PLANNED CHANGES FOR THE NATIONAL HIGH-LEVEL WASTE FORM VITRIFICATION SPECIFICATIONS FOR NATIONAL VITRIFICATION OPERATIONS AND RECENT WASTE FORM PRODUCTION DATA

Denis J. Koutsandreas
The Department of Energy
Office of Environmental Management, Office of Eastern Operations, EM-32
January 1999

ABSTRACT

The Department of Energy (DOE) Office of Environmental Management (EM) developed the Waste Acceptance Product Specifications (EM-WAPS) for High-Level Waste (HLW) form processing/production as the basis for EM's waste acceptance program. This paper provides: a brief listing of the more significant required HLW regulatory technical specifications; a short summarization of HLW glass Product Consistency Test (PCT) production test results to date; HLW canister production and scheduled production; and EM-WAPS changes planned in the next 12 months.

INTRODUCTION

The DOE Office of Environmental Management (EM) developed the Waste Acceptance Product Specifications (EM-WAPS) for the HLW[a] form Producers[b] as the basis for their waste acceptance programs. The EM-WAPS are the top technical specifications the HLW form Producers are required to meet in order to ensure acceptance of their vitrified HLW into the DOE Office of Civilian Radioactive Waste Management's (RW) Civilian Radioactive Waste Management System (CRWMS) for ultimate disposal in a repository. Originally, RW intended to provide HLW specifications when the waste acceptance process was first defined in 1985. However, RW has not completely defined, in detail, all HLW specifications. Most HLW processing requirements are sufficiently defined to allow production, however, further clarification is needed for some specifications. RW is currently refining its technical and functional baseline, as necessary, to comply with applicable laws as they are enacted or revised and/or as new scientific information concerning HLW glass waste forms becomes available and is accepted by the scientific community. RW has opted to pass to EM the responsibility for providing product specifications to the waste form Producers. EM ensures that the EM-WAPS are in concert with the RW technical baseline, as defined in the Civilian Radioactive Waste Management System Requirements Document (CRD) (1) and the EM and RW comprehensive Memorandum of Agreement for Acceptance of Department of Energy Spent Nuclear Fuel and High-Level Radioactive Waste (MOA) (2). The EM-WAPS is a living document and is revised, as necessary, to reflect relevant changes to the DOE's HLW mission and Congressional policy. Past EM-WAPS changes have been based upon: modifications or enactment of relevant national and international HLW laws, regulations, and requirements; response to DOE HLW Producer processing requirements; and HLW customer (RW) requirements including changes to the CRD and/or the MOA. The EM-WAPS govern all elements of the canistered waste form.

These elements include: the borosilicate waste glass; the stainless steel canister; and the sealed canistered waste form. The EM-WAPS also provide quality assurance requirements which must be imposed on HLW form production, and specifications outlining waste Producer, DOE-EM and DOE-RW Waste Acceptance documentation requirements.

MAJOR EM-WAPS HLW SPECIFICATIONS

The HLW specifications may be broadly divided into five parts: chemical waste form, canister material, canistered (borosilicate) waste forms, quality assurance, and documentation requirements. Some of the key specifications are reviewed below:

Chemical Waste Form Specifications

The HLW chemical composition is projected before and during HLW processing. The chemical composition, identifying crystalline phases expected to be present and their amounts for each waste type are projected. Waste form oxide composition for all elements, excluding oxygen, present in concentrations greater than 0.5% by weight of the glass are reported. Radio nuclides with half-lives longer than 10 years and that are, or will be, present in concentrations greater than 0.05% of the total radioactive inventory for each waste type, are reported and indexed to the years 2015 and 3115. These index years are being revised. The new years are discussed later in this paper in NEW SPECIFICATIONS AND OTHER KEY CHANGES.

HLW form production quality assurance/control and consistency is demonstrated by comparing, directly or indirectly, HLW production samples to the Environmental Assessment (EA) benchmark glass (3) using the chemical Product Consistency Test (PCT) (4). The mean leachate concentrations of lithium, sodium and boron, must be less than those of the EA benchmark glass for acceptance. This criterion is accomplished by ensuring that the mean PCT results for each waste type are at least two standard deviations below the mean PCT results of the EA glass. Summary PCT result ranges from recent DOE Savannah River Site Defense Waste Processing Facility (DWPF) and the DOE West Valley Demonstration Project (WVDP) PCT data are shown in TABLE I, SYNOPSIS OF DWPF AND WVDP PCT RESULTS. The DWPF measured PCT data are pour stream samples taken from the 1st, 10th, 50th, 61st, and 409th canisters from Macrobatch 1. The WVDP PCT data is calculated from 20 randomly selected canisters shards taken from the first 180 canisters produced during the Phase I Vitrification Campaign. Table I lists only the extreme minimum and maximum measured or calculated PCT values. Note that these PCT range values are well below the EA limits by a factor of approximately 10.

TABLE I: SYNOPSIS OF DWPF AND WVDP PCT DATA RESULTS

Facility	Boron (g/L)	Lithium (g/L)	Sodium (g/L)
Maximum EA Limit	16.70	9.57	13.35
DWPF	0.81 - 1.10	0.77 - 1.08	0.75 - 1.03
WVDP	0.67 - 0.91	0.70 - 0.91	0.57 - 0.76

The liquid to solid glass transition temperature and a time-temperature-transformation exposure duration diagram are also recorded. The waste form temperature cannot have exceeded 400°C, after initial pouring and cool-down, at the time of acceptance into the CRWMS.

Canister Material Specifications

The waste form canister, which has a concentric neck and lifting flange, and canister label used by the Producer is fabricated from austenitic stainless steel. The outermost canister closure method is leak tight to less than $1x10^{-4}$ atm-cc/sec. helium. The overall length of the unfilled canister, after accounting for the closure method, is 3.000m (+ 0.005m, - 0.020m) including the neck and lifting flange. The outer unfilled diameter is 61.0cm (+ 1.5cm, - 1.0cm).

Canistered Waste Forms

The final HLW form encloses the HLW in a continuous borosilicate glass matrix by melting them together in a joule heated furnace (melter) at approximately 1100°C. The canistered waste form cannot contain detectable amounts of free liquids and free gas other than air, the residuals of air, an inert gas cover, and radiogenic gases. The internal gas pressure cannot exceed 150 kPa at 25°C immediately after canister closure. The canistered waste form cannot contain detectable amounts of explosive, pyrophoric, or combustible materials nonpyrophoric, and noncombustible in the event that the temperature exceeds 400°C. After canister closure, the canistered waste form cannot contain detectable amounts of organic materials or cause internal canister corrosion. The 3.0m canisters are filled to a minimum height equivalent of 80% or more of the empty canister's volume. Non-fixed radioactive canister exterior surface contamination cannot exceed 22,000 disintegrations per minute per $100cm^2$ (dpm/100c m^2) of canister surface for beta and gamma emitting radio nuclides and 2,200 dpm/$100cm^2$ for alpha emitting radio nuclides when the canister is accepted into the CRWMS. The 3.0m canister heat generation rate cannot exceed 1,500 watts (W) per canister at the year of shipment. The 3.0m canistered waste form cannot exceed a maximum surface (on contact) gamma (γ) dose rate of 10^5 Roentgen Equivalent Man/ hour (REM/hr.) and a maximum neutron (η) dose rate of 10 REM/hr., at the time of shipment. The maximum 3.0m filled canistered waste form mass is 2,500 kilograms (kg). A brief synopsis concerning measured and calculated DWPF and WVDP HLW production results to date for canister masses, fill heights, thermal generation, and surface radiation doses are listed in TABLE II PRELIMINARY HLW CANISTER PRODUCTION DATA TO DATE. All WVDP production data is preliminary through the first 212 canisters and this data is estimated except for the surface contact dose which was measured. Final WVDP data will be provided after all vitrification campaigns have been completed. All DWPF data is measured, except for heat generation which is calculated.

TABLE II: PRELIMINARY HLW CANISTER PRODUCTION DATA TO DATE

Facility	Min. Fill Height ≥80% of volume	Mass Limit, Filled & Sealed ≤2500 kg	Max. Heat Generation ≤1500 watts	Max. Surface (Contact) Dose $\gamma \leq 10^5$ REM/hr., $\eta \leq 10$ REM/hr.
DWPF	avg. 91.7% (≈675 liters)	2223-2268	9-20	γ - 1 to 4
WVDP	avg. 91.8% (≈747 liters)	1888-2313	173-358	γ - 2423

The total and fissile uranium and plutonium element content and the concentration of plutonium in grams per cubic meter for each HLW canister is recorded. The maximum allowable concentration of plutonium in any size HLW canister is less than 2,500 grams/cubic meter (g/m^3). Estimates of the minimum canister wall thickness of the filled, decontaminated canister, and the amount of canister material that is removed during surface decontamination is recorded. All canistered waste forms shall be capable of withstanding a seven meter drop onto a flat, essentially unyielding surface without breaching or dispersing radio nuclides. The HLW form is processed/ stored to ensure that, under normal and accident conditions, a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. The calculated effective multiplication factor, k_{eff}, must be sufficiently below unity to show at least a 5% margin after allowing for bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

To date, DWPF has produced 561 HLW canisters of the projected 5,084[c] HLW canisters to be completed by Fiscal Year (FY) 2025. These numbers exclude Immobilized Plutonium Waste Form (IPWF) canisters. In FY 1998, DWPF produced 250 HLW canisters and is projecting to produce 200 canisters in FY 1999. WVDP has produced 232 of the approximately 300[d] HLW canisters projected. WVDP vitrification operations are scheduled to be completed by FY 2001. In FY 1998, WVDP produced 81 HLW canisters. WVDP plans to produce 15-35 HLW canisters in FY 1999. The DOE Hanford Tank Waste Remediation System (TWRS) is scheduled to begin HLW vitrification operations in approximately 2007 and is projecting to produce 14,537[e] HLW canisters. TWRS plans to use a new longer canister with a nominal length of 4.5m. This new DOE Richland 4.5m canister is discussed later in this paper in NEW SPECIFICATIONS AND OTHER KEY CHANGES.

Quality Assurance

The HLW Producer is responsible for establishing, maintaining, and executing a Quality Assurance (QA) program that applies to the testing and analysis activities that demonstrate compliance with these EM-WAPS during waste form qualification, production, acceptance, handling, storage, and preparation for shipment. The Producer has imposed a QA program consistent with the QA requirements that govern HLW as identified in the RW Quality Assurance Requirements and Description (QARD) (6), the CRD, and the MOA.

The Producer is required to submit a detailed action plan, signed by authorized personnel**,** through EM to DOE-RW for correction or disposition of nonconforming waste forms for

verification and documented approval from RW. The action plan must identify and describe the non-conformance and any action to change or correct the existing non-conformance.

Documentation Requirements

The waste acceptance process requires demonstration of compliance with the EM WAPS via four different documents, each developed by the Producers, reviewed and accepted by EM, maintained as lifetime records, and provided to RW. These four documents are: (1) the Waste Form Compliance Plan (WCP), (2) the Waste Form Qualification Report (WQR), (3) Production Records (PRs) and (4) Storage and Shipping Records (SSRs). The WCP describes the Producer's plan for demonstrating compliance with each waste acceptance specification, including descriptions of the tests, analyzes, and process controls to be performed. The WQR is a compilation of results from waste form testing and analysis which develops in detail the case for compliance with each waste acceptance specification. The PRs contain production data and describe the actual canistered waste forms. The SSRs describe the physical attributes of each canistered waste form and also identify any unexpected events, such as thermal excursions, which have occurred during storage. These four key documents contain the necessary information to assure quality control of the finished product. The contents of these documents are specified throughout the EM-WAPS.

NEW SPECIFICATIONS AND OTHER KEY CHANGES

Regulatory changes, new national vitrification missions, and new HLW processing facilities, have all necessitated changes to the EM-WAPS. The major changes that are planned in the next 12 months include additions and deletions. Major additions encompass:

- An alternative canister for the DOE Richland facility. Key canister dimensions are a length of 4.500m (+ 0.005m, - 0.020m), a mass of ≤4,200kg, a canister heat generation of ≤2,540W, and a canister fill height volume of ≥87%. All other waste form specifications are identical to the 3.0m canister, however, Immobilized Plutonium Waste Form (IPWF) canisters are exempt form the plutonium concentration 2,500 g/m^3 limit . DOE Richland intends to use the 4.5m canister in lieu of a 3.0m canister primarily for operations efficiency and reduced costs. However, DOE Richland will use the 3.0m canister as a backup solution if the EM-WAPS required canister drop test(s) have not been completed, for the 4.5m canister, by radioactive startup (i.e. EM-WAPS, section 3.12 Canister Drop Test Specification). Currently, DOE Richland is projecting a 4.5m canister fill height of 90-95% yielding a waste volume of 1008-1150 liters;
- An addendum for the new IPWF 'Can-in-Canister' specifications. IPWF is composed of a solid ceramic plutonium matrix encased in a steel cylinder which is then inserted inside of a HLW canister, in an array configuration.. HLW glass is then poured into the canister surrounding the steel cylinders. IPWF is one of two proposed alternatives to treat and eliminate a portion or all of the surplus fissile weapons-usable plutonium stockpile that has accumulated from dismantled nuclear weapons. IPWF program implementation is awaiting a Record of Decision (ROD) expected on or after May 1999, from the Secretary of Energy, that will decide the immobilization technology, identify the treatment facility, and the amount of surplus plutonium to be immobilized. Many IPWF specifications are still under development and/or testing (e.g. an equivalent ceramic water leaching test for the PCT test). Tentatively identified requirements include a standard ceramic waste form, and compliance

documentation including treatment, storage, and physical waste form attributes. An addendum will be used because it minimizes the impact to the rest of the EM-WAPS and other HLW Producers who are not treating or storing IPWFs. Also, the addendum can easily be removed if/when the IPWF requirements are changed or terminated

- Completion of NRC Form 742, Nuclear Material Balance Report, for external DOE required documentation
- The potential "retrievability" of HLW canisters, from the repository waste package, for a period of 100 years beginning after repository waste emplacement operation are initiated. The latest repository design concepts and information include a requirement for retrieval of the HLW packages (i.e. HLW canister overpack), if necessary, up to 100 years after HLW package emplacement (7). HLW canister retrieval, from the waste package (overpack), is uncertain. The HLW 3.0m canister was never specifically designed nor tested for physical retrieval, from a repository waste package, after final emplacement into a repository environment. However, the EM-WAPS canister material specifications and canister testing, to date, make it probable that physical canister retrieval can be successfully accomplished, without breaching the canister, for a limited time after final canister repository emplacement; and
- New glossary definitions and text/table changes to accommodate inclusion of the DOE Richland 4.5m canister and IPWF specifications.

Significant deletions and other changes:

- Radionuclide reference index years decreased by five years each to 2010 and 3110 to conform with the latest schedule for HLW canister acceptance into the CRWMS, including IPWF canisters, and/or potential shipment to other DOE storage locations/sites;

- Deletion of the hazardous waste specification. RW will no longer accept any HLW containing hazardous waste, that is subject to regulation as hazardous waste as defined in the Resource Conservation and Recovery Act (RCRA) Subtitle C, for treatment or disposal into the CRWMS, Under this criteria, DWPF and WVDP do not have any hazardous waste in their HLW, however, TWRS does have known RCRA components in their HLW; and

- Clarification of radioactive nonconforming and nonstandard HLW material definitions concerning the RW HLW requirements. Nonconforming is HLW that does not meet the RW HLW requirements. Nonstandard waste is nonconforming HLW that has been reviewed and deemed acceptable, into the CRWMS, by RW.

Other significant CRD changes which are not in the EM-WAPS, but do affect HLW Producers, include: relocation of selected HLW specifications, such as the primary QA specification, to the MOA from the CRD; and the exclusion of WVDP HLW from the CRWMS pending establishment of an acceptance and disposal contract between RW and the New York State Energy Research and Development Authority (NYSERDA). NYSERDA holds title to the commercial HLW at WVDP. DOE is processing the HLW in accordance with the West Valley Demonstration Act of 1980.

CONCLUSIONS

The EM-WAPS contain the DOE technical HLW specifications for the HLW form Producers as the basis for their waste acceptance programs. The EM-WAPS are the top tier EM technical specifications that the vitrified HLW waste forms are required to meet in order to ensure acceptance of their vitrified HLW into the CRWMS. The EM-WAPS govern all elements of the HLW canistered waste form. EM ensures that the EM-WAPS are in concert with the OCRWM HLW baseline. The EM-WAPS is a living document that is amended, as needed, to meet the needs imposed by new or revised regulations, the Producers, or changing DOE missions.

REFERENCES

(1) U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Civilian Radioactive Waste Management Systems Requirements Document, U.S. DOE Document Number DOE/RW-0406 Rev. 04, May 1998.

(2) Memorandum of Agreement for Acceptance of Department of Energy Spent Nuclear Fuel and High-Level Radioactive Waste between the Assistant Secretary for Environmental Management (EM) U.S. Department of Energy (DOE), Washington, D.C. and the Director Office of Civilian Radioactive Waste Management (RW) U.S. DOE, Washington, D.C., dated September 1, 1998.

(3) C. M. Jantzen, "Characterization of the Defense Waste Processing Facility (DWPF) Environmental Assessment (EA) Glass Standard Reference Material," WSRC-TR-92-346, Westinghouse Savannah River Company, Aiken, SC., Revision 1, dated 1993.

(4) ASTM Standards, American Society of Testing and Materials, Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT), C-1285-94.

(5) U.S. Code of Federal Regulations, Protection of Environment, 40 Parts 260 to 299, 40CFR261.31 through 40CFR261.33.

(6) U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program, U.S. DOE Document Number DOE/RW-0333P, Rev. 08, November 13, 1997.

(7) U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Viability Assessment of a Repository at Yucca Mountain. Volume 2: Preliminary Design Concept for the Repository Waste Package, December 1998, DOE/RW-0508/V2

FOOTNOTES

[a] High-Level Radioactive Waste (HLW) means (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel in defense or commercial facilities, including liquid waste produced directly in the reprocessing operation, and (2) other highly radioactive material which requires permanent isolation as determined by rule from the NRC and consistent with existing law. In this paper, HLW is vitrified borosilicate glass that has been cast in a stainless steel canister.

[b] The "Producers" are the HLW sites which currently or plan to process HLW into a solid borosilicate glass mixture. They include the Defense Waste Processing Facility (DWPF) at the Savannah River Site, South Carolina; the West Valley Demonstration Project (WVDP) at West Valley, New York; and the Tank Waste Remediation System (TWRS) at the Hanford Reservation, Richland, Washington.

[c] High Level Waste Management Division, High Level Waste System Plan, Revision 9 (U), HLW-OVP-98-0037, April 1998, Appendix J.7. NOTE: The preliminary Yucca Mountain Repository Environmental Impact Statement projects 5,900 DWPF canisters, excluding IPWF canisters.

[d] The ≈300 HLW canister number is the latest estimate from DOE WVDP and has remained consistent for the last several years of WVDP HLW operations.

[e] Tank Waste Remediation System Operations And Utilization Plan, HNF-SD-WM-SP-012, Rev. 0, September 12, 1997. This number utilizes a 4.5m canister. NOTE: The preliminary Yucca Mountain Repository Environmental Impact Statement cites TWRS canister projections of 14,500 using a 4.5m canister.