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INCINERATOR DEVELOPMENT PROGRAM FOR PROCESSING TRANSURANIC WASTE AT THE IDAHO NATIONAL ENGINEERING LABORATORY[a]

T. G. Hedahl
EG&G Idaho, Inc.

ABSTRACT

In the fall of 1981, two short-term tests were conducted on a controlled air and a rotary kiln incinerator to assess their potential for processing transuranic (TRU) contaminated waste at the Idaho National Engineering Laboratory (INEL). The primary purpose of the test program was a "proof-of-principle" verification that the incinerators could achieve near-complete combustion of the combustible portion of the waste, while mixed with high percentages of noncombustible and metal waste materials. Other important test objectives were to obtain system design information including off-gas and end-product characteristics and incinerator operating parameters. Approximately 7200 kg of simulated (non-TRU) waste from the INEL were processed during the two tests.

INTRODUCTION

Thousands of metric tons of waste contaminated with TRU radionuclides, predominantly plutonium, have been stored or buried at the INEL. This waste, comprised of both combustible and noncombustible materials, will be retrieved and shipped to the Waste Isolation Pilot Plant (WIPP) in New Mexico for permanent disposal. That portion of the waste which does not meet the WIPP waste acceptance criteria will be processed. One processing option for a proposed Transuranic Waste Treatment Facility (TWTF) includes incineration for removal of combustibles and liquid, thereby reducing the volume, and then cementing for immobilization of fines. Waste, packaged in drums and wooden boxes, would be shredded prior to incineration. The shredded waste, containing a large percentage of noncombustibles and metal, would be charged to the incinerator. The combustibles would be burned, and the remaining ash and noncombustible material from the incinerator would be immobilized by cementing and then packaged for disposal at WIPP.

During fiscal year 1981, a detailed systems' evaluation, using the Kepner-Tregoe (K-T) decision analysis methodology, was performed on incineration alternatives. Two incineration systems (controlled air and rotary kiln) were selected as being most applicable for INEL TRU waste processing. However, further evaluation and testing were necessary to select a truly superior incineration process for TWTF.

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INCINERATOR TESTS

SCOPE

The series of tests, initiated by EG&G Idaho, Inc., for the Department of Energy, were conducted on two existing incineration systems:

1. A controlled air incinerator (Consumat C-325) operated by Thermal Reduction Company, Inc., in Bellingham, Washington (see Figure 1);

2. A rotary kiln incinerator (ThermAll, Inc., Customer Test Facility) located in High Bridge, New Jersey (see Figure 2).

Various off-gas measurements and chemical analyses on the incinerator end-product were a part of the test scope. Off-gas measurements included: flow rates; temperatures; particulate loading; particle size distribution; elemental analyses; and gaseous sampling for NO_x, HC, SO_2, H_2O, CO, HCl, O_2, and CO_2. Incinerator end-product samples were analyzed for unburned combustibles, sulfates, chlorides, and up to 30 specific elements. Incinerator operating parameters (temperature, fuel usage, feed rate, etc.) were also documented.

INCINERATOR SYSTEMS' DESCRIPTION

Controlled Air

Controlled air incineration systems typically use primary and secondary combustion chambers to achieve complete waste combustion. Wastes are usually ram-charged to the primary chamber where they burn at near stoichiometric conditions at temperatures up to 800°C. Products of combustion and volatilized species flow into a secondary chamber where excess air conditions provide complete combustion at temperatures approaching 1100°C. This mode of operation produces a nonturbulent combustion environment which minimizes entrainment of flyash.

Rotary Kiln

The rotary kiln is a highly efficient combustion system because it attains excellent mixing of unburned waste and oxygen as the kiln rotates. Solid waste, supplemental fuel, and combustion air are introduced at one end of the unit. The rotating kiln action provides for the automatic continuous removal of ash. Most kilns are refractory lined and are usually equipped with a secondary combustion chamber to complete the combustion process. Kiln temperatures are normally 650° to 870°C, with the secondary chamber approaching 1400°C.

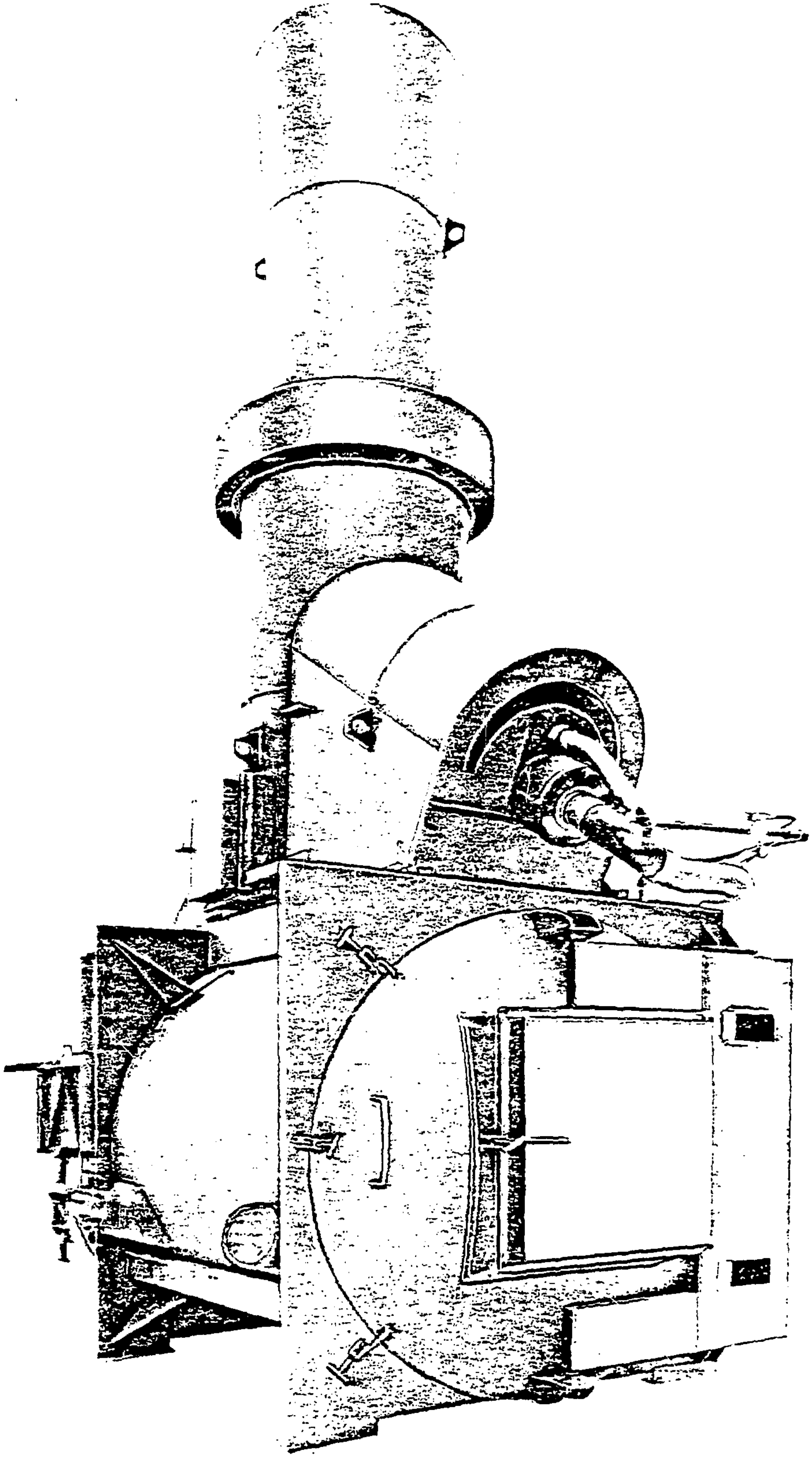

FIGURE 1. Consumat C-325 Controlled Air Incinerator.

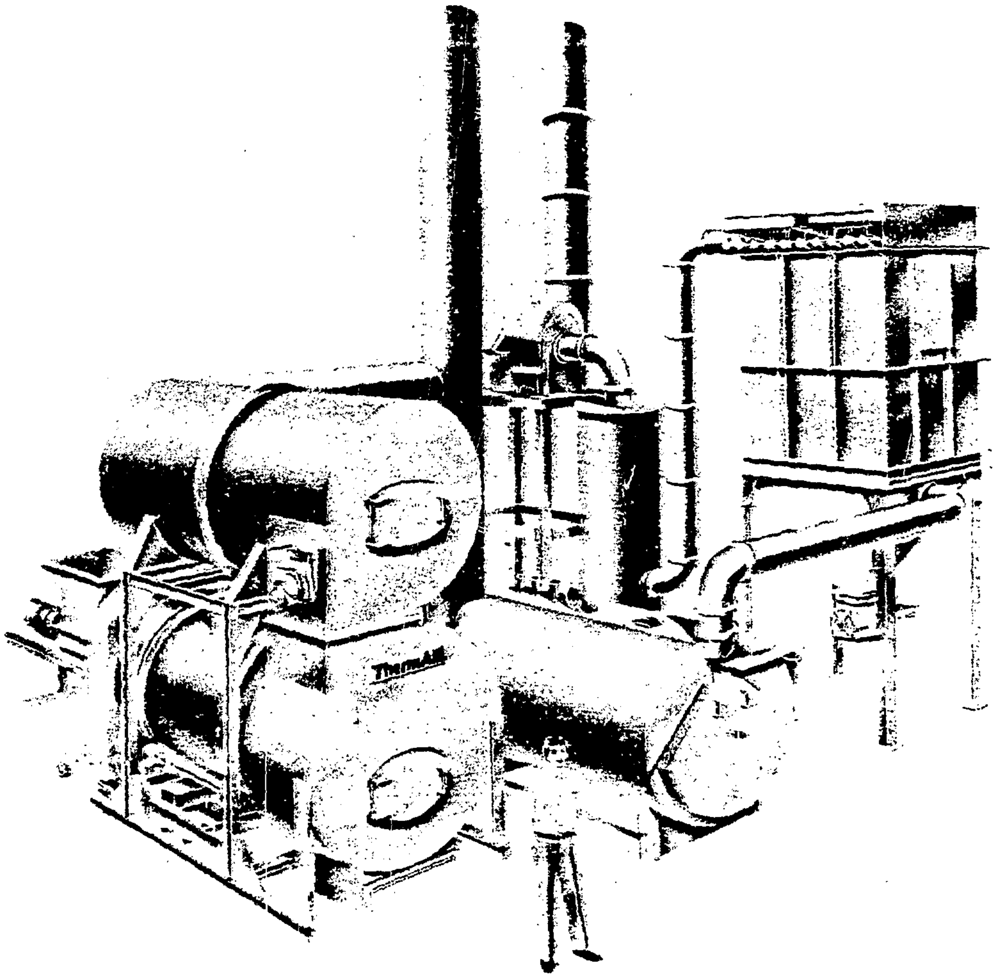

FIGURE 2. ThermAll Rotary Kiln Incinerator.

TEST PROGRAM

Testing of each incinerator was performed over a three day period with each day's testing utilizing a different waste composition. Individual waste components were prepared and shipped from the INEL in drums and boxes to each testing site. If needed, waste items were manually sized prior to shipment to a maximum dimension of 15 cm.

The waste components were mixed by small front-end loaders and shovels at each incinerator test site to obtain a homogeneous mixture of the waste ingredients. Table 1 shows the three primary waste compositions

TABLE 1. Test Waste Compositions.

	High Noncombustible (%)	Average (%)	Low Noncombustible (%)
Metals			
Carbon steel	30.0	20.0	15.0
Stainless steel	30.0	20.0	15.0
	60.0	40.0	30.0
Noncombustibles			
Sand and dirt	9.0	10.5	3.0
Concrete	7.5	8.8	2.5
Asphalt	6.0	7.0	2.0
Glass	4.5	5.2	1.5
Filters & insulation	3.0	3.5	1.0
	30.0	35.0	10.0
Combustibles			
Paper	2.0	5.0	12.0
Cloth	2.0	5.0	12.0
PVC plastic	0.5	1.3	3.0
Polyethlene	1.0	2.5	6.0
Wood	4.5	11.2	27.0
	10.0	25.0	60.0
Total	100%	100%	100%

used during the tests. Average processing rates for INEL-type wastes were approximately 275 kg/h for the controlled air system and 120 kg/h for the rotary kiln.

TEST RESULTS

Results from the two incinerator test programs are presented. Key data information has been evaluated and summarized to illustrate systems' performance at processing INEL-type wastes.

OFF-GAS CHARACTERIZATION

Table 2 provides the off-gas compositions downstream of the secondary combustion chambers for the controlled air and rotary kiln incinerators. Off-gas monitoring for the controlled air system was performed at the stack; the rotary kiln system was sampled upstream and downstream of a waste heat boiler. No off-gas treatment was conducted upstream of the sampling equipment.

Off-gas composition differences between the two systems primarily involve the concentrations of NO_x, HC, HCl, and particulates. The higher incineration temperatures in the rotary kiln are probably the reason for the increased NO_x levels. The 297 ppm value for the high noncombustible waste mixture should be a maximum value expected for the types of wastes processed.

The high HCl concentrations experienced during the controlled air incinerator tests exceed what is theoretically possible for the type of waste processed. It is suspected that residual chlorine in the incinerator refractories was the source for the high HCl concentrations. The rotary kiln test results from processing identical waste ingredients, show very little HCl formation in the off-gas.

The HC concentrations reported for the rotary kiln tests are significantly higher than those from the controlled air incinerator. Apparently, the secondary combustion system on the controlled air incinerator was more efficient at completing the combustion process. Such efficiency may be due to the relatively larger excess air conditions in the controlled air system (approximately 300%) than those in the rotary kiln (200-250%).

Particulate loading measurements were taken at the off-gas stack of the controlled air incinerator and at the inlet to the waste heat boiler for the rotary kiln system. In general, the rotating kiln generates a particulate loading in the off-gas an order of magnitude higher than the nonturbulent conditions in the controlled air system.

TABLE 2. Off-gas Characterization.

Waste Composition	NO (ppm)	SO_2 (ppm)	HC (ppm)	HCl (ppm)	O_2 (%)	CO (%)	CO_2 (%)	H_2O (%)	Particulate (g/dscm)[d]
				Rotary Kiln					
High noncombustible	86.1	6.12	71.0	0.05	14.2	0.0	4.4	4.24	0.72
	297	3.74	95.8	0.03	16.4	0.0	2.8	5.61	1.19
	47.8	6.81	72.8	0.13	b	b	b	0.86	--
			31.6						
Average	65	11.8	92.52	0.087	15.0	0.0	3.8	6.05	0.23
	a	7.83	35.5	0.164	16.0	0.0	3.4	5.51	0.46
	a	15.53	37.77	0.361	16.8	0.0	3.0	6.32	--
Low noncombustible	81	7.9	48.73	0.55	13.2	0.0	5.6	8.57	0.20
	87.3	9.51	39.93	0.29	14.6	0.0	4.6	6.61	0.57
	71.3	17.68	35.11	0.38	14.0	0.0	5.0	5.60	--
				Controlled Air					
High noncombustible	16.3	2.9	1.0	1283	16.0	0.0	3.2	6.1	0.03
	17.1	2.4	0.9	816	16.6	0.0	2.7	5.6	0.01
Average	15.2	2.6	1.1	1669	16.1	0.0	3.2	7.3	0.03
	17.7	2.4	3.1	1804	15.3	0.0	3.7	6.9	0.04
Low noncombustible	c	c	1.2	5069	15.7	0.0	4.0	6.8	0.08
	27.7	4.3	1.9	5659	16.2	0.0	3.4	6.0	0.06

[a]Invalid test.

[b]No data.

[c]No data due to line leakage.

[d]Grams per dry standard cubic meter of off-gas.

LOSS ON IGNITION TESTS

Loss on Ignition (LOI) tests were performed on the end-product material for all three waste compositions from both incinerators. The end-products were hand-sorted into ash, unburned combustible, noncombustible, and metal fractions. Unburned pieces of wood and cloth were visible in the ash from the controlled air incinerator. The rotary kiln end-product did not have discernible unburned combustible material. The ash and unburned combustible portions of the end products were used in the LOI tests. Table 3 provides the average percentage weight loss of the ash (after drying) during the LOI tests. The rotary kiln ash showed significantly less weight loss than the ash from the controlled air incinerator for all three waste compositions, indicating the greater combustion efficiency of the rotary kiln.

Table 4 also provides the total "combustible" waste percentage for a drum of each waste composition, based on the weighted average of all material in the drum. As the data indicate, the total amount of "combustible" material in a typical drum is relatively small compared to the weight of the noncombustible and metal fractions.

VOLUME REDUCTION

Table 4 provides the waste volume reduction ratios for the two tests. The rotary kiln achieved significantly better volume reduction for the "high noncombustible" and "average" waste mixtures. Minimal unburned combustibles (char only) were noticeable in the rotary kiln ash. The unburned combustibles evidenced in the controlled air incinerator end-product prevented efficient volume reduction for that process.

DISCUSSION AND CONCLUSIONS

The proof-of-principle tests on the rotary kiln and controlled air incinerators provided information on the characteristics of the ash end-products, off-gas emissions, and general system design characteristics. For the INEL TRU waste application, complete combustion of the waste is preferred to ensure the production of a stable, immobilized waste form. Flexibility of processing is also important to handle the widely varying, heterogeneous nature of the INEL TRU waste. The test results indicated that the rotary kiln incinerator is more capable of achieving near-complete combustion of the waste and obtaining good volume reduction. Flexibility of processing also appears to be better accomplished by the rotary kiln incinerator because kiln rotation rate, kiln incline, and waste feed rate and method are all modifiable system variables.

The rotary kiln incineration system allows for a practical concept for processing the majority of TRU waste at the INEL. However, further engineering tests will be performed to determine the necessary processing ranges and design information for INEL TRU waste processing.

TABLE 3. Ash Loss On Ignition (LOI).

Waste Composition	Ash	Total Drum[a]
Rotary Kiln — Average % Weight Loss For LOI Tests		
High noncombustible	4	1
Average	6	2
Low noncombustible	23	7
Controlled Air — Average % Weight Loss for LOI Tests	Ash[b]	Total Drum[a]
High noncombustible	12	3
Average	10	3
Low noncombustible	40	20

[a]Weighted average for ash, noncombustibles, and metal in a drum.

[b]Includes ash and unburned combustibles.

TABLE 4. Waste Volume Reduction.

	Before Incineration		After Incineration Density (g/cm^3)		Volume Reduction Ratio[b]	
Waste Composition	Bulk Density (g/cm^3)	Compacted Density[a] (g/cm^3)	Controlled Air	Rotary Kiln	Controlled Air	Rotary kiln
High noncombustible	0.37	0.61	1.70	2.27	2.8:1	3.7:1
Average	0.26	0.43	1.44	1.76	3.3:1	4.0:1
Low noncombustible	0.14	0.26	1.23	1.20	4.8:1[c]	4.7:1

[a]Compacted density was determined by tightly packing the waste composition in a drum.

[b]Based on compacted density before incineration.

[c]A portion of the controlled air incinerator waste output was damp due to water spray in primary chamber during ash removal.