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# West Valley Demonstration Project

WASTE COMPLIANCE PLAN

FOR THE WEST VALLEY DEMONSTRATION PROJECT

HIGH-LEVEL WASTE FORM

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# RECORD OF REVISION

## PROCEDURE

If there are changes to the procedure, the revision number increases by one. These changes are indicated in the left margin of the body by an arrow (>) at the beginning of the paragraph that contains a change.

Example:

> The arrow in the margin indicates a change.

| Rev. No. | Description of Changes | Revision On Page(s) | Dated |
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| 0 | Original Issue | All | |
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FOR THE

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HIGH-LEVEL WASTE FORM

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## INTRODUCTION

The West Valley Demonstration Project (WVDP) will solidify the liquid High-Level Waste (HLW) remaining at the former commercial nuclear fuel reprocessing plant at West Valley, New York, and will provide a qualified HLW product to the waste repository operators for disposal. Borosilicate glass is the waste form (Eisenstatt et al 1984, Hannum 1986). Based on a recent vitrification process mass balance projection, about 490,000 kg of waste glass will be poured into stainless steel canisters. Eisenstatt (1986) described the reference WVDP canistered HLW form and canister.

### > West Valley Waste and Processing Description

> The total volume of WVDP waste is about $2 \times 10^6$ ℓ and is stored in two tanks. The liquid high-level waste was produced from processing 27 lots of spent fuel from numerous nuclear reactors. Most (98 percent) of the stored waste was generated from reprocessing uranium fuel by the PUREX process. This HLW was neutralized by adding sodium hydroxide and is stored in a carbon steel tank, 8D-2. The waste has separated into a supernatant and about 30 cm of a precipitated hydroxide sludge that has settled to the bottom of the tank. The non-PUREX waste came from processing a small batch of thorium fuel from the Indian Point Unit 1 reactor using the THOREX process. This acidic waste is stored in a stainless steel tank, 8D-4. Tanks 8D-1 and 8D-3 are spare storage tanks for the PUREX and THOREX wastes, respectively. The current reference HLW composition and radionuclide inventory based upon an ongoing liquid HLW characterization program (Rykken et al 1984, Rykken et al 1985, Rykken 1986, Crocker 1989) is shown in appendix A.

A flow diagram of the West Valley reference HLW vitrification process is shown in figure 1. Prior to vitrification, the PUREX waste will be pretreated as described below.

The PUREX supernatant will be decontaminated of Cs-137 and other cesium radionuclides by passing through ion exchange columns containing zeolite IE-96. The PUREX sludge will then be washed to remove soluble sulfates and interstitial supernatant from the sludge. The wash solution will also be treated with the zeolite. The decontaminated supernatant and wash solutions will be solidified in the cement solidification system (CSS) and disposed as low-level waste. The zeolite and THOREX waste will be transferred to and homogenized with the washed PUREX solids in HLW Storage Tank 8D-2 where the PUREX waste is currently stored. Thus, one batch containing all the HLW constituents will be vitrified by the WVDP.

Following these pretreatment activities the slurried homogenized waste will be transferred to the Concentrator Feed Makeup Tank (CFMUT) in the Shielded Solidification System, sampled, and concentrated. Bulk glass formers will be added to the CFMUT; the amount will depend upon waste volume and the sample analysis results. The reference waste loading of the glass will be about 33 weight percent waste oxides. About 23 weight percent will be from the PUREX sludge and THOREX waste, and 10 weight percent will be from the zeolite. The slurry in the CFMUT will be equivalent to about three to four canisters. After concentrating, sampling, and mixing, the waste and glass former slurry will be transferred to the Melter Feed Holding Tank (MFHT). From the MFHT it is metered to the Slurry Fed Ceramic Melter (SFCM). The feed slurry will be introduced from the top of the melter and form a cold cap on the melt surface. As the water evaporates, the steam will be removed by the process off-gas treatment system. Three electrodes will supply energy directly to the melt. The cold cap will melt from the bottom and form the borosilicate waste glass. Molten glass will flow from the bottom of the melter up through a riser and fall into a stainless steel canister by either periodic batch pouring or continuous flow. Glass pouring will be initiated by airlifting. The fill level in the canister will be monitored by a vertical line of gamma detectors. When the canister is empty, a Co-60 source will be detected. As it is filled, the glass will shield the Co-60 gamma and emit the Cs-137 (Ba-137m) gamma. The glass level will be inferred from the height of each detector as they sense the change. During filling the canister will be in a turntable. The canister turntable will contain a maximum of four canisters and rotate through four positions. After a canister is filled, it will remain in the turntable for typically 70 to 80 hours. During this time period the cooling will be accomplished via the turntable cooling jacket to lower the turntable interior temperature. After 70 to 80 hours the full canister will be removed from the turntable and placed in an open air cooling rack located in the Vitrification Cell. The canister closure will be applied as soon as practical following removal from the turntable. Prior to interim storage, the canisters will be decontaminated by rinsing in a tank containing nitric acid and $Ce^{+4}$ for about an hour and then rinsing the canister with water. The radioactive $Ce^{+4}$ solution will be sent to the waste header and transferred to tank 8D-2. After rinsing the canisters will be moved to and stored in the Chemical Process Cell of the existing reprocessing plant facility. Because this storage facility is a decontaminated cell in the fuel reprocessing plant with possibly some residual contamination, and failed vitrification process equipment may be stored there which could spread contamination, the canisters will be decontaminated again if necessary to meet the surface contamination limits. Much of this process equipment is currently being tested at the Component Test Stand (CTS) at West Valley. This CTS facility will be converted to the Shielded Solidification System prior to waste vitrification.

Waste Compliance Plan Purpose and Format

The U. S. Department of Energy has developed Waste Acceptance Preliminary Specifications for the West Valley Demonstration Project High-Level Waste Form (Office of Civilian Radioactive Waste Management 1987) that establish minimum requirements that WVDP HLW must meet to be acceptable for disposal in a repository. Components of the waste form (glass), canister, and canistered waste form must be shown to meet these specifications. This

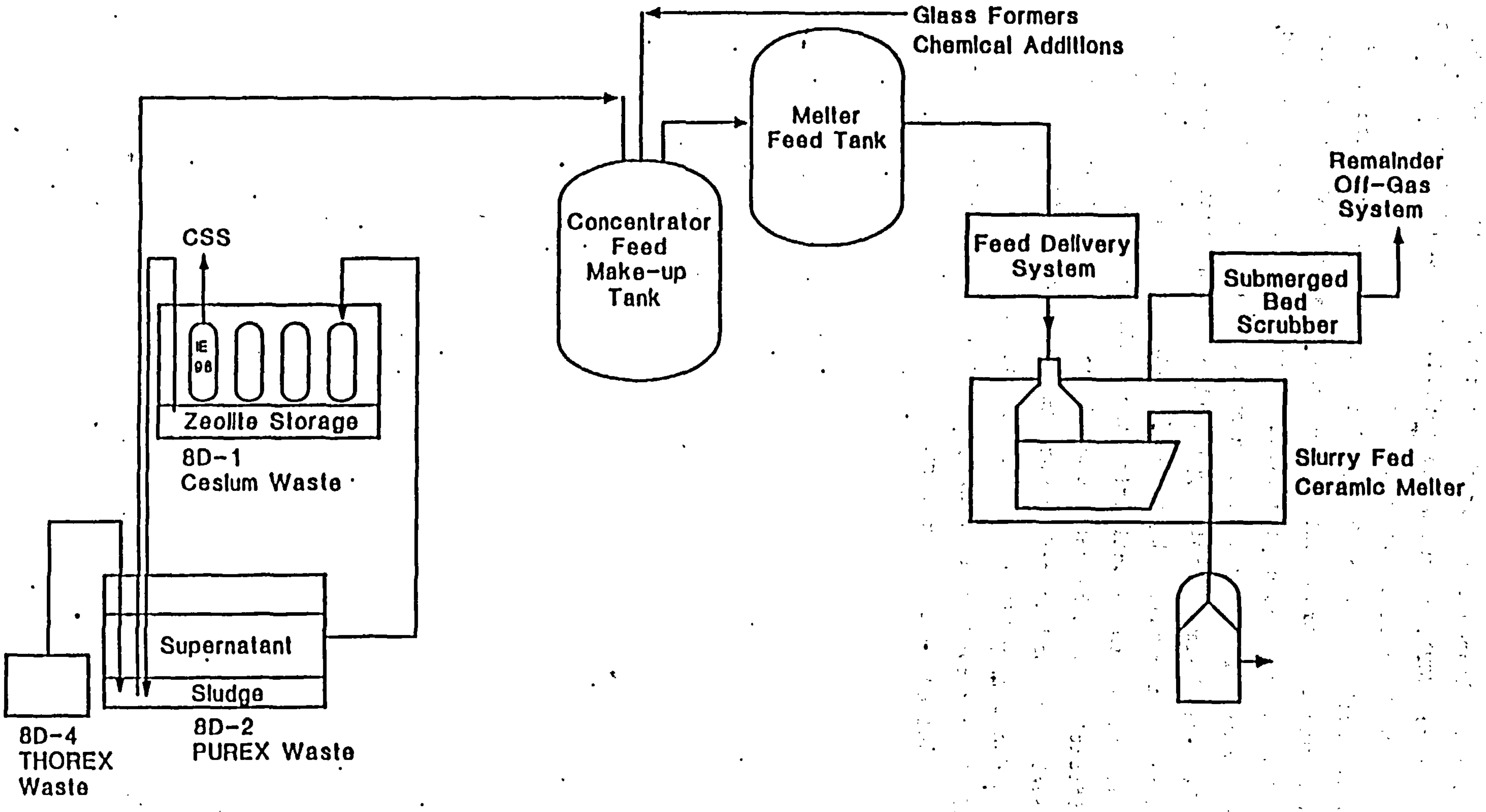


FIGURE 1: WVDP High-Level Waste Processing Flow Sheet

> document the Waste Compliance Plan for the West Valley Demonstration Project High-Level Waste Form (WCP), provides the methods that the WVDP will use to show compliance with the specifications. The data collected on tests performed to show compliance with the specifications before the start of radioactive waste vitrification will be reported in a Waste Qualification Report (WQR). Data on production radioactive waste glass, canisters, and canistered waste glass will be reported in production records. Each specification is given below in bold type followed by a strategy that summarizes the activities that will be performed. The compliance section describes the details of those activities that will be performed to show that the specifications will be met. One of the specifications, (1.3), is still under development and therefore not fixed. This specification is reserved and is denoted by "[R#]" in the text of the specification. An explanation of the reserved item is in appendix B. This reservation is expected to be resolved in the near term.

# 1.0 WASTE FORM SPECIFICATIONS

## 1.1 Chemical Specification

The waste form for WVDP is borosilicate waste glass.

### 1.1.1 Chemical Composition Projections

**The producer shall include in the Waste Form Qualification Report (WQR), sufficient chemical and microstructural data to characterize the elemental composition and crystalline phases for the product of the waste production facility and expected variations in the product due to process variations during the life of the facility. The method used to make these projections shall be described by the producer in the Waste Form Compliance Plan (WCP).**

Strategy

> The WVDP will vitrify one batch of waste containing all of the HLW constituents and produce glass with one target composition. The standard deviations of the measured components due to process variations will be calculated to assess the potential variation of the product.

> Based upon prototypic, full-scale tests, typical canistered glass cooling rates will be determined. Laboratory glasses with a nominal composition will be fabricated and heat treated based on the prototypic cooling rates. These glasses will be characterized by defining the crystalline phases that will be present.

Compliance

The WVDP will vitrify one batch of high-level waste and process glass with one target composition. This target composition will be tested for acceptability according to Specification 1.3 and will be tested to determine its processing characteristics in the full-size vitrification equipment. The compositional uncertainties associated with this glass result from the sampling, analysis, and glass former addition activities. Slurry feed samples will be collected and analyzed during nonradioactive testing. The standard deviations resulting from the process uncertainties will be estimated for the required chemical components during testing. These standard deviations, along with the standard deviation of the resulting waste glass, will be reported in the WQR to provide an assessment of the potential variation in the product due to inherent process variations.

Typical cooling rates of the canistered glass will be determined from full-scale, nonradioactive tests that duplicate targeted production glass pouring conditions. Identification of the crystalline phase compositions and concentrations will then be made on the canistered glass and on laboratory glass specimens that have experienced the same prototypic cooling rates.

The glass compositions that will be prepared in the laboratory will represent the statistical variability found during production of the target product. These glasses will be characterized to assess the affect of glass composition on the nature and amount of crystalline phases. Certain of the laboratory glass samples will contain radioactive thorium and uranium. The balance of the TRU constituents will be simulated with thorium, uranium, rare earths and/or other appropriate elements. Insoluble waste constituents such as ruthenium, palladium, and rhodium will also be present at reference concentrations since they can serve as nucleating sites for crystal growth. The thermal history of the glass in a typical canister varies as a function of position in the filling canister. Based upon the temperature history measured in the full scale tests, laboratory specimens will generally be heat treated in a programmed cool down rate corresponding approximately to the following canister locations:

- o 1 cm from the canister wall
- o 5 cm from the canister wall
- o 10 cm from the canister wall
- o canister centerline

> All these temperature histories will be taken near the mid fill height of the test canister.

> Glass samples also will be removed from near the above locations in canisters filled at West Valley during testing. (Note: this glass does not include Th, U, and possibly the noble metals.)

> These specimens will be characterized for crystalline phases by x-ray diffraction and petrography. A weighted average of the percentage of crystalline phases will be calculated to estimate the overall percentage expected in a canistered waste form. It will be calculated based upon the measured crystal content for a given cooling rate at a given radial position and the corresponding volume at the radial position. The expected total volumetric quantity of nonvitreous material and estimated uncertainties will be reported in the WQR.

### 1.1.2 Chemical Composition During Production

**For the canistered waste forms, the producer shall include in the production records the elemental composition of the glass waste form for all elements, excluding oxygen, present in concentrations greater than 0.5 percent by weight. The producer shall describe the method to be used for compliance in WCP. An estimate of the precision accuracy and the basis for the estimate of the precision shall be reported in the WCP.**

Strategy

The composition of the one batch of WVDP vitrified waste will be provided by sampling the melter slurry feed and the canistered glass that can be removed from the opening at the canister top. The sampling frequency, as well as the precision and accuracy, will be based upon the results of qualification testing at the CTS.

Compliance

> The composition of the production glass will be derived from production feed and glass samples. Because one target glass composition will be melted, the melter feed (waste and glass former) and glass will be approximately equivalent at any time. During full-scale nonradioactive qualification testing in the waste vitrification equipment, frequent samples of the feed, draining glass, and canistered glass will be taken and analyzed. Feed samples will be removed from the CFMUT, MFHT, and the slurry delivery system and the standard deviations associated with the chemical compositions will be calculated. These standard deviations will be used to project those anticipated for the slurry sampling in the radioactive campaign. Also, samples of the canistered glass will be removed from the top of the canister and compared with the results from the feed, the bulk of the casting, and the drain glass

samples. The relationship between the feed, the glass that can be removed from the canister opening, the draining glass, and the bulk test glass compositions will be determined. The bulk glass will be characterized by cutting filled canisters such that samples can be removed. Samples will be removed at different places along the axis and radius of the canisters. It will be determined if any differences in mean compositions that may exist between the samples removed from the bulk glass, canister top, draining samples, and feed are statistically significant (i.e., by applying the "t-test" at a 95 percent confidence level or other appropriate statistical methods). If so, the use of process models to account for the differences will be investigated. The application of a process model to waste vitrification is discussed by Eisenstatt and Chapman (1986). It will further be determined how frequently the feed and canisters must be sampled to demonstrate that the composition of the waste form falls within the acceptance region when process variations and upsets are considered. The precision and accuracy of the method for providing chemical composition will be reported in a supplement to the WCP and will be based on the above characterization performed during qualification testing.

Vitrification qualification testing will include fully integrated melter runs. These melter runs will have durations ranging up to about 45 days. Simulated waste based on the most recent chemical analyses of waste tank samples (e.g., see appendix A), with Zr or other appropriate elements substituting for the radioactive elements, will be used during these tests. Glass formers will be in the form expected during radioactive vitrification. During the melter runs the above samples will be tested and results analyzed. Methods currently planned to be used for compositional analysis of samples include inductively coupled plasma, atomic emission spectroscopy and atomic absorption spectrophotometry. The critical melter control parameters that will be monitored during these runs are glass composition and melt temperature. Glass composition will be monitored and controlled by analyzing feed and glass samples;

operating procedures for doing this will be used during qualification testing and waste vitrification. Glass melt temperature is measured with thermocouples and recorded according to operating procedures. Operating procedures will also specify thermocouple replacement schedule and associated instrumentation calibration schedules determined during nonradioactive testing. Before and between these melter runs component specific tests (e.g., for sampling systems and feed tank characterization) may be performed. Other details of this testing are provided by Eisenstatt and Routt (1988).

During waste vitrification the glass composition for the one batch of WVDP HLW will be provided by analysis of feed samples and glass samples, and will be reported in production records as percent present of each required element. One mean and one standard deviation will be reported from samples removed from the melter feed hold tank and from the canisters. The feed will be sampled from an accessible location that resulted in a mean closest to the expected composition and the smallest standard deviation during qualification testing. Glass will be sampled after the canistered waste form is removed from the turntable. A glass shard will be removed from the top of the canistered glass, transferred to the analytical laboratory, and chemically analyzed for composition. This analysis will include the use of analytical procedures and glass standards. The number of samples required will be based on the variability of the results of samples taken during cold testing at the CTS. The required number will be sufficient to ensure a confidence level of 95 percent for those elements that must be reported to meet this specification. (See table I for the expected list.) The production records will include the chemical analysis results of the feed samples and glass shards that were analyzed.

## TABLE I

## ELEMENTS EXPECTED IN THE WASTE FORM THAT SPECIFICATION 1.1.2 REQUIRES TO BE REPORTED

| Element | Planned Analytical Method* |
|---|---|
| Al | ICP-AE |
| B | ICP-AE |
| Ca** | ICP-AE |
| Ce | ICP-AE |
| Fe | ICP-AE |
| K | AA or ICP-AE |
| Li | ICP-AE |
| Mg | ICP-AE |
| Mn | ICP-AE |
| Na | ICP-AE |
| P | ICP-AE |
| Si | ICP-AE |
| Th | ICP-AE |
| Ti | ICP-AE |
| U | ICP-AE |

* ICP-AE - Inductively Coupled Plasma, Atomic Emission spectroscopy;
AA - Atomic Absorption spectrophotometry.

** This element is expected to be in concentration in the glass below that which is required to be reported, but it is sufficiently close to be considered for planning purposes.

## 1.2 Radionuclide Inventory Specification

> For all radionuclide inventory estimates required by this specification, the producer shall report all radioisotopes that have half-lives longer than 10 years and are present in concentrations greater than 0.05 percent of the total radioactive inventory in curies (in the aggregate or in the canistered waste form, as applicable) at any time up to 1100 years after production.

### 1.2.1 Radionuclide Inventory Projections

The producer shall provide in the WQR estimates of the total quantities of individual radionuclides to be shipped to the repository and of the uncertainties in the expected values. The producer shall also provide in the WQR estimates of the inventories of individual radionuclides expected to be present in each canistered waste form produced at the facility and the expected range of variations due to process variations during the life of the facility. These estimates shall be calculated for the year 2025. The method used to make these projections shall be described by the producer in the WCP.

Strategy

The estimated total radionuclide inventory estimates will be based upon an ongoing waste characterization program for WVDP HLW. The projected estimated inventory in canisters will be based upon filling canisters nominally 85 percent full.

Compliance

The estimated radionuclide inventory projections will be based on an ongoing liquid high-level waste characterization program being performed at West Valley (Rykken et al 1984, Rykken et al 1985, Rykken 1986). Computer simulations using ORIGEN2 [Radiation Shielding Information Center (a)] computer code runs have been made using available data for each of the separate irradiated fuel campaigns from which the waste was generated. Plutonium and uranium recovery data were used to separate the waste from the usable fuel components, and processing dates were used to input decay times. Summation of all the campaigns then yielded total waste tank contents. Comparison of the ORIGEN2 output with other data, e.g., analytical, results in some adjustments and enables uncertainties to be estimated. These uncertainties are used to establish ranges (i.e., upper and lower estimates) for the radionuclide inventory.

The estimated total radionuclide inventory projection expected to be shipped from the WVDP and the projected inventory in the canister will be reported in the WQR. The average expected inventory in a canister will be based upon a canister 85 percent full (see section 3.5) and the average expected inventory. The lower bound will be based upon a canister 80 percent full and using the lower uncertainty estimates for the total expected inventory in the waste. The upper bound will be based upon a canister 90 percent full and using the upper estimate for the total expected inventory.

To decay the radionuclide inventory to ensure the required radionuclides are reported, radioactivity of each nuclide will be used as input to the ORIGEN2 computer code. Decay of radionuclides and buildup of daughter nuclides in the canister will be calculated.

### 1.2.2 Radionuclide Inventory During Production

**At the time of shipment the producer shall provide in the production records estimates of inventories of individual radionuclides in each canistered waste form. The producer shall also report the expected precision and accuracy of these estimates in the WCP.**

Strategy

> The radionuclide inventory in the vitrified waste will be provided by statistically sampling the melter feed and the glass that can be removed from the top of the canister. Radionuclide inventory in the feed and glass sample will be obtained by measuring the inventory of key radionuclides and relating these values to other necessary values through the use of scaling factors derived from the WVDP waste characterization program. Sampling frequency, precision, and accuracy will be based upon the results of qualification testing.

Compliance

> The same sampling approach used to provide chemical composition during waste vitrification will be used to provide radionuclide inventory in a canistered waste forms, i.e., a statistically determined number of samples of the melter feed and the glass that can be removed from the canister will be analyzed for the radionuclide inventory and related to the inventory in the canistered waste forms. This is discussed in section 1.1.2. Available decontamination factors for the process equipment will be used to account for the potential loss of volatile radionuclides (e.g., Tc-99 and Cs-137). The sampling frequency will be reported in the WQR. The expected precision and accuracy of the estimates made during vitrification are not available at this time; they will be reported in a supplement to the WCP. They will have the same basis as those for chemical composition.

A preliminary analysis indicates that those radionuclides listed in table II will have to be reported. During vitrification, the samples are expected to be analyzed as listed in table II. Values for those radionuclides not directly analyzed will be obtained by using scaling factors developed during the West Valley HLW Characterization Program.

Scaling factors are ratios between any of the radionuclide inventories that are measured and others that must be reported. These scaling factors will be based on a waste sample removed after waste homogenization. The analytical results from this sample will be compared with the previous results of the waste characterization program to ensure that a representative sample is used to develop the scaling factors. Additional samples will be taken if necessary. The scaling factors will be reported in the WQR.

The weight of glass in each canister will be measured and will be included in the production records for the canisters. From this, and the specific activity in the process samples, the amount of each reportable radionuclide present in the canisters will be estimated and reported in production records. The specific activity will be the mean for the batch of WVDP HLW. ORIGEN2 calculations will be used to calculate the radionuclide content of canisters at time of shipment and to ensure that all radionuclides with half lives greater than ten years in concentrations greater than 0.05 percent of the total radioactive inventory at any time up to 1,100 years after production will be reported.

## 1.3 Specification for Radionuclide Release Properties

### 1.3.1 Control of Radionuclide Release

> The WVDP is performing the leach test program consistent with the DWPF-WAPS 1.3 language as given in appendix B.

> 

## TABLE II

Radionuclides Expected In the Vitrification Feed
That Specification 1.2.2 Requires To Be Reported*

| Radionuclide | Planned Reporting Method |
|---|---|
| Ni-59 | ICP/MS |
| Ni-63 | Separation and Scintillation or ICP/MS |
| Sr-90 | Beta analysis |
| Zr-93 | ICP/MS |
| Nb-93m | ICP/MS |
| Tc-99 | Separation and beta analysis or ICP/MS |
| Pd-107 | ICP/mass spectrometry |
| Sn-126 | Gamma spectrometry or ICP/MS |
| Cs-135 | Ratio to Cs-137 or ICP/MS |
| Cs-137 | Gamma spectrometry of Ba-137m |
| Sm-151 | Ratio or ICP/MS |
| Ac-227 | ICP/mass spectrometry |
| Pa-231 | Gamma scan Ac-227 daughter or ratio to U elemental or ICP/MS |
| U-233 | ICP/MS |
| U-234 | ICP/MS |
| Np-236 | ICP/mass spectrometry |
| Np-237 | Separation and alpha or gamma spectrometry or ICP/MS |
| Pu-238<br>Pu-239<br>Pu-240 | Separation and alpha spectrometry or ICP/MS |
| Pu-241 | ICP/MS |
| Am-241 | ICP/MS |
| Am-242m | ICP/MS |
| Am-243 | ICP/MS |
| Cm-244 | ICP/MS |

* Half life >10 years, concentration >0.05 percent of total radioactive inventory up to 1,100 years.

> Strategy

> The WVDP will investigate those factors which significantly affect radionuclide release properties of the waste glass form and specify the target range of acceptable glass compositions. Process controls will be implemented to ensure that a durable and processible glass product can be consistently produced within the specified compositional envelope.

Compliance

> Radionuclide release properties of waste glass can be dependent on a number of factors including glass composition, glass redox, cooling rates, and melt temperature. These variables are either currently or will in the future be investigated as required to confirm existing models, data, etc., and to assess their relative importance to glass durability.

> Experimental studies at Savannah River Laboratory, Battelle-PNL, Catholic University (VSL), as well as considerable literature information, suggest that glass composition is the single most important factor affecting radionuclide leach resistance of waste glass forms. This assessment is supported by theoretical models by Jantzen and Plodinec (1984) and Feng et. al. (1988) where they demonstrate that the leach rates of a large variety of natural glasses, nuclear waste glasses, and synthetic glasses can be related to the free energy of hydration ($\Delta G_{hyd}$) of the glass which in turn is a direct function of glass composition. The good correlation between glass composition (i.e., $\Delta G_{hyd}$) and leach rates over several orders of magnitude is evidence that the other factors mentioned above probably have relatively little effect on glass durability.

> The WVDP strategy for selecting its reference waste glass is to determine that specific target composition which; (a) best satisfies this specification for low radionuclide release rates; (b) is capable of solubilizing a high percentage of waste oxides ($\geq$ 33 percent waste oxides and zeolite); and (c) is also processible, i.e., the viscosity is $\leq$ 100 poise at the 1150°C melter operating point, the composition is resistant to reboil and crystal formation, etc. Because there are inherent uncertainties in manufacturing a specific composition, due for example to errors in sampling, chemical analysis and in adding glass formers, the specific target glass point must expand into a finite compositional field or envelope. Therefore, in order to ensure the production of a quality glass product, it is necessary to demonstrate that variations in feed composition will not cause the glass composition to fall outside the region where the above criteria are fulfilled. Accordingly, durability tests (see appendix C) are being performed on glass compositions surrounding the WVDP reference glass composition to thoroughly map the limits of acceptability.

> The composition of the WVDP reference-4 glass is given in table III. Based upon this target composition, glasses of varying compositions doped with Th and U are melted and tested to provide a phase field in which the glass is characterized. The compositional boundaries for the elements listed in table IV are being investigated singly, i.e., one element is being raised or lowered at a time. These elements make up about 85 percent of the glass on an oxide basis. Statistically selected multiple component variations are undergoing durability tests. Leach rate data from this testing will be empirically modeled to characterize the phase field. This will provide the basis for control of the release properties by composition.

TABLE III

Composition of WVDP Reference 4 Glass

| Oxide | Concentration (wt. %) Radioactive | Cold |
|---|---|---|
| $Al_2O_3$ | 6.54 | 6.54 |
| $AmO_2$ | 0.01 | 0.00 |
| $B_2O_3$ | 10.26 | 10.26 |
| BaO | 0.07 | 0.07 |
| CaO | 0.50 | 0.50 |
| $CeO_2$ | 0.16 | 0.16 |
| $Cr_2O_3$ | 0.14 | 0.14 |
| $Cs_2O$ | 0.10 | 0.10 |
| CuO | 0.06 | 0.06 |
| $Fe_2O_3$ | 12.12 | 12.12 |
| $K_2O$ | 3.73 | 3.73 |
| $La_2O_3$ | 0.04 | 0.04 |
| $Li_2O$ | 3.15 | 3.15 |
| MgO | 0.90 | 0.90 |
| $MnO_2$ | 1.00 | 1.00 |
| $MoO_3$ | 0.05 | 0.05 |
| $Na_2O$ | 11.42 | 11.42 |
| $Nd_2O_3$ | 0.14 | 0.14 |
| NiO | 0.25 | 0.25 |
| $NpO_2$ | 0.01 | 0.00 |
| $P_2O_5$ | 2.36 | 2.36 |
| PdO | 0.03 | 0.03 |
| $Pr_6O_{11}$ | 0.04 | 0.04 |
| $PuO_2$ | 0.01 | 0.00 |
| $RhO_2$ | 0.02 | 0.02 |
| $RuO_2$ | 0.08 | 0.08 |
| $SO_3$ | 0.23 | 0.23 |
| $SiO_2$ | 41.24 | 43.35 |

>

TABLE III (CONTINUED)

Composition of WVDP Reference 4 Glass

| Oxide | Concentration (wt. %) Radioactive | Cold |
|---|---|---|
| $Sm_2O_3$ | 0.03 | 0.03 |
| $SnO_2$ | 0.03 | 0.03 |
| SrO | 0.03 | 0.03 |
| $TeO_2$ | 0.02 | 0.02 |
| $ThO_2$ | 3.61 | 0.00 |
| $TiO_2$ | 0.80 | 0.80 |
| $UO_2$ | 0.58 | 0.00 |
| $Y_2O_3$ | 0.02 | 0.02 |
| ZnO | 0.02 | 0.02 |
| $ZrO_2$ | 0.19 | 2.30 |

## TABLE IV

### Elements that Will Be Varied to Define the Durability Bound

| Element | High | Low |
|---|---|---|
| Si | X | X |
| Th | X | X |
| Fe | X | |
| B | X | X |
| Na, K, Li | X | |
| Al | X | X |

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> The WVDP compositional control program (see section 1.1.2) involves sampling and analyzing the slurry feed, adjusting its composition within control limits, followed by resampling and reanalysis to confirm the new composition. Correlations and statistical error bands will be developed between the slurry feed composition and the resulting waste glass composition. This will establish the compositional control limits on the feed slurry necessary to yield an acceptably durable waste glass product. During production, the composition of the CFMUT slurry will be verified as acceptable (will produce a glass within the durable glass region) prior to transfer to the MFHT. Samples will be taken from the MFT to verify that the composition of the melter feed is within control limits.

> The effect of various processing variables, other than composition, on waste glass durability will also be investigated. Nominal glass compositions with Th and U are being melted at various redox states ($Fe^{+2}/Fe^{+3}$) and characterized by durability tests (appendix C) to assess the effect of glass redox state on radionuclide release. The redox state of the glass is a result of processing conditions. The range of glass redox states which process well will be identified. Glasses of that redox state and of redox states on either side will be tested in the Product Consistency Test (PCT) in deionized water. This will provide data on the effect of changes in redox state that could be generated during waste vitrification.

> During cold testing at the CTS the cooling rate of the glass in the canister will be monitored such that the test specimens fabricated in the laboratory can be heat treated to simulate the canistered glass (see section 1.1.1). After monitoring the glass temperatures in a series of canisters, a reference cooling heat treatment will be developed. Laboratory specimens of the nominal glass composition containing Th and U will then be subjected to this heat treatment and characterized by the PCT test. This will provide an assessment of the effect of the cooling rate on durability.

The role of melt temperatures on radionuclide release will be investigated, on non-radioactive glass samples obtained from laboratory and full-scale melter runs, on the WVDP Reference 4 glass composition. Temperatures will be varied approximately +50°C and -100°C around the nominal melt temperature of 1150°C to assess the impact of thermally induced changes in solubility and crystallinity on leachability.

The WVDP is characterizing the radionuclide release properties of glass specimens described above using a variety of leach tests, simulating static and flowing conditions with deionized water and, in some cases, with ground water expected to be found in the candidate repository. These WVDP durability tests include an MCC-1 test, a Partial Exchange Interactive Flow test (Barkatt, et. al. 1981, Barkatt, et. al. 1983) and a powder leach test called the Product Consistency Test (PCT). The test method summaries are in appendix C. Correlations between the MCC-1 and PCT tests will be investigated. The PCT is being used for most scoping evaluations since it is sensitive to glass homogeneity and composition; also in a relatively short period of time the steady-state leach region is reached, thereby permitting a more rapid and meaningful assessment of processing variables on glass durability. The boron release rate data from the PCT will generally be used to define a durability compositional field as studies have shown that this is a good indicator of the waste glass matrix dissolution rate (Scheetz, et. al., 1986).

Target and glass variation compositions that meet this specification and are also processible will be reported in the WQR. The results of each test performed will be reported with a standard deviation from leachant analysis and will include the leach rates of the elements Si, B, Na, U, and Cs in units of grams per meter$^2$ per day

($g/m^2d$); final leachate pH will also be reported. PCT results will be compared to the MCC-1 test data at 28 days in deionized water. Compositional limits that provide an acceptable glass will be reported. The effect of glass redox state, canister cooling rates, melt temperatures and repository ground waters on the durability of the nominal glass composition will be discussed. The test results will be applied to the process model and to the models on glass durability to provide a basis for predicting the behavior of the glass after disposal in a repository.

### 1.3.2 Verification of Radionuclide Release Properties

**The producer shall document that the canistered waste form at the time of production met the limits of specification 1.3.1. Verification of compliance shall be included in the production records.**

Compliance

> During production, rigorous control of process variables will be maintained to ensure that the target glass composition is produced. Verification of compliance will be provided by monitoring the canistered glass composition. This will be performed and recorded on production records as discussed in section 1.1.2.

## 1.4 Specification for Chemical and Phase Stability

**The producer shall provide the following data on the borosilicate glass waste form:**

**a) The transition temperature where the slope of the thermal expansion vs. temperature curve shows a sharp increase.**

b) A Time-Temperature-Transformation (TTT) diagram that identifies temperatures and the duration of exposure at the temperature that causes significant changes in either the phase structure or the phase compositions of the borosilicate glass waste form. The producer shall provide TTT diagrams characteristic of the expected range of waste form composition. The waste form radionuclide release properties called for under Specification 1.3 shall also be provided for representative samples covering the same ranges of temperature, duration of exposure, and waste form composition.

The requested data, analysis, and appropriate technical support shall be provided in the WQR. The method used to produce these data shall be described in the WCP.

At the time of shipment, the producer shall certify that the maximum waste form temperature is at least 100°C below the transition temperature of 1.4 (a) above. In addition, the producer shall certify that after the initial cool down, the canistered waste forms to be shipped have been handled and stored in a manner such that the maximum temperature of the waste form has not exceeded the transition temperature specified in Specification 1.4 (a). The producer shall describe the method of certification in the WCP. The canistered waste forms shall be transported under conditions that ensure that the transition temperature of Specification 1.4 (a) above is not exceeded; certification that this has been accomplished will be required on receipt at the repository.

Strategy

The glass transition temperature will be measured on WVDP test glass.. The Time-Temperature-Transformation behavior of the glass will be developed over the applicable time and temperature range. Thermal analysis calculations will be performed to show that the temperature limits during storage and at the time of shipment are not exceeded. The storage facility will be designed to keep the glass below the glass transition temperature.

Compliance

a) Glass Transition Temperature

The glass transition temperature is that temperature reached on cooling when a super cooled liquid becomes a glass. More specifically, it is the temperature at which a marked change in atomic mobility takes place. Typically, the glass transition occurs over a short temperature range of about 5°C, below which atomic mobility is too limited to allow secondary phase formation, and above which the glass becomes more like a liquid (atomic mobility is increased). Above the glass transition temperature nucleation and growth of second phases are possible up to the liquidus temperature (the temperature at which the material essentially finishes melting on heating) of the system, beyond which these phases redissolve.

This change in atomic mobility, the glass transition temperature, is generally detected using a thermal expansion measurement by dilatometry and/or differential scanning calorimetry.

In case of detection by thermal expansion, as a glass sample is heated, a sharp increase in thermal expansion is noted at the glass transition temperature range. The glass transition temperature is determined by the intersection of extrapolations of the lower expansion response and the higher expansion response.

In the case of differential scanning calorimetry, an endothermic peak is detected at the glass transition temperature range, and the glass transition temperature is defined as the onset of this endothermic response.

> The WVDP will provide the glass transition temperature for the range of WVDP test glasses that contain uranium and thorium, in the WQR. These data will be determined using one or both of the two techniques cited above: differential scanning calorimetry and dilatometry.

b) Time-Temperature-Transformation Response

As discussed above for the glass transition temperature, atomic mobility can permit nucleation and growth of secondary phases. Defining this behavior is facilitated through the use of a Time-Temperature-Transformation (TTT) diagram. The TTT diagram is a graphical representation of isothermal heat treatments of glass samples for specific lengths of time.

> The WVDP will produce TTT diagrams for nominal glass compositions (containing Th and U) representing the statistical variability found in testing in section 1.1.1. Phases resulting from the heat treatments will be identified for type and volume percent abundance by standard analytical techniques (e.g.,

optical microscopy image analyses, x-ray diffraction, scanning transmission electron microscopy). Specimens within the cooling curve region will be tested in deionized water according to the Product Consistency Test (PCT) method (see section 1.3).

Additionally, samples from the melter pour stream and canisters cast during nonradioactive testing at the CTS will be extracted and compared statistically through like analyses to the time-temperature-transformation results. The samples from the melter pour stream will give an indication of the affect of pre-existing crystals.

The temperatures used to develop the TTT curve will be between the glass transition temperature and the liquidus temperature. The time length of heat treatments will be between 0.5 hours and as long as canister cooling data from the CTS dictates for reaching the glass transition temperature.

The TTT diagram, analysis, comparison to actual cold test canister samples, and corresponding release rate characteristics along the canister cooling curve will be provided in the WQR.

Canistered Waste Form Storage and Shipment

> The maximum glass temperature at time of shipment to the repository (in the first decade of the twenty-first century (Office of Civilian Radioactive Waste Management 1985)) will be shown to be at least 100°C below the glass transition temperature by considering the West Valley canister geometry (see figure 2), with a radionuclide inventory loading representing an upper activity bounded canister (see section 1.2), and assuming that the surrounding air is 25°C. The heat generation rate from the nuclides will be calculated by

ORIGEN 2. The heat source will then be an input in the thermal analysis computer program HEATING5 (Turner). Additional inputs to this program are density, heat capacity, and thermal conductivity. Standard canister material data and measurements on WVDP test glass will be used for these inputs. The production records will include a certification that the maximum glass temperature is as stated above.

The West Valley storage facility in the existing plant Chemical Process Cell (CPC) is being designed to maintain the maximum glass temperature below the glass transition temperature. The current reference flow path and storage of the canistered waste forms after glass pouring is discussed below.

Cooling in the CPC will be provided by three cell coolers having a total expected capability of 210,000 watts (720,000 BTU/hr). This provides 50 percent redundancy after conservatively assuming that 400 canisters will be stored, each with an output of 350 watts. (This heat generation rate of 140,000 watts is more than that expected in the total HLW). One cell cooler will be held in stand-by for redundancy. A thermal analysis will be performed to assess the amount of time that passes after all three coolers are off until the glass centerline temperature exceeds the glass transition temperature. The cooling to each cell cooler will be through existing 7.6 cm (3-in) closed loop transport systems. Fans within the cell coolers will move air over the coils to the cell. Operating procedures will require that the temperature in the CPC will be monitored during HLW storage. The ambient cell temperature will be related to the canistered waste form centerline temperature.

Ventilation flow to the cell is through the Equipment Decontamination Room (EDR) to the CPC and is ducted out of the CPC to the main plant HVAC system. Nominal CPC pressure is 2.3 cm (0.92 inches) water differential. HVAC flow thru the cell is 170,000 to 230,000 litres/min. (6,000 - 8,000 $ft^3$/min) and is protected from backflow and contamination by a HEPA filtration system.

The CPC has windows on two sides of the cell, and TV cameras with monitors will be available.

The production records for each canistered waste form will include a certification that after cool down the maximum glass temperature did not exceed the glass transition temperature during storage.

If the WVDP is responsible for shipment, then the transportation cask that the WVDP will use to ship the waste off-site will undergo thermal analysis to show that the maximum activity loaded canister remains below the glass transition temperature during normal conditions of transportation as given in 10 CFR 71.71. The specific method that will be used to perform this analysis will be selected by the cask designer and submitted for approval by the WVDP.

# 2.0 CANISTER SPECIFICATIONS

## 2.1 Material Specification

> **The waste form canister and any secondary canisters to be supplied by the producer shall be fabricated from austenitic stainless steel. The ASTM alloy specification and the composition of the canister material, the secondary canister material, and any filler material used in welding shall be included in the WCP.**

Strategy

The canister material composition is provided in table V. Certified materials will be used for canister fabrication.

Compliance

West Valley plans to fabricate its canisters from austenitic stainless steel 304L, ATM A240 and A479 UNS Designation S30403. The current composition of this alloy is shown in table V. The composition of the weld filler metal, ER308L, that is expected to be used during canister fabrication is shown in table VI. (If the composition of the weld filler metal changes it will be reported in the WQR.) The composition of any closure weld filler metal used will be provided when the closure method is selected as discussed in section 2.2.

Procurement and fabrication documents will require that the fabricator use certified materials and provide certified material test reports on the heats from which the canister parts were cast. Part of canister inspection at the WVDP will be verification that these certifications are included for each canister shipped. Canistered waste form production records will include the certified material test reports for the canister parts and the receipt inspection report.

TABLE V: CHEMICAL COMPOSITION REQUIREMENTS FOR TYPE 304L STAINLESS STEEL (S30403)

| ELEMENT | PERCENT * |
|---|---|
| C | 0.030 |
| Mn | 2.000 |
| P | 0.045 |
| S | 0.030 |
| > Si | 0.750 |
| Cr | 18.00-20.00 |
| Ni | 8.00-12.00 |
| N | 0.100 |
| Fe | Balance |

* Maximum values unless range is indicated.

TABLE VI: CHEMICAL COMPOSITION REQUIREMENT OF ER308L*

| ELEMENT | PERCENT |
|---|---|
| C | 0.03 |
| Cr | 19.5-22.0 |
| Ni | 9.0-11.0 |
| Mo | 0.75 |
| Mn | 1.0-2.5 |
| Si | 0.30-0.65 |
| P | 0.03 |
| S | 0.03 |
| Cu | 0.75 |
| Fe | Balance |

* Single values shown are maximum. Other elements should not be present in excess of 0.50 percent.

## 2.2 Fabrication and Closure Specification

The canister fabrication methods, as well as those for any secondary canisters applied by the producer, shall be identified in the WCP and documented in the WQR. The outermost closure shall be leak tight in accordance with the definition of "leaktightness" in ANSI 14.5-1977, "American National Standard for Leakage Testing on Packages for Shipment of Radioactive Materials." The method for demonstrating compliance shall be described by the producer in the WCP and documented in the WQR.

### Strategy

> The stainless-steel canister will be fabricated from pipe, bar, a dished head and a reverse dished bottom. Canister integrity will be ensured by specifications of the components, specification of the method of fabrication and by an exacting program of inspection and verification. Final, leak-tight weld closure of the canisters will be performed directly after filling and will effectively isolate the waste glass from the environment during subsequent handling and storage at the repository. The resistance of the final closure to leakage will be assured at WVDP by close control of the welding parameters and by visual weld inspection.

### Compliance

> The reference West Valley canister design is shown in figure 2. WVDP plans to have its canister fabricated by cold rolling steel sheet with a minimum thickness of 0.34 cm to form the canister wall. The canister bottom will be a flanged and reverse dished head; the top will be an ASME flanged and dished head. The top and bottom thicknesses are shown to be 0.48 cm. The lifting flange will be formed by cold rolling square bar. All canister components will be annealed and pickled prior to assembly.

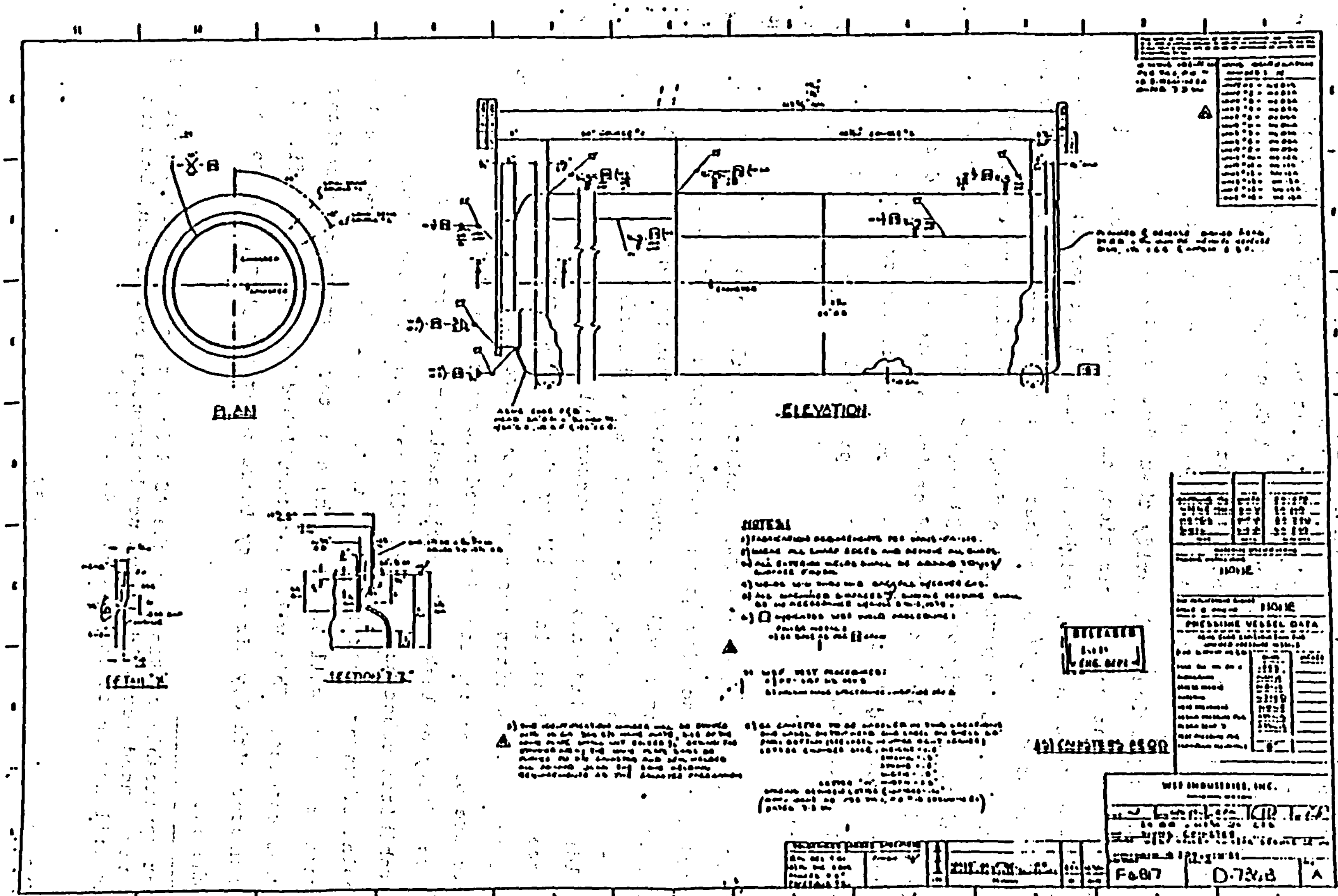


Figure 2

WVNS Canister

> Fabrication welding is to be by gas tungsten arc welding. All welds will be ground and inspected by dye penetrant according to section V of the ASME Boiler and Pressure Vessel Code* and meet the criteria of section VIII. Certifications that the welds were made and inspected as specified will be required from the fabricator. Canister inspection will verify that these certifications are included. After weld fabrication, the canisters will be labeled (see specification 2.3), weighed and helium leak tested to a maximum leak rate of $<1 \times 10^{-7}$ atm cc/sec. The WVDP will perform inspection and data reviews as part of the fabrication effort to ensure that the canisters comply with design requirements. The results of weld inspections and leak testing of canisters used during cold testing will be provided in the WQR; the same results for canisters used during waste vitrification will be provided in the production records.

> Final weld closure of the WVDP canisters will be performed in the Vitrification Facility at the earliest practical time after filling. Canisters will be transferred from the enclosed turntable to a controlled welding station where weld surface preparation and welding of the lid onto the canister will occur. Under normal process conditions, it is likely that weld closure will be performed within 1.5 days after canister removal from the turntable. Prompt closure of the canister is deemed necessary to minimize any possibility of leakage into the canister of water and other prohibited substances. Care will be taken to ensure that the dew point of water vapor contained in the gas inside the weld-sealed waste canister will be above the canister storage and repository temperatures. This will be accomplished by purging the filled canister with dry air or dry inert cover gas just prior to welding the lid.

* Note that applicable sections of the ASME Boiler and Pressure Vessel Code will be referenced for welding and nondestructive evaluation, but the canister will not be classified as a code vessel.

> The reference WVDP welding process has not yet been established. Welders considered suitable for the WVDP canister geometry are discussed in appendix D. Upon selection of the specific welding technique, closure development and qualification (i.e., leak tightness) testing will be performed on nonradioactive canisters. Tests will be performed to develop the parameters that will result in a leak tight closure. Those parameters that will produce a leak tight closure will be recorded and repeated on the canisters containing the waste glass.

> The Production Record for each canistered waste form will certify that canister components and the entire canister were fabricated according to approved drawings and procedures and meets the procurement specifications. Records of inspection to verify that canisters were fabricated according to specification will be included in the Production Records. The Production Record will also certify the integrity of the final closure weld made at WVDP by visual inspection and by reporting the critical welding process parameters.

## 2.3 Identification and Labeling Specifications

### 2.3.1 Identification

The producer shall assign an alphanumeric code to each canister or secondary canister, if one is used, that is produced. This alphanumeric code shall appear on the labels of the canistered waste form and on all documentation pertinent to that particular canistered waste form.

### 2.3.2 Labeling

Each canister shall be labeled with the identification code specified above. Two labels shall be firmly affixed, with one visible from the top and one from the side of the canister. The identification code shall be printed in a type size of at least 92 points using a sans serif type face (Megaron Bold Condensed or equivalent). A proposed layout shall be provided in the WCP. Labels meeting the requirements above shall be applied to the exterior of the outermost canister. Labels affixed to the outside of the outermost canister shall not cause the dimensional limits of Specification 3.11 to be exceeded. The label materials and method of attachment shall be selected to be compatible with the canister material. The label shall be designed to withstand filling and storage at the producer's facility, shipment to the repository, and possible lag storage at the repository prior to final packaging. The producer shall describe the label materials and method of attachment in the WCP. The producer shall estimate the service life of the label and provide a strategy for meeting that estimate in the WCP.

Strategy

The identification code for each canister will be of the form WVXXX. This code will be placed on the side and top shoulder of the canister with lettering as shown in figure 3.

Compliance

Each West Valley canister will have a unique identification code of the form WVXXX where X is a digit. This identification code will appear on the production records that describe the canistered waste. The format for the production records will be included in the WQR.

> This identification code will be on two places on the canister. One will be on the top shoulder of the canister such that the code can be seen from the vertical direction; the other will be on the side of the canister about 60 cm from the top as shown in figure 3. The characters for these labels will be at least 3.25 cm (92 points) and as large as 5.1 cm (144 points) tall and will be modified block. Characters are to have a profile height not exceeding 0.15 cm. It is planned that these characters will be inscribed in the canisters as weld beads using a 308L austenitic stainless-steel welding rod. Because the label is planned to be a weld bead, it will be compatible with the canister and the service life of the label should be as long as the fabrication welds of the canister.

# WEST VALLEY HLW CANISTER LABELING

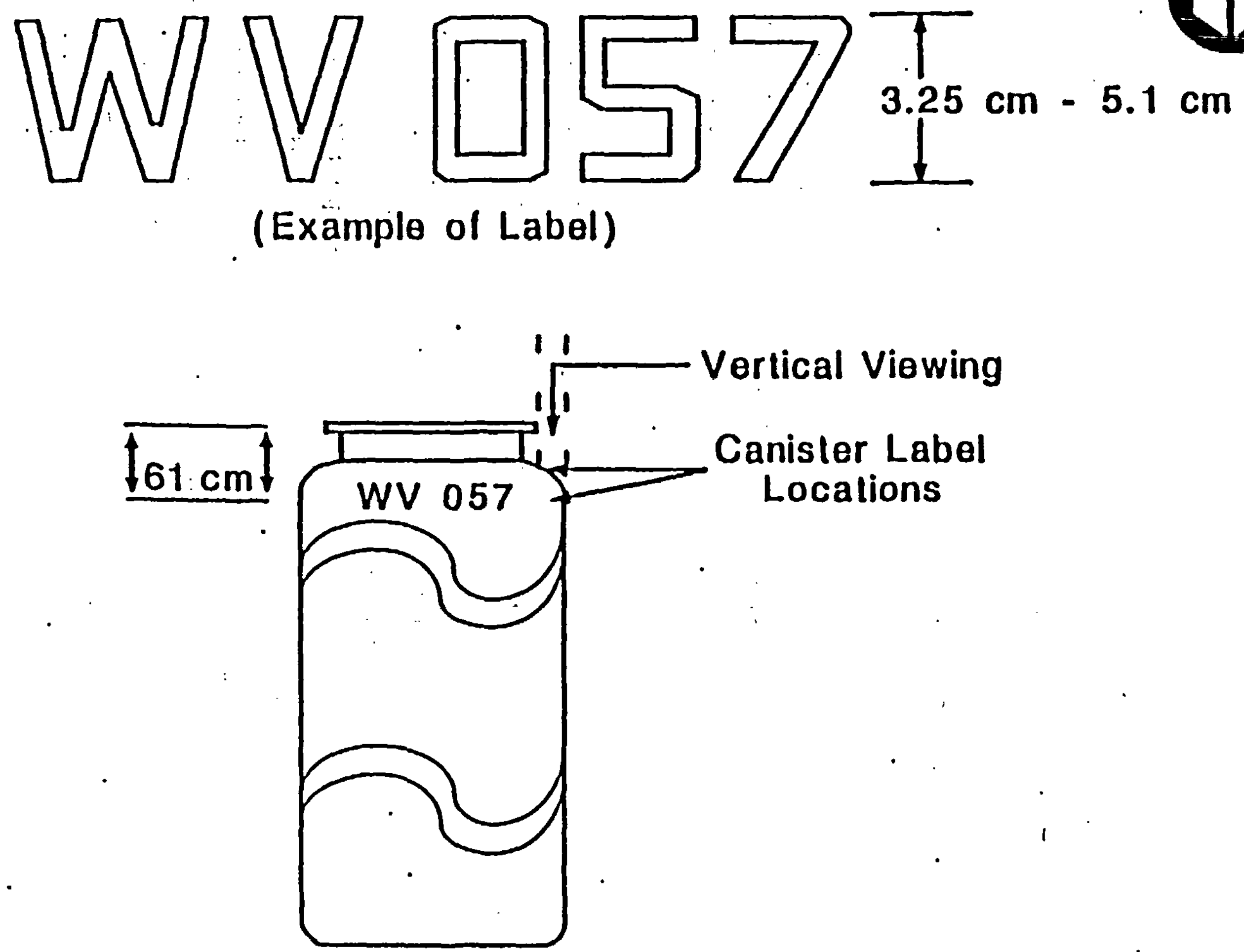


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FIG 3

During nonradioactive testing at the CTS, reference canisters will be filled at various pour rates. The effect of glass pouring and subsequent handling and decontamination on the legibility of the label will be assessed and discussed in the WQR. The labeling method will be reported in the WQR.

The identification code that will be assigned to a canister or batch of canisters will be provided to the fabricator by the WVDP. Canister receipt inspection will include verification that both labels on a canister are the same and that these identification numbers are unique (i.e., not on a previous canister). Additional inspections will require that the weld character height profile is correct and that any defects which could trap contamination be removed before the canisters will be accepted at the WVDP. The results of the above inspections will be recorded in the production records.

After waste vitrification and after temporary storage, the canistered waste form labels will be visually inspected via a television camera or shield window before placement in the transportation cask to ensure that the labels are still attached and legible. An assessment will be made of the ability of the label to remain attached and legible through the normal conditions of transport and handling at the repository facility until the canistered waste form is placed in the repository container. The results of this inspection will be included on the production records. This will ensure that the service life of the label is long enough for placement in the repository container.

## 3.0 CANISTERED WASTE FORM SPECIFICATIONS

### 3.1 Free-Liquid Specification

**After closure the canistered waste form shall not contain free-liquids that could be drained from the canister either initially or after having been subjected to the transition temperature of Specification 1.4(a). The producer shall describe the method of compliance in the WCP and provide documentation in the WQR.**

Strategy

\> The vitrification process will evaporate free liquid in the feed. The canisters will be inspected prior to entry into the vitrification facility to ensure they contain no drainable liquid. Administrative controls and the permanent weld closure of the canister lid will ensure that free liquid cannot enter into or condense inside the filled waste canister.

Compliance

\> The vitrification process will take place at about 1150°C and 1 atm, and the liquid in the waste feed will be evaporated from the glass. The empty canisters will be inspected prior to filling to ensure that they do not contain drainable liquids. Any trace of free liquids residing in the empty canister are unlikely to remain after it is filled with the hot glass (pour temperatures >1000°C). The thermal conditions of Specification 1.4 (a) define the temperature limit below which the glass is phase stable; therefore, no free liquid will be generated by the glass up to that limit.

Prior to final welding of the canisters, temporary covers will remain on the canistered waste forms. They will be warmer than the storage cell ambient air, because the canister waste forms are a heat source. Therefore, there will not be any generation of free liquid by condensation in or on the canisters.

A potential source of free liquids in the canister is the aqueous decontamination solution. Since the lids will be promptly welded onto the as-filled canister under controlled conditions that ensure helium leak tightness, it will be impossible for decontamination liquid to enter the canister. Furthermore, the use of dried gases (~0 percent relative humidity) to purge the filled canister before final lid weld closure will prevent water vapor from condensing inside the canister i.e., the dew point of any entrapped water vapor will be above the canister storage and repository temperatures.

The WQR will report on the absence of free liquids in the waste glass below the transition temperature and on the controls administered to prevent free liquids from entering the canistered waste form.

## 3.2 Gas Specification

After closure the canistered waste form shall not contain free gases, other than cover and radiogenic gases. Cover gases shall be helium, argon, other inert gases, or air, or combinations thereof. The maximum internal gas pressure immediately after closure shall be 7 psig at 25°C. The producer shall describe the method of compliance in the WCP and shall document in the WQR the quantities and compositions of any gases that might accumulate inside the canister after the canister has been subjected to temperatures up to the transition temperature of Specification 1.4 (a).

**The producer shall also document in the WQR the quantities and compositions of any gases that might accumulate inside the canisters as a result of radioactive decay.**

Strategy

Glass pouring and permanent closure of the canister will be in an air atmosphere. The technical literature has been reviewed and it shows that an insignificant amount of gas would be generated at the glass transition temperature. Based upon the activity in the waste, the amount of radiogenic gases that could be generated will be calculated.

Compliance

The glass will pour into the canister in an air environment. Storage and final closure is planned to be in air and/or inert cover/dry purge gases. Therefore, void spaces will contain air and/or inert gases. The prompt final weld closure which will be at atmospheric pressure will prevent other gases from entering the canistered waste form. When the final closure is performed, the cell temperature and pressure will be recorded on the production records.

Data published in the open technical literature has been compiled to provide estimates of the quantities and compositions of gases that could vaporize in the glass at about the glass transition temperature. Because the WVDP glass will be stored below the glass transition temperature (see section 1.4), the data provides an upper bound on the amount of anticipated volatility. The results of this literature review are in appendix E and show that no significant amount of gas will accumulate inside the canister by this process.

> The amount of gaseous products produced from the decay chains of Th-232, U-234, U-235, U-238 and the higher actinides in a canister filled with WVDP HLW glass, radon and helium, will be calculated. A canister with the upper bound radionuclide inventory (see section 1.2.1) will be the basis for this calculation. These results will be reported in the WQR.

### 3.3 Specification for Explosiveness, Pyrophoricity, and Combustibility

After closure the canistered waste form shall not contain explosive, pyrophoric, and combustible materials. The producer shall describe in the WCP those administrative controls and other factors that prevent the introduction of explosive, pyrophoric, or combustible materials into canistered waste forms. The producer shall present in the WQR an evaluation of the canistered waste form to demonstrate that, for the range of material compositions, it remains nonexplosive, nonpyrophoric, and noncombustible after having been subjected to the temperatures up to the transition temperature of Specification 1.4(a).

Strategy

> Borosilicate glass is not any of the above types of materials. Prior to entry into the Vitrification Facility, the canisters will be inspected to ensure they do not contain any of these materials. Administrative controls and prompt weld closure of the canister will prevent entry of prohibited materials into the canistered waste forms.

Compliance

> Borosilicate glass, the WVDP HLW form, is oxidized and is not explosive, pyrophoric, or combustible. It is phase stable up to the glass transition temperature and will not change into these types of materials.

Prior to entry into the Vitrification Facility cell, the canisters (which are specified to be cleaned and degreased by the manufacturer) will be visually inspected to ensure that they do not contain any prohibited materials. Verification that this inspection took place will be recorded on the production records for the canister. Permanent weld closure after filling will ensure against ingress of explosive, pyrophoric of combustible materials into the canister. The reference flow path of the canister in the Vitrification Cell is presented conceptually in the Introduction. The WQR will present a detailed canister flow path in the Vitrification Cell to interim storage which will show that there are no locations available for these materials to enter the canister.

3.4 Organic Materials Specification

**After closure the canistered waste form shall not contain organic materials. The producer shall describe the method for complying with this specification in the WCP and document the detection limit for organic materials in the WQR.**

Strategy

> Borosilicate glass is an inorganic material. Prior to entry into the Vitrification Facility, the canisters will be visually inspected to ensure that no observable organic material is present. Administrative controls and permanent weld closure will prevent organics from entering the canister after glass filling.

Compliance

Borosilicate glass is an inorganic material. Organic compounds in the melter feed will decompose in the melter. Standard test methods for assessing the amount of ash from organic materials, i.e., ASTM D482-80 and ASTM E830-81, use temperatures of 575°C to 775°C to decompose the organic molecules. These temperatures are less than the operating temperature of the melter, 1150°C. Therefore, no organics will remain in the glass. To document the detection limit for organics, a sample of glass poured into a canister at West Valley during testing will be analyzed for total organic carbon.

The canisters will be cleaned, degreased, and visually inspected by the fabricator according to applicable sections of ASTM A 380. Certification that this took place will be required from the fabricator. The receipt of this certification will be recorded on production records. Before use the canisters will be stored in a clean, dry environment. Prior to entry into the vitrification facility, the canisters will be visually inspected to ensure that organics used during fabrication were removed. Production records will show that this inspection took place. Furthermore, the heat of the glass pouring into the canister will cause trace quantities of organics in the canister to decompose.

> Administrative steps to prohibit storage of organics in the Vitrification Facility and controls to ensure that lubricants and fluids from the processing and handling equipment cannot drip or spill into the canisters will be taken. Early weld closure of the canister will limit the possibility of contaminating the waste glass with organics.

### 3.5 Free-Volume Specification

**After closure, the free-volume within the canistered waste form shall not exceed 20 percent of the total internal volume of an empty canister. The producer shall identify the nominal free-volume and expected range of variation in the WCP and describe the method of compliance in the WCP. The producer shall provide in the WCP the expected frequency distribution of free volumes in canistered waste forms. The free volume within the canistered waste form shall be reported in the production records.**

Strategy

> The WVDP plans to fill its canisters nominally 85 percent full. During filling, glass level will be monitored by a $\gamma$-transmission/emission detection system. The free volume will be provided by dividing the canistered glass mass by the glass density and comparing the resultant fill volume with the internal canister volume.

Compliance

> The WVDP is planning to fill its canisters nominally 85 percent full with a range of 80 percent to 90 percent. Therefore, the free volume in a canister is expected to be 10 percent to 20 percent with the nominal being 15 percent. The above range of values were readily realized in experimental work at Pacific Northwest Laboratory's Radioactive Liquid Fed Ceramic (B-Cell) Melter, utilizing similar canistered glass level detection systems. Other level detection systems, including visual methods, are also under consideration for West Valley use.

> The B-Cell level detection system is a vertical line of gamma detectors placed near the canister. When the canister is empty a Co-60 source is detected. As it is filled, the glass shields the Co-60 and emits the Cs-137 (Ba-137m) gamma. The glass level is inferred from the height of each detector that senses the change. The B-Cell target fill height was 85 percent with a resultant range of generally 80 percent to 90 percent. The absolute standard deviation of the levels of 30 canisters that were filled was 2.75 percent; this represents the expected frequency distribution of free volumes.

> Canister weight may also be used to monitor glass fill level. Investigations will be made to evaluate if turntable load cells can provide continuous data on the mass of glass in the canister.

> Estimates of the void volume in production canistered waste forms will be provided through calculations that use the canister internal volume, glass density, and weight. The use of canister volume, glass density, and weight will include the presence of internal voids, if any, as well as the void on top of the canister. An estimate of the nominal internal volume of the West Valley canister will be made based on the canister fabrication drawings and specifications, or measurements of canisters used during cold testing. The density of WVDP test glass will be measured. This glass will be subjected to the same heat treatment as that expected during canister cooling. This volume and density information will be documented in the WQR. During waste vitrification the weights of each empty canister will be measured prior to filling. The weight of each filled canister will also be measured. These weights will be recorded on the production records. The difference between these two sets of weights will equal the weight of glass present in a canister. The weight divided by the density of glass will be used to calculate the volume of glass present in each canister. The fraction of the filled volume in each canister will be calculated

from the volume of glass present in the canister divided by the nominal internal canister volume. The free volume fraction is the difference between one and the fill volume fraction. This free volume will be documented in the production records for each canistered waste form. If there is excess free volume in a canister and it needs to be filled, this will be done by pouring silica sand through the canister opening.

> It is estimated that perhaps 1 to 2 percent of the canisters produced may be nonreference canisters i.e., the West Valley evacuated canisters of which there can be more than three. These will be used to drain the melter at the end of the campaign, or if necessary, during the campaign, e.g., to remove crystals that may accumulate on the bottom of the melter. These canisters may be only half full and of nonstandard dimensions. Furthermore, the pipes connected to the evacuated canisters and dipped into the melter will contain waste glass. These will be cut off and placed in canisters that will result in additional partly filled canisters. One canister will be required for these pipes for each set of three evacuated canisters. Silica sand can be used to fill the void space, if necessary. It is expected that these canisters can be handled in the same manner as reference canisters. Glass of the estimated composition in the melter at the time of removal will undergo powder testing described in section 1.3. The results will be a part of the production records for those nonreference canisters.

### 3.6 Specification for Removable Radioactive Contamination on External Surfaces

The level of removable radioactive contamination on all external surfaces of each canistered waste form shall not exceed the following limits:

**Alpha radiation: 220 dpm/100 cm²**

**Beta and Gamma radiation: 2200 dpm/100 cm²**

**In addition, the producer shall visually inspect the canistered waste forms, and remove visible waste glass on the exterior of the canistered waste form before shipment. The producer shall also provide in the WCP an estimate of the amount of canister material that is removed during the decontamination and the basis for that estimate. The producer shall describe the method of compliance in the WCP and provide supporting documentation in the WQR.**

Strategy

> The canistered waste form will be decontaminated with a nitric acid and $Ce^{+4}$ solution. The WVDP will smear the canister external surfaces according to 10 CFR 71.87(i)(1) before shipout to the repository. The external surfaces of the canistered waste forms will also be visually inspected for visible glass, and if present, the glass will be physically removed.

Compliance

> Before transport to the repository, the external surface of the canister will be smeared according to the procedure in 10 CFR 71.87(i)(1). Smearing will be done under the lifting flange, on the canister wall halfway up, and on the canister bottom. The smears will be counted using standard instruments and the results will be reported in the production records. If the smear results do not meet the specified limits, the canister will be decontaminated and smeared again. The reference canister decontamination techniques for the WVDP is rinsing in a tank containing nitric acid and $Ce^{+4}$ ions followed by water washing and air drying. It has been estimated that 3 to 50 $\mu m$ may be removed to effect decontamination of stainless steel surfaces that are not heavily corroded (Larson et al 1987). The solution concentration and/or exposure time will be

controlled to remove the contamination and an amount of stainless steel within that range. Spent decontamination solution will be recycled to the vitrification process via the tank farm. Testing using $Ce^{+4}$ is continuing; updated results will be reported in the WQR. The affect on the label will be considered.

> Visual inspection of the canisters to ensure that no waste glass is adhering to the canister will be made before shipout either through shield windows or a television camera. The results of this inspection will be reported on production records. If glass is adhering to the canister before or after decontamination, it will be removed, e.g., by mechanical or abrasive means; smear tests would then be repeated to ensure compliance.

## 3.7 Heat Generation Specification

The canistered waste form shall not exceed a total heat generation rate of 800 watts per canister at the time of shipment to the repository.

### 3.7.1 Heat Generation Projections

The producer shall document in the WQR the expected thermal output and the range of expected variation due to process variations during the life of the production facility. The method to be used in making these projections shall be described by the producer in the WCP.

### 3.7.2 Heat Generation During Production

The producer shall specify in the production records the heat generation rate and its accuracy for canistered waste forms at time of shipment. The expected accuracy of the heat generation rates shall be supplied in the WCP. The producer shall describe the plan for compliance in the WCP.

Strategy

The projected heat generation rate will be calculated by ORIGIN2 using the projected radionuclide inventory as input. The same approach will be used for obtaining the heat generation rate of production canisters after the radionuclide inventory is estimated. ORIGIN2 will be used to account for decay until time of shipment.

Compliance

Heat generation rate in a canistered waste form is dependent upon the radionuclides in the canister. The projected radionuclide inventory in the canistered waste will be estimated as discussed in section 1.2.1. The projected inventory in canistered waste with its range will be used as input to ORIGIN2 to calculate the projected heat generation rate and range. The projected heat generation rate will be reported in the WQR. The same approach will be used to provide the heat generation rate at the time of shipment, i.e., the radionuclide inventory for the canistered waste will be estimated during waste vitrification as discussed in section 1.2.2. The inventory will be decayed to the appropriate time and converted to heat generation rate by ORIGIN2. This will be reported in the production records. The same accuracy considerations applied to the radionuclide inventory will be applied to heat generation and reported in the WQR. The expected accuracy will be reported in a supplement to the WCP. It will include the accuracy considerations included in the radionuclide inventory and in converting the inventory to heat generation rate.

3.8 Specification for Dose Rates

At the time of shipment, the canistered waste form shall not exceed a maximum surface gamma dose rate of $10^5$ rem/hr and a maximum neutron dose rate of $10^3$ rem/hr.

3.8.1 Projections of Dose Rates

**The producer shall specify in the WQR the expected values and the range of expected variation for both gamma and neutron dose rates. The producer shall describe in the WCP the method to be used in making these projections.**

3.8.2 Maximum Dose Rates at Time of Shipment

**The producer shall provide in the production records the gamma and neutron dose rates for the canistered waste forms at the time of shipment. The producer shall describe the method of compliance in the WCP.**

Strategy

Using the radionuclide inventory as input the QAD computer code supplemented by the ANISN computer code will be used to calculate canister surface neutron and gamma fluxes. These will then be converted to dose rates.

Compliance

> Gamma and neutron surface dose rates for the canistered waste form depends on the radionuclide inventory and the characteristics of the glass media (e.g., density). The projected radionuclide inventory in the canistered waste will be estimated as discussed in section 1.2.1. The gamma and neutron source strength thus calculated will be input to the QAD computer code (Price and Blattner) and supplemented with the ANISN computer code [(Radiation Shielding Information Center (b)]. The energy dependent flux at the surface of the West Valley canister will be calculated assuming the source to be uniformly distributed inside the canister. The energy dependent flux at the surface will then be converted into gamma or neutron dose rates using appropriate conversion factors. The expected dose rates will be reported in the WQR.

The same approach will be used to provide the dose rates at time of shipment. The radionuclide inventory will be estimated as discussed in section 1.2.2. The dose rates will be calculated using the above codes and reported on the production records.

### 3.9 Chemical Compatibility Specification

**The contents of the canistered waste form shall not lead to internal corrosion of the canister such that there will be an adverse effect on normal handling during storage, transportation, and repository operation. The producer shall describe the method of compliance in the WCP and document in the WQR the extent of corrosiveness and chemical reactivity among the waste form, the canister, and any filler materials. Corrosion, chemical interactions, and any reaction products generated within the canistered waste forms after exposure to temperatures up to the transition temperature of Specification 1.4(a) shall be evaluated in the WQR.**

Strategy

> Existing data and calculations have been used to show that the canister does not react with the solidified glass. The moisture content in the canister void space and resultant potential canister corrosion will be estimated. Controls will ensure that liquid water, a potential corrodent, will not be present within the canistered waste form.

Compliance

> Evidence indicates that significant internal corrosion of the canister will not occur as a result of the canister material being in contact with a solidified glass waste form at temperatures up to the glass transition temperature (approximately 500°C). A temperature low enough to reduce the mobility of the glass below

that capable of aggressive attack would be expected to lie between the "softening point" ($3.0 \times 10^7$ poise) and the "strain point" ($3.2 \times 10^{14}$ poise) (Mecham, et al. 1976). At temperatures below 500°C, borosilicate waste glass viscosities are at or above $10^{13}$ poise (Slate, et al. 1981). This viscosity is great enough to ensure that the glass will not cause significant internal corrosion of the canister. Any reaction that might occur would be nearly undetectable because the diffusion of reactants to the glass-metal interface, and of reaction products away from this interface, will be extremely slow in both the glass and in the metal from which the canister will be fabricated (Rankin, 1980).

In a study conducted by Oak Ridge National Laboratory, various canister and waste form materials were held in contact at temperatures of 100 and 300°C in air and the atmospheres for periods of 6888 and 8821 hours (McCoy, 1983). It was reported that no significant interaction was detected between a typical borosilicate waste glass and 304L stainless steel, the WVDP canister material. This conclusion is based on a visual examination of the surface of the metal where it had been in contact with the glass, and weighing of the glass and metal before and after the test.

Other waste form-canister material compatibility studies have been conducted by Savannah River Laboratory in support of the Defense Waste Processing Facility. In one study, a borosilicate waste glass was melted and cast in 304L stainless steel crucibles. After being annealed at 500°C and furnace cooled, the crucibles were held at 350°C for 10,000 hours. A metallographic examination was used to determine the changes in the dimensions of cross sections of the crucibles that had been in contact with the glass. From this examination it was determined that no significant corrosion of the crucibles had occurred (Angerman and Rankin, 1977). In a second series of tests conducted in the same manner, no detectable corrosion was noted after the crucibles of glass had been held at 600°C for 20,000h (Rankin, 1980).

Corrosion tests have been done at PNL using a procedure adapted from the ANSI/ASTM C 621-68 "Standard Method for Static Test for Corrosion Resistance of Refractories to Molten Glass." In one series of tests, 304L stainless steel was subjected to a glass that is similar in composition to WVDP glass. The composition of glass used in these tests, TDS-411, is shown below:

| Component | Wt.% | Component | Wt.% |
|---|---|---|---|
| $SiO_2$ | 42.2 | $Fe_2O_3$ | 15.1 |
| $B_2O_3$ | 7.8 | NiO | 1.9 |
| $Al_2O_3$ | 3.1 | $MnO_2$ | 4.0 |
| $Li_2O$ | 8.8 | Zeolite | 2.5 |
| $Na_2O$ | 9.0 | $Na_2SO_4$ | 0.4 |
| CaO | 5.2 | | |

At 1150°C the bulk corrosion rate of 304L in TDS-411 glass was 18 micrometres per day. The flux line corrosion (corrosion at the top surface of the glass where the metal, glass, and furnace atmosphere are all present) was 78 micrometres per day. At 1050°C corrosion rates were found to be significantly lower, about 0.1 micrometers per day for the immersed portion of the specimen and 9 micrometers per day at the flux line. From these data, an activation energy of about 161 Kcal/mole at the flux line can be calculated. Extrapolating to 500°C, the temperature near which the glass transition temperature is found, no detectable corrosion (i.e., $<1$Å/day)would occur.

The presence of liquid water inside the canister can lead to localized corrosion (i.e., SCC corrosion of 304L stainless-steel, especially if $Cl^-$ and to a lesser extent $NO_3^-$ leach from the glass). Internal liquid water corrosion, however, will not be a problem at WVDP because of the following procedures; weld closure soon after canister filling will prevent the entry of water into the canister during subsequent decontamination and storage operations, and purging the canister with dry cover gas prior to weld closure should eliminate the possibility for condensation of trapped water vapor inside the canister during storage.

The amount of corrosion that could result from moisture trapped with the air in the canister void space after closure will be calculated. The approach will be to calculate the maximum weight loss of metal that could occur assuming that all of the water and oxygen in the canister airspace reacts with the canister wall. The calculated weight loss then will be converted to a penetration thickness to determine the extent of uniform corrosion. The kinetics of corrosion reactions will be ignored; only the ultimate extent of corrosion will be considered. Uniform and nonuniform corrosion, i.e., intergranular corrosion, stress corrosion cracking, and pitting, will be addressed.

The following assumptions will be made:

- The canister is filled with glass to 70 percent of its height. This is a conservative assumption because the West Valley canisters are expected to be filled to at least 80 percent of their height (so there will be less air volume per unit surface area of canister wall).

- Dry air is 21 volume percent oxygen.

- All metal atoms in the stainless steel, designated as M, have a molecular weight of 55.4 g/g-mole, which is the average molecular weight of the stainless steel (based on a composition of 19 percent Cr, 9 percent Ni, and Fe as the balance):

$$0.19(52.0) + 0.09(58.7) + 0.72(55.85) = 55.4 \text{ g/g-mole}$$

- All water reacts with M to form $M(OH)_2$.

- All oxygen not participating in water reactions reacts with M to form $M_3O_4$. $M_3O_4$ is believed to be the composition of the metal oxide in the protective film on the stainless steel surface (American Society of Metals 1980).

The results of this analysis will be reported in the WQR.

## 3.10 Subcriticality Specification

**The producer shall ensure that the canistered waste form will remain subcritical under all credible conditions likely to be encountered from production through receipt at the repository. The calculated effective neutron multiplication factor, $k_{eff}$, shall be sufficiently below unity to show at least a 5 percent margin after allowance for bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation. The producer shall describe the method of compliance in the WCP and provide supporting documentation in the WQR. The WQR shall also include sufficient information on the nuclear characteristics of the canistered waste forms to enable the repository designer to confirm subcriticality under repository storage and disposal conditions.**

### Strategy

$K_{eff}$ for the canistered waste will be calculated using the KENO computer code. It will be shown that $K_{eff}$ is less than or equal to 0.95.

### Compliance

The criticality calculations for the canistered waste will be performed by the Criticality Safety Engineer as required in the WVDP Radiological Controls Manual (West Valley Nuclear Services, 1985). The composition, radionuclide inventory including fissionable radionuclides, and fill volume of the canister will be estimated as explained in sections 1.1, 1.2, and 3.5, respectively. These and the canister geometry (figure 3) will be input to the KENO computer code (Petrie and Landers). (KENO validation will involve the use of existing experimental/calculated results). The calculated reactivity of the canistered waste form will be shown to be less than or equal to 0.95 within a 95 percent probability and 95 percent confidence level. Normal operating conditions and credible accident scenarios at West Valley will be considered. The WQR will report the reactivity for the compositions developed during the waste variability study discussed in section 1.1.1 that are most likely to be a criticality concern (e.g., lowest boron). The amount of fissionable radionuclides used in this analysis will be conservatively based upon a canister with maximum nuclide loading and will assume the fissionable radionuclides are uniformly dispersed in the glass matrix. The WQR will also report the nuclear characteristics of the canistered waste. This will include the final canister geometry, variations of the glass composition, and fissionable radionuclide concentrations. This will ensure that the canistered waste forms will be subcritical.

## 3.11 Specifications for Weight, Length, Diameter, and Overall Dimensions

The configuration, dimensions, and weights of the canistered waste form shall be controlled as indicated below, and the following parameters of the canistered waste form shall be documented at the time of shipment.

### 3.11.1 Weight Specification

The weight of the canistered waste form shall not exceed 3,000 kg. The measured weight shall be reported in the production records, accurate to within ±5 percent.

Strategy

The canisters will be weighed before shipment to the repository.

Compliance

> The canistered waste forms will be weighed by a scale attached to the crane or by a platform scale when the canisters are in the Vitrification Facility and are being moved for shipment to the repository. This weight measurement will be made after the permanent closure process has been completed. The specification for this scale will require that it measure the weight accurately (one standard deviation) at least to within ±5 percent of full scale. The expected canistered waste form weight will be at approximately midscale. Canistered waste form weights will be recorded on the production records.

3.11.2 Length Specification

The overall length of the final canistered waste form at the time of shipment shall be 3.000 m (+ 0.005 m, - 0.020 m)

3.11.3 Diameter Specification

The outer diameter of the canistered waste form shall be 61.0 cm (+ 1.5 cm, - 1.0 cm). The minimum wall thickness of the empty canister shall be 0.34 cm. The producer shall state in the WCP the minimum canister wall thickness of the filled canister, and the thickness of any secondary canisters, along with their technical bases.

Strategy

A correlation between the prepour and postpour lengths and diameters will be developed during nonradioactive testing at West Valley. From this, dimensions and tolerances will be developed for canister fabrication.

The minimum postpour wall thickness will be estimated by measuring the thickness loss of the stainless steel after being in contact with the nonradioactive pouring glass.

Compliance

During nonradioactive preoperational systems testing, West Valley will produce a number of filled canisters. The prepour and postpour lengths and diameters of these canisters will be measured. From these measurements, a correlation between the two lengths and diameters will be developed. From this correlation, a range of prepour canister lengths and diameters will be determined that will yield production canisters whose lengths and diameters are within the range given in the specification at 20°C. All of the above information will be documented in the WQR. For the canisters used during production, West Valley will include in the fabrication specification the prepour lengths and diameters of their canisters to assure that they are within the range that will produce filled canisters whose time-of-production length and diameters are within the correct range. These prepour lengths and diameters at an ambient temperature of about 20°C will be recorded on the production records.

The postpour wall thickness estimate of the West Valley canister will be based on measurements of 304L stainless steel WVDP canisters exposed to glass pouring during nonradioactive cold testing. Wall thicknesses will be measured before the test or inferred from the sheet thickness specified in the fabrication specification. The stainless steel will then be exposed to the glass pour stream. After the glass has cooled, the canister wall thickness will be measured to assess the amount of material lost from the canister. The amount of material lost will be subtracted from the minimum wall thickness. This value will be reported in the WQR. The average and range of the measurements will be reported.

### 3.11.4 Specification for Overall Dimensions

**The dimensions of the canistered waste form shall be controlled so that, at the time of shipment to a repository, the canister will stand upright without support on a flat horizontal surface and will fit without forcing when lowered vertically into a right-circular, cylindrical cavity 64.0 cm in diameter and 3.01 m in length.**

Strategy

> Canisters filled during nonradioactive testing and during production at West Valley will be inserted into a close fitting test cylinder to ensure that they meet dimensional specifications.

Compliance

> West Valley has a steel cylinder with an inner diameter and length less than 64.0 cm and 301 cm, respectively. Selected nonradioactive canisters filled during qualification testing and all radioactive waste canisters will be inserted into this test cylinder to verify that the canister fits without forcing and meets the maximum dimensional specifications. Before insertion into the shipping casks, the waste canisters will be placed on a flat, horizontal surface to assess their ability to stand upright. The results of these tests will be reported in the WQR.

## 3.12 Drop Test Specification

> **The canistered waste form at time of shipment shall be capable of withstanding a drop of 7 m onto a flat essentially unyielding surface without breaching. The producer shall describe the method of compliance in the WCP and present the supporting documentation of analysis and test results in the WQR. The test results shall include information on measured canister leak rates and canister deformation after the drop test.**

Strategy

West Valley canisters filled during nonradioactive testing will be dropped on their bottom centers.

Compliance

Three full scale reference canisters filled at least 85 percent full will be dropped from a height of 7m on a flat essentially unyielding surface with the center of gravity over the bottom center. This is the drop position which has the highest potential drop height during canister handling. It results if the canister is dropped while being unloaded from the transportation cask in such a manner that it falls back into the cask. Prior to the test a lid will be welded to close the canister. Leak rates will be measured in the vicinity of the impact. Strain on the canister in the vicinity of the impact will be characterized. The length, diameter, and overall dimensions will be characterized. The results of the qualification drop tests will be documented in the WQR.

## 3.13 Handling Features Specification

**The canistered waste form shall have a neck with a lifting flange. The lifting flange geometry and maximum loading capacity shall be described in the WCP.**

The producer shall design the lifting flange and a suitable grapple, which could be used at the repository, that meets applicable codes and standards for use at the repository.* The grapple and the flange shall be designed to satisfy the following requirements:

(a) The grapple shall be capable of being remotely engaged and disengaged from the flange.

(b) The grapple, when attached to a suitable hoist (to be supplied by the repository), and when engaged with the flange, shall be capable of raising and lowering a canistered waste form in a vertical direction.

(c) The grapple, in the disengaged position, shall be capable of being inserted into and withdrawn in a vertical direction from a right-circular, cylindrical cavity with a diameter equal to that of the canistered waste form.

The design of the flange and the grapple shall be capable of fulfilling the requirements of Specifications 3.13(a) through 3.13(c) without contacting or penetrating the walls of an imaginary right-circular, cylindrical cavity with a diameter equal to that of the canistered waste form, coaxial with the canistered waste form, and extending for a height of 0.7 m above the highest point on the canistered waste form. The design of the grapple shall include features that will prevent an inadvertent release of a suspended canistered waste form when the grapple is engaged with the flange. The producer shall describe the grapple and the flange design concepts in the WCP and provide the detailed designs in the WQR.

* The applicable codes and standards will be identified in the site-specific Repository Subsystem Design Requirements documents, which are schedules to be issued early FY 1987, and will be added to the WAPS when the WAPS are updated.

<u>Strategy</u>

The lifting flange geometry for the West Valley canister is shown in figure 2. A grapple concept is illustrated in figure 4.

<u>Compliance</u>

The planned lifting flange geometry is included in figure 2. The lifting flange for the canisters will be load tested to provide at least a 50 percent safety margin over the mass of a 100 percent full canister. A conceptual design of the grapple that has been used at West Valley is shown in figure 4. Other designs are also being considered. The grapple is being designed and will be tested to verify that it meets the requirements of 3.13(a) to 3.13(c) without penetrating the walls of an imaginary right circular cylinder with diameter equal to the canister. When attached to a crane, the grapple will be able to lift the canister vertically. The design will also consider positive assurances against inadvertent release of a suspended canister. The detailed design of the remotized grapple and codes and standards that will be used during its fabrication will be given in the WQR.

# WEST VALLEY CANISTER GRAPPLE

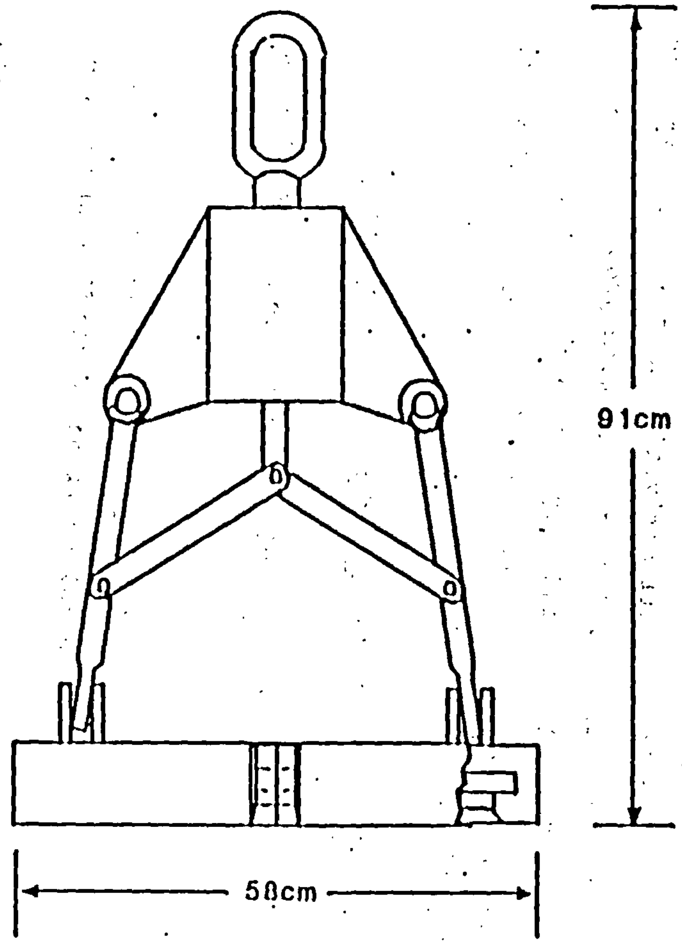


FIGURE 4

# 4.0 QUALITY ASSURANCE SPECIFICATION

>

The producer shall establish, maintain, and execute a quality assurance (QA) program that complies with OGR/B-14, "Quality Assurance Requirements for High-Level Waste Form Production". The QA program shall be applied to all testing and analysis activities that provide information to be included in WQRs. The WCPs shall be prepared in accordance with the QA program; however, existing data generated prior to the inception of the subject QA program may be included in the WCP so long as the specific quality assurance measures that were in effect when the data was generated are described. The QA program shall also be applied to all activities that affect compliance with waste acceptance specifications during waste form production, handling, storage, preparation for shipment and shipment to the repository. The producer shall describe his QA program in the WCP and certify compliance with it in the WQR and in production records.

## 4.1 Specific Topics for the Waste Compliance Plan (WCP)

The following requirements imposed by OGR/B-14 apply to the producer's WCP.

> A. Essential Software (software that is essential to meeting the WAPS) shall be identified in the WCP.

B. Production processes that have a significant effect on quality characteristics of the canistered waste form and produce results that cannot be readily verified by inspection or testing of the final product are to be identified in the WCP.

> C. The Selective Application of Quality Levels to Program Activities is described in section 4.2.4.1.

## 4.2 Overall West Valley Demonstration Project (WVDP) Quality Assurance Program

The overall QA program for the production of canister waste form at West Valley is a composite of the WVDP programs for the four major Project participants. These are:

- The DOE/NE Headquarters Waste Technology Division
- The DOE/ID Fuel Processing and Waste Management Division
- The DOE West Valley Project Office, and
- The West Valley Nuclear Services Operating Contractor

The overall Project QA program consists of the integrated program descriptions for each of these four participants. Summary descriptions for each are provided by the following paragraphs, and the organizational relationship is shown in figure 4-1.

### 4.2.1 DOE/NE WVDP Quality Assurance Program Summary (QAPD-1)

The WVDP QA program established and implemented by the Waste Technology Division of the DOE Nuclear Energy Office (DOE/NE) provides actions necessary for appropriate DOE oversight and monitoring of the overall Project QA program for development, qualification, and production of an acceptable WVDP canistered high-level waste form. Responsibility for those activities necessary for achieving overall product quality are delegated by DOE/NE to other Project participants through the DOE Idaho Operations Office (DOE/ID). The DOE/NE portion of the program is conducted in accordance with DOE Order 5700.6B (Quality Assurance) and complies with the applicable portions of OGR/B-14 (QA Requirements for High-Level Waste Form Production).

WEST VALLEY DEMONSTRATION PROJECT (WVDP)

ORGANIZATION STRUCTURE

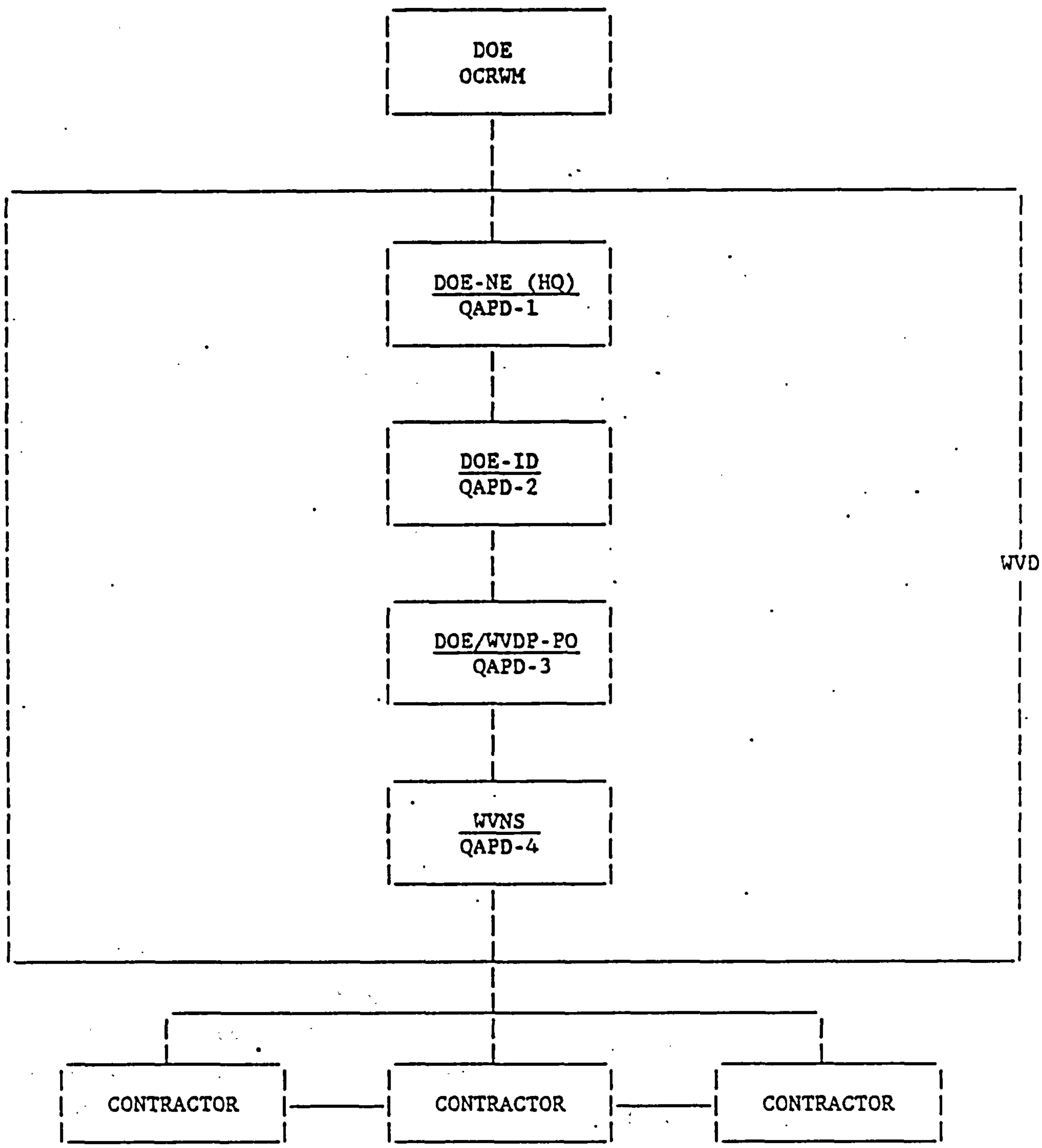


FIGURE 4-1

4.2.2 DOE/ID WVDP Quality Assurance Program Summary (QAPD-2)

The WVDP QA program established and implemented by the Fuel Processing and Waste Management Division of the DOE Idaho Operations Office (DOE/ID) compliments and expands the DOE Headquarters responsibility for oversight and monitoring of the adequacy and effectiveness of the overall Project quality assurance program for development, qualification, and production of an acceptable WVDP canistered high-level waste form. Responsibility for these functions has been delegated to DOE/ID by the DOE/NE. Also delegated to other Project participants are appropriate quality assurance responsibilities for the conduct of activities necessary for achieving overall product quality. Responsibility for delegation to other Project participants is delegated by the DOE/ID Assistant Manager for Nuclear Programs (ID-PM) to the West Valley Project Office Project Manager (WV-PM). The DOE/ID portion of the program is conducted in accordance with DOE Order 5700.6B (Quality Assurance) and complies with the applicable portions of OGR/B-14 (QA Requirements for High-Level Waste form Production).

> 4.2.3 DOE/WVPO WVDP Quality Assurance Program Summary (QAPD-3)

The WVPO QA program established and directed by the WV-PM provides the primary and on-line DOE responsibility for establishing and assuring the adequacy and effectiveness of the overall Project QA program for the development, qualification, and production of an acceptable WVDP canistered high-level waste form. Responsibility for these functions has been delegated to the WV-PM by DOE/NE through DOE/ID. This delegation from DOE/ID includes direct authority and responsibility for establishing delegation to lower tier project participants of appropriate quality assurance responsibilities for the conduct of activities necessary for achieving overall product quality. Responsibility delegated to the WV-PM is implemented through contractual agreements and the associated DOE review and approval of contractor documentation. The WVPO portion of the program is conducted in accordance with DOE Order 5700.6B, and complies with the applicable portions of OGR/B-14 (QA Requirements for High-Level Waste Form Production).

4.2.4 WVNS WVDP Quality Assurance Program Summary (QAPD-4)

The WVNS QA program implemented by the West Valley Nuclear Services Operating Contractor provides for assuring the adequacy and effectiveness of the Project QA program for the development, qualification, and production of an acceptable WVDP canistered high-level waste form at the operations level. Responsibility for these functions has been delegated to the WVNS by the WVPO. This delegation from WVPO includes direct authority and responsibility for establishing delegation to lower tier Project participants of appropriate quality assurance responsibilities for the conduct of activities necessary for achieving overall product quality. Responsibility delegated to the WVNS is implemented through selective contractural agreements and the associated DOE review and approval of applicable contractor documentation.

WVNS conducted or directed activities for implementing the WVNS portion of the WVDP Project QA program include the reviews and approval of contractor QA programs, reviews and approval of significant operating levels documents, participation in Project meetings, generation of Project status reports, conduct or direction of audits, and annual documented effectiveness evaluations of the overall program. The WVNS portion of the program is conducted in accordance with DOE Order 5700.6b (Quality Assurance) and complies with the applicable portions OGR/B-14 (QA Requirements for High-Level Waste Form Production). Specific QA elements, as defined by the ASME/ASNI NQA-1, 1986, QA standard, applicable to the WVNS program are: 1) Organization; 2) QA program; 3) Design Control and Essential Computer Software Control; 4) Procurement Control; 5) Instructions, Procedures, and Drawings; 6) Document Control; 7) Control of Purchased Material, Equipment, and Services; 8) Identification and Control of Materials, Parts, and Components; 9) Process Control; 10) Inspection; 11) Test Control and Control of Experiments; 12) M&TE Control; 13) Preservation, Packaging, Storage, and Shipping; 14) Inspection, test, and Operating Status; 15) Control of Nonconforming Items; 16) Corrective Action; 17) QA Records; and 18) Audits. WVNS has established procedures for implementation of these QA elements and specific supplemental requirements from OGR/B-14.

4.2.4.1 Selective Application of Quality Levels

WVNS has established a system for the selective application of QA program activities which are utilized to determine quality levels (Q-Levels).

The overall QA Program is a graded approach using Q-Levels that relate to items and services which are important to safety. The Q-Levels System (A, B, C, or N) reflects the objectives which are based on the degree of activity necessary to identify, analyze, verify, and document the attributes that are requirement to achieve a specific level of confidence in equipment, items, and systems. The QA Program covers all levels with the lowest level being the responsibility of the performer to achieve and document the quality. The Program provides for judicious and selective application of controls based upon complexity and failure consequences.

## 4.3 WVDP Quality Assurance Program Description Documents

The QA program applied to the Waste Acceptance Activities of high-level waste form production, as described in QAPD-1, QAPD-2, QAPD-3, and QAPD-4 provides guidance and direction for program implementation and a concise description of what the WVDP QA Program contains and how it functions.

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# APPENDIX A
# WVDP HLW CHARACTERISTICS

## TABLE A-IA: PUREX (TANK 8D-2) INSOLUBLE SOLIDS REFERENCE CHEMICAL COMPOSITION

| | Component | Mass (Kg) |
|---|---|---|
| | $Fe(OH)_3$ | 66,040 |
| | $FePO_4$ | 6,351 |
| > | $Al(OH)_3$ | 5,916 |
| > | $AlF_3$ | 582 |
| > | $MnO_2$ | 4,513 |
| > | $CaCO_3$ | 3,358 |
| | $UO_2(OH)_2$ | 3,087 |
| > | $Ni(OH)_2$ | 938 |
| > | $SiO_2$ | 2,583 |
| > | $Zr(OH)_4$* | 964 |
| > | $MgCO_3$ | 511 |
| | $Cu(OH)_2$ | 376 |
| > | $Zn(OH)_2$ | 187 |
| > | $Cr(OH)_3$ | 146 |
| | $Hg(OH)_2$ | 23 |
| | **Fission Products**** | |
| > | Rare Earth Hydroxides | 1,607 |
| > | Other Hydroxides | 888 |
| > | Sulfates | 478 |
| | **Transuranics** | |
| > | $NpO_2$ | 35 |
| | $PuO_2$ | 37 |
| > | $Am_2O_3$ | 27 |
| > | $Cm_2O_3$ | 0.4 |
| > | TOTAL | 98,456 |

* Excludes fission product zirconium.
** See table A-IB for breakdown.

## TABLE A-IB: PUREX (TANK 8D-2) SOLIDS FISSION PRODUCTS

| | | |
|---|---|---|
| | **Rare Earths** | |
| > | $Nd(OH)_3$ | 630 |
| > | $Ce(OH)_3$ | 375 |
| > | $La(OH)_3$ | 174 |
| > | $Pr(OH)_3$ | 170 |
| > | $Sm(OH)_3$ | 143 |
| > | $Eu(OH)_3$ | 8 |
| > | $Gd(OH)_3$ | 2 |
| | $Tb(OH)_3$ | 0.3 |
| | $Dy(OH)_3$ | 0.2 |
| > | $Pm(OH)_3$ | 1.5 |
| | **Other Components*** | |
| > | $Zr(OH)_4$ | 964 |
| > | $Ru(OH)_4$ | 458 |
| > | $BaSO_4$ | 303 |
| > | $SrSO_4$ | 175 |
| > | $Y(OH)_3$ | 103 |
| > | $Rh(OH)_4$ | 79 |
| > | $Pd(OH)_2$ | 34 |
| > | $Sn(OH)_4$ | 3 |
| > | $Cd(OH)_2$ | 2 |
| > | $Sb(OH)_3$ | 1 |
| > | AgOH | 1 |
| > | $In(OH)_3$ | 0.3 |
| > | $Ge(OH)_3$ | 1.7 |

* Sulfate converted to hydroxides.

TABLE A-II: PUREX (TANK 8D-2) SUPERNATANT CHEMICAL COMPOSITION

| | Compound | Wt. Percent Wet Basis | Wt. Percent Dry Basis | Mass (Kg) |
|---|---|---|---|---|
| | $NaNO_3$ | 21.10 | 53.38 | 602,659 |
| | $NaNO_2$ | 10.90 | 27.57 | 311,326 |
| > | $NaSO_4$ | 2.67 | 6.75 | 76,261 |
| | $NaHCO_3$ | 1.49 | 3.77 | 42,557 |
| | $KNO_3$ | 1.27 | 3.21 | 36,274 |
| | $Na_2CO_3$ | 0.884 | 2.24 | 25,249 |
| | NaOH | 0.614 | 1.55 | 17,537 |
| | $K_2CrO_4$ | 0.179 | 0.45 | 5,113 |
| | NaCl | 0.164 | 0.42 | 4,684 |
| | $Na_3PO_4$ | 0.133 | 0.34 | 3,799 |
| | $Na_2MoO_4$ | 0.0242 | 0.06 | 691 |
| | $Na_3BO_3$ | 0.0209 | 0.05 | 597 |
| | $CsNO_3$ | 0.0187 | 0.05 | 534 |
| | NaF | 0.0176 | 0.04 | 503 |
| > | $Sn(NO_3)_4$ | 0.00858 | 0.02 | 245 |
| > | $Na_2U_2O_7$ | 0.00809 | 0.02 | 231 |
| > | $Si(NO_3)_4$ | 0.00805 | 0.02 | 230 |
| | $NaTcO_4$ | 0.00620 | 0.02 | 177 |
| > | $RbNO_3$ | 0.00417 | 0.01 | 119 |
| > | $Na_2TeO_4$ | 0.00287 | 0.007 | 82 |
| > | $AlF_3$ | 0.00270 | 0.007 | 77 |
| > | $Fe(NO_3)_3$ | 0.00151 | 0.004 | 43 |
| > | $Na_2SeO_4$ | 0.00053 | 0.001 | 15 |
| > | $LiNO_3$ | 0.00049 | 0.001 | 14 |
| | $H_2CO_3$ | 0.00032 | 0.0008 | 9 |
| > | $Cu(NO_3)_2$ | 0.00021 | 0.0005 | 6 |
| > | $Sr(NO_3)_2$ | 0.00014 | 0.0004 | 4 |
| > | $Mg(NO_3)_2$ | 0.00007 | 0.0002 | 2 |
| > | TOTAL | 39.53 | 100.00 | 1,129,038 |
| > | $H_2O$ | 60.47 | | 1,727,164 |

## TABLE A-III: THOREX (TANK 8D-4) WASTE REFERENCE CHEMICAL COMPOSITION

| | Compound | Weight Percent | Mass (Kg) | Compound | Weight Percent | Mass (Kg) |
|---|---|---|---|---|---|---|
| > | $Th(NO_3)_4$ | 36.43 | 31,054 | $Zr(NO_3)_4$ | 0.014 | 12 |
| > | $Fe(NO_3)_3$ | 9.43 | 8,462 | $Na_3PO_4$ | 0.014 | 12 |
| > | $Al(NO_3)_3$ | 4.90 | 4,175 | $NaTcO_4$ | 0.013 | 11 |
| > | $HNO_3$ | 3.29 | 2,805 | $Y(NO_3)_3$ | 0.016 | 14 |
| > | $Cr(NO_3)_3$ | 2.25 | 1,918 | $Rh(NO_3)_4$ | 0.013 | 11 |
| > | $Ni(NO_3)_2$ | 0.93 | 791 | $Zn(NO_3)_2$ | 0.012 | 10 |
| > | $H_3BO_3$ | 0.56 | 480 | $Pd(NO_3)_4$ | 0.0094 | 8 |
| > | $NaNO_3$ | 0.27 | 227 | $UO_2(NO_3)_2$ | 0.0070 | 6 |
| > | $Na_2SO_4$ | 0.21 | 180 | $RbNO_3$ | 0.00704 | 6 |
| > | $KNO_3$ | 0.12 | 191 | $Na_2TeO_4$ | 0.0059 | 5 |
| > | $Na_2SiO_3$ | 0.15 | 126 | $Co(NO_3)_2$ | 0.0035 | 3 |
| > | $K_2MnO_4$ | 0.11 | 98 | $Na_2SeO_4$ | 0.0012 | 1 |
| > | $Mg(NO_3)_3$ | 0.067 | 57 | NaF | 0.0012 | 1 |
| > | $Na_2MoO_4$ | 0.063 | 54 | $Eu(NO_3)_3$ | 0.00117 | 1 |
| > | NaCl | 0.059 | 50 | $Np(NO_3)_4$ | 0.00106 | 0.9 |
| > | $Nd(NO_3)_3$ | 0.086 | 73 | $Sn(NO_3)_3$ | 0.00082 | 0.7 |
| > | $Ce(NO_3)_4$ | 0.050 | 43 | $Cu(NO_3)_2$ | 0.00094 | 0.8 |
| > | $Ru(No_3)_4$ | 0.049 | 42 | $Pa(NO_3)_4$ | 0.00082 | 0.7 |
| > | $ZrO_2$* | 0.014 | 12 | $Pu(NO_3)_4$ | 0.00082 | 0.7 |
| > | $Ca(NO_3)_2$ | 0.035 | 30 | $Gd(NO_3)_3$ | 0.00047 | 0.4 |
| > | $CsNO_3$ | 0.033 | 28 | $Cd(NO_3)_2$ | 0.00035 | 0.3 |
| > | $Ba(NO_3)_2$ | 0.032 | 27 | $X(NO_3)_4$** | 0.00025 | 0.2 |
| > | $La(NO_3)_3$ | 0.026 | 22 | $Sb(NO_3)_3$ | 0.00012 | 0.1 |
| > | $Pr(NO_3)_3$ | 0.025 | 21 | $AgNO_3$ | 0.00009 | 0.08 |
| > | $Sr(NO_3)_2$ | 0.019 | 16 | $In(NO_3)_3$ | 0.00005 | 0.04 |
| > | $Sm(NO_3)_3$ | 0.016 | 14 | $Pm(NO_3)_2$ | 0.00001 | 0.01 |
| > | | | | TOTAL | 59.94 | 51,090 |
| > | | | | $H_2O$ | 40.06 | 34,148 |

* Insolubles Assumed to be $ZrO_2$.
** Am, Cm, and Miscellaneous Actinides.

Table A-IV: Reference 1987 Radionuclide Content (Curies) of West Valley Wastes

| | PUREX | | | | | PUREX | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nuclide | Supernatant | Solids | THOREX | Total | Nuclide | Supernatant | Solids | THOREX | Total |
| 3-H | 9.74E+01 | 0.00E+00 | 1.74E+00 | 9.91E+01 | 217-At | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 |
| 14-C | 1.37E+02 | 0.00E+00 | 0.00E+00 | 1.37E+02 | 219-Rn | 0.00E+00 | 9.14E-04 | 7.52E+00 | 7.52E+00 |
| 55-Fe | 0.00E+00 | 1.00E+03 | 5.53E+02 | 1.55E+03 | 220-Rn | 0.00E+00 | 1.19E-01 | 9.76E+00 | 9.88E+00 |
| 59-Ni | 0.00E+00 | 8.55E+01 | 2.03E+01 | 1.06E+02 | 221-Fr | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 |
| 63-Ni | 8.99E+02 | 5.35E+03 | 2.31E+03 | 8.75E+03 | 223-Fr | 0.00E+00 | 1.23E-03 | 1.04E-01 | 1.04E-01 |
| 60-Co | 0.00E+00 | 4.70E+00 | 1.14E+03 | 1.14E+03 | 223-Ra | 0.00E+00 | 9.14E-04 | 7.52E+00 | 7.52E+00 |
| 79-Se | 5.68E+01 | 0.00E+00 | 3.35E+00 | 6.02E+01 | 224-Ra | 0.00E+00 | 1.19E-01 | 9.76E+00 | 9.88E+00 |
| 90-Sr | 2.59E+03 | 6.74E+06 | 4.54E+05 | 7.20E+06 | 225-Ra | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 |
| 90-Y | 2.99E+03 | 6.74E+06 | 4.54E+05 | 7.20E+06 | 228-Ra | 0.00E+00 | 4.31E-09 | 1.48E+00 | 1.48E+00 |
| 93-Zr | 2.56E-01 | 2.56E+02 | 1.62E+01 | 2.72E+02 | 225-Ac | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 |
| 93m-Nb | 1.59E-01 | 1.59E+02 | 1.02E+01 | 1.69E+02 | 227-Ac | 0.00E+00 | 9.14E-04 | 7.52E+00 | 7.52E+00 |
| 99-Tc | 1.60E+03 | 0.00E+00 | 1.04E+02 | 1.70E+03 | 228-Ac | 0.00E+00 | 4.31E-09 | 1.48E+00 | 1.48E+00 |
| 106-Ru | 1.10E-01 | 1.10E+02 | 6.24E-01 | 1.11E+02 | 227-Th | 0.00E+00 | 9.01E-04 | 7.42E+00 | 7.42E+00 |
| 106-Rh | 1.10E-01 | 1.10E+02 | 6.24E-01 | 1.11E+02 | 228-Th | 0.00E+00 | 1.19E-01 | 9.76E+00 | 9.88E+00 |
| 107-Pd | 1.08E-02 | 1.08E+01 | 1.14E-01 | 1.09E+01 | 229-Th | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 |
| 113m-Cd | 2.41E+00 | 2.41E+03 | 3.75E+01 | 2.45E+03 | 230-Th | 0.00E+00 | 1.45E-02 | 4.38E-02 | 5.83E-02 |
| 121m-Sn | 1.76E-02 | 1.76E+01 | 5.99E-01 | 1.82E+01 | 231-Th | 6.41E-03 | 8.94E-02 | 5.17E-03 | 1.01E-01 |
| 126-Sn | 1.01E-01 | 1.01E+02 | 3.11E+00 | 1.04E+02 | 232-Th | 0.00E+00 | 5.37E-09 | 1.54E+00 | 1.54E+00 |
| 125-Sb | 4.90E+01 | 1.51E+04 | 2.39E+02 | 1.54E+04 | 234-Th | 5.71E-02 | 7.97E-01 | 7.11E-05 | 8.54E-01 |
| 126-Sb | 1.41E-02 | 1.41E+01 | 4.35E-01 | 1.45E+01 | 231-Pa | 0.00E+00 | 2.86E-04 | 1.52E-01 | 1.52E-01 |
| 126m-Sb | 1.01E-01 | 1.01E+02 | 3.11E+00 | 1.04E+02 | 233-Pa | 0.00E+00 | 2.30E-01 | 3.02E-01 | 2.33E-01 |
| 125m-Te | 3.49E+00 | 3.49E+03 | 6.56E+01 | 3.56E+03 | 234m-Pa | 5.71E-02 | 7.97E-01 | 7.11E-05 | 8.54E-01 |
| 129-I | 2.10E-01 | 0.00E+00 | 1.80E-01 | 3.90E-01 | 232-U | 3.13E-01 | 4.36E+00 | 2.74E+00 | 7.41E+00 |
| 134-Cs | 1.39E+04 | 0.00E+00 | 3.10E+02 | 1.42E+04 | 233-U | 4.98E-01 | 6.94E+00 | 2.09E+00 | 9.53E+00 |
| 135-Cs | 1.56E+02 | 0.00E+00 | 5.47E+00 | 1.61E+02 | 234-U | 2.80E-01 | 3.90E+00 | 2.17E-01 | 4.40E+00 |
| 137-Cs | 7.26E+06 | 0.00E+00 | 4.75E+05 | 7.74E+06 | 235-U | 6.41E-03 | 8.94E-02 | 5.17E-03 | 1.01E-01 |
| 137m-Ba | 6.87E+06 | 0.00E+00 | 4.49E+05 | 7.32E+06 | 236-U | 1.91E-02 | 2.67E-01 | 9.30E-03 | 2.95E-01 |
| 144-Ce | 2.97E-05 | 9.21E+00 | 1.39E-01 | 9.35E+00 | 238-U | 5.71E-02 | 7.97E-01 | 7.11E-05 | 8.54E-01 |
| 144-Pr | 2.97E-05 | 9.21E+00 | 1.39E-01 | 9.35E+00 | 236-Np | 0.00E+00 | 9.35E+00 | 1.22E-01 | 9.47E+00 |
| 146-Pm | 1.41E-04 | 2.10E+01 | 6.06E-01 | 2.16E+01 | 237-Np | 0.00E+00 | 2.30E+01 | 3.02E-01 | 2.33E+01 |
| 147-Pm | 1.67E+02 | 1.85E+05 | 9.11E+03 | 1.94E+05 | 239-Np | 0.00E+00 | 3.43E+02 | 4.49E+00 | 3.47E+02 |
| 151-Sm | 1.10E+00 | 8.15E+04 | 4.78E+03 | 8.63E+04 | 236-Pu | 1.36E-02 | 8.24E-01 | 1.09E-02 | 8.49E-01 |
| 152-Eu | 4.25E-02 | 3.77E+02 | 4.32E+01 | 4.25E+02 | 238-Pu | 1.27E-02 | 8.00E+03 | 4.50E+02 | 8.61E+03 |
| 154-Eu | 1.37E+01 | 1.19E+05 | 2.53E+03 | 1.22E+05 | 239-Pu | 2.54E+01 | 1.61E+03 | 1.54E-01 | 1.65E+03 |
| 155-Eu | 2.37E+00 | 3.54E+04 | 8.44E+02 | 3.62E+04 | 240-Pu | 1.37E+01 | 1.19E+03 | 8.09E+00 | 1.21E+03 |
| 207-Tl | 0.00E+00 | 9.12E-04 | 7.50E+00 | 7.50E+00 | 241-Pu | 1.46E+03 | 9.23E+04 | 8.50E+02 | 9.46E+04 |
| 208-Tl | 0.00E+00 | 4.23E-02 | 3.51E+00 | 3.55E+00 | 242-Pu | 2.54E-02 | 1.51E+00 | 1.19E-02 | 1.55E+00 |
| 209-Pb | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 | 241-Am | 0.00E+00 | 5.30E+04 | 2.41E+02 | 5.32E+04 |
| 211-Pb | 0.00E+00 | 9.14E-04 | 7.52E+00 | 7.52E+00 | 242-Am | 0.00E+00 | 2.94E+02 | 6.79E+00 | 3.01E+02 |
| 212-Pb | 0.00E+00 | 1.19E-01 | 9.76E+00 | 9.88E+00 | 242m-Am | 0.00E+00 | 2.94E+02 | 6.77E+00 | 3.01E+02 |
| 211-Bi | 0.00E+00 | 9.14E-04 | 7.52E+00 | 7.52E+00 | 243-Am | 0.00E+00 | 3.37E+02 | 7.33E+00 | 3.47E+02 |
| 213-Bi | 0.00E+00 | 1.19E-01 | 9.76E+00 | 9.88E+00 | 242-Cm | 0.00E+00 | 2.43E+02 | 5.59E+00 | 2.49E+02 |
| 213-Bi | 0.00E+00 | 6.51E-06 | 2.07E-01 | 2.07E-01 | 243-Cm | 0.00E+00 | 1.44E+02 | 2.34E-01 | 1.44E+02 |
| 212-Po | 0.00E+00 | 7.62E-02 | 6.25E+00 | 6.33E+00 | 244-Cm | 0.00E+00 | 8.53E+03 | 1.37E+01 | 8.55E+03 |
| 213-Po | 0.00E+00 | 6.47E-06 | 2.03E-01 | 2.03E-01 | 245-Cm | 0.00E+00 | 8.52E-01 | 2.00E-02 | 8.92E-01 |
| 215-Po | 0.00E+00 | 9.14E-04 | 7.52E+00 | 7.52E+00 | 246-Cm | 0.00E+00 | 9.87E-02 | 2.29E-03 | 1.01E-01 |
| 216-Po | 0.00E+00 | 1.19E-01 | 9.76E+00 | 9.88E+00 | | | | | |

** Radionuclides totaling [illegible] 0.1 Curies

# APPENDIX B

## > SPECIFICATION 1.3 RADIONUCLIDE RELEASE PROPERTIES

>

Specification 1.3 - Radionuclide Release Properties

The WVDP is continuing to perform its leach testing program consistent with the DWPF-WAPS Specification 1.3 which is given below in bold type. Our goal is to comply with the same requirements as DWPF.

**1.3 DWPF SPECIFICATION FOR RADIONUCLIDE RELEASE PROPERTIES**

**The producer shall control the radionuclide release properties of the waste form during waste form production to satisfy the requirements of Specifications 1.3.1 and 1.3.2, or Specification 1.3.3. The producer shall describe the intended method for demonstrating compliance in the WCP. Supporting technical documentation for the selected method of control shall be included in the WQR. Documentation supporting the selected method of verification of compliance and the verification of results shall be included in the production records.**

**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.**

### 1.3.3 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.

# APPENDIX C

## GLASS DURABILITY TEST METHODS

>

## SUMMARY OF THE WVDP PRODUCT CONSISTENCY TEST (PCT)

Waste samples are pulverized and screened to -100 and +200 mesh. This sized powder is immersed in standard leachants and agitated at the start of the test, and in some cases, once every 24 hours. Standardized test temperatures usually 90°C, and a number of time periods, usually 7 days and sometimes 28 days are specified. Standard leachants may be used in the test including deionized water. In addition to the reference leachants, site-specific leachants or actual samples of repository water may be used. A separate powdered specimen, leach container, and leachant are required for each data point. Test results are based on analyses of cooled leachates which may be filtered to remove >0.45 μm fines. Leachate pH is measured. Tests can be run in air or $CO_2$ free atmospheres.

## SUMMARY OF PARTIAL-EXCHANGE INTERACTIVE FLOW TEST

The test procedure is based on partial exchange of the leachant in contact with the solid at fixed intervals until the composition of the leachate shows no further significant changes with time. (This requires the total exchanged volume to exceed three times the leachant volume in contact with the solid, and completion of the rapid initial processes such as the rapid dissolution of fines and surface irregularities and the rapid stage of build-up of surface layers.) This ensures the applicability of the test to the evaluation of long-term durability and the suppression of short-term transient effects. Continued repetitive sampling after the concentration readings have stabilized also makes it possible to obtain a very high degree of analytical accuracy.

The results of the test, based on the stabilized leachate concentration readings, may be reported both in terms of conventional leach rates ($g \cdot m^{-2} \cdot d^{-1}$) and in terms of annual fractional releases ($yr^{-1}$). The latter representation is directly applicable to the evaluation of long-term durability.

The actual flow rate in the test is directly determined by the frequency of leachant exchange on one hand and by the ratio between the volume removed and changed and the total leachant volume in contact with the solid on the other hand.

However, the experimental flow rate can be translated into the effective flow rate under any given repository configuration by means of applying a simple scaling factor which consists of the quotient of the surface-to-volume ratio in the test configuration by the corresponding ratio in the case of the waste-form package.

The test should be carried out at several combinations of leachant-exchange frequency and surface-to-volume ratio so as to cover the range of effective flow rates expected under service conditions and to include the flow rate at which the maximum corrosion rate occurs.

The measured leach rates or fractional release rates are reported as a function of both the contact or residence time and the effective flow rate.

The test specifications require that the test results will be reported only when comprehensive leachate analysis, including reliable pH measurements, shows a good agreement (within ±10 percent) between the analyzed levels of total cationic species and total anionic species, respectively. This requirement ensures that all major species which determine the reactivity of the medium toward the solid are identified and taken into account, and that the relative contribution of species originating in the test environment to the composition of the leachate, compared with the contribution of leached species, can be evaluated and controlled.

> SUMMARY OF MCC-1 LEACH TEST

(Material Characterization Center 1983)

> Specimens of known volume and geometric surface area are immersed in reference leachants without agitation for defined time periods at defined temperatures normally 90°C. The SA/V is held constant within 0.0005 of $0.0100 mm^{-1}$. Reference temperatures, and a number of specific time periods usually 28 days may be selected. In the test method, reference leachants may be used including pure water. In addition to the reference leachants, site-specific leachants or actual samples of repository water may be used. The test is for application to simulated waste forms and to radioactive specimens. When using Teflon leach vessels, the absorbed dose may not exceed $10^4$ rad. Inert materials for the testing of radioactive specimens such as fused quartz and gold may be used when the absorbed dose will exceed $10^4$ rad. There is no upper limit for the use of Teflon leach vessels for alpha-emitting isotopes. However, when the specimen activity times the test period exceeds $1.4 \times 10^9$ (Bq·h)/g, the Teflon must remain at least 1 mm away from the specimen.

# APPENDIX D

# POTENTIAL CANISTER CLOSURE METHODS

> The WVDP is currently investigating methods for the canister closure weld that can limit the leak rate to the specified value. This includes the type of welders at the DOE's EMAD Facility in Nevada, the welder developed for closing the remote handled (RH) TRU Container (Hauptmann 1985), and the welder being used in the PAMELA Project. One of the EMAD welders is a gas tungsten arc welder, and the other is a plasma arc welder. Both use a fixture that attaches to the top of the canister and the weld arc rotates around it. The RH TRU welder is a remotely operated gas metal arc welder. During welding, the canister is rotated via a turntable. The welder includes a rework cutter in case weld repairs are needed. The PAMELA welder is a plasma arc welder on a rotating fixture. Other potential weld techniques being considered for use at the WVDP are friction and laser welding; these techniques can provide reliable welds with a reduced level of in-cell system maintenance.

# APPENDIX E

## GAS ACCUMULATION IN A CANISTERED WASTE FORM UP TO THE GLASS TRANSITION TEMPERATURE.

No significant amount of gas will accumulate inside the canister after closure as a result of the canister being heated up to the glass transition temperature.

After manufacture, volatility from waste glass is a factor only in accident analyses. Waste glass manufacturing temperatures are several hundred degrees above the maximum design storage temperatures. This assures that any volatiles that might pressurize the canisters during storage have been removed (Mendel 1978).

Numerous volatility studies, related to accident performance [primarily fires during production or transport (Rusin 1980)] have been conducted at the Pacific Northwest Laboratory (PNL). These studies have used an apparatus in which air (either dry or moist) flows past a heated sample and then past a water cooled "cold finger" where condensibles are collected for chemical analysis. The heated sample is suspended from a balance, thus enabling the weight of the sample to be continuously monitored (Gray 1976). Typical volatiles from waste glasses at high temperatures ($800^{\circ}$ to $1200^{\circ}C$) include the fission products Rb, Mo, Te, and Cs, and the glass formers B, Na, and K (Gray 1976, Gray 1980, Mendel et al 1981, Ross et al 1978, Wald et al 1980); Cs has been found to be the most volatile. Other studies have also confirmed these behaviors (Hastie 1983, Terai and Kosaka 1976).

Although Cs and other elements are released, the vapor pressures of the compounds that these elements will form [e.g., oxides, hydroxides, or alkali borates (Terai and Kosaka 1976)] are extremely low at the glass transition temperature referred to in the specification. For example, alkali metal (Cs, Na, K) hydroxides have vapor pressures of 1 mm Hg (0.0013 atm.) or less at temperatures between $700^{\circ}$ to $750^{\circ}C$, and volatility will not be significant. At the glass transition temperature of WVDP glass (approximately $500^{\circ}C$) the vapor pressures of the compounds that will incorporate the volatilized elements will be even lower.

## ATTACHMENT B

## WAPS Spec. 2.2 - The Effect of Increasing Canister Wall Thickness to 3/8 Inch

| Issue | Impact Assessment |
|---|---|
| Increased number of canisters needed | Glass volume reduction per given fill level is ~4 percent (e.g., 4 percent increase in number of canisters). |
| Canister weight increase | ~350 lb/canister or over 2/3 ton increased load on turntable. |
| Effect on capabilities of handling/auxiliary equipment | Redesign needed to strengthen storage racks, reinforce turntable?, grapple? |
| Canister Corrosion Properties | Improved overall corrosion protection but increased chance of weld corrosion. Confirmed with DWPF that no credit is given to canister in repository performance model. |
| Perceived benefit from concordance with SRLs design | Not really because WV canister is structurally different due to dissimilar head. Results of drop test on top, etc., will still have to be assessed at WV. |
| Design | Apparent simple scale-up, but still need new, engineering released drawings with appropriate analyses. |
| Manufacture | Need new forging dies for top/bottom. Delivery time at least 23 weeks for new canisters which preclude arrival for SF-12 filling in order to obtain reference canisters for impact testing. |
| Procurement for SF-12 | 5 to 6 new test canisters needed, but time is inadequate as described above. |
| Canister Mechanical Properties | Higher strength, but greater probability of weld defects and embrittlement. |
| Annealing | Greater need to anneal before or after canister fabrication because of thicker wall. |
| Free volume detection | Thicker wall attenuates gamma radiation reducing sensitivity of fill level technique. |