OVERVIEW OF THE DEFENSE WASTE PROCESSING FACILITY'S WASTE FORM COMPLIANCE PLAN

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ABSTRACT

Construction of the Defense Waste Processing Facility (DWPF) at the Savannah River Plant (SRP), will be completed in 1989. The DWPF will be the first facility in the nation capable of immobilizing high-level nuclear waste. Production of DWPF canistered waste forms will begin prior to repository licensing, and shipment of waste forms to a civilian repository is not anticipated until after the year 2008. By 2008 the DWPF will have produced about 5,000 canistered waste forms from existing SRP waste. The Department of Energy's Office of Civilian Radioactive Waste Management (RW) has addressed this scheduling discrepancy by defining a Waste Acceptance Process to provide reasonable assurance that the waste glass produced in the DWPF will be acceptable for permanent storage in a federal repository. As part of this process, detailed specifications have been developed for:

- the waste glass.
- the canister which will confine the waste glass.
- the sealed, glass-filled canister.
- quality assurance of canistered waste form production.

Savannah River has developed a detailed strategy for demonstrating compliance with each of the specifications, which is documented in the Waste Form Compliance Plan for the Defense Waste Processing Facility (WCP). In this paper, an overview of the WCP is provided. Particular emphasis is placed on the strategy to control radionuclide release, as an example of the overall approach to waste acceptance.

INTRODUCTION

At the Savannah River Plant (SRP) in Aiken, South Carolina, over thirty years of reprocessing nuclear fuels for national defense purposes has produced 100 million liters of radioactive waste. This waste is currently stored as an alkaline slurry in carbon steel tanks on site. Construction of the nation's first facility to immobilize defense high-level nuclear waste, the Defense Waste Processing Facility (DWPF), is scheduled to be completed in 1989. In the DWPF, SRP high-level radioactive waste will be immobilized in durable borosilicate glass.

Production of canistered waste forms by the DWPF is scheduled to begin in 1992, well before submission of the license application for the first repository to the Nuclear Regulatory Commission (NRC). The first repository will most likely be located in the tuff geology of Yucca Mountain, Nevada. It is likely that DWPF glass waste forms will not be shipped to Nevada until after the year 2008. At this point, the DWPF will have produced approximately 5,000 canisters, and processed nearly all of the high-level waste currently stored at SRP. Because of the very different schedules of the defense and civilian programs, the Department of Energy, through its Office of Civilian Radioactive Waste Management (RW), has defined a Waste Acceptance Process (WAP) for DWPF canistered waste forms.

As part of the Waste Acceptance Process, RW, through its Waste Acceptance Committee (WAC), developed Waste Acceptance Preliminary Specifications (WAPS) (1). The WAPS identify the requirements that the DWPF waste forms must meet in order to be compatible with the repository. DWPF compliance with the specifications will ensure that canistered waste forms produced in the DWPF will be acceptable for disposal there.

The DWPF must demonstrate compliance with the WAPS by means of three documents: (1) the Waste Form Compliance Plan (WCP), (2) the Waste Form Qualification Report (WQR), and (3) Production Records. The Waste Form Compliance Plan (WCP) is the producer's plan for demonstrating compliance with each specification in the WAPS. The WCP describes the tests, analyses, and process controls to be used by the producer, in this case the DWPF. The Waste Form Qualification Report (WQR) is a compilation of all of the results from the testing and analysis programs identified in the WCP, presenting detailed evidence of compliance with each specification. Production Records (PR) are documents that describe the actual canistered waste forms as produced.

The Draft Waste Form Compliance Plan (WCP) for the DWPF has been prepared for the DWPF by the Savannah River Laboratory. The overall strategy for complying with the repository specifications is to assure the quality of the product by component specifications and process controls. In this paper, the compliance strategy for some of the more important specifications is outlined, and progress toward demonstrating compliance is reviewed.

DWPF PROCESS

To understand the compliance strategy, some understanding of the DWPF process is necessary (2-4). A diagram of the waste immobilization process is shown in Fig. 1. The SRP waste is currently stored on site in carbon steel tanks, in three forms: sludge, saltcake, and salt solution. The sludge consists primarily of precipitates of the hydroxides

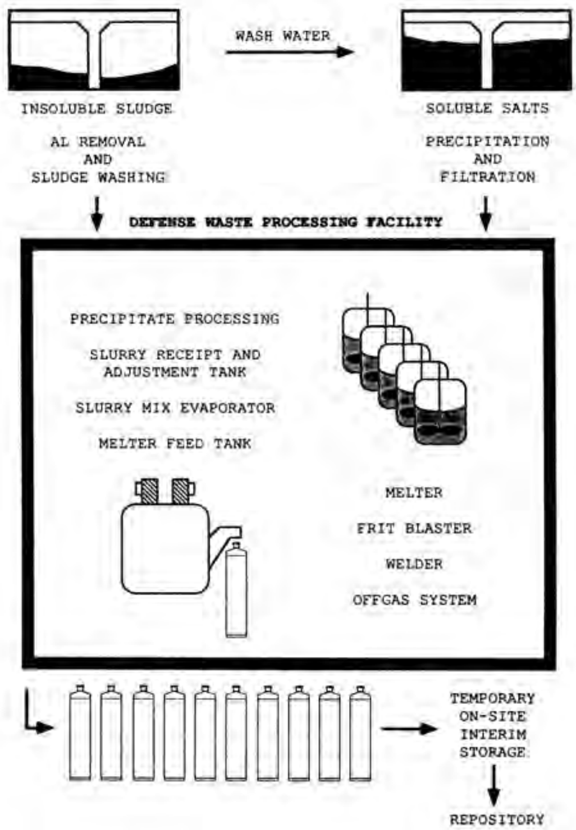

Fig. 1. SRP Waste Immobilization Process.

of iron, aluminum, and manganese, and contains most of the radioactivity in the waste, except for radioactive cesium. The saltcake and salt solution is largely sodium salts of common anions, such as nitrate, nitrite, aluminate, and hydroxide. The salt fraction of the waste contains most of the radioactive cesium, and little of other radioactive species.

Radioactive cesium is removed from the salt fraction of the waste by precipitation as cesium tetraphenylborate. Residual Sr and Pu in the salt waste is adsorbed on a small amount of sodium titanate. The resulting slurry is concentrated by continuous filtration, and pumped to the DWPF.

Sludge waste is also pretreated in existing waste storage tanks, to remove as much of the nonradioactive ingredients as possible. For example, sludges are washed with water to reduce the soluble salt content of the slurry, and with hot caustic to remove a portion of the aluminum.

Within the DWPF, a formic acid hydrolysis process is used to remove most of the organic content of the tetraphenylborate salt before vitrification. The washed sludge slurry and the precipitate hydrolysis product are then mixed together in the Sludge Receipt and Adjustment Tank (SRAT), and mercury in the waste is removed.

The slurry is then transferred to the Slurry Mix Evaporator (SME) where premelted glass frit is added. Most of the necessary frit is pumped directly to the SME. However, some of the frit is first used for canister decontamination, and is later added to the SME. After mixing, the frit-waste slurry is then transferred to the Melter Feed Tank (MFT), for delivery to the melter.

Vitrification of the frit-waste slurry is accomplished in a Joule-heated ceramic-lined melter. The feed slurry is dropped directly onto the melt surface. Two pairs of electrodes supply power directly to the melt, and maintain the glass temperature at 1150°C. The feed slurry dries and melts from the bottom, forming borosilicate waste glass. The glass is poured into stainless steel canisters by maintaining a slight negative pressure in the canister relative to the melter. After completion of the fill, a temporary seal is inserted into the nozzle of the canister, to prevent the introduction of water during decontamination.

Contamination is removed from the canister surface by air-injected slurry blasting. The canister is placed in an enclosed chamber, and a slurry of glass frit is used to clean all exposed surfaces. After decontamination, the canister is sealed by welding a stainless steel plug into the canister nozzle, using an upset resistance welding technique. The cleaned and sealed canisters are then sent to an interim storage facility, where they will remain until shipment to a repository.

WASTE FORM SPECIFICATIONS

The WAPS are divided into four sections. Each section individually addresses either the waste glass, the canister, the canistered waste form, or quality assurance. Those WAPS relating to the waste glass specify requirements for projection and analysis of the glass composition (chemical and radionuclide), control and verification of the radionuclide release properties, and data relating to the chemical and phase stability of the glass. Those WAPS relating to the canister specify the required material, the integrity of the closure, and labeling of the canisters. Those WAPS relating to the canistered waste form detail a wide range of requirements for the sealed canister after filling, including dimensional stability, canister cleanliness, handling features, and ability to withstand a 7m drop.

The following section illustrates the rigorous consideration each specification has been given.

SPECIFICATIONS CONCERNING RADIONUCLIDE RELEASE PROPERTIES

1.3.1 Control of Radionuclide Release Properties

For the Nevada Nuclear Waste Storage Investigations Project, the ability of the waste form to limit releases of radionuclides shall be demonstrated using test MCC-1 (Materials Characterization Center-1, Nuclear Waste Materials Handbook, DOE/TIC-11400, 1983) conducted in deionized water at 90°C. The test duration is to be 28 days. The acceptance criterion is that the normalized elemental leach rate for the matrix elements sodium, silicon, and boron, and for the radionuclides cesium-137 and uranium-238 shall be less than one gram per square meter per day averaged over the 28 day test duration.

1.3.2 Verification of Radionuclide Release Properties

The capability of the waste form to meet this specification shall be demonstrated by testing actual production samples of waste forms. The sampling schedule shall be sufficient to demonstrate at the 95 percent confidence level that 95 percent of the production waste forms would yield leach test results that conform to the criterion. Test samples shall be taken from a convenient location near the mouth of the waste form canister before the canister is sealed closed. The temperature of the waste form at the time of sampling shall be no higher than 90°C.

1.3.3 Alternative Means of Compliance

The producer may use an alternative approach to demonstrate control of the radionuclide release properties of the waste form from that of Specifications 1.3.1 and 1.3.2 provided that the producer relates, to the satisfaction of the repository project, the radionuclide release properties of the waste form obtained using the alternative approach to those that would be obtained by adhering to the requirements of Specifications 1.3.1 and 1.3.2.

Compliance Strategy

The approach to meeting these specifications is shown is Fig. 2. Borosilicate glass was chosen as the waste form for the DWPF because of its ability to retard the release of radionuclides (5). The DWPF will demonstrate that the entire range of expected glass compositions will meet this specification. Chemical composition is the only process variable which has been shown to affect the glass's ability to meet the specification, as long as a vitrified product has been formed. The DWPF process will be controlled to deliver only feed which will produce acceptable glass to the melter. As long as the melter is operated within the range of temperatures for which it is designed, delivery of a vitrified product to the canister is assured.

The MCC-1 procedure requires a test period of 28 days. The MCC-1 would not supply information quickly enough to allow adjustments of process parameters to be made for control of radionuclide release properties of the waste glass. Thus, it is not useful for direct control of the consistency of plant operations. For this reason, an indirect strategy of control has been developed for operation of the DWPF, as allowed by Specification 1.3.3.

This strategy requires identification of those variables which significantly affect the radionuclide release properties of the glass, and then development and implementation of process controls to ensure that the DWPF consistently produces an acceptable product. For each variable which significantly affects the radionuclide release properties of the glass, the DWPF will describe the process control program for that variable in the WCP. The WQR will then contain the documentation demonstrating how well the variable is controlled. As noted previously, the melter has been designed so that only vitrified material can be delivered to the canister.

Progress

Current evidence indicates that the durability of the waste glass can best be controlled by controlling the composition of the feed going to the melter. This can be demonstrated both experimentally and theoretically. Experimentally, the durability of glasses typical of those to be produced in the DWPF have been shown to be affected very little by variation in melting time, the size of the melter, and crystalline content of the glass (6-8). Theoretically, the hydration thermodynamic approach (9-11), originally developed to explain differences in durability of ancient glasses, leads to the prediction that the long-term durability of glass should depend most strongly on the composition, and very little on process parameters.

During the Integrated Cold Runs, samples of DWPF feed and glass (12) will be taken to verify the feed composition/glass composition correlation developed from laboratory and pilot plant tests. If deviations from this correlation are detected, the correlation will be modified to be consistent with the test results.

The sampling regimen described in Specification 1.3.2 is not compatible with the DWPF process and product. A glass sampler, suitable for remote use, has been developed and tested, which takes a sample from the molten glass stream as it is poured from the melter into the canister.

The MCC-1 test, because it requires monolithic samples, is not suitable for the unannealed samples of glass that will be taken during production, since unannealed glasses fracture unpredictably during cutting. For this reason, the DWPF has developed an alternate leach test procedure that is suitable for the DWPF product. This procedure, the Product Consistency Test (PCT) (13), has

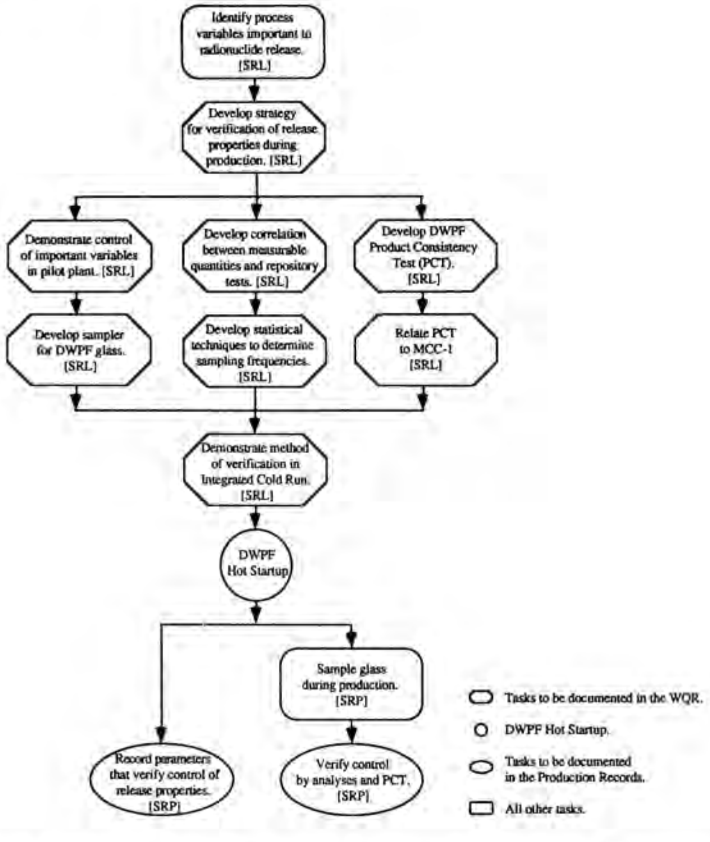

Fig. 2. Control and Verification of Radionuclide Release Properties.

been demonstrated to be reproducible, precise, compatible with remote operation and sensitive to glass composition and homogeneity. The PCT has a seven day test duration, and is performed on crushed glass. The results of the PCT will be related to results from the MCC-1 test, as is called for in Specification 1.3.3.

BENEFITS OF THE WASTE ACCEPTANCE PROCESS

The Waste Acceptance Process was developed to provide a method to assure that the waste forms produced at DWPF would be acceptable for disposal in a federal repository. This is a concern, as the DWPF will be in operation well before the federal repository is licensed. However, the Waste Acceptance Process has also benefitted the DWPF internally.

As a result of the Waste Acceptance Process the DWPF prepared a very useful document, the WCP. The WCP contains information about almost every aspect of the DWPF process and product. This information is in condensed form, and references other, more detailed sources of information. As a result, the WCP provides a useful introduction to the DWPF product, as well as serving its intended function.

The Waste Acceptance Process has also caused the DWPF to critically reexamine and revise the Integrated Cold Runs schedule. The Cold Runs will be the "dress rehearsal" for DWPF hot startup. They will mimic radioactive DWPF operations using simulated waste glass. The Waste Acceptance Process forced DWPF to closely examine the Cold Run plans sooner, and more formally, than would have been done otherwise. SRL involvement was also brought into the planning, causing pilot plant experiences to be better reflected in the scheduling plans. Through this planning it was realized that at least 19 months was needed to gather the necessary data and operating experience required by the Cold Runs, instead of the 12 months originally planned. As a result of the pre-planning inspired by the Waste Acceptance Process, procurement of the materials required for the Cold Runs is proceeding smoothly and ahead of schedule. Through the waste acceptance activities required by WAPS 1.1.1, the Chemical Composition Projections specification, seven compositions which are representative of DWPF waste glass were identified (see Table I). These compositions represent: a nominal blend, the first four batches that will be processed in the DWPF, and two potential extreme waste compositions. Of the compositions cited in Table I, the Blend, Batch 1, HM and Purex will be those *simulated* and processed in the DWPF during the Cold Runs. The Integrated Cold Runs, are very important to the DWPF, as they will provide valuable statistical information regarding sampling and compositional correlations, as well as supplying invaluable operating experience.

Preparation of the WCP required compiling existing information about the DWPF product and process,

TABLE I
Projected DWPF Waste Glass Compositions.

MAJOR GLASS COMPONENTS weight %	CONSTITUENT SLUDGE TYPE						
	Blend	Batch 1	Batch 2	Batch 3	Batch 4	HM	Purex
Al_2O_3	3.98	4.87	4.46	3.25	3.32	7.08	2.89
B_2O_3	8.01	7.69	7.70	7.69	8.11	6.94	10.21
$BaSO_4$	0.27	0.22	0.24	0.26	0.38	0.18	0.29
CaO	0.97	1.17	1.00	0.93	0.83	1.00	1.02
$CaSO_4$	0.077	0.12	0.11	0.10	0.0034	trace	0.12
Cr_2O_3	0.12	0.10	0.12	0.13	0.14	0.086	0.14
CuO	0.44	0.40	0.41	0.40	0.46	0.25	0.42
Fe_2O_3	6.95	8.39	7.11	7.48	7.59	4.95	8.54
FeO	3.11	3.72	3.15	3.31	3.36	2.19	3.78
Group A*	0.14	0.099	0.14	0.10	0.20	0.20	0.078
Group B§	0.36	0.22	0.44	0.25	0.60	0.89	0.084
K_2O	3.86	3.49	3.50	3.47	3.99	2.14	3.58
Li_2O	4.40	4.42	4.42	4.42	4.32	4.62	3.12
MgO	1.35	1.36	1.35	1.35	1.38	1.45	1.33
MnO	2.03	2.06	1.62	1.81	3.08	2.07	1.99
Na_2O	8.73	8.62	8.61	8.51	8.88	8.17	12.14
Na_2SO_4	0.10	0.10	0.12	0.096	0.13	0.14	0.12
NaCl	0.19	0.31	0.23	0.22	0.090	0.093	0.26
NiO	0.89	0.75	0.90	1.07	1.09	0.40	1.21
SiO_2	50.20	49.81	50.17	49.98	49.29	54.39	44.56
ThO_2	0.19	0.36	0.63	0.77	0.24	0.55	0.011
TiO_2	0.90	0.66	0.67	0.66	1.02	0.55	0.65
U_3O_8	2.14	0.53	2.30	3.16	0.79	1.01	2.89

* Group A: radionuclides of Tc, Se, Te, Rb, Mo.
§ Group B: radionuclides of Ag, Cd, Cr, Pd, Tl, La, Ce, Pr, Pm, Nd, Sm, Tb, Sn, Sb, Co, Zr, Nb, Eu, Np, Am, Cm.

organizing it into a logical form, and reporting the information as it pertained to the WAPS. As a result, the entire scope of the DWPF process and the corresponding WAPS requirements could be reviewed for potential problems that may have been previously overlooked. Integrated Cold Run planning is a prime example of how the waste acceptance process has benefitted the DWPF. Other scheduling priorities have also been identified by reviewing all the information in this manner.

Our compliance with the Waste Acceptance Process has resulted in increased confidence in the ability of DWPF to safely produce an acceptable product; thereby facilitating a positive startup decision. DWPF hot startup is currently scheduled in 1992.

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