United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
Washington DC 20460

EPA 540 X-88 006
December 1988

Superfund

EPA

High Temperature Thermal Treatment for CERCLA Waste:

Internal Use Only

Evaluation and Selection of Onsite and Offsite Systems

EPA/540/X-88/006
December 1988

HIGH TEMPERATURE THERMAL TREATMENT FOR CERCLA WASTE

Evaluation and Selection of Onsite and Offsite Systems

by

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EPA Contract No. 68-01-6939

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NOTICE

FOREWORD

The Environmental Protection Agency is committed to a broader use of treatment technologies for the management of Superfund waste. These technologies provide permanent long-term remedies which serve as alternatives to land disposal. Incineration (thermal treatment) has been selected as the preferred remedy for a number of sites and it is frequently evaluated as a treatment alternative.

This document is intended to provide site managers with practical assistance in the evaluation of thermal treatment alternatives. This report discusses waste characteristics which could pose problems for incineration and reviews material handling requirements. The report discusses and compares the three major thermal technologies which are available as mobile systems. Off-site stationary systems are addressed along with their requirements for waste acceptance. In addition, a comparison is given of on-site versus off-site operation, including a breakeven cost analysis.

The report has not undergone a formal peer review. It is published as a draft because the information is timely and should be available for immediate use. We would like to encourage your comments on the report's utility and on how it might be improved to better serve the Superfund program needs. Comments can be forwarded to either John Kingscott or Linda Galer of my staff.

Thomas W. Devine, Director
Office of Program Management
and Technology

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ACKNOWLEDGMENTS

This documents was prepared by several individuals at the Boston office of Camp, Dresser and McKee. The following people have contributed to this document.

Walter Niessen	-	Project Manager
Charles Marks (Senior Engineer)	-	Procurement Specifications for Mobile Systems
Colin Baker (Project Coordinator)	-	Fixed Incineration Facilities Mobile Systems vs. Fixed Facilities
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1.0 INTRODUCTION

1.1 INTRODUCTION

While thermal treatment is often costly in comparison to land disposal, it is becoming more attractive as an alternative to land disposal for several reasons, including:

- hazardous organic constituents are destroyed by thermal treatment;

- since land disposal is not a "treatment" per se, there is long-term risk and liability associated with this alternative which is not associated with thermal treatment; and

- there are existing and planned restrictions on land disposal of certain hazardous wastes.

Thermal treatment has been selected as the preferred remediation technology for several sites on the National Priority List (NPL) list as well as several non-NPL sites. The increasingly frequent selection of thermal treatment as a remedial alternative has been paralleled by an increase in commercial availability of thermal treatment services, particularly mobile systems. Mobile systems are defined in this document as transportable or field-erected modular thermal treatment systems. As the demand for thermal treatment services increases, the need for detailed information on the capabilities and limitations of these systems has increased. This document addresses these needs by providing detailed information on both onsite and offsite thermal treatment services.

1.2 BACKGROUND

High temperature thermal treatment of hazardous wastes is one of the most effective ways of detoxifying or destroying toxic organic compounds. High temperature thermal treatment (e.g., incineration, pyrolysis) is readily distinguished from low temperature thermal treatment (e.g., thermal stripping) in that substantially higher operating temperatures (>1400°F) are used with the former. This allows for destruction of all organic compounds including such compounds as PCBs and the chlorinated dioxins. Low temperature thermal treatment processes operate at temperatures between 200°-800°F and are only appropriate for treatment (removal but not contaminant destruction) of soils contaminated with organic compounds that will volatilize readily within this temperature range. Heat is used only to volatilize the organics from the soil in these processes. Subsequent capture of the organics from the air stream can be accomplished through use of activated carbon cannisters and/or water scrubbers. Alternatively, an afterburner can be used to destroy the volatilized contaminants but at higher net operating cost.

In comparison, high temperature thermal processes utilize extreme heat to volatilize and thermally degrade or oxidize compounds. Since high temperature thermal treatment processes are generally appropriate for waste solids, liquids, sludges, and slurries in addition to contaminated soil, they are often applicable to waste sites with diversified waste streams (e.g., CERCLA sites). All subsequent references to "thermal treatment" in the following discussions pertain to high temperature thermal processes only.

1.3 OBJECTIVES

This document is designed to provide CERCLA site managers and on-scene coordinators with guidance in evaluation of alternatives using thermal treatment. This includes the basic decision on the suitability of thermal treatment as an alternative, the evaluation of onsite versus offsite systems, and regulatory considerations for onsite systems. Information on the capabilities, limitations and costs of these systems is provided to assist in the decision-making process. The document is not, however, a replacement for detailed technical and economic analysis of thermal processing by engineers experienced in dealing with the complexity, cost and technical design of these systems.

1.4 APPROACH

Information on thermal treatment is presented as follows:

Section 2: Overview of the data collection and analysis required for evaluation of thermal treatment alternatives.

Section 3: Detailed discussion of waste characteristics that can pose problems for incineration. The section includes guidelines on bench and pilot scale treatability testing, identification of restrictive waste characteristics, and a review of material handling requirements.

Section 4: Review of the three major incineration technologies (rotary kiln, infrared furnace, circulating fluidized bed) currently available as mobile systems. This section includes a comparative analysis of these three technologies, as well as a listing of companies currently marketing mobile systems.

Section 5: Comparison of onsite versus offsite thermal treatment systems, including volume requirements, costs, environmental impacts and materials handling. This section provides guidance in determining whether onsite or offsite incineration is the most viable option.

Section 6: Overview of potentially applicable environmental regulations, including RCRA, TSCA, CAA, NEPA and NPDES. This section outlines which aspects of a site remediation may require regulatory compliance.

The information presented in these sections should be used in conjunction with an engineering analysis of the site and the physical and chemical characteristics of the waste. Vendors of thermal treatment systems will provide evaluations of the suitability of the system for the specific site under consideration.

The following Appendices contain additional information in support of report sections:

Appendix A: Review of several commercially available mobile thermal systems (rotary kilns, infrared and circulating fluidized bed) including information on system design, operation, mobilization, and testing. This section is intended to provide technical information on specific mobile systems which are available for onsite treatment.

Appendix B: Review of the waste acceptance requirements for five major fixed thermal treatment facilities, including sampling and containerization, restrictions on chemical and physical waste characteristics, and cost ranges. This section provides guidance in selection of offsite facilities to which contaminated wastes may be shipped for treatment.

2.0 INFORMATION AND DATA REQUIREMENTS

There are many planning considerations which must be incorporated into an assessment of the viability of thermal treatment systems for a particular site. A detailed discussion of these considerations for remedial Superfund projects is found in the recent EPA publication "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA". Some of the more critical planning considerations are:

- o Waste characteristics,
- o Site constraints,
- o Potential environmental impacts,
- o Costs, and
- o Technology support requirements.

Information provided in this report will help to evaluate these considerations. This section briefly discusses data and information gathering requirements.

2.1 Planning for Data Collection

It is important to note that the type and quality of data needed to make assessments of the feasibility of utilizing thermal treatment systems may be different from the data collected to characterize the site. In the past the initial data on site contamination was collected for the purposes of assessing the potential risk to human health and the environment and these data generally are not sufficient to assess the viability of thermal treatment. Therefore, in situations where thermal treatment appears to be feasible, the data required to assess treatability should be considered when establishing data collection objectives during the initial project planning stages

2.2 Waste Characteristics

Certain information about the material that is being considered for incineration should be determined early in the planning process. This information includes estimated volumes of each waste type (e.g., sludge, liquid, and solids), concentration of contaminants, and waste characteristics.

For each waste type, knowledge of the following characteristics (often called a proximate analysis) is required to evaluate the cost and feasibility of thermal treatment:

- Moisture content,
- Ash (noncombustible) content,
- Combustible content,
- Heating value (Btu's), and
- Specific gravity (density).

This information is considered with the restrictive waste characteristics which are discussed in Section 3.

In addition to the proximate analysis, useful data which would eventually be required if an actual design were pursued is an ultimate analysis (this includes analysis for elemental carbon, hydrogen, sulfur, chlorine, phosphorus, bromine, fluorine, and metals, as well as analyses of ash composition and other waste characteristics). Additional information required at the design stage includes waste flashpoint, reactivity, corrosivity, and handling requirements. Site- or waste-specific conditions may warrant additional tests. These tests might include viscosity (for liquids or sludges), melting point (for meltable solids such as waxes), pH, and halogen content. Pilot testing is rarely necessary, except with unusual waste types. Testing should be discussed with thermal treatment specialists to ensure that the proper tests are performed. See Section 3 for more detail.

The waste must be properly defined in terms of chemical and physical characteristics (see Appendix B) in order for offsite thermal treatment facilities to provide cost estimates and/or to accept material for disposal. In order to ship the waste, critical characteristics of the material must be documented and manifested. Treatment facilities will sample the waste prior to acceptance, and reject any waste where the observed waste properties are at variance with the documentation. The required information on waste characteristics is similar to the analyses described in the previous paragraph and includes elemental analyses as well as information on Btu content, reactivity, corrosivity, and handling characteristics. See Appendix B for specific data requirements.

2.3 Site Information

Additional information which should be considered when assessing the feasibility and cost of onsite incineration include:

- Site conditions, including general soil-bearing capacities; 100-year flood levels; access roads; areas available for staging, storage, or placement of thermal treatment equipment; and proximity to surface water and people. The status of utilities at the site and the ease of upgrading services should also be noted, particularly for power and water supply.

- Clean-up objectives for the site, including time to complete site activities and level of clean-up desired.

At this stage it is important to note any conditions that would greatly affect the use of thermal treatment at a site. The availability of water, power, auxiliary fuel, grade of land, location in a flood plain, and site access are particularly important. These site conditions will affect siting cost and feasibility. Sites with limited area or very poor soil conditions may not be practical for onsite thermal treatment.

2.4 Cost Estimates

Rough cost estimates can be readily prepared by thermal treatment companies, given adequate site data and certain assumptions. These estimates typically contain considerable margins of error due to uncertainties about site conditions, materials handling requirements, residuals disposal, labor requirements, and permit conditions, among others. Some of these uncertainties can be removed by providing detailed information to vendors.

A list of companies actively pursuing the onsite thermal treatment market is included in Section 4.0. It is important to begin the site characterization early to allow vendors sufficient time to evaluate the site if a cost estimate is desired. Estimates will typically be expressed on a cost per unit basis (per ton or cubic yard). It is important to request a breakdown of total costs into specific categories which will allow flexibility for comparison with other alternatives and aid in the preparation of the cost analysis required for a FS. It also is important to state explicitly any assumptions or definitions used.

3.0 REQUIREMENTS FOR THERMAL TREATMENT

3.1 THERMAL TREATABILITY TESTING

Treatability testing is an important component of the development of treatment alternatives as it provides important information on feasibility and cost for both onsite and offsite options. In the past treatability testing has not been heavily emphasized due to a reliance on land disposal options which require little testing. The necessary treatability data for evaluating alternatives should be collected via bench and pilot scale tests before alternatives are recommended and Record of Decision (ROD's) signed. This is especially true for innovative technologies that have not been fully demonstrated.

Laboratory Analysis

Thermal treatability testing can provide important information, but the extent of testing that is necessary varies significantly from site to site. In general, complete laboratory analyses is useful for any sites being considered for thermal treatment. This analysis, which includes both proximate and ultimate analyses (standard analyses for thermal testing), should include the following:

- Specific gravity - determines feed rate and handling requirements.

- Btu content - typically low for soils, this parameter determines feedrate and fuel requirements.

- % moisture - very important, as all water must be driven off during heating phase. Determines feed rate, fuel consumption and handling requirements.

- Flash point - particularly important for liquids and sludges, determines feed rate and handling requirements.

- Viscosity - important for liquids and sludges, determines handling requirements.

- Non-combustible content (ash) - very important for offsite and onsite incineration, determines the volume of ash to be disposed of. Offsite facilities must pay for secure landfilling,and hence soil (high ash content) is expensive to incinerate offsite.

- Particle size analysis - important for soils processing, determines requirements for materials handling and particulate control.

- Dry weight chemical composition; C,H,O,N,S,P - important for determining basic combustion requirements, feedrate and air pollution control requirements.

- pH - important for determining handing and equipment maintenance requirements, may require neutralization.

- Halogens (Br, F,I, Cl) - form acid gases during combustion, requiring scrubbing of stack emission. Often includes analysis for forms of chlorine and sulfur to determine potential for acid gas formation.

- Alkali Metals (Na, K) - important for equipment maintenance requirements.

- Toxic Metals (e.g. Hg, Cd) - important for air pollution control requirements and ash disposal or delisting. These analyses are generally part of the Priority Pollutant Analysis.

- Organic Pollutants - important for materials handling and personnel exposure, pollution control, and ash disposal. These analyses are generally part of the Priority Pollutant Analyses.

These analyses (besides the Priority Pollutant Analysis) can be done at reasonable cost by many labs, or can be done by making special arrangements through the CLP program, as they are not standard tests for contract laboratories.

These tests are also done by offsite incineration facilities (see Appendix B) at reasonable cost. It is important to use representative samples that are typical of the site. Sampling should also be done to define the worst case conditions in order that an appropriate strategy can be developed for handling and treatment. Vendors of incineration services may provide rough costs estimates for soil treatment if provided with good estimates of density, Btu content (negligible if organic contamination <1000 ppm), % moisture and levels of metals present. Clearly stated assumptions may be made on other waste characteristics which can be verified following additional testing. Additional information on restrictive waste characteristics is presented in the Section 3.2.

Bench and Pilot Scale Testing - Requirements for bench or pilot testing are highly dependent on the results of the laboratory analysis, as well as any regulatory requirements which may apply to the site. Review of the laboratory data by vendors of incineration services should allow them to identify any waste characteristics that may cause problems either for regulatory compliance, cleanup implementation, system operation or ash disposal.

Ultimately, the burden of identifying and solving these problems will be the responsibility of the vendor that is selected to conduct the thermal treatment onsite. It is in a company's own interest to identify problematic waste charateristics that could hinder a cleanup, since the federal contracts that are awarded for cleanup of a site specify performance goals and financially penalize the vendor for non-attainment of these goals.

The site manager or on-scene coordinator must determine if bench or pilot testing is necessary for a particular site. If such additional data will allow vendors to produce more accurate bids then the cost of cleanup may be reduced. Currently, most pilot scale thermal systems are scaled down versions of full scale systems supplied by particular vendors. The information gained from pilot scale operations is specific to that particular system (e.g. rotary kiln, infrared furnace or circulating bed combustor) and may not be applicable to other commercial systems which could be used for a cleanup.

A vendor may propose pilot work (particularly for innovative systems) in order to identify important design and operational considerations prior to assembly of a full-scale system. However, system specific test data may be less useful to vendors of other thermal systems in developing proposals. A vendor may be allowed the freedom to pilot test at company expense if schedule and regulations permit. Regulations that hinder offsite testing of relatively small volumes (up to 1000 kg) of waste have been revised to expedite this type of testing.

Ash Disposal - Certain bench scale tests may provide useful information for ash disposal. The ash produced in muffle furnace tests is likely to be similar in heavy metal content to that produced from many full scale incineration systems. This ash can be tested using the TCLP and EP test for toxicity, and this data can be used to estimate whether the ash from a full scale cleanup can be delisted as a toxic waste. This information can be very useful during the feasibility study if delisting is required for the ash. Problems with delisting can substantially increase the cost for an incineration alternative, requiring either chemical fixation of the ash or shipment offsite for disposal, which can be prohibitively expensive. Muffle furnace testing can provide the preliminary data needed to identify delisting requirements. However, these furnace tests may not be accurate for borderline cases since ash characteristics are to some degree dependent on the type of incineration system used. Samples for testing should be of sufficient size to permit subsequent TCLP testing of ash.

Proper safety procedures should be used to ensure that contaminants desorbed during furnace testing are properly captured or vented.

3.2 FACTORS AFFECTING SUITABILITY OF WASTE FOR THERMAL TREATMENT

3.2.1 GENERAL

Waste characteristics are the key factors in selecting the most appropriate method of waste treatment. While all organic waste contaminants can be thermally treated (i.e., reduced to non-hazardous compounds at high temperatures), various characteristics such as the presence of heavy metals may limit the application of thermal treatment or favor an alternative treatment method.

Every hazardous waste site and every waste is unique. This is particularly true of CERCLA sites. Specific site conditions and/or a particular combination of wastes may make the wastes unsuitable for thermal treatment. General guidelines regarding waste suitability are provided in this section. However, treatment selection ultimately must be determined only after detailed engineering and environmental analysis on a site-specific basis.

Information on both the physical and chemical characteristics of waste material is necessary to determine the suitability of that waste for thermal processing and the possible need for pre-treatment. Physical characteristics affect the ability to properly handle, feed and process the waste material and therefore strongly influence the nature and degree of pretreatment required. Physical characteristics of particular importance include physical state (e.g., soils, solids, sludges, slurries, liquids, containerized wastes), viscosity, moisture content, and the particle size of solids. The chemical characteristics of waste determine combustibility of the wastes themselves and their contaminants. The need for auxiliary fuel and the type and efficiency of air pollution control systems are also determined from the chemical characteristics.

The major factors affecting suitability of a waste for incineration are discussed in the following paragraphs.

3.2.2 IDENTIFICATION OF CONTAMINANTS

The identification of all contaminant(s) constitutes the most important step in determining the suitability of thermal methods for the treatment of waste material. While most organic contaminants are oxidized to non-toxic products at high temperatures, many inorganic contaminants are not detoxified. For most inorganic toxics, toxicity is associated with the presence of specific elements (e.g., lead, arsenic) and, therefore, combustion does not result in detoxification. Additionally, particular waste characteristics can interfere with or adversely impact either the environment or the effectiveness, safety, cost or reliability of the thermal treatment process.

Specific contaminants that impact or restrict the application of thermal treatment are discussed in detail below. Special consideration must be given to waste material containing elevated concentrations of these contaminants.

Toxic Elements and Heavy Metals

Toxic elements in the waste (arsenic, beryllium, nickel, copper, mercury, lead, cadmium, and chromium, among others) are not destroyed by combustion. Such elements present in the waste feed are concentrated in the ash residue. Also, at operating temperatures (1600°-2200°), some metals (e.g. mercury, lead) present in the waste or formed by reactions in the furnace are volatilized and released into the flue gas as a gas or finely divided fume. Other metals may be present as oxides, some of which may vaporize into a gas when temperatures exceed the boiling point (Table 3-1). Incineration of wastes with elevated levels of chlorine can lead to the formation of chlorides, many of which have boiling points at or below the operating temperatures of most incinerators and will vaporize (Table 3-1). The gaseous materials and/or sub-micron fume particles are removed only to a limited extent by conventional air pollution control equipment such as dry scrubbers. Increasingly, onsite incineration systems use high energy wet scrubbers (e.g. Hydro-Sonic Systems) and/or baghouses for capture of fine partuclates. Even with good gas cleaning systems, most combustion

TABLE 3-1

BOILING POINTS OF SELECTED COMPOUNDS

Compound	TBoil (°F) *	
As_2O_3	379	(sublimes)
BaO	3632	
$BeCl_2$	7052	
Cd	1412	
$CdCl_2$	1760	
CdO	1652-1832	(decomposes)
CrO_2Cl_2	243	(sublimes)
CuCl	2491	
$CuCl_2$	1819	(decomposes to CuCl)
$FeCl_2$	1238	
$FeCl_3$	599	
$PbCl_2$	1742	
Hg	674	
HgCl	575	
SeO_2	603	
$SnCl_2$	1153	
ZnO_2	3272	
$ZnCl_2$	1350	

* Temperatures in the primary chamber of hazardous waste incinerators may exceed 1800°, and the secondary combustion chamber often exceeds 2200°F. At these temperatures many of the compounds listed above will exist in the gas phase. Capture of the gaseous forms of these compounds requires expensive modifications to the air pollution control systems.

systems are particularly inappropriate for wastes containing trivalent chromium (Cr^{+3}) since Cr^{+3} can be oxidized to the more toxic and carcinogenic hexavalent chromium (Cr^{+6}) valence state in systems with oxidizing atmospheres.

Criteria for some key toxic elements are presented in the following table (Table 3-2). The values represent levels for waste acceptance used by the major stationary incineration facilities discussed later in Section 4.

The specific limits for each element are dependent on a facility's business policy as well as their operating permit, which considers major environmental impacts associated with the facility operation. Some of these impacts include: (1) the quantity and quality of air emissions (2) the type and efficiency of air pollution systems, and (3) the quality of the treated wastewater effluent discharged from scrubber systems.

The range of values presented in Table 3-2 is quite broad and, importantly, is driven by both air emission restrictions (Clean Air Act) and scrubber water discharge limitations (NPDES Standards). For example, emissions of mercury and arsenic are limited by state and federal standards for air pollution control while other metals such as zinc, nickel and copper are limited by state and federal regulations on the quality of scrubber effluent discharged. Table 3-2 indicates that commercial facilities will accept only very low levels of elements such as mercury (Hg) and arsenic (As) (less than 10 ppm) for incineration. Other elements have more lenient standards. Current federal regulations do not control emissions of many metals. However, the regulatory process for approval of new incinerators include analysis of health risks from these emissions, and air pollution control systems are designed to reduce emissions to comply with these guidelines. Specific limits were not available for mobile systems. Mobile systems are able to modify their air pollution control systems to handle specific waste streams at a site. It is recommended that mobile system vendors be contacted to determine the restrictions that may apply to their system.

TABLE 3-2

ACCEPTANCE CRITERIA FOR TOXIC ELEMENTS AND HEAVY METALS IN WASTES AT EXISTING COMMERCIAL THERMAL TREATMENT FACILITIES*

Element	Range of Acceptance Limits (ppm) From Stationary Facilities**			Median Value (ppm)
	Low		High	
Mercury (Hg)	0.2	-	10	3
Arsenic (As)	2	-	10	8
Lead (Pb)	25	-	750	150
Chromium (Cr)	5	-	500	300
Cadmium (Cd)	1	-	1,000	5
Zinc (Zn)	150	-	10,000	1,500
Nickel (Ni)	75	-	1,000	150
Copper (Cu)	100	-	1,000	750

* Values current as of 1987.

** See Section 4.0 for additional details.

Conclusion: Significant levels of toxic elements and metals require detailed study of the ability of air pollution control equipment to remove vapor phase compounds and particulates.

Halogens

When thermally treated, hydrocarbons containing fluorine, bromine and chlorine form acid gases. This causes corrosive attack of equipment (e.g., refractory, brick, ferrous metal, stainless steel, scrubber equipment, and stacks) as well as acid gas emissions. Acid gas control equipment and special construction materials are necessary to minimize these impacts. While most stationary incineration facilities do not limit chlorine content (extra charges may apply, however) they generally limit fluorides, bromides, and iodides to less than 1%.

Additionally, a high concentration of halogenated organics may call for higher temperatures and longer residence times since the halogens act to inhibit the oxidation combustion reactions. The cost for acid gas neutralization (both capital, reagent and other operating costs) adds to the expense of thermal treatment of halogen-bearing wastes. This additional cost may be reduced by blending with highly contaminated material.

Phosphorus

Similar to halogens, when thermally treated, organic phosphorus compounds form phosphorous pentoxide, an acid gas (phosphoric acid). Phosphorous pentoxide formation often results in refractory attack and/or slagging problems (the phosphorous pentoxide forms low-melting eutectics with other ash constituents). However, thermal treatment of inorganic phosphorous compounds does not result in the phosphorus pentoxide although some inorganic compounds (e.g., ferric phosphate) have low melting points and can cause slagging problems. Blending of waste may reduce phosphorous to acceptable levels.

Cyanides

Thermal oxidation of cyanides requires very high temperatures which may result in slagging and defluidization of fluid beds, slagging in other combustors, and increased NO_x formation which may exceed ambient air standards. Thermal oxidation of alkali metal cyanides produces alkali oxides that either volatilize to form a hard-to-collect fume or melt and attack the refractory wall. However, cyanides are not common at Superfund sites as they tend to degrade rapidly in the natural environment.

Alkali Metals

Sodium (Na) or other alkali metals such as potassium (K) in the waste can create two problems in the combustion process: severe refractory attack and formation of a sticky, low-melting submicron particulate. The refractory attack is particularly a problem in kilns where sodium reacts with silica in the brick to form low-melting sodium silicate glass at the refractory surface. This material is readily eroded by the movement of the material through the kiln, exposing new surface to attack and continuing the degradation process. This attack can be controlled by proper refractory selection, which can add significantly to the installation and maintenance costs, but does not really preclude on-site incineration.

The sticky particulate from high sodium wastes can cause fouling or slagging of convective heat transfer surfaces in incineration systems that incorporate waste heat boilers as an integral part of the process. Operators of rotary kilns generally use a guidelines of 1% as a maximum for feed stream concentrations of Na and K which may be achieved through blending.

3.2.3 CONCENTRATION OF CONTAMINANTS

An important consideration in assessing waste suitability for thermal treatment is the variability of the waste stream fed to the thermal processing system. Because of the nature of CERCLA waste, material from "hot spots" as well as materials with low contaminant concentration may be fed into the unit, possibly one immediately following the other. This variability in feed concentration may affect system performance. Some thermal systems have specified feed limits for various contaminants, particularly heavy metals (see Table 3-1) to satisfy environmental criteria. In other circumstances (e.g., alkali metals), slagging or other waste chemistry-related process criteria set feed limits. In order to maintain a more uniform feed, high concentration waste can be mixed with low concentration waste to form a blend within specification.

Inorganic corrosives (i.e, most acids and bases), salts, and cyanides cannot be detoxified by oxidation. However, thermal treatment of small quantities may be possible by dilution or blending with other non-corrosive wastes that also require incineration.

3.2.4 PHYSICAL FORM OF WASTES

While contaminant type and concentration are critical in determining suitability for thermal treatment, the physical form of the waste also has an important bearing on pre-treatment needs and treatment methods. This subsection addresses the physical forms wastes may take -- i.e., containerized wastes, liquids, sludge, soils and debris -- and describes how these forms affect the methods required to prepare these wastes for thermal treatment.

Tanks and Drums

Waste contained in tanks or drums, is often separated into several layers of material of varying physical and chemical properties. The top layer may be an organic liquid suitable for thermal treatment, and serve as auxiliary fuel for a thermal system. The next layer may be an organic or aqueous sludge which may be blended with combustible liquid wastes or solidified for treatment as a solid. The bottom layer may be solid sediments which may be treated much like highly contaminated wet soil. Drums often require considerable time and manpower for separation and removal of multiphase wastes, especially sludge and solids.

Fixed incineration facilities will only accept waste in specified forms. Metal drums are not readily processed in rotary kilns, and the contents will have to be repacked prior to incineration. Empty metal drums may be shredded for incineration or shipped to a drum decontamination facility. Liquids and pumpable sludges are accepted in bulk form. Nonpumpable sludges and solids must be stabilized (no free liquid) using either available soil or an absorbent such as sawdust and containerized in plastic or fiber drums for feeding into the rotary kiln.

Mobile thermal treatment systems have slightly different feed requirements. Liquid organic waste from drums and tanks can be kept in storage tanks on site and used as auxiliary fuel. Sludge can be pumped into the unit or, if nonpumpable, stabilized and fed into the unit using bulk feed systems developed for handling soils. Containerization in plastic or fiber drums is unnecessary for feeding.

Liquids

Organic liquids. Organic liquids are the most "incinerable" of all contaminated waste types since they generally can easily be pumped to and atomized in the combustion chamber. Key source considerations applying to liquid wastes include the following:

- Percent organics: the fraction of organic material has a dominant effect on the heating value of the waste being burned, thereby affecting needs, if any, for additional energy input (and cost) to the thermal system from virgin fuel.

- Flash point: The flash point is the temperature at which vapor will be ignited by a spark. The flash point roughly scales the relative combustibility of the organic liquid. Those liquids with relatively low flash points (<1400°F) must be carefully handled to avoid fire hazards, but as long as normal precautions (vapor capture, spill control) are taken such wastes can serve as auxiliary fuels by themselves or be blended with other organic liquids.

- Solids content: The amount, type and size of solids in liquid waste feeds should be determined to evaluate potential pumping and atomization problems and amount of ash that may result. Filtration or decontamination may be required to prevent clogging of liquid injection systems.

- Viscosity: The viscosity of a liquid determines pumpability and affects atomization behavior. Highly viscous liquids with poor pumpability may require heating for pumping or blending with low viscosity liquids.

- Halogen Content: The presence of high levels of chlorine or other halogens will result in acid gas formation and can inhibit combustion reactions. The halogen content of the waste stream feed should be monitored, as it will affect system operating parameters, potentially requiring additional fuel use to maintain operating temperatures. Excessive acid gas emission may also result.

Aqueous liquids. Aqueous liquids may be suitable for thermal treatment if they contain a substantial amount of organic matter. Usually an aqueous waste should contain no less than 10 % organics and, preferably, more than 25 % organics for thermal treatment unless the waste constitutes only a small portion of the total feed. Higher concentrations of organic will add further to the fuel value. This is particularly important due to the large energy demand for evaporation when treating large volumes of aqueous liquids. There is a site-specific or system-specific quantity and concentration at which it is no longer economically feasible to incinerate the waste; therefore, pretreatment to dewater or combination with some other treatment technology may be more cost effective.

Sludges

Sludges have highly variable physical and chemical characteristics and are often difficult to excavate and handle. Sludges may range in character from a near-liquid state to a viscous semi-solid. Sludges requiring incineration at CERCLA sites are often by-products of petroleum or chemical manufacturing processes and may contain elevated levels of heavy metals. Several factors of particular importance are discussed below:

- Moisture Content: Moisture content of a sludge often ranges from 40 percent to 95 percent. The higher the moisture content, the more energy input or fuel input is required to adequately dry and then incinerate the sludge (see Figure 3-1).

- Type and Origin of Sludge: A broad range of sludge types may be found at CERCLA sites including:

  Refinery sites - acid asphaltic sludges, still bottoms, often with a high heavy metal content

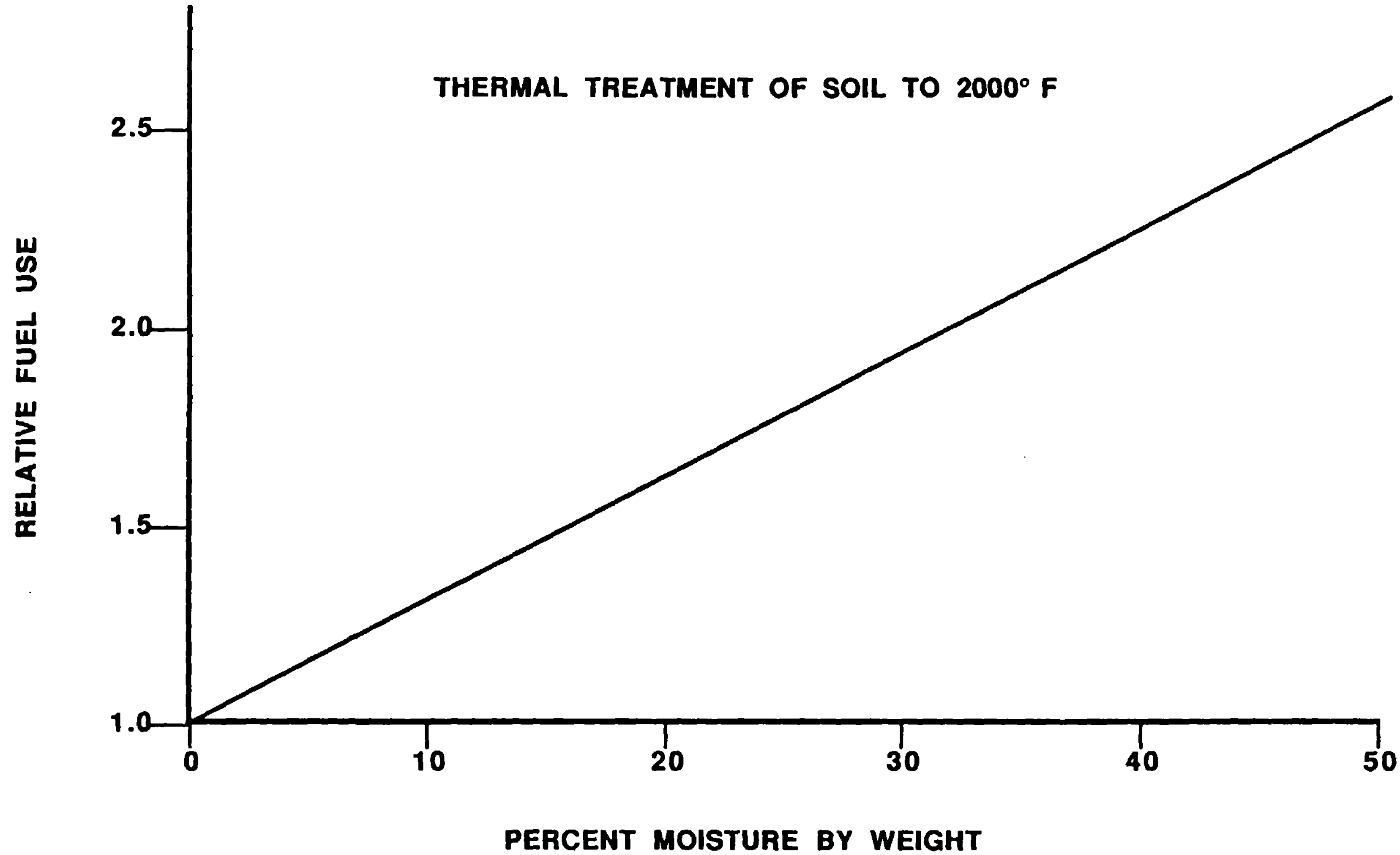
  Chemical manufacturing sites - resins, polymers, still bottoms, process residuals

  Recycling/recovery sites - blends of all of the above plus PCBs

  Wood preserving facilities - creosote sludges and tars, chlorinated phenols and, possibly, associated dioxins.

- Handling considerations: The viscosity of the sludge should be assessed to determine its pumpability. High viscosity sludges may require either fluidization (by heating or blending) for pumping or stabilization for handling as a solid. Handling of high viscosity sludges is often improved by mixing with adjacent soils, which reduces adhesion problems. The sludge may then be handled by heavy equipment in a similar fashion as a soil.

  Lower viscosity sludges may be pumped using cement pumps or similar equipment. The variation in liquid content and viscosity associated with lagoon sludges often requires continual adjustment and/or defouling of pumps and intakes. Generally the sludges can be pumped directly into a rotary kiln, but feed rate and Btu content are critical factors. Onsite thermal treatment systems may have special



Source: CDM Estimates (1987)

Figure 3-1

Effects of Moisture Content on Fuel Use

feed requirements for sludges and temporary storage in tanks may be required.

- Solids content: The solids content of the sludge will determine its handlability to a large degree. The solids content will also determine the type of pumps that can be used (if it is pumpable) and whether the sludges must be screened for removal of oversize material.

Soils

Type of soil. Different soil types require different handling and pretreatment. Sand or sandy soil is relatively easy to feed and requires no special handling procedures. Clay, on the other hand, may be in large clumps which may require size reduction before being fed to the incinerator. Contaminants adsorbed throughout a moist clump may not be completely destroyed in the available residence time unless fragment size is reduced to expose the inner surface.

Rocky soils may require screening to remove oversize cobbles or boulders. Rounded stones may roll rapidly through an inclined kiln, preventing thorough heating of the stone. Porous stones (sandstone, limestone, shale) may absorb organic compounds, requiring longer residence time for devolatilization.

Moisture content. The moisture content in a soil affects several aspects of thermal treatment. The higher the moisture content, the more auxiliary fuel is required to heat the contaminated soil to the temperature where evaporization and/or decomposition occurs (see Figure 3-1). Moisture must be evaporated before combustion of the solid phase contaminants can take place. The fluctuation of soil moisture content with changes in weather conditions can have a significant effect on incinerator performance. Periods of heavy rainfall can raise soil moisture levels to the point that incineration processing rates are cut by up to 50%, adding weeks or months to the cleanup schedule and escalating costs beyond original estimates.

Moisture content also affects the handling of soils and dewatering may be advisable or necessary.

Concentration of contaminants. Contaminated soils are likely to have low concentrations of contaminants relative to the large volumes of soil to be incinerated. There is a risk that "hot spots" or high contaminant concentrations may arise and overload the design heat capacity of the unit, particularly when incinerating soil/sludge mixtures. For this reason, soils may have to be mixed to achieve more uniform concentrations. Frequent sampling is required to determine the actual Btu content of the feed stream. Soil feed rates and auxiliary fuel input may require frequent adjustment to compensate for variation in Btu content.

3.3 MATERIALS HANDLING AND PREPARATION

The problems posed by materials handling and preparation are often considered the most significant obstacles at most sites. While these problems are generally amenable to engineering solutions, they may add considerably to remediation time and cost. A general overview of handling and preparation requirements for both onsite and offsite thermal treatment is discussed below.

Solids/Soil

Excavation activities would normally be carried out by bulldozers, front-end loaders and/or other conventional excavation equipment. The excavated material would be moved to the processing area either directly with front-end loaders or via transfer truck or conveyor. The exact excavation and transfer equipment would depend upon the type of material and the layout of the site.

If solids are to be sent to an offsite thermal facility, they must be containerized in plastic or fiber drums. At this time, no stationary facilities have bulk solids handling capabilities. However, these capabilities are being developed by commercial facilities in response to the increased demand for bulk solids disposal. Rollins Environmental

Services Facility in Deer Park, Texas and ENSOCOS Facility in El Dorado, Arkansas will have bulk handling capacity in late 1988 or 1989. Depending on the nature of the soil and the size of solid pieces to be treated (e.g., tree stumps, construction debris), solids preparation may be necessary to facilitate containerization. The preparation system may include a combination of grizzles and screens, breakers, crushers, shredders, power saws and dewatering equipment. Upon receipt at the commercial facility, in-place handling equipment is available to complete material preparation and to process the solid material.

Solids handling and preparation requirements for onsite thermal treatment systems are typically more complex due to the need for complete preparation and handling facilities. Many of these components would otherwise be standard features at commercial facilities. Mobile systems, because of the limitations on their size imposed by highway weight and size (length, width, height) constraints, also have to be more restrictive on acceptable feed size than stationary facilities. Therefore more elaborate preparation systems may be necessary although the basic equipment (e.g., grizzlies, breakers, shredders) would be similar to that discussed above. Provisions should normally be made for blending of excavated solids to achieve a more uniform feed both as regards to size distribution and moisture. This procedure would normally be performed on a blending floor with the use of front-end loaders.

The method of feeding the prepared waste into the onsite processing unit is generally an integral part of unit design and similar to methods used in stationary facilities. Gravity feed has been used where free flowing bulk solids are encountered. Screw feeders operate reliably as long as the solids do not contain large proportions of rags, wires, ribbons or paper which may wrap around the flights and jam the conveyor. Another feed method consists of a ram-type feeder which injects the solids through an opening controlled by a guillotine-type door. Apart from its suitability of handling the specific waste types for which the unit is proposed, the feeding system must be designed to control air infiltration through the feed opening. In addition to using the feed material as a plug in the feed chute, mechanical devices to eliminate extraneous air should be included, such as mechanically controlled lids and doors.

Where the major feed stream consists of contaminated soil, the volume and weight of the treated material discharged is essentially the same as that fed into the unit. With the exception of the equipment required for feed preparation, materials handling equipment of similar size and capacity as used at the "front-end" must therefore be provided at the "back-end" to remove the treated soil. In addition, some type of cooling must be allowed before the residue can be moved. Cooling can be achieved with water only or by simply piling the hot material and allowing it to cool. In onsite applications, the cleaned soil would normally be suitable as back-fill at the same site. Stationary facilities are required by operating permits to dispose of all ash (including decontaminated soil) in secure landfills due to the variability in waste feeds processed.

Drums

The handling of drums for offsite treatment would depend on several factors including the condition of the drums, their contents and the specific acceptance requirements of the commercial facility. Damaged or leaking drums would required repacking prior to shipment while unsuitably sized drums or containers may require repacking prior to or after delivery. Upon delivery and acceptance, containers would be handled according to normal facility operations. Depending upon the contents, drums may be emptied, shredded whole or fed whole into the thermal system.

The handling of drums with an onsite thermal unit poses a more difficult challenge because current mobile systems are not equipped to accept whole drums. Drums containing pumpable materials must be pumped directly to the burners or emptied into a receiving tank first. Drums containing solids must be emptied on shredded whole, if feasible, prior to processing. Empty drums can either be shredded before feeding into the thermal destructor or shipped off site for decontamination.

Liquids and Sludges

The presence of liquids or sludges in drums and lagoons call for a pumping system which must be capable of handling highly viscous liquids and liquids carrying solid particles of various amounts and sizes. Other than the need for oversized piping and the avoidance of any piping restrictions (such as valves or sharp bends) special purpose pumps (often reciprocating pumps) are used to handle the liquids and sludges. The piping system should be so designed as not to require filters or screens within the system. Open screens at the discharge end to the receiving tank may be used provided the solids accumulating on the screens can easily be removed, either manually or mechanically.

Liquids and sludges destined for offsite treatment must be pumped into tank trucks (if pumpable) or containerized in plastic or fiber drums. The selected method would depend primarily on the volume of material and the acceptance requirements of the facility. Most stationary facilities accept liquids and pumpable sludges in bulk shipments. Nonpumpable sludges, however, must be packed in suitable containers. Nonpumpable sludges are often stabilized by mixing with adjacent soils or other suitable materials (e.g., lime). This simplifies handling by permitting use of conventional soil excavation and transport equipment (e.g., conveyors) combined with hoppers for container loading.

For onsite treatment, liquids and pumpable sludges can be pumped either directly or indirectly to the thermal system. The final method of injecting the liquids and sludges into the combustion chamber depends primarily on viscosity. Low viscosity liquids may be injected through oversized air or steam atomizing burners of more or less conventional design while high viscosity sludges or highly contaminated liquids may be introduced into the unit through open pipes (rotary kiln or fluidized bed). It may be advantageous to plan for blending and provide separate tanks to segregate the "good" waste liquids from the "dirty" ones. Controlled blending can then take place in a separate blending tank equipped with agitators. Care must be taken not to blend liquids that may be mutually reactive. The blending of certain proportions of high BTU liquids with the solid waste may also be considered.

While care can be exercised to separate the water layers in drums and lagoons from the organic layers, provision may have to be made for further water removal before injection into the incinerator. Such procedure may be performed through commercially available water separators (oily waste separators) or simply by allowing the water to settle out in a settling tank. The decanted water layer would normally still contain some contamination and may have to be treated before discharge back into the ground, the sewer (if available) or appropriate wastewater treatment plant. The means selected for the ultimate disposal of water is essentially an economic decision. If the volume of water is such that it can be vaporized in the treatment unit with waste fuel, or only relatively small amounts of virgin fuel, the water would not be disposed of externally.

Environmental/Health Impacts

The control of fugitive emission from the preparation and handling equipment bears carefully thought. Not only must the emission of toxic vapors into the environment be prevented for reasons of environmental safety but the work crew must not be exposed to health hazards. Safety gear for workers, enclosures of machines and equipment, and ventilation and air filtering systems may have to be provided.

4.0 ONSITE THERMAL TREATMENT SYSTEMS

4.1 INTRODUCTION

A number of thermal technologies have been applied to onsite treatment of hazardous wastes. System components and process operation of mobile units is generally similar to stationary equipment. The scale of equipment, however, is often smaller. This is due, in large part, to transportation and assembly limitations. Mobile systems are typically designed to be transported via tractor trailer trucks. System components are therefore sized to meet length, width, height and weight constraints imposed for over-the-road travel. Components are often "modularized" to simplify assembly of the system by minimizing field-erection requirements.

Since a wide variety of waste types are often encountered at CERCLA sites, the most effective thermal systems are those that offer flexibility in the types of wastes accepted. The most versatile systems at this time appear to be rotary kilns, circulating fluidized beds and infrared processing systems. Each system is capable of processing solids (including contaminated soils), liquids and sludges.

The following section presents a review of the rotary kiln, circulating fluidized bed and infrared systems. Included in this review is a description of process operation and a discussion of the comparative advantages and disadvantages of each system. A listing of known mobile service companies is also provided.

4.2 ROTARY KILN INCINERATORS

The most common thermal system applied to hazardous waste treatment is the rotary kiln incinerator which can accept a broad range of wastes. For example, pumpable and atomizable liquid wastes can be injected through conventional burners into the kiln, sludges and viscous liquids can be pumped through open pipes into the rotary chamber, and soils and other solid materials as well as suitable-sized containers can be fed through entrance chutes. Kiln rotation continuously exposes fresh surfaces to oxidation and provides for constant removal of the treated soil and ash at the discharge end. A secondary combustion chamber (afterburner) is provided for the further destruction of unburned gaseous and suspended particulate organics. This combustion system provides turbulent mixing of the waste gases with excess oxygen at high temperatures. If properly designed and operated, the combination of adequate combustion volume, turbulence and temperature will normally provide sufficient residence times to destroy the organics within the allowable limits. The off-gases must be quenched and scrubbed of acids and particulates before discharge to the environment.

Rotary kiln incinerators have been used extensively at fixed facilities for treatment of both hazardous and nonhazardous waste material. The majority of these installations are used for in-plant industrial waste destruction. Due to their ability to effectively destroy diversified waste feeds, rotary kilns have also been developed as mobile or transportable systems. This allows for waste treatment on site, thereby eliminating the need to transport waste off site. Once remediation is complete, the system is designed to be disassembled and moved to another site.

Process operation of rotary kiln systems begins with solid or sludge waste material being fed into the feed chute of the unit. Once charged to the feed chute, the feed is introduced into the upper end of the kiln by various methods including hydraulic rams, screw augers or inclined chutes. As waste material is charged to the kiln, it is exposed to high temperature gases that flow either concurrent or countercurrent to the waste movement. Waste movement through the kiln is promoted by a combination of the rotation and inclination of the cylindrical kiln.

As wastes pass through the kiln, they are first dried and then the organic content of the waste is substantially oxidized to gases and ash. Ash and non-combustible detoxified solids, such as soil, are removed at the lower end of the kiln and discharged into a residue receiving container. Meanwhile, exhaust gases from the kiln enter a secondary combustion chamber or afterburner to complete oxidation of the combustible waste. Fossil fuel or liquid combustible wastes can be burned in the secondary combustor as well as the primary chamber. As the exhaust gases exit the secondary chamber, they are directed through pollution control equipment such as cyclones and scrubbers for particulate and acid gas control before being released through a process stack. A process flow diagram of a mobile rotary kiln system is presented in Figure 4-1.

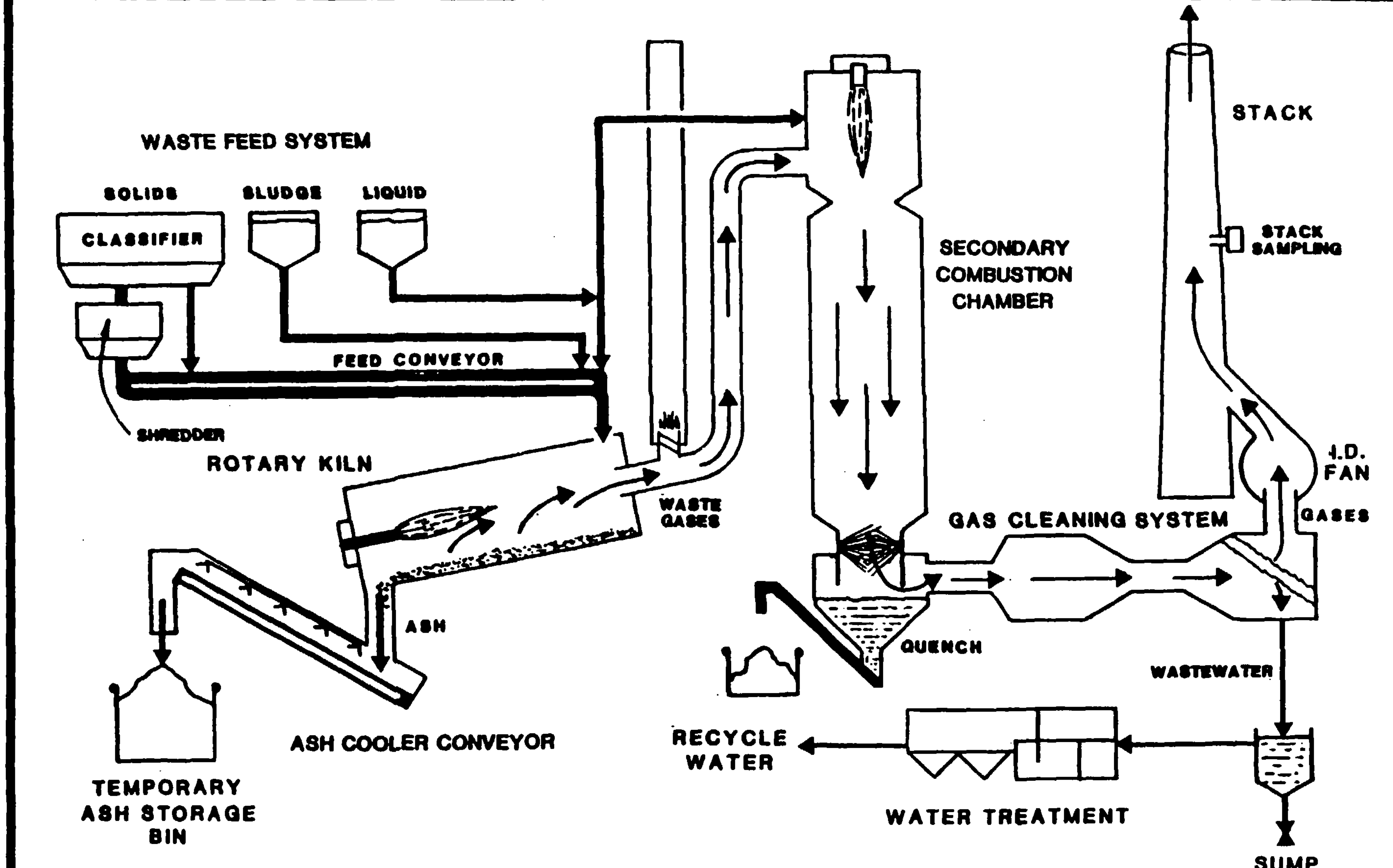
4.3 CIRCULATING FLUIDIZED BED INCINERATORS

Fluidized bed combustion is the process of burning fuel/waste particles in a state of suspension. Suspension is achieved by passing air upward through a bed of particles. The velocity at which the drag on the particles will support them is referred to as the fluidization velocity. Conventional fluidized beds operate at a fixed bed depth and within a narrow range of gas fluidization velocities. Operation above the fluidization velocity entrains the bed material in the air stream resulting in a carryover of unburned particles from the combustion chamber into the pollution control equipment. If fluidized beds are operated below the fluidization velocity, the bed slumps and, in effect, becomes a fixed bed combustor.

Fluidized bed systems used for liquid or sludge treatment use a particle bed of inert material such as sand for the fluidized medium. When these systems are used for soil treatment, the soil feed acts as the bed material. Soil is fed at a rate that ensures adequate contaminant destruction. The decontaminated soil is removed at the same rate.

Relative to fixed bed combustors, fluidized beds offer relatively fast and efficient combustion of waste material because of the high degree of mixing provided and the resulting uniformity of the combustion environment. An air velocity of about 5 ft/sec results in expansion and fluidization of the bed. This allows for increased contact time between the waste material and air, thereby improving combustion efficiency.

Variations of the conventional fluidized bed have been applied to further improve performance. The most significant of these is the circulating bed concept. The circulating bed system offers increased mixing and longer



Source: International Technology Corp.

Camp Dresser & McKee Inc.

FIGURE 4-1
PROCESS FLOW DIAGRAMOF THE IT HYBRID THERMAL TREATMENT SYSTEM (ROTARY KILN)

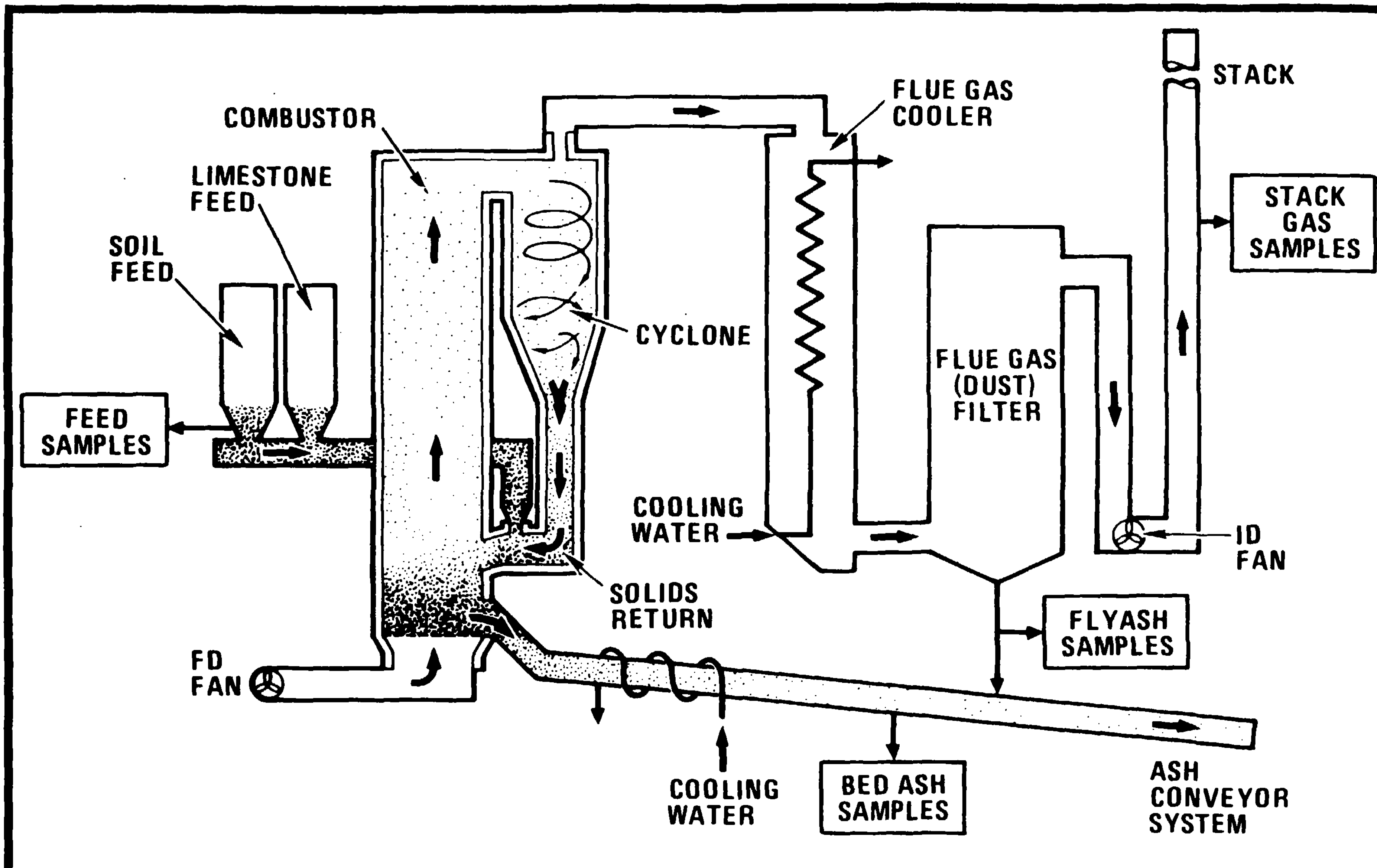
residence time. Process operation of circulating fluidized bed systems involves introducing combustible waste and/or contaminated soil with dry limestone (for in-situ acid gas absorption) into the combustor loop along with recycled bed material returned from the hot cyclone. The combined material is entrained by high velocity air (greater than 12 ft/sec) introduced at the bottom of the refractory-lined combustion chamber. Combustion of waste then occurs along the entire height of the combustion section. Bed material and unburned waste carried out of the combustor with flue gases pass into a conventional solids separation cyclone. The refractory-lined cyclone separates flue gases from the heavier particles. The recovered solids are recirculated into the bottom of the combustion chamber via a return loop seal. The non-mechanical seal allows for rapid solids return while preventing backflow of combustion chamber air into the cyclone.

Bottom ash and decontaminated soil are removed from the combustor by a water-jacketed screw conveyor and combined with fly ash before being discharged into a collection bin. Meanwhile, hot flue gases are passed through pollution control equipment (such as baghouses) for particulate removal. Gas cooling (possibly, with a boiler) is required to reduce flue gas temperature for acceptable entry into the baghouse. A process flow diagram of a mobile circulating fluidized bed system is presented in Figure 4-2.

4.4 INFRARED PROCESSING SYSTEMS

Infrared systems are used for destroying combustible materials under high temperatures with infrared energy, as opposed to the direct firing of fossil fuels, supplying auxiliary heat. Infrared energy is produced either via electrical resistance heating elements or indirect fuel-fired radiant U-tubes.

Infrared processing systems have been used primarily for industrial applications such as carbon regeneration and for domestic sewage sludge incineration. This technology has been applied to hazardous waste treatment for contaminated soil first on a pilot-scale basis and more recently on a full-scale level.



Source: Ogden Environmental Services Inc.

Camp Dresser & McKee Inc.

FIGURE 4-2
PROCESS FLOW DIAGRAM OF THE OGDEN ENVIRONMENTAL SERVICES CIRCULATING BED COMBUSTOR

Process operation begins with solid or sludge waste material being fed into the feed chute of the primary chamber. Once deposited into the feed chute, waste material passes through a rotary airlock, which restricts air infiltration into the furnace, prior to deposit on a woven conveyor belt constructed of selected metal alloys for increased durability. Spreading and leveling devices are provided to distribute waste material evenly on the alloy mesh belt. The conveyor belt moves the material through the furnace at the desired rate for optimum processing. Throughput is reportedly highly controllable due to the ability to adjust the depth of material on the belt (up to 2 inches thick) and the length of residence time (eight to 50 minutes). The selection of a processing rate can be determined initially on the pilot level and confirmed through testing in full-scale equipment.

As the material is conveyed through the furnace, it passes under infrared heating elements or alloy U-tubes, depending upon the energy source selected. Infrared energy released by these sources is used to heat the material on the belt to temperatures up to 1,850°F. Rotary rakes are positioned along the entire length of the furnace to gently stir the material for maximum exposure to air and infrared radiation. Combustion air is injected at various points along the length of the furnace through a manifold system. The furnace interior can be protected with either ceramic fiber insulation, refractory brick or castables. Fiber insulation is immune to thermal shock, and is therefore more advantageous in mobile application since rapid heating and cooling of the furnace is possible compared to the other insulation material.

At the discharge end of the furnace, ash or processed material such as soil exits the primary furnace and is discharged through a chute equipped with an air seal to a collection hopper or bin. Exhaust gases meanwhile flow countercurrent to the conveyor belt and exit the furnace through an exhaust duct. The exhaust gases pass through an infrared or gas-fired secondary chamber to ensure complete combustion of any remaining organics. Systems equipped with a gas-fired secondary chamber typically include a liquid injection system to allow for the atomization of combustible liquid wastes into the secondary chamber. Before discharge to the stack, exhaust gases from the secondary furnace pass through pollution control equipment such as a scrubber for particulate removal, acid gas control and gas cooling. A process flow diagram of a mobile infrared processing stem is presented in Figure 4-3.

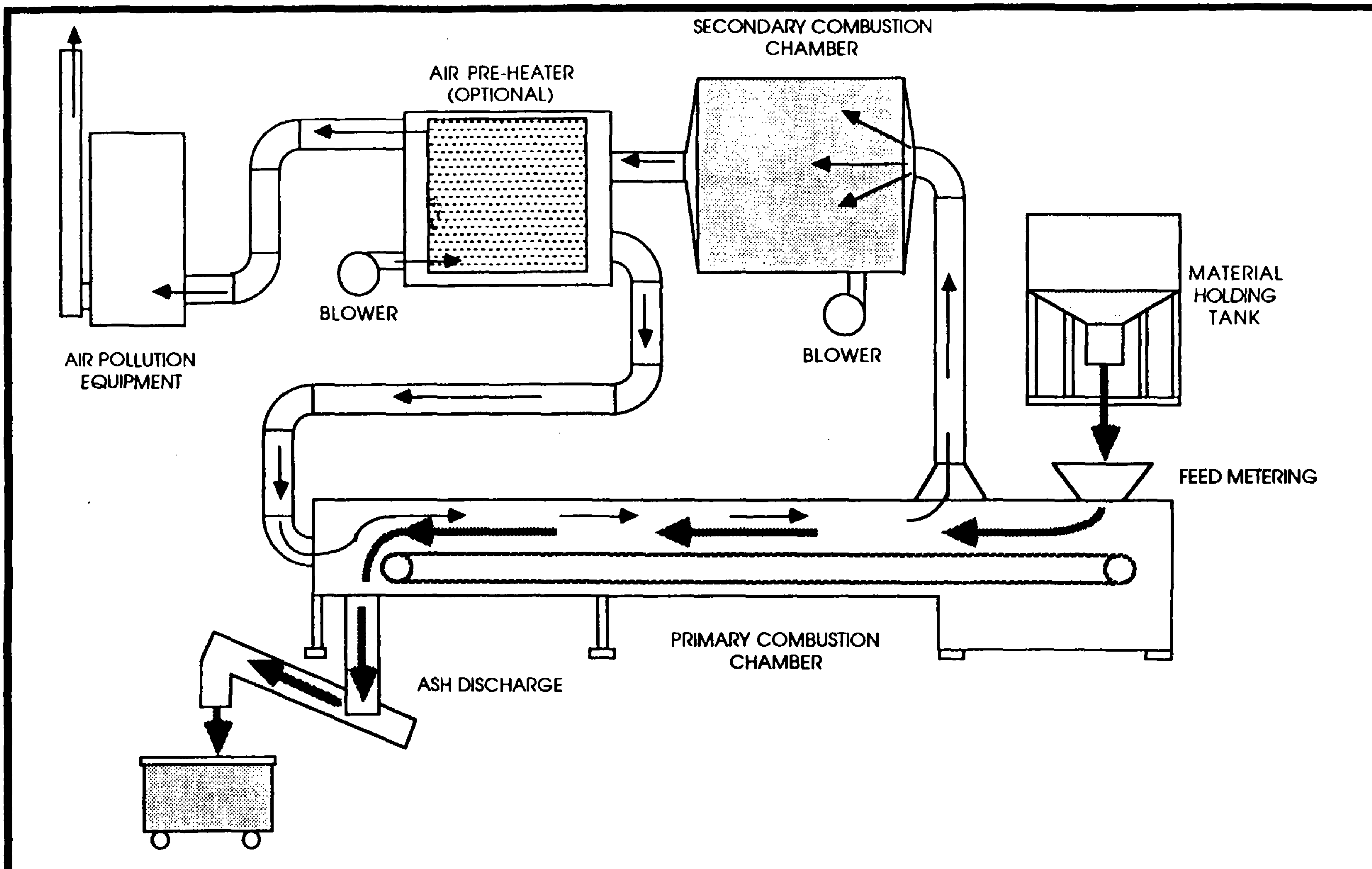
4.5 COMPARATIVE ANALYSIS

Although each of the three processes presented can process solid, liquid and sludge waste materials, distinctive differences exist between them. The most significant differences are discussed below and summarized in Table 4.1. It is important to note that, by themselves, these factors do not necessarily favor one system over another or render a particular system unfeasible. The selection of a specific treatment system for a particular site can only be made upon a detailed evaluation of the quantity and physical form of wastes to be treated, the type of contaminants present and the total cost of treatment. In many cases it may be feasible to use either one of these systems on a particular site with cost being the only distinguishable difference.

Of the three processes, rotary kilns are, by far, the most well-developed and proven. Extensive operating experience with hazardous wastes exists on both a commercial and industrial scale. A number of vendors are offering mobile rotary kiln systems. Circulating bed and infrared systems, while developed to the full-scale level, have more limited operating experience. The majority of this experience has been performed on the pilot-scale level.

The destruction capabilities of each system have been well-demonstrated. All three have successfully destroyed toxic organics including PCBs. In addition, full-scale rotary kilns have been used successfully to destroy dioxins. Both rotary kilns and infrared processing systems utilize a secondary combination chamber to ensure complete destruction. Circulating fluidized bed systems do not require a separate secondary chamber due to the high degree of turbulence and mixing provided by the recirculating bed.

In comparison to circulating bed and infrared systems, rotary kiln equipment tends to be relatively large in size for a given throughput due to the high



Source: ACOVA
(Formerly Shirco
Infrared Systems Inc.)
Camp Dresser & McKee Inc.

FIGURE 4-3
PROCESS FLOW DIAGRAM OF THE SHIRCO INFRARED PROCESSING SYSTEM

TABLE 4.1

COMPARATIVE ANALYSIS SUMMARY

	Rotary Kiln	Circulating Fluidized Bed	Infrared Processing System
Process Technology	Well-developed and proven, extensive operating experience	Developed, more limited operating experience	Developed, more limited operating experience
Destruction Capabilities	Demonstrated destruction of toxic organics including PCBs and dioxins, secondary combustion chamber required	Demonstrated destruction of toxic organics including PCBs, secondary combustion chamber not required	Demonstrated destruction of toxic organics including PCBs (full-scale), and dioxins (pilot-scale), secondary combustion chamber required
Gas Volume	Large gas volume due to high excess air requirements	Moderate gas volume	Low gas volume
Mobilization	Longer set-up time, larger set-up area required	Smallest set-up area required, shortest set-up time	Shorter set up time
Solid Feed Size	Non-uniform feed size acceptable, max size typically 12 inches	Uniform feed size of less than one inch required for all solids	Uniform feed size of less than two inches required for all solids
Acid Gas Control	External scrubbing system required	Acid gas absorbed in the circulating bed. No external control necessary	External scrubbing system required
Particulate Loading	High particulate loading due to kiln rotation, high excess air requirements	High particulate loading due to the turbulent nature of the bed	Low particulate loading due to the quiescent nature of the bed
Combustion Chamber Insulation Material	Refractory brick susceptible to attack by alkal metals and acid gases. Rebricking may be necessary in order to transport	Refractory brick susceptible to attack by alkali metals and acid gas	Ceramic fiber insulation immune to thermal shock and lighter than refractory brick
Process Water required for scrubbing closed-looped	Process water (and wastewater water scrubber, all cooling system	No process water required, no disposal) required for scrubbing	Process water (and wastewater disposa system syste
Energy Source	Fuel oil, natural gas, propane and/or waste liquids	Fuel oil, natural gas, propane	Electric power for primary, propane and/or waste liquids for secondary
System Capacity	Available mobile systems up to 20 tons per hour	Available mobile systems up to 3 tons per hour	Available mobile systems up to 4 tons per hour

percentage of excess air normally required for this system. The required high gas volume is reflected in the size, and therefore cost, of the combustion chambers and the air pollution control equipment. The other two systems, particularly infrared units, have lower gas volumes and therefore smaller sized components. System size also impacts on mobilization requirements. The larger the system, the greater the set-up area required. Larger systems also tend to require a longer set-up time. Of the three, rotary kilns generally require the most set-up area and time because of system size and layout. Circulating fluidized beds, meanwhile, require the smallest set-up area because of the compact configuration of the system.

Acceptable solid feed sizes also differ between the systems. Both circulating fluidized bed and infrared processing systems require a uniform feed size of less than one inch and two inch, respectively. Rotary kilns do not require a uniform feed. Maximum feed size is typically limited to 12 inches. The impact of ash disposal or delisting may require all systems to reduce inert particle sizes in order to achieve consistently treated residue. Good ash destruction and removal efficiency (DRE) depends on good gas-solid contact and that is enhanced when feed input is small in size. In this case, this would tend to eliminate the particle size differential between all these systems when inert feeds (such as soil) are processed.

Air pollution control for acid gases and particulates are provided within each system. While rotary kiln and infrared processing systems require external acid gas scrubbing systems, circulating fluidized beds do not. Acid gas control is achieved within the circulating bed by introducing dry limestone directly into the combustor loop along with waste materials. Particulate control in these systems is achieved with scrubbing systems and/or baghouses. The particulate loading differs widely between the systems though. Rotary kilns have a high particulate loading due to the rotation of the kiln and the high gas volume. Circulating beds also have a high particulate loading due to the turbulent nature of the bed. Infrared systems, however, have a comparatively low particulate loading due to the quiescent nature of the bed and the low gas volume. The only agitation provided is by rotary rakes positioned along the belt. Despite differences in pollution control, each system is capable of meeting air emission requirements.

The insulation materials used within combustion chambers also varies among systems. Rotary kiln and circulating fluidized bed systems use refractory brick and castables within the primary and secondary chambers. Refractory linings, however, are susceptible to attack by alkali metals (e.g., sodium, potassium) and acid gases (e.g., hydrogen chloride, sulfuric acid) and damage from the movement of solids and soil in the chamber. The furnace interior of infrared systems is protected with ceramic fiber insulation. Since this material is immune to thermal shock, rapid heating and cooling of the furnace is possible thereby permitting periodic operation is warranted. Operating temperatures of 1800° F can be achieved in a period of a few hours or less. Refractory-lined systems, meanwhile, are susceptible to dramatic changes in temperature and therefore must be heated and cooled at uniform increments. Heating and cooling refractory systems generally requires a period of 24 hours or more. This relatively long start-up period necessitates continuous operation. Fiber insulation is also advantageous in mobile applications since it is lighter in weight than other insulation materials. In order to transport some rotary kiln systems, refractory brick must be removed because of weight restrictions and rebricked at the site. Rebricking may also be necessary prior to use at another site due to excessive refractory wear or damage due to previous operation or transportation.

Process water is required for those systems which provide for gas cooling and have external scrubbing systems; rotary kiln and infrared systems. No process water is required for circulating fluidized bed systems equipped with bag houses since no external scrubber is normally required and all cooling systems are closed-looped. Those systems that use process water also generate a wastewater residual which then requires disposal.

Another utility difference pertains to energy requirements. Fuel oil, natural gas, propane and or waste liquids are suitable as auxiliary fuel for rotary kiln and circulating bed systems. Infrared systems generally require a more expensive energy source for the primary chamber, electrical power. Propane and/or waste liquids are suitable for use in the secondary chamber.

The final area of comparison involves system capacity. Operating mobile rotary kiln systems have nominal solids throughput capacities of up to 20 tons per hour. The most practical rotary kiln systems appear to be those with capabilities around 5 tons per hour. These systems can be transported and assembled relatively easily and can provide for a reasonable remediation period at most sites. Available mobile circulating fluidized bed and infrared systems have nominal throughputs up to three and four tons per hour respectively. These systems sizes also appear to represent the most practical transportable systems. Should waste quantities preclude a reasonable clean-up period at a site, consideration can be given to use of multiple systems or a larger custom designed unit.

4.6 MOBILE SERVICE COMPANIES

A number of vendors are known to be offering mobile thermal treatment services. While most firms own and operate systems, some provide only equipment manufacturing, sales and service. Companies that offer thermal processes other than rotary kilns, circulating fluidized bed and infrared processing are also included.

TABLE 4.2
MOBILE THERMAL TREATMENT SERVICES

Company	Services Offered	Commercial System Status	Solid/Liquid Throughput	Suitable Waste Types
Acova	Exclusive owner and operator of future Shirco infrared processing systems	Two systems under fabrication	4 tons/hr	S,L,SL, Soil
Chemical Waste Management	Own & operate rotary kiln & thermal separator (volatilizer) systems	Rotary kiln & separator systems under fabrication	Rotary kiln - 4 to 5 tons/hr Separator - 6 to 8 tons/hr	S,L,SL, Soil Soil
DETOXCO	Own & operate rotary kiln systems	System designs completed	8 to 9 & 16 to 18 tons/hr designs	S,L,SL, Soil
ENSCO Environmental Services	Own & operate rotary kiln systems	Three systems in operation, three additional units under fabrication	(5) 4 to 5 ton/hr units (1) 20 ton/hr unit	S,L,SL, Soil
Haztech	Own & operate a Shirco infrared processing system	One system in operation	4 tons/hr	S,L,SL, Soil
International Technology	Own & operate rotary kiln & thermal separator systems	One rotary kiln system in operation, separator system design completed	Rotary kiln - 20 tons/hr Separator - 8 to 12 tons/hr	S,L,SL, Soil Soil
John Zink	Own & operate rotary kiln systems	System designs completed	1 to 10 ton/hr designs	S,L,SL, Soil
Modar	Manufacturer & supplier of supercritical water oxidation systems	System designs completed	50 to 1,250 gallons/hr designs	L
National Applied Scientific Systems	Manufacturer & supplier of infrared processing systems	System designs completed	4 tons/hr	S,L,SL, Soil
Ogden Environmental Services	Own & operate circulating fluidized bed systems	System designs completed, two 3 ton/hr system under fabrication	0.6 to 3 tons/hr	S,L,SL, Soil
O.H. Materials	Own & operate a Shirco infrared processing system	One system in operation	4 tons/hr	S,L,SL, Soil
Reidel Environmental Services	Own & operate a Shirco infrared processing system	One system in operation	4 tons/hr	S,L,SL, Soil
Vesta Technology	Own & operate rotary kiln systems	One system in operation	1 ton/hr	S,L,SL, Soil
Waste-Tech Services	Own & operate conventional fluidized bed systems	Systems under design	Not available	S,L,SL, Soil
Westinghouse Plasma Systems	Own & operate plasma arc systems	Systems under design	Not available	L
Weston Services	Own & operate rotary kiln systems	One system in operation	4 to 5 tons/hr	S,L,SL, Soil
Zimpro	Own, operate & supply wet air oxidation systems	System designs completed	300 to 600 gallons/hr	L,SL

Waste Types: S=Solids, L=Liquids, SL=Sludges
Information in table current as of October 1987

5.0 ONSITE THERMAL TREATMENT VS. OFFSITE THERMAL TREATMENT

Once the determination has been made that the wastes are suitable for thermal treatment, it may then be necessary to determine whether treatment on site has significant advantages or disadvantages over shipping the waste to an offsite facility approved for thermal treatment of hazardous waste. The factors to be considered for each option are presented in Table 5-1 and are discussed in this section and Section 6.0.

5.1 *VOLUME OF WASTE*

In general, the volume of waste will be a key factor in the decision to thermally treat on site, ship to a fixed treatment facility, or utilize an alternative treatment method. Large volumes of solids and sludges cannot be handled efficiently or at reasonable cost by fixed facilities. Small volumes are better handled by these facilities because the high cost of mobilization generally makes these actions too expensive for onsite incineration.

There are exceptions to this, particularly in the case of dioxin-contaminated material. Currently, no commercial facilities are allowed to accept dioxins, nor is transportation off site allowed except under special circumstances. At present, dioxin cleanups can only be done on site by mobile thermal systems, which have demonstrated their ability to safely destroy this waste.

5.1.1 OFFSITE THERMAL TREATMENT

Permanent waste management installations with thermal treatment facilities handle large volumes of industrial hazardous waste. Currently, there are at least 16 commercial liquid injection incinerators accepting liquid waste and 6 commercial rotary kilns handling liquids, sludges and solids. In addition, there are several facilities that accept liquid organic wastes as supplemental fuel for energy recovery purposes. Most of these facilities serve the industrial sector for disposal of spent solvents or

TABLE 5-1

FACTORS TO BE CONSIDERED IN EVALUATING ONSITE VS. OFFSITE THERMAL TREATMENT

Factor	Onsite	Offsite
Volume of Waste	Large volume (>1000 cu. yd) required to be cost effective.	Volumes <1000 cu. yd are practical and cost effective. Larger volumes >1000 cu. yd may exceed available capacity and are expensive to ship and treat.
Form and Type of Waste (i.e., solid, sludge)	Reliable material handling systems must be developed to transport, prepare and feed the waste to the thermal unit.	Solids and sludges must be excavated and containerized, then shipped to the treatment facility. Liquids may be pumped into tank trucks for shipment.
Waste Contaminants	Extent and nature of contamination must be well defined. Onsite thermal systems require careful monitoring of feedstream characteristics.	All waste constituents must be identified prior to shipping. Proper handling and treatment is the responsibility of the waste management facility.
Ash Disposal	Ash often (not always) may be disposed of onsite, after testing for toxic contaminants. RCRA delisting requirements must be considered.	Ash disposal is handled by the waste management facility.
Transport	The waste stays on site. Transportation of the unit to the site is handled by the cleanup contractor. Mobilization/demobilization are primary costs.	The waste must often be transported considerable distances to an available facility. Transportation costs can be a large percentage of disposal costs.

TABLE 5-1 (Cont'd)

FACTORS TO BE CONSIDERED IN EVALUATING ONSITE VS. OFFSITE THERMAL TREATMENT

Factor	Onsite	Offsite
Scrubber Effluent Disposal	Effluents must be treated to applicable standards prior to discharge. Disposal means (severs, etc.) may not be available.	Effluent disposal handled by treatment facility under their operating permit.
Site Preparation	Includes preparing graded, graveled work area, concrete pads, and all weather access roads. Utilities must be provided. After remediation, clean-up and closure is required.	Includes preparation of excavation and loading zones. Limited utilities required.
Regulatory Requirements	Mobile systems must comply with applicable federal and state regulations on waste treatment, air emissions, discharge of process waters, and ash disposal.	Requirements apply to transportation and Superfund offsite disposal policy. Waste management facility has met all regulatory requirments as a condition of operation.
Community Relations	Implementation of a program of onsite thermal treatment may generate community opposition.	Large volume of truck traffic may disruption community.

manufacturing by-products. Many facilities do not accept waste from CERCLA sites as business policy, preferring more uniform RCRA waste streams to the highly variable waste characteristics typical of CERCLA waste. A small number of these do accept CERCLA (i.e., Superfund) wastes but capacity is limited, particularly for contaminated soils.

Disposal of large volumes (i.e., more than 1000 cu. yds.) of contaminated soils, solids and sludges at existing commercial rotary kiln facilities is generally not economically practical and the availability of adequate capacity is questionable. At current prices of roughly $1/lb (see Appendix B), 1000 cu. yds. (2700 lb/cu. yd.) would cost approximately $2,700,000, not including excavation or transportation. Most available rotary kiln capacity is currently reserved for the needs of industrial customers. However, small containerized shipments of soil can be handled by using phased delivery schedules (most facilities have limited storage capacity and tightly scheduled kiln utilization) or allocating the waste among several facilities. It should be noted that, while none of the existing facilities presently accept bulk (i.e., noncontainerized) shipments of soil, ENSCO in El Dorado, Arkansas and Rollins Deer Park, Texas facility are planning to develop that capability in late 1988, which may reduce costs for this disposal option (see Figure 5-2).

Of the six existing commercial facilities with rotary kilns that handle liquids, sludges and solids, only three are permitted to incinerate PCBs. Heavy demand for this service is generated by utilities and private industries, which are required by law to dispose of PCB-contaminated transformer oil, transformers, and associated material within a specified time period. Addition demand is generated by the increased pace of remediating both NPL and non-NPL sites by private industry. This heavy utilization of available fixed incineration facility capacity plus the high cost of transportation makes mobile thermal treatment systems a viable method at sites where more than 1000 cu. yds of soil must be excavated and thermally treated.

Currently, for small volumes of contaminated soil (1 to 1000 cubic yards) or large volumes (up to several thousand gallons) of pumpable organic liquids or sludges that require thermal treatment, shipment to an offsite facility may be the most practical alternative. Numerous transportation and onsite service companies are available that will containerize or repack the soils, sludges, liquids, or drums and ship them to a designated facility. Large liquid volumes can be shipped in tank trucks. This process can be done on short notice, and does not require the extensive site preparation or time-consuming design and procurement required for onsite treatment.

The waste must be well defined in terms of chemical and physical characteristics (see Appendix B) in order for thermal treatment facilities to provide cost estimates and/or to accept material for disposal. In order to ship the waste, critical characteristics of the material must be documented and manifested. Treatment facilities will sample the waste prior to acceptance, and reject any waste where the observed waste properties are at variance with the documentation.

5.1.2 ONSITE THERMAL TREATMENT

Onsite thermal treatment is a viable alternative when significant volumes (1,000 cu. yds. minimum) of contaminated material require thermal treatment. Volumes less than 1,000 cu. yds. may be handled using small scale mobile systems, but unit costs will be higiher. The use of mobile systems for limited periods at CERCLA sites involves high unit costs due to the time and effort required to complete the following tasks:

- Define and ensure compliance with ARAR's (several weeks)
- Prepare the site for operations (several weeks)
- Mobilize these systems and transport to the site (2 to 8 weeks)
- Set up the system for operations (1 to 2 weeks)
- Test the unit and/or conduct trial burns (if part of complaince with applicable environmental regulations, several weeks to months)
- Shake down materials handling systems (several weeks)
- Demobilize and decontaminate the system (2 to 6 weeks)

Many of these activities can be done concurrently. Overall, however, the process will take several months to complete.

5.2 COSTS OF OFFSITE VS. ONSITE THERMAL TREATMENT

Because offsite thermal systems have a longer history of operation, costs of offsite thermal treatment are more easily and reliably quantified than onsite treatment costs. Typical costs for disposal at commercial thermal treatment facilities (including ash disposal at a secure landfill) are presented in Table 5-2. Additional information is presented in Appendix B.

Average costs will vary significantly depending on the physical and chemical characteristics of the waste, pretreatment requirements and total volume to be treated and the business policies of the disposal facilities. The costs in Table 5-2 do not include the cost of transportation to the facility. For a truck with a full 40,000 lb (20 ton) load, truck costs may run approximately $4.00/mile or $0.20/ton/mile, depending on the total volume to be shipped and the distance to the disposal facility (costs are usually estimated on a one way basis). For smaller volumes of material, the trucking costs (wages, fuel, etc.) do not decrease substantially so costs per ton per mile will increase significantly. Costs for long distance trucking may make offsite disposal too costly. For example, shipping a 20 ton load of waste 800 miles will add $0.08/lb (or $160/ton) to the ultimate cost of disposal.

The costs associated with onsite and offsite alternatives for thermal treatment are illustrated schematically in Figure 5-1. This figure shows the fixed (i.e., non-volume related) and variable (i.e., volume related) cost components of mobile systems versus the costs of thermal treatment at fixed facilities. The costs for mobile systems represent averages of cost estimates for several different types of systems (rotary kiln, circulating bed combustor, infrared processing system) and are not representative of a particular system or a particular site. Actual estimates will vary widely depending on the vendors, the waste types and characteristics of the waste being treated, the volume of material, amd the site conditions.

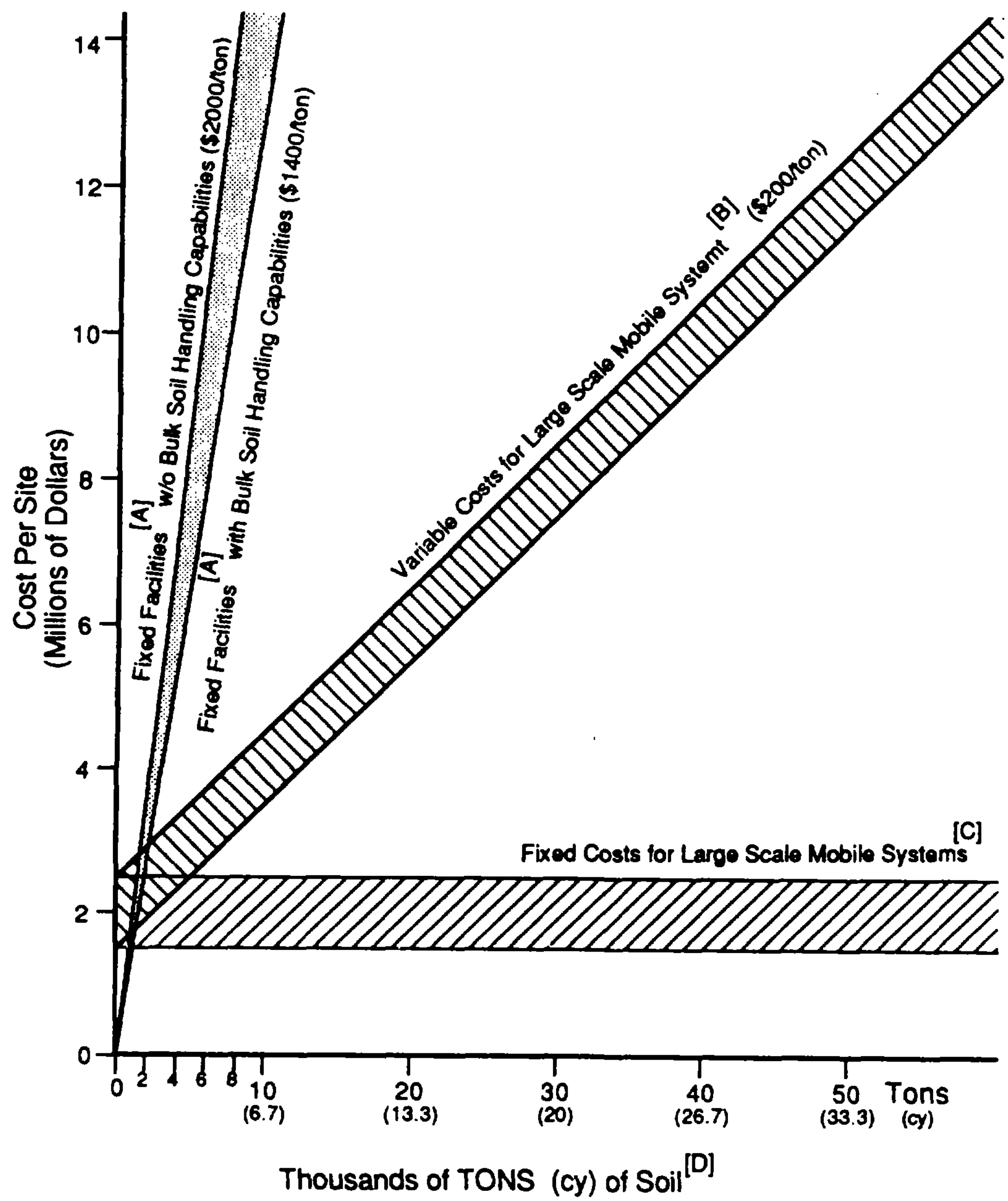
TABLE 5-2

COST RANGES FOR THERMAL TREATMENT AT COMMERCIAL FACILITIES

Waste Form	Cost per Lb.	Cost per Ton or Gallon*
Heavily Contaminated Soils (Containerized in 20-30 gal. plastic or fiber drums)	$0.60 to $1.00/lb	$1,200 to $2,000 per ton (1 cu. yd ≈ 1.5 ton)
High Btu Content Sludges** (2,000 to 7,000 Btu/lb)	$0.50 to $0.80/lb	$1,000 to $1,600 per ton (1 cu. yd ≈ 1.0 ton)
Organic Liquids (less than 20% water)	$0.20 to $0.35/lb	$1.75 to $2.80/gal. @ 7 lbs/gal.

* Price quotes for larger volumes of material will be less.

** Nonpumpable sludges must be solidified, containerized, and thermally treated in a manner similar to soils.



<u>Assumptions</u>

[A] Includes all treatment costs except excavation and transportation; transportation costs estimated at $40/cy /100 miles.
[B] Includes all labor (thermal system, excavation equipment, ect.), utilities, equipment use fees,lab analysis and site restoration activities.
[C] Includes all site preparation activities, mobilization/demobilization of equipment and permitting (trial burn).
[D] Soil density is 1.5 ton/cy

Data based on preliminary cost estimates from various thermal treatment vendors for contaminated soil treatment. Data current as of November 1987.

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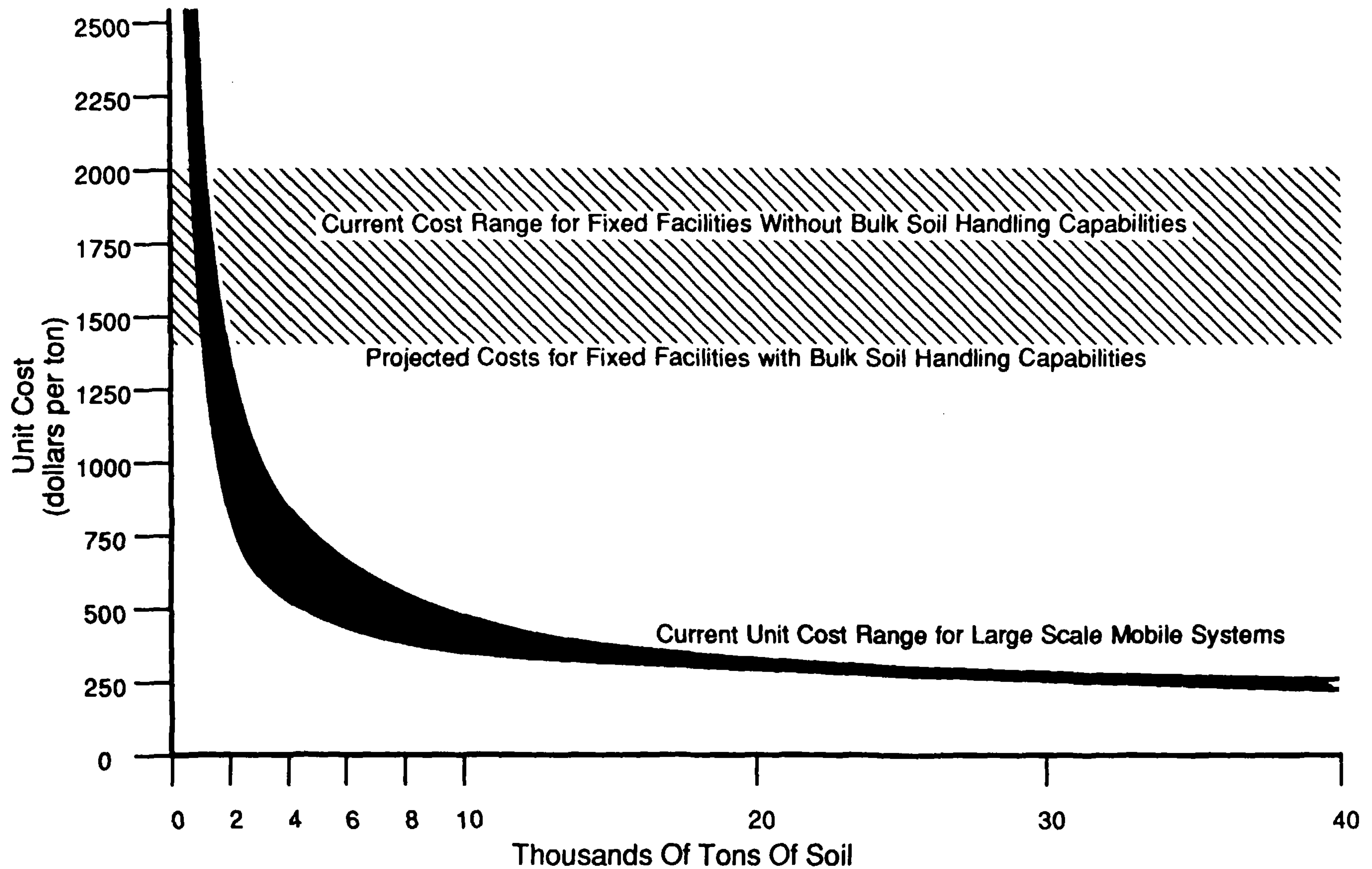
FIGURE 5-1
COSTS FOR ONSITE VS. OFFSITE THERMAL TREATMENT OF CONTAMINATED SOILS

The primary purpose of the figure is to illustrate the high fixed costs associated with bringing a mobile system to a site. The data indicate that, compared to thermal treatment at fixed facilities, large scale mobile systems are not cost effective for waste volumes less than 1000 cu. yds. This is also illustrated by Figure 5-2, which illustrates that unit costs remain high for fixed facilities, while dropping significantly for mobile units.

Currently, most commercially available onsite systems are only used for much larger waste volumes. ENSCO has stated, for example, that their mobile rotary kiln is not cost effective for sites with less than 5,000 cu. yds of waste. This volume restriction is based on a cost comparison with alternative methods of disposal not involving thermal treatment (e.g., land disposal). Other vendors (see Appendix A, VESTA Technologies) can handle smaller sites with volumes between 500 and 5000 cubic yards, using a small-scale incineration system. This unit is one-fifth the size of ENSCO's unit, and requires less staff and equipment than larger units.

Sites with processible volumes of contaminated soil or sludge between 500 cu yds and 1,000 cu. yds fall in an uncertain zone where the economic advantages of onsite vs. offsite thermal treatment are highly site specific. Use of available full scale systems for onsite thermal treatment of soil volume in this range will result in very high unit volume costs. Smaller transportable thermal treatment systems can process these small volumes of waste much more cost-effectively. However, the issues of regulatory compliance and public perception of incineration may favor using offsite disposal facilities.

There are presently no offsite fixed facilities in a position to accept bulk shipments of soil. However, ENSCO and Rollins are planning to expand or modify their equipment in late 1988 to 1989 to process bulk quantities at their incineration facilities. Implementation of these plans can be expected to provide in the future a more economical and practical means for the offsite disposal of larger bulk quantities of contaminated soil. The estimated cost for bulk soils processing is illustrated in Figure 5-2.



Source: Based upon data in Figure 5-1.

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FIGURE 5-2
UNIT COSTS FOR ONSITE AND OFFSITE THERMAL TREATMENT

5.3 MATERIALS HANDLING AND PREPARATION

The problems posed by materials handling and preparation are significant obstacles at most sites. While these problems are generally ameneable to engineering solutions, they may add considerably to the time requirements for onsite thermal treatment, and may significantly increase the downtime of the onsite treatment system.

If the wastes are to be sent offsite to a stationary facility, liquids or sludges must be pumped into tank trucks (if pumpable). Soils, non-pumpable sludges or solids should be containerized in plastic or fiber drums. Handling can pose significant problems if sludges are too viscous to pump, as excavation equipment may become fouled or clogged. Sludges are often solidified by mixing with adjacent soils, which simplifies handling by permitting use of conventional soil excavation and transport equipment (e.g., conveyors) combined with hoppers for container loading.

Materials handling systems for onsite thermal treatment systems are typically more complex. Any required preprocessing of the material (e.g., screening, shredding, crushing, solidification, or liquefaction) must be integrated into the system. Storage systems for waste blending and material feeding to the primary combustion chamber must be included. Organic liquids must often be filtered and/or thinned prior to injection, and aqueous wastes may require a separate treatment system. Sludges may require either liquefaction or solidification, depending on initial characteristics. Liquids, sludges or solids may require blending prior to incineration for incineration in the mobile system to bring Btu content within acceptable ranges. Each site is unique and will require careful evaluation by cleanup contractors. Additional system specific information on materials handling is presented in Section 3.3 and Appendix A.

5.4 ENVIRONMENTAL REGULATION

Onsite thermal treatment differs from offsite thermal treatment in that the activation of a mobile system must comply with substantive federal and state environmental requirements for each cleanup site (see Section 6.0).

Offsite systems have already completed the permitting process required for operation, and customers need to comply with transportation regulations, the waste acceptance requirements of the facility, and Superfund offsite disposal policy.

Onsite treatment programs may be implemented either as an emergency removal action or as a remedial action. Removal actions can be conducted within a period of months in response to an emergency when wastes on site present an immediate threat to the local population. Remedial actions are implemented over a longer time period (perhaps years) and provide complete cleanup of sites that pose significant long-term risk to the population.

6.0 COMPLIANCE WITH ENVIRONMENTAL REGULATIONS

This section discusses regulatory requirements and compliance with applicable environmental standards. The purpose of the discussion is to provide an awareness of provisions that may apply to incinerators. Actual regulatory requirements are determined on a case by case basis.

6.1 THE IMPACT OF SARA

This section discusses the requirement for onsite remedial actions to comply in principle with any applicable federal or state regulations.

- Under SARA, federal, state, or local permits are not required for those portions of removal or remedial actions that are conducted entirely onsite.

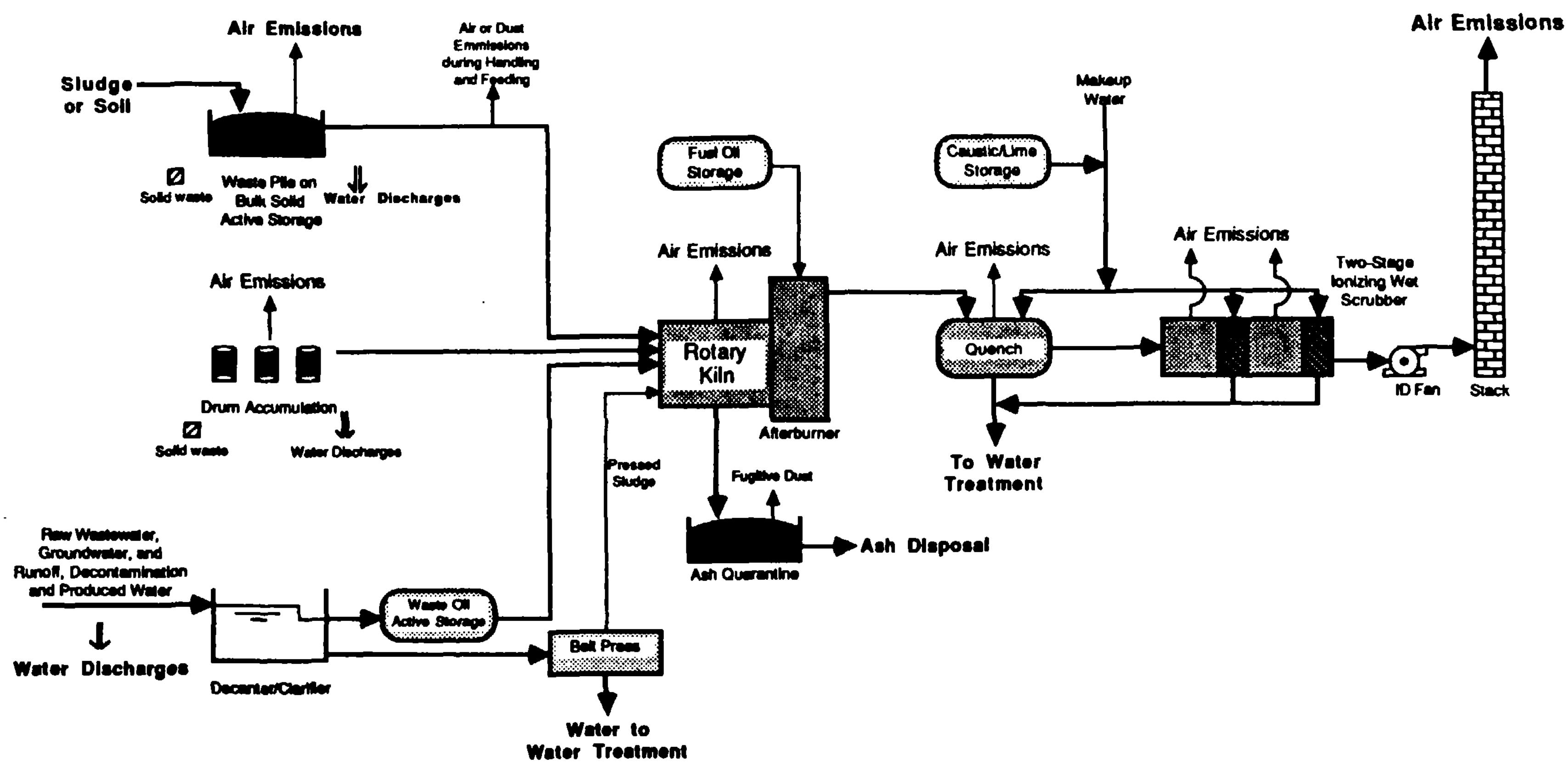
- However, remedial actions must meet all applicable or relevant and appropriate federal or state environmental requirements (ARAR's), including state ARAR's that are more stringent than federal requirements. However, SARA provides waivers allowing selection of remedies that do not meet all ARAR's if any one of six circumstances apply to the site.

  Those circumstances are: fund-balancing, technical impracticability, interim remedy, greater risk to health and the environment, equivalent standard of performance, and inconsistent application of state standards.

6.2 OVERVIEW OF REGULATORY COMPLIANCE

The following environmental laws could be applicable or relevant and appropriate for the site illustrated in Figure 6-1. The citations are listed in Table 6-1.

- For air emissions: Clean Air Act
  State air quality laws



Source: CH_2M HILL.

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FIGURE 6-1

BLOCK FLOW DIAGRAM FOR INCINERATOR SITE

TABLE 6-1

PERMIT REQUIREMENTS FOR OPERATION OF MOBILE TREATMENT UNITS

Federal Requirements

Clean Air Act (CAA)	40 CFR 52.21
Toxic Substances Control Act (TSCA)	40 CFR 761.40
National Environmental Policy Act (NEPA)	40 CFR 6
Resource Conservation and Recovery Act (RCRA)	40 CFR 261
	40 CFR 262
	40 CFR 264
	40 CFR 270
National Pollutant Discharge Elimination System (NPDES)	33 U.S.C. 1251
Delisting	40 CFR 261
Noise Control Act	P.L. 92-574

State Requirements (if more stringent than federal)

Air Pollution Control

State Pollutant Discharge Elimination System

Hazardous Waste Facility Registration Requirement

Solids Waste Management Requirements

- For water discharges: Clean Water Act
  State water resource laws

- For solid wastes: State solid waste management laws
  RCRA
  TSCA
  State hazardous waste laws

6.3 SITE OPERATIONS AND RCRA

The following discussion outlines some important considerations in identifying the waste generation, treatment, storage, and disposal operations that would fall within the purview of RCRA regulation. The actual determination will be based on analysis documented in EPA's Compliance Guidance Document.

Generation (40 CFR 261, 262)

Hazardous waste generation occurs from excavation, production of ash from the incinerator, production of water from incinerator scrubbers and production of solids from wastewater treatment.

Treatment (40 CFR 264)

This section specifies performance standards for the incinerator. Hazardous waste is treated in the incinerator. Treatment of hazardous waste may also occur in the water treatment area, or in another part of the facility where wastes are prepared for incineration.

- RCRA requires a thermal treatment facility seeking an operating permit to demonstrate that it can achieve the following:

  - At least 99.99-percent destruction and removal efficiency (DRE) for each principal organic hazardous constituent (POHC) in the waste feed.

- For PCB (regulated under TSCA) and TCDD incineration, at least 99.9999-percent DRE.

- At least 99-percent removal of hydrogen chlorine from the exhaust gas if hydrogen chlorine stack emissions are greater than 1 kg/hr (4 lb/hr).

- Particulate emissions no greater than 180 mg/dscf (0.08 grains/dscf), corrected to 7-percent oxygen in the stack gas.

Storage (40 CFR 264)

Hazardous waste is stored in the sludge area, drum storage area, waste oil tank, and the ash quarantine structures. These may or may not be long-term storage sites, depending on the operating plan, throughput rates, and the length of time necessary to delist the ash, if such is appropriate.

Disposal (40 CFR 262, 263, 264)

There are no disposal operations shown on Figure 6-1. However, the presence of waste such as the ash and scrubber water indicates that disposal of these materials, either onsite or offsite, must be integral part of the option.

6.4 CLEAN AIR ACT (CAA)

Permitting authority usually is under the auspices of state agencies, but sometimes is delegated to the local level. The states use criteria based on the National Ambient Air Quality Standards (NAAQS) and a set of regulations established to help achieve the CAA-designated air quality standards known as the Prevention of Significant Deterioration (PSD) regulations. The standards adopted by the state or local agency always are as stringent as federal standards, and can be more stringent.

An incinerator sited in a designated "nonattainment" area could be subject to additional considerations. (A "nonattainment" area is one in which ambient air quality does not meet standards, primarily for suspended particulate matter, sulfur dioxide, carbon monoxide, ozone, hydrocarbons, or nitrogen dioxide.) A new source of air pollutants for a nonattainment area may generate demands for stringent emission control.

Major Factors

- State regulators may have control technology or emission limit standards that differ from federal standards.

- State regulators may bar the use of a mobile incinerator in a nonattainment area, or require emission offsets.

- State regulators may require an environmental assessment.

- PSD regulations basically cover stationary sources. They may not be applicable for short term incineration projects.

- Stack testing to demonstrate compliance with specified performance standards may be necessary.

6.5 TOXIC SUBSTANCES CONTROL ACT (TSCA)

This act regulates the use and disposal of PCB's and the production of new chemicals. TSCA applies to mobile incinerators in the area of PCB treatment and disposal. The standards for PCB incineration are more stringent than are RCRA standards for incineration of hazardous wastes. TSCA requires:

- Destruction and removal of PCB's at 99.9999-percent efficiency

- Continuous monitoring of flow, temperature (<1600°F), and residence time (>2 seconds) in the secondary in the combustion zone while PCB's are incinerated

- Continuous monitoring of oxygen and carbon monoxide while PCB's are incinerated

- Control of particulate and HCl emissions from PCB incineration

- A trial burn demonstratiang satisfactory compliance with the above standards

Major Factors

- TSCA and RCRA are separate laws, administrated by separate offices in EPA. TSCA compliance does not mean RCRA compliance is waived.

- PCB incineration technology is relatively standard and should not present major difficulties. EPA has primary responsibility for administrating TSCA; however, states and localities are never excluded from providing significant input to the permitting process.

6.6 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMITS

Discharge to surface waters are regulated by state agencies, typically with oversight and review by EPA, to prevent deterioration of water resources. Standards vary from state to state, but all generally require monitoring of the following minimum data:

- Flow
- BOD_5
- Total dissolved solids
- Total suspended solids
- pH
- Heavy metals (e.g., chromium, lead, mercury, nickel, and selenium)

Some state agencies require monitoring for specific chemicals (e.g., lindane, 2,4-dichlorophenoxy acetic acid, methylene chloride, and carbon tetrachloride). These vary from site to site, depending on the usage of the various materials or inventory at the site.

Discharge to a POTW may require pretreatment before the POTW may receive the effluent.

Important Considerations

- o Typical incinerator water effluents will be relatively low in BOD, high in dissolved and suspended solids
- o pH adjustment probably will be required
- o Heavy metal content in the scrubber water may vary depending on the materials being incinerated (treatment prior to discharge may be required)
- o Various organic species may be present from the combustion process, typically below 0.1 mg/l for any particular species

6.7 DELISTING

Hazardous waste treatment system residues are identified by RCRA regulations as hazardous until those residues are proven nonhazardous, and therefore delisted. If the residues cannot be delisted, they must be handled and disposed of as a hazardous waste.

The formal delisting process is initiated by submitting a delisting petition to the EPA Office of Solid Waste that asks EPA to remove from the RCRA hazardous waste list the byproducts generated by the particular mobile treatment unit. Delisting is begun by EPA's publication of an exclusion notice in the Federal Register for 30 days; the agency then decides whether to delist the residue.

Formal delisting is not necessary for remedial action in which the ash remains onsite. However, onsite disposal of ash may require meeting the state substantive requirements for permitting as a solid waste disposal facility.

APPENDIX A

COMMERCIAL SYSTEM REVIEW

A.1 INTRODUCTION

This appendix provides a review of three thermal treatment technologies that are currently being applied as mobile or transportable systems for hazardous waste treatment at the waste site (i.e., on site). The three technologies were identified in Section 4 and include rotary kiln incineration, infrared processing and circulating fluidized bed incineration. These three technologies offer different capabilities for the wide range of wastes encountered at CERCLA sites. While rotary kiln incineration handles the broadest range of waste types and forms, infrared processing or circulating fluidized bed incineration may offer advantages from the view point of pollution control and cost.

Several vendors were identified that currently offer these technologies as mobile systems. Three types of systems were selected for in-depth review, the ENSCO Environmental Services Modular Waste Processor, the Shirco Infrared Processing System and the Ogden Environmental Services Circulating Bed Combustor. Although several firms currently offer mobile rotary kiln and infrared processing systems, the ENSCO Environmental Services and the Shirco Infrared Processing Systems have the most operating experience with respect to mobile applications. The Ogden Environmental Services System was reviewed since it is the only circulating fluidized bed system being applied to mobile hazardous waste treatment at the time of this writing. A discussion of other mobile systems is also provided.

The following sections provide a review of the technical aspects of each individual commercial system selected. Included in the review is a discussion of system components, acceptable waste feeds, waste restrictions and specific onsite utilization requirements such as utilities and site preparation. System performance is evaluated based on available test data and operating history.

It is stressed that selection of these systems for review (or mention of any other vendor) does not constitute endorsement. Instead, these systems were selected in order to illustrate a typical mobile system that utilizes these basic technologies.

A.2 ROTARY KILN INCINERATORS

Several U.S. vendors offer mobile rotary kiln systems for onsite waste treatment. Those firms operating mobile rotary kiln systems at present include:

ENSCO Environmental Services (EES) of Freemont California (formerly of Little Rock, Arkansas),

Vesta Technology (Vesta) of Ft. Lauderdale, Florida,

International Technology Corporation (IT) of Knoxville, Tennessee, and

Weston Services (Weston) of West Chester, Pennsylvania.

Of these, only EES, a subsidiary of Environmental Systems Company, has completed an onsite cleanup program to date. A detailed review of EES's mobile system is presented below. General information on other vendors follows this review.

A.2.1 EES ROTARY KILN INCINERATOR

System Description

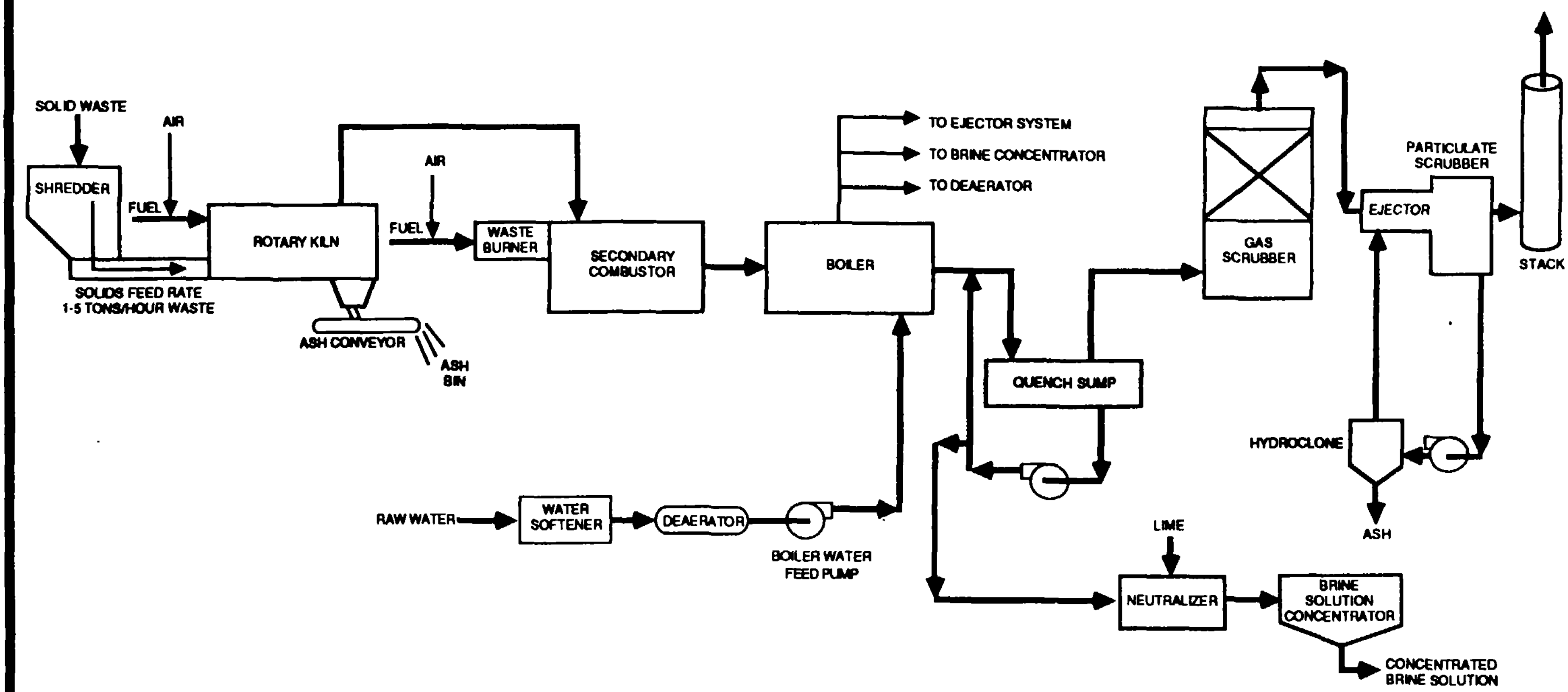
EES currently operates three commercial-scale rotary kiln systems referred to as Modular Waste Processors (MWP-2000). Two additional MWP-2000 units are reportedly under fabrication as is a new model, MWP-2001, that has a solids throughput capcity of 4 to 5 times the MWP-2000 system. Each unit is mounted on multiple flatbed trailers for transport to a site. The system consists of six basic process modules common to many rotary kiln units:

- o Rotary kiln or primary combustion chamber,
- o Secondary combustion chamber,
- o Heat recovery boiler,
- o Air pollution control train,
- o Control room and laboratory, and
- o Effluent neutralization and concentration equipment

Figure A-1 presents a process flow diagram for the MWP-2000 system.

MWP-2000 systems operate similar to conventional rotary kiln units. The rotary kiln or primary combustion chamber operates within a temperature range of 1,200°-1,800°F. Auxiliary fossil fuel or waste liquids are used in the primary chamber to maintain temperatures. Residence times in the rotary kiln range from seconds for gases to 30-40 minutes for solids. The secondary combustion chamber operates at a temperature between 1,400°-2,400°F. Gas residence time ranges from 1.7-2.2 seconds at 2200°F. Auxiliary fossil fuel or high Btu content waste liquids are also introduced into the secondary chamber to maintain the desired temperature.

The air pollution control train contained within the MWP-2000 consists of a water quench, a packed tower scrubber and a proprietary ejector scrubber system. The water quench section provides for gas washing and additional cooling. Acid gas removal in excess of 99 percent is attained within the packed tower while additional particulate removal is provided by the



SOURCE:
ENSCO ENVIRONMENTAL SERVICES

Camp Dresser & McKee Inc.

FIGURE A-1
PROCESS FLOW DIAGRAM OF THE ENSCO MWP-2000
ROTARY KILN INCINERATION SYSTEM

high-energy ejector scrubber system. Wastewater blowdown for the scrubbing system is neutralized and concentrated prior to disposal.

Acceptable Wastes

Waste Types Handled. Like most rotary kiln systems, MWP-2000 systems can handle many types of solid, liquid and gaseous organic wastes, including sludges and slurries. However, rotary kiln systems in general are most appropriate for solids handling, particularly soil treatment. Acceptable waste contaminants include PCBs, dioxins, pesticides and other halogenated and nonhalogenated organics.

Both containerized and noncontainerized wastes are acceptable with MWP-2000 systems. Containerized wastes such as steel and fiber drums reportedly would be shredded whole. Liquid product would be collected and injected into the primary and/or secondary chamber. The shredded material would be ram fed or augered directly into the kiln. Should the drum contents preclude shredding whole because of the potential for explosion or ignition, the pumpable contents will be removed prior to shredding. Open lagoons could also be treatable with a MWP-2000 system. The organic liquid layer would be removed for injection into the primary and/or secondary combustor and the sludge and sediment layers would be fed to the rotary kiln. The contaminated water layer would be treated onsite by conventional (i.e., biological, physical, or chemical) methods. Where necessary, liquid organic waste streams could be mixed or blended in onsite tanks to provide a more uniform feed in terms of physical and chemical characteristics.

Method of Feeding/Charging. Acceptable solids and sludges are fed directly to the feed or high end of the rotary kiln. Solid waste material and nonpumpable sludges are first conveyed to the feed chute of the kiln. A ram feeder or auger is then used to charge the material at the desired rate. Alternatively, pumpable sludges and slurries are pumped to the feed end of the kiln and charged via a sludge lance. Liquid wastes can be injected into both the primary or secondary chambers although in the latter case, the liquid waste must have sufficient heat content to act as a suitable auxiliary fuel. Clean fossil fuel may also be injected if necessary. Clean fuel is primarily used only during startup and shutdown/decontamination unless insufficient liquid wastes exist on site. Atomization of liquid wastes must be possible for proper injection.

Restrictions/Limitations. MWP-2000 systems are capable of processing virtually any physical form of waste. The throat or opening for solid feed to the kiln however is only 13 inches wide. Therefore, oversized debris such as rocks, tree roots, drums and other miscellaneous items must be reduced to an acceptable feed size. Size reduction can generally be obtained by shredding, grinding or crushing although such processing requirements introduce additional cost, employee hazard and the potential for fugitive emissions of Principal Organic Hazardous Constituents (POHC) materials. If size reduction equipment is employed, particle size is reduced to approximately two inches.

MWP-2000 systems are also capable of processing materials of virtually any chemical composition. However, radioactive waste material is not accepted, nor are wastes containing mercury due to mercury's high volatility and potential for escape from the stack. Several other characteristics require specific evaluation. Wastes containing bromine, fluorine and phosphorus require special consideration due to the potential for refractory attack within the kiln. The toxic element (e.g., heavy metal) content of waste streams also requires special evaluation because of the potential for vaporization and subsequent difficulties in removing these elements and associated compounds from the exhaust gas. The inorganic salt content of wastes, particularly sodium salts, is important since they tend to cause degradation of the refractory and slagging of the ash. If wastes contain unacceptable levels of contaminants, consideration will usually be given to mixing or blending waste streams to obtain an acceptable feed.

Onsite Utilization

Processing Capacities. MWP-2000 units have a thermal rating of 35 million Btu per hour. Of this total, the rotary kiln component accounts for 15 million Btu per hour while the secondary combustor accounts for the remaining 20 million Btu per hour. The mobile system is designed to incinerate solid and liquid waste simultaneously. Solid wastes are fed to the rotary kiln at a rate of four to five tons per hour. Liquid wastes are fed to the rotary kiln and secondary combustion chamber at feed rates of 3,000 and 4,000 lbs per hour, respectively. Exact feed rates will be dependent on the heat content and moisture content of the waste material.

Waste Quantity. Waste quantities must be substantial enough to warrant onsite treatment with a MWP-2000 system. EES reports that the optimum waste quantity for this system size would be 15,000 tons. The maximum practical project size for a single system is reported by EES to be 150,000 tons. Depending on the anticipated remediation time, project economics may favor the use of multiple MWP-2000 units or a custom-designed system. The reported online availability of MWP-2000 systems is 75 percent. Downtime for scheduled and unscheduled repairs accounts for 20 percent while the remaining five percent is standby time.

Information Required of Client. Detailed site and waste descriptions are required to evaluate the technical and economic suitability of a MWP-2000 application. Specific waste information required includes total volume, physical form, heat content, moisture content and chemical composition. Site characteristics of interest include topography, space limitations, hydrology, surface water locations, availability of utilities, and population proximity. EES requires a prospective client to complete a Waste Material Data Sheet (WMDS). The information requested on the WMDS is relevant to both EEES's mobile system and ENSCO'sfixed base facility. Additional data and site investigation are generally required. A copy of ENSCO's WMDS is attached in Appendix B.

Mobilization/Demobilization. The six basic modules of the MWP-2000 incinerator system are mounted on flatbed trailers or, in the case of the control room and laboratory, is contained within a trailer. Each component is designed to be interconnected at the site.

Transportation of the system requires approximately 15 to 20 tractor trailer loads depending on the application. This includes both system components and ancillary equipment such as material handling systems, staging equipment and storage and blending tanks. Once on site, assembly of the equipment generally requires six weeks. Another one to two weeks are necessary for system startup/checkout procedures. Depending upon the complexity of the system, additional time may be required to shake down the materials handling system. Once remediation is complete, a 48-hour burn with clean fuel is undertaken to decontaminate system internals. Equipment exteriors are steam cleaned prior to disassembling. Dismantling of the system requires anywhere from 4 to 6 weeks.

Site Preparation/Space Requirements. An access road suitable for heavy equipment must be available to accommodate tractor trailers. A 150 ft by 150 ft graded, graveled area is required for incinerator set up only. The rotary kiln module must be positioned on a concrete slab. Total staging and support areas are reported to be approximately one to two acres.

Utility Requirements. MWP-2000 systems require electrical power, auxiliary fuel, process water and process steam. Electrical power requirements for the unit are 500 KVA/440 volt. If this supply is not available on site, a portable diesel powered generator must be brought on site. Auxiliary fuel such as fuel oil is required primarily during startup and shutdown (decontamination). Auxiliary fuel may also be required during operation to maintain temperatures if sufficient waste liquids are not available.

Operation of the heat recovery boiler and three-stage scrubbing system requires process water make-up. Approximately 50 gpm are reportedly required under normal operation. A feed water treatment system is provided to supply boiler quality water. Process water must be piped or brought on site in tankers if not available from onsite wells or surface water. Process steam is required by the ejector scrubber and brine concentrator. Steam generated by the system's heat recovery boiler is used to satisfy these demands. No additional steam generation is required.

Labor Requirements. MWP-2000 incinerator systems are operated on a three shift, 24 hour a day basis. Continuous operation requires a total labor force of 20 to 30 people, depending on the application. This figure includes both incinerator operators as well as feed handling, preparation, and residue disposal personnel.

Residuals/Effluents. Three residual/effluent streams are generated by MWP-2000 systems -- ash/decontaminated soil, scrubber water and flue gas. Disposal of ash/decontaminated soil depends on the cleanup goals and applicable regulations (e.g., delisting). The desired situation would be to return the decontaminated soil/ash directly to the site. Regulations may necessitate further treatment such as solidification/fixation or require disposal off site in either a secure landfill or a sanitary landfill.

Scrubber blowdown is neutralized by the addition of lime and concentrated by a steam heated concentrator. The preferred disposal source would be to discharge the concentrated effluent directly to a sewer system or wastewater treatment facility. If this alternative is not available, further onsite or offsite treatment would be necessary. Under normal operation, exhaust gases released from the process stack are expected to meet or exceed all local, state and federal emissions standards.

System Performance

Test Data. All preliminary testing prior to system employment on site is currently undertaken at ENSCO's El Dorado, Arkansas facility. One of EES's three MWP-2000 systems is located at the facility. While available for testing purposes, this unit is primarily used for commercial waste incineration along with another large-scale fixed-base rotary kiln. Pre-trial burn tests on this system have indicated greater than 99.9999 percent DRE for PCBs, carbon tetrachloride, perchloroethylene, trichloroethane, chlorobenzene, and trichlorobenzene.

Operating History. EES is the only firm to date that has completed a full scale site cleanup (although not a CERCLA site) using a mobile rotary kiln treatment system. A MWP-2000 system was used at the Sydney Mines Site in Hillsborough County, Florida. Onsite cleanup took place between January 1985 and January 1986. Approximately 11,000 cubic yards of oily sludge, septage sludge and soil were treated during this period.

EES has since deployed their MWP-2000 systems at two additional sites. EES is presently remediating both the Lenz Oil Site in DuPage County, Illinois and a Department of Defense site in Gulfport, Mississippi. The Lenz Oil Site, a former oil recycling facility, contains similar material to the Sydney Mines Site. EES is under contract to the Illinois Environmental Protection Agency (IEPA). The Gulfport Site, an operating military base, has over 10,000 cubic yards of dioxin contaminated soil. Following an extended period for permitting, EES began operations at this site late 1987.

As noted, EES is fabricating a larger system (MWP-2001) with a solids throughput capacity of 20 tons/hr making it comparable in size to IT's system. This system, along with two additional MWP-2000 units, will reportedly be available in late 1988. The MWP-2001 system will be employed at sites with waste quantities not practical for MWP-2000 systems.

A.2.2 VESTA ROTARY KILN INCINERATOR

Vesta (formerly Winston Technology) operates a mobile rotary kiln incinerator contained entirely on a single trailer. Similar to most rotary kiln system's, Vesta's unit consists of a rotary kiln, a secondary combustion chamber, a flue gas cooler, a venturi scrubber and a packed scrubber.

The unit has a total thermal rating of eight million Btu per hour, approximately one-third that of EES's system. Throughput reportedly is one ton per hour. Compared to larger systems, this unit is more appropriate for smaller sites where waste quantities are less than several thousand tons. Furthermore, the unit is not presently permitted for PCB acceptance. The unit is reportedly marketed primarily toward pesticide wastes.

In October, 1987, Vesta's unit was placed in operation at the Nyanza Superfund site in Ashland, Massachusetts. Approximately 1,600 tons of contaminated soil was processed during a subsequent four month remediation period. The soil was contaminated with various volatile organic chemical including nitrobenzene. The unit was previously employed in the fall of

1986 at a pesticide dump in Aberdee, North Carolina. The unit achieved DREs of 99.999 percent during five days of continuous operation. This exceeded EPA standards (99.99%) by 10 percent. Vesta reports that a second unit, rated at 16 million Btu per hour, will be available in 1988.

A.2.3 WESTON ROTARY KILN INCINERATOR

Weston, a division of Roy F. Weston, has recently designed and constructed a mobile rotary kiln system similar in concept to EES's MWP-2000 units. The five ton per hour system consists of a rotary kiln, a vertically-mounted secondary combustion chamber, a spray quench, two flue gas heat exchangers (one to preheat combustion air and the second to further cool the flue gas), a fabric filter baghouse and a packed tower scrubber. All of the components of the system are designed to be transported via flat bed trailers.

System components and processing capabilities of the Weston system are similar to EES's. Some differences, particularly in the area of gas cooling and pollution control, can be noted though. For examples, Weston's secondary chamber is vertically-mounted as compared to EES's horizontal chamber. Also, EES incorporates a boiler and quench sump for gas cooling and heat recovery while conventional heat exchangers and a spray tower serve this purpose on Weston's unit. Particulate and acid gas control in Weston's unit is accomplished by the combination of the spray tower (particulate), baghouse (particulate) and packed tower scrubber (acid gas). EES achieves particulate and acid gas control through use of a combination of a quench sump, gas scrubber and ejector scrubber.

Weston's unit is presently assembled at the Beardstown Lauder Salvage Yard in Cass County, Illinois. The Illinois EPA (IEPA) has contracted with Weston to thermally treat between 5,000 and 10,000 tons of PCB-contaminated soil at the site. Performance testing using background soil spiked with PCB Aroclor-1260 to a concentration of 10,000 ppm (one percent by weight) was reportedly initiated in late 1987. Remediation will commence upon successful demonstration and permit approval. Remedial operations are expected to be completed within three to four months.

A.2.4 IT ROTARY KILN INCINERATOR

IT has developed and fabricated a high capacity transportable rotary kiln system referred to as the Hybrid Thermal Treatment System (HTTS). The 56 million Btu per hour HTTS has an inert solids throughput capacity of up to 20 tons per hour, approximately four times that of EES's MWP-2000 and Weston's systems and similar in size to EES's MWP-2001 system under design. The system consists of three core process modules - a counter-current rotary kiln primary combustion chamber, a vertically - orientated secondary combustion chamber (similar to Weston's) with a down-fired burner and a quench and wet scrubber gas cleaning system (similar to EES's). Ancillary systems available to support the core modules include a waste preparation and feed system for liquids, sludges, soils, drums and other solids, a raw material storage and feed system for auxiliary fuel, process water, feed chemicals and compressed air, a power distribution module complete with an emergency diesel generator, a distributed control system and a continuous emissions monitoring system. Each auxiliary component is also designed as a transportable module.

IT's HTTS is presently being employed at the Cornhusker Army Ammunition Plant (CAAP) site in ______, Nebraska. Approximately 22,000 tons of explosive - contaminated soils will be treated during a two to three month remediation period which is scheduled for completion in early 1988. The CAAP was used intermittently up to 1973 to load, assemble and pack a variety of conventional munitions containing the explosives RDX and TNT. Wastewaters fro the load line and packing areas, which contained TNT and RDX, were disposed of onsite in cesspools and leaching pits. IT is conducting the clean-up under contract to the U.S. Army. The U.S. Army is coordinating efforts with both the U.S. EPA Region VII and the Nebraska Department of Environmental Control (NDEC). IT also has an option to thermally treat 120,000 tons of contaminated lagoon sediments at the Louisiana Army Ammunition Plant near Shreveport, Louisana.

A.3 INFRARED PROCESSING SYSTEMS

Up until late 1987, two vendors were known to be marketing infrared technology for hazardous waste treatment - Shirco Infrared Systems Inc. (Shirco) of Dallas, Texas and National Applied Scientific Systems (NASS) of York, Pennsylvania. Shirco's interests have recently been acquired by Acova, headquartered in Redmond, Washington. Unlike in the past where Shirco supplied infrared processing equipment, Acova will now be the exclusive owner and operator of the Shirco mobile technology. The mobile technology will not be offered for sale although fixed-based stationary infrared equipment will still be supplied for industrial applications. Prior to this development, three mobile Shirco units were purchased by three service vendors. NASS's thermal processing systems are similar in configuration to the Shirco system with the major exception of the use of indirect-fired radiant U-tubes for an energy source as opposed to electrical resistance heating elements.

A detailed review of Shirco's full-scale system and a general review of NASS's system is presented below.

A.3.1 SHIRCO INFRARED PROCESSING SYSTEM

System Description

Full-scale Shirco infrared processing systems consist of four basic components:

- Electrically powered, infrared primary furnace,
- Gas fired secondary furnace,
- Air pollution control system, and
- Process management and monitoring center

A process flow diagram of the Shirco infrared system is presented in Figure A-2.

The primary chamber operates within a temperature range of 500° to 1,850°F depending upon the waste material. Infrared energy supplied by the heating elements is used as necessary to maintain the desired temperature level. The solids residence time in the primary furnace can range from 10-180 minutes. Oxidizing, reducing or neutral atmospheres can be provided in the primary furnace.

The secondary chamber has a process temperature range of 1,000 to 2,300°F. A two to five second gas residence time is provided. The secondary chamber can operate with 0-100 percent excess air. Natural gas or propane is used as an auxiliary fuel to maintain combustion temperatures within the secondary chamber.

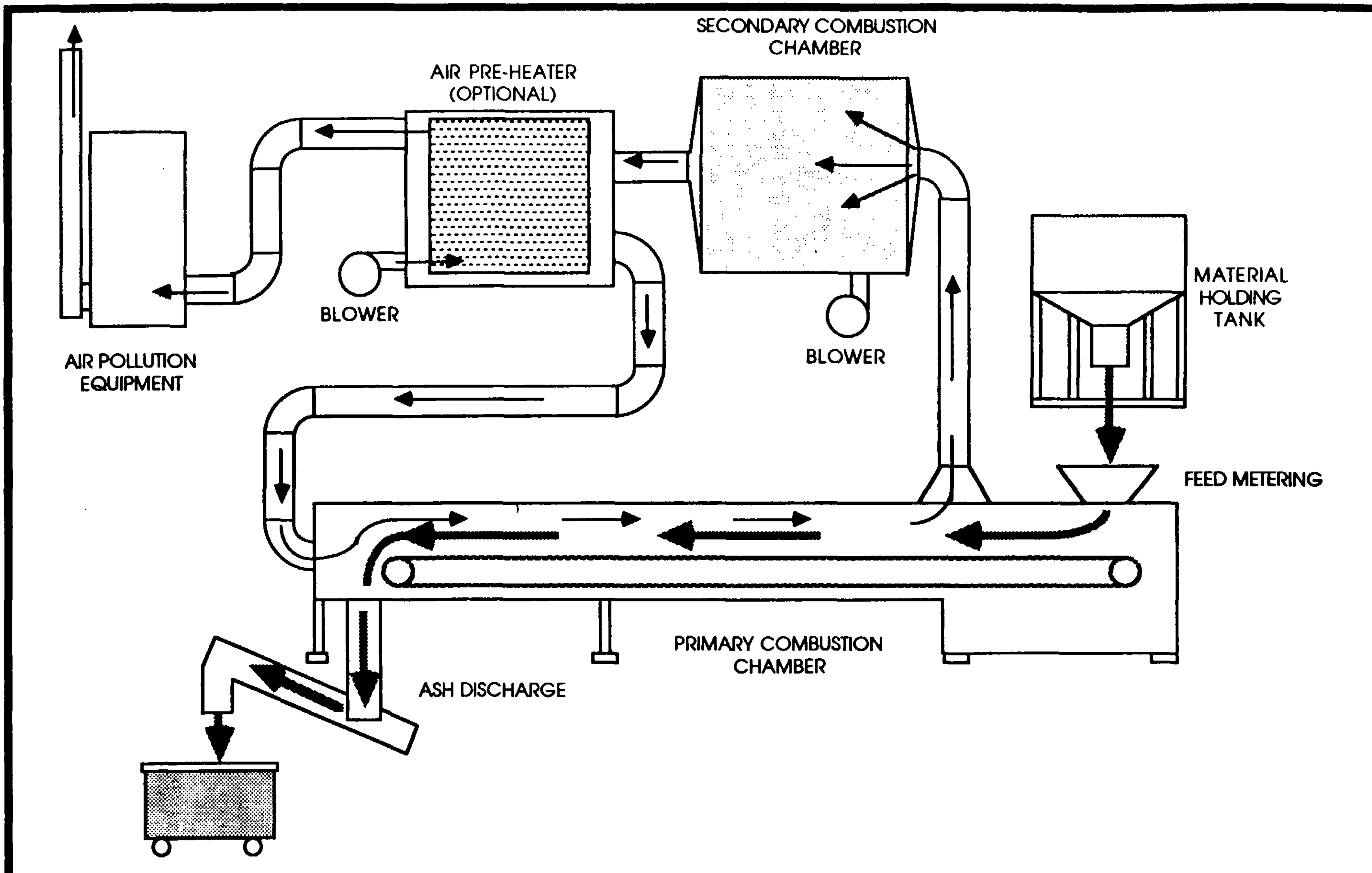
Air pollution control is achieved by a number of measures within the system. Since infrared energy is used in the primary chamber as the heat source, gaseous emissions (e.g., nitrogen oxides and sulfur dioxide) that result from combustion of alternative auxiliary fuels such as fossil fuels are reduced. Particulate emissions for organic materials are also minimized by the relatively quiescent nature of gas flow in the primary furnace.

An air pollution control system is provided to reduce emissions further. The system consists of a venturi wet scrubber and a packed bed absorber. The venturi scrubber is equipped with a sump tank from which recirculated water is pumped to the scrubber sprays. Materials such as lime can be added directly to the scrubber sump tank for removal of acid gases (e.g., HCl, SO_2). In addition to particulate removal and acid gas control, the scrubber cools exhaust gases from 1,000° - 2,300°F to approximately 180°F. A packed bed absorber is also provided to remove remaining organic and inorganic contaminant gases prior to release through the stack.

Acceptable Wastes

Waste Types Handled. Infrared systems are reported to handle a wide variety of hazardous and nonhazardous materials in the form of solids, liquids and sludges although operation to date has been limited to soil feeds. Appropriate waste contaminants include PCBs, dioxin, halogenated and nonhalogenated organics, mixed organic/inorganics and low-level radioactive wastes. Infrared systems are also capable of regenerating spent activated carbon. This feature may be useful on sites where technologies requiring activated carbon are also utilized (e.g., carbon adsorption of contaminated groundwater).

Both containerized and noncontainerized wastes are acceptable. For containerized wastes such as steel and fiber drums, liquid product would be removed and stored in a storage tank prior to injection into the unit's secondary chamber. Pumpable sludges would be removed and solidified to allow for feeding to the unit's feed hopper. The container and remaining solid contents would then have to be shredded or crushed to an acceptable size for subsequent treatment. Open lagoons could also be treatable with an infrared system. The free liquid layer would be removed first followed by excavation of the sludge and sediment layers. Liquids would be injected



Source: ACOVA
(Formerly Shirco
Infrared Systems Inc.)
Camp Dresser & McKee Inc.

FIGURE A-2
PROCESS FLOW DIAGRAM OF THE SHIRCO INFRARED PROCESSING SYSTEM

into the secondary chamber while the soil and sludge material is fed to the primary chamber. Sludge materials may require solidification to allow for proper feeding. Where necessary, liquid waste streams could be mixed or blended to provide a more uniform feed in terms of physical and chemical characteristics. It is reported by Shirco that liquid waste and/or auxiliary fuel may also be added directly to a soil feed prior to feeding. This approach is presently being performed at a PCB site near Indiantown, Florida. The added fuel would increase the heat content of the soil material thereby reducing the large electrical demand necessary to heat large quantities of soil with infrared energy. This will involve increased handling up front to ensure adequate fuel distribution.

Methods of Feeding/Charging. Appropriately sized solids and sludges (i.e., less than two inch particle size) are transported and discharged directly into the unit's feed hopper. The feed hopper is mounted over the furnace conveyor belt and separated by a rotary airlock which minimizes air leakage into the furnace. Feed material passes through the rotary airlock and is deposited on the conveyor belt from which it is evenly distributed across the entire width of the belt. A uniform bed depth of one-half to two inches depth must be provided for proper conveyance and treatment. Because even distribution of waste is important, infrared systems are not suited for direct feeding of bulk items such as intact drums. Though these units are primarily a solids processing system, liquid wastes may be fed to the secondary chamber for use as auxiliary fuel. Atomization of the liquid wastes must be possible for proper injection.

Restrictions/Limitations. Since proper waste distribution is essential within the primary chamber, solid waste material is restricted in size. All solid waste material must be reduced to a maximum particle size of two inches for proper feeding. Oversized items such as stones, tree roots, metal or fiber containers and other miscellaneous items must be reduced to an acceptable size. Size reduction can generally be obtained by shredding, grinding or crushing although such processing requirements introduce additional cost, employee hazard and the potential for fugitive emissions of POHC materials. Particular equipment requirements will be site specific. Careful attention must, therefore, be paid to the waste characteristics.

Wastes such as sludges and soil must be at least 22 percent solids prior to feeding. This is necessary since the waste material must be evenly distributed on a conveyor belt. For wastes with solids contents less than 22 percent, dewatering or the addition of a bulking agent or absorbent may be required.

Special consideration is given to wastes containing high concentrations of toxic elements. Volatile metals such as mercury and lead tend to vaporize at high temperatures. The resulting vaporized metals are difficult to remove with conventional air pollution control equipment.

Onsite Utilization

Processing Capacities. The full-scale mobile Shirco infrared processing systems have nominal capacities of 100 tons per day of soils, sludges or solids. Depending on the waste material being processed, the system can theoretically treat as much as 250 tons per day. The exact feed rate will depend primarily on the moisture and heat content of the waste material. As a comparison, Shirco's mobile pilot unit can only treat from 50 to 100 lbs per hour or approximately 0.6 to 1.2 tons per day.

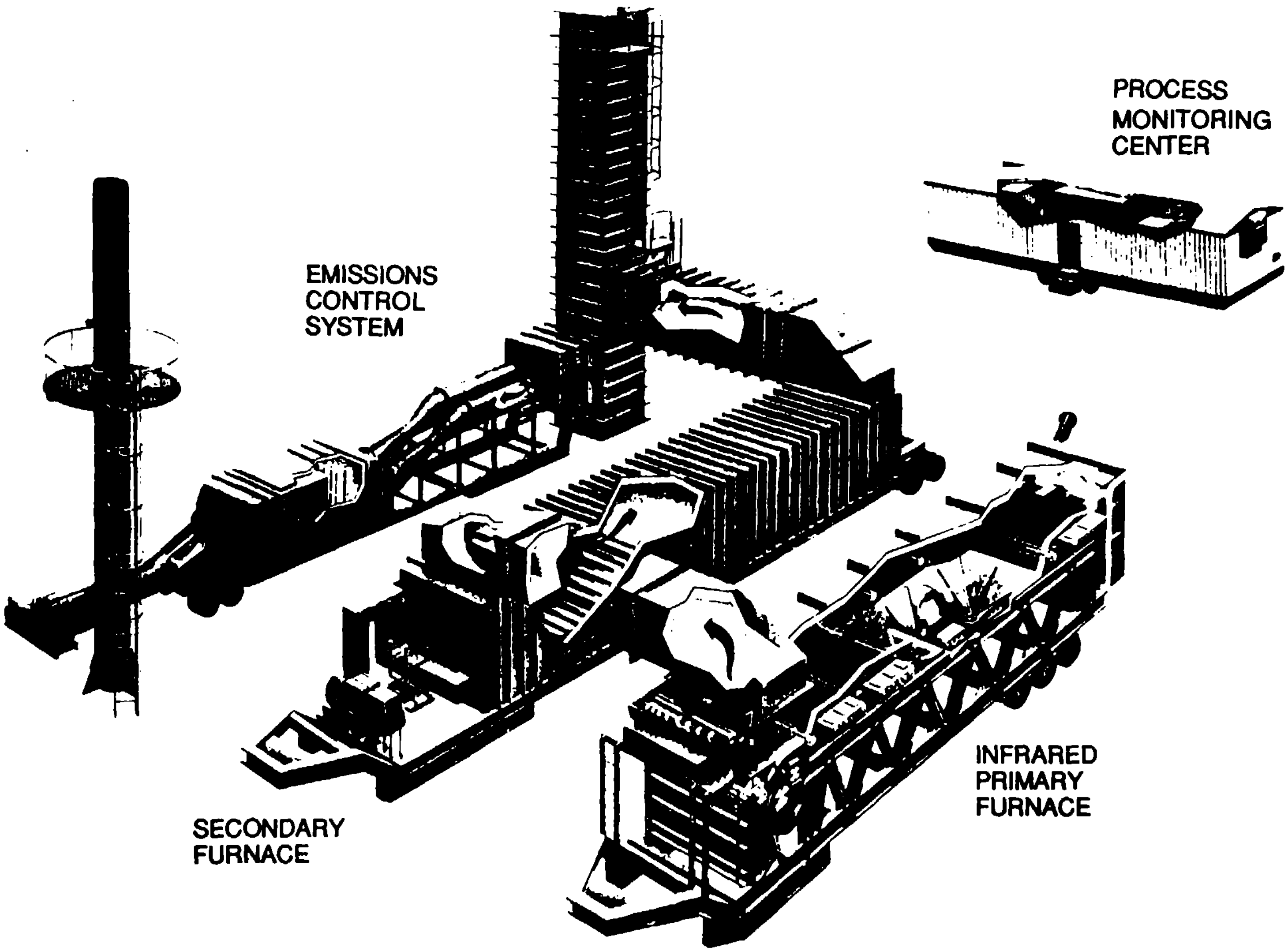
Waste Quantity. In general, waste quantities must be greater than 5,000 yd^3 to warrant onsite treatment with a 100 ton per day infrared system. For sites with waste quantities less than 5000 yd^3 (and greater than 500 yd^3) the 50 ton per day unit is reportedly more economical. It is reported by Shirco that full-scale systems would be appropriate for sites that would require anywhere from six to 24 months of remediation time. For sites with projected remediation times greater than 24 months, consideration would be given to use of multiple units on site.

Information Required of Client. In order to evaluate the technical and economic suitability of a particular site for onsite treatment with an infrared system, detailed information on waste streams and site characteristics are required. Specific information such as estimated quantities, physical (e.g., form, size) and chemical (e.g., heat content, moisture content) characteristics, location of wastes and the availability of utilities are particularly important. Operations typically require a prospective client to complete waste material data sheets. This allows them to make a preliminary estimate of the feasibility of an infrared system application. Additional data and investigation (e.g., site inspection) are generally required. A pilot test may also be necessary to generate more accurate economic data.

Mobilization/Demobilization. Full-scale infrared systems are comprised of four components -- the primary chamber, the secondary chamber, the emissions control system and the control center. The 67-foot primary chamber and the 60-foot emissions control system are each chassis mounted. The control room is contained within a single van trailer. The 72-foot secondary chamber is mounted on two wheel-mounted chassis. Each component is designed to be interconnected at the site. Additional trailers may be needed for ancillary equipment depending on the particular needs of a site. A rendering of the assembled four-component system is presented in Figure A-3.

Delivery of a full-scale system to a site location will require approximately seven days. Once the site is prepared, assembly of the system reportedly takes approximately five to fourteen days. After installation, another several weeks may be necessary for system startup/checkout procedures including materials handling. Following the completion of site remediation, the system can be decontaminated and dismantled in one week. Decontamination measures will include a bake-out of the primary and secondary chambers and steam cleaning of the feed and ash collection system.

Site Preparation/Space Requirements. Use of an infrared system on site will require the location of an access road suitable for flat bed trailers and other heavy equipment. Set-up of the four component system will require a graded, graveled staging area. Each component will be positioned on 80 ft x 40 ft concrete pads. Individual component sizes range from 60 to 72 feet in length with a width of nine ft. Additional area must be



SOURCE:
SHIRCO INFRARED SYSTEMS INC.

Camp Dresser & McKee Inc.

FIGURE A-3
TRANSPORTABLE SHIRCO INFRARED SYSTEM

provided for any necessary feed handling and preparation equipment, storage bins or tanks, residue disposal equipment and personnel and maintenance facilities.

Utility Requirements. Mobile infrared systems require electrical power, a propane or other suitable gas supply, and process water. Two electrical power supplies are necessary, 1500 KVA/480 volt and 15 amp/120 volt. The 1500 KVA/480 volt supply is used as the power source for the primary infrared chamber and other large electric demand items such as fans and pumps. The 15 amp/120 volt supply is used for the ancilliary systems and site needs though one would expect this supply to be fairly light for such an operation. If electrical power is not available on site, portable diesel-powered generators are required. A propane, or other suitable fuel gas or fuel oil source is required for operation of the secondary chamber. Process water is also necessary. An average of 35 gallons per minute of water may be required for operation of the venturi wet scrubber.

Recirculation of scrubber water is provided to reduce water demand and subsequent scrubber blowdown. Process water must be piped or brought on site in tankers if not available from onsite wells or surface water. Water for this purpose is not required to be potable.

Labor Requirement. Infrared systems are designed to operate on a 24 hours a day, seven days per week basis. Continuous operation typically requires a total labor force of 12 operators (4 per shift). Experience indicates that the system can, however, operate with as few as two operators in certain instances. Additional workers will be required for other activities such as feed handling and preparation and residue disposal. Assembly and dismantling of the unit requires a labor force of eight people.

Residuals/Effluent. Infrared systems generate three residual/effluent streams -- ash/decontaminated soil, scrubber blowdown and flue gases. Disposal of ash/decontaminated soil depends on the cleanup goals and applicable regulations (affecting the delistability of the residue). The desired situation would be to return the decontaminated soil/ash directly to the site. Regulations may necessitate further treatment such as solidification/fixation or could require disposal off site in either a secure landfill or a sanitary landfill.

Disposal of scrubber blowdown depends upon the concentration of contaminants in the blowdown. Blowdown may be acceptable for discharge to a nearby municipal or industrial sewer. If the blowdown is unacceptable or no sewer system exists nearby, treatment such as neutralization and precipitation/ sedimentation will be required either on site or off site. If treated on site, disposal of additional solids generated must be addressed. Normal operation of infrared systems reportedly will emit flue gases that meet or exceed all local, state and federal emission control requirements.

System Performance

Test Data. A number of pilot tests have been conducted on both hazardous and non-hazardous waste material using transportable pilot-scale infrared units. These demonstration units operate similarly to the 100 ton per day infrared systems discussed in the preceeding sections, although of much smaller scale (maximum of 100 lbs/hour).

Three of the most significant demonstrations to date occurred with dioxin and PCB-contaminated soils. Each is breifly discussed below. The first demosntration test was conducted during July 8-12, 1985 at the Times Beach Dioxin Research Facility operated by the Missouri Department of Natural Resources (DNR). A mobile pilot-scale unit was successfully used to thermally treat soil laden with 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). The test was observed by DNR personnel and by independent contractors who were responsible for analysis of emissions and soil samples. A summary of tests results is presented in Table A-1.

The second test was conducted on PCB-contaminated soils at a Superfund site in Indiantown, Florida during May 1986. Destruction and removal efficiencies (DREs) were at or in excess of 99.9999 percent on all but two runs using the mobile pilot-scale unit. The two runs which showed DRE of only 99.9997 percent were attributed to invalid quality assurance/quality control (QA/QC) issues. A full-scale system has since been employed to remediate the site.

The third test, conducted in two parts, occurred was conducted at the Twin Cities Army Ammunition Depot the U.S Army. The test was conducted for the U.S. Army. In January 1987, the mobile pilot unit was used to regenerate spent trichloroethylene (TCE) contaminated activated carbon for reuse in an ongoing groundavter clean-up program. The second part was conducted in May 1987 when the same unit was used to treat PCB-contaminated soils at the same site. Test results are presented on Table A-2.

<u>Operating History</u>.

The first Shirco full-scale unit was delivered to the Peak Oil Superfund site in Tampa, Florida in December 1986. The unit, owned and operated by Haztech of Decature, Georgia, began operations at the former motor oil recycling facility in early 1987. The site remediation, completed in late 1987, was performed for the EPA under the SITE program. Startup problems were experienced in February, March and April which restricted the unit to an average daily throughput of 30 tons over this three month period. Problems were experienced with the soil feed system, ash discharge systems and the scrubber. It was reported that the majority of downtime occurred because of delays in receipt of replacement parts. Minor operating problems continued in May and June with daily tonnage averaging approximately 50 tons. Following several equipment modifications, daily throughputs from that plant have reportedly averaged around 90 tons with an equipment utilization rate of over 85 percent. Approximately 7,000 tons of PCB-contaminated soil was processed during the clean-up.

The unit reportedly achieved the required 99.9999 percent DRE during a demonstration burn using a soil feed spiked with PCB's. Particulate emissions, however, exceeded the acceptable particulate standard. This has resulted from lead oxides in the soil (10,000-12,000 ppm) forming submicron particles. A final performance evaluation under the SITE program had not been released as of this writing.

TABLE A-1

SUMMARY OF PERFORMANCE DATA
INFRARED PROCESSING SYSTEM

On-Site Incineration of Dioxin Contaminated Soil
Times Beach Dioxin Research Facility
Times Beach, Missouri
July 8-12, 1985

	EPA Standard	30 Minute Residence	15 Minute Residence
Composite feed soil 2,3,7,8 TCDD concentration		227 ppb	156 ppb
Composite discharge soil 2,3,7,8 TCDD concentration	<1 ppb	Not detected at 38 ppt	Not detected at 33 ppt
Particulate emissions at 7% O_2	.08 gr/dscf	0.001 gr/dscf	0.002 gr/dscf
Gas phase DRE of 2,3,7,8 TCDD	$\geq$99.9999%	>99.999996%	>99.999989%

SOURCE: Acova (formerly Shirco Infrared Systems Inc.)

TABLE A-2

SUMMARY OF PILOT TEST RESULTS AT THE TWIN CITIES ARMY AMMUNITION DEPOT INFRARED PROCESSING SYSTEM

Date: January 1987
Waste Material: Spent Activated Carbon
Contaminant: TCE

TCE CONC.	GAS PHASE DRE (%)
1,070 ppm	99.99998
18,000 ppm	99.99999
24,000 ppm	99.99999
28,000 ppm	99.99999

Date: May 1987
Waste Material: Contaminated Soil
Contaminant: PCB

PCB CONC.	GAS PHASE DRE (%)
43,070 ppm	99.99998
45,000 ppm	99.99998
45,000 ppm	99.99998

SOURCE: Acova (formerly Shirco Infrared Systems Inc.)

The second unit was installed by OH materials at the Florida Steel Superfund Site in Indiantown, FL. OH Materials is under Contract with the Florida Steel Corporation to treat approximately 16,000 yd^3 of PCB contaminated soil. Testing for a nationwide TSCA permit was conducted in September 1987. The results of the test were not available as of this writing. Completion of remediation is expected in mid 1988.

A third Shirco system was delivered to Reidel Environmental Services, Portland, Oregon in mid 1987. This system has not been employed for a site remediation as of this writing.

Acova, the present owner of the Shirco infrared technology, reportedly is fabricating two full-scale units which are expected to be available in early 1989. The first unit will be used to remediate PCB-contaminated soil at a U.S. Army installation in Minneapolis, Minnesota.

A.3.2 NASS INFRARED PROCESSING SYSTEM

The NASS infrared processing system is similar in design concept to the Shirco system. As with the Shirco system, a conveyor belt furnace is the central processing unit. Other components of the NASS system include a hot cyclone, an afterburner and a quench venturi and caustic scrubber pollution control system.

The physical size and processing capabilities of the NASS system is comparable to that of the 100 ton per day Shirco transportable unit. Several differences exist within the belt furnace of each system though. NASS's belt furnace is heated with indirect fuel-fired radiant U-tubes as opposed to electrical resistance heating elements. U-tubes, used traditionally in the manufacture of metals and ceramics, reportedly offer decreased operation and maintenance costs and a longer lifespan than electrical resistance heating elements while maintaining high thermal efficiency.

Another difference concerns the metal alloy feed belt itself. The feed belt on the NASS system returns outside of the furnace whereas the Shirco belt is totally contained within the furnace. This feature reportedly allows for cooling of the belt and the incorporation of external riding rollers for use in automatically adjusting the belt tension and tracking.

NASS markets their infrared processing system for both fixed-based (i.e., stationary) and mobile applications. To date, NASS has fabricated one system. The unit is owned by Alchem-Tron and presently located at their Cleveland, Ohio industrial waste treatment, storage and disposal (TSD) facility. Alchem-Tron has, in the past, operated the unit exclusively on non-hazardous feed materials but expects to conduct a trial burn in late 1987 to demonstrate the destruction of hazardous waste. Upon successful demonstration and permit approval, the unit will be placed in commercial operation for both hazardous and non-hazardous solids treatment.

A.4 CIRCULATING FLUIDIZED BED INCINERATORS

Several manufacturers offer circulating fluidized bed systems for the utility industry where most of the operating experience of fluidized/circulating bed systems is found. Only one company, however, currently offers a circulating fluidized bed system for the treatment of combustible hazardous waste. Ogden Enviromental Services (OES) of San Diego, California is marketing a transportable system referred to as the circulating bed combustor (CBC). A review of OES's CBC is presented below.

A.4.1 OES CIRCULATING FLUIDIZED BED INCINERATOR

System Description

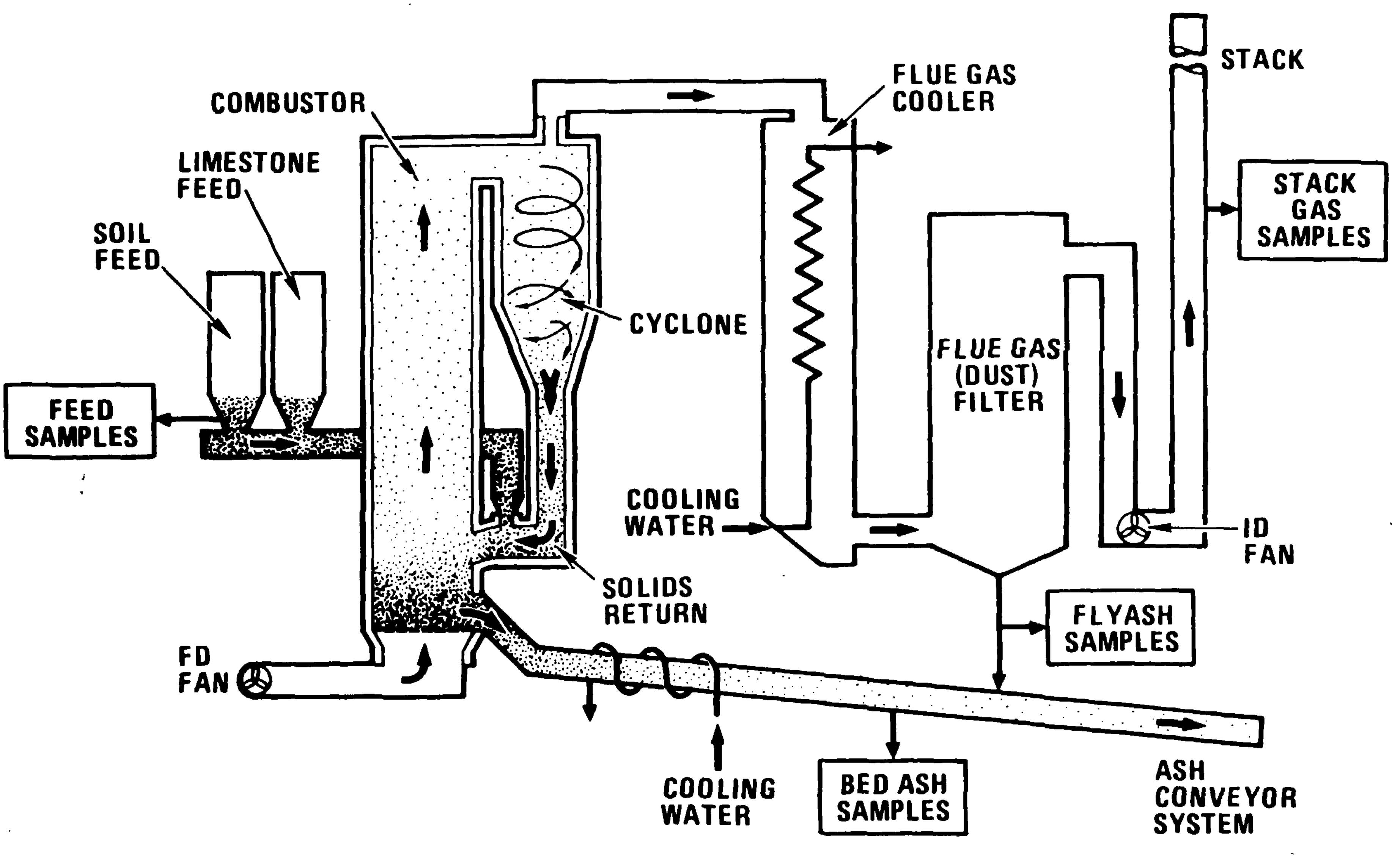
OES's CBC system is an advanced fluidized bed system. It consists of several components, many of which are common to fixed based circulating fluidized bed units:

- o Combustion chamber,
- o Hot cyclone and return loop,
- o Convective flue gas cooler, and
- o Flue gas dust filter (baghouse)

A process flow diagram of the circulating bed combustor is presented in Figure A.4.

The combustion loop (combustor chamber, hot cyclone, return loop seal) operates at a temperature of 1,400°-1,800°F. A uniform temperature ($\pm$ 50°F) is reported to be maintained around the entire combustion loop as a result of the high turbulence caused by high air velocity and the thermal inertia of the large mass of circulating solids. Auxiliary fuel is used in the combustor as necessary to maintain temperature. This is necessary with low heat content feeds such as contaminated soil. Residence time for gases is approximately 2 seconds while residence time for solids within the combustion loop ranges from minutes to hours. Pressure within the system is ambient to slightly negative.

Air pollution control is achieved by a number of measures within the system. Efficient combustion created by vigorous mixing and long residence time is reported to be effective in the destruction of principal organic hazardous constituents (POHCs). Carbon monoxide (CO) and nitrogen oxides (NO_x) are reportedly controlled to low levels by the high degree of mixing, the relatively low temperatures (1,400°-1,800°F) -- a factor which reportedly strongly influences the levels of thermal NO_x -- and the potential for staged combustion achieved by injecting secondary air at different locations in the combustor. The trade-off between reduced NO_x and inadequate oxidation of POHC's is not known. Particulate (i.e., fly ash) removal is achieved by use of a fabric filter dust collector (baghouse). A convective gas cooler precedes the baghouse. The gas cooler consists of a heat exchanger used to preheat the combustion air while reducing flue gas temperatures from 1400°-1800°F to 350°F for acceptable entry into the baghouse. Acid gases (SO_2, HCl, HF) formed during combustion can be neutralized by fine, dry limestone added into the combustor along with other feed materials. Acid gas removal efficiency reportedly exceeds 99 percent. Inert salts such as calcium chloride ($CaCl_2$) and calcium sulfate ($CaSO_4$) result from the reaction of acid gases with the limestone.



Source: Ogden Environmental Services Inc.

Camp Dresser & McKee Inc.

Figure A-4

PROCESS FLOW DIAGRAM OF THE OGDEN ENVIRONMENTAL SERVICES CIRCULATING BED COMBUSTOR

Acceptable Wastes

Waste Types Handled. The CBC unit is reported to handle a wide variety of hazardous and non-hazardous materials in the form of organic solids, liquids, sludges and slurries. The technology is particularly appropriate for soils contaminated with highly toxic materials such as PCBs and dioxin. Other halogenated and non-halogenated organic wastes that can, in concept, be treated include pesticides and oily wastes, munitions and chemical agents. However, there is very limited experience with hazardous waste incineration at a commerical scale and/or over extended periods of time.

Both containerized and noncontainerized wastes are acceptable. For containerized wastes such as steel and fiber drums, any liquid or pumpable product would be removed and stored in a storage tank prior to feeding to the CBC unit. The container and remaining solid contents would then have to be shredded to an acceptable size for subsequent treatment. Open lagoons could also be treatable with a CBC although, without dewatering, the energy consumption could be prohibitively expensive as with any thermal system. The pumpable layer (i.e., contaminated water or liquid layer) would be removed first followed by excavation of the nonpumpable sludge and sediment layers. Where necessary, liquid waste streams could be mixed or blended to provide a more uniform feed.

Method of Feeding/Charging. Solids, liquids, sludges and slurries are injected directly into the combustion loop of CBCs. Atomization of liquids, sludges and slurries is not required. The inherently high degree of turbulence and mixing provides good waste distribution. Solid wastes and non-pumpable sludges are introduced into the loop seal region along with limestone fed via a screw feed auger. Liquids, pumpable sludges and slurries are injected directly into the lower section of the combustor section. Auxiliary fuel, if required, is also injected into this area. Problems associated with plugged nozzles in conventional liquid injection systems are avoided since atomization is not required.

Restrictions/Limitations. Oversized pieces of waste must be reduced to one inch in size in order to be fed into the CBC. A uniform size feed is particularly important for combustion efficiency as well as solids removal from the bed. Oversized debris often includes stones, tree roots, metal or fiber containers and other miscellaneous items (e.g., wood). Waste size can generally be reduced by shredding, grinding or crushing although such processing requirements introduce additional cost, employee hazard and the potential for fugitive emissions of POHC materials. Particular equipment requirements will be site-specific. Careful attention must therefore be paid to the characteristics of the waste.

Wastes with appreciable concentrations of low-melting point constituents (<1600°F) such as alkali metal salts may cause operational difficulties. Defluidization of the bed may occur when particles become "sticky". As a general rule, the alkali metal content of the waste should be less than five percent and the chlorine content should be less than eight percent. Additionally, wastes with appreciable concentrations of volatile metals (e.g., mercury) are not appropriate for standard CBC units since they volatilize at high temperatures and are not efficiently captured by the standard air pollution system. An external scrubber train would be required to improve the collection efficiency. Since thermal treatment does not destroy heavy metals, use of a CBC or any other thermal treatment alternative is not recommended for wastes streams with heavy metals as the primary contaminant.

Onsite Utilization

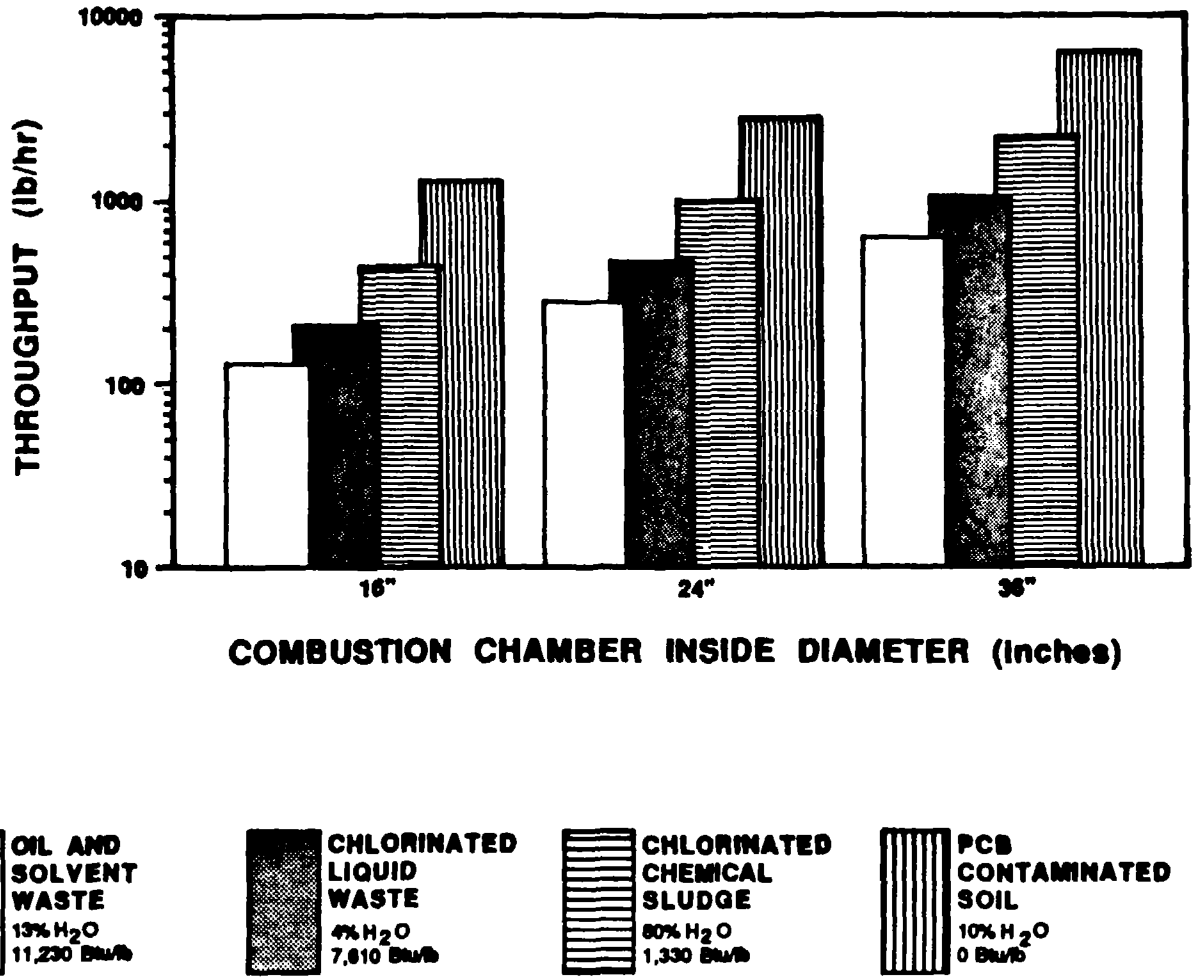
Processing Capacities. Three different transportable CBC sizes have been designed by OES -- a 16-inch, 24-inch and 36-inch I.D. CBC. The numerical value refers to the inside diameter (I.D.) of the combustion chamber. A 16-inch I.D. unit is currently operating as a pilot plant at OES's San Diego, California facility. A 36-inch I.D. unit, the largest transportable model available, is under design. Larger CBC models are available as fixed facilities.

The 36-inch I.D. CBC is intended to have a throughput of four to ten tons per hour of contaminated soil. The exact feed rate will depend on the moisture content of the soil. It should be noted that moisture content is not a technical but an economic issue common to all thermal systems. The higher the moisture content, the more heat required to dry the soil. In order to provide the additional heat, a longer residence time is necessary. The feed throughput must be reduced accordingly. The economic trade-off is to mechanically or thermally dewatered and satisfy throughput requirements. It is expected that liquids can be processed at a rate of 500-900 lbs/hr dependent upon the heating value of the waste and the volume of combustion gas generation. The throughput of representative waste streams for each transportable CBC model is presented in Figure A-5. The effect of moisture content in soil is shown on the throughput curve for a 36-inch I.D. CBC in Figure A-6.

Waste Quantity. Waste quantities must be substantial enough to warrant onsite treatment with a CBC. In general, if a site contains contaminated soil, OES indicates that about 10,000 cubic yards or more are required for a practical application with a single 36-inch I.D. CBC. Smaller quantities could be handled with smaller scale units. Larger soil volumes suggest the use of multiple units on site. A 36-inch I.D. CBC is capable of processing approximately 20,000 cubic yards per year assuming a typical processing rate and on line availability. For such a system, about six months or more residence is needed for an economically practical application.

Information Required of Client. In order to evaluate the suitability of a particular site for onsite treatment with a CBC, detailed information on waste streams and site characteristics is required. Specific information such as estimated quantities, physical (e.g. form, size) and chemical (e.g. composition, heat content) characteristics, location of wastes and the availability of utilities are particularly important. OES requires a prospective client to complete a Waste Survey Form. This allows them to make a preliminary estimate of the technical and economic feasibility of a CBC application. Additional data and investigation (e.g., site inspection) are generally required. A copy of OES's Waste Survey Form is attached in Appendix B.

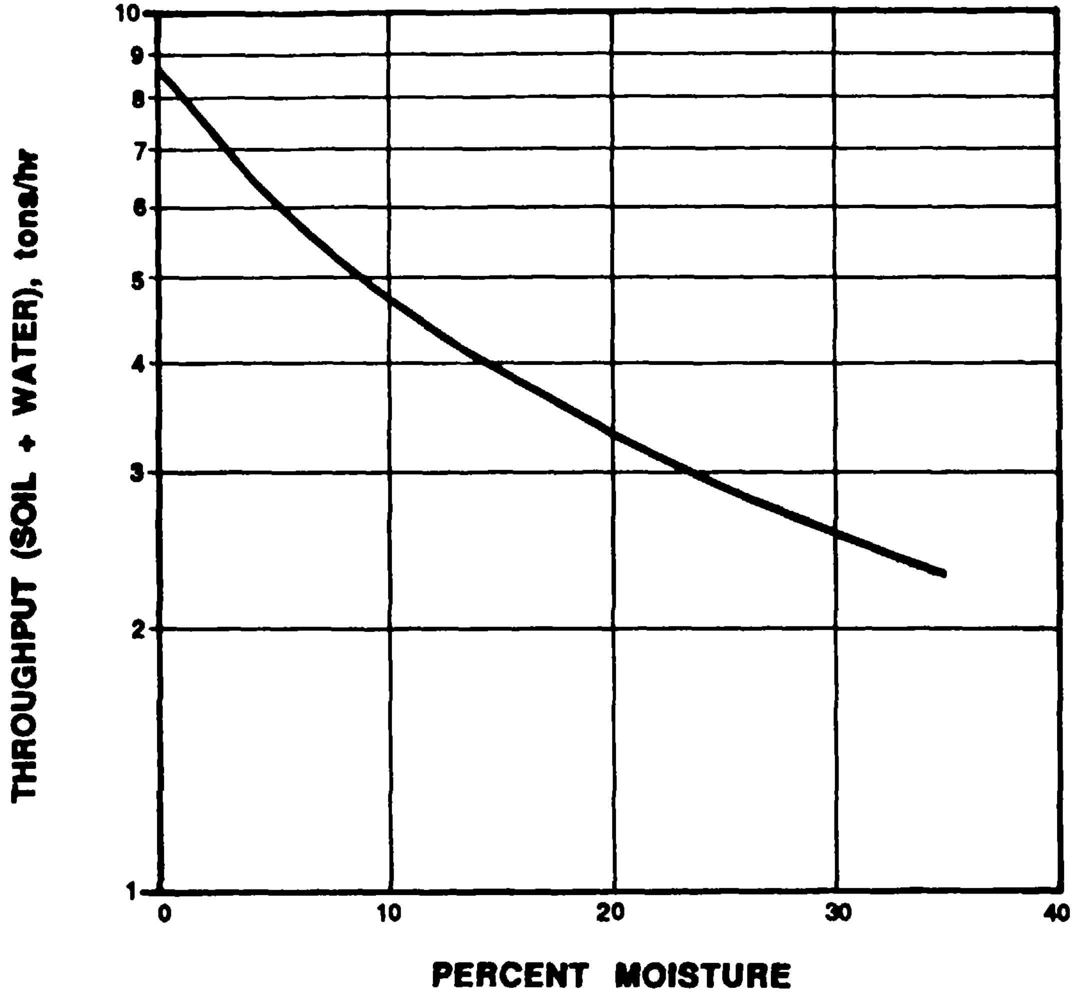
Mobilization/Demobilization. Transportable CBCs consist of a series of modules transported on five to seven flat-bed tractor trailers. Each



Source: Ogden Environmental Services Inc.

Camp Dresser & McKee Inc.

FIGURE A-5
TRANSPORTABLE CIRCULATING BED COMBUSTOR (CBC) THROUGHPUT



PROCESS ASSUMPTIONS
BED TEMP 1600F
AIR PREHEAT 500F
GAS VEL 18FT/S
EXCESS AIR 20%
AUX FUEL CH4

Source: Ogden Environmental Services Inc.

Camp Dresser & McKee Inc.

FIGURE A-6
CBC SOIL THROUGHPUT
FOR 36 INCH TRANPORTABLE UNIT

module contains both the plant components and the structural members. This modular design reportedly allows for reduced field erection time, field labor and overall cost of the plant. A diagram of an assembled transportable CBC is presented in Figure A-7.

Assembly of a CBC at a site requires about four to six weeks. After installation, start-up/checkout procedures require an additional two weeks. Once site remediation is complete, demobilization requires approximately three to four weeks. Prior to disassembling, equipment must be decontaminated. The necessary decontamination measures depend upon the application. Decontamination measures generally include a period of operation with clean fuel and washing and scrubbing of equipment exteriors.

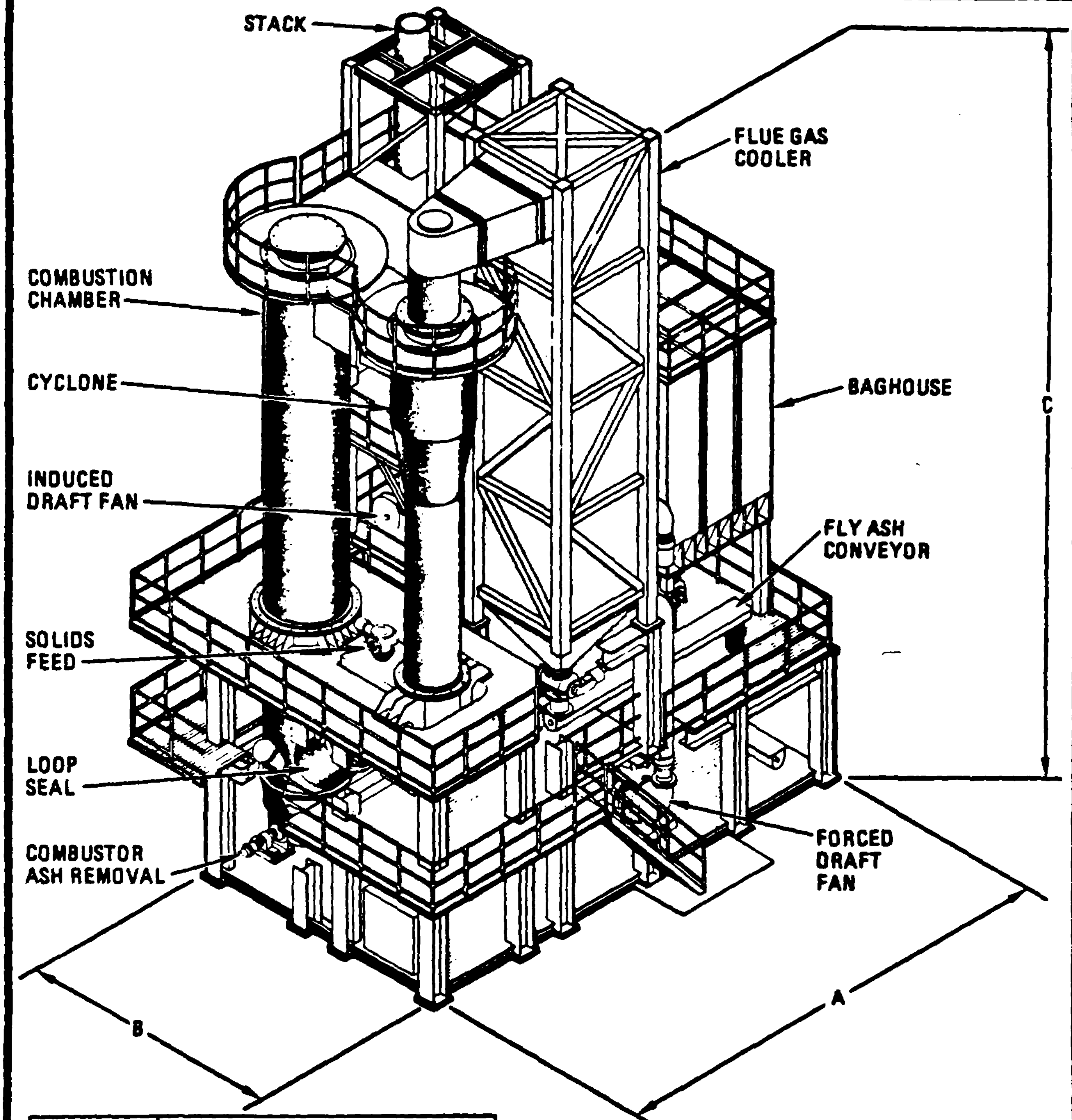
Site Preparation/Space Requirements. Utilization of a CBC on site requires the location of an access road suitable for 45 foot long tractor trailers and other heavy equipment. A 20 ft by 60 ft graded, graveled area is required for assembly of the unit. The actual dimensions of individual transportable CBC models are included in Figure A-7. Additional space must be provided for a control trailer and a laboratory trailer. A staging area will be required for any necessary feed handling and preparation equipment, storage bins or tanks, residue disposal equipment and personnel and maintenance facilities. Site security (e.g., fencing) must also be provided to restrict access to the area.

Utility Requirements. Utilities are an important consideration since sites may be located in remote areas. CBCs require access to auxiliary fuel and electrical power. Either gas (e.g., methane) or fuel oil may be used as auxiliary fuel. For soil treatment, approximately 6.5 million Btu/hr are necessary to maintain combustion temperatures. The exact quantity will vary according to soil moisture content. For waste feeds with heat contents greater than 3000 Btu/lb, no auxiliary fuel is typically required during operation. Normal auxiliary fuel requirements for unit startup and shutdown would still be necessary. Approximately 200 KW of electrical power are necessary for operation. This includes electrical requirements of the CBC (e.g., fans, motors) as well as that for ancillary facilities (e.g., laboratory).

Scrubber water is not required since CBC units do not utilize an auxiliary scrubber. Water is used for flue gas and bottom ash cooling, but is contained within a closed loop system, therefore little make-up water is required. Heat removed via the cooling water is used to preheat combustion air to a temperature of 650°F. The remainder of the heat removed within the heat exchanger and water-jacketed ash screw conveyor is dissipated by fin-fan heat exchangers.

Labor Requirement. CBCs are designed to be operated on a 24 hours a day, seven days per week basis. Three operators are required per shift, or a total of about 12 people for continuous operation. Additional workers will be required for other activities such as feed handling and preparation and residue disposal.

Residuals/Effluents. CBCs generate two residual/effluent streams -- ash/decontaminated soil and flue gases. Disposal of ash/decontaminated soil depends on the cleanup goals and applicable regulations (e.g.,



APPROXIMATE DIMENSION	PLANT SIZE (COMBUSTOR I.D. IN.)		
	16 IN.	24 IN.	36 IN.
A (FT)	20	24	33
B (FT)	12	16	19
C (FT)	50	60	60

*FEED AND ASH HOPPERS NOT SHOWN

Source: Ogden Environmental Services Inc.

Camp Dresser & McKee Inc.

FIGURE A-7
TRANSPORTABLE CBC EQUIPMENT ARRANGEMENT

delisting). The desired situation would be to return the decontaminated soil/ash directly to the site. Regulations may necessitate further treatment such as solidification/fixation or require disposal off site in either a secure landfill or sanitary landfill.

Normal operation of CBCs will emit flue gases that meet or exceed all local, state and federal emission standards. Requirements for 99.99 percent destruction of toxic organic chemicals and 99 percent retention of acid gases are reported by OES to be attainable. Since all cooling water is contained within a closed loop system, no blowdown or wastewater discharge results.

System Performance

Test Data. A number of pilot tests have been performed on various waste streams. These tests have been carried out in a 16-inch I.D. CBC located at OES's San Diego, California facility. This pilot plant is similar to transportable CBCs that are now under design. The results of several pilot tests as reported by OES are summarized below.

A pilot test on PCB-contaminated soil was conducted at OES's pilot plant on May 20-29, 1985. The test was conducted in accordance with a test plan approved by the Environmental Protection Agency (EPA). The test was observed by EPA personnel and by EPA contractors who were responsible for analysis of flue gas and bed ash samples. An EPA modified Method 5 sample train was used to sample stack gas emissions while a separate volatile organic sampling train (VOST) was used to sample for volatile organic products of incomplete combustion (PICS), such as dioxin, furan, and trichlorbenzene.

The PCB-contaminated soil samples were prepared by mixing transformer oil with soil to a concentration of about 10,000 ppm PCB. A total of 10,000 lbs of spiked soil were pneumatically transferred and screw fed to the unit during three tests. Each test was operated under identical operating conditions to meet EPA requirements for triplicate sets of data relating to destruction and removal efficiency (DRE). The operation data and results from this test are tabulated in Table A-3. Based on the successful test results, OES was issued a TSCA permit by the EPA. This permit allows OES to burn PCBs in this CBC unit nationwide.

Additional testing has been performed on other waste solids, liquids and sludges. Test results have demonstrated that CBCs are capable of meeting RCRA specified DREs of 99.99 for Principal Organic Hazardous Constituents (POCHs). Acid gas collection has exceeded the 99 percent requirement. The test results of various waste contaminants are summarized in Table A-4.

Operating History. Operating history to date is limited to the operation of the 16-inch I.D. pilot unit. An extensive file of test burn data has been generated with this unit. Two 36-inch CBC units are reportedly being constructed. The first unit is scheduled to be employed in the summer of 1988 at ARCO Alaska Inc., Swanson River Field on the Kenai peninsula in Alaska. The other unit is reportedly committed to a soil remediation project in California. CES is considering fabricating two additional units.

TABLE A-3

PCB TRIAL BURN OPERATIONAL DATA AND TEST RESULTS
CIRCULATING BED COMBUSTOR PILOT PLANT

TSCA Parameter	Test Number Requirement	1	2	3
Test Duration, hr	~4	4	4	4
Operation Temperature, °F	--	1,800	1,800	1,800
Soil Feed Rate, lb/hr	--	328	412	324
Total Soil Feed, lb	--	1592	1321	1711
PCB Concentration in Feed, ppm		11,000	12,000	9,800
DRE, %	>99.9999	99.999995	99.999981	99.999977
PCB Concentration				
- Bed Ash, ppm	<2	0.0035	0.033	0.186
- Fly Ash, ppm	<2	0.066	0.0099	0.0032
Dioxin/Furan Concentration				
- Stack Gas, pp	--	ND[a]	ND	ND
- Bed Ash, ppm	--	ND	ND	ND
- Fly Ash, ppm	--	ND	ND	ND
Combustion Efficiency, %	>99.9	99.94	99.95	99.97
Acid Gas Release, lb/hr	<4.0	0.16	0.58	0.70
Particulate Emissions, grain/scf (dry)	<0.08	0.095[b]	0.043	0.0024
Excess Oxygen, %	>3.0	7.9	6.8	6.8
CO, ppm	--	35	28	22
CO_2, %	--	6.2	6.0	7.5
NO_x, ppm	--	26	25	76

[a] ND = Not detected

[b] Derived from 2-hr makeup test

SOURCE: Ogden Environmental Services
Tests conducted on a 16-inch I.D. CBC pilot plant located in San Diego, California, May 1985.

TABLE A-4

ADDITIONAL TEST RESULTS ON HAZARDOUS WASTES
CIRCULATING BED COMBUSTOR PILOT PLANT

Chemical Name	Chemical Formula	Physical Form	Destruction Efficiency (%)	HCl Capture (%)
Carbon Tetrachloride	CCl_4	Liquid	99.9992	99.3
Freon	$C_2Cl_3F_3$	Liquid	99.9995	99.7
Malathion	$C_{10}H_{19}O_6PS_2$	Liquid	>99.9999 (undectable)	--
PCB	$C_{12}H_7Cl_3$	Soil	>99.9993 (undetectable)	99.1
Dichlorobenzene	$C_6H_4Cl_2$	Sludge	99.999	99
Aromatic Nitrite	$C_8N_2H_4$	Tacky Solid	>99.9999 (undetectable)	--
Trichloroethene	C_2HCl_3	Liquid	99.9999	99

SOURCE: Ogden Environmental Services

A.4 ECONOMICS

The unit cost for onsite thermal treatment will vary depending on the treatment technology, waste material (e.g., type, form) and particular site characteristics (e.g., waste location, waste quantity). It is expected that the handling, preparation and feeding of waste material will be a significant cost factor along with thermal treatment, particularly if pretreatment such as size reduction, dewatering or mixing/blending is necessary.

The unit cost of onsite treatment consists of both fixed and variable costs. Fixed costs are those costs that are inherent in applying a mobile system for onsite treatment and exist irrespective of the quantity of waste on site. These costs include site preparation, mobilization/demobilization, permitting, pre-operational testing (e.g. trial burn) and administration. Those costs directly related to waste quantity are referred to as variable costs. Variable costs include labor, operating expenses (e.g., utilities, treatment additives), system and ancilliary equipment capital use fees, and laboratory analyses. Unit costs for onsite thermal treatment with rotary kiln, infrared, or circulating bed systems are expected to range from $200-$500/ton. A comparative cost analysis between onsite and offsite treatment is presented in Section 5.

As an aid to further assessing onsite treatment costs with each of these systems, approximate treatment costs for two site scenarios are attached. These cost analyses were obtained in response to previous inquiry and reflect only "representative" costs. The costs shown are not actual vendor bids though the site scenarios presented are representative of many CERCLA sites. A description of each site scenario is also included. Responses from EES and OES include complete site services (i.e., excavation, waste transport, thermal treatment). The Shirco response, however, is for thermal treatment services only.

A.6 CONCLUSION

As noted in Section 5, capacity for treating CERCLA contaminated soils in offsite facilities is currently restricted to limited containerized quantities. Therefore, the need exists for onsite thermal treatment capabilities. Each of the technologies discussed in this section have traditionally been utilized as fixed facilities but, in response to the CERCLA market, have been sized and modified for transport to a particular site location. The broad processing capabilities of rotary kiln systems makes them particularly well suited for CERCLA site cleanups. The circulating fluidized bed and infrared systems have been successfully demonstrated in pilot-scale operations but have not yet operated under continuous field conditions at the scale of operation needed for commercial viability. However, such field trials are expected in the near future.

Despite the limited operating history of mobile thermal treatment systems in general, the increased demand for onsite treatment is expected to expedite the application and development of these systems. Mobile thermal treatment systems are capable of offering an effective means of clean-up for many hazardous waste sites, particularly those with highly toxic waste contaminants such as PCBs and dioxin.

APPENDIX B

OFFSITE STATIONARY SYSTEMS

B.1 INTRODUCTION

Permanent waste management installations with thermal treatment facilities handle large volumes of industrial hazardous waste. Currently, there are at least 16 commercial liquid injection incinerators accepting liquid waste and 6 commercial rotary kilns handling liquids, sludges and solids. In addition, there are several facilities that accept liquid organic wastes as supplemental fuel for energy recovery purposes. Most of these facilities serve the industrial sector for disposal of spent solvents or manufacturing by-products. A limited number of these accept CERCLA (i.e., Superfund) wastes but capacity is limited, particularly for contaminated soils. In addition to problems with inadequate capacity, some facilities do not accept waste from CERCLA sites as business policy, prefering more uniform RCRA waste streams to the highly variable waste characteristics typical of CERCLA waste.

Disposal of large volumes (i.e., more than 1,000 cu. yds) of contaminated soils at existing commercial rotary kiln facilities is generally not a economically practical and the availability of adequate capacity is questionable. Most available rotary kiln capacity is currently reserved for the needs of industrial customers. However, small containerized shipments of soil can be handled by using phased delivery schedules (most facilities have limited storage capacity and tightly scheduled kiln utilization) or allocating the waste among several facilities. It should be noted that, while none of the existing facilities presently accept bulk (i.e., noncontainerized) shipments of soil, some facilities are planning to develop that capability.

Of the six existing commercial facilities with rotary kilns that handle liquids, sludges and solids, only three are permitted to incinerate PCBs. Heavy demand for this service is generated by utilities and private industries, which are required by law to dispose of PCB-contaminated transformer oil, transformers, and associated material within a specified time period. Additional demand is generated by the increased pace of remediating both NPL and non-NPL sites by private industry. This heavy utilization of available fixed incineration facility capacity plus the high cost of transportation makes mobile thermal treatment systems a viable method at sites where more than 1000 cu. yds of soil must be excavated and thermally treated.

B.2 GUIDELINES FOR WASTE ACCEPTANCE AT FIXED THERMAL TREATMENT FACILITIES

Liquids, sludges or soils must meet specific guidelines in order to be accepted for thermal treatment by a waste management facility. These guidelines are different for each facility. They include:

(1) Requirements for sampling and containerization,

(2) Limitations on the concentration of PCBs, heavy metals, bromides, and fluorides. These limitations are often dictated by the facilities operating permits. The contaminants present in the waste must be fully identified and maximum levels of contamination documented, and

(3) Full identification of contaminants and documentation of maximum contaminant levels

(4) Overall Btu or heat content of each waste material.

The restrictions and limitations for acceptance of waste have been identified for five major commercial incineration facilities having rotary kilns and liquid injection incinerators. These facilities include:

- SCA's Chicago, Illinois rotary kiln incinerator,
- Rollins Environmental Services rotary kiln incinerators in
  - Bridgeport, New Jersey
  - Baton Rouge, Louisiana
  - Deer Park, Texas
- Environmental System Company's (ENSCO) rotary kiln system in El Dorado, Arkansas

Most of these facilities also offer a range of other treatment options, including land disposal, but this study focuses only on thermal treatment capabilities. The specific requirements for each facility for containerization and waste characterization are documented in the remainder of this section. Samples of questionaires are found in Appendix B.

B.3 SCA CHEMICAL SERVICES

B.3.1 GENERAL

SCA, now a subsidiary of Chemical Waste Management, operates a rotary kiln/liquid injection incinerator in Chicago. This is one of three facilities that is permitted to incinerate PCBs. The rotary kiln is rated at 30 million Btu/hr and can handle a range of containerized solids or solidified sludges. The organic constituents are volatilized in the kiln at 1600° to 1800°F, and then drawn into a secondary combustion chamber (rated at 90 million Btu/hr), where they are destroyed at temperatures between 2200° and 2350°F. Sludges can be pumped directly into the kiln from tank trucks, or solidified and containerized for incineration as a solid. Liquids are burned in both the kiln and secondary chamber, providing most of the thermal energy needed for contaminant destruction.

B.3.2 REQUIREMENTS FOR WASTE ACCEPTANCE AT SCA CHICAGO FACILITY

1. A full description of the wastes to be incinerated must be provided. This includes detailed descriptions of the physical characteristics of the waste, the chemical composition of the waste and its hazardous

characteristics. An example of a typical waste material survey from SCA is presented as Appendix A.

2. A representative sample must be provided for analysis by the SCA laboratory. This serves to confirm the data supplied in survey form, and provides the company with supplemental information on processing characteristics of the waste. If the company agrees to process the waste, they will provide a price quote for that waste type.

3. Approved waste material must be delivered to the facility in a specified form as described below:

   Liquids - bulk tanker deliveries only
   Sludges - bulk tanker deliveries if pumpable, otherwise must be solidified and put in plastic drums
   Solids - plastic drums only - absorbent must be added such that there is no free liquid
   Containers - max size = 55-gallon plastic drums, 30 gallons is standard
   max weight = 250 lb
   max Btu content = 2 million Btu/container

   Prior to accepting the waste, SCA will inspect and sample the shipment. If results do not agree with the waste survey form, the shipment will be returned at the shipper's expense. Hence, transportation companies will not ship wastes unless they are sure the waste will be accepted.

4. Restrictions on physical/chemical characteristics of the waste that can be accepted are determined by the facilities equipment capabilities and permit specifications. Maximum levels of some restricted contaminants are as follows:

Contaminant	Maximum
Pb	3 gms/container
Hg	300 mgs/container
Na, K, Li	1 lb/container
F	1 lb/container
Cyanide	3 gms/container

5. Due to the high demand for incineration services and relatively limited processing capacities, there is usually a significant backlog of wastes to be incinerated. A two to three week backlog is typical for acceptance of solids. Maximum permitted drum storage capacity is approximately 1,000 drums. There is a four to five week backlog of liquid wastes. Liquid wastes can be stored on site in tanks. However, storage capacity is limited to six days.

6. Treatment cost ranges (excluding transportation) are:

   - Containerized soil or sludge - $1.00 to $1.15/lb
   - Bulk pumpable sludge - $0.55 to $0.65/lb
     (Btu content - 2,000 to 7,000 Btu/lb)
   - Organic liquids - $0.30 to $0.45/lb

B.4 ROLLINS ENVIRONMENTAL SERVICES

B.4.1 GENERAL

Rollins has three facilities (Bridgeport, New Jersey; Baton Rouge, Louisiana; Deer Park, Texas) equipped with rotary kilns that accept liquids, sludges and solids. However, only the Deer Park facility is permitted for PCB incineration. As is typical for rotary kiln systems, solid material is processed within the kiln component. Liquids are injected into both the rotary kiln and in the secondary combustion chamber where they provide the required thermal input for both the rotary kiln and secondary combustion chamber.

Rollins offers onsite cleanup and transportation services through a separate division of the company. The three facilities will accept a variety of wastes, and offer a range of treatment and disposal methods, including land disposal.

B.4.2 REQUIREMENTS FOR WASTE ACCEPTANCE AT ROLLINS BRIDGEPORT, NEW JERSEY FACILITY

The rotary kiln and liquid injection incinerator at the Rollins Bridgeport facility is rated at 110 million Btu/hr. This is the only Rollins facility that will accept wastes containing moderate levels of bromides and fluorides. Specific requirements for waste acceptance are listed below.

1. A detailed description of the wastes and a representative sample must be provided. See the waste survey form provided as Appendix A.

2. Approved waste material must be delivered to the facility in a specified form as listed below:

   Liquids - bulk or drums (plastic or fiber)

   Sludges - no bulk delivery, drum only (viscosity limit 120-200 centipoids)

   Solids - plastic or fiber drums only

   Drum size - 20 gallon plastic is standard, no metal
Repacking available for 55 gal metal drums

   Weight limit - 150 lbs/container

   Btu limit - 1.0 million Btu/100 lbs material

3. Restrictions on waste characteristics include:

Heavy Metals	Maximum
As	7 ppm
Cd	1 ppm
Ni, Pb, Cu, Cr	100 ppm
Zn	150 ppm
Hg	0.5 ppm

Waste material containing bromides and fluorides is accepted.

No PCBs (all PCB material, including material with less than 50 ppm PCBs, must go to Deer Park)

No Mercaptans

4. Average costs or cost ranges for incineration services only were provided. Transportation costs are not included. Actual costs are dependent on specific chemical and physical characteristics of the waste.

Soils/solids/sludges	- \$80 to \$90 for 20 gal drum
	- higher rates for certain waste types
	- 55 gallon drum with repacking can range as high as \$700 - \$800, depending on the waste
Liquids	- \$.11 to \$.90/lb (\$.30 to \$.40 typical)
Storage capacity	- maximum 1,000 drums
Ash disposal	- off site

B.4.3 REQUIREMENTS FOR ACCEPTANCE AT ROLLINS BATON ROUGE FACILITY

The Baton Rouge facility differs slightly from Bridgeport in that this facility is equipped to handle sludges in bulk. Sludges can be pumped directly from the tank truck into the kiln. The facility can also handle bulk liquids and containerized solids. Specific requirements for waste acceptance are listed below.

1. A detailed description of the waste and a representative sample must be provided.

2. The wastes must be delivered to the facility in a specified form as listed below:

Liquids	- bulk or drum
Sludges	- bulk or drum (if drum, must be solidified)
Solids/soils	- drum only (can handle stones, material fragments)
Drum requirements	- plastic or fiber only (can handle small 5 gal metal containers)
	- repacking not available at facility
	- Max drum diameter = 27 inches (30 gallons is standard)

- Maximum weight - 250 lb

- Maximum Btu content = 1.2 million Btu/container

Required Sludge Characteristics

- Viscosity less than 400 centipoids

- Maximum particle size less than 1/4 inch

- 2000-7000 Btu/lb

- Must be pumpable

- Styrenes and polymers can not be stored in onsite tanks

3. Restrictions on waste characteristics include:

Heavy Metals	Maximum
Ni, Cu, Zn	1000 ppm
Pb	25-75 ppm
Cr, Cd	5200 ppm
Hg	1-2 ppm
Be	5-10 ppm
As	2-7 ppm

No limit on chlorine content

No freon, bromides or fluorides (Bridgeport only)

Waste material must have pH >3

No PCBs (all PCB material, including material with less than 50 ppm PCBs, must go to Deer Park)

4. Cost ranges depend on waste physical/chemical characteristics, as follows:

Bulk Sludges	- \$0.50 to \$0.80/lb
Containerized Soils and sludges (elevated levels of contamination)	- \$140 to \$150/20 gal. container
Bulk Organic Liquids	- \$0.25 to \$0.30/lb

B.4.4 REQUIREMENTS FOR ACCEPTANCE AT ROLLINS DEER PARK FACILITY

The Deer Park facility is the only Rollins facility authorized to burn PCBs. The facility is equipped with shredders and can shred capacitors, steel drums and other debris prior to incineration in the rotary kiln. The facility accepts containerized solids, bulk liquids, and bulk sludges. Specific requirements for waste acceptance are listed below.

1. A detailed description of the waste and a representative sample must be provided.

2. Approved waste material must be delivered to the facility in a form specified below:

Liquid	- bulk or drum
Sludges	- bulk or drum (if drum, must be solidified)
Solids/Soils	- drum only
Drum requirements	- plastic or fiber
	- repacking available for 55 gallon metal drum
	- 10-47 gals, 22 in. maximum drum diameter
	- 2.5 million Btu/container

Required Sludge Characteristics

- Viscosity less than 150 centipoise
- must be pumpable
- nonpumpable sludges should be solidified and containerized

3. Restrictions on chemical characteristics of waste include:

Metals	Maximum
Ba, Fe, V	10,000 ppm
Pb	100 ppm
As, Hg	10 ppm
Se, Cd	10 ppm
Cu, Cr, N	500 ppm
Zu, Mg	1000 ppm
Al, Sb, Sn, Ti, Co, Mo	1000 ppm

Fluorides < 1%
Bromides, Iodides < 0.5%

B. Cost ranges listed below are for incineration services only. Transportation costs are not included.

PCB solids, soils - $0.95/lb

Other wastes - comparable to other Rollins facilities

B.5 ENVIRONMENTAL SYSTEMS COMPANY (ENSCO)

B.5.1 GENERAL

ENSCO owns and operates a large rotary kiln facility in El Dorado, Arkansas for incineration of PCBs and other hazardous waste. The rotary kiln and secondary combustion unit are rated at 160 million Btu/hr, and can handle liquids, sludges and solids, including capacitors contaminated with PCBs. Currently, a large percentage of available capacity is dedicated to handling PCB contaminated liquids, solids (including capacitors), and soils from electric utilities and private industry. The time schedule for disposal of PCB transformer oils, capacitors, and associated material is regulated by federal law and generally takes precedence over other waste types. As the backlog of PCB materials requiring disposal is reduced, more of ENSCO's capacity will be shifted to RCRA or CERCLA waste streams.

B.5.2 REQUIREMENTS FOR WASTE ACCEPTANCE AT ENSCO

Requirements for acceptance of waste at ENSCO include:

1. A full description of the wastes and a representative sample must be provided.

2. The waste must be delivered to the facility in a specified form:

   Liquids - bulk or drum (metal or plastic)

   Sludges - drums (metal or plastic)

   Soils/Solids - drums (metal or plastic)

   Capacitors - lined boxes may be used

   Drum size - 55 gal metal drums will be emptied, and depending on the waste, the material will be repacked into 10 gal plastic drums (solids or sludges) for the rotary kiln or stored in tanks for incineration (liquids)

   - Depending on drum conditions and contents, the metal drum will be shredded and fed into the kiln or decontaminated and reused

   - Max weight = 60 lb/10 gal plastic drum

3. Restrictions on chemical waste characteristics are as follows:

Elements/Heavy Metals	Average (ppm)	Maximum (ppm)
Al, Ti, Zr	25,000	none
As, Cr, Mb, Sb	5	50
B (Boron)	15,000	150,000
Ba, Sr	100	1,000
Be	10	100
Ca	80,000	none
Cd, Se	1	10
Co	250	2,500
Cu	1,000	10,000

Elements/Heavy Metals	Average (ppm)	Maximum (ppm)
Fe	5,000	50,000
Hg	0.2	2*
Mg	30,000	none
Mn	20,000	none
Ni	75	750
Pb, Sn	750	7,500*
V	2,500	25,000
Zn	2,000	20,000
Bromine, Fluorine	less than 1%	
Sulfur	less than 5%	

* Requires additional analysis.

4. Cost ranges for incineration services (transportation costs not included) at ENSCO are competitive with Rollins and SCA.

B.6 SUMMARY

In this section, the capabilities and restrictions of five commercial incineration facilities were reviewed and presented. All of these facilities have specific requirements that must be met prior to waste acceptance.

Each facility reviewed in this study requires a detailed waste description and waste sample be provided for analysis before the waste will be considered for treatment and cost estimates provided. The waste material must also be delivered to the facility in a specified form (e.g., bulk tanker, drum) and have certain physical characteristics (e.g., maximum particle size, pumpability in the case of sludges, or absence of free liquids in the case of soils and solids). It also may be noted that bulk shipments of contaminated soils are not accepted at any of the existing commercial facilities.

Likewise, there are restrictions on the nature and concentration of chemical contaminants (e.g., heavy metals) in the waste material.

Ranges of treatment costs were provided for each facility. On a per ton basis, incineration of soils will range from $1600 ($0.80/lb) to $2400 ($1.20/lb) per ton. Costs for incineration of sludges are highly dependent on Btu content, but apparently range from $1000 ($0.50/lb) to $1600 ($0.80/lb) per ton. Liquids with substantial Btu content are less costly to incinerate and range from $500 ($0.25/lb) to $800 ($0.40/lb) per ton, or $2.00 to $3.20 per gallon. These cost ranges are only estimates and actual costs may differ significantly.

ensco

WASTE MATERIAL DATA SHEET

LABORATORY MANAGER
ENSCO, INC
AMERICAN OIL ROAD
EL DORADO, AR 71730

No. 3333

A GENERAL INFORMATION

CUSTOMER NAME: ______
MAILING ADDRESS: ______
FACILITY ADDRESS: ______
If previously assigned by ENSCO, give CUSTOMER NO. ______
Give WMDS NO. ______ previously submitted for this waste stream.

CUSTOMER CONTACT

NAME ______
TITLE ______
PHONE ______
FACILITY ______
EPA I.D. NO. ______
and LOCATION NO. ______

B WASTE IDENTIFICATION

WASTE NAME ______
Is this waste normally generated at FACILITY?
Name of process generating waste ______ SIC ______
Does waste vary by Amount? Composition? Specify ______

C NFPA HAZARD CODE (x appropriate boxes)

HEALTH	0	1	2	3	4
FLAMMABILITY	0	1	2	3	4
REACTIVITY	0	1	2	3	4

Attachments ______

D GENERAL CHARACTERISTICS (at 70°F unless otherwise specified)

COLOR ______
ODOR ______
☐ NONE ☐ STRONG
☐ MILD

☐ LIQUID ____ % FREE
☐ SOLID
☐ SLUDGE
☐ POWDER

PHASES
☐ SINGLE LAYER
☐ DOUBLE LAYER
☐ MULTI-LAYER

GIVE THE FOLLOWING FOR EACH LAYER	1	2	3	4	5
% WT. of TOTAL					
DENSITY					
% SOLIDS					

E SPECIAL HANDLING INSTRUCTIONS

If special handling techniques are required, specify: ______ Attachments

Does waste contain ETIOLOGICAL AGENTS? Is it RADIOACTIVE? Is it regulated under TSCA?
If yes, specify: ______ Attachments

F RCRA INFORMATION

Is this a USEPA hazardous waste?
Please give USEPA hazardous waste codes:
______ ______ ______ ______
______ ______ ______ ______
Describe nature of reactivity if D003 waste:

G SHIPPING INFORMATION

DOT hazardous material

PROPER SHIPPING NAME ______
HAZARD CLASS ______ ID # ______ R/Q ______
ANTICIPATED VOLUME ______ GAL., ______ YDS., ______ LBS., PER:
☐ ONE TIME ☐ WK ☐ MO. ☐ YR. OTHER ______, in bulk? by rail?
Specify type and size of container: ______

H PHYSICAL CHEMICAL PROPERTIES

1 SPECIFIC GRAVITY
☐ < 0.8 ☐ 1.4-1.7
☐ 0.8-1.0 ☐ > 1.7
☐ 1.0-1.2 ☐ ____
☐ 1.2-1.4 Actual

2 VISCOSITY (centipoise)
☐ 1-100 ☐ ____
☐ 100-1,000 Actual
☐ 1,000-10,000
☐ > 10,000

3 ASH (% WT.)
☐ < 0.1
☐ 0.1-1.0
☐ 1-5
☐ 5-20 ☐ ____
☐ > 20 Actual

4 TOTAL SUSPENDED SOLIDS (% WT.)
☐ < 0.5 ☐ > 20
☐ 0.5-2.0 ☐ ____
☐ 2-5 Actual
☐ 5-20

5 pH
☐ < 2 ☐ > 12.5
☐ 2-6 ☐ ____
☐ 6-8 Actual
☐ 8-10 ☐ ____
☐ 10-12.5 Continuous

6 BTU's 1000/lbs.
☐ < 1 ☐ 12-16
☐ 1-4 ☐ > 16
☐ 4-8 ☐ ____
☐ 8-12 Actual

7 FLASH POINT (closed cup)
☐ < 100°F ☐ > 200°F
☐ 100°-140°F ☐ ____
☐ 140°-200°F Actual

8 SULFUR (% WT.)
☐ < 0.5 ☐ > 5
☐ 0.5-2.0 ☐ ____
☐ 2-5 Actual

9 HALOGENS (% WT.)

	< 1	1-10	10-50	> 50	ACTUAL
☐ BROMINE	☐	☐	☐	☐	☐ ____
☐ CHLORINE	☐	☐	☐	☐	☐ ____
☐ FLUORINE	☐	☐	☐	☐	☐ ____

10 CONSTITUENTS

	TOTAL (% WT.)	EP EXTRACT (PPM)		TOTAL (% WT.)	EP EXTRACT (PPM)		TOTAL (% WT.)	EP EXTRACT (PPM)		TOTAL (% WT.)	EP EXTRACT (PPM)
Ag			Pb			P			PCB		
As			Se			Sb			CYANIDES		
Ba			Cu			Si			SULFIDES		
Cd			K				organic silicon only		DIOXIN		
Cr			Na			Sn			OTHERS (SPECIFY)		
Hg			Mn			Zn					

I

Does waste contain SOLVENTS? If yes, specify ______
LIST EACH SOLVENT AND APPROXIMATE PERCENTAGE ______ Attachments

I HEREBY CERTIFY THAT ALL INFORMATION SUBMITTED IN THIS AND ALL ATTACHED DOCUMENTS IS COMPLETE AND ACCURATE AND THAT ALL KNOWN OR SUSPECTED HAZARDS HAVE BEEN DISCLOSED

AUTHORIZED SIGNATURE ______ TITLE ______ DATE ______

ENSCO USE ONLY

PC
DATE RECEIVED

2

LAB COPY

FORM NO. LR-85115 (10/84)

Waste Management, Inc.

GENERATOR'S WASTE MATERIAL PROFILE SHEET

WASTE PROFILE SHEET CODE

TSDR G06022

A. GENERAL INFORMATION

GENERATOR NAME ______ TRANSPORTER ______

FACILITY ADDRESS ______ TRANSPORTER PHONE ______

______ GENERATOR USEPA I D ______

______ GENERATOR STATE I D ______

TECHNICAL CONTACT ______ TITLE ______ PHONE ______

NAME OF WASTE ______

PROCESS GENERATING WASTE ______

B. PHYSICAL CHARACTERISTICS OF WASTE

COLOR

ODOR ☐ NONE ☐ MILD ☐ STRONG

DESCRIBE ______

PHYSICAL STATE @ 70°F ☐ SOLID ☐ SEMI SOLID ☐ LIQUID ☐ POWDER

LAYERS ☐ MULTILAYERED ☐ BI-LAYERED ☐ SINGLE PHASED

FREE LIQUIDS ☐ YES ☐ NO

VOLUME ______%

pH ☐ < 2 ☐ 2-4 ☐ 4.1-6.9 ☐ 7 ☐ 7.1-10 ☐ 10.1-12.5 ☐ > 12.5 ☐ EXACT ______ ☐ N/A

SPECIFIC GRAVITY ☐ < .8 ☐ .8-1.0 ☐ 1.1-1.2 ☐ EXACT ______ ☐ 1.3-1.4 ☐ 1.5-1.7 ☐ > 1.7

FLASH POINT ☐ < 70°F ☐ 70°F - 100°F ☐ 101°F - 139°F ☐ 140°F - 200°F ☐ > 200°F ☐ NO FLASH ☐ EXACT ______ ☐ CLOSED CUP ☐ OPEN CUP

C. CHEMICAL COMPOSITION (TOTALS MUST ADD TO 100%)

______	______%
______	______%
______	______%
______	______%
______	______%
______	______%
______	______%
______	______%
______	______%
______	______%

D. METALS ☐ TOTAL (PPM) ☐ EPA EXTRACTION PROCEDURE (mg/L)

ARSENIC (As)	______	SELENIUM (Se)	______
BARIUM (Ba)	______	SILVER (Ag)	______
CADMIUM (Cd)	______	COPPER (Cu)	______
CHROMIUM (Cr)	______	NICKEL (Ni)	______
MERCURY (Hg)	______	ZINC (Zn)	______
LEAD (Pb)	______	THALLIUM (Tl)	______
CHROMIUM HEX (Cr + 6)	______	______	______

E. OTHER COMPONENTS - TOTAL (PPM)

CYANIDES ______ PCB'S ______

SULFIDES ______ PHENOLICS ______

F. SHIPPING INFORMATION

D O T HAZARDOUS MATERIAL? ☐ YES ☐ NO

PROPER SHIPPING NAME ______

HAZARD CLASS ______ I D NO ______ R Q ______

METHOD OF SHIPMENT. ☐ BULK LIQUID ☐ BULK SOLID ☐ DRUM (TYPE/SIZE) ______

ANTICIPATED VOLUME ______ GALS ______ CUBIC YARDS

______ OTHER ______

PER. ☐ ONE TIME ☐ WEEK ☐ MONTH ☐ QUARTER ☐ YEAR ☐ ______

G. HAZARDOUS CHARACTERISTICS

REACTIVITY ☐ NONE ☐ PYROPHORIC ☐ SHOCK SENSITIVE ☐ EXPLOSIVE ☐ WATER REACTIVE ☐ OTHER ______

OTHER HAZARDOUS CHARACTERISTICS

☐ NONE ☐ RADIOACTIVE ☐ ETIOLOGICAL ☐ PESTICIDE MANUFACTURING WASTE ☐ OTHER ______

USEPA HAZARDOUS WASTE? ☐ YES ☐ NO

USEPA HAZARDOUS CODE(S) ______ ______ ______ ______

STATE HAZARDOUS WASTE? ☐ YES ☐ NO

STATE CODE(S) ______

H. SPECIAL HANDLING INFORMATION ______

______

______ ☐ ADDITIONAL PAGE(S) ATTACHED

I HEREBY CERTIFY THAT ALL INFORMATION SUBMITTED IN THIS AND ALL ATTACHED DOCUMENTS IS COMPLETE AND ACCURATE AND THAT ALL KNOWN OR SUSPECTED HAZARDS HAVE BEEN DISCLOSED

AUTHORIZED SIGNATURE ______ TITLE ______ DATE ______

FORM WMI 6000-8/83

The following information is required for all waste to be considered for transportation, storage, treatment or disposal. It is used to determine that the waste may be transported, stored, treated or disposed of in a legal, safe and environmentally sound manner. This information will be maintained in strict confidence. Answers must be made to all questions and must be completed in ink. Responses of "NONE" or "NOT APPLICABLE" should be made if appropriate. Most items required are self-explanatory. Other items need definition or instruction as follows.

PART A GENERAL INFORMATION

TRANSPORTER - If you transport the waste, indicate "SELF". Otherwise, the transporting company's name and phone number should be filled in.
USEPA ID - For the facility generating the waste. **STATE ID** - If applicable.
TECHNICAL CONTACT - A person who could give additional information about the waste if needed.
WASTE NAME - A name which will be generally descriptive of its major chemical composition.
PROCESS GENERATING WASTE - Specific process or source which generates the waste.

PART B - PHYSICAL CHARACTERISTICS OF WASTE

ODOR - If present, describe as well as possible (e.g. solvent, acrid, sweet, etc.)
PHYSICAL STATE - Check as many as apply.
FREE LIQUID - If any as packaged for shipment, estimate percent of volume.
pH - Indicate for liquid or liquid portions of waste. Check as many boxes as necessary to cover the expected range of the waste. For solid or organic liquid wastes, indicate "NOT APPLICABLE" or the pH of a 10% aqueous solution of the waste if available.
SPECIFIC GRAVITY - The weight of the waste in terms of the weight of an equal volume of water.
FLASH POINT - A value attained using the appropriate testing method as set forth in 40 CFR 261.

PART C - CHEMICAL COMPOSITION

List all organic and/or inorganic components of the waste using <u>specific chemical names</u>. If trade names are used, attach Material Safety Data sheets, or other documents which adequately describe the composition of the waste. For each component, indicate expected percent or range in which the component is present. In case of extreme pH (less than 2 or greater than 12.5), indicate specific acid or caustic species. Any hazardous components present in "trace" amounts and not specifically mentioned in PARTs D and/or E should be included even if specific concentrations are not known. Any components listed in PARTs D and/or E which exceed 10,000 PPM (1%) must be included. Components must total to 100% including water, earth, or other components. If a unit of measure other than percent must be used, indicate that unit.

PART D - METALS

Use the appropriate box to indicate if the metals concentrations listed in this section are represented as the total metals or as leachable metals as defined by the Extraction Procedure, 40 CFR 261, Appendix II.

PART E - OTHER COMPONENTS

If data for this PART (or any other PART) were obtained from a laboratory analysis of the waste, please attach the analytical method used.

PART F - SHIPPING INFORMATION

DOT HAZARDOUS MATERIAL - Is the waste a USDOT hazardous material as defined in 49 CFR 172.101? If YES, enter the **SHIPPING NAME, HAZARD CLASS, DOT ID NUMBER,** and **R.Q.** (Reportable Quantity) as defined in 40 CFR 302.

METHOD OF SHIPMENT - If drums are specified, they must be as specified in 49 CFR 173, 178 or 179.

ANTICIPATED VOLUME - Gallons and cubic yards are emphasized as units of volume measurement. If another unit of measure must be used, indicate that unit.
FREQUENCY - The period during which the above **ANTICIPATED VOLUME** will be generated.

PART G - HAZARDOUS CHARACTERISTICS

REACTIVITY - **PYROPHORIC**, will ignite spontaneously in air at below 130°F (54.4°C). **SHOCK SENSITIVE**, normally unstable and readily undergoes violent change without detonating. **EXPLOSIVE**; capable of detonation or explosive reaction if subjected to a strong initiating source or if heated under confinement; or a forbidden explosive as defined in 49 CFR 173.53, or a Class B explosive as defined in 49 CFR 173.88. **WATER REACTIVE**; reacts violently with water, or forms potentially explosive mixtures with water, or when mixed with water forms toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment. **OTHER**; indications of other reactive characteristics must be included (e.g. autopolymerization, peroxide-forming, etc.).
OTHER HAZARDOUS CHARACTERISTICS - Complete if the waste contains or has ever contained any component which is considered to be any of the following. **RADIOACTIVE**; emits alpha, beta or gamma radiation above normal background levels. **ETIOLOGICAL**; a viable micro-organism or its toxin which causes or may cause human disease. **PESTICIDE MANUFACTURING WASTE**; the waste was produced from a pesticide or herbicide manufacturing process; or, the waste is or contains waste pesticide or herbicide. Include as a specific item in PART C. **OTHER**, list any known hazardous characteristics and elaborate in PART H (e.g. carcinogenic, teratogenic, mutagenic).
USEPA HAZARDOUS WASTE - As defined according to RCRA in 40 CFR 261. If yes, enter applicable **USEPA CODES.**
STATE HAZARDOUS MATERIAL - Indicate whether the waste is regulated as a hazardous waste in your state. If yes, then complete the **STATE CODES.**

PART H - SPECIAL HANDLING INFORMATION

Describe those hazards which you know or reasonably believe are or may be associated with short or prolonged human exposure to this waste. Attach relevant documents as a part of your response if appropriate. If documents are attached, identify those attachments (e.g. toxicology reports, TSCA notifications of significant adverse reactions to health, TSCA notifications of substantial risk, or Material Safety Data sheets). Failure to make an entry in this PART is considered as a representation that you neither know nor believe that there are any adverse human health effects associated with exposure to this waste.

Also include in this PART any information that will aid in the management of the waste (i.e. transportation, storage, treatment, disposal).

SIGNATURE

The generator of the waste or the generator's agent must sign and date the Generator's Waste Material Profile Sheet.

Collect, package and label for shipment and analysis one liter (about one quart) representative sample of the waste to be considered. This sample must be collected in accordance with "Test Methods for the Evaluation of Solid Waste, Physical / Chemical Methods", SW846, USEPA, Office of Solid Waste, Washington, DC, 20460. A suitable sample container for most waste is a wide mouth glass bottle with a plastic cap containing a non-reactive liner. Waste containing strong caustics or fluorides require a plastic container. Fill to approximately 90% of capacity to allow for expansion during transportation. An identification label must be attached to the sample and contain: Generator Name, Waste Name (from PART A), Generator's Waste Profile Sheet Code number, and Sampling Date.

If the waste is a hazardous material, the sample must be packaged and shipped in accordance with USDOT regulations for the waste material (49 CFR 171.2 May 22, 1980). If shipping via United Parcel Service, consult its "Guide for Shipping Hazardous Materials Via UPS". Any waste sample not shipped in conformance with the specified instructions may be disposed of immediately.

DISTRIBUTION OF COPIES - Retain the LAST copy for your records. Send the NEXT LAST copy to the address listed to the below-left. Include all remaining copies of this Generator's Waste Material Profile Sheet and attachments within the sample shipping package, ensuring that if the sample leaks, the paperwork will remain intact. Send this package to the address at the below-right.

______________________	______________________
______________________	______________________
______________________	______________________
(Sales Office)	(Analytical Lab)

Waste Management, Inc.

GENERATOR'S WASTE MATERIAL PROFILE SHEET: INCINERATION TREATMENT ADDENDUM

WASTE PROFILE SHEET CODE

TSDR ____

A. GENERAL INFORMATION

GENERAL NAME ____

NAME OF WASTE ____

PROCESS GENERATING WASTE ____

B. CHEMICAL CHARACTERISTICS OF WASTE

1 Heat Value (BTU/lb) ____ 2 Percent Ash ____ % 3 Percent Total Halogens ____ %

4 Percent Sulfur ____ % 5 Percent Nitrogen ____ % 6 Percent Water ____ %

C. PHYSICAL CHARACTERISTICS OF WASTE

1 Viscosity (cps) ____ 2 Percent Total Solids ____ % 3 Percent Susp Solids ____ %

4 Percent Dissolved Solids ____ % 5 Vapor Pressure 50 F (psia) ____ %

D SPECIAL LISTED CONSTITUENTS: 40 CFR 261 APPENDIX VIII

E. ADDITIONAL WASTE INFORMATION

1 Pumpable? @ 50°F ☐ Yes ☐ No 1a Method ____

1b Can the waste be heated to improve flow? ☐ Yes ☐ No

2 Soluble in Water? ☐ Yes ☐ No

3 Particle Size Will solid portion of waste pass through a ⅛" screen? ☐ Yes ☐ No

4 Other Information: ____

F. I hereby certify that all information submitted in this and all attached documents is complete and accurate, and that all known or suspected hazards have been disclosed

AUTHORIZED SIGNATURE **TITLE** **DATE**

ATTACH TO SAMPLE SHIPPING PACKAGE

SCA CHEMICAL SERVICES
11700 S. Stony Island Avenue
Chicago, Illinois 60617
(312) 646-5700

SCA CHEMICAL SERVICES

CHICAGO ANALYTICAL REQUIREMENTS

Disposal approval for incineration will be based on the information on the completed Generator's Waste Material Profile Sheet and Incineration Treatment Addendum, accompanied by a representative sample of the waste stream. Your sample will be analyzed for the following parameters for a fee of $200.00.

Analysis

Heat of Combustion
% Chlorine
% Sulfur
% H_2O
Specific Gravity
Total Ash
Organics
pH
Flash Point

Total Metals
Viscosity
PCB's
Pb (Lead)
Hg (Mercury)
Na (Sodium)
K (Potassium)

When total halogens are greater than 20%, organic compounds must be identified. If heavy metals are suspected to be greater than 500 ppm in total, with the exception of Mercury at 50 ppm, analysis must be run.

SCA CHEMICAL SERVICES
11700 S. Stony Island Avenue
Chicago, Illinois 60617
(312) 646-5700

SCA CHEMICAL SERVICES

SCA CHICAGO INCINERATOR

Phone: 1-800-722-9999
1-312-646-5700
1-312-646-2138 (FAX)

General Contact: Debbie Mullen
Customer Service Manager

Other Personnel:

Bruce Marti
Customer Service Representative

Sharon Pilachowski
Customer Service Representative

Linda Witham
Scheduling Coordinator

Jackie Rios
DCS Coordinator

For information on pricing and/or acceptance criteria contact:

Debbie Mullen
Bruce Marti

For information on status of waste stream contact:

Bruce Marti
Sharon Pilachowski

For information on contract related matters contact:

Sharon Pilachowski

For all scheduling related matters contact:

Linda Witham
Debbie Mullen

WASTE DATA SHEET

Rollins® Environmental Services

CUSTOMER INFORMATION:

Company Name	RES Stream No.
Plant Address	Mailing Address
State	State Zip
Company Contact, Technical	Phone
Company Contact, Business	Phone
USEPA Generator I.D. No.	State Generator I.D. No.

GENERAL WASTE DESCRIPTION:

Type of Process Generating Waste: ____________________

Quantity Generated (per mo.)	Frequency (of removal)

TRANSPORTATION INFORMATION:

Hazardous Material:

Hazardous Substances:	Concentration	Hazardous Substances	Concentration

Hazardous Characteristics: ____________________

Transporter: ____________________ Placarding ____________________

TRANSPORTATION EQUIPMENT:

Tank Truck ☐ Vacuum Truck ☐ Flatbed ☐ Dump Truck ☐

Bin ☐ Barge ☐ Tank Car ☐ Other ☐ ____________

Method of Collection:

Fiberpaks ☐ Drums ☐ Tanks ☐ Sumps ☐ Other ☐ ____________

Other available transportation information: ____________________

RES-80-419 REV. 9/85

DETAILED WASTE DESCRIPTION AND REGULATORY COMPLIANCE:

RCRA Characterization Codes ________ ________ ________ ________

Reason for above characterization: ________________________________

____

State Characterization Codes ________ ________ ________ ________

OSHA: Contain listed compounds? ________ EPA : PCB conc > 50 ppm? ________

NRC: Radioactive? ________ PHS: Infectious Wastes? ________

FIFRA: Does this waste contain a pesticide for which the EPA has issued specific disposal requirements? ________

CHEMICAL COMPOSITION:

Compound Name	CAS No.	Norm. Conc. Range % W	Chemical Formula

LABORATORY ANALYSIS		PHYSICAL PROPERTIES	
Metals	CN ______ Mg/L	PHYSICAL STATE @ $25^{o}C$	BTU ______ /lb
Pb ______ Mg/L	TOC ______ Mg/L	GAS ___ LIQUID ___	ASH ______ %
Hg ______ Mg/L	COD ______ Mg/L	SOLID ___ SLUDGE ___	VAPOR PRESS
Cd ______ Mg/L	BOD ______ Mg/L	SLURRY ___ PASTE ___	@ ______
Be ______ Mg/L	SS ______ Mg/L	GRANULAR ___ CRYSTAL ___	SPEC. GRAVITY ______
As ______ Mg/L	TDS ______ Mg/L	POLYMERIC ___ AMORPHOUS ___	
Na/K ______ Mg/L	Br ______ % Wt		MELTING PT ______
Cr ______ Mg/L	Cl ______ % Wt	SINGLE PHASE ______	BOILING PT ______
Ni ______ Mg/L	F ______ % Wt	MULTI PHASE ______	pH ______
Zn ______ Mg/L	I ______ % Wt	OIL/WATER ______	FLASH PT ______
Cu ______ Mg/L	S ______ % Wt	VISCOSITY ______	

Is the waste reactive with water? ________ with air? ________

Is a representative sample provided? ________

Give any other additional information on the hazards of the waste: ________

____

I hereby certify that the above information is complete and accurate.

Customer Signature ________ Title ________ Date ________