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EPA

Combustion Emissions Technical Resource Document (CETRED)

DRAFT

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EXECUTIVE SUMMARY

The Draft Combustion Emissions Technical Resource Document (CETRED) contains the initial technical analysis by the U.S. Environmental Protection Agency (EPA) concerning emissions of dioxins/furans and particulate matter from certain types of devices that burn hazardous waste: cement kilns, light-weight aggregate kilns, incinerators, and industrial boilers. CETRED represents the first, preliminary step in the development of regulations under the Resource Conservation and Recovery Act (RCRA) and the Clean Air Act (CAA) to impose upgraded standards on hazardous waste combustors (HWCs). CETRED also represents a major effort towards implementing the commitment made by EPA Administrator Carol M. Browner in the Draft Hazardous Waste Minimization and Combustion Strategy, released on May 18, 1993, to upgrade the technical standards governing emissions from HWCs.

EPA's intention in releasing CETRED at this time is to give the regulated community and other interested persons the earliest possible opportunity to understand the nature of the technical analysis that EPA is pursuing. CETRED can appropriately be regarded as a preliminary technical analysis of certain HWCs and their emissions of particulate matter (PM) and dioxins/furans. CETRED represents the current state of analysis of EPA's technical staff in the Office of Solid Waste as regards the emission levels of PM and dioxins/furans achievable by the best controlled sources.

At this time, CETRED does not contain a characterization of emissions for toxic metals and other hazardous air pollutants from the HWCs studied. EPA will initiate a technical analysis to characterize these emissions in the near future. EPA expects to make the results of that analysis available to the public for review prior to the time that any regulatory proposal would be developed.

Process Descriptions

Cement Kilns. Many cement facilities burning hazardous wastes use "wet" process kilns where the raw materials are slurried before introduction to the kiln. Hazardous waste is burned in other types of cement kilns, however, including long dry kilns, preheater kilns, and preheater/precalciner kilns.

Liquid hazardous waste fuels are fired into the hot, lower end of the kiln as a supplement to fossil fuels. Solid hazardous waste fuels are also fired using several methods, including: (1) in long wet or dry kilns, containerized waste can be charged through a hatch on the rotating kiln wall in the calcining zone of the kiln; (2) in preheater or precalciner kilns, solid waste fuels can be injected directly into the precalciner vessel or preheater inlet; (3) in long wet or dry kilns, containerized waste can be injected at the hot end of the kiln using an "air cannon" at a high enough velocity to project the containers in the calcining zone; and (4) powdered hazardous waste can be pneumatically fired into the hot end of the kiln.

Cement kilns are normally equipped with either an electrostatic precipitator (ESP) or fabric filter (FF) to control emissions of PM.

Light-weight Aggregate Kilns. Light-weight aggregate kilns slowly heat raw materials such as clay, shale, or slate to expand the particles to form light-weight materials generally for use in concrete products. The light-weight aggregate concrete is produced either for structural or thermal insulation purposes. When burning hazardous waste, these kilns generally burn the liquid waste as their sole fuel.

Most light-weight aggregate kilns burning hazardous waste are equipped with FFs to control PM emissions.

Hazardous Waste Incinerators. Hazardous waste incineration technology has been developed over a number of years as a means of treating various types of waste to destroy toxic organics in the waste and reduce the volume of the waste. There are many types of incinerators in use including rotary kilns, fluidized bed units, liquid injection units, and fixed hearth units.

Incinerators use many types of air pollution control devices to control emissions of particulate matter, metals, and acid gases. In general, the control systems can be grouped into the following three categories: (1) wet systems, where a wet scrubber is used for both particulate and acid gas control; (2) dry systems, where a FF or ESP is used for PM control, sometimes in combination with dry scrubbing for acid gas control; and (3) hybrid wet/dry systems where a dry technique (ESP or FF) is used for PM (and possibly acid gas control with use of dry scrubbing) followed by a wet technique (venturi or packed bed scrubber) for acid gas control.

Boilers. The three common boiler design categories that burn hazardous waste are firetube, watertube, and stoker-fired. Although most boilers burn liquid hazardous waste, some burn solid hazardous waste. The hazardous waste firing rate (percentage of heat input contributed by the hazardous waste) ranges from less than 10% to 100%.

PM Emission Levels

EPA is evaluating PM emission levels because controlling PM will control emissions of most toxic metals and toxic organic compounds absorbed into the PM. PM levels are evaluated for several different source categories (or subsets thereof), as well as various degrees of aggregation of these source categories. For example, commercial incinerators are evaluated separately from on-site incinerators as a crude attempt to determine if the best controlled of the generally smaller on-site incinerators are achieving PM emissions levels substantially different from the best controlled commercial incinerators. Further, PM emissions from the best controlled incinerators, boilers, and industrial furnaces are evaluated as an aggregated group representing the hazardous waste combustor source category. While the Agency is interested in examining the appropriateness and implementability of establishing standards that apply across all types of hazardous waste combustors, EPA recognizes that in doing so there may be technical and policy determinations that have not yet been fully illuminated or explored. The Agency emphasizes that , at this time, it has not decided if and which source categories will be grouped in determining PM emission limits.

For this study, EPA is evaluating PM emission data that facilities had submitted to the EPA Regional Offices and the States as part of Certifications of Compliance under the Agency's Boiler and Industrial Furnace (BIF) Rule, and from incinerator trial burns used to consider issuance of operating permits. To identify the best controlled sources, the sources are ranked in order of ascending PM emission levels considering the average emission level for the source and the variability of the emissions data. The best 12% (or best 5 sources, which ever is greater) of the sources are then selected as (potentially) the best controlled sources. Each of the sources in the selected pool is then evaluated to determine if they achieve low PM emissions because they use advanced control techniques or because they simply burn wastes or other materials with low levels of ash. Sources with low PM levels because of low ash feed rates are screened out of the pool as being unrepresentative of best controlled sources, and the next best controlled sources are brought into the pool as replacements.

Once the pool of the best controlled sources is established, their emissions data are analyzed statistically to predict a PM emission level that could be achieved under two alternative approaches. Under Option 1, a PM emission level is identified that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95% confidence. Under Option 2, a PM emission level is identified that a source with the average emission level of the best controlled source pool could be expected to meet 99% of the time, with 95% confidence, and assuming that the variability of the source's emissions data is similar to the variability of the emissions data from the sources in the pool. Under Option 1, all of the sources in the best controlled source pool should be able to achieve the PM level without modifications, while under Option 2, some of the sources in the pool may not be able to achieve the PM level without modifications to the facility design or operation.

The table below presents the PM emission levels achievable by the best controlled sources for the source categories and groups of source categories, and for the alternative analytical approaches:

PM EMISSION LEVELS ACHIEVABLE BY THE BEST CONTROLLED SOURCES
(gr/dscf @ 7% O_2)

Source Category	Option 1*	Option 2+
Cement Kilns	0.033	0.010
Light-weight Agg. Kilns	0.022	0.0077
Commercial Incinerators	0.010	0.0049
On-Site Incinerators	0.015	0.0075
All HW Incinerators	0.0057	0.004
Boilers	0.021	0.011
All Hazardous Waste Combustors	0.0086	0.0052

* Under Option 1, a PM emission level is identified that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95% confidence.

\+ Under Option 2, a PM emission level is identified that a source with emissions equivalent to the average for the pool of the best controlled sources could be expected to meet 99% of the time, with 95% confidence, and assuming that the variability of the source's emissions is similar to the variability of emissions for the sources in the pool.

Dioxin/Furan Emission Levels

Dioxin/furan emission levels are evaluated for hazardous waste burning incinerators, cement kilns, light-weight aggregate kilns, and boilers in the aggregate (i.e., as a hazardous waste combustor (HWC) source category). EPA is not currently aware of any overriding technical reason why all HWCs should not be able to meet the emission level achievable by the best controlled sources.

The dioxin/furan emissions data used for the analysis are obtained from BIF Certifications of Compliance and incinerator Trial Burn results. The Agency is using the same methodology used for PM to identify the best controlled sources, except that the sources in the (potentially) best controlled source pool are screened for three criteria. First, the pool sources are screened to determine if they have low dioxin/furan emissions because their feedstreams contain insignificant levels of chlorine.

Then, two additional screening criteria are used because of concern about the potential conflict between minimizing dioxin/furan and PM emissions at the same time. Given that dioxins/furans may be formed in HWCs operating under good combustion practices by surface-catalyzed reactions, dioxin/furan emissions can be affected by PM emissions. Thus, these screening criteria ensure that the dioxin/furan emissions from the pool sources are representative of emissions from sources that use best operating practices to control both PM and dioxin/furans. The first of these criteria screened out of the pool sources that had low PM emissions because they are feeding materials with low ash content. These sources may have low dioxin emissions simply because there was little PM to promote surface-catalyzed formation. The second criterion screened out sources that have high PM emissions. These sources may have low dioxin emissions simply because they are not removing PM and thereby providing an attenuated residence time (e.g., in an ESP or FF) for surface-catalyzed reactions to take place.

After the pool of best controlled and representative sources is identified, the same statistical approaches used to analyze PM emissions are used to analyze dioxin/furan emissions. The following table presents the dioxin/furan emission levels achievable by the best controlled HWC sources under the alternative analytical approaches:

DIOXIN/FURAN EMISSION LEVELS ACHIEVABLE
BY THE BEST CONTROLLED SOURCES
(ng/dscm @ 7% O_2)

Basis	Option 1*	Option 2+
TEQ	0.17	0.12
Total Tetra through Octa Congeners	9.4	5.4

* Under Option 1, an emission level is identified that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95% confidence.

\+ Under Option 2, an emission level is identified that a source with emissions equivalent to the average for the pool of best controlled sources could be expected to meet 99% of the time, with 95% confidence, and assuming that the variability of the source's emissions is similar to the variability of emissions for the sources in the pool.

Note that EPA believes that it is appropriate to control dioxin/furan emissions for HWCs based on toxicity equivalents (TEQs). Under this approach, weighting functions knows as toxicity equivalence factors are assigned to the various dioxin and furan congeners to account for their toxicity relative to 2, 3, 7, 8 TCDD. EPA is considering whether it is also appropriate to control emissions based on total tetra-octa congeners. If so, emission limits would be established on the basis of total congeners as well as TEQ.

European Emission Regulations

On March 23, 1992, the European Economic Community (EEC) issued a proposal for a Council Directive on the Incineration of Hazardous Waste. The Directive requires all its Member States to establish laws, regulations, and administrative procedures to comply with the directive by June 30, 1994. The directive stipulates that any new incinerator must comply immediately and existing facilities by June 30, 1997.

The regulatory approach adopted in the 1992 EEC Directive establishes a wide array of continuous emission monitoring requirements, including continuous monitors for carbon monoxide and total dust emission levels, and monthly measurements for metals, dioxins, and furans. A summary of European guidelines and limits for PM and dioxins/furans is presented in the following table.

EMISSION GUIDELINES/LIMITS FOR WASTE INCINERATION IN EUROPE

Pollutant (Daily Averages)	EEC Guideline	Netherlands Limit	Germany Limit
Total Dust (mg/m^3)	5	5	5
Dioxin/furan ($ngTEQ/m^3$)[1]	0.1	0.1	0.1

Waste incineration has been in use in Europe longer than in North America. The air pollution control device (APCD) systems are similar. However, because the majority of the European facilities have undergone retrofits and have faced more stringent emission standards, design differences exist. Incinerators in Europe currently incorporate some sort of dust control device, such as wet and dry electrostatic precipitators (ESP) or fabric filters (FF). Most facilities have added multi-stage wet and dry scrubbers or spray drying and dry absorption processes for controlling acid gas and heavy metal emissions. The future trend is expected to be toward wet scrubbers, even though all APCD systems must be zero liquid discharge systems. Some new technologies that are emerging include adding Selective Catalytic Reduction DeNOx reactors, activated carbon filters, and gas suspension absorbers. As new options arise, it appears to be the general practice in Europe to continue to retrofit facilities with new APCDs in series with existing equipment.[1]

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[1] It is important to note that the European guideline or limit of 0.1 TEQ is corrected to 11% oxygen, and compliance is based on daily averaging. EPA requires that dioxin/furan emissions be corrected to a stack gas oxygen level of 7%. A 0.1 limit at a 11% oxygen correction factor is equivalent to a 0.14 limit at a 7% correction factor. Further, EPA requires hazardous waste burning devices operating under RCRA regulations to comply with emissions standards generally on a hourly rolling averaging period. The European guidelines/limits are based on daily averaging, a less stringent approach in terms of operational variability. Finally, RCRA regulations require a facility to comply with the emissions standard for each of three triplicate runs during a Trial Burn or Compliance Test. Compliance with the European guidelines/limits is based on the average of test runs.

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1.0 INTRODUCTION

The Draft Combustion Emissions Technical Resource Document (CETRED) contains the initial technical analysis of the U.S. Environmental Protection Agency (EPA) concerning certain types of devices that combust hazardous waste — cement kilns, lightweight aggregate kilns, incinerators, and industrial boilers. Other devices can and do burn hazardous waste, but are not yet included in this draft of CETRED. EPA expects to update CETRED to include information on these other devices in the future.

In releasing this draft of CETRED, EPA is interested in comments from all interested persons on the information and analyses presented. CETRED represents an initial technical step in the development of regulations under the Resource Conservation and Recovery Act (RCRA) and the Clean Air Act (CAA) to impose upgraded standards on the various types of incinerators and boilers and industrial furnaces (BIFs) that burn hazardous waste. Thus, CETRED is not any form of regulatory proposal. Rather, CETRED represents the current state of analysis of EPA's emission levels achievable by the best controlled sources for certain types of hazardous waste combustion facilities. EPA's intention in releasing CETRED at this time, as a preliminary technical analysis, is to give the regulated community and other interested persons the earliest possible opportunity to understand the nature of the technical analysis that EPA is pursuing.

This document includes a detailed overview of the thermal processes and equipment used to combust hazardous waste (Chapter 2), the air pollution control techniques used in these processes and equipment (Chapter 3), and a characterization of the resulting particulate matter (PM) and dioxin and furan emissions (Chapter 4). At this time, CETRED does not contain a characterization of emissions for toxic metals and other hazardous air pollutants from the processes and equipment studied. EPA will initiate a technical analysis to characterize these emissions in the near future. EPA expects to make the results of that analysis available to the public for review prior to the time that any regulatory proposal would be developed.

In Chapter 5, the determination of emissions achievable by the best controlled sources is presented. This determination is based on EPA's current emissions data base for the incinerators and BIFs studied. This data base may be expanded, either by additional information collected by EPA or by other data submitted by operators of hazardous waste combustors or members of the public. Depending on the nature of this additional information (for example, it must meet basic quality assurance/quality control criteria), EPA intends to update its determinations accordingly. Finally, in Chapter 6, a survey of European emissions guidelines and regulations is presented.

CETRED represents a major step towards implementing the commitment made by EPA Administrator Carol M. Browner in the Draft Hazardous Waste Minimization and Combustion Strategy, released on May 18, 1993, to upgrade the technical standards governing emissions from hazardous waste incinerators and BIFs. Specifically, EPA announced that it would "develop and impose implementable and rigorous state-of-the-art safety controls on hazardous waste combustion facilities by using the best available technologies and the most current science." EPA remains committed to taking all necessary steps to tighten the emission standards for hazardous waste combustors in a manner that reflects the best operating practices and the maximum achievable emission controls.

2.0 PROCESS DESCRIPTIONS

Process descriptions for the major types of industrial equipment that burn hazardous waste are contained in this section. These include cement kilns, lightweight aggregate kilns, hazardous waste incinerators and boilers. For each process, the process components and operating parameters related to burning hazardous waste are discussed.

2.1 Cement Kiln Process Description

This section presents an overview of the cement kiln process and the types of kilns used for cement making. Process operating parameters important to hazardous waste treatment and a characterization of cement kilns currently burning hazardous wastes are also presented.

2.1.1 Process Components

Cement is made from a carefully proportioned mixture of raw materials containing calcium (typically limestone), silica and alumina (typically clay, shale, slate, and/or sand), and iron (typically steel mill scale or iron ore). These materials are ground to a fine powder (80% passing 200 mesh), homogenized, and heated to a very high temperature to produce a cement "clinker" product. The raw feed material, known as "meal", is heated in a kiln which is a large, inclined, rotating cylindrical steel furnace lined with refractory materials. The kilns are operated in a "counter-current" configuration; the gases and solids flow in opposite directions through the kiln, providing for more efficient heat transfer compared with "co-current" operations. The raw meal is fed at the upper, "cold" end; the slope (3-6 °) and rotation (50-70 revolutions per hour) cause the meal to move toward the "hot" lower end. The kiln is fired at the "hot" end, usually with coal or petroleum coke as the primary fuel; natural gas or fuel oil may also be used as a supplemental fuel. As the meal moves through the kiln and is heated, it undergoes drying and pyro-processing reactions to form the clinker. The reactions can be categorized into three major stages (see Figure 2.1-1):

- Drying and Preheating Zone -- Residual water is evaporated from the raw meal feed, and clay materials begin to decompose and are dehydrated (removal of bound water) in a temperature range of 70 to 1100 °F.

- Calcining Zone -- Material is "calcined"; that is, calcium carbonate in the limestone is dissociated producing calcium oxide ("burnt lime") and carbon dioxide in the temperature range of 1100 to 1650 °F.

- Burning Zone -- In the "burning" zone, also known as the "clinkering" or "sintering" zone, calcium oxide reacts with silicates, iron, and aluminum to form "clinker." The clinker is a chemically complex mixture of calcium silicates, aluminates, and alumino-ferrites. A minimum meal temperature of 2700 °F is necessary in the burning zone of the kiln to produce the clinker.

The clinker is removed from the kiln at the hot end. After it passes through the burning zone and by the kiln flame, it enters a short cooling area where the clinker melt begins to solidify; the cooling rate from the burning zone to the kiln exit is important since it determines the microstructure of the clinker. The clinker leaves the kiln at about 2000 °F and falls into a clinker cooler. The cooler is typically a moving grate onto which the clinker sits. Cooling air is blown through the clinker bed. The cooled clinker consists of grey colored nodules of variable diameters, typically up to 2 inches. The clinker is blended with gypsum and ground in a ball mill to produce the final product, cement. Hot exhaust air produced from the clinker cooler is either directed to the kiln where it is used as combustion air or used to pre-dry the raw feed material in the case of dry process kilns.

Kiln exhaust flue gases contain significant amounts of entrained particulate matter due to the turbulence in the kiln from the rotary action and from the use of finely ground feed material. The entrained particulate matter, known as "cement kiln dust" (CKD), is removed from the flue gas by some type of air pollution control device. Many plants return a portion of the CKD to the raw feed materials. However, in most cases, some CKD must be removed from the kiln system entirely to lower the buildup of alkali salts. CKD can be used in other industries as neutralizers or additives; however, the excess CKD is usually land disposed.

2.1.2 Cement Kiln Types

Cement can be produced in three different types of arrangements — wet, dry, or semi-dry processes — as described below.

2.1.2.1 *Wet Process Kilns*

A schematic of the wet cement making process is shown in Figure 2.1-1. Ground raw materials are mixed with water (about 30% by weight) to form a slurried meal. The slurry is fed to the kiln through a flow metered pump. Solids in the slurry typically occupy no more than 15 to 20% of the internal kiln volume. Wet kilns typically have a length to diameter ratio of about 30:1 to 40:1 and rotate from 70-80 revolutions per hour. Kiln rotational speed is adjusted to maintain clinker quality and heat transfer. The wet cement making process is the older process, characterized in part by handling, mixing, and blending of the raw materials in the slurry form and lower emissions of kiln dust. However, because all water must be evaporated out of the slurry mixture, wet process kilns require greater energy input than other types of cement kilns; typically, from 5 to 7 MMBtu/ton of clinker product is required.

To improve the energy efficiency of the process, steel chains are typically attached to the inside of the kiln shell in the drying zone. The chains acts as a heat transfer mechanism. As the kiln rotates, the chains hang by gravity and pick up heat from the kiln flue gases. When the chains settle back, the heat is transferred to the raw meal.

A typical solids/gas temperature profile of a wet kiln is shown in Figures 2.1-2a and 2.1-2b. Note that the feed does not begin to heat up until all of the water in the raw meal slurry is evaporated. The gas temperature in the burning zone approaches 4000 °F, while the clinker reaches a maximum temperature of approximately 2700 °F, which is required for the formation of clinker. Flue gas velocity is also shown as a function of kiln axial location (see Figure 2.1-2b). This relates to a kiln gas residence time of over 10 seconds. Typical solids residence time in the kiln is 2-3 hours.

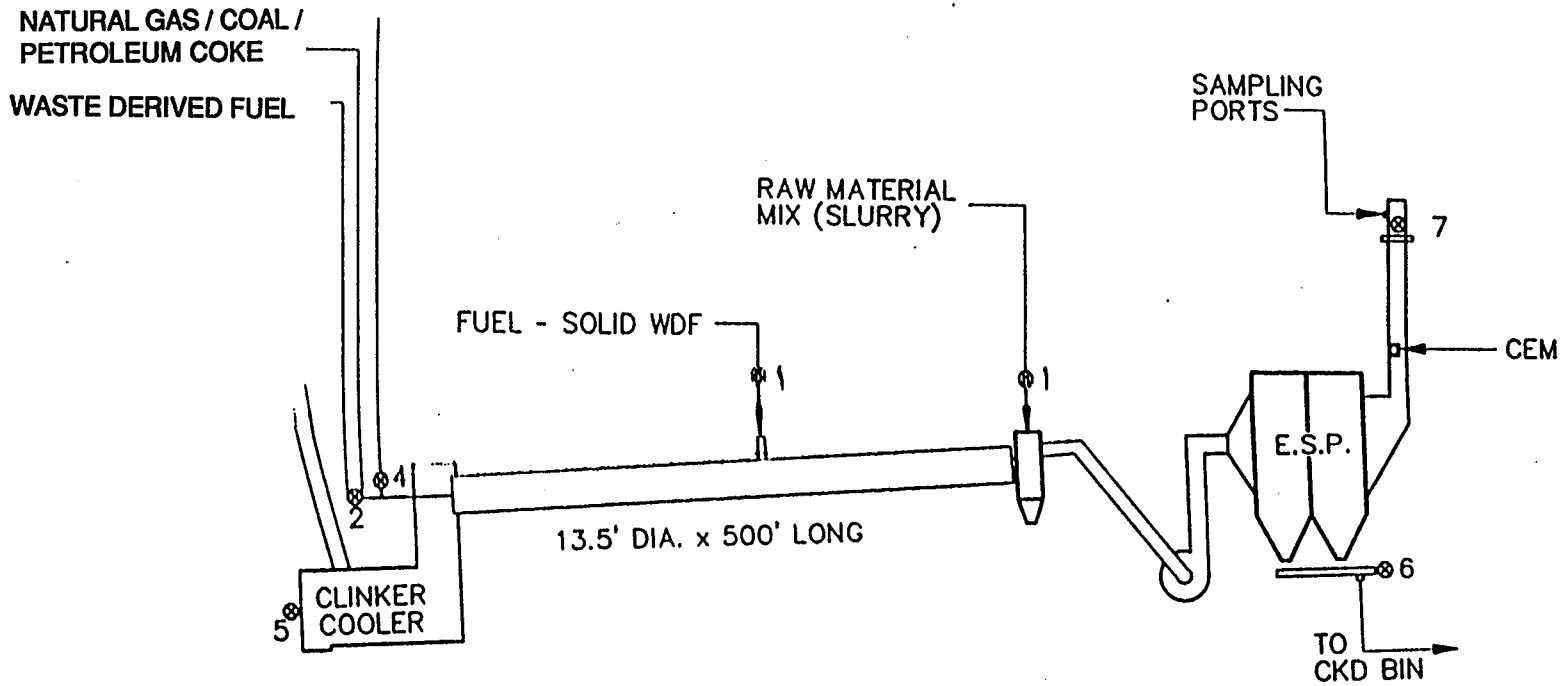

Figure 2.1-1 Wet cement making process schematic.

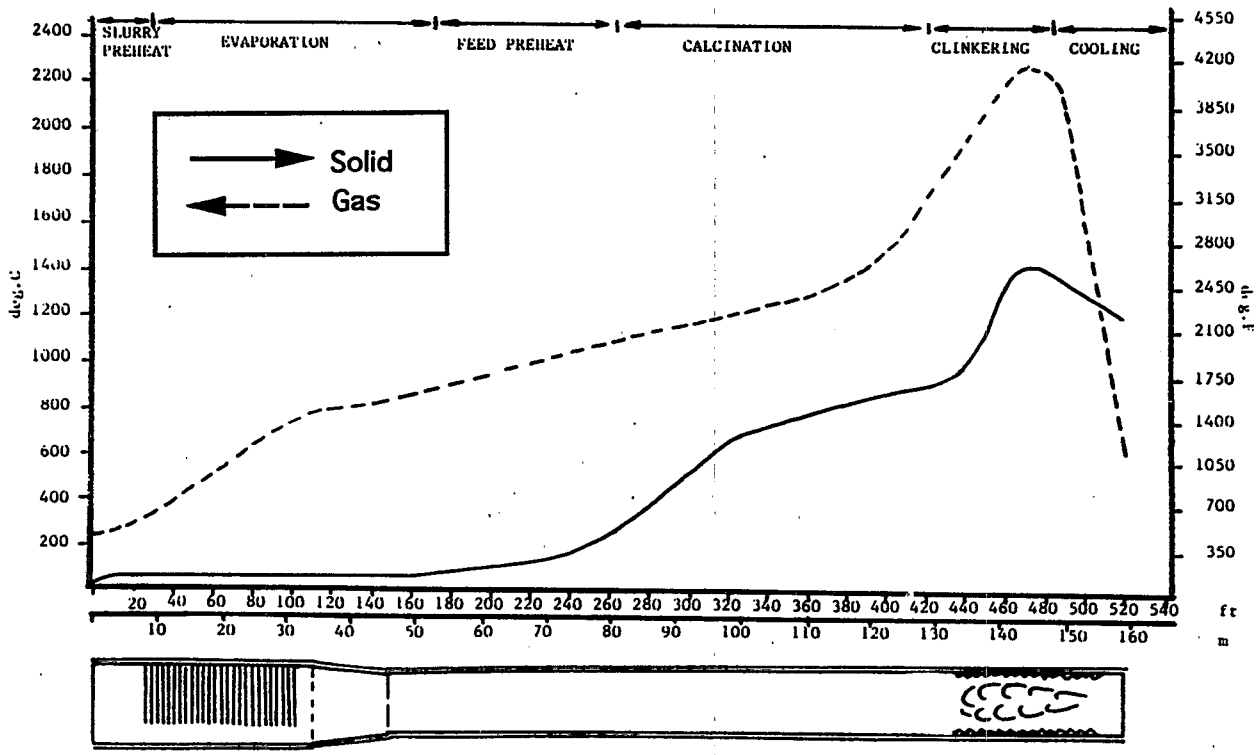

Figure 2.1-2a Typical gas (dashed line) and solids (solid line) temperature profiles for a long wet-process cement kiln.[1]

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[1] Dellinger, H., Pershing, D., and Sarofim, A., "Evaluation of the Origin, Emissions and Control of Organic and Metal Compounds from Cement Kilns Co-fired With Hazardous Wastes," Scientific Advisory Board on Cement Kiln Recycling, June 8, 1993, p. 20.

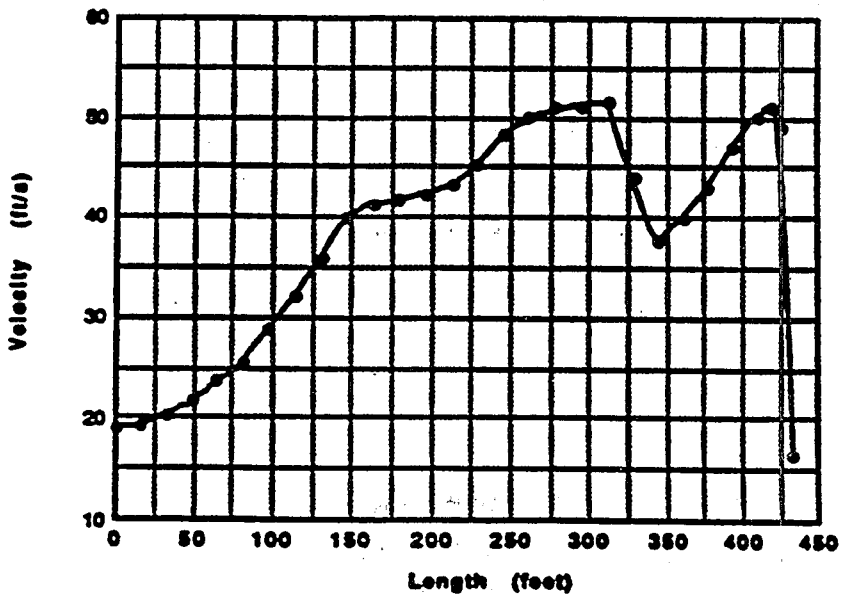

Figure 2.1-2b Typical gas velocities for a long wet-process cement kiln.[1]

2.1.2.2 *Dry Process Kilns*

Due to higher energy efficiency compared with wet kilns (3.4 to 4.5 MMBtu/ton clinker), dry processes have become popular. In the dry process, the ground raw material is dried and pneumatically transported to the kiln, or to a preheater if used. Kiln exhaust flue gases or hot clinker cooler air are typically used for drying the raw materials. There are three different dry process configurations: long, preheater, or preheater/precalciner.

2.1.2.2.1 *Long Dry Process Kilns*

A long dry process kiln schematic is shown in Figure 2.1-3. It has the same configuration as the wet type; the only difference is that the raw meal is fed in a dry form. Similar to wet kilns, long dry kilns have typical length-to-diameter ratios of about 30:1. A typical long dry kiln solid/gas temperature profile is shown in Figure 2.1-4. Note that in comparison to wet kilns, the raw meal feed is heated more rapidly since the energy required for the evaporation of water is small. Kiln gas and solids residence times are similar to those of wet kilns (order of 10 seconds and 2-3 hours, respectively). Internal chains are also used in dry process long kilns to increase energy efficiency.

2.1.2.2.2 *Preheater Dry Process Kiln*

The preheater arrangement process schematic is shown in Figure 2.1-5. Preheaters are used to further increase the thermal efficiency of the cement making process. A suspension preheater ("Humboldt" Design) consists of a vertical tower containing a series of cyclone-type vessels (typically containing four stages). Raw meal is introduced at the top of the tower. Hot kiln exhaust flue gases pass counter-current through the downward moving meal to heat the meal prior to introduction into the kiln. The meal is separated from the kiln flue gases in the cyclone, and then dropped into the next stage. Because the meal enters the kiln at a higher temperature than that of the conventional long dry kilns, the length of the pre-heater kiln is shorter; kilns with preheaters typically have length-to-diameter ratios of about 15:1. A typical solid/gas temperature profile is shown in Figure 2.1-6. The kiln has a gas residence time of about 6 seconds and a solids residence time of about 30 minutes. The gas residence time through the preheater cyclones (typically four stages) is about 5.5 seconds [2].

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[2] Dellinger.

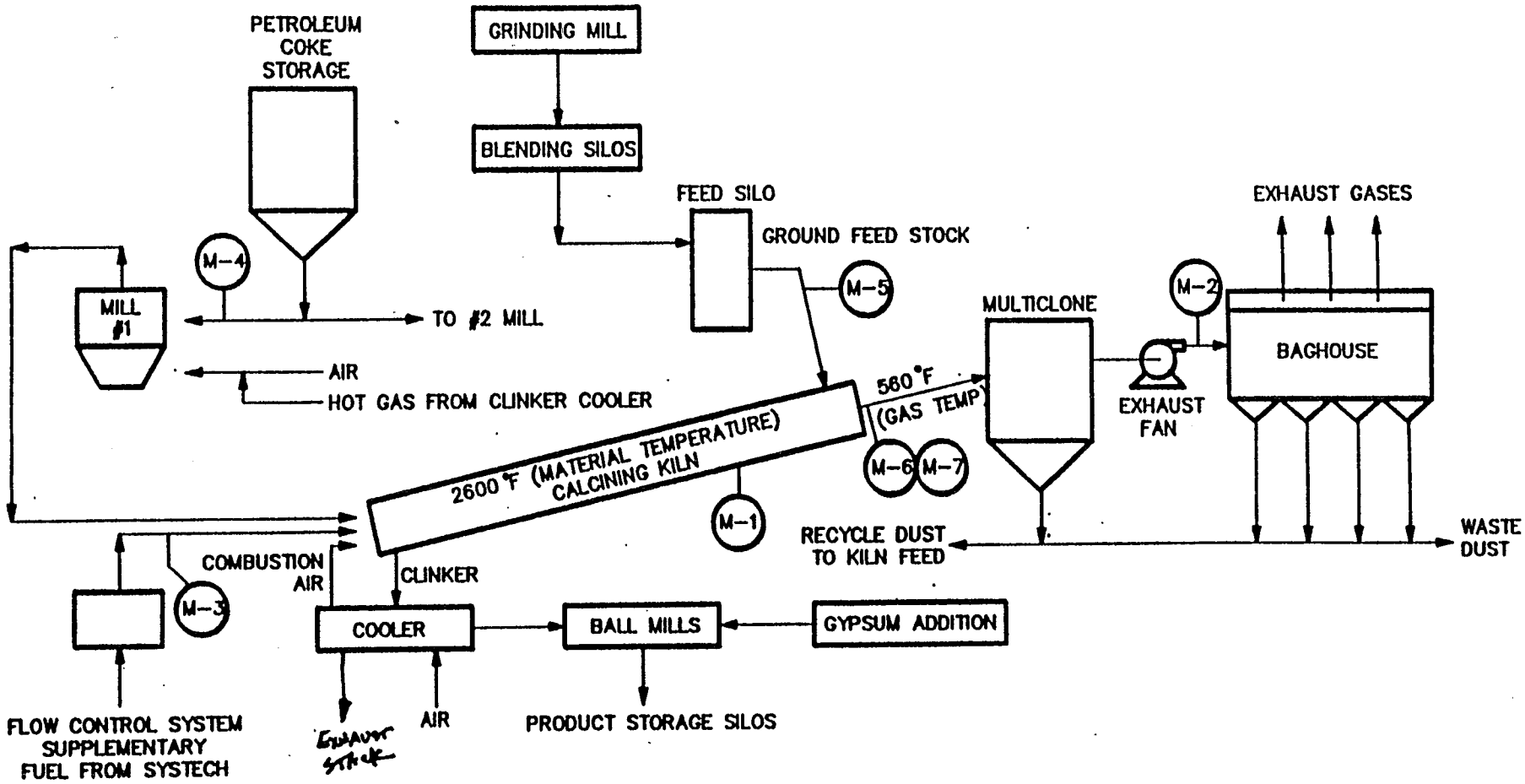

Figure 2.1-3 Dry long kiln schematic.

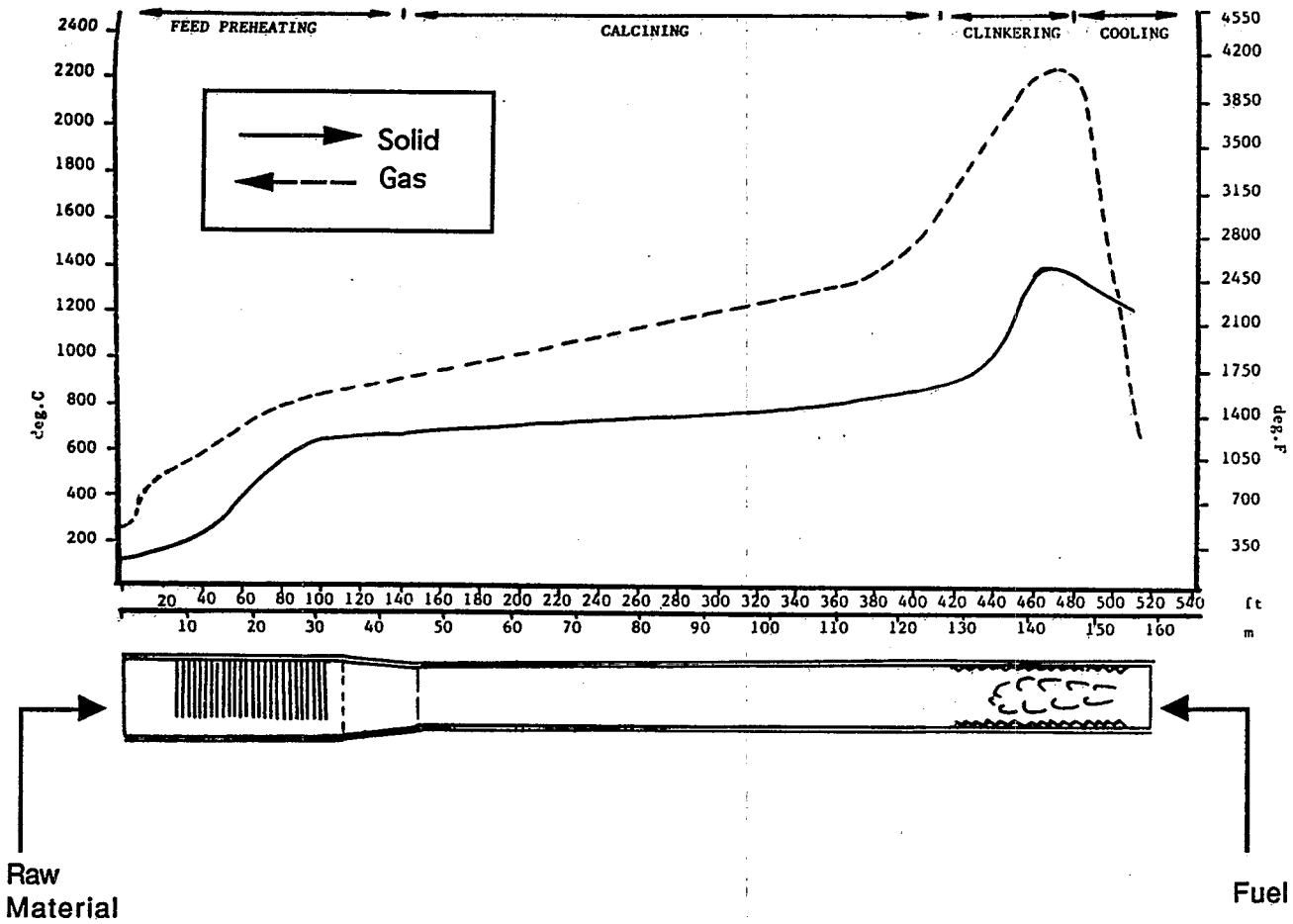

Figure 2.1-4 Dry kiln process material (solid line) and gas temperatures (dashed line).[2]

[2] Dellinger, p. 21.

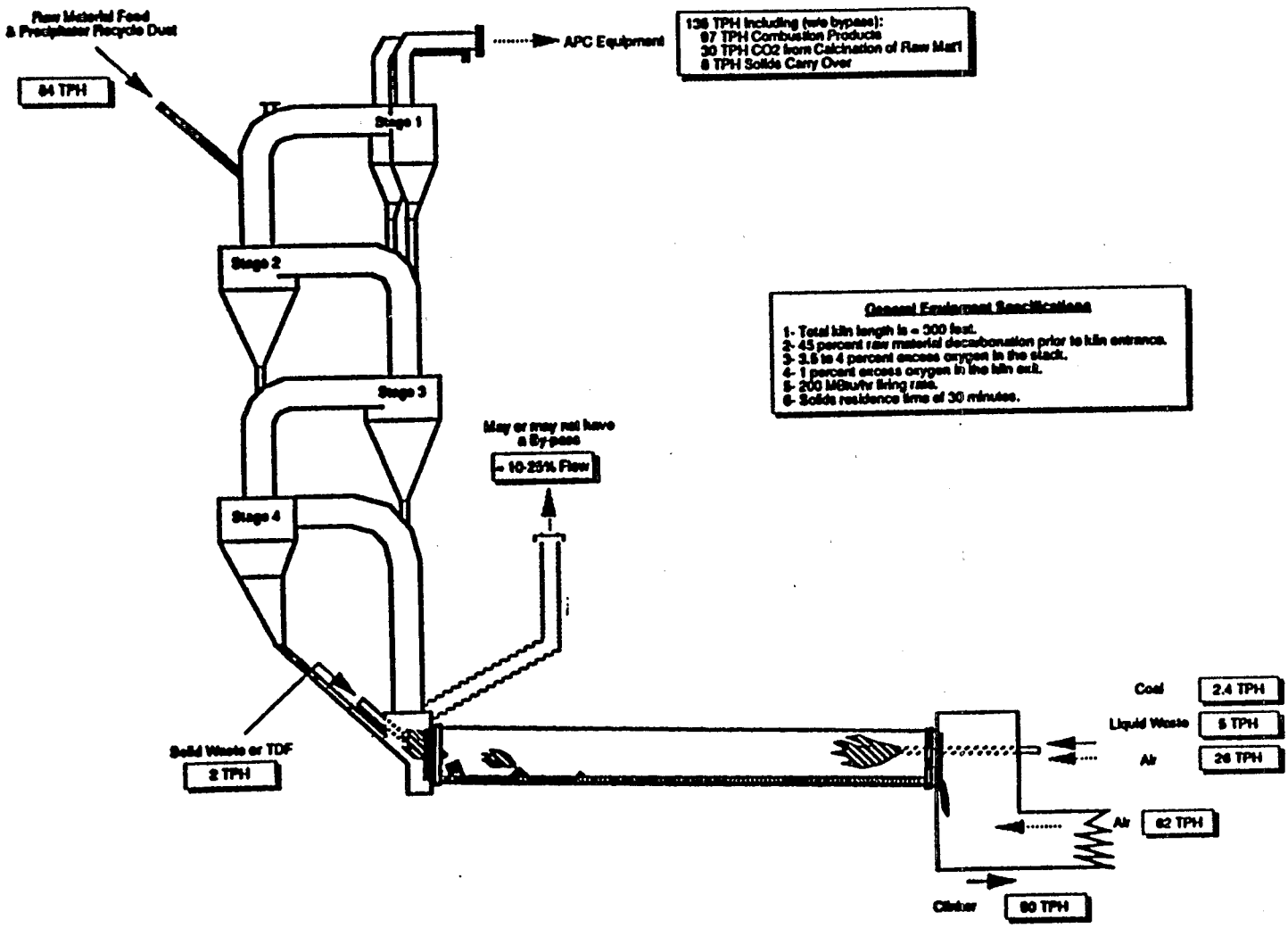

Figure 2.1-5 Dry preheater cement kiln schematic.

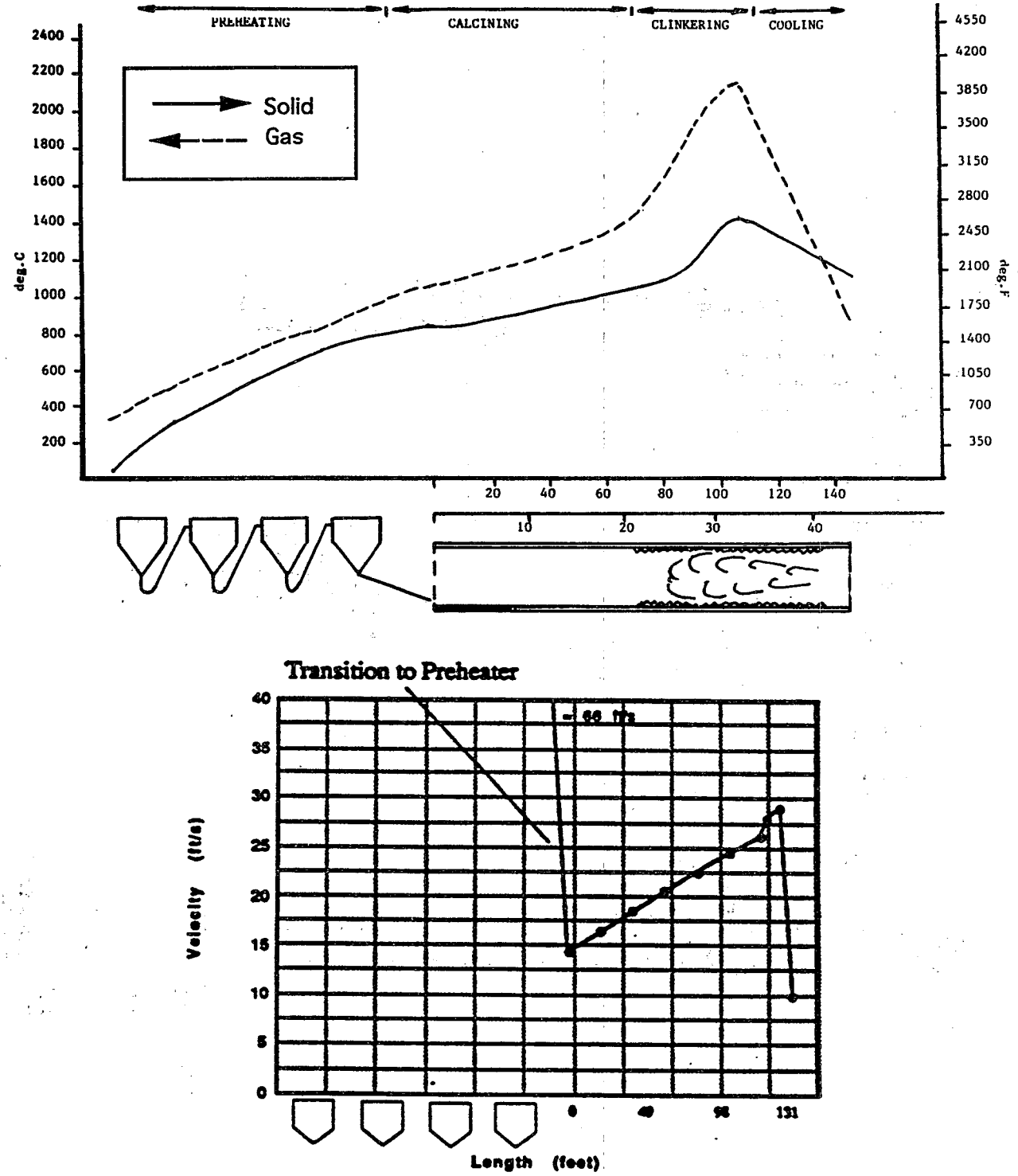

Figure 2.1-6 Typical gas (dashed line) and solids (solid line) temperature and gas velocities for a preheater cement kiln.[4]

[4] Dellinger, p. 23.

With preheater systems, it is often necessary to utilize an "alkali" bypass in which a portion of the kiln flue gases are routed away from the preheater tower at a location between the feed end of the rotary kiln and the preheater tower. The bypass is used to remove undesirable components, such as certain alkali constituents, that may accumulate in the kiln due to an internal circulation loop caused by volatilization at high temperatures in the kiln and condensation in the lower temperatures of the preheater. Accumulated alkali salts may cause preheater operating problems such as clogging of the cyclones and an increase in fine NaCl or KCl fume in the emissions gases. Typically 10 to 15% of the flue gas is routed through the bypass. Systems without bypasses are limited with respect to raw meal and waste concentrations of alkali metals, chloride (greater than 0.015% Cl by weight), and sulfur that can be tolerated in the raw materials.

The internal circulation of alkali components is greater in systems with preheaters compared to systems without preheaters due to the filtering effect of feed material flow in the preheater cyclones. Systems without preheaters have a kiln dust with a high content of alkali salts, which can be removed from the internal cycle when caught in the air pollution control device. However, for a preheater, a bypass is required to reduce the alkali buildup.

2.1.2.2.3 *Preheater/Precalciner Dry Process Kiln*

A preheater/precalciner process schematic shown in Figure 2.1-7. A preheater/precalciner is similar to the preheater arrangement described above, with the addition of an auxiliary firing system to further increase the raw materials temperature prior to introduction into the kiln. An additional precalciner combustion vessel is added to the bottom of the preheater tower. Typical systems use 30 to 60% of the kiln fuel in the precalciner to release up to 95% of the CO_2 from the raw material. Precalciner air can be supplied either directly with the precalciner fuel, or it can be supplied at the hot end of the kiln. In another arrangement, the kiln flue gas may be routed around the calciner directly to the preheater. Kilns with preheater/precalciners can be even shorter than those with preheaters only (length-to-diameter ratio of 10:1).

The primary advantage of using the precalciner is that it increases the production capacity of the kiln since only the clinker burning is performed there. The use of the precalciner also increases the kiln refractory lifetime due to reduced thermal load on the burning zone. These configurations also require a bypass system for alkali control.

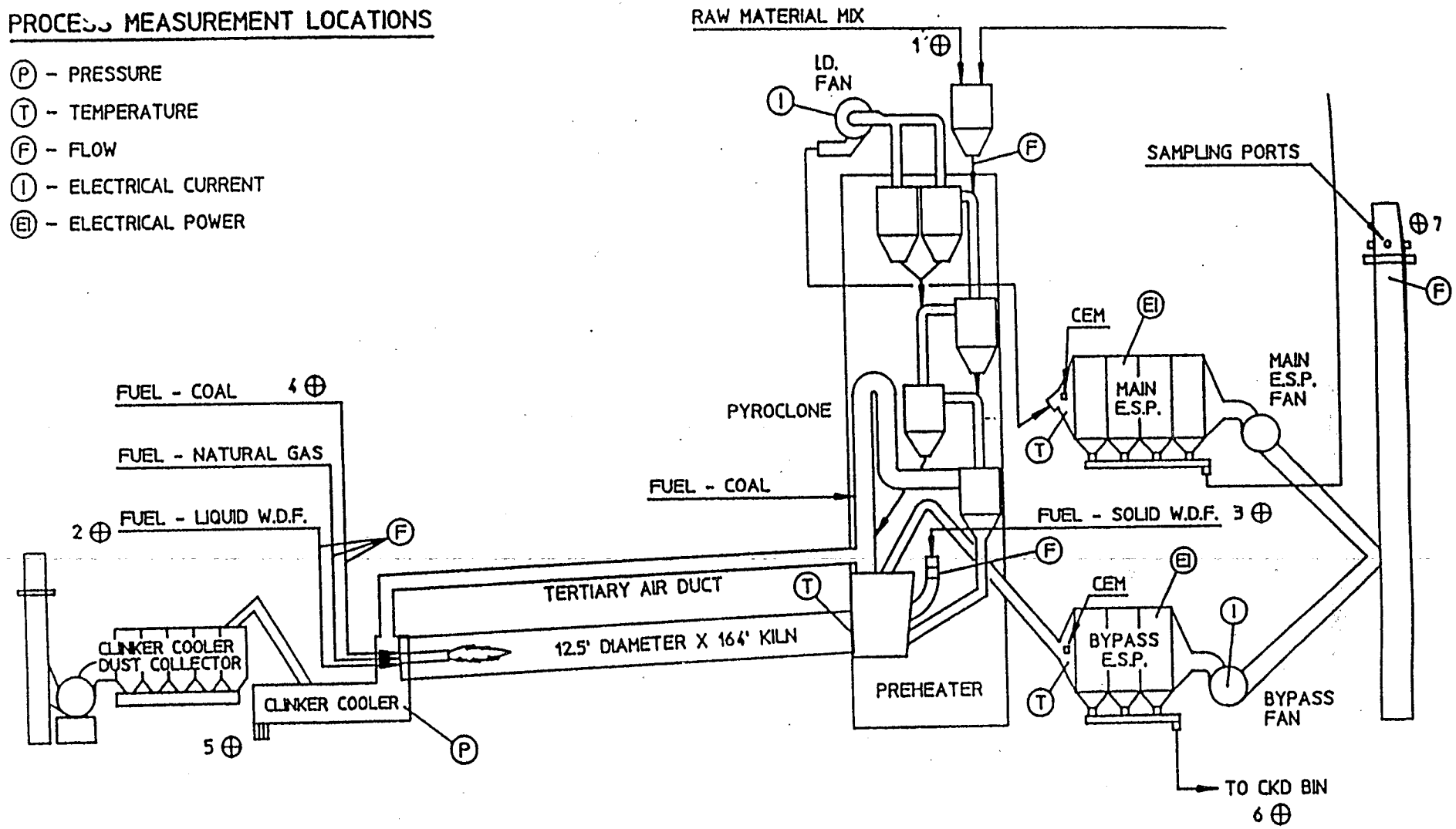

Figure 2.1-7 Dry preheater/precalciner cement kiln schematic.

A typical solid/gas temperature profile of a kiln with a preheater and precalciner is shown in Figure 2.1-8. It is similar to that of the preheater kiln; however, the time at which the gas temperature is above 1650 °F is slightly less in a precalciner type kiln [5].

2.1.2.3 *Semi-Dry Process Kilns*

In the semi-dry process, the ground feed material is pelletized with 12 to 14% water. The pellets are put on a moving "Lepol" grate on which they are dried and partially calcined by hot kiln exhaust gases before being fed to the rotary kiln. A semi-dry process schematic is shown in Figure 2.1-9. A typical solids/gas temperature diagram is given in Figure 2.1-10.

2.1.3 Hazardous Waste Feeding

The method of feeding hazardous waste into the kiln is a primary factor in determining the destruction of the waste, which is dependent on temperature and residence time. The method of introducing the waste also depends on its physical state, as discussed in the following sections.

2.1.3.1 *Liquids*

Liquid wastes are either blended directly with conventional fuels provided at the hot end of the kiln, or they are injected separately through a separate burner/atomizer into the primary kiln flame.

2.1.3.2 *Solids*

In the past, solid wastes were fed at the cold end of the kiln with the raw meal. However, the addition of wastes at the cold end is no longer practiced because as the wastes move down the kiln and get hotter, volatile components are driven off at temperatures below those required for complete oxidation and destruction. Thus, significant emissions of unburned volatiles may have occurred without the use of an afterburner or other add-on volatile emissions control techniques. Solid wastes are not charged directly into the hot end burning zone since they can create local reducing conditions which adversely affect clinker quality such as strength, stability, set-up time,

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[5] Dellinger.

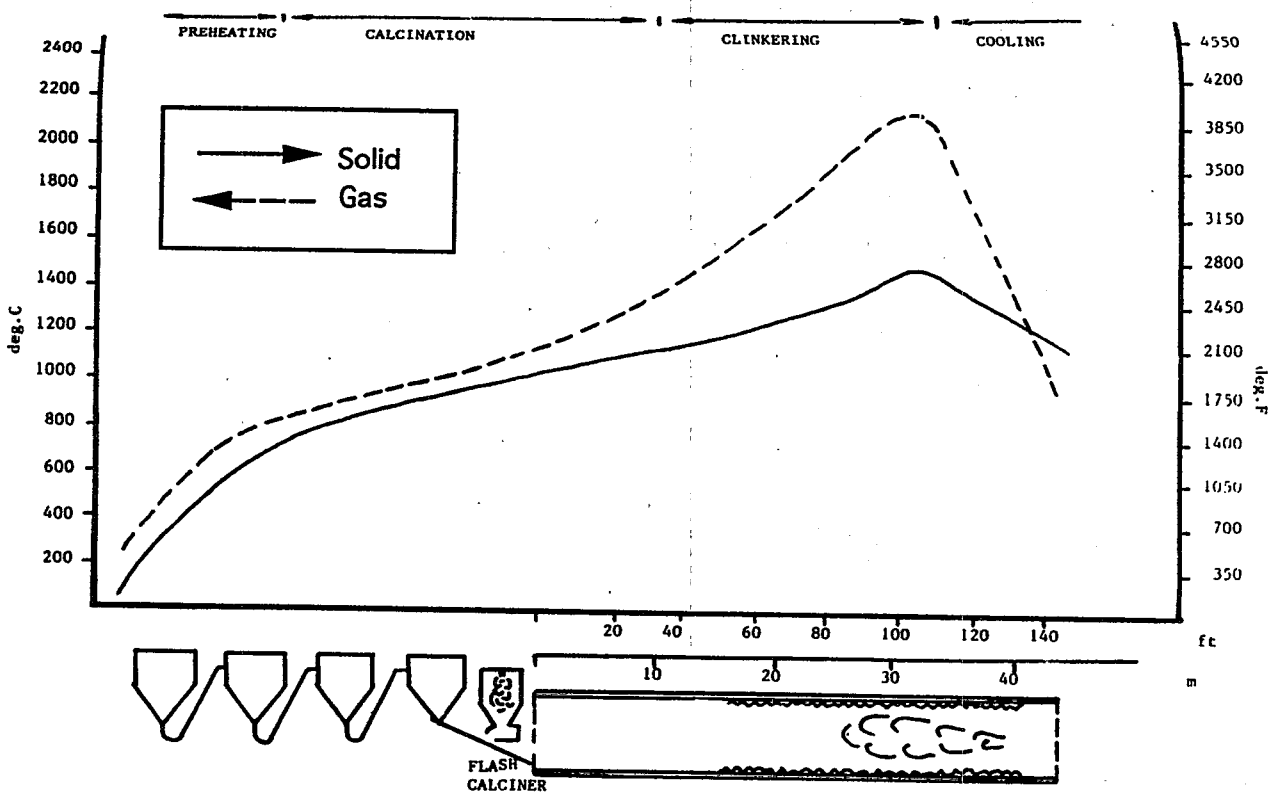

Figure 2.1-8 Typical gas (dashed line) and solids (solid line) temperature for a preheater/precalciner cement kiln.[6]

6 Dellinger, p. 26

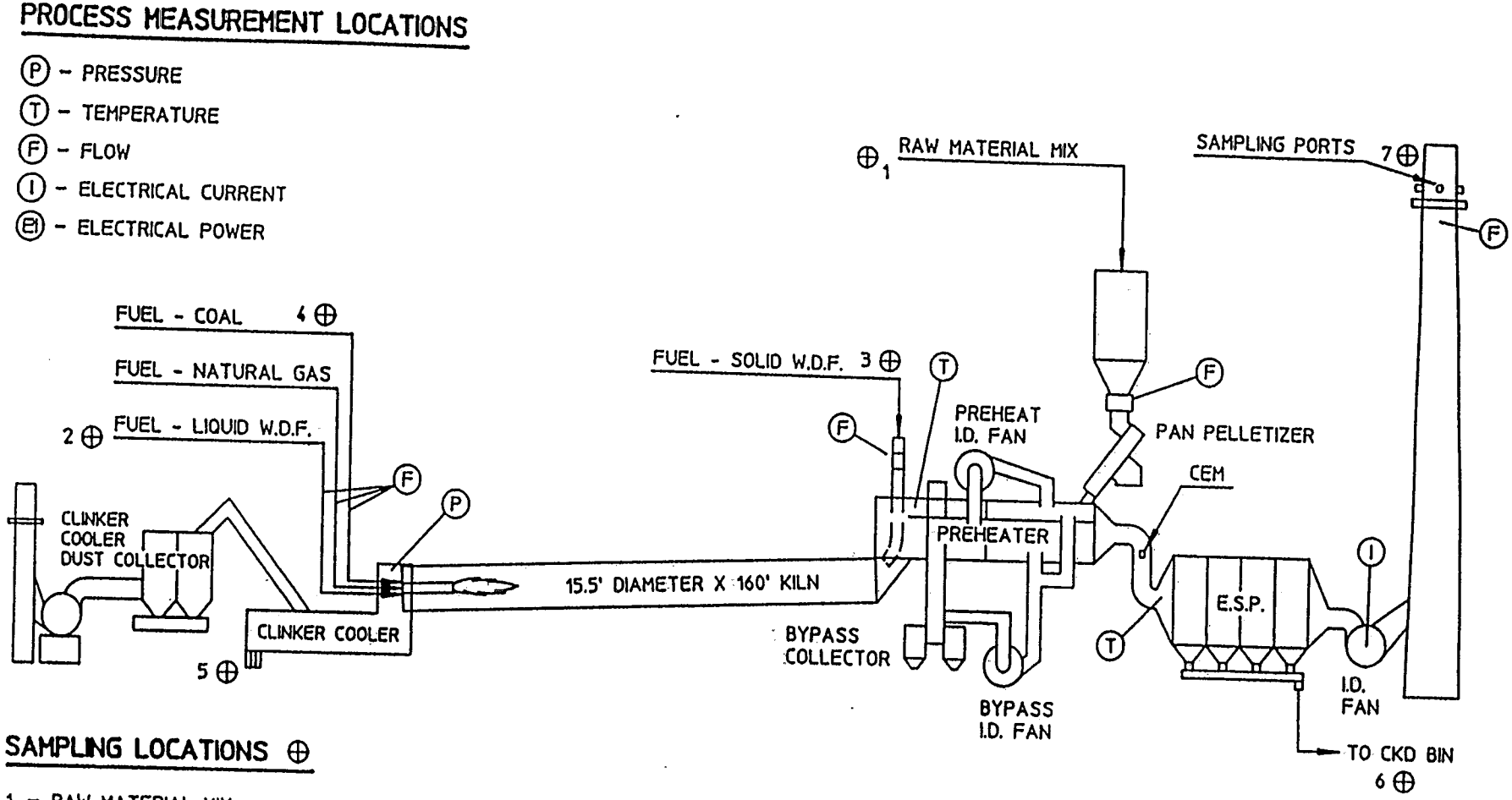

Figure 2.1-9 Semidry cement kiln schematic.

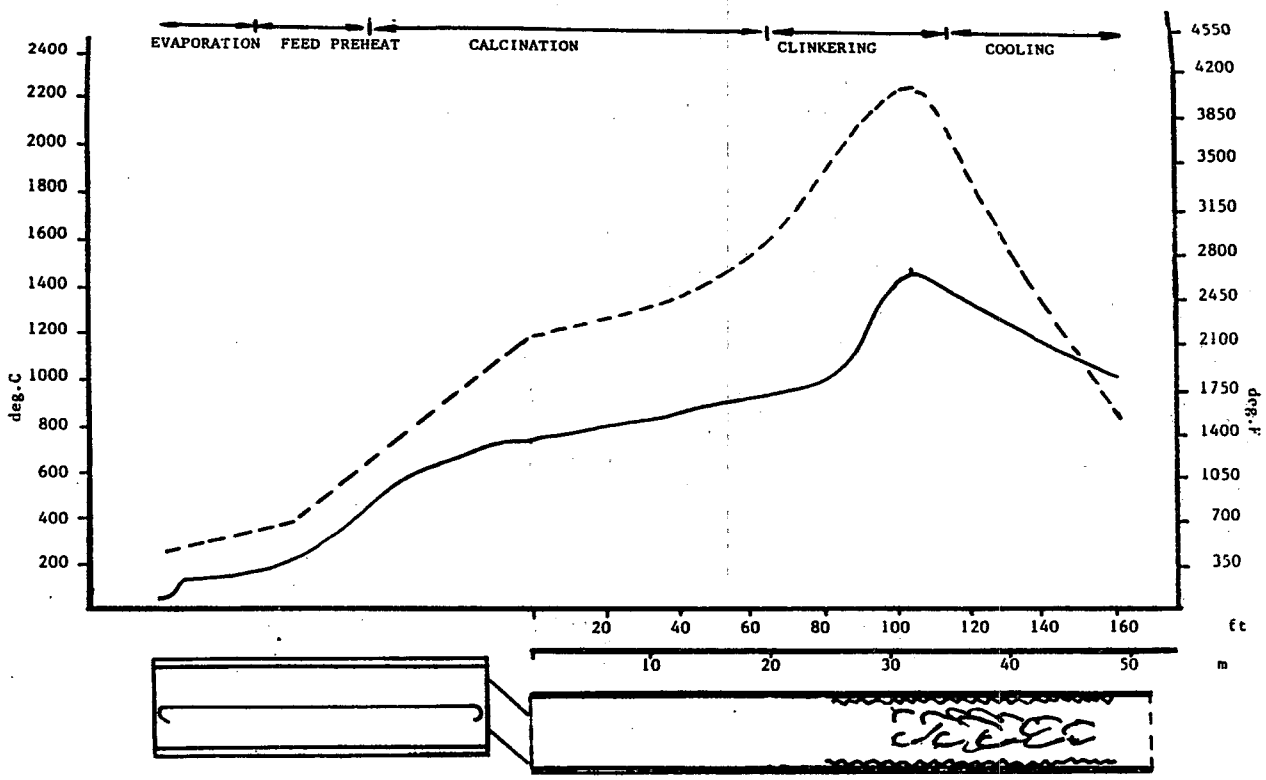

Figure 2.1-10 Semidry kiln material (solid line) and gas (dashed line) temperatures.[7]

[7] Peray, K., *The Rotary Cement Kiln*, Second Edition, Chemical Publishing Company, New York, 1986, p. 91.

and color [8]. Oxidizing conditions must be maintained in the burning zone. If insufficient oxygen is present, a key component of cement clinker, tetra calcium alumino ferrite, does not form; instead, Fe_2O_3 is reduced to FeO. This leads to a clinker product that produces a quick setting cement with decreased final strength. Additionally, the presence of unburned carbon in the burning region produces a clinker with an undesirable brown color. To overcome these feeding location limitations, a variety of techniques are used for the introduction of solid wastes into cement kilns. The choice depends on the solid waste type (composition and physical attributes) and kiln configuration (dry long, dry with preheater, wet, etc.).

Three techniques rely on the introduction of the solid waste into the calcining zone. Note that Boiler and Industrial Furnace (BIF) rules require that if hazardous waste is fed at any location other than the hot end, the combustion gas temperature must exceed 1800 °F at the point of introduction and sufficient oxygen must be present to ensure complete combustion of organic constituents in the waste. For long kilns, this means that the waste is introduced mid-kiln, while for preheater/precalciner kilns, it is introduced onto the feed shelf. At this location, the solids have sufficient residence time for the organics to be driven off so that the presence of waste combustibles do not reach the burning zone and create reducing conditions which are detrimental to clinker quality, but yet far enough away form the cold end to provide sufficient temperature and residence time for complete destruction of volatile gaseous organics. These three methods are:

1. For long type wet and dry kilns, and dry kilns with preheaters, a method has been patented by Benoit et al. (1989) for charging solid wastes directly through a hatch on the rotating kiln wall at a intermediate location within the calcining zone. [9] At each rotation, the hatch is opened, and containerized waste solids are fed down a drop tube that is inserted through the hatch and into the rotating kiln. The drop tube prevents hot mineral material from escaping through the port or contacting the enclosure. It is important that the volume of the volatile components do not exceed the capacity for their complete combustion in the gas stream. Thus, wastes are containerized to minimizing the potential for overloading the combustion capacity (create local reducing conditions).

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[8] Sprung, S., "Technological Problems in Pyroprocessing Cement Clinker: Cause and Solution," Berton-Verlag, Dusseldorf, Germany, 1985.

[9] Benoit, M., Hansen, E., et al., U.S. Patent No. 4,850,290, "Method for Energy Recovery from Solid Hazardous Wastes," July 25, 1989.

2. For preheater or precalcining kilns, the solid waste may be injected directly into the precalciner vessel or preheater inlet.

3. Containerized solid wastes may also be injected at the hot end of the kiln at a high enough velocity so that they are projected into the calcining zone. An "air cannon," which is mounted to the kiln hood, is used to propel the waste containers. Lone Star Industries (Greencastle, IN) and Continental Cement Co. (Hannibal, MO) use this method for waste solids feeding.

If the waste is in powdered form, it may injected directly into the primary burning zone coal flame of the cement kiln, as is done at Heartland Cement Co. (Independence, MO). In another set up, solid waste is burned in a separate kiln or combustor and the flue gas is routed to the hot end of the cement kiln, which is used as an afterburner and for acid gas control. This is done at Giant Cement Co. (Harleyville, SC), which has four "resource recovery kilns" in addition to cement kilns.

2.2 Lightweight Aggregate Kiln Process Description

Lightweight aggregates include a wide variety of raw materials which when combined with cement form concrete products. Lightweight aggregate concrete is produced either for structural purposes or for thermal insulation purposes. Estimates indicate that the rotary kiln method is used in the production of 80% of all structural lightweight aggregates. [10] This section presents an overview of the lightweight aggregate kiln process and a characterization of the lightweight aggregate kilns currently burning hazardous waste.

2.2.1 Process Components

A lightweight aggregate plant is composed of a quarry, a raw material preparation area, a kiln, a cooler, and a product storage area. The material flows from the quarry to the raw material preparation area. From there, the material is fed into the rotary kiln. Figure 2.2-1 provides a schematic of a lightweight aggregate kiln.

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[10] Expanded Shale Clay and Slate Institute, *Lightweight Concrete - History, Applications and Economics*. Washington, D.C., 1971.

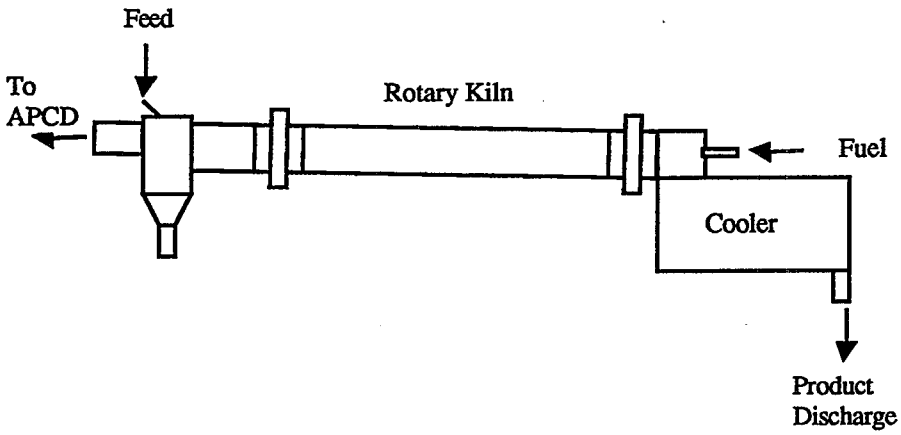

Figure 2.2-1 Lightweight aggregate kiln schematic

A rotary kiln consists of a long steel cylinder, lined internally with refractory bricks, which is capable of rotating about its axis and is inclined at an angle of about 5° to the horizontal. The length of the kiln depends in part upon the composition of the raw material to be processed but is usually 30 to 60 meters. The prepared raw material is fed into the kiln at the higher end, while firing takes place at the lower end. The dry raw material fed into the kiln is initially preheated by hot combustion gases. Once the material is preheated, it passes into a second furnace zone where it melts to a semiplastic state and begins to generate gases which serve as the bloating or expanding agent. In this zone, specific compounds begin to decompose and form gases such as SO_2, CO_2, SO_3, and O_2 that eventually trigger the desired bloating action within the material. As temperatures reach their maximum (approximately 2100 °F), the semiplastic raw material becomes viscous and entraps the expanding gases. This bloating action produces small, unconnected gas cells, which remain in the material after it cools and solidifies. The product exits the kiln and enters the cooler section of the process where it is cooled with cold air and then conveyed to the discharge.

2.2.2 Operating Parameters

Kiln operating parameters such as flame temperature, excess air, feed size, material flow, and speed of rotation vary from plant to plant and are determined by the characteristics of the raw material. Raw materials include clay, shale or slate which have varying properties linked to their geological formation. Maximum temperature in the rotary kiln varies from 1120 ° to 1260 °C (2050 ° to 2300° F), depending on the type of raw material being processed and its moisture content. Exit temperatures may range from 150 ° to 650 °C (300 °F to 1200 °F), again depending on the raw material and on the kiln's internal design. Approximately 80% to 100% excess air is forced into the kiln to aid in expanding the raw material.

A typical lightweight aggregate rotary kiln has a combustion gas residence time of 4 seconds, based on maximum temperature and a temperature range of 700 °F to 2100 °F. A typical rotary kiln processes approximately 450 Mg (500 tons) of lightweight aggregate per day. This kiln has an average furnace volume of 1000 cubic meters (35,343 cubic feet) and an average volumetric flow rate of 1920 Nm^3/min (73,170 scfm). [11] Lightweight aggregate kilns that burn hazardous waste typically burn 100% liquid hazardous waste (i.e., hazardous waste is the sole fuel).

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[11] "Evaluation of the Feasibility of Incinerating Hazardous Waste in High-Temperature Industrial Processes", PEDCo-Environmental, Inc., PB84-159391, February, 1984, p. 4-94.

2.3 Hazardous Waste Incinerators

Incineration has developed over a number of years as a means of treating various types of waste materials. During incineration, the volume of waste is reduced and toxic organic compounds in the waste are destroyed by thermal decomposition. Three important operating conditions for proper combustion in incineration systems are temperature, residence time and proper mixing of fuels and combustion gases. These conditions vary with the chemical structure and physical form of the waste as well as the incinerator design. There are many incinerator designs which are used on-site and commercially. The following incinerator designs are discussed in this section: rotary kiln, fluidized bed, liquid injection, and fixed hearth.

2.3.1 Rotary Kiln Incinerators

Rotary kilns are commonly used in both off-site (commercial) and on-site hazardous waste incineration applications. These kilns handle most if not all forms of wastes (bulk and containerized solids, sludges, slurries, bulk and containerized liquids, and less common wastes such as Department of Defense propellants, ammunitions, and nerve agents), as well as most waste compositions (organics, halogens, heating value, principal organic hazardous constituents (POHCs), etc.).

2.3.1.1 *Process Description*

Rotary kiln systems used for hazardous waste incineration typically consist of two incineration chambers: the rotary kiln and an afterburner. A rotary kiln system is shown in Figure 2.3-1. The rotary kiln itself is a cylindrical refractory-lined steel shell with a diameter which is typically less than 15-20 feet (to allow for truck or rail shipment) and a length-to-diameter ratio of 2 to 10. The shell is supported by two or more steel "trundles" that ride on rollers, allowing the kiln to rotate around its horizontal axis. The refractory is an acid resistance brick. Rotary kiln incinerators are typically sized around 60 MMBtu/hr, but they may be as big as 150 MMBtu/hr.

Usually, the inside of the kiln is lined with a smooth refractory, although recent designs have included internal vanes or paddles to encourage solids mixing along the kiln length. The kiln is oriented on a slight incline from the horizontal, known as the "rake." The rake is less than 5 ° and typically from 2 to 4 °. The kiln rotation rate typically ranges from 0.5-2 RPM. Mixing may be improved by increased rotation rate; however, this also acts to reduce solids residence time.

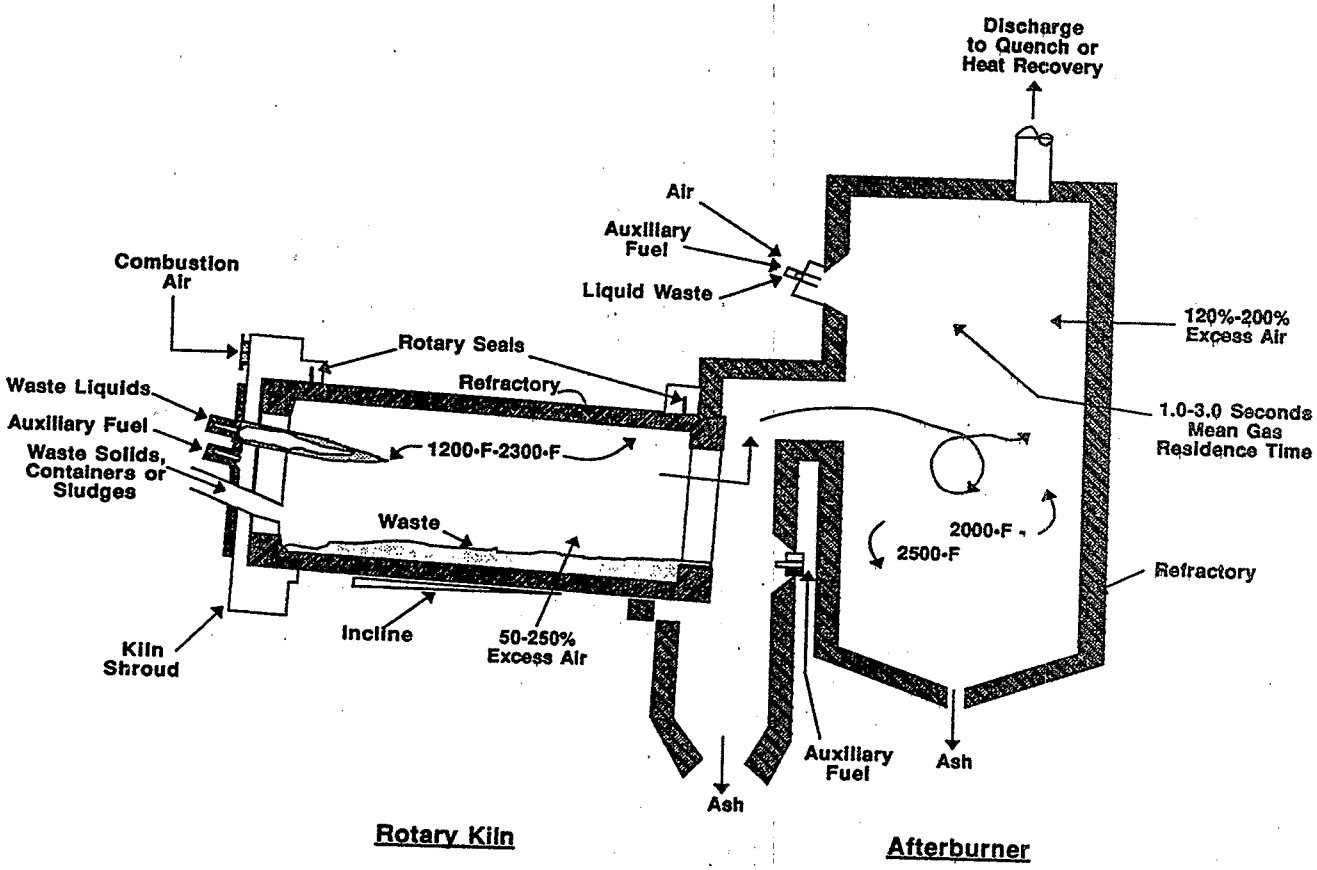

Figure 2.3-1 Typical rotary kiln incinerator.[12]

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[12] Dempsey, C., and Oppelt, T., "Incineration of Hazardous Waste: A Critical Review", *Air & Waste*, Vol. 43, January, 1993, p. 35.

Kiln rotation and incline serve three purposes; 1) to promote the mixing of wastes with combustion air, 2) to facilitate the heat transfer between the waste and hot flames and refractory, and 3) to move the wastes through the rotary section.

Almost all hazardous waste rotary kiln incinerators are of the co-current design because they are better suited for treating combustible solid wastes. In the co-current design, as shown in Figure 2.3-1, wastes and auxiliary fuels are fed at the same end (i.e., the waste and flue gas travel in the same direction). Co-current designs provide for rapid ignition of the cold wastes and maximum gas residence time for the products of combustion, and thus achieve the largest amount of volatile organic destruction in the rotary section.

Solid and liquid wastes are fed directly into the rotary kiln. Solids can be fed, on a continuous or semi-continuous basis, through a variety of waste feed mechanisms such as a ram feeder, auger screw feeder, or belt feeder for drums. For batch feeding, an air lock is usually used to reduce the amount of air infiltration through the feeding chute. Liquid wastes may also be injected, with steam or air assisted atomizing nozzles, directly into the kiln through the main burner. These liquid wastes may also be injected through a waste lance and/or mixed with the solid wastes. In most cases, rotary kilns can handle unprocessed wastes. Waste pretreatment may include mixing of liquid and solid wastes, as well as neutralizing corrosive wastes prior to being fed to the kiln. Waste grinding and sizing may aid in smooth kiln operation.

Wastes are heated by the primary flame, bulk gases, and refractory walls. Through a series of volatilization and partial combustion reactions, combustible fractions of the wastes are gasified. The solids continue to heat and burn as they travel down the kiln. Typically, solids retention time in the kiln is between 0.5 and 1.5 hours, while gas residence time through the kiln is usually around 2 seconds. Waste feed to the kiln is controlled so that the waste contributes no more than 20% of the kiln volume. Typical flame/solids temperatures in the rotary kiln range from 1200 to 3000 °F. [13]

An auxiliary gas or oil burner, located at the feeding end of the kiln, is used for start-up (bring unit up to temperature) and to maintain desired kiln temperature when sufficient heat input is not available from the waste. Wastes with an average heating value of 4500 Btu/lb are adequate to sustain combustion at kiln temperatures between 1600 to 1800 °F. Combustion air is provided through ports on the face of the kiln, as well as through rotary seal leakage. The kiln typically

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13 Dempsey, p. 35.

operates at 50 to 200% excess air. Kiln operating pressure is maintained at negative to the atmosphere, typically -0.5-2.0 in. H_2O gauge, through the use of an induced draft fan which is located downstream of the air pollution control system. Operation at negative pressure assures that fugitive emissions of combustion gases to the atmosphere through rotary seal leaks are avoided.

To avoid over-pressurization caused by feeding highly combustible wastes, a "dump stack" or other emergency relief vent, typically located between the afterburner and the air pollution control system, can be installed to protect the equipment. Use of the dump stack will allow potentially harmful gases to be released to the environment. A hot cyclone may be positioned between the kiln and afterburner for removal of entrained solid particles that may cause slagging problems in the afterburner.

Inorganics, ash, slag, and other incombustible items that remain when the waste reaches the end of the kiln are removed by gravity into an ash pit. Typically, the ash is water quenched with the ash removal system normally provided with a water seal trough. Dry collection systems allow for undesirable air leakage into the kiln. Dropping of solids into the water seal trough can result in steam explosions, often resulting in positive pressure excursions.

Flue gas from the kiln is usually routed to a secondary refractory lined combustion chamber, referred to as an "afterburner". The afterburner typically operates at 2000 to 2500°F, with 100 to 200% excess air, turbulence flow, and a gas residence time from 1-3 seconds to ensure complete combustion of the remaining volatile gas phase of unburned components in the kiln flue gas. An auxiliary fuel, and sometimes pumpable liquid hazardous wastes, are used to maintain the afterburner temperature.

Design modifications to the rotary kiln have included: 1) a "fast" rotary kiln which rotates at a rate greater than 20 RPM to provide efficient mixing, 2) starved air and oxygen assisted kilns to reduce flue gas volume and auxiliary fuel requirements, and 3) "slagging" kilns. The slagging kiln operates above the ash melting point (2600 to 2800 °F) to generate a molten ash. Eutectic properties of slag are controlled using additives to the feed. Slagging kilns typically have a negative rake, permitting for the accumulation of slag in the kiln. In addition, these kilns have the ability to accept metal drums and salt laden wastes, provide better destruction efficiency, and generate lower particulate emissions and production of a slag product known as "frit" which is less leachable than non-slagging kiln ash. However, such kilns also have increased NO_x emissions, shorter refractory lifetime, and the potential for slag to solidify in the kiln.

2.3.1.2 *Operating Parameters*

Critical rotary kiln incinerator operating parameters include:

- Kiln and afterburner exit temperature — This is typically maintained above 1500 °F. Temperature must be maintained above the minimum demonstrated for adequate destruction of POHCs and to minimize formation of products of incomplete combustion (PIC). Monitoring limitations include errors in measurement from furnace and flame radiation. The temperature may be controlled through adjustment of waste, auxiliary fuel, and combustion air feedrates.

- Kiln pressure — Kiln pressure must be maintained at negative to atmosphere and the afterburner pressure must be below that of the kiln to prevent kiln fugitive emissions through kiln rotary seals. Pressure is controlled by use of an induced draft fan and damper system downstream of the combustion chambers.

- Combustion gas velocity (flowrate) — This is controlled to ensure proper combustion gas residence time at operating temperature for complete destruction of volatile PICs. Gas flowrate is dependent on waste feed composition and feed rate, as well as auxiliary fuel and combustion air rates.

- Waste feed rate — This is adjusted to avoid over-loading, over-pressuring, and depleting kiln oxygen, which may result in kiln fugitives and excessive kiln flue gas volatiles. If the kiln is fed semi-continuously, the maximum size of each batch must be controlled.

- Oxygen level at kiln and afterburner exit — This is controlled to assure availability of oxygen, and thus the potential for complete combustion (i.e., lower CO, THC, and possibly PIC levels). The kiln is typically operated at 50-100% excess air, while the afterburner is typically operated at 100-200% excess air.

- CO and THC combustion gas levels — Monitored to ensure satisfactory operation of kiln and afterburner and to minimize PIC formation.

- Kiln solids residence time — This is typically maintained at between 0.5 and 1.5 hours and is controlled by rotation rate and kiln rake to ensure that the waste spends enough

time in the kiln to be thoroughly treated. Controlling residence time is important for treatment of relatively non-combustible wastes.

- Kiln solids and combustion air mixing — These assure that volatiles are thoroughly combusted.

2.3.2 Liquid Injection Incinerators

Liquid injection and rotary kiln incinerators are the most commonly used incinerators for hazardous waste incineration. [14] Liquid injection combustors can be used to dispose of virtually any combustible liquid or liquid-like waste (liquid, slurries, sludges).

2.3.2.1 *Process Description*

The typical liquid injection incinerator includes a waste burner system, an auxiliary fuel system, an air supply system, a combustion chamber, and an air pollution control system. A typical liquid injection incinerator is shown in Figure 2.3.-2. Liquid wastes are fed and atomized into the combustion chamber through the waste burner nozzles. These nozzles atomize the waste and mix it with air. Atomization is usually achieved either by mechanical methods such as a rotary cup or pressure atomization systems, or by twin-fluid nozzles which use high-pressure air or steam. With a relatively large surface area, the atomized particles vaporize quickly, forming a highly combustible mix of waste fumes and combustion air. This mixture ignites and burns in the combustion chamber. Typical combustion chamber residence time and temperature ranges are 0.5 to 2 seconds and 1,300 °F to 3,000 °F (700 °C to 1650° C), respectively. Typical liquid feed rates are as high as 200 cubic feet per hour (5,600 L/hr). [15]

The liquid injection incinerator may dispose of aqueous or non-aqueous waste which can be atomized through a burner nozzle (i.e., a viscosity less than 10,000 SSU). The waste must be atomized to small droplets of 40 μm or less. Atomization is usually accomplished mechanically using rotary cup or pressure atomization systems. Wastes with high solids are filtered prior to entering the feed tank. The liquid waste fuel system transfers waste from drums into a feed tank.

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[14] Bonner, T., *Hazardous Waste Incineration Engineering*, Noyes Data, 1981, p. 3.

[15] Bonner, p. 12.

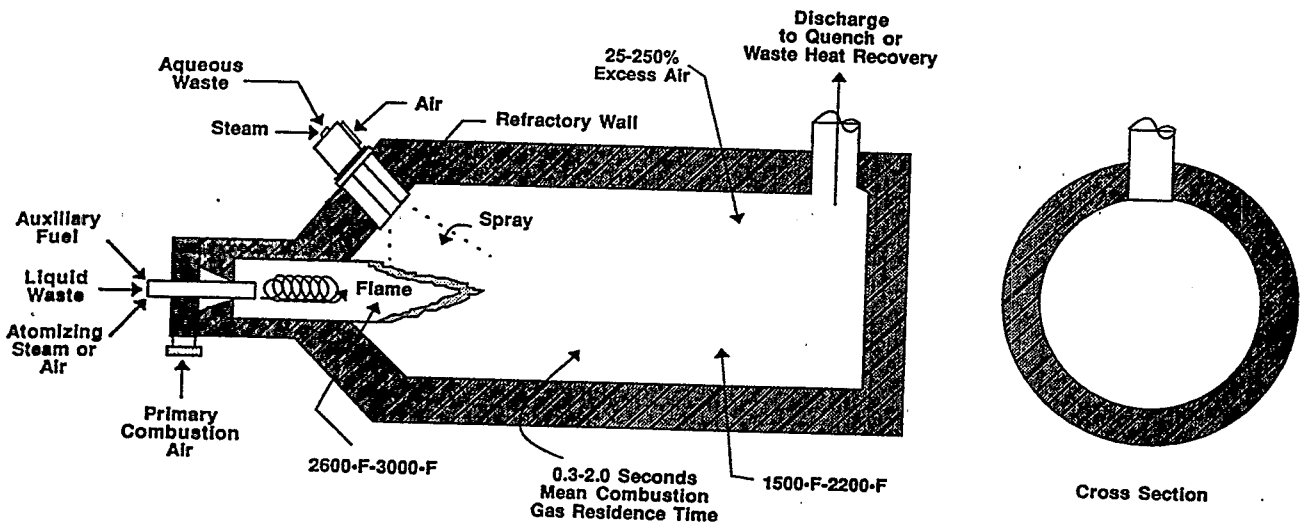

Figure 2.3-2 Typical liquid injection incinerator.[16]

16 Dempsey, p. 35.

The tank is pressurized with nitrogen, and waste is fed to the incinerator using a control valve and a flow meter. The fuel supply line is purged with nitrogen after use. A recirculation system is used to mix the tank contents.

The combustion chamber can be as simple in design as a refractory-lined cylinder, or it can be relatively complex with combustion air preheat around the chamber and firing multiple fuel streams. The incinerator can be designed using either a horizontal or vertical orientation. In either case, flame impingement on the combustion chamber wall is undesirable because it can lead to refractory corrosion and loss of heat. Thus, the burner(s) is/are located to prevent flame impingement on the walls.

2.3.3 Fluidized Bed Incinerators

A fluidized bed is essentially a vertical cylinder containing a bed of granular material at the bottom. Combustion air is introduced at the bottom of the cylinder and flows up through the bed material, suspending the granular particles. Solid, liquid, and gaseous waste fuels may be injected into the bed, where they mix with the combustion air and burn. This section provides a process description and a discussion of the process operating parameters.

2.3.3.1 *Process Description*

A fluidized bed incinerator consists of a fluidized bed reactor, fluidizing air blower, waste feed system, auxiliary fuel feed system, and an air pollution control device system. A typical reactor, as shown in Figure 2.3-3, has an inside diameter of 26 feet (8 meters) and elevation of 33 feet (10 meters). Silica beds are commonly used and have a depth of 3 feet (1 meter) at rest and extending up to 6.5 feet (2 meters) in height when fluidizing air is passed through the bed. The waste is put in direct contact with the bed media, causing heat transfer from the bed particles. At the proper temperature, waste ignition and combustion occur. The bed media acts to scrub the waste particles, exposing fresh surface by the abrasion process which encourages rapid combustion of the waste. Waste and auxiliary fuels are injected radially into the bed and react at temperatures from 840 °F to 1500 °F (450 °C to 810 °C). Further reaction occurs in the volume above the bed at temperatures up to 1,800 °F (980 °C). [17] An auxiliary burner is located above the bed to provide heat for start up, reheat, and maintenance of bed temperature.

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[17] Bonner, p. 15.

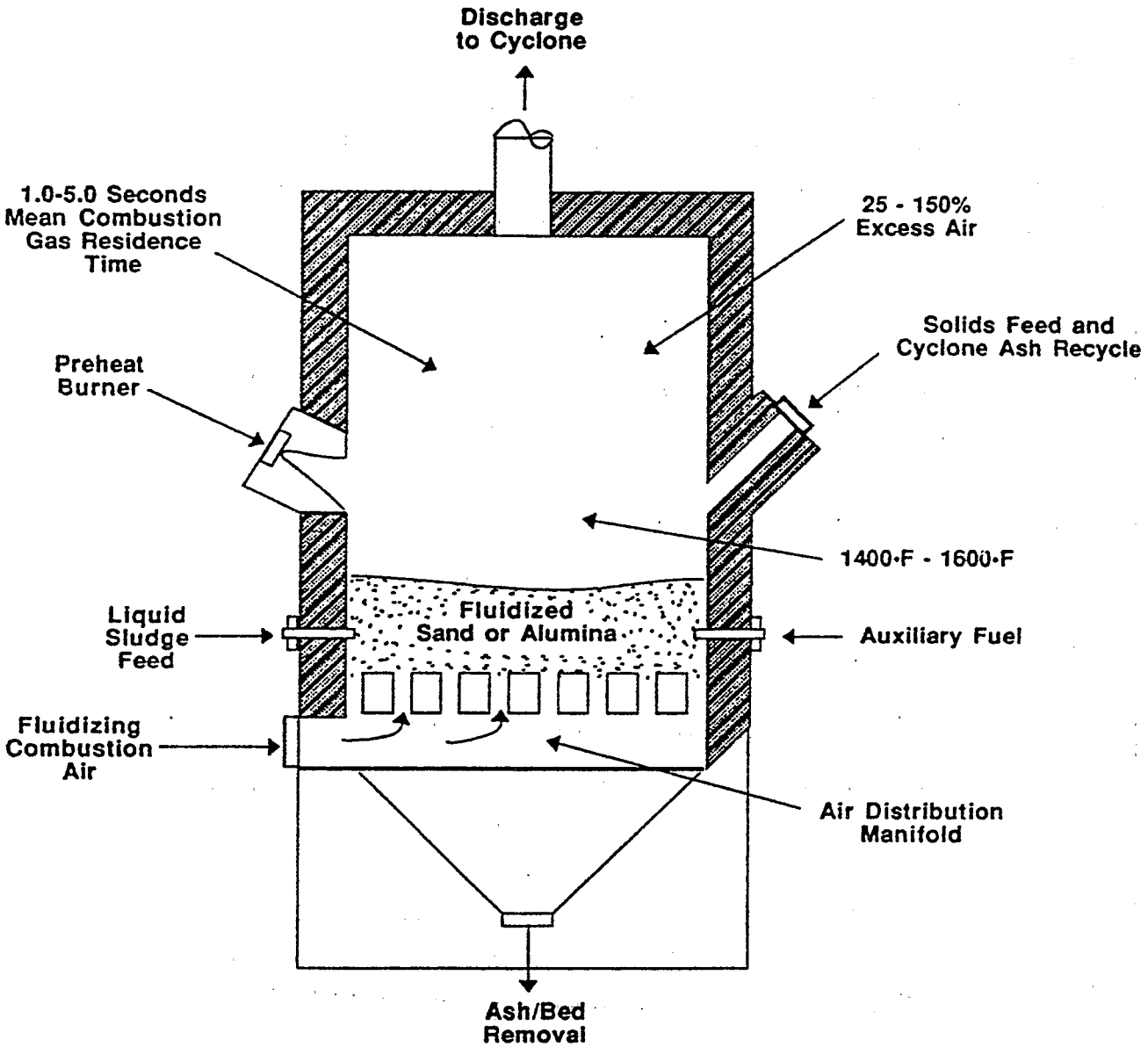

Figure 2.3-3 Typical fluidized bed incinerator.

Generally, fluidized bed incinerators have two separate waste preparation/feed systems — one for solids and one for liquids. In some cases, four feed systems are employed: wet solids, dry solids, viscous fluids and non-viscous fluids. Solid wastes are usually fed into a coarse shredder. The coarsely shredded waste falls into a classifier which separates the light and dense particles. The lighter particles are transferred to a secondary shredder, and from there they are conveyed to the hopper for feeding the fluidized bed. Liquid waste is pumped into a larger holding tank. To ensure that the mixture is as homogeneous as possible, the liquid waste is continuously pumped through a recirculating loop from the bottom of the tank to the top. A metering pump draws the waste fuel to be burned from the tank to the primary reactor. Nozzles are used to atomize and distribute the liquid waste within the bed.

2.3.3.2 *Operating Parameters*

Critical parameters for optimum performance include fluidized bed temperature, oxygen level in the bed, solids residence time, bed fluidization, and combustion gas residence time.

- The fluidized bed temperature must be monitored and controlled by waste feed and auxiliary burner to assure that the temperature remains above an established minimum. Operating temperatures are normally maintained in the 1,400 to 1,600 °F range.

- The oxygen level in the bed must be maintained to ensure the potential for complete combustion.

- Monitoring the carbon monoxide and total hydrocarbon concentration in the flue gas is also an indication of complete combustion.

- Solids retention time in the bed is a measure of the thorough treatment of the waste. Retention time is especially important for relatively non-combustible wastes.
- Uniform bed fluidization must be maintained to properly treat the waste.

- The combustion gas residence time must be monitored to assure that the combustion gas has been exposed to volatile destruction temperature for a sufficient period of time.

The use of a control system could aid in maintaining fluidized bed temperature and flue gas residence time. The control system would involve the adjustment of waste and auxiliary fuel feed rates, as well as the ratio of oxidation/inert fluidization gases.

2.3.4 Fixed Hearth Incinerators

Fixed hearth incinerators, which are used extensively for medical waste incineration, are less commonly used to incinerate hazardous wastes. Fixed hearths can handle bulk solids and liquids, however, this design does not have the versatility of a rotary kiln.

2.3.4.1 *Process Description*

Fixed hearth incinerators typically contain two furnace chambers: a primary and secondary chamber. A typical fixed hearth system is shown in Figure 2.3-4 Solid and liquid wastes may be charged into the primary chamber. Small units are normally batch-fed, while larger units may be continuously fed with a screw feeder or moving grate, or semi-continuous fed with a raw pusher. In some designs, there may be two or three step hearths on which the ash and waste are pushed with rams through the system. In other designs, rotating rabble arms stir the solid waste material on the grate (Du Pont, Wilmington, DE). A controlled flow of "underfire" combustion air is introduced, usually up through the hearth on which the waste sits. In some designs, combustion air may also be provided from the wall over the waste bed.

In many fixed hearth incinerators, known as controlled air or starved air incinerators, 70 to 80% of the stoichiometric air required is provided in the primary chamber, thus the primary chamber is operated in a "starved-air" mode. In this situation, the waste is pyrolyzed and partially combusted. In some cases, steam injection into the primary combustor is used to enhance waste fixed carbon burnout (fixed carbon is non-volatile carbon which will burn only when exposed to combustion air).

Temperature in the primary chamber must be high enough to destroy hazardous organics in the waste (1000 °F) but low enough to reduce the potential for slagging and refractory damage (1800 °F). Waste slagging may clog the underfire air ports. Bottom ash is removed using a continuous or semi-continuous method, depending on the unit design. The ash is usually dumped into a water bath, which provides a seal between the primary unit and the atmosphere.

For controlled air units, due to insufficient supply of air, the primary chamber flue gas will contain unburned hydrocarbons and high levels of CO and H_2. These volatiles are burned out in a secondary or afterburner chamber. In the secondary chamber, 140 to 200% excess air is provided, as well as sufficient residence time at temperature for complete volatiles burnout. Liquid wastes may be injected either in the primary or secondary chamber. Supplementary fuel may be provided

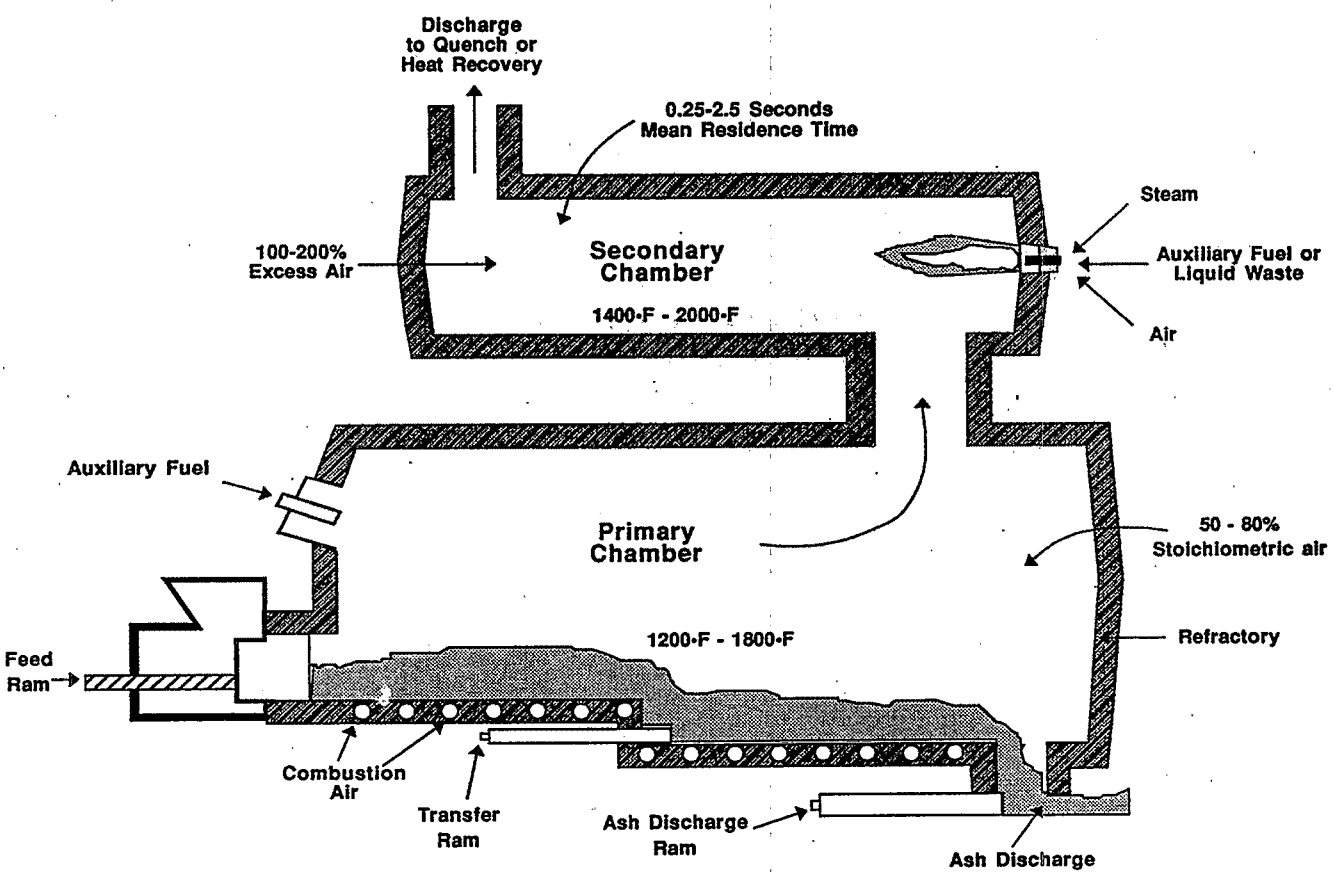

Figure 2.3-4 Typical fixed hearth incinerator. [18]

[18] Dempsey, p. 36.

in both chambers for the maintenance of temperature. Secondary chamber temperature may be as high as 2000 °F. Temperatures beyond this are avoided to prevent refractory damage, decreased gas residence time, and usage of auxiliary fuel.

2.3.4.2 *Operating Parameters*

Critical fixed hearth operating parameters include primary chamber and afterburner temperature. Primary chamber temperature is controlled by the underfire air supply. Afterburner temperature can be controlled by auxiliary fuel firing and primary waste feedrate adjustments. Note that the capacity of afterburner or secondary chamber limits the primary chamber burning rate. The afterburner must have adequate volume to accept and oxidize all volatile gases generated in the primary chamber. Additionally, afterburner must be kept operating at excess air conditions to ensure complete volatile burnout.

2.4 Hazardous Waste Boilers

By definition, a boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. More specifically, EPA has defined the following characteristics of a boiler for regulatory purposes under the Resource Conservation and Recovery Act (RCRA): 1) the combustion chamber and primary energy recovery section must be of integral design; 2) thermal recovery efficiency must be at least 60%; and 3) at least 75% of the recovered energy must be "exported" (i.e., not for internal boiler uses). [19] Boilers come in a variety of sizes, configurations, and designs. The three common boiler design categories which burn hazardous waste are the firetube boiler, the watertube boiler, and stoker-fired boiler.

2.4.1 Firetube Boilers

The firetube boiler can be described in simple terms as a water-filled cylinder with tubes running through it which provide the escape path for the combustion gases or flue gas (as shown in Figure 2.4-1). As the flue gas passes through the tubes, the hot gases heat the tubes which then heat the water to produce steam. The firetube boiler is primarily used in industrial applications.

Firetube boilers are compact, low in initial cost, and easy to modularize based on plant requirements. However, they are also slow to respond to changes in demand for steam (load)

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[19] Federal Register, Vol. 56, No. 35, February, 1991, p. 7138.

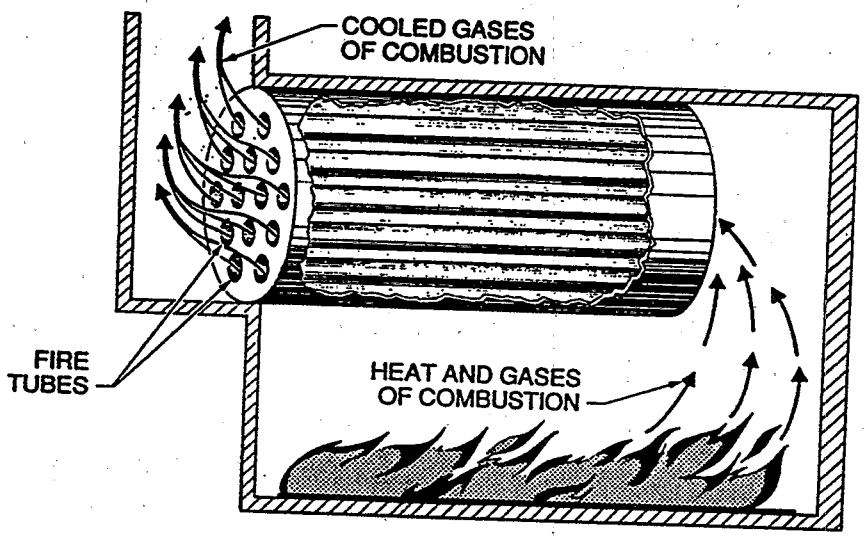


Figure 2.4-1 Firetube boiler.

compared to watertube boilers, and circulation is slower. Also, stresses are greater in firetube boilers because of their rigid design and subsequent inability to expand and contract easily. Firetube boilers usually range in size from less than 2 to 50 million Btu per hour. Most industrial firetube boilers are either horizontal return tube (HRT), scotch marine, or firebox.

Horizontal Return Tube

A horizontal return tubular (HRT) boiler, as shown in Figure 2.4-2, has a separate furnace area that is built of refractory brick. In a HRT boiler, the firetubes are horizontal. The fuel firing burner assembly is at one end, and the products of combustion are recirculated or "returned" to make two, three, or four passes through the tubes surrounded by the boiler water. A HRT is classified as an externally-fired firetube boiler since the furnace area is separated from the heat transfer area. The boiler is encased with brick, and the furnace is set on rollers or suspended on hangers to allow for expansion and contraction which occurs when the boiler increases and decreases in temperature.

Scotch Marine

Scotch marine boilers are an example of internally-fired firetube boilers. The original scotch marine boilers were used on ships and typically fire natural gas or fuel oil to maximize the convenience of automatic operation. A scotch marine boiler has a water-cooled flue furnace within a horizontal shell. The flue furnace is composed of a large tube or pipe, usually corrugated, that passes through the length of the shell. The fuel burner is located at the front end of the flue so that the combustion flame extends across most of the length of the flue. The combustion gases first pass through the furnace tube, heating the bottom of the water basin, and then pass through the fire tubes, heating the water in the basin. Scotch marine boilers may be designed in two-, three-, and four pass units, as shown in Figure 2.4-3.

Firebox

A firebox boiler is a firetube boiler in which the furnace is surrounded on the sides by water leg area, as illustrated in Figure 2.4-4. The water space is extended downward so that the furnace walls are surrounded by water. These flat, side water leg areas are supported by staybolts to prevent them from bulging. Most firebox boilers burn natural gas or fuel oil. Early firebox boilers burned coal. Many of these have been converted to natural gas or fuel oil for convenience. Coal or other fuels and waste may also be burned depending upon the design of the furnace.

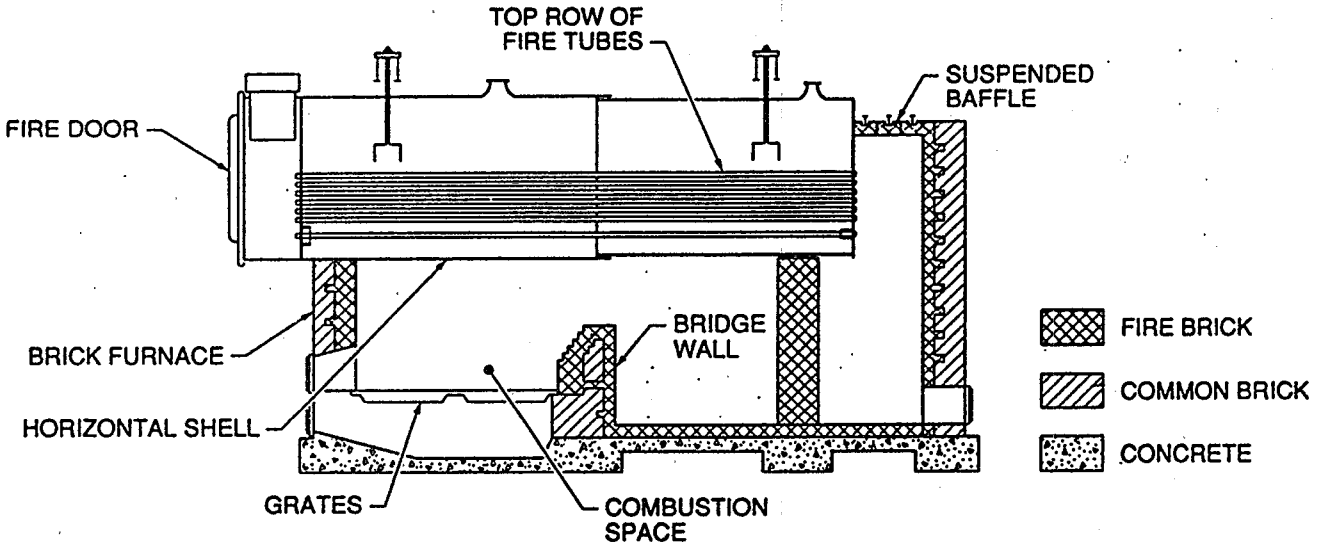
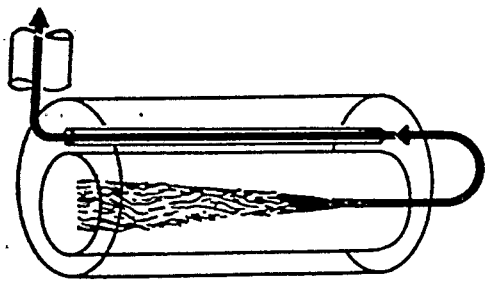
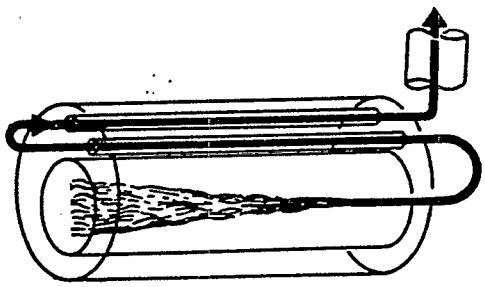


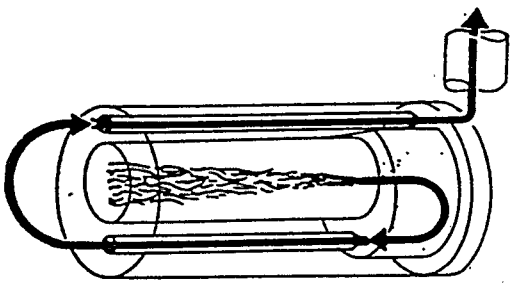
Figure 2.4-2 Horizontal return tubular boiler.



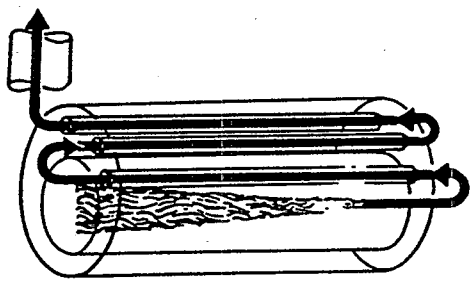
2-pass Dryback



3-pass Dryback



3-pass Wetback



4-pass Dryback

Figure 2.4-3 Multiple pass arrangements.

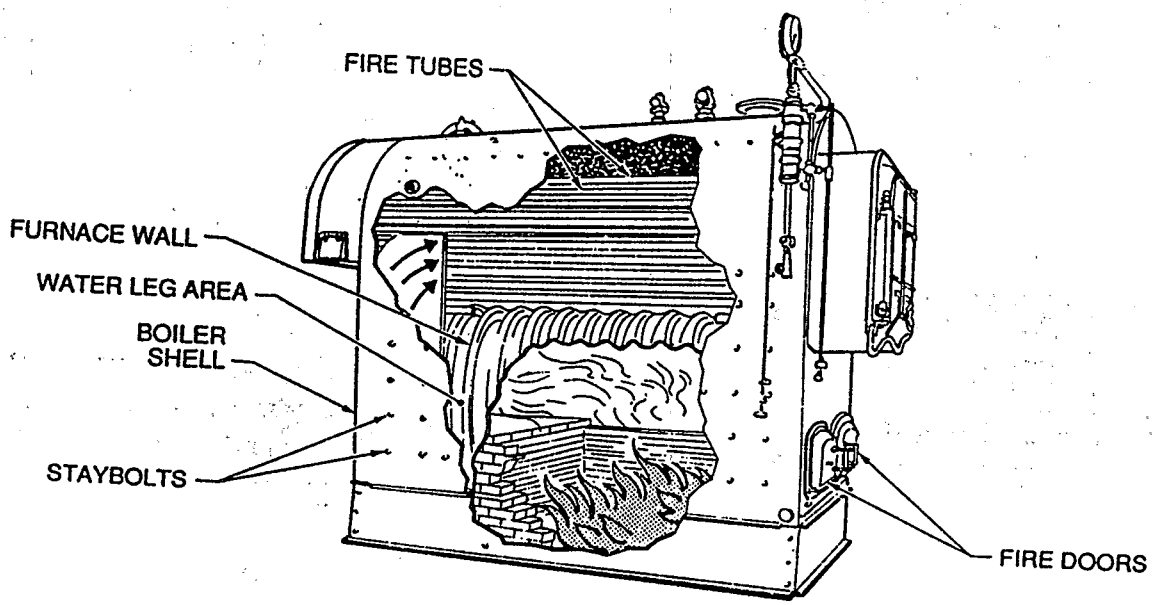


Figure 2.4-4 Firebox boiler.

2.4.2 Watertube Boiler

The basic design of a water tube boiler circulates the water through tubes, with the hot combustion gases passing over the outside surfaces of the tubes. Generally, the boiler can be physically divided into two sections, the furnace and the convection pass, as shown in Figure 2.4-5. Furnaces (fireboxes, combustion chambers) will vary in configuration and size, but their function is to contain the flaming combustion gases and transfer the heat energy to the water-cooled walls. The convection pass contains the *superheaters, reheater, economizer* and *air preheater* heat exchangers, where the heat of the combustion flue gases is used to increase the temperature of the steam, water, and combustion air.

The *superheaters* and *reheaters* are designed to increase the temperature of the steam generated within the tubes of the furnace walls. Steam flows inside the tubes and flue gas passes along the outside surface of the tubes.

The *economizer* is a counterflow heat exchanger designed to recover energy from the flue gas after the superheater and the reheater. The boiler economizer is a tube bank type, hot-gas-to-water heat exchanger. It increases the temperature of the water entering the steam drum. The tube bundle is typically an arrangement of parallel horizontal serpentine tubes with the water flowing inside but in an opposite direction to the flue gas. Tube spacing is as small as possible to promote heat transfer while still permitting adequate tube surface cleaning and limiting flue gas side pressure loss. By design, steam is usually not generated inside these tubes.

The *air heater* is not a portion of the steam-water circuit, but serves a key role in the steam generator system to provide heat transfer and efficiency. In many cases, especially in a high pressure boiler, the temperature of the flue gas leaving the economizer is still quite high. The air heater recovers much of this energy and adds it to the combustion air. Heating the combustion air prior to its entrance to the furnace reduces fuel usage.

Watertube boilers are rapid steamers and respond quickly to changes in demand for steam due to improved water circulation. They can withstand much higher operating pressures and temperatures than firetube boilers. In addition, the watertube boiler design is safer. They can also burn a wide variety of fuels and have the ability to expand and contract more easily than firetube boilers. The major drawback is that watertube boilers are more expensive to install. They also require more complicated furnaces and repair techniques.

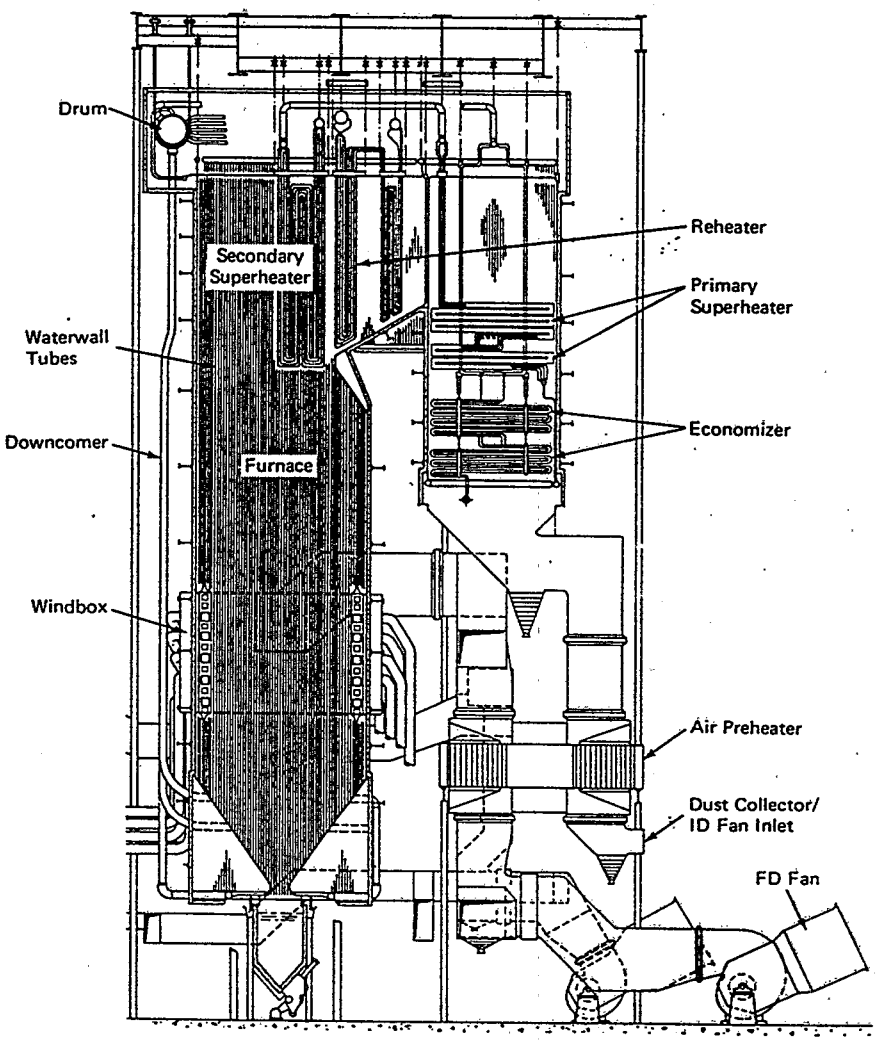


Figure 2.4-5 Watertube boiler.

There are several common designs for watertube boilers. An "O" style boiler is a watertube boiler with a top steam and water drum and a bottom mud drum. These are interconnected by banks of symmetrical tubes in an "O" shape. The burner is in the center of the "O", as shown in Figure 2.4-6. This boiler can be made with a waterwall furnace, which is a popular configuration for package type boilers. An "O" style boiler commonly burns natural gas and fuel oil.

An "A" style boiler is a watertube boiler with a top steam and water drum and two bottom mud drums. The steam and water drum is connected to the mud drums by banks of symmetrical tubes in an "A" shape. This is a popular configuration for package types.

A "D" style boiler is a watertube boiler similar to the "O" style except that the steam-generating tubes on one side are extended to leave an open area close to the center. This area is for the combustion of the fuel. The two sides are separated by a baffle so that the gases pass to the rear on the combustion side and then turn back toward the front for the convection side. There is either a top or side outlet for the gases to leave the unit.

The final watertube boiler configuration discussed in this document is the Stirling boiler. The Stirling boiler is a watertube boiler with three steam and water drums on the top and a mud drum, as shown in Figure 2.4-7. Water enters the top rear drum and passes downward through the rear bank of tubes to the mud drum. It then goes upward to the top front drum and top center drum. As the steam separates from the water, equalizing tubes connecting the steam spaces of all three drums allow the steam pressure to equalize. The steam then flows either to the rear or center drum to leave the boiler. Circulating tubes connect the water spaces of the top front and top center drums, allowing the water levels in these drums to balance. Usually, there are no circulating tubes between the top center and the top rear drums. Circulating tubes in this location would allow water to short-circuit to the other drums without first flowing through the water tubes.[20]

2.4.3 Stokers

Stokers are mechanical devices that feed solid fuels such as coal, wood wastes and bagasse (as well as residential and commercial refuse) onto a grate at the bottom of the furnace and remove the ash residue after combustion. Stokers are designed to permit continuous or intermittent fuel feed, fuel ignition, air supply for combustion, free passages for the resulting gaseous products,

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[20] Wilson, R. Dean, *Boiler Operator's Workbook*, American Technical Publishers, Inc., 1991.

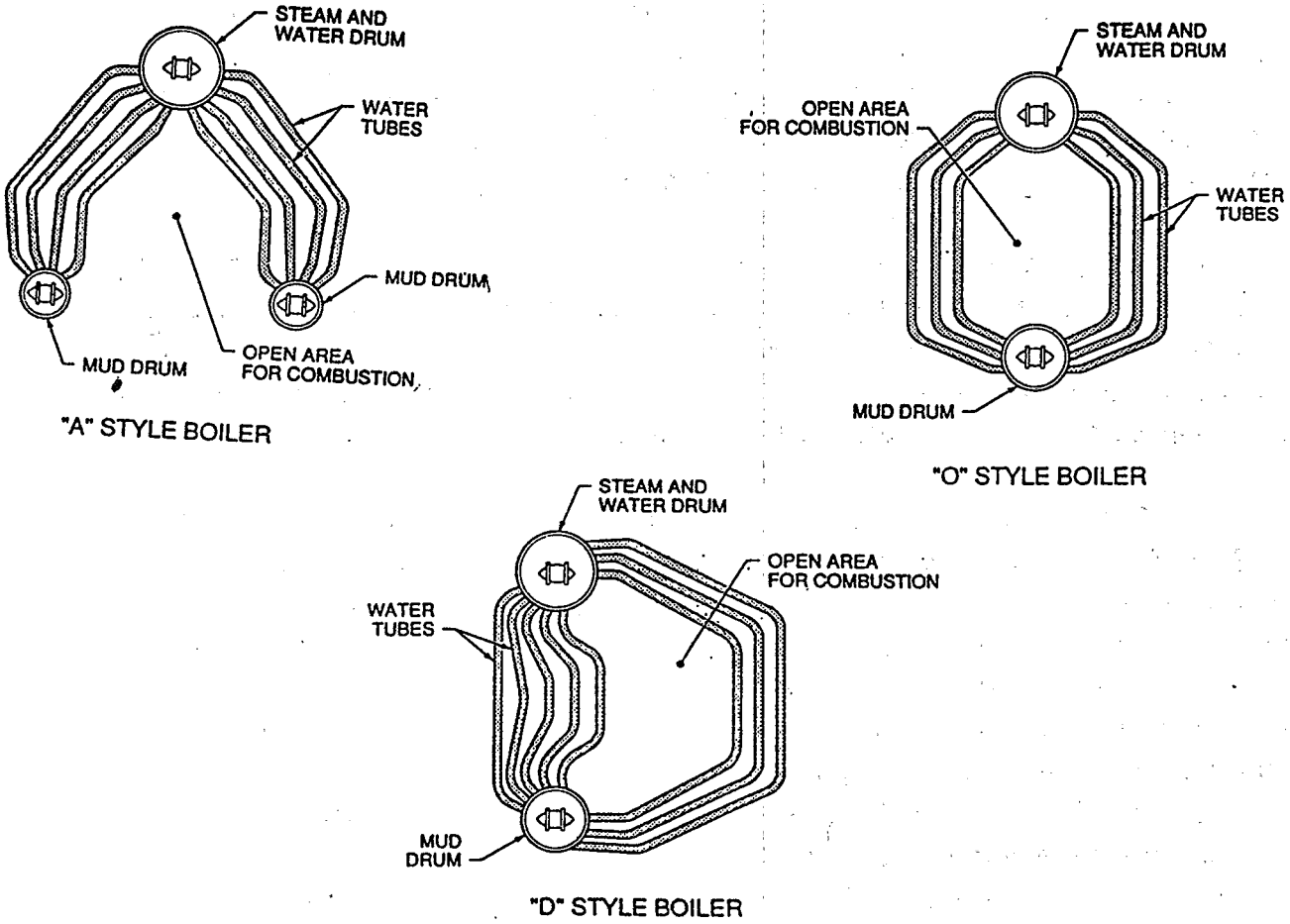

Figure 2.4 -6 Watertube boiler configurations.

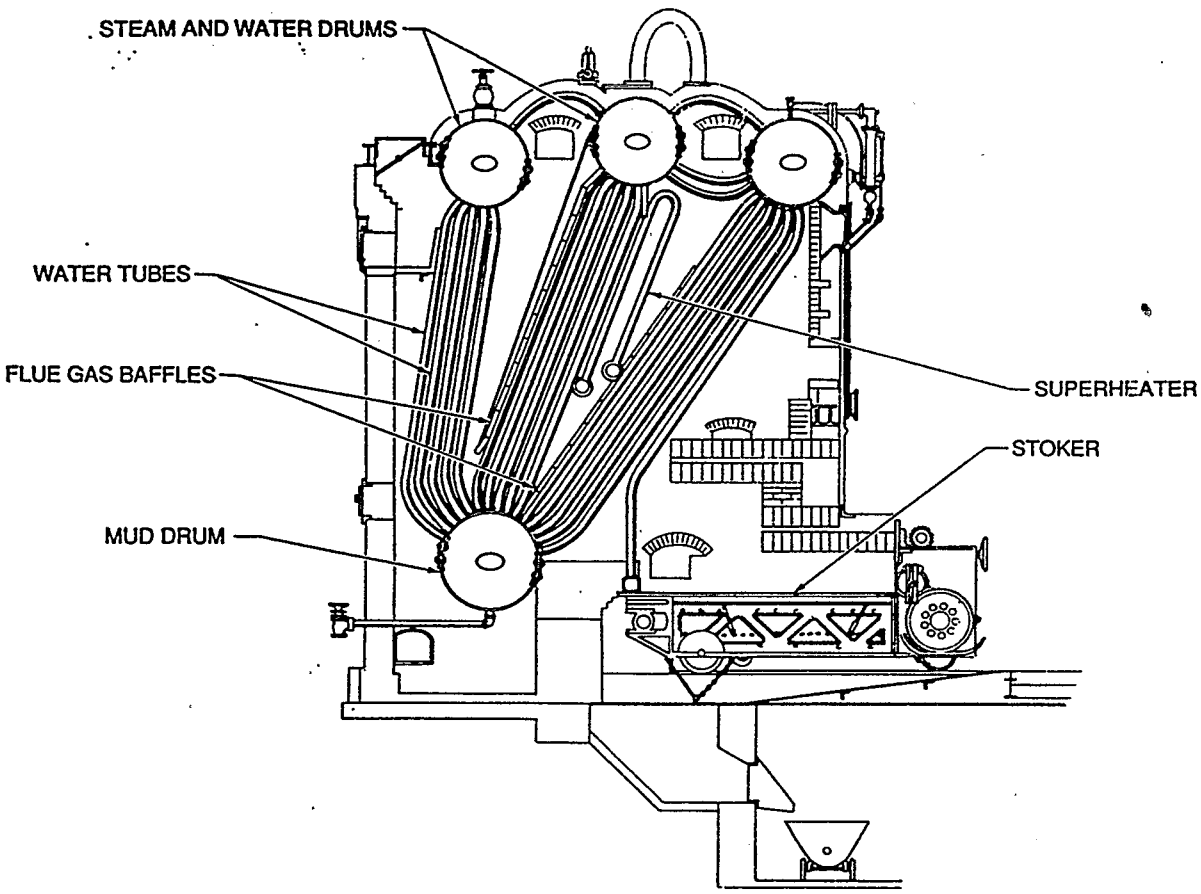

Figure 2.4-7 Stirling boiler.

and disposal of non–combustible materials. A stoker firing system typically consists of a fuel supply system, a stationary or moving grate assembly which supports the burning mass of fuel and admits most of the combustion air to the fuel, an overfire air system to complete combustion, and an ash or residual discharge system. A typical vibrating grate stoker is shown in Figure 2.4-8.

There are two general types of stokers: *underfeed* and *overfeed.* In an underfeed stoker, the fuel and air are both supplied from underneath the surface of the grate. Underfeed stokers use both stationary–grate and moving–grate *tuyeres* (openings in a shell through which air is forced). In an overfeed stoker, the fuel is fed from a hopper above the moving grate, and combustion air is supplied from below the grate, as illustrated in Figure 2.4-8.

Underfeed Stokers

To be more specific, there are two general types of underfeed stokers, the *horizontal feed side ash discharge type* and the *gravity feed rear ash discharge type.*

In the side ash discharge type, shown in Figure 2.4-9, the fuel is fed from a hopper to a central trough or retort by a screw or a ram pusher. In larger units, a ram assisted by pusher blocks or a sliding retort bottom (fuel distributors) moves the fuel upward and into the retort. As the retort is filled from the bottom, coal moves upward and out of the retort onto the grate area where it is exposed to air and radiant heat from the furnace. As the fuel moves along the grate to the sides and/or rear, the distillation of the volatiles in the fuel occurs and the remaining fuel is burned out near the edges or end of the grate. High pressure overfire air is added to produce high turbulence to enhance mixing and reduce smoke.

Burning fuel in side ash discharge underfeed stokers increases the chance of producing large agglomerates of ash slags (clinkering) and layers of ash slag (matting). To reduce this tendency, alternate fixed and moving grate sections are applied to the underfeed stoker design to break-up and distribute the fuel.

The gravity feed rear ash discharge underfeed stoker, illustrated in Figure 2.4-10, has a grate that is inclined at an angle of 20 to 25° above the horizontal, so that gravity assists in distributing the fuel over the length of the retorts. This type of stoker uses a series of retorts installed side-by-side and normally extending from front to rear of a boiler, with tuyere sections between the retorts and along the side walls of the boiler.

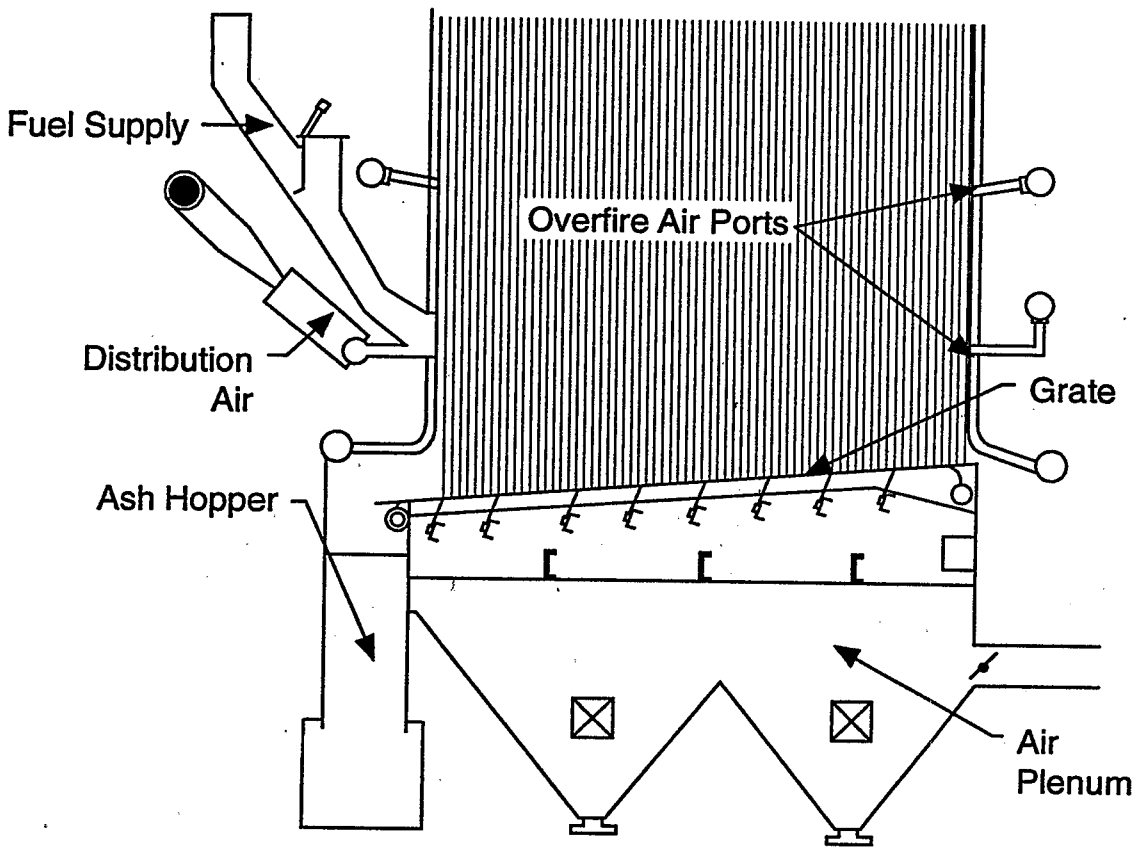

Figure 2.4-8 Vibrating grate stoker.

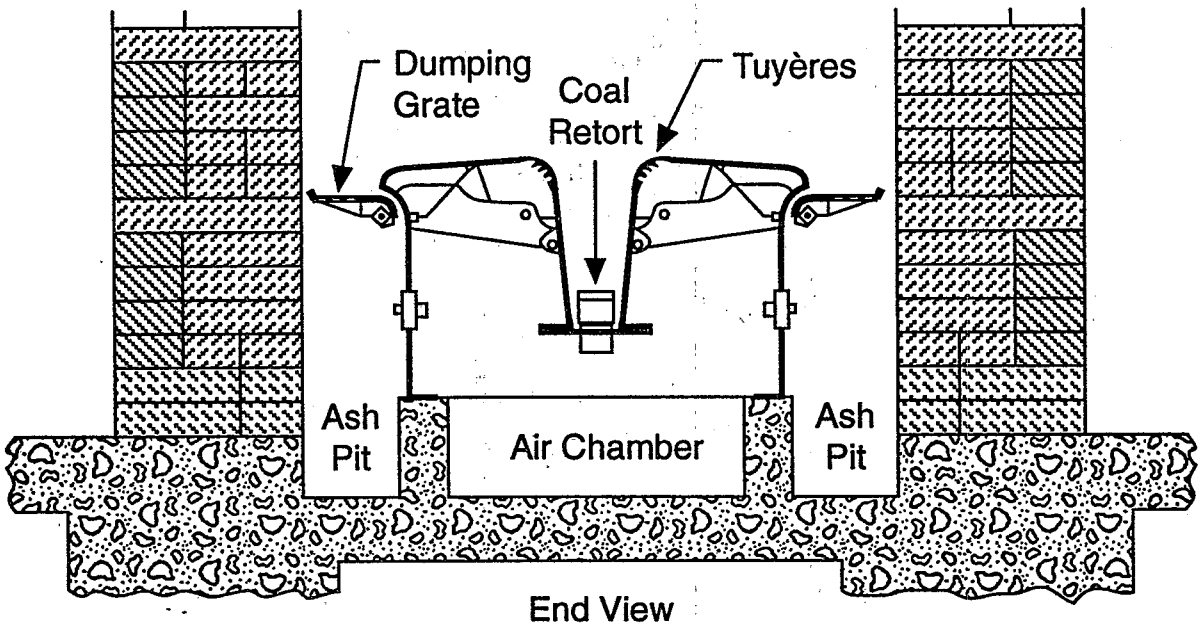

Figure 2.4-9 Single retort underfeed stoker with horizontal feed, side ash discharge.

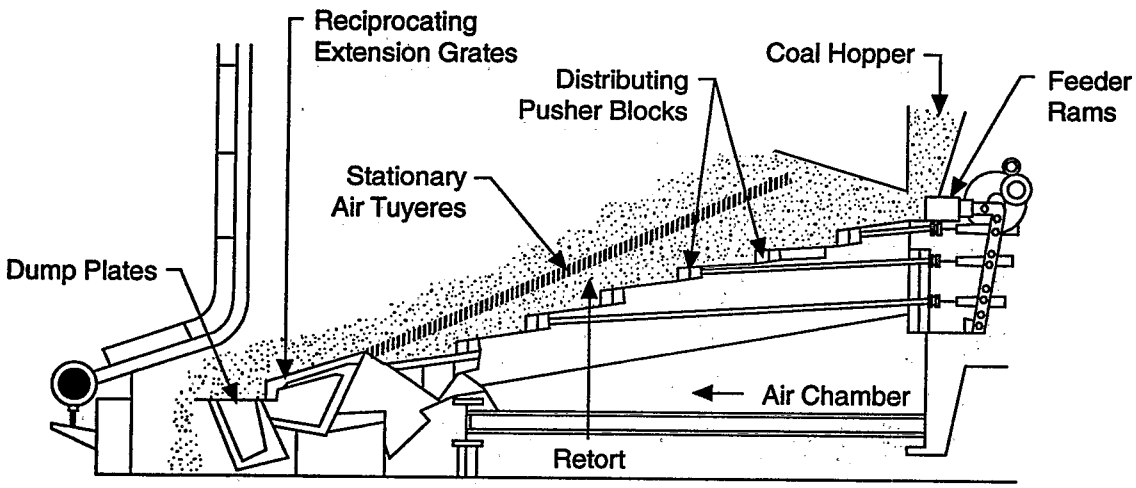

Figure 2.4-10 Underfeed stoker with rear ash discharge.

Round or square rams are installed to move the fuel from the hopper into the upper or front end of the retorts below the point of combustion air supply. Secondary rams or pusher plates move the fuel along the retort and upward into the burning zone immediately above the retorts, where combustion air is supplied to the fuel bed through tuyeres located between and above the retorts. An adjustable dump grate section is used at the rear end of the retorts to retain the ash and prevent an avalanching of unburned fuel into the ash pit.

Water–cooled furnaces are preferred with underfeed stokers. On the smaller sizes of side charge stokers, however, satisfactory performance can be obtained with refractory walls. Adequate furnace volume must be provided according to manufacturer recommendations.

All underfeed stokers should be provided with an overfire air system designed to provide adequate furnace turbulence to complete burnout of the hydrocarbons. Depending on the width of the stoker, load conditions, and fuel burning characteristics, overfire air will represent 7.5 to 12% of the total combustion air (theoretical air plus excess air).

Overfeed Stokers

The overfeed stokers are divided into mass feed and spreader categories based on the method of introducing the fuel into the furnace. For mass feed stokers, there are three basic types of grates: *chain-grate, traveling-grate, and water–cooled vibrating grate.*

The grate surface of the *chain-grate stoker* consists of narrow grates which form links. The links are staggered and connected by rods extending across the stoker width to form a wide–continuous–chain assembly, which is pulled or pushed through the furnace by an electric or a hydraulic drive. A cross section of a chain-grate stoker is illustrated in Figure 2.4-11.

The grate surface of the *traveling grate* consists of narrow grate clips mounted on lateral carrier bars attached to the grate chains, which pull or push through the furnace using an electric or a hydraulic drive. These grate clips are illustrated in Figure 2.4-12.

The grate surface of the *water–cooled vibrating–grate stoker* consists of tuyere–type grates mounted on and in close contact with a grid of water-cooled tubes which are connected to the boiler circulation system for positive cooling, as illustrated in Figure 2.4-13. The entire structure is supported on steel flexing plates, permitting the entire water–cooled grid and grate surface to vibrate with a preset amplitude that moves the fuel bed through the furnace. Vibration of the grate is intermittent, and the vibration period and delay between vibrations are regulated by a timing device synchronizing the fuel feeding rate with steam demand.

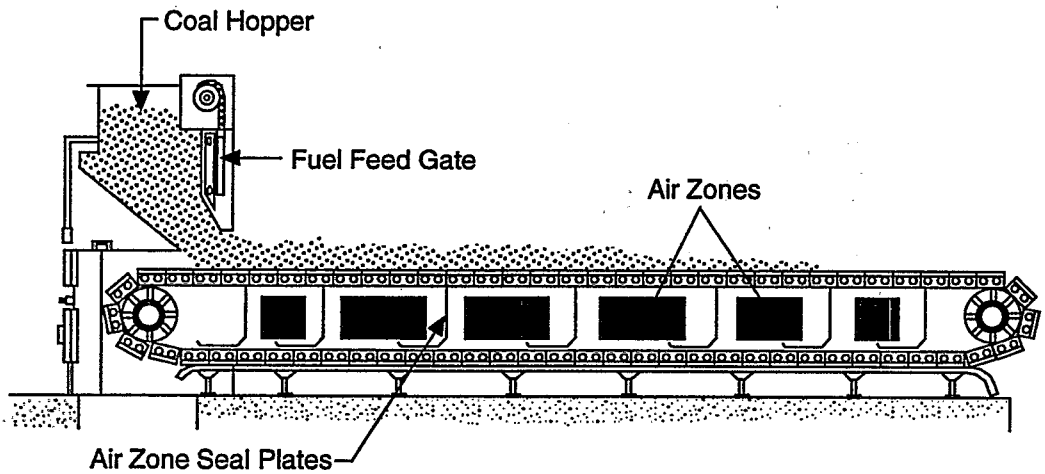

Figure 2.4-11 Cross section of overfeed mass-burning chain-grate stoker.

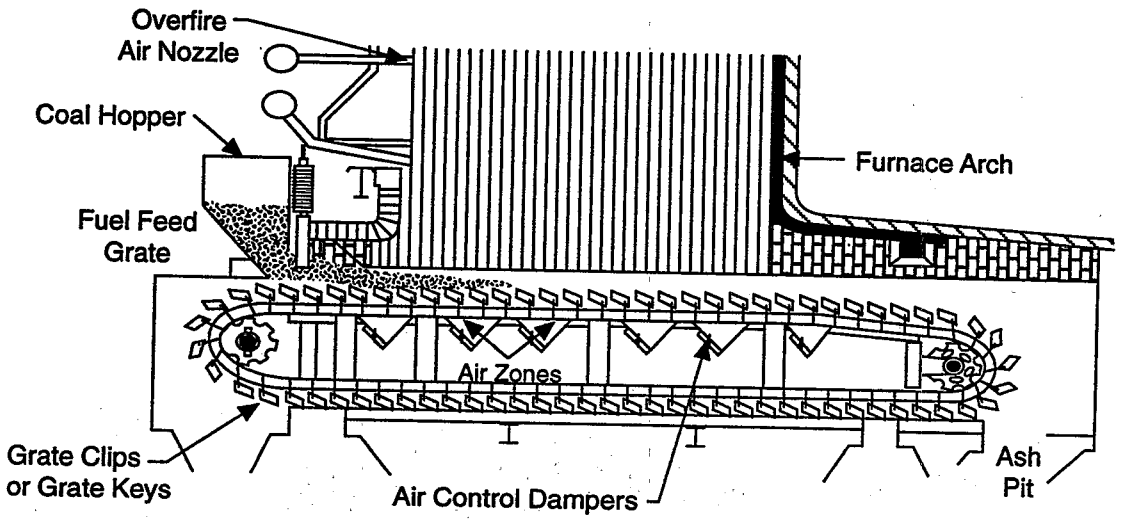

Figure 2.4-12 Cross section of overfeed mass-burning traveling-grate stoker.

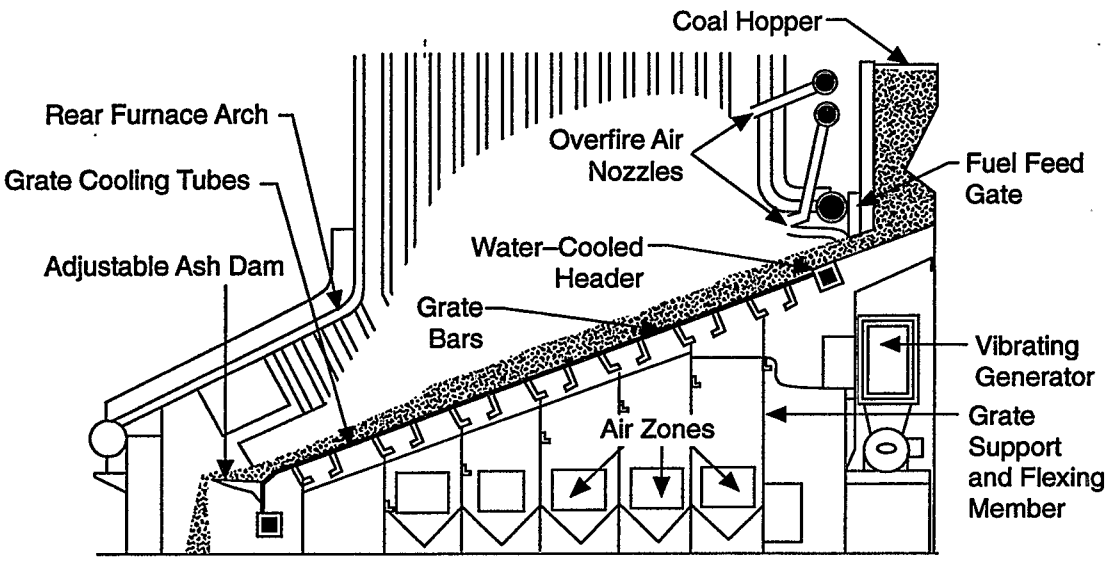

Figure 2.4-13 Water-cooled, vibrating-grate stoker.

In general, overfeed stokers are best suited for industrial and institutional power plants with steady load demands. Since all the fuel is consumed on the grate, the stoker grate surface must be conservatively sized. The grate heat release rate (quantity of heat released per hour divided by grate area) should be limited to a maximum of 425 Btu/hr–ft^2 of active grate area. These stokers are normally designed for capacities up to 150,000 lb/hr of steam.

Water–cooled furnaces are preferred with all moving–grate stokers to prevent slag formation on the furnace walls. The tube spacing of the furnace walls should not exceed twice the tube diameter. Adequate furnace volume must be provided as recommended by the boiler and stoker manufacturers.

Overfeed stokers are provided with a high–pressure, overfire–air system consisting of one or two rows of closely spaced air jets located above the fuel bed in the front wall of the furnace. The jets provide adequate furnace turbulence to complete the burnout of the hydrocarbons. The high–pressure air fans will be sized to provide approximately 10% of total air. The static pressure of the fan is selected to provide proper penetration of the air into the furnace.

The second category of overfeed stokers are spreader stokers. In spreader stokers, the fuel is spread into the furnace over the grates from feeders located across the front of the unit. The purpose is to feed the fuel evenly over the grate surface in order to release an equal amount of energy from each square foot of active grate surface. The air for combustion should then be admitted evenly through the grate to provide the oxygen for burning. Above the grates, an overfire–air system is provided for additional oxygen and turbulence in the lower–furnace zone temperature to ensure efficient performance. Since spreader stokers can burn a wide range of solid fuels and cover a wide range of boiler sizes, the arrangement and design of each of the three basic components — fuel feeders, type of grate, and overfire–air system — depend on the specific project.

Fuel Burning

As the fuel is fed to the furnace in a manner to spread it evenly over the complete grate surface, it burns both in suspension and on the grate. The amount burned in suspension depends on a number of factors. Fine fuel burns more in suspension; high–volatile fuels release more energy in suspension. High moisture can increase the energy release on the grate. The burning fuel bed on the grate may be only about 1 inch thick. This depth depends on fuel characteristics and firing rate. Under the burning fuel, an ash bed is formed which is usually about 3 inches thick. The ash–bed thickness also depends on fuel characteristics, but not on the firing rate since

the rate of ash discharge is regulated to the firing rate. The ash bed provides an insulating barrier between the burning fuel and the metal–grate surface, which is additionally cooled by the combustion airflow across the grate.

Fuel Feeders

There are three types of fuel feeders utilized in spreader stokers: *reciprocating feeder, chain feeder, and drum feeder*. In general, fuel feeders have a device which meters the fuel to the combustion control system and delivers it to the built–in rotor.

Reciprocating Feeder: The reciprocating feeder has one or more feed plates which travel back and forth on a spill plate. On the back stroke, the fuel drops from the hopper in front of the plate. On forward stroke, the fuel is pushed off from the spill plate onto the rotor. The amount of fuel per stroke is adjusted by (1) the length of stroke of the feed plate through mechanical devices, (2) the number of strokes per minute through mechanical variable–speed devices, or (3) electronic devices such as variable–frequency power units to alternating–current (ac) motors, or silicon controller rectifier control units to direct–current (dc) motors.

Chain Feeder: A chain feeder has a drag conveyor deliver the fuel out of a hopper, off the end of the chain, and onto the rotor. The amount of fuel is a function of the speed of the chain and the depth of the fuel. The depth of the fuel is adjusted by the position of a gate above the chain. The speed can be regulated by an internal mechanical variable–speed device, or electronically, as described previously.

Drum Feeder: The drum feeder utilizes a revolving drum with semipockets to deliver the fuel out of a hopper onto the rotor. As with the chain feeder, the amount of fuel is regulated by the speed of the drum and the depth of fuel coming out of the hopper onto the drum. A vibrating feeder delivers the fuel to the rotor out of the fuel hopper on a vibrating conveyor. The amount of fuel may be adjusted by the frequency of vibration and the depth of the fuel on the conveyor.

Types of Grates

A number of grate types are utilized for spreader–stoker firing. The purpose of the grate is threefold: 1) to provide a floor on which the fuel can burn, 2) a means of distributing air evenly through the grates, and 3) a method of discharging the ashes that accumulate on the grate from the consumed fuel. The various grate designs include stationary and dumping grate, reciprocating grate, vibrating grate, traveling grate, and vibrating, water–cooled grate. A description of each of these grate types is given below.

Stationary and Dumping: The intermittent cleaning types of grates are stationary and dumping. The stationary grate is rarely used because of hazards to the operator when removing ashes through the open fire door. It is extremely difficult to clean fires without creating a smoky fire condition of high opacity.

This manual dumping type of grate, shown in Figure 2.4-14, has one section for each fuel feeder. To remove ashes, the fuel feed is stopped in front of one of the grate sections to allow complete burnout of combustible products. The air supply to that section is then cut off with appropriate dampers, and the ashes can be dumped into a pit below. While this cleaning occurs, it is necessary for the remaining sections to burn additional fuel to maintain the boiler rating.

After the ashes are dumped, the fuel feeder is started again. When the fuel ignites, the undergrate damper to that section is reopened to resume normal combustion. It is very difficult to accomplish this cleaning process without high opacity. Consequently, the dumping grate is seldom used for burning fuel with a high percentage of volatiles and a low ash content.

Reciprocating: The reciprocating grate, shown in Figure 2.4-15, discharges ashes by a slow back–and–forth motion of moving grates alternating with stationary grates. Each row of grates rests on the row in front and has a raised nose which pushes the ashes toward and off the end of the grate into an ash hopper. It is preferable to discharge the ashes at the front under the feeders. Since the fuel is thrown toward the rear, the best control of ash discharge with minimum combustibles in the ashes can be achieved with front ash discharge from any type of conveying grate. Because of the stepped nature of the reciprocating grate, it is used only for fuels with sufficient ash quantity to provide an adequate ash depth insulation on top of the grate. The undergrate air temperature is ambient.

Vibrating: The vibrating or oscillating grate (Figure 2.4-16) is suspended on flexing plates. Either an eccentric drive or rotating weights impart a vibrating action to the grate surface, which conveys ashes to the front and discharges them into an ash pit. The frequency of vibration is kept well below the natural frequency, to minimize the forces on the support structure. The rate of ash discharge is regulated by a timer system that controls the off time between vibrating cycles and the length of vibrating time.

Traveling: The traveling–grate spreader stoker (Figure 2.4-17) is by far the most popular type, and there are numerous types of construction. The most important consideration is that the design of the grate surface should provide a high resistance to airflow through the grate to ensure even distribution of air through the grate. The traveling grate moves forward to discharge the ashes at the front end under the fuel feeders. The return grate then passes underneath in the air

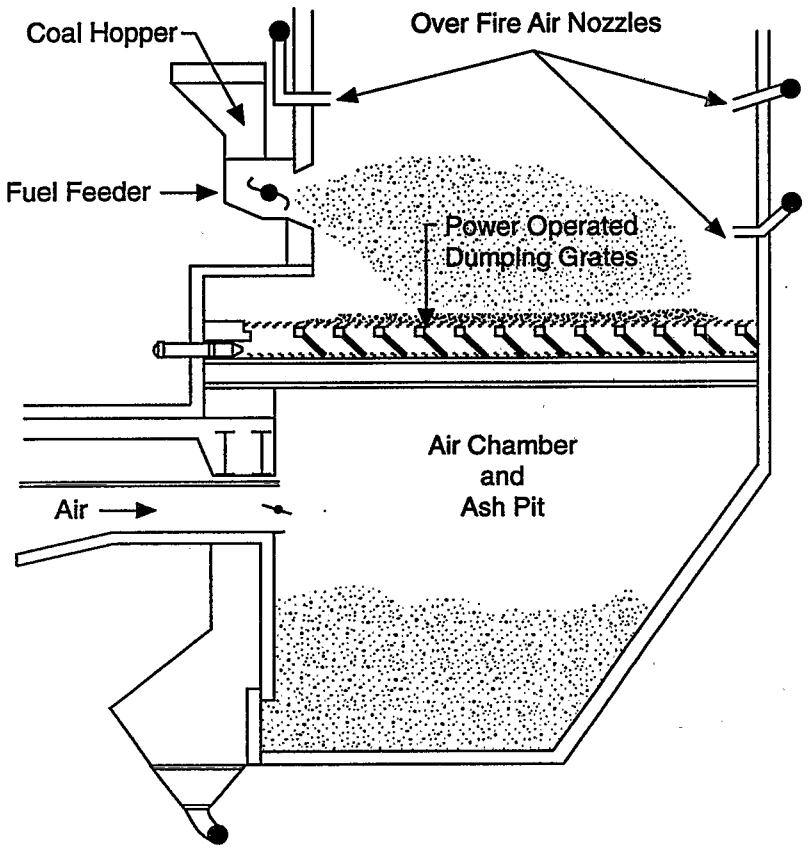

Figure 2.4 -14 Spreader stoker with dumping grates.

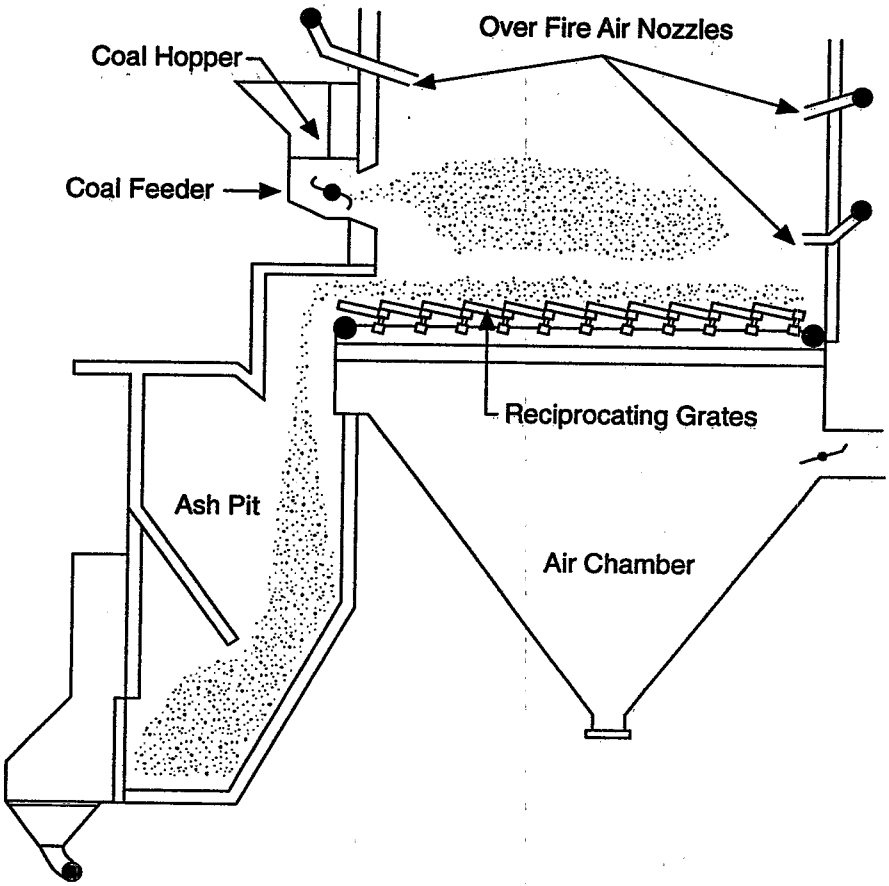

Figure 2.4-15 Spreader stoker with reciprocating grates.

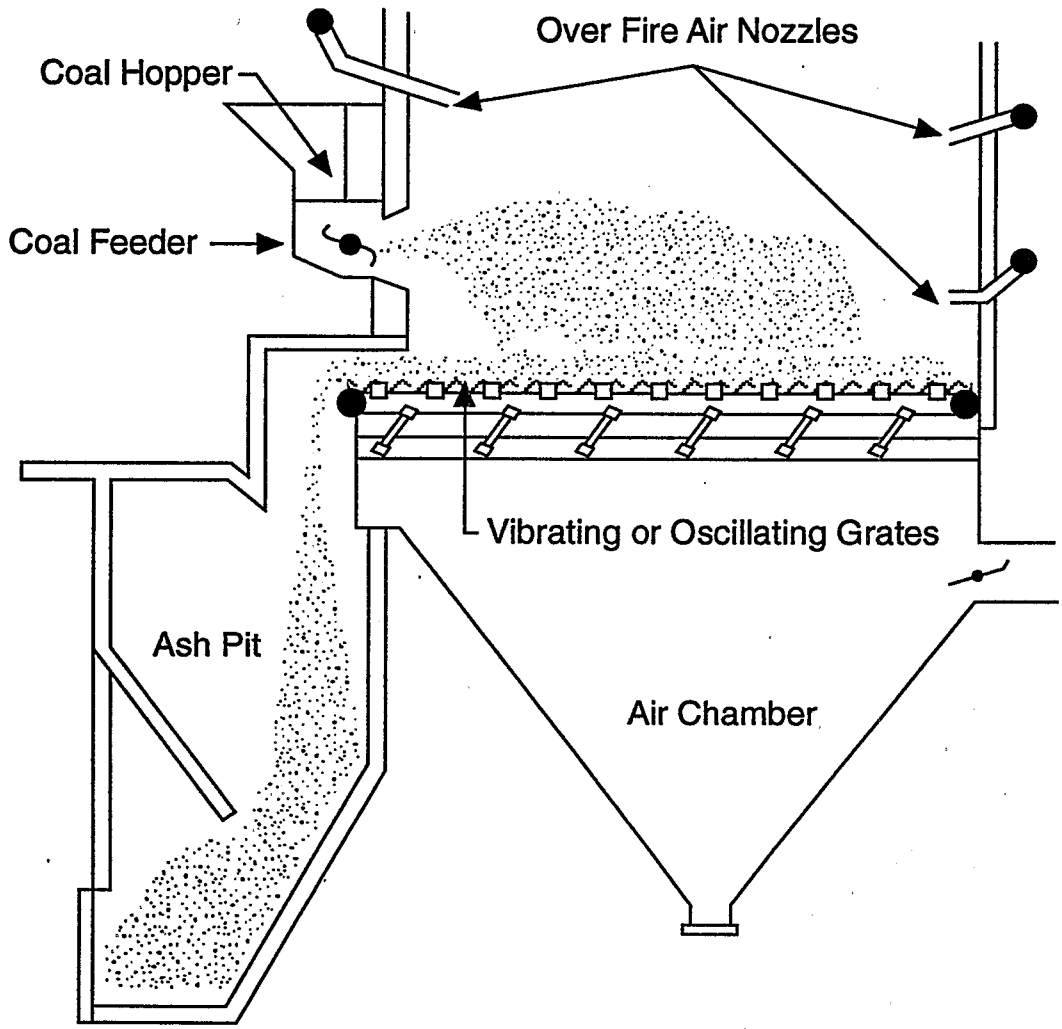

Figure 2.4-16 Spreader stoker with vibrating grates.

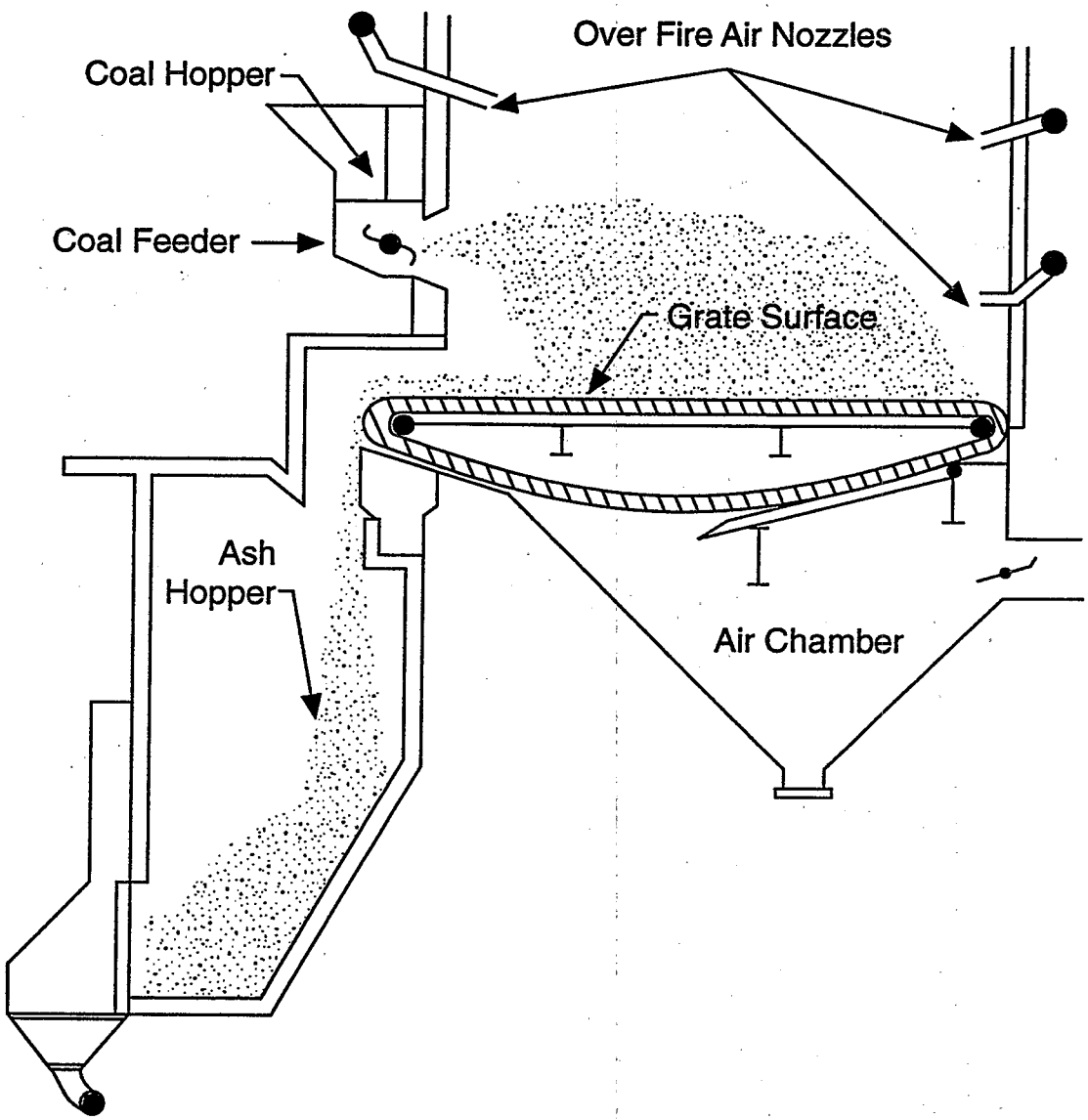

Figure 2.4-17 Spreader stoker with traveling grates.

chamber. The traveling grate is driven either mechanically or hydraulically through appropriate mechanical devices, electronic devices, or hydraulic flow–control valves.

When the ash content in the fuel is consistent, the speed of the grates can be regulated by the combustion controls to maintain an even ash–bed thickness. The grate bars can be made from cast iron with small amounts of alloy for heat and wear resistance, or from ductile iron for increased heat resistance and impact resistance.

Vibrating, Water–Cooled: The water–cooled vibrating grate spreader stoker (Figure 2.4-18) is used for refuse burning. A water–cooled grid on which a grate surface is fastened is mounted on a frame. The whole assembly is supported on flexing plates on an angle of 6° down toward the ash discharge end. An eccentric drive vibrates the grate assembly through a timing circuit that controls the amount of off and on time. The vibrating action moves the ash to the front of the grate and into the ash pit. The vibration frequency is kept well below the natural frequency. The water–cooled grid is cooled by tying into the boiler water–circulation circuit or a separate forced–cooling system.

Overfire Air

The overfire air system on spreader–stokers has three functions: (1) to provide oxygen and turbulence to mix the fuel and oxygen in the lower high–temperature zone of the furnace for complete burnout, (2) to distribute fuel and assist in distribution when the design dictates the use of air for this purpose, and (3) to provide cooling air for mechanical fuel feeders. The air can come from a common fan that would have static pressure capabilities of 25 to 30 in H_2O to provide the necessary energy for turbulence or fuel distribution.

Overfire air nozzles are placed in rows in the front and rear walls of the furnace. The design should place the air nozzles at elevations which will ensure mixing of the furnace gases in the high–temperature zones, so that the combustion processes can be completed in the furnace. Air–nozzle spacing in each row should be on centers 10 to 12 inches for complete coverage of the furnace.

The size of the air nozzles in the various rows is a function of the depth of the penetration desired and the amount of overfire air required. Bituminous–coal–fired boilers are designed with 15 to 25% overfire air. Lignite–fired boilers are designed with 20 to 25% overfire air. The overfire air temperature may be either ambient or the temperature of the undergrate air. The choice of temperature is generally a function of air heater and boiler system design.

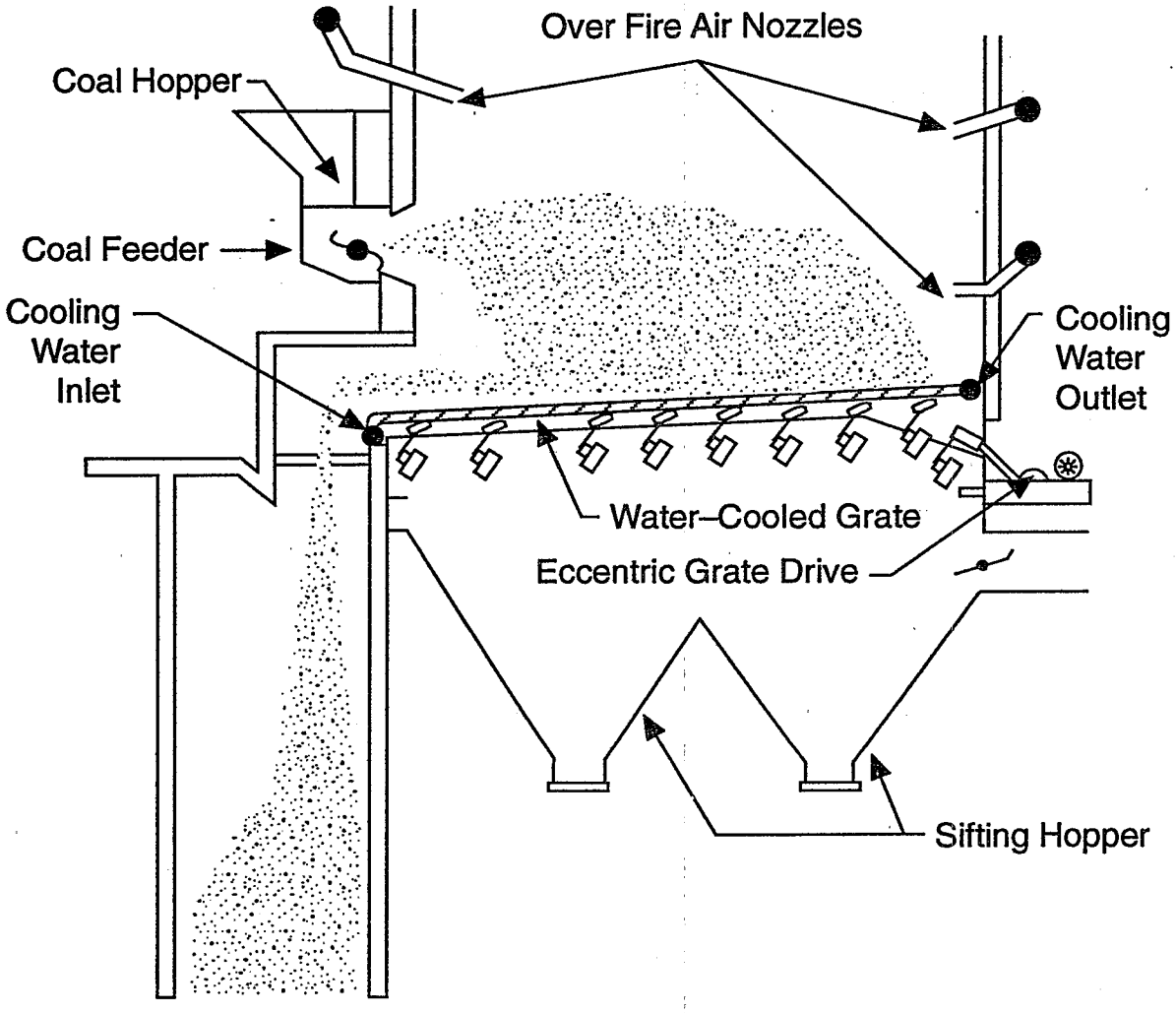

Figure 2.4.-18 Spreader stoker with water-cooled vibrating grates.

Fly Carbon Reinjection

The particulate leaving the furnace of a spreader stoker can contain considerable combustible material, and thus is termed *fly carbon*. It is beneficial to return some percentage of this fly carbon to the furnace for burning to improve the boiler efficiency. This is accomplished by the conveying system, which transfers the fly carbon from hoppers through a pipeline to the furnace using air as the conveying medium. By using a nozzle and venturi arrangement, air at a pressure up to 25 inches of water can create a suction to draw the fly carbon into the pipeline and pressure–convey it to the furnace.

The air supplied is generally from the overfire air fan; however, a separate fan can be used. The fly carbon can be collected in hoppers under the boiler's steam generating section, economizer, air heater, or mechanical dust collector, although continuous evacuation of the hopper is required. The amount of reinjection sets the increase in boiler efficiency.

2.5 References

1. Singer, J. G., Combustion: Fossil Power Systems, 3rd edition, Combustion Engineering, Inc., 1981.

2. Steam, Its Generation and Use, 40th Edition, Babcock and Wilcox Company, 1992.

3. Elliot, C.T., Standard Handbook of Powerplant Engineering, McGraw–Hill Publishing Company, New York, 1989.

3.0 PROCESS CHARACTERIZATION

In this section, each of the hazardous waste processes is characterized in terms of population within the United States and the air pollution control techniques currently in use. A detailed description of air pollution devices is provided in Appendix A.

3.1 Cement Kilns

3.1.1 *Population*

Of the 211 cement facilities in the United States, 33 are currently burning hazardous waste derived fuel. Most cement kilns burning hazardous wastes use "wet" process cement kilns. However, all kiln types, including long dry, dry preheater/precalciner, dry preheater and semi-dry, are currently co-firing hazardous waste derived fuels.

3.1.2 *Air Pollution Control Techniques in Use*

Most cement kilns are equipped with flue gas emissions control devices specifically designed for the control of particulate matter. Either electrostatic precipitators (ESPs) or fabric filters (FFs), occasionally in combination with mechanical cyclone collectors, are used. ESPs have been the more common choice due to their reliability and low maintenance requirements. Recently however, with increasingly strict particulate control standards, FFs have also become common. Typically, fabric filters are more efficient at collection of submicron particulate and provide lower guaranteed particulate matter emissions levels. Fabric filter technology at the time of construction of many of the wet kilns was not capable of operating effectively in high moisture conditions. For this reason, ESP technology is more commonly found in the present population of wet kilns. However, there are currently several wet kilns which are equipped with modern FFs capable of operating in the high moisture conditions found in the flue gas of wet kilns.[1] FF particulate control is more common at dry process kilns. Depending on the facility, the flue gas at the kiln exit may need to be cooled before entering the air pollution control device. Air dilution or water spray may be used for this purpose. For one facility, hot gases leaving the kiln are cooled in a waste heat boiler which produces steam; the steam is then converted to electricity that is used on-site.

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1 Memo From Frank Behan, EPA, May 16, 1994. Conversations with operators of the following wet cement kilns employing FFs: Dragon Cement,, Thomaston, ME, and Giant Cement, Harleyville, SC.

3.2 Lightweight Aggregate Kilns

3.2.1 *Population*

There are more than 36 lightweight aggregate kiln locations in the United States. Of these, there are currently seven facilities that burn hazardous waste. Within these facilities, there are 11 kilns.

3.2.2 *Air Pollution Control Techniques in Use*

The lightweight aggregate kilns have one or a combination of air pollution control devices (APCDs) which include cyclones, fabric filters, venturi scrubbers, wet scrubbers, and spray dryers, as well as flue gas cooling devices such as quench chambers and heat exchangers.

3.3 Hazardous Waste Incinerator Process Characterization

3.3.1 *Population*

Hazardous waste incinerators are grouped as either "commercial" or "on-site" facilities. For a tipping fee, commercial facilities accept and treat wastes which have been generated off-site. There are currently 20 commercial hazardous waste incineration facility sites operated by 18 companies. There are an additional 15 facilities which are not operating, are under construction, or are pursuing permits. However, these facilities are a low priority for the Agency to process. The majority of the commercial incinerators are rotary kilns. Additionally, there are liquid injection, fluidized bed, fixed hearth, and two-stage furnace devices.

On-site facilities treat only wastes which have been generated at the facility. Currently, there are 163 on-site hazardous waste incinerators. The on-site facilities consist of approximately equal numbers of rotary kilns and liquid injection facilities, with a few fixed hearths and fluidized beds.

3.3.2 *Air Pollution Control Techniques in Use*

Many different types of air pollution control devices are used, including wet scrubbers such as venturi and packed bed type wet scrubbers, ionizing wet scrubbers, electrostatic precipitators and fabric filters. In general, the control systems can be grouped into the following three categories:

1) *Wet systems*

In wet systems, a wet scrubber is used for both particulate and acid gas control. Typically, a venturi scrubber and packed bed scrubber are used in series. Also, ionizing wet scrubbers, wet electrostatic precipitators, and novel venturi-type scrubbers may be used for more efficient particulate control. The primary drawbacks of using wet systems include generation of a wet effluent liquid waste stream (scrubber blowdown), relatively inefficient fine particulate control compared to dry control techniques, and corrosion concerns. However, these types of systems provide efficient control of acid gases and lower operating temperatures which may help control the emissions of volatile metals.

2) *Dry systems*

In dry systems, a fabric filter or electrostatic precipitator is used for particulate control, sometimes in combination with dry scrubbing for acid gas control. The primary drawback of the dry system is a less efficient control of acid gases compared with wet systems.

3) *Hybrid wet/dry systems*

In hybrid systems, a dry technique (ESP or fabric filter) is used for particulate control (and possibly acid control with use of dry scrubbing) followed by a wet technique (venturi and/or packed bed scrubber) for acid gas control. These systems are both wet and dry (lower operating temperature for capture of volatile metals, efficient collection of fine particulate, efficient capture of acid gases), which avoids the drawbacks discussed above. In some hybrid systems (known as zero discharge systems), the wet scrubber liquid is used in the spray drying operation, thus minimizing the amount of liquid byproduct waste.

Some liquid injection facilities do not utilize post-combustion air pollution control devices. These are facilities which generate low levels of particulate when treating low ash content wastes and/or may not generate acid gases when burning non-halogen containing wastes.

4.0 INTRODUCTION: PM AND DIOXIN/FURAN EMISSIONS CHARACTERIZATIONS

This chapter examines the body of particulate matter (PM) and dioxin data accumulated to date for hazardous waste burning cement kilns, lightweight aggregate kilns, incinerators and boilers. The data presented in this chapter have been compiled from Certificate of Compliance (CoC) and Trial Burn Reports submitted to EPA's Regional Offices and to the States. EPA's information gathering effort is ongoing, and the material presented in both this Chapter and in Chapter 5 will be updated as the data base is expanded. The cement kiln dioxin data are analyzed in detail to establish parametric relationships which provide key insights into both the formation mechanism(s) and potential control options associated with dioxin/furan emissions. Subsequent revisions of this report are expected to contain similar analysis of the data pertaining to lightweight aggregate kilns, incinerators and boilers. In Chapter 5, further analysis of the current body of data is presented to identify the expected PM and dioxin/furan emissions of the best performing units incorporating defined control technologies.

4.1 Cement Kiln PM Emission Summary

Table 4.1-1 presents a summary of the PM data compiled to date from the CoC/ Trial Burn Reports. None of the data presented in Table 4.1-1 have been extracted from open literature or previous compilations. Currently, data have been compiled from 26 separate facilities and 36 separate kilns, with 36 separate data sets and a total of 161 data points. Comparison with the current kiln population suggests that the PM data set is virtually complete, with minor additions and revisions anticipated in subsequent revisions of this report. Appendix B presents a more detailed summary of the current PM data set for cement kilns.

Figure 4.1-1 presents the cumulative distribution of PM emissions for cement kilns. As shown in this figure, the data indicate that 50% of the kiln population exhibits PM emissions of less than 0.0125 gr/dscf @ 7% O_2 based on the minimum reported data. Similarly, 50% of the kiln population reported PM emissions of less than 0.02 and 0.03 gr/dscf @ 7% O_2 based on the average and maximum reported emissions, respectively.

The variation in the minimum, maximum and average reported PM emissions from any specific facility is not only dependant on the scatter in the data anticipated from a facility running at uniform conditions, but is also largely dependant on trial burn requirements as well as the sensitivity of the PM emissions to systematic variations in process or APCD operation. Figures 4.1-2 and 4.1-3 present the plot of PM emissions versus ESP operating power (KVA) for eight of

TABLE 4.1-1. SUMMARY OF CEMENT KILN PM DATA

Company	Location	Unit Tested	Report Date	Facility Type	APCS	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Chanute, KS	1	Apr-92	w	ESP	4	0.0609	0.04808	0.0375	0.00967
Ash Grove Cement Co.	Chanute, KS	2	Mar-92	w	ESP	4	0.0494	0.03255	0.0219	0.01201
Ash Grove Cement Co.	Foreman, AR	1	Jul-92	w	ESP	11	0.049	0.02958	0.0154	0.01050
Ash Grove Cement Co.	Foreman, AR	2	May-92	w	ESP	2	0.0326	0.02020	0.0078	0.01754
Ash Grove Cement Co.	Foreman, AR	3	Jul-92	w	ESP	6	0.0183	0.00748	0.0043	0.00542
Ash Grove Cement Co.	Louisville, NE	1	May-92	sd (ph/bp)	ESP	5	0.0653	0.03658	0.016	0.02479
Ash Grove Cement Co.	Louisville, NE	2	Aug-92	d (ph/pc/bp)	ESP	8	0.026	0.01859	0.0142	0.00417
Continental Cement Co.	Hannibal, MO	1	Jul-92	w	ESP	3	0.0403	0.03737	0.03430	0.00300
Essroc Materials	Dorado, PR	1	Jun-93	d (ph/pc/bp)	FF	3	0.0682	0.04877	0.02310	0.02319
Essroc Materials	Logansport, IN	1	Aug-92	w	ESP	4	0.083	0.07075	0.057	0.01103
Giant Cement Co.	Harleyville, SC	4	Aug-92	w	FF	3	0.0155	0.01300	0.01050	0.00250
Giant Cement Co.	Harleyville, SC	5	Aug-92	w	FF	3	0.0152	0.01133	0.00800	0.00363
Heartland Cement Co.	Independence, KS	1	Oct-92	d	FF	6	0.0425	0.02660	0.019	0.00815
Holnam Inc.	Clarksville, MO	1	Jul-92	w	ESP	3	0.0352	0.03370	0.03250	0.00137
Holnam Inc.	Holly Hill, SC	1	Aug-92	w	ESP	3	0.0581	0.04967	0.04630	0.00735
Holnam Inc.	Holly Hill, SC	2	Aug-92	w	ESP	3	0.0291	0.02263	0.01480	0.00725
Holnam, Inc.	Artesia, MS	1	Aug-93	w	ESP	3	0.0173	0.01380	0.01500	0.00340
Keystone Cement Co.	Bath, PA	1	Aug-92	w	ESP	10	0.0323	0.02204	0.0092	0.00664
Keystone Cement Co.	Bath, PA	2	Aug-92	w	ESP	10	0.025	0.01500	0.011	0.00383
Lafarge Corp.	Alpena, MI	1	Aug-92	d (?)	FF	3	0.006	0.00333	0.00100	0.00252
Lafarge Corp.	Demopolis, AL	1	Aug-92	d (ph/bp)	ESP	3	0.0306	0.01820	0.01000	0.01092
Lafarge Corp.	Fredonia, KS	1	Aug-92	w	ESP	3	0.033	0.01900	0.01100	0.01217
Lafarge Corp.	Fredonia, KS	2	Aug-92	w	ESP	3	0.033	0.02200	0.00500	0.01493
Lafarge Corp.	Paulding, OH	2	Aug-92	w	ESP	3	0.06	0.03333	0.02000	0.02309
Lone Star Industries	Cape Girardeau, MO	1	Jan-93	d (ph/pc/bp)	FF	6	0.026	0.02350	0.021	0.00187
Lone Star Industries	Greencastle, IN	1	Aug-92	w	ESP	3	0.0637	0.05563	0.04560	0.00921
Medusa Cement Co.	Wampum, PA	3	Jul-92	d	ESP	3	0.032	0.02247	0.01610	0.00841
Medusa Cement Co.	Wampum, PA	1,2	Jul-92	d	ESP	3	0.0789	0.07687	0.07500	0.00196
Medusa Cement Co.	Wampum, PA	1,2	Mar-93		ESP	3	0.0724	0.06543	0.05200	0.01164
National Cement Co.	Lebec, CA	1	Aug-92	d	FF	4	0.0228	0.01713	0.016	0.00408
North Texas Cement	Midlothian, TX	2	Oct-92	w	ESP	3	0.024	0.02067	0.01600	0.00416
River Cement Co.	Festus, MO	1	Oct-92	d	ESP	6	0.0352	0.02443	0.0129	0.00786
Southdown/Dixie	Knoxville, TN	1	Mar-92	d (ph/pc/bp)	FF	6	0.0131	0.01183	0.00988	0.00114
Southdown/Kosmos	Kosmosdale, KY	1	May-92	d (ph)	FF	9	0.00354	0.00261	0.00139	0.00094
Southdown/Southwestern	Fairborn, OH	1	Aug-92	d (?/bp)	FF	3	0.003	0.00300	0.00300	0.00000
Texas Industries	Midlothian, TX	1	May-93	w	ESP	3	0.01135	0.00962	0.00827	0.00158

w = wet kiln	# of facilities	26
d = dry kiln	# of Kilns	36
sd = semi dry kiln	# of Data Sets	36
ph = preheater	# of Data Points	161
pc = precalcinator		
bp = by-pass		

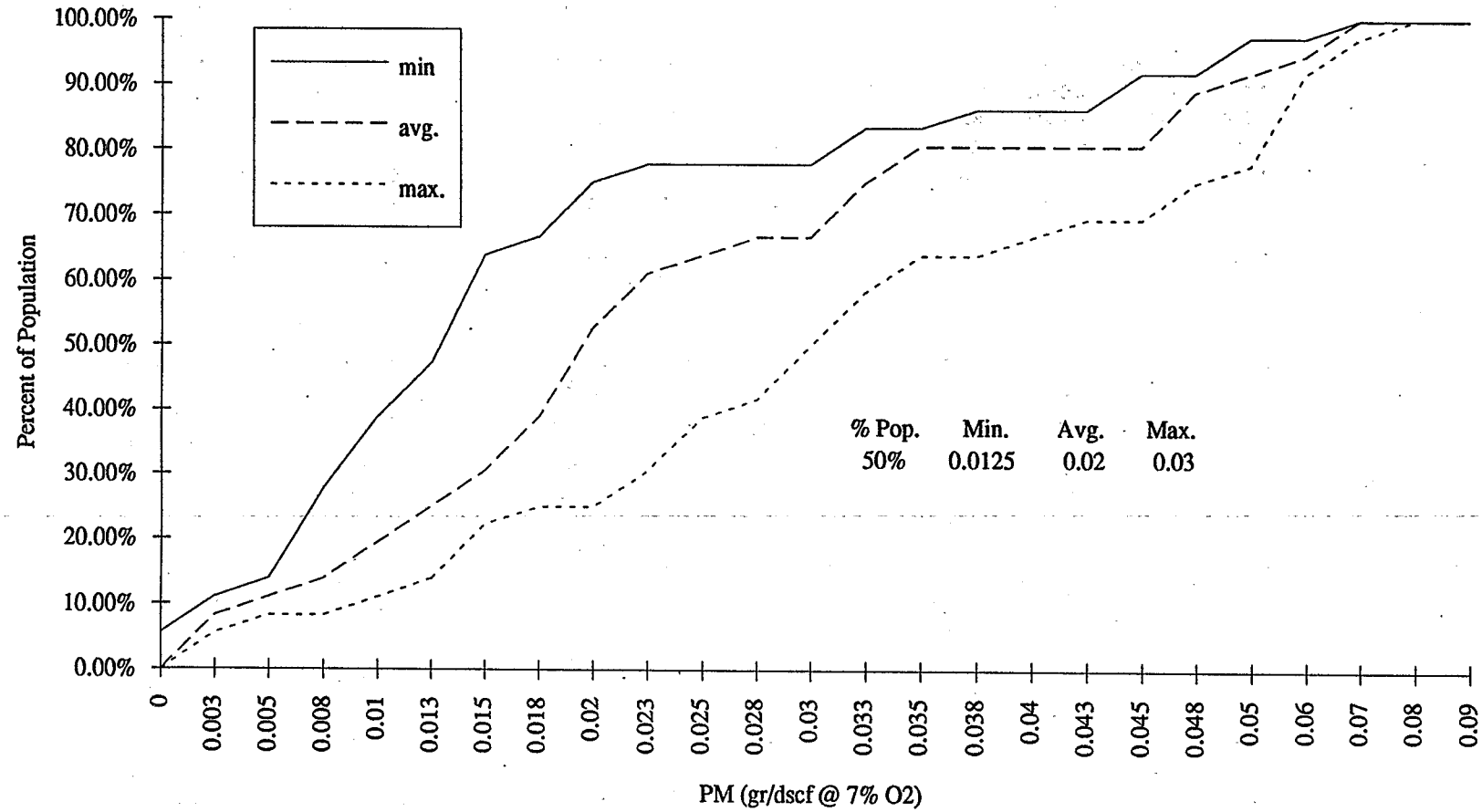

Figure 4.1-1. Cumulative distribution of cement kiln PM emissions.

CK.pm/sum Chart 2

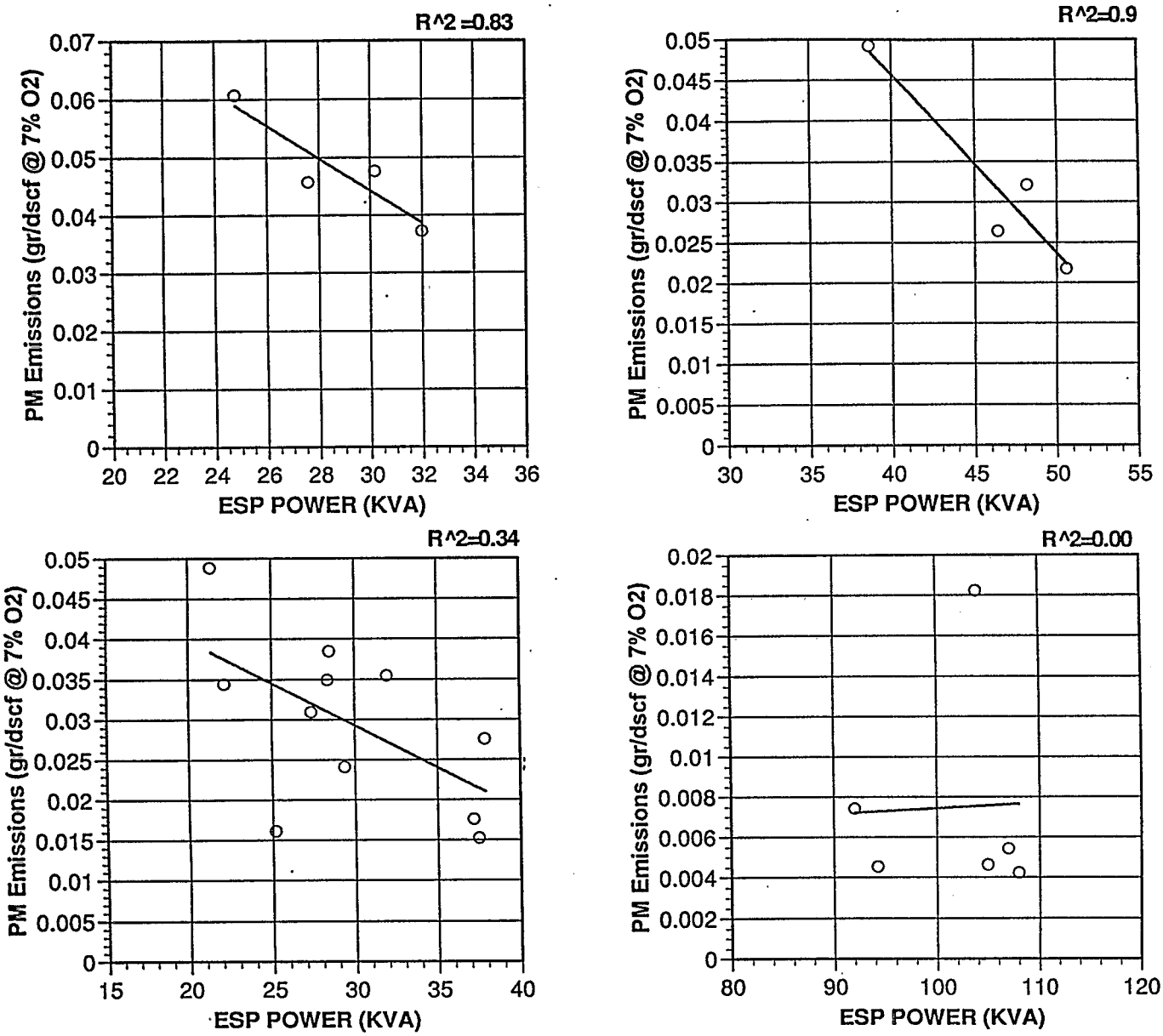

Figure 4.1-2. Plot of cement kiln PM emissions versus ESP operating power (KVA) .

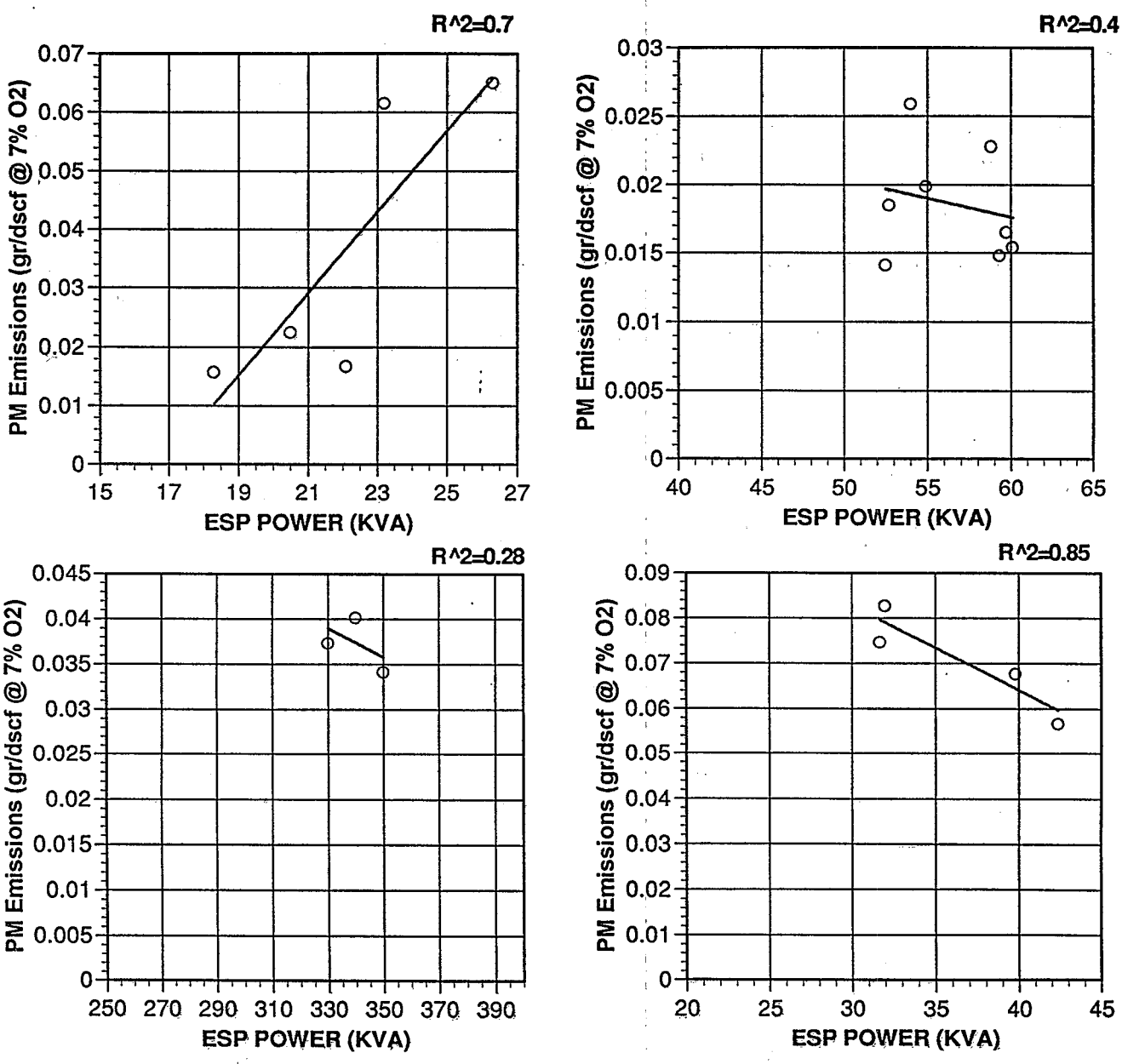

Figure 4.1-3. Plot of cement kiln PM emissions versus ESP operating power (KVA).

the data sets. Examining the data in this fashion is important when analyzing the reported PM emission data. As seen in these eight plots, some of the reported data sets for PM have a strong inverse correlation with ESP operating power. When this occurs, the interpretation of data must consider:

- That the minimum reported emission MAY not reflect the actual expected minimum PM emission at the maximum tested KVA level.

- That the scatter in the data does not reflect the natural scatter that would be found in PM emissions from tests at more uniform conditions.

The absence of a consistent trend (decreasing PM with increasing KVA) between all data sets suggests that site-specific conditions can dominate in controlling the variability of PM emissions. As will be discussed further in Chapter 5, the systematic trends in the data from each of the kiln data sets must be considered in calculating the anticipated PM levels of the best performing units, as well as in estimating the variability that would be found in PM measurements from these facilities.

4.2 Lightweight Aggregate Kiln PM Emission Summary

Table 4.2-1 summarizes the PM emissions from the LWA kiln data set. Particulate matter data have been compiled from six facilities and 13 units. A total of 12 data sets are available with a total of 48 points. A more detailed summary of the PM data is provided in Appendix C. Figure 4.2-1 presents the cumulative distribution of PM emissions for LWA kilns. As shown in this figure, 50% of the LWA kiln data set exhibit PM emissions of less than 0.0025 gr/dscf @ 7% O_2 based on the minimum reported data. Similarly, 50% of the LWA kiln data set exhibit PM emissions of less than 0.004 and 0.0075 gr/dscf @ 7% O_2 based on the average and maximum reported emissions, respectively. Note that the small sample size makes interpolation of the data to estimate the median values subject to uncertainty.

4.3 Commercial Hazardous Waste Incinerators PM Emission Summary

Table 4.3-1 presents a summary of the PM data compiled to date from CoC/Trial Burn reports for commercial HW incinerators. None of the data presented in Table 4.3-1 have been extracted from open literature or previous compilations. Currently, data have been compiled from 17 separate facilities and 19 separate units, with 22 separate data sets and a total of 133 data points.

TABLE 4.2-1. SUMMARY OF PM EMISSIONS FROM LIGHTWEIGHT AGGREGATE KILNS

Company	Location	Unit Tested	Report Date	APCS	# Points	Particulate (gr/dscf @ 7% O2)			
						Maximum	Average	Minimum	Sdev
Norlite Corp.	Cohoes, NY	1	Dec-92	SD/FF/VS/WS	15	0.0371	0.01227	0.0056	0.00863
Solite Corp.	Arvonia, VA	7	Aug-92	FF	3	0.008	0.00667	0.006	0.00115
Solite Corp.	Arvonia, VA	8	Aug-92	FF	3	0.033	0.02533	0.013	0.01079
Solite Corp.	Brooks, KY	2	Aug-92	FF	3	0.026	0.01833	0.013	0.00681
Solite Corp.	Cascade, VA	1	Mar-94	FF	3	0.0111	0.00864	0.00726	0.00213
Solite Corp.	Cascade, VA	2	Aug-92	FF	3	0.007	0.00567	0.004	0.00153
Solite Corp.	Cascade, VA	4	Aug-92	FF	3	0.018	0.01000	0.007	0.00700
Solite Corp.	Green Cove Springs, FL	5	Jan-94	FF	3	0.00157	0.00144	0.00127	0.00016
Solite Corp.	Norwood, NC	5	Aug-93		3	0.00796	0.00429	0.00229	0.00318
Solite Corp.	Norwood, NC	6	Aug-93		3	0.0102	0.00512	0.00229	0.00441
Solite Corp.	Norwood, NC	7	Aug-93		3	0.000765	0.00048	0.000298	0.00025
Solite Corp.	Norwood, NC	8	Jul-93		3	0.00093	0.00190	0.00375	0.00161

# of Facilities	**6**
# of Kilns	**12**
# of Data Sets	**12**
# of Data Points	**48**

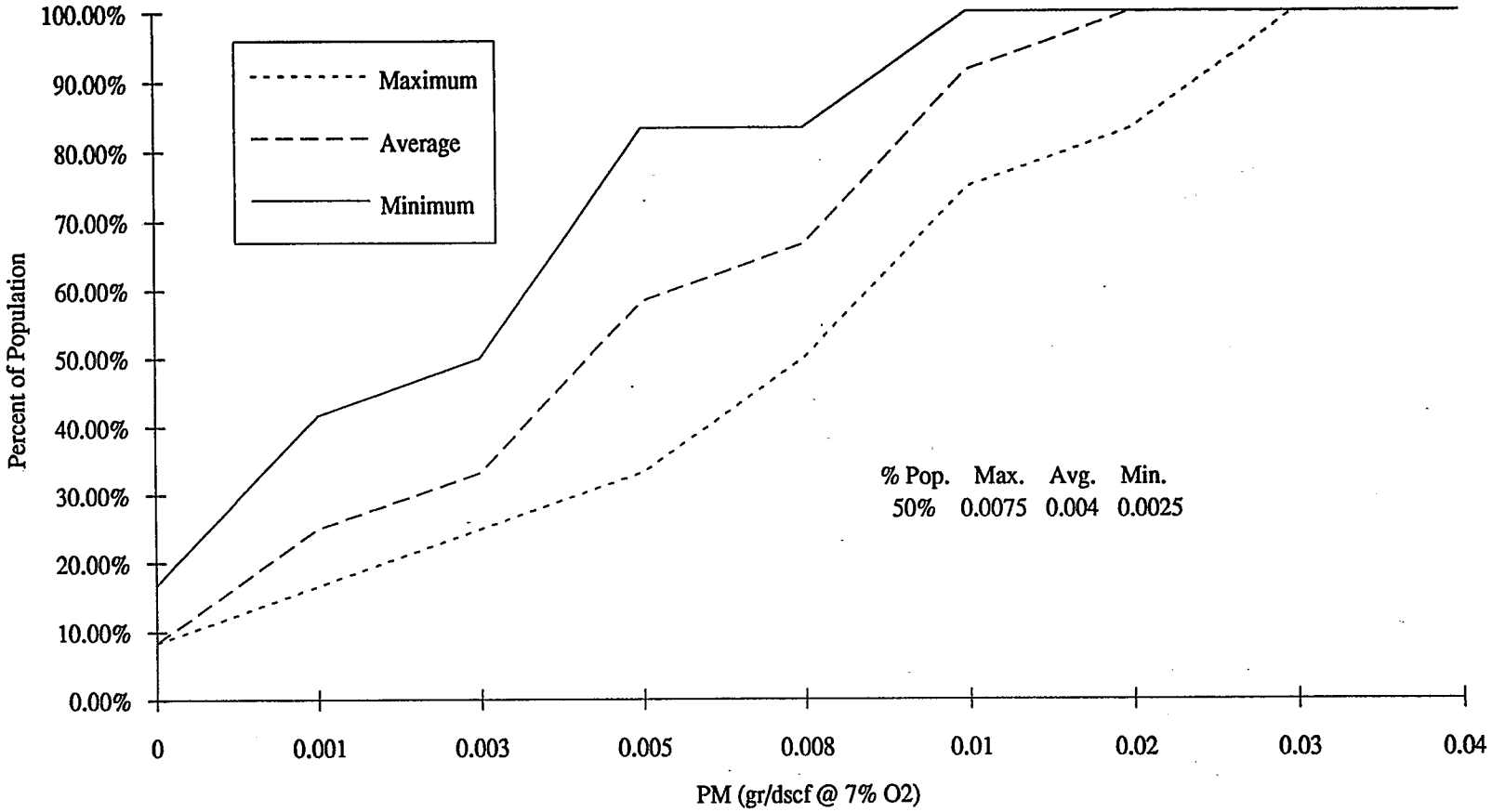

Figure 4.2-1. Cumulative distribution of LWA kiln PM emissions.

AK.pm/sum Chart 2

TABLE 4.3-1. SUMMARY OF PM DATA FOR COMMERCIAL HW INCINERATORS

Company	Location	No. Units	Unit Tested	Report Date	Facility Type	APCS	# Points	Particulate (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdedv
Allied Chemical	Birmingham, AL	1	1	Feb-89	BPF	none	7	0.06690	0.01965	0.00447	0.02195
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	RK	FF/WS/ESP	9	0.00160	0.00063	0.00000	0.00057
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	RK	FF/WS/IWS	12	0.00600	0.00342	0.00100	0.00138
Atochem	Carrollton, KY	1	1	Jun-90	RK	FF/WS	9	0.09540	0.02954	0.00270	0.03681
CWM Chemical Services	Chicago, IL	1	1	Mar-92	RK	IWS/PS	4	0.03680	0.03110	0.02670	0.00492
General Electric	Pittsfield, MA	1	1	Apr-91	LI	PS	6	0.06320	0.04100	0.01590	0.02054
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	LI	FF/VS/AFS	8	0.00160	0.00076	0.00050	0.00035
LWD, Inc.	Calvert City, KY	3	1	Mar-93	RK	FF/WS	3	0.01140	0.00854	0.00383	0.00411
LWD, Inc.	Calvert City, KY	3	2	Mar-93	RK	FF/WS	3	0.02390	0.02267	0.02030	0.00205
LWD, Inc.	Calvert City, KY	3	3	Jan-93	RK	FF/WS	3	0.01840	0.00843	0.00183	0.00879
Marine Shale	Amelia, LA	2	1	Jul-95	AK	SD/FF	3	0.0079	0.00580	0.00466	0.00182
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	RK	WS	3	0.02410	0.01717	0.00860	0.00788
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	RK	IWS	9	0.08970	0.03321	0.00620	0.02492
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-88	RK	WS	3	0.03200	0.02700	0.02300	0.00458
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	RK	WS	3	0.02950	0.02753	0.02630	0.00172
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	RK	WS	3	0.07140	0.05937	0.04190	0.01548
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88	RK		15	0.02040	0.01385	0.01050	0.00414
Ross Incineration Services	Grafton, OH	1	1	Mar-93	RK	PT/IWS	3	0.01000	0.00833	0.00700	0.00153
ThermalKEM	Rock Hill, SC	1	1	Jun-87	FH	WS	7	0.06700	0.05256	0.03450	0.01449
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	RK	SD/FF	8	0.00460	0.00168	0.00040	0.00140
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	RK	ESP	9	0.00350	0.00240	0.00100	0.00087
LWD, Inc.	Calvert City, KY	3	3	Jan-94	RK	FF/WS	3	0.01260	0.00685	0.00270	0.00514
	# of Facilities		17								
	# of Units		19								
	# of Data Sets		22								
	# of Data Points		133								

Comparison with the current population suggests that the PM data set is 61% complete. Appendix D presents a more detailed summary of the current PM data set.

Figure 4.3-1 presents the cumulative distribution of PM emissions. As shown in this figure, the data indicate that 50% of the commercial HW incinerators exhibit PM emissions of less than 0.0075 gr/dscf @ 7% O_2 based on the minimum reported data. Similarly, 50% of the population reported PM emissions of less than .012 and .02 gr/dscf @ 7% O_2 based on the average and maximum reported emissions, respectively.

4.4 On-Site Hazardous Waste Incinerator PM Emission Summary

Table 4.4-1 presents a summary of the PM data compiled to date. None of the data presented in Table 4.4-1 have been extracted from open literature or previous compilations. Currently, data have been compiled from 50 separate facilities and 53 separate units, with 61 separate data sets and a total of 392 data points. Comparison with the estimated total population suggests that the PM data set represents approximately 36% of the facilities. Appendix E presents a more detailed summary of the current PM data set.

Figure 4.4-1 presents the cumulative distribution of PM emissions. As shown in this figure, 50% of the data set exhibit PM emissions of less than 0.0075 gr/dscf @ 7% O_2 based on the minimum reported data. Similarly, 50% of the data set reported PM emissions of less than 0.012 and 0.02 gr/dscf @ 7% O_2 based on the average and maximum reported emissions, respectively. Note that for on-site incinerators, low efficiency or no PM control is used in many instances because of the low ash content in the combined (waste plus primary) fuel.

4.5 Hazardous Waste Burning Boiler PM Emission Summary

Table 4.5-1 presents the summary of the PM data compiled to date from CoC/Trial Burn reports. None of the data presented in Table 4.5-1 have been extracted from open literature or previous compilations. Currently, data have been compiled from 87 separate facilities and 135 separate units, with 141 separate data set and a total of 572 data points. Comparison with the total population suggests that the PM data set is 78% complete. Appendix F presents a more detailed summary of the current PM data set.

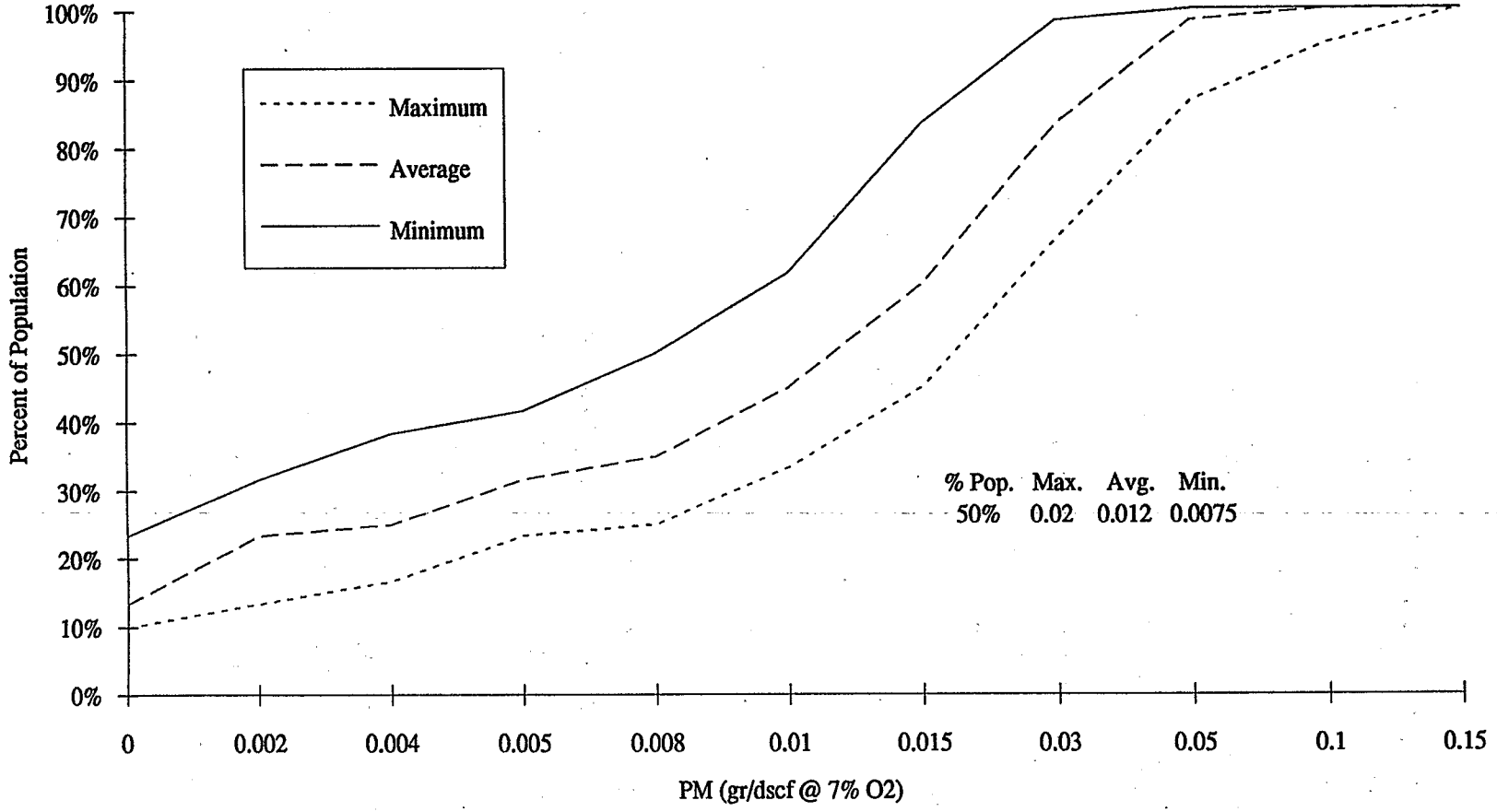

Figure 4.3-1. Cumulative distribution of HWI PM emissions.

OSHWI.pm/sum Chart 1

TABLE 4.4-1. SUMMARY OF PM DATA FOR ON-SITE HW INCINERATORS

Company	Location	Unit No. Tested	Report Date	Facility Type	APCS	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
3M	Cottage Grove, MN	1	Sep-90	RK	WS	8	0.107	0.05995	0.0368	0.024145
American Cyanamid	Hannibal, MO	1	Aug-89	LI & CA	PT	3	0.0577	0.0544	0.0489	0.004795
Amoco Oil	Whiting, IN	1	Jun-89	FB	C/VS	6	0.0649	0.04365	0.0303	0.015427
Aristech Chemical	Colton, CA	1	Jan-89		None	6	0.004	0.002833	0.001	0.001169
Ashland Chemical	Los Angeles, CA	1	Dec-88	LI	None	6	0.02	0.018667	0.011	0.006501
Burroughs Wellcome	Greenville, NC	2	Jan-93	LI	WS/ESP	9	0.0823	0.032056	0.0121	0.022656
Cargill	Lynwood, CA	1	Jul-89	LI	None	4	0.106	0.0505	0.014	0.039543
Cargill	Lynwood, CA	1	Jan-88	LI	None	3	0.0114	0.006933	0.0022	0.004606
Chevron	Belle Chase, LA	1	Feb-88	RH & LI	VS/PT	9	0.049	0.032	0.018	0.01254
Chevron	Philadelphia, PA	1	Sep-91	FB	VS/WS	5	0.0193	0.01978	0.0093	0.011075
Chevron	Richmond, CA	1	Jun-93	LI	VS	3	1.88E-05	1.82E-05	1.75E-05	6.51E-07
Chevron	Richmond, CA	1	Jul-88	LI	VS	9	0.0054	0.002311	0.0008	0.001606
Ciba-Geigy	MacIntosh, AL	1	Mar-90	RK	VS/PT/ESP	6	0.17	0.062333	0.02	0.056302
Ciba-Geigy	St. Gabriel, LA	1	May-88	LI	VS/Cyclone	9	0.066	0.042711	0.0253	0.01536
Cook Composites	Port Washington, WI	1	Apr-90	LI	?	3	0.039	0.037	0.034	0.002646
Department of the Army	Johnston Atoll	DFS	Jun-92	RK	VS/PBS	4	0.00191	0.001261	0.000485	0.000799
Department of the Army	Johnston Atoll	LIC	Jun-91	LI	VS/PBS	3	0.00183	0.001713	0.00161	0.000111
Department of the Army	Johnston Atoll	LIC	Jun-92	LI	VS/PBS	4	0.00196	0.001438	0.00072	0.000559
Department of the Army	Tooele, UT	??	Apr-92	RK	VS	4	0.01518	0.010988	0.00436	0.004955
Department of the Army	Tooele, UT	??	Oct-93	RK	VS	4	0.01349	0.011635	0.00802	0.002508
Dow Chemical Co.	Freeport, TX	1	Nov-88	RK	IWS	6	0.012	0.0075	0.004	0.00345
Dow Chemical Co.	Midland, MI	703	Jun-89	RK	VS/ESP	11	0.0492	0.019804	0.00516	0.017404
Dow Chemical Co.	Midland, MI	830	Mar-92	RK	VS/IWS	16	0.0366	0.008641	0.0001	0.012625
Dow Chemical Co.	Plaquemine, LA	1	Feb-88	RK	ESP/PBS	6	0.109	0.032192	0.00835	0.038227
Dupont	Deepwater, NJ	FR-1	Jun-89	LI	PT/CCS/RJS/ESP	3	0.0033	0.0029	0.0022	0.000608
Dupont	La Place, LA	1	Sep-89	RK & LI	WS	9	0.0443	0.0268	0.015	0.011897
Dupont	La Porte, TX	1	Mar-89	LI	FF	9	0.0127	0.002177	0.0004	0.003962
Dupont	La Porte, TX	CSI (1)	Jan-89	LI	WS	9	0.0567	0.036767	0.0149	0.011892
Dupont	La Porte, TX	N-THF	Feb-89	LI	WS	13	0.189	0.112769	0.042	0.04818
Dupont	Orange, TX	1	Aug-90	RK		6	0.002	0.00125	0.0005	0.000554
Dupont	Wilmington, DE	1	Dec-92	FH	SD/VS	6	0.0609	0.043633	0.0283	0.015178
Dupont	Louisville, KY	1	Jul-89	LI	WS	3	0.035	0.032333	0.031	0.002309
Eastman Kodak Co.	Rochester, NY		Sep-92	RK		9	0.078	0.052667	0.015	0.024052
Eli Lilly and Co.	Clinton, IN	C-10	Feb-89	??	VS/PT	10	0.0784	0.0415	0.0243	0.020123
Eli Lilly and Co.	Lafayette, IN	TJZ	Feb-89	LI	VS/PT	13	0.0448	0.032238	0.0245	0.007016
Eli Lilly and Co.	Mayaguez, PR	1	Nov-87	LI	PT/VS	3	0.0453	0.043567	0.0425	0.001514
First Chemical Corp.	Pascagoula, MS	1	Jul-91	??	??	9	0.0282	0.010922	0.0103	0.007875
Glaxo Inc.	R.T.P., NC	1	Oct-93	RH	DS/FF	6	0.00499	0.001935	0.00064	0.001587
Honeywell	Pinellas County, FL	1	Jun-88	LI	??	4	0.069	0.06	0.044	0.011343
Iowa Army	Middletown, IA	1	Nov-88	RK	FF	6	0.216	0.0835	0.009	0.088163
Iowa Army	Middletown, IA	1	Oct-91	RK	FF	6	0.0071	0.00495	0.0039	0.001102
Iowa Army	Middletown, IA	1	Jul-93	RK	FF	3	0.0153	0.0138	0.0126	0.001375
Iowa Army	Middletown, IA	1	Oct-91	RK	FF	9	0.0152	0.007344	0.0039	0.004078
Lake City Army	Independence, MO	1	Mar-93	RK	FF	6	0.035	0.028167	0.024	0.004355
M&T Chemicals	Carrollton, KY	1	Jan-89	RK	FF/WS	10	0.0436	0.01339	0.0057	0.013931
Miles Inc.	New Martinsville, WV	1	Sep-92	FB	ESP/WS	6	0.009	0.0065	0.004	0.002168

TABLE 4.4-1. SUMMARY OF PM DATA FOR ON-SITE HW INCINERATORS (Continued)

Company	Location	Unit No. Tested	Report Date	Facility Type	APCS	# points	PM (gr/dscf @ 7% O2)			
							Maximum	Average	Minimum	Sdev
Monsanto Agricultural Co.	Muscatine, IA	1	May-89	LI	PBS	15	0.114	0.07013	0.029	0.023727
Nepera Inc.	Herriman, NY	1	Feb-93	LI	??	3	0.0661	0.0375	0.023	0.024769
Nepera Inc.	Herriman, NY	1	Sep-92	LI	??	3	0.0271	0.022833	0.0207	0.003695
Occidental Chemical Corp.	Niagara Falls, NY	1	Feb-94	LI	IWS	3	0.0009	0.0017	0.0032	0.0013
Olin Corp.	East Alton, IL	2	Feb-92	SA	FF	4	0.00053	0.000291	0.00016	0.000173
Olin Corp.	Lake Charles, LA	1	Jan-89	LI	WS	15	0.053	0.02227	0.004	0.01758
Pfizer Inc.	Groton, CT	1	Jul-90	RH	WS	3	0.04	0.036	0.033	0.003606
Pfizer Pharmaceuticals Inc.	Barceloneta, PR	1	5/89	RK	VS/PT	3	0.0684	0.064933	0.0589	0.005244
Radford Army Ammo. Plnt	Radford, VA	6A	Jun-93	RK	FF/PBS	9	0.00638	0.00233	0.00077	0.002046
Thermal Oxidation Corp.	Roebuck, SC	1	Mar-87	LI	FF/WS	6	0.0109	0.005743	0.00153	0.003542
U.S. Dept. of Energy	Oak Ridge, TN	1	Aug-89	RK	VS/PB/IWS	3	0.0327	0.024933	0.0177	0.007514
Upjohn Co.	Kalamazoo, MI	1	Dec-90	RK	PT/VS	3	0.00602	0.003983	0.00187	0.002076
Vulcan Materials Co.	Wichita, KS	1	Apr-91	LI	WS	6	0.126	0.011362	0.00917	0.001342
Vulcan Materials Co.	Wichita, KS	1	Feb-91	LI	WS	8	0.035	0.022925	0.0149	0.006745

?? Unable to be determined from information given
na not available

# of Facilities	49
# of Units	52
# of Data Sets	60
# of Data Points	389

OSHWI.pm/sum

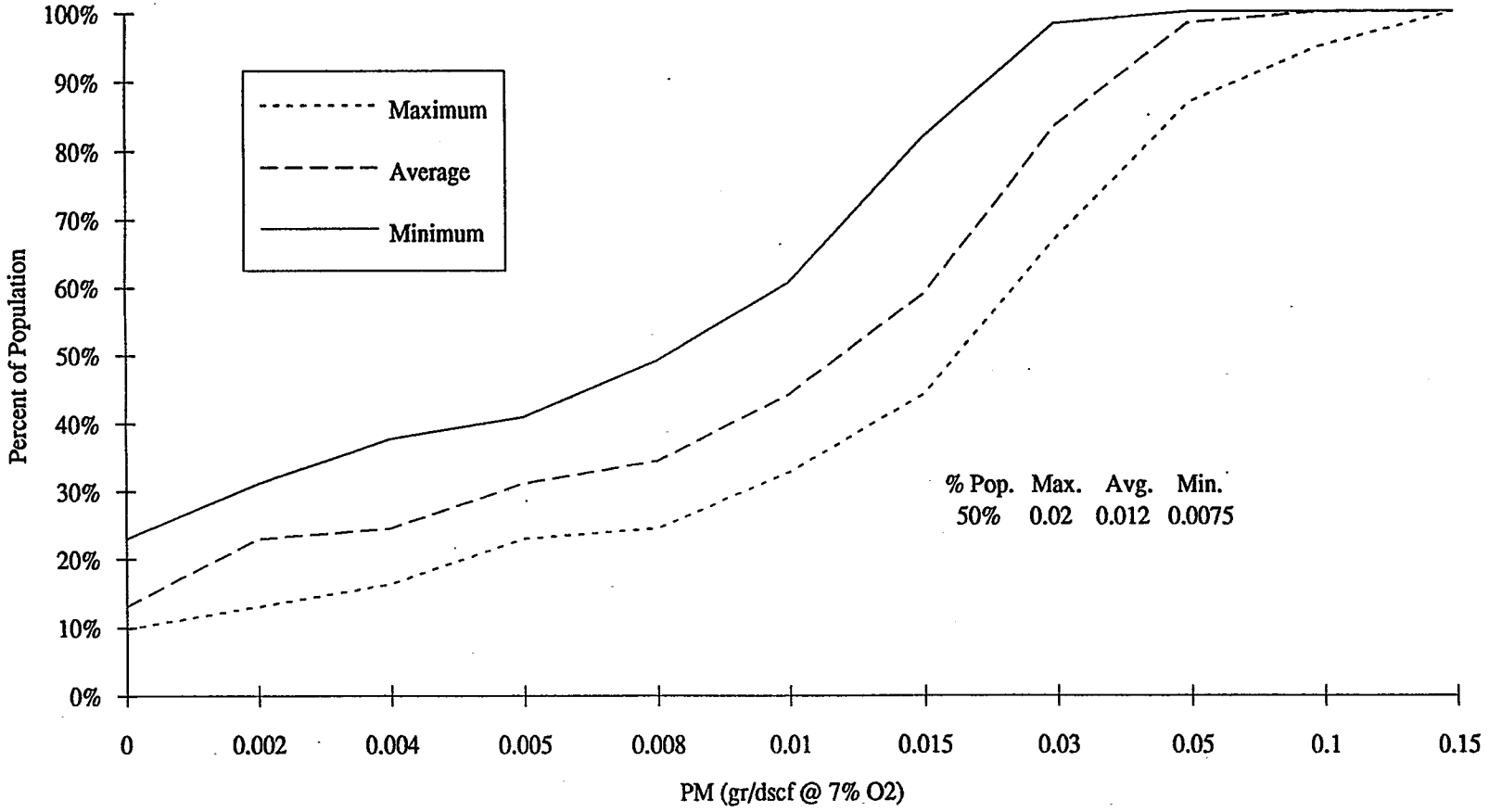

Figure 4.4-1. Cumulative distribution of on-site HW incinerator PM emissions.

TABLE 4.5-1. SUMMARY OF HW BURNING BOILER PM DATA

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	APCS	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
3M	Decatur, AL	1	Mar-92	Boiler		??	3	0.0038	0.00263	0.0013	0.00126
3M	Decatur, AL	1	Aug-92	Boiler		??	3	0.0092	0.00607	0.0034	0.00293
Air Products	Pasadena, TX	15.2	Jun-92	Boiler		??	6	0.0752	0.03143	0.009	0.02759
Air Products	Pasadena, TX	15.6	Jun-92	Boiler		??	7	0.0612	0.02944	0.0046	0.02549
Air Products	Wichita, KS	1	Aug-93	Boiler	Natural Gas	??	6	0.0316	0.02055	0.0125	0.00759
Allied Signal	Philadelphia, PA	BL-701	Aug-92	Boiler	Natural Gas	??	3	0.0287	0.02463	0.0213	0.00375
American Cyanamid Co.	Kalamazoo, MI	3	Mar-93	Boiler		??	6	0.0197	0.00965	0.0013	0.00877
American Cyanamid Co.	Wallingford, CT	1	Apr-93	Boiler	Solvents	None	6	0.0296	0.01062	0.0005	0.01304
Angus Chemical	Sterlington, LA	4	May-93	Boiler		??	3	0.0026	0.00180	0.0014	0.00069
Angus Chemical	Sterlington, LA	7	Apr-93	Boiler		??	3	0.0024	0.00157	0.0011	0.00072
ARCO	Channelview, TX	Boiler 1	Dec-92	Boiler		None	3	0.0052	0.00397	0.0033	0.00107
ARCO	Channelview, TX	Boiler 2	Aug-92	Boiler	Refinery Gas	None	3	0.0054	0.00397	0.0029	0.00129
ARCO	Channelview, TX	F-57180	Dec-92	Furnace		None	3	0.0048	0.00307	0.002	0.00151
ARCO	Channelview, TX	F-57180	Aug-92	Furnace	Refinery Gas	None	4	0.0127	0.01078	0.0099	0.00140
ARCO	Channelview, TX	F-630	Aug-92	Furnace	Refinery Gas	None	3	0.0032	0.00277	0.0023	0.00045
Aristech	Haverhill, OH	UB	Aug-92	Boiler			9	0.0159	0.00703	0.0012	0.00560
Arizona Chemical Co.	Gulfport, MS	1	Aug-92	Boiler	Oils &	None	13	0.024	0.01608	0.004	0.00492
Arizona Chemical Co.	Panama City, FL	2	Aug-92	Boiler (Waste)	Natural Gas	None	12	0.057	0.04025	0.016	0.01329
Arkansas Eastman	Magness, AR	1	May-92	Boiler	Coal	??	6	0.034	0.02270	0.0149	0.00695
BASF Corp.	Freeport, TX	1	Aug-92	Boiler (NEOL)	Liquid Waste	None	12	0.0216	0.01398	0.0042	0.00738
BASF Corp.	Geismar, LA	3	Aug-92	Boiler	Natural Gas	None	3	0.0044	0.00317	0.002	0.00120
BASF Corp.	Geismar, LA	6	Aug-92	Boiler	Natural Gas	None	3	0.0019	0.00153	0.0013	0.00032
BASF Corp.	Geismar, LA	Amines	Aug-92	Boiler	Waste Fuel	None	4	0.0065	0.00418	0.0025	0.00168
Bostik, Inc.	Middleton, MA	1	Dec-92	Boiler	Fuel Oil	??	3	0.0107	0.00853	0.0055	0.00271
BP Chemicals	Port Lavaca, TX	2	Aug-92	Boiler	Fuel Gas	??	3	0.002271	0.00173	0.001066	0.00061
Diversified Scientific Systems	Kingston, TN	1	Aug-93	Boiler	LW	SD/FF/WS/HEPA	3	0.00075	0.00043	0.00025	0.00028
Dow Chemical	Freeport, TX	B-901	Aug-92	Boiler	NG	WS	3	0.011	0.00500	0.002	0.00520
Dow Chemical	Freeport, TX	B-902	Aug-92	Boiler	NG	WS	3	0.009	0.00767	0.006	0.00153
Dow Chemical	Freeport, TX	B-903	Aug-92	Boiler	NG	WS	3	0.009	0.00500	0.003	0.00346
Dow Chemical	Freeport, TX	F-210	Aug-92	Boiler	NG	WS	3	0.017	0.00900	0.003	0.00721
Dow Chemical	Freeport, TX	F-2A/B	Aug-92	Boiler	FG	WS	3	0.016	0.01033	0.004	0.00603
Dow Chemical	Freeport, TX	F-820A	Aug-92	Boiler		WS	3	0.006	0.00600	0.006	0.00000
Dow Chemical	Freeport, TX	FTB-400	Aug-92	Boiler	FG	WS	3	0.003	0.00300	0.003	0.00000
Dow Chemical	Gales Ferry, CT	A	Aug-92	Heater	Fuel oil	None	3	0.0035	0.00240	0.0014	0.00105
Dow Chemical	Ironton, OH	1	Aug-92	Boiler	Oil	None	3	0.0019	0.00143	0.0011	0.00042
Dow Chemical	Midland, MI	1142	Aug-92	Boiler	Natural Gas	None	3	0.0316	0.01820	0.0098	0.01173
Dow Chemical	Midland, MI	1276	Aug-92	Boiler	Natural Gas	None	3	0.0016	0.00123	0.0009	0.00035
Dow Chemical	Plaquemine, LA	F-410	Aug-92	Boiler		??	3	0.0028	0.00343	0.0028	0.00057
Dow Chemical	Plaquemine, LA	R-4	Aug-92	Boiler		??	3	0.025	0.01800	0.014	0.00608
Dow Chemical	Plaquemine, LA	R-750	Aug-92	Boiler		??	3	0.072	0.05933	0.053	0.01097
Dow Chemical	Torrance, CA	U-305	Aug-92	Boiler		None	3	0.0021	0.00180	0.0013	0.00044
DSM Chemicals	Addis, LA	3	Aug-93	Boiler	Natural Gas	None	3	0.000605	0.00035	0.000092	0.00026
DSM Chemicals	Augusta, GA	H-002	Jul-92	Boiler		??	3	0.0053	0.00443	0.0039	0.00076
DSM Chemicals	Augusta, GA	H-2002	Jul-92	Boiler		??	3	0.0036	0.00210	0.0011	0.00132
Dupont	Axis, AL	1	Aug-93	Boiler (VGI)		WS	3	0.0405	0.03733	0.0332	0.00374
Dupont	Beaumont, TX	6	Aug-92	Boiler		??	3	0.0075	0.00707	0.0067	0.00040
Dupont	Belle, WV	1	Aug-92	Boiler	Coal	??	3	0.0013	0.00117	0.0011	0.00012
Dupont	Orange, TX	"#7"	Aug-92	Boiler	waste + NG	None	3	0.0112	0.00973	0.0077	0.00182

TABLE 4.5-1. SUMMARY OF HW BURNING BOILER PM DATA (Continued)

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	APCS	# points	Particulate (gr/dscf @ 7% O2)			
								Max	Avg	Min	Sdev
Dupont	Orange, TX	"#8"	Aug-92	Boiler	waste + NG	None	3	0.0481	0.02730	0.008	0.02009
Dupont	Orange, TX	North	Aug-92	Boiler (ADN)	ADN + NG	None	3	0.033	0.02783	0.0195	0.00729
Dupont	Orange, TX	South	Aug-92	Boiler (ADN)	ADN + NG	None	3	0.005	0.00400	0.003	0.00100
EPI	Toledo, OH	1	Aug-93	Boiler	Natural Gas	None	3	0.0185	0.01600	0.014	0.00229
EPI	Toledo, OH	2	Aug-93	Boiler	Natural Gas	None	3	0.0013	0.00120	0.001	0.00017
Ethyl Corp.	Orangeburg, SC	"4"	Aug-93	Boiler	WL	FF	6	0.0027	0.00157	0.001	0.00067
Exxon Chemical	Baton Rouge, LA	"C"	Aug-92	Boiler	Waste Liquid	None	3	0.0021	0.00187	0.0016	0.00025
Exxon Chemical	Baton Rouge, LA	"D"	Aug-92	Boiler	Waste Liquid	None	3	0.0035	0.00280	0.0024	0.00061
FINA Oil	Deer Park, TX	1	Oct-92	Boiler	W	VS	9	0.0574	0.04401	0.0324	0.00821
General Electric Plastics	Mount Vernon, IN	"A"	Feb-93	Boiler	NG + Phenol	None	4	0.078	0.05967	0.044	0.01716
General Electric Plastics	Mount Vernon, IN	"B"	Feb-93	Boiler	NG +phenol	None	6	0.0769	0.05083	0.033	0.01808
General Electric Plastics	Selkirk, NY	1	Aug-92	A/P Oil Heater	Natural Gas	None	3	0.032	0.02233	0.013	0.00950
General Electric Plastics	Selkirk, NY	3	Aug-92	Boiler	Natural Gas	None	3	0.078	0.05633	0.043	0.01893
Georgia Gulf	Pasadena, TX	1	Aug-92	Hot Oil Heater		None	6	0.0174	0.01070	0.0059	0.00514
Georgia Gulf	Plaquemine, LA	1	Aug-92	Boiler	Natural Gas	None	3	0.0521	0.05143	0.0504	0.00091
Goodyear Tire and Rubber	Beaumont, TX	B103	Aug-92	Boiler	Natural Gas	None	3	0.047	0.02467	0.013	0.01935
Goodyear Tire and Rubber	Pasadena, TX	M-526	May-93	Boiler	Natural Gas	None	3	0.0086	0.00710	0.0055	0.00155
Hercules	West Elizabeth, PA	3	Aug-92	Boiler	Natural Gas	None	3	0.0286	0.02460	0.022	0.00352
Hercules	West Elizabeth, PA	5	Aug-92	Boiler	Natural Gas	None	3	0.025	0.01507	0.006	0.00953
Hoechst Celanese	Pasadena, TX	MH5A	Jan-93	Heater	Natural Gas	None	9	0.0056	0.00281	0.0008	0.00185
Hoechst Celanese Chemical	Bay City, TX	4	Aug-92	Boiler	Natural Gas	None	4	0.0235	0.02110	0.0156	0.00373
Hoechst Celanese Chemical	Bay City, TX	5	Aug-92	Boiler	Natural Gas	None	3	0.0165	0.01447	0.0125	0.00200
Hoechst Celanese Chemical	Mount Holly, NC	1	Aug-93	Boiler	Natural Gas	None	3	0.044	0.01534	0.00011	0.02484
Hulls America	Chestertown, ML	1	Nov-92	Heater	Oil	None	3	0.0733	0.04427	0.0285	0.02517
Hulls America	Chestertown, ML	2	Nov-92	Heater	Oil	None	4	0.032	0.02825	0.026	0.00263
Hulls America	Chestertown, ML	3	Nov-92	Heater	Oil	None	3	0.0317	0.01830	0.0097	0.01176
Hulls America	Chestertown, ML	4	Nov-92	Boiler	Oil	None	3	0.0153	0.01367	0.0018	0.00176
Kalama Chemical	Kalama, WA	U2	Jun-92	Boiler	NG	FF	6	0.0072	0.00460	0.0027	0.00174
Kalama Chemical	Kalama, WA	U3	Jun-92	Boiler	NG	FF	6	0.0073	0.00532	0.0036	0.00147
Lonza Inc.	Pasadena, TX	1 or A	Dec-92	Boiler	Natural Gas	??	6	0.0409	0.02865	0.0153	0.01095
Lonza Inc.	Pasadena, TX	2 or B	Dec-92	Boiler	Natural Gas	??	6	0.0137	0.00930	0.0069	0.00250
Lyondell Petrochem Co.	Channelview, TX	4	Nov-92	Boiler	Waste Oils	None	6	0.007142	0.00339	0.00082	0.00275
Mallinckrodt	Raleigh, NC	1	Sep-92	Boiler	Aniline Tar	??	3	0.00445	0.00391	0.00336	0.00055
Maybelline Products Co. Inc.	North Little Rock, AR	TO4	Aug-92	Boiler		??	6	0.094	0.08267	0.072	0.00745
Mayo Clinic	Rochester, MN	3	Nov-92	Boiler	Natural Gas/	None	3	0.00282	0.00246	0.00186	0.00052
Merck & Co. Inc.	Rahway, NJ	7	Jul-93	Boiler	Natural Gas/	??	3	0.0101	0.00820	0.00797	0.00022
Merck & Co. Inc.	Rahway, NJ	8	Jul-93	Boiler	Natural Gas/	??	3	0.00996	0.00781	0.00566	0.00215
Merichem Co.	Houston, TX	4	Sep-92	Boiler	NG & LW	WS	6	0.0105	0.00452	0.0021	0.00302
Mobile Chemical	Beaumont, TX	B 701 A	Aug-92	Boiler	Natural Gas	None	3	0.0122	0.00793	0.0043	0.00399
Monsanto Chemical Co.	Addyston, OH	B - 4	Aug-92	Boiler	Natural Gas	None	3	0.00374	0.00303	0.00242	0.00067
Monsanto Chemical Co.	Alvin, TX	30H5	Aug-92	Boiler	Natural Gas	None	6	0.00026	0.00013	0	0.00017
Monsanto Chemical Co.	Alvin, TX	B51H5	Apr-93	Boiler	Natural Gas	None	6	0.0006	0.00033	0.0002	0.00015
Monsanto Chemical Co.	Nitro, WV	B-8	May-93	Boiler (Stoker)	Coal	ESP/Cycl	6	0.007	0.00347	0.0007	0.00229
Monsanto Chemical Co.	Springfield , MA	B-11	Jan-93	Boiler (Stoker)	Coal	FF	3	0.01	0.00840	0.0087	0.00177
Natural Gas Odorizing	Baytown, TX	B-2	Oct-92	Boiler	LW	DS/FF/WS	3	0.006	0.00540	0.005	0.00053
Neville Chemical Co.	Pittsburgh, PA	B-4	Jul-93	Boiler	Natural Gas	None	3	0.0074	0.00420	0.0019	0.00286
Neville Chemical Co.	Pittsburgh, PA	B-6	Jul-93	Boiler	Natural Gas	None	3	0.0029	0.00227	0.0016	0.00065
Neville Chemical Co.	Pittsburgh, PA	B-7	Jul-93	Boiler	Natural Gas	None	3	0.0048	0.00423	0.0032	8.96E-04
Novacar Chemicals	Decatur, AL	Line 1	May-93	Therminol	Liquid waste	None	3	0.0015	0.00127	0.0011	0.00021

TABLE 4.5-1. SUMMARY OF HW BURNING BOILER PM DATA (Continued)

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	APCS	# points	Particulate (gr/dscf @ 7% O2)			
								Max	Avg	Min	Sdev
Novacar Chemicals	Indian Orchard, MA	1	Jun-93	Therminol	Liquid waste	None	3	0.00692	0.00396	0.00142	0.00277
NutraSweet	Augusta, GA	1	Aug-92	Boiler	WF	WS	3	0.0153	0.01507	0.0148	0.00025
NutraSweet	Augusta, GA	2	Aug-92	Boiler	WF	WS	3	0.0053	0.00491	0.00463	0.00035
Parke Davis	Holland, MI	??	Aug-92	Boiler	Natural Gas/	??	3	0.0028	0.00210	0.0016	0.00062
Reilly Industries	Indianapolis, IN	1	Aug-93	Boiler	Natural Gas	None	9	0.0337	0.02218	0.0141	0.00525
Reilly Industries	Indianapolis, IN	2	Aug-93	Boiler	Natural Gas	None	9	0.0321	0.01444	0.0064	0.00886
Rhone-Poulenc	Institute, WV	3	Aug-92	Boiler	FG	ESP	3	0.0193	0.01333	0.01	0.00518
Richmond Gravure	Richmond, VA	1	Jan-93	Boiler	Natural Gas/	None	6	0.0016	0.00053	0	0.00072
Rohm and Haas	Bristol, PA	1	Oct-92	Boiler	Oil Fired	None	3	0.0169	0.01327	0.0111	0.00317
Rohm and Haas	Deer Park, TX	1	Aug-92	Boiler	Natural Gas	??	3	0.003	0.00200	0.001	0.00100
Rohm and Haas	Louisville, KY	100	Mar-93	Boiler	Oil/Solvents	??	6	0.0156	0.01212	0.0092	0.00260
Rohm and Haas	Philadelphia, PA	2	Dec-92	Boiler	Natural Gas/	None	6	0.0258	0.01417	0.0052	0.00960
Rubicon	Geismar, LA	Aniline II	Aug-92	Boiler		FF	3	0.0766	0.06523	0.0427	0.01951
Rubicon	Geismar, LA	DPA I	Aug-92	Superheater		??	3	0.0128	0.01237	0.0121	0.00038
Rubicon	Geismar, LA	DPA II	Aug-92	Superheater		??	3	0.013	0.00970	0.0078	0.00287
Rubicon	Geismar, LA	TDI	Aug-92	Boiler	NG	WS	3	0.0056	0.00387	0.0018	0.00192
S.C. Johnson and Sons Inc.	Sturtevant, WI	1	Jun-93	Boiler	Natural Gas	None	3	0.0715	0.06507	0.0573	0.00719
Schenectady Chemical	Freeport, TX	B-503	Aug-93	Boiler		??	3	0.0059	0.00403	0.0022	0.00185
Schenectady Chemical	Rotterdam Junction, NY	4	Mar-89	Boiler		None	3	0.0299	0.02793	0.0256	0.00217
Shell Chemical	Belpre, OH	2	Aug-92	Boiler	Coal	ESP	6	0.07	0.04400	0.034	0.01417
Shell Chemical	Deer Park, TX	FUT 100	May-93	Boiler	Liquid Waste	None	3	0.0165	0.01580	0.0146	0.00104
Shell Chemical	Deer Park, TX	FUT 130	May-93	Boiler	Liquid Waste	None	3	0.0224	0.02023	0.0185	0.00199
Shell Chemical	Deer Park, TX	FUT100	Dec-92	Boiler	Natural Gas	None	3	0.0633	0.05277	0.0387	0.01267
Shell Chemical	Deer Park, TX	FUT130	Dec-92	Boiler	Natural Gas	None	3	0.0352	0.03047	0.0255	0.00485
Shell Oil	Martinez, CA	Co #2	Nov-91	Boiler (CO)	RG	ESP	7	0.0028	0.00221	0.0014	0.00050
Shell Oil	Martinez, CA	Co#1	Apr-89	Boiler (CO)		ESP	9	0.286	0.05133	0.011	0.08934
Sterling Chemicals	Texas City, TX	UB 9	Aug-93	Boiler	Natural Gas	None	3	0.0138	0.01060	0.0088	0.00278
Sterling Chemicals	Texas City, TX	WOB 1	Aug-92	Boiler	Vent Gas	None	3	0.007	0.00500	0.002	0.00265
Sterling Pharmaceutical	Barceloneta,PR	1	Aug-93	Boiler	Natural Gas	None	9	0.0382	0.03480	0.0285	0.00303
Tennessee Eastman	Kingsport, TN	19	Aug-92	Boiler	Coal	ESP	3	0.0562	0.05420	0.0527	0.00180
Tennessee Eastman	Kingsport, TN	21	Apr-91	Boiler	Coal	ESP	3	0.0184	0.01720	0.0158	0.00131
Tennessee Eastman	Kingsport, TN	23	Aug-92	Boiler	Coal	ESP	3	0.0545	0.03930	0.0237	0.01540
Tennessee Eastman	Kingsport, TN	24	Apr-91	Boiler	Coal	ESP	3	0.00538	0.00530	0.00521	8.62E-05
Tennessee Eastman	Kingsport, TN	30	Aug-92	Boiler	Coal	ESP	3	0.0095	0.00907	0.0087	0.00040
Tennessee Eastman	Kingsport, TN	30	Aug-92	Boiler	Coal	ESP	3	0.0675	0.04893	0.031	0.01826
Tennessee Eastman	Kingsport, TN	30	Aug-92	Boiler	Coal	ESP	3	0.0061	0.00593	0.0057	0.00021
Texaco Chemical Co.	Port Neches, TX	2	Oct-92	Boiler	Natural Gas	None	3	0.00617	0.00477	0.00406	0.00121
Union Carbide	Hahnville, LA	B 30	Jun-93	Boiler	60% H	None	3	0.0017	0.00107	0.0007	0.00055
Union Carbide	Hahnville, LA	B 31	Jun-93	Boiler	60% H	None	3	0.021	0.01890	0.0177	0.00182
Union Carbide	South Charleston, WV	16	Feb-93	Boiler	Coal	ESP	3	0.0781	0.06963	0.061	0.00855
Union Carbide	South Charleston, WV	25	Feb-93	Boiler	Coal	ESP	3	0.0075	0.00703	0.0066	0.00045
Union Carbide	Texas City, TX	4	Aug-93	Boiler	Natural Gas	None	3	0.0597	0.02703	0.0075	0.02847
Union Carbide	Texas City, TX	5	Oct-92	Boiler	Natural Gas	None	3	0.0404	0.01770	0.0063	0.01966
Westvaco Corp.	DeRidder, LA	B2 & B4	Aug-92	Boiler	NG	ESP	3	0.0295	0.01727	0.008	0.01105

* indicates that a soot blow was performed during this run
** Sootblow weighted average for runs indicated
?? Unable to be determined from information given

# of Facilities 87
# of Units 135
# of Data Sets 141
# of Data Points 572

Figure 4.5-1 presents the cumulative distribution of PM emissions. As shown in this figure, 50% of the data set exhibit PM emissions of less than 0.003 gr/dscf @ 7% O_2 based on the minimum reported data. Similarly, 50% of the reported PM emissions are less than 0.004 and 0.008 gr/dscf @ 7% O_2 based on the average and maximum reported emissions, respectively. Note that for the boiler population, low efficiency or no PM control is used at a significant number of the facilities because of low ash content fuel usage. This is considered in identifying the best performing facilities in the next chapter.

4.6 Dioxin/Furan Formation Mechanisms

A significant body of work has been completed to identify the emission characteristics, formation mechanisms, and applicability and performance of APCDs to control polychlorinated dibenzo-p-dioxin (PCDD) and polychlorinated dibenzo furan (PCDF) emissions. Within the U.S., a preponderance of the work thus far has focused on Municipal Waste Combustors (MWCs) and Medical Waste Incinerators (MWIs) as a result of the ongoing development of New Source Performance Standards (NSPS's). The degree of applicability of the body of experience acquired in the development of the MWC/MWI NSPS's to the population of cement kilns, lightweight aggregate kilns, and hazardous waste incinerators is determined in part by similarities in emissions characteristics found between the various combustion sources.

Laboratory research has produced PCDD/PCDF when simulating post-furnace conditions of MWCs. Experiments with MWC fly ash have shown substantial dioxin/furan formation when treated under temperature and gas composition conditions similar to those found in the post furnace region of an MWC [1,2]. Maximum formation of PCDD/PCDF's using MWC fly ash plugs has been shown to occur around 300 °C [3]. Maximum PCDD/PCDF formation in the absence of fly ash, using PCDD/PCDF precursors (phenol, Cl_2, O_2, Cu based catalysts), has been shown to occur around 400 °C [4]. Experiments with both HCl and Cl_2 without fly ash surfaces have shown that the chlorination of phenol is more than 4 orders of magnitude greater with Cl_2 than with HCl [5]. In the absence of available Cl_2, the Deacon process of chlorine production from HCl in the presence of a copper-based catalyst, followed by chlorination of aromatic ring structures through substitution reactions, has been proposed [6] and validated [7,8]. The importance of the roles of both the fly ash and flue gas characteristics in the formation of PCDD/PCDF can be seen in recent experiments conducted to explain the apparent reduced PCDD/PCDF levels found from coal- fired boilers. Experiments have been completed [9] documenting the potential for sulfur "poisoning" of the copper-based catalysts necessary in the Deacon reaction. These experiments have shown that while the gas phase SO_2 has little effect on the production of PCDD, the reaction of the SO_2 with

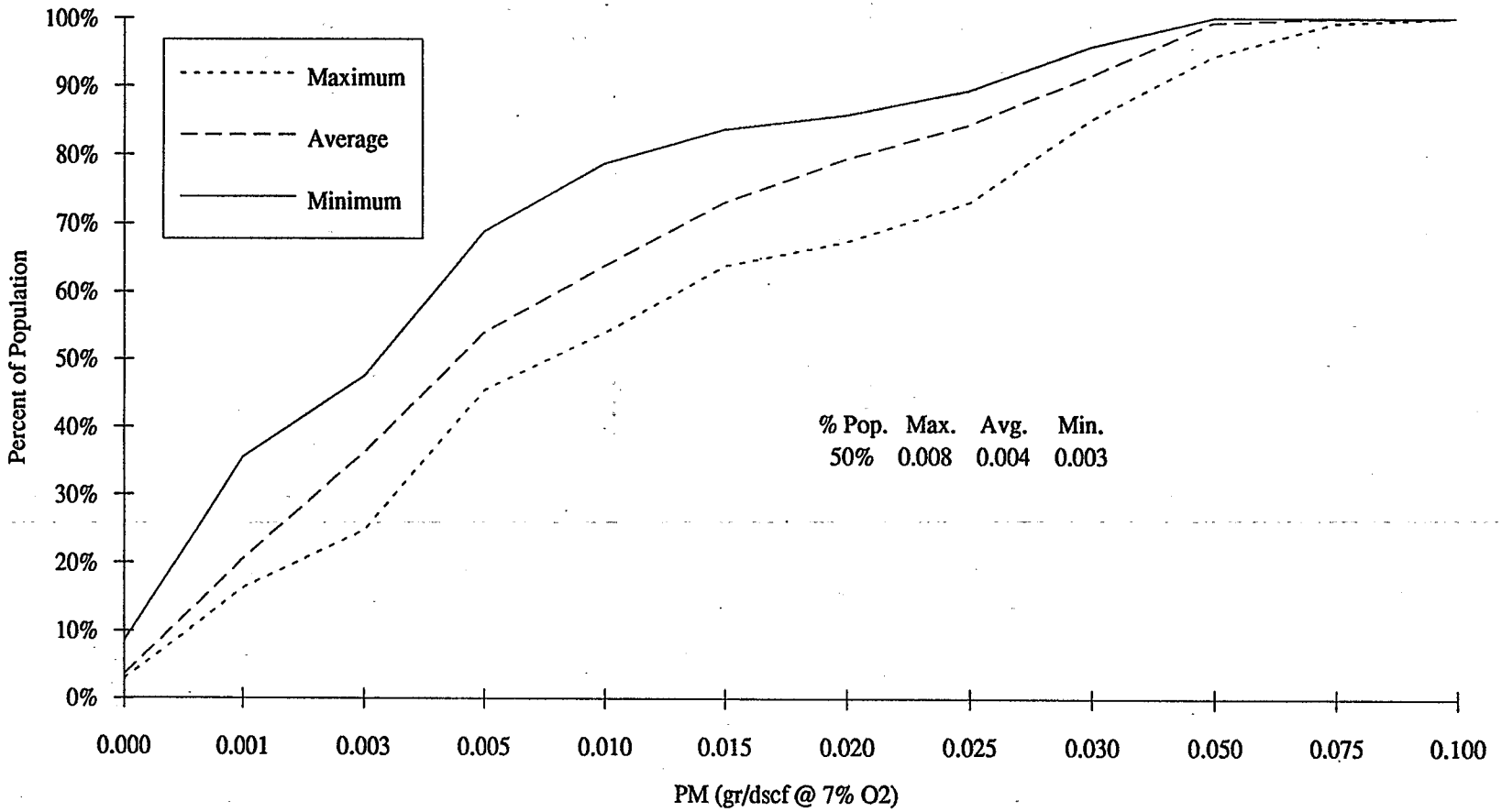

Figure 4.5-1. Cumulative distribution of PM emissions for hazardous waste burning boilers.

BLR.pm/sum.all Chart 1

the available copper in the fly ash to form $CuSO_4$ produces a less active catalyst for the synthesis of PCDD.

Based on the above discussion, the role of the fly ash in both the ability to reduce PCDD/PCDF emissions exiting the high temperature regions of the furnace, and the formation of PCDD/PCDF in post combustion regions, is summarized below.

(1) The carbonaceous content of the fly ash provides active sites for adsorption of PCDD/PCDF exiting the high temperature region of the furnace. This adsorption (chemi-sorption) of PCDD/PCDF by the PM provides the basic mechanism of particulate control as a means of removing PCDD/PCDF formed upstream of the APCD. The effectiveness of activated carbon injection as a means of PCDD/PCDF control is based on the adsorption of the PCDD/PCDF. Additionally, the higher PCDD/PCDF emission levels found from MWIs over MWCs with similar flue gas characteristics have been attributed to the lower carbon content in the fly ash found in MWIs over MWCs [10].

(2) The PM provides active sites for the adsorption of PCDD/PCDF precursors, allowing surface chlorination and formation of PCDD/PCDF which subsequently may or may not be de-adsorbed from the PM.

(3) The PM itself may provide PCDD/PCDF precursors. These may be chlorinated on the PM, leading to the production of PCDD/PCDF which subsequently may or may not be de-adsorbed from the PM.

(4) The particulate matter provides copper-based catalyst sites for the production of Cl_2 through the Deacon reaction for subsequent chlorination of PCDD/PCDF precursors.

(5) The particulate matter provides carbon for the de novo synthesis of PCDD/PCDF with O_2 and Cl_2.

While the above discussion emphasizes the role of particulate matter in the post combustion production and capture of PCDD/PCDF, it is important to note that other parameters can dominate the production of PCDD/PCDF, and tight post combustion control of PM emissions without

attention to these other parameters can lead to higher, not lower, dioxin/furan emissions. It is also important to note that the above discussion does not imply that low PM emissions are necessarily accompanied by low dioxin emissions. As will be discussed further in the next chapter, it is possible to minimize post combustion formation of dioxin by limiting APCD inlet temperatures (for example, by rapidly quenching combustion gases). When this occurs, low dioxin/furan emissions can be achieved without significant PM control.

As will be discussed further in this Chapter and in Chapter 5, it appears to be quite possible for HW burning facilities with moderate or even no PM control to exhibit low PCDD/PCDF emissions. Similarly, facilities can exhibit extremely high dioxin/furan emissions in the presence of very low PM emissions.

There are additional parameters which can influence dioxin/furan emissions. The Office of Solid Waste, through the Air and Energy Engineering Research Laboratory (AEERL) in Research Triangle Park, has initiated a parametric study evaluating the effect of Cl, HCl, Na and various combustion parameters on dioxin formation. This study will initially utilize cement kiln dust to establish the relative reactivity in forming dioxin/furan.

4.6.1 Historical Basis For Technology-Based Dioxin/Furan Regulations

It is important to note the form of the PCDD/PCDF regulation adopted by the EPA air program and to contrast that limit to regulations developed by several states and foreign governments. The EPA NSPS sets a limit on the sum of the mass concentration of tetra- through octa-chlorinated dibenzo-p-dioxin and dibenzofuran homologues. An objection often expressed about this type of quantification is that it does not account for the significant variability in toxicity of different PCDD and PCDF isomers. An alternate system used by several states and most European countries is to apply weighting functions to the measured mass emission rate of each PCDD and PCDF congener, thereby accounting for the relative toxicity of the different congener groups. A relative toxicity of 1.0 is assigned to 2, 3, 7, 8 tetra-chlorinated dibenzo-p-dioxin, since it is the most toxic of the various congeners. Other congeners are assigned smaller weighting functions, known as Toxicity Equivalence Factors (TEFs), to account for their toxicity relative to 2, 3, 7, 8 TCDD. Emission rates calculated though application of TEFs are referred to as Toxic Equivalents, or TEQs. For the NSPS process, the EPA rejected that approach, arguing that TEFs are not permanent and are subject to revision. The EPA further argued that a TEQ-based standard would create confusion because, given current knowledge, there was no way to select or operate a technology for control of specific PCDD/PCDF isomers.

For purposes such as development of risk assessments, the most direct choice is to use the TEQ process. Table 4.6-1 lists six different TEF schemes suggested by various international groups, including the EPA. The columns labeled UBA, BUS, and Nordic refer to TEQ weighting systems established in Ontario, Canada, in Switzerland, and in the Nordic countries of Europe, respectively. As shown, there are differences between the various systems. Recently, the EPA decided to abandon its system of TEFs in favor of the NATO compilation.

Notwithstanding the EPA's decision in the NSPS process, several states have adopted a risk-based standard for MWC PCDD/PCDF emissions, limiting the stack TEQ rather than total mass of PCDDs/PCDFs. For instance, Pennsylvania has a TEQ limit of 1 ng/dscm and New York has a limit of 2 ng/dscm. Under the New York regulation, a facility must show an effort to meet a TEQ target value of 0.2 ng/dscm. Conversely, Kentucky and Minnesota established limits on total PCDD/PCDF mass emissions but set maximum allowable concentration above the Federal limit. Internationally, most European countries have selected the weighted TEQ system. The fact that PCDD/PCDF emission regulations are expressed in both total mass and TEQ raises the issue regarding the relationship between the two.

4.7 Cement Kiln Dioxin Emission Characteristics

Dioxin emission data (both total ng/dscm and TEQ) have been extracted from the CoC/Trial Burn Reports. In general, this body of data is less complete than in the case of PM emissions. Table 4.7-1 summarizes the current body of dioxin data reported in total ng/dscm. Appendix G contains a more detailed summary of the total dioxin data. Currently, data are available from 14 separate facilities on 23 separate kilns, with a total of 24 sets of multiple dioxin runs and a total of 86 data points. Comparison with the estimated total population suggests that the kiln total PCDD/PCDF data set is approximately 46% complete. Note that the kilns are not actually controlling dioxin emissions, and the data does not indicate the emission levels that could be achieved.

Figure 4.7-1 presents the cumulative distribution of total dioxin/furan emissions from cement kilns. As shown in this figure, the data indicate that 50% of the reported minimum dioxin/furan emissions are less than 20 ng/dscm. Similarly, 50% of the reported average and maximum dioxin/furan data are less than 70 and 100 ng/dscm, respectively.

Table 4.7-2 summarizes the current body of dioxin data reported in TEQ. Appendix H presents a more detailed summary of the cement kiln TEQ data. Currently, data are available from 16 facilities and 25 kilns. There are 26 separate data sets with a total of 85 data points.

TABLE 4.6-1. COMPARISON OF TOXIC EQUIVALENT FACTOR WEIGHTING SCHEMES

	Toxic Equivalent Factors					
Congeners	*(NATO/CCMS) (I-TEF)*	*Eadon 86 (83)*	*EPA*	*UBA*	*BUS*	*Nordic*
2,3,7,8-TCDD	1	1	1	1	1	1
not 2,3,7,8-TCDDs			0.01	0.01	0.01	
1,2,3,7,8-PeCDD	0.5	1	0.5	0.1	0.1	0.5
not 2,3,7,8-PeCDDs			0.005	0.01	0.1	
2,3,7,8-HxCDD		0.033 (0.03)	0.04	0.1	0.1	0.1
not 2,3,7,8-HxCDDs			0.0004	0.01	0.1	
1,2,3,4,7,8-HxCDDs	0.1					
1,2,3,6,7,8-HxCDDs						
1,2,3,7,8,9-HxCDDs						
2,3,7,8-HpCDD			0.001	0.01	0.01	0.01
not 2,3,7,8-HpCDD			0.001	0.001	0.01	
1,2,3,4,6,7,8-HpCDD	0.01					
OCDD	0.001				0.001	0.001
2,3,7,8-TCDF	0.1	0.33	0.1	0.1	0.1	0.1
not 2,3,7,8-TCDFs			0.001	0.01	0.1	
1,2,3,7,8-PeCDF	0.05					0.01
2,3,4,7,8-PeCDF	0.5					0.5
2,3,7,8-PeCDF		0.33	0.1	0.1	0.1	
not 2,3,7,8-PeCDFs			0.001	0.01	0.1	
2,3,7,8-HxCDF		0.021 (0.011)	0.01	0.1	0.10	0.1
not 2,3,7,8-HxCDFs			0.0001	0.01	0.1	
1,2,3,4,7,8-HxCDF	0.1					
1,2,3,7,8,9-HxCDF						
1,2,3,6,7,8-HxCDF						
2,3,4,6,7,8-HxCDF						
2,3,7,8-HpCDF			0.01	0.01	0.1	0.01
not 2,3,7,8-HpCDFs			0.00001	0.001	0.1	
1,2,3,4,6,7,8-HpCDFs	0.01					
1,2,3,4,7,8,9-HpCDFs						
OCDF	0.001					0.001

Sources: Department of the Environment, United Kingdom (1989), Carlsson (1988)

TABLE 4.7-1. SUMMARY OF CEMENT KILN DIOXIN DATA IN TOTAL NG/DSCM

Company	Location	Unit Tested	Report Date	Facility Type	APCS	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Chanute, KS	1	Apr-92	w	ESP	4	277.3	156.2000	68.56	87.3979
Ash Grove Cement Co.	Chanute, KS	2	Mar-92	w	ESP	4	556.57	303.8175	158.84	174.7120
Ash Grove Cement Co.	Foreman, AR	1	Jul-92	w	ESP	4	874.64	327.3500	72.34	374.7511
Ash Grove Cement Co.	Foreman, AR	2	Jul-93	w	ESP	3	9.68	5.3200	2.88	3.7848
Ash Grove Cement Co.	Foreman, AR	2	May-92	w	ESP	3	62.35	32.2700	14.19	26.2268
Ash Grove Cement Co.	Foreman, AR	3	Jul-92	w	ESP	3	160.9	99.7333	58.8	53.9735
Ash Grove Cement Co.	Louisville, NE	1	May-92	sd (ph/bp)	ESP	5	16.28	8.4400	4.96	4.5866
Ash Grove Cement Co.	Louisville, NE	2	Aug-92	d (ph/pc/bp)	ESP	4	20.69	12.8700	8.28	5.7731
Continental Cement Co.	Hannibal, MO	1	Dec-90	w	ESP	2	630	476.0000	322	217.7889
Continental Cement Co.	Hannibal, MO	1	Jul-92	w	ESP	3	1369	1209.1967	952.32	224.6619
Essroc Materials	Logansport, IN	1	Aug-92	w	ESP	4	1863	1542.7500	1295	235.7122
Holnam Inc.	Holly Hill, SC	1	Aug-92	w	ESP	6	198	70.9000	5.6	81.4300
Holnam Inc.	Holly Hill, SC	2	Aug-92	w	ESP	4	409	182.8750	2.2	211.3549
Holnam, Inc.	Artesia, MS	1	Aug-93	w	ESP	3	58.9	41.8633	19.12	20.4948
Keystone Cement Co.	Bath, PA	1	Aug-92	w	ESP	3	2.66	2.4133	1.98	0.3765
Keystone Cement Co.	Bath, PA	2	Aug-92	w	ESP	3	0.77	0.6833	0.59	0.0902
Lafarge Corp.	Fredonia, KS	1	Aug-92	w	ESP	3	1066.37	827.7100	627.96	221.7799
Lafarge Corp.	Fredonia, KS	2	Aug-92	w	ESP	3	950	525.4667	280.4	369.1169
Medusa Cement Co.	Wampum, PA	3	Jul-92	d	ESP	3	2174	1603.3333	1093	543.0196
Medusa Cement Co.	Wampum, PA	1,2	Jul-92	d	ESP	3	3172	2392.3333	1598	787.1025
National Cement Co.	Lebec, CA	1	Aug-92	d	FF	3	6.91	6.5967	6.23	0.3431
River Cement Co.	Festus, MO	1	Oct-92	d	ESP	3	2299	2008.3333	1599	364.7757
Southdown/Dixie	Knoxville, TN	1	Mar-92	d (ph/pc/bp)	FF	6	112.05	31.7450	8.45	39.7863
Southdown/Kosmos	Kosmosdale, KY	1	May-92	d (ph)	FF	4	121.52	111.2975	95.67	11.3203

w: wet kiln	# of Facilities	14
d: dry kiln	# of Kilns	23
sd: semi-dry kiln	# of Data Sets	24
ph: preheater	# of Data Points	86
pc: precalciner		
bp: by-pass		

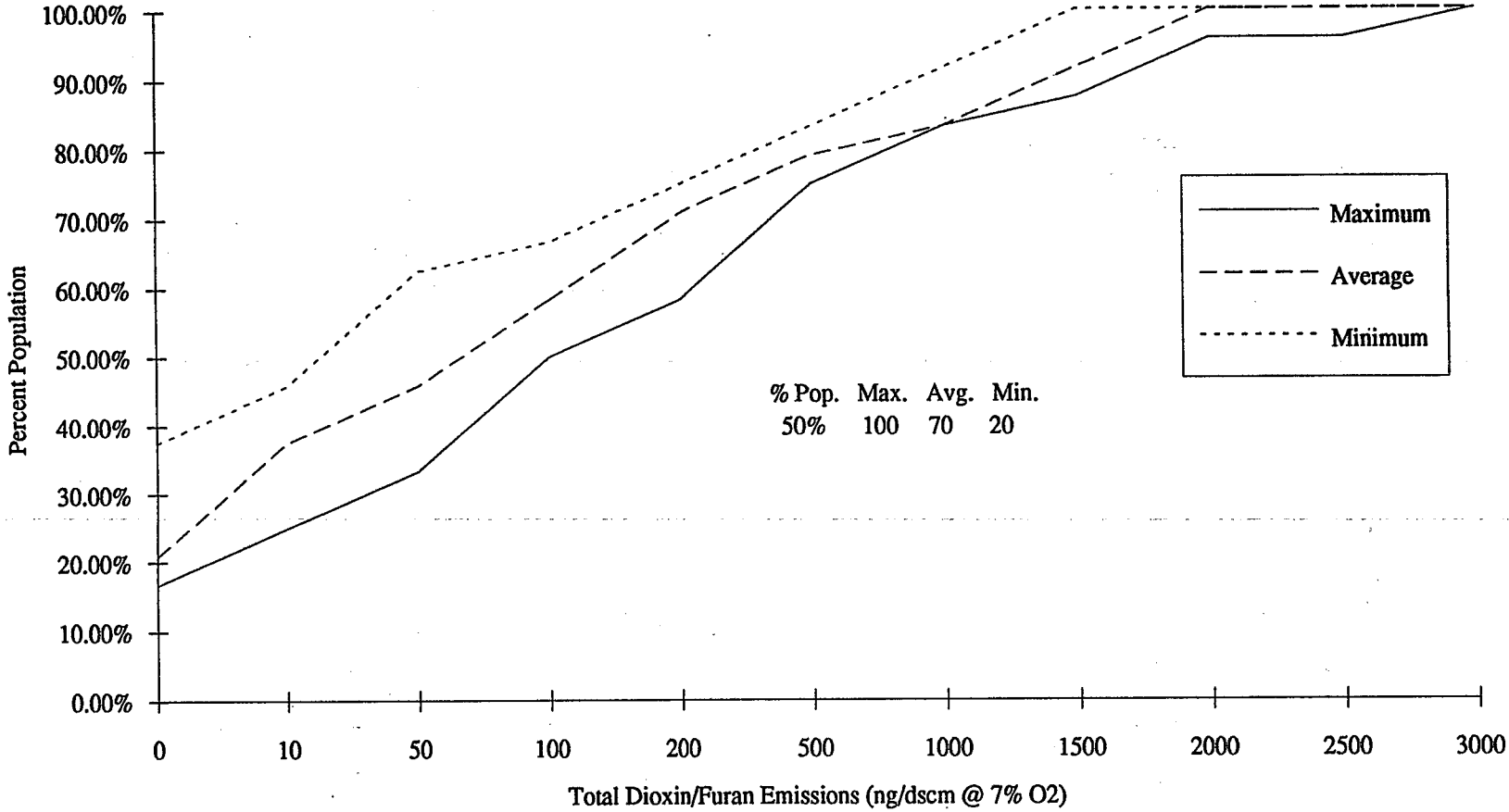

Figure 4.7-1. Cumulative distribution of cement kiln total dioxin emissions.

CK.total/sum Chart 1

TABLE 4.7-2. SUMMARY OF CEMENT KILN DIOXIN DATA IN TEQ

Company	Location	Unit Tested	Report Date	Facility Type	APCS	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Chanute, KS	1	Apr-92	w	ESP	4	3.050	1.55250	0.350	1.11805
Ash Grove Cement Co.	Chanute, KS	2	Mar-92	w	ESP	4	1.370	1.01300	0.641	0.30473
Ash Grove Cement Co.	Foreman, AR	1	Jul-92	w	ESP	4	12.600	3.80625	0.500	5.87936
Ash Grove Cement Co.	Foreman, AR	2	May-92	w	ESP	3	0.571	0.37033	0.207	0.18485
Ash Grove Cement Co.	Foreman, AR	2	Jul-93	w	ESP	3	0.203	0.11597	0.068	0.07549
Ash Grove Cement Co.	Foreman, AR	3	Jul-92	w	ESP	3	1.550	1.02000	0.600	0.48446
Ash Grove Cement Co.	Louisville, NE	1	May-92	sd (ph/bp)	ESP	5	0.281	0.16734	0.099	0.06958
Ash Grove Cement Co.	Louisville, NE	2	Aug-92	d (ph/pc/bp)	ESP	4	0.952	0.50400	0.300	0.30473
Continental Cement Co.	Hannibal, MO	1	Jul-92	w	ESP	3	25.471	17.14967	11.524	7.35389
Continental Cement Co.	Hannibal, MO	1	Dec-90	w	ESP	2	4.130	3.26500	2.400	1.22329
Essroc Materials	Logansport, IN	1	Aug-92	w	ESP	4	13.200	10.98500	6.640	3.02758
Holnam Inc.	Clarksville, MO	1	Jul-92	w	ESP	3	0.564	0.21643	0.033	0.30115
Holnam Inc.	Holly Hill, SC	1	Aug-92	w	ESP	3	0.370	0.19733	0.049	0.16168
Holnam Inc.	Holly Hill, SC	2	Aug-92	w	ESP	3	2.470	1.96667	1.430	0.52080
Holnam, Inc.	Artesia, MS	1	Aug-93	w	ESP	3	7.420	4.94833	1.925	2.78873
Keystone Cement Co.	Bath, PA	1	Aug-92	w	ESP	3	0.016	0.01600	0.016	0.00000
Keystone Cement Co.	Bath, PA	2	Aug-92	w	ESP	3	0.006	0.00440	0.003	0.00125
Lafarge Corp.	Alpena, MI	1	Aug-92	d (?)	FF	3	0.088	0.05867	0.035	0.02695
Lafarge Corp.	Fredonia, KS	1	Aug-92	w	ESP	3	5.900	3.72333	2.590	1.88559
Lafarge Corp.	Fredonia, KS	2	Aug-92	w	ESP	3	9.400	5.18667	2.560	3.68572
Lone Star Industries	Greencastle, IN	1	Aug-92	w	ESP	3	4.230	3.62000	3.180	0.54525
Medusa Cement Co.	Wampum, PA	3	Jul-92	d	ESP	3	50.900	32.96667	23.000	15.56288
Medusa Cement Co.	Wampum, PA	1,2	Jul-92	d	ESP	3	61.730	48.86000	29.890	16.77361
National Cement Co.	Lebec, CA	1	Aug-92	d	FF	3	0.057	0.05300	0.048	0.00458
River Cement Co.	Festus, MO	1	Oct-92	d	ESP	3	57.300	49.84333	40.130	8.80464
Southdown/Kosmos	Kosmosdale, KY	1	May-92	d (ph)	FF	4	1.320	1.17500	1.060	0.10755

w = wet kiln	# of Facilities	16
d = dry kiln	# of Kilns	25
sd = semi dry kiln	# of Data Sets	26
ph = preheater	# of Data Points	85
pc = precalcinator		
bp = by-pass		

Comparison with the estimated total population suggests that the kiln total PCDD/PCDF data set is approximately 56% complete. The lack of uniformity in reporting dioxin emissions (total or TEQ) from the trial burns and compliance tests accounts for the differences in the number of facilities and kilns with dioxin data sets in the current compilation.

Figure 4.7-2 presents the cumulative distribution of dioxin/furan emissions from cement kilns reported in TEQ ng/dscm. As indicated on this figure, 50% of the minimum reported kiln data are less than 0.4 TEQ. Similarly, 50% of the reported average and maximum reported data are less than 0.8 and 1.0 TEQ, respectively.

The relationship between total dioxin/furan emissions and TEQ is generally a "foot print" of a specific combustion facility (specific kiln, for example). This "foot print" can vary significantly within a class of combustion sources; however, there is a large body of data to suggest that the average ratio of total dioxin/furan emissions to TEQ emissions for cement kilns is statistically different across classes of combustion facilities (i.e., cement kilns versus municipal waste incinerators). Figure 4.7-3 presents plots of total dioxin/furan emissions versus TEQ for HWIs, cement kilns, MWCs and MWIs. As shown in the statistical analysis presented in Table 4.7-3, the average ratio of total dioxin/furan emissions to TEQ for HWIs, kilns, MWCs and MWIs is 57, 119, 43, and 55, respectively. As presented in this analysis, cement kilns display a statistically different "foot print" than the other three combustor devices at the 95% confidence level. Interestingly, this analysis indicates that the average ratio between total dioxin/furan and TEQ for hazardous waste incinerators cannot be distinguished (at the 95% confidence level) from either MWCs or MWIs.

It is generally accepted that the combustion device, fuel, operating characteristics, and the APCD system will contribute to the dioxin/furan congener distribution. Given this, it might be suggested that APCDs with similar inlet conditions and different APCDs will display different total dioxin/TEQ ratios. Table 4.7-4 presents the body of MWC data in more detail. In this table, the total/TEQ data is subdivided by the APCD control device type including: ESPs; spray dryer/fabric filter combinations (sd/ff); duct injection/ESPs (di/esp); and spray dryer/ESPs (sd/ESP). As indicated in Table 4.7-5, the total/TEQ ratios cannot be distinguished by APCD category. In addition, the MWCs with either spray dryer/FF or duct injection (high PM, alkaline) conditions are still significantly different than the average foot print data exhibited by the cement kiln population. This analysis would tend to suggest that conditions upstream of the APCD (combustion systems, fuel types, operation) are more strongly influencing the ultimate dioxin/furan congener distribution. The data thus suggest that independent control of congener distribution (and therefore TEQ) will probably not be possible through APCD device type selection.

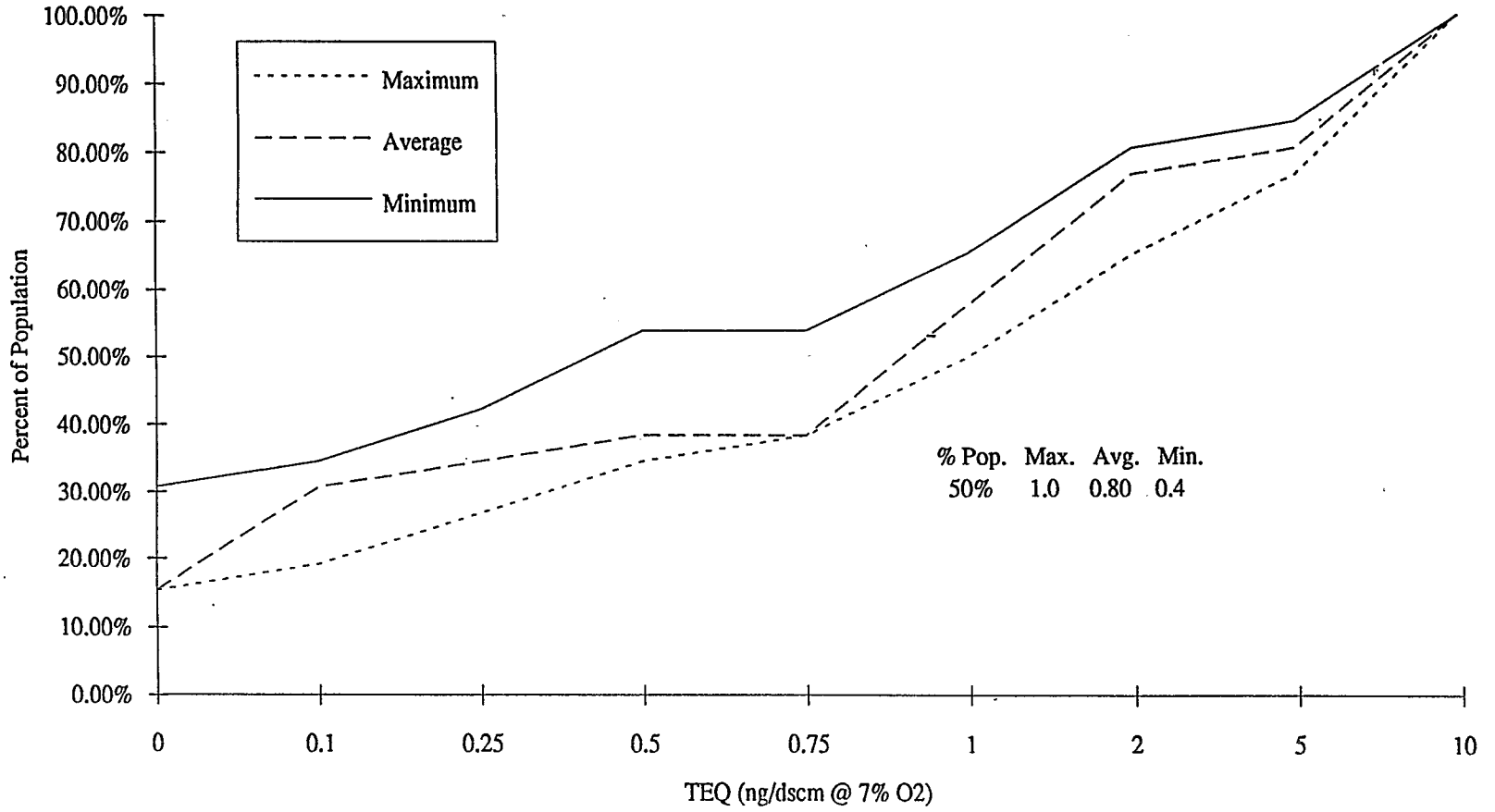

Figure 4.7-2. Cumulative distribution of cement kiln dioxin TEQ emissions.

CK.teq/sum Chart 1

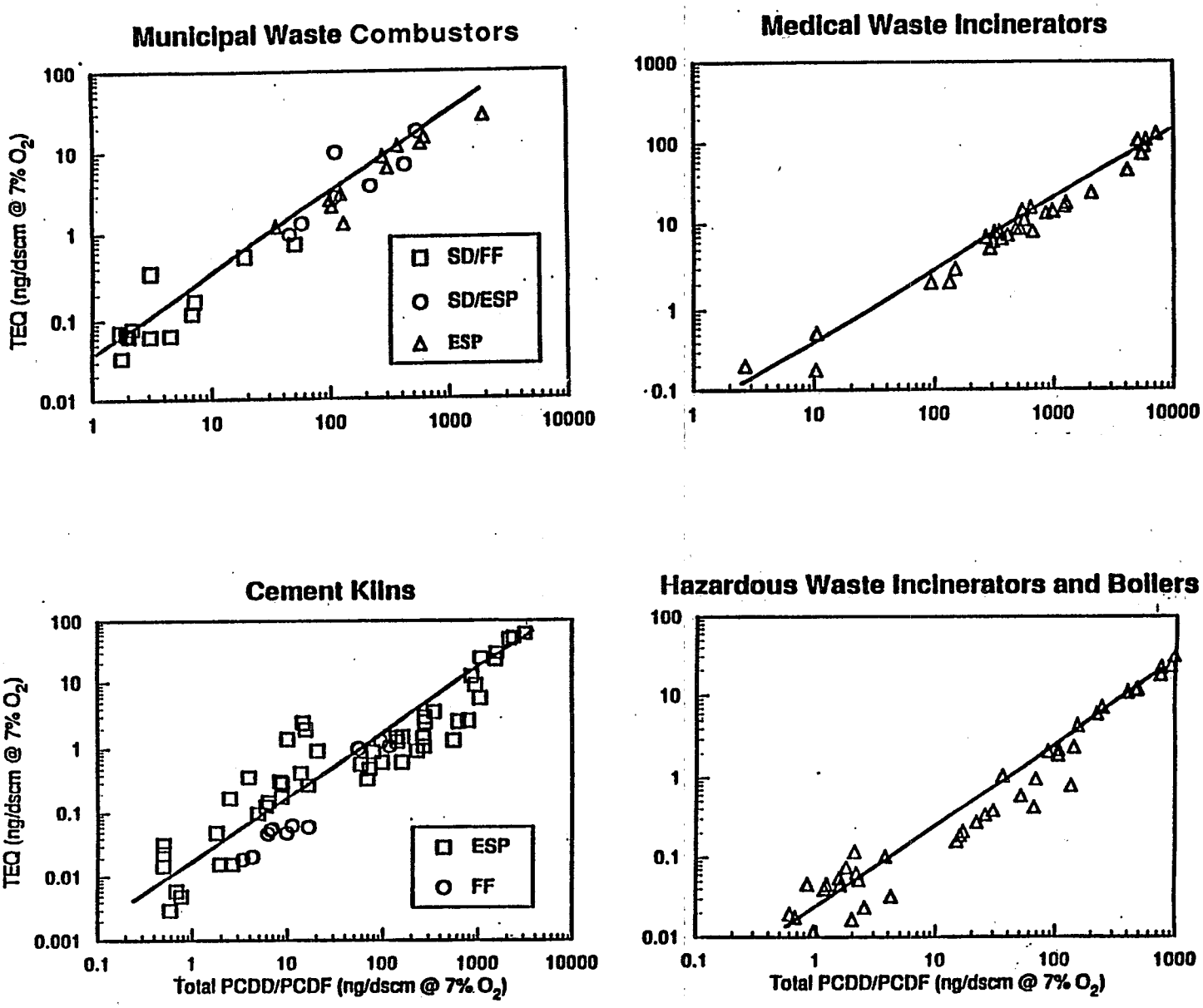

Figure 4.7-3. Total versus TEQ dioxin emissions for various source categories.

TABLE 4.7-3. STATISTICAL ANALYSIS OF TOTAL DIOXIN TO TEQ RATIOS FOR VARIOUS SOURCE CATEGORIES

total/TEQ Ratio	MWC	MWI	CK	HWI
No. Points	30	31	52	41
Mean	43.2	55.5	119.4	57.3
Sdev.	18.1	16.9	84.2	35.5

Measured Difference in Means

	MWI	MWC	CK	HWI
MWI				
MWC	12.3			
CK	63.9	76.2		
HWI	1.8	14.1	62.1	

Joint Degrees of Freedon (n1+n2 -2)

	MWI	MWC	CK	HWI
MWI				
MWC	59			
CK	81	80		
HWI	70	69	91	

Joint variance ((n1-1)s1^2 + (n2-1)s2^2)/(n1+n2-2)

	MWI	MWC	CK	HWI
MWI				
MWC	306.3			
CK	4569.6	5377.9		
HWI	842.5	868.3	4527.3	

Joint t statistic (alfa/2 @ 95%)

	MWI	MWC	CK	HWI
MWI				
MWC	2			
CK	2	2		
HWI	2	2	2	

Critical Minimum Difference (t*S/sqrt(1/n1+1/n2)

	MWI	MWC	CK	HWI
MWI				
MWC	9.0			
CK	30.7	33.6		
HWI	13.8	14.2	28.1	

TABLE 4.7-4. MWC TOTAL AND TEQ EMISSION DATA SORTED BY APCD TYPE

Location	APCD	NG/DSCM @ 7% O2					
		Total	*TEQ*	*ratio*	No. Points	Average	Sdev
Alexandria	di/esp	426	7.1	60.0			
Alexandria	di/esp	57	1	42.9			
Pittsfield	di/esp	110	2.799	39.3			
					3.0	47.4	11.1
Zurich	esp	305.6	6.622	46.1			
North Andover	esp	374	12.1	30.9			
Westchester	esp	100	2.6	38.5			
Saugus	esp	623	15.5	40.2			
Pinellas	esp	104	2.132	48.8			
Chicago	esp	277	9.007	30.8			
Tulsa	esp	34.5	1.213	28.4			
Lawrence	esp	123.5	3.095	39.9			
Sheridan	esp	580	13.125	44.2			
Pigeon Pt. (*)	esp	131.4	1.324	99.2			
Occidentral (*)	esp	1938	28.7	67.5			
					11.0	46.8	20.5
Stellinger	sd/esp	109.6	10.13	10.8			
Stapelfeld	sd/esp	219	3.9	56.2			
Millbury	sd/esp	45	0.964	46.7			
Borgstrasse	sd/esp	533	18.22	29.3			
					4.0	35.7	20.0
Long Beach	sd/ff	4.57	0.065	70.3			
Commerce	sd/ff	1.94	0.067	29.0			
Stainislaus	sd/ff	6.91	0.122	56.6			
Bridgeport	sd/ff	3.07	0.354	8.7			
Bristol	sd/ff	7.23	0.167	43.3			
Marrion	sd/ff	2.04	0.063	32.4			
Jackson	sd/ff	1.73	0.073	23.7			
West Babylon	sd/ff	18.8	0.535	35.1			
Wurzburg	sd/ff	49.95	0.746	67.0			
GE	sd/ff	2.183	0.079	27.6			
Maine (*)	sd/ff	1.784	0.034	52.5			
Mid Conn (*)	sd/ff	3.076	0.063	48.8			
					12.0	41.2	18.5
(*) RDF units or mixed RDF MSW fired							

TABLE 4.7-5. STATISTICAL ANALYSIS OF MWC TOTAL TO TEQ RATIOS

total/TEQ Ratio	di/esp	esp	sd/esp	sd/ff
No. Points	3	11	4	12
Mean	47.4	46.8	35.7	41.2
Sdev.	11.1	20.5	20	18.5

Measured Difference in Means

	esp	di/esp	sd/esp	sd/ff
esp				
di/esp	-0.6			
sd/esp	-11.1	-11.7		
sd/ff	-5.6	-6.2	-5.5	

Joint Degrees of Freedon (n1+n2 -2)

	esp	di/esp	sd/esp	sd/ff
esp				
di/esp	12			
sd/esp	13	5		
sd/ff	21	13	14	

Joint variance ((n1-1)s1^2 + (n2-1)s2^2)/(n1+n2-2)

	esp	di/esp	sd/esp	sd/ff
esp				
di/esp	370.7			
sd/esp	415.6	111.3		
sd/ff	379.4	308.6	354.6	

Joint t statistic (alfa/2 @ 95%)

	esp	di/esp	sd/esp	sd/ff
esp				
di/esp	2.17			
sd/esp	2.16	2.57		
sd/ff	2.08	2.16	2.14	

Critical Minimum Difference (t*S/sqrt(1/n1+1/n2)

	esp	di/esp	sd/esp	sd/ff
esp				
di/esp	27.2			
sd/esp	25.7	20.7		
sd/ff	16.9	24.5	23.3	

MWCR.XLS

4.8 Analysis of Cement Kiln Dioxin/Furan Emissions

Figure 4.8-1 presents a plot of total cement kiln PCDD/PCDF emissions versus APCD operating temperature. The data utilized in this analysis was extracted from both the CoC/Trial Burn Reports compiled as of 1/12/93 and previous compilations. It is anticipated that the analysis presented in this section will be updated with additional data in subsequent revisions. However, it is not expected that significant changes to the major observations or conclusions will arise as the data set is expanded. When the PCDD/PCDF emissions are plotted in this fashion (semi-log), the straight line drawn through the data is indicative of an exponential relationship between PCDD/PCDF emissions and APCD operating temperature. As shown on this plot, two distinct groups of data points exist within the temperature window of 400 °F to 575 °F. However, each group exhibits a similar dependency on temperature. This relationship, characterized by the line passing through the group 1 data set, indicates a 1 order magnitude increase in PCDD/PCDF emissions for every 161 °F increase in ESP/FF operating temperature. The line passing through the group 2 data is characterized by a 1 order magnitude increase in PCDD/PCDF emissions with every 196 °F increase in ESP/FF operating temperature. The PCDD/PCDF temperature relationships extracted from the cement kiln CoC data are virtually the same as that found during detailed EPA testing at the Montgomery County MWC [11]. The Montgomery County MWC was equipped with a water quench upstream of an ESP. With this configuration, the ESP operating temperature could be controlled independently of upstream furnace conditions. Results from the MWC testing produced a semi-log, linear relationship between ESP operating temperature and PCDD/PCDF formation in the ESP, with PCDD/PCDF production increasing 1 order of magnitude with every 110 °C (196 °F) increase in ESP operating temperature. The apparent consistency with the MWC experience suggests but does not conclusively affirm that the PCDD/PCDF emissions from kilns are predominately generated across the APCD.

As discussed previously, the characteristic "foot print" (ratio of total dioxin/furan emissions to TEQ) of cement kilns is different than those of other combustion facilities. Generally, the ratio of total PCDD/PCDF to TEQ is on the order of twice that found from MWCs, MWIs and HW incinerators. The scatter in the total/TEQ ratio for kilns is large, as evidenced by the distribution curve presented in Figure 4.8-2. The average ratio is 115, and the median of the ratio value (50% above and below) is 101. Calculation of an average total to TEQ ratio implicitly assumes that the plot of total PCDD/PCDF emissions in ng/dscm versus TEQ passes through zero. Clearly, this is not necessarily the case. It is quite possible that a facility can still exhibit positive total PCDD/PCDF emissions at zero TEQ. Stated differently, a facility with total PCDD/PCDF

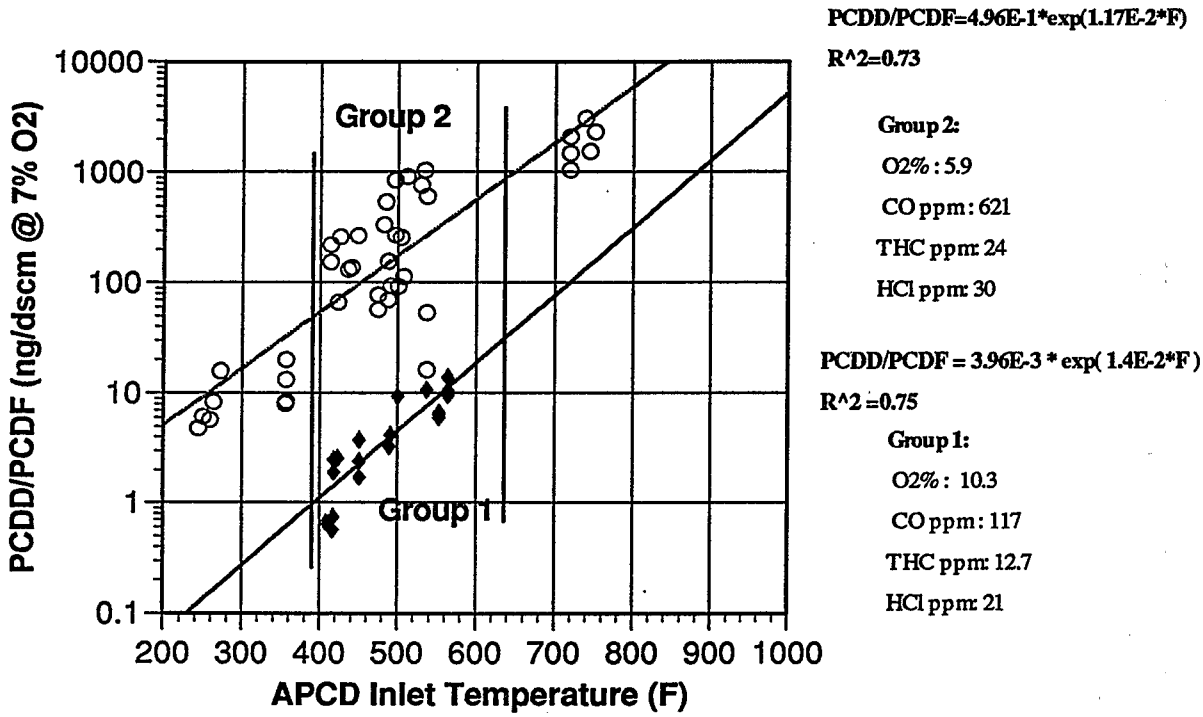

Figure 4.8-1. Total cement kiln PCDD/PCDF versus APCD temperature.

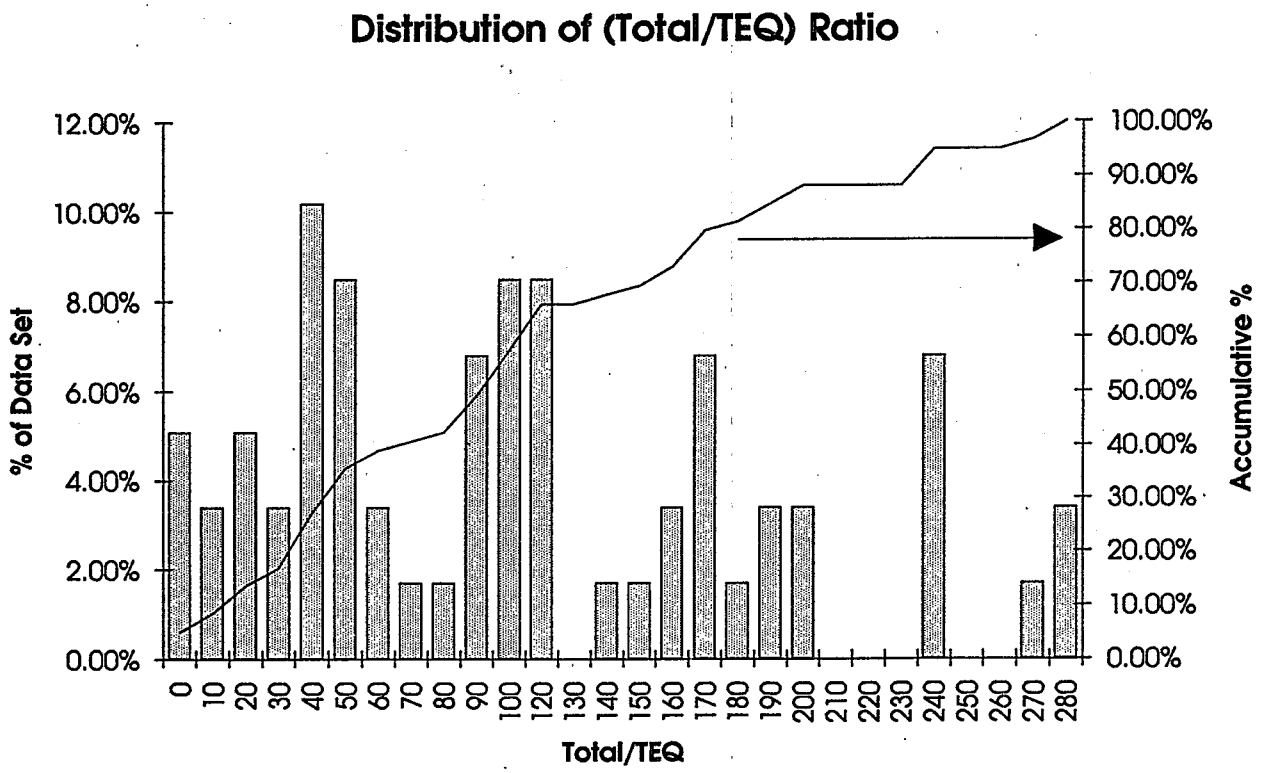

Figure 4.8-2. Distribution of total/TEQ ratio for cement kilns.

PAPER.XLS Chart 2

emissions can be emitting zero PCDD/PCDF on a TEQ basis. If the cement kiln PCDD/PCDF total emissions data are regressed versus TEQ, then the slope of least squares fit line is 47, with positive intercept of 87.5. The 95% confidence intervals on the slope and intercept are 43 to 51 and 33 to 141 ng/dscm, respectively. A summary of the regression analysis is provided in Table 4.8-1. For comparison purposes, the regression analysis for the MWC is also provided. For MWCs, the 95% confidence interval on the slope and intercept ranges from 42 to 58 and -101 to 37.8 ng/dscm, respectively. Negative intercepts are meaningless, illustrating the significant scatter in the MWC data. However, when analyzed in this fashion, the incremental change in total PCDD/PCDF emissions per incremental change in TEQ for kilns cannot be distinguished from MWCs. This is in contrast to the statistical analysis in the previous section where on an average ratio basis, there is a clear distinction between the kiln footprint and that exhibited by the MWC population. A constant incremental (slope) relationship between total PCDD/PCDF emissions and TEQ can be interpreted as implying that the congener distribution remains constant with total PCDD/PCDF production, and that only the levels of the individual congeners are increased. One possible interpretation of the apparent incremental change uniformity in TEQ per unit change in total PCDD/PCDF (slope) between kilns and MWCs is that the constant slope is associated with the formation of PCDD/PCDF across similar APCDs (ESP, or baghouses). The apparent statistical difference in the average ratio (foot print) is associated with different intercepts and may be linked to the initial nontoxic congener distribution upstream of the APCDs.

Total kiln PCDD/PCDF emissions versus stack HCl emissions are presented in Figure 4.8-3. No apparent trend is exhibited for either the kiln data in aggregate or when subdivided into the group 1 and group 2 data sets.

Total kiln PCDD/PCDF emissions versus stack THC emissions are presented in Figure 4.8-4. As with the HCl data, no apparent trend is exhibited for either the kiln data in aggregate or when subdivided into the group 1 and group 2 data sets.

The absence of any apparent trends in the PCDD/PCDF emission data versus either HCl or THC does not preclude these as important parameters in characterizing dioxin/furan emissions. It does suggest, however, that the scatter in the data set combined with other potential dominant trends can mask smaller effects that might be anticipated.

Figure 4.8-5 presents a plot of total PCDD/PCDF emissions versus stack % oxygen (% O_2). The oxygen data ranges from approximately 5-16%, suggesting significant entrainment into

TABLE 4.8-1: REGRESSION ANALYSIS OF CEMENT KILN TOTAL PCDD/PCDF TO TEQ EMISSIONS DATA

Regression Statistics (cement kilns)

Multiple R	0.96
R Square	0.91
Adjusted R Square	0.91
Standard Error	192.59
Observations	59.00

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	1.00	22577382.72	22577382.72	608.68	0.0000
Residual	57.00	2114281.29	37092.65		
Total	58.00	24691664.01			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	87.54	27.06	3.24	0.00	33.35	141.72
x1	47.15	1.91	24.67	0.00	43.32	50.98

Regression Statistics (MWC's)

Multiple R	0.917283558
R Square	0.841409127
Adjusted R Square	0.835745167
Standard Error	152.6114066
Observations	30

Analysis of Variance

	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*
Regression	1	3459880.10	3459880.10	148.55	0.00
Residual	28	652126.76	23290.24		
Total	29	4112006.86			

	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-31.85665438	34.04	-0.94	0.36	-101.58	37.87
x1	50.26881416	4.12	12.19	0.00	41.82	58.72

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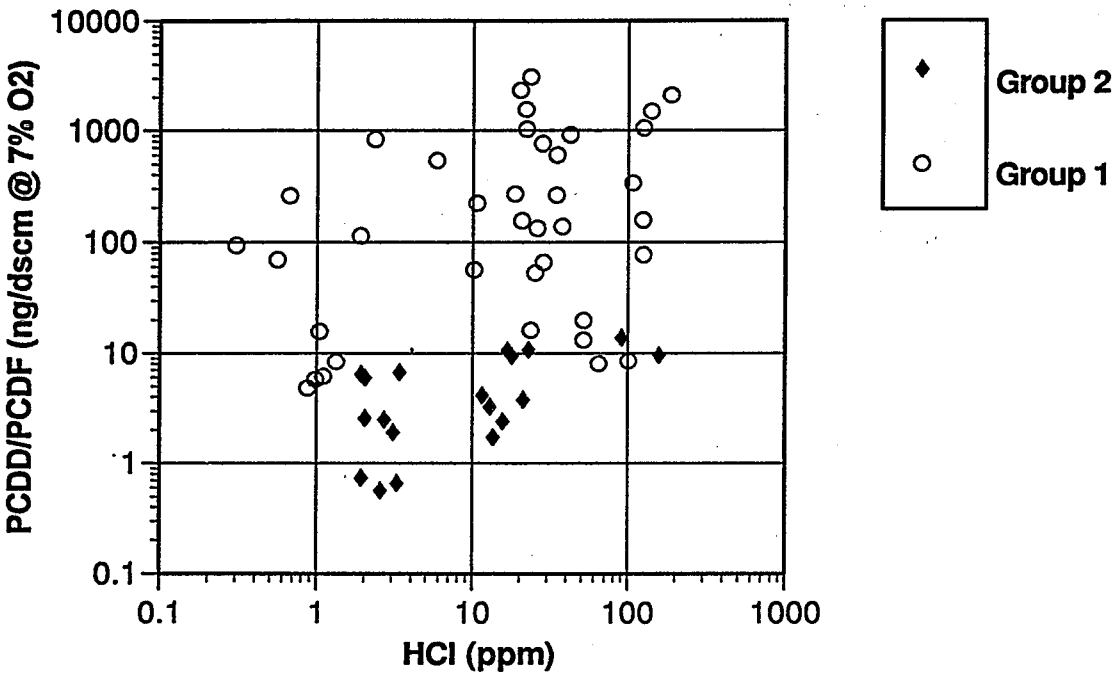

Figure 4.8-3. Total kiln PCDD/PCDF emissions versus stack HCl emissions.

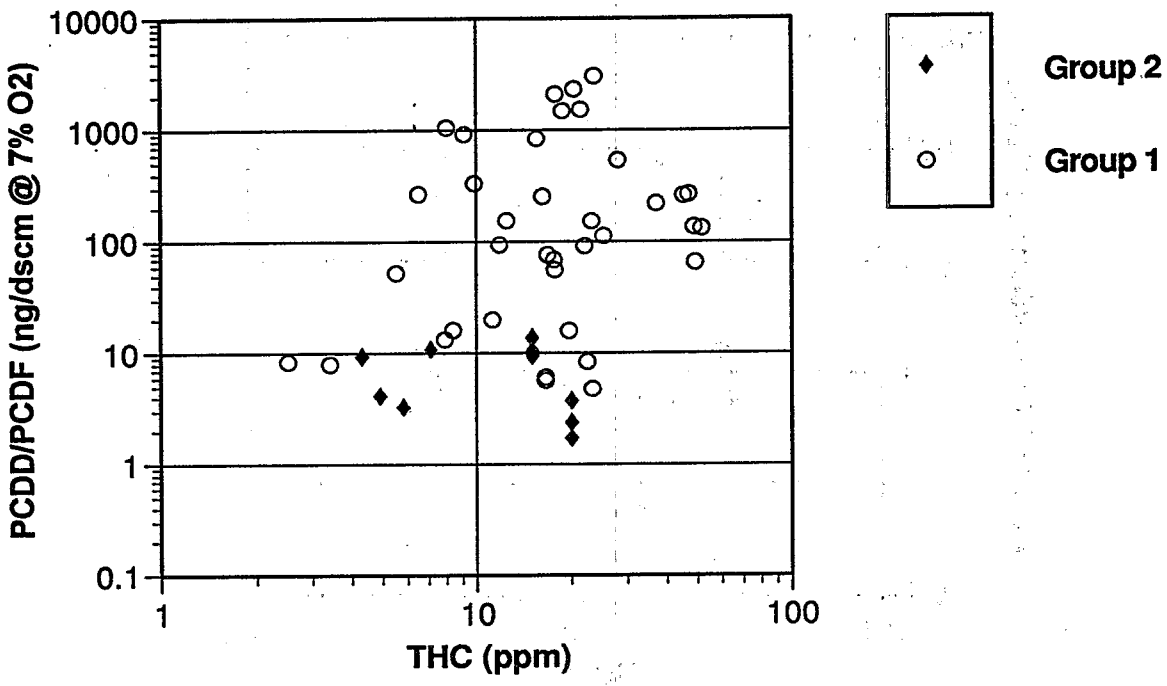

Figure 4.8-4. Total PCDD/PCDF emissions versus stack THC emissions.

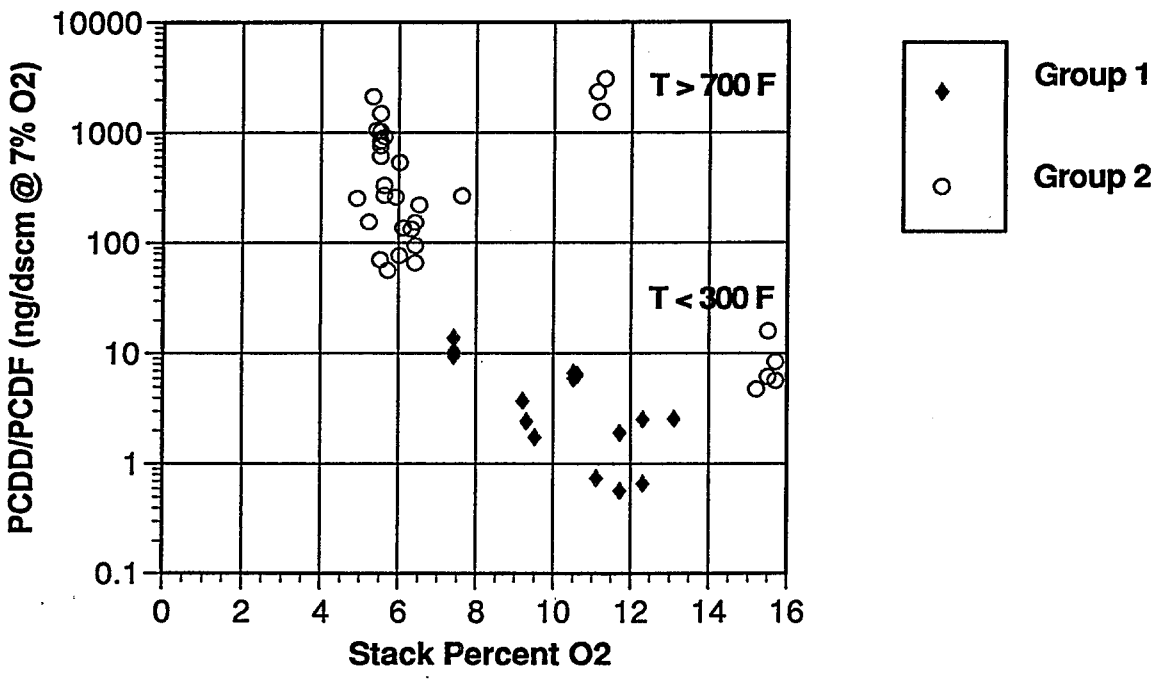

Figure 4.8-5. Total PCDD/PCDF emissions versus stack percent O_2.

the flue gas path. The data also suggest an inverse oxygen/dioxin relationship. There are, however, two sets of data which do not follow the dominant trend. As indicated in Figure 4.8-5, these data correspond to the extremes in APCD temperature in the data set.

Figure 4.8-6 presents a plot of total PCDD/PCDF emissions versus stack carbon monoxide (CO) levels. The data have been subdivided into the group 1 and group 2 data sets corresponding to the two data groups seen in the PCDD/PCDF versus temperature graph of Figure 4.8-1. When viewed in this fashion, the data suggest that higher levels of total dioxin emissions are associated with higher measured CO levels. This does not imply, however, that CO is the fundamental correlating parameter since elevated CO levels are often associated with elevated products of incomplete combustion (PIC) formation.

Figure 4.8-7 presents a plot of stack CO versus stack O_2. The aggregate body of data has also been subdivided into the group 1 and group 2 data sets corresponding to Figure 4.8-1. This plot (Figure 4.8-7) displays the characteristic inverse relationship between CO and O_2 found in all combustion systems. However, it also displays two sets of data which do not follow this trend. Cement kiln CO emissions occur not only from incomplete combustion, but can also easily be a product of the calcining process. For this reason, any plot of CO versus O_2 should not only display the characteristic relationship between CO and O_2, but should also show significant scatter with groups of outliers from this trend (as in Figure 4.8-7).

Figure 4.8-8 presents a plot of stack CO versus stack total hydrocarbon (THC). No consistent trend in the data set is observed. Given the discussion in the previous paragraph, it is quite possible that elevated CO levels can be associated with good combustion and low THC levels. For this reason, it would not be expected that a consistent trend for kilns across the large variety of units and data sets would be found.

The cement kiln PCDD/PCDF data set suggests a strong APCD inlet temperature dependency consistent with previous MWC experience. In addition, there would appear to be a dependency on measured CO levels (mostly likely indirect) and stack O_2 levels. The temperature dependency is dominant, with a ten-fold increase in total dioxin/furan emissions as APCD inlet temperature is raised approximately 178 °F (average of 161 °F and 196 °F). It is likely that the dominate trend of increasing PCDD/PCDF emissions with APCD inlet temperature masks lesser relationships. One approach to further examining the cement kiln dioxin/furan data is to remove the dominate trends from the data set and try to identify these other less apparent relationships.

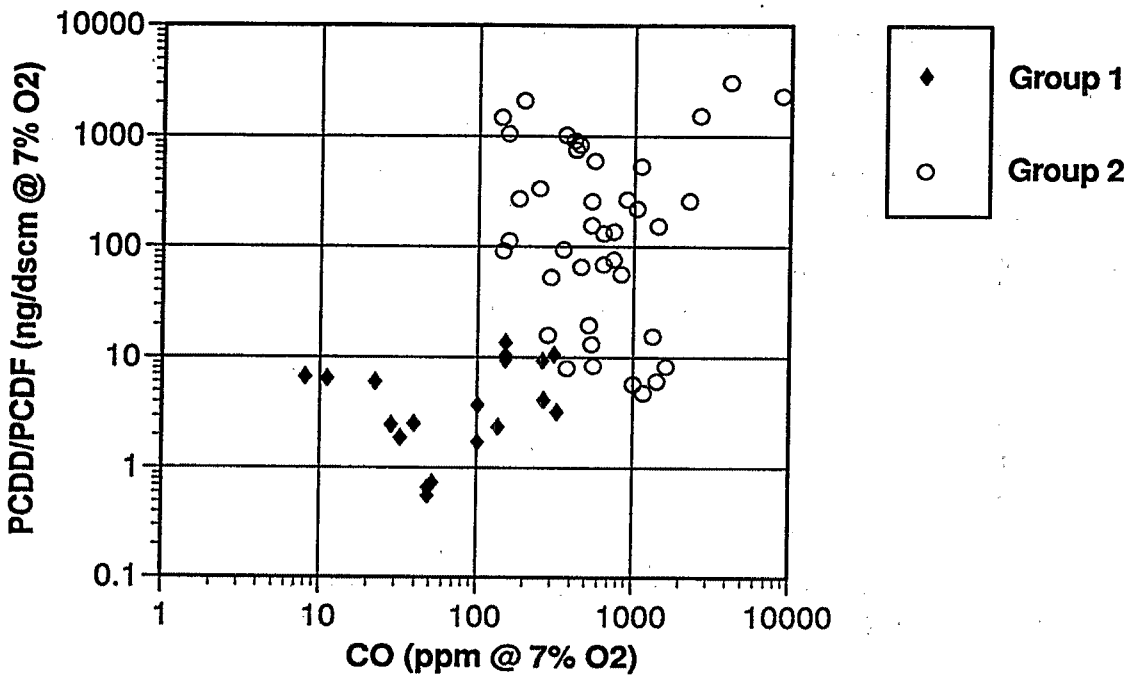

Figure 4.8-6. Total PCDD/PCDF emissions versus stack CO.

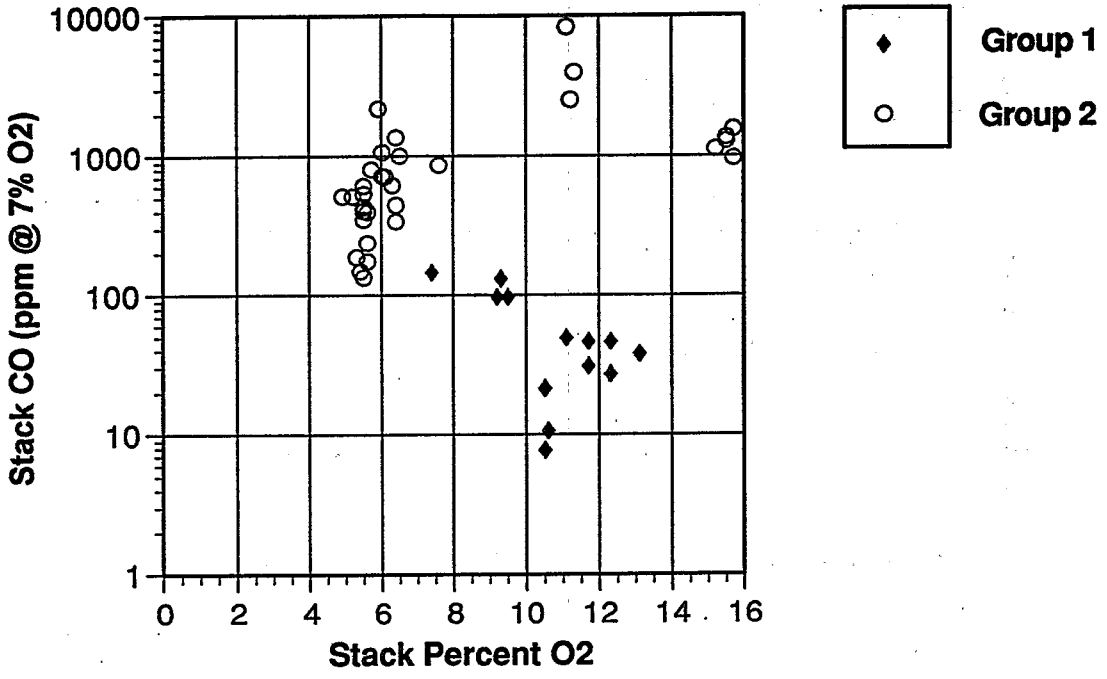

Figure 4.8-7. Stack CO versus stack O_2 .

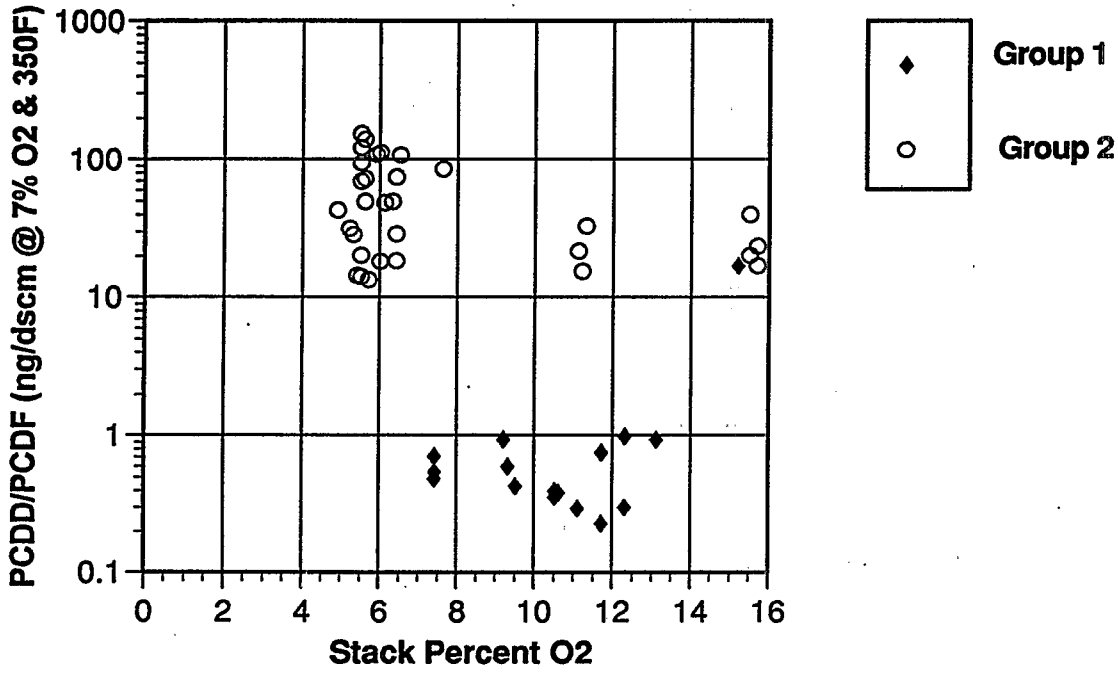

Figure 4.8-9. Temperature normalized PCDD/PCDF versus stack O_2.

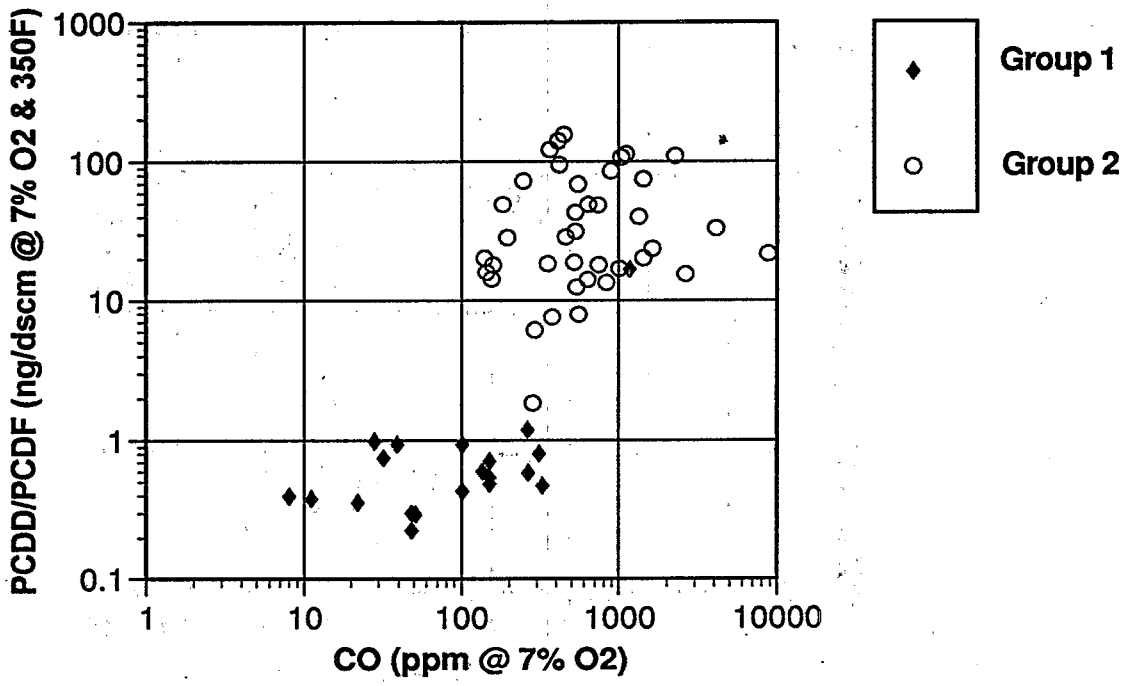

Figure 4.8-10. Temperature normalized PCDD/PCDF versus stack CO.

of the NSPS for MWCs. As stated previously, it is important to note that this analysis does not necessarily point to CO as the correlating factor, but more likely points to the existence of PICs which generally correlate with CO.

The temperature normalized data suggest that CO is a parameter which delineates the PCDD/PCDF data. To more clearly identify other potential relationships, the temperature normalized data can be further manipulated to remove the gross effects of CO on the dioxin data. Equation 4.2 has been implemented on the temperature normalized data set.

$$PCDD/PCDF_{(@350F,100\ ppm\ CO)} = PCDD/PCDF_{(@350F)} * (100/CO)^{(1.04)} \qquad 4.2$$

Note that there are various ways of normalizing the data with respect to CO. One approach is to shift the data along a line drawn through the centroid of the separate regions of the data. An alternate approach, which is reflected in Equation 4.2, is to shift the data along a best fit curve through the entire data set. Given the scatter in the data, and the clear separation in the two regions, it is not expected that significant differences will arise in the subsequent observations and conclusions from either approach.

Figure 4.8-11 presents the temperature and CO normalized PCDD/PCDF emissions data versus stack % oxygen. The data show a considerable collapse over the data set with just the temperature normalization (Figure 4.8-9). This collapse in the data supports the assertion of a CO related dependance and also tends to indicate and confirm the O_2 dependance. Note the significant collapse in the data set of the two separate outlier regions from Figure 4.8-9.

The apparent inverse oxygen dependance exhibited by the PCDD/PCDF data is consistent with data observed in recent laboratory-scale research [12]. Possible explanations for the apparent inverse relationship include:

- Elevated oxygen levels are associated with oxidation of the char, thereby reducing the potential active sites and participation in the catalyzed surface reactions associated with PCDD/PCDF formation.

- Reduced oxygen levels are associated with poor combustion and elevated PIC levels which are not completely accounted for in the CO dependency.

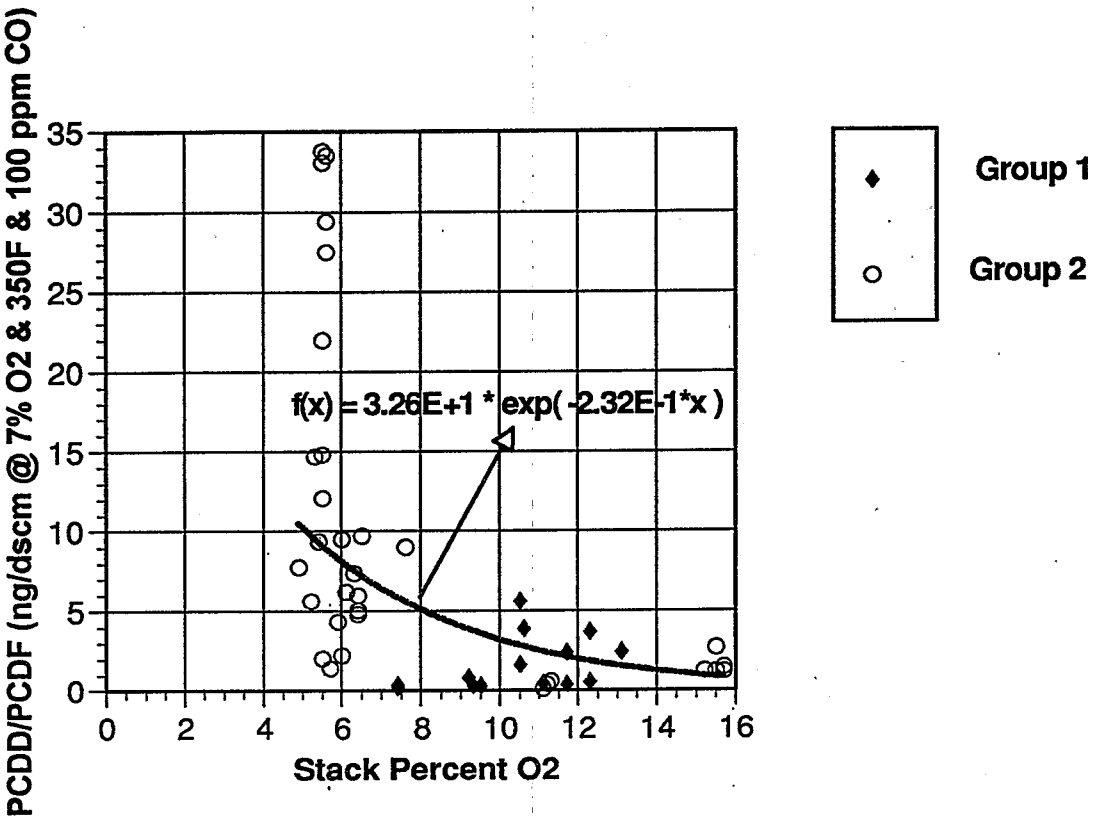

Figure 4.8-11. Temperature and CO normalized PCDD/PCDF versus stack O_2.

The effect of the various data normalizations and assertions of correlating parameters is summarized in Figure 4.8-12. The baseline set of cement kiln data analyzed in this section had an average value of 338 ng/dscm. The relative percent error, defined as the standard deviation of the data set divided by the average value, was just over 190%. Application of Equations 4.1, which has the effect of estimating the population dioxin emissions with APCD inlet temperature of a uniform 350 °F, reduced the average PCDD/PCDF emission levels to 38 ng/dscm and collapsed the relative standard error to 130%. Normalizing the data further to a uniform CO level of 100 ppm lowered the average further to 6.5 ng/dscm. Note the slight increase in scatter with respect to the mean from 130% to 140%. Removing the apparent dependency on O_2, and normalizing the data to a uniform stack level of 10% O_2 using Equation 4.3, further reduces the average dioxin/furan emission levels to 3.1 ng/dscm (with a relative error with respect to the mean level of 100%).

$$PCDD/PCDF_{(@350F,100\ ppm\ CO,10\%\ O2)} = PCDD/PCDF_{(@350F,100ppm\ CO)} * \exp^{-.232*(10-O2)} \quad 4.3$$

There remains considerable scatter (relative to the mean) in the dioxin/furan data following the temperature, CO, and O_2 normalization. However, dioxin/furan measurement is prone to large precision errors. Recovery limits of ± 30% are commonly cited. Relative errors of 70-100% in multiple data points at ostensibly the same operating conditions are common. Given these limitations, the final relative standard error of 100% following data normalization suggests that the dominant parameters have been identified and that further trends in the data will be difficult to find. This is in fact the case with the current data set. No further trends were observed in the normalized dioxin/furan data sets with HCl, PM or other data currently extracted from the CoC/Trial Burn Reports.

4.9 Commercial Hazardous Waste Incinerator Dioxin/Furan Emissions

Table 4.9-1 summarizes the current body of PCDD/PCDF data reported in total ng/dscm for the commercial HW incinerator population. Data have been extracted from seven facilities and from seven units with a total of 45 data points from eight data sets. This represents approximately 23% of the estimated unit population. Appendix I presents a more detailed summary of the data. Note that the dioxin data reported from the Rollins facilities are significantly below the other facilities. The Rollins facilities at Baton Rouge, Bridgeport and Deer Park incorporate a rapid water quench wet scrubber. These particular wet scrubber systems lower flue gas temperatures

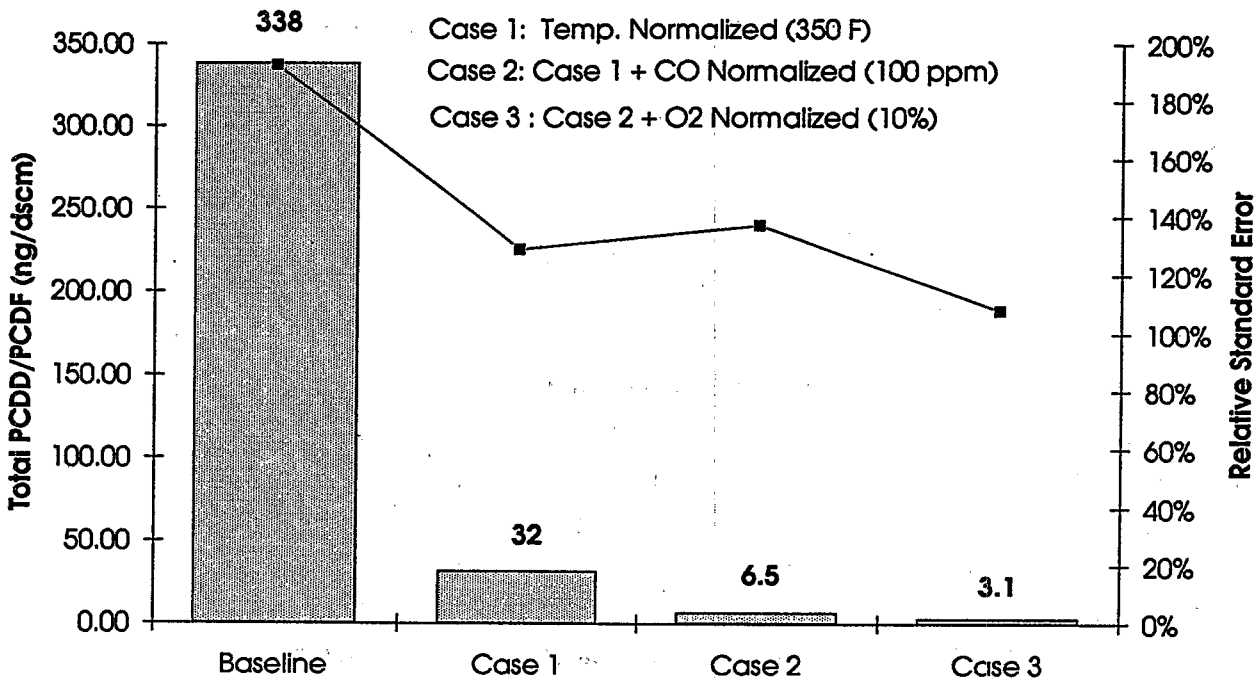

Figure 4.8-12. Impact of cement kiln PCDD/PCDF data normalization.

PAPER.XLS Chart 1

TABLE 4.9-1. PCDD/PCDF DATA IN TOTAL NG/DSCM FOR COMMERCIAL HW INCINERATOR POPULATION

Company	Location	Unit Tested	Report Date	Facility Type	APCS	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Aptus, Inc.	Aragonite, UT	1	Aug-92	RK	FF/WS/ESP	9	877.44	567.23	259.01	240.46
Aptus, Inc.	Coffeyvillle, KS	1	Dec-90	RK	FF/WS/IWS	12	222.86	117.14	42.07	50.62
General Electric	Pittsfield, MA	1	Apr-91	LI	PS	5	1232.38	548.61	100.93	529.86
Rollins Environmental Services	Baton Rouge, LA	1	Apr-87	RK	WS	3	4.36	2.26	1.14	1.82
Rollins Environmental Services	Bridgeport, NJ	1	Dec-86	RK	WS	3	10.70	6.58	3.50	3.71
Rollins Environmental Services	Deerpark, TX	1	Aug-88	RK	VS	5	5.77	4.31	3.06	1.05
Ross Incineration Services	Grafton, OH	1	Mar-93	RK	PT/IWS	3	1.80	1.46	1.60	0.43
Waste Tech. Industries*	East Liverpool, OH	1	Jul-93	RK	ESP	5	23.54	12.50	7.62	6.49
	# of Facilities	8								
	# of Units	8								
	# of Data Sets	8								
	# of Data Points	45								

* These data do not reflect the results of tests conducted in February 1994. The preliminary draft report on these recent tests indicates that total dioxin/furan emissions were 5 ng/dscm (with a TEQ of 0.065 ng/dscm).

from secondary chamber exit levels to stack exit levels in a time period on the order of milliseconds (10^{-3} seconds). This process precludes the downstream formation of dioxin/furans, and based on the levels summarized in Table 4.9-1, results in both dioxin/furan levels which are significantly lower than the remaining units and levels which must be associated with those emissions exiting the secondary chamber. It is important to note, however, that the Rollins facilities exhibit lower PCDD/PCDF levels, while the particulate matter control of the rapid quench wet scrubber is generally below that achieved at the other facilities incorporating either ESP or baghouses (Table 4.3-2). The existence of significantly lower PCDD/PCDF emissions yet higher PM emissions illustrates the point made earlier: low PM emissions do not necessarily lead to low PCDD/PCDF emissions, and other parameters and operating conditions can lead to low PCDD/PCDF emissions in the presence of high PM emissions.

Table 4.9-2 summarizes the current body of PCDD/PCDF data reported in TEQ for the commercial HW incinerator population. Data have been compiled for six facilities and six units with a total of 30 data points from six data sets. Appendix J presents a more detailed summary of the PCDD/PCDF TEQ data. The non-uniformity in reporting requirements in the CoC/Trial Burn Reports account for the one unit difference in data quantity between the TEQ and total emissions for commercial HW incinerators.

4.10 On-Site Hazardous Waste Incinerator Dioxin/Furan Emissions

Table 4.10-1 summarizes the current body of PCDD/PCDF data reported in total ng/dscm for the on-site HW incinerators. Currently, data have been compiled from 10 facilities and from 11 units with a total of 49 data points. This represents approximately 7.8% of the facilities based on the current number of units in the population. Appendix K summarizes the PCDD/PCDF total data from the on-site facilities in more detail. In general, the average reported PCDD/PCDF levels are below 4 ng/dscm.

Table 4.10-2 summarizes the current body of PCDD/PCDF data reported in ng/dscm TEQ for the on-site HW incinerators. Currently, data have been compiled from 11 facilities and from 12 units with a total of 56 data points. Appendix L summarizes the PCDD/PCDF data reported on a TEQ basis in more detail. Note that of the four facilities with higher PCDD/PCDF emissions on a total basis level, all four are significantly different than the remaining facilities when viewed on a TEQ basis.

TABLE 4.9-2. PCDD/PCDF DATA IN TEQ FOR COMMERCIAL HW INCINERATOR POPULATION

Company	Location	Unit Tested	Report Date	Facility Type	APCS	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Aptus, Inc.	Aragonite, UT	1	Aug-92	RK	FF/WS/ESP	9	26.02384	15.29889	7.64476	6.78866
General Electric	Pittsfield, MA	1	Apr-91	LI	PS	5	76.60000	34.17800	3.99000	34.38260
Rollins Environmental Services	Baton Rouge, LA	1	Apr-87	RK	WS	3	0.22300	0.10310	0.03260	0.10437
Rollins Environmental Services	Deerpark, TX	1	Aug-88	RK	VS	5	0.77700	0.42000	0.10200	0.28492
Ross Incineration Services	Grafton, OH	1	Mar-93	RK	PT/IWS	3	0.10640	0.06330	0.01710	0.04473
Waste Tech. Industries	East Liverpool, OH	1	Jul-93	RK	ESP	5	0.44914	0.22245	0.14775	0.12738
	# of Facilities	6								
	# of Units	6								
	# of Data Sets	6								
	# of Data Points	30								

TABLE 4.10-1. PCDD/PCDF DATA IN TOTAL NG/DSCM FOR ON-SITE HW INCINERATORS

Company	Location	Unit No. Tested	Report Date	Facility Type	APCS	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
3M	Cottage Grove, MN	1	Sep-90	RK	WS	8	168.63	80.4750	8.65	61.661
Chevron	Richmond, CA	1	Jul-88	LI	VS	6	0.23	0.1917	0.12	0.040
Ciba-Geigy	St. Gabriel, LA	1	May-88	LI	VS/Cyclone	3	1.34	0.9767	0.76	0.317
Department of the Army	Johnston Atoll	DFS	Jun-92	RK	VS/PBS	4	1.84	1.0054	0.63	0.563
Department of the Army	Johnston Atoll	LIC	Jun-91	LI	VS/PBS	3	0.53	0.4357	0.353	0.089
Department of the Army	Tooele, UT	??	Apr-92	RK	VS	4	0.63	0.4850	0.41	0.099
Department of the Army	Tooele, UT	??	Oct-93	RK	VS	4	0.09	0.0700	0.06	0.014
Dow Chemical Co.	Midland, MI	703	Jun-89	RK	VS/ESP	3	135.6	105.0733	78.35	28.814
Dow Chemical Co.	Plaquemine, LA	1	Feb-88	RK	ESP/PBS	2	12.97	12.0750	11.18	1.266
Pfizer Inc.	Groton, CT	1	Jul-90	RH	WS	3	4.5	3.0873	2.12	1.251
Vulcan Materials Co.	Wichita, KS	1	Apr-91	LI	WS	6	401.35	240.0900	71.47	147.320

?? Unable to be determined from information given
na not available

# of Facilities 9
# of Units 10
# of Data Sets 11
# of Data Points 46

TABLE 4.10-2. PCDD/PCDF DATA IN TOTAL NG/DSCM TEQ FOR ON-SITE HW INCINERATORS

Company	Location	Unit No. Tested	Report Date	Facility Type	APCS	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
3M	Cottage Grove, MN	1	Sep-90	RK	WS	8	4.53	2.08325	0.336	1.58687
Chevron	Richmond, CA	1	Jul-88	LI	VS	6	0.0474	0.03680	0.0299	0.00768
Ciba-Geigy	St. Gabriel, LA	1	May-88	LI	VS/Cyclone	3	0.00857	0.00591	0.00292	0.00284
Department of the Army	Johnston Atoll	DFS	Jun-92	RK	VS/PBS	4	0.14	0.12515	0.11	0.01175
Department of the Army	Tooele, UT	??	Apr-92	RK	VS	4	0.0284	0.02495	0.0224	0.00251
Department of the Army	Tooele, UT	??	Oct-93	RK	VS	4	0.00902	0.00673	0.00491	0.00170
Dow Chemical Co.	Midland, MI	703	Jun-89	RK	VS/ESP	3	0.218	0.13773	0.0942	0.06960
Dow Chemical Co.	Midland, MI	830	Mar-92	RK	VS/IWS	4	0.1198	0.06575	0.04112	0.03650
Dow Chemical Co.	Plaquemine, LA	1	Feb-88	RK	ESP/PBS	2	0.115	0.10170	0.0884	0.01881
Eastman Kodak Co.	Rochester, NY		Sep-92	RK		6	0.837	0.45867	0.176	0.26163
Pfizer Inc.	Groton, CT	1	Jul-90	RH	WS	3	0.023	0.01903	0.012	0.00636
Vulcan Materials Co.	Wichita, KS	1	Apr-91	LI	WS	6	12	6.49333	1.08	5.22629

?? Unable to be determined from information given
na not available

# of Facilities 10
# of Units 11
# of Data Sets 12
# of Data Points 53

4.11 Hazardous Waste Burning Boiler Dioxin/Furan Emissions

Table 4.11-1 summarizes the current body of PCDD/PCDF data reported in total ng/dscm for the HW burning boilers. Table 4.11-2 summarizes the current body of PCDD/PCDF data reported in ng/dscm TEQ (same populations). Currently, data have been compiled from two facilities and from two units with a total of six data points.

4.12 Lightweight Aggregate Kiln Dioxin/Furan Emissions

Table 4.12-1 summarizes the current body of PCDD/PCDF data reported in total ng/dscm and TEQ for the LWA kilns. Currently, data have been compiled from one facility and from one unit with a total of three data points.

4.13 Summary

This chapter has presented a summary of the current compilations of PM and PCDD/PCDF (both total and TEQ) from the various HW burning facilities. In addition, a detailed analysis of the cement kiln population for which a more thorough data set is available has been completed. This analysis has shown that the APCD inlet temperature is a dominant parameter keying elevated PCDD/PCDF emissions. In addition, CO and O_2 were parameters which collapsed the PCDD/PCDF data. The analysis of the cement kiln PCDD/PCDF emissions and resulting observed trends are consistent with the large body of data and analysis producing the MWC NSPS and Guidelines for existing MWC facilities.

The correlation between APCD inlet temperature and PCDD/PCDF emissions, and the consistency with the MWC experience, points to the formation of dioxin/furan across the APCD as the dominant source of stack PCDD/PCDF emissions in the presence of good combustion conditions. The link with elevated CO emissions and elevated PCDD/PCDF emissions is consistent with the MWC experience which led to the definition of good combustion practices (GCP) as a first requirement to control PICs and reduce the potential for elevated PCDD/PCDF emissions. This chapter also discussed the potential role of PM in the dioxin formation process(es). However, as evidenced by many data sets, low PM emissions are not a prerequisite

TABLE 4.11-1. PCDD/PCDF DATA IN TOTAL NG/DSCM FOR HW BURNING BOILERS

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	APCS	# of Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Union Carbide	South Charleston, WV	16	Feb-93	Boiler	Coal	ESP	3	1.242	0.8447	0.614	0.3456
Westvaco Corp.	DeRidder, LA	B2 & B4	Aug-92	Boiler	Natural Gas	ESP	3	1.907	1.1263	0.574	0.6952

# of Facilities	2
# of Units	2
# of Data Sets	2
# of Data Points	6

TABLE 4.11-2. PCDD/PCDF DATA IN NG/DSCM TEQ FOR HW BURNING BOILERS

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	APCS	# of Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Union Carbide	South Charleston, WV	16	Feb-93	Boiler	Coal	ESP	3	0.0461	0.0279	0.0179	0.0158
Westvaco Corp.	DeRidder, LA	B2 & B4	Aug-92	Boiler	Natural Gas	ESP	3	0.051	0.0297	0.0149	0.0189

# of Facilities	2
# of Units	2
# of Data Sets	2
# of Data Points	6

BLR.teq/total

TABLE 4.12-1. PCDD/PCDF DATA IN TOTAL NG/DSCM AND TOTAL NG/DSCM TEQ FOR LIGHTWEIGHT AGGREGATE KILNS

TEQ DATA FOR LWA KILNS

Company	Location	Unit Tested	Report Date	APCS	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Solite Corp.	Cascade, VA	1	Mar-94	FF	3	0.0508	0.0421	0.0372	0.00755

TOTAL DIOXIN DATA FOR LWA KILNS

Company	Location	Unit Tested	Report Date	APCS	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Solite Corp.	Cascade, VA	1	Mar-94	FF	3	1.65	1.5767	1.48	0.08737

to low PCDD/PCDF emissions. Control of APCD inlet temperature and PICs (through good combustion practices) can lead to low PCDD/PCDF levels irrespective of PM levels. Similarly, poor control of PICs followed by elevated APCD inlet temperatures and good control of PM can lead to high levels of PCDD/PCDF emissions. The data suggest, however, that at appropriate APCD (FF, ESP) inlet temperatures, stack PCDD/PCDF emission levels are likely to be reduced with increased levels of PM control.

4.14 References

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5.0 DETERMINATION OF TECHNICALLY ACHIEVABLE EMISSIONS

This chapter presents a methodology for establishing PM and PCDD/PCDF technology-based emission levels for the various hazardous waste combustors (HWCs). It presents a rigorous procedure for establishing numerical levels which takes into account the natural uncontrolled variability that is exhibited in PM and PCDD/PCDF emissions data. PM emission levels for various source categories and combinations of source categories are determined using the predefined analysis procedures. For dioxins/furans, best operating practices currently employed by HWCs and emission levels achievable by the best controlled sources are identified. The dioxin/furan emission levels are presented in both total (tetra through octa) ng/dscm and ng/dscm TEQ.

5.1 Discussion of Technology-based Emission Level Determination

The procedures outlined in this chapter incorporate much of the language and intent of the Clean Air Act Amendments (CAAA's) of 1990 which the Agency is using to establish technology-based regulations for hazardous air pollutants (HAPS). Prior to the 1990 CAAA's, the national emission standards for hazardous air pollutants (NESHAPS) were to be established by the EPA Administrator at the level, which in the Administrators judgement, provided ample margin of safety to protect the public health for each hazardous air pollutant. The 1990 amendments abandoned that approach for technology-based alternatives. The language and process by which the NESHAPS are to be established has led the Agency to develop the MACT (maximum achievable control technology) standards. The amendments provide some guidance as to what is meant by MACT in the context of new and existing sources. For existing sources, MACT standards may be less stringent than for new sources, but shall not be less stringent in a category or subcategory than the average emission level achieved by the best performing 12% (but not fewer than 5 units) of the existing sources (for which the Administrator has emissions data). This emission level is referred to as the "floor." The evident intent of the directives for technology-based standards are that emissions reduction will be achieved by truly demanding maximum achievable control technology.

This chapter does not define, establish, or otherwise attempt to implement the complete MACT procedures in establishing PM and dioxin emission standards. It does, however, present a methodology for deriving emission levels that are achievable by the best controlled sources in the current population of HW burners and would be equivalent to the "floor" emission level under the MACT process.

The procedure followed in this chapter to identify emission levels achievable by the best controlled sources (i.e., the MACT floor) can be broadly characterized by two steps:

1) Identify the best performing facilities (12% or 5 units)

2) Establish a numerical emission level from the average of the emissions from the pool of facilities identified in Step 1.

The emission levels for PM and dioxins/furans are established under two alternative approaches. Under Option 1, an emission level is identified that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95 % confidence. Under Option 2, an emission level is identified that a source with emissions equivalent to the average for the pool of best controlled sources could be expected to meet 99% of the time, with 95% confidence, and assuming that the variability of the source's emissions is similar to the variability of emissions for the sources in the pool. There is a significant impact on the regulated sources between these two approaches, as discussed in Section 5.7.

An additional analysis is conducted for dioxins/furans given that EPA has emissions data on only one HWC that is designed and operated specifically to control dioxin/furan emissions. Thus, the pool of the best performing facilities identified in Step 1 is comprised virtually entirely of sources that are not specifically designed and operated to control dioxin/furan emissions. Therefore, an evaluation is conducted to confirm that HWCs operated under best current operating practices for dioxin/furan control could be expected to achieve the "floor" emission levels. In this evaluation, the best technology and operating procedures currently employed to minimize control of dioxin/furan emissions is defined APRIORI. Having defined the technology and operating procedures, the current data base is screened to identify those facilities incorporating the technology and operating procedures. To increase the body of data from which to estimate an emission level (taking into account the variability of the emissions), the procedure utilizes the analysis of the cement kiln PCDD/PCDF data presented in the last chapter to estimate what the emissions would be if the population were to adopt the specified technology and operating procedures.

The definition of best current operating practice (BOP) for PCDD/PCDF control is based on the analysis of the body of data presented in the last chapter, as well as the large body of experience acquired in the development of the MWC NSPS and guidelines for existing facilities. Best operating practice for PCDD/PCDF has been preliminarily determined to be the use of good

combustion practices (GCP) and a temperature limitation of 350 °F on the inlet to post combustion PM control devices. Rapid quenching of the combustion device exhaust gas to temperature below 350 °F is also considered BOP. Best operating practice for PCDD/PCDF control recognizes that the vast majority of HW burners will require PM control to meet the PM standards. PM control in ESPs and baghouses at reduced temperatures (below 350 °F) will generally reduce PCDD/PCDF emissions leaving the stack. The current definition of BOP excludes activated carbon injection and carbon bed technologies because EPA has data on only one HWC using carbon injection. Thus, these technologies are not considered to be current practice.

As illustrated in the previous chapter, low PM levels are not a prerequisite for low PCDD/PCDF levels. Under conditions of poor combustion and elevated APCD control temperatures, low PM emission levels can lead to high PCDD/PCDF emissions. In addition, the data clearly indicate that low PCDD/PCDF emissions can be achieved through rapid quenching the flue gas in the presence of elevated PM emissions.

Good combustion practice (GCP) for the PCDD/PCDF standards, which is part of overall best operating practices, consists of system design, operation and maintenance techniques which, when applied with appropriate APCD systems, can increase combustion efficiency and minimize products of incomplete combustion (PICS). The two major objectives of GCP are to maximize the destruction of organics and to minimize PM carryover out the combustion device. Good combustion is associated with low emissions of PCDD/PCDFs and trace organics from the high temperature regions of the device. Good combustion is typically associated with low carbon monoxide (CO) levels in the flue gas. Other GCP principles which are more difficult to quantify but which also participate in the reduction of PCDD/PCDF's and trace organics include combustion temperature, residence time, adequate mixing of combustion air and control of the amount and distribution of excess air.

The low temperature formation within the APCD device is in many situations the dominant source of PCDD/PCDF emissions from combustion devices. The control of the APCD inlet temperature to less than 350 °F, or rapid quenching of the exhaust gas, is aimed at reducing the potential for the downstream formation of PCDD/PCDF's. Application of GCP, in concert with restrictions on APCD inlet temperature, provides a BOP that attempts to limit the formation and emissions of PCDDs/PCDFs, PICs and suspected precursors leaving the high temperature region of the device, and reduce the potential for downstream formation.

5.2 Methodology for Estimating PM Emission Levels

This section describes a rigorous procedure for analyzing the PM emissions data to estimate levels that the best performing 12% (but no fewer than 5 units) of the population within each source category can be expected to achieve.

The approach is divided into two major steps. The first is to identify the best performing facilities within each category (cement kilns, LWA kilns, commercial HW incinerators, on-site incinerators, all incinerator boilers, and all hazardous waste combustors). The best performing 12% (or best 5 units, whichever is greater) within each source category employing APCDs to control PM emissions are defined as the best performing (BPF) facilities. The data from these BPF facilities are further analyzed to establish emission levels representative of the sources under two alternative approaches, as discussed in Section 5.1

5.2.1 *Identification of Best Performing (BPF) Facilities*

As discussed in the previous chapter, for APCDs incorporating an ESP, the variability exhibited in the PM emissions data can arise in part from systematic variations in ESP operating power. When the PM emissions are correlated with ESP power, the average PM emissions and variability in the data set do not reflect the expected performance from that facility. For each data set where ESP power was recorded and varied, the PM emissions are regressed against ESP KVA to determine if the PM data are correlated with ESP operating power at the 95% confidence level. Table 5.2.1-1 presents a sample regression of a PM data set. When the two-tailed probability value is less than 0.1, the PM data is considered dependant on the ESP KVA. For this particular data set, the two-tailed probability estimate is 0.080 (labeled significance F), and the PM data is correlated with ESP KVA. Note that the more commonly used R^2 value alone (in this case 0.84) does not establish the existence of a significant linear relationship.

When the PM and KVA values are correlated, the expected PM value from the facility at the average KVA utilized in the test data is determined from the slope (x1) and intercept determined in the regression using:

$$PM_i = \text{Intercept} + x1 * \text{Avg KVA} \qquad 5.1a$$

where:

PM_i = Expected PM level at Average KVA

TABLE 5.2.1-1. SAMPLE REGRESSION ANALYSIS OF PM DATA VERSUS ESP OPERATING POWER

Essroc Materials		Logansport, IN		1		1
KVA		PM				
	32.00000		0.08300			
	31.70000		0.07500			
	39.80000		0.06800			
	42.40000		0.05700			

Regression Statistics

Multiple R	0.91986877
R Square	0.84615855
Adjusted R S	0.76923783
Standard Err	0.00529687
Observation	4

Analysis of Variance

	df	Sum of Squares	Mean Square	F	Significance F
Regression	1	0.00030864	0.00030864	11.0003978	0.08013123
Residual	2	5.6114E-05	2.8057E-05		
Total	3	0.00036475			

	Coefficients	Standard Error	t Statistic	P-value	Lower 95%	Upper 95%
Intercept	0.13867886	0.02065148	6.71520235	0.00674008	0.04982266	0.22753506
x1	-0.00186234	0.00056151	-3.31668476	0.04516581	-0.00427831	0.00055363

When the PM values are not dependant on the ESP power levels, or when other PM devices were used (i.e., baghouses) and systematic trends could not be determined, the expected value from the facility is taken as the average PM level in the facility data set using:

$$PM_i = \text{Simple Average of facility data set} \qquad 5.1b$$

When a PM versus KVA dependance has been determined, the variability about the expected PM level is given by the standard error estimate in the regression (Equation 5.2a). For the data sets where no dependance was found, the variability about the expected PM level is given by the standard deviation in the data set (Equation 5.2b).

$$S_i = \text{Standard Err.} \qquad 5.2a$$

$$S_i = \text{Standard Deviation (facility data set)} \qquad 5.2b$$

For the example data set displayed in Table 5.2.1-1, the standard error is 0.0053 gr/dscf at 7% O_2.

The expected PM levels (Equations 5.1) are combined with the facility variability estimates (Equations 5.2) to identify the best performing facilities. Equation 5.3 is used to define a combined parameter (P1), which is then used to sort and rank the facilities within each source category. After sorting and ranking by P1, the best 12% (but no fewer than 5 units) are selected as the BPF facilities.

$$P1 = PM_i + 2 * S_i \qquad 5.3$$

The advantage of using P1 instead of the expect value (PM_i) in sorting and ranking the facilities can be illustrated in the simple example as follows. Facility A has 4 data points (1, 10, 10, 10), the average value (PMi) is 7.75, the standard deviation is 4.5, giving a P1 value of 16.75. Facility B has 4 data points (9, 9, 9, 9), the average is 9, and the P1 value is also 9. On the basis of average values, Facility A would rank ahead of Facility B. However, on the basis of P1, Facility B (as is intuitively apparent) would be expected to produce values lower than Facility A . As discussed in the previous chapter, there are facilities (particularly in the on-site incinerator and

boiler population) which burn exclusively low ash content wastes and fuels and can achieve very low PM levels without PM control. These facilities are not representative of the best controlled sources and are not included in defining the BPF population.

The approach to identifying the BPF facilities within each source category can be summarized as follows.

1) Eliminate from the source category population those facilities which do not incorporate or require APCD devices to achieve low PM levels.

2) For each facility, estimate PM_i, S_i, and P1 using Equations 5.2 and 5.3.

3) Sort the facilities in ascending levels according to the P1 levels.

4) Select the top 12% (but no fewer than 5 units) from the sorted list and define these as the pool of BPF facilities within the source category.

5.2.2 *Statistical Approach for Data Analysis* (1, 2, 3, 4)

Under Option 1*, the PM data from the BPF group of facilities within each source category are further analyzed to established numerical emission levels that any facility within this group can be expected to achieve. The analysis accounts for the variability associated with the emissions data exhibited by the individual facility, as well as the ability to select any facility within the BPF group and achieve the emission level. A statistical tolerance limit approach is used in establishing the PM value. Using this method, previously acquired data (CoC/trial burn data) are used to establish an emission level which a specified portion of the population can achieve in the future at a specified confidence level. The form of the computed limit is:

$$PM_{tl} = PM_a + K * S_a \qquad 5.4$$

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* Where an emission level is identified that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95% confidence.

Where PM_{tl} is the computed PM level, PM_a is an average PM_i value estimated from the BPF facilities, S_a is an overall estimate of the variability, and K is a statistical quantity defining the confidence level and the proportion of facilities achieving the level. Both the confidence level and the proportion of the facilities achieving the levels are required to obtain a mathematically correct statement concerning levels. Statistical tolerance limits are sometimes confused with other limits used in engineering and statistical analyses. Statistical tolerance limits are calculated from data to define the amount of variation that the process (in this case, BPF facilities) exhibits. These limits will contain a specified proportion of the total population. Confidence limits, a commonly used approach in data analysis, define an interval within which a population parameter lies.

Within each source category, PM_a is computed from the BPF population using Equation 5.5, where (nf) is the number of facilities in the BPF population, and PM_i are the facilities' expected PM values computed using Equations 5.1.

$$PM_a = \frac{1}{nf} \sum_{i=1}^{nf} PM_i \qquad 5.5$$

The population variability is computed using:

$$S_a = \sqrt{S_1^2 + S_2^2} \qquad 5.6a$$

where:

$$S_1^2 = \left(\sum_{i=1}^{nf} \sum_{j=1}^{np} PM_{ij}^2 - \sum_{i=1}^{nf} np_i * PM_i^2 \right) / (N_t - nf) \qquad 5.6b$$

and (np) is the number of points in a facility data set, and (nf) are the number of facilities in the BPF group. N_t is the total number of data points in the pool of facilities given by:

$$N_t = \sum_{i=1}^{nf} np_i \qquad 5.6c$$

and:

$$S_2^2 = \left(\left(\sum_{i=1}^{nf} np_i * PM_i^2 \right) - \left(\sum_{i=1}^{nf} \sum_{j=1}^{np} PM_{ij} \right)^2 / N_t - (nf-1) * S_1^2 \right) / \left(N_t - \frac{1}{N_t} * \sum_{i=1}^{nf} np_i^2 \right) \qquad 5.6d$$

Equation 5.6b, producing the quantity (S_1^2), will return the weighted average (by np_i -1) of the individual facility variances (S_i^2). Equation 5.6d, producing (S_2^2), essentially accounts for the variability across the BPF group.

The statistical quantity K (Equation 5.4) can be selected from Table 5.2.2-1 utilizing the degrees of freedom associated with the joint variance estimate and both the proportion of the distribution to be covered and the confidence level. Several alternative approaches exist in determining the joint degrees of freedom. The approach used here is to estimate a K value based on the relative proportion of S_1 and S_2.

$$K = \frac{K(N_t) - K(nf)/\sqrt{J} + (K(nf) - K(N_t))/\sqrt{1 + (j-1)/Q)}}{(1 - 1/\sqrt{J})} \quad 5.7a$$

where:

$$Q = \frac{(\sum_{i=1}^{nf} np_i * PM_i^2) - (\sum_{i=1}^{nf}\sum_{j=1}^{np} X_{ij})^2 / N_t)}{(nf-1) * S_1^2} \quad 5.7b$$

and (J) represents the average number of data points per facility.

Equations 5.7 essentially produce a K value <u>at the degrees of freedom</u> associated with the S_1^2 and S_2^2 weighted average of the degrees of freedom associated with S_1^2 and S_2^2 . The degrees of freedom associated with application of equations 5.7 can be approximated by:

$$DOF \cong \frac{(S_1^2 * (N_t - nf) + S_2^2 * (nf-1))}{S_1^2 + S_2^2} \quad 5.8$$

In general, for S_1^2 values much greater than S_2^2, the K value is associated with the degrees of freedom producing S_1^2 which are (N_t-nf). For S_2^2 values much greater than S_1^2, the K value is associated with the degrees of freedom producing S_2^2 which are (nf).

TABLE 5.2.2-1. ONE-SIDED AND TWO-SIDED STATISTICAL TOLERANCE LIMIT FACTORS FOR A NORMAL DISTRIBUTION

Factors k such that the probability is γ that at least a proportion P of the distribution will be less than $\bar{X} + ks$ for greater than $\bar{X} - ks$) where $\bar{X}$ and s are estimates of the mean and standard deviation computed from a sample size of n. Two-sided factors cover $\bar{X} \pm ks$.

n \ P	$\gamma = 0.90$				$\gamma = 0.95$				$\gamma = 0.99$			
	0.90	0.95	0.99	0.999	0.90	0.95	0.99	0.999	0.90	0.95	0.99	0.999
	One-sided Factors*											
3	4.258	5.310	7.340	9.651	6.158	7.655	10.552	13.857				
4	3.187	3.957	5.437	7.128	4.163	5.145	7.042	9.215				
5	2.742	3.400	4.666	6.112	3.407	4.202	5.741	7.501				
6	2.494	3.091	4.242	5.558	3.006	3.707	5.062	6.612	4.408	5.409	7.334	9.540
7	2.333	2.894	3.972	5.201	2.755	3.399	4.641	6.061	3.856	4.730	6.411	8.346
8	2.219	2.755	3.783	4.955	2.582	3.188	4.353	5.686	3.496	4.287	5.811	7.560
9	2.133	2.649	3.641	4.772	2.454	3.031	4.143	5.414	3.242	3.971	5.389	7.014
10	2.065	2.568	3.532	4.629	2.355	2.911	3.981	5.203	3.048	3.739	5.075	6.603
11	2.012	2.503	3.444	4.515	2.275	2.815	3.852	5.036	2.897	3.557	4.828	6.284
12	1.966	2.448	3.371	4.420	2.210	2.736	3.747	4.900	2.773	3.410	4.633	6.032
13	1.928	2.403	3.310	4.341	2.155	2.670	3.659	4.787	2.677	3.290	4.472	5.826
14	1.895	2.363	3.257	4.274	2.108	2.614	3.585	4.690	2.592	3.189	4.336	5.651
15	1.866	2.329	3.212	4.215	2.068	2.566	3.520	4.607	2.521	3.102	4.224	5.507
16	1.842	2.299	3.172	4.164	2.032	2.523	3.463	4.534	2.458	3.028	4.124	5.374
17	1.820	2.272	3.136	4.118	2.001	2.486	3.415	4.471	2.405	2.962	4.038	5.268
18	1.800	2.249	3.106	4.078	1.974	2.453	3.370	4.415	2.357	2.900	3.961	5.167
19	1.781	2.228	3.078	4.041	1.949	2.423	3.331	4.364	2.315	2.855	3.893	5.078
20	1.765	2.208	3.052	4.009	1.926	2.396	3.295	4.319	2.275	2.807	3.832	5.003
21	1.750	2.190	3.028	3.979	1.905	2.371	3.262	4.276	2.241	2.768	3.776	4.932
22	1.736	2.174	3.007	3.952	1.887	2.350	3.233	4.238	2.208	2.729	3.727	4.866
23	1.724	2.159	2.987	3.927	1.869	2.329	3.206	4.204	2.179	2.693	3.680	4.806
24	1.712	2.145	2.969	3.904	1.853	2.309	3.181	4.171	2.154	2.663	3.638	4.755
25	1.702	2.132	2.952	3.882	1.838	2.292	3.158	4.143	2.129	2.632	3.601	4.706
30	1.657	2.080	2.884	3.794	1.778	2.220	3.064	4.022	2.029	2.516	3.446	4.508
35	1.623	2.041	2.833	3.730	1.732	2.169	2.994	3.934	1.957	2.431	3.334	4.364
40	1.598	2.010	2.793	3.679	1.697	2.126	2.941	3.868	1.902	2.365	3.250	4.255
45	1.577	1.986	2.762	3.638	1.669	2.092	2.897	3.811	1.857	2.313	3.181	4.168
50	1.560	1.965	2.735	3.604	1.646	2.065	2.863	3.769	1.821	2.296	3.124	4.099

* Table A-7, reference 3

The confidence level and the proportion of the BPF population expected to achieve the emission levels are independently selected. For the analysis presented in this report, the K values are extracted such that 99% of the BPF population would be expected to achieve the computed emission levels at the 95% confidence level.

It is important to note that the numerical emission levels arrived at through implementation of the procedure described in this section are values applied to the individual data points. In this manner, the numerical level is applied to future data acquired in a similar manner, with similar procedures and acquired over similar time durations. As such, the numerical levels are values never to be exceeded by data acquired in the same manner over the same time duration as those producing the levels.

5.3 Further Analysis of the Dioxin/Furan Data

The calculation of the dioxin/furan floor emission levels is presented in Sections 5.3.4 and 5.6. As discussed in Section 5.1, an analysis is presented here to estimate the emissions and subsequent emission limits from the population of HWCs operating under BOP. This analysis provides a check on the ability to achieve the "floor" limits.

There is currently one HW burning facility incorporating technology designed specifically for the control of dioxin/furan emissions. As discussed in Appendix A, this facility has incorporated the use of activated carbon injection at multiple locations in the APCD train. There are, however, other facilities which employ operating practices in conjunction with APCDs which have the effect of reducing and controlling PCDD/PCDF emissions. It might be suggested that all these facilities form a basis for deriving the PCDD/PCDF levels in precisely the same manner as presented in the previous section. Using the terminology adopted in establishing the NESHAPS, the level identified in this approach is labeled the PCDD/PCDF "FLOOR" emission level. The potential problems associated with this approach include selecting an emission level which does not reflect the actual performance capability of control technologies and best operating practices. In order to address this issue, an alternative approach is presented which estimates the expected PCDD/PCDF emissions from the current population of HW burners employing pre-defined technologies and operating practices suitable for dioxin/furan control. This analysis approach relies heavily on the analysis of the PCDD/PCDF kiln data presented in the previous chapter, as well as the body of experience developed in completion of the MWC NSPS and guidelines for existing facilities. Both approaches (estimation of the FLOOR and estimation of expected emissions) utilize the same statistical procedures presented in the previous section to account for the variability observed in the dioxin/furan emissions.

5.3.1 *Estimation of Expected PCDD/PCDF Emission Levels*

As discussed in Section 5.1, the approach selected and adopted to reduce PCDD/PCDF emissions is three-fold. The first component is to adopt the policy of good combustion practices (GCP). The second component is designed to minimize the potential for the formation of dioxin/furans in the downstream or post-combustion regions of the device by encouraging rapid quenching of the flue gas and establishing an upper limit on the flue gas temperature entering the APCD. The third component is a recognition that a significant proportion of the HW burning facility population will require PM control to meet PM emission levels. When combined with the GCP and a limit on the APCD inlet temperature, an appropriate PM APCD will participate in the capture of PCDD/PCDF entering the device. Note that the effectiveness of PCDD/PCDF capture in a PM APCD will be dependant on several parameters, including the carbon content of the PM.

The approach to establishing a numerical level on the PCDD/PCDF emissions presented in this section consists of two main components. The first component is to estimate what the dioxin/furan emissions would be from the current population of HW burning facilities after adopting the BOP definition. The second step is to use this body of data to establish a numerical level which takes into account the natural variability of PCDD/PCDF emissions that those facilities adopting the predefined operating conditions and suitable technology provision can be expected to achieve.

5.3.2 *Estimation of Total PCDD/PCDF Emissions from BOP Facilities*

In the previous chapter, a detailed examination of the cement kiln PCDD/PCDF data was presented. This analysis indicated an APCD inlet temperature dependency, a CO dependency and an inverse O_2 dependency for PCDD/PCDF emissions. These relationships are consistent with the MWC experience and support the basis for the PCDD/PCDF BOP provisions. These relationships (temperature, CO and O_2) can be used to estimate the PCDD/PCDF emissions from the cement kiln population following adoption of the PCDD/PCDF BOP provisions. Specifically, the cement kiln PCDD/PCDF data (total ng/dscm) can be manipulated to estimate the PCDD/PCDF data if APCD inlet temperature were restricted to 350 °F. Application of Equation 5.9 to those facilities (and data points) with reported APCD temperatures greater than 350 °F produces a data set of PCDD/PCDF emissions that would be anticipated from the kiln population if APCD inlet temperature were restricted to an upper limit of 350 °F. Note that data from kilns with APCD temperature of less

than 350 °F are not shifted upwards. Also note that the temperature dependency of Equation 5.9 assumes a 1 order of magnitude increase in PM emission every 180 °F (average of 196 and 164 estimates presented in Chapter 4).

$$PCDD/PCDF_{(@350F)} = PCDD/PCDF_{(@T)} * \exp^{(0.0128*(350-T))} \qquad 5.9$$

Sequential application of Equations 5.10 and 5.11 to the temperature corrected PCDD/PCDF data evaluated using Equation 5.9 generates the PCDD/PCDF data (in total ng/dscm) that would be anticipated from facilities implementing GCP for PIC control. Note that equation 5.10 is applied only to those data points with CO levels greater than 100 ppm (@ 7% O_2), and Equation 5.11 is applied only to those data points with reported O_2 levels below 10%. As discussed in Chapter 4, application of Equation 5.10 to the data with CO levels greater than 100 ppm (@ 7% O_2) reduces the dioxin/furan emissions along a best fit line through the body of CO data. Similarly, application of Equation 5.11 to the temperature and CO corrected data to those data sets with reported stack oxygen levels below 10% reduces the PCDD/PCDF emission levels.

$$PCDD/PCDF_{(@350F,100\ ppm\ CO)} = PCDD/PCDF_{(@350F)} * (100/CO)^{(1.04)} \qquad 5.10$$

$$PCDD/PCDF_{(@350F,100\ ppm\ CO,10\%\ O2)} = PCDD/PCDF_{(@350F,100ppm\ CO)} * \exp^{-.232*(10-O2)} \qquad 5.11$$

Sequential application of Equations 5.9 through 5.11 produces a PCDD/PCDF emissions estimate (in total ng/dscm) that would be expected from the cement kiln population following adoption of the BOP control guidelines. With this body of data, the statistical procedure outlined in Section 5.2.1 can be applied, where the PM values are replaced by the corresponding PCDD/PCDF entries. Note that all facilities, following manipulation of the data, are effectively implementing the control guidelines. For this reason, the data is not sorted with the top 5 units (12%) selected. With the statistical quantity K selected from the same column (Table 5.2.1-1) as used in the PM calculations, a PCDD/PCDF emission value based on total congener mass flow can be calculated.

5.3.3 *TEQ PCDD/PCDF Level Procedures*

The procedure described in Section 5.3.1 will estimate the PCDD/PCDF emissions in total ng/dscm from BOP facilities. The TEQ emission level is estimated using the same temperature, CO and O_2 corrected (if required) total PCDD/PCDF emissions data combined with the reported TEQ value, and the facility specific foot print ratio (PCDD/PCDF to TEQ ratio). Equations 5.12 are used to estimate the PCDD/PCDF emission in TEQ for each data point reported in the cement kiln data base from a BOP equipped and operated kiln.

$$(TEQ)^{*}_{(@350F,\ 100\ ppm\ CO,10\%\ O2)} = (TEQ)_p - \frac{\Delta(PCDD/PCDF)}{R_p} \qquad 5.12a$$

where $(TEQ)_p$ is the original reported data and:

$$\Delta(PCDD/PCDF) = (PCDD/PCDF)_p - (PCDD/PCDF)_{(@350F,100\ ppm,CO,10\%\ O2)} \qquad 5.12b$$

and:

$$R_p = \frac{(PCDD/PCDF)_p}{(TEQ)_p} \qquad 5.12c$$

Note that R_p is the ratio of the original PCDD/PCDF data reported in total ng/dscm to the original TEQ value. As discussed in the previous chapter, this is generally facility/device type specific. Also note that the data point $(PCDD/PCDF)^{*}_{(350F,100\ ppm\ CO,10\%\ O2)}$ represents either the corrected data or the original data point in total ng/dscm if the temperature, CO or O^2 correction has not been applied.

5.3.4 *Estimation of PCDD/PCDF Floor Emission Levels*

The approach used to estimate the dioxin/furan FLOOR emission level follows the same procedures outlined in Section 5.2. A pool of facilities are identified from which the best performing 12% (no fewer than 5 units) are selected. The data from these best performing facilities (BPF) are further analyzed to establish the numerical emission levels. The statistical

approach described in Section 5.2.2 is used to account for the observed variability in the emission data. As discussed previously, the combined goals for best operating practices of incorporating both GCP and a temperature limit on the PM APCD device are to limit both the PCDD/PCDF formed in the PM control device and to improve the dioxin/furan capture efficiency on the PM matter. This strategy recognizes the potential for significant PCDD/PCDF production from units controlling PM, as well as the potential for dioxin/furan capture in the PM control device. It is important to note that this control strategy correctly implies that measured dioxin/furan levels from facilities may be low and not representative if PM levels from those facilities are not controlled and are higher than PM levels typically achieved by ESPs and baghouses. Similarly, those facilities achieving very low PM levels without the need for PM control (i.e., facilities with low fuel ash content) may exhibit low dioxin/furan levels which again are not reflective of the combustion technology when burning higher ash content fuels. Finally, in establishing the pool of data from which the floor can be estimated, only those facilities burning halogenated fuels were considered.

5.4 Summary of PM Level Estimates

Table 5.4-1 summarizes the analysis of the cement kiln PM emissions. A brief description of the spread sheet calculation is provided below illustrating the application of the statistical procedures described in Section 5.2.1. Appendix M summarizes the kiln and LWA population sorted by P1.

The values in the column labeled Vi are the square of the facility standard deviation estimates. Where a correlation between PM and KVA has been determined, Vi is the square of the standard error in the regression analysis. The column labeled "Total" is the sum of the PM data points from each facility. This column is added (summed), squared, then divided by the total number of data points in the BPF population (value 0.00076). The next column labeled (total^2/np) is the square of the previous column entries divided by the number of points at the particular facility. The values in this column are added together to generate the value 0.00076. The next column labeled (np^2) is the square of the number of facility data points. This column of data is added together to generate the sum of the squares of the number of facility data points (value 117). The next column labeled np-1 is the number of data points at each facility minus 1. These are added together to generate the quantity (Nt-nf), value 16. The next column labeled Vi * (np-1) is the facility variance (Vi) multiplied by (np-1). These quantities are totaled giving the value 2.47e-5. The value of S_1^2 (Equation 5.6b) is simply the weighted average of the facility variances

TABLE 5.4-1. PM LEVEL ANALYSIS FOR CEMENT KILNS

Company	Location	No. Units	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	VI*(np-1)
Southdown/Southwestern	Fairborn, OH	1	1	3	0.00300	0.00000	0.00%	0.00300	0.00E+00	0.00900	0.00003	9	2	0.00E+00
Southdown/Kosmos	Kosmosdale, KY	1	1	9	0.002614444	0.000943042	36.07%	0.00450	8.89E-07	0.02353	0.00006	81	8	7.11E-06
Lafarge Corp.	Alpena, MI	2	1	3	0.00333	0.00252	75.50%	0.00837	6.33E-06	0.01000	0.00003	9	2	1.27E-05
Lafarge Corp.	Fredonia, KS	2	1	3	0.01100	0.00000	64.03%	0.01100	3.91E-35	0.03300	0.00036	9	2	7.82E-35
Texas Industries	Midlothian, TX	4	1	3	0.00962	0.00158	16.39%	0.01277	2.48E-06	0.02885	0.00028	9	2	4.97E-06
									SUM(Total)^2/Nt	0.0005188				
	Total Number of Points (Nt)			21					SUMMATIONS		0.00076	117	16	2.47E-05
	Total Number of Facilities (nf)			5										

S1^2 (gr/dscf @ 7% O2)^2	1.55E-06
S2^2 (gr/dscf @ 7% O2)^2	1.54E-05
Sa (gr/dscf @ 7% O2)	0.00411
Avg PMi (gr/dscf @ 7% O2)	0.00591
K @ Nt	3.262
K @ np	6.7
Degrees of Freedom	5.10
Q	39.35
J	4.20
K @ 95%-p, 99%-d	6.48
LIMIT (gr/dscf @ 7% O2)	0.033

and is given by the sum of VI * (np-1) divided by the sum of (np-1), or (2.47e-5)/16 and has the value 1.55E-6. The quantity S_2^2 is calculated using equation 5.6d, and has the value (0.00076-0.000518-(5-1) * (1.55E-6))/(21-117/21). Sa is simply the orthogonal addition of the S12 and S22 (equation 5.6a) and is equal to the sqrt (1.55E-6 + 1.54E-5) and has the value 0.00411. The statistical quantity K at the total number of points (21) is extracted from Table 5.2.1-1 with alfa=95 and P = 99 and has the value 3.262. The statistical quantity K at the total number of facilities (5) is extracted from Table 5.2.1-1 with alfa=95 and P = 99 and has the value 6.7. The average number of points per facility (J) is 4.2. The quantities Q and the degrees of freedom (Equations 5.7b, 5.8) are computed to give the values as shown of 39.35 and 5.1. The effective K value is computed using Equation 5.7a and has the value of 6.48. Note that from Table 5.2.1-1, the K value with 5.1 degrees of freedom and alfa = 95 and P = 99 is very close to the computed K value and provides a check on the K calculation. The emission level number is given by Equation 5.4 and is the sum of the average of the facility averages (0.0059) plus the K value times Sa. This is equal to (0.0059 + 6.48 * 0.00411), which has the value 0.033. This value is the PM emission level at the 95% confidence level that 99% of the BPF employing BOP would be expected to achieve.

Table 5.4-2 presents the PM analysis of the LWA kiln population. The PM level is calculated to be 0.022 gr/dscf @ 7% O_2. Table 5.4-3 presents the PM calculation for the commercial HW incinerator population. The PM level is calculated to be 0.010 gr/dscf at 7% O_2. Table 5.4-4 presents the PM calculation for the on-site HW incinerator population. The PM level is calculated as 0.0153 gr/dscf @ 7% O_2. Table 5.4-5 presents the PM analysis of the HW burning boiler population. The PM level is calculated to be 0.021 gr/dscf @ 7% O_2.

Table 5.4-6 presents the PM analysis of the combined CK and LWA population. The emission level is calculated to be 0.0076 gr/dscf @ 7% O_2. Table 5.4-7 presents the PM level analysis of the combined on-site and commercial incinerator population. The level is calculated to be 0.0057 gr/dscf @ 7% O_2. Note that the process of combining populations reduces the level. This is expected since the process of combining populations results in selection of the best performers from each population. Also note that when the CK and on-site (OS) populations are combined, the best units are all using baghouses, which may not define suitable APCD technology for all kiln processes. Table 5.4-8 presents the analysis of the PM data with all source categories combined. The limit is calculated as 0.0086 gr/dscf @ 7% O_2.

TABLE 5.4-2. PM LEVEL ANALYSIS FOR AGGREGATE KILNS

Company	Location	No. Units	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	VI*(np-1)
*Solite Corp.	Norwood, NC	0	7	3	0.00048	0.00025	53.30%	0.00098	6.41E-08	0.00143	0.00000	9	2	1.28E-07
*Solite Corp.	Green Cove Springs,	0	5	3	0.00144	0.00016	10.76%	0.00175	2.41E-08	0.00433	0.00001	9	2	4.83E-08
*Solite Corp.	Norwood, NC	0	8	3	0.00190	0.00161	84.65%	0.00511	2.58E-06	0.00569	0.00001	9	2	5.16E-06
*Solite Corp.	Cascade, VA	2	2	3	0.00567	0.00153	26.96%	0.00872	2.33E-06	0.01700	0.00010	9	2	4.67E-06
*Solite Corp.	Arvonia, VA	2	7	3	0.00667	0.00115	17.32%	0.00898	1.33E-06	0.02000	0.00013	9	2	2.67E-06
									SUM(Total)^2/Nt	0.0001565				
	Total Number of Points (Nt)			15					SUMMATIONS		0.00025	45	10	1.27E-05
	Total Number of Facilities (nf)			5										

* LW Aggregate Kiln

S1^2 (gr/dscf @ 7% O2)^2	1.27E-06
S2^2 (gr/dscf @ 7% O2)^2	7.15E-06
Sa (gr/dscf @ 7% O2)	0.00290
Avg PMi (gr/dscf @ 7% O2)	0.00323
K @ Nt	3.520
K @ np	6.7
Degrees of Freedom	4.90
Q	17.95
J	3.00
K @ 95%-p, 99%-d	6.35
LIMIT (gr/dscf @ 7% O2)	0.022

TABLE 5.4-3. PM LEVEL ANALYSIS FOR COMMERCIAL HWI'S

Company	Location	No. Units	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Laidlaw Environmental Services	Roebuck, SC	1	1	8	0.0008	0.0004	46.62%	0.00147	1.26E-07	0.00608	4.62E-06	64	7	8.79E-07
Aptus, Inc.	Aragonite, UT	1	1	9	0.0006	0.0006	89.32%	0.00176	3.20E-07	0.00570	3.61E-06	81	8	2.56E-06
Waste Tech. Industries	East Liverpool, OH	1	1	9	0.0024	0.0009	36.08%	0.00413	7.50E-07	0.02160	5.18E-05	81	8	6.00E-06
Trade Waste Incineration	Sauget, IL	4	4	8	0.0017	0.0014	83.32%	0.00447	1.95E-06	0.01340	2.24E-05	64	7	1.36E-05
Aptus, Inc.	Coffeyvillle, KS	1	1	12	0.0034	0.0014	40.36%	0.00617	1.90E-06	0.04100	1.40E-04	144	11	2.09E-05
									SUM(Total)^2/Nt	0.00016751				
	Total Number of Points (Nt)			46						SUMMATIONS	0.00022	434	41	4.40E-05
	Total Number of Facilities (nf)			5										

S1^2 (gr/dscf @ 7% O2)^2	1.07E-06
S2^2 (gr/dscf @ 7% O2)^2	1.39E-06
Sa (gr/dscf @ 7% O2)	0.00157
Avg PMi (gr/dscf @ 7% O2)	0.00178
K @ Nt	2.800
K @ nf	6.7
Degrees of Freedom	20.12
Q	12.84
J	9.20
K @ 95%-p, 99%-d	5.45
LIMIT (gr/dscf @ 7% O2)	0.0103

TABLE 5.4-4. PM LEVEL ANALYSIS FOR ON-SITE HWI'S

Company	Location	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Olin Corp.	East Alton, IL	2	4	0.00029	0.00017	59.35%	0.00064	2.99E-08	0.00117	3.39E-07	16	3	8.97E-08
Dupont	Orange, TX	1	6	0.00125	0.00055	44.33%	0.00236	3.07E-07	0.00750	9.38E-06	36	5	1.54E-06
Dupont	Deepwater, NJ	FR-1	3	0.00290	0.00061	63.36%	0.00412	3.70E-07	0.00870	2.52E-05	9	2	7.40E-07
Glaxo Inc.	R.T.P., NC	1	6	0.00193	0.00159	163.36%	0.00511	2.52E-06	0.01161	2.25E-05	36	5	1.26E-05
Upjohn Co.	Kalamazoo, MI	1	3	0.00398	0.00208	89.93%	0.00814	4.31E-06	0.01195	4.76E-05	9	2	8.62E-06
Miles Inc.	New Martinsville	1	6	0.00650	0.00217	22.27%	0.01084	4.70E-06	0.03900	2.54E-04	36	5	2.35E-05
								SUM(Total)^2/Nt	2.28E-04				
	Total Number of Points (Nt)		**28**					**SUMMATIONS**		**0.00036**	**142**	**22**	**4.71E-05**
	Total Number of Facilities (nf)		**6**										

S1^2 (gr/dscf @ 7% O2)^2	**2.14E-06**
S2^2 (gr/dscf @ 7% O2)^2	**5.22E-06**
Sa (gr/dscf @ 7% O2)	**0.00271**
Avg PMi (gr/dscf @ 7% O2)	**0.00281**
K @ Nt	**3.100**
K @ nf	**5.062**
Degrees of Freedom	**9.94**
Q	**12.18**
J	**4.67**
K @ 95%-p, 99%-d	**4.61**
LIMIT (gr/dscf @ 7% O2)	**0.0153**

TABLE 5.4-5. PM LEVEL ANALYSIS FOR BOILERS

Company	Location	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	Pl (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Tennessee Eastman	Kingsport, TN	24	3	0.00530	8.62E-05	2%	0.00548	7.43E-09	0.01591	8.44E-05	9	2	1.49E-08
Tennessee Eastman	Kingsport, TN	30	3	0.00593	0.00021	4%	0.00635	4.33E-08	0.01780	1.06E-04	9	2	8.67E-08
Union Carbide	South Charleston, '	25	3	0.00703	0.00045	6%	0.00794	2.03E-07	0.02110	1.48E-04	9	2	4.07E-07
Monsanto Chemical Co.	Nitro, WV	B-8	6	0.00347	0.00229	66%	0.00804	5.23E-06	0.02080	7.21E-05	36	5	2.61E-05
Tennessee Eastman	Kingsport, TN	30	3	0.00907	0.00040	4%	0.00987	1.63E-07	0.02720	2.47E-04	9	2	3.27E-07
								SUM(Total)^2/Nt	0.00059				
	Total Number of Points (Nt)		18						SUMMATIONS	0.00066	72	13	2.70E-05
	Total Number of Facilities (nf)		5										

S1^2 (gr/dscf @ 7% O2)^2	2.07E-06
S2^2 (gr/dscf @ 7% O2)^2	4.40E-06
Sa (gr/dscf @ 7% O2)	0.00254
Avg PMi (gr/dscf @ 7% O2)	0.00616
K @ Nt	3.370
K @ nf	6.7
Degrees of Freedom	6.88
Q	8.42
J	3.60
K @ 95%-p, 99%-d	5.84
LIMIT (gr/dscf @ 7% O2)	0.0210

TABLE 5.4-6. PM LEVEL ANALYSIS FOR CEMENT KILNS AND LWA KILNS

Company	Location	No. Units	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	VI*(np-1)
*Solite Corp.	Norwood, NC	0	7	3	0.00048	0.00025	53.30%	0.00098	6.41E-08	0.00143	0.00000	9	2	1.28E-07
*Solite Corp.	Green Cove Springs,	0	5	3	0.00144	0.00016	10.76%	0.00175	2.41E-08	0.00433	0.00001	9	2	4.83E-08
Southdown/Southwestern	Fairborn, OH	1	1	3	0.00300	0.00000	0.00%	0.00300	0.00E+00	0.00900	0.00003	9	2	0.00E+00
Southdown/Kosmos	Kosmosdale, KY	1	1	9	0.00261	0.00094	36.07%	0.00450	8.89E-07	0.02353	0.00006	81	8	7.11E-06
*Solite Corp.	Norwood, NC	0	8	3	0.00190	0.00161	84.65%	0.00511	2.58E-06	0.00569	0.00001	9	2	5.16E-06
Lafarge Corp.	Alpena, MI	2	1	3	0.00333	0.00252	75.50%	0.00837	6.33E-06	0.01000	0.00003	9	2	1.27E-05
									SUM(Total)^2/Nt	0.0001214				
	Total Number of Points (Nt)			24						SUMMATIONS	0.00014	126	18	2.51E-05
	Total Number of Facilities (nf)			6										

* LW Aggregate Kiln

S1^2 (gr/dscf @ 7% O2)^2	1.40E-06
S2^2 (gr/dscf @ 7% O2)^2	5.98E-07
Sa (gr/dscf @ 7% O2)	0.00141
Avg PMi (gr/dscf @ 7% O2)	0.00213
K @ Nt	3.181
K @ np	5.1
Degrees of Freedom	14.10
Q	2.61
J	4.00
K @ 95%-p, 99%-d	3.87
LIMIT (gr/dscf @ 7% O2)	0.0076

TABLE 5.4-7. PM LEVEL ANALYSIS FOR COMMERCIAL AND ON-SITE HWI'S

Company	Location	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Olin Corp.	East Alton, IL	2	4	0.0003	0.0002	59.35%	0.00064	2.99E-08	0.00117	3.39E-07	16	3	8.97E-08
Laidlaw Environmental Services	Roebuck, SC	1	8	0.0008	0.0004	46.62%	0.00147	1.26E-07	0.00608	4.62E-06	64	7	8.79E-07
Aptus, Inc.	Aragonite, UT	1	9	0.0006	0.0006	89.32%	0.00176	3.20E-07	0.00570	3.61E-06	81	8	2.56E-06
Dupont	Orange, TX	1	6	0.0013	0.0006	44.33%	0.00236	3.07E-07	0.00750	9.38E-06	36	5	1.54E-06
Dupont	Deepwater, NJ	FR-1	3	0.0029	0.0006	20.98%	0.00412	3.70E-07	0.00870	2.52E-05	9	2	7.40E-07
Waste Tech. Industries	East Liverpool, OH	1	9	0.0024	0.0009	36.08%	0.00413	7.50E-07	0.02160	5.18E-05	81	8	6.00E-06
Trade Waste Incineration	Sauget, IL	4	8	0.0017	0.0014	83.32%	0.00447	1.95E-06	0.01340	2.24E-05	64	7	1.36E-05
Glaxo Inc.	R.T.P., NC	1	6	0.0019	0.0016	82.03%	0.00511	2.52E-06	0.0T161	2.25E-05	36	5	1.26E-05
								SUM(Total)^2/Nt	0.00010827				
									SUMMATIONS	0.00014	387	45	3.80E-05
	Total Number of Points (Nt)		53										
	Total Number of Facilities (nf)		8										

S1^2 (gr/dscf @ 7% O2)^2	8.45E-07
S2^2 (gr/dscf @ 7% O2)^2	5.63E-07
Sa (gr/dscf @ 7% O2)	0.00119
Avg PMi (gr/dscf @ 7% O2)	0.00148
K @ Nt	2.800
K @ nf	4.4
Degrees of Freedom	29.81
Q	5.35
J	6.63
K @ 95%-p, 99%-d	3.59
LIMIT (gr/dscf @ 7% O2)	0.0057

TABLE 5.4-8. PM LEVEL ANALYSIS FOR ALL FACILITIES

Company	Location	Unit Tested	np	PMi gr/dscf @ 7% O2	Sdev gr/dscf @ 7% O2	RSD (%)	P1 (gr/dscf @ 7% O2)	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Olin Corp.	East Alton, IL		4	0.00029	0.00017	59%	0.00064	2.99E-08	0.00117	3.39E-07	16	3	8.97E-08
Solite Corp.	Norwood, NC	7	3	0.00048	0.00025	53%	0.00098	6.41E-08	0.00143	6.77E-07	9	2	1.28E-07
Laidlaw Environmental Services	Roebuck, SC		8	0.00076	0.00035	47%	0.00147	1.26E-07	0.00608	4.62E-06	64	7	8.79E-07
Solite Corp.	Green Cove Springs, FL	5	3	0.00144	0.00016	11%	0.00175	2.41E-08	0.00433	6.25E-06	9	2	4.83E-08
Aptus, Inc.	Aragonite, UT		9	0.00063	0.00057	89%	0.00176	3.20E-07	0.00570	3.61E-06	81	8	2.56E-06
Dupont	Orange, TX		6	0.00125	0.00055	44%	0.00236	3.07E-07	0.00750	9.38E-06	36	5	1.54E-06
Southdown/Southwestern	Fairborn, OH	1	3	0.00300	0.00000	0%	0.00300	0.00E+00	0.00900	2.70E-05	9	2	0.00E+00
Dupont	Deepwater, NJ		3	0.00290	0.00061	21%	0.00412	3.70E-07	0.00870	2.52E-05	9	2	7.40E-07
Waste Tech. Industries	East Liverpool, OH		9	0.00240	0.00087	36%	0.00413	7.50E-07	0.02160	5.18E-05	81	8	6.00E-06
Trade Waste Incineration	Sauget, IL		8	0.00168	0.00140	83%	0.00447	1.95E-06	0.01340	2.24E-05	64	7	1.36E-05
Southdown/Kosmos	Kosmosdale, KY	1	9	0.00261	0.00094	36%	0.00450	8.89E-07	0.02353	6.15E-05	81	8	7.11E-06
Solite Corp.	Norwood, NC	8	3	0.00190	0.00161	85%	0.00511	2.58E-06	0.00569	1.08E-05	9	2	5.16E-06
Glaxo Inc.	R.T.P., NC		6	0.00193	0.00159	82%	0.00511	2.52E-06	0.01161	2.25E-05	36	5	1.26E-05
Tennessee Eastman	Kingsport, TN	24	3	0.00530	0.00009	2%	0.00548	7.43E-09	0.01591	8.44E-05	9	2	1.49E-08
Aptus, Inc.	Coffeyvillle, KS		12	0.00342	0.00138	40%	0.00617	1.90E-06	0.04100	1.40E-04	144	11	2.09E-05
Tennessee Eastman	Kingsport, TN	30	3	0.00593	0.00021	4%	0.00635	4.33E-08	0.01780	1.06E-04	9	2	8.67E-08
Union Carbide	South Charleston, WV	25	3	0.00703	0.00045	6%	0.00794	2.03E-07	0.02110	1.48E-04	9	2	4.07E-07
								SUM(Total)^2/Nt	0.00049				
									SUMMATIONS	0.00072	675	78	7.19E-05

Total Number of Points (Nt)	95
Total Number of Facilities (nf)	17

S1^2 (gr/dscf @ 7% O2)^2	9.22E-07
S2^2 (gr/dscf @ 7% O2)^2	2.51E-06
Sa (gr/dscf @ 7% O2)	0.00185
Avg PMi (gr/dscf @ 7% O2)	0.00253
K @ Nt	2.800
K @ nf	3.4
Degrees of Freedom	32.64
Q	15.97
J	5.59
K @ 95%-p, 99%-d	3.25
LIMIT (gr/dscf @ 7% O2)	0.0086

Appendix M summarizes the source categories individually and is category-sorted by the expected P1 value. The facilities within the on-site incinerator and boiler populations which have been removed from the population are noted. As discussed in the previous section, the pool of facilities considered for the analysis do not contain those facilities in which low ash content fuels are burned and those which can achieve low PM levels without high performance scrubbers or ESP/FF technology. The PM levels established in this section are single point limits. The expected average PM emission levels from the BPF pool are well below the levels. The expected averages are presented in Table 5.4-1 through Table 5.4-8 and reflect the average PM emission that the BPF would be expected to achieve and still achieve the PM level in a single test at the specified confidence level.

5.5 Summary of PCDD/PCDF Emission Level Estimates

Table 5.5-1 provides a summary of the PCDD/PCDF data in total ng/dscm following application of Equations 5.9 through 5.11. This table presents the expected data from the population of cement kilns with all facilities satisfying the PCDD/PCDF BOP requirements. This table also includes the dioxin data from the HW population. With the exception of the Aptus facilities, which are temperature corrected, the HW data is as reported in the Trial Burn/CoC reports. Note that the average data from the cement kilns now ranges from 0.3 ng/dscm to a maximum of 50.65 ng/dscm. This is significantly less than the range of the original data set with facility averages ranging from 0.68 to more than 2000 ng/dscm.

Table 5.5-2 provides an outlier evaluation of the complete set of manipulated PCDD/PCDF data set in ng/dscm (from Table 5.5-1). Given the extreme data manipulation associated with the application of Equations 5.8 through 5.9, an outlier evaluation is essential to identify those facilities which do not follow the trends assumed in the analysis. The outlier test essentially combines the average data with the suspect data excluded, with some multiplier of the standard deviation of the data set with the suspect data excluded. The test presented in Table 5.5-2 uses the "t" statistic from the students-t distribution at the 99% confidence level. The average value for those facilities, excluding the last eight data sets, is 3.47 ng/dscm. The standard deviation of the facility averages is 2.65. The t value for the 22 facilities is 2.518. The 99%-one sided confidence limit is 3.47 + 2.518 * 2.65 and has the value 10.15 ng/dscm. The facility average for each of the bottom eight facilities in the list are above the level of 10.15 ng/dscm and are considered outliers from the expected average of the remaining 22 facilities.

TABLE 5.5-1. SUMMARY OF TOTAL PCDD/PCDF DATA

Company	Location	Report Date	APCS	Avg. APCD Temp degrees F	Avg. CO ppm @ 7% O2	Avg. O2 Percent	Number of of Points	Avg. PCDD/PCDF (uncorrected) (ng/dscm @ 7%)	Avg. T corrected PCDD/PCDF (ng/dscm @ 7%)	Avg. T,CO corrected PCDD/PCDF (ng/dscm @ 7%)	Avg. PCDD/PCDF * T,CO, and O2 corrected (ng/dscm @ 7%)	Stdev PCDD/PCDF* corrected data
Aptus, Inc.	Aragonite, UT	Aug-92	FF/WS/ESP	470.00		10.82	9	567.21	122.09	122.09	122.086	51.760
*General Electric	Pittsfield, MA	Apr-91	PS			9.73	5	548.61	548.61	548.61	512.24	497.696
*Rollins Environmental Services	Baton Rouge, LA	Apr-87	WS			10.87	3	2.26	2.26	2.26	2.26	1.820
*Rollins Environmental Services	Deerpark, TX	Aug-88	VS			11.46	5	4.31	4.31	4.31	4.31	1.049
*Rollins Environmental Services	Bridgeport, NJ	Dec-86	WS			10.63	3	6.58	6.58	6.58	6.58	3.711
*Ross Incineration Services	Grafton, OH	Mar-93	PT/TWS			11.17	3	1.46	1.46	1.46	1.46	0.433
*Solite Corp.	Cascade, VA	Mar-98	FF			16.97	3	1.58	1.58	1.58	1.58	0.087
*Waste Tech. Industries	East Liverpool, OH	Jul-93	ESP	350.00		12.62	5	12.50	12.50	12.50	12.50	6.488
Aptus, Inc.	Coffeyvillle, KS	Dec-90	FF/WS/TWS	470.00		11.79	12	117.14	25.21	25.21	25.21	10.896
Ash Grove Cement Co.	Louisville, NE	May-92	ESP	250.40	648.20	15.52	5	8.44	8.44	1.68	1.68	1.153
Ash Grove Cement Co.	Foreman, AR	May-92	ESP	468.33	462.33	5.63	3	99.73	21.33	5.30	1.84	1.401
Ash Grove Cement Co.	Louisville, NE	Aug-92	ESP	355.00	240.75	10.53	4	12.87	12.07	4.80	4.75	1.705
Ash Grove Cement Co.	Chanute, KS	Apr-92	ESP	436.00	617.50	10.65	4	156.20	49.49	7.25	7.25	2.227
Ash Grove Cement Co.	Foreman, AR	Jul-92	ESP	476.75	248.00	5.58	4	327.35	58.51	22.89	8.11	8.007
Ash Grove Cement Co.	Chanute, KS	Mar-92	ESP	433.25	631.00	10.30	4	303.82	94.81	15.06	14.70	6.364
Continental Cement Co.	Hannibal, MO	Dec-90	ESP	540.00	245.45	1.95	2	476.00	41.82	17.25	2.65	1.540
Continental Cement Co.	Hannibal, MO	Jul-92	ESP	593.33	344.00	4.67	3	1209.20	54.47	15.07	4.30	0.772
Essroc Materials	Logansport, IN	Aug-92	ESP	608.00	98.75	12.10	4	1542.75	56.53	50.65	50.65	17.167
Holnam Inc.	Holly Hill, SC	Aug-92	ESP	495.20	141.00	8.98	4	85.35	6.88	4.64	2.94	2.639
Holnam Inc.	Holly Hill, SC	Aug-92	ESP	563.00	146.25	7.05	4	182.88	11.97	8.01	4.10	4.796
Holnam, Inc.	Artesia, MS	Aug-93	ESP	507.33	278.23	8.03	3	41.86	5.09	1.76	1.10	0.091
Keystone Cement Co.	Bath, PA	Aug-92	ESP	413.17	46.33	11.70	3	0.68	0.30	0.30	0.30	0.045
Keystone Cement Co.	Bath, PA	Aug-92	ESP	419.17	26.00	12.37	3	2.41	0.99	0.99	0.99	0.145
Lafarge Corp.	Fredonia, KS	Aug-92	ESP	532.67	440.67	5.50	3	827.71	80.11	18.39	6.47	3.029
Lafarge Corp.	Fredonia, KS	Aug-92	ESP	496.00	276.67	5.60	3	525.47	76.31	25.75	9.28	0.847
Medusa Cement Co.	Wampum, PA	Jul-92	ESP	744.00	4076.33	11.20	3	2392.33	15.60	0.35	0.35	0.126
Medusa Cement Co.	Wampum, PA	Jul-92	ESP	718.00	161.33	6.10	3	1603.33	14.43	8.71	3.45	0.184
National Cement Co.	Lebec, CA	Aug-92	FF	547.33	13.60	10.52	3	6.60	0.53	0.53	0.53	0.024
River Cement Co.	Festus, MO	Oct-92	ESP	638.33	135.00	10.10	3	2008.33	50.16	36.71	36.71	6.901
Southdown/Kosmos	Kosmosdale, KY	May-92	FF	505.07	154.25	14.88	4	111.30	35.92	23.26	23.26	26.328

Notes
* Data not corrected

TABLE 5.5-2. OUTLIER EVALUATION FOR TOTAL PCDD/PCDF

Company	Location	Index (i)	Average Corrected PCDD/PCDF (ng/dscm @ 7% O2) PCDD/PCDF (i)	Avg. (1 to i) (ng/dscm @ 7% O2)	sdev(1-i) (ng/dscm @ 7% O2)	dof -1	t(dof-1) @ alfa=0.01	c 99% (ng/dscm @ 7% O2)
Keystone Cement Co.	Bath, PA	1	0.305	0.30	na	na	na	na
Medusa Cement Co.	Wampum, PA	2	0.349	0.33	0.03	1	31.821	1.31
National Cement Co.	Lebec, CA	3	0.528	0.39	0.12	2	6.965	1.22
Keystone Cement Co.	Bath, PA	4	0.995	0.54	0.32	3	4.541	1.98
Holnam, Inc.	Artesia, MS	5	1.103	0.66	0.37	4	3.747	2.04
*Ross Incineration Services	Grafton, OH	6	1.457	0.79	0.47	5	3.365	2.36
*Solite Corp.	Cascade, VA	7	1.577	0.90	0.52	6	3.143	2.53
Ash Grove Cement Co.	Louisville, NE	8	1.676	1.00	0.55	7	2.998	2.66
Ash Grove Cement Co.	Foreman, AR	9	1.840	1.09	0.59	8	2.896	2.80
*Rollins Environmental Services	Baton Rouge, LA	10	2.260	1.21	0.67	9	2.821	3.09
Continental Cement Co.	Hannibal, MO	11	2.652	1.34	0.77	10	2.764	3.46
Holnam Inc.	Holly Hill, SC	12	2.938	1.47	0.86	11	2.718	3.82
Medusa Cement Co.	Wampum, PA	13	3.454	1.63	0.99	12	2.681	4.29
Holnam Inc.	Holly Hill, SC	14	4.102	1.80	1.16	13	2.650	4.88
Continental Cement Co.	Hannibal, MO	15	4.299	1.97	1.29	14	2.624	5.36
*Rollins Environmental Services	Deerpark, TX	16	4.306	2.11	1.38	15	2.602	5.70
Ash Grove Cement Co.	Louisville, NE	17	4.748	2.27	1.48	16	2.583	6.09
Lafarge Corp.	Fredonia, KS	18	6.472	2.50	1.74	17	2.567	6.98
*Rollins Environmental Services	Bridgeport, NJ	19	6.580	2.72	1.94	18	2.552	7.66
Ash Grove Cement Co.	Chanute, KS	20	7.254	2.94	2.14	19	2.539	8.38
Ash Grove Cement Co.	Foreman, AR	21	8.108	3.19	2.37	20	2.528	9.18
Lafarge Corp.	Fredonia, KS	22	9.276	3.47	2.65	21	2.518	10.15
***Waste Tech. Industries**	**East Liverpool, OH**	**23**	**12.502**	**3.86**	**3.20**	**22**	**2.508**	**11.89**
Ash Grove Cement Co.	**Chanute, KS**	**24**	**14.695**	**4.31**	**3.84**	**23**	**2.500**	**13.90**
Southdown/Kosmos	**Kosmosdale, KY**	**25**	**23.264**	**5.07**	**5.34**	**24**	**2.492**	**18.36**
Aptus, Inc.	**Coffeyvillle, KS**	**26**	**25.214**	**5.84**	**6.55**	**25**	**2.485**	**22.13**
River Cement Co.	**Festus, MO**	**27**	**36.714**	**6.99**	**8.75**	**26**	**2.479**	**28.68**
Essroc Materials	**Logansport, IN**	**28**	**50.647**	**8.55**	**11.91**	**27**	**2.473**	**38.00**
Aptus, Inc.	**Aragonite, UT**	**29**	**122.086**	**12.46**	**24.11**	**28**	**2.467**	**71.94**
***General Electric**	**Pittsfield, MA**	**30**	**512.242**	**29.12**	**94.27**	**29**	**2.462**	**261.22**

* Data not corrected

Table 5.5-3 presents the analysis of the PCDD/PCDF data in total ng/dscm with the outliers removed. The analysis presented in this table is exactly the same as described previously and produces a PCDD/PCDF level in total ng/dscm of 13.88.

Table 5.5-4 presents a summary of the corrected TEQ values from the cement kiln population following application of Equations 5.9 through 5.12. This data represents the anticipated TEQ data from the cement kiln population with all facilities operating under the BOP guidelines. Table 5.5-5 presents an outlier evaluation performed on the manipulated TEQ data. The analysis has been done in precisely the same manner as that used to produce Table 5.5-2. Note that the Logansport Essroc Materials facility and the River Cement Co. facility have again been identified as outliers. Also note that the Ashgrove facility identified on a total ng/dscm basis as an outlier has not been identified in this analysis.

Table 5.5-6 presents the analysis for the TEQ * data. The analysis presented in this table is the same as described previously and produces a PCDD/PCDF level in ng/dscm TEQ of 0.2.

5.6 Estimation of PCDD/PCDF FLOOR Emission Level

This section estimates PCDD/PCDF emission levels in precisely the same manner used to establish the PM levels. Scaling and manipulation of the dioxin/furan data is not performed. As discussed previously, low dioxin/furan emissions from burners with uncontrolled or high PM levels do not necessarily reflect the performance of the same facility requiring reduced PM levels. In addition, low PM levels arising from the burning of low ash content fuels do not necessarily reflect the performance of the same facility with respect to dioxin/furan emissions if higher ash content fuel was burned and PM control required. Finally, dioxin/furan emissions from facilities burning fuels with extremely low halogen content are not representative of the HW burning community. For these reasons, the dioxin/furan data from the on-site HW burners and boiler population have been removed from the pool of data to establish the PCDD/PCDF emission level. Table 5.6-1 presents the pool of facilities and PCDD/PCDF data (in TEQ ng/dscm) used to establish the emission limit. Note that all of the facilities at the bottom of the table in bolded italics are not suitable for use in the pool for reasons just described including:

1. High PM levels.
2. Extremely low PM levels achieved because of the burning of low ash content feed streams.
3. Halogenated fuels are not burned.

TABLE 5.5-3. TOTAL PCDD/PCDF LEVEL ANALYSIS

Company	Location	np	Average Corrected PCDD/PCDF (ng/dscm @ 7% O2)	STDEV (ng/dscm @ 7% O2)	RSD %	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Keystone Cement Co.	Bath, PA	3	0.30	0.045	15%	1.99E-03	0.91	0.279	9	2	3.98E-03
Medusa Cement Co.	Wampum, PA	3	0.35	0.126	36%	1.59E-02	1.05	0.365	9	2	3.18E-02
National Cement Co.	Lebec, CA	3	0.53	0.024	5%	5.99E-04	1.58	0.835	9	2	1.20E-03
Keystone Cement Co.	Bath, PA	3	0.99	0.145	15%	2.12E-02	2.98	2.967	9	2	4.23E-02
Holnam, Inc.	Artesia, MS	3	1.10	0.091	8%	8.30E-03	3.31	3.650	9	2	1.66E-02
*Ross Incineration Services	Grafton, OH	3	1.46	0.433	30%	1.88E-01	4.37	6.366	9	2	3.75E-01
*Solite Corp.	Cascade, VA	3	1.58	0.087	6%	7.63E-03	4.73	7.458	9	2	1.53E-02
Ash Grove Cement Co.	Louisville, NE	5	1.68	1.153	69%	1.33E+00	8.38	14.051	25	4	5.32E+00
Ash Grove Cement Co.	Foreman, AR	3	1.84	1.401	76%	1.96E+00	5.52	10.160	9	2	3.93E+00
*Rollins Environmental Services	Baton Rouge, LA	3	2.26	1.820	81%	3.31E+00	6.78	15.323	9	2	6.62E+00
Continental Cement Co.	Hannibal, MO	2	2.65	1.540	58%	2.37E+00	5.30	14.062	4	1	2.37E+00
Holnam Inc.	Holly Hill, SC	4	2.94	2.639	90%	6.96E+00	11.75	34.522	16	3	2.09E+01
Medusa Cement Co.	Wampum, PA	3	3.45	0.184	5%	3.39E-02	10.36	35.791	9	2	6.78E-02
Holnam Inc.	Holly Hill, SC	4	4.10	4.796	117%	2.30E+01	16.41	67.303	16	3	6.90E+01
Continental Cement Co.	Hannibal, MO	3	4.30	0.772	18%	5.96E-01	12.90	55.456	9	2	1.19E+00
*Rollins Environmental Services	Deerpark, TX	5	4.31	1.049	24%	1.10E+00	21.53	92.708	25	4	4.40E+00
Ash Grove Cement Co.	Louisville, NE	4	4.75	1.705	36%	2.91E+00	18.99	90.161	16	3	8.72E+00
Lafarge Corp.	Fredonia, KS	3	6.47	3.029	47%	9.18E+00	19.42	125.678	9	2	1.84E+01
*Rollins Environmental Services	Bridgeport, NJ	3	6.58	3.711	56%	1.38E+01	19.74	129.889	9	2	2.75E+01
Ash Grove Cement Co.	Chanute, KS	4	7.25	2.227	31%	4.96E+00	29.01	210.466	16	3	1.49E+01
Ash Grove Cement Co.	Foreman, AR	4	8.11	8.007	99%	6.41E+01	32.43	262.937	16	3	1.92E+02
Lafarge Corp.	Fredonia, KS	3	9.28	0.847	9%	7.18E-01	27.83	258.158	9	2	1.44E+00
						SUM(Total)^2/Nt	951.1				
	Total Number of Points (Nt)	74									
	Total Number of Facilities (nf)	22					SUMMATIONS	1438.6	260	52	3.78E+02

* Data not corrected

S1^2 (ng/dscm @ 7% O2)^2	7.26
S2^2 (ng/dscm @ 7% O2)^2	4.75
Sa (ng/dscm @ 7% O2)	3.47
Avg. (ng/dscm @ 7% O2)	3.47
K @ Nt	2.8
K @ nf	3.233
Degrees of Freedom	39.74
Q	3.1971
J	3.36
K @ 95%-p,99%-d	3.00
LIMIT (ng/dscm @ 7% O2)	13.88

TABLE 5.5-4. SUMMARY OF TEQ PCDD/PCDF DATA

Company	Location	Report Date	APCS	Number of of Points	Avg. Delta PCDD/PCDF (ng/dscm @ 7%)	Orginal Average TEQ (ng/dscm @ 7%)	Orginal STDEV TEQ (ng/dscm @ 7%)	Corrected Average TEQ (ng/dscm @ 7%)	Corrected STDEV TEQ (ng/dscm @ 7%)	Avg. Ratio (PCDD/PCDF) / TEQ Corrected data
*Rollins Environmental Services	Baton Rouge, LA	Apr-87	WS	3	0.00	0.103	0.10437	0.103	0.10437	21.92
*Rollins Environmental Services	Deerpark, TX	Aug-88	VS	5	0.00	0.420	0.28492	0.420	0.28492	10.25
*Ross Incineration Services	Grafton, OH	Mar-93	PT/IWS	3	0.00	0.063	0.04473	0.063	0.04473	23.01
*Solite Corp.	Cascade, VA	Mar-98	FF	3	0.00	0.042	0.00755	0.042	0.00755	37.45
*Waste Tech. Industries	East Liverpool, OH	Jul-93	ESP	5	0.00	0.222	0.12738	0.222	0.12738	56.20
Aptus, Inc.	Aragonite, UT	Aug-92	FF/WS/ESP	9	445.12	15.299	6.78866	3.293	1.46119	37.08
Ash Grove Cement Co.	Foreman, AR	May-92	ESP	3	97.89	1.020	0.48446	0.019	0.01285	98.90
Ash Grove Cement Co.	Louisville, NE	May-92	ESP	5	6.76	0.167	0.06958	0.035	0.02535	47.98
Ash Grove Cement Co.	Chanute, KS	Mar-92	ESP	4	289.12	1.013	0.30473	0.055	0.03056	266.60
Ash Grove Cement Co.	Chanute, KS	Apr-92	ESP	4	148.95	1.553	1.11805	0.069	0.03645	105.38
Ash Grove Cement Co.	Foreman, AR	Jul-92	ESP	4	319.24	3.806	5.87936	0.091	0.13020	89.32
Ash Grove Cement Co.	Louisville, NE	Aug-92	ESP	4	8.12	0.504	0.30473	0.187	0.10043	25.41
Ciba-Geigy	St. Gabriel, LA	May-88	VS/Cyclone	3	0.65	0.006	0.00284	0.002	0.00101	162.98
Continental Cement Co.	Hannibal, MO	Dec-90	ESP	2	473.35	3.265	1.22329	0.018	0.00910	146.63
Continental Cement Co.	Hannibal, MO	Jul-92	ESP	3	1204.90	17.150	7.35389	0.059	0.01281	73.31
Essroc Materials	Logansport, IN	Aug-92	ESP	4	1492.10	10.985	3.02758	0.373	0.16469	135.93
General Electric	Pittsfield, MA	Apr-91	PS	5	36.36	34.178	34.38260	31.824	32.16712	16.10
Holnam Inc.	Holly Hill, SC	Aug-92	ESP	4	82.41	0.702	0.95157	0.014	0.01917	204.75
Holnam Inc.	Holly Hill, SC	Aug-92	ESP	4	178.77	1.150	1.29793	0.026	0.02941	159.14
Holnam, Inc.	Artesia, MS	Aug-93	ESP	3	40.76	4.948	2.78873	0.127	0.02287	8.72
Keystone Cement Co.	Bath, PA	Aug-92	ESP	3	0.38	0.004	0.00125	0.002	0.00069	153.69
Keystone Cement Co.	Bath, PA	Aug-92	ESP	3	1.42	0.016	0.00030	0.007	0.00014	151.61
Lafarge Corp.	Fredonia, KS	Aug-92	ESP	3	821.24	3.723	1.88559	0.030	0.02041	218.42
Lafarge Corp.	Fredonia, KS	Aug-92	ESP	3	516.19	5.187	3.68572	0.091	0.01230	101.72
Medusa Cement Co.	Wampum, PA	Jul-92	ESP	3	2391.98	48.860	16.77361	0.007	0.00208	50.26
Medusa Cement Co.	Wampum, PA	Jul-92	ESP	3	1599.88	32.967	15.56288	0.070	0.01322	49.43
National Cement Co.	Lebec, CA	Aug-92	FF	3	6.07	0.053	0.00458	0.004	0.00034	124.48
River Cement Co.	Festus, MO	Oct-92	ESP	3	1971.62	49.843	8.80464	0.911	0.16668	40.29
Southdown/Kosmos	Kosmosdale, KY	May-92	FF	4	88.03	1.175	0.10755	0.290	0.38410	80.30

* Data not corrected

TABLE 5.5-5. OUTLIER EVALUATION FOR TEQ DATA

Company	Location	Index (i)	Average Corrected PCDD/PCDF (TEQ ng/dscm @ 7% O2)	Avg. (1 to i) (ng/dscm @ 7% O2)	sdev(1-i) (ng/dscm @ 7% O2)	dof -1	t(dof-1) @ alfa=0.01	c 99% (ng/dscm @ 7% O2)
Keystone Cement Co.	Bath, PA	1	0.002	0.00	na	na	na	na
Ciba-Geigy	St. Gabriel, LA	2	0.002	0.00	0.00	1	31.821	0.00
National Cement Co.	Lebec, CA	3	0.004	0.00	0.00	2	6.965	0.01
Keystone Cement Co.	Bath, PA	4	0.007	0.00	0.00	3	4.541	0.01
Medusa Cement Co.	Wampum, PA	5	0.007	0.00	0.00	4	3.747	0.01
Holnam Inc.	Holly Hill, SC	6	0.014	0.01	0.00	5	3.365	0.02
Continental Cement Co.	Hannibal, MO	7	0.018	0.01	0.01	6	3.143	0.03
Ash Grove Cement Co.	Foreman, AR	8	0.019	0.01	0.01	7	2.998	0.03
Holnam Inc.	Holly Hill, SC	9	0.026	0.01	0.01	8	2.896	0.04
Lafarge Corp.	Fredonia, KS	10	0.030	0.01	0.01	9	2.821	0.04
Ash Grove Cement Co.	Louisville, NE	11	0.035	0.01	0.01	10	2.764	0.05
*Solite Corp.	Cascade, VA	12	0.042	0.02	0.01	11	2.718	0.05
Ash Grove Cement Co.	Chanute, KS	13	0.055	0.02	0.02	12	2.681	0.06
Continental Cement Co.	Hannibal, MO	14	0.059	0.02	0.02	13	2.650	0.07
*Ross Incineration Services	Grafton, OH	15	0.063	0.03	0.02	14	2.624	0.08
Ash Grove Cement Co.	Chanute, KS	16	0.069	0.03	0.02	15	2.602	0.09
Medusa Cement Co.	Wampum, PA	17	0.070	0.03	0.02	16	2.583	0.09
Ash Grove Cement Co.	Foreman, AR	18	0.091	0.03	0.03	17	2.567	0.11
Lafarge Corp.	Fredonia, KS	19	0.091	0.04	0.03	18	2.552	0.11
*Rollins Environmental Services	Baton Rouge, LA	20	0.103	0.04	0.03	19	2.539	0.12
Holnam, Inc.	Artesia, MS	21	0.127	0.04	0.04	20	2.528	0.14
Ash Grove Cement Co.	**Louisville, NE**	**22**	**0.187**	**0.05**	**0.05**	**21**	**2.518**	**0.17**
***Waste Tech. Industries**	**East Liverpool, OH**	**23**	**0.222**	**0.06**	**0.06**	**22**	**2.508**	**0.20**
Southdown/Kosmos	**Kosmosdale, KY**	**24**	**0.290**	**0.07**	**0.07**	**23**	**2.500**	**0.25**
Essroc Materials	**Logansport, IN**	**25**	**0.373**	**0.08**	**0.09**	**24**	**2.492**	**0.32**
***Rollins Environmental Services**	**Deerpark, TX**	**26**	**0.420**	**0.09**	**0.11**	**25**	**2.485**	**0.38**
River Cement Co.	**Festus, MO**	**27**	**0.911**	**0.12**	**0.19**	**26**	**2.479**	**0.60**
Aptus, Inc.	**Aragonite, UT**	**28**	**3.293**	**0.24**	**0.63**	**27**	**2.473**	**1.79**
General Electric	**Pittsfield, MA**	**29**	**31.824**	**1.33**	**5.90**	**28**	**2.467**	**15.88**

* Data not Corrected

TABLE 5.5-6 TEQ PCDD/PCDF LEVEL ANALYSIS

Company	Location	np	Average PCDD/PCDF (TEQ ng/dscm @ 7% O2)	STDEV (TEQ ng/dscm @ 7% O2)	RSD %	Vi	Total	Total^2/np	np^2	np-1	Vi*(np-1)
Keystone Cement Co.	Bath, PA	3	0.002	0.00069	35%	4.71E-07	0.01	0.000	9	2	9.42E-07
Ciba-Geigy	St. Gabriel, LA	3	0.002	0.00101	51%	1.03E-06	0.01	0.000	9	2	2.06E-06
National Cement Co.	Lebec, CA	3	0.004	0.00034	8%	1.18E-07	0.01	0.000	9	2	2.36E-07
Keystone Cement Co.	Bath, PA	3	0.007	0.00014	2%	1.86E-08	0.02	0.000	9	2	3.72E-08
Medusa Cement Co.	Wampum, PA	3	0.007	0.00208	30%	4.33E-06	0.02	0.000	9	2	8.66E-06
Holnam Inc.	Holly Hill, SC	4	0.014	0.01917	134%	3.67E-04	0.06	0.001	16	3	1.10E-03
Continental Cement Co.	Hannibal, MO	2	0.018	0.00910	50%	8.29E-05	0.04	0.001	4	1	8.29E-05
Ash Grove Cement Co.	Foreman, AR	3	0.019	0.01285	69%	1.65E-04	0.06	0.001	9	2	3.30E-04
Holnam Inc.	Holly Hill, SC	4	0.026	0.02941	114%	8.65E-04	0.10	0.003	16	3	2.59E-03
Lafarge Corp.	Fredonia, KS	3	0.030	0.02041	69%	4.17E-04	0.09	0.003	9	2	8.33E-04
Ash Grove Cement Co.	Louisville, NE	5	0.035	0.02535	73%	6.42E-04	0.17	0.006	25	4	2.57E-03
*Solite Corp.	Cascade, VA	3	0.042	0.00755	18%	5.71E-05	0.13	0.005	9	2	1.14E-04
Ash Grove Cement Co.	Chanute, KS	4	0.055	0.03056	55%	9.34E-04	0.22	0.012	16	3	2.80E-03
Continental Cement Co.	Hannibal, MO	3	0.059	0.01281	22%	1.64E-04	0.18	0.010	9	2	3.28E-04
*Ross Incineration Services	Grafton, OH	3	0.063	0.04473	71%	2.00E-03	0.19	0.012	9	2	4.00E-03
Ash Grove Cement Co.	Chanute, KS	4	0.069	0.03645	53%	1.33E-03	0.28	0.019	16	3	3.99E-03
Medusa Cement Co.	Wampum, PA	3	0.070	0.01322	19%	1.75E-04	0.21	0.015	9	2	3.49E-04
Ash Grove Cement Co:	Foreman, AR	4	0.091	0.13020	143%	1.70E-02	0.36	0.033	16	3	5.09E-02
Lafarge Corp.	Fredonia, KS	3	0.091	0.01230	13%	1.51E-04	0.27	0.025	9	2	3.03E-04
*Rollins Environmental Services	Baton Rouge, LA	3	0.103	0.10437	101%	1.09E-02	0.31	0.032	9	2	2.18E-02
Holnam, Inc.	Artesia, MS	3	0.127	0.02287	18%	5.23E-04	0.38	0.048	9	2	1.05E-03
	Total Number of Points (Nt)	**69**				**SUM(Total)^2/Nt**	**1.40E-01**				
	Total Number of Facilities (nf)	**21**									
							SUMMATIONS	**2.25E-01**	**235**	**48**	**9.31E-02**

* Data not corrected

S1^2 (TEQ ng/dscm @ 7% O2)^2	1.94E-03
S2^2 (TEQ ng/dscm @ 7% O2)^2	7.17E-04
Sa (TEQ ng/dscm @ 7% O2)	5.15E-02
Avg. TEQ (TEQ ng/dscm @ 7% O2)	0.044
K @ Nt	2.800
K @ nf	3.262
Degrees of Freedom	40.44
Q	2.212
J	3.286
K @ 95%-p,99%-d	2.954
LIMIT (TEQ ng/dscm @ 7% O2)	**0.20**

TABLE 5.6-1. POOL OF FACILITIES FOR TEQ FLOOR ESTIMATE

Company	Location	Report Date	Facility Type	APCS	PCDD/PCDF TEQ Average	PCDD/PCDF TEQ Sdev	P1(ng/dscm)	facilities	Particulate gr/dscf
Keystone Cement Co.	Bath, PA	Aug-92	w	ESP	0.00440	0.00125	0.00691	ck	0.0150
Keystone Cement Co.	Bath, PA	Aug-92	w	ESP	0.01600	0.00000	0.01600	ck	0.0220
Solite Corp.	Cascade, VA	Mar-98	AK	FF	0.0421	0.00755	0.05721	LWA	
National Cement Co.	Lebec, CA	Aug-92	d	FF	0.05300	0.00458	0.06217	ck	0.0171
Lafarge Corp.	Alpena, MI	Aug-92	d (?)	FF	0.05867	0.02695	0.11257	ck	0.00333
Ross Incineration Services	Grafton, OH	Mar-93	RK	PT/IWS	0.06330	0.04473	0.15276	chi	0.0083
Ash Grove Cement Co.	Foreman, AR	Jul-93	w	ESP	0.11597	0.07549	0.26694	ck	
Dow Chemical Co.	Midland, MI	Jun-89	RK	VS/ESP	0.13773	0.06960	0.27693	osinc	0.0198
Ash Grove Cement Co.	Louisville, NE	May-92	sd (ph/bp)	ESP	0.16734	0.06958	0.30650	ck	0.0366
Rollins Environmental Ser	Baton Rouge, LA	Apr-87	RK	WS	0.10310	0.10437	0.31184	chi	0.0172
Waste Tech. Industries	East Liverpool, OH	Jul-93	RK	ESP	0.22245	0.12738	0.47721	chi	0.0024
Holnam Inc.	Holly Hill, SC	Aug-92	w	ESP	0.19733	0.16168	0.52069	ck	0.0497
Ash Grove Cement Co.	Foreman, AR	May-92	w	ESP	0.37033	0.18485	0.74003	ck	0.0202
Holnam Inc.	Clarksville, MO	Jul-92	w	ESP	0.21643	0.30115	0.81874	ck	0.0337
Rollins Environmental Ser	Deerpark, TX	Aug-88	RK	VS	0.42000	0.28492	0.98985	chi	0.0270
Ash Grove Cement Co.	Louisville, NE	Aug-92	d (ph/pc/bp)	ESP	0.50400	0.30473	1.11347	ck	0.0186
Southdown/Kosmos	Kosmosdale, KY	May-92	d (ph)	FF	1.17500	0.10755	1.39010	ck	0.0026
Ash Grove Cement Co.	Chanute, KS	Mar-92	w	ESP	1.01300	0.30473	1.62247	ck	0.0326
Ash Grove Cement Co.	Foreman, AR	Jul-92	w	ESP	1.02000	0.48446	1.98892	ck	0.0075
Holnam Inc.	Holly Hill, SC	Aug-92	w	ESP	1.96667	0.52080	3.00827	ck	0.0226
Ash Grove Cement Co.	Chanute, KS	Apr-92	w	ESP	1.55250	1.11805	3.78859	ck	0.0481
Lone Star Industries	Greencastle, IN	Aug-92	w	ESP	3.62000	0.54525	4.71050	ck	0.05563
Continental Cement Co.	Hannibal, MO	Dec-90	w	ESP	3.26500	1.22329	5.71159	ck	
Lafarge Corp.	Fredonia, KS	Aug-92	w	ESP	3.72333	1.88559	7.49450	ck	0.0190
Holnam, Inc.	Artesia, MS	Aug-93	w	ESP	4.94833	2.78873	10.52579	ck	0.0138
Lafarge Corp.	Fredonia, KS	Aug-92	w	ESP	5.18667	3.68572	12.55811	ck	0.0220
Ash Grove Cement Co.	Foreman, AR	Jul-92	w	ESP	3.80625	5.87936	15.56496	ck	0.0296
Essroc Materials	Logansport, IN	Aug-92	w	ESP	10.98500	3.02758	17.04016	ck	0.0708
Aptus, Inc.	Aragonite, UT	Aug-92	RK	FF/WS/ESI	15.29889	6.78866	28.87620	chi	0.0034
Continental Cement Co.	Hannibal, MO	Jul-92	w	ESP	17.14967	7.35389	31.85744	ck	0.0374
Medusa Cement Co.	Wampum, PA	Jul-92	d	ESP	32.96667	15.56288	64.09243	ck	0.0225
River Cement Co.	Festus, MO	Oct-92	d	ESP	49.84333	8.80464	67.45261	ck	0.0244
Medusa Cement Co.	Wampum, PA	Jul-92	d	ESP	48.86000	16.77361	82.40721	ck	0.0769
General Electric	Pittsfield, MA	Apr-91	LI	PS	34.17800	34.38260	102.94319	chi	0.0410
Department of the Army	***Tooele, UT***	***Oct-93***	***RK***	***VS***	***0.00633***	***0.00172***	***0.00978***	***osinc***	***0.0098***
Ciba-Geigy	***St. Gabriel, LA***	***May-88***	***LI***	***VS/Cyclone***	***0.00591***	***0.00284***	***0.01159***	***osinc***	***0.0427***
Department of the Army	***Tooele, UT***	***Apr-92***	***RK***	***VS***	***0.02806***	***0.00728***	***0.04263***	***osinc***	***0.0089***
Chevron	***Richmond, CA***	***Jul-88***	***LI***	***VS***	***0.03680***	***0.00768***	***0.05216***	***osinc***	***0.0023***
Union Carbide	***South Charleston,***	***Feb-97***	***Boiler***	***ESP***	***0.0279***	***0.0158***	***0.05947***	***BIF***	***0.0696***
Westvaco Corp.	***DeRidder, LA***	***Aug-96***	***Boiler***	***ESP***	***0.0297***	***0.0189***	***0.06751***	***BIF***	***0.0173***
Department of the Army	***Johnston Atoll***	***Jun-92***	***RK***	***VS/PBS***	***0.12515***	***0.01175***	***0.14865***	***osinc***	***0.0013***
Pfizer Inc.	***Groton, CT***	***Jul-90***	***RH***	***WS***	***0.01903***	***0.00636***	***0.03176***	***osinc***	***0.0360***
Dow Chemical Co.	***Midland, MI***	***Mar-92***	***RK***	***VS/IWS***	***0.06575***	***0.03650***	***0.13875***	***osinc***	***0.15714***
Dow Chemical Co.	***Plaquemine, LA***	***Feb-88***	***RK***	***ESP/PBS***	***0.10170***	***0.01881***	***0.13932***	***osinc***	***0.0322***
New Bedford Harbor	***New Bedford, MA***	***Jan-92***	***RK***	***VS/PBS***	***0.09587***	***0.04250***	***0.18088***	***osinc***	***0.0370***
3M	***Cottage Grove, MI***	***Sep-90***	***RK***	***WS***	***2.08325***	***1.58687***	***5.25700***	***osinc***	***0.0600***
Vulcan Materials Co.	***Wichita, KS***	***Apr-91***	***LI***	***WS***	***6.49333***	***5.22629***	***16.94591***	***osinc***	***0.0114***
Eastman Kodak Co.	***Rochester, NY***	***Sep-92***	***RK***		***0.45867***	***0.26163***	***0.98192***	***osinc***	***0.05267***

Table 5.6-2 presents the emission level analysis of the body of data. Note that the level of 0.17 ng/dscm TEQ is consistent with the results of the previous analysis (0.2 ng/dscm TEQ). This agreement would tend to support the analysis used in the previous section, as well as the assertion that the analysis estimates the emissions from the best performing facilities under BOP.

Table 5.6-3 presents the pool of facilities and the corresponding PCDD/PCDF emission levels in total ng/dscm. Table 5.6-4 presents the level analysis. Note that the computed value of 9.35 ng/dscm is consistent with the previously estimated limit of 13.8.

5.7 Summary and Discussion

Rigorous procedures have been defined and implemented to derive numerical emission levels for PM and PCDD/PCDF's. These levels reflect the expected performance of a well-run, well-maintained facility incorporating defined operating guidelines and control technologies. The PM level calculations analyzed the data from the best performing facilities within each source category. In addition, the PM levels were established from the combined population of cement kilns and LWA kilns, combined population of commercial and on-site incinerators, and an overall estimate with all source categories combined. The PM levels were established under two alternative approaches. Under Option 1, the PM levels are estimates (at the 95% confidence level) that would be expected to be exceeded 1% of the time by the pool of best performing facilities from a single test run. This analysis procedure estimates the PM level that all of the best performing facilities (12% or 5 units) can be expected to achieve 99% of the time in a single run. For comparison purposes, an upper bound estimate of the 99th percentile (at the 95% confidence level) of the best performing facilities has been computed (Option 2). This estimate represents a level that a facility with the average PM level exhibited in the best performing pool, and with the same variability in PM emission as exhibited by the best performing facilities, would be expected to exceed 1 % of the time. Both of these PM levels are presented in Table 5.7-1. The difference in context between these estimates are subtle, yet significant. The Option 1 level is a number that any of the best performing facilities can be expected to achieve in a single test. The Option 2 estimate is a level that not all of the facilities would be expected to achieve with the same regularity. A facility in the BPF pool would not be expected to retrofit and modify the APCD to achieve the Option 1 level. However, the worst performers in the BPF pool would require retrofit to confidently achieve the Option 2 level in a single test.

TABLE 5.6-2. FLOOR ESTIMATE OF PCDD/PCDF (TEQ ng/dscm)

Company	Location	Number of Points	Average PCDD/PCDF TEQ (ng/dscm @ 7% O2)	STDEV (ng/dscm)	RSD %	Vi (ng/dscm)^2	SUM(i)	SUM^2/np	np^2	np-1	Vi*(np-1) (ng/dscm)^2
Keystone Cement Co.	Bath, PA	3	0.00440	0.00125	28%	1.57E-06	0.013	0.000	9	2	3.14E-06
Keystone Cement Co.	Bath, PA	3	0.01600	0.00000	0%	0.00E+00	0.048	0.001	9	2	0.00E+00
Solite Corp.	Cascade, VA	3	0.0421	0.00755	18%	5.71E-05	0.126	0.005	9	2	1.14E-04
National Cement Co.	Lebec, CA	3	0.05300	0.00458	9%	2.10E-05	0.159	0.008	9	2	4.20E-05
Lafarge Corp.	Alpena, MI	3	0.05867	0.02695	46%	7.26E-04	0.176	0.010	9	2	1.45E-03
Ross Incineration Services	Grafton, OH	3	0.06330	0.04473	71%	2.00E-03	0.190	0.012	9	2	4.00E-03
						sum^2/np	0.028		54	12	5.61E-03
	Total Number of Points	18									
	Total Number of Facilities	6					sum(sum^2/np)	0.037			

S1^2 (ng/dscm)^2	0.0005
S2^2 (ng/dscm)^2	0.0004
Sa (ng/dscm)	0.03
Avg. (TEQ ng/dscm)	0.04
K @ Nt	3.37
K @ Nf	5.062
Degrees of Freedom	8.67
Q	3.73
J	3.00
K @ 95%-p,99%-d	4.29
FLOOR (TEQ ng/dscm)	0.17

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TABLE 5.6-3. POOL OF FACILITIES FOR TOTAL FLOOR ESTIMATE

Company	Location	Report Date	Facility Type	APCS	PCDD/PCDF Total ng/dscm Average	PCDD/PCDF Total ng/dscm Sdev	P1	Category	Particulate gr/dscf Average
Keystone Cement Co.	Bath, PA	Aug-92	w	ESP	0.6833	0.0902	0.864	ck	0.0150
Solite Corp.	Cascade, VA	Mar-98	AK	FF	1.5767	0.08737	1.751	LWA	
Ross Incineration Services	Grafton, OH	Mar-93	RK	PT/IWS	1.46	0.43	2.320	chi	0.0083
Keystone Cement Co.	Bath, PA	Aug-92	w	ESP	2.4133	0.3765	3.166	ck	0.0220
Rollins Environmental Services	Baton Rouge, LA	Apr-87	RK	WS	2.26	1.82	5.900	chi	0.0172
Rollins Environmental Services	Deerpark, TX	Aug-88	RK	VS	4.31	1.05	6.404	chi	0.0270
National Cement Co.	Lebec, CA	Aug-92	d	FF	6.5967	0.3431	7.283	ck	0.0171
Ash Grove Cement Co.	Foreman, AR	Jul-93	w	ESP	5.3200	3.7848	12.890	ck	0.0202
Rollins Environmental Services	Bridgeport, NJ	Dec-86	RK	WS	6.58	3.71	14.002	chi	0.0275
Ash Grove Cement Co.	Louisville, NE	May-92	sd (ph/bp)	ESP	8.4400	4.5866	17.613	ck	0.0366
Ash Grove Cement Co.	Louisville, NE	Aug-92	d (ph/pc/bp)	ESP	12.8700	5.7731	24.416	ck	0.0186
Waste Tech. Industries	East Liverpool, OH	Jul-93	RK	ESP	12.50	6.49	25.477	chi	0.0024
Holnam, Inc.	Artesia, MS	Aug-93	w	ESP	41.8633	20.4948	82.853	ck	0.0138
Ash Grove Cement Co.	Foreman, AR	May-92	w	ESP	32.2700	26.2200	84.710	ck	
Southdown/Dixie	Knoxville, TN	Mar-92	d (ph/pc/bp)	FF	31.7450	39.7863	111.318	ck	0.0118
Southdown/Kosmos	Kosmosdale, KY	May-92	d (ph)	FF	111.2975	11.3203	133.938	ck	0.0026
Ash Grove Cement Co.	Foreman, AR	Jul-92	w	ESP	99.7333	53.9735	207.680	ck	0.0075
Aptus, Inc.	Coffeyvillle, KS	Dec-90	RK	FF/WS/IWS	117.14	50.62	218.389	chi	0.0006
Holnam Inc.	Holly Hill, SC	Aug-92	w	ESP	70.9000	81.4300	233.760	ck	0.0497
Ash Grove Cement Co.	Chanute, KS	Apr-92	w	ESP	156.2000	87.3979	330.996	ck	0.0481
Holnam Inc.	Holly Hill, SC	Aug-92	w	ESP	182.8750	211.3549	605.585	ck	0.0226
Ash Grove Cement Co.	Chanute, KS	Mar-92	w	ESP	303.8175	174.7120	653.241	ck	0.0326
Continental Cement Co.	Hannibal, MO	Dec-90	w	ESP	476.0000	217.7889	911.578	ck	
Aptus, Inc.	Aragonite, UT	Aug-92	RK	FF/WS/ESP	567.23	240.46	1048.145	chi	0.0034
Ash Grove Cement Co.	Foreman, AR	Jul-92	w	ESP	327.3500	374.7511	1076.852	ck	0.0296
Lafarge Corp.	Fredonia, KS	Aug-92	w	ESP	525.4667	369.1169	1263.700	ck	0.0220
Lafarge Corp.	Fredonia, KS	Aug-92	w	ESP	827.7100	221.7799	1271.270	ck	0.0190
General Electric	Pittsfield, MA	Apr-91	LI	PS	548.61	529.86	1608.317	chi	0.0410
Continental Cement Co.	Hannibal, MO	Jul-92	w	ESP	1209.1967	224.6619	1658.521	ck	0.0374
Essroc Materials	Logansport, IN	Aug-92	w	ESP	1542.7500	235.7122	2014.174	ck	0.0708
Medusa Cement Co.	Wampum, PA	Jul-92	d	ESP	1603.3333	543.0196	2689.373	ck	0.0225
River Cement Co.	Festus, MO	Oct-92	d	ESP	2008.3333	364.7757	2737.885	ck	0.0244
Medusa Cement Co.	Wampum, PA	Jul-92	d	ESP	2392.3333	787.1025	3966.538	ck	0.0769
Department of the Army	*Tooele, UT*	*Oct-93*	*RK*	*VS*	*0.0820*	*0.029*	*0.141*	*osinc*	*0.0098*
Chevron	*Richmond, CA*	*Jul-88*	*LI*	*VS*	*0.1917*	*0.040*	*0.271*	*osinc*	*0.0023*
Department of the Army	*Johnston Atoll*	*Jun-91*	*LI*	*VS/PBS*	*0.4357*	*0.089*	*0.614*	*osinc*	*0.0017*
Department of the Army	*Tooele, UT*	*Apr-92*	*RK*	*VS*	*0.5400*	*0.150*	*0.840*	*osinc*	*0.0089*
Union Carbide	*South Charleston, WV*	*Feb-97*	*Boiler/Coal*	*ESP*	*0.8447*	*0.3456*	*1.536*	*BIF*	*0.0696*
Ciba-Geigy	*St. Gabriel, LA*	*May-88*	*LI*	*VS/Cyclone*	*0.9767*	*0.317*	*1.610*	*osinc*	*0.0427*
Department of the Army	*Johnston Atoll*	*Jun-92*	*RK*	*VS/PBS*	*1.0054*	*0.563*	*2.131*	*osinc*	*0.0013*
Westvaco Corp.	*DeRidder, LA*	*Aug-92*	*Boiler/NG*	*ESP*	*1.1263*	*0.6952*	*2.517*	*BIF*	*0.0173*
Pfizer Inc.	*Groton, CT*	*Jul-90*	*RH*	*WS*	*3.0873*	*1.251*	*5.589*	*osinc*	*0.0360*
New Bedford Harbor	*New Bedford, MA*	*Jan-92*	*RK*	*VS/PBS*	*3.5463*	*1.461*	*6.469*	*osinc*	*0.0370*
Dow Chemical Co.	*Plaquemine, LA*	*Feb-88*	*RK*	*ESP/PBS*	*12.0750*	*1.266*	*14.606*	*osinc*	*0.0322*
Dow Chemical Co.	*Midland, MI*	*Jun-89*	*RK*	*VS/ESP*	*105.0733*	*28.814*	*162.701*	*osinc*	*0.0198*
3M	*Cottage Grove, MN*	*Sep-90*	*RK*	*WS*	*80.4750*	*61.661*	*203.796*	*osinc*	*0.0600*
Vulcan Materials Co.	*Wichita, KS*	*Apr-91*	*LI*	*WS*	*240.0900*	*147.320*	*534.730*	*osinc*	*0.0114*

TABLE 5.6-4. FLOOR ESTIMATE OF PCDD/PCDF (TOTAL ng/dscm)

Company	Location	Number of Points	Average PCDD/PCDF (ng/dscm @ 7% O2)	STDEV (ng/dscm)	RSD %	Vi (ng/dscm)^2	SUM(i)	SUM^2/np	np^2	np-1	Vi*(np-1) (ng/dscm)^2
Keystone Cement Co.	Bath, PA	3	0.68	0.09	13%	8.13E-03	2.05	1.40	9	2	1.63E-02
Solite Corp.	Cascade, VA	3	1.58	0.09	6%	7.63E-03	4.73	7.46	9	2	1.53E-02
Ross Incineration Services	Grafton, OH	3	1.46	0.43	29%	1.85E-01	4.38	6.39	9	2	3.70E-01
Keystone Cement Co.	Bath, PA	3	2.41	0.38	16%	1.42E-01	7.24	17.47	9	2	2.83E-01
Rollins Environmental Services	Baton Rouge, LA	3	2.26	1.82	81%	3.31E+00	6.78	15.32	9	2	6.62E+00
Rollins Environmental Services	Deerpark, TX	5	4.31	1.05	24%	1.10E+00	21.53	92.71	25	4	4.40E+00
						sum^2/np	109.1		70	14	1.17E+01
	Total Number of Points	20									
	Total Number of Facilities	6					sum(sum^2/np)	140.8			

S1^2 (ng/dscm)^2	0.84
S2^2 (ng/dscm)^2	1.67
Sa (ng/dscm)	1.58
Avg. (ng/dscm)	2.12
K @ Nt	3.295
K @ Nf	5.062
Degrees of Freedom	8.01
Q	7.5715
J	3.33
K @ 95%-p,99%-d	4.57
FLOOR (ng/dscm)	9.35

TABLE 5.7-1. EMISSION LEVELS ACHIEVABLE BY THE BEST CONTROLLED SOURCES

SOURCE	OPTION 1 (d) (gr/dscf @ 7% O_2)	OPTION 2 (e) (gr/dscf @ 7% O_2)
CK	0.033	0.010
LWA	0.022	0.0077
CK + LWA (a)	0.0076	0.0061
(C) HWI	0.010	0.0049
(OS) HWI	0.015	0.0075
(C+OS) HWI (b)	0.0057	0.004
BOILERS	0.021	0.011
ALL (c)	0.0086	0.0052

(a) 3 LWA and 3 CK's, all Fabric Filter APCD's

(b) 5 (C) HWI's and 4 (OS) HWI's

(c) 2 CK's, 3 boilers, 4 (OS) HWI's, 5 (C) HWI's, 3 LWA

(d) An emission level that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95% confidence.

e) An emission level that a source with emissions equivalent to the average for the pool of best controlled sources (and displaying emissions variability similar to the pool sources) could be expected to meet 99% of the time with 95% confidence.

Table 5-7-2 presents the emission level calculations under both analytical options for dioxin/furans in ng/dscm TEQ and in total tetra though octa congeners. Interpretation of the data is identical to that discussed in the previous paragraph. The Option 1 level is a value at the 95% confidence level that any of the BOP pool would be expected to achieve 99% of the time. None of the facilities in the pool used to establish the level would be expected to require retrofit or modification to achieve the level. The Option 2 level is a level that a facility with the pool average, and displaying similar variability as those facilities used to establish the average, would be expected to exceed 1% of the time. It would be expected that the worst performers in the pool used to establish this level would require modification or changes in operation to confidently achieve the Option 2 level.

The estimates of dioxin/furan emissions from sources that are operating under BOP are in close agreement with the floor calculations in both total ng/dscm and TEQ, as expected. (The BOP estimate for TEQ is 0.20 under Option 1 and 0.16 under Option 2. The BOP estimate for total congeners is 14 under Option 1 and 11 under Option 2.) The floor levels are derived from the best performing units and define to a large extent the operating practices and control technologies establishing BOP. The BOP levels are derived from the expected emissions of facilities incorporating BOP. The close agreement between BOP and the floor calculations provides reassurance in the ability of facilities to achieve the calculated levels.

The analysis presented in this chapter is based on the data currently compiled and summarized. Further data is needed to establish and identify those parameters affecting emissions (particularly PCDD/PCDF emissions) that the current body of data cannot resolve. Efforts are ongoing to identify these data needs, and it is anticipated that subsequent revisions to this document will reflect the additional insight gained from further focused testing.

The PM level calculations of Table 5.7-1 are presented in several different ways that represent individual source categories (or subsets thereof), as well as various degrees of aggregation of source categories. While the Agency is interested in examining the appropriateness and implementability of establishing standards that apply across all types of hazardous waste combustion facilities, we recognize that in doing so there may be technical and policy determinations that have not yet been fully illuminated or explored. Hence, comments on this particular issue will be most helpful. The Agency emphasizes that, at this time, we have not decided if and which source categories will be grouped in determining the PM level calculations, and we will consider all comments on the appropriateness of such aggregation.

TABLE 5.7-2. SUMMARY OF PCDD/PCDF FLOOR CALCULATIONS

CASE	OPTION 1 [a] (ng/dscm @ 7% O_2)	OPTION 2 [b] (ng/dscm @ 7% O_2)
Total Congeners (tetra through octa)	9.4	5.4
TEQ	0.17	0.12

(a) An emission level that all of the sources in the best controlled source pool could be expected to meet 99% of the time, with 95% confidence.

(b) An emission level that a source with emissions equivalent to the average for the pool of best controlled sources (and displaying emissions variability similar to the pool sources) could be expected to meet 99% of the time with 95% confidence.

With respect to dioxin/furan emission levels, note that EPA believes that it is appropriate to control dioxin/furan emissions for HWCs based on toxicity equivalents (TEQs). Under this approach, weighting functions known as toxicity equivalence factors are assigned to the various dioxin and furan congeners to account for their toxicity relative to 2, 3, 7, 8 TCDD. EPA is considering whether it is also appropriate to control emissions based on total tetra through octa congeners. If so, emission limits would be established on the basis of total congeners as well as TEQ. Comments on this issue will be helpful.

5.8 References

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4. Vangel, M., New Methods for One-Sided Tolerance Limits for a One-Way Balanced Random-Effects ANOVA Model, Technometrics, May 34(2): 176-185, 1992.

6.0 EUROPEAN EMISSION REGULATIONS

This section provides a brief overview of emerging regulations throughout Europe to control operation and emissions from hazardous waste incineration systems. Each of the countries in Europe is an independent nation with the freedom to establish environmental policy as it sees fit. However, the advent of the European Economic Community (EEC) now provides a strong impetus and framework for adoption of uniform policy and regulations, although full uniformity has not yet been achieved.

Since the turn of the century, European countries have pursued incineration as an alternative to landfilling. This is especially true for countries with high population density and topography or geology which is not conducive to extensive landfilling. Over the last 15 years, incineration of waste (municipal as well as hazardous) has played an increasingly important role in meeting European energy demands and is now an integral part of the continent's industrial base.

The above factors have led to several trends. Because of the high population density, European countries are acutely concerned with environmental issues. This is particularly true relative to toxic air emissions (especially dioxins and furans) and the characteristics of materials that are landfilled. For example, evidence exists that the presence of carbon in landfilled materials increases the mobility of trace metals. Based on that information, Germany has recently promulgated regulations banning the landfilling of any material containing more than 5 weight % carbon. Thus, by regulation, Germany effectively directs that virtually all organic waste streams will either be recycled or incinerated. This official German position supporting incineration does not imply a lack of concern for air, water, or solid waste emissions from incinerators. This fact will be illustrated in the following paragraphs.

In reviewing European emission regulations, it is important to note that European industry and governments often interact cooperatively, leading to development of advanced environmental control technologies. Countries have often issued environmental "regulations" in the form of research objectives and then supported the affected industry in technology development efforts for meeting those research objectives. This type of cooperation has helped European companies remain at the developmental forefront for waste combustion technology, as well as for air pollution control technologies.

6.1 Regulatory Framework for EEC Directives

As noted above, each European country is free to develop its own environmental regulations, but there is a growing movement toward standardization of requirements. This trend is intimately tied to development of the EEC, which issues directives for use by the various member countries. An initial set of directives was issued on June 21, 1989, with the intent of requiring control of certain pollutants from large combustion plants. This directive specifically included municipal waste combustion systems and required that a study be performed leading to a new directive specifically addressing hazardous waste incineration. As a result, on March 23, 1992, the Proposal for a Council Directive on the Incineration of Hazardous Waste (92/c 130/01) was issued. This EEC guideline requires all Member States to establish laws, regulations and administrative provisions necessary to comply with the directive by June 30, 1994. A review of regulations for the Member States reveals that:

1) Only Germany, France, the Netherlands, and Spain currently have legally binding regulations for hazardous waste incineration;

2) Denmark, Ireland and the United Kingdom have recorded emission guidelines in the regulations on incineration of hazardous waste. These guidelines serve as goals for the plants to meet;

3) Belgium, Italy, Luxembourg and Portugal have neither legal nor guideline limits on emissions at this time. The legal authorities in Luxembourg and Belgium do take into account the German and Dutch legal limits when negotiating the operating permits with incineration facilities. In Italy, there is an article that requires all industrial facilities to install Air Pollution Control Devices (APCDs) to lower emissions to "the lowest level technically feasible." Portugal defines emission limits for every facility during the permitting process. The government agencies do consider the emission limits set by other countries when defining the limits for a facility.

4) The regulatory situation in Greece is unknown at this time. No information about emission limits and/or guidelines has been made available to the EEC commission.

It is important to note that the EEC directive stipulates a timetable for compliance. Specifically, it stipulates that all Member States should establish laws, regulations and administrative provisions necessary for compliance by July 30, 1994. The directive stipulates that any new incinerator must comply with the directive immediately and that existing units must comply by June 30, 1997. Small units which cannot afford to retrofit the facility with air pollution controls will be allowed to continue operation for a period of 5 years but must cease operation on or before June 30, 1999.

6.2 Regulatory Content

The regulatory approach adopted in the 1992 EEC Directive covers all aspects of the hazardous waste incinerator system operation. This includes requirements associated with waste feeding, incinerator operation, ash quality, APCD operation, stack emission limits, and continuous monitoring.

Each hazardous waste incineration facility is assumed to have been specially designed and is permitted to treat specific types and quantities of waste. The guidelines require the operators to have proof of the waste composition prior to treatment of the waste. Compliance with this requirement may be achieved by obtaining an MSDS type form from the waste generator or through chemical analysis of each lot of waste received. Moreover, the plant must have demonstrated that it is appropriately designed to treat this type of waste.

Stringent operating conditions and monitoring requirements are also imposed upon the incineration process. For any incinerator burning organic waste, monitors are required to determine the temperature and oxygen content of the combustion products as well as the temperature of the gases as they leave the incinerator. Specifically, the rules require a minimum temperature of the "gases resulting from the combustion process" measured at the furnace wall of at least 850 °C and a minimum oxygen concentration of 6%. If the incinerator is burning halogenated organics, the minimum furnace temperature is set at 1200 °C. There are also requirements for continuous measurement of furnace chamber pressure, furnace exhaust gas temperature, and moisture content of the exhaust gases.

To achieve the stack gas emission limits, all incinerators will need to be equipped with downstream air pollution control systems. Many of the facilities use wet scrubbing technologies (either alone or in conjunction with dry type controls). Any APCD system used must be a zero

liquid discharge system. There are also stipulations regarding the quality of the solid residue. The specific requirement is that each facility must treat the residue to lower the concentration of hazardous constituents as much as possible before disposal. Several facilities actually recycle the solid residue to improve the ash quality. Hazardous waste and municipal waste combustion facilities in Germany are reported to apply thermal treatment to their ash. One of the main purposes of ash thermal treatment is to destroy dioxins and furans that may be associated with dust collected in the particulate control device.

Stack emissions are also closely regulated. In general, the emission guidelines establish limits based on dry combustion gases under metric standard conditions (273° K, 101.3 kPa) and corrected to 11 % oxygen in the flue gas. Emissions of dioxin and furan are expressed as 2,3,7,8 — TCDD toxic equivalent using the International toxic equivalency factors. The specific limits provided in the EEC Directive are set out in Table 6.2-1 below. Note that all stack limits are expressed as daily averages. Also included in the following table are the stack emission limits formally required in Germany and the Netherlands.

In addition to the above stack emission performance requirements, the EEC directive also establishes a wide array of continuous emission monitoring requirements. These include continuous monitors for carbon monoxide and total dust emission levels. Further, there are requirements that hazardous waste incineration facilities must perform monthly measurements to quantify emissions of metals, dioxins and furans.

6.3 European Technology

There are a variety of technologies currently available in Europe for control of the specific pollutants generated by incineration. Technology transfer has reached a stage where the successful application of any air pollution control technology will rapidly lead to worldwide application.

Waste incineration has been utilized in Europe for a longer period than in North America. The Air Pollution Control Device (APCD) systems used in North America and Europe possess the same basic technology, however, there are significant design differences. The design differences exist in Europe because the majority of the installations are retrofits to existing incinerators with no emission controls or an ESP as a minimum. These existing incinerators also face more stringent air pollution regulations. North American applications for APCD technology are usually on new facilities, and these facilities tend to be larger.

TABLE 6.2-1. EMISSION GUIDELINES FOR INCINERATION OF WASTE MATERIALS IN EUROPE

Component (Daily Averages)	Emission Limit Value (mg/m^3)		
	EEC	Netherlands	Germany
Total Dust	5	5	10
Gaseous inorganic Chlorides as HCl	5	10	10
Gaseous inorganic Fluorides as HF	1	1	1
Carbon Monoxide (CO)	50	50	50
Gases Organic Compounds as C (TOC)	5	10	10
SO_2	25	40	50
NO_x	-	70	-
Heavy Metals and their compounds:			
Cadmium (Cd)	-	0.05	-
Thallium (Tl) plus Cadmium (Cd)	0.05	-	0.05
Mercury (Hg)	0.05	0.05	0.05
Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni), Vanadium (V) and Tin (Sn)	0.50	1 *	0.50
Dioxin and Furans (nanograms TEQ/m^3)	0.1	0.1	0.1

* Includes Selenium (Se) and Tellurium (Te) in addition to the 10 metals listed.

NOTE: These numbers are based on 11% O_2.

Significant incineration design and operating experience has been gained in Europe over the past 25 years. Incinerators in Europe currently incorporate some type of APCD such as wet and dry electrostatic precipitators (ESPs) or fabric filters (FFs) for dust control. Most of the incinerators have also added multi-stage wet and dry scrubbers or spray drying and dry adsorption processes for controlling acid gas and heavy metal emission.

Europe uses an integrated approach toward the control of emissions from hazardous waste incineration by controlling all potential waste streams. The choice between scrubbing technologies has been influenced by the regulatory climate in the European community. The future trend is expected to be more toward wet scrubbers. Wet scrubbers produce less solid residues; they also require a good liquid effluent management system. Many treatment technologies for the liquid effluents from the scrubbers are being developed.

In addition, there are a number of newer technologies being used to try to drive air emissions to lower levels. These new technologies include the addition of Selective Catalytic Reduction $DeNO_x$ reactors (SCR-$DeNO_x$), activated carbon filters, and gas suspension absorbers.

In Europe, the general practice has been to continue to retrofit facilities with new APCDs in series with the existing equipment. The typical facility will have an ESP for dust control, followed by a multistage scrubber for acid gases and metals. Facilities seeking to incorporate more efficient emission controls have added SCR-$DeNO_x$ for NO_x control. For additional organics and metals removal, activated carbon filters are often added to the end of the existing systems.

Limited emission data has been collected on the more advanced APCD control schemes. One gas treatment system used on a hazardous waste incinerator in Europe consisted of a dust collector, a two-stage acid scrubber, and an activated carbon filter. Emission measurements performed on this system have yielded the results given in Table 6.3-1.

This unit demonstrates, at least under the operational conditions at this facility, that the limits set forth in the European standards can be met. Table 6.3-2 lists several incinerators in Europe and their associated air pollution control equipment. Most are older incinerators that currently operate with ESP's and some type of wet scrubber.

TABLE 6.3-1. OBSERVED STACK EMISSIONS: HW INCINERATOR

Parameter	mg/Nm^3 SC
Total Dust	<0.50
HCl	0.19
HF	0.05
SO_2	6
NO_x	177
Hg	0.002
Dioxin/Furans	0.03 ng TE/m^3 SC

TABLE 6.3-2. EXAMPLES OF APCD EQUIPMENT CURRENTLY INSTALLED ON INCINERATORS IN EUROPE

NAME	LOCATION	GENERAL TYPE	INPUT	POLUTION CONTROL EQUIPMENT	SPECIAL FEATURES
Amagerforbraending	Copenhagen, Denmark	Grate furnace incinerator (3 furnaces)	Municipal waste	None	Inadequate capacity, no time for maintenance
SaKab	Sweden	Rotary Kiln incinerator	Hazardous waste	ESP & scrubber	All piping heated; Above ground landfill; Most dioxin-analyzed facility in the world
REO Facility	Oslo, Norway	Combination grate incinerator, mechanical separation, pulp production and plastic extrusion facility	Municipal waste	ESP scrubber to be installed	6,000 kw hrs/week production capacity
Rotterdam		Rotary Kilns (2); grate furnaces (6-rollergrates)	Hazardous & municipal waste	ESP & scrubber	Slag & ash use, no scrubbers on MW, very large, plastic stack, collection of household HW, 500 tons in 198
Isenlohen	Isenlohen, West Germany	Grate furnaces and roller furnaces	Municipal waste	Wet scrubber & ESP	Salt sold to Bayer, Inc. for chemical production; Old, overcapacity $15 million in next 2 years; operating wel
BASF	Ludvighaven	6 Rotary kiln incinerators, #7 proposed	Industrial waste	ESP (all) & wet scrubbers (planned for 1-5)	52,000 employees and 320 production lines
Mullheizkraftwrek	Wrutzburg	Martin grate furnace	Municipal waste	Baghouse and 3-stage dry scrubber	Excellent slag, good emissions, much dioxin testing .008-.002 nanograms/M3
Schwabach Facility	Schwabach, West Germany	Incinerator; chemical and physical landfill	Hazardous waste	Retrofitted with ESP and wet scrubber	Undercapacity; too small to burn barrels
Herton Incinerator	Herton, West Germany	1 rotary kiln, 1 grate furnace & RDF facility	Municipal & hazardous waste	2-stage wet scrubber & ESP	Drum explosion killed worker; only RDF facility still operating in Germany; many problems
GBS	Vienna, Austria	2 rotary kilns (HW & 2 fluidized beds for sewage sludge	Hazardous waste & sewage sludge	ESP now, 4-stage "French scrubber planned in 1987	Telephone link monitoring
Bern Incinerator	Berne, Switzerland	Martin grate furnace	Municipal waste	Dry scrubber	Once a year monitoring inspection by private institute

APPENDIX A:

AIR POLLUTION CONTROL TECHNIQUES

APPENDIX A: AIR POLLUTION CONTROL TECHNIQUES

Particulate matter (PM) constitutes a major source of air pollution. Particles generated by kilns and incinerators have a variety of shapes and sizes, with a wide range of physical and chemical properties. This appendix presents information on the design, performance, and operation of common particulate control devices used for the removal of particles from flue gas from cement kilns, lightweight aggregate kilns, and hazardous waste incinerators.

For cement kilns, the APCDs consist of electrostatic precipitators (ESP) and fabric filters (FF). Lightweight aggregate kilns utilize fabric filter baghouses and fabric filter baghouses with a spray dryer (SD) upstream. Many hazardous waste incinerators in the U.S. operate with the following combinations of systems: SD/FF; FF with venturi scrubbers (VS); SD/FF with High Energy Scrubber (HES); ESP with VS; wet ESP with a wet scrubber (WS) and VS. A hazardous waste incinerator's APCD design is more varied and includes ESP, FF, Venturi Scrubbers, other wet scrubber designs, and spray dryers.[1]

The following is a description of the design principles, performance parameters, process monitoring requirements, and the necessary inspection and maintenance for optimum APCD operation for:

- Cyclones
- Fabric Filters
- Electrostatic Precipitators
- Venturi Scrubbers
- Wet Scrubbers
- Spray Dryers

In addition, a discussion of flue gas conditioning to improve APCD performance is included.

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[1] "Assessment of Air Pollution Control Devices for Particulate Matter", EPA Contract 68-0-0094, Work Assignment 2-4, Subtask 1 Report, September 30, 1993. p. 2 - 3.

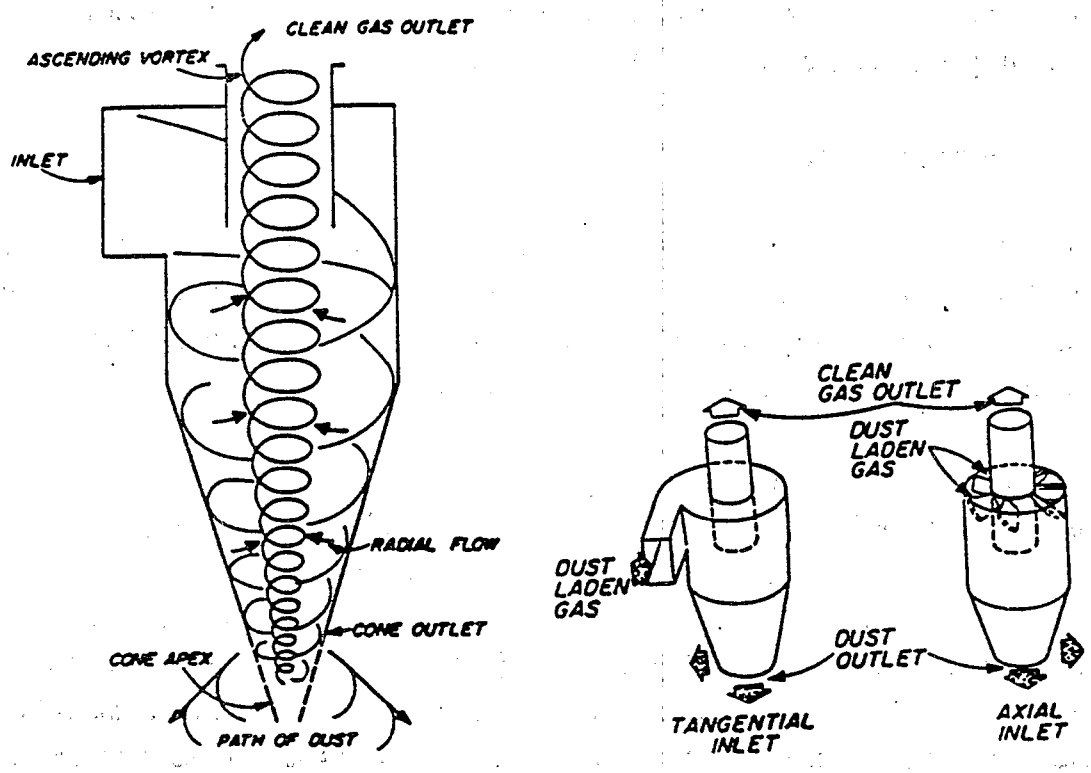
A.1 Cyclones

The cyclone separator is typically incorporated as a pre-filtering process for removing larger particles. Cyclones can operate at relatively high temperatures and function without moving parts, making operation simple. The cyclone chamber provides angular (swirling) gas flow which causes the suspended particles to accelerate toward the chamber walls. Particles, being denser than gas, separate from the gas stream and impact the cyclone chamber walls. The cyclones are erected vertically and the particles fall under gravity to the collection hopper.

A.1.1 *Design Principles*

The cyclone device is typically positioned immediately downstream of the primary combustion chamber. The cyclone's service environment is dependent on its construction material. Cyclones can be constructed to withstand harsh environments such as extreme weather conditions and high temperatures since they have no moving parts.

The cyclone is typically a vertically erected conical or cylindrical shaped chamber which receives particle laden gas in the upper chamber region, as shown in Figure A.1-1. The gas enters either tangentially or axially in a downward spiral path around the chamber walls. The spiralling motion causes the particles in the gas flow to accelerate to the chamber walls, where their momentum causes them to separate and fall out of the gas stream. The particles drop to the bottom of the cyclone by gravity and downward motion of the gas. The particles fall into the collection hoppers and are removed by an ash removal system. The cleaned gas still carries significant levels of fine particulate which remain suspended in the flow due to their airborne characteristics. The treated gas reverses direction at the bottom of the chamber and returns up the center of the chamber and exits out the top.



(Reprinted from "Pollution Engineering Guide to Fine Particulate Control in Air Pollution" by P. Cherminisoff with permission from Conner Publishing)

Figure A.1-1 Cyclone particle collector.

A.1.2 *Performance*

Cyclone removal efficiency is dependent on the gas velocity, rate of change of gas direction and the particle size distribution, density and composition. The main limitation of the cyclone is the inability to effectively remove small particles less than 5μm in diameter. For small particles, the inertial separating force (particle momentum) is low and the particles are more prone to remain suspended in the gas stream.

The removal efficiency of a cyclone can be expanded by increasing the swirling velocity of the gas, which increases the inertial separating force or particle momentum. This is effectively accomplished by reducing the diameter of the cyclone chamber or increasing the gas flow rate. Cyclone performance is affected by gas flow rate, since this affects the swirling velocity in the cyclone. Cyclone efficiency is relatively insensitive to dust loading, and in fact, the efficiency can increase with higher loading due to particle interactions.

Cyclone efficiency is generally poor compared with the efficiency of electrostatic precipitators and fabric filters. Cyclone efficiency is less than 20% for sub-micron particulate. Efficiency varies linearly with particle size from 5% for 0.5 micron particles to 50% for 3 micron particles.

A.1.3 *Process Monitoring*

The pressure drop and inlet gas temperature are monitored to assure proper operation. The pressure drop is monitored so that any tendency of the cyclone to plug can be signaled by high pressure drop. Also, leaks and cracks in the cyclone can be detected by reduced pressure drop. Pressure drop is also a function of gas flow and may be used as an indicator of capture efficiency. Generally, efficiency increases with higher pressure (i.e., higher gas flow). Monitoring of the inlet gas temperature may be required, depending on the cyclone's application and construction material, to operate above the acid dew point and avoid corrosive conditions.

A.1.4 *Inspection and Maintenance*

Cyclones have minimal maintenance requirements due to the lack of moving parts. Cyclone wall corrosion, leakage, particle deposits and plugging should be regularly checked. Life expectancy of cyclones is long and is only limited by material corrosion, erosion and thermal stresses and cracking. Overall, the cyclone requires very little routine maintenance.

A.2 Fabric Filters

Fabric filters (FF), also commonly known as baghouses, are used to remove gas suspended particles much like the filtration device on a common household vacuum cleaner. The fabric filter is utilized in relatively low temperature environments (around 350 °F) but always above the dew point of water and common acid gases. The particle laden gas stream enters the FF chamber and passes through vertically suspended filter bags. Particles then collect on the filters. Particle build-up is periodically removed from the filters by one of a variety of methods. The collected particles fall to the collection hopper situated below the filter bags. The attributes of fabric filters are:

- High Capture Efficiency
- Capture Efficiency Independent of Particle Characteristics
- Frequent Routine Maintenance
- Monitoring, Inspection and Maintenance is Simple

The following is a description of the design principles, performance parameters, process monitoring requirements, and the necessary inspection and maintenance for optimum FF operation.

A.2.1 *Design Principles*

Fabric filters are used to remove suspended particles from flue gas by capturing the particles on the surface of a porous fabric. Particle laden gas enters the collection device and passes through an array of cylindrical filtering bags which retain the particles; and the clean gas exits through the outlet duct. The design of the FF system slows the gas velocity and evenly distributes the gas to all the filter bags. Particles collect on the filters and form a dust cake on the surface of the filters. As the dust layer builds, it becomes more difficult for particles to penetrate. This increases both the pressure drop across the filters and the collection of the particles. It is actually the dust cake which achieves the high efficiency collection of particulate. For this reason, unless the filters are preconditioned (i.e., an artificial filter cake is built-up) prior to operation, filter efficiency is lowest at start-up and after the bags are cleaned.

Fabric filters are usually externally heated and/or insulated to ensure that the device remains above the minimum required operating temperature to prevent condensation which can plug and corrode the filter bags. This is especially important during start-up and shutdown operations, when temperatures are likely to drop below the gas dew point. A FF's maximum operating

temperature is limited by the working temperature of the fabric. For many common filtering fabrics, the maximum operating temperature is less than 500 °F. Fabric filters are equipped with spark arresters upstream to prevent fugitive sparks and hot flash from burning the filters.

Filters are most effective at collecting particles when coated with dust, however, too high a coating will create a high pressure drop across the filter. The filters need to be cleaned periodically. When removing the dust build-up, it is important not to remove too much dust cake or else excessive dust leakage will occur while fresh cake develops. There are four principal types of cleaning systems: pulse jet, reverse gas, shaker, and sonic.

The pulse jet system utilizes high pressure air to clean the filters, as shown in Figure A.2.1-1. The high pressure air inflates the bags, cracking the external dust cake. When the air is removed, the bags return to their original shape and the dust cakes drop into the collection hopper. Pulse jet systems can be cleaned while on-line, allowing continuous operation of the unit. Filters can be maintained from outside the collector, which allows the maintenance to be performed in a clean, safe environment. This vigorous cleaning technique tends to limit filter bag life.

In reverse air systems, the dirty gas enters the fabric filter and passes from the interior to the exterior of the bags, as illustrated in Figure A.2.1-2. The FF must be divided into modules which are taken off-line during cleaning. Low pressure air is introduced from the exterior of the bags, collapsing the bags and cracking the interior dust cake which falls to the collection hopper. The cleaning is accomplished with relatively low air pressure, resulting in maximum bag life.

Shaker systems move the tops of the bags in a circular path, causing a wave motion through the bag length. This causes the dust to crack and fall to the hopper. Bags must have high abrasion resistance for this cleaning technique. In addition, individual bags must be taken off-line for the cleaning process.

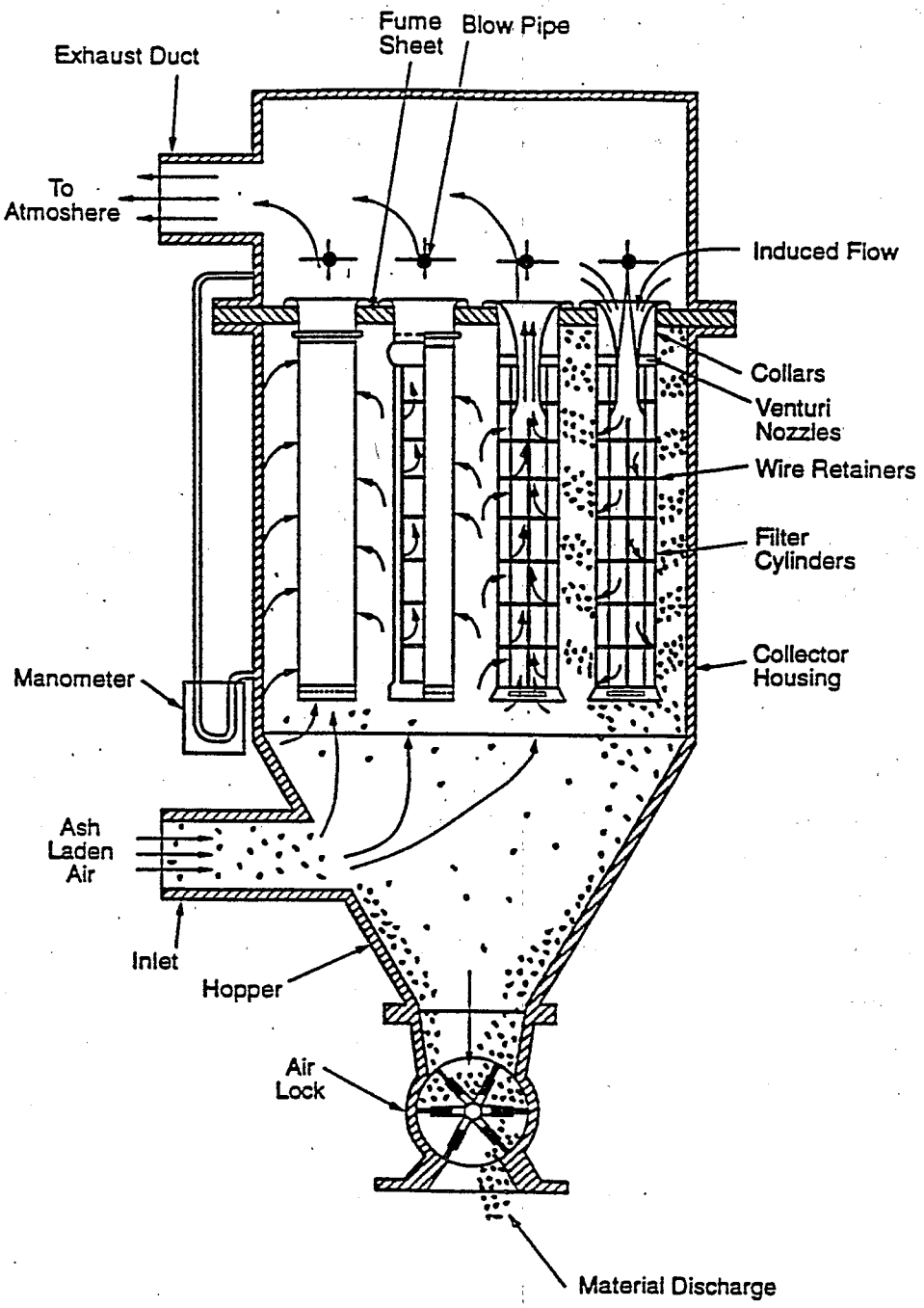


Figure A.2.1-1. Pulse jet cleaning baghouse. [3]

[3] Mc Keena, , J.D., Turner, J.H., *Fabric Filter - Baghouses I: Theory, Design, and Selection*, ETS International, Inc., 1989.

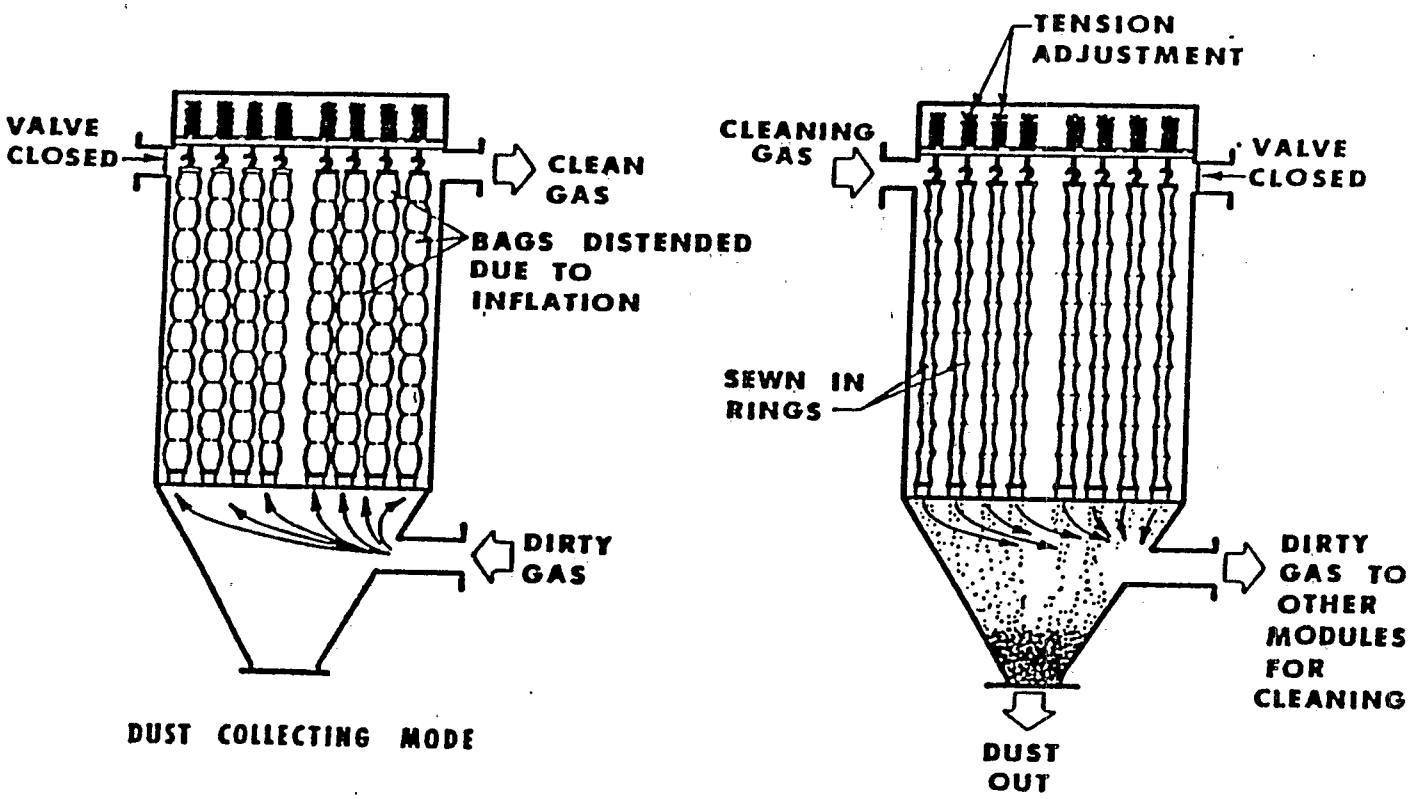


Figure A.2.1-2. Reverse air cleaning baghouse. [4]

[4] McKeena.

Sonic cleaning, if used, usually augments another cleaning method. Sonic energy is introduced into the filtering device. The sonic waves generate acceleration forces that tend to separate the dust from the fabric.

A.2.2 *Performance*

Fabric filters are very efficient at removal of particles of all sizes. Efficiency ranges between 99% and 99.9% for particle sizes as low as 0.1 microns. Particle capture is relatively insensitive to particle and dust physical characteristics such as particle resistivity and dust loading. Efficiency is decreased as the gas-to-cloth ratio increases as gas velocity rises. Gas-to-cloth ratio is a ratio of the gas volume flow rate to the filter surface area and is a measure of the superficial gas velocity through the filter. Typical gas-to-cloth ratios range from 3 to 5 acfm/ft^2 , with lower gas-to-cloth ratios of 2 acfm/ft^2 providing improved performance. Particle capture efficiency is also dependent on the frequency of bag cleaning, cake build-up, and fabric type and weave, as well as on the physical condition of the bags.

Fabric filter technology has made significant advances with the improvement in FF bag materials. As a result, FFs are quickly becoming a preferred APCD, especially since ash effluent is dry and does not require the handling and disposal of liquid waste. Fabric filter collection efficiency is reported to be independent of inlet mass loading.

Upgrades to improve FF performance would involve enlarging the device to achieve a lower gas-to-cloth ratio and selecting improved filtering materials and pre-coating agents. Fabric filters generally operate at temperatures under 500 °F. The pressure drop across the FF is an important parameter since it relates directly to energy cost for the induced draft fan. Typical differential pressures for FFs are 1-6" w.c.[2]

Factors which specifically affect the efficiency of a baghouse are:

- Holes and tears in the bag and fabric abrasion mainly due to too vigorous a cleaning
- Chemical attack of the fabric
- Inadequate cake buildup

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2 Dalton, R.S. et. al., " An Assessment of Off-Gas Treatment Technologies for Application to Thermal Treatment of Department of Energy Wastes." Prepared for U.S. DOE under contract DE-AC05-84OR21400, September, 1992.

- Thermal degradation of the bag fabric
- Gas-to-cloth ratio
- Frequency of cleaning
- Fabric specifications (i.e., fabric type and weave)

Three options are available for improving the performance of fabric filters including: 1) Replacing existing FF unit with larger unit to reduce air to cloth ratio, 2) Adding to existing baghouse a parallel FF and thereby reducing the AC ratio, and 3) Upgrading the existing FF material to high performance filters. The last approach, upgrading the cloth material, represents the least costly option and is examined more fully below.

Basic filter bags were presented at \$0.6 /ft^2 (Sink, 1991)[1] for polyester and polyethylene bags with a 2-year service life. A service life of 4 years can be achieved with a Teflon membrane coating (i.e., GORE-TEX® bags) (Brinckman, 1993). These bags cost 3 to 4.5 times the base bag price (Sink, 1991). It is anticipated that the teflon membrane coated bags for reverse flow application will cost on the order of \$1.9 /ft^2 (current estimates), with pulse jet application bags costing \$2.9 /ft^2. The costs to retro fit a 2 acfm/ft^2 air-to-cloth ratio fabric filter with the upgraded bags operating on a 200,000 acfm flue gas flow rate would be approximately \$127,000 to \$193,000. This retrofit results in a doubling of the life expectancy. If such an approach is selected, O&M labor costs would be reduced, but material costs would increase. The average yearly O&M costs would increase from approximately \$28,000 to \$68,000 for material and labor based on the following equation (Sink, 1991):

$$\text{BRC (\$/yr)} = (\text{BC (\$)} + \text{labor (\$)})^* \ \text{CRF} \qquad \text{Eq. 2-1}$$

where:

BRC is yearly bag replacement costs
BC is bag costs
labor equals 0.14 times Cloth Area
CRF is costs recovery factor (taken as 0.58 for 2 year bags, 0.4 for 4 year bags)

The annual O&M costs differential for an upgrade in fabric material would be \$39,000, \$9,750, and \$2,930 for a 200,000, 50,000, and 15,000 acfm device, respectively.

A.2.3 *Process Monitoring*

Fabric filter operations are monitored by flue gas inlet temperature, gas flow rate and pressure drop across the system. The baghouse temperature must be maintained above the acid condensation point in order to reduce corrosion and fabric wear. This is important during boiler start-up and shutdown conditions. If acid deposition occurs after shutdown, the acid moisture will settle on the fabric and eventually leave behind a residue which may contribute to the brittleness of the bags and cause failure when put into operation again. An atypically high pressure drop can signify that bags are binding or plugging, gas flow is excessive, or fabric cleaning is inadequate. Low pressure drop signifies possible filter holes and leakage, leakage between the bag and bag supports, or inadequate dust cake formation. The FF performance can be monitored with an opacity meter.

A.2.4 *Inspection and Maintenance*

Fabric filters are relatively simple to operate and require minimal maintenance and repair. However, they require frequent routine inspection and maintenance. Several FF inspections and maintenance items are required on a daily and weekly basis. Filter bags require periodic inspection for correct tensioning and conditions such as tears, holes due to abrasion, and dust accumulation on the surface. The typical filter bag life is as much as 10 years using reverse air cleaning, but this can be reduced to 2 years for improperly operated systems. Filter bags are fragile and prone to hole formation if not handled carefully.

A.3 Electrostatic Precipitators

ESPs are common APCDs which have been utilized for many years in both the United States and abroad. Electrostatic precipitators (ESPs) are very efficient at removing fine particles from flue gas. Electrostatic precipitators are available in a variety of designs and can operate in a dry or wet mode and in hot or cold gas conditions. ESPs are known for the following characteristics:

- High capture efficiency
- Lowest capture occurs with 0.1 to 1 micron particles
- Extensive monitoring requirements
- Automatic controls
- Low routine maintenance

ESPs have several advantages, but most significant is the high collection efficiency and low gas pressure drop.

The following is a description of the design principles, performance parameters, process monitoring requirements, and the necessary inspection and maintenance for optimum ESP operation.

A.3.1 *Design Principles*

Electrostatic precipitation is a process by which gas suspended particles are electrically charged and passed through an electric field which propels the charged particles towards the collecting plates. The charged particles stick to the plates, and periodically a rapping (impact) mechanism dislodges the collected particles from the plates. The dislodged particles drop into the collection hopper for removal. Therefore, the principle of electrostatic precipitation is carried out in three main steps, namely; particle charging, particle collection, and particle removal. A schematic of an ESP operation is shown in Figure A.3.1-1.

Electrostatic precipitators can be found in both high and low temperature applications from the material temperature limits of 1,300 °F and down to the condensation point of flue gas constituents. Precipitators are commonly designed for either hot- or cold-side treatment. Hot-side precipitators, located upstream of the air preheater, have larger collecting plate areas and are constructed of suitable steels to handle continuous high temperature operation. The "cold-side" categorization refers to the ESP located downstream of the air preheater. Dry cold-side ESPs operate without water spray and at gas temperatures below 500 °F.

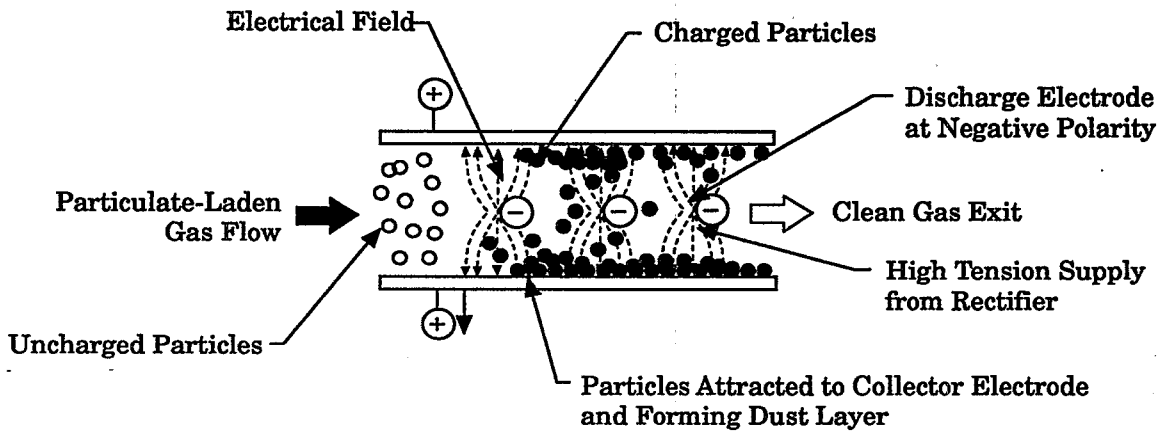

Figure A.3.1-1. ESP particle collection process.

The general configuration of an ESP is a wire (or rod) discharge electrode positioned at an equal distance between two collecting plates. The electrostatic precipitator casing houses many passages of parallel collecting plates with wires (or rods) suspended at regular intervals through the passage. The plates are further compartmentalized into fields, with each field typically energized by its own set of power supplies. A negative high-voltage direct-current power is applied to the discharge electrodes, and the collecting plates are grounded. The high-voltage direct-current power produces a corona in the wire-to-plate spacing by ionizing the gas. The corona then creates an avalanche of negative ions traveling from the negative discharge electrode to the grounded collecting plates. Suspended particles passing through the wire-to-plate spacing are bombarded by negative ions and become charged. The high voltage electricity produces an electric field between the wire and the plate which provides the electromotive force to attract the charged particles to the collecting plates.

Electrostatic precipitators can be classified into three types; tubular, wire-to-plate, and flat plate. A plate type ESP is shown in Figure A.3.1-2. Some ESPs have prechargers which divide the precipitator into a charging stage and a collecting stage.

The following process characteristics dictate the specific ESP design:

- Gas volume flow rate
- Particle loading
- Gas temperature
- Particle size distribution
- Particle composition

To accommodate these process characteristics, the following physical and electrical characteristics of an ESP may be varied:

- Number of fields
- Number of passages per field
- Wire-to-plate spacing
- Collection plate surface area
- Wire (or rod) diameter
- Aspect ratio (length to height)
- Maximum secondary voltage

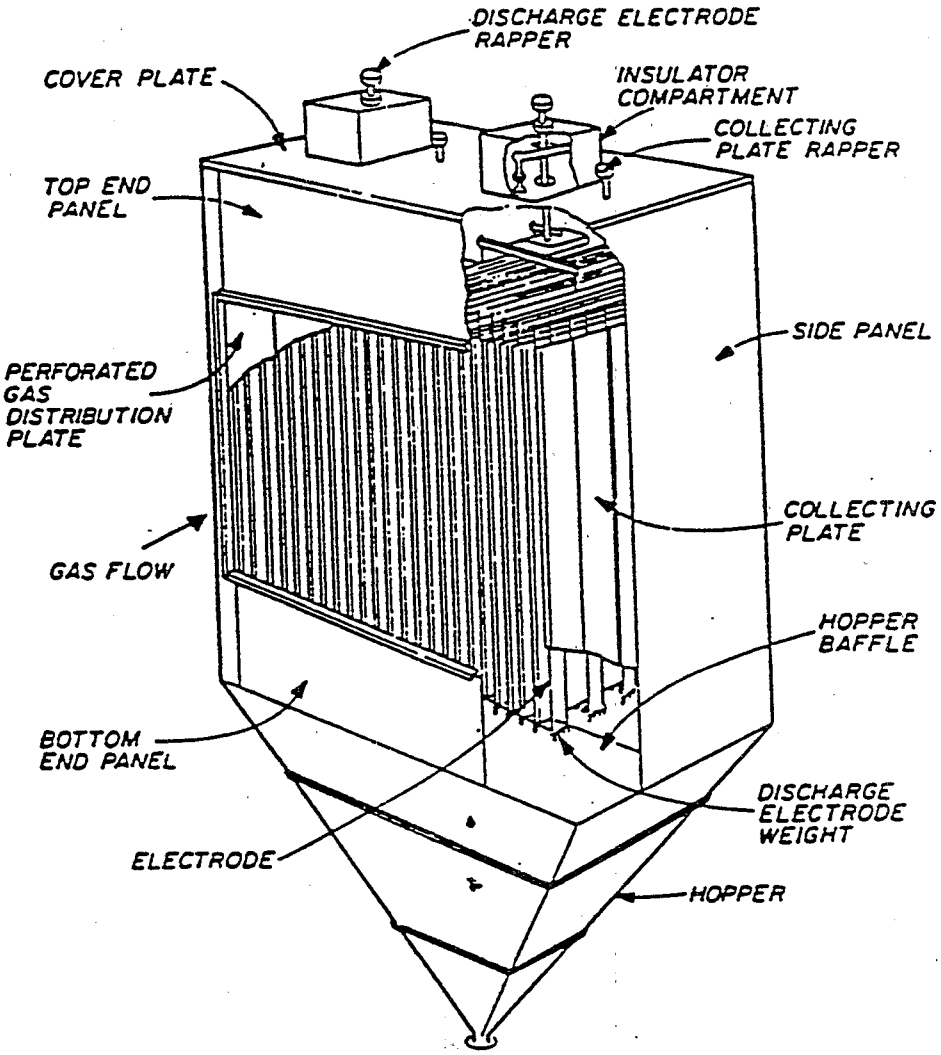

Figure A.3.1-2. Plate type ESP.

(Reprinted from "Pollution Engineering Guide to Fine Particulate Control in Air Pollution" by P. Cherminisoff, Connor Publishing)

- Maximum secondary current
- Number of sparks per minute

The charged particles which accumulate on the collecting surfaces must be periodically dislodged. Dislodging the collected particle layer is accomplished in several ways using either mechanical rapping devices or water. Wet electrostatic precipitators utilize water to rinse the collected particle layer of the collecting surface.

The wet electrostatic precipitator is used effectively in the following conditions:

- after flue gas has been through a wet scrubber,
- low gas temperature and high moisture content,
- high sub-micron particle concentration,
- liquid particle collection,
- for handling dust wet.

Typically, dry electrostatic precipitators utilize mechanical rapping devices which strike the collecting plates and dislodge the particles. The particles fall into the collection hoppers and are removed for disposal.

Newly designed ESPs have larger wire-to-plate spacings and use rigid rod discharge electrodes instead of wire. The newer electrostatic precipitators are capable of operating at higher voltage, which increases the electric field strength and the subsequent particle capture. Many electrostatic precipitators are equipped with advanced controlled power supplies which monitor electrical condition and maximize performance while minimizing power consumption. Advanced control units provide features such as intermittent energization and spark rate control. Intermittent energization switches off power repeatably for extremely short durations and maintains ESP performance while minimizing power consumption. Spark rate is important in the electrical operation. Sparking is a phenomenon which occurs because an ionized discharge to the collecting surface resembles an electrical arc. Excessive sparking will reduce the applied voltage and waste power; insufficient sparking may indicate that the ESP is not operating near its full potential. With automatic controls, a desired spark rate can be specified and will automatically be monitored and maintained.

A.3.2 *Performance*

Operating efficiency of the ESP increases with increasing plate area, increasing voltage and decreasing gas flow rate. Capture efficiency is dependent on:

- Specific collection area (SCA)
- Operating voltage
- Particle characteristics

The precipitator's size is measured in terms of specific collection area (SCA), which is the ratio of collection surface area to gas volume flow rate. Older ESP designs have specific collection areas (SCAs) which are typically under 300 ft^2/kacfm with a plate-to-plate spacing of about 9 inches. The newer designs incorporate wider plate-to-plate spacings with rigid rod discharge electrodes replacing weighted wire type electrodes. The newer ESPs have state-of-the-art microprocessor power controls, and the geometry permits higher voltage potentials. The particle collection is also subsequently improved.

Electrostatic precipitators are least efficient at capturing particles in the 0.1 to 1 micron diameter size range; however, when designed and operated properly, the ESP is still capable of excellent collection of particles in this size range. Electrostatic precipitators capture submicron particulate with approximately 90% to 95% efficiency. From the efficiency on submicron particles, the efficiency increases linearly to 99.9% for particles of 5 microns. Operation is sensitive to fluctuations in gas flows, temperature, particulate and gas composition, and particle loadings. This is because the electrostatic precipitator's effectiveness is strongly influenced by the resistivity of the particles in the gas stream.

The ESP is very efficient at capturing particles of all sizes, however, it is not efficient at capturing particles that have either high or low resistivities. Resistivity is a measure of the resistance of the particulate matter to being charged and is a function of particle composition and gas temperature. Resistivity of the particle affects collection in the following manner (U.S. EPA, draft):

- Low resistivity ($<2X10^8$ ohm-cm) - Easily charged, however , too low a resistivity will cause the collected particles to give up their charge to the collector plate and easily become re-entrained in the flue gas.

- High resistivity (>2X10^{11} ohm-cm) - Difficult to charge and collect. Also, once collected, they do no readily give up charge to the collector plate and tend to build up on the electrode.

- Normal resistivity (between 2X10^{8} and 2X10^{11} ohm-cm) - Most efficiently collected.

Factors which may adversely affect ESP performance include:

- Flyby of the particle due to exceptionally high operating flow rates in which the particle travels past the collection plates with enough speed so as not to be affected by the charged field.

- Misalignment of the electrodes and collectors plates.

- Dust buildup on the electrodes or collection plates.

- Erosion or corrosion of the collection plates.

- Leakage of scrubber liquid when pH is too high (wet ESP only).

- Re-entrainment occurring from redispersion of collected particles during rapping of the electrodes, seepage of collected dust from the hoppers, and direct scouring of collecting electrode surfaces by the gas streams.

- Undersized equipment.

- Presence of "back corona" which is due to particle buildup on collection plates. Ion current generated by the electrodes must pass through the particle layer before reaching the grounded plate. The current gives rise to an electrical field in the layer and can become large enough to cause local electrical breakdown. This condition causes sparking and is called back corona.

A four-stage (four-field) ESP would be more efficient for toxic metals removal than a single-stage ESP. Under reasonable comparable incinerator designs and operating conditions, this supposition was verified. At two different mass-burn, waterwall incinerators (both using Wheelabrator-Frye ESPs), the arsenic and chromium recovery efficiencies using one- and four-stage ESPs were 68% and 83.1% versus 97.4% and 99%, respectively.[3]

Within the last 2 to 3 years, manufacturers have developed advanced PC-based ESP controllers which regulate ESP control to improve power delivery. The advanced controllers are limited to the same peak power, however, the controllers are capable of managing power delivery and avoiding slow power ramping, such that over time an higher average power through put is achieved. In addition, these "smart" ESP controllers can incorporate a PM setpoint and use data from an opacity type meter to provide feedback to control PM emissions directly. In addition, these controllers can be readily modem linked to allow remote ESP performance monitoring, potentially reducing maintenance costs. Purchase costs estimates for these type controllers are on the order of $70,000.

A:3.3 *Process Monitoring*

To assure proper operation, the inlet gas temperature, flue gas flow rate and electrical conditions are monitored. On-line electrostatic precipitator performance is typically monitored with an opacity meter, however, continuous and reliable monitoring of electrostatic precipitator performance is difficult. An electrostatic precipitator's performance is sensitive to flow rate, particle composition and temperature, and the electrostatic precipitator's response to these parameters is relatively slow.

Temperature has a direct effect on particle resistivity, and therefore electrostatic precipitators must be operated within the designed temperature range. For cold-side ESPs, the temperature range is limited to temperatures above the condensation point and below the electrostatic precipitator's material limit usually specified by the manufacturer. For hot-side

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[3] "A Review of Air Pollution Control l Devices Used at Hazardous Waste Incineration Facilities and Their Removal Efficiencies for Toxic Metals", EPA Contract NO. 68-01-7053, Draft Final Report, August 28, 1987, p. 56.

electrostatic precipitators, high temperature is preferred within the maximum operating range specified by the manufacturer. Particle resistivity peaks at around 400 °F and is lowest at high and low temperature.

The electrical conditions do depend on the type of ESP. For the conventional cold-side wire-to-plate ESP, the voltage will range from 25 to 50 kV with even higher voltage for wider wire-to-plate designed electrostatic precipitators. Spark rate is often optimized on site but is generally between 50 and 150 sparks per minute. The higher the secondary current the better. Secondary current may be quenched by excessive particle loading. The secondary current density, which is the secondary current divided by the collecting plate surface area, is often less than 100 nA/cm^2. The secondary current density can be calculated for each field by dividing the field secondary current by the plate surface area in that field. Generally, the first fields have the lowest current density because a significant percentage of the current goes into charging the particles which are captured in fields downstream.

To summarize, the following monitoring activities are required for optimum ESP operation:

- Inlet gas temperature
- Gas flow rate
- Electrical conditions
- Rapper intensity
- Hopper ash level

A.3.4 *Inspection and Maintenance*

Maintenance is required for cleaning carbon deposits on plates which can cause short circuits, corrosion of plates, and erosion of electrodes. Electrostatic precipitators are fairly sophisticated devices requiring automatic controls for rectifier equipment, measurements systems for rapper intensity, hopper dust level, and metering systems of gas process variables such as gas flow and temperature. Because of this complexity, highly trained maintenance personnel are required. However, routine maintenance requirements for electrostatic precipitators are low compared with fabric filters. The frequency of inspections and maintenance are typically monthly for external systems such as power supplies, monitors, etc., and annually for internal systems such as electrode conditions, electrical connections, etc. Internal inspections and maintenance are conducted in difficult environments due to the potential mechanical and electrical energy of the

electrostatic precipitator. Annual inspections of the following are necessary: electrode alignment; electrode pitting; ash build-ups; ash hardening; hopper performance; electrode insulation; and rapper operations.

To summarize, the following inspection and maintenance activities are required for optimum ESP operation:

- Low routine maintenance
- Inspection of electrode misalignment, pitting, ash build-up, ash hardening, hopper blockage, electrode insulation cracks, and rapper performance.

A.4 Venturi Scrubbers

Venturi scrubbers, the primary type of scrubber used for particulate control, are more common on smaller units. Occasionally, a venturi scrubber is used on large units downstream of an ESP or FF for specific emission control such as acid gas or metal emissions.

The following is a description of the design principles, performance parameters, process monitoring requirements, and the necessary inspection and maintenance for optimum venturi scrubber operation.

A.4.1 *Design Principles*

The conventional venturi scrubber consists of a converging section, a throat section (either rectangular or circular), and an expansion section. An alkaline recirculating liquid is usually injected at an angle, in one or more streams, into the throat section or just upstream. The engineering principle is to accelerate the gas to a high velocity in the throat section, causing atomization of the liquid. In some cases, however, spray nozzles are used to atomize the liquid. The solution droplets are then accelerated to their terminal velocity. These droplets provide a large surface area for collection of fine particles and are many times larger than the particles in the flue gas. The particles are captured when they collide with the slower moving droplets. As the mixture decelerates in the expanding section, further impaction occurs and causes the droplets to agglomerate. Particle capture is primarily related to the amount of liquid atomization achieved.

Once the particles have been trapped by the liquid, a separator (e.g., cyclone, demister, swirl vanes) is used to remove the liquid from the cleaned gas. Mist eliminators consist of a mesh

of fine wire or wave plates. They provide a large area of collection surface area while maintaining a high void space.

As seen in Figure A.4.1-1, the most prominent feature of the venturi design is a converging throat section which causes acceleration of the flue gas flow. The scrubbing slurry is introduced at the inlet of the throat and is sheared into fine droplets by the high velocity flue gas stream. A turbulent zone downstream of the throat promotes thorough mixing of the gas and slurry droplets. As the droplets slow down through the diverging section, they collide and agglomerate and are separated from the cleaned gas stream by gravity as the gas passes on to the stack.

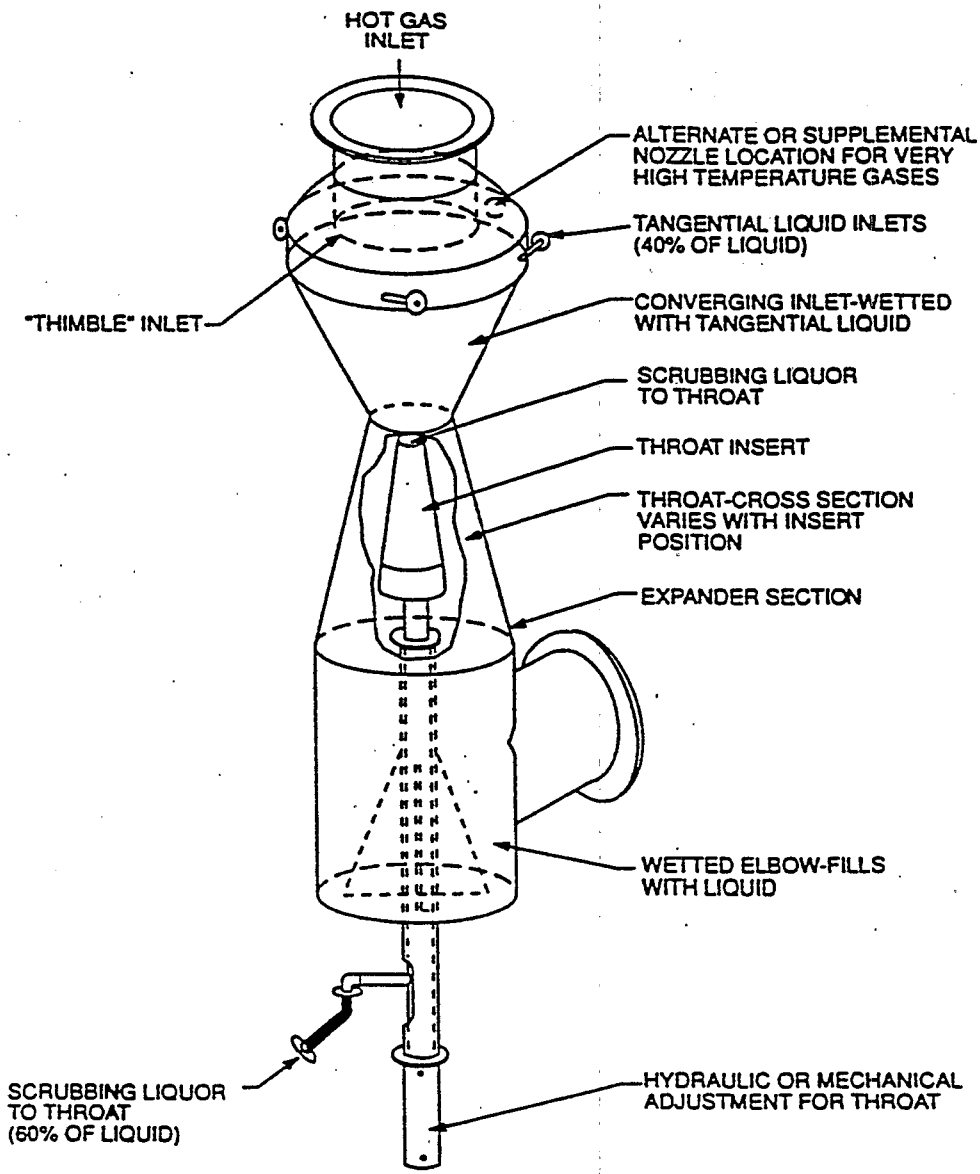

Figure A.4.1-1. Venturi scrubber schematic.

Venturi scrubbers use one of two approaches: wetted or non-wetted. When the gas entering the venturi is not at saturated conditions, the wetted approach is used. In this approach, a protective film of liquid is established on the convergent portion of the venturi. This liquid is introduced upstream of the throat and flows down the converging sides into the throat, where it is atomized. The gas is cooled by evaporation and reaches the throat at near saturation conditions. When inlet gases are hot and a significant amount of liquid needs to be evaporated, the wetted approach is preferred. The non-wetted approach is restricted to gases with subsaturation temperatures entering the throat.

Flux force/condensation/collisions scrubbers are a variation on the venturi type scrubber. Initially, the flue gas is quench with cooled scrubber water. Gases entering the scrubber are split into two streams which are directed to separate venturi throats where scrubber liquid is injected into the gas steam. The discharged gas/liquid streams from the two venturies are directed toward each other, causing them to collide at a high relative velocity. The head-on collision of the streams causes the droplets to shear into fine droplets, thus improving the efficiency of the device. Mist eliminator is used to remove entrained droplets. Through the use of cooled scrubber liquid, a "flux force condensation" technique is utilized. Flux force condensation is based upon the principle that when a gas stream is saturated with water and then cooled, a portion of the moisture will condense, and the fine particles in the gas stream serve as condensation nuclei. As moisture condenses on the particles, they grow in mass and are more easily collected by conventional impaction. Therefore, the condensation enhances the scrubbing system's collection of fine particles, acid gases and metals. (Calvert Co. product literature, 1992).

Free jet scrubbers have the same basic configuration of venturi type scrubbers (i.e., quench, scrubber, and moisture separator). The energy for moving gases through the system and cleaning the gases is provided by the injection of a compressible fluid (typically steam or air) from a supersonic ejector nozzle which is located inside the flue gas duct. The amount of fluid added through the ejector is proportional to the mass of gas flowing through the system. The turndown capacity of the system is high because the ejector supplies the energy required to move the gases through the system. At the exit of the ejector nozzle, water is injected into the high velocity flow. The velocity of the steam or air breaks the water into small droplets. The flue gas and ejector fluid mixture then passes through a subsonic nozzle in which additional water spray is injected. Finally, the gas passes into an expansion section where free jet mixing takes place, aiding in further particulate agglomeration and capture. The primary advantage is improved capture efficiency compared with conventional venturi scrubbers and lower total energy requirements. Disadvantages include the potential need for on-site steam supply. (John Zink product literature, 1992).

A.4.2 *Performance*

To obtain a high collection efficiency, the flue gas throat velocity must be maintained at a specified level. Approaches that can be used to adjust for varying flue gas flow conditions include:

- Variable throat geometries with adjustable throat inserts.
- Adjustable butterfly valve in the throat region.
- Adjustment of the elbow area in the throat section.
  (Most scrubbers have a "flooded elbow" which helps collect entrained droplets before exiting the venturi.)

The liquid surface tension and liquid turbidity also are important to capture efficiency. If the surface tension is too high, small particles will "bounce" off the water droplets. High surface tension also has an adverse effect on droplet formation. High liquid turbidity will cause erosion and abrasion of the venturi section.

High pressure differential VS achieve higher particle removal, however, capture of submicron particles is still relatively inefficient. High pressure differential venturi scrubbers, also known as high energy scrubbers (HESs), are often equipped with a variable throat for tuning the capture performance and minimizing pressure drop. The high pressure differential is costly in terms of electrical power requirements and is impractical for larger units.

Efficiency of a scrubber is affected by the following:

- Inadequate scrubber liquid feed due to erosion and corrosion of the scrubber liquid transport system.
- Erosion of the venturi wall dimensions.
- Erratic pressure drops due to changes in the gas flow rate.
- Scaling of internal parts.
- High temperatures resulting in atomized scrubber liquid droplets evaporation.

A.4.3 *Process Monitoring*

The essential parameters which should be monitored for optimum venturi scrubber performance include:

- Scrubber blowdown frequency
- Scrubber water suspended solids
- Liquid pH
- Gas inlet temperatures
- Pressure drop across the venturi
- Gas flow rate
- Liquid feed rate
- Liquid/gas ratio

The scrubber operation is monitored by liquid spray rate, gas flow rate, liquid pH, scrubber blowdown rate and inlet gas temperature. The pressure drop is a good indication of system performance (particle capture efficiency). The pressure drop is usually controlled with a variable venturi throat. A pH monitor is used to measure the scrubber liquid pH in order to control the amount of caustic material added to the scrubber sump. A low scrubber liquor pH will cause corrosion, while a high pH will cause scaling. Ionizing scrubbers require additional monitoring of the voltage and current to assure proper operation.

A.4.4 *Inspection and Maintenance*

Maintenance concerns include prevention of corrosion and scaling on all scrubber internal surfaces, excessive dust build-up, nozzle damage (abrasion/erosion), plugging and fluid leakage. However, because the venturi is self cleaning, it has high resistance to fouling. Visual inspection is usually required for the throat, nozzles and liquid pump. VSs are often applied to hazardous waste incinerator facilities since they are easily operated and integrated with acid gas control technologies. A more detailed discussion of the inspection and maintenance of all types of wet scrubbers in included in Section A.5.4 of this appendix.

A.5 Wet Scrubbers

Wet scrubbers appear in a variety of configurations with widely variable efficiencies for controlling particulate emissions. Wet scrubbers are used for the simultaneous removal of soluble gaseous pollutants and particulates. The majority of hazardous waste incinerators use packed bed scrubbers, plate tower scrubbers and venturi scrubbers for air pollution control[4]. The advantages of wet scrubbers include high acid gas removal efficiencies coupled with high collection efficiencies on fine particulates. The following sections describe wet scrubber design principles, performance, process monitoring, and the necessary inspection and maintenance activities.

A.5.1 *Design Principles*

Wet scrubbers remove particles from the gas by capturing the particles in liquid droplets and separating the droplets from the gas stream. The liquid injected to capture the pollutants can be water or a solution. This solution is often referred to as scrubbing liquor or scrubbing slurry. The majority of operating scrubbers use lime or limestone as the scrubbing solution because of its wide availability and low cost. Sodium-based scrubbing solutions are also used, but to a lesser extent. This section will focus on lime slurry injection type wet scrubbers which have been proven effective in the removal of particulate, HCl, SO_2, dioxin, and volatile metals.[5]

A.5.1.1 *Scrubber Designs*

There are a number of scrubber designs currently used in the hazardous waste burning community. This section of Appendix A contains a description of the wet limestone scrubber, tray tower, packed tower, flux force/condensation/collisions scrubbers, free jet scrubbers, and ionized wet scrubbers.

A popular wet limestone scrubber design is the spray tower (shown schematically in Figure A.5.1.1-1). A spray tower is a wet scrubbing device that directs the atomized scrubbing liquid (usually water or a dilute solution of an alkaline agent in water) into a chamber where the

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[4] Bonner, T. et al., *Hazardous Waste Incineration Engineering*, Noyes Data Corporation, 1981, p. 135.

[5] Buonicore, Anthony J., Davis, Wayne T., *Air Pollution Engineering Manual*, Air & Waste Management Association, Van Nostrand Reinhold, New York, 1992, p. 293.

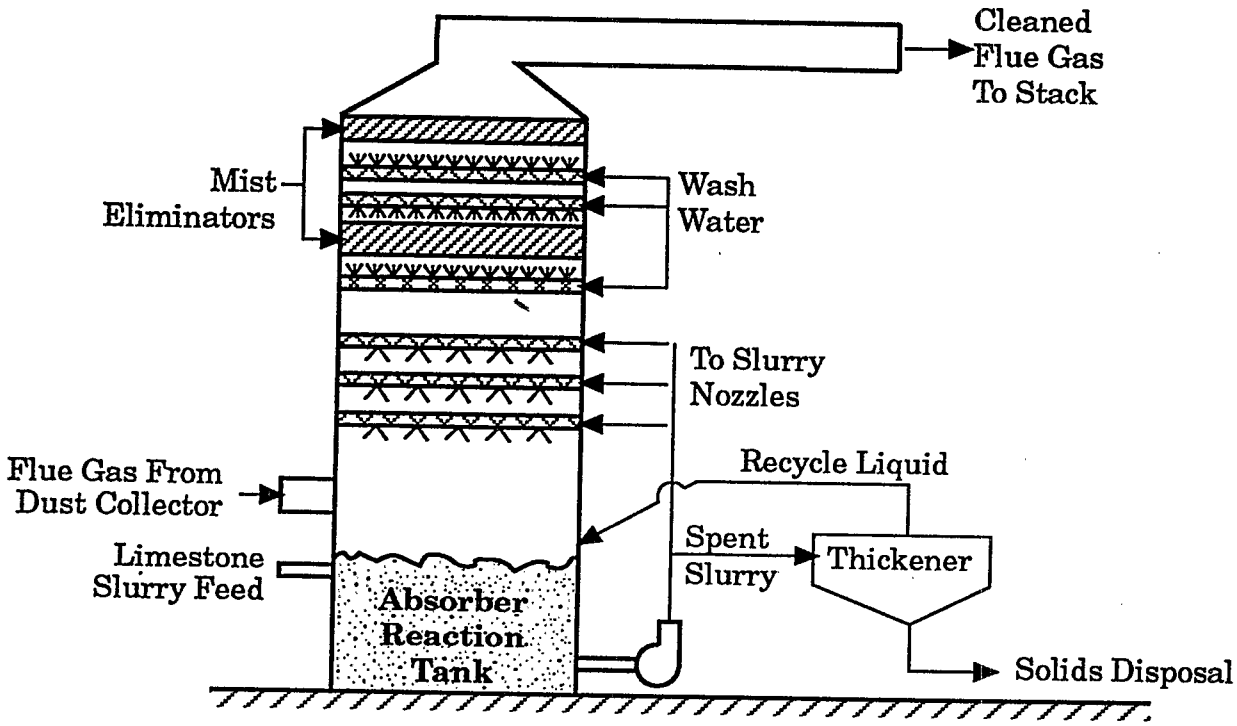


Figure A.5.1.1-1. Schematic of wet scrubbing spray tower system.

contaminated gases are flowing in a countercurrent, concurrent, or crossflow direction. This system will remove principally gaseous plus some particulate pollutants.

After the flue gas passes through the ESP or baghouse, it enters the scrubber horizontally just above the scrubber solution level. The flue gas travels up through the spray nozzles, where it contacts the scrubbing slurry. The acid gas in the flue gas is absorbed into the scrubbing solution and forms a disposable sludge. The cleaned gas passes through the mist eliminators and travels to the stack.

Another scrubber design is the tray tower scrubber, which is similar in design to the spray tower. The flue gas enters at the base and passes upward through the holes in a perforated plate mounted across the scrubber. Scrubbing slurry is sprayed onto the top of the tray from above. The slurry on the tray becomes a froth due to the gas passing through it, providing very good contact of the flue gas with the slurry. The main disadvantage of tray tower scrubbers is that they cannot handle load variations (flue gas flow variations). At low flue gas flow rates, the slurry will drop through the sieve (weeping), while at too high of a flow rate, the slurry mixture is blown out of the scrubber. Additionally, the tray holes are prone to plugging, and the scrubber must be shut down and cleaned periodically.

Packed tower scrubbers incorporate a bed of packing material (normally small glass balls) mounted across the scrubber vessel. The flue gas enters at the base of the tower and flows up through the packing against the slurry flow which is introduced at the top of the scrubber. The packing slows the flue gas down and provides increased surface area for the gas to contact the slurry, resulting in high removal efficiencies.

Ionizing wet scrubbers (IWS) combine the principles of electrostatic particle charging, inertial impaction, and gas absorption to simultaneously collect submicron particles, liquid droplets, and acid gases. The IWS consists of two sections: a high voltage ionization section and a packed scrubber section. The gas stream passes through the ionization section where the particles are electrostatically charged. The charged particles then enter the packed bed section where particles are removed by attraction to neutral surfaces (collection plates) and impaction on the packed bed materials. A water or caustic recirculating stream continuously washes the packed bed to remove collected particles and acid gases. Because the IWS is a fractional removal device, particle removal efficiency can be increased by employing multiple units in series. IWS advantages

include increased collection efficiency compared to typical venturi type scrubbers and low pressure drops. (Ceilcot Product Literature).

A.5.1.2 *Reagent Preparation and Injection Equipment*

The scrubber slurry side of the process starts with the fresh scrubber slurry being pumped into the scrubber. The portion of the scrubber that contains the slurry solution is often referred to as the reaction tank. Next, the scrubbing slurry is pumped from the bottom of the tank to the slurry nozzles located approximately two-thirds of the way up the tower. The nozzles spray down against the flue gas flow. The scrubbing solution reacts with the flue gas and most of the particles fall back into the reaction tank, but some of the slurry (the smaller particles) can become entrained in the flue gas flow and travel up toward the mist eliminators. The mist eliminators serve to trap most of the particles entrained in the flue gas, and they are then washed down to the reaction tank by wash water spray.

Not all of the slurry pumped from the bottom of the reaction tank is sent to the slurry nozzles. A small percent is removed as waste and is made up for by the fresh slurry feed. The spent slurry is diverted to a thickener or hydroclone which removes moisture. The dewatered slurry is disposed of, and the excess moisture is recycled back into the reaction tank and is also used as mist eliminator wash water.

Limestone and lime-based scrubbing slurries are by far the most commonly used scrubbing reagents. The main advantages of using lime or limestone include:

1. The process is simple and has few process steps.
2. Capital and operating costs are low and limestone is abundant.
3. SO_2 removal efficiency can be as high as 95%.

The main disadvantages of lime and limestone based scrubbing systems include:

1. Large quantities of waste must be disposed of in an acceptable manner.
2. Limestone systems have a tendency for scaling, plugging and erosion.
3. Large slurry flows are needed, resulting in large pumps with high electrical consumption.

In addition to lime and limestone scrubbing slurries, dual alkali systems are also in use which utilize a mix of sodium carbonate ($NaCO_3$) and lime or limestone. The main drawback of the dual alkali process is that scaling (deposits of calcium solids on the scrubber surfaces) is minimized. The main disadvantage is that sodium may leak out of the system with the waste and potentially contaminate the area.

Typically, wet limestone and lime scrubbers employ on-site wet grinding (slaking for lime) for slurry preparation. Figure A.5.1.2-1 shows a typical limestone reagent preparation system. The raw limestone with a diameter of approximately 1 inch is fed through a weigh belt feeder to a ball mill.

Water is added at the feed chute of the mill. From the mill, the limestone is sent to a classifier which separates the coarse limestone from the fine limestone. The classifier sends the fine limestone to the limestone feed tank to be made into scrubber slurry. The coarse limestone is sent back to the mill for more grinding. Grinds ranging from coarse (70% of the limestone passing through a 200 mesh sieve) to fine (95% passes through a 325 mesh sieve). The finer the grind, the better the reduction will be, but the energy consumption for fine grinding is high.

The spray nozzles used to control the slurry mixing with the flue gas typically operate between 5 and 20 psi and have corkscrew tips. The nozzles produce many droplets of approximately 2,500 to 4,000 microns in diameter. The SO_2 reduction chemistry occurs on the droplet surfaces, so the smaller the droplets, the greater the amount of surface area that is available for reaction, improving SO_2 removal efficiency. However, to decrease the droplet size, nozzles with smaller openings are required. The pressure required to push the slurry through smaller nozzles is high, and smaller nozzles tend to plug.

A.5.1.3 *Mist Eliminators*

Mist eliminators are used on wet scrubbers to collect slurry droplets entrained in the scrubbed flue gas stream and return them to the scrubbing liquor at the bottom of the scrubber. Mist eliminators are located at the exit to the scrubber as shown earlier in Figure A.5.1.1-1. Most of the droplets leave the flue gas flow due to gravity, but the small droplets can be carried out with the gas. If these droplets are not removed from the gas before it exits the scrubber, it can deposit on the ductwork, the induced draft fan, and the walls of the stack. This may lead to pluggage and corrosion.

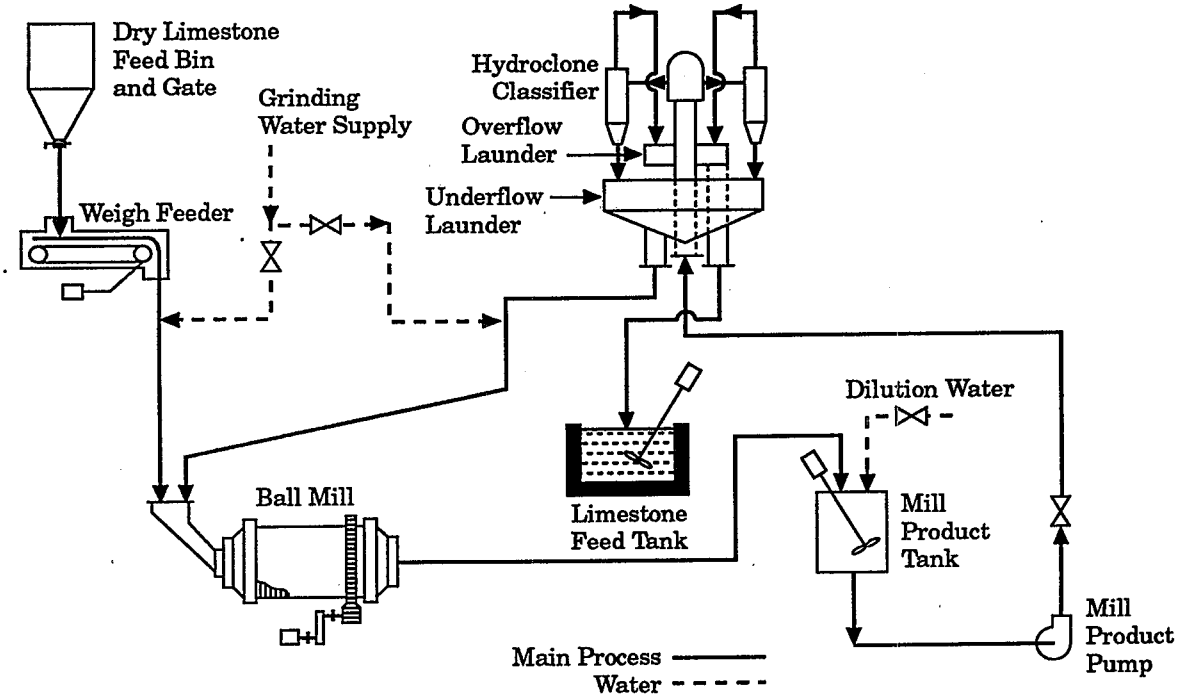


Figure A.5.1.2-1. Limestone reagent preparation system.

Most mist eliminators are of the impingement type — the small liquid droplets impact a collection plate, coalesce and fall by gravity back into the scrubbing liquor. The mist eliminators are sprayed with wash water to remove accumulated solids. The wash water is generally a mixture of fresh water and clear water from the slurry dewatering system.

A.5.1.4 *Waste Treatment and Disposal*

There are several types of waste treatment and disposal methods currently in use. The earliest method of waste disposal was simply to discharge the spent wet slurry to a settling pond. However, site availability and pond management costs have limited ponding in recent years. The most popular disposal approach in practice in the U.S. today is to perform two separate stages of dewatering and then sending the filter cake to a landfill.

The first stage of dewatering (primary dewatering) can use thickeners or hydroclones. After the primary dewatering, the sludge is between 20% and 30% solids. Secondary dewatering is accomplished with vacuum filters, or centrifuges. Vacuum drum filters make up 80% of the secondary dewatering equipment population. Normally, before the dried sludge goes to a landfill, the sulfites must be mixed with flash and lime. Since gypsum needs no further treatment before it can be landfilled or sold to wallboard manufacturers, some scrubbers employ forced oxidation equipment in the reaction tank to convert the calcium sulfite hemihydrate to gypsum.

A.5.2 *Performance*

To achieve optimum performance, several design and operating parameters must be considered including:

- Concentration and pH of limestone in scrubbing slurry;
- Scrubbing slurry flow rate compared to gas flow rate;
- Uniform distribution of the scrubbing slurry; and
- Uniform distribution of the flue gas.

The amount of limestone in the slurry controls the amount of calcium ion available to react with the bisulfite ion. The chemical equations show that, theoretically, 1 molecule of limestone is required to remove 1 SO_2 molecule. However, due to practical limitations on how well the limestone and flue gas can mix, up to 1.2 molecules of limestone are typically used for every molecule of SO_2.

To achieve very good contacting of limestone to acid gases, one might consider increasing the concentration of limestone in the scrubber solution. However, if too much limestone is added, the pH of the solution will rise (the solution will become less acidic). The acid gas removal reactions work most efficiently at pH levels below approximately 6.3. Therefore, the amount of limestone added must be high enough to allow contacting with the acid gases, but not so high as to raise the pH above 6.3. Figure A.5.2-1 shows the effect of scrubber solution pH on SO_2 removal.

In addition to limestone concentration in the scrubbing solution and scrubbing solution pH, the slurry solution flow rate also determines what level of acid gas reduction can be achieved. The slurry flow rate is related to the flue gas flow rate and is referred to as the liquid to gas ratio (l/g). In general, the higher the liquid to gas ratio, the better the acid gas removal efficiency will be. Typical limestone scrubbers operate at liquid to gas ratios of approximately 30 gallons of slurry for every 1000 cubic feet of flue gas. Since the flue gas flow rate varies with load, so must the slurry flow rate if the design liquid to gas ratio is maintained. Figure A.5.2-2 demonstrates how the liquid to gas ratio (at a constant pH) impacts the SO_2 removal efficiency. As may be seen, liquid to gas ratios above 30 gallons per 1000 cubic feet of flue gas do not significantly impact SO_2 reduction efficiency.

Even if the concentration of limestone, the pH, and the liquid-to-gas ratio are optimum, good acid gas removal efficiencies will not be achieved unless the scrubbing slurry is sprayed evenly into the flue gas. To mix the slurry with the flue gas as rapidly and evenly as possible, it is best to have many small nozzles distributed across the scrubber cross section. If only one or two nozzles are used, pockets of flue gas can escape the scrubber without being treated. Unfortunately, small nozzles have a tendency to plug, so the final design must be a compromise between many small nozzles that evenly distribute the scrubbing slurry but have a tendency to plug and a few large nozzles that do not evenly distribute the slurry but will not plug.

Finally, the flue gas flow should be evenly distributed across the scrubber. For example, if most of the flue gas goes up the right side of the scrubber and the scrubbing solution is evenly sprayed across the scrubber, there will not be enough scrubbing solution to react with all the acid gas on the right side, causing poor acid gas reduction. The flue gas inlet duct at the bottom of the scrubber is designed to promote even distribution of the flue gas across the scrubber cross section. In some cases, perforated plates are used to help distribute the flow, but these cause the pressure drop across the scrubber to increase and results in a higher electricity consumption by the fan.

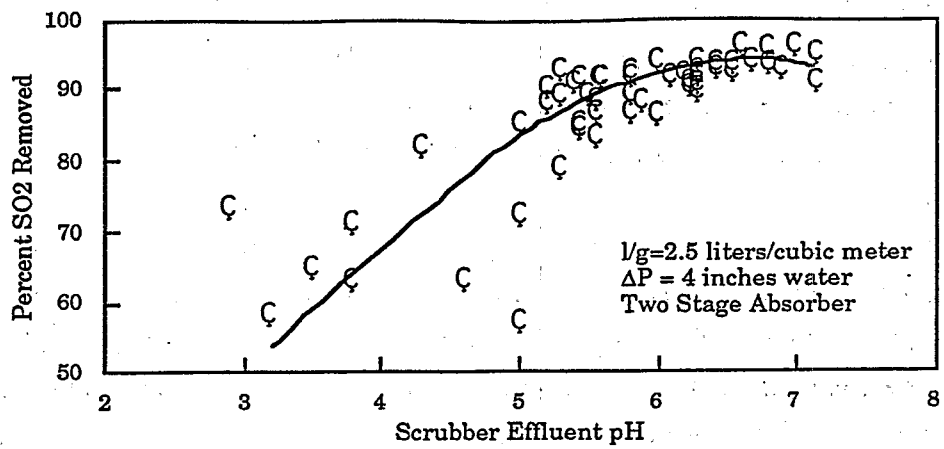


Figure A.5.2-1. Impact of slurry pH (acidity) on SO_2 removal efficiency.

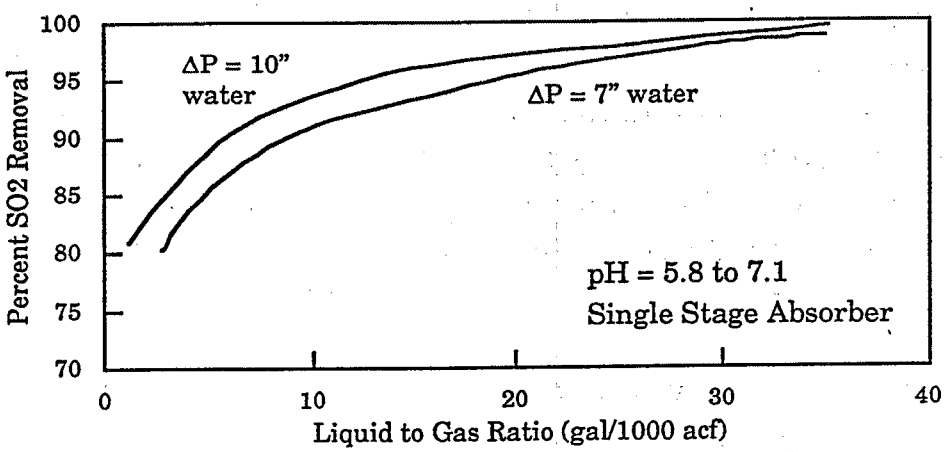


Figure A.5.2-2. Impact of liquid to gas ratio on SO_2 removal efficiency[6].

6 Elliott, Thomas C., *Standard Handbook of Powerplant Engineering*, McGraw-Hill Publishing Co., 1989.

A.5.3 *Process Monitoring*

For the reasons previously stated, wet scrubber operation is monitored by the following key parameters:

- Pressure drop across the scrubber;
- Concentration and pH of scrubbing slurry;
- Liquid-to-gas ratio via gas flow rate and slurry flow rate;
- Accumulation of solids within the scrubber;
- Induced draft fan power consumption;
- Reagent preparation system operation;
- Inlet and outlet gas temperatures;
- Dewatering process

A.5.4 *Inspection and Maintenance*

No matter how well the scrubber has been designed, it will only work as well as the operation system allows it to. Operators must constantly monitor and control the system to ensure proper performance. For example, when load changes occur, the scrubber operator needs to reset the limestone feed rate and use the pH monitor as a backup. In addition to good operation and communication, a preventive maintenance program specified by the manufacturer should be implemented. Table A.5.4-1 is an example checklist list.

Visual inspection of the scrubber section and tanks should be performed on a regular basis to identify leaks, scaling, corrosion and erosion problems. Visual inspection can allow identification of small problems before damage becomes so extensive that major repair is required.

Mist eliminators tend to be subject to buildup of slurry solids and chemical scale, causing the passages to restrict the flow of the flue gas. The first sign of scale buildup is typically noticed by an increase in pressure drop across the scrubber. Water washing is typically sufficient to prevent serious buildup problems.

Because the scrubber control system is based on flue gas and scrubber flow rates, the operating staff should routinely monitor and record readings from all instruments used to measure these flows. If any of the readings appear abnormal, they should be investigated. To verify liquid

TABLE A.5.4-1. WET SCRUBBER INSPECTION CHECKLIST

Equipment	Action	Frequency
Scrubber Module	Visually inspect for scale & corrosion	Annually
Agitators	Inspect for corrosion and erosion Check bearings and seals.	Annually
Mist Eliminators	Check for scale	Based on history
Wash Water Nozzles	Monitor pressure	Once per shift
Dampers, Fans, Ducts	Inspect for corrosion and erosion	Annually
Limestone Mill	Inspect visually, lubricate	Each usage
Slurry pump	Check lining, bearings and seals	Annually
Slurry pipes	Check for deposits and wear	Annually
Valves	Test functionality, leakage, packing	Annually
Thickener	Check coating for corrosion Check moving parts for wear Lubricate motor	Annually Annually Frequently
Instrumentation	Flush slurry lines Calibrate	Daily Once per shift

flow rates or evaluate pump/nozzle erosion, the operator should monitor pressure in the slurry header and the recirculation pump discharge. An increase in the pressure usually indicates plugging of nozzles. A decrease can indicate wear of the nozzles or pump impellers. Slurry flow in pipes can be checked by touching the pipe. If it is cold at the normal operating temperature, then the line is plugged.

The slurry feed requirement is usually controlled by the pH indicator. The sensor lines where pH measurement elements are used should be frequently backflushed and calibrated with buffer solutions to ensure reliable operation.

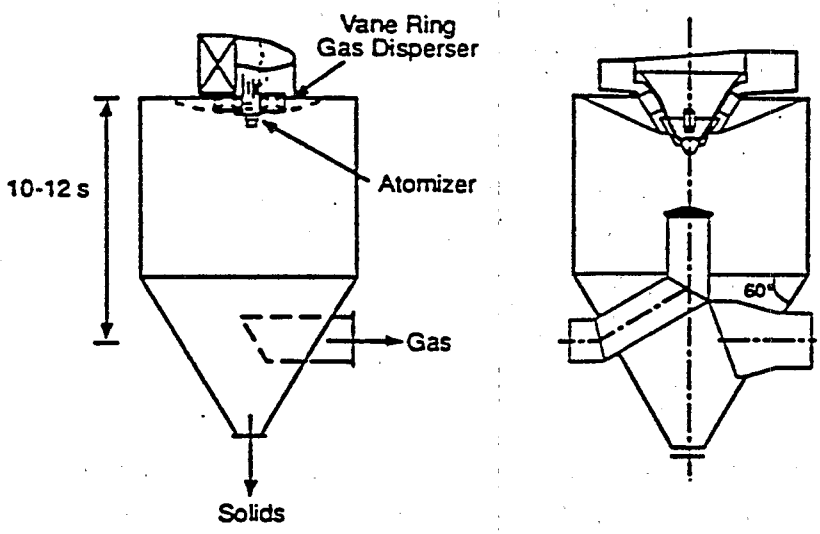
A.6 Spray Dryers

In some respects, the spray dryer system represents a less complicated control system than wet scrubbers. This is because no mist eliminator is required, the number of pumps and amount of piping are greatly reduced, and the waste material is in the form of dry particulates, which eliminates the need to treat liquid scrubber wastes and significantly reduces the waste volume.

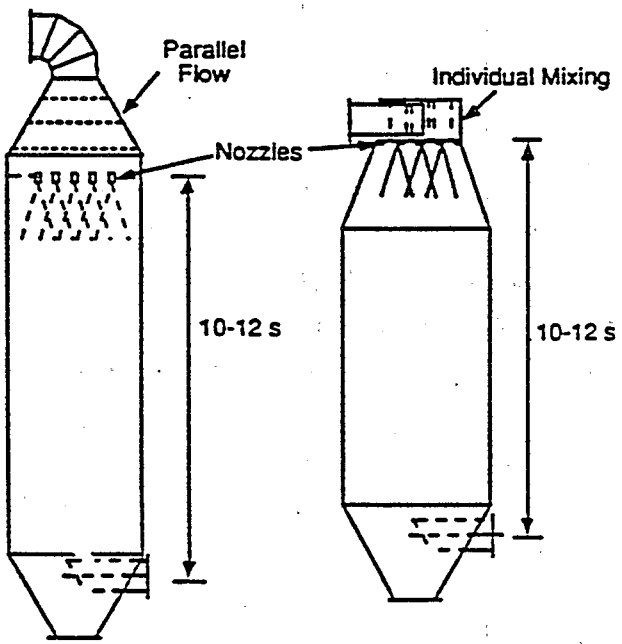
A.6.1 *Design Principles*

For spray dryers, also known as wet/dry scrubbers, hot flue gas enters the top of the dryer (scrubber) vessel where it is intimately mixed and cooled with a finely atomized lime slurry spray. Figure A.6.1-1 illustrates several spray dryer arrangements. The moisture is completely evaporated, leaving the solids as suspended particulates. Mixing occurs in a turbulent flow field. The quenched and chemically conditioned flue gas then flows to a fabric filter and/or an electrostatic precipitator. The major equipment found in a typical spray dryer scrubbing system includes the spray dryer absorber, the particulate-collection system, reagent and slurry preparation and handling equipment, solids transfer, and process control and instrumentation. In spray dryer systems, the particulate collector is downstream and is considered an integral part of the system.

The spray dryer absorber provides the initial contact between the atomized reactive alkali and the acid-gas contaminants. There are two types of atomizers illustrated in Figure A.6.1-1: rotatory disks (or wheels) and dual-fluid pneumatic nozzles. In each case, the slurry is atomized as droplets into the dryer, reacts with the acid gases, and dries to a fine powder which is then carried over into the ESP or fabric filter and removed. The particulate collector also serves as an additional contact point between the dried reactants and acid gases, providing additional removal. Some



A. Rotary-Atomizer Dryers



B. Two-Fluid Pneumatic Nozzle Dryers

Figure A.6.1-1. Spray dryer designs. [10]

spray dryer systems operate with partial recycling of the particulates by mixing the captured particulates with the fresh lime in either slurry or dry form before being reinjected into the associated scrubber.

The chosen atomization method affects the design of the spray dryer absorber vessel, including the physical dimensions. For a rotary-atomizer type of spray dryer, which projects the droplets radially outward and perpendicular to the gas flow, the length-to-diameter ratio of the dryer (L/D) is typically 0.8 to 1. The droplets decelerate rapidly owing to the drag forces of the downward-moving flue gas and eventually attain the speed and direction of the flue gas. To avoid wall deposition, the designed radial distance between the atomizer and the dryer wall must be sufficient to allow for adequate drying of the largest droplets. In a dual-fluid pneumatic nozzle type of spray dryer, which atomizes the droplets in the direction of the gas flow (downward), the L/D is typically 2:1. In this design, the sidewall deposition is a minor problem. For either design, optimum spray dryer performance is achieved through proper choice of the L/D, droplet size, and residence time. The designed residence time for most spray dryers is 10-12 seconds, however few systems operate at 100% of the design flow rate. Thus, actual residence time for most systems is 12-15 seconds. Spray dryers range from 25 to 50 feet in diameters.

A.6.2 *Performance*

The application of a spray dryer results in: a flue-gas temperature of 150-170 °F; approximately 20% less gas flow through the particulate-matter collector due to lower gas temperatures; a particle size distribution with a mean diameter of 20-30 μm; and a significantly increased dust loading. The increased particle size distribution and decreased flow rate are beneficial, but the decreased temperature and increased dust loading tend to increase pressure drops across fabric filters and to decrease efficiency across ESPs. The increased dust loading caused by the reacted products ranges from as little as 1.5 gr/acf at 500 ppm of SO_2 to as high as 14 gr/acf at 3000 ppm of reacted products.[7] Therefore, increased dust loading must be taken into account in the design of the particulate-matter collector and the associated dust-handling support system.

A.6.3 *Process Monitoring*

The following process monitoring parameters are the same as those for wet scrubber applications, with the exception of waste treatment system.

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[7] *Air Pollution Engineering Manual, p. 238.*

- Pressure drop across the scrubber.
- Concentration and pH of scrubbing slurry.
- Liquid-to-gas ratio via gas flow rate and slurry flow rate.
- Accumulation of solids within the scrubber.
- Induced draft fan power consumption.
- Reagent preparation system operation.
- Inlet and outlet gas temperatures.

Most operational problems associated with spray dryers are due to low temperatures at the exit of the dryer. When the gas approaches the water dew point, acid condensation may result in the downstream equipment. Therefore, the flue gas exit temperature is a critical process monitoring parameter.

A.6.4 *Inspection and Maintenance*

Spray dryer inspection and maintenance is very similar to that required by wet scrubbers. Operators must constantly monitor and control the system to ensure proper performance. For example, when load changes occur, the scrubber operator needs to reset the limestone feed rate and use the pH monitor as a backup. In addition to good operation and communication, a preventive maintenance program specified by the manufacturer should be implemented which is similar to the wet scrubber activities summarized in Table A.5.4-1.

Visual inspection of the scrubber section and tanks should be performed on a regular basis to identify leaks, scaling, corrosion and erosion problems. Visual inspection can allow identification of small problems before damage becomes so extensive that major repair is required.

Because the scrubber control system is based on flue gas and scrubber flow rates, the operating staff should routinely monitor and record readings from all instruments used to measure these flows. If any of the readings appear abnormal, they should be investigated. To verify liquid flow rates or evaluate pump/nozzle erosion, the operator should monitor pressure in the slurry header and the recirculation pump discharge. An increase in the pressure usually indicates plugging of nozzles. A decrease can indicate wear of the nozzles or pump impellers. Slurry flow in pipes can be checked by touching the pipe. If it is cold at the normal operating temperature, then the line is plugged.

The slurry feed requirement is usually controlled by the pH indicator. The sensor lines where pH measurement elements are used should be frequently backflushed and calibrated with buffer solutions to ensure reliable operation.

A.7 Flue Gas Conditioning Techniques

APCD performance may be enhanced by conditioning the flue gas upstream of the APCDs. The term conditioning includes cooling, humidification, and reagent injection, all of which will be described in the following paragraphs.

A.7.1 *Flue Gas Cooling*

The objectives of flue gas cooling are to:

- Protect low-temperature APC equipment.
- Condense vaporized pollutants such as volatile toxic metals.
- Prevent the formation of certain classes of organics due to fly ash catalyzed reactions. By cooling the flue gas rapidly, the formation of dioxins and furans can be reduced.[8]

Flue gas cooling is required prior to particle removal in low temperature devices such as baghouses, cold ESPs, and wet scrubbers. There are four methods for cooling the flue gas leaving the incinerator:

- Air dilution;
- Heat exchanger;
- Water quench; and
- Radiation and convection duct cooling.

Radiation and convection cooling utilizes heat transfer from the flue gas flow in a long uninsulated duct. This is the simplest method in principle. However, this method is not considered for further review due to large space requirements, particle sedimentation in the duct, and the lack of the ability for precise temperature control during flue gas temperature and flow

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8 Gullett, B.K., Lemieux, P.M., Kilgroe, J.D., and Dunn, J.E., "Formation and Prevention of Polychlorinated Dibenzo-p-Dioxin and Poly chlorinated Dibenzofuran During Waste Combustion : The Role of Combustion and Sorbent Parameters".

fluctuations. The three other methods are reliable and proven technologies which have excellent track records for use with waste incinerators.

A.7.1.1 *Air Dilution*

The air dilution cooling method, shown in Figure A.7.1.1-1, is a simple procedure. Air dilution cooling is performed by injecting cool air directly into the hot flue gas stream. The amount of dilution air required is dependent on the initial temperature of the flue gas and the amount of temperature reduction desired, as shown in Figure A.7.1.1-2. The resulting mix of the two gas streams produces a stream at an intermediate temperature. Air is usually injected tangentially into the axially flowing flue gas stream. Special air mixing jets may be used so that thorough mixing of the two streams is obtained within a relatively short distance.

Performance

The use of air dilution as a cooling method has certain drawbacks, including:

- Air dilution creates a substantial increase in the total flue gas volume flow rate. This additional flow requires downstream pollution control equipment to be considerably larger.

- The control of both flue gas temperature and velocity is not possible. Downstream devices which are affected by velocity (e.g., pressure drop and efficiency for filters and venturi scrubbers) may be adversely affected by changes in quench air requirements to maintain a target flue gas temperature.

- There is potential for the intake of ambient moisture and dust if the dilution air is not preconditioned. This may cause problems in the downstream equipment and may introduce additional pollutants into the flue gas.

Because of these limitations, air dilution cooling is not generally used as the only means of gas cooling; however, it is often used to make small changes in flue gas temperature, such as pre-cooling of the flue gas upstream of a heat exchanger to protect the heat exchanger tubes from high temperature degradation.

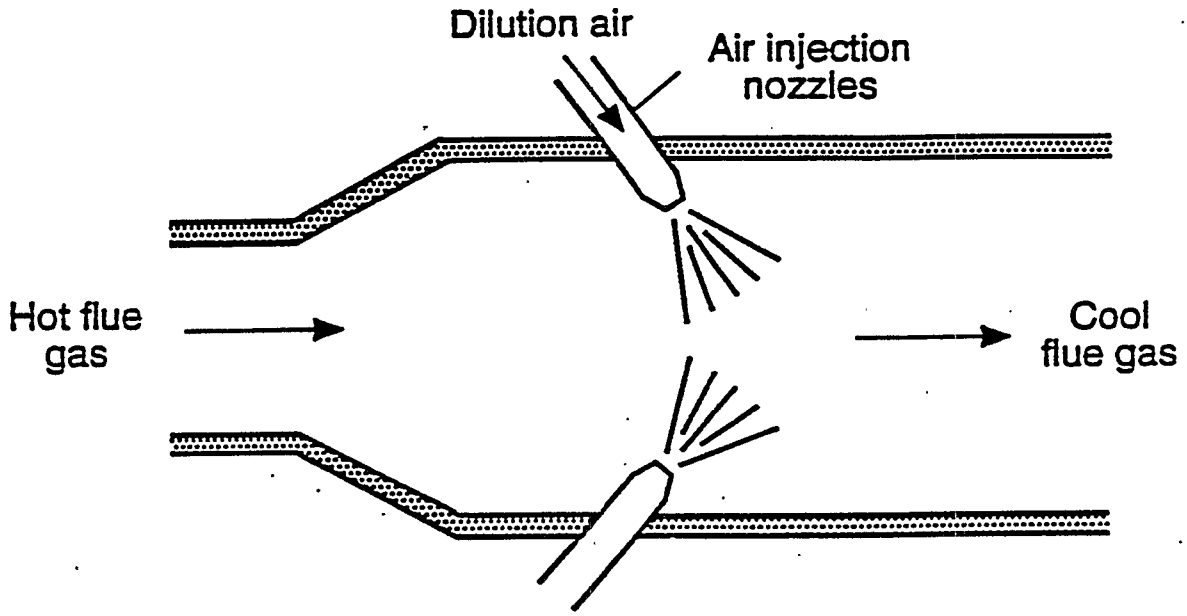
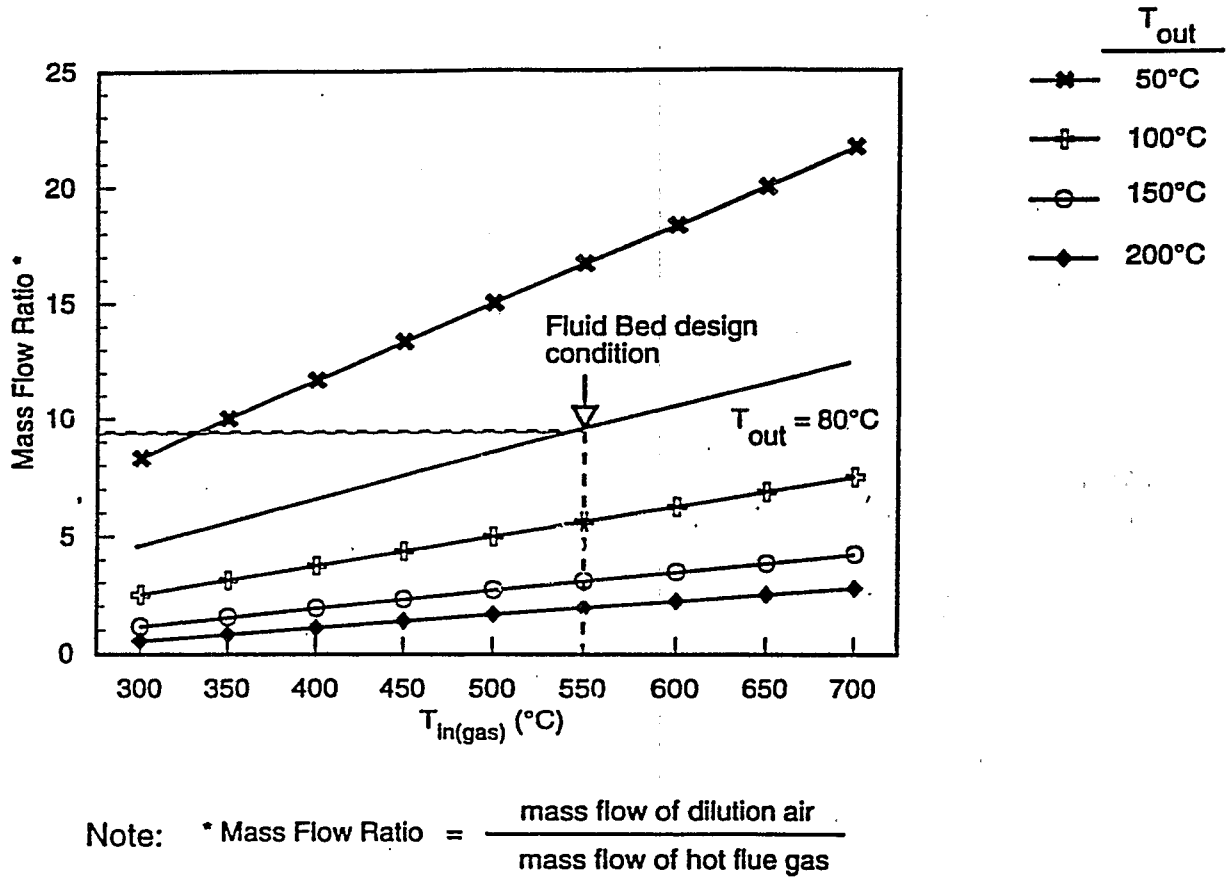


Figure A.7.1.1.-1. Air dilution cooling procedure.



Note: * Mass Flow Ratio = $\frac{\text{mass flow of dilution air}}{\text{mass flow of hot flue gas}}$

Figure A.7.1.1-2. Example of the increase in flue gas flow rate using air dilution cooling.

Monitorability — The outlet gas temperature and blower flow rate are easily monitored by thermocouple and flowmeter, respectively, to assure proper operation.

Failure Modes — Possible failure modes of the air dilution system under normal conditions include:

- Exceeding the capacity of the blower, causing the exiting flue gas stream to be too hot.
- The blower flow rate cannot be turned down sufficiently to provide minimum air flow, causing the flue gas stream to be too cold.

The air dilution cooling system has the following failure modes under upset conditions:

- Loss of air flow due to loss of power to the air blower, resulting in system failure.
- Increased flue gas flow rate or temperature, resulting in an inability to provide sufficient dilution cooling air, causing a possible system failure due to the flue gas temperature levels.

A.7.1.2 *Heat Exchanger*

Heat exchangers can also be used for cooling of the hot flue gas stream. Note that boilers (which are a type of heat exchanger) are not treated in this review because the low incinerator temperature makes the use of a boiler impractical. In a heat exchanger, heat is transferred from the flue gas through a common wall to a cooling fluid. The heat is transferred through a combination of convective and conductive processes. A wide variety of heat exchangers are commercially available, including gas-to-gas and gas-to-liquid types, as shown schematically in Figure A.7.1.2-1. In a gas-to-gas heat exchanger, the cooling fluid is typically air (e.g., a recuperator used to preheat combustion air). In a gas-to-liquid heat exchanger, the cooling fluid is a liquid, typically water. The liquid is usually contained in a closed circuit, and liquid cooling is often provided by ambient air blowing.

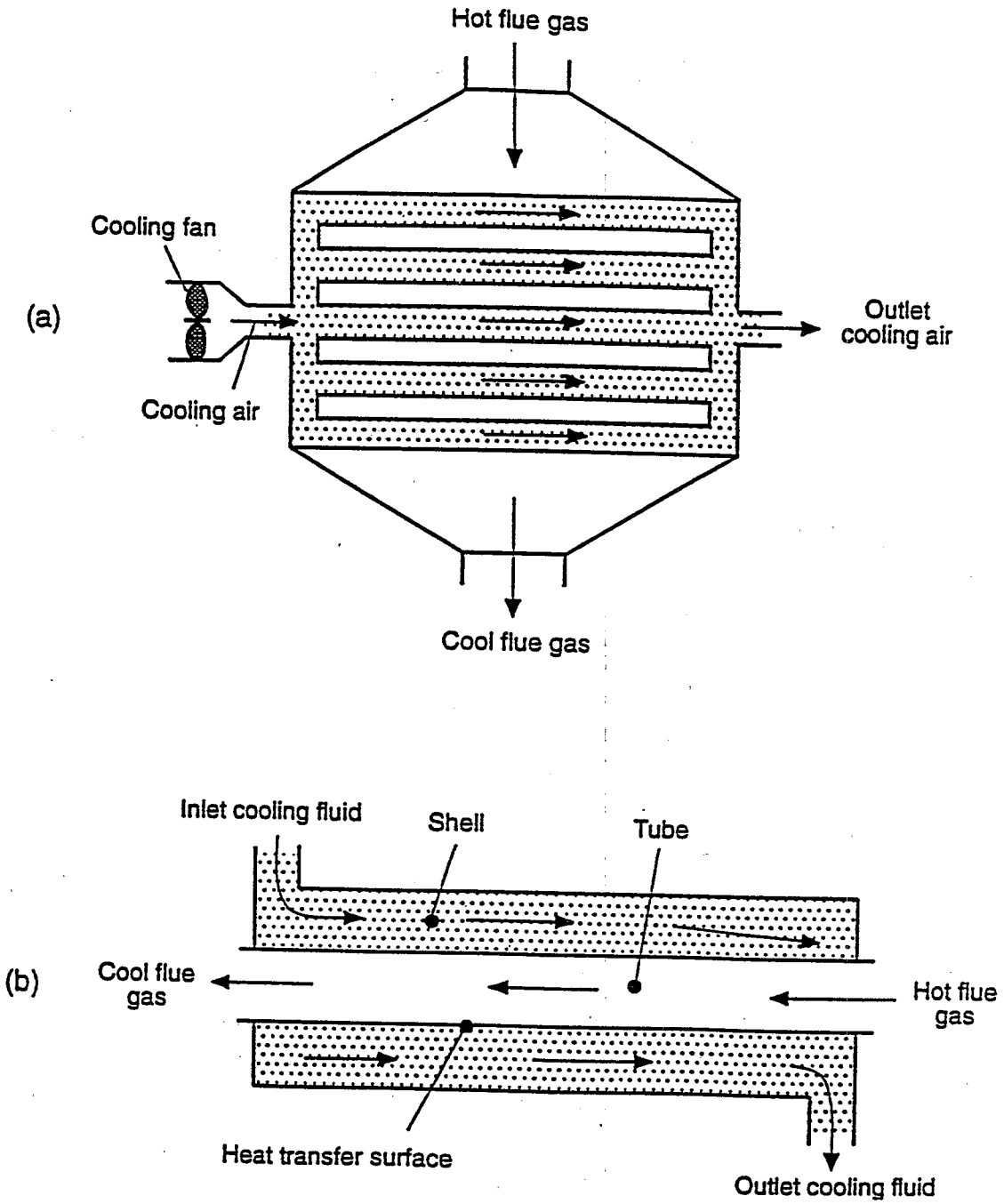


Figure A.7.1.2-1. Heat exchanger schematics (a) Gas-gas recuperator (b) Shell and tube type

Performance

Unlike air dilution, and due to the cooling fluid and hot flue gas streams being separated, the volume of the flue gas remains the same. Therefore, it is not necessary to increase the size of flue gas cleaning equipment. The heat exchanger cooling capacity is limited by the heat transfer rate, which is determined by the cooling fluid flow rate, the inlet temperature, and the thickness of deposits on the cooling surface.

Liquid heat exchangers are more efficient than gas-to-gas heat exchangers due to their increased capacity to remove heat. However, as mentioned earlier, they have increased complexity since they typically utilize a closed loop cooling fluid. Liquid heat exchanges also have an increased tendency to promote the condensation of acid gases and subsequent corrosion of common walls.

Maintenance

If the hot flue gas contains significant amounts of particles, the heat exchanger tubes will require frequent cleaning. This problem can be mitigated by the use of a high temperature particle removal device upstream of the heat exchanger or by the use of soot blowers to keep the tubes clean. Other maintenance procedures include service of the pumps and blowers.

Monitorability

The outlet gas temperature and coolant flow rate are easily monitored by thermocouple and flowmeter, respectively. The temperature of the cooling fluid is also monitored to assure proper operation, especially if the system has one pass.

Failure Modes

Heat exchangers are subject to the following failures under normal conditions:

- Tube corrosion from condensation of flue gas components (chlorine, sulfur, metals).
- Mechanical failure due to thermal expansion of different exchanger parts at different rates.
- Particle deposits collecting on tubes act as an insulator and impair the heat transfer efficiency (tube fouling).

- Hot-side tube blockage from soot and flash deposits.

- Tube erosion in heavily dust laden gas streams.

Heat exchangers have the following failure modes under upset conditions:

- Loss of coolant from fire, explosion, power outage, system leak, or mechanical failure of the pump, resulting in a system failure. For heat exchangers using liquid cooling, however, loss of coolant will not cause an immediate rise in temperature due to the remaining thermal inertia of liquid coolant. Additionally, liquid heat exchangers can avoid the immediate effects of a power or pump failure by the use of an elevated supply tank to provide the head necessary to push the fluid through the system.

- Increased flue gas flow rate and temperature, resulting in an inability to provide sufficient cooling liquid, causing a possible system failure due to the flue gas temperature levels.

A.7.1.3 *Quench*

In a water-quench cooler, as shown in Figure A.7.1.3-1, the hot flue gas is cooled by injection of water into the gas stream. The gas temperature is reduced as the water spray evaporates. The quench is performed in a cooling vessel. Hot gases enter the vessel and are decelerated so that water droplet evaporation occurs completely within the vessel. To ensure evaporation, the water spray must be atomized into small droplets in sufficient quantities to maintain a constant outlet gas temperature. The amount of injected water must be controlled in response to fluctuations in the flue gas temperature. Because it is difficult for the water nozzles to maintain a small droplet size over a wide range of flow rates, nozzles that are used have either variable flow areas or utilize two-phase flow (high pressure air or steam can atomize water over a wide range of flow rates). Rotary nozzles can also be used to maintain a uniform distribution of water droplets over a wide range of flows.

A water quench is almost always used upstream of a gas scrubber when the inlet flue gas temperature is above the saturation point. In this situation, to ensure that the temperature is

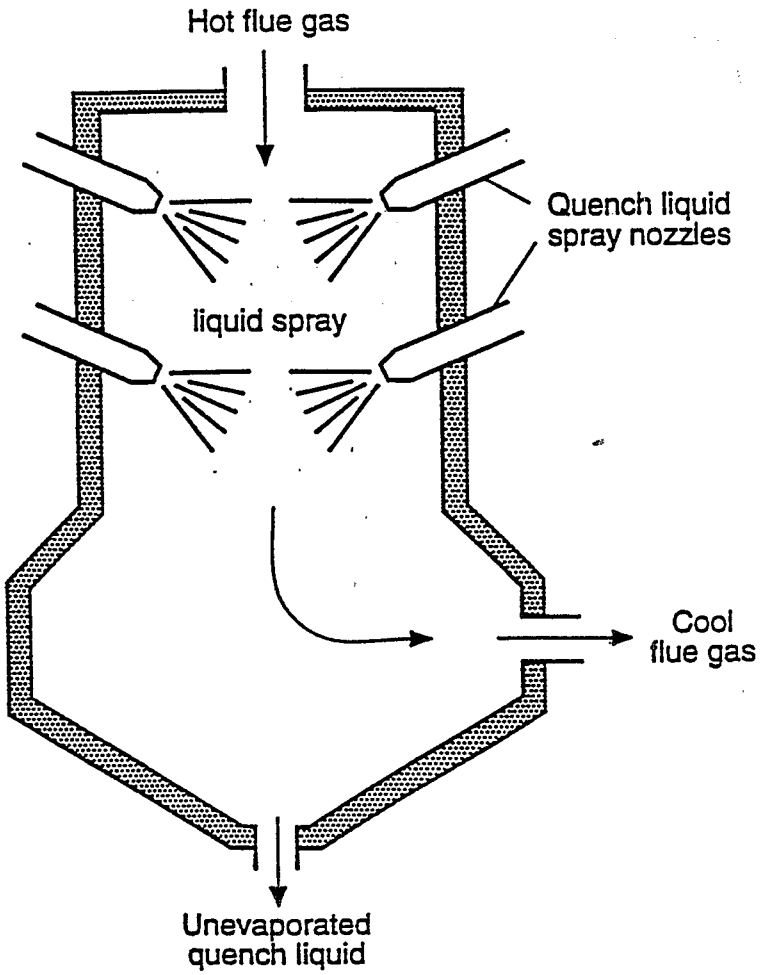


Figure A.7.1.3-1. Water quench cooling procedure.

lowered to its saturation temperature (which is required by the scrubber for effective scrubbing efficiency), a surplus of water is introduced. Because droplets and particles will tend to migrate to the cooler wall, an inside film of water is often used to wash collected particles from the walls. This water is drained from bottom of the cooling vessel and discarded or recycled. The amount of water required to cool the flue gas is shown in Figure A.7.1.3-2.

However, when a water quench is used prior to a baghouse, it is critical that the gas temperature remain above the saturation level and that all the water droplets completely evaporate. Otherwise, corrosion and plugging problems may occur in these devices from condensed moisture and other gases. Complete evaporation is assured by fine atomization and large gas residence times in the cooler vessel.

Performance

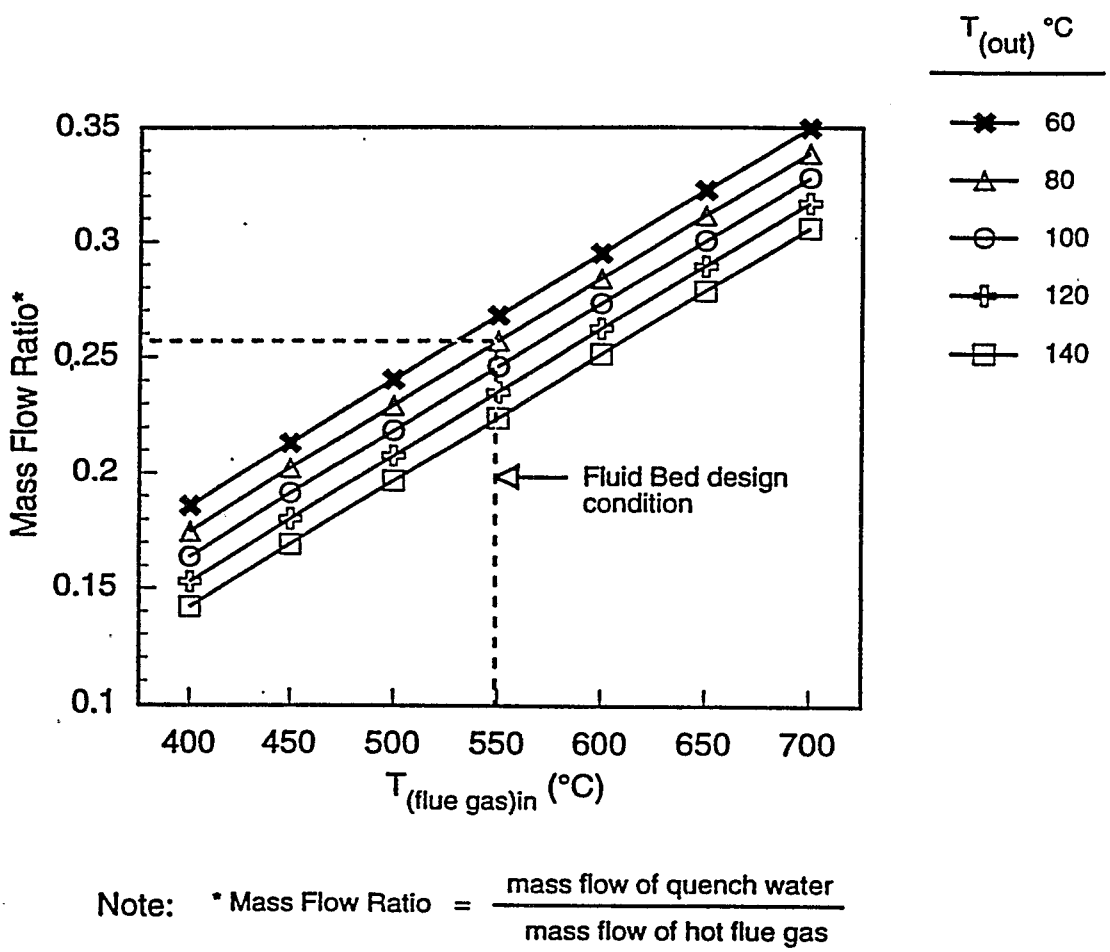
When excess moisture in the flue gas is undesirable, the most important consideration is that the injected droplets have a uniformly small size range. Large unevaporated droplets may exit the cooling vessel before they have time to completely evaporate. These droplets may cause problems with downstream equipment and may create a non-uniform temperature distribution in the flue gas. Also, droplets may migrate to the vessel wall, reducing the cooling potential of the device.

Water quench is used often as a cooling method because it has the following characteristics:

- Provides the quickest temperature control of the three cooling methods.
- Potential for capturing acid gases and particles if reagents are injected with the water.
- Low maintenance requirements.

The use of water cooling does create some problems, however, including:

- It has an increased chance of a visible steam plume.
- It has difficulty in accommodating low flow rates and variations in moisture feed.



Note: * Mass Flow Ratio = $\frac{\text{mass flow of quench water}}{\text{mass flow of hot flue gas}}$

Figure A.7.1.3-2. Example of increase in flue gas flow rate using water quench cooling.

Secondary Wastes — Quench has the potential to produce a secondary liquid waste stream when the liquid spray is not fully evaporated.

Monitorability — Quench operation is indicated by monitoring the outlet gas temperature, water flow rate, and nozzle pressure. The outlet gas temperature is easily monitored by thermocouple. Water flow and nozzle pressure are also easily monitored.

Maintenance — Maintenance requirements include checking (and occasionally replacing) spray nozzles for corrosion and pluggage, and inspecting the water pump system.

Failure Modes — Possible failure modes of the water quench system under normal conditions include:

- Plugged spray nozzles, especially if a dry reagent is used for acid gas control.
- Corrosion of spray nozzles. This becomes more of a problem if the spray liquor is collected and recycled and/or if acid gases are present in the flue gas.

Water quench cooling has the following failure modes under upset conditions:

- Loss of quench water from fire, explosion, power outage, system leak, or mechanical failure of the pump, resulting in system failure.
- Increased flue gas flow rate and temperature result in an inability to provide sufficient quench liquid, causing a possible system failure due to flue gas temperature levels.

The lowest temperature which can be achieved by quenching/evaporative cooling is determined by the flue gas dew point. Due to localized temperature variations, the target APCD inlet temperature is usually 350°F. The amount of water required to achieve this depends on the flue gas flow rate and temperature.

The simplest approach is to inject water using a high pressure air carrier. This represents a low dollar cost approach to cooling the exhaust gas. However, if very high dust loading exists, the possibility for agglomeration and formation of "mud" may also exist and this approach may not be feasible. It is anticipated that this approach may be implemented at a cost on the order of $50,000. The second approach is to install an advanced humidification system, potentially requiring significant duct work modification upstream of the APCD with multiple location temperature feedback control. In the absence of a detailed engineering analysis, a budgetary estimate for this system is $500,000. Depending on the application, a quench system cost will likely range between $50,000 and $500,000.

A.8 Activated Carbon

Recent work has focused on the capture of mercury and dioxins and furans from combustion source flue gases with the use of activated carbon. Activated carbon has been shown to enhance the removal of these species. Various mechanisms have been suggested for the capture of these species on activated carbon; these include physical adsorption in the pores of the carbon, catalytic oxidation to mercury oxides, and/or chemically mediated adsorption based on the presence of oxygen and/or chlorine. The presence of chlorine has been demonstrated to augment capture efficiency.[9]

Activated carbon has a very large inner pore surface (large surface to volume ratio), which can adsorptively bond a very broad range of substances. Typical activated carbon has a surface area of from 300-800 m^2/g; high grade carbon can have surface area of 1500 m^2/g.[10] Additionally, it posses catalytic properties that can be used for simultaneous NO_x control if required. Two types of activated carbon are commonly used: formation coke (based on coal) and lignite coke. Lignite coke is more common due to its low cost. In some attempts, impregnation agents have been added to the activated carbon to enhance its control efficiency. Note that activated carbon capture of mercury is sometimes considered as an additional benefit to its 99+%

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9 Felsvang, K., Gleiser. R., Juip, G., and Nielsen, K., "Activated Carbon Injection in Spry Dryer/ESP/FF for Mercury and Toxics Control", Trace Elements Transformation in Coal-Fired Power Systems Workshop, Scottsdale, AZ, April 19-21, 1993.

10 Dalton, D., Gillins, R., Harris, T., and Wollerman, A., "An Assessment of Off-Gas Treatment Technologies for Application to Thermal Treatment of Department of Energy Wastes", DOE/MWIP-1, September, 1992.

demonstrated control of organics, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) in particular.[11]

Activated carbon can be used in a couple of different arrangements for the control of mercury and organics in combustion system flue gases. These include:

- Fixed bed process -- In the fixed bed process, flue gas flows through one or more beds of activated carbon arranged in a series; spent activated carbon is withdrawn from the bottom of each bed segment. Carbon monoxide levels are continuously monitored across bed to minimize risk of fire. To prevent plugging and contamination, the bed is usually placed after a flue gas particulate control device. Although capture performance tends to increase at lower temperatures, the gas should not be below saturation temperature to avoid condensation of moisture in bed. Activated carbon tends to lose its adsorption capacity when it gets contaminated with moisture.[12]

- Fluidized bed process -- In the fluidized bed process, flue gas is used to fluidized a bed containing activated carbon. The fluidized bed arrangement consumes less coke compared to the fixed bed, however, has a higher pressure drop. Circulating beds have also been used, and have demonstrated very high mercury and dioxin removal.

- Duct injection -- In the duct injection process, activated carbon is injected into the flue gas upstream of a particulate control device, typically a fabric filter or ESP. Because of the corona discharge phenomena of an ESP and combustible nature of activated carbon, an ESP is not considered the best choice for activated carbon collection from carbon injection system. Additionally, a fabric filter provides for extended hold-up of the injected activated carbon in the flue gas, allowing for additional mercury removal compared to an ESP; for the same level of control, a higher activated carbon feed rate may be required for ESPs compared to fabric

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11 Blumbach, J., and Nethe, L., "Sorbalit - A New Economic Approach Reduction Mercury and Dioxin Emissions", Proceedings of 85th Annual Air and Waste Management Association (AWMA) meeting, Kansas City, Missouri, June, 1992, 92-41.09.

12 Frillici, P., Li, R., Bacon, G., and Hayes, D., "Evaluation of Mercury Emission Reduction Alternative for the Fort Dix Resource Recovery Facility", Proceedings of the 86th Annual AWMA meeting, Denver, Colorado, June, 1993, 93-RP-154.03.

filters. However, relatively no difference between capture using ESP and fabric filter has been demonstrated.[13] In some versions, a cyclone reactor is used to improve the mixing of the flue gas and the activated carbon before it passes to the particulate control device. Activated carbon may also be injected upstream of a rotary atomizer, similar in design to conventional spray drying units. The activated carbon may be injected either by itself as a powder or in a dry or wet solution in combination with an acid gas removing sorbent such as lime, calcium hydroxide, or sodium sulfide. The duct injection process consumes the least activated carbon of the three methods, typically from 50-400 mg/m^3 of flue gas for municipal waste combustors.

Potential effects on the duct injection activated carbon effectiveness have been investigated, including:

- Activated carbon type -- Coal-based, lignite-based, and wood-based activated carbon all perform at similar levels.[14]

- Activated carbon feedrate -- Removal rate increases with increasing activated carbon feedrate.

- Injection location for duct injection process -- No noticeable difference in performance when activated carbon was injected either downstream of the municipal waste combustor economizer, at spray drier outlet, or along with lime used for the spray dryer.[15]

- Temperature -- Removal efficiency has been shown to increase at temperatures.

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13 Felsvang.

14 White, D., et al., "Parametric Evaluation of Powdered Activated Carbon Injection of Control of Mercury Emissions form a Municipal Waste Combustor", Proceedings of 85th Annual AWMA meeting, Kansas, Missouri, June, 1992, 92-40.06.

15 Ibid.

below 425 °F.[16] However, there may be a tradeoff; other research has shown that at higher temperature, the bond between the mercury and the activated carbon is stronger compared to the bonding occurring at lower temperature.

Potential drawbacks to the use of activated carbon include:

- Secondary waste volume -- Activated carbon adds to the total amount (mass and volume) of secondary waste for disposal.

- Secondary waste treatment -- The byproduct residue (activated carbon and fly ash capture in the air pollution control device or the spent activated carbon in a fixed bed) may require some type of post-treatment (i.e., stabilization, metals removal, etc.). The primary concern is to avoid re-releasing capture metals and organics.

Current treatment ideas include a wash process to remove metals, followed by destruction in the primary combustion source, or vitrifying the activated carbon and fly ash into a glass substance. Recent studies have shown that post-treatment may not be necessary.[17] Captured activated carbon and fly ash were stored for 3 years in different arrangements: open container, plastic bag, solidified by water addition, and stored in open container at elevated temperature (50 °C). No significant revolatilzation of mercury was seen in any of the situations during the three year period. Additionally, leaching studies performed on by-product ash gave results that were typically below EPA levels. However, the oxygen deficient methane rich environment of a landfill may enhance the desorption of previously captured mercury.

- Fire hazards -- Use of combustible substances like activated carbon requires consideration due to risk of fire and explosion. When present with oxygen, activated carbon may self-ignite at temperatures as low as 200 °C.[18]

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16 Christiansen, O., and Brown,'B., "Control of Heavy Metals and Dioxins from Hazardous Waste Incinerators by Spry Dryer Absorption Systems and Activated Carbon Injection", Proceedings of 85th Annual AWMA meeting, Kansas City, Missouri, June, 1992, 92-41.09.

17 Felsvang.

18 Dalton.

A.9 Other Technologies

The Rotorfilter was developed by Kurt Jonsson, an Icelandic mechanical engineer. The device has been used in Iceland since the early 1970s to control pollution from municipal incinerators and cement kilns. Two Rotorfilter units recently purchased by Our Lady of Lourdes Memorial Hospital in Binghamton, N.Y., reduce particulates to 0.0067 grain per dry standard cubic foot. In the typical Rotorfilter configuration, incineration flue gas enters the unit through its inlet plenum. The gas passes through two rotors, each made up of five counter-rotating wheels and driven by a separate electrical motor. The wheels project V-shaped airfoil-type spokes that generate vacuum and centrifugal forces when they are in rotation. This will mechanically remove pollutants from the flue gas stream by the centrifugal force of rotation, which will funnel them into the cape, or walls, of the Rotorfilter. The leading edge of the spoke causes the molecular particles of pollutants to conglomerate into large particles, which facilitate their removal along with the solid particulates. Although the Rotorfilter is not tested specifically for dioxin control, it could reduce the gaseous pollutant by conglomeration, as it does sulfur oxides, carbon dioxide, and nitrogen oxides.[19]

A.10 Combined Technologies

The technologies discussed thus far may be applied individually to various hazardous waste incinerators. However, in practice, some incinerators use these devices in a serial "treatment train" to control more than one pollutant. These air pollution control systems (APCS) are designed to achieve high acid gas removal efficiency and low particulate emission rate. As an illustration of systems using a combination of devices, this section presents two case studies of hazardous waste incinerators which use multiple air pollution control devices in series. The presentation of these systems should not be interpreted as recommendations, requirements, or endorsements by the EPA.

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19 Valenti, Michael, "Tougher Standards for Burning Hazardous Waste", *Mechanical Engineering*, Vol. 115 / No. 8, August, 1993, p. 69.

A.10.1 *Aptus, Inc.*

Aptus, Inc. currently operates a slagging rotary kiln hazardous waste incinerator at its Coffeyville, Kansas facility. The information presented in this section was obtained from the December, 1991 "Trial Burn Report" for this facility and from the "Particulate, Metals and HCl Emissions Testing Report."

The slagging rotary kiln has a diameter of 9.8 feet and a length of 32.8 feet. The afterburner chamber has a 13-foot diameter and a height of 35 feet. This incinerator system is designed for a heat input of 61.9 million Btu/hr. The primary fuel is waste oil which is fired in both the kiln and afterburner chamber.

The kiln operates at a temperature of approximately 1,800 °F to 2,100 °F. Combustion of the wastes in the kiln produce off-gases which flow into the afterburner chamber where additional fuel and liquid wastes may be introduced to maintain the temperature above the minimum of 2,012 °F and a normal operating temperature of 2,200 °F. The residence time within the afterburner is over 2 seconds. Combustion gases exit the afterburner chamber, pass by an emergency relief vent into the hot duct, and then go into the air pollution control equipment.

The air pollution control system consists of a spray dryer, a baghouse, a spray saturator, cross-flow wet absorber, a cross-flow scrubber, and two ionizing wet scrubbers (as shown in Figure A.10.1-1). An induced draft fan is employed to draw the exhaust gases through the pollution control equipment. The treated gas is then vented to the atmosphere through the top of a 110-foot stack.

Spray Dryer

Flue gas exiting the afterburner passes through a spray dryer chamber where it is cooled to approximately 450 °F. The functions of the spray dryer are to reduce the flue gas temperature to allow proper functioning of the downstream baghouse, provide acid gas control, and condense and agglomerate the metals and particulate in the combustion gases. These functions are accomplished by injecting a soda ash acid neutralizing solution (Brine Solution #1). The cooling occurs as the water in the solution evaporates. The decrease in temperature causes materials in the flue gas to condense and agglomerate. The soda ash forms a dry powder along with any salts created by the reaction of the acid gases. These solids are partially removed by falling to the bottom of the spray dryer. The remaining solids travel with the flue gas to the baghouse.

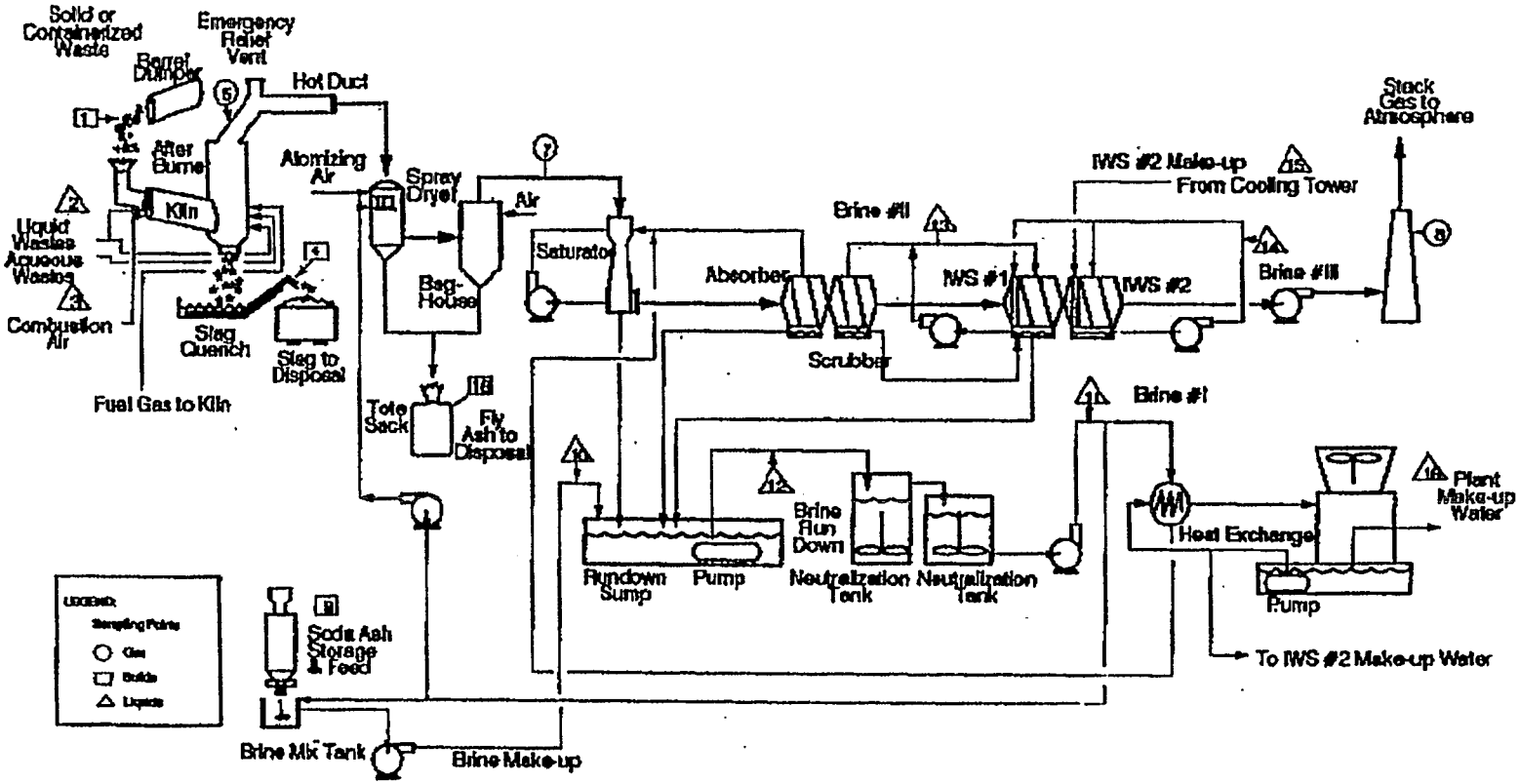

Figure A.10.1-1. APTUS incineration system in Coffeyville, Kansas.

There are three brine solutions/systems designed so that there is no net discharge of liquid from the incinerator system. Brine Solution #1 is composed of soda ash, and the discharges from the saturator, the absorber and the second ionizing wet scrubber (IWS #2). This blended solution is neutralized and then pumped to the spray dryer and recirculated to the saturator and the absorber. Brine Solution #2 is circulated from the bottom of IWS #1 to the liquid inlet of both the IWS #1 and the scrubber. Brine Solution #3 is circulated from the bottom of the IWS #2 to its charged pack bed. A slip stream from this recirculation line is fed to IWS #1. Any make-up water that is feed to these brine systems is evaporated with small amounts of water emitted in the flue gas exiting the stack.

Baghouse

From the spray dryer, the flue gas travels to the baghouse for removal of particulate. The baghouse is a four-chambered unit with vertically mounted filter sacks in each chamber. The filter cake that develops is removed via pulse jet air, which causes the solids to fall to the bottom of each chamber. These solids are combined with the solids from the spray dryer and then disposed. In addition to particulate control, the fabric filter also acts as a reactor to aid in acid-gas absorption. Acid gases in the flue gas are absorbed by alkaline material in the filter cake on the bags.

Saturator

Next, the flue gas passes through a saturator where it is cooled to a saturation temperature of approximately 170 °F by the injection of Brine Solution #1. Materials in the gaseous phase at the inlet of the saturator are condensed at the outlet, which enables the liquid and solids formed to be removed by the absorber and scrubber downstream.

Cross-flow Absorber

Saturated gases exiting the saturator enter the absorber. In the absorber, most of the halogen content and some more of the solids are removed by the Brine Solution #1 contacting the gas stream as it passes through the bed packing. The absorber is arranged for crossflow of gases and liquids.

Cross-flow Scrubber

Next, the gases enter the cross-flow wet scrubber. Wet scrubbers are used for the simultaneous removal of soluble gaseous pollutants and particulates. Wet scrubbers have been proven effective in the removal of particulate, HCl, SO_2, dioxin, and volatile metals. Like the absorber, the brine solution contacts the flue gases on the brine wetted packed bed.

Ionizing Wet Scrubbers

The ionizing wet scrubbers remove acid gas aerosols and fine particulates less than 10 microns in size. Each IWS is arranged for cross-flow of the gases through the charging zone, which is wetted with Brine Solution #3. The charged droplets and particulates enter the packed/charged scrubber section. The final exhaust gas treatment occurs in IWS #2 where trace amounts of contaminants are removed prior to the discharge to the atmosphere.

A.10.2 *Waste Technologies Industries (WTI)*

WTI operates a hazardous waste incineration system at its facility in East Liverpool, Ohio. The information presented in this section was extracted from the draft of the "WTI Phase II Risk Assessment Project Plan", EPA Contract No. 68-W9-0040, dated November, 1993. This system is designed to treat liquid, solid and sludge type wastes. The WTI incineration system consists of waste feed mechanisms, a rotary kiln, a secondary combustion chamber or afterburner, a heat recovery boiler, a spray dryer, activated carbon injection, an ESP, a flue gas quench, and a pack bed scrubber as shown in Figure A.10.2-1.

The rotary kiln is 15 feet in diameter and 43 feet long and rotates at approximately 5 to 7 revolutions per hour. Wastes enter the rotary kiln and are oxidized at the internal kiln temperature of approximately 2,400 °F. Gases from the kiln exit the kiln and enter to the secondary combustion chamber. The secondary combustion chamber achieves burnout of flue gas and fly ash by maintaining an elevated temperature which ranges from 1,800 °F to 2,200 °F. Before leaving the secondary combustion chamber, recycled flue gas is introduced to lower the temperature of the gas stream to 1,400 °F. This lower temperature causes some entrained particles to fall out and be removed from the gas stream.

Next, the flue gas is further cooled to approximately 700 °F as it passes through the heat recovery boiler. The heat absorbed by the boiler is used to generate steam for plant use. From the

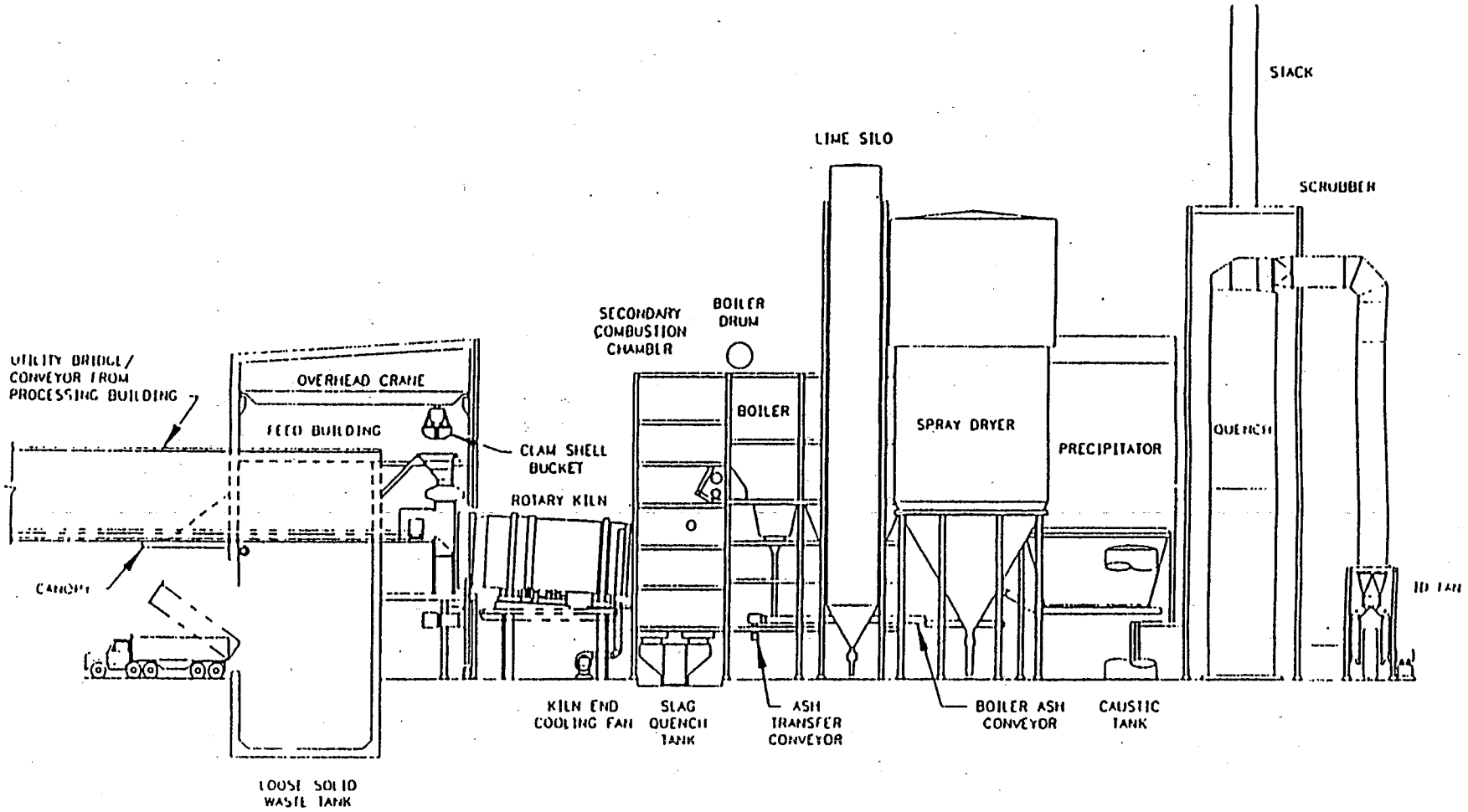

Figure A.10.2-1. WTI Incineration System in East Liverpool, Ohio.

boiler, the flue gas enters the spray dryer. The spray dryer rapidly cools flue gases to approximately 320 °F using a spray of scrubber water. The scrubber water spray removes acid gases and particulates.

Downstream of the spray dryer, dry, powdered, activated carbon is introduced into the system through two injection points. The carbon removes residual organic compounds in the flue gas through adsorption. Immediately downstream of the injection points is the ESP.

The ESP is sized for a the gas flow rate of approximately 72,000 standard cubic feet per minute at the stack exit. The ESP removes up to 99% of the solids from the flue gas stream. The flue gas then passes through the quench, which lowers the temperature from 320 °F to approximately 170 °F. The gas leaves the quench saturated with water and is then drawn into the wet scrubber.

The wet scrubber consists of four stages which are designed to remove acid gases (HCl, Cl_2, SO_2) and residual particulates from the gas stream. Stages within the scrubber system consists of two packed bed sections, a venturi stage section, and mist eliminators which dissolve gas in water, absorb hydrogen halides in packed beds, neutralize acids with sodium hydroxide, and remove particulates and aerosols from the gas stream.

The flue gas is pulled through the APCS via the induced draft (ID) fan. At the exit of the ID fan is a plume suppression reheater where hot air is added to the flue gas stream to suppress the visible plume so that the opacity can be measured by the continuous monitor.[20] All the gas is exhausted through the 150-feet tall stack at an exit temperature of approximately 190 °F.

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20 "Final Trial Burn Report for the Rotary Kiln Incinerator", May, 1993, Document Number 7136-001-800, p. 2-4.

APPENDIX B:

DETAILED SUMMARY OF CURRENT PM DATA SET FOR CEMENT KILNS

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @ 7% O2	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Chanute, KS	1	Apr-92	y	w	1	ESP	10.8	422	31.96	468	0.03750	4	0.0609	0.04808	0.0375	0.00967
Ash Grove Cement Co.	Chanute, KS			y		2	ESP	10.4	439	30.19	669	0.04790					
Ash Grove Cement Co.	Chanute, KS			y		3	ESP	10.7	435	27.58	636	0.04600					
Ash Grove Cement Co.	Chanute, KS			y		4	ESP	10.7	448	24.76	697	0.06090					
Ash Grove Cement Co.	Chanute, KS	2	Mar-92	y	w	1	ESP	9.5	484	46.43	691	0.02660	4	0.0494	0.03255	0.0219	0.01201
Ash Grove Cement Co.	Chanute, KS			y		2	ESP	10.3	412	50.55	415	0.02190					
Ash Grove Cement Co.	Chanute, KS			y		3	ESP	10.6	425	38.73	665	0.04940					
Ash Grove Cement Co.	Chanute, KS			y		4	ESP	10.8	412	48.18	753	0.03230					
Ash Grove Cement Co.	Foreman, AR	1	Jul-92	y	w	1-1	ESP	8.0	387	25.2		0.01630	11	0.049	0.02958	0.0154	0.01050
Ash Grove Cement Co.	Foreman, AR			y		1-2	ESP	8.0	360	28.4		0.03510					
Ash Grove Cement Co.	Foreman, AR			y		1-3	ESP	6.8	371	32		0.03560					
Ash Grove Cement Co.	Foreman, AR			y		1-4	ESP	7.7	356	28.5		0.03860					
Ash Grove Cement Co.	Foreman, AR			y		2-1	ESP	5.5	470	27.4	312	0.03110					
Ash Grove Cement Co.	Foreman, AR			y		2-2	ESP	5.5	487	29.4	259	0.02430					
Ash Grove Cement Co.	Foreman, AR			y		2-3	ESP	4.9	494	21.4	226	0.04900					
Ash Grove Cement Co.	Foreman, AR			y		2-4	ESP	6.4	456	22.2	195	0.03460					
Ash Grove Cement Co.	Foreman, AR			y		P1	ESP	7.1	408	37.5		0.01540					
Ash Grove Cement Co.	Foreman, AR			y		P2	ESP	7.0	405	37.2		0.01770					
Ash Grove Cement Co.	Foreman, AR			y		P3	ESP	6.0	399	37.9		0.02770					
Ash Grove Cement Co.	Foreman, AR	2	May-92	y	w	1	ESP		500	58		0.00780	2	0.0326	0.02020	0.0078	0.01754
Ash Grove Cement Co.	Foreman, AR			y		2	ESP		485	60		0.03260					
Ash Grove Cement Co.	Foreman, AR			y		3	ESP		506	58							
Ash Grove Cement Co.	Foreman, AR	2	Jul-93	y		2	ESP		371	72.1		na					
Ash Grove Cement Co.	Foreman, AR			y		3	ESP		365	71.8							
Ash Grove Cement Co.	Foreman, AR			y		4	ESP		373	70							
Ash Grove Cement Co.	Foreman, AR	3	Jul-92	y	w	2-1	ESP	5.2	475	104.5	296	0.00470	6	0.0183	0.00748	0.0043	0.00542
Ash Grove Cement Co.	Foreman, AR			y		2-2	ESP	6.0	470	107.3	540	0.00550					
Ash Grove Cement Co.	Foreman, AR			y		2-3	ESP	5.7	460	107.5	551	0.00430					
Ash Grove Cement Co.	Foreman, AR			y		2-4	ESP	6.3	512	104.1		0.01830					
Ash Grove Cement Co.	Foreman, AR			y		2-5	ESP	4.0	522	92.1		0.00750					
Ash Grove Cement Co.	Foreman, AR			y		2-6	ESP	4.0	517	94.3		0.00460					
Ash Grove Cement Co.	Louisville, NE	1	May-92	y	sd (ph/bp)	1-1	ESP	15.5	258	18.3	898	0.01600	5	0.0653	0.03658	0.016	0.02479
Ash Grove Cement Co.	Louisville, NE			y		1-2	ESP	15.2	238	20.5	933	0.02280					
Ash Grove Cement Co.	Louisville, NE			y		1-3	ESP	15.7	255	22.1	899	0.01700					
Ash Grove Cement Co.	Louisville, NE			y		1-4	ESP	15.5	243	26.3	243	0.06530					
Ash Grove Cement Co.	Louisville, NE			y		1-5	ESP	15.7	258	23.2	268	0.06180					
Ash Grove Cement Co.	Louisville, NE	2	Aug-92	y	d (ph/pc/bp)	2-1	ESP	10.5	355	54.9	211	0.02000	8	0.026	0.01859	0.0142	0.00417

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @ 7% O2	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Louisville, NE			y		2-2	ESP	9.8	355	52.7	181	0.01860					
Ash Grove Cement Co.	Louisville, NE			y		2-3	ESP	10.7	355	52.5	256	0.01420					
Ash Grove Cement Co.	Louisville, NE			y		2-4	ESP	11.1	355	54	315	0.02600					
Ash Grove Cement Co.	Louisville, NE			y		2-5	ESP	10.8	350	60.1		0.01550					
Ash Grove Cement Co.	Louisville, NE			y		2-6	ESP	11.2	350	59.7		0.01660					
Ash Grove Cement Co.	Louisville, NE			y		2-7	ESP	10.0	350	59.3		0.01490					
Ash Grove Cement Co.	Louisville, NE			y		2-8	ESP	10.7	350	58.8		0.02290					
Continental Cement Co.	Hannibal, MO	1	Jul-92	y	w	1	ESP	4.0	600	340	344	0.04030	3	0.0403	0.03737	0.03430	0.00300
Continental Cement Co.	Hannibal, MO			y		2	ESP	5.6	600	330	344	0.03750					
Continental Cement Co.	Hannibal, MO			y		3	ESP	4.4	580	350	344	0.03430					
Continental Cement Co.	Hannibal, MO	1	Dec-90	y	w	3	ESP	2.0	540		183.9	na					
Continental Cement Co.	Hannibal, MO			y		4	ESP	1.9	540		271.9						
Continental Cement Co.	Hannibal, MO			n		1	ESP	3.1	443		219.4						
Continental Cement Co.	Hannibal, MO			n		5	ESP	2.0	469		228.6						
Essroc Materials	Logansport, IN	1	Aug-92	y	w	3	ESP		496	32		0.08300	4	0.083	0.07075	0.057	0.01103
Essroc Materials	Logansport, IN			y		4	ESP		504	31.7		0.07500					
Essroc Materials	Logansport, IN			y		5	ESP		492	39.8		0.06800					
Essroc Materials	Logansport, IN			y		6	ESP		517	42.4		0.05700					
Essroc Materials	Logansport, IN			y		8	ESP	11.6	606	44.7	186						
Essroc Materials	Logansport, IN			y		9	ESP	12.6	605	34.2	56						
Essroc Materials	Logansport, IN			y		10	ESP	11.9	607	40.5	70						
Essroc Materials	Logansport, IN			y		11	ESP	12.3	614	39.1	79						
Essroc Materials	Dorado, PR	1	Jun-93	y	d (ph/pc/bp)	3-1	FF	6.0		--		0.02310	3	0.0682	0.04877	0.02310	0.02319
Essroc Materials	Dorado, PR			y		3-2	FF	4.5		--		0.05500					
Essroc Materials	Dorado, PR			y		3-3	FF	4.0		--		0.06820					
Giant Cement Co.	Harleyville, SC	4	Aug-92	y	w	1	FF	10.1	553	--		0.01050	3	0.0155	0.01300	0.01050	0.00250
Giant Cement Co.	Harleyville, SC			y		3	FF	10.4	553	--		0.01300					
Giant Cement Co.	Harleyville, SC			y		4	FF	10.2	553	--		0.01550					
Giant Cement Co.	Harleyville, SC	5	Aug-92	y	w	1	FF	10.5	549	--		0.01080	3	0.0152	0.01133	0.00800	0.00363
Giant Cement Co.	Harleyville, SC			y		2	FF	10.2	549	--		0.00800					
Giant Cement Co.	Harleyville, SC			y		3	FF	10.4	549	--		0.01520					
Heartland Cement Co.	Independence, KS	1	Oct-92	y	d	1-1	FF	14.3	440	--		0.02480	6	0.0425	0.02660	0.019	0.00815
Heartland Cement Co.	Independence, KS			y		1-2	FF	14.4	440	--		0.02160					
Heartland Cement Co.	Independence, KS			y		1-3	FF	13.9	440	--		0.01960					
Heartland Cement Co.	Independence, KS			y		2-1	FF	14.5	440	--		0.02580					
Heartland Cement Co.	Independence, KS			y		2-2	FF	14.3	440	--		0.02530					
Heartland Cement Co.	Independence, KS			y		2-3	FF	14.4	440	--		0.04250					

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @ 7% O2	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Holnam, Inc.	Artesia, MS	1	Aug-93	y	w	2	ESP	8.4	470	140	273	0.01360	3	0.0173	0.01380	0.01500	0.00340
Holnam, Inc.	Artesia, MS			y		4	ESP	7.4	530	140	270.8	0.01730					
Holnam, Inc.	Artesia, MS			y		6	ESP	8.3	522	140	290.9	0.01050					
Holnam Inc.	Clarksville, MO	1	Jul-92	y	w	1	ESP	4.4	597	707		0.03340	3	0.0352	0.03370	0.03250	0.00137
Holnam Inc.	Clarksville, MO			y		2	ESP	4.4	597	732		0.03250					
Holnam Inc.	Clarksville, MO			y		3	ESP	4.4	597	700		0.03520					
Holnam Inc.	Clarksville, MO			n		1	ESP	4.9									
Holnam Inc.	Clarksville, MO			n		2	ESP	4.3									
Holnam Inc.	Clarksville, MO			n		3	ESP	5.6									
Holnam Inc.	Holly Hill, SC	1	Aug-92	y	w	1	ESP	10.1	450	30	110	0.04460	3	0.0581	0.04967	0.04630	0.00735
Holnam Inc.	Holly Hill, SC			y		2	ESP	10.1	450	30	110	0.04630					
Holnam Inc.	Holly Hill, SC			y		3	ESP	10.1	450	30	110	0.05810					
Holnam Inc.	Holly Hill, SC			n		1	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC			n		2	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC			n		3	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC	2	Aug-92	y	w	1	ESP	7.0	563	30	150	0.02910	3	0.0291	0.02263	0.01480	0.00725
Holnam Inc.	Holly Hill, SC			y		2	ESP	7.0	563	30	150	0.02400					
Holnam Inc.	Holly Hill, SC			y		3	ESP	7.2	563	30	145	0.01480					
Holnam Inc.	Holly Hill, SC			n		1	ESP	7.0	563		145						
Holnam Inc.	Holly Hill, SC			n		2	ESP	7.0	563		145						
Keystone Cement Co.	Bath, PA	1	Aug-92	y	w	1	ESP	12.1	421	23		0.02400	10	0.0323	0.02204	0.0092	0.00664
Keystone Cement Co.	Bath, PA			y		2	ESP	13.1	422.5	22	27	0.02800					
Keystone Cement Co.	Bath, PA			y		3	ESP	11.7	418	25	26	0.02550					
Keystone Cement Co.	Bath, PA			y		4	ESP	12.3	417	23	25	0.02620					
Keystone Cement Co.	Bath, PA			y		5	ESP	12.5	416	19		0.03230					
Keystone Cement Co.	Bath, PA			y		6	ESP	11.8	410	21		0.02210					
Keystone Cement Co.	Bath, PA			y		7	ESP	11.7	415	19		0.01860					
Keystone Cement Co.	Bath, PA			y		8	ESP	11.4	403	19		0.00920					
Keystone Cement Co.	Bath, PA			y		9	ESP	11.2	393	19		0.01750					
Keystone Cement Co.	Bath, PA			y		10	ESP	11.3	407	21		0.01700					
Keystone Cement Co.	Bath, PA	2	Aug-92	y	w	1	ESP	12.3	407	56	47	0.01300	10	0.025	0.01500	0.011	0.00383
Keystone Cement Co.	Bath, PA			y		2	ESP	11.1	416.5	48	47	0.01400					
Keystone Cement Co.	Bath, PA			y		3	ESP	11.7	416	49	45	0.01500					
Keystone Cement Co.	Bath, PA			y		4	ESP	12.6	419	61		0.01400					
Keystone Cement Co.	Bath, PA			y		5	ESP	11.7	386			0.01500					
Keystone Cement Co.	Bath, PA			y		6	ESP	11.5	410			0.01100					
Keystone Cement Co.	Bath, PA			y		7	ESP	12.1	401			0.02500					
Keystone Cement Co.	Bath, PA			y		8	ESP	11.7	401			0.01500					
Keystone Cement Co.	Bath, PA			y		9	ESP	11.3	407			0.01200					
Keystone Cement Co.	Bath, PA			y		10	ESP	11.7	412			0.01600					

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Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @ 7% O2	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Lafarge Corp.	Alpena, MI	1	Aug-92	y	d (?)	1	FF	6.9	493	--	1365	0.00600	3	0.006	0.00333	0.00100	0.00252
Lafarge Corp.	Alpena, MI			y		2	FF	7.6	488	--	1499	0.00300					
Lafarge Corp.	Alpena, MI			y		3	FF	9.4	478	--	1708	0.00100					
Lafarge Corp.	Demopolis, AL	1	Aug-92	y	d (ph/bp)	4	ESP		229	120		0.01400	3	0.0306	0.01820	0.01000	0.01092
Lafarge Corp.	Demopolis, AL			y		6	ESP		243	65		0.03060					
Lafarge Corp.	Demopolis, AL			y		7	ESP		230	55		0.01000					
Lafarge Corp.	Fredonia, KS	1	Aug-92	y	w	1	ESP	5.5	533	5	359	0.03300	3	0.033	0.01900	0.01100	0.01217
Lafarge Corp.	Fredonia, KS			y		2	ESP	5.5	536	15	547	0.01300					
Lafarge Corp.	Fredonia, KS			y		3	ESP	5.5	529	16	416	0.01100					
Lafarge Corp.	Fredonia, KS	2	Aug-92	y	w	1	ESP		470	38		0.03300	3	0.033	0.02200	0.00500	0.01493
Lafarge Corp.	Fredonia, KS			y		2	ESP	5.6	481	38	244	0.02800					
Lafarge Corp.	Fredonia, KS			y		3	ESP	5.6	511	78	406	0.00500					
Lafarge Corp.	Fredonia, KS			y		4	ESP	5.6	496	60	180						
Lafarge Corp.	Paulding, OH	2	Aug-92	y	w	4	ESP	7.0	408	123		0.02000	3	0.06	0.03333	0.02000	0.02309
Lafarge Corp.	Paulding, OH			y		5	ESP	7.5	404	122		0.06000					
Lafarge Corp.	Paulding, OH			y		6	ESP	7.0	404	123		0.02000					
Lone Star Industries	Cape Girardeau, MO	1	Jan-93	y	d (ph/pc/bp)	1-2	FF	10.2	435	--		0.02200	6	0.026	0.02350	0.021	0.00187
Lone Star Industries	Cape Girardeau, MO			y		1-3	FF	10.3	435	--		0.02500					
Lone Star Industries	Cape Girardeau, MO			y		1-4	FF	10.6	435	--		0.02100					
Lone Star Industries	Cape Girardeau, MO			y		2-3	FF	10.0	435	--		0.02600					
Lone Star Industries	Cape Girardeau, MO			y		2-4	FF	11.0	435	--		0.02400					
Lone Star Industries	Cape Girardeau, MO			y		2-5	FF	10.8	435	--		0.02300					
Lone Star Industries	Greencastle, IN	1	Aug-92	y	w	1-1	ESP	5.4	465	60		0.06370	3	0.0637	0.05563	0.04560	0.00921
Lone Star Industries	Greencastle, IN			y		1-2	ESP	5.4	457	60		0.04560					
Lone Star Industries	Greencastle, IN			y		1-3	ESP	5.4	456	60		0.05760					
Lone Star Industries	Greencastle, IN			n		2-1	ESP	5.0	415			na					
Lone Star Industries	Greencastle, IN			n		2-2	ESP	4.6	419			na					
Lone Star Industries	Greencastle, IN			n		2-3	ESP	5.3	416			na					
Medusa Cement Co.	Wampum, PA	1,2	Jul-92	y	d	E-4	ESP	11.2	744	107	2602	0.07670	3	0.0789	0.07687	0.07500	0.00196
Medusa Cement Co.	Wampum, PA			y		E-5	ESP	11.3	738	149	4076	0.07500					
Medusa Cement Co.	Wampum, PA			y		E-6	ESP	11.1	750	138	8651	0.07890					
Medusa Cement Co.	Wampum, PA	1,2	Mar-93	y		1	ESP	14.6	711	50		0.07190	3	0.0724	0.06543	0.05200	0.01164
Medusa Cement Co.	Wampum, PA			y		2	ESP	13.9	712	46.8		0.07240					
Medusa Cement Co.	Wampum, PA			y		3	ESP	14.8	701	57.2		0.05200					
Medusa Cement Co.	Wampum, PA	3	Jul-92	y	d	B-4	ESP	7.3	718	20	153	0.01930	3	0.032	0.02247	0.01610	0.00841

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Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @ 7% O2	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Medusa Cement Co.	Wampum, PA			y		B-5	ESP	5.7	718	22.8	138	0.03200					
Medusa Cement Co.	Wampum, PA			y		B-6	ESP	5.3	718	24	193	0.01610					
National Cement Co.	Lebec, CA	1	Aug-92	y	d	1	FF	10.6	547	--	10.7	0.01310	4	0.0228	0.01713	0.016	0.00408
National Cement Co.	Lebec, CA			y		2	FF	10.5	548	--	7.9	0.02280					
National Cement Co.	Lebec, CA			y		3	FF	10.5	547	--	22.2	0.01600					
National Cement Co.	Lebec, CA			y		4	FF	10.7				0.01660					
North Texas Cement	Midlothian, TX	2	Oct-92	y	w	1	ESP	8.4	441	230		0.02200	3	0.024	0.02067	0.01600	0.00416
North Texas Cement	Midlothian, TX			y		2	ESP	8.5	439	227		0.02400					
North Texas Cement	Midlothian, TX			y		3	ESP	8.4	449	223		0.01600					
River Cement Co.	Festus, MO	1	Oct-92	y	d	1	ESP	10.1	638		135	0.02890	6	0.0352	0.02443	0.0129	0.00786
River Cement Co.	Festus, MO			y		2	ESP	10.1	638		135	0.02790					
River Cement Co.	Festus, MO			y		3	ESP	10.1	639		135	0.02190					
River Cement Co.	Festus, MO			y		4	ESP					0.03520					
River Cement Co.	Festus, MO			y		5	ESP					0.01980					
River Cement Co.	Festus, MO			y		6	ESP					0.01290					
Southdown/Southwestern	Fairborn, OH	1	Aug-92	y	d (?/bp)	2-1	FF			--		0.00300	3	0.003	0.00300	0.00300	0.00000
Southdown/Southwestern	Fairborn, OH			y		2-2	FF			--		0.00300					
Southdown/Southwestern	Fairborn, OH			y		2-3	FF			--		0.00300					
Southdown/Southwestern	Fairborn, OH			y		I	FF/main		379	--	37						
Southdown/Southwestern	Fairborn, OH			y		II	FF/main		379	--	2.3						
Southdown/Southwestern	Fairborn, OH			y		I	FF/bypass		547	--	37						
Southdown/Southwestern	Fairborn, OH			y		II	FF/bypass		547	--	2.3						
Southdown/Dixie	Knoxville, TN	1	Mar-92	y	d (ph/pc/bp)	1-1	FF	12.4	524	--	145	0.01130	6	0.0131	0.01183	0.00988	0.00114
Southdown/Dixie	Knoxville, TN			y		1-2	FF	12.0	507	--	119	0.00988					
Southdown/Dixie	Knoxville, TN			y		1-3	FF	12.0	490	--	134	0.01200					
Southdown/Dixie	Knoxville, TN			y		2-1	FF	11.7	499	--	114	0.01200					
Southdown/Dixie	Knoxville, TN			y		2-2	FF	12.6	489	--	95	0.01270					
Southdown/Dixie	Knoxville, TN			y		2-3	FF	12.4	490	--	183	0.01310					
Texas Industries	Midlothian, TX	1	May-93	y	w	1	ESP	6.3	418	79.5		0.01135	3	0.01135	0.00962	0.00827	0.00158
Texas Industries	Midlothian, TX			y		2	ESP	7.0	414	82.5		0.00827					
Texas Industries	Midlothian, TX			y		3	ESP	7.0	412	98.8		0.00923					
Southdown/Kosmos	Kosmosdale, KY	1	May-92	y	d (ph)	C1-1	FF		519			0.00242	9	0.00354	0.00261	0.00139	0.00094
Southdown/Kosmos	Kosmosdale, KY			y		C1-2	FF		514.8			0.00192					
Southdown/Kosmos	Kosmosdale, KY			y		C1-3	FF		518.7			0.00288					
Southdown/Kosmos	Kosmosdale, KY			y		C2-1	FF	14.9	505.4		158	0.00264					
Southdown/Kosmos	Kosmosdale, KY			y		C2-2	FF	14.6	504.7		153	0.00438					
Southdown/Kosmos	Kosmosdale, KY			y		C2-3	FF	14.6	505.1		156	0.00276					
Southdown/Kosmos	Kosmosdale, KY			y		C3-1	FF	15.4			150	0.00354					

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @ 7% O2	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7%O2) Maximum	Average	Minimum	Sdev
Southdown/Kosmos	Kosmosdale, KY			y		C3-2	FF					0.00139					
Southdown/Kosmos	Kosmosdale, KY			y		C3-3	FF					0.00160					
Ash Grove Cement Co.	Foreman, AR	2	May-92	Y	w	C2-1	ESP			55			This data is the same as list above for the				
Ash Grove Cement Co.	Foreman, AR			Y		C2-2	ESP			60		0.00780	same facility, unit and test report				
Ash Grove Cement Co.	Foreman, AR			Y		C2-3	ESP			59		0.03260					
Ash Grove Cement Co.	Foreman, AR			y		C3-1	ESP		500	58	531						
Ash Grove Cement Co.	Foreman, AR			y		C3-2	ESP		485	60	291						
Ash Grove Cement Co.	Foreman, AR			y		C3-3	ESP		506	58	176						
Holnam Inc.	Holly Hill, SC	1	Aug-92	y	w	1	ESP	10.1	450	30	110	0.04460	New Total Data, PM data is the same				
Holnam Inc.	Holly Hill, SC			y		2	ESP	10.1	450	30	110	0.04630					
Holnam Inc.	Holly Hill, SC			y		3	ESP	10.1	450	30	110	0.05810					
Holnam Inc.	Holly Hill, SC			n		1	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC			n		2	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC			n		3	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC	2	Aug-92	y	w	1	ESP	7.0	563	30	150	0.02910	New Total Data, PM data is the same				
Holnam Inc.	Holly Hill, SC			y		2	ESP	7.0	563	30	150	0.02400					
Holnam Inc.	Holly Hill, SC			y		3	ESP	7.2	563	30	145	0.01480					
Holnam Inc.	Holly Hill, SC			n		1	ESP	7.0	563		145						
Holnam Inc.	Holly Hill, SC			n		2	ESP	7.0	563		145						

w = wet kiln
d = dry kiln
sd = semi dry kiln
ph = preheater
pc = precalcinator
bp = by-pass
j =information is missing because report is still incomplete

APPENDIX C:

DETAILED SUMMARY OF CURRENT PM DATA SET FOR LIGHTWEIGHT AGGREGATE KILNS

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	BSP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	TEQ (ng/dscm @ 7% O2)	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
Norlite Corp.	Cohoes, NY	2	1	Dec-92	y	AK	B-1	SD/FF/VS/WS	14.9		--	na	na	0.0112	15	0.0371	0.0123	0.0056	0.00863
Norlite Corp.	Cohoes, NY				y	AK	B-2	SD/FF/VS/WS	15.2		--	na	na	0.0082					
Norlite Corp.	Cohoes, NY				y	AK	B-3	SD/FF/VS/WS	15.2		--	na	na	0.0058					
Norlite Corp.	Cohoes, NY				y	AK	B-4	SD/FF/VS/WS	15.4		--	na	na	0.0157					
Norlite Corp.	Cohoes, NY				y	AK	D-1	SD/FF/VS/WS	14.2		--	na	na	0.0081					
Norlite Corp.	Cohoes, NY				y	AK	D-2	SD/FF/VS/WS	14.9		--	na	na	0.0059					
Norlite Corp.	Cohoes, NY				y	AK	D-3	SD/FF/VS/WS	15.4		--	na	na	0.0056					
Norlite Corp.	Cohoes, NY				y	AK	A-1	SD/FF/VS/WS	15.7		--	na	na	0.0085					
Norlite Corp.	Cohoes, NY				y	AK	A-2	SD/FF/VS/WS	15.5		--	na	na	0.0076					
Norlite Corp.	Cohoes, NY				y	AK	A-3	SD/FF/VS/WS	15.8		--	na	na	0.0117					
Norlite Corp.	Cohoes, NY				y	AK	A-4	SD/FF/VS/WS	15.5		--	na	na	0.0060					
Norlite Corp.	Cohoes, NY				y	AK	C-1	SD/FF/VS/WS	15		--	na	na	0.0142					
Norlite Corp.	Cohoes, NY				y	AK	C-2	SD/FF/VS/WS	14.9		--	na	na	0.0130					
Norlite Corp.	Cohoes, NY				y	AK	C-3	SD/FF/VS/WS	14.8		--	na	na	0.0371					
Norlite Corp.	Cohoes, NY				y	AK	C-4	SD/FF/VS/WS	15		--	na	na	0.0254					
Solite Corp.	Brooks, KY	1	2	Aug-92	y	AK	1	FF	17.6	324	--	na	na	0.01300	3	0.026	0.01833	0.013	0.006807
Solite Corp.	Brooks, KY				y	AK	2	FF	17.8	324.6	--	na	na	0.02600					
Solite Corp.	Brooks, KY				y	AK	3	FF	17.7	325.7	--	na	na	0.01600					
Solite Corp.	Cascade, VA	2	2	Aug-92	y	AK	1	FF	17.0	423	--	na	na	0.00400	3	0.007	0.00567	0.004	0.001528
Solite Corp.	Cascade, VA				y	AK	2	FF	17.3	401	--	na	na	0.00700					
Solite Corp.	Cascade, VA				y	AK	3	FF	17.1	412	--	na	na	0.00600					
Solite Corp.	Cascade, VA	2	4	Aug-92	y	AK	1	FF	16.0	423	--	na	na	0.00700	3	0.018	0.01000	0.007	0.007
Solite Corp.	Cascade, VA				y	AK	2	FF	15.9	401	--	na	na	0.00500					
Solite Corp.	Cascade, VA				y	AK	3	FF	16.1	412	--	na	na	0.01800					
Solite Corp.	Arvonia, VA	2	7	Aug-92	y	AK	1	FF	15.0	419	--	na	na	0.00800	3	0.008	0.00667	0.006	0.001155
Solite Corp.	Arvonia, VA				y	AK	2	FF	14.8	419	--	na	na	0.00600					
Solite Corp.	Arvonia, VA				y	AK	3	FF	14.6	420	--	na	na	0.00600					
Solite Corp.	Arvonia, VA	2	8	Aug-92	y	AK	1	FF	15.5	443	--	na	na	0.01300	3	0.033	0.02533	0.013	0.010786
Solite Corp.	Arvonia, VA				y	AK	2	FF	15.5	440	--	na	na	0.03000					
Solite Corp.	Arvonia, VA				y	AK	3	FF	15.1	429	--	na	na	0.03300					
Solite Corp.	Norwood, NC	4	5	Aug-93	Y	AK	1					na	na	0.00262	3	0.00796	0.00429	0.00229	0.003183
Solite Corp.	Norwood, NC		5		Y		2					na	na	0.00229					
Solite Corp.	Norwood, NC		5		Y		3					na	na	0.00796					
Solite Corp.	Norwood, NC	4	6	Aug-93	Y	AK	1					na	na	0.0102	3	0.0102	0.00512	0.00229	0.004412
Solite Corp.	Norwood, NC		6		Y		2					na	na	0.00286					
Solite Corp.	Norwood, NC		6		Y		3					na	na	0.00229					
Solite Corp.	Norwood, NC	4	7	Aug-93	Y	AK	1					na	na	0.000298	3	0.000765	0.00048	0.000298	0.000253
Solite Corp.	Norwood, NC		7		Y		2					na	na	0.000765					
Solite Corp.	Norwood, NC		7		Y		3					na	na	0.000362					
Solite Corp.	Norwood, NC	4	8	Jul-93	Y	AK	1					na	na	0.00101	3	0.00375	0.00190	0.00093	0.001606
Solite Corp.	Norwood, NC		8		Y		2					na	na	0.00093					
Solite Corp.	Norwood, NC		8		Y		3					na	na	0.00375					
Solite Corp.	Green Cove Springs, FL		5	Jan-94	Y	AK	1	FF	12.2			na	na	0.00157	3	0.00157	0.00144	0.00127	0.000155
Solite Corp.	Green Cove Springs, FL				Y		2		12.6			na	na	0.00149					
Solite Corp.	Green Cove Springs, FL				Y		3		12.9			na	na	0.00127					
Solite Corp.	Cascade, VA	3	1	Mar-94		AK	1	FF	16.8			1.65	0.0508	0.00757	3	0.0111	0.00864	0.00726	0.002133
Solite Corp.	Cascade, VA						2		17			1.6	0.0372	0.0111					
Solite Corp.	Cascade, VA						3		17.1			1.48	0.0383	0.00726					

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7% O2) Maximum	Average	Minimum	Stdev
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	1	none	na	na	na	0.00703	7	0.06690	0.01965	0.00447	0.02195
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	2					0.01770					
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	3					0.06690					
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	4					0.02420					
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	5					0.00947					
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	6					0.00447					
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	7					0.00779					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	11	FF/WS/ESP	9.91	143.1		0.00050	9	0.00160	0.00063	0.00000	0.00057
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	12		9.42	145.5		0.00000					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	13		9.59	147.8		0.00140					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	4		10.5	144		0.00060					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	5		8.88	146		0.00160					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	6		8.96	144		0.00060					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	7		8.06	150		0.00000					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	8		9.9	146		0.00080					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	9		12.2	143		0.00020					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-1	FF/WS/IWS	10.9	172		0.00300	12	0.00600	0.00342	0.00100	0.00138
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-2		11.6	173		0.00300					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-3		11.1	174		0.00500					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-1		11.5	170		0.00400					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-2		12.1	168		0.00300					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-3		11.5	166		0.00400					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-1		12.1	174		0.00100					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-2		11.5	170		0.00200					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-3		12.6	171		0.00200					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-1		11.5	170		0.00600					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-2		12.5	172		0.00400					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-3		12.6	170		0.00400					
Aptus, Inc.	Coffeyville, KS	1	1	Dec-91	Y	RK		FF/WS/IWS			na		na				
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-2	FF/SW				0.00270	9	0.09540	0.02954	0.00270	0.03681
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-3					0.00340					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-4					0.00300					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-1					0.00840					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-2					0.00550					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-3					0.01270					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-1					0.07790					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-2					0.09540					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-3					0.05690					

Company	Location	No. Units	Unit Tested	Report Date	Burn Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdedv
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	1	IWS/PS	8.7	164		0.03680	4	0.03680	0.03110	0.02670	0.00492
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	2		8.4	166		0.03360					
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	3		8.4	162		0.02670					
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	4		8.4	165		0.02730					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-4	PS	10.2	168.9	na	0.02610	6	0.06320	0.04100	0.01590	0.02054
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-5		9.8	169		0.01590					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-6		10.2	169		0.02600					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-4		9.6	170.6		0.05820					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-5		9.6	170.6		0.05660					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-6		9.3	170.8		0.06320					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-1		9.8	169.1							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-2		9.9	168.7							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-3		9.7	169							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-1		9.5	170.6							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-2		10.1	169.6							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-3		9.4	170.6							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	1	FF/VS/AFS	9.8	153	na	0.00160	8	0.00160	0.00076	0.00050	0.00035
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	2		10.1	152		0.00070					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	3		10.2	152		0.00060					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	4		9.6	151		0.00050					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	5		10.3	154		0.00080					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	6		10	154		0.00070					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	7		10	154		0.00070					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	8		10.3	155		0.00050					
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	1	FF/WS	15.7	156	na	0.01140	3	0.01140	0.00854	0.00383	0.00411
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	2		15.6	157		0.01040					
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	3		15.7	155		0.00383					
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	1	FF/WS	15.3	159	na	0.02030	3	0.02390	0.02267	0.02030	0.00205
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	2		14.9	163		0.02390					
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	3		15.7	157		0.02380					
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	1	FF/WS	16.2	153	na	0.01840	3	0.01840	0.00843	0.00183	0.00879
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	2		15.3	154		0.00505					
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	3		15	153		0.00183					
Marine Shale	Amelia, LA	2	1	Jul-95	y	AK	1	SD/FF	10.7	387	--	0.00460	3	0.0079	0.00580	0.00466	0.00182
Marine Shale	Amelia, LA				y	AK	2	SD/FF	10.4	398	--	0.00490					
Marine Shale	Amelia, LA				y	AK	3	SD/FF	10.5	400	--	0.00790					
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	1	WS	11	94	na	0.02410	3	0.02410	0.01717	0.00860	0.00788

Company	Location	No. Units	Unit Tested	Report Date	Burn tz. Wa:	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdedv
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	2		10.6	97		0.01880					
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	3		11	95		0.00860					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	1	IWS	10.7	108	na	0.01640	9	0.08970	0.03321	0.00620	0.02492
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	2		10.3	113		0.03340					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	3		10.6	111.7		0.03320					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	4		9.3	106.6		0.02570					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	5		10	100.5		0.02060					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	6		9.7	99		0.02070					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	7		9.3	92		0.08970					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	8		9.6	103.7		0.00620					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	9		10.4	97.5		0.05300					
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-88	Y	RK	4	WS	??	??		0.032	3	0.03200	0.02700	0.02300	0.00458
					Y		5	WS	??	??		0.026					
					Y		6	WS	??	??		0.023					
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	1	WS	10.7	103	na	0.02950	3	0.02950	0.02753	0.02630	0.00172
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	2		10.2	106		0.02630					
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	4		10.6	109		0.02680					
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	1	WS	10	101	na	na					
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	3		10.7	102							
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	4		11.2	102							
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	1	WS	11	na	na	0.07140	3	0.07140	0.05937	0.04190	0.01548
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	2		10.3			0.04190					
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	3		10.2			0.06480					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	1		11.5	122.6	na	0.01160	15	0.02040	0.01385	0.01050	0.00414
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	2		12.5	119		0.01510					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	3		12.8	121.2		0.01610					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	4		12.1	112.7		0.01250					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	5		11.8	117.8		0.01380					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	6		11.6	118.2		0.01770					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	7		8.4	113.6		0.01670					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	8		8.2	124.5		0.01930					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	9		8.7	130.9		0.00320					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	10		8.2	120.2		0.02040					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	11		7.5	115.5		0.01330					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	12		8.2	118.5		0.01050					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	13		9	125.6		0.01240					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	14		9.2	129.9		0.01300					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	15		7.9	128.4		0.01220					

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# Points	Particulate (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdedv
Ross Incineration Services	Grafton, OH	1	1	Mar-93		RK	1	PT/IWS	11.3	122	na	0.00700	3	0.01000	0.00833	0.00700	0.00153
Ross Incineration Services	Grafton, OH	1	1	Mar-93		RK	2		11.2	125		0.00800					
Ross Incineration Services	Grafton, OH	1	1	Mar-93		RK	3		11	119		0.01000					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-1	WS	8.6	172		0.06600	7	0.06700	0.05256	0.03450	0.01449
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-2		6.2	181		0.06700					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-3		8.7	167		0.05600					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	1		8.8			0.03450					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	2		9.2			0.04160					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	3		10.2			0.03710					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	4		9			0.06570					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	1	SD/FF	11.6	367		0.00460	8	0.00460	0.00168	0.00040	0.00140
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	3	SD/FF	11.6	367		0.00120					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	4	SD/FF	11.6	361		0.00040					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	5	SD/FF	11.6	364		0.00150					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	6	SD/FF	11.8	363		0.00170					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	7	SD/FF	11.6	354		0.00270					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	8	SD/FF	11.6	366		0.00050					
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	:otary Kil	9	SD/FF	11.6	362		0.00080					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	:otary Kil	1	ESP	11.3			0.00300	9	0.00350	0.00240	0.00100	0.00087
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	:otary Kil	2	ESP	11.3			0.00350					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	:otary Kil	3	ESP	11.7			0.00170					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	:otary Kil	4	ESP	10.9			0.00180					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	:otary Kil	5	ESP	11.4			0.00250					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	:otary Kil	6	ESP	12.8			0.00340					

APPENDIX E:

DETAILED SUMMARY OF CURRENT PM DATA SET FOR ON-SITE HW INCINERATORS

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
American Cyanamid	Hannibal, MO	1	1	Aug-89	Y	LI & CA	2	PT	5.8			0.0566	3	0.0577	0.0544	0.0489	0.004795
					Y		3	PT	5.2			0.0577					
					Y		4	PT	5.1			0.0489					
Amoco Oil	Whiting, IN	1	1	Jun-89	Y	FB	1	C/VS	14.0			0.0449	6	0.0649	0.04365	0.0303	0.015427
					Y		2	C/VS	13.2			0.0649					
					Y		3	C/VS	13.7			0.0594					
					Y		4	C/VS	14.6			0.0307					
					Y		5	C/VS	13.8			0.0303					
					Y		6	C/VS	14.5			0.0317					
Aristech Chemical	Colton, CA	1	1	Jan-89	Y		1-1	None	9			0.004	6	0.004	0.002833	0.001	0.001169
					Y		1-2	None	9.5			0.004					
					Y		1-3	None	9.2			0.003					
					Y		2-1	None	8.6			0.001					
					Y		2-2	None	8.1			0.003					
					Y		2-3	None	8			0.002					
Ashland Chemical	Los Angeles, CA	1	1	Dec-88		LI	1-1	None	10.2			0.02	6	0.02	0.018667	0.011	0.006501
							1-2	None	8			0.015					
							1-3	None	8.2			0.011					
							2-1	None	7.4			0.014					
							2-2	None	6.4			0.024					
							2-3	None	4.8			0.028					
Burroughs Wellcome	Greenville, NC	??	2	Jan-93	Y	LI	I-2	WS/ESP	11.6			0.0258	9	0.0823	0.032056	0.0121	0.022656
					Y		I-3	WS/ESP	11.7			0.0225					
					Y		I-4	WS/ESP	11.8			0.0287					
					Y		II-1	WS/ESP	12.1			0.0823					
					Y		II-2	WS/ESP	12.3			0.0535					
					Y		II-3	WS/ESP	12.1			0.0332					
					Y		III-1	WS/ESP	12.2			0.0177					
					Y		III-2	WS/ESP	12.5			0.0127					
					Y		III-3	WS/ESP	12.5			0.0121					
Cargill	Lynwood, CA	1	1	Jul-89	Y	LI	6-19	None	8.8			0.106	4	0.106	0.0505	0.014	0.039543
					Y		6-20	None	9			0.048					
					Y		6-21	None	9.1			0.034					
					Y		6-22	None	9.6			0.014					
Cargill	Lynwood, CA	1	1	Jan-88	Y	LI	1600A	None	10.26			0.0022	3	0.0114	0.006933	0.0022	0.004606
					Y		1600B	None	9.61			0.0114					
					Y		1600C	None	9.46			0.0072					
Chevron	Philadelphia, PA	1	1	Sep-91	Y	FB	1	VS/WS	15	161		0.0385	5	0.0193	0.01978	0.0093	0.011075
					Y		2A	VS/WS	11	177		0.0193					
					Y		2B	VS/WS	11	176		0.0158					
					Y		2C	VS/WS	10	176		0.016					
					Y		3	VS/WS	13	160		0.0093					
Chevron	Belle Chase, LA	1	1	Feb-88	Y	RH & LI	1-2	VS/PT	12.4			0.018	9	0.049	0.032	0.018	0.01254
							1-3	VS/PT	12.7			0.018					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
							1-4	VS/PT	12.5			0.029					
							2-3	VS/PT	11.7			0.022					
							2-4	VS/PT	11.3			0.023					
							2-5	VS/PT	12.0			0.049					
							3-1	VS/PT	11.8			0.045					
							3-2	VS/PT	13.5			0.045					
							3-3	VS/PT	12.9			0.039					
Chevron	Richmond, CA	1	1	Jun-93	Y	LI	1	VS	3.3			0.0000175	3	1.88E-05	1.82E-05	1.75E-05	6.51E-07
					Y		2	VS	3.5			0.0000182					
					Y		3	VS	3.5			0.0000188					
Chevron	Richmond, CA	1	1	Jul-88	Y	LI	A-2	VS	3.4	175		0.0028	9	0.0054	0.002311	0.0008	0.001606
					Y		A-3	VS	3.2	176		0.0016					
					Y		A-4	VS	2.8	174		0.0012					
					Y		B-5	VS	3.3	174		0.0017					
					Y		B-6	VS	3.1	171		0.0054					
					Y		B-7	VS	2.8	173		0.0044					
					Y		C-8	VS	2.9	171		0.0008					
					Y		C-9	VS	3.6	170		0.0009					
					Y		C-10	VS	3	172		0.002					
					Y		A-11	VS	2.7	171							
Ciba-Geigy	MacIntosh, AL	1	1	Mar-90	Y	RK	1	VS/PT/ESP				0.17	6	0.17	0.062333	0.02	0.056302
					Y		2	VS/PT/ESP				0.029					
					Y		3	VS/PT/ESP				0.02					
					Y		4	VS/PT/ESP				0.052					
					Y		5	VS/PT/ESP				0.074					
					Y		6	VS/PT/ESP				0.029					
Ciba-Geigy	St. Gabriel, LA	1	1	May-88	Y	LI	I-1	VS/Cyclone	3.8			0.0388	9	0.066	0.042711	0.0253	0.01536
					Y		I-2	VS/Cyclone	3.9			0.0404					
					Y		I-3	VS/Cyclone	3.8			0.0344					
					Y		II-1	VS/Cyclone	5.5			0.063					
					Y		II-2	VS/Cyclone	5.3			0.0565					
					Y		II-3	VS/Cyclone	4.9			0.066					
					Y		III-1	VS/Cyclone	5.7			0.0337					
					Y		III-2	VS/Cyclone	5.8			0.0263					
					Y		III-3	VS/Cyclone	5.6			0.0253					
Department of the Army	Johnston Atoll	1	LIC	Jun-91	Y	LI	1	VS/PBS	14.6	194		1.61E-03	3	0.00183	0.001713	0.00161	0.000111
					Y		2	VS/PBS	14.4	198		1.83E-03					
					Y		3	VS/PBS	14.6	198		1.70E-03					
Department of the Army	Johnston Atoll	1	LIC	Jun-92	Y	LI	1	VS/PBS				1.96E-03	4	0.00196	0.001438	0.00072	0.000559
					Y		2	VS/PBS				7.20E-04					
					Y		3	VS/PBS				1.79E-03					
					Y		4	VS/PBS				1.28E-03					
Department of the Army	Johnston Atoll	1	DFS	Jun-92	Y	RK	1	VS/PBS	13.9			0.000485	4	0.00191	0.001261	0.000485	0.000799
					Y		2	VS/PBS	13.0			0.00199					
					Y		3	VS/PBS	13.2			0.00191					
					Y		4	VS/PBS	13.1			0.00066					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
Department of the Army	Tooele, UT	??	??	Apr-92	Y	RK	2	VS	11.2			0.01518	4	0.01518	0.010988	0.00436	0.004955
					Y	RK	3	VS	11.4			0.01435					
					Y	RK	4	VS	11.5			0.00436					
					Y	RK	5	VS	11.3			0.01006					
					N	RK	1	VS	11.2			0.00058					
Department of the Army	Tooele, UT	??	??	Oct-93	Y	RK	3	VS	11.4	163.77		0.00802	4	0.01349	0.011635	0.00802	0.002508
					Y	RK	4	VS	11.2	164.26		0.01349					
					Y	RK	5	VS	11.3	164		0.01188					
					Y	RK	6	VS	11.6	162.45		0.01315					
					N	RK	1	VS	11.4	161.15		0.00255					
Dow Chemical Co.	Plaquemine, LA	1	1	Feb-88	Y	RK	C1-1	ESP/PBS	13.5	??	??	0.109	6	0.109	0.032192	0.00835	0.038227
					Y		C1-2		13.3			0.0247					
					Y		C1-3		13.3			0.0163					
					Y		C2-1		9.3			0.00835					
					Y		C2-2		9.8			0.0106					
					Y		C2-3		10.7			0.0242					
					Y		1		13.3	??	??						
					Y		2		13	??	??						
Dow Chemical Co.	Freeport, TX	1	1	Nov-88	Y	RK	C1-1	IWS	14.4			0.012	6	0.012	0.0075	0.004	0.00345
					Y		C1-2		13.6			0.011					
					Y		C1-3		14.1			0.008					
					Y		C2-1		13.3			0.004					
					Y		C2-2		13.8			0.006					
					Y		C2-3		13.3			0.004					
Dow Chemical Co.	Midland, MI	1	830	Mar-92	Y	RK	C1-1	VS/IWS	11.8			0.0002	16	0.0366	0.008641	0.0001	0.012625
					Y		C1-2		11.5			0.0012					
					Y		C1-3		12.1			0.0001					
					Y		C1-4		11.7								
					Y		C2-1		11.1			0.0018					
					Y		C2-2		10.8			0.0007					
					Y		C2-3		11.1			0.00058					
					Y		C2-4		10.8			0.00038					
					Y		C3-1		11.7			0.0011					
					Y		C3-2		11.4			0.0017					
					Y		C3-3		11.8			0.0017					
					Y		C3-4		11.7			0.0011					
					Y		C4-1		11.8			0.0366					
					Y		C4-2		11.9			0.033					
					Y		C4-3		11.1			0.0226					
					Y		C4-4		11.1			0.0188					
					Y		C4-5		10.9			0.0167					
Dow Chemical Co.	Midland, MI	1	703	Jun-89	Y	RK	C1-1	VS/ESP				0.0114	11	0.0492	0.019804	0.00516	0.017404
					Y		C1-2					0.0102					
					Y		C1-3					0.00516					
					Y		C1-4					0.00668					
					Y		C2-1		11.9			0.0133					
					Y		C2-2		10.7			0.0096					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		C2-3		11.4			0.0115					
					Y		C2-4		10.2			0.0101					
					Y		C3-1					0.0458					
					Y		C3-2					0.0449					
					Y		C3-3					0.0492					
Dupont	Deepwater, NJ	1	FR-1	Jun-89	Y	LI	P1	PT/CCS/RJS/ESP	11.4			0.0022	3	0.0033	0.0029	0.0022	0.000608
					Y		P2		11.4			0.0033					
					Y		P3		11.5			0.0032					
Dupont	La Place, LA	1	1	Sep-89	Y	RK & LI	1	WS	9.6			0.0177	9	0.0443	0.0268	0.015	0.011897
							2		9			0.015					
							3		8.8			0.0177					
							4		10.2			0.0212					
							5		10.4			0.0222					
							6		9.4			0.0207					
							7		12.2			0.0441					
							9		13.6			0.0443					
							10		12.8			0.0383					
Dupont	La Porte, TX	2	N-THF	Feb-89	Y	LI	6.1	WS	5			0.08	13	0.189	0.112769	0.042	0.04818
					Y		6.2		3.5			0.104					
					Y		6.3		2.8			0.092					
					Y		6.4		2.5			0.084					
					Y		7.1		6			0.066					
					Y		7.2		7.8			0.042					
					Y		7.3		3.6			0.107					
					Y		8.1		6.3			0.081					
					Y		8.2		5.1			0.132					
					Y		8.3		5.6			0.115					
					Y		9.1		6.8			0.189					
					Y		9.2		6.2			0.186					
					Y		9.3		6.4			0.188					
Dupont	La Porte, TX	1	CSI (1)	Jan-89	Y	LI	1	WS	4.6			0.0381	9	0.0567	0.036767	0.0149	0.011892
					Y		2		5.5			0.0337					
					Y		3		5.13			0.0149					
					Y		4		6.57			0.0367					
					Y		7		5			0.0276					
					Y		8		6.4			0.0449					
					Y		9		6.2			0.0567					
					Y		10		6			0.0456					
					Y		11		7.4			0.0327					
Dupont	La Porte, TX	1	1	Mar-89	Y	LI	C-1	FF	na		na	0.00160	9	0.0127	0.002177	0.0004	0.003962
					Y		C-2					0.00053					
					Y		C-3					0.00070					
					Y		C-4					0.00083					
					Y		C-5					0.00077					
					Y		C-6					0.00040					
					Y		C-8					0.01270					
					Y		C-9					0.00093					
					Y		C-10					0.00113					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
Dupont	Louisville, KY	1	1	Jul-89	Y	LI	1	WS	7.8			0.03500	3	0.035	0.032333	0.031	0.002309
					Y		2		7.2			0.03100					
					Y		3		7.0			0.03100					
Dupont	Orange, TX	1	1	Aug-90	Y	RK	C1-1		8.2			0.00130	6	0.002	0.00125	0.0005	0.000554
					Y		C1-2		8.5			0.00200					
					Y		C1-3		8.4			0.00080					
					Y		C2-4		10.7			0.00170					
					Y		C2-5		10.1			0.00050					
					Y		C2-6		10.6			0.00120					
Dupont	Wilmington, DE	1	1	Dec-92	Y	FH	1	SD/VS	10.4	na	na	0.06090	6	0.0609	0.043633	0.0283	0.015178
					Y		2		10.4			0.05250					
					Y		3		11.1			0.05810					
					Y		4		11.2			0.03340					
					Y		5		11.0			0.02860					
					Y		6		11.0			0.02830					
Eastman Kodak Co.	Rochester, NY			Sep-92	Y	RK	I-1		12.2			0.07400	9	0.078	0.052667	0.015	0.024052
							I-2		12.0			0.07700					
							I-3		11.9			0.07800					
					Y		II-1		13.0			0.06200					
							II-2		14.1			0.06000					
							II-3		13.1			0.05200					
					Y		III-1		14.6			0.01500					
							III-2		14.8			0.01900					
							III-3		14.9			0.03700					
Eli Lilly and Co.	Mayaguez, PR	1	1	Nov-87	Y	LI	1	PT/VS	10.3			0.04530	3	0.0453	0.043567	0.0425	0.001514
					Y		2		10.4			0.04290					
					Y		3		10.2			0.04250					
First Chemical Corp.	Pascagoula, MS	1	1	Jul-91	Y	??	I-2	??				0.01530	9	0.0282	0.010922	0.0103	0.007875
							I-3		2.6			0.01300					
							I-4					0.01080					
					Y		II-5					0.00410					
							II-6		2.4			0.00290					
							II-7					0.00300					
					Y		III-8					0.01030					
							III-9		2.6			0.01070					
							III-10					0.02820					
Honeywell	Pinellas County, FL	1	1	Jun-88	Y	LI	1	??		na	na	0.06000	4	0.069	0.06	0.044	0.011343
					Y		2					0.06700					
					Y		3					0.06900					
					Y		4					0.04400					
Iowa Army Ammunition Plant	Middletown, IA	1	1	Nov-88	Y	RK	1	FF	19.2		na	0.00900	6	0.216	0.0835	0.009	0.088163
					Y		2		19.2			0.01000					
					Y		3		19.3			0.01200					
					Y		4		17.2			0.21600					
					Y		5		17.9			0.15400					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		6		18.7			0.10000					
Iowa Army Ammunition Plant	Middletown, IA	1	1	Oct-91	Y	RK	1	FF				0.00450	6	0.0071	0.00495	0.0039	0.001102
					Y		2					0.00710					
					Y		3					0.00470					
					Y		4					0.00390					
					Y		5					0.00470					
					Y		6					0.00480					
Iowa Army Ammunition Plant	Middletown, IA	1	1	Jul-93	Y	RK	4	FF				0.01530	3	0.0153	0.0138	0.0126	0.001375
					Y		5					0.01260					
					Y		6					0.01350					
Lake City Army Ammunition Plant	Independence, MO	1	1	Mar-93	Y	RK	1	FF	16.6			0.03200	6	0.035	0.028167	0.024	0.004355
							2		16.6			0.02500					
							3					0.02600					
							5		15.9			0.02400					
							7		16.0			0.03500					
							8		15.7			0.02700					
M&T Chemicals	Carrollton, KY	1	1	Jan-89	Y	RK	1.1	FF/WS	15.9			0.00870	10	0.0436	0.01339	0.0057	0.013931
					Y		1.2		15.9			0.00630					
					Y		1.3		15.2			0.03540					
					Y		1.4		15.3			0.00570					
					Y		2.3		14.8			0.00620					
					Y		2.4		16.2			0.04360					
					Y		2.5		15.1			0.00830					
					Y		3.1		14.6			0.00720					
					Y		3.2		15.3			0.00660					
					Y		3.3		15.2			0.00590					
Miles Inc.	New Martinsville, WV	1	1	Sep-92	Y	FB	C1-1	ESP/WS	7.7	162	na	0.00900	6	0.009	0.0065	0.004	0.002168
					Y		C1-2		8.8	158		0.00900					
					Y		C1-3		8.9	157		0.00500					
					Y		C2-4		8.0	162.2		0.00500					
					Y		C2-5		8.6	159.8		0.00700					
					Y		C2-6		7.9	160.7		0.00400					
Monsanto Agricultural Co.	Muscatine, IA	1	1	May-89	Y	LI	I-1	PBS	12.3		na	0.09300	15	0.114	0.07013	0.029	0.023727
							I-2		8.7			0.04800					
							I-3		9.0			0.05700					
							II-1		9.4			0.07800					
							II-2		7.7			0.11400					
							II-3		10.4			0.07600					
							III-1		7.8			0.06800					
							III-2		7.8			0.07400					
							III-3		7.8			0.07500					
							IV-1		7.3			0.09100					
							IV-2		6.7			0.09400					
							IV-3		7.0			0.07600					
							V-1		7.8			0.04300					
							V-2		7.5			0.02900					
							V-3		9.0			0.03600					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
Nepera Inc.	Herriman, NY	1	1	Feb-93	Y	LI	1	??	5.2			0.02340	3	0.0661	0.0375	0.023	0.024769
					Y		2		5.1			0.02300					
					Y		3		5.1			0.06610					
Nepera Inc.	Herriman, NY	1	1	Sep-92	Y	LI	1	??	5.1			0.02070	3	0.0271	0.022833	0.0207	0.003695
							2		4.6			0.02710					
							3		4.4			0.02070					
Olin Corp.	East Alton, IL	2	2	Feb-92	Y	SA	1	FF	17.1	401	na	0.00053	4	0.00053	0.000291	0.00016	0.000173
					Y		2		16.0	401		0.00016					
					Y		3		16.2	398		0.00031					
					Y		4		16.6	399		0.00017					
Olin Corp.	Lake Charles, LA	1	1	Jan-89	Y	LI	I-1	WS	9.3	na	na	0.03500	15	0.053	0.02227	0.004	0.01758
							I-2		10.6			0.05300					
							I-3		11.8			0.05000					
							II-1		6.9			0.00800					
							II-2		13.0			0.01600					
							II-3		11.2			0.01600					
							III-1		13.5			0.00700					
							III-2		13.3			0.00900					
							III-3		11.6			0.00700					
							IV-1		15.0			0.00500					
							IV-2		13.4			0.00400					
							IV-3		18.9			0.01300					
							V-1		10.8			0.04000					
							V-2		9.0			0.02700					
							V-3		10.7			0.04400					
Pfizer Inc.	Groton, CT	1	1	Jul-90	Y	RH	2	WS	7.3	151	na	0.04000	3	0.04	0.036	0.033	0.003606
					Y		3		7.7	153		0.03500					
					Y		5		7.7	168		0.03300					
Pfizer Pharmaceuticals Inc.	Barceloneta, PR	1	1	5/89	Y	RK	1	VS/PT	10.8	187	na	0.06750	3	0.0684	0.064933	0.0589	0.005244
					Y		2		10.6	187		0.05890					
					Y		3		11.4	185		0.06840					
Radford Army Ammunition Plant	Radford, VA	2	6A	Jun-93	Y	RK	M6-1	FF/PBS	13.1	172		0.00317	9	0.00638	0.00233	0.00077	0.002046
					Y		M6-2		14.3	173		0.00638					
					Y		M6-3		14.9	172		0.00484					
					Y		A-1		12.1	174		0.00172					
					Y		A-2		12.1	174		0.00095					
					Y		A-3		12.0	174		0.00081					
					Y		AA-1		10.4	180		0.00149					
					Y		AA-2		10.6	178		0.00080					
					Y		AA-3		10.6	179		0.00077					
					N		B-1		14.1	172		0.00100					
					N		B-2		12.5	178		0.00053					
					N		B-3		12.9	177		0.00221					
Thermal Oxidation Corp.	Roebuck, SC	1	1	Mar-87	Y	LI	1	FF/WS	15.0	141	na	0.00813	6	0.0109	0.005743	0.00153	0.003542
					Y		2		14.7	133		0.00253					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		3		12	141.7		0.00677					
					Y		4		10.4	147.7		0.0109					
					Y		5		12.5	143.7		0.00153					
					Y		6		13.2	140		0.0046					
U.S. Dept. of Energy	Oak Ridge, TN	1	1	Aug-89	Y	RK	1	VS/PB/IWS	11.5	183	na	0.0327	3	0.0327	0.024933	0.0177	0.007514
					Y		2		11.1	180		0.0244					
					Y		3		11.4	179		0.0177					
Upjohn Co.	Kalamazoo, MI	1	1	Dec-90	Y	RK	1	PT/VS	14.1	116	na	0.00406	3	0.00602	0.003983	0.00187	0.002076
					Y		2		11.7	119		0.00602					
					Y		3		13.5	118		0.00187					
Vulcan Materials Co.	Wichita, KS	1	1	Apr-91	Y	LI	I-2	WS	5.8	161	na	0.0117	6	0.126	0.011362	0.00917	0.001342
					Y		I-3		3.9	162		0.0103					
					Y		I-4		4.4	161		0.00917					
					Y		II-1		4.5	162		0.0121					
					Y		II-2		5.1	164		0.0123					
					Y		II-3		4.3	165		0.0126					
Vulcan Materials Co.	Wichita, KS	1	1	Feb-91	Y	LI	I-1	WS	8	117	na	0.02	8	0.035	0.022925	0.0149	0.006745
							I-2		5.8	121		0.0149					
							II-1		6.8	133		0.0193					
							II-2		5.9	139		0.0157					
							III-1		2.9	149		0.035					
							III-2		3.7	157		0.0275					
							IV-1		2	142		0.0258					
							IV-2		3.7	141		0.0252					

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Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
Eli Lilly and Co.	Lafayette, IN		TJZ	Feb-89	Y	LI	C1-1	VS/PT	2.5			0.0315	13	0.0448	0.032238	0.0245	0.007016
					Y		C1-2		3.5			0.0305					
					Y		C1-3		1.9			0.0339					
					Y		C1-4		2			0.0361					
					Y		C2-1		1.5			0.0245					
					Y		C2-2		2.3			0.0246					
					Y		C2-3		3.1			0.0288					
					Y		C3-1		5.6			0.0411					
					Y		C3-2		5.7			0.0448					
					Y		C3-3		5.6			0.0429					
					Y		C4-1		2.4			0.0269					
					Y		C4-2		2.5			0.0262					
					Y		C4-3		2.4			0.0273					
Eli Lilly and Co.	Clinton, IN	3	C-10	Feb-89	Y	??	C1-1	VS/PT	10.1			0.0384	10	0.0784	0.0415	0.0243	0.020123
					Y		C1-2		10.1			0.0283					
					Y		C1-3		10.6			0.0289					
					Y		C1-4		11.5			0.0329					
					Y		C2-1		9.9			0.0272					
					Y		C2-2		10.4			0.0243					
					Y		C2-3		10			0.0267					
					Y		C3-1		11.4			0.0784					
					Y		C3-2		11.2			0.0601					
					Y		C3-3		12.6			0.0698					
Cook Composites	Port Washington, WI	1	1	Apr-90	?	LI	1	?	7.7			0.039	3	0.039	0.037	0.034	0.002646
							2		9			0.038					
							3		9			0.034					
Glaxo Inc.	R.T.P., NC	1	1	Oct-93	Y	RH	S1-1	DS/FF				0.00176	6	0.00499	0.001935	0.00064	0.001587
					Y		S1-2					0.00499					
					Y		S1-3					0.00095					
					Y		S2-1					0.00208					
					Y		S2-2					0.00119					
					Y		S2-3					0.00064					
Iowa Army Ammunition Plant	Middletown, IA	1	1	Oct-91	Y	RK	1	FF	14.7			0.00450	9	0.0152	0.007344	0.0039	0.004078
					Y		2		14.0			0.00710					
					Y		3		13.8			0.00470					
					Y		4		14.3			0.00390					
					Y		5		14.7			0.00470					
					Y		6		15.0			0.00480					
					Y		7		15.0			0.00840					
					Y		8		14.2			0.01520					
					Y		9		14.4			0.01280					
Occidental Chemical Corp.	Niagara Falls, NY	1	1	Feb-94	Y	LI	1	IWS	11.3			0.00320	3	0.0009	0.0017	0.0032	0.0013
					Y		2		11.3			0.00090					
					Y		3		11.0			0.00100					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	PM (gr/dscf @ 7% O2) Maximum	Average	Minimum	Sdev
3M	Cottage Grove, MN	1	1	Sep-90	Y	RK	1	WS	14.2			0.10700	8	0.107	0.05995	0.0368	0.024145
					Y		2	WS	14.0			0.0643					
					Y		3	WS	13.5			0.0414					
					Y		4	WS	13.9			0.0368					
					Y		5	WS	15.4			0.0708					
					Y		6	WS	14.2			0.0746					
					Y		7	WS	14.6			0.0395					
					Y		8	WS	13.2			0.0452					

?? Unable to be determined from information given
na not available

APPENDIX F:

DETAILED SUMMARY OF CURRENT PM DATA SET FOR HW BURNING BOILERS

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
3M	Decatur, AL	1	Mar-92	Boiler		1	??				0.0013	3	0.0038	0.00263	0.0013	0.00126
3M	Decatur, AL					2					0.0038					
3M	Decatur, AL					3					0.0028					
3M	Decatur, AL	1	Aug-92	Boiler		1	??				0.0056	3	0.0092	0.00607	0.0034	0.00293
3M	Decatur, AL					2					0.0092					
3M	Decatur, AL					3					0.0034					
Air Products	Pasadena, TX	15.2	Jun-92	Boiler		1	??	4.2			0.0752	6	0.0752	0.03143	0.009	0.02759
Air Products	Pasadena, TX					2		4.1			0.0419					
Air Products	Pasadena, TX					3		4.2			0.0458					
Air Products	Pasadena, TX					4		4.1			0.0102					
Air Products	Pasadena, TX					5		3.9			0.0065					
Air Products	Pasadena, TX					6		4.1			0.009					
Air Products	Pasadena, TX	15.6	Jun-92	Boiler		1	??	4.1			0.0549	7	0.0612	0.02944	0.0046	0.02549
Air Products	Pasadena, TX					2		4			0.0532					
Air Products	Pasadena, TX					3		4.1			0.0612					
Air Products	Pasadena, TX					4		3.5			0.0129					
Air Products	Pasadena, TX					5		3.6			0.0109					
Air Products	Pasadena, TX					6		3.6			0.0084					
Air Products	Pasadena, TX					7		3.5			0.0046					
Air Products	Wichita, KS	1	Aug-93	Boiler	Natural Gas	A-1	??				0.0243	6	0.0316	0.02055	0.0125	0.00759
Air Products	Wichita, KS					A-2					0.0155					
Air Products	Wichita, KS					A:1-3**					0.0316					
Air Products	Wichita, KS					B-1					0.0125					
Air Products	Wichita, KS					B-2					0.0142					
Air Products	Wichita, KS					B:1-3**					0.0252					
Air Products	Wichita, KS					B-3*					0.0488					
Air Products	Wichita, KS					A-3*					0.055					
Allied Signal	Philadelphia, PA	BL-701	Aug-92	Boiler	Natural Gas	1	??				0.0239	3	0.0287	0.02463	0.0213	0.00375
Allied Signal	Philadelphia, PA					2					0.0213					
Allied Signal	Philadelphia, PA					1-3**					0.0287					
Allied Signal	Philadelphia, PA					3*					0.0432					
American Cyanamid Co.	Wallingford, CT	1	Apr-93	Boiler	Solvents	8	None				0.0006	6	0.0296	0.01062	0.0005	0.01304
American Cyanamid Co.	Wallingford, CT					9					0.0005					
American Cyanamid Co.	Wallingford, CT					8-10**					0.0006					
American Cyanamid Co.	Wallingford, CT					4					0.0083					
American Cyanamid Co.	Wallingford, CT					6					0.0296					
American Cyanamid Co.	Wallingford, CT					4-6**					0.0241					
American Cyanamid Co.	Wallingford, CT					10*					0.011					
American Cyanamid Co.	Wallingford, CT					5*					0.0352					
American Cyanamid Co.	Kalamazoo, MI	3	Mar-93	Boiler		4	??				0.0172	6	0.0197	0.00965	0.0013	0.00877

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
American Cyanamid Co.	Kalamazoo, MI					5					0.0158					
American Cyanamid Co.	Kalamazoo, MI					6					0.0197					
American Cyanamid Co.	Kalamazoo, MI					1					0.0022					
American Cyanamid Co.	Kalamazoo, MI					2					0.0013					
American Cyanamid	Kalamazoo, MI					3					0.0017					
Angus Chemical	Sterlington, LA	4	May-93	Boiler		1	??				0.0026	3	0.0026	0.00180	0.0014	0.00069
Angus Chemical	Sterlington, LA			(Watertube)		2					0.0014					
Angus Chemical	Sterlington, LA					4					0.0014					
Angus Chemical	Sterlington, LA	7	Apr-93	Boiler		4	??				0.0011	3	0.0024	0.00157	0.0011	0.00072
Angus Chemical	Sterlington, LA			(Watertube)		5					0.0012					
Angus Chemical	Sterlington, LA					6					0.0024					
ARCO	Channelview, TX	Boiler 1	Dec-92	Boiler		1	None				0.0033	3	0.0052	0.00397	0.0033	0.00107
ARCO	Channelview, TX					2					0.0052					
ARCO	Channelview, TX					3					0.0034					
ARCO	Channelview, TX	Boiler 2	Aug-92	Boiler	Refinery Gas	8	None	4.52			0.0036	3	0.0054	0.00397	0.0029	0.00129
ARCO	Channelview, TX					9		4.62			0.0029					
ARCO	Channelview, TX					10		4.89			0.0054					
ARCO	Channelview, TX	F-57180	Dec-92	Furnace		1	None				0.002	3	0.0048	0.00307	0.002	0.00151
ARCO	Channelview, TX					2					0.0048					
ARCO	Channelview, TX					3					0.0024					
ARCO	Channelview, TX	F-630	Aug-92	Furnace	Refinery Gas	1	None	7.64			0.0023	3	0.0032	0.00277	0.0023	0.00045
ARCO	Channelview, TX					2		7.72			0.0028					
ARCO	Channelview, TX					3		7.55			0.0032					
ARCO	Channelview, TX	F-57180	Aug-92	Furnace	Refinery Gas	4	None	7.86			0.0096	4	0.0127	0.01078	0.0099	0.00140
ARCO	Channelview, TX					5		7.16			0.0127					
ARCO	Channelview, TX					6		6.75			0.0109					
ARCO	Channelview, TX					7		5.88			0.0099					
Arkansas Eastman	Magness, AR	1	May-92	Boiler	Coal	H-1	??	7.5			0.0278	6	0.034	0.02270	0.0149	0.00695
Arkansas Eastman	Magness, AR					H-1		7.6			0.0187					
Arkansas Eastman	Magness, AR					H:1-3**					0.0198					
Arkansas Eastman	Magness, AR					M-1		7.5			0.034					
Arkansas Eastman	Magness, AR					M-2		7.6			0.0149					
Arkansas Eastman	Magness, AR					M-3		7.5			0.021					
Arkansas Eastman	Magness, AR					H-3*		7.5			0.0131					
Arizona Chemical Co.	Gulfport, MS	1	Aug-92	Boiler	Oils &	1A	None	10.1			0.004	13	0.024	0.01608	0.004	0.00492
Arizona Chemical Co.	Gulfport, MS				Solvent	1A2		10.5			0.022					
Arizona Chemical Co.	Gulfport, MS					1B		11			0.014					
Arizona Chemical Co.	Gulfport, MS					1C		11			0.016					
Arizona Chemical Co.	Gulfport, MS					2A		9.5			0.015					
Arizona Chemical Co.	Gulfport, MS					2B		9.5			0.014					

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
Arizona Chemical Co.	Gulfport, MS					2C		11.5			0.018					
Arizona Chemical Co.	Gulfport, MS					3A		11			0.019					
Arizona Chemical Co.	Gulfport, MS					3B		11.3			0.024					
Arizona Chemical Co.	Gulfport, MS					3C		11..2			0.02					
Arizona Chemical Co.	Gulfport, MS					4A		7.2			0.014					
Arizona Chemical Co.	Gulfport, MS					4B		7.4			0.014					
Arizona Chemical Co.	Gulfport, MS					4C		7.1			0.015					
Arizona Chemical Co.	Panama City, FL	2	Aug-92	Boiler (Waste)	Natural Gas	1-A	None	6.4			0.018	12	0.057	0.04025	0.016	0.01329
Arizona Chemical Co.	Panama City, FL					1-B		6.4			0.016					
Arizona Chemical Co.	Panama City, FL					1-C		6.8			0.038					
Arizona Chemical Co.	Panama City, FL					2-A		6.3			0.031					
Arizona Chemical Co.	Panama City, FL					2-B		6.5			0.037					
Arizona Chemical Co.	Panama City, FL					2-C		6.5			0.054					
Arizona Chemical Co.	Panama City, FL					3-A		5.5			0.046					
Arizona Chemical Co.	Panama City, FL					3-B		5.5			0.04					
Arizona Chemical Co.	Panama City, FL					3-C		5.7			0.057					
Arizona Chemical Co.	Panama City, FL					4-A		5.04			0.045					
Arizona Chemical Co.	Panama City, FL					4-B		5.4			0.047					
Arizona Chemical Co.	Panama City, FL					4-C		5.4			0.054					
BASF Corp.	Freeport, TX	1	Aug-92	Boiler (NEOL)	Liquid Waste	C1-R1	None	6			0.0049	12	0.0216	0.01398	0.0042	0.00738
BASF Corp.	Freeport, TX					C1-R2		5.6			0.0043					
BASF Corp.	Freeport, TX					C1-R3		6			0.0042					
BASF Corp.	Freeport, TX					C2-R1		4.2			0.0216					
BASF Corp.	Freeport, TX					C2-R2		4.6			0.0215					
BASF Corp.	Freeport, TX					C2-R3		4.4			0.0184					
BASF Corp.	Freeport, TX					C3-R1		4.2			0.0111					
BASF Corp.	Freeport, TX					C3-R2		4.4			0.0107					
BASF Corp.	Freeport, TX					C3-R3		3.6			0.0084					
BASF Corp.	Freeport, TX					C4-R1		4			0.0208					
BASF Corp.	Freeport, TX					C4-R2		4.6			0.021					
BASF Corp.	Freeport, TX					C3-R3		4.4			0.0208					
BASF Corp.	Geismar, LA	Amines	Aug-92	Boiler	Waste Fuel	1	None				0.0065	4	0.0065	0.00418	0.0025	0.00168
BASF Corp.	Geismar, LA					2					0.0025					
BASF Corp.	Geismar, LA					3					0.0038					
BASF Corp.	Geismar, LA					4					0.0039					
BASF Corp.	Geismar, LA	3	Aug-92	Boiler (Watertube)	Natural Gas	1	None	4			0.0044	3	0.0044	0.00317	0.002	0.00120
BASF Corp.	Geismar, LA					2		4			0.0031					
BASF Corp.	Geismar, LA					3		4			0.002					
BASF Corp.	Geismar, LA	6	Aug-92	Boiler (Firetube)	Natural Gas	1	None	4			0.0014	3	0.0019	0.00153	0.0013	0.00032
BASF Corp.	Geismar, LA					2		4.5			0.0019					
BASF Corp.	Geismar, LA					3		4.2			0.0013					
Bostik, Inc.	Middleton, MA	1	Dec-92	Boiler	Fuel Oil	1	??	5.3			0.0107	3	0.0107	0.00853	0.0055	0.00271
Bostik, Inc.	Middleton, MA					2		4.8			0.0094					

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
Bostik, Inc.	Middleton, MA					3		6.2			0.0055					
BP Chemicals	Port Lavaca, TX	2	Aug-92	Boiler	Fuel Gas	1	??	1.8			0.001857	3	0.002271	0.00173	0.001066	0.00061
BP Chemicals	Port Lavaca, TX					2		1.9			0.002271					
BP Chemicals	Port Lavaca, TX					3		1.8			0.001066					
Diversified Scientific Systems	Kingston, TN	1	Aug-93	Boiler	Liquid Wastes	1	SD/FF/				0.00025	3	0.00075	0.00043	0.00025	0.00028
Diversified Scientific Systems	Kingston, TN			(Firetube)		2	WS/HEPA				0.00029					
Diversified Scientific Systems	Kingston, TN					3					0.00075					
Dow Chemical	Freeport, TX	F-2A/B	Aug-92	Boiler	Fuel Gas	1	WS				0.016	3	0.016	0.01033	0.004	0.00603
Dow Chemical	Freeport, TX			(Firetube)		2					0.004					
Dow Chemical	Freeport, TX					3					0.011					
Dow Chemical	Freeport, TX	F-210	Aug-92	Boiler	Natural Gas	1	WS				0.017	3	0.017	0.00900	0.003	0.00721
Dow Chemical	Freeport, TX					2					0.007					
Dow Chemical	Freeport, TX					3					0.003					
Dow Chemical	Freeport, TX	FTB-400	Aug-92	Boiler	Fuel gas	1	WS				0.003	3	0.003	0.00300	0.003	0.00000
Dow Chemical	Freeport, TX			(Firetube)		2					0.003					
Dow Chemical	Freeport, TX					3					0.003					
Dow Chemical	Freeport, TX	F-820A	Aug-92	Boiler		1	WS				0.006	3	0.006	0.00600	0.006	0.00000
Dow Chemical	Freeport, TX			(Firetube)		2					0.006					
Dow Chemical	Freeport, TX					3					0.006					
Dow Chemical	Freeport, TX	B-901	Aug-92	Boiler	Natural Gas	1	WS				0.002	3	0.011	0.00500	0.002	0.00520
Dow Chemical	Freeport, TX			(Watertube)		2					0.002					
Dow Chemical	Freeport, TX					3					0.011					
Dow Chemical	Freeport, TX	B-902	Aug-92	Boiler	Natural Gas	1	WS				0.009	3	0.009	0.00767	0.006	0.00153
Dow Chemical	Freeport, TX			(Watertube)		2					0.006					
Dow Chemical	Freeport, TX					3					0.008					
Dow Chemical	Freeport, TX	B-903	Aug-92	Boiler	Natural Gas	1	WS				0.003	3	0.009	0.00500	0.003	0.00346
Dow Chemical	Freeport, TX			(Watertube)		2					0.003					
Dow Chemical	Freeport, TX					3					0.009					
Dow Chemical	Gales Ferry, CT	A	Aug-92	Heater	Fuel oil	1	None				0.0035	3	0.0035	0.00240	0.0014	0.00105
Dow Chemical	Gales Ferry, CT					2					0.0014					
Dow Chemical	Gales Ferry, CT					3					0.0023					
Dow Chemical	Ironton, OH	1	Aug-92	Boiler	Oil	1	None				0.0013	3	0.0019	0.00143	0.0011	0.00042
Dow Chemical	Ironton, OH					2					0.0011					
Dow Chemical	Ironton, OH					3					0.0019					
Dow Chemical	Midland, MI	1142	Aug-92	Boiler	Natural Gas	1	None				0.0316	3	0.0316	0.01820	0.0098	0.01173
Dow Chemical	Midland, MI					2					0.0132					

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Dow Chemical	Midland, MI					3					0.0098					
Dow Chemical	Midland, MI	1276	Aug-92	Boiler	Natural Gas	1	None				0.0009	3	0.0016	0.00123	0.0009	0.00035
Dow Chemical	Midland, MI					2					0.0016					
Dow Chemical	Midland, MI					3					0.0012					
Dow Chemical	Plaquemine, LA	F-410	Aug-92	Boiler		1	??				0.0028	3	0.0028	0.00343	0.0028	0.00057
Dow Chemical	Plaquemine, LA			(Firetube)		2					0.0039					
Dow Chemical	Plaquemine, LA					3					0.0036					
Dow Chemical	Plaquemine, LA	R-4	Aug-92	Boiler		1	??				0.014	3	0.025	0.01800	0.014	0.00608
Dow Chemical	Plaquemine, LA			(Firetube)		2					0.025					
Dow Chemical	Plaquemine, LA					3					0.015					
Dow Chemical	Plaquemine, LA	R-750	Aug-92	Boiler		1	??				0.072	3	0.072	0.05933	0.053	0.01097
Dow Chemical	Plaquemine, LA			(Firetube)		2					0.053					
Dow Chemical	Plaquemine, LA					3					0.053					
DSM Chemicals	Augusta, GA	H-002	Jul-92	Boiler		1	??				0.0053	3	0.0053	0.00443	0.0039	0.00076
DSM Chemicals	Augusta, GA					2					0.0039					
DSM Chemicals	Augusta, GA					3					0.0041					
DSM Chemicals	Augusta, GA	H-2002	Jul-92	Boiler		1	??				0.0016	3	0.0036	0.00210	0.0011	0.00132
DSM Chemicals	Augusta, GA					2					0.0036					
DSM Chemicals	Augusta, GA					3					0.0011					
DSM Chemicals	Addis, LA	3	Aug-93	Boiler	Natural Gas	1	None				0.000092	3	0.000605	0.00035	0.000092	0.00026
DSM Chemicals	Addis, LA					2					0.000605					
DSM Chemicals	Addis, LA					3					0.000341					
Dupont	Axis, AL	1	Aug-93	Boiler (VGI)		1	WS				0.0332	3	0.0405	0.03733	0.0332	0.00374
Dupont	Axis, AL					2					0.0405					
Dupont	Axis, AL					3					0.0383					
Dupont	Beaumont, TX	6	Aug-92	Boiler		1	??	2.7			0.0067	3	0.0075	0.00707	0.0067	0.00040
Dupont	Beaumont, TX					2		2.6			0.007					
Dupont	Beaumont, TX					3		2.8			0.0075					
Dupont	Belle, WV	1	Aug-92	Boiler	Coal	1	??	12.16			0.0011	3	0.0013	0.00117	0.0011	0.00012
Dupont	Belle, WV					2		14.22			0.0011					
Dupont	Belle, WV					3		13.91			0.0013					
Dupont	Orange, TX	"#7"	Aug-92	Boiler	waste + NG	1	None	7.1			0.0103	3	0.0112	0.00973	0.0077	0.00182
Dupont	Orange, TX					2		7.6			0.0077					
Dupont	Orange, TX					1-3**					0.0112					
Dupont	Orange, TX					3*		9.1			0.0222					
Dupont	Orange, TX	"#8"	Aug-92	Boiler	waste + NG	1	None	10.3			0.0481	3	0.0481	0.02730	0.008	0.02009
Dupont	Orange, TX					2		11.3			0.008					

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Dupont	Orange, TX					1-3**					0.0258					
Dupont	Orange, TX					3*		9.3			0.0145					
Dupont	Orange, TX	North	Aug-92	Boiler (ADN)	ADN + NG	1	None	12.6			0.033	3	0.033	0.02783	0.0195	0.00729
Dupont	Orange, TX					2		12			0.031					
Dupont	Orange, TX					3		12.7			0.0195					
Dupont	Orange, TX	South	Aug-92	Boiler (ADN)	ADN + NG	1	None	9.3			0.005	3	0.005	0.00400	0.003	0.00100
Dupont	Orange, TX					2		9.4			0.004					
Dupont	Orange, TX					3		9.4			0.003					
EPI	Toledo, OH	1	Aug-93	Boiler	Natural Gas	A-1	None				0.0185	3	0.0185	0.01600	0.014	0.00229
EPI	Toledo, OH					A-2					0.0155					
EPI	Toledo, OH					A-3					0.014					
EPI	Toledo, OH	2	Aug-93	Boiler	Natural Gas	B-1	None				0.0013	3	0.0013	0.00120	0.001	0.00017
EPI	Toledo, OH					B-2					0.0013					
EPI	Toledo, OH					B-3					0.001					
Ethyl Corp.	Orangeburg, SC	"4"	Aug-93	Boiler	Waste liquid	MIN 1	FF	10.06	341		0.002	6	0.0027	0.00157	0.001	0.00067
Ethyl Corp.	Orangeburg, SC					MIN 2		10.13	340		0.0027					
Ethyl Corp.	Orangeburg, SC					MIN 3		9.87	341		0.0015					
Ethyl Corp.	Orangeburg, SC					MAX 1		4	420		0.001					
Ethyl Corp.	Orangeburg, SC					MAX 2		3.93	421		0.0012					
Ethyl Corp.	Orangeburg, SC					MAX 3		4.2	423		0.001					
Exxon Chemical	Baton Rouge, LA	"C"	Aug-92	Boiler	Waste Liquid	1	None	9.2			0.0016	3	0.0021	0.00187	0.0016	0.00025
Exxon Chemical	Baton Rouge, LA			(Watertube)		2		9.2			0.0021					
Exxon Chemical	Baton Rouge, LA					3		9.6			0.0019					
Exxon Chemical	Baton Rouge, LA	"D"	Aug-92	Boiler	Waste Liquid	1	None	3.6			0.0035	3	0.0035	0.00280	0.0024	0.00061
Exxon Chemical	Baton Rouge, LA			(Watertube)		2		3.8			0.0024					
Exxon Chemical	Baton Rouge, LA					3		5.5			0.0025					
FINA Oil	Deer Park, TX	1	Oct-92	Boiler	Waste	c1-r1	VS	15.5			0.0574	9	0.0574	0.04401	0.0324	0.00821
FINA Oil	Deer Park, TX			(Waste Heat)	Polymer	c1-r2		16			0.0537					
FINA Oil	Deer Park, TX				Gasses	c1-r3		15			0.0437					
FINA Oil	Deer Park, TX					c2-r1		15.5			0.0402					
FINA Oil	Deer Park, TX					c2-r2		13.5			0.0324					
FINA Oil	Deer Park, TX					c2-r3		12.5			0.0348					
FINA Oil	Deer Park, TX					c3-r1		15.5			0.043					
FINA Oil	Deer Park, TX					c3-r2		15.5			0.0418					
FINA Oil	Deer Park, TX					c3-r3		15.5			0.0491					
General Electric Plastics	Mount Vernon, IN	"A"	Feb-93	Boiler	NG + Phenol	1	None	13.5			0.057	4	0.078	0.05967	0.044	0.01716
General Electric Plastics	Mount Vernon, IN					2		12.8			0.044					
General Electric Plastics	Mount Vernon, IN					1-3**					0.078					
General Electric Plastics	Mount Vernon, IN					3*		13.8			0.101					

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General Electric Plastics	Mount Vernon, IN	"B"	Feb-93	Boiler	NG +phenol	1	None	9.3			0.0505	6	0.0769	0.05083	0.033	0.018Q8
General Electric Plastics	Mount Vernon, IN					2		7.5			0.0415					
General Electric Plastics	Mount Vernon, IN					1-3**					0.0769					
General Electric Plastics	Mount Vernon, IN					5		13			0.035					
General Electric Plastics	Mount Vernon, IN					6		13			0.033					
General Electric Plastics	Mount Vernon, IN					4-6**					0.0681					
General Electric Plastics	Mount Vernon, IN					3*		10			0.133					
General Electric Plastics	Mount Vernon, IN					4*		13.5			0.13					
General Electric Plastics	Selkirk, NY	3	Aug-92	Boiler	Natural Gas	1	None	2.1			0.078	3	0.078	0.05633	0.043	0.01893
General Electric Plastics	Selkirk, NY					2		5.4			0.043					
General Electric Plastics	Selkirk, NY					3		4.3			0.048					
General Electric Plastics	Selkirk, NY	1	Aug-92	A/P Oil Heater	Natural Gas	1	None	8			0.032	3	0.032	0.02233	0.013	0.00950
General Electric Plastics	Selkirk, NY					2		7			0.022					
General Electric Plastics	Selkirk, NY					3		7.5			0.013					
Georgia Gulf	Pasadena, TX	1	Aug-92	Hot Oil Heater		1-1	None	1.1			0.0174	6	0.0174	0.01070	0.0059	0.00514
Georgia Gulf	Pasadena, TX					1-2		1.2			0.0132					
Georgia Gulf	Pasadena, TX					1:1-3**					0.0151					
Georgia Gulf	Pasadena, TX					2-1		1			0.0063					
Georgia Gulf	Pasadena, TX					2-2		1			0.0063					
Georgia Gulf	Pasadena, TX					2-3		1			0.0059					
Georgia Gulf	Pasadena, TX					1-3*		1.3			0.0113					
Georgia Gulf	Plaquemine, LA	1	Aug-92	Boiler	Natural Gas	1	None				0.0504	3	0.0521	0.05143	0.0504	0.00091
Georgia Gulf	Plaquemine, LA					2					0.0518					
Georgia Gulf	Plaquemine, LA					1-3**					0.0521					
Georgia Gulf	Plaquemine, LA					3*					0.0552					
Goodyear Tire and Rubber	Beaumont, TX	B103	Aug-92	Boiler	Natural Gas	1-1	None	6.5			0.014	3	0.047	0.02467	0.013	0.01935
Goodyear Tire and Rubber	Beaumont, TX					1-2		6.5			0.013					
Goodyear Tire and Rubber	Beaumont, TX					1-3		6.5			0.047					
Goodyear Tire and Rubber	Pasadena, TX	M-526	May-93	Boiler	Natural Gas	1	None	6.3			0.0086	3	0.0086	0.00710	0.0055	0.00155
Goodyear Tire and Rubber	Pasadena, TX					2		6.2			0.0055					
Goodyear Tire and Rubber	Pasadena, TX					1-3**					0.0072					
Goodyear Tire and Rubber	Pasadena, TX					3*		6.5			0.0082					
Hercules	West Elizabeth, PA	3	Aug-92	Boiler	Natural Gas	1	None	12.8			0.0232	3	0.0286	0.02460	0.022	0.00352
Hercules	West Elizabeth, PA					3		12.6			0.0286					
Hercules	West Elizabeth, PA					1-3**					0.022					
Hercules	West Elizabeth, PA					2*		12.7			0.0485					
Hercules	West Elizabeth, PA	5	Aug-92	Boiler	Natural Gas	1	None	3.5			0.006	3	0.025	0.01507	0.006	0.00953
Hercules	West Elizabeth, PA					2		3.1			0.0142					
Hercules	West Elizabeth, PA					1-3**					0.025					
Hercules	West Elizabeth, PA					3*		4.2			0.0164					

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Hoechst Celanese	Pasadena, TX	MH5A	Jan-93	Heater	Natural Gas	A-1	None	9.7			0.0021	9	0.0056	0.00281	0.0008	0.00185
Hoechst Celanese	Pasadena, TX					A-2		10			0.0034					
Hoechst Celanese	Pasadena, TX					A-3		10.1			0.0016					
Hoechst Celanese	Pasadena, TX					B-1		5.9			0.005					
Hoechst Celanese	Pasadena, TX					B-2		5.8			0.0045					
Hoechst Celanese	Pasadena, TX					B-3		6.6			0.0056					
Hoechst Celanese	Pasadena, TX					C-1		6.4			0.0012					
Hoechst Celanese	Pasadena, TX					C-2		6.6			0.0011					
Hoechst Celanese	Pasadena, TX					C-3		5.8			0.0008					
Hoechst Celanese Chemical	Bay City, TX	4	Aug-92	Boiler	Natural Gas	4	None	6.6			0.022	4	0.0235	0.02110	0.0156	0.00373
Hoechst Celanese Chemical	Bay City, TX					5		5.7			0.0233					
Hoechst Celanese Chemical	Bay City, TX					6		6.3			0.0235					
Hoechst Celanese Chemical	Bay City, TX					7		7.5			0.0156					
Hoechst Celanese Chemical	Bay City, TX	5	Aug-92	Boiler	Natural Gas	1	None	4.8			0.0165	3	0.0165	0.01447	0.0125	0.00200
Hoechst Celanese Chemical	Bay City, TX					2		5.2			0.0125					
Hoechst Celanese Chemical	Bay City, TX					3		5.2			0.0144					
Hoechst Celanese Chemical	Mount Holly, NC	1	Aug-93	Boiler	Natural Gas	1	None	6.85			0.00011	3	0.044	0.01534	0.00011	0.02484
Hoechst Celanese Chemical	Mount Holly, NC	--				2		7.25			0.0019					
Hoechst Celanese Chemical	Mount Holly, NC					3		7.4			0.044					
Hulls America	Chestertown, ML	1	Nov-92	Heater	Oil	1	None	9.4			0.031	3	0.0733	0.04427	0.0285	0.02517
Hulls America	Chestertown, ML					2		9.5			0.0285					
Hulls America	Chestertown, ML					3		9.3			0.0733					
Hulls America	Chestertown, ML	2	Nov-92	Heater	Oil	1	None	7.5			0.032	4	0.032	0.02825	0.026	0.00263
Hulls America	Chestertown, ML					2		7.1			0.026					
Hulls America	Chestertown, ML					3		7.1			0.028					
Hulls America	Chestertown, ML					4		7.1			0.027					
Hulls America	Chestertown, ML	3	Nov-92	Heater	Oil	1	None	10			0.0317	3	0.0317	0.01830	0.0097	0.01176
Hulls America	Chestertown, ML					2		10.4			0.0135					
Hulls America	Chestertown, ML					3		9.9			0.0097					
Hulls America	Chestertown, ML	4	Nov-92	Boiler	Oil	1	None	4.3			0.0153	3	0.0153	0.01367	0.0018	0.00176
Hulls America	Chestertown, ML					2		4.4			0.0118					
Hulls America	Chestertown, ML					3		4.3			0.0139					
Kalama Chemical	Kalama, WA	U2	Jun-92	Boiler	Natural Gas	1	FF				0.0059	6	0.0072	0.00460	0.0027	0.00174
Kalama Chemical	Kalama, WA					2					0.0047					
Kalama Chemical	Kalama, WA					1-3**					0.0072					
Kalama Chemical	Kalama, WA					10					0.0029					
Kalama Chemical	Kalama, WA					11					0.0027					
Kalama Chemical	Kalama, WA					10-12**					0.0042					
Kalama Chemical	Kalama, WA					3*					0.011					
Kalama Chemical	Kalama, WA					12*					0.0069					

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
Kalama Chemical	Kalama, WA	U3	Jun-92	Boiler	Natural Gas	4	FF				0.0067	6	0.0073	0.00532	0.0036	0.00147
Kalama Chemical	Kalama, WA					5					0.0043					
Kalama Chemical	Kalama, WA					4-6**					0.0073					
Kalama Chemical	Kalama, WA					7					0.0044					
Kalama Chemical	Kalama, WA					8					0.0036					
Kalama Chemical	Kalama, WA					7-9**					0.0056					
Kalama Chemical	Kalama, WA					6*					0.011					
Kalama Chemical	Kalama, WA					9*					0.0088					
Lonza Inc.	Pasadena, TX	2 or B	Dec-92	Boiler	Natural Gas	C1-R1	??	3.6			0.0137	6	0.0137	0.00930	0.0069	0.00250
Lonza Inc.	Pasadena, TX					C1-R2		3.4			0.0099					
Lonza Inc.	Pasadena, TX					C1-R3		3.4			0.0081					
Lonza Inc.	Pasadena, TX					C2-R1		3.6			0.0099					
Lonza Inc.	Pasadena, TX					C2-R2		3.6			0.0073					
Lonza Inc.	Pasadena, TX					C2-R3		3.4			0.0069					
Lonza Inc.	Pasadena, TX	1 or A	Dec-92	Boiler	Natural Gas	C1-R1	??	2.6			0.0408	6	0.0409	0.02865	0.0153	0.01095
Lonza Inc.	Pasadena, TX					C1-R2		2.6			0.0296					
Lonza Inc.	Pasadena, TX					C1-R3		2.6			0.0409					
Lonza Inc.	Pasadena, TX					C2-R1		3.8			0.0277					
Lonza Inc.	Pasadena, TX					C2-R2		3.8			0.0153					
Lonza Inc.	Pasadena, TX					C2-R3		3.8			0.0176					
Lyondell Petrochem Co.	Channelview, TX	4	Nov-92	Boiler	Waste Oils	C1-1	None	6.2			0.007142	6	0.007142	0.00339	0.00082	0.00275
Lyondell Petrochem Co.	Channelview, TX					C1-2		7.3			0.004031					
Lyondell Petrochem Co.	Channelview, TX					C1:1-3**					0.006					
Lyondell Petrochem Co.	Channelview, TX					C2-1	None	5.4			0.00082					
Lyondell Petrochem Co.	Channelview, TX					C2-2		6			0.0013					
Lyondell Petrochem Co.	Channelview, TX					C2-3		5.4			0.00104					
Lyondell Petrochem Co.	Channelview, TX					C1-3*		7.2			0.02561					
Mallinckrodt	Raleigh, NC	1	Sep-92	Boiler (Watertube)	Aniline Tar	1	??	3.1			0.00336	3	0.00445	0.00391	0.00336	0.00055
Mallinckrodt	Raleigh, NC					2		3.1			0.00393					
Mallinckrodt	Raleigh, NC					3		3.3			0.00445					
Maybelline Products Co. Inc.	North Little Rock, AR	TO4	Aug-92	Boiler		1.1	??	10.2			0.094	6	0.094	0.08267	0.072	0.00745
Maybelline Products Co. Inc.	North Little Rock, AR					1.2		11.2			0.087					
Maybelline Products Co. Inc.	North Little Rock, AR					1.3		12			0.083					
Maybelline Products Co. Inc.	North Little Rock, AR					2.2		9.9			0.081					
Maybelline Products Co. Inc.	North Little Rock, AR					2.3		11.65			0.072					
Maybelline Products Co. Inc.	North Little Rock, AR					2.4		10.8			0.079					
Mayo Clinic	Rochester, MN	3	Nov-92	Boiler (Watertube)	Natural Gas/ Fuel Oil	1	None				0.00282	3	0.00282	0.00246	0.00186	0.00052
Mayo Clinic	Rochester, MN					2					0.00186					
Mayo Clinic	Rochester, MN					3					0.0027					
Merck & Co. Inc.	Rahway, NJ	7	Jul-93	Boiler	Natural Gas/ Waste Solvent	1	??				0.00797	3	0.0101	0.00820	0.00797	0.00022
Merck & Co. Inc.	Rahway, NJ					2					0.00841					

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
Merck & Co. Inc.	Rahway, NJ					1-3**					0.00821					
Merck & Co. Inc.	Rahway, NJ					3*					0.0101					
Merck & Co. Inc.	Rahway, NJ	8	Jul-93	Boiler	Natural Gas/	1	??				0.00996	3	0.00996	0.00781	0.00566	0.00215
Merck & Co. Inc.	Rahway, NJ				Waste Solvent	2					0.00566					
Merck & Co. Inc.	Rahway, NJ					1-3**					0.00782					
Merck & Co. Inc.	Rahway, NJ					3*					0.0104					
Merichem Co.	Houston, TX	4	Sep-92	Boiler	Natural Gas/	N-1	WS				0.0042	6	0.0105	0.00452	0.0021	0.00302
Merichem Co.	Houston, TX				Liquid Waste	N-2					0.0031					
Merichem Co.	Houston, TX					N-3					0.0021					
Merichem Co.	Houston, TX					R-4					0.0033					
Merichem Co.	Houston, TX					R-5					0.0039					
Merichem Co.	Houston, TX					R-6					0.0105					
Mobile Chemical	Beaumont, TX	B 701 A	Aug-92	Boiler	Natural Gas	1	None	2.6			0.0073	3	0.0122	0.00793	0.0043	0.00399
Mobile Chemical	Beaumont, TX					2		2.5			0.0122					
Mobile Chemical	Beaumont, TX					3		2.5			0.0043					
Monsanto Chemical Co.	Addyston, OH	B - 4	Aug-92	Boiler	Natural Gas	1	None	10			0.00242	3	0.00374	0.00303	0.00242	0.00067
Monsanto Chemical Co.	Addyston, OH					2		10.1			0.00292					
Monsanto Chemical Co.	Addyston, OH					1-3**					0.00374					
Monsanto Chemical Co.	Addyston, OH					3*		10			0.00918					
Monsanto Chemical Co.	Alvin, TX	B51H5	Apr-93	Boiler	Natural Gas	C1-R1	None	8			0.0004	6	0.0006	0.00033	0.0002	0.00015
Monsanto Chemical Co.	Alvin, TX					C1-R2		7.1			0.0003					
Monsanto Chemical Co.	Alvin, TX					C1-R3		7.3			0.0006					
Monsanto Chemical Co.	Alvin, TX					C2-R1		7.6			0.0002					
Monsanto Chemical Co.	Alvin, TX					C2-R2		8.4			0.0003					
Monsanto Chemical Co.	Alvin, TX					C2-R3		9.8			0.0002					
Monsanto Chemical Co.	Alvin, TX	30H5	Aug-92	Boiler	Natural Gas	C1- R1	None	6			0	6	0.00026	0.00013	0	0.00017
Monsanto Chemical Co.	Alvin, TX					C1-R2		3.5			0.00041					
Monsanto Chemical Co.	Alvin, TX					C1-R3		5.2			0.00026					
Monsanto Chemical Co.	Alvin, TX					C2-R1		5.6			0.00004					
Monsanto Chemical Co.	Alvin, TX					C2-R2		5.7			0					
Monsanto Chemical Co.	Alvin, TX					C2-R3		6.3			0.00004					
Monsanto Chemical Co.	Nitro, WV	B-8	May-93	Boiler (Stoker)	Coal Fired	C1- R1	Cyclone/	12.7			0.0007	6	0.007	0.00347	0.0007	0.00229
Monsanto Chemical Co.	Nitro, WV					C1-R2	ESP	11.2			0.0015					
Monsanto Chemical Co.	Nitro, WV					C1-R3		12.2			0.0032					
Monsanto Chemical Co.	Nitro, WV					C2-R1		8.9			0.007					
Monsanto Chemical Co.	Nitro, WV					C2-R2		9.1			0.0035					
Monsanto Chemical Co.	Nitro, WV					C2-R3		9			0.0049					
Monsanto Chemical Co.	Springfield , MA	B-11	Jan-93	Boiler (Stoker)	Coal Fired	1	FF	10.2			0.0087	3	0.01	0.00840	0.0087	0.00177
Monsanto Chemical Co.	Springfield , MA					2		9.8			0.0065					
Monsanto Chemical Co.	Springfield , MA					3		9			0.01					

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Natural Gas Odorizing	Baytown, TX	B-2	Oct-92	Boiler	Liquid waste	1	DS/FF/WS	2			0.006	3	0.006	0.00540	0.005	0.00053
Natural Gas Odorizing	Baytown, TX					2		1.89			0.005					
Natural Gas Odorizing	Baytown, TX					1-3**					0.0052					
Natural Gas Odorizing	Baytown, TX					3*		1.91			0.0045					
Neville Chemical Co.	Pittsburgh, PA	B-4	Jul-93	Boiler	Natural Gas	1	None	4			0.0033	3	0.0074	0.00420	0.0019	0.00286
Neville Chemical Co.	Pittsburgh, PA					2		4.8			0.0019					
Neville Chemical Co.	Pittsburgh, PA					3		5.4			0.0074					
Neville Chemical Co.	Pittsburgh, PA	B-6	Jul-93	Boiler	Natural Gas	1	None	6.8			0.0023	3	0.0029	0.00227	0.0016	0.00065
Neville Chemical Co.	Pittsburgh, PA					2		5.8			0.0016					
Neville Chemical Co.	Pittsburgh, PA					3		4.8			0.0029					
Neville Chemical Co.	Pittsburgh, PA	B-7	Jul-93	Boiler	Natural Gas	1	None	4.1			0.0032	3	0.0048	0.00423	0.0032	8.96E-04
Neville Chemical Co.	Pittsburgh, PA					2		3.2			0.0048					
Neville Chemical Co.	Pittsburgh, PA					3		3.6			0.0047					
Novacar Chemicals	Decatur, AL	Line 1	May-93	Therminol	Liquid waste	1	None	7.9			0.0012	3	0.0015	0.00127	0.0011	0.00021
Novacar Chemicals	Decatur, AL			Heater		2		8.7			0.0015					
Novacar Chemicals	Decatur, AL					3		7.9			0.0011					
Novacar Chemicals	Indian Orchard, MA	1	Jun-93	Therminol	Liquid waste	1	None	11.6			0.00355	3	0.00692	0.00396	0.00142	0.00277
Novacar Chemicals	Indian Orchard, MA			Heater		2		11.6			0.00692					
Novacar Chemicals	Indian Orchard, MA					3		11.6			0.00142					
NutraSweet	Augusta, GA	2	Aug-92	Boiler	Waste fuels	1	WS	0.8			0.00481	3	0.0053	0.00491	0.00463	0.00035
NutraSweet	Augusta, GA					2		0.9			0.00463					
NutraSweet	Augusta, GA					3		0.9			0.0053					
NutraSweet	Augusta, GA	1	Aug-92	Boiler	Waste fuels	1	WS	2.8			0.0148	3	0.0153	0.01507	0.0148	0.00025
NutraSweet	Augusta, GA					2		2.5			0.0153					
NutraSweet	Augusta, GA					3		2.9			0.0151					
Parke Davis	Holland, MI	??	Aug-92	Boiler	Natural Gas/	1	??	5.5			0.0028	3	0.0028	0.00210	0.0016	0.00062
Parke Davis	Holland, MI			(Watertube)	Waste Solvent	2		5.5			0.0016					
Parke Davis	Holland, MI					3		5.5			0.0019					
Reilly Industries	Indianapolis, IN	1	Aug-93	Boiler	Natural Gas	1	None	5.22			0.0221	9	0.0337	0.02218	0.0141	0.00525
Reilly Industries	Indianapolis, IN			(Watertube)		2		4.89			0.0194					
Reilly Industries	Indianapolis, IN					1-3**					0.0337					
Reilly Industries	Indianapolis, IN					4		5.57			0.0194					
Reilly Industries	Indianapolis, IN					5		5.68			0.0141					
Reilly Industries	Indianapolis, IN					4-6**					0.0239					
Reilly Industries	Indianapolis, IN					8		4.65			0.0214					
Reilly Industries	Indianapolis, IN					10		4.59			0.0216					
Reilly Industries	Indianapolis, IN					8-10**					0.024					
Reilly Industries	Indianapolis, IN					3*		4.87			0.0822					
Reilly Industries	Indianapolis, IN					6*		5.5			0.0457					
Reilly Industries	Indianapolis, IN					9*		4.77			0.0506					

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
Shell Chemical	Deer Park, TX					3*		8.9			0.0865					
Shell Chemical	Deer Park, TX	FUT 100	May-93	Boiler	Liquid Waste	1	None				0.0163	3	0.0165	0.01580	0.0146	0.00104
Shell Chemical	Deer Park, TX					2					0.0146					
Shell Chemical	Deer Park, TX					1-3**					0.0165					
Shell Chemical	Deer Park, TX					3*					0.0187					
Shell Chemical	Deer Park, TX	FUT 130	May-93	Boiler	Liquid Waste	1	None				0.0185	3	0.0224	0.02023	0.0185	0.00199
Shell Chemical	Deer Park, TX					2					0.0198					
Shell Chemical	Deer Park, TX					1-3**					0.0224					
Shell Chemical	Deer Park, TX					3*					0.0288					
Shell Oil	Martinez, CA	Co #2	Nov-91	Boiler (CO)	Refinery Gas	A-1	ESP	5.7			0.0028	7	0.0028	0.00221	0.0014	0.00050
Shell Oil	Martinez, CA					A-2		5.4			0.0027					
Shell Oil	Martinez, CA					A-3		5.2			0.0022					
Shell Oil	Martinez, CA					A-4		5.3			0.0025					
Shell Oil	Martinez, CA					B-1		2			0.0021					
Shell Oil	Martinez, CA					B-2		2			0.0018					
Shell Oil	Martinez, CA					B-3		1.9			0.0014					
Shell Oil	Martinez, CA	Co#1	Apr-89	Boiler (CO)		1	ESP				0.286	9	0.286	0.05133	0.011	0.08934
Shell Oil	Martinez, CA					2					0.06					
Shell Oil	Martinez, CA					3					0.017					
Shell Oil	Martinez, CA					4B					0.013					
Shell Oil	Martinez, CA					5					0.025					
Shell Oil	Martinez, CA					6					0.011					
Shell Oil	Martinez, CA					7					0.013					
Shell Oil	Martinez, CA					8					0.026					
Shell Oil	Martinez, CA					9					0.011					
Sterling Chemicals	Texas City, TX	WOB 1	Aug-92	Boiler	Vent Gas	1	None				0.002	3	0.007	0.00500	0.002	0.00265
Sterling Chemicals	Texas City, TX					2					0.006					
Sterling Chemicals	Texas City, TX					3					0.007					
Sterling Chemicals	Texas City, TX	UB 9	Aug-93	Boiler	Natural Gas	A-1	None	7.4			0.0092	3	0.0138	0.01060	0.0088	0.00278
Sterling Chemicals	Texas City, TX					A-3		7.4			0.0088					
Sterling Chemicals	Texas City, TX					A:1-3**					0.0138					
Sterling Chemicals	Texas City, TX					A-2*		7.4			0.00234					
Sterling Pharmaceutical	Barceloneta,PR	1	Aug-93	Boiler	Natural Gas	B1-1	None	6.9			0.0321	9	0.0382	0.03480	0.0285	0.00303
Sterling Pharmaceutical	Barceloneta,PR					B1-2		8.3			0.037					
Sterling Pharmaceutical	Barceloneta,PR					B1-3		7.3			0.0371					
Sterling Pharmaceutical	Barceloneta,PR					B2-2		4.3			0.0342					
Sterling Pharmaceutical	Barceloneta,PR					B2-3		4.8			0.0382					
Sterling Pharmaceutical	Barceloneta,PR					B2-4		5.6			0.0367					
Sterling Pharmaceutical	Barceloneta,PR					B3-1		7.3			0.0341					
Sterling Pharmaceutical	Barceloneta,PR					B3-2		9.1			0.0353					
Sterling Pharmaceutical	Barceloneta,PR					B3-3		8.2			0.0285					

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Tennessee Eastman	Kingsport, TN	30	Aug-92	Boiler	Coal Fired	1	ESP	4.4	339	266	0.0095	3	0.0095	0.00907	0.0087	0.00040
Tennessee Eastman	Kingsport, TN					2		5.2	351	255	0.0087					
Tennessee Eastman	Kingsport, TN					1-3**					0.009					
Tennessee Eastman	Kingsport, TN					3*		4.8	347	262	0.0086					
Tennessee Eastman	Kingsport, TN	30	Aug-92	Boiler	Coal Fired	1	ESP	5.5	351	257	0.031	3	0.0675	0.04893	0.031	0.01826
Tennessee Eastman	Kingsport, TN					2		5.8	353	257	0.0675					
Tennessee Eastman	Kingsport, TN					1-3**					0.0483					
Tennessee Eastman	Kingsport, TN					3*		6	349	256	0.0466					
Tennessee Eastman	Kingsport, TN	30	Aug-92	Boiler	Coal Fired	1	ESP	5.6	351	256	0.0061	3	0.0061	0.00593	0.0057	0.00021
Tennessee Eastman	Kingsport, TN					2		5.2	354	256	0.0057					
Tennessee Eastman	Kingsport, TN					1-3**					0.006					
Tennessee Eastman	Kingsport, TN					3*		5.2	356	258	0.0064					
Tennessee Eastman	Kingsport, TN	21	Apr-91	Boiler	Coal Fired	1	ESP	6.8	295.6	*161.3	0.0174	3	0.0184	0.01720	0.0158	0.00131
Tennessee Eastman	Kingsport, TN					2		6.7	298.7	*158.5	0.0158					
Tennessee Eastman	Kingsport, TN					3		6.7	298.4	*157.3	0.0184					
Tennessee Eastman	Kingsport, TN	19	Aug-92	Boiler	Coal Fired	1	ESP	10	441	168	0.0562	3	0.0562	0.05420	0.0527	0.00180
Tennessee Eastman	Kingsport, TN					2		10	443	168	0.0527					
Tennessee Eastman	Kingsport, TN					1-3**					0.0537					
Tennessee Eastman	Kingsport, TN					3*		9.8	443	169	0.0437					
Tennessee Eastman	Kingsport, TN	23	Aug-92	Boiler	Coal Fired	1	ESP	9.8	366.5	226	0.0237	3	0.0545	0.03930	0.0237	0.01540
Tennessee Eastman	Kingsport, TN					3		10	362.2	219	0.0397					
Tennessee Eastman	Kingsport, TN					1-3**					0.0545					
Tennessee Eastman	Kingsport, TN					2*		10	362.6	225	0.0909					
Tennessee Eastman	Kingsport, TN	24	Apr-91	Boiler	Coal Fired	1	ESP	8.4			0.00532	3	0.00538	0.00530	0.00521	8.62E-05
Tennessee Eastman	Kingsport, TN					2		8.4			0.00538					
Tennessee Eastman	Kingsport, TN					3		8.5			0.00521					
Texaco Chemical Co.	Port Neches, TX	2	Oct-92	Boiler	Natural Gas	a-1	None	10.2			0.00617	3	0.00617	0.00477	0.00406	0.00121
Texaco Chemical Co.	Port Neches, TX					a-2		8.6			0.00408					
Texaco Chemical Co.	Port Neches, TX					a-3		9.1			0.00406					
Union Carbide	Hahnville, LA	B 31	Jun-93	Boiler	60% H	5	None	9.48			0.018	3	0.021	0.01890	0.0177	0.00182
Union Carbide	Hahnville, LA				40% Ch4	6		9.13			0.0177					
Union Carbide	Hahnville, LA					5-7**					0.021					
Union Carbide	Hahnville, LA					7*		9.15			0.0411					
Union Carbide	Hahnville, LA	B 30	Jun-93	Boiler	60% H	2	None	2.78			0.0008	3	0.0017	0.00107	0.0007	0.00055
Union Carbide	Hahnville, LA				40% Ch4	3		2.78			0.0007					
Union Carbide	Hahnville, LA					4		2.79			0.0017					
Union Carbide	South Charleston, WV	16	Feb-93	Boiler	Coal	1	ESP	9.1		33.34	0.061	3	0.0781	0.06963	0.061	0.00855
Union Carbide	South Charleston, WV					2		8.7		32.2	0.0781					
Union Carbide	South Charleston, WV					1-3**					0.0698					

Company	Location	Unit Tested	Report Date	Facility Type	Primary Fuel	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	Particulate (gr/dscf @ 7% O2)	# points	Particulate (gr/dscf @ 7% O2) Max	Avg	Min	Sdev
Union Carbide	South Charleston, WV					2		7.9								
Union Carbide	South Charleston, WV					3		7.9								
Union Carbide	South Charleston, WV					4		8.4								
Union Carbide	South Charleston, WV					3*		9.2		29.79	0.0717					
Union Carbide	South Charleston, WV	25	Feb-93	Boiler	Coal	5	ESP	6.3		54.56	0.0075	3	0.0075	0.00703	0.0066	0.00045
Union Carbide	South Charleston, WV					7		6		50.43	0.0066					
Union Carbide	South Charleston, WV					5-7**					0.007					
Union Carbide	South Charleston, WV					6*		6		52.2	0.0063					
Union Carbide	Texas City, TX	4	Aug-93	Boiler	Natural Gas	1	None	7.77			0.0075	3	0.0597	0.02703	0.0075	0.02847
Union Carbide	Texas City, TX					2		7.75			0.0139					
Union Carbide	Texas City, TX					1-3**					0.0597					
Union Carbide	Texas City, TX					3*		8.7			0.574					
Union Carbide	Texas City, TX	5	Oct-92	Boiler	Natural Gas	1	None	6.3			0.0064	3	0.0404	0.01770	0.0063	0.01966
Union Carbide	Texas City, TX					2		6.3			0.0063					
Union Carbide	Texas City, TX					3		6.3			0.0404					
Westvaco Corp.	DeRidder, LA	B2 & B4	Aug-92	Boiler	Natural Gas	1	ESP	15.5	461	*370	0.0143	3	0.0295	0.01727	0.008	0.01105
Westvaco Corp.	DeRidder, LA					2		14.4	503	*370	0.008					
Westvaco Corp.	DeRidder, LA					3		14.5	469	*370	0.0295					
REVISED DATA 4/4/94																
Aristech	Haverhill, OH	UB	Aug-92	Boiler		LHC-1		3.29			0.0036	9	0.0159	0.00703	0.0012	0.00560
Aristech	Haverhill, OH					LHC-3		3.69			0.0012					
Aristech	Haverhill, OH					LHC:1-3**					0.0047					
Aristech	Haverhill, OH					HHC-4		3.6			0.0138					
Aristech	Haverhill, OH					HHC-6		3.72			0.0133					
Aristech	Haverhill, OH					HHC:4-6**					0.0159					
Aristech	Haverhill, OH					LHC-8		3.72			0.0033					
Aristech	Haverhill, OH					LHC-9		3.69			0.0038					
Aristech	Haverhill, OH	UE				LHC:7-9**					0.0037					
Aristech	Haverhill, OH					LHC-2*		3.48			0.0117					
Aristech	Haverhill, OH					HHC-5*		3.77			0.0231					
Aristech	Haverhill, OH					LHC-7*		3.83			0.004					
Dow Chemical	Torrance, CA	U-305	Aug-92	Boiler		2	None				0.002	3	0.0021	0.00180	0.0013	0.00044
Dow Chemical	Torrance, CA					3					0.0021					
Dow Chemical	Torrance, CA					4					0.0013					

* indicates that a soot blow was performed during this run

** Sootblow weighted average for runs indicated

?? Unable to be determined from information given

APPENDIX G:

DETAILED SUMMARY OF CURRENT TOTAL PCDD/PCDF DATA SET FOR CEMENT KILNS

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @7%O2	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev.
Ash Grove Cement Co.	Chanute, KS	2	1	Apr-92	y	w	1	ESP	10.8	422	31.96	468	68.56	4	277.3	156.2000	68.56	87.3979
Ash Grove Cement Co.	Chanute, KS				y		2	ESP	10.4	439	30.19	669	141.64					
Ash Grove Cement Co.	Chanute, KS				y		3	ESP	10.7	435	27.58	636	137.30					
Ash Grove Cement Co.	Chanute, KS				y		4	ESP	10.7	448	24.76	697	277.30					
Ash Grove Cement Co.	Chanute, KS	2	2	Mar-92	y	w	1	ESP	9.5	484	46.43	691	556.57	4	556.57	303.8175	158.84	174.7120
Ash Grove Cement Co.	Chanute, KS				y		2	ESP	10.3	412	50.55	415	229.16					
Ash Grove Cement Co.	Chanute, KS				y		3	ESP	10.6	425	38.73	665	270.70					
Ash Grove Cement Co.	Chanute, KS				y		4	ESP	10.8	412	48.18	753	158.84					
Ash Grove Cement Co.	Foreman, AR	3	1	Jul-92	y	w	1-1	ESP	8.0	387	25.2			4	874.64	327.3500	72.34	374.7511
Ash Grove Cement Co.	Foreman, AR				y		1-2	ESP	8.0	360	28.4							
Ash Grove Cement Co.	Foreman, AR				y		1-3	ESP	6.8	371	32							
Ash Grove Cement Co.	Foreman, AR				y		1-4	ESP	7.7	356	28.5							
Ash Grove Cement Co.	Foreman, AR				y		2-1	ESP	5.5	470	27.4	312	72.34					
Ash Grove Cement Co.	Foreman, AR				y		2-2	ESP	5.5	487	29.4	259	874.64					
Ash Grove Cement Co.	Foreman, AR				y		2-3	ESP	4.9	494	21.4	226	265.01					
Ash Grove Cement Co.	Foreman, AR				y		2-4	ESP	6.4	456	22.2	195	97.41					
Ash Grove Cement Co.	Foreman, AR				y		P1	ESP	7.1	408	37.5							
Ash Grove Cement Co.	Foreman, AR				y		P2	ESP	7.0	405	37.2							
Ash Grove Cement Co.	Foreman, AR				y		P3	ESP	6.0	399	37.9							
Ash Grove Cement Co.	Foreman, AR	3	2	May-92	y	w	1	ESP		500	58		62.35	3	62.35	32.2700	14.19	26.2268
Ash Grove Cement Co.	Foreman, AR				y		2	ESP		485	60		14.19					
Ash Grove Cement Co.	Foreman, AR				y		3	ESP		506	58		20.27					
Ash Grove Cement Co.	Foreman, AR	3	2	Jul-93	y	w	2	ESP		371	72.1		2.88	3	9.68	5.3200	2.88	3.7848
Ash Grove Cement Co.	Foreman, AR				y		3	ESP		365	71.8		3.40					
Ash Grove Cement Co.	Foreman, AR				y		4	ESP		373	70		9.68					
Ash Grove Cement Co.	Foreman, AR	3	3	Jul-92	y	w	2-1	ESP	5.2	475	104.5	296	160.90	3	160.9	99.7333	58.8	53.9735
Ash Grove Cement Co.	Foreman, AR				y		2-2	ESP	6.0	470	107.3	540	79.50					
Ash Grove Cement Co.	Foreman, AR				y		2-3	ESP	5.7	460	107.5	551	58.80					
Ash Grove Cement Co.	Foreman, AR				y		2-4	ESP	6.3	512	104.1							
Ash Grove Cement Co.	Foreman, AR				y		2-5	ESP	4.0	522	92.1							
Ash Grove Cement Co.	Foreman, AR				y		2-6	ESP	4.0	517	94.3							
Ash Grove Cement Co.	Louisville, NE	2	1	May-92	y	sd (ph/bp)	1-1	ESP	15.5	258	18.3	898	16.28	5	16.28	8.4400	4.96	4.5866
Ash Grove Cement Co.	Louisville, NE				y		1-2	ESP	15.2	238	20.5	933	4.96					
Ash Grove Cement Co.	Louisville, NE				y		1-3	ESP	15.7	255	22.1	899	5.95					
Ash Grove Cement Co.	Louisville, NE				y		1-4	ESP	15.5	243	26.3	243	6.36					
Ash Grove Cement Co.	Louisville, NE				y		1-5	ESP	15.7	258	23.2	268	8.65					
Ash Grove Cement Co.	Louisville, NE	2	2	Aug-92	y	d (ph/pc/bp)	2-1	ESP	10.5	355	54.9	211	8.75	4	20.69	12.8700	8.28	5.7731
Ash Grove Cement Co.	Louisville, NE				y		2-2	ESP	9.8	355	52.7	181	8.28					
Ash Grove Cement Co.	Louisville, NE				y		2-3	ESP	10.7	355	52.5	256	20.69					

CK.total

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @7%O2	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Louisville, NE				y		2-4	ESP	11.1	355	54	315	13.76					
Ash Grove Cement Co.	Louisville, NE				y		2-5	ESP	10.8	350	60.1							
Ash Grove Cement Co.	Louisville, NE				y		2-6	ESP	11.2	350	59.7							
Ash Grove Cement Co.	Louisville, NE				y		2-7	ESP	10.0	350	59.3							
Ash Grove Cement Co.	Louisville, NE				y		2-8	ESP	10.7	350	58.8							
Continental Cement Co.	Hannibal, MO	1	1	Jul-92	y	w	1	ESP	4.0	600	340	344	1369.00	3	1369	1209.1967	952.32	224.6619
Continental Cement Co.	Hannibal, MO				y		2	ESP	5.6	600	330	344	952.32					
Continental Cement Co.	Hannibal, MO				y		3	ESP	4.4	580	350	344	1306.27					
Continental Cement Co.	Hannibal, MO			Dec-90	y	w	3	ESP	2.0	540		271.9	322.00	2	630	476.0000	322	217.7889
Continental Cement Co.	Hannibal, MO				y		4	ESP	1.9	540		219.4	630.00					
Continental Cement Co.	Hannibal, MO				n		1	ESP	3.1	443		183.9	84.00					
Continental Cement Co.	Hannibal, MO				n		5	ESP	2.0	469		228.6	777.00					
Essroc Materials	Logansport, IN	1	1	Aug-92	y	w	3	ESP		496	32			4	1863	1542.7500	1295	235.7122
Essroc Materials	Logansport, IN				y		4	ESP		504	31.7							
Essroc Materials	Logansport, IN				y		5	ESP		492	39.8							
Essroc Materials	Logansport, IN				y		6	ESP		517	42.4							
Essroc Materials	Logansport, IN				y		8	ESP	11.6	606	44.7	186	1295.00					
Essroc Materials	Logansport, IN				y		9	ESP	12.6	605	34.2	56	1514.00					
Essroc Materials	Logansport, IN				y		10	ESP	11.9	607	40.5	70	1499.00					
Essroc Materials	Logansport, IN				y		11	ESP	12.3	614	39.1	79	1863.00					
Essroc Materials	Dorado, PR	1	1	Jun-93	y	d (ph/pc/bp)	3-1	FF	6.0		--		na					
Essroc Materials	Dorado, PR				y		3-2	FF	4.5		--		na					
Essroc Materials	Dorado, PR				y		3-3	FF	4.0		--		na					
Giant Cement Co.	Harleyville, SC	4	4	Aug-92	y	w	1	FF	10.1	553	--		na					
Giant Cement Co.	Harleyville, SC				y		3	FF	10.4	553	--		na					
Giant Cement Co.	Harleyville, SC				y		4	FF	10.2	553	--		na					
Giant Cement Co.	Harleyville, SC	4	5	Aug-92	y	w	1	FF	10.5	549	--		na					
Giant Cement Co.	Harleyville, SC				y		2	FF	10.2	549	--		na					
Giant Cement Co.	Harleyville, SC				y		3	FF	10.4	549	--		na					
Heartland Cement Co.	Independence, KS	4	1	Oct-92	y	d	1-1	FF	14.3	440	--		na					
Heartland Cement Co.	Independence, KS				y		1-2	FF	14.4	440	--		na					
Heartland Cement Co.	Independence, KS				y		1-3	FF	13.9	440	--		na					
Heartland Cement Co.	Independence, KS				y		2-1	FF	14.5	440	--		na					
Heartland Cement Co.	Independence, KS				y		2-2	FF	14.3	440	--		na					
Heartland Cement Co.	Independence, KS				y		2-3	FF	14.4	440	--		na					
Holnam, Inc.	Artesia, MS	1	1	Aug-93	y	w	2	ESP	8.4	470	140	273	19.12	3	58.9	41.8633	19.12	20.4948
Holnam, Inc.	Artesia, MS				y		4	ESP	7.4	530	140	270.8	58.90					
Holnam, Inc.	Artesia, MS				y		6	ESP	8.3	522	140	290.9	47.57					

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @7%O2	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Holnam Inc.	Clarksville, MO	1	1	Jul-92	y	w	1	ESP	4.4	597	707							
Holnam Inc.	Clarksville, MO				y		2	ESP	4.4	597	732							
Holnam Inc.	Clarksville, MO				y		3	ESP	4.4	597	700							
Holnam Inc.	Clarksville, MO				n		1	ESP	4.9									
Holnam Inc.	Clarksville, MO				n		2	ESP	4.3									
Holnam Inc.	Clarksville, MO				n		3	ESP	5.6									
Holnam Inc.	Holly Hill, SC	2	1	Aug-92	y	w	1	ESP	10.1	450	30	110						
Holnam Inc.	Holly Hill, SC				y		2	ESP	10.1	450	30	110						
Holnam Inc.	Holly Hill, SC				y		3	ESP	10.1	450	30	110						
Holnam Inc.	Holly Hill, SC				n		1	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC				n		2	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC				n		3	ESP	10.3	450		135						
Holnam Inc.	Holly Hill, SC	2	2	Aug-92	y	w	1	ESP	7.0	563	30	150						
Holnam Inc.	Holly Hill, SC				y		2	ESP	7.0	563	30	150						
Holnam Inc.	Holly Hill, SC				y		3	ESP	7.2	563	30	145						
Holnam Inc.	Holly Hill, SC				n		1	ESP	7.0	563		145						
Holnam Inc.	Holly Hill, SC				n		2	ESP	7.0	563		145						
Keystone Cement Co.	Bath, PA	2	1	Aug-92	y	w	1	ESP	12.1	421	23			3	2.66	2.4133	1.98	0.3765
Keystone Cement Co.	Bath, PA				y		2	ESP	13.1	422.5	22	27	2.66					
Keystone Cement Co.	Bath, PA				y		3	ESP	11.7	418	25	26	1.98					
Keystone Cement Co.	Bath, PA				y		4	ESP	12.3	417	23	25	2.60					
Keystone Cement Co.	Bath, PA				y		5	ESP	12.5	416	19							
Keystone Cement Co.	Bath, PA				y		6	ESP	11.8	410	21							
Keystone Cement Co.	Bath, PA				y		7	ESP	11.7	415	19							
Keystone Cement Co.	Bath, PA				y		8	ESP	11.4	403	19							
Keystone Cement Co.	Bath, PA				y		9	ESP	11.2	393	19							
Keystone Cement Co.	Bath, PA				y		10	ESP	11.3	407	21							
Keystone Cement Co.	Bath, PA	2	2	Aug-92	y	w	1	ESP	12.3	407	56	47	0.69	3	0.77	0.6833	0.59	0.0902
Keystone Cement Co.	Bath, PA				y		2	ESP	11.1	416.5	48	47	0.77					
Keystone Cement Co.	Bath, PA				y		3	ESP	11.7	416	49	45	0.59					
Keystone Cement Co.	Bath, PA				y		4	ESP	12.6	419	61							
Keystone Cement Co.	Bath, PA				y		5	ESP	11.7	386								
Keystone Cement Co.	Bath, PA				y		6	ESP	11.5	410								
Keystone Cement Co.	Bath, PA				y		7	ESP	12.1	401								
Keystone Cement Co.	Bath, PA				y		8	ESP	11.7	401								
Keystone Cement Co.	Bath, PA				y		9	ESP	11.3	407								
Keystone Cement Co.	Bath, PA				y		10	ESP	11.7	412								
Lafarge Corp.	Alpena, MI	2	1	Aug-92	y	d (?)	1	FF	6.9	493	--	1365	42.00					
Lafarge Corp.	Alpena, MI				y		2	FF	7.6	488	--	1499	79.50					
Lafarge Corp.	Alpena, MI				y		3	FF	9.4	478	--	1708	88.40					
Lafarge Corp.	Demopolis, AL	1	1	Aug-92	y	d (ph/bp)	4	ESP		229	120		na					

CK.total

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @7%O2	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Lafarge Corp.	Demopolis, AL				y		6	ESP		243	65		na					
Lafarge Corp.	Demopolis, AL				y		7	ESP		230	55		na					
Lafarge Corp.	Fredonia, KS	2	1	Aug-92	y	w	1	ESP	5.5	533	5	359	1066.37	3	1066.37	827.7100	627.96	221.7799
Lafarge Corp.	Fredonia, KS				y		2	ESP	5.5	536	15	547	627.96					
Lafarge Corp.	Fredonia, KS				y		3	ESP	5.5	529	16	416	788.80					
Lafarge Corp.	Fredonia, KS	2	2	Aug-92	y	w	1	ESP		470	38							
Lafarge Corp.	Fredonia, KS				y		2	ESP	5.6	481	38	244	346.00	3	950	525.4667	280.4	369.1169
Lafarge Corp.	Fredonia, KS				y		3	ESP	5.6	511	78	406	950.00					
Lafarge Corp.	Fredonia, KS				y		4	ESP	5.6	496	60	180	280.40					
Lafarge Corp.	Paulding, OH	2	2	Aug-92	y	w	4	ESP	7.0	408	123		na					
Lafarge Corp.	Paulding, OH				y		5	ESP	7.5	404	122		na					
Lafarge Corp.	Paulding, OH				y		6	ESP	7.0	404	123		na					
Lone Star Industries	Cape Girardeau, MO	1	1	Jan-93	y	d (ph/pc/bp)	1-2	FF	10.2	435	--		na					
Lone Star Industries	Cape Girardeau, MO				y		1-3	FF	10.3	435	--		na					
Lone Star Industries	Cape Girardeau, MO				y		1-4	FF	10.6	435	--		na					
Lone Star Industries	Cape Girardeau, MO				y		2-3	FF	10.0	435	--		na					
Lone Star Industries	Cape Girardeau, MO				y		2-4	FF	11.0	435	--		na					
Lone Star Industries	Cape Girardeau, MO				y		2-5	FF	10.8	435	--		na					
Lone Star Industries	Greencastle, IN	1	1	Aug-92	y	w	1-1	ESP	5.4	465	60							
Lone Star Industries	Greencastle, IN				y		1-2	ESP	5.4	457	60							
Lone Star Industries	Greencastle, IN				y		1-3	ESP	5.4	456	60							
Lone Star Industries	Greencastle, IN				n		2-1	ESP	5.0	415								
Lone Star Industries	Greencastle, IN				n		2-2	ESP	4.6	419								
Lone Star Industries	Greencastle, IN				n		2-3	ESP	5.3	416								
Medusa Cement Co.	Wampum, PA	3	1,2	Jul-92	y	d	E-4	ESP	11.2	744	107	2602	1598.00	3	3172	2392.3333	1598	787.1025
Medusa Cement Co.	Wampum, PA				y		E-5	ESP	11.3	738	149	4076	3172.00					
Medusa Cement Co.	Wampum, PA				y		E-6	ESP	11.1	750	138	8651	2407.00					
Medusa Cement Co.	Wampum, PA	3	1,2	Mar-93	y	d	1	ESP	14.6	711	50							
Medusa Cement Co.	Wampum, PA				y		2	ESP	13.9	712	46.8							
Medusa Cement Co.	Wampum, PA				y		3	ESP	14.8	701	57.2							
Medusa Cement Co.	Wampum, PA	3	3	Jul-92	y	d	B-4	ESP	7.3	718	20	153	1093.00	3	2174	1603.3333	1093	543.0196
Medusa Cement Co.	Wampum, PA				y		B-5	ESP	5.7	718	22.8	138	1543.00					
Medusa Cement Co.	Wampum, PA				y		B-6	ESP	5.3	718	24	193	2174.00					
National Cement Co.	Lebec, CA	1	1	Aug-92	y	d	1	FF	10.6	547	--	10.7	6.65	3	6.91	6.5967	6.23	0.3431
National Cement Co.	Lebec, CA				y		2	FF	10.5	548	--	7.9	6.91					
National Cement Co.	Lebec, CA				y		3	FF	10.5	547	--	22.2	6.23					
National Cement Co.	Lebec, CA				y		4	FF	10.7									

CK.total

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @7%O2	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
North Texas Cement	Midlothian, TX	3	2	Oct-92	y	w	1	ESP	8.4	441	230		na					
North Texas Cement	Midlothian, TX				y		2	ESP	8.5	439	227		na					
North Texas Cement	Midlothian, TX				y		3	ESP	8.4	449	223		na					
River Cement Co.	Festus, MO	2	1	Oct-92	y	d	1	ESP	10.1	638		135	2127.00	3	2299	2008.3333	1599	364.7757
River Cement Co.	Festus, MO				y		2	ESP	10.1	638		135	2299.00					
River Cement Co.	Festus, MO				y		3	ESP	10.1	639		135	1599.00					
River Cement Co.	Festus, MO				y		4	ESP										
River Cement Co.	Festus, MO				y		5	ESP										
River Cement Co.	Festus, MO				y		6	ESP										
Southdown/Southwestern	Fairborn, OH	1	1	Aug-92	y	d (?/bp)	2-1	FF			--							
Southdown/Southwestern	Fairborn, OH				y		2-2	FF			--							
Southdown/Southwestern	Fairborn, OH				y		2-3	FF			--							
Southdown/Southwestern	Fairborn, OH				y		I	FF/main		379	--	37	2.11					
Southdown/Southwestern	Fairborn, OH				y		II	FF/main		379	--	2.3	1.48					
Southdown/Southwestern	Fairborn, OH				y		I	FF/bypass		547	--	37	11.40					
Southdown/Southwestern	Fairborn, OH				y		II	FF/bypass		547	--	2.3	8.88					
Southdown/Dixie	Knoxville, TN	1	1	Mar-92	y	d (ph/pc/bp)	1-1	FF	12.4	524	--	145	22.52	6	112.05	31.7450	8.45	39.7863
Southdown/Dixie	Knoxville, TN				y		1-2	FF	12.0	507	--	119	112.05					
Southdown/Dixie	Knoxville, TN				y		1-3	FF	12.0	490	--	134	21.15					
Southdown/Dixie	Knoxville, TN				y		2-1	FF	11.7	499	--	114	17.29					
Southdown/Dixie	Knoxville, TN				y		2-2	FF	12.6	489	--	95	9.01					
Southdown/Dixie	Knoxville, TN				y		2-3	FF	12.4	490	--	183	8.45					
Texas Industries	Midlothian, TX	4	1	May-93	y	w	1	ESP	6.3	418	79.5		na					
Texas Industries	Midlothian, TX				y		2	ESP	7.0	414	82.5		na					
Texas Industries	Midlothian, TX				y		3	ESP	7.0	412	98.8		na					
Southdown/Kosmos	Kosmosdale, KY	1	1	May-92	y	d (ph)	C1-1	FF		519				4	121.52	111.2975	95.67	11.3203
Southdown/Kosmos	Kosmosdale, KY				y		C1-2	FF		514.8								
Southdown/Kosmos	Kosmosdale, KY				y		C1-3	FF		518.7								
Southdown/Kosmos	Kosmosdale, KY				y		C2-1	FF	14.9	505.4		158	117.25					
Southdown/Kosmos	Kosmosdale, KY				y		C2-2	FF	14.6	504.7		153	110.75					
Southdown/Kosmos	Kosmosdale, KY				y		C2-3	FF	14.6	505.1		156	121.52					
Southdown/Kosmos	Kosmosdale, KY				y		C3-1	FF	15.4			150	95.67					
Southdown/Kosmos	Kosmosdale, KY				y		C3-2	FF										
Southdown/Kosmos	Kosmosdale, KY				y		C3-3	FF										
Ash Grove Cement Co.	Foreman, AR	3	2	May-92	Y	w	C2-1	ESP			55			3	62.35	32.2700	14.19	26.2268
Ash Grove Cement Co.	Foreman, AR				Y		C2-2	ESP			60							
Ash Grove Cement Co.	Foreman, AR				Y		C2-3	ESP			59							
Ash Grove Cement Co.	Foreman, AR				y		C3-1	ESP		500	58	531	62.35					
Ash Grove Cement Co.	Foreman, AR				y		C3-2	ESP		485	60	291	14.19					
Ash Grove Cement Co.	Foreman, AR				y		C3-3	ESP		506	58	176	20.27					

CK.total

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO, run avg ppmv @7%O2	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Foreman, AR	3	2	Jul-93	y		2	ESP		371	72.1	240	2.88	3	9.68	5.3200	2.88	3.7848
Ash Grove Cement Co.	Foreman, AR				y		3	ESP		365	71.8	256	3.40					
Ash Grove Cement Co.	Foreman, AR				y		4	ESP		373	70	247	9.68					
Holnam Inc.	Holly Hill, SC	2	1	Aug-92	y	w	1	ESP	10.1	450	30	110	61.00	6	198	70.9000	5.6	81.4300
Holnam Inc.	Holly Hill, SC				y		2	ESP	10.1	450	30	110	198.00					
Holnam Inc.	Holly Hill, SC				y		3	ESP	10.1	450	30	110	142.00					
Holnam Inc.	Holly Hill, SC				n		1	ESP	10.3	450		135	12.40					
Holnam Inc.	Holly Hill, SC				n		2	ESP	10.3	450		135	6.40					
Holnam Inc.	Holly Hill, SC				n		3	ESP	10.3	450		135	5.60					
Holnam Inc.	Holly Hill, SC	2	2	Aug-92	y	w	1	ESP	7.0	563	30	150	na	4	409	182.8750	2.2	211.3549
Holnam Inc.	Holly Hill, SC				y		2	ESP	7.0	563	30	150	317.00					
Holnam Inc.	Holly Hill, SC				y		3	ESP	7.2	563	30	145	409.00					
Holnam Inc.	Holly Hill, SC				n		1	ESP	7.0	563		145	3.30					
Holnam Inc.	Holly Hill, SC				n		2	ESP	7.0	563		145	2.20					

w: wet kiln
d: dry kiln
sd: semi-dry kiln
ph: preheater
pc: precalciner
bp: by-pass

CK.total

APPENDIX H:

DETAILED SUMMARY OF CURRENT PCDD/PCDF TEQ DATA SET FOR CEMENT KILNS

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO Run Av ppmv@7%O2	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Chanute, KS	1	Apr-92	y	w	1	ESP	10.8	422	31.96	468	0.350	4	3.05000	1.55250	0.35000	1.11805
Ash Grove Cement Co.	Chanute, KS			y		2	ESP	10.4	439	30.19	669	1.310					
Ash Grove Cement Co.	Chanute, KS			y		3	ESP	10.7	435	27.58	636	1.500					
Ash Grove Cement Co.	Chanute, KS			y		4	ESP	10.7	448	24.76	697	3.050					
Ash Grove Cement Co.	Chanute, KS	2	Mar-92	y	w	1	ESP	9.5	484	46.43	691	1.370	4	1.37000	1.01300	0.64100	0.30473
Ash Grove Cement Co.	Chanute, KS			y		2	ESP	10.3	412	50.55	415	0.941					
Ash Grove Cement Co.	Chanute, KS			y		3	ESP	10.6	425	38.73	665	1.100					
Ash Grove Cement Co.	Chanute, KS			y		4	ESP	10.8	412	48.18	753	0.641					
Ash Grove Cement Co.	Foreman, AR	1	Jul-92	y	w	1-1	ESP	8.0	387	25.2			4	12.60000	3.80625	0.50000	5.87936
Ash Grove Cement Co.	Foreman, AR			y		1-2	ESP	8.0	360	28.4							
Ash Grove Cement Co.	Foreman, AR			y		1-3	ESP	6.8	371	32							
Ash Grove Cement Co.	Foreman, AR			y		1-4	ESP	7.7	356	28.5							
Ash Grove Cement Co.	Foreman, AR			y		2-1	ESP	5.5	470	27.4	312	0.500					
Ash Grove Cement Co.	Foreman, AR			y		2-2	ESP	5.5	487	29.4	259	12.600					
Ash Grove Cement Co.	Foreman, AR			y		2-3	ESP	4.9	494	21.4	226	1.500					
Ash Grove Cement Co.	Foreman, AR			y		2-4	ESP	6.4	456	22.2	195	0.625					
Ash Grove Cement Co.	Foreman, AR			y		P1	ESP	7.1	408	37.5							
Ash Grove Cement Co.	Foreman, AR			y		P2	ESP	7.0	405	37.2							
Ash Grove Cement Co.	Foreman, AR			y		P3	ESP	6.0	399	37.9							
Ash Grove Cement Co.	Foreman, AR	2	May-92	y	w	1	ESP		500	58		0.571	3	0.57100	0.37033	0.20700	0.18485
Ash Grove Cement Co.	Foreman, AR			y		2	ESP		485	60		0.207					
Ash Grove Cement Co.	Foreman, AR			y		3	ESP		506	58		0.333					
Ash Grove Cement Co.	Foreman, AR	2	Jul-93	y	w	2	ESP		371	72.1		0.077	3	0.20300	0.11597	0.06800	0.07549
Ash Grove Cement Co.	Foreman, AR			y		3	ESP		365	71.8		0.068					
Ash Grove Cement Co.	Foreman, AR			y		4	ESP		373	70		0.203					
Ash Grove Cement Co.	Foreman, AR	3	Jul-92	y	w	2-1	ESP	5.2	475	104.5	296	1.550	3	1.55000	1.02000	0.60000	0.48446
Ash Grove Cement Co.	Foreman, AR			y		2-2	ESP	6.0	470	107.3	540	0.910					
Ash Grove Cement Co.	Foreman, AR			y		2-3	ESP	5.7	460	107.5	551	0.600					
Ash Grove Cement Co.	Foreman, AR			y		2-4	ESP	6.3	512	104.1							
Ash Grove Cement Co.	Foreman, AR			y		2-5	ESP	4.0	522	92.1							
Ash Grove Cement Co.	Foreman, AR			y		2-6	ESP	4.0	517	94.3							
Ash Grove Cement Co.	Louisville, NE	1	May-92	y	sd (ph/bp)	1-1	ESP	15.5	258	18.3	898	0.281	5	0.28100	0.16734	0.09900	0.06958
Ash Grove Cement Co.	Louisville, NE			y		1-2	ESP	15.2	238	20.5	933	0.099					
Ash Grove Cement Co.	Louisville, NE			y		1-3	ESP	15.7	255	22.1	899	0.130					
Ash Grove Cement Co.	Louisville, NE			y		1-4	ESP	15.5	243	26.3	243	0.151					
Ash Grove Cement Co.	Louisville, NE			y		1-5	ESP	15.7	258	23.2	268	0.176					
Ash Grove Cement Co.	Louisville, NE	2	Aug-92	y	d (ph/pc/bp)	2-1	ESP	10.5	355	54.9	211	0.300	4	0.95200	0.50400	0.30000	0.30473
Ash Grove Cement Co.	Louisville, NE			y		2-2	ESP	9.8	355	52.7	181	0.325					

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO Run Av ppmv@7%O2	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev	O2) um	Sdev
Lafarge Corp.	Alpena, MI			y		3	FF	9.4	478	--	1708	0.088							
Lafarge Corp.	Demopolis, AL	1	Aug-92	y	d (ph/bp)	4	ESP		229	120		na							
Lafarge Corp.	Demopolis, AL			y		6	ESP		243	65		na							
Lafarge Corp.	Demopolis, AL			y		7	ESP		230	55		na							
Lafarge Corp.	Fredonia, KS	1	Aug-92	y	w	1	ESP	5.5	533	5	359	5.900	3	5.90000	3.72333	2.59000	1.88559		
Lafarge Corp.	Fredonia, KS			y		2	ESP	5.5	536	15	547	2.590						100	7.35389
Lafarge Corp.	Fredonia, KS			y		3	ESP	5.5	529	16	416	2.680							
Lafarge Corp.	Fredonia, KS	2	Aug-92	y	w	1	ESP		470	38			3	9.40000	5.18667	2.56000	3.68572		
Lafarge Corp.	Fredonia, KS			y		2	ESP	5.6	481	38	244	3.600						00	1.22329
Lafarge Corp.	Fredonia, KS			y		3	ESP	5.6	511	78	406	9.400							
Lafarge Corp.	Fredonia, KS			y		4	ESP	5.6	496	60	180	2.560							
Lafarge Corp.	Paulding, OH	2	Aug-92	y	w	4	ESP	7.0	408	123		na							
Lafarge Corp.	Paulding, OH			y		5	ESP	7.5	404	122		na						00	3.02758
Lafarge Corp.	Paulding, OH			y		6	ESP	7.0	404	123		na							
Lone Star Industries	Cape Girardeau, MO	1	Jan-93	y	d (ph/pc/bp)	1-2	FF	10.2	435	--		na							
Lone Star Industries	Cape Girardeau, MO			y		1-3	FF	10.3	435	--		na							
Lone Star Industries	Cape Girardeau, MO			y		1-4	FF	10.6	435	--		na							
Lone Star Industries	Cape Girardeau, MO			y		2-3	FF	10.0	435	--		na							
Lone Star Industries	Cape Girardeau, MO			y		2-4	FF	11.0	435	--		na							
Lone Star Industries	Cape Girardeau, MO			y		2-5	FF	10.8	435	--		na							
Lone Star Industries	Greencastle, IN	1	Aug-92	y	w	1-1	ESP	5.4	465	60		3.180	3	4.23000	3.62000	3.18000	0.54525		
Lone Star Industries	Greencastle, IN			y		1-2	ESP	5.4	457	60		3.450							
Lone Star Industries	Greencastle, IN			y		1-3	ESP	5.4	456	60		4.230							
Lone Star Industries	Greencastle, IN			n		2-1	ESP	5.0	415			0.175							
Lone Star Industries	Greencastle, IN			n		2-2	ESP	4.6	419			0.140							
Lone Star Industries	Greencastle, IN			n		2-3	ESP	5.3	416			0.093							
Medusa Cement Co.	Wampum, PA	1,2	Jul-92	y	d	E-4	ESP	11.2	744	107	2602	29.890	3	61.73000	48.86000	29.89000	16.77361		
Medusa Cement Co.	Wampum, PA			y		E-5	ESP	11.3	738	149	4076	61.730							
Medusa Cement Co.	Wampum, PA			y		E-6	ESP	11.1	750	138	8651	54.960							
Medusa Cement Co.	Wampum, PA	1,2	Mar-93	y		1	ESP	14.6	711	50			na						
Medusa Cement Co.	Wampum, PA			y		2	ESP	13.9	712	46.8									
Medusa Cement Co.	Wampum, PA			y		3	ESP	14.8	701	57.2									
Medusa Cement Co.	Wampum, PA	3	Jul-92	y	d	B-4	ESP	7.3	718	20	153	25.000	3	50.90000	32.96667	23.00000	15.56288		
Medusa Cement Co.	Wampum, PA			y		B-5	ESP	5.7	718	22.8	138	23.000							
Medusa Cement Co.	Wampum, PA			y		B-6	ESP	5.3	718	24	193	50.900						500	2.78873
National Cement Co.	Lebec, CA	1	Aug-92	y	d	1	FF	10.6	547	--	10.7	0.054	3	0.05700	0.05300	0.04800	0.00458		

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Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO Run Av ppmv@7%O2	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
National Cement Co.	Lebec, CA			y		2	FF	10.5	548	--	7.9	0.057					
National Cement Co.	Lebec, CA			y		3	FF	10.5	547	--	22.2	0.048					
National Cement Co.	Lebec, CA			y		4	FF	10.7									
North Texas Cement	Midlothian, TX	2	Oct-92	y	w	1	ESP	8.4	441	230		na					
North Texas Cement	Midlothian, TX			y		2	ESP	8.5	439	227		na					
North Texas Cement	Midlothian, TX			y		3	ESP	8.4	449	223		na					
River Cement Co.	Festus, MO	1	Oct-92	y	d	1	ESP	10.1	638		135	52.100	3	57.30000	49.84333	40.13000	8.80464
River Cement Co.	Festus, MO			y		2	ESP	10.1	638		135	57.300					
River Cement Co.	Festus, MO			y		3	ESP	10.1	639		135	40.130					
River Cement Co.	Festus, MO			y		4	ESP										
River Cement Co.	Festus, MO			y		5	ESP										
River Cement Co.	Festus, MO			y		6	ESP										
Southdown/Southwestern	Fairborn, OH	1	Aug-92	y	d (?/bp)	2-1	FF			--							
Southdown/Southwestern	Fairborn, OH			y		2-2	FF			--							
Southdown/Southwestern	Fairborn, OH			y		2-3	FF			--							
Southdown/Southwestern	Fairborn, OH			y		I	FF/main		379	--	37						
Southdown/Southwestern	Fairborn, OH			y		II	FF/main		379	--	2.3						
Southdown/Southwestern	Fairborn, OH			y		I	FF/bypass		547	--	37						
Southdown/Southwestern	Fairborn, OH			y		II	FF/bypass		547	--	2.3						
Southdown/Dixie	Knoxville, TN	1	Mar-92	y	d (ph/pc/bp)	1-1	FF	12.4	524	--	145						
Southdown/Dixie	Knoxville, TN			y		1-2	FF	12.0	507	--	119						
Southdown/Dixie	Knoxville, TN			y		1-3	FF	12.0	490	--	134						
Southdown/Dixie	Knoxville, TN			y		2-1	FF	11.7	499	--	114						
Southdown/Dixie	Knoxville, TN			y		2-2	FF	12.6	489	--	95						
Southdown/Dixie	Knoxville, TN			y		2-3	FF	12.4	490	--	183						
Texas Industries	Midlothian, TX	1	May-93	y	w	1	ESP	6.3	418	79.5		na					
Texas Industries	Midlothian, TX			y		2	ESP	7.0	414	82.5		na					
Texas Industries	Midlothian, TX			y		3	ESP	7.0	412	98.8		na					
Southdown/Kosmos	Kosmosdale, KY	1	May-92	y	d (ph)	C1-1	FF		519				4	1.32000	1.17500	1.06000	0.10755
Southdown/Kosmos	Kosmosdale, KY			y		C1-2	FF		514.8								
Southdown/Kosmos	Kosmosdale, KY			y		C1-3	FF		518.7								
Southdown/Kosmos	Kosmosdale, KY			y		C2-1	FF	14.9	505.4		158	1.160					
Southdown/Kosmos	Kosmosdale, KY			y		C2-2	FF	14.6	504.7		153	1.060					
Southdown/Kosmos	Kosmosdale, KY			y		C2-3	FF	14.6	505.1		156	1.160					
Southdown/Kosmos	Kosmosdale, KY			y		C3-1	FF	15.4			150	1.320					
Southdown/Kosmos	Kosmosdale, KY			y		C3-2	FF										
Southdown/Kosmos	Kosmosdale, KY			y		C3-3	FF										
Ash Grove Cement Co.	Foreman, AR	2	May-92	Y	w	C2-1	ESP			55			3	0.57100	0.37033	0.20700	0.18485
Ash Grove Cement Co.	Foreman, AR			Y		C2-2	ESP			60							

Company	Location	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	CO Run Av ppmv@7%O2	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ash Grove Cement Co.	Foreman, AR			Y		C2-3	ESP			59							
Ash Grove Cement Co.	Foreman, AR			y		C3-1	ESP		500	58	531	0.571					
Ash Grove Cement Co.	Foreman, AR			y		C3-2	ESP		485	60	291	0.207					
Ash Grove Cement Co.	Foreman, AR			y		C3-3	ESP		506	58	176	0.333					
Ash Grove Cement Co.	Foreman, AR	2	Jul-93	y		2	ESP		371	72.1	240	0.077	3	0.20300	0.11597	0.06800	0.07549
Ash Grove Cement Co.	Foreman, AR			y		3	ESP		365	71.8	256	0.068					
Ash Grove Cement Co.	Foreman, AR			y		4	ESP		373	70	247	0.203					
Holnam Inc.	Holly Hill, SC	1	Aug-92	y	w	1	ESP	10.1	450	30	110	0.049	3	0.37000	0.19733	0.02400	0.16168
Holnam Inc.	Holly Hill, SC			y		2	ESP	10.1	450	30	110	0.173	THIS IS SAME AS HOLNAM, HOLLY HILL				
Holnam Inc.	Holly Hill, SC			y		3	ESP	10.1	450	30	110	0.370	DESCRIBED ABOVE, DISREGARD THIS TEQ DAT.				
Holnam Inc.	Holly Hill, SC			n		1	ESP	10.3	450		135	0.024					
Holnam Inc.	Holly Hill, SC			n		2	ESP	10.3	450		135	0.015					
Holnam Inc.	Holly Hill, SC			n		3	ESP	10.3	450		135	0.032					
Holnam Inc.	Holly Hill, SC	2	Aug-92	y	w	1	ESP	7.0	563	30	150	1.430	3	2.51000	1.98333	1.43000	0.54049
Holnam Inc.	Holly Hill, SC			y		2	ESP	7.0	563	30	150	2.010	RECALCULATED DATA, USE ORIGINAL DATA				
Holnam Inc.	Holly Hill, SC			y		3	ESP	7.2	563	30	145	2.510	DESCRIBED ABOVE				
Holnam Inc.	Holly Hill, SC			n		1	ESP	7.0	563		145	0.055					
Holnam Inc.	Holly Hill, SC			n		2	ESP	7.0	563		145	0.025					

APPENDIX I:

DETAILED SUMMARY OF CURRENT TOTAL PCDD/PCDF DATA SET FOR COMMERCIAL HW INCINERATORS

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	1	none	na	na	na	na	na				
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	2										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	3										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	4										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	5										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	6										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	7										
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	11	FF/WS/ESP	9.91	143.1		823.64	9	877.44	567.23	259.01	240.46
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	12		9.42	145.5		731.12					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	13		9.59	147.8		395.84					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	4		10.45	144		548.11					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	5		8.88	146		877.44					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	6		8.96	144		778.65					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	7		8.06	150		400.74					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	8		9.9	146		259.01					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	9		12.17	143		290.53					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-1	FF/WS/IWS	10.9	172		112.95	12	222.86	117.14	42.07	50.62
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-2		11.6	173		61.52					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-3		11.1	174		85.34					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-1		11.5	170		169.41					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-2		12.1	168		159.56					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-3		11.5	166		89.50					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-1		12.1	174		42.07					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-2		11.5	170		222.86					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-3		12.6	171		87.26					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-1		11.5	170		120.06					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-2		12.5	172		148.08					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-3		12.6	170		107.11					
Aptus, Inc.	Coffeyville, KS	1	1	Dec-91	Y	RK		FF/WS/IWS				na					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-2	FF/SW				na					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-3										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-4										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-1										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-2										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-3										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-1										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-2										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-3										
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	1	IWS/PS	8.7	164		na					
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	2		8.4	166							

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	3		8.4	162							
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	4		8.4	165							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-4	PS	10.2	168.9	na		5	1232.38	548.61	100.93	529.86
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-5		9.8	169							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-6		10.2	169							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-4		9.6	170.6							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-5		9.6	170.6							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-6		9.3	170.8							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-1		9.8	169.1		206.39					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-2		9.9	168.7		1232.38					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-3		9.7	169		194.06					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-1		9.5	170.6	na						
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-2		10.1	169.6		100.93					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-3		9.4	170.6		1009.27					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	1	FF/VS/AFS	9.8	153	na	na					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	2		10.1	152							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	3		10.2	152							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	4		9.6	151							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	5		10.3	154							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	6		10	154							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	7		10	154							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	8		10.3	155							
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	1	FF/WS	15.7	156	na	na					
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	2		15.6	157							
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	3		15.7	155							
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	1	FF/WS	15.3	159	na	na					
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	2		14.9	163							
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	3		15.7	157							
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	1	FF/WS	16.2	153	na	na					
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	2		15.3	154							
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	3		15	153							
Marine Shale	Amelia, LA	2	1	Jul-95	y	AK	1	SD/FF	10.7	387	--	na					
Marine Shale	Amelia, LA				y	AK	2	SD/FF	10.4	398	--	na					
Marine Shale	Amelia, LA				y	AK	3	SD/FF	10.5	400	--	na					
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	1	WS	11	94	na	4.36	3	4.36	2.26	1.14	1.82
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	2		10.6	97		1.28					
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	3		11	95		1.14					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	1	IWS	10.7	108	na	na					

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	2		10.3	113							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	3		10.6	111.7							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	4		9.3	106.6							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	5		10	100.5							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	6		9.7	99							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	7		9.3	92							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	8		9.6	103.7							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	9		10.4	97.5							
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-88	Y	RK	4	WS	??	??							
					Y		5	WS	??	??							
					Y		6	WS	??	??							
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	1	WS	10.7	103	na	na					
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	2		10.2	106							
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	4		10.6	109							
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	1	WS	10	101	na	10.70	3	10.70	6.58	3.50	3.71
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	3		10.7	102		5.54					
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	4		11.2	102		3.50					
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	1	WS	11	na	na	na					
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	2		10.3								
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	3		10.2								
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	1		11.5	122.6	na		5	5.77	4.31	3.06	1.05
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	2		12.5	119		4.05					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	3		12.8	121.2							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	4		12.1	112.7							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	5		11.8	117.8		3.06					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	6		11.6	118.2							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	7		8.4	113.6							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	8		8.2	124.5		5.77					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	9		8.7	130.9							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	10		8.2	120.2							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	11		7.5	115.5		4.89					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	12		8.2	118.5							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	13		9	125.6							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	14		9.2	129.9		3.76					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	15		7.9	128.4							
Ross Incineration Services	Grafton, OH	1	1	Mar-93	Y	RK	1	PT/IWS	11.3	122	na	1.60	3	1.80	1.46	1.60	0.43
					Y		2	PT/IWS	11.2	125		.97					
					Y		3	PT/IWS	11	119		1.80					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-1	WS	8.6	172							

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	PCDD/PCDF (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-2		6.2	181							
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-3		8.7	167							
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	1		8.8								
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	2		9.2								
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	3		10.2								
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	4		9								
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	1	SD/FF	11.6	367							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	3	SD/FF	11.6	367							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	4	SD/FF	11.6	361							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	5	SD/FF	11.6	364							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	6	SD/FF	11.8	363							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	7	SD/FF	11.6	354							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	8	SD/FF	11.6	366							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	9	SD/FF	11.6	362							
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	1	ESP	11.3			240.35	9	281.57	130.45	48.00	80.42
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	2	ESP	11.3			107.90					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	3	ESP	11.7			281.57					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	4	ESP	10.9			92.88					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	5	ESP	11.4			58.31					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	6	ESP	12.8			48.00					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	7	ESP	14.1			76.87					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	9	ESP	14.1			136.31					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	11	ESP	14.3			131.85					

APPENDIX J:

DETAILED SUMMARY OF CURRENT PCDD/PCDF TEQ DATA SET FOR COMMERCIAL HW INCINERATORS

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	1	none	na	na	na	na	na				
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	2										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	3										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	4										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	5										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	6										
Allied Chemical	Birmingham, AL	1	1	Feb-89	Y	BPF	7										
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	11	FF/WS/ESP	9.91	143.1		26.1	9	26.02384	15.29889	7.64476	6.78866
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	12		9.42	145.5		21.1					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	13		9.59	147.8		10.7					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	4		10.45	144		13.6					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	5		8.88	146		22					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	6		8.96	144		18.5					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	7		8.06	150		9.98					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	8		9.9	146		7.67					
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	Y	RK	9		12.17	143		8.04					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-1	FF/WS/IWS	10.9	172		n/a					
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-2		11.6	173							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c1-3		11.1	174							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-1		11.5	170							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-2		12.1	168							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c2-3		11.5	166							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-1		12.1	174							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-2		11.5	170							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c3-3		12.6	171							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-1		11.5	170							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-2		12.5	172							
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	Y	RK	c4-3		12.6	170							
Aptus, Inc.	Coffeyville, KS	1	1	Dec-91	Y	RK		FF/WS/IWS				na					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-2	FF/SW				na					
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-3										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t1-4										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-1										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-2										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t2-3										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-1										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-2										
Atochem	Carrollton, KY	1	1	Jun-90		RK	t3-3										

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	1	IWS/PS	8.7	164		na					
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	2		8.4	166							
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	3		8.4	162							
CWM Chemical Services	Chicago, IL	1	1	Mar-92	Y	RK	4		8.4	165							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-4	PS	10.2	168.9	na		5	76.60000	34.17800	3.99000	34.38260
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-5		9.8	169							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-6		10.2	169							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-4		9.6	170.6							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-5		9.6	170.6							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-6		9.3	170.8							
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-1		9.8	169.1		9.50000					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-2		9.9	168.7		76.60000					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	O-3		9.7	169		14.60000					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-1		9.5	170.6		na					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-2		10.1	169.6		3.99000					
General Electric	Pittsfield, MA	1	1	Apr-91	Y	LI	OW-3		9.4	170.6		66.20000					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	1	FF/VS/AFS	9.8	153	na	na					
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	2		10.1	152							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	3		10.2	152							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	4		9.6	151							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	5		10.3	154							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	6		10	154							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	7		10	154							
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	Y	LI	8		10.3	155							
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	1	FF/WS	15.7	156	na	na					
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	2		15.6	157							
LWD, Inc.	Calvert City, KY	3	1	Mar-93	Y	RK	3		15.7	155							
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	1	FF/WS	15.3	159	na	na					
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	2		14.9	163							
LWD, Inc.	Calvert City, KY	3	2	Mar-93	Y	RK	3		15.7	157							
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	1	FF/WS	16.2	153	na	na					
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	2		15.3	154							
LWD, Inc.	Calvert City, KY	3	3	Jan-93	Y	RK	3		15	153							
Marine Shale	Amelia, LA	2	1	Jul-95	y	AK	1	SD/FF	10.7	387	--	na	na				
Marine Shale	Amelia, LA				y	AK	2	SD/FF	10.4	398	--	na					
Marine Shale	Amelia, LA				y	AK	3	SD/FF	10.5	400	--	na					
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	1	WS	11	94	na	0.22300	3	0.22300	0.10310	0.03260	0.10437

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	2		10.6	97		0.03260					
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	Y	RK	3		11	95		0.05370					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	1	IWS	10.7	108	na	na					
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	2		10.3	113							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	3		10.6	111.7							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	4		9.3	106.6							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	5		10	100.5							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	6		9.7	99							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	7		9.3	92							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	8		9.6	103.7							
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	Y	RK	9		10.4	97.5							
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-88	Y	RK	4	WS	??	??							
					Y		5	WS	??	??							
					Y		6	WS	??	??							
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	1	WS	10.7	103	na	na					
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	2		10.2	106							
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	Y	RK	4		10.6	109							
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	1	WS	10	101	na						
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	3		10.7	102							
Rollins Environmental Services	Bridgeport, NJ	1	1	Dec-86	Y	RK	4		11.2	102							
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	1	WS	11	na	na	na					
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	2		10.3								
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	Y	RK	3		10.2								
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	1		11.5	122.6	na		5	0.77700	0.42000	0.10200	0.28492
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	2		12.5	119		0.38700					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	3		12.8	121.2							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	4		12.1	112.7							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	5		11.8	117.8		0.19900					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	6		11.6	118.2							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	7		8.4	113.6							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	8		8.2	124.5		0.63500					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	9		8.7	130.9							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	10		8.2	120.2							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	11		7.5	115.5		0.10200					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	12		8.2	118.5							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	13		9	125.6							
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	14		9.2	129.9		0.77700					
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88		RK	15		7.9	128.4							

Company	Location	No. Units	Unit Tested	Report Date	Burn Haz Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ross Incineration Services	Grafton, OH	1	1	Mar-93		RK	1	PT/IWS	11.3	122	na	0.06640	3	0.10640	0.06330	0.01710	0.04473
Ross Incineration Services	Grafton, OH	1	1	Mar-93		RK	2		11.2	125		0.01710					
Ross Incineration Services	Grafton, OH	1	1	Mar-93		RK	3		11	119		0.10640					
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-1	WS	8.6	172							
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-2		6.2	181							
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	T-3		8.7	167							
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	1		8.8								
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	2		9.2								
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	3		10.2								
ThermalKEM	Rock Hill, SC	1	1	Jun-87	Y	FH	4		9								
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	1	SD/FF	11.6	367							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	3	SD/FF	11.6	367							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	4	SD/FF	11.6	361							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	5	SD/FF	11.6	364							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	6	SD/FF	11.8	363							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	7	SD/FF	11.6	354							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	8	SD/FF	11.6	366							
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	Y	RK	9	SD/FF	11.6	362							
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	1	ESP	11.3			4.10	9	4.85000	2.34300	0.81700	1.35327
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	2	ESP	11.3			1.87					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	3	ESP	11.7			4.85					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	4	ESP	10.9			1.7					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	5	ESP	11.4			1.11					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	6	ESP	12.8			0.817					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	7	ESP	14.1			1.51					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	9	ESP	14.1			2.57					
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	Y	RK	11	ESP	14.3			2.56					

APPENDIX K:

DETAILED SUMMARY OF CURRENT PCDD/PCDF TOTAL DATA SET FOR ON-SITE HW FACILITIES

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
American Cyanamid	Hannibal, MO	1	1	Aug-89	Y	LI & CA	2	PT	5.8								
					Y		3	PT	5.2								
					Y		4	PT	5.1								
Amoco Oil	Whiting, IN	1	1	Jun-89	Y	FB	1	C/VS	14.0								
					Y		2	C/VS	13.2								
					Y		3	C/VS	13.7								
					Y		4	C/VS	14.6								
					Y		5	C/VS	13.8								
					Y		6	C/VS	14.5								
Aristech Chemical	Colton, CA	1	1	Jan-89	Y		1-1	None	9								
					Y		1-2	None	9.5								
					Y		1-3	None	9.2								
					Y		2-1	None	8.6								
					Y		2-2	None	8.1								
					Y		2-3	None	8								
Ashland Chemical	Los Angeles, CA	1	1	Dec-88		LI	1-1	None	10.2								
							1-2	None	8								
							1-3	None	8.2								
							2-1	None	7.4								
							2-2	None	6.4								
							2-3	None	4.8								
Burroughs Wellcome	Greenville, NC	??	2	Jan-93	Y	LI	I-2	WS/ESP	11.6								
					Y		I-3	WS/ESP	11.7								
					Y		I-4	WS/ESP	11.8								
					Y		II-1	WS/ESP	12.1								
					Y		II-2	WS/ESP	12.3								
					Y		II-3	WS/ESP	12.1								
					Y		III-1	WS/ESP	12.2								
					Y		III-2	WS/ESP	12.5								
					Y		III-3	WS/ESP	12.5								
Cargill	Lynwood, CA	1	1	Jul-89	Y	LI	6-19	None	8.8								
					Y		6-20	None	9								
					Y		6-21	None	9.1								
					Y		6-22	None	9.6								
Cargill	Lynwood, CA	1	1	Jan-88	Y	LI	1600A	None	10.26								
					Y		1600B	None	9.61								
					Y		1600C	None	9.46								
Chevron	Philadelphia, PA	1	1	Sep-91	Y	FB	1	VS/WS	15	161							
					Y		2A	VS/WS	11	177							
					Y		2B	VS/WS	11	176							
					Y		2C	VS/WS	10	176							
					Y		3	VS/WS	13	160							

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Chevron	Belle Chase, LA	1	1	Feb-88	Y	RH & LI	1-2	VS/PT	12.4								
							1-3	VS/PT	12.7								
							1-4	VS/PT	12.5								
							2-3	VS/PT	11.7								
							2-4	VS/PT	11.3								
							2-5	VS/PT	12.0								
							3-1	VS/PT	11.8								
							3-2	VS/PT	13.5								
							3-3	VS/PT	12.9								
Chevron	Richmond, CA	1	1	Jun-93	Y	LI	1	VS	3.3								
					Y		2	VS	3.5								
					Y		3	VS	3.5								
Chevron	Richmond, CA	1	1	Jul-88	Y	LI	A-2	VS	3.4	175		0.12	6	0.23	0.191667	0.12	0.039707
					Y		A-3	VS	3.2	176		0.19					
					Y		A-4	VS	2.8	174		na					
					Y		B-5	VS	3.3	174		na					
					Y		B-6	VS	3.1	171		na					
					Y		B-7	VS	2.8	173		na					
					Y		C-8	VS	2.9	171		0.23					
					Y		C-9	VS	3.6	170		0.22					
					Y		C-10	VS	3	172		0.18					
					Y		A-11	VS	2.7	171		0.21					
Ciba-Geigy	MacIntosh, AL	1	1	Mar-90	Y	RK	1	VS/PT/ESP									
					Y		2	VS/PT/ESP									
					Y		3	VS/PT/ESP									
					Y		4	VS/PT/ESP									
					Y		5	VS/PT/ESP									
					Y		6	VS/PT/ESP									
Ciba-Geigy	St. Gabriel, LA	1	1	May-88	Y	LI	I-1	VS/Cyclone	3.8				3	1.34	0.976667	0.76	0.316596
					Y		I-2	VS/Cyclone	3.9								
					Y		I-3	VS/Cyclone	3.8								
					Y		II-1	VS/Cyclone	5.5								
					Y		II-2	VS/Cyclone	5.3			1.34					
					Y		II-3	VS/Cyclone	4.9			0.76					
					Y		III-1	VS/Cyclone	5.7								
					Y		III-2	VS/Cyclone	5.8								
					Y		III-3	VS/Cyclone	5.6			0.83					
Department of the Army	Johnston Atoll	1	LIC	Jun-91	Y	LI	1	VS/PBS	14.6	194		0.53	3	0.53	0.435667	0.353	0.089075
					Y		2	VS/PBS	14.4	198		0.353					
					Y		3	VS/PBS	14.6	198		0.424					
Department of the Army	Johnston Atoll	1	LIC	Jun-92	Y	LI	1	VS/PBS									
					Y		2	VS/PBS									
					Y		3	VS/PBS									
					Y		4	VS/PBS									

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Department of the Army	Johnston Atoll	1	DFS	Jun-92	Y	RK	1	VS/PBS	13.9			1.84	4	1.84	1.01	0.63	0.562703
					Y		2	VS/PBS	13.0			0.84					
					Y		3	VS/PBS	13.2			0.71					
					Y		4	VS/PBS	13.1			0.63					
Department of the Army	Tooele, UT	??	??	Apr-92	Y	RK	2	VS	11.2			0.41	4	0.63	0.485	0.41	0.098826
					Y	RK	3	VS	11.4			0.46					
					Y	RK	4	VS	11.5			0.63					
					Y	RK	5	VS	11.3			0.44					
					N	RK	1	VS	11.2			0.76					
Department of the Army	Tooele, UT	??	??	Oct-93	Y	RK	3	VS	11.4	163.77		0.09	4	0.09	0.07	0.06	0.014142
					Y	RK	4	VS	11.2	164.26		0.07					
					Y	RK	5	VS	11.3	164		0.06					
					Y	RK	6	VS	11.6	162.45		0.06					
					N	RK	1	VS	11.4	161.15		0.13					
Dow Chemical Co.	Plaquemine, LA	1	1	Feb-88	Y	RK	C1-1	ESP/PBS	13.5	??	??		2	12.97	12.075	11.18	1.265721
					Y		C1-2		13.3								
					Y		C1-3		13.3								
					Y		C2-1		9.3								
					Y		C2-2		9.8								
					Y		C2-3		10.7								
					Y		1		13.3	??	??	11.18					
					Y		2		13	??	??	12.97					
Dow Chemical Co.	Freeport, TX	1	1	Nov-88	Y	RK	C1-1	IWS	14.4								
					Y		C1-2		13.6								
					Y		C1-3		14.1								
					Y		C2-1		13.3								
					Y		C2-2		13.8								
					Y		C2-3		13.3								
Dow Chemical Co.	Midland, MI	1	830	Mar-92	Y	RK	C1-1	VS/IWS	11.8								
					Y		C1-2		11.5								
					Y		C1-3		12.1								
					Y		C1-4		11.7								
					Y		C2-1		11.1								
					Y		C2-2		10.8								
					Y		C2-3		11.1								
					Y		C2-4		10.8								
					Y		C3-1		11.7								
					Y		C3-2		11.4								
					Y		C3-3		11.8								
					Y		C3-4		11.7								
					Y		C4-1		11.8								
					Y		C4-2		11.9								
					Y		C4-3		11.1								
					Y		C4-4		11.1								
					Y		C4-5		10.9								

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Dow Chemical Co.	Midland, MI	1	703	Jun-89	Y	RK	C1-1	VS/ESP					3	135.6	105.0733	78.35	28.81388
					Y		C1-2										
					Y		C1-3										
					Y		C1-4										
					Y		C2-1		11.9								
					Y		C2-2		10.7			78.35					
					Y		C2-3		11.4			135.6					
					Y		C2-4		10.2			101.27					
					Y		C3-1										
					Y		C3-2										
					Y		C3-3										
Dupont	Deepwater, NJ	1	FR-1	Jun-89	Y	LI	P1	PT/CCS/RJS/ESP	11.4								
					Y		P2		11.4								
					Y		P3		11.5								
Dupont	La Place, LA	1	1	Sep-89	Y	RK & LI	1	WS	9.6								
							2		9								
							3		8.8								
							4		10.2								
							5		10.4								
							6		9.4								
							7		12.2								
							9		13.6								
							10		12.8								
Dupont	La Porte, TX	2	N-THF	Feb-89	Y	LI	6.1	WS	5								
					Y		6.2		3.5								
					Y		6.3		2.8								
					Y		6.4		2.5								
					Y		7.1		6								
					Y		7.2		7.8								
					Y		7.3		3.6								
					Y		8.1		6.3								
					Y		8.2		5.1								
					Y		8.3		5.6								
					Y		9.1		6.8								
					Y		9.2		6.2								
					Y		9.3		6.4								
Dupont	La Porte, TX	1	CSI (1)	Jan-89	Y	LI	1	WS	4.6								
					Y		2		5.5								
					Y		3		5.13								
					Y		4		6.57								
					Y		7		5								
					Y		8		6.4								
					Y		9		6.2								
					Y		10		6								
					Y		11		7.4								
Dupont	La Porte, TX	1	1	Mar-89	Y	LI	C-1	FF		na	na	na					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		C-2										
					Y		C-3										
					Y		C-4										
					Y		C-5										
					Y		C-6										
					Y		C-8										
					Y		C-9										
					Y		C-10										
Dupont	Louisville, KY	1	1	Jul-89	Y	LI	1	WS	7.8								
					Y		2		7.2								
					Y		3		7.0								
Dupont	Orange, TX	1	1	Aug-90	Y	RK	C1-1		8.2								
					Y		C1-2		8.5								
					Y		C1-3		8.4								
					Y		C2-4		10.7								
					Y		C2-5		10.1								
					Y		C2-6		10.6								
Dupont	Wilmington, DE	1	1	Dec-92	Y	FH	1	SD/VS	10.4	na	na	na					
					Y		2		10.4								
					Y		3		11.1								
					Y		4		11.2								
					Y		5		11.0								
					Y		6		11.0								
Eastman Kodak Co.	Rochester, NY			Sep-92	Y	RK	I-1		12.2								
							I-2		12.0								
							I-3		11.9								
					Y		II-1		13.0								
							II-2		14.1								
							II-3		13.1								
					Y		III-1		14.6								
							III-2		14.8								
							III-3		14.9								
Eli Lilly and Co.	Mayaguez, PR	1	1	Nov-87	Y	LI	1	PT/VS	10.3								
					Y		2		10.4								
					Y		3		10.2								
First Chemical Corp.	Pascagoula, MS	1	1	Jul-91	Y	??	I-2	??									
							I-3		2.6								
							I-4										
					Y		II-5										
							II-6		2.4								
							II-7										
					Y		III-8										
							III-9		2.6								
							III-10										

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Honeywell	Pinellas County, FL	1	1	Jun-88	Y	LI	1	??		na	na	na					
					Y		2										
					Y		3										
					Y		4										
Iowa Army Ammunition Plant	Middletown, IA	1	1	Nov-88	Y	RK	1	FF	19.2		na	na					
					Y		2		19.2								
					Y		3		19.3								
					Y		4		17.2								
					Y		5		17.9								
					Y		6		18.7								
Iowa Army Ammunition Plant	Middletown, IA	1	1	Oct-91	Y	RK	1	FF									
					Y		2										
					Y		3										
					Y		4										
					Y		5										
					Y		6										
Iowa Army Ammunition Plant	Middletown, IA	1	1	Jul-93	Y	RK	4	FF									
					Y		5										
					Y		6										
Lake City Army Ammunition Plant	Independence, MO	1	1	Mar-93	Y	RK	1	FF	16.6								
							2		16.6								
							3										
							5		15.9								
							7		16.0								
							8		15.7								
M&T Chemicals	Carrollton, KY	1	1	Jan-89	Y	RK	1.1	FF/WS	15.9								
					Y		1.2		15.9								
					Y		1.3		15.2								
					Y		1.4		15.3								
					Y		2.3		14.8								
					Y		2.4		16.2								
					Y		2.5		15.1								
					Y		3.1		14.6								
					Y		3.2		15.3								
					Y		3.3		15.2								
Miles Inc.	New Martinsville, WV	1	1	Sep-92	Y	FB	C1-1	ESP/WS	7.7	162	na	na					
					Y		C1-2		8.8	158							
					Y		C1-3		8.9	157							
					Y		C2-4		8.0	162.2							
					Y		C2-5		8.6	159.8							
					Y		C2-6		7.9	160.7							
Monsanto Agricultural Co.	Muscatine, IA	1	1	May-89	Y	LI	I-1	PBS	12.3		na	na					
							I-2		8.7								
							I-3		9.0								

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
							II-1		9.4								
							II-2		7.7								
							II-3		10.4								
							III-1		7.8								
							III-2		7.8								
							III-3		7.8								
							IV-1		7.3								
							IV-2		6.7								
							IV-3		7.0								
							V-1		7.8								
							V-2		7.5								
							V-3		9.0								
Nepera Inc.	Herriman, NY	1	1	Feb-93	Y	LI	1	??	5.2								
					Y		2		5.1								
					Y		3		5.1								
Nepera Inc.	Herriman, NY	1	1	Sep-92	Y	LI	1	??	5.1								
							2		4.6								
							3		4.4								
Olin Corp.	East Alton, IL	2	2	Feb-92	Y	SA	1	FF	17.1	401	na	na					
					Y		2		16.0	401							
					Y		3		16.2	398							
					Y		4		16.6	399							
Olin Corp.	Lake Charles, LA	1	1	Jan-89	Y	LI	I-1	WS	9.3	na	na	na					
							I-2		10.6								
							I-3		11.8								
							II-1		6.9								
							II-2		13.0								
							II-3		11.2								
							III-1		13.5								
							III-2		13.3								
							III-3		11.6								
							IV-1		15.0								
							IV-2		13.4								
							IV-3		18.9								
							V-1		10.8								
							V-2		9.0								
							V-3		10.7								
Pfizer Inc.	Groton, CT	1	1	Jul-90	Y	RH	2	WS	7.3	151	na	2.64	3	4.5	3.09	2.12	1.251058
					Y		3		7.7	153		2.12					
					Y		5		7.7	168		4.50					
Pfizer Pharmaceuticals Inc.	Barceloneta, PR	1	1	5/89	Y	RK	1	VS/PT	10.8	187	na	na					
					Y		2		10.6	187							
					Y		3		11.4	185							
Radford Army	Radford, VA	2	6A	Jun-93	N	RK	B-1	FF/PBS	14.1	172							

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Ammunition Plant					N		B-2		12.5	178							
					N		B-3		12.9	177							
					Y		M6-1		13.1	172							
					Y		M6-2		14.3	173							
					Y		M6-3		14.9	172							
					Y		A-1		12.1	174							
					Y		A-2		12.1	174							
					Y		A-3		12.0	174							
					Y		AA-1		10.4	180							
					Y		AA-2		10.6	178							
					Y		AA-3		10.6	179							
Thermal Oxidation Corp.	Roebuck, SC	1	1	Mar-87	Y	LI	1	FF/WS	15.0	141	na	na					
					Y		2		14.7	133							
					Y		3		12	141.7							
					Y		4		10.4	147.7							
					Y		5		12.5	143.7							
					Y		6		13.2	140							
U.S. Dept. of Energy	Oak Ridge, TN	1	1	Aug-89	Y	RK	1	VS/PB/IWS	11.5	183	na	na					
					Y		2		11.1	180							
					Y		3		11.4	179							
Upjohn Co.	Kalamazoo, MI	1	1	Dec-90	Y	RK	1	PT/VS	14.1	116	na	na					
					Y		2		11.7	119							
					Y		3		13.5	118							
Vulcan Materials Co.	Wichita, KS	1	1	Apr-91	Y	LI	I-2	WS	5.8	161	na	71.47	6	401.35	240.09	71.47	147.32
					Y		I-3		3.9	162		116.63					
					Y		I-4		4.4	161		388.34					
					Y		II-1		4.5	162		139.98					
					Y		II-2		5.1	164		322.77					
					Y		II-3		4.3	165		401.35					
Vulcan Materials Co.	Wichita, KS	1	1	Feb-91	Y	LI	I-1	WS	8	117	na	na					
							I-2		5.8	121							
							II-1		6.8	133							
							II-2		5.9	139							
							III-1		2.9	149							
							III-2		3.7	157							
							IV-1		2	142							
							IV-2		3.7	141							

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Revision I: 4/4/94																	
Eli Lilly and Co.	Lafayette, IN		TJZ	Feb-89	Y	LI	C1-1	VS/PT	2.5			na					
					Y		C1-2		3.5								
					Y		C1-3		1.9								
					Y		C1-4		2								
					Y		C2-1		1.5								
					Y		C2-2		2.3								
					Y		C2-3		3.1								
					Y		C3-1		5.6								
					Y		C3-2		5.7								
					Y		C3-3		5.6								
					Y		C4-1		2.4								
					Y		C4-2		2.5								
					Y		C4-3		2.4								
Eli Lilly and Co.	Clinton, IN	3	C-10	Feb-89	Y	??	C1-1	VS/PT	10.1			na					
					Y		C1-2		10.1								
					Y		C1-3		10.6								
					Y		C1-4		11.5								
					Y		C2-1		9.9								
					Y		C2-2		10.4								
					Y		C2-3		10								
					Y		C3-1		11.4								
					Y		C3-2		11.2								
					Y		C3-3		12.6								
Cook Composites	Port Washington, WI	1	1	Apr-90	?	LI	1	?	7.7			na					
							2		9								
							3		9								
Glaxo Inc.	R.T.P., NC	1	1	Oct-93	Y	RH	S1-1	DS/FF				na					
					Y		S1-2										
					Y		S1-3										
					Y		S2-1										
					Y		S2-2										
					Y		S2-3										
Iowa Army Ammunition Plant	Middletown, IA	1	1	Oct-91	Y	RK	1	FF	14.7			na					
					Y		2		14.0								
					Y		3		13.8								
					Y		4		14.3								
					Y		5		14.7								
					Y		6		15.0								
					Y		7		15.0								
					Y		8		14.2								
					Y		9		14.4								
Occidental Chemical Corp.	Niagara Falls, NY	1	1	Feb-94	Y	LI	1	IWS	11.3								

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	APCS Temp (°F)	ESP Power (kVA)	PCDD/PCDF (ng/dscm @ 7% O2)	# Points	Total (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		2		11.3								
					Y		3		11.0								
3M	Cottage Grove, MN	1	1	Sep-90	Y	RK	1	WS	14.2			18.61	8	168.63	80.48	8.65	61.66063
					Y		2	WS	14.0			8.65					
					Y		3	WS	13.5			28.7					
					Y		4	WS	13.9			44.93					
					Y		5	WS	15.4			168.63					
					Y		6	WS	14.2			127.59					
					Y		7	WS	14.6			120.41					
					Y		8	WS	13.2			126.28					

?? Unable to be determined from information given
na not available

APPENDIX L:

DETAILED SUMMARY OF CURRENT PCDD/PCDF TEQ DATA SET FOR ON-SITE HW INCINERATORS

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
American Cyanamid	Hannibal, MO	1	1	Aug-89	Y	LI & CA	2	PT	5.8						
					Y		3	PT	5.2						
					Y		4	PT	5.1						
Amoco Oil	Whiting, IN	1	1	Jun-89	Y	FB	1	C/VS	14.0						
					Y		2	C/VS	13.2						
					Y		3	C/VS	13.7						
					Y		4	C/VS	14.6						
					Y		5	C/VS	13.8						
					Y		6	C/VS	14.5						
Aristech Chemical	Colton, CA	1	1	Jan-89	Y		1-1	None	9						
					Y		1-2	None	9.5						
					Y		1-3	None	9.2						
					Y		2-1	None	8.6						
					Y		2-2	None	8.1						
					Y		2-3	None	8						
Ashland Chemical	Los Angeles, CA	1	1	Dec-88		LI	1-1	None	10.2						
							1-2	None	8						
							1-3	None	8.2						
							2-1	None	7.4						
							2-2	None	6.4						
							2-3	None	4.8						
Burroughs Wellcome	Greenville, NC	??	2	Jan-93	Y	LI	I-2	WS/ESP	11.6						
					Y		I-3	WS/ESP	11.7						
					Y		I-4	WS/ESP	11.8						
					Y		II-1	WS/ESP	12.1						
					Y		II-2	WS/ESP	12.3						
					Y		II-3	WS/ESP	12.1						
					Y		III-1	WS/ESP	12.2						
					Y		III-2	WS/ESP	12.5						
					Y		III-3	WS/ESP	12.5						
Cargill	Lynwood, CA	1	1	Jul-89	Y	LI	6-19	None	8.8						
					Y		6-20	None	9						
					Y		6-21	None	9.1						
					Y		6-22	None	9.6						
Cargill	Lynwood, CA	1	1	Jan-88	Y	LI	1600A	None	10.26						
					Y		1600B	None	9.61						
					Y		1600C	None	9.46						
Chevron	Philadelphia, PA	1	1	Sep-91	Y	FB	1	VS/WS	15						
					Y		2A	VS/WS	11						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		2B	VS/WS	11						
					Y		2C	VS/WS	10						
					Y		3	VS/WS	13						
Chevron	Belle Chase, LA	1	1	Feb-88	Y	RH & LI	1-2	VS/PT	12.4						
							1-3	VS/PT	12.7						
							1-4	VS/PT	12.5						
							2-3	VS/PT	11.7						
							2-4	VS/PT	11.3						
							2-5	VS/PT	12.0						
							3-1	VS/PT	11.8						
							3-2	VS/PT	13.5						
							3-3	VS/PT	12.9						
Chevron	Richmond, CA	1	1	Jun-93	Y	LI	1	VS	3.3						
					Y		2	VS	3.5						
					Y		3	VS	3.5						
Chevron	Richmond, CA	1	1	Jul-88	Y	LI	A-2	VS	3.4	3.18E-02	6	0.0474	0.0368	0.0299	0.007682
					Y		A-3	VS	3.2	2.99E-02					
					Y		A-4	VS	2.8	na					
					Y		B-5	VS	3.3	na					
					Y		B-6	VS	3.1	na					
					Y		B-7	VS	2.8	na					
					Y		C-8	VS	2.9	4.47E-02					
					Y		C-9	VS	3.6	4.74E-02					
					Y		C-10	VS	3	3.71E-02					
					Y		A-11	VS	2.7	2.99E-02					
Ciba-Geigy	MacIntosh, AL	1	1	Mar-90	Y	RK	1	VS/PT/ESP							
					Y		2	VS/PT/ESP							
					Y		3	VS/PT/ESP							
					Y		4	VS/PT/ESP							
					Y		5	VS/PT/ESP							
					Y		6	VS/PT/ESP							
Ciba-Geigy	St. Gabriel, LA	1	1	May-88	Y	LI	I-1	VS/Cyclone	3.8		3	0.00857	0.005913	0.00292	0.00284
					Y		I-2	VS/Cyclone	3.9						
					Y		I-3	VS/Cyclone	3.8						
					Y		II-1	VS/Cyclone	5.5						
					Y		II-2	VS/Cyclone	5.3	8.57E-03					
					Y		II-3	VS/Cyclone	4.9	2.92E-03					
					Y		III-1	VS/Cyclone	5.7						
					Y		III-2	VS/Cyclone	5.8						
					Y		III-3	VS/Cyclone	5.6	6.25E-03					
Department of the Army	Johnston Atoll	1	LIC	Jun-91	Y	LI	1	VS/PBS	14.6	na					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		2	VS/PBS	14.4	na					
					Y		3	VS/PBS	14.6	na					
Department of the Army	Johnston Atoll	1	LIC	Jun-92	Y	LI	1	VS/PBS							
					Y		2	VS/PBS							
					Y		3	VS/PBS							
					Y		4	VS/PBS							
Department of the Army	Johnston Atoll	1	DFS	Jun-92	Y	RK	1	VS/PBS	13.9	0.14	4	0.14	0.13	0.11	0.011752
					Y		2	VS/PBS	13.0	0.11					
					Y		3	VS/PBS	13.2	0.13					
					Y		4	VS/PBS	13.1	0.12					
Department of the Army	Tooele, UT	??	??	Apr-92	Y	RK	2	VS	11.2	0.0224	4	0.0284	0.02495	0.0224	0.002505
					Y	RK	3	VS	11.4	0.0246					
					Y	RK	4	VS	11.5	0.0284					
					Y	RK	5	VS	11.3	0.0244					
					N	RK	1	VS	11.2	0.0405					
Department of the Army	Tooele, UT	??	??	Oct-93	Y	RK	3	VS	11.4	0.00902	4	0.00902	0.00673	0.00491	0.001704
					Y	RK	4	VS	11.2	0.00491					
					Y	RK	5	VS	11.3	0.00664					
					Y	RK	6	VS	11.6	0.00635					
					N	RK	1	VS	11.4	0.00475					
Dow Chemical Co.	Plaquemine, LA	1	1	Feb-88	Y	RK	C1-1	ESP/PBS	13.5		-2	0.115	0.1017	0.0884	0.018809
					Y		C1-2		13.3						
					Y		C1-3		13.3						
					Y		C2-1		9.3						
					Y		C2-2		9.8						
					Y		C2-3		10.7						
					Y		1		13.3	0.0884					
					Y		2		13	0.115					
Dow Chemical Co.	Freeport, TX	1	1	Nov-88	Y	RK	C1-1	IWS	14.4						
					Y		C1-2		13.6						
					Y		C1-3		14.1						
					Y		C2-1		13.3						
					Y		C2-2		13.8						
					Y		C2-3		13.3						
Dow Chemical Co.	Midland, MI	1	830	Mar-92	Y	RK	C1-1	VS/IWS	11.8		4	0.1198	0.065753	0.04112	0.036499
					Y		C1-2		11.5						
					Y		C1-3		12.1						
					Y		C1-4		11.7						
					Y		C2-1		11.1	0.05529					
					Y		C2-2		10.8	0.04112					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		C2-3		11.1	0.0468					
					Y		C2-4		10.8	0.1198					
					Y		C3-1		11.7						
					Y		C3-2		11.4						
					Y		C3-3		11.8						
					Y		C3-4		11.7						
					Y		C4-1		11.8						
					Y		C4-2		11.9						
					Y		C4-3		11.1						
					Y		C4-4		11.1						
					Y		C4-5		10.9						
Dow Chemical Co.	Midland, MI	1	703	Jun-89	Y	RK	C1-1	VS/ESP			3	0.218	0.137733	0.0942	0.069596
					Y		C1-2								
					Y		C1-3								
					Y		C1-4								
					Y		C2-1		11.9						
					Y		C2-2		10.7	0.101					
					Y		C2-3		11.4	0.218					
					Y		C2-4		10.2	0.0942					
					Y		C3-1								
					Y		C3-2								
					Y		C3-3								
Dupont	Deepwater, NJ	1	FR-1	Jun-89	Y	LI	P1	PT/CCS/RJS/ESP	11.4						
					Y		P2		11.4						
					Y		P3		11.5						
Dupont	La Place, LA	1	1	Sep-89	Y	RK & LI	1	WS	9.6						
							2		9						
							3		8.8						
							4		10.2						
							5		10.4						
							6		9.4						
							7		12.2						
							9		13.6						
							10		12.8						
Dupont	La Porte, TX	2	N-THF	Feb-89	Y	LI	6.1	WS	5						
					Y		6.2		3.5						
					Y		6.3		2.8						
					Y		6.4		2.5						
					Y		7.1		6						
					Y		7.2		7.8						
					Y		7.3		3.6						
					Y		8.1		6.3						
					Y		8.2		5.1						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		8.3		5.6						
					Y		9.1		6.8						
					Y		9.2		6.2						
					Y		9.3		6.4						
Dupont	La Porte, TX	1	CSI (1)	Jan-89	Y	LI	1	WS	4.6						
					Y		2		5.5						
					Y		3		5.13						
					Y		4		6.57						
					Y		7		5						
					Y		8		6.4						
					Y		9		6.2						
					Y		10		6						
					Y		11		7.4						
Dupont	La Porte, TX	1	1	Mar-89	Y	LI	C-1	FF		na					
					Y		C-2								
					Y		C-3								
					Y		C-4								
					Y		C-5								
					Y		C-6								
					Y		C-8								
					Y		C-9								
					Y		C-10								
Dupont	Louisville, KY	1	1	Jul-89	Y	LI	1	WS	7.8						
					Y		2		7.2						
					Y		3		7.0						
Dupont	Orange, TX	1	1	Aug-90	Y	RK	C1-1		8.2						
					Y		C1-2		8.5						
					Y		C1-3		8.4						
					Y		C2-4		10.7						
					Y		C2-5		10.1						
					Y		C2-6		10.6						
Dupont	Wilmington, DE	1	1	Dec-92	Y	FH	1	SD/VS	10.4	na					
					Y		2		10.4						
					Y		3		11.1						
					Y		4		11.2						
					Y		5		11.0						
					Y		6		11.0						
Eastman Kodak Co.	Rochester, NY			Sep-92	Y	RK	I-1		12.2		6	0.837	0.459	0.176	0.261628
							I-2		12.0						
							I-3		11.9						
					Y		II-1		13.0	0.322					

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
							II-2		14.1	0.217					
							II-3		13.1	0.176					
					Y		III-1		14.6	0.633					
							III-2		14.8	0.567					
							III-3		14.9	0.837					
Eli Lilly and Co.	Mayaguez, PR	1	1	Nov-87	Y	LI	1	PT/VS	10.3						
					Y		2		10.4						
					Y		3		10.2						
First Chemical Corp.	Pascagoula, MS	1	1	Jul-91	Y	??	I-2	??							
							I-3		2.6						
							I-4								
					Y		II-5								
							II-6		2.4						
							II-7								
					Y		III-8								
							III-9		2.6						
							III-10								
Honeywell	Pinellas County, FL	1	1	Jun-88	Y	LI	1	??			na				
					Y		2								
					Y		3								
					Y		4								
Iowa Army Ammunition Plant	Middletown, IA	1	1	Nov-88	Y	RK	1	FF	19.2		na				
					Y		2		19.2						
					Y		3		19.3						
					Y		4		17.2						
					Y		5		17.9						
					Y		6		18.7						
Iowa Army Ammunition Plant	Middletown, IA	1	1	Oct-91	Y	RK	1	FF							
					Y		2								
					Y		3								
					Y		4								
					Y		5								
					Y		6								
Iowa Army Ammunition Plant	Middletown, IA	1	1	Jul-93	Y	RK	4	FF							
					Y		5								
					Y		6								
Lake City Army Ammunition Plant	Independence, MO	1	1	Mar-93	Y	RK	1	FF	16.6						
							2		16.6						
							3								
							5		15.9						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
							7		16.0						
							8		15.7						
M&T Chemicals	Carrollton, KY	1	1	Jan-89	Y	RK	1.1	FF/WS	15.9						
					Y		1.2		15.9						
					Y		1.3		15.2						
					Y		1.4		15.3						
					Y		2.3		14.8						
					Y		2.4		16.2						
					Y		2.5		15.1						
					Y		3.1		14.6						
					Y		3.2		15.3						
					Y		3.3		15.2						
Miles Inc.	New Martinsville, WV	1	1	Sep-92	Y	FB	C1-1	ESP/WS	7.7	na					
					Y		C1-2		8.8						
					Y		C1-3		8.9						
					Y		C2-4		8.0						
					Y		C2-5		8.6						
					Y		C2-6		7.9						
Monsanto Agricultural Co.	Muscatine, IA	1	1	May-89	Y	LI	I-1	PBS	12.3	na					
							I-2		8.7						
							I-3		9.0						
							II-1		9.4						
							II-2		7.7						
							II-3		10.4						
							III-1		7.8						
							III-2		7.8						
							III-3		7.8						
							IV-1		7.3						
							IV-2		6.7						
							IV-3		7.0						
							V-1		7.8						
							V-2		7.5						
							V-3		9.0						
Nepera Inc.	Herriman, NY	1	1	Feb-93	Y	LI	1	??	5.2						
					Y		2		5.1						
					Y		3		5.1						
Nepera Inc.	Herriman, NY	1	1	Sep-92	Y	LI	1	??	5.1						
							2		4.6						
							3		4.4						
Olin Corp.	East Alton, IL	2	2	Feb-92	Y	SA	1	FF	17.1	na					
					Y		2		16.0						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		3		16.2						
					Y		4		16.6						
Olin Corp.	Lake Charles, LA	1	1	Jan-89	Y	LI	I-1	WS	9.3	na					
							I-2		10.6						
							I-3		11.8						
							II-1		6.9						
							II-2		13.0						
							II-3		11.2						
							III-1		13.5						
							III-2		13.3						
							III-3		11.6						
							IV-1		15.0						
							IV-2		13.4						
							IV-3		18.9						
							V-1		10.8						
							V-2		9.0						
							V-3		10.7						
Pfizer Inc.	Groton, CT	1	1	Jul-90	Y	RH	2	WS	7.3	0.022	3	0.023	0.019	0.012	0.006363
					Y		3		7.7	0.012					
					Y		5		7.7	0.023					
Pfizer Pharmaceuticals Inc.	Barceloneta, PR	1	1	5/89	Y	RK	1	VS/PT	10.8	na					
					Y		2		10.6						
					Y		3		11.4						
Radford Army Ammunition Plant	Radford, VA	2	6A	Jun-93	N	RK	B-1	FF/PBS	14.1						
					N		B-2		12.5						
					N		B-3		12.9						
					Y		M6-1		13.1						
					Y		M6-2		14.3						
					Y		M6-3		14.9						
					Y		A-1		12.1						
					Y		A-2		12.1						
					Y		A-3		12.0						
					Y		AA-1		10.4						
					Y		AA-2		10.6						
					Y		AA-3		10.6						
Thermal Oxidation Corp.	Roebuck, SC	1	1	Mar-87	Y	LI	1	FF/WS	15.0	na					
					Y		2		14.7						
					Y		3		12						
					Y		4		10.4						
					Y		5		12.5						
					Y		6		13.2						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
U.S. Dept. of Energy	Oak Ridge, TN	1	1	Aug-89	Y	RK	1	VS/PB/IWS	11.5	na					
					Y		2		11.1						
					Y		3		11.4						
Upjohn Co.	Kalamazoo, MI	1	1	Dec-90	Y	RK	1	PT/VS	14.1	na					
					Y		2		11.7						
					Y		3		13.5						
Vulcan Materials Co.	Wichita, KS	1	1	Apr-91	Y	LI	I-2	WS	5.8	1.29	6	12	6.493333	1.08	5.226286
					Y		I-3		3.9	1.08					
					Y		I-4		4.4	12					
					Y		II-1		4.5	2.99					
					Y		II-2		5.1	11.3					
					Y		II-3		4.3	10.3					
Vulcan Materials Co.	Wichita, KS	1	1	Feb-91	Y	LI	I-1	WS	8	na					
							I-2		5.8						
							II-1		6.8						
							II-2		5.9						
							III-1		2.9						
							III-2		3.7						
							IV-1		2						
							IV-2		3.7						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
Revision I: 4/4/94															
Eli Lilly and Co.	Lafayette, IN		TJZ	Feb-89	Y	LI	C1-1	VS/PT	2.5	na					
					Y		C1-2		3.5						
					Y		C1-3		1.9						
					Y		C1-4		2						
					Y		C2-1		1.5						
					Y		C2-2		2.3						
					Y		C2-3		3.1						
					Y		C3-1		5.6						
					Y		C3-2		5.7						
					Y		C3-3		5.6						
					Y		C4-1		2.4						
					Y		C4-2		2.5						
					Y		C4-3		2.4						
Eli Lilly and Co.	Clinton, IN	3	C-10	Feb-89	Y	??	C1-1	VS/PT	10.1	na					
					Y		C1-2		10.1						
					Y		C1-3		10.6						
					Y		C1-4		11.5						
					Y		C2-1		9.9						
					Y		C2-2		10.4						
					Y		C2-3		10						
					Y		C3-1		11.4						
					Y		C3-2		11.2						
					Y		C3-3		12.6						
Cook Composites	Port Washington, WI	1	1	Apr-90	?	LI	1	?	7.7	na					
							2		9						
							3		9						
Glaxo Inc.	R.T.P., NC	1	1	Oct-93	Y	RH	S1-1	DS/FF		na					
					Y		S1-2								
					Y		S1-3								
					Y		S2-1								
					Y		S2-2								
					Y		S2-3								
Iowa Army Ammunition Plant	Middletown, IA	1	1	Oct-91	Y	RK	1	FF	14.7	na					
					Y		2		14.0						
					Y		3		13.8						
					Y		4		14.3						
					Y		5		14.7						
					Y		6		15.0						
					Y		7		15.0						

Company	Location	No. Units	Unit No. Tested	Report Date	Burn Haz. Waste	Facility Type	Run No.	APCS	O2 (%)	TEQ (ng/dscm @ 7% O2)	# Points	TEQ (ng/dscm @ 7% O2) Maximum	Average	Minimum	Sdev
					Y		8		14.2						
					Y		9		14.4						
Occidental Chemical Corp.	Niagara Falls, NY	1	1	Feb-94	Y	LI	1	IWS	11.3						
					Y		2		11.3						
					Y		3		11.0						
3M	Cottage Grove, MN	1	1	Sep-90	Y	RK	1	WS	14.2	0.410	8	4.53	2.083	0.336	1.586873
					Y		2	WS	14.0	0.336					
					Y		3	WS	13.5	0.77					
					Y		4	WS	13.9	1.23					
					Y		5	WS	15.4	4.53					
					Y		6	WS	14.2	3.14					
					Y		7	WS	14.6	2.97					
					Y		8	WS	13.2	3.28					

?? Unable to be determined from information given
na not available

APPENDIX M:

SUMMARY OF POOLED PM DATA SORTED BY P1

COMBINED CEMENT KILN AND LIGHT WEIGHT AGGREGATE KILN POPULATION SORTED BY P1

Company	Location	No. Units	Unit Tested	No. Pts.	Particulate gr/dscf @ 7% O2 average	Stdev	Std Err	Pred. @ Ave. KVA	P1
*Solite Corp.	Norwood, NC	0	7	3	0.00048	0.00025			0.00098
*Solite Corp.	Green Cove Springs, FL	0	5	3	0.00144	0.00016			0.00175
*Solite Corp.	Norwood, NC	0	8	3	0.00190	0.00161			0.00511
*Solite Corp.	Cascade, VA	2	2	3	0.00567	0.00153			0.00872
*Solite Corp.	Arvonia, VA	2	7	3	0.00667	0.00115			0.00898
*Solite Corp.	Norwood, NC	4	5	3	0.00429	0.00318			0.01066
*Solite Corp.	Cascade, VA	3	1	3	0.00864	0.00213			0.01291
*Solite Corp.	Norwood, NC	0	6	3	0.00512	0.00441			0.01394
*Solite Corp.	Cascade, VA	2	4	3	0.01000	0.00700			0.02400
*Norlite Corp.	Cohoes, NY	2	1	15	0.01227	0.00863			0.02953
*Solite Corp.	Brooks, KY	1	2	3	0.01833	0.00681			0.03195
*Solite Corp.	Arvonia, VA	2	8	3	0.02533	0.01079			0.04690
Southdown/Southwestern	Fairborn, OH	1	1	3	0.00300	0.00000			0.00300
Southdown/Kosmos	Kosmosdale, KY	1	1	9	0.00261	0.00094			0.00450
Lafarge Corp.	Alpena, MI	2	1	3	0.00333	0.00252			0.00837
Lafarge Corp.	**Fredonia, KS**	**2**	**1**	**3**	**0.01900**	**0.01217**	**0.00000**	**0.01100**	**0.01100**
Texas Industries	Midlothian, TX	4	1	3	0.00962	0.00158	0.00209	0.00898	0.01277
Southdown/Dixie	Knoxville, TN	1	1	6	0.01183	0.00114			0.01411
Keystone Cement Co.	Bath, PA	2	2	4	0.01400	0.00082	0.00088	0.01354	0.01563
Giant Cement Co.	Harleyville, SC	4	4	3	0.01300	0.00250			0.01800
Ash Grove Cement Co.	Foreman, AR	3	3	6	0.00748	0.00542	0.00606	0.00774	0.01833
Giant Cement Co.	Harleyville, SC	4	5	3	0.01133	0.00363			0.01859
Holnam, Inc.	Artesia, MS	1	1	3	0.01380	0.00340			0.02061
National Cement Co.	Lebec, CA	1	1	4	0.01713	0.00408			0.02529
Ash Grove Cement Co.	Louisville, NE	2	2	8	0.01859	0.00417	0.00440	0.01758	0.02693
Lone Star Industries	Cape Girardeau, MO	1	1	6	0.02350	0.00187			0.02724
North Texas Cement	Midlothian, TX	3	2	3	0.02067	0.00416	0.00372	0.02373	0.02899
Keystone Cement Co.	Bath, PA	2	1	10	0.02204	0.00664	0.00640	0.02711	0.03532
Holnam Inc.	Clarksville, MO	1	1	3	0.03370	0.00137	0.00094	0.03234	0.03645
Holnam Inc.	Holly Hill, SC	2	2	3	0.02263	0.00725			0.03713
Medusa Cement Co.	Wampum, PA	3	3	3	0.02247	0.00841	0.01189	0.02272	0.03929
Lafarge Corp.	Demopolis, AL	1	1	3	0.01820	0.01092	0.01515	0.01577	0.04005
River Cement Co.	Festus, MO	2	1	6	0.02443	0.00786			0.04015
Ash Grove Cement Co.	**Chanute, KS**	**2**	**2**	**4**	**0.03255**	**0.01201**	**0.00484**	**0.03255**	**0.04223**
Heartland Cement Co.	Independence, KS	4	1	6	0.02660	0.00815			0.04291
Continental Cement Co.	Hannibal, MO	1	1	3	0.03737	0.00300	0.00359	0.03577	0.04337
Ash Grove Cement Co.	Foreman, AR	3	1	11	0.02958	0.01050	0.01089	0.01536	0.05058
Lafarge Corp.	Fredonia, KS	2	2	3	0.02200	0.01493	0.00354	0.00500	0.05187
Ash Grove Cement Co.	Foreman, AR	3	2	2	0.02020	0.01754	0.00000	0.03260	0.05527
Ash Grove Cement Co.	**Chanute, KS**	**2**	**1**	**4**	**0.04808**	**0.00967**	**0.00491**	**0.04808**	**0.05790**
Holnam Inc.	Holly Hill, SC	2	1	3	0.04967	0.00735			0.06437
Ash Grove Cement Co.	**Louisville, NE**	**2**	**1**	**5**	**0.03658**	**0.02479**	**0.01564**	**0.03658**	**0.06785**
Lone Star Industries	Greencastle, IN	1	1	3	0.05563	0.00921			0.07405
Lafarge Corp.	Paulding, OH	2	2	3	0.03333	0.02309	0.00000	0.02000	0.07952
Medusa Cement Co.	Wampum, PA	3	1,2	3	0.07687	0.00196	0.00272	0.07658	0.08078
Essroc Materials	**Logansport, IN**	**1**	**1**	**4**	**0.07075**	**0.01103**	**0.00530**	**0.07075**	**0.08134**
Medusa Cement Co.	Wampum, PA		1,2	3	0.06543	0.01164	0.00460	0.05313	0.08871
Essroc Materials	Dorado, PR	1	1	3	0.04877	0.02319			0.09514

* LW Aggregate Kiln

Facilities in bold suggest KVA and PM correlation

BOILER POPULATION SORTED BY P1

Company	Location	No. Units	Unit Tested	Report Date	Facility Type	Primary Fuel	APCS	# points	Particulate (gr/dscf @ 7% O2) Avg	Sdev	P1
Tennessee Eastman	Kingsport, TN		24	Apr-91	Boiler	Coal	ESP	3	0.00530	8.62E-05	0.00548
Tennessee Eastman	Kingsport, TN		30	Aug-92	Boiler	Coal	ESP	3	0.00593	0.00021	0.00635
Union Carbide	South Charleston, WV		25	Feb-93	Boiler	Coal	ESP	3	0.00703	0.00045	0.00794
Monsanto Chemical Co.	Nitro, WV	3	B-8	May-93	Boiler (Stoker)	Coal	ESP/Cycl	6	0.00347	0.00229	0.00804
Tennessee Eastman	Kingsport, TN	8	30	Aug-92	Boiler	Coal	ESP	3	0.00907	0.00040	0.00987
Merichem Co.	Houston, TX	1	4	Sep-92	Boiler	NG & LW	WS	6	0.00452	0.00302	0.01056
Dow Chemical	Freeport, TX	11	B-902	Aug-92	Boiler	NG	WS	3	0.00767	0.00153	0.01072
Dow Chemical	Freeport, TX	11	B-903	Aug-92	Boiler	NG	WS	3	0.00500	0.00346	0.01193
Monsanto Chemical Co.	Springfield , MA	1	B-11	Jan-93	Boiler (Stoker)	Coal	FF	3	0.00840	0.00177	0.01194
Dow Chemical	Freeport, TX	11	B-901	Aug-92	Boiler	NG	WS	3	0.00500	0.00520	0.01539
NutraSweet	Augusta, GA		1	Aug-92	Boiler	WF	WS	3	0.01507	0.00025	0.01557
Tennessee Eastman	Kingsport, TN		21	Apr-91	Boiler	Coal	ESP	3	0.01720	0.00131	0.01982
Dow Chemical	Freeport, TX	11	F-2A/B	Aug-92	Boiler	FG	WS	3	0.01033	0.00603	0.02239
Dow Chemical	Freeport, TX	11	F-210	Aug-92	Boiler	NG	WS	3	0.00900	0.00721	0.02342
Rhone-Poulenc	Institute, WV	2	3	Aug-92	Boiler	FG	ESP	3	0.01333	0.00518	0.02369
Westvaco Corp.	DeRidder, LA	4	B2 & B4	Aug-92	Boiler	NG	ESP	3	0.01727	0.01105	0.03937
Dupont	Axis, AL	2	1	Aug-93	Boiler (VGI)		WS	3	0.03733	0.00374	0.04482
Tennessee Eastman	Kingsport, TN		19	Aug-92	Boiler	Coal	ESP	3	0.05420	0.00180	0.05781
FINA Oil	Deer Park, TX	1	1	Oct-92	Boiler	W	VS	9	0.04401	0.00821	0.06043
Tennessee Eastman	Kingsport, TN		23	Aug-92	Boiler	Coal	ESP	3	0.03930	0.01540	0.07011
Shell Chemical	Belpre, OH	??	2	Aug-92	Boiler	Coal	ESP	6	0.04400	0.01417	0.07234
Tennessee Eastman	Kingsport, TN		30	Aug-92	Boiler	Coal	ESP	3	0.04893	0.01826	0.08545
Union Carbide	South Charleston, WV	2	16	Feb-93	Boiler	Coal	ESP	3	0.06963	0.00855	0.08674
Rubicon	Geismar, LA		Aniline II	Aug-92	Boiler		FF	3	0.06523	0.01951	0.10426
Shell Oil	Martinez, CA		Co#1	Apr-89	Boiler (CO)		ESP	9	0.05133	0.08934	0.23001
Diversified Scientific Systems	***Kingston, TN***	***1***	***1***	***Aug-93***	***Boiler***	***LW***	***SD/FF/WS/IIEPA***	***3***	***0.00043***	***0.00028***	***0.00099***
Ethyl Corp.	***Orangeburg, SC***	***1***	***"4"***	***Aug-93***	***Boiler***	***WL***	***FF***	***6***	***0.00157***	***0.00067***	***0.00291***
Dow Chemical	***Freeport, TX***	***11***	***FTB-400***	***Aug-92***	***Boiler***	***FG***	***WS***	***3***	***0.00300***	***0.00000***	***0.00300***
Shell Oil	***Martinez, CA***	***3***	***Co #2***	***Nov-91***	***Boiler (CO)***	***RG***	***ESP***	***7***	***0.00221***	***0.00050***	***0.00322***
NutraSweet	***Augusta, GA***	***2***	***2***	***Aug-92***	***Boiler***	***WF***	***WS***	***3***	***0.00491***	***0.00035***	***0.00561***
Dow Chemical	***Freeport, TX***	***11***	***F-820A***	***Aug-92***	***Boiler***		***WS***	***3***	***0.00600***	***0.00000***	***0.00600***
Natural Gas Odorizing	***Baytown, TX***	***2***	***B-2***	***Oct-92***	***Boiler***	***LW***	***DS/FF/WS***	***3***	***0.00540***	***0.00053***	***0.00646***
Rubicon	***Geismar, LA***	***4***	***TDI***	***Aug-92***	***Boiler***	***NG***	***WS***	***3***	***0.00387***	***0.00192***	***0.00771***
Kalama Chemical	***Kalama, WA***	***2***	***U2***	***Jun-92***	***Boiler***	***NG***	***FF***	***6***	***0.00460***	***0.00174***	***0.00808***
Kalama Chemical	***Kalama, WA***		***U3***	***Jun-92***	***Boiler***	***NG***	***FF***	***6***	***0.00532***	***0.00147***	***0.00825***

COMMERCIAL HAZARDOUS WASTE INCINERATOR POPULATION SORTED BY P1

Company	Location	No. Units	Unit Tested	Report Date	Facility Type	APCS	# Points	Particulate (gr/dscf @ 7% O2) Average	Stdev	P1
Laidlaw Environmental Services	Roebuck, SC	1	1	Jun-91	LI	FF/VS/AFS	8	0.0008	0.0004	0.0015
Aptus, Inc.	Aragonite, UT	1	1	Aug-92	RK	FF/WS/ESP	9	0.0006	0.0006	0.0018
Waste Tech. Industries	East Liverpool, OH	1	1	May-93	RK	ESP	9	0.0024	0.0009	0.0041
Trade Waste Incineration	Sauget, IL	4	4	Sep-92	RK	SD/FF	8	0.0017	0.0014	0.0045
Aptus, Inc.	Coffeyvillle, KS	1	1	Dec-90	RK	FF/WS/IWS	12	0.0034	0.0014	0.0062
Marine Shale	Amelia, LA	2	1	Jul-95	AK	SD/FF	3	0.0058	0.0018	0.0094
Ross Incineration Services	Grafton, OH	1	1	Mar-93	RK	PT/IWS	3	0.0083	0.0015	0.0114
LWD, Inc.	Calvert City, KY	3	1	Mar-93	RK	FF/WS	3	0.0085	0.0041	0.0168
LWD, Inc.	Calvert City, KY	3	3	Jan-94	RK	FF/WS	3	0.0069	0.0051	0.0171
Rollins Environmental Services	Deerpark, TX	3	1	Aug-88	RK	VS	15	0.0139	0.0041	0.0221
LWD, Inc.	Calvert City, KY	3	3	Jan-93	RK	FF/WS	3	0.0084	0.0088	0.0260
LWD, Inc.	Calvert City, KY	3	2	Mar-93	RK	FF/WS	3	0.0227	0.0021	0.0268
Rollins Environmental Services	Bridgeport, NJ	1	1	Nov-86	RK	WS	3	0.0275	0.0017	0.0310
Rollins Environmental Services	Baton Rouge, LA	1	1	Apr-87	RK	WS	3	0.0172	0.0079	0.0329
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-88	RK	WS	3	0.0270	0.0046	0.0362
CWM Chemical Services	Chicago, IL	1	1	Mar-92	RK	IWS/PS	4	0.0311	0.0049	0.0409
ThermalKEM	Rock Hill, SC	1	1	Jun-87	FH	WS	7	0.0526	0.0145	0.0815
General Electric	Pittsfield, MA	1	1	Apr-91	LI	PS	6	0.0410	0.0205	0.0821
Rollins Environmental Services	Baton Rouge, LA	1	1	May-88	RK	IWS	9	0.0332	0.0249	0.0830
Rollins Environmental Services	Bridgeport, NJ	1	1	Aug-83	RK	WS	3	0.0594	0.0155	0.0903
Atochem	Carrollton, KY	1	1	Jun-90	RK	FF/SW	9	0.0295	0.0368	0.1032
Allied Chemical	Birmingham, AL	1	1	Feb-89	BPF	none	7	0.0197	0.0220	0.0636

COMBINED COMMERCIAL HAZARDOUS WASTE INCINERATOR AND ON-SITE HAZARDOUS WASTE INCINERATOR POPULATION SORTED BY P1

Company	Location	No. Units	Unit Tested	No. Pts.	Particulate (gr/dscf @ 7% O2) PMi	Stdev	P1	Facility
Solite Corp.	Brooks, KY	1	2	3	0.01833	0.00681	0.03195	lwa
Rollins Environmental Services	Baton Rouge, LA	1		3	0.01717	0.00788	0.03292	INC
Dow Chemical Co.	Midland, MI	830		16	0.00864	0.01262	0.03389	onsinc
Keystone Cement Co.	Bath, PA	2	1	10	0.02204	0.00664	0.03532	ck
Rollins Environmental Services	Bridgeport, NJ	1		3	0.02700	0.00458	0.03617	INC
Vulcan Materials Co.	Wichita, KS	1		8	0.02293	0.00675	0.03642	onsinc
Holnam Inc.	Clarksville, MO	1	1	3	0.03370	0.00137	0.03645	ck
Lake City Army Ammunition Plant	Independence, MO	1		6	0.02817	0.00436	0.03688	onsinc
Dupont	Louisville, KY	1		3	0.03233	0.00231	0.03695	onsinc
Holnam Inc.	Holly Hill, SC	2	2	3	0.02263	0.00725	0.03713	ck
Medusa Cement Co.	Wampum, PA	3	3	3	0.02247	0.00841	0.03929	ck
Westvaco Corp.	DeRidder, LA	4	B2 & B4	3	0.01727	0.01105	0.03937	bif
U.S. Dept. of Energy	Oak Ridge, TN	1		3	0.02493	0.00751	0.03996	onsinc
Lafarge Corp.	Demopolis, AL	1	1	3	0.01820	0.01092	0.04005	ck
River Cement Co.	Festus, MO	2	1	6	0.02443	0.00786	0.04015	ck
CWM Chemical Services	Chicago, IL	1		4	0.03110	0.00492	0.04093	INC
M&T Chemicals	Carrollton, KY	1		10	0.01339	0.01393	0.04125	onsinc
Chevron	Philadelphia, PA	1		5	0.01978	0.01108	0.04193	onsinc
Ash Grove Cement Co.	Chanute, KS	2	2	4	0.03255	0.00484	0.04223	ck
Cook Composites	Port Washington, WI	1		3	0.03700	0.00265	0.04229	onsinc
Heartland Cement Co.	Independence, KS	4	1	6	0.02660	0.00815	0.04291	ck
Pfizer Inc.	Groton, CT	1		3	0.03600	0.00361	0.04321	onsinc
Continental Cement Co.	Hannibal, MO	1	1	3	0.03737	0.00300	0.04337	ck
Dupont	Axis, AL	2	1	3	0.03733	0.00374	0.04482	bif
Eli Lilly and Co.	Lafayette, IN	TJZ		13	0.03224	0.00702	0.04627	onsinc
Eli Lilly and Co.	Mayaguez, PR	1		3	0.04357	0.00151	0.04660	onsinc
BROS Lagoon Clean-Up	Bridgeport, NJ	1		9	0.02227	0.01228	0.04682	onsinc
Solite Corp.	Arvonia, VA	2	8	3	0.02533	0.01079	0.04690	lwa
New Bedford Harbor	New Bedford, MA	1		3	0.03700	0.00656	0.05011	onsinc
Ash Grove Cement Co.	Foreman, AR	3	1	11	0.02958	0.01050	0.05058	ck
Dupont	La Place, LA	1		9	0.02680	0.01190	0.05059	onsinc
Lafarge Corp.	Fredonia, KS	2	2	3	0.02200	0.01493	0.05187	ck
Dow Chemical Co.	Midland, MI	703		11	0.01980	0.01740	0.05461	onsinc
Ash Grove Cement Co.	Foreman, AR	3	2	2	0.02020	0.01754	0.05527	ck
Chevron	Belle Chase, LA	1		9	0.03200	0.01254	0.05708	onsinc
Olin Corp.	Lake Charles, LA	1		15	0.02227	0.01758	0.05743	onsinc
Tennessee Eastman	Kingsport, TN		19	3	0.05420	0.00180	0.05781	bif
Ash Grove Cement Co.	Chanute, KS	2	1	4	0.04808	0.00491	0.05790	ck
FINA Oil	Deer Park, TX	1	1	9	0.04401	0.00821	0.06043	bif
Dupont	La Porte, TX	CSI (1)		9	0.03677	0.01189	0.06055	onsinc
American Cyanamid	Hannibal, MO	1		3	0.05440	0.00479	0.06399	onsinc
Holnam Inc.	Holly Hill, SC	2	1	3	0.04967	0.00735	0.06437	ck
Tennessee Eastman	Kingsport, TN		23	3	0.03930	0.01540	0.07011	bif
Shell Chemical	Belpre, OH	??	2	6	0.04400	0.01417	0.07234	bif
Ciba-Geigy	St. Gabriel, LA	1		9	0.04271	0.01536	0.07343	onsinc
Dupont	Wilmington, DE	1		6	0.04363	0.01518	0.07399	onsinc
Lone Star Industries	Greencastle, IN	1	1	3	0.05563	0.00921	0.07405	ck
Amoco Oil	Whiting, IN	1		6	0.04365	0.01543	0.07450	onsinc
Pfizer Pharmaceuticals Inc.	Barceloneta, PR	1		3	0.06493	0.00524	0.07542	onsinc
Burroughs Wellcome	Greenville, NC	2		9	0.03206	0.02266	0.07737	onsinc
Lafarge Corp.	Paulding, OH	2	2	3	0.03333	0.02309	0.07952	ck
Medusa Cement Co.	Wampum, PA	3	1,2	3	0.07687	0.00196	0.08078	ck
Essroc Materials	Logansport, IN	1	1	4	0.07075	0.00530	0.08134	ck
ThermalKEM	Rock Hill, SC	1		7	0.05256	0.01449	0.08153	INC
General Electric	Pittsfield, MA	1		6	0.04100	0.02054	0.08208	INC
Rollins Environmental Services	Baton Rouge, LA	1		9	0.03321	0.02492	0.08304	INC
Tennessee Eastman	Kingsport, TN		30	3	0.04893	0.01826	0.08545	bif
Ash Grove Cement Co.	Louisville, NE	2	1	5	0.03658	0.02479	0.08616	ck
Union Carbide	South Charleston, WV	2	16	3	0.06963	0.00855	0.08674	bif
Medusa Cement Co.	Wampum, PA		1,2	3	0.06543	0.01164	0.08871	ck
Rollins Environmental Services	Bridgeport, NJ	1		3	0.05937	0.01548	0.09033	INC
Essroc Materials	Dorado, PR	1	1	3	0.04877	0.02319	0.09514	ck
Atochem	Carrollton, KY	1		9	0.02954	0.03681	0.10317	INC
Rubicon	Geismar, LA		Aniline I	3	0.06523	0.01951	0.10426	bif
3M	Cottage Grove, MN	1		8	0.05995	0.02414	0.10824	onsinc
Dow Chemical Co.	Plaquemine, LA	1		6	0.03219	0.03823	0.10865	onsinc

COMBINED COMMERCIAL HAZARDOUS WASTE INCINERATOR AND ON-SITE HAZARDOUS WASTE INCINERATOR POPULATION SORTED BY P1

Company	Location	No. Units	Unit Tested	No. Pts.	Particulate (gr/dscf @ 7% O2) PMi	Stdev	P1	Facility
Monsanto Agricultural Co.	Muscatine, IA	1		15	0.07013	0.02373	0.11759	onsinc
Ciba-Geigy	MacIntosh, AL	1		6	0.06233	0.05630	0.17494	onsinc
Dupont	La Porte, TX	N-THF		13	0.11277	0.04818	0.20913	onsinc
Shell Oil	Martinez, CA		Co#1	9	0.05133	0.08934	0.23001	bif