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**TRU Waste Cyclone Drum Incinerator
and Treatment System:
July-September 1977**

Don F. Luthy and Jay W. Doty

February 3, 1978

Monsanto

MOUND FACILITY

Miamisburg, Ohio

operated by

MONSANTO RESEARCH CORPORATION

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for the

U. S. DEPARTMENT OF ENERGY

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

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Summary

Task I

Equipment for continuously feeding the Cyclone Incinerator was installed and tested. Preliminary tests were performed on finely shredded papers. Simulated waste was shredded and used in the primary testing. Extensive equipment modifications were made during the test period until significant results were achieved. The results strongly indicated that further development of the continuous feed mechanism is warranted.

Eleven incinerator runs were made during the quarter to determine a mass balance of chlorides in the incinerator system. Most of the chloride in the offgas was removed in the spray tank. Smaller amounts were retained in the resultant ash and in the offgas. These experiments also demonstrated the effectiveness of the spray tank and compared the use of sodium carbonate and potassium hydroxide in the scrubber solution.

Task II

A conceptual design was presented and modifications were begun on a glovebox which will be used for the demonstration phase of incinerator ash immobilization. Two major forms of immobilization -- concrete and pressed pellets -- were studied and compared. Criteria used were crush strength, mechanical strength, loading rates, leach rates, and waste content.

Task III

During FY-1977, the program to specify conceptual Acceptance and Design Criteria for defense transuranic waste packaging for Interim Storage and/or Terminal Isolation was completed.

Task I: Cyclone incinerator development

Milestone B: Operational capabilities

The Cyclone Drum Incinerator program, as authorized by DoE/DWM, concentrated on the assessment of the advantages and disadvantages of continuous feed versus the normal batch (in-situ) mode of incineration. The ability to perform in either feeding/burning situation would greatly enhance the adaptability of the Cyclone Incinerator in meeting the varied waste conditions that would be encountered during field applications. A need was recognized for the measurement of a chloride mass-balance across the entire system. This measurement would provide information on the chloride absorption or removal of each section of the incinerator, particularly the spray tank.

CONTINUOUS FEED

Experimentation with continuously feeding the cyclone incinerator began in July. The primary purpose for this development effort was to identify and evaluate the advantages and disadvantages of continuous feeding versus batch feeding. It was anticipated that continuous feed would permit an increased combustion rate and also eliminate the small rise in offgas combustibles found on cold startup of the incinerator.

The problems of waste preparation (shredding, metal removal, etc.) and ash handling were not addressed at this time. The fuel used in the initial trial burns was paper chopped to a confetti size (a large supply of this material was readily available). The bulk of the testing was performed using a contaminated feed

mixture (Table 1) prepared to simulate the mixture of LSA wastes generated at Mound.

Table 1 - COMPOSITION OF CONTAMINATED FEED MIXTURE

Paper	33%
PVC	10%
Polyethylene	30%
Polypropylene	9%
Rubber	14%
Cloth	4%

This mixture was shredded in a commercial shredder during demonstration runs at the vendor's factory. The resulting feed was composed of pieces less than 1-in. wide and from 1 to 4-in. long.

The equipment designed for continuous feed incineration is shown schematically in Figure 1. The prepared feed material is pneumatically conveyed to a storage hopper. At the base of the hopper, a rotary valve meters the feed into a chute. The chute then directs the material into a pipe serving as the primary combustion air inlet. The air stream being induced into this pipe serves to pneumatically convey the waste material into the combustion chamber. Inside the chamber the fuel is ignited instantly by the hot gases, then swirled around the chamber perimeter down to the drum base by the cyclone air flow. Larger ash particles are drawn in a tight vortex to the drum outlet. Burning of particles and combustible gases continues to the scrubber inlet.

Data from the runs made are assembled in Table 2. The number of burns that could be made was limited by the available feed material.

FIGURE 1 - Equipment design for continuous feed incinerator.

Several difficulties were encountered in moving the wastes into the burning chamber. The initial problem was bridging in the hopper. Techniques are available for solving this problem, but the limited time frame prevented implementation of any of these. Burning was continued by manually feeding the hopper.

A second problem was the tendency of the rotary valve to jam. Several changes were made on the valve, greatly improving operation. The problem was not completely corrected, however, and replacement of the valve may become necessary to achieve satisfactory operation.

Another difficulty was maintaining flow through the air/fuel inlet pipe. Long pieces of waste material occasionally became entangled, plugging the pipe. Available shredding techniques could, most likely, eliminate this problem.

Because of these problems, the feeding during all the runs was, to some degree, intermittent, permitting the fire to quickly diminish in intensity and temperature. The low combustion rates obtained in most runs reflect more the time spent unplugging the feed system than the actual capability of continuous feed. The comparatively trouble-free run (#7) comes

Table 2 - PRELIMINARY TEST BURNS IN CYCLONE INCINERATOR

Run	Weight (lb)	Material	Time (min)	Combustion Rate (lb/hr)	Ash (lb)
A	70	Shredded Paper	43	97.7	
B	No data	Shredded Paper			
C	94.3	Shredded Paper	60	94.3	
1	70.5	Shredded Simulated Waste	81	52.2	6
2	21.5	Shredded Simulated Waste	15	86.0	1.5
3	52.5	Shredded Simulated Waste	45	70.0	2.3
4	70.5	Shredded Simulated Waste	93	45.5	4.3
5	88.5	Shredded Simulated Waste	132	40.2	9.5
6	75.0	Shredded Simulated Waste	75	60.0	
7	170.5	Shredded Simulated Waste	83	123.3	8.0
8	55.5	Shredded Simulated Waste	60	55.5	3.5
9	35.5	Shredded Simulated Waste	45	47.3	3.2
10	136.0	Shredded Simulated Waste	125	65.3	9.0
11	278.5	Shredded Simulated Waste	240	69.6	17.5
12	18.5	Resin (9.75 lb) Simulated Waste (8.75 lb)	7	150.0	--
13	34.3	Resin (5.75 lb) Shredded HEPA (10.5 lb) Simulated Waste (18 lb)	35	58.7	5.5
14	66.0	Shredded Paper	52	76.2	2.8

closest to indicating the feed rate capabilities of the system.

Another problem that resulted from the feeding difficulties was an accumulation of ash. When temperatures dropped in the burning zone, fuel passed through the zone without being completely burned. Layers of ash with high carbon content were then deposited at the bottom of the chamber.

Despite the problems encountered with the feed system as presently designed, it is believed that continuous feed is a viable combustion mode provided that the shredding of waste material to a sufficiently small size (1 x 1 in.) is economical. Continuous feed rates of 100-150 lb/hr are probably obtainable with the present offgas system, whereas the expected upper limit for batch feed is <100 lb/hr. Fly-ash entrainment in the offgas was considerably lower for continuous feed than for batch feed. Combustible gases were essentially eliminated from the offgas except for small percentages at cold startup. This was true for the most part even when chamber temperatures dropped due to feed pipe pluggage. Continuous feeding eliminated the downtime necessary in batch feed to handle drums between burns.

Efforts were also made to burn resins and shredded HEPA filters fed continuously to the cyclone incinerator. The resins were effectively burned with no problems. The HEPA filters used were shredded 24 x 24 x 11 in. box filters. Since the wood and paper portions of the filter were treated for fire resistance, they did not burn readily. When combined with

other combustible wastes, however, a considerable reduction in waste volume was achieved.

CHLORIDE MASS BALANCE EXPERIMENTS

Experiments were run during the quarter to more clearly define the disposition of chlorides generated by the combustion of polyvinyl chloride (PVC) in the cyclone incinerator. Known quantities of PVC were added to drums of wastes containing no other significant sources of chloride. The PVC was mixed thoroughly with the other waste in drums and constituted 25% of the total weight of each drum. The PVC used was determined by analysis to contain 43% by weight of chloride.

Eleven runs were made. For the first five runs, a solution of sodium carbonate served as the scrubber solution. For the remaining six runs, a potassium hydroxide solution was used as the scrubber solution.

Before the first run and after each of the following runs, the scrubber solution stream was sampled for chloride, carbonate/hydroxide, sodium, and sulfate. Additional samples were taken between burns when it was necessary to replace water lost by evaporation.

Data obtained during the investigation are given in Table 3. It can be seen that nearly 17% of the chloride burned is unaccounted for. This is a common experience in attempts to perform a chloride material balance in a large system. Some chloride was probably lost through chemical attack in the system. Other chloride was probably lost because it was attached to solids removed from

Table 3 - DISPOSITION OF CHLORIDES GENERATED BY COMBUSTION OF PVC

Run	Base added To Scrub Sol'n	Cl ⁻ in Fuel	Cumulative Cl ⁻ Burned	Vol. Flue Gas (ft ³) Saturated at 160°	Cl ⁻ in Flue Gas (Analysis)	Cumulative Cl ⁻ in Flue Gas	Volume Scrubber Sol'n	Cl ⁻ in Solution (Analysis)
9216 g Soda Ash							910 l	409.5 g
1		1075 g	1075 g	16,368	4.7 g	4.7 g		
							908 l	1362.0 g
2		860 g	1935 g	11,904	5.4 g	10.1 g		
							900 l	2070.0 g
3		860 g	2795 g	9,884	5.1 g	15.2 g		
							900 l Added H ₂ O	2790.0 g
							1115 l	2787.5 g
4		860 g	3655 g	8,928	4.7 g	19.9 g	1072 l	3108.8 g
5		860 g	4515 g	8,472	3.2 g	23.1 g	1072 l	3752.0 g
1342 g KOH							888 l	257.5 g
6		860 g	860 g	11,904	4.7 g	4.7 g		
							869 l	995.9 g
7		860 g	1720 g	12,648	4.1 g	8.8 g	809 l	1618.0 g
2015 g KOH							941 l	1787.9 g
8		860 g	2580 g	11,160	4.1 g	12.9 g	939 l	2159.7 g
5372 g KOH							968 l	2226.4 g
9		860 g	3440 g	8,472	320.8 g	333.7 g		
							942 l	2637.6 g
10		860 g	4300 g	14,880	67.6 g	401.3		
							939 l	3474.3 g
11		860 g	5160 g	12,648	8.1 g	409.4 g	934 l	4483.2 g

solution by the liquid filter. This sludge was not analyzed, but it is reasonable to assume that the chloride concentration of the sludge would be similar to that of the ash.

The amount of chloride remaining in the flue gas after scrubbing was quite low for the majority of the runs. For runs 9 and 10, however, the analytical results show the chloride in the flue gas to be relatively high. The reasons for this are not known. There are two plausible explanations: sampling-analytical error and, most likely, contamination of the sample scrubber solution. The very dilute nature of the chloride/scrubber solution would make minute contamination significant.

The scrubber solution was permitted to drop into the acid range during runs 7 and 8. The chloride content of the flue gas was low for both of these burns, but it has been speculated that the drop in pH or subsequent addition of KOH to raise the pH triggered a chloride release, either on the following run or which at least appeared on the following run analysis.

No chloride samples taken before or after this series of runs (since the present scrubber system has been in place) had flue gas chloride contents nearly as high as that given for run #9. Periodic monitoring of the flue gas for chloride content will continue.

Milestone D: Determination of equipment life

Samples of Hastelloy C, Carpenter 20, titanium alloy (5 Al, 2.5 Sn), and stainless steel types 304 and 347 were positioned in the secondary residence chamber

for 16 hr of incineration runs. The titanium alloy could not withstand the conditions in the chamber and was completely consumed. The samples of types 304 and 347 stainless steel were about one-half gone, and the Hastelloy and Carpenter 20 had only surface corrosion.

The 304 stainless steel was used, in this experiment, as a comparison standard because corrosion rates were obtained for 304 under these conditions [1]. As can be seen, the Carpenter 20 and Hastelloy C were superior to both the 304 and 347 stainless steels.

According to literature and consultation information, Hastelloy X and 188 are expected to withstand this environment. Samples were ordered and will be installed in the residence chamber next quarter.

Milestone review

Table 4 shows in which quarterly report of the TRU Waste Cyclone Drum Incinerator and Treatment System project each milestone is discussed. The milestone chart is given in Table 5.

The current status of each milestone is as follows: A) the incinerator demonstration will continue throughout the duration of the project. B) Continuous feeding experiments will continue in FY-1978. Volume throughput and incineration rates of various feeds have been completed, although updating will continue. C) Overall volume reduction determinations have also been completed and updating, when considered necessary, will continue. D) The investigation of appropriate incinerator construction materials will continue throughout FY-1978. E) Liquid treatment methods have been started and

Table 4 - MILESTONE REPORTING IN FY-1977 QUARTERLY REPORTS

<u>Milestone</u>	<u>Oct-Dec</u>	<u>Jan-Mar</u>	<u>April-June</u>	<u>July-Sept</u>
A	X	X		
B			X	X
C			X	
D	X	X	X	X
E	X	X	X	
F	X	X	X	

Table 5 - MILESTONE CHART FOR TASK I: CYCLONE INCINERATOR DEVELOPMENT

ACTIVITY	CURRENT YEAR				BUDGET YEAR			
	FY-1977				FY-1978			
A. Demonstration of Cyclone Incinerator	▲			▲				
B. Definition of Operational Capabilities		▲		▲				
C. Determination of Overall Volume Reduction	▲			▲				
D. Determination of Equipment Life	▲			▲				
E. Determination of Method to Treat Liquids			▲	▲				
F. Demonstration of Chamber Containment System		▲		▲				
G. Operation of Cyclone Incinerator					▲			▲
H. Off-Site Application of Incineration Concept					▲			▲
I. Upgrading of Incinerator System					▲			▲

will be completed in FY-1978. F) Installation of the containment system has been completed except for the drum extinguishing system which is expected to be finished the first quarter of FY-1978.

Task II: Waste immobilization

The objectives of this task are to evaluate various immobilization methods and to determine the existing and newly developing criteria for accepting immobilized

waste product forms (low/intermediate-level TRU-contaminated waste) for interim storage and terminal isolation. In addition, this program has as its objectives the development of processes to effectively immobilize various waste residues such as sludges, resins, absorbents, and incinerator ash.

Concrete vs. pressed pellets

The major effort the past quarter was the comparison of concrete and cold pressed pellets as waste immobilization forms. Portland type 1A and Luminite* cement were mixed with cyclone incinerator ash and pressed into pellets or cast as concrete. All samples were 0.5-in. diameter cylinders. Water was used as a binder for both forms. Table 6 shows the mixtures that were used. Water used is not expressed as a weight percent; water content is proportional to the weight percent cement used in the respective mixtures and is expressed as a water/cement ratio. Pellets were pressed at 25,000 psi.

CRUSH STRENGTH

Tables 7 and 8 show the crush strengths of cast concrete and pressed pellet samples. Each value listed is an average of two samples. The samples were crushed in a FORNEY model FT-21 compression tester. The compression tester has a lower gauge detection limit of 400 lb. Samples of concrete mixtures C, D, E, and F had crush strengths below the 400-lb detection limit. "Dry" cured samples were cured at room temperature and atmosphere whereas "wet" cured samples were cured

in a high-humidity atmosphere. Concrete samples were cured for a minimum of 28 days, and pressed pellets were cured for a minimum of seven days. Wet and dry cured samples of each mixture were sintered at 800°C for 1 hr to prove nonflammability. Crush strengths of heated samples were determined. Data listed in Tables 7 and 8 for heated samples are for those that were dry cured only; however, wet cured samples behave in a like manner.

LOADING RATE

Loading rate in this report is defined as the grams of ash immobilized per cubic centimeter of the total matrix. Geometric measurements were used to determine volumes (Table 9). Loading rates are virtually identical for both portland and Lumnite cement. Loading rates can be increased by pressing at pressures greater than 25,000 psi. Additional pellet pressings at higher pressures are planned to investigate the further reduction of fines clinging to the pellet surface.

MECHANICAL STRENGTH

Cylindrical cast concrete and pressed pellet samples were placed in stainless steel containers which were clamped into a model BT Burrell 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 100 hr, and the percent weight loss was determined (Table 10).

Wet cured samples of concrete mixtures were placed directly into the stainless

*Trademark of the Atlas Cement Company.

*Trademark of Burrell Corporation.

Table 6 - PELLET MIXTURES AND WATER CONTENT

Mix	Cement (wt %)	Ash (wt %)	Water Content	
			Pressed pellets Water/cement ratio	Concrete Water/cement ratio
A	70	30	0.10	0.55
B	60	40	0.12	0.80
C	50	50	0.16	0.98
D	40	60	0.19	1.52
E	30	70	0.29	1.83
F	20	80	0.70	2.76
		Bone Char (wt %)		
G	60	40	-	0.48
H	50	50	-	0.50
		Sludge (wt %)		
I	65	35	-	0.43
J	58	42	-	0.58

Table 7 - AVERAGE CRUSH STRENGTH OF CAST CONCRETE SAMPLES

Mix	Crush Strength of Portland Cement (psi)			Crush Strength of Lumnite Cement (psi)		
	Dry Cure	Wet Cure	800°C 1 hr	Dry Cure	Wet Cure	800°C 1 hr
A	3622	3205	3547	3725	3665	3657
B	3519	3228	3508	3659	3640	3619
C	a	a	a	3591	3670	3604
G	3638	3654	3498	3620	3549	3580
H	3587	3619	3538	3633	3554	3510
I	3636	3649	3582	-	-	-
J	a	-	-	3681	3630	2507

^a Failed to reach lower limit of compression tester.

Table 8 - AVERAGE CRUSH STRENGTH OF PRESSED PELLET SAMPLES

Mix	Crush strength of Portland Cement (psi)			Crush Strength of Lumnite Cement (psi)		
	Dry Cure	Wet Cure	800°C 1 hr	Dry Cure	Wet Cure	800°C 1 hr
A	3690	4698	3569	3553	4425	3527
B	3665	4440	3604	3545	4079	3527
C	3672	3980	3604	3571	4008	3579
D	3672	3900	3614	3609	3829	3604
E	3662	3838	3619	3614	3786	3614
F	3984	3723	3985	3617	3641	3614

Table 9 - LOADING RATES

<u>Mix</u>	<u>Ash/Matrix Loading in Cast Samples (g/cm³)</u>	<u>Ash/Matrix Loading in Pressed Pellets (g/cm³)</u>
A	0.41	0.62
B	0.51	0.85
C	-	1.00
D	-	1.17
E	-	1.32
F	-	1.50

Table 10 - COMPARATIVE MECHANICAL STRENGTH AS DETERMINED
BY WEIGHT LOSS DURING 100-HOUR SHAKE TEST

<u>Mix</u>	<u>Wt Loss from Cast Concrete (%)</u>		<u>Wt Loss from Pressed Pellets (%)</u>	
	<u>Dry Cure</u>	<u>Wet Cure</u>	<u>Dry Cure</u>	<u>Wet Cure</u>
A	0.928 ^a	8.730 ^a	1.78	0.708
B	1.658 ^a	13.840 ^a	1.31	0.663
C	-	-	1.32	0.954
D	-	-	2.280	0.745
E	-	-	3.70	0.801
F	-	-	5.062	0.786
G	2.640	10.37	-	-
H	0.664	10.86	-	-
I	1.05	13.58	-	-

^aAverage of three samples. Remaining samples are of a single determination.

steel containers; consequently, a large portion of the weight loss is from water evaporation. Wet cured pellet samples were dried at room temperature for 72 hr. As a result, the disparity between wet and dry cured samples is not as evident. All the samples experienced a slight rounding of the edge that contacted the bottom of the stainless container, and abrasion occurred on the walls of the samples. Visual examination showed no cracks in any of the samples.

LEACH RATES

Concrete and pellet samples of nonradioactive mixtures A through J were suspended in distilled water for leach rate determinations. The leach rate (Table 11) is expressed as a percent weight loss derived by boiling the leachant to dryness and weighing the residue. The leachant was changed weekly. However, the results in Table 11 are expressed as monthly totals. All samples listed in Table 11 were fabricated using portland cement. Initial data indicate that samples fabricated with Lumnite cement have higher leach rates.

WATER CONTENT

Radiolysis of water contained in packaged radioactive wastes causes gas production and possible pressure problems. These problems could be minimized by using pressed pellets as a waste form for incinerator ash immobilization. The water/cement (w/c) ratios illustrated in Table 6 for concrete and pellet mixtures A through F show that a much greater amount of water is required for concrete immobilization than is required for pellets. Pressed pellets require 48 hr of curing

to reach their maximum strength. Cast concrete requires several days. After the 48-hr cure, pellets can be heated to 110°C for 1 hr thus reducing the water content, as determined by weight differences, to less than 1% by weight. Moisture contents of pellets will be determined by analytical methods next quarter.

BONE CHAR/SLUDGE

Work has continued on the immobilization of bone char and sludge as illustrated in Tables 6, 7, 10, and 11. Bone char and sludge have been mixed with cement and pressed into pellets on a limited basis, to date, but this work is expected to be expanded next quarter.

Pilot plant

Plans were drawn and construction began on a glovebox line for the pelletization of incinerator ash/cement mixtures using a small automatic press. The completion date is set for January, 1978. Bone char/cement mixtures will also be pelletized. The expected flow is shown in Figure 2.

Task III: Acceptable TRU Package for interim storage and/or terminal isolation

The program was completed during FY-1977 specifying Conceptual Acceptance and Design Criteria for defense transuranic waste packaging for Interim Storage and/or Terminal Isolation. A contractor questionnaire was used to gather pertinent data. Site visits were made to formulate an integrated contractor consensus; a packaging meeting was held to examine,

Table 11 - COMPARATIVE LEACH RATES AS DETERMINED BY WEIGHT LOSS

Mix	Weight Loss from Cast Concrete (%)				Weight Loss from Pressed Pellets (%)			
	Dry Cure		Wet Cure		Dry Cure		Wet Cure	
	1 month	2 month	1 month	2 month	1 month	2 month	1 month	2 month
A	1.81	0.31	1.86	0.62	2.04	0.755	0.44	
B	3.56	0.454	3.62	0.96	1.92	0.62	0.57	
C	-	-	-	-	1.37	0.50	0.48	
D	-	-	-	-	1.67	0.65	0.42	
E	-	-	-	-	2.0	0.38	0.41	
F	-	-	-	-	2.32	0.39	0.11	
G	2.57	0.80	2.76	2.08	-	-	-	
H	2.09	0.68	3.68	0.87	-	-	-	
I	2.84	0.84	3.52	1.06	-	-	-	
J	-	-	-	-	-	-	-

FIGURE 2 - Pelletization process flow sheet.

discuss, and integrate packaging philosophies; and data collected from these activities and from Task Force meetings were consolidated to provide input to the Basic Application Checklist and Criteria Checklists. Conceptual Design Criteria have now been developed from an analysis and evaluation of the application data against federal regulations and interim/terminal storage constraints. A final report was issued [2].

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2. J. W. Doty and J. B. Peterson, Acceptable TRU Packaging for Interim Storage and/or Terminal Isolation: FY-1977 Final Report, MLM-2489 (January 16, 1978), 10 pp.

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