THERMAL TREATMENT TECHNOLOGY STUDY AND DATA BASE FOR DEPARTMENT OF ENERGY MIXED WASTE

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ABSTRACT

The Department of Energy (DOE) has a wide variety of waste streams that must be treated to meet various regulations before final disposal. One category of technologies for treating many of these waste streams is thermal treatment. A study of known thermal treatment technologies was conducted to aid DOE in the development of strategies to meet its waste management needs. The study was specifically addressed to mixed waste, but it is also applicable to hazardous and radioactive wastes. The data collected in the study, along with other waste management data, are being included in a comprehensive data base that DOE is developing.

INTRODUCTION

As evidenced by its Environmental Restoration and Waste Management Five-Year Plan, the Department of Energy (DOE) is committing to a long-range waste management program. This Five-Year Plan states that the program's fundamental goal is "to ensure that risks to human health and safety and to the environment posed by the Department's past, present, and future operations are either eliminated or reduced to prescribed safety levels."

Thermal treatment of wastes will play a significant role in achieving the Five-Year Plan goals. Thermal destruction of wastes remains the most expensive of "terminal" treatment technologies. However, use of these technologies continues to grow because properly designed thermal systems are capable of the highest overall degree of destruction and control for the broadest range of hazardous waste streams. Thermal treatment is the preferred, or in some cases mandated, treatment method to meet Environmental Protection Agency (EPA) land disposal restriction (LDR) standards before disposal for a large fraction of DOE's wastes.

Most DOE sites are now using commercial facilities to treat and dispose of transportable hazardous wastes and will likely continue this practice. DOE's practice is to treat and dispose of radioactive wastes on DOE-owned property whenever practicable to reduce the likelihood of human and environmental exposure and to reduce potential future liability.

A category of waste that represents a sizable portion of the total DOE waste picture and that also presents significant complications in management is waste that contains both hazardous and radioactive components. This category of wastes, called mixed waste, is present at most of the Department's sites. Mixed waste must be managed to meet both Resource Conservation and Recovery Act (RCRA) treatment standards for its hazardous components and DOE's performance objectives for its radioactive constituents. The presence of radioactive constituents in this waste category implies that it be managed, like radioactive-only wastes, on DOE-owned property.

DOE's existing or currently planned capacity for thermal treatment of waste, including mixed waste, is much less than its projected needs. Development of appropriate and adequate thermal treatment capability will require a significant investment by DOE over the next 30 years. The decisions regarding the types, locations, and sizes of thermal treatment systems must be made in the very near future. To optimize the expenditures for these systems, it is necessary that DOE have a basic understanding of existing and potential thermal treatment technologies.

A study of known thermal treatment technologies was requested by the DOE Office of Technology Development (OTD). The objective was to aid in evaluation of Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) proposals that employ thermal treatment. The results of this study will also be useful to other DOE Environmental Restoration and Waste Management (EM) offices in assessing priorities for competing treatment facility budget requests and for overall strategy development, and to waste management managers in the field in selecting candidate technologies for their waste treatment needs. The study was funded through the Hazardous Waste Remedial

* Hazardous Waste Remedial Actions Program managed by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under contract DE-AC05-84OR21400.

Actions Program (HAZWRAP) and had the following objectives:

- to determine DOE's generic waste management needs to which thermal treatment could possibly be applied,
- to identify existing and emerging thermal treatment technologies,
- to gather consistent technical and cost parameters about the identified technologies,
- to assess the applicability of each technology to each need and perform initial cost-effectiveness comparisons,
- to submit the treatment technology data for entry into the Waste Management Information System (WMIS) being developed on HAZWRAP's Waste Information Network (WIN) system, and
- to prepare a report on the evaluation of thermal treatment applications to DOE waste needs.

The study focused on thermal technologies for processing mixed wastes because this category constitutes a sizeable portion of DOE's wastes; mixed wastes present a complex management problem; recent DOE-wide data were available on this waste category; and technologies assessed against mixed wastes would be applicable to hazardous-only or radioactive-only wastes.

TECHNOLOGY DATA BASE

DOE is in the process of updating information on the various types of wastes being generated or stored in the DOE complex; the currently available treatment, storage, and disposal (T/S/D) capability within the complex; and the T/S/D technologies, existing or emerging, that could be employed to resolve the various waste problems that exist or are anticipated. It is essential that the vast quantities of data within this scope be available for ready access by DOE and contractor program managers at all levels so that informed decisions can be made regarding waste management strategies.

All DOE waste management information is being consolidated into a single data base with universal availability. The vehicle selected for development of an integrated, multifaceted waste management data base is the WIN system, managed by the DOE HAZWRAP Program out of the Oak Ridge Operations Office. Development and population of this data base, called WMIS, is currently underway.

The stated mission of WMIS is to:

- profile DOE's waste streams,
- track ongoing DOE waste generation and processing,
- define the capabilities and capacities of DOE's T/S/D units,
- identify T/S/D technologies for management of DOE's wastes, and
- serve as a central resource to support all of DOE's waste management functions.

The initial waste stream data assembled on WMIS were the mixed waste data used as the base data for the thermal study. The data on thermal technologies collected for the study represent the first formal attempt to populate the T/S/D technology portion of the data base. Access to the WMIS data base is currently limited to DOE and DOE contractor employees who are registered WIN system users. However, the thermal technology data are available in a separate report published by HAZWRAP (1).

STUDY METHODOLOGY

A methodology for performing the thermal study was selected that would provide a comprehensive evaluation of technologies and yield a useful final product while minimizing the amount of data required to be collected, derived, and evaluated. A key element of this methodology was the use of simplifying assumptions that reduced the number of study variables to a manageable level and provided performance and cost data that are directly comparable. The major assumptions are listed below:

- similar technologies were grouped under a single methodology title with a description of the most representative application, and variations of the basic technology were pointed out in the technology description;
- the number of waste streams to be considered was reduced to a set of seven standardized, representative waste streams;
- cost and performance data for each technology were based on a standardized thermal capacity;
- all technologies requiring off-gas treatment were assumed to employ a standardized off-gas treatment system;
- technology performance evaluations did not include the performance of off-gas treatment systems; and
- operating staff requirements were standardized for all technologies to represent a staffing philosophy consistent with typical DOE operating facilities, including regulatory requirements and safety considerations.

A brief description of the methodology employed to accomplish the technology evaluations is outlined below.

Waste Streams

The number of DOE waste streams is too large to allow assessment of all of them against each technology. The study focused on mixed waste, for which sufficient up-to-date characterization data existed. From the data available, seven common, standardized waste streams were defined to represent a majority of DOE wastes considered candidates for thermal treatment.

Technology Survey

Technologies were identified and technology data were collected from a variety of sources, consisting primarily of published literature; telephone communications with vendors; developers, or experts on a technology; and first-hand experience. The scope of this project did not allow for a complete and thorough evaluation of all technologies, which can only be attained by site visits to vendor facilities and operating plants.

Technology/Waste Stream Evaluations

The capabilities of each technology were assessed against the seven standard waste streams to determine which waste streams were reasonably treatable by that technology. Technology by-products were identified and characterized.

Performance and Cost Data

Baseline performance and cost data for each technology were developed based on the most compatible waste stream identified for the technology. Technology waste treatment capacities were standardized to a 10-MMBtu/h facility to allow a common basis for comparison. Performance data were calculated for other applicable waste streams, and cost data for these waste streams were then estimated from the baseline cost data by a simple linear extrapolation based on comparative throughputs.

Evaluation Criteria

A set of evaluation criteria was chosen that was believed to be representative of DOE needs. The five evaluation criteria chosen, given in assumed order of importance, are listed below:

1. LDR compliance
2. operability
3. applicability
4. radioactive contamination control
5. cost

Ranking guidelines were developed to quantify how well each technology met the requirements of each criteria, with a ranking level of high, medium, or low to be assigned. Numerical values were assigned to these ranking levels and weighting factors, based on the assumed order of importance, were assigned to each criteria.

Technology/Criteria Evaluations

Each technology was evaluated against the criteria listed above to determine its relative effectiveness in treating, to DOE's needs, each of the standard DOE waste streams considered applicable to the technology. A numerical score was calculated for each technology and waste stream combination.

Technology Comparisons

The numerical scores calculated above for each technology/waste stream combination serve as a basis for comparison of the technologies. Technologies with the highest scores for each waste stream can be viewed as the best candidates to meet DOE's particular needs in treating that waste stream. Combining the scores for all applicable waste streams for each technology gives an indication of the technology's versatility relative to the other technologies.

It was not intended that an organization dealing with a particular problem waste be able to pick the highest rated technology as the best solution for its circumstances. For any particular application, many variables will influence the ultimate solution. The intention of this study was to identify technologies with high potential for various specific waste treatment applications, allowing enlightened selection of treatment options for further evaluation.

STANDARDIZED WASTE STREAM DEFINITION

The task of defining DOE's waste treatment needs is complicated by the large number of sites, each with multiple site-specific waste streams, and the lack of a comprehensive waste data base. There is currently no single source of waste information from which complete and accurate data can be drawn for determining all of DOE's waste treatment needs. The objective of this study was focused to address the treatment needs for mixed waste, a waste category that is high in volume and visibility, presents significant complications in treatment and handling, and for which current data are available.

Source of Waste Data

The most current and comprehensive set of DOE waste data available was used as the basis for defining DOE's mixed waste treatment needs. These data are contained in the "Department of Energy National Report on Prohibited Wastes and Treatment Options," hereafter referred to as the National Report, that was released on January 16, 1990 (2). The report was generated to satisfy a requirement of the Rocky Flats Plant Federal Facilities Compliance Agreement (FFCA) between the DOE, the Environmental

Protection Agency (EPA), and the Colorado Department of Health under RCRA and deals with mixed wastes (subject to LDRs) that are generated and stored throughout the DOE system.

Standard Waste Categories

The National Report included 221 reported DOE mixed waste streams. Any attempt to address the applicability of even one thermal treatment technology to this number of waste streams would be difficult, and to do so for all technologies would be futile. Because thermal process data are highly dependent on waste characteristics, seven common, standardized waste types were defined to represent the wide variety of DOE waste streams considered candidates for thermal treatment. These waste types are identified in the following table.

Standard Waste Stream	Waste Description
A	Aqueous organic liquids - wastewaters
B	Organic liquids - low heating value (chlorinated)
C	Organic liquids - high heating value
D	Aqueous sludges
E	Combustible solids
F	Inert solids
G	Corrosives - liquid high-level waste

THERMAL TREATMENT TECHNOLOGIES

A variety of sources were consulted to identify and characterize thermal treatment technologies currently available or emerging that could conceivably be used to treat DOE's mixed wastes. These sources included EPA publications, literature searches on a variety of computerized data bases, and numerous personal telephone contacts with technology developers, equipment vendors, and facility operators.

A small number of technologies were identified while compiling the listing of known technologies that were not included in the study. In general, they were excluded because of lack of adequate information or lack of demonstrated feasibility.

A total of 35 distinct technologies were identified and included in the study. Of the 35 technologies, five are industrial processes (e.g., cement kilns) in which waste could be cofired with fuel, and so would be limited to hazardous, nonradioactive wastes to prevent contamination of the process and its product. Five other technologies are only suitable for sanitary (municipal solid or industrial) waste processing, but were included to cover the spectrum of thermal technologies. Sufficient data were available on 23 of the remaining 25 technologies to conduct a comparative evaluation.

The type of data collected for assessment of each technology included:

- technology description and theory of operation;
- development status;
- process support requirements for energy, utilities, and raw materials;
- by-product information, including treatment requirements;
- safety considerations;
- environmental considerations;
- cost data, including capital and operating costs;
- number of facilities applying the technology; and
- list of references and contacts.

The study addressed thermal technologies in the broad general groupings of "operational" and "emerging." Operational technologies may be conventional in that they are a variation of historical incineration configurations employing open flame combustion or unique in their approach to thermal destruction, but they are all commercially available and in general use. Emerging technologies were identified by their level of development and size (e.g., bench scale, pilot scale or demonstration scale).

Operational Technologies

Operational thermal technologies for the destruction of hazardous wastes were divided into two categories: 1) those designed specifically to treat wastes and 2) industrial thermal processes that can also be used to process waste by cofiring with fuel.

Conventional operational thermal treatment technologies in this study are defined as those technologies employing variations of open flame combustion of wastes for thermal destruction. The most recent EPA data on hazardous waste incinerators indicate that approximately 175 conventional incinerators burn hazardous wastes in the United States, processing 2 to 3 million metric tons of waste annually (3). Although numerous variations in configuration and capability within incinerator types exist, conventional incinerators can generally be subdivided into the following types:

- Slagging kiln (SKI),
- Fluidized bed (FBI),
- Multiple hearth (MHI),
- Rotary kiln (RKI),
- Liquid injection (LII), and

- Controlled air (CAI).

Unique operational thermal treatment technologies in this study are defined as those technologies employing other approaches to waste destruction than historical open flame combustion. Most of these technologies are new, and their operational application is limited compared with the conventional technologies. Many are targeted for a specific category of waste for which their performance exceeds the conventional technologies. Others, such as the glass furnace, are broad in their application to waste types. Operational thermal treatment technologies that may be considered unique include:

- Cyclone incinerator (CYI),
- Infrared furnace (IRF),
- Conventional temperature pyrolysis (CTP),
- Wet air oxidation (WAO),
- Calciner (CAL), and
- Glass furnace vitrifier (GFV).

The second general category of operational thermal devices currently used to destroy hazardous wastes is industrial thermal processes. In these processes, waste is cofired with fuel to provide part or all of the heat required to operate the process, thus saving fuel costs. Recent EPA data indicate 1.8 to 3.8 million metric tons of waste, mostly liquids, are processed annually in 200 such facilities in the United States (3). Typically, the wastes processed in these facilities are limited to high heating value, low metal-and-chlorine-content wastes because the process either produces a product that may be sensitive to impurities or the facilities do not have adequate air pollution control equipment.

The types of processes identified in the study that are currently available and are being or could be employed to thermally destroy hazardous wastes include:

- Industrial boilers,
- Cement kilns,
- Lime kilns,
- Aggregate kilns, and
- Blast furnaces.

It is not likely that these processes will be available for treating radioactively contaminated wastes, which would negate their ability to produce a marketable product and dramatically increase operating, maintenance, and closure costs. However, the magnitude of existing thermal capacity represented by this category of thermal devices justified their inclusion in the study for their potential for strictly hazardous waste treatment.

<u>Emerging Technologies</u>

Emerging technologies, by definition, are processes that provide an innovative or specialized approach to problems that have not been solved effectively by existing technologies. These technologies, therefore, may be more restricted by waste characteristics, technological complexity, or economic feasibility than the established systems. On the other hand, they may prove capable of achieving high destruction and removal efficiency (DRE) levels, an accomplishment not possible for some established technologies, or they may provide a radical improvement for a specific application. In general, these technologies have not been tested extensively on a full-scale basis, nor have they been independently evaluated by an entity such as EPA.

The technologies in the emerging category that were included in the study include:

- Low temperature thermal separator (LTS),
- Molten salt furnace (MSF),
- Plasma centrifugal reactor (PCR),
- Plasma arc furnace (PAF),
- Plasma pyrolysis reactor (PPR),
- High temperature fluid wall reactor (FWR),
- Supercritical fluid oxidation (SFO),
- Microwave discharge (MWD),
- In situ vitrification (ISV),
- Microwave melter (MWM), and
- Liquid fed ceramic melter (LCM).

<u>Technology Versatility</u>

A sixth and important criterion that is not directly included in the evaluation is technology versatility. A technology that can operate on a wide variety of waste streams, such as all six of the non-HLW standard waste streams, presents some significant advantages to DOE, including decreased capital cost, localized risk, streamlined permitting (over permitting several, less versatile technologies), and quicker implementation. The disadvantages, however, can include reduced treatment effectiveness on some waste streams.

By summing the rankings of a technology for all applicable waste streams, both versatility and effectiveness are considered. The potential weakness in this approach is that all the waste streams are assumed to be equally important. In some cases, it may be most important for a technology to be capable of processing one or two of the standard waste streams used in this study because of relative volumes or other factors. When this is the case, weighting factors could be applied to the overall index to skew it in favor of those technologies that rate highly on the most important waste streams. No attempt was made to weight the relative importance of the standard waste streams used in this study because of the general nature of the scope of the study (DOE mixed waste).

Figure 1 presents a summary of the results of the thermal treatment study. The scores for each technology for all applicable waste streams are indicated by the heights of the corresponding patterned blocks. For each technology, the sum of the scores from each of the waste streams treatable in the technology add up to the overall score, which is equivalent to relative technology versatility.

CONCLUSIONS

The results of the technology evaluations and comparisons are heavily dependent on the waste stream characteristics and the simplifying assumptions employed. Conclusions as to the superiority of one technology over others are not valid based on this study alone, although some general conclusions can be drawn:

- None of the evaluated technologies ranked high on all of the DOE standard waste stream types. While some technologies were applicable to all six of the low-level mixed waste streams, these systems would not perform effectively on some of the streams.
- The highest-rated technologies overall on DOE mixed wastes were fluidized bed incinerators, rotary kiln incinerators, plasma arc furnaces, and glass furnaces. The versatility of these technologies was the primary reason for their high ratings.
- The most effective facility (considering cost and benefit) to treat the six non-HLW DOE waste types would involve at least two of the evaluated technologies based on this study. A facility employing a controlled air incinerator and a plasma arc furnace, for example, would be highly effective on all six standard non-HLW mixed waste streams.

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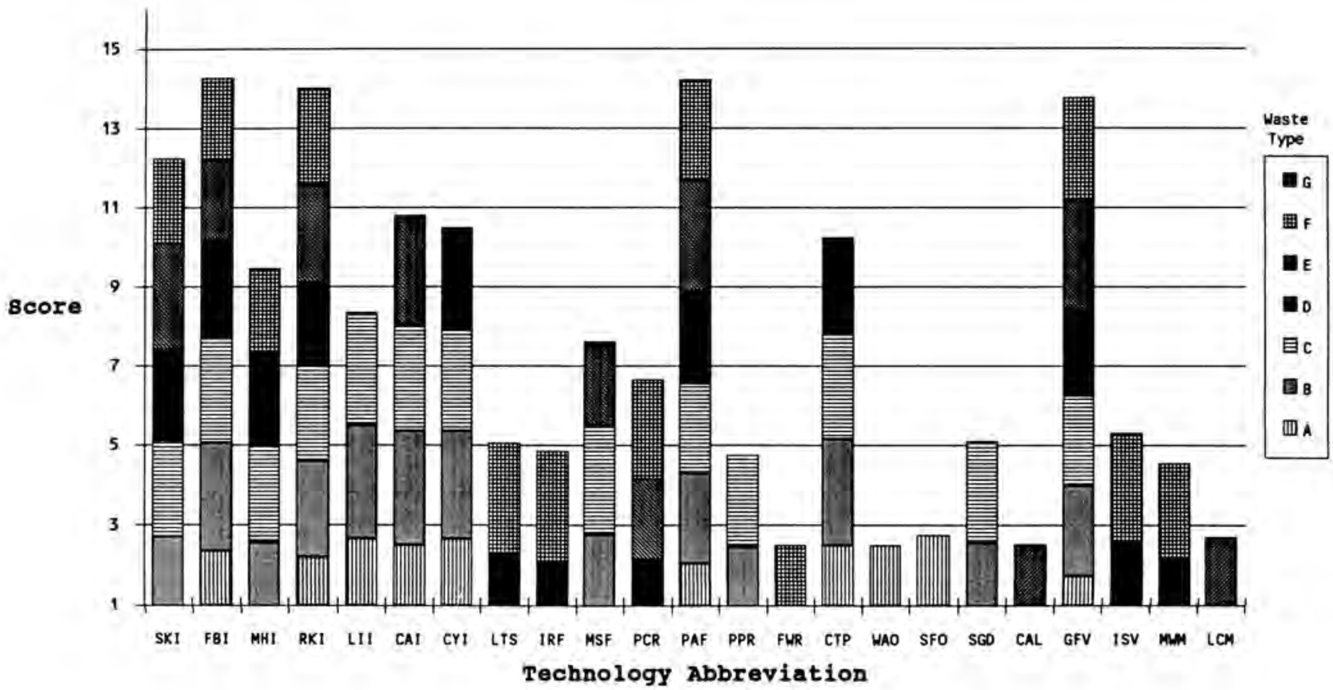

Fig. 1. Overall score by waste type and technology.