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**TRU Waste Cyclone Drum Incinerator
and Treatment System:
January-March 1978**

**Larry M. Klingler, Dana M. Batchelder
and Edward L. Lewis
May 5, 1978**

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MOUND FACILITY
Miamisburg, Ohio

operated by
MONSANTO RESEARCH CORPORATION
a subsidiary of Monsanto Company

for the
U. S. DEPARTMENT OF ENERGY

Contract No. EY-76-C-04-0053

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Foreword

Under the sponsorship of the DOE Division of Waste Management, Production, and Reprocessing, Mound is responsible for the development of a volume reduction system to treat TRU combustible waste generated at DOE sites.

This report is submitted by W. T. Cave, Nuclear Operations, and B. R. Kokenge, Manager, Nuclear Technology, from contributions prepared by members of the Nuclear Waste Technology Section, K. V. Gilbert, Manager, the Volume Reduction Technology group, W. H. Bond, Leader, and the Waste Immobilization Group, J. W. Doty, Leader.

Previous reports of this and the related project, Volume Reduction System for Solid and Liquid TRU Waste from the Nuclear Fuel Cycle, are listed below:

TRU Waste Cyclone Drum Incinerator and Treatment System:

October-December 1977	MLM-2510
July-September 1977	MLM-2496
April-June 1977	MLM-2482
January-March 1977	MLM-MU-77-64-0004

Volume Reduction System for Solid and Liquid TRU Waste From the Nuclear Fuel Cycle:

October-December 1977	MLM-2509
July-September 1977	MLM-2498
April-June 1977	MLM-2463
January-March 1977	MLM-2436

Contents

	<u>Page</u>
SUMMARY	4
TASK I. CYCLONE INCINERATOR DEVELOPMENT	
Demonstration of the Cyclone Incinerator	5
Selection of Methods to Treat Scrubber Liquid.	5
Determination of Equipment Life.	5
Upgrading the Incinerator System	7
Continuous Feed Refinement	7
WASTE IMMOBILIZATION	
Introduction	8
Pressed Ash-Cement Pellet Experiments.	8
Volume Reduction Efficiency.	10
Pressed Sludge-Cement Pellets.	11
Elemental Analysis of Type I Incinerator Ash	12
Particle Distribution of Sintered Incinerator Ash.	12
REFERENCES.	13
DISTRIBUTION.	14

Summary

The cyclone incinerator was operated throughout the past quarter, generating additional data on system characteristics, equipment life expectancies, and by-product generation.

Several changes in the incinerator system are in various stages of completion. The lid assembly, secondary chamber, and expansion unit for the new exhaust equipment are nearly ready for installation. A new heat exchanger has been installed in the scrubber system. An ash handling system has been designed for possible future addition to the system.

Continuing studies will determine the best delivery mechanism for continuously feeding the cyclone incinerator.

Preliminary investigations are being conducted to select an independent system to treat incinerator scrubber solution for recycling and to remove salts and sludge for disposal.

Metal samples of two possible materials for incinerator construction were examined for corrosion degradation suffered at the incinerator exhaust outlet.

Controlled experiments were conducted on the pressed ash-cement pellet matrix to define compressive strength, mechanical stability, density, and effect of curing environment (wet cure and dry cure). Leachability studies were initiated on pressed sludge/cement matrix in distilled water at ambient temperature. Compressive strengths of sludge/cement pressed matrix samples were investigated. Physical and chemical attributes of incinerated ash were evaluated in relationship to the ash/cement matrix.

Task I: Cyclone incinerator development

Demonstration of the cyclone incinerator

L. M. Klinger

Low specific activity waste generated at Mound Facility continued to serve as fuel for the demonstration of the cyclone incinerator during January and February, 1978.

All the <10 nCi/g combustible waste generated at the Facility was burned in 49 runs during this period. A summary of data collected from the runs is given in Table 1.

The 1082 kg of waste was burned in drum batches which varied considerably in percentages of nonburnables, polyvinyl chlorides, and moisture. Although somewhat lower burning rates were obtained with wet waste (rags and mops), the nonburnables and polyvinyl chlorides had no discernable effect on burning rate. Good combustion was achieved in all burns made.

All components of the incinerator and off-gas system have continued to function satisfactorily. Burning rates and ash percentages shown in Table 1 compare favorably with data collected in the past.

Selection of methods to treat scrubber liquid

L. M. Klinger

Neutralization of acid gases in the flue gas stream by caustic scrubber solution results eventually in high concentrations of salts in the scrubber liquor. These salts must either be removed in a desalting process or be released to the environment.

Highly concentrated salt solutions generated at Mound are greatly diluted with other plant water when sent to the Central Waste Disposal Facility and do not require desalination. Incinerators placed at other sites, however, may, because of environmental considerations or lack of a Central Waste Disposal Facility, require a scrubber liquor treatment system which will remove salts as well as radioactivity from effluent liquid streams.

A Pilot Plant Desalting and Sludge Handling System is being designed to treat the cyclone incinerator scrubber liquor and sludge filtered from this liquor. Evaporation has been selected as the desalination technique, and vendors whose equipment is applicable to our solution and sludge are being contacted.

Determination of equipment life

W. H. Bond

The samples of Haynes 25 and Hastalloy X placed in the upper burn chamber were monitored twice during the quarter for corrosion. The amount of sample weight loss is used as the measure of the corrosion rate. The first weighing occurred after a waste throughput of 738 kg:

Metals	Weight (g)		
	Before	After	Loss
Haynes 25	30.04	20.22	9.82
Hastalloy X	25.21	23.45	1.76

The second weighing was performed after an additional waste throughput of 750 kg:

Metals	Weight (g)		
	Before	After	Loss
Haynes 25	20.22	10.60	9.62
Hastalloy X	23.45	21.10	2.35

As may be seen, the Hastalloy X is superior

Table 1: SUMMARY OF CYCLONE INCINERATOR RUNS FOR JANUARY AND FEBRUARY, 1978

<u>Runs</u>	<u>Number of Drum</u>	<u>Waste Weight (kg)</u>	<u>Total Burn Time (min)</u>	<u>Average Combustion Rate (kg/hr)</u>	<u>Total Ash Weight (kg)</u>	<u>Total Ash Volume (liters)</u>	<u>Ash (wt % of Feed)</u>	<u>Ash (vol % of Feed)</u>
105-113	6	202.95	446	27.30	8.31	16.09	4.1	1.3
114-119	3	129.25	292	26.55	3.94	9.46	3.0	1.5
120-129	7	231.07	511	27.13	7.91	13.63	3.4	0.9
130-133	3	89.8	191	28.21	3.01	6.32	3.4	1.0
134-144	6	234.92	597	23.61	7.51	16.39	3.2	1.3
145-153	6	194.33	449	25.97	6.26	16.39	3.2	1.3
TOTALS	31	1082.32	2486		36.94	78.28		
AVERAGE (one-drum basis)	1	34.9	80.2	26.12	1.19	2.53	3.4	1.2

to the Haynes 25 in the cyclone incinerator environment.

Upgrading the incinerator system

L. M. Klingler

ASH HANDLING SYSTEM

A new ash handling system was designed for possible future use for in situ operation of the cyclone incinerator. The purpose of the system is to reduce operator contact with contaminated equipment and ash. The system will incorporate a remotely operated drum inverter. Ash will be dumped from the burn chamber through a valved, screening funnel into storage cans. The canned ash will then be transported to the immobilization area where the ash will be prepared for shipment and long term storage.

HEAT EXCHANGER

A new heat exchanger was installed in the liquid scrubber system loop. This unit has 3.5 times the surface area of the previous unit and will provide sufficient cooling capacity for the continuous burning of either liquids or solids.

The new heat exchanger is constructed of 316 stainless steel which will offer better protection against corrosion-induced leakage between the coolant and scrubber liquid than the copper tubing of the previous unit.

LID ASSEMBLY

The new lid assembly and exhaust system equipment described previously [1] is being fabricated and will be installed early in the 3rd quarter, FY-1978. Test-

ing of the new system will begin immediately after the installation is completed.

Continuous feed refinement

L. M. Klingler

CONTINUOUS FEED

A number of problems were encountered with the continuous feed system designed for the cyclone incinerator. This prevented accurate assessment of this mode of burning. These problems included bridging the storage hopper and jamming of the rotary valve which metered feed into the incinerator [2].

Several changes are under consideration for eliminating these problems. The storage hopper geometry will be modified to reduce bridging potential. In addition, a screw feeder (Figure 1) will replace the present rotary valve (Figure 2) to meter feed from the storage hopper into the pneumatic feed chute. If an air lock is found to be necessary, the rotary valve will be placed between the screw feeder and feed chute.

FIGURE 1 - Proposed equipment design for continuous feed incinerator.

Tests will be conducted with nonradioactive feed material at vendors' facilities to determine the type of screw feeder to be used in the system.

FIGURE 2 - Present equipment design for continuous feed incinerator.

Waste immobilization

D. A. Batchelder, E. L. Lewis and J. W. Doty

Introduction

The objectives of this task are to evaluate various TRU waste immobilization methods and to evaluate performance of the immobilized waste forms against existing and newly developing criteria for accepting immobilized waste product forms for terminal isolation. In addition, this program has as its objective the development of processes to effectively immobilize various waste residues such as sludges, absorbents, and incinerator ash.

Pressed ash-cement

pellet experiments

Controlled experiments were conducted this quarter on the selected pressed-pellet matrix chosen for the immobilization process of incinerator ash residue. The experiments were designed to provide data for evaluation and selection of the best pellet matrix for incinerator ash and Portland Type 1A cement.

Certain process parameters previously determined and evaluated during screening studies previously reported with the pressed ash-cement matrix were fixed throughout the entire experimental sequence. The parameters in the process which were held constant are:

1. Pressing pressure of 25,000 psi for 1-min duration.
2. Three-gram matrix weight.
3. One-half inch pressing die, which, with a 3-g charge, produces a relatively standard 1/2-in. diameter by 1/2-in. high pellet (L/D ratio approximately 1).
4. Dry Cure Cycle - two days (48 hr) in open atmosphere.
5. Wet Cure Cycle - four-day (96 hr) cure in distilled water followed by a two-day cure in open atmosphere.

Four groups of waste matrices samples were evaluated during this reporting period. Pellets were pressed with 60%, 70%, 80%, and 0% ash residue (100% Portland 1A cement). The pure cement pellets were pressed for control comparison conditions. The water-to-cement ratio was varied in each sample group to determine

the water-to-cement ratio which would produce acceptable pressed pellets. Normally six water-to-cement ratios were evaluated ranging from a too dry condition (fracturing pellet matrix after pressing) to a wet condition (excess water ejected from die during pressing operation).

The control condition matrix (100% Portland 1A cement) containing 0% incinerator ash at acceptable water-to-cement ratios produced nearly identical pressed pellets. The dry-cure method produced pressed pellets of uniform compressive

strength, density, and final weight. Based on the final weight of the pellets the calculated percentage of water remaining in the matrix is approximately 2% for the dry-cure method. Similarly the wet-cure method produced pressed pellets also of uniform but higher compressive strength, density, and final pellet weight. However, the wet-cure method retained approximately 10% water in the matrix form.

The data shown in Table 3 for the 60%, 70% and 80% ash-cement pressed matrices are given only for the two best water-

Table 3 - PRESSED ASH-CEMENT PELLET MATRIX
CONTROLLED EXPERIMENTAL PROCESS

Ash Type	Ash Weight (g)	Cement Weight (g)	Water/Cement	Cure		Initial Pellet Weight (g)	Final Pellet Weight (g)	Calculated Weight Loss (g)	Density (g/cm ³)	Average Compressive Strength (psi)	Weight % Loss
				Dry	Wet						
	0	3.0	0.10	x		3.23	3.04	0.19	2.29	3635	
	0	3.0	0.125	x		3.25	3.05	0.20	2.30	3661	
	0	3.0	0.15	x		3.23	3.02	0.21	2.32	3668	0.50
	0	3.0	0.175	x		3.26	3.04	0.22	2.33	3670	
	0	3.0	0.10		x	3.32	3.25	0.07	2.43	4580	
	0	3.0	0.125		x	3.36	3.29	0.07	2.45	4330	
	0	3.0	0.15		x	3.34	3.29	0.05	2.47	4192	0.84
	0	3.0	0.175		x	3.32	3.28	0.04	2.49	4293	
1-3	1.8	1.2	0.45	x		3.22	3.02	0.20	2.00	3470	4.45
1-3	1.8	1.2	0.45		x	3.38	3.52	(0.14)	2.30	3600	3.21
1-3	1.8	1.2	0.50	x		3.34	3.04	0.30	2.00	3470	0.62
1-3	1.8	1.2	0.50		x	3.40	3.52	(0.12)	2.29	3620	4.33
1-3	2.1	0.9	0.70	x		3.43	3.05	0.38	1.96	2480	1.78
1-3	2.1	0.9	0.70		x	3.41	3.24	0.17	2.01	3640	3.70
1-3	2.1	0.9	0.75	x		3.40	3.02	0.38	1.96	3470	2.27
1-3	2.1	0.9	0.75		x	3.42	3.31	0.11	2.11	3625	3.63
1-3	2.4	0.6	1.10	x		3.23	3.00	0.23	1.92	2480	3.72
1-3	2.4	0.6	1.10		x	3.38	3.27	0.11	2.08	3600	3.84
1-3	2.4	0.6	1.15	x		3.26	3.00	0.26	1.92	2480	1.85
1-3	2.4	0.6	1.15		x	3.40	3.30	0.10	2.08	3570	4.45
1-1	2.4	0.6	0.70	x		3.30	3.00	0.30	2.03	~2507	
1-1	2.4	0.6	0.70		x	3.30	3.21	0.09	2.15	~3640	
1-1	2.4	0.6	0.05	x		3.30	3.00	0.30	2.04	~2500	
1-1	2.4	0.6	0.85		x	3.18	3.00	0.18	2.10	~3670	

to-cement ratios even though four acceptable and tested water-to-cement ratios were attained. The data clearly indicate that the wet-cure method produces ash-cement matrix having higher compressive strength than pellets which were dry cured. In general, the compressive strength increased as the percent of ash in the matrix decreased. This result was expected since the cement (binder) contributes significantly to the pellet compressive strength.

As the percent of incinerator ash was increased, the water-to-cement ratio also increased. This was also expected as observed in past screening studies conducted on the ash-cement pressed matrices. Although a small portion of water must be required for cement interaction and blending, the ash requires significant amounts of water to wet the ash because of its hydrophilic characteristic. Although this condition exists, the final pellet weights after curing are close in final weight value as the 0% ash matrix final weight. The 60/40 ash-cement matrix after wet-cure processing, however, gained weight; the reason for this is presently being investigated.

The density of the various ash-cement pressed pellets increased as the percent of ash decreased. The density ranged from 83-88% of the 0% ash-cement pressed matrix; however, the density values calculated for the ash-cement various matrices were taken, and the radiographs clearly show that no void, crack, and/or fissure exist in any of the ash-cement pressed pellet matrices.

Mechanical strength and corresponding percent weight loss of the various pressed pellets were also determined.

The pressed pellets were placed in stainless steel containers which were clamped into a Model BT Wrist Action Shaker. The shaker was set at the maximum 10° shake angle to vibrate the samples in a circular motion inside the fixed container. The shaking action was continued for 50 hr, and the weight loss was determined. The resulting weight losses are also shown in Table 3. All the samples experienced a slight rounding of the edge that contacted the stainless steel container; one slight abrasion occurred on the walls of the samples. Figures 6 and 7 are photographs of the 100% cement pressed pellet before and after the shake test. Radiographs of the pellets taken before and after the shake test showed that the pellets were still homogeneous and contained no voids, cracks, and/or fissures. Although the percent weight loss is higher for the 60%, 70%, and 80% ash-cement pressed matrices as compared to the 100% cement pressed matrices, this result would be expected based on the lower compressive strength values.

Volume reduction efficiency

Prior to the initiation of the controlled experimentation on the ash-cement matrix process, a new batch of incinerator ash was prepared with the cyclone incinerator. The composition of the incinerator feed was Type I, that consisted of 32 wt % paper, 9 wt % PVC, 29 wt % polyethylene, 8 wt % polypropylene, 13 wt % rubber, 3 wt % cloth, and 6 wt % metal. A total of 11.2 kg (24.6 lb) of the uncompacted combustible composition (2.2 ft^3) was burned in a 55-gal drum. The resulting ash, containing approximately 20% carbon, was then sintered for 1 hr at 800°C to reduce the carbon content to approximately 0.04% carbon. After grinding and sizing, the sintered ash weighed 340 g and contained a volume of 570 cm^3 .

FIGURE 6 - Pellet before shake test.

Based on the pelletization process for a pressed ash-cement matrix ratio of 70/30, approximately 162 pressed pellets could be produced. These pellets would weigh approximately 494 g if dry cured and approximately 534 g if wet cured. The resulting volume of the immobilized matrix would be approximately 252 cm^3 for the dry-cure product and approximately 256 cm^3 for the wet-cure method. This analysis is based on the preliminary data obtained during the experimentation controlled processes (Table 3).

The data indicate the overall process efficiency starting with uncompactible Type I composition through incineration and immobilization is approximately 95% in weight reduction and approximately 90% in volume reduction.

FIGURE 7 - Pellet after shake test.

Pressed sludge-cement pellets

Screening studies continued on development of the pressed sludge-cement pellet matrix. Two groups of 1/2-in. diameter pellets were pressed at 25,000 psi. The amount of sludge in the pressed cement matrix was selected at 15 and 20%. The prepared matrices were subjected to both dry-cure and wet-cure methods of curing. As shown in Table 4, again the wet-cured pellets exhibited higher compressive strength than the dry-cured pellets for both sludge percentages prepared.

Leach experiments were also initiated on the 1/2-in. diameter sludge-cement matrix in distilled water at ambient temperature. The leach rate (grams as solid residue leached per cm^2 per hour) is reported in Table 4 for the wet cured pellets.

Elemental analysis of

Type I incinerator ash

Three batches of Type I incinerator ash were sampled and analyzed by emission spectrography after sintering at 800°C. Elements that are present in the three batches of Type I ash are shown in Table 5. Silicon and aluminum are the major constituents and were determined by wet chemistry techniques. As noted, the percent of each element varied considerably in the three batches of ash even though the starting combustible feed composition was identical. As shown in Table 3, the 80/20 ash-cement pressed pellet matrix for Ash Type 1-1 and Ash Type 1-3 varied in water-to-cement ratio in the pressing operation. Ash Type 1-3 required a higher water-to-cement ratio to produce acceptable pellets than the Ash Type 1-1 material. Ash Type 1-3 contains a larger percentage of CaO (quicklime), a compound employed in mortars and cements, which would require water for shaking, leaving a white powder, $\text{CaO} \cdot \text{H}_2\text{O}$. Additionally, the Ash Type 1-3 was fresh-

ly prepared and sintered, and since the ash is hydrophobic, it had not had sufficient time to absorb moisture. Ash Type 1-1 has a lower percent of CaO and is aged ash (having absorbed moisture). Thus, it is believed that these factors contributed to lower water-to-cement ratios for pressing the Ash Type 1-1.

Particle distribution of sintered incinerator ash

The three batches of Type I incinerator ash were sieved using standard stainless steel sieves after sintering at 800°C. The three batches of ash as shown in Table 6 are very similar in particle size distribution; however, the average particle size of Type 1-1 ash is slightly smaller. Although the Type I combustible feed composition is identical, after incineration, the resulting ash residue will vary in particle distribution and elemental composition which will affect the water-to-cement ratios required for acceptable pelletization.

Table 4 - PRESSED SLUDGE-CEMENT PELLETS SCREENING STUDY DATA

Sludge (%)	Cement (%)	Water/Cement Ratio	Cure Method	Average Crush Strength (psi)	Leach Rate (g/cm ² /hr)
20	80	0.20	Dry	3730	
20	80	0.20	Wet	4600	3.55x10 ⁻⁶
15	85	0.14	Dry	3690	
15	85	0.14	Wet	4510	5.05x10 ⁻⁶

Table 5 - ELEMENTAL CONTENT OF SINTERED INCINERATOR ASH

Table 5 - ELEMENTAL CONTENT OF SINTERED INCINERATOR ASH																	
Ash	Element (wt %) ^a																
	B	Si	P	Al	Fe	Mn	Pb	Mg	Cr	Sn	Ni	Ca	Cu	Ag	Zn	Na	Ti
1-1	<0.05	17.8	0.05	17.8	2.5	0.06	0.04	3.0	0.30	<0.05	0.08	2.0	0.05	<0.05	3.0	0.35	3.0
1-2	<0.05	>5	<0.05	>5	3.0	0.05	-	1.5	0.10	-	0.08	2.5	0.10	-	1.0	0.25	1.5
1-3	<0.05	5.0	0.06	3.0	>5	0.10	-	1.0	0.30	<0.05	<0.05	>5	<0.05	-	0.15	0.30	>5

^aElemental analysis will not approach 100% because of volatile products at combustion, the method of determination, and oxide values.

Table 6 - PARTICLE SIZE DISTRIBUTION OF SINTERED INCINERATOR ASH

Ash Type	Ash (wt %) in Size Range			
	>212μm	>106μm	>53μm	<53μm
1-1	20.6	47.0	79.3	20.7
1-2	28.6	57.2	78.6	21.4
1-3	25.3	54.6	79.1	20.9

References

1. D. F. Luthy and J. W. Doty, TRU Waste Cyclone Drum Incinerator and Treatment System: October-December 1977, MLM-2510 (April 21, 1978), 14 pp.
2. D. F. Luthy and J. W. Doty, TRU Waste Cyclone Drum Incinerator and Treatment System: July-September 1977, MLM-2496 (February 3, 1978), 17 pp.

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