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INCINERATION OF PLUTONIUM CONTAMINATED
WASTE MATERIALS

A Preliminary Study for Replacement of the
Existing Rocky Flats Incinerator

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CONTRACT AT(29-1)-1106

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by

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ABSTRACT

Present contaminated waste incinerator design trends are presented along with references to recent incineration literature. Constant heat release is recommended as a basis for design of waste incinerators.

Incineration costs were found to be only a small portion of overall costs associated with recovery of plutonium from combustible wastes.

SUMMARY

1. Very few manufacturers of commercial incinerators have the experience or capability to design complete contaminated waste incineration facilities.
2. At the present time, most contaminated waste incinerators burn prepackaged waste in direct fired, refractory lined incinerators equipped with dry-off gas treating systems.
3. Combustion temperatures must be maintained at or above 1600°F.
4. Finely divided, free flowing ash must be produced by the combustion process.
5. Incineration system designs should be based on constant heat release in BTU/hr. rather than constant feed rate in #/hr.
6. Initial cost of incineration systems will depend more on the required operating conditions than on the type of system employed.
7. Expected variations in the initial cost of plutonium contaminated waste incinerators will not significantly affect the overall cost of recovering plutonium from combustible wastes.

RECOMMENDATIONS

It is recommended that the replacement waste incinerator for Rocky Flats be designed to:

1. Combust prepackaged wastes in such a manner as to maintain reasonably constant heat release.
2. Maintain positive but variable control over hot zone residence time of both residual ash and fly ash.
3. Remove greater than 99.9% of the solids from the off-gas stream prior to absolute filtration.
4. Produce a finely divided, completely combusted, free flow ash which is free of tramp materials and ready for leaching.

It is further recommended that funds be appropriated for construction of the new incinerator sufficient to insure adequate design, thus optimizing overall recovery costs.

INTRODUCTION

This study summarizes present incineration practice as applied to the destruction of contaminated waste and compares alternate incinerator designs. Several sites were visited which have operating contaminated waste incinerators. Three air pollution authorities were contacted regarding incinerator design and off-gas treatment. Design and construction proposals were solicited from numerous incinerator manufacturers. The results of the site survey, literature survey and conclusions reached from discussions with incinerator manufacturers are included in this report.

One interesting observation was made during this study; very few industrial or commercial incinerators are presently equipped for off-gas treatment, even fewer are designed to recover a free flowing, powdered ash, and none are designed specifically for convenient operation inside glovebox lines.

SITE SURVEY INFORMATION

Incinerator Trends

Four operating incinerator facilities were visited during the summer and fall of 1965 to observe procedures and discuss incineration problems.

Descriptions of these and the present Rocky Flats incinerator are presented in Table I. Several trends were apparent:

- Four of the five incinerators were fed by mechanical feeders. Of these, one feeder was automatic, and two feeders were of the remote control type.
- Three of the five units burned prepackaged feed.
- Four of the five units employed cyclones for fly ash recovery.
- Combustion in three of the five units was carried out on solid surfaces as opposed to grates.
- Four of the five incinerators produce fine, free flowing ash.
- Two incinerators employed cylindrical combustion chambers, two used rectangular combustion chambers, and one used a continuous wire belt enclosed in a metal tube.
- Four of the five units were lined with refractory.
- Four of the five incinerators employed dry off-gas processing systems.

TABLE I

Incineration Facility SurveySites Processing High Level Wastes - Recoverable Metal Values

<u>Site</u>	<u>Type</u>	<u>Waste Feed</u>		<u>Incinerator Type</u>	<u>Off-Gas System</u>	<u>Comments</u>
		<u>Rate[#]/Hr.</u>	<u>Feeding Method</u>			
Hanford (200 West Area)	Pu	10-50	Continuous belt feeder.	Indirect heated, variable speed, metal belt primary burning chamber with indirect heated secondary combustion chamber, continuous ash removal. Incinerator feed and discharge ends in glovebox.	Cyclones followed by wet scrubber and absolute filters.	Requires shredded feed with careful tramp removal, produces fine free flowing ash, provides close control of residence time. Combustion temperature limited by exposed metal construction.
Oak Ridge (Y-12 Plant)	U	50-100	Remote operated ram, pre-package feed.	Direct gas fired, vertical cylindrical primary combustion chamber with solid hearth. Remote ash removal with rotary arm. Ash continuously screened and pulverized in dry ball mill-no secondary combustion chamber. Incinerator installed under hood.	Air to water heat exchange, two stage cyclone separation of fly ash backed-up with bag filter unit.	Rotary arm provides control of residence time, ash treating system handles tramp metal - cyclones retain fly ash, bag filters retain soot. Absolute filters not required for stack release of off-gas.
Rocky Flats (71 Building)	Pu	20-50	Hand sorting and feeding of loose combustibles.	Commercial, rectangular shaped primary combustion chambers with fixed grate, direct gas firing, secondary combustion chamber with gas afterburner and baffles. Incinerator completely enclosed in glovebox. Manual batch removal of ash.	Air to air heat exchange, slag wool pre-filter followed by absolute filter.	Operating temperature limited by thickness of combustion chamber insulation which leads to sooty off-gas. Partially burned plastic agglomerates ash-tramp metal - damages ash size reduction equipment. High percentage of unburned material in ash. Soot blinds absolute filters. Unit has fairly long operating life and generally good reliability.

Sites Processing Low Level Wastes - Non-Recoverable Values

<u>Site</u>	<u>Waste Feed</u>		<u>Feeding Method</u>	<u>Incinerator Type</u>	<u>Off-Gas System</u>	<u>Comments</u>
	<u>Type</u>	<u>Rate#/Hr.</u>				
Edgewood Arsenal (ANDL)	Various Isotopes	50	Hand operated mechanical ram, prepackaged feed.	Direct gas fired, vertical cylindrical primary combustion chamber with fixed grate. High velocity tangential gas fired afterburner. Continuous or batch ash removal. No glovebox or hoods.	Air dilution cooling, cyclone separation of fly ash followed by electrostatic precipitator. This is backed up with absolute filters.	Facility well equipped for experimental work. E.S.P. unit rather large for most plutonium applications.
Harvard (Power Plant)	Various Isotopes	100-400	Automatic feeding of prepackaged combustibles.	Use is made of fire box under oil fired power boiler. Ash removed periodically.	Cyclones followed by electrostatic precipitators.	Unit depends on very large flow of flue gas. Gas dilution of contaminants. Low cost disposal of biological wastes.

COMMENTS ON DESIGN CONCEPTS OF EXISTING INCINERATORS

If the trends noted while observing five operating incinerators were summarized into one composite design, the resulting unit would look like this:

The incinerator would be fed prepackaged feed by a mechanical feeder. It would burn continuously in campaigns and would produce a free flowing, finely powdered ash. Combustion would be carried out on a solid surface with over fire air. The incinerator would be lined with refractory brick. Combustion chamber temperatures would be maintained above 1600°F. Dry-off-gas treatment would be used to collect fly ash and soot. Not all of these incinerators were designed to perform the same function. Each design feature does seem to have merit when considered singly. Design by consensus is not advocated, however.

A few comments are in order on process concepts. Feed preparation beyond crude hand sorting appears to be impractical. Choppers and shredders are sensitive to tramp metal. Tramp metal is very difficult to remove from fibrous material, particularly non-magnetic tramp. On the other hand, packaging to some constant size or volume does have advantages. The ratio of charge volume to combustion chamber volume should be maintained within limits. Prepackaged feed can be easily handled by automatic feeders. Charging rate should be controlled by combustion chamber temperature.

Residence time in the combustion chamber must be controlled for the flue gases as well as the residual ash. Unless positive control is maintained, unburned material will be found in both effluent streams. Combustion chamber temperatures must be

maintained above 1600°F. Combustion temperatures and residue times must be matched with the materials to be destructed.

Wet off-gas treatment introduces more problems than it solves. Nuclear Safety considerations eliminate virtually all conventional gas scrubbing systems. Foaming and metal complexing agents may be formed during combustion of various organics. Off-gas from an efficient scrubber will be saturated with water vapor. Condensation may occur during final filtration unless heat exchangers are incorporated in the system. Very high pressure drops may be encountered with certain types of scrubbers.

Both bag filters and electrostatic precipitators are sensitive to organic materials in the flue gases. Complete combustion is essential for successful operation of dry-off gas treating systems. Fly ash loading in the off-gas from incinerators is not too important since most of this material can be easily removed with a cyclone or multi-cyclone system. Pressure drop across absolute filters is due principally to unburned organics rather than fly ash.

ROCKY FLATS COMBUSTIBLE WASTES

Combustible waste currently incinerated at Rocky Flats contains a wide variety of materials such as paper, rags, plastics, rubber, wood, sponges and ion exchange resin. Water content varies from that of wet rags to that of dry plastic. Cellulosic materials may or may not be nitrated from contact with nitric acid.

Bulk density averages 5.5 pounds per ft.³ but varies from 3 to 11#/ft.³. Ash content averages 8% with present combustion practices. Heating values range from very low values for wet rags to more than 20,000 BTU/# for certain plastics.

These wastes generally meet the description of Type I waste as shown in the Incinerator Standards published by the Incinerator Institute of America.

Combustibles are accumulated and stored in plastic lined, 55 gallon steel drums. Drum contents are introduced into the incinerator box through an airlock. Feed is hand sorted to remove rubber gloves, PVC plastics and large pieces of non-combustible material such as wire brushes, pipe fittings and old tools. Small tramp such as nuts, bolts, wire, etc., remains in the feed and must be separated from the ash after incineration.

Material is fed to the incinerator by hand in 2 to 5 pound charges. Feed is introduced so as to maintain a fairly constant combustion chamber temperature.

COMPARISON OF INCINERATOR TYPES

Incinerator designs are best compared on the basis of economics. Cost of recovering plutonium from waste materials includes the initial cost of the incinerator facility, the cost of operating the incinerator including off-gas treatment and the cost of leaching plutonium from the incinerator ash. The initial cost of the incinerator facility may or may not be an important part of the overall recovery cost as this study will show.

Incineration equipment must be considered as an overall system. For the purpose of comparing alternates, only those systems which are capable of producing a completely oxidized, finely divided ash and a clean off-gas stream should be considered. The schematic flow diagram shown in Figure 1 was used for this study. Operating and plutonium recovery costs may be much higher.

The basis chosen for sizing the incinerator has a strong influence on the remainder of the system. Three choices are obvious: feed rate in $\#/\text{hr.}$, feed rate in $\text{ft.}^3/\text{hr.}$ or combustion rate in $\text{BTU}/\text{hr.}$ Of these three possible basis, feed rate in $\#/\text{hr.}$ is the least desirable from the standpoint of design. These bases may be compared as follows:

Feed Rate - $\#/\text{Hr.}$

The assumption of constant feed rate in $\#$ of feed per hour gives no reliable information concerning heat release, air requirements, flue gas volumes or velocities. Combustion chamber volumes and off-gas treating equipment must be sized for the maximum heat release expected from high energy fuels fed at the assumed feed rate. System efficiencies at conditions other than this maximum may be poor. This basis does give

FIGURE 1
INCINERATOR FLOW SHEET
FOR DIRECT FIRED INCINERATOR AND DRY
OFF-GAS SYSTEM

information on the ash generation rate, however, this is normally a very small stream.

Feed Rate - $\text{Ft.}^3/\text{Hr.}$

Assuming a constant volumetric feed rate provides better information for sizing the combustion chamber but, in general, suffers the same limitations described above for constant mass rate.

Heat Release Rate - $\text{BTU}/\text{Hr.}$

The assumption of constant heat release rates provides a sound basis for design of the combustion chamber and subsequent off-gas treating equipment. Heat release rates must be known so that primary and secondary heating can be provided and controlled within proper limits.

Gross heat release rate in $\text{BTU}/\text{hr.}$ was chosen as the basis for the present study.

Table II shows alternate incinerator systems, 1 and 2, and alternate off-gas systems, A and B. Gas flow and installed cost comparisons will be made between combination 1-B, 2-A, and 2-B. The following assumptions apply:

- That feed will be prepackaged in proper size packages for each unit.
- That a fairly constant heat release will be achieved by automatic loading through an airlock feeder.
- That complete combustion will be achieved.
- That combustion temperatures and residence time requirements will be the same for each system (for the same feed).
- That operating and maintenance costs will not vary appreciably from one design to the next provided the capacities are the same per hour.

- That the cost of recovering plutonium from ash will not be affected by the design (assumes complete oxidation of the ash).

TABLE II

Description of Alternate Incineration SystemsIncinerator Systems

<u>Primary Combustion</u>	<u>Secondary Combustion</u>	<u>Ash Removal</u>
Direct fired - with rectangular or cylindrical combustion chamber.	Direct fired - ring or tangential gas firing.	Remote, mechanical ash removal.
Indirect fired or electrically heated. Belt or rotary tube combustion chamber.	Indirect or electrical heating.	Continuous mechanical ash removal.

Off-Gas Systems

<u>Method</u>	<u>Primary Solids Removal</u>	<u>Secondary Solids Removal</u>	<u>Final Removal</u>
Dry off-gas treatment.	Cyclone	Automatic bag filter	Absolute filters
Combination dry-wet off-gas treatment.	Cyclone	Scrubber	Absolute filters

DISCUSSION

Comparison of Gas Flows

Gas flows, temperatures and filter loadings are given in Table III.

Gas flows, and heat exchanger duties are not too different for the various systems while operating temperatures are in the range of 1700°F. However, with a direct fired unit, the picture changes sharply as higher temperatures or excess air rates are considered.

An increase of 100°F in the afterburner effluent temperature increases the off-gas flow by approximately 500 #/hr. An increase in excess air by 30% increases the off-gas flow by more than 500#/hr.

Indirect heated units are not as susceptible to these problems.

Comparison of Installed Equipment Costs

Table IV shows estimated costs for three of the incineration systems described in Table II. Cost of the various systems are comparable for the particular operating conditions chosen. The direct fired, dry off-gas system is the most reasonable at \$135,000 installed cost, however, this cost could go up rapidly as conditions change.

These calculations indicate that for normal operating conditions (1700°F combustion and 50 to 100% excess air), any one of the various systems will cost approximately the same in terms of initial investment. Further calculations (not included in this report) indicate that the initial cost of a plutonium recovery incineration facility may not appreciably affect the overall cost of recovery. The cost of

TABLE III

Gas Flows and Temperatures in Alternate Incineration Systems

<u>System</u>	<u>Combustion Products #/Hr.*</u>		<u>Flue Gas Temp. -°F</u>		<u>Exit Gas Velocity-Ft./Min.</u>	<u>Heat Exch. Area-Ft.²</u>		<u>Bag Filter Area-Ft.²</u>	<u>Expected Solids Loading in Flue Gas to Absolute Filters #/Month</u>
	<u>Primary</u>	<u>Total</u>	<u>Primary</u>	<u>Secondary</u>		<u>High Temp.</u>	<u>Low Temp.</u>		
1-A	865	1365	1515	1715	1300	53	410	145	0.44
2-A	700	860	1515	1715	820	33	260	100	0.24
2-B	700	860	1515	1715	820	82	-0-	Use high eff. scrubber	0.02

* Basis: 100% excess primary combustion air, 50% excess secondary combustion air.

Estimated Cost of Incineration Systems - Table IV

<u>System</u>	<u>Incinerator</u>	<u>Off-Gas Treating Equipment</u>	<u>Misc. Eq. & Controls</u>	<u>Engrg. & Install. Costs</u>	<u>Total</u>
1-A	15,000	15,000	25,000	80,000	\$135,000
2-A	25,000	10,000	25,000	80,000	\$140,000
2-B	25,000	20,000	25,000	85,000	\$155,000

incineration with the present Rocky Flats incinerator represents only 22% of the total cost of recovering plutonium from combustibles. The bulk of the recovery cost is involved with leaching and purifying plutonium found in the ash.

Cost of incineration with a new high efficiency incinerator could be reduced from 22% for the present unit to an estimated 14.3% assuming an initial investment of \$200,000 and an operating life of 10 years.

If the initial cost were increased to \$300,000, unit incineration costs would be increased by only 2.4%. This illustrates the importance of the leaching operation.

In summary, several types of waste incineration systems can be employed to destruct contaminated wastes. Costs for the systems will depend more on the air flow, combustion temperature and method of feeding than on component type. In terms of overall recovery costs, equipment cost variations will not be significant. Incinerators constructed to destruct plutonium contaminated wastes must be designed so that an easily leachable ash is produced. Other considerations will almost certainly be subordinate to this aim.

SUPPLEMENTARY DATA

Partial List of Incinerator Manufacturers Interested in
Designing or Constructing Contaminated Waste Incinerators

<u>Company</u>	<u>Address</u>
Brulé Incinerators	Blue Island, Illinois
Electric Furnace Company	Anaheim, California
Nash, Cadmus & Voelker, Inc.	Freeport, New York
Morse, Boulger, Inc.	Corona, New York
Plibrico Company	Chicago, Illinois
Sargent Incinerators	Kearney, New Jersey
John Zink Company	Tulsa, Oklahoma

Authorities in the Field of Incineration or Incinerator

Off-Gas Treatment

<u>Person</u>	<u>Group</u>
R. J. Mac Knight*	Los Angeles County Air Pollution Control District Los Angeles, California
A. H. Rose, Jr. *	R. A. Taft Sanitary Engineering Center Cincinnati, Ohio
Dr. Leslie Silverman*	Air Cleaning Laboratory Harvard University School of Public Health Boston, Massachusetts
Professor Calvert	Pennsylvania State University University Park, Pennsylvania

*Contacted during the course of this study.

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