1 of 1

Mixed Waste Solidification Testing on Polymer and Cement-Based Waste Forms in Support of Hanford's WRAP 2A Facility

D. A. Burbank
K. M. Weingardt

Date Published
October 1993

To be presented at
ASTM Symposium
Williamsburg, Virginia
November 1-5, 1993

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

**Westinghouse
Hanford Company**

P.O. Box 1970
Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Copyright License By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Approved for Public Release

MASTER

OK

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Dewey A. Burbank, Jr.¹ and Kent M. Weingardt¹

MIXED WASTE SOLIDIFICATION TESTING ON POLYMER AND CEMENT-BASED WASTE FORMS IN SUPPORT OF HANFORD'S WRAP 2A FACILITY

REFERENCE: Burbank, D. A., Jr., and Weingardt, K. M., "Mixed Waste Solidification Testing on Polymer and Cement-Based Waste Forms in Support of Hanford's WRAP 2A Facility," American Society for Testing and Materials, 1993.

ABSTRACT: A testing program has been conducted by the Westinghouse Hanford Company to confirm the baseline waste form selection for use in Waste Receiving and Processing (WRAP) Module 2A. WRAP Module 2A will provide treatment required to properly dispose of containerized contact-handled, mixed low-level waste at the U.S. Department of Energy Hanford Site in south-central Washington State. Solidification/stabilization has been chosen as the appropriate treatment for this waste. This work is intended to test cement-based, thermosetting polymer, and thermoplastic polymer solidification media to substantiate the technology approach for WRAP Module 2A.

Screening tests were performed using the major chemical constituent of each waste type to measure the gross compatibility with the immobilization media and to determine formulations for more detailed testing. Surrogate materials representing each of the eight waste types were prepared in the laboratory. These surrogates were then solidified with the selected immobilization media and subjected to a battery of standard performance tests. Detailed discussion of the laboratory work and results are contained in this report.

KEYWORDS: immobilization, stabilization, polymer, cement, grout, polyethylene

INTRODUCTION

A testing program has been conducted by Westinghouse Hanford Company (WHC) to confirm the baseline waste form selection for use in Waste Receiving and Processing (WRAP) Module 2A. WRAP Module 2A will provide treatment required to properly dispose of contact-handled (CH), mixed low-level waste (MLLW) accumulating at the U.S. Department of Energy (DOE) Hanford Site in south-central Washington State. Solidification/stabilization has been chosen as the appropriate treatment for this waste.

The testing used a phased approach consisting of first screening the compatibility of surrogate wastes with the immobilization media and then performing detailed physical and chemical tests on laboratory-prepared surrogate waste forms. This will be followed by testing of surrogate waste form specimens prepared by full-scale mixing equipment.

¹Engineer, Westinghouse Hanford Company, Richland, Washington 99352.

The focus of this first phase of test work is to verify the ability of the conceptual design identified immobilization media to adequately solidify those waste types proposed as feed to WRAP Module 2A [1]. Two matrices for waste solidification have been selected: cement-based materials and thermosetting polymer resins. Thermoplastic polymer (specifically low-density polyethylene) was also investigated due to some perceived advantages over the thermosetting system. Eight different waste types were used for these initial phases of testing. Four of the waste types were tested with grout waste forms, and four waste types were tested with the thermosetting and thermoplastic polymers.

Test criteria for solidified mixed waste were assembled from applicable regulatory documentation [2,3,4], including guidance documents from the U.S. Nuclear Regulatory Commission [5] and the Environmental Protection Agency [6].

Screening tests were performed using the major chemical constituent of each waste type to measure the gross compatibility with the immobilization media. The results of these tests were positive and are discussed later in the report.

Surrogate wastes were then prepared by WHC to represent each of the eight waste types for testing. Surrogates for thermosetting polymer testing were sent to a vendor commissioned for that portion of the test work. Surrogates for the grout testing were used in the WHC laboratory responsible for the grout performance testing. Solidified test specimens were prepared for both the grout and thermosetting polymer waste forms with the surrogate wastes, and tests were performed. Detailed discussion of the laboratory work and results are contained in this report. All grout specimens performed as expected and confirmed baseline process selection. Test results from the thermosetting polymer demonstrated that an adequate product could be made that passed all acceptance criteria. Some negative results were encountered on the leachability of some hazardous constituents (chrome at high waste loadings and mercury). The thermosetting polymer tests also indicated that leaching results for hazardous constituents, as tested by the toxic characteristic leach procedure (TCLP) method, are very dependant on the sample preparation method.

The polyethylene specimens were able to pass TCLP for all heavy metals except mercury in one of the surrogates. It is anticipated that the leaching of higher mercury concentrations in any stabilization media would need to be controlled with the addition of specific mercury stabilizing chemicals.

WASTE TYPES DESCRIPTION AND WASTE FORM SELECTION

A general description of the feedstreams chosen for this test work follows.

Liquid Effluent Treatment Facility Secondary Solids

Two liquid effluent treatment facilities are planned for construction at the Hanford Site. The C-018 Facility and the L-045 Facility will produce several secondary waste streams that may be both radiologically and chemically hazardous. The following are two major waste streams from these facilities.

Ammonium sulfate--The major secondary waste from the C-018 process will be an ammonium sulfate cake produced in an evaporative crystallization process using a thin film evaporator. The high ammonia content of the treatment waste water and the addition of sulfuric acid in the C-018 process led to the formation of ammonium sulfate. This

waste stream will be generally greater than 90 wt% ammonium sulfate with trace regulated contaminants such as chromium and mercury. The waste will be dried before shipment out of the C-018 Facility.

Metal sludge--The L-045 Facility will use a co-precipitation process to remove dissolved contaminants. An iron hydroxide is the baseline precipitation agent in the process. The precipitates are assumed to include various soluble metal contaminants that will be regulated. The sludge will be filtered and possibly dried before shipment from the L-045 Facility.

183H Solar Basin Waste

The 183H Solar Evaporation Basins were used to reduce waste by natural evaporation of liquid chemical wastes generated as part of reactor fuel fabrication activities. The liquid waste discharged to the four concrete basins consisted primarily of spent acid etch solutions (sulfuric, nitric, hydrofluoric, and chromic acids). This waste was generally neutralized with sodium hydroxide before discharge to the basins. The wastes contained various metallic contaminants. Several types of nonroutine wastes were also discharged to the basins. The basins eventually ceased accepting waste and subsequently were found to have failed and leaked. A timely cleanup and closure of the basins was then pursued. The following waste streams from this cleanup were included in this testing program.

183H Crystalline solid--The evaporation of the liquid waste also produced a crystalline solid consisting mostly of salts of nitrate, sulfate, fluoride, and sodium. These wastes were removed from the basins and packaged in poly-lined 208-L (55-gal) drums without further treatment.

183H Sludge--The remaining fraction of waste in the 183H Basins was a sludge-like material consisting of a mixture of mostly sodium sulfate and sodium nitrate. This fraction was also relatively high in copper content and had more apparent water content than the other wastes (thus its sludge-like consistency). The sludge was packaged in drums with an absorbent material, but had no further treatment.

183H Miscellaneous cleanup--After removal of the waste from the basins, contamination remained on the concrete floors and walls. These areas were sandblasted to remove this contamination, resulting in another waste form. Also, cleanup of tumbleweeds and various tools and structures used in the operation were packaged as additional waste.

Ash From Thermal Treatment

This waste will be produced by the proposed thermal treatment facility for organic mixed waste. The ash residue from this process may need to be treated to account for residual contamination in the waste or to meet treatment standards for mixtures of waste types.

Table 1 shows the specific waste types and selected waste forms.

TABLE 1--Treatability testing waste types and waste forms.

Test ID	Title	Cement-Based Testing	Polymer Testing
Type 1	C-018 Ammonium Sulfate	Yes*	Yes
Type 2	183H Sludge (Basins #1 and #2)		Yes
Type 3	183H Sludge (Basins #3 and #4)		Yes
Type 4	183H Crystalline Solid		Yes
Type 5	183H Misc. Clean-up (High Cu)	Yes	
Type 6	183H Misc. Clean-up (High NO ₃)	Yes	
Type 7	L-045 Metal Sludge	Yes	
Type 8	Ash from Thermal Treatment	Yes	

*Envirostone - A trademark of the American Gypsum Company.

Table 1 shows that several of the feedstreams were split into numerous waste types for testing to group wastes with similar chemical constituents. The first four waste types were chosen for testing with the polymer because of their high soluble salt content (including high nitrate content), which is known to cause problems with cement solidification. Waste types 5 through 8 were chosen for testing with cement waste forms because they do not contain a high content of any constituents that interfere with cement solidification.

Type 1 waste demonstrates a special problem with cement; that is, the ammonium sulfate would react with the high pH solutions in ordinary portland cement, evolving ammonia gas. Envirostone,² a gypsum-based cement that exhibits a neutral pH, was selected as an alternative to ordinary portland cement for this waste stream.

Surrogate formulas for each of the eight feedstreams were developed and then prepared in the WHC laboratories. Table 2 shows approximate compositions for the surrogates.

Test Selection and Acceptance Criteria

The main objective of the waste treatability testing is to demonstrate the successful treatment of CH-LLMW feed streams using the technologies proposed for use in WRAP Module 2A. To demonstrate successful treatment, the final waste forms must be subjected to numerous tests to show compliance with all applicable regulatory requirements. Table 3 summarizes the tests that were performed and the performance acceptance criteria. The tests were selected to cover a broad spectrum criteria that could be imposed on the final waste form. The acceptance criteria are composed of a conservative set of tests and requirements that were compiled from several sources including the U.S. Nuclear Regulatory Commission [7], U.S. Environmental Protection Agency [3,5,6], Washington State Department of Ecology [3], and Hanford Site specific solid waste acceptance criteria [7].

²Envirostone is a trademark of American Gypsum Company.

TABLE 2--Surrogate wastes approximate composition.

Component	Waste Type 1 LETF Salts	Waste Type 2 Basins #1, #2 Sludge	Waste Type 3 Basins #3, #4 Sludge	Waste Type 4 Basin Crystal Solids
Silver (ppm)		218	190	
Barium (ppm)			24	100
Beryllium(ppm)		6	2.3	
Cadmium (ppm)			6	
Chromium (ppm)	187.5	900	390	500
Copper (ppm)	201.0	130 000	112 000	63 000
Mercury (ppm)	9.2	1.3		
Nickel (ppm)	46.5	100	130	400
Subtotal (ppm)	444.20	131 225.30	112 742.30	64 000.00
Ammonium (%)	22.83			
Fluoride (%)		6.0	1.3	7.1
Nitrate (%)	1.1	13.5	26	1.6
Sodium (%)		20.0	24	22.9
Sulfate (%)	64.61	20.2	3.7	35.5
Water (%)	10.0	21.58	25.03	24.5
Subtotal (%)	98.54	81.28	80.03	91.60
Inerts (%)	1.42	5.6	8.7	2.0
Total (%)	100.00	100.00	100.00	100.00

Waste Surrogates for Cement Testing:

Type 5 - 90% Sandblast Grit w/10% Type 2 similar contamination.*

Type 6 - 90% Sandblast Grit w/10% Type 4 similar contamination.*

Type 7 - 98.7% Ferric Oxide Reagent, 1.3% Sodium Sulfide, 0.7% Polymer Flock.*

Type 8 - 90% Fly Ash, 8% Clay, 2% Sand.*

*Trace contaminants and concentrations used for cement testing surrogates are detailed later in the report on the table reporting results for solidified product leach testing.

TABLE 3--WRAP Module 2A waste form performance specifications.

Waste Form Characteristic	Test Method	Acceptance Criteria
Compressive Strength	ASTM D695 or ASTM C39	Strength > 500 psi
Leachability Index	ANS 16.1	Leach Index > 6
Biodegradation	ASTM G21 and G22, ASTM D695 or ASTM C39	No growth, Strength > 500 psi
Thermal Cycling	ASTM B553, ASTM D695 or ASTM C39	Strength > 500 psi after 30 thermal cycles
Radiation Stability	ASTM D695 or ASTM C39	Strength > 500 psi after irradiation to 10^8 rad
Immersion	ASTM D695 or ASTM C39	Strength > 500 psi after 90-day water immersion
Free Liquids	ANS 55.1	Free liquid < 0.5%
Hazardous Characteristics	40 CFR 261	Not ignitable, not corrosive, not reactive
Toxicity Characteristics	EPA 1311 (TCLP), EPA 6010	TCLP leachable constituents below EPA limits*

NOTE: Multiply psi by 0.07031 to obtain kg/cm².

*EPA limits as described in 40 CFR 268.41, Table CCWE.

ASTM = American Society for Testing and Materials

ANS = American Nuclear Society

EPA = U.S. Environmental Protection Agency.

Testing Description and Results

The waste treatability test work for WRAP Module 2A is using a phased approach. Test work can be broken down into three phases.

- Phase 1. Screening tests - Screening of waste form compatibility with waste types.
- Phase 2. Surrogate performance testing - Detailed testing of waste forms produced on a laboratory scale with surrogate waste.
- Phase 3. Full-scale and advanced laboratory studies aimed at developing chemical and physical operating parameters for the selected processes, which is not covered by this report.

Phase 1: Screening tests - cement-based waste forms--The cement-based waste form screening was performed in WHC laboratories to test the raw compatibility of the waste chemicals with cement and to narrow in on the best type of cement formulation, given a specific waste type. Several types of cements and various formulations (waste loadings) were used with each waste type, and setting characteristics were observed. Table 4 lists the selected cement formulations based on these screening tests.

TABLE 4--Cement binder formulations from screening tests.

	Type 1	Type 5	Type 6	Type 7	Type 8
Waste	Ammonium sulfate 11.5 wt%	Grit/Sludge 41.7 wt%	Grit/Solids 41.7 wt%	Ferric oxide 15.4 wt%	Ash mix 30.0 wt%
Primary binding agent	Envirostone 57.5 wt%	Type III 41.6 wt%	Slag cement 37.5 wt%	Type III 42.6 wt%	Slag cement 40.5 wt%
Additive 1	Citric acid 1.1 wt%	-	Type III 4.2 wt%	-	Type III 4.5 wt%
Additive 2	Sodium bicarb. 1.1 wt%	-	-	-	-
Water	28.7 wt%	16.7 wt%	16.7 wt%	38.5%	25 wt%

Some special complications were discovered through the fast set characteristics exhibited by the Envirostone when mixed with an ammonium sulfate (Type 1). The set occurred too rapidly to be of use in a typical mechanical mixer. A slow set Envirostone was tried with little or no success; however, the use of citric acid or sodium citrate retarders were successful.

Phase 1: Screening tests - thermosetting polymer waste form--
Screening tests for the thermosetting polymer immobilization process were performed at a private vendor's (Diversified Technologies) rented laboratory space at Saginaw Valley State University. Fifteen screening tests were performed using Diversified Technologies vinyl ester polymer immobilization process. The technique was observed by the attenders and videotaped by WHC. The materials that were solidified were intended to represent the major chemical characteristics of the wastes selected for thermosetting polymer testing and some waste samples that the vendor had prepared for demonstration. The materials that were solidified included reagent grade sodium nitrate, ammonium sulfate, and hydrated sodium sulfate (major chemical constituents of waste being treated with polymer). The chemicals were used in both wet and dry form and in combination with diatomaceous earth to simulate both crystalline and sludge-type material.

All specimens gelled within a short period of time (approximately 1 to 10 minutes) and reached full strength and hardness within 30 minutes. The process successfully immobilized sodium nitrate and ammonium sulfate at 60 wt% loading with no apparent side reactions. The samples that contained hydrated sodium sulfate crystals exuded some free liquid during the curing exotherm of the polymer (as much as 2 wt%). This occurred both with wet and dry waste loadings.

Formulation development tests were then performed by Stock Equipment Company to obtain a qualitative measure of waste loading capacity, chemical compatibility, and free water generation. The initial trials were successful for Type 1 and Type 3 surrogates. Additional investigation of Type 2 waste revealed that the pH of the surrogate did not resemble the actual waste. The pH of Type 2 surrogate was adjusted to 10.5 to more closely resemble the actual waste, and a

suitable formulation was developed for Type 2 and 4 waste using a different binder material. Table 5 summarizes the formulations that were used to prepare the waste form specimens.

TABLE 5--Polymer formulation parameters.

Formulation Parameter	Type 1	Type 2	Type 3	Type 4
Waste/Binder ratio, Kg/Kg	4/2	3/3	4/2	3/2
Binder type	A*	B*	A*	B*
Catalyst dose, wt% of binder	2.5	7.5	2.5	5.0
Promoter dose, wt% of binder	0.1	2.0	0.1	1.0
Total mixing time, minutes	25	8.5	8.5	10.5
Peak mixing power, watts	45	12.3	9.9	13.9
Peak exotherm, degrees C	38.2	70	57.5	63
Peak exotherm time, minutes	75	30	120	25

*Note: The use of 'A' and 'B' denotes that two different binders were used for this test work to accommodate the waste types.

Phase 2: Surrogate Performance Tests - Cement-Based Waste Form Results. The cementitious waste forms were prepared by combining the waste surrogates and the cementitious binders according to the formulations developed during the screening tests. The surrogate material and the cementitious binder were measured into a 18.9-L (5-gal) capacity, heavy duty Hobart variable mixer, where they were mixed until a homogeneous mixture was obtained. A minimum of 9.5 L (2.5 gal) of cement-waste slurry was required for each set of experiments. For each waste type tested, a cement-waste slurry was prepared in three batches and poured out separately into the appropriate sized molds. Sample molds included 5-cm by 5-cm (2-in. by 2-in.) cubes, small cylinders (7.6 cm [3 in.] diameter by 15.2 cm [6 in.] high), and large cylinders (15.2 cm [6 in.] diameter by 30.5 cm [12 in.] high). The wet specimens were covered with plastic or placed in plastic bags to simulate placement in a 208-L (55-gal) drum or another sealed container. The cube samples were removed from their metal molds after approximately 3 days. The samples were labeled and placed in plastic bags at room temperature until the appropriate cure time was achieved. After curing, the samples were weighed and then tested. The cylinders were kept in their molds and covered until tested. Cement controls (no waste) were made for compression strength reference. Tables 6 and 7 describe the results of the tests.

TABLE 6--Cement-based waste form results.

Waste Type	Compressive Strength* (psi)	Radiation Stability	Biodegradation	Leach Index	Water Immersion 14/42/90 days	Thermal Cycle
Control	7 400/4 500	-	-	-	-	-
5	7 100/5 400	8 500/ 9 100	10 300	12.2 (Ru)	8 900/ 3 900/ 8 400	5 500/ 8 000
6	3 500/4 200	3 800/ 4 800	6 100	12.7 (Co)	5 300/ 2 600/ 5 500	4 000/ 4 400
7	2 800/2 100	2 500/ 2 000	3 100	9.7 (Na)	2 400/ 1 100/ 3 000	2 200/ 2 400
8	3 400/2 400	4 100/ 3 900	4 600	12.7 (Ru)	3 900/ 2 500/4 380	2 900/ 3 100
1	<50/70	35/<50	>50	9.9 (Ce)	failed	>50/50

NOTE: Multiply psi by 0.07031 to obtain kg/cm².

*Compressive Strength reported for small cylinder/large cylinder per ASTM Standards specified in Performance Specifications - large cylinder specific to cement forms.

TABLE 7--TCLP results for WRAP Module 2A cement waste forms.

Waste Type	Species	Orig. Cont.	TCLP Cont.	Limit	Pass/Fail
5	Chromium	50 ppm	0.07 ppm	5 ppm	Pass
	Copper	1.7%	0.09 ppm	No limit	N/A
6	Chromium	50 ppm	<0.02 ppm	5 ppm	Pass
7	Chromium	100 ppm	<0.03 ppm	5.0 ppm	Pass
	Mercury	100 ppm	<0.1 ppb	0.2 ppm	Pass
8	Barium	100 ppm	0.05 ppm	100 ppm	Pass
	Cadmium	100 ppm	<0.01 ppm	1.0 ppm	Pass
	Chromium	500 ppm	0.3 ppm	5.0 ppm	Pass
	Lead	100 ppm	<0.12 ppm	5.0 ppm	Pass
	Mercury	100 ppm	0.5 ppb	0.2 ppm	Pass
	Selenium	100 ppm	<0.12 ppm	1.0 ppm	Pass
1	Silver	100 ppm	<0.02 ppm	5.0 ppm	Pass
	Chromium	700 ppm	4.0 ppm	5.0 ppm	Pass
	Mercury	10 ppm	0.3 ppb	0.2 ppm	Pass
	Nickel	50 ppm	0.25 ppm	No limit	Pass

The results indicate that the formulations developed in Phase I were successful at immobilizing each of the waste types, with the exception of the ammonium-sulfate waste. The waste forms produced from waste types 5, 6, 7, and 8 contained no free water, exhibited

compressive strengths well above what is required, and passed the TCLP tests. These waste types will be further evaluated for grout processing in WRAP Module 2A.

Phase 2: Surrogate performance testing - thermosetting polymer waste form. Polymer waste forms testing was performed at vendor facilities (Stock Equipment Company). Solidified test specimens were prepared from waste surrogates in a batch size of approximately 4.7 L (1.25 gal). A variable speed lab mixer with propeller blades operating at 1 800 rpm was used. Each set of specimens was made from a single batch and poured into cylindrical molds. The tests described above were performed on the specimens. Replicate tests were also performed.

Table 8 summarizes results of the testing. All specimens were successfully immobilized and exhibited strength and durability characteristics meeting or exceeding the waste form performance specifications. Type 3 surrogate met all of the performance specifications. Leaching characteristics for all surrogates met the requirements for low-level waste, but some TCLP constituents of types 1, 2, and 4 surrogates exceeded the allowable limits.

The TCLP results prompted additional work to develop formulations that could meet the regulatory limits for chromium and mercury. Additional testing was performed using waste loading of 25 wt%. Three methods for preparing the TCLP extraction specimens were investigated. One method involved casting pellets from the mixture so no size reduction was required. The other two methods used larger specimens, which were crushed to meet the size requirements for TCLP; all material was extracted for one method, and the other method discarded fines less than 1-mm screen size prior to extraction.

Both crushing methods were unable to meet TCLP limits for mercury. The pellet method passed for all TCLP constituents present. The use of reduced waste loadings was successful in decreasing the concentrations of TCLP metals observed in the waste extracts, but the sample preparation method apparently has a larger influence on the final results than waste loading. Further investigation is planned to address these concerns.

Follow On Testing: Thermoplastic Polymer Waste Form

Although not included in the conceptual design for WRAP Module 2A, polyethylene waste form performance was investigated due to perceived processing advantages over the thermosetting polymer. The approach utilized a heated extruder to melt and mix the low-density polyethylene with the surrogate materials. This follows the approach previously demonstrated in support of Rocky Flats Nitrate Salt waste [8]. Screening tests were not performed due to successful demonstration on similar waste types in the Rocky Flats program. Physical properties of the waste form was also expected to be similar, therefore, testing has concentrated on the leachability of the heavy metal constituents.

Solidified specimens were prepared using the Rocky Flats laboratory extruder and the same waste surrogates used for thermosetting polymer tests. Calcium oxide was added to the higher waste loading specimens to help control the leachability of some of the heavy metals. TCLP tests were run on strands of the solidified PE/waste mixture that had been cut to meet the 3/4 inch size requirement.

Table 9 presents a summary of all TCLP test data obtained to date for polymer waste forms. Polyethylene results indicate generally better performance than VES for all metals except mercury, where the performance is roughly the same. Calcium oxide does not appear to effect the leachability of mercury.

TABLE 8--Summary of polymer waste form testing results.

Waste Form Characteristic	Acceptance Criteria	Test Results			
		Type 1	Type 2	Type 3	Type 4
Compressive Strength	Strength > 500 psi	2 472 psi	1 085 psi	1 411 psi	942 psi
Leachability Index	Leach Index > Cs	7.7/7.4	7.0/7.0	7.3/7.2	7.1/7.1
	6 Co	8.2/7.9	9.2/9.3	10.1/10.3	7.5/7.7
	Demin/Seawater Sr	8.9/8.7	9.3/9.1	10.2/9.4	9.1/9.0
Biodegradation	No growth, Strength > 500 psi	No Growth	No Growth	No Growth	No Growth
Thermal Cycling	Strength > 500 psi	2 247 psi	3 710 psi	994 psi	1 114 psi
	after 30 thermal cycles	5 111 psi	640 psi	990 psi	850 psi
Radiation Stability	Strength > 500 psi after irradiation to 10 ⁸ rad	5 127 psi	6 028 psi	964 psi	2 575 psi
Immersion	Strength > 500 psi after 90-day immersion	1 114 psi/ 1 151 psi	1 034 psi/ 842 psi	1 048 psi/ 952 psi	981 psi/ 1 028 psi
Free Liquids	Free liquid < 0.5%	Pass	Pass	Pass	Pass
Hazardous Characteristics	Not ignitable, not corrosive, not reactive	Pass	Pass	Pass	Pass
	TCLP leachable metals below EPA limits (parts per million)	N/A*	N/A	0.511 pass	0.183 pass
Toxicity Characteristics	Ba 100	N/A	N/A	0.270 pass	N/A
	Cd 1.0	2.43 pass	9.61 fail	4.65 pass	8.88 fail
	Cr 5.0	1.65 fail	1.54 fail	N/A	N/A
	Hg 0.2	N/A	0.355 pass	0.397 pass	N/A
	Ag 5.0				

NOTE: Multiply psi by 0.07031 to obtain kg/cm².

*N/A = Not applicable.

TABLE 9--WRAP 2A polymer testing TCLP results.

TCLP Results		VES				PE	
Waste Loading		25%	50%	60%	66%	40%	50% +CaO
Size Red. Method		pellet	crush	crush	crush	string	string
Type 1	Cr	0.275			2.43	0.098	0.054
	(5.0)	pass			pass	pass	pass
Stream 2A-1	Hg	0.182			1.65	0.442	1.07
	(0.2)	pass			fail	fail	fail
Type 2	Ag	0.045	0.355			<0.010	<0.010
	(5.0)	pass	pass			pass	pass
Stream 1C	Cr	1.76	9.61			1.650	1.770
	(5.0)	pass	fail			pass	pass
	Hg	0.194	1.54			0.122	0.107
	(0.2)	pass	fail			pass	pass
Type 3	Ag				0.397	0.015	<0.010
	(5.0)				pass	pass	pass
Stream 1C	Ba				0.511	<0.200	<0.200
	(100)				pass	pass	pass
	Cd				0.270	<0.005	<0.005
	(1.0)				pass	pass	pass
	Cr				4.65	2.740	1.900
	(5.0)				pass	pass	pass
Type 4	Ba	0.022		0.183		<0.200	<0.200
	(100)	pass		pass		pass	pass
Stream 1B	Cr	2.03		8.88		0.200	0.450
	(5.0)	pass		fail		pass	pass

CONCLUSIONS

The immobilization/stabilization technologies selected for use in WRAP Module 2A have been tested on waste surrogates reflecting the chemical characteristics of 80% of the baseline feed volume. The baseline process selection has been confirmed for the feed streams studied. Suitable formulations have been developed and waste form performance testing has shown that the technologies are capable of meeting all applicable regulatory acceptance criteria.

Cementitious grout formulas based on type I and type III portland cement, type S slag cement, or blends of these materials have been developed for four baseline waste streams. Performance test results met or exceeded all waste form performance specifications. Attempts to develop a gypsum-based formulation for the ammonium sulfate waste surrogate were unsuccessful.

Thermosetting polymer formulations have been developed for four additional baseline waste streams. Waste surrogates were successfully immobilized at waste loadings from 50 wt% to 66 wt%. Performance test results met all specifications except TCLP for chromium and mercury. Specimens prepared with a 25 wt% waste loading met TCLP limits for all constituents. TCLP results for polymer waste forms were shown to be highly dependent on the method used for TCLP sample preparation.

Polyethylene waste forms have been produced that perform similarly or slightly better than VES for the TCLP. In both cases it appears that wastes forms containing higher concentrations of mercury will need to incorporate specific additives to decrease the solubility of mercury under TCLP conditions.

REFERENCES

- [1] UE&C, WRAP Module 2A Conceptual Design Report, United Engineers and Constructors, Englewood, Colorado, 1992.
- [2] NRC, Technical Position on Waste Form, Revision 1, Final Waste Classification and Waste Form Technical Position Papers, U.S. Nuclear Regulatory Commission, Washington, DC, 1991.
- [3] EPA, Handbook for Stabilization and Solidification of Hazardous Wastes, U.S. Environmental Protection Agency, Washington, DC, 1984.
- [4] Washington Administrative Code, "Dangerous Waste Regulations," WAC-173-303, Washington State Department of Ecology, Olympia, Washington, 1991.
- [5] Code of Federal Regulations, 40 CFR 260-268, Office of the Federal Register National Archives and Records Administration, Washington, DC, 1989.
- [6] Code of Federal Regulations, 10 CFR 61, Office of the Federal Register National Archives and Records Administration, Washington, DC, 1992.
- [7] Willis, N. P., Hanford Site Solid Waste Acceptance Criteria, WHC-EP-0063-3, Westinghouse Hanford Company, Richland, Washington, 1991.
- [8] Tyler, R. W., S. A. Anderson, and T. L. Rising, Land Disposal Restriction (LDR) Waste Management Strategy at Rocky Flats, Proceedings of the Second International Mixed Waste Symposium, A. Alan Moghissi et. al (eds.), Temple University, August 17-20, 1993.

DISTRIBUTION

Number of copies

ONSITE

10

Westinghouse Hanford Company

D. A. Burbank	H1-60
C. E. McDonald (5)	G6-46
K. M. Weingardt	H1-60
Information Release	
Administration	L8-07
Document Processing	
and Distribution (2)	L8-15

**DATE
FILMED**

1 / 24 / 94

END