and a venturi scrubber (unknown pressure drop) showed a consistent relationship between volume and mass concentration (R=0.95) but with an equivalence of 0.65 Kg/Mg (1.3 lb/ton) dry sludge input at 0.055 grams/dscm (0.024 grains/dscf).

Factors that may be at least partially responsible for the difference in equivalent emission factors are the moisture content and percent volatile matter in the input sludge. The amount of combustion and combustion air required per dry pound of sludge increases as the moisture content of the sludge increases and the percent volatile matter decreases. The sludge used in the fluidized



Source: Kroneberger, 1978

FIGURE 5-4
EMISSIONS ON A MASS VERSUS VOLUME BASIS: LOW SLUDGE SOLIDS



Source: Kroneberger, 1978

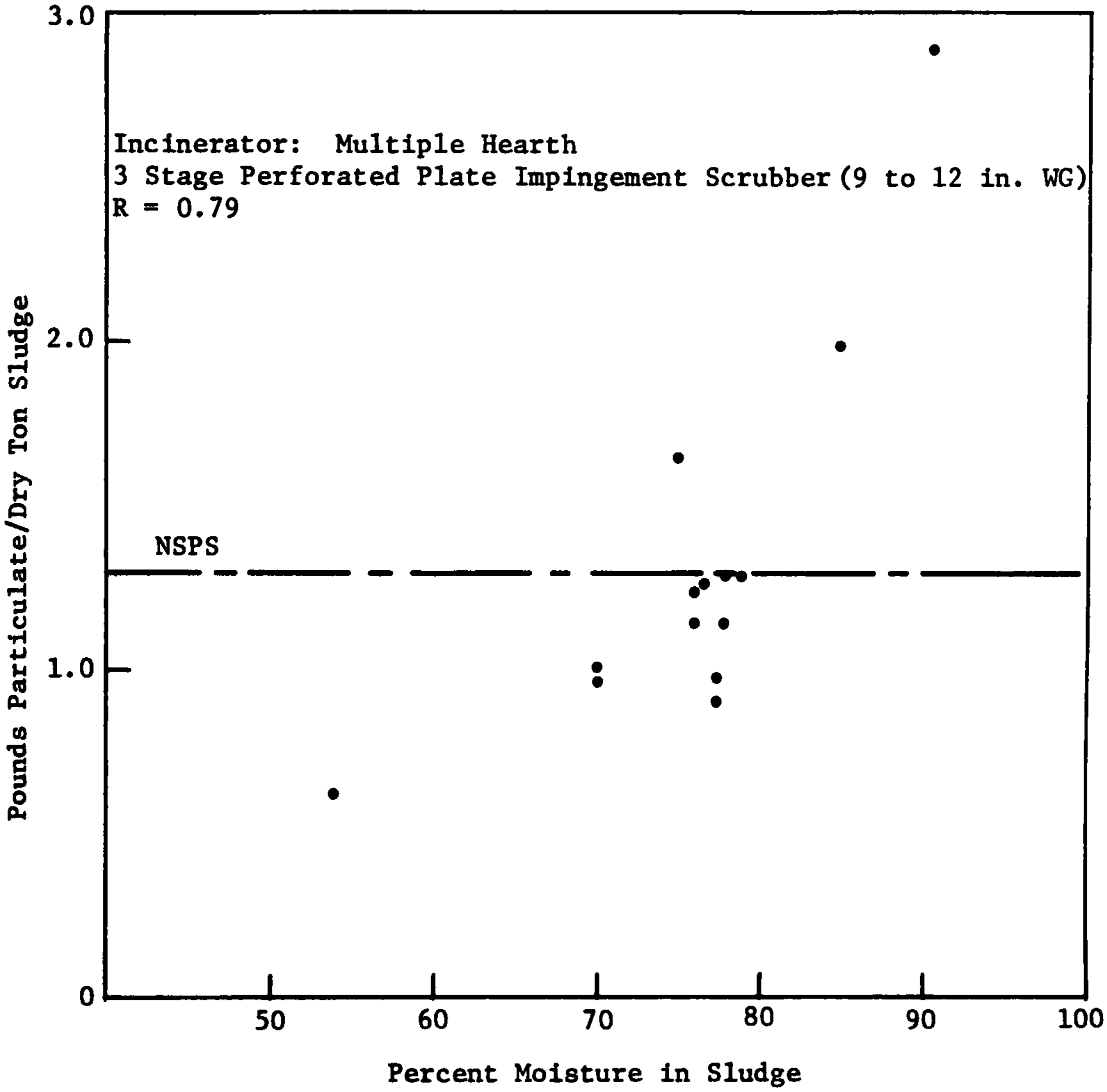
FIGURE 5-5
EMISSIONS ON A MASS VERSUS VOLUME BASIS:
HIGH SLUDGE SOLIDS

bed incinerator of the background document was on the order of 20 percent solids with 80 percent volatile matter (Baer, 1978).* The average solids content in Table 5-1 is 24 percent. Interestingly, the Cincinnati and upper Blackstone results were about equivalent to the results found by EPA in 1973 (e.g., 0.07 grams/dscm (0.03 grains/dscf) equivalent to 0.65 Kg/Mg (1.3 lb/ton dry sludge input). Each of the tests at these facilities involved input sludge with a relatively high solids content of between 27 and 33 percent. Conversely, the incinerators at Merrimack, New Hampshire, operating on 16 percent sludge solids, have been tested several times and, even with high scrubber pressure drops of 30 in. WG or more, have just managed to reach the sludge standard despite low volume concentrations of 0.020 and 0.023 grams/acm (0.009 and 0.010 grains/acf).**

The importance of sludge moisture content is strongly suggested by the results in Figure 5-6, where a relatively high correlation coefficient of 0.79 between sludge moisture content and increasing mass concentrations was found (Kroneberger, 1978). Of particular interest is the fact that this plant could meet the standard with a three-stage impingement scrubber operating at the relatively low pressure drop of 9 to 12 in. WG as long as the moisture content

*It should be noted that EPA records indicate that the tested facility operated on 35 to 45 percent solids (Salotto, 1978). The difference in these values has not been reconciled and it is unknown which value was used to calculate sludge solids input.

**Unit 2 was considered not in compliance at 1.34 lb/dry ton sludge input.



Source: Kroneberger, 1978

FIGURE 5-6
EMISSIONS VERSUS SLUDGE MOISTURE CONTENT IN A MULTIPLE HEARTH INCINERATOR

remained less than 75 percent. The data in Table 5-1 only weakly suggest this relationship (R=0.45) and, therefore, one can only conclude that facilities incinerating high moisture sludge may run the risk of not meeting the NSPS requirement and/or may require very high energy scrubbers for particulate removal.

5.1.3 Particulate Emissions Analysis Summary

From the above analysis it appears that the current NSPS is a more stringent standard than originally acknowledged but, nevertheless, the majority of units can comply with this level. The stack concentrations at complying units are very low and reflect removal efficiencies of 98.5 to 99.5 percent at nominal input concentrations of 40 to 75 Kg/Mg (80 to 150 lb/ton) of dry sludge input. The average scrubber pressure drop of 20 in. WG produced an average mass emission rate of 0.46 Kg/Mg (0.91 lb/ton) of dry sludge input and an average volume emission rate of 0.050 grams/dscm (0.022 grains/dscf) at incinerators operating on a sludge with an average of 24 percent solids.

The data are suggestive of a relationship between the percent of sludge solids incinerated and mass emission concentrations with higher solids content leading to lower emissions on a per dry ton input basis. This implies a tradeoff between improving dewatering operations or increasing capital and operating costs for emissions control equipment (e.g., higher energy costs for increased scrubber pressure drops, extra scrubbing units).

5.2 Opacity Measurements

While not indicated in Table 5-1 several tests included opacity measurements. In only one case was an opacity level as high as 15 percent reported. The majority of reports were either 0 or 5 percent. This appears consistent with the reported particulate emissions levels. The opacity standard was proposed as 10 percent with exemptions in 1973 and then revised to 20 percent without exemptions except for startup and shutdown. No information received to date contradicts the rationale used in setting the opacity level at 20 percent.

5.3 Mercury Levels

Information on mercury levels was collected from four incinerators. At Erie, Pennsylvania samples contained an estimated 600 grams/day in emissions exiting the scrubber of incinerator #1 and 450 grams/day exiting incinerator #2. In Appolo, Pennsylvania the mercury concentration was 17 grams/day in the exit gas of the scrubber. Samples of sludge input to the fluidized bed reactor in Tyrone, Pennsylvania indicated a 21 gram/day input rate. All these values are well below the 3200 gram/day Federal emission level.

6.0 FINDINGS AND RECOMMENDATIONS

The primary objective of this report has been to assess the need for revision of the existing NSPS for sewage sludge incineration and to describe any new developments that have occurred since the standard was proposed in 1973. The findings and recommendations are presented below.

6.1 Findings

6.1.1 Incinerator Developments Since 1973

- Approximately 240 SSIs are currently in operation. A total of 19 MSSIs have been identified as candidates for the NSPS and an additional 92 units were in the planning or construction stage as of mid-1977. This contrasts strongly with the EPA mid-1973 estimate of 70 new MSSIs per year. The 1973 Oil Embargo and subsequent rise in energy prices and recent emphasis on land disposal of sludge most likely had a strong impact on the reduction of the projected number of units. Most new units are projected to be of the multiple hearth design.

- The increase in fuel prices has led to increased efforts toward autogeneous sludge incineration or, at a minimum, recovery and use of waste heat. Improved dewatering techniques from the increased use of chemicals, heat treatment of sludge, and improved filtering equipment has helped reduce the need for auxiliary fuel. Many new units are now planned to utilize exhaust gases to produce steam to run equipment or heat treat incoming sludge and should operate as net energy exporters.

- The electric incinerator, not operational in 1973, has been tested for emissions in at least two locations. Uncontrolled emissions from these units are much lower than those found in the fluidized bed or multiple hearth incinerators. Collection efficiency requirements for these units may, therefore, be lower than those needed for the multiple hearth or fluidized bed incinerators. However, it is noted that the indirect emissions due to electrical power generation were not included in the emission rate calculations for these units.

6.1.2 Process Emissions and Control Technology

- The current best demonstrated control technology is the venturi scrubber in series with perforated impingement plate scrubbers operating at about 20 in. WG pressure drop. Data collected from tests indicate, however, that other factors such as input sludge solids contents may be important parameters in selecting a control device. At least one facility burning 30 percent sludge solids was tested and met the standard using three-stage perforated plate impingement scrubbers at pressure drops of 7 to 9 in. WG.

- The equivalence of 0.071 grams/dscm (0.031 grains/dscf) to 0.65 Kg/Mg (1.3 lb/ton) dry sludge input used to set the NSPS in 1974 appears to be incorrect with respect to multiple hearth furnaces meeting the NSPS. The 0.65 Kg/Mg (1.3 lb/ton) dry sludge input standard has tested out to be equivalent to 0.05 grams/dscm (0.022 grains/dscf). The reasons for this are possibly related to differences in combustion air requirements between multiple hearth incinerators and the single fluidized bed incinerator used to set the NSPS and the input sludge characteristics of the single unit versus that found in the test data.

- The NSPS has been complied with in most cases. The test results were calculated to be 0.46 ± 0.17 Kg/Mg (0.91 ± 0.33 lb/ton) dry sludge input and 0.032 ± 0.018 grams/dscm (0.014 ± 0.008 grains/dscf).

- Particulate removal efficiences of 98.5 to 99.5 percent are required and are being achieved based on uncontrolled emissions of from 40 to 75 Kg/Mg (80 to 150 lb/ton) dry sludge input.

- Units burning relatively wet sludge (e.g., 15 percent solids) may have trouble meeting the NSPS with the best demontrated control technology. This may be due to the increased fuel and combustion air requirements per unit of dry sludge burned necessary for evaporating the moisture. The resulting particulate concentrations are lower and may even tax the removal capacity of scrubbers operating at relatively high pressure drops.

6.1.3 Opacity Standard

Opacity measurements taken during NSPS tests ranged from 0 to 15 percent with the majority of measurements in the 0 to 10 percent range.

6.1.4 Coincineration with Refuse

Various possibilities exist for incinerating municipal solid waste and sewage sludge. There is currently no explicit statement in either Subparts E or O that covers the appropriate standard to be used when jointly incinerating both types of waste.

6.1.5 State Standards

The NSPS is the more stringent standard in most states. The Solid Waste Management Association of America (SWMAA) categorization of solid wastes appears in several state incineration standards. Sewage sludge is not categorized within the SWMAA definitions. Several states have minimum stack temperature regulations of 1200° to 1600°F and/or incinerator design constraints.

6.2 Recommendations

6.2.1 Revision of the Standard

At this time there appears to be sufficient evidence to recommend no revision of the values of the particulate standard or the opacity standard. The rationale for this is based on the following considerations:

- The standard is more stringent than originally indicated. Removal efficiencies of 98.5 to 99.5 with volume concentrations of 0.058 to 0.062 grams/dscm (0.022 to 0.027 grains/dscf) are required to meet the standard.

- There is no clear relationship between control technology parameters and emission control. Factors such as percent of sludge moisture and incinerator type may be as important in achieving compliance as pressure drops in scrubbers.

- The average emission level achieved was 0.45 $\pm$ 0.15 Kg/Mg (0.9 $\pm$ 0.3 lb/ton) dry sludge input. The range of this value and the relatively high pressure drops currently employed indicate best demonstrated control technology is meeting the standard with about a 25 percent margin of error.

- Very low opacity readings have been associated with most NSPS particulate tests. However the rationale used to set the 20 percent standard to include upsets, etc. is still valid.

6.2.2 Definitions

Clarification of the applicable standard when jointly incinerating refuse and solid waste is desirable.

6.2.3 Research Needs

Given the poor correlation between emission values and scrubber pressure drop, it would be desirable to ascertain those factors responsible for this situation. Evidence has been presented to indicate that insufficient dewatering of sludge may cause problems in achieving compliance. If this were shown to be so, for example, then designs submitted to EPA as part of the grants program should be evaluated on dewatering capability if incineration is to be used.

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16. ABSTRACT

This report reviews the current Standards of Performance for New Stationary Sources: Subpart O - Sewage Sludge Incinerators. It includes a summary of the current standards, the status of applicable control technology, and the ability of sewage sludge incinerators to meet current standards. Compliance test results are analyzed and a recommendation made to retain the current standard. Information used in this report is based upon data available as of November 1978.

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