30
2/2/87 ps 30 Oct 86
(27)

DR# 0119-8

PNL-5929
UC-70

128983

DO NOT MICROFILM
COVER

Nuclear Waste Treatment Program

**Qualification of Commercial
High-Level Waste Forms:
Approach and Status**

**R. A. Brouns
W. L. Kuhn**

December 1986

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

PNL-5929

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Received by OSTI
DEC 19 1986

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

PNL--5929

DE87 003354

NUCLEAR WASTE TREATMENT PROGRAM.

QUALIFICATION OF COMMERCIAL HIGH-LEVEL
WASTE FORMS: APPROACH AND STATUS

R. A. Brouns
W. L. Kuhn

December 1986

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

U

2

SUMMARY

The waste acceptance process as defined by the U.S. Department of Energy (DOE) outlines activities leading to the establishment of acceptance specifications for geologic disposal of high-level waste forms from existing waste solidification projects. In the absence of a licensed repository, acceptance specifications are needed to provide current waste solidification projects with a basis for making the critical design and operation decisions that affect waste form qualification. Since the specifications also provide a waste form basis for repository design, they could also influence the design and operation of future waste producers' facilities.

During fiscal year (FY) 1982, the DOE assigned responsibility for managing the development of future civilian nuclear waste treatment technology to the Nuclear Waste Treatment Program (NWTP) at Pacific Northwest Laboratory (PNL). One of the principal objectives of this program is to establish relationships between the reference vitrification process control and glass product quality. This is because such relationships are considered key elements in demonstrating waste form compliance with acceptance specifications, and thus developing the technology to ensure that waste management is not an obstacle to the further deployment of commercial reactors and nuclear fuel cycle closure.

In this document, the NWTP proposes an approach for demonstrating compliance with acceptance specifications. The proposed approach relies first on developing models of the process (vitrification) and product (waste form) to relate measurable process variables to the product quality, and then on using process control and sampling of melter feed input as the quality control method. Coordinated test programs, using pilot-scale nonradioactive and radioactive tests, will be used to establish these models at the confidence level needed to assure compliance to waste acceptance specifications. The test programs are broadly focused to encompass the range of anticipated future wastes, but the results should also be equally applicable to current wastes as well.

Demonstration of waste form compliance by some other method would likely require extensive product testing, including glass sampling during production and routine destructive examination of canisters. The process and product

modeling approach eliminates the need for this type of testing and should result in a very high level of statistical confidence that the individual waste forms are acceptable for disposal.

CONTENTS

SUMMARY	iii
INTRODUCTION	1
CONCLUSIONS	5
WASTE ACCEPTANCE PROCESS	7
WASTE FORM QUALIFICATION	9
QUALIFICATION USING MODELS	10
IMPLEMENTATION OF APPROACH	14
Development of the Product Model	17
Development of the Process Model	19
REFERENCES	23

FIGURES

1	Simplified Waste Acceptance Process	2
2	Waste Form Qualification Process	11
3	Product Acceptance Envelope	15

TABLE

1	Applicable Product Acceptability Regulations	12
---	--	----

INTRODUCTION

Federal regulations concerning the immobilization and disposal of high-level liquid waste require that proposed waste forms meet specific requirements during handling, storage, transportation, and disposal. Compliance with the disposal requirements appears to be the most difficult and is receiving the greatest attention. To help establish an acceptable disposal system for high-level waste (HLW), the U.S. Department of Energy (DOE) defined a waste acceptance process.^(a) This process outlined the steps by which waste producers must certify that their waste forms are acceptable for disposal, and it defined the process by which the waste acceptance specifications would be developed. Figure 1 is a simplified diagram of this process, emphasizing the role of the waste producer. As indicated in the figure, the producer is responsible for several major activities that input to the waste acceptance specifications and to the licensing process. Site selection and license application are planned for the early 1990s.

The DOE assigned the responsibility for ensuring that waste management is not an obstacle in the future expansion of nuclear power and commercial reprocessing of spent fuel to the Nuclear Waste Treatment Program (NWTP) at Pacific Northwest Laboratory (PNL). An important part of this responsibility will be the NWTP's participation in the waste acceptance process as a representative of future commercial waste producers to ensure that the potentially unique characteristics and processing requirements of future wastes are adequately considered during the development of the acceptance specifications. Another important aspect of fulfilling the program's responsibility to provide waste treatment technology for future commercial wastes is to establish an approach for qualifying HLW forms that provides a high degree of confidence in their acceptability for disposal without being unnecessarily restrictive or costly to the future producer. The NWTP intends to establish a uniform qualification approach (for current and future wastes) that is acceptable to the producers,

(a) July 8, 1985, memo to distribution by W. J. Purcell, Associate Director, U.S. DOE Office of Geologic Repositories, Establishment of Waste Acceptance Process and Waste Acceptance Committee.

FIGURE 1. Simplified Waste Acceptance Process

receivers, and regulatory agencies, so that the test programs supporting current producers will directly benefit all future producers through dramatically reduced validation efforts.

This document describes the current NWTP approach to waste form qualification that is intended to serve as the basis for initial interactions with the repository projects and current waste producers. Programmatic and technical aspects of the approach, and progress in developing the process and product models that are the key to demonstrating waste form compliance are also described.

22

CONCLUSIONS

The relationships between product variables and product quality will be established by the NWTP for selected reference waste forms by using standardized tests applied under reference test conditions. In the same manner, the NWTP will establish the relationships between process variables and product variables for a reference vitrification system. This latter effort will require coordinated pilot-scale nonradioactive and radioactive testing using reference vitrification equipment and reference waste forms. Waste form receivers will then be able to relate their site-specific conditions for the repository and storage site(s) to the reference test conditions used by the NWTP. Likewise the producers will be able to relate their actual waste forms and vitrification equipment performance to the reference waste forms and vitrification equipment performance used by the NWTP. The producers will do this by nonradioactively testing their full-scale equipment prior to the start of radioactive operation and perhaps, if necessary, by limited radioactive testing during the radioactive "shakedown" test period that precedes the start of production.

The NWTP approach to waste form qualification that is outlined in this document has several advantages over the more industry-related standard qualification test program based on product sampling. Product quality control using process models to control and relate operating data and feed samples to the product quality is simple, effective, and should eliminate the need for direct product sampling and testing during production. Relating the easily measurable and controllable variables to product quality allows waste form producers to:

- effectively design the process and product for the efficient production of a high-quality product
- design the appropriate process and administrative controls for plant operations for optimum performance and production of acceptable quality canisters
- demonstrate compliance without destructive examinations of the product during production.

Development of the process models will reduce the need for future producers to establish an extensive data base with their specific waste form and plant design. With process models in place, waste form producers should only need to generate relatively limited waste-specific data to demonstrate that the behavior of their specific design and glass formulation is predictable. As the confidence level in the models improves through comparison with actual radioactive data from current producers, significantly less waste-specific testing will be necessary. In general, the public's willingness to accept the proposed disposal system should also improve with the increased understanding of the process and the resulting high statistical confidence level that can be assigned to the quality of canisters produced in this manner.

WASTE ACCEPTANCE PROCESS

The waste acceptance process (Figure 1) involves waste form producers, receivers (repositories), and a number of regulatory and review/approval organizations. In addition to the DOE, the regulatory, review, and approval phase involves the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), and the individual states and Indian tribes that are affected by the candidate repository site locations.

The repository projects will translate regulations established and proposed by the NRC and EPA into waste acceptance requirements, based on each site's specific licensing strategy. The DOE repository program has appointed a Waste Acceptance Committee (WAC) to review the requirements and develop acceptance specifications applicable to all the candidate repository sites for each waste form producer. The WAC is composed of representatives from 1) the West Valley Demonstration Project (WVDP) and the Nuclear Waste Treatment Program as commercial producers; 2) the Defense Waste Processing Facility (DWPF), Hanford Waste Vitrification Plant (HWVP), and Idaho National Engineering Laboratory (INEL) as defense producers; and 3) each of the repository projects. The committee also includes representatives of the DOE and of PNL's Materials Characterization Center.

With input from the waste form test programs of the repository projects, preliminary waste acceptance specifications have been drafted for two of the waste producers. The final specifications will be based on the repository site selected, with appropriate input from the waste producers' testing programs and performance models. The waste form producers must use certified compliance tests to show that the intended waste form will meet the acceptance specifications. The resulting data will become part of the information available to a repository program during licensing proceedings. A repository will be licensed on the basis of predictions that it will comply with NRC and EPA regulations if the waste form received at the repository sufficiently matches that tested as part of the repository research and development activities. During waste form production, a method is required to determine waste conformance to the intended

waste form, and thus to establish the acceptability of the actual product. This qualifying method will define the production records needed and relate these records to the specifications to demonstrate compliance.

WASTE FORM QUALIFICATION

The process of waste form qualification proceeds from a definition of product acceptability and ends with acceptance of the product actually produced. The process includes three phases:

- Quality of Product Design - establishing that the intended product is acceptable, i.e., meets acceptance requirements
- Quality of Process Design - establishing at several points during design and construction that the intended vitrification process will produce the intended product
- Quality of Conformance - establishing during vitrification that the actual product is the intended product.

Although common in the manufacturing industry, contact inspection and periodic destructive examination of products for quality control is not an acceptable option for a process that manufactures canisters of vitrified high-level nuclear waste. This method of control is procedurally complicated and costly to perform. In addition, canisters that have been destructively examined, whether found acceptable or not, could present a disposal problem of their own. The only acceptable approach is to establish, by pre-production testing and modeling of the process, that waste forms of the desired quality will result if the parameters of the process are controlled within certain ranges, and then operate the process in a manner that assures this.

Therefore, the NWTP waste form qualification approach has been developed using process and product models to relate measurable process variables to the quality of the individual canisters of vitrified waste (Kuhn and Slate 1983). The models help to increase the understanding of the process and product so that waste form producers can:

- effectively design the process and product for the efficient production of a high-quality product
- define the appropriate process and administrative controls of plant operations

- demonstrate compliance without destructive examinations of the product during production.

These models will be developed for a generic vitrification process so that they are applicable to both existing and future users of liquid-fed ceramic melter (LFCM) vitrification technology. Their purpose is to eliminate the necessity for destructive product examination by future users. Additionally, this approach will enable statistical confidence limits to be placed on the product quality for each canister made.

QUALIFICATION USING MODELS

Under the NWTP-proposed qualification process, producers will qualify their products for acceptance by the repository using performance models and associated data bases along with the production records for each canister. This process will provide control and assessment of the chemical composition of the waste glass, its physical characteristics when placed in the canister (i.e., quantity and type of crystals, total volume of glass, and percent void), and the overall canister quality, including closure and decontamination.

Based on this quality control strategy, the waste form qualification process comprises the following steps (shown in Figure 2).

Acceptability of the intended product is based on the product's intended use. Specifically, the product is to be handled, stored, transported, and disposed of in a repository. Each of these uses involves constraints in the form of regulations or specifications written by the waste form receivers that the product must meet (Table 1).

Those who are responsible for various operations must apply or interpret the regulations to obtain quantitative **quality characteristics** that numerically define the acceptability of the product. These quality characteristics are a numerical standard with which the mean and standard deviation of the same characteristics for the actual product are to be compared. Examples of some quality characteristics are as follows:

- inventories of radionuclides
- radionuclide solubilities in a repository environment

FIGURE 2. Waste Form Qualification Process

TABLE 1. Applicable Product Acceptability Regulations

Operation	Responsibility for Compliance	Governing Regulation
Handling, storage	Plant Operator, and/or DOE	DOE 5480.1 ^(a) and 5480.1A ^(b) (noncommercial), or 10 CFR 20 ^(c) and 10 CFR 50 ^(d) (commercial)
Transportation	Plant Operator or DOE	10 CFR 71 ^(e) and 49 CFR 173 ^(f)
Disposal	DOE	10 CFR 60 ^(g) and 40 CFR 191 ^(h)

(a) U.S. DOE 1981 (c) U.S. NRC 1984a (e) U.S. NRC 1984c (g) U.S. NRC 1984d
 (b) U.S. DOE 1982 (d) U.S. NRC 1984b (f) U.S. DOT 1984 (h) U.S. EPA 1985

- dissolution rate of the glass in a repository environment
- generation of respirable fines upon dropping or impact
- heat-generation rate (calculable from inventories)
- radiation field near a canister (calculable from inventories)
- surface contamination of a canister
- leak rate (e.g., of particles) from a welded canister.

Because many quality characteristics cannot be directly specified and measured during the operation of the plant (e.g., the leach rate in a repository environment), they must be inferred from measurements of **product characteristics**. These are quantitative characteristics that numerically describe the product in terms that can be directly specified during the design of the product and measured during the operation of the vitrification process.

Product characteristics include:

- composition of the glass (including radionuclides)
- mass of the glass
- microstructure of the glass (devitrification, homogeneity)
- macrostructure of the glass (cracking, voids, height of fill)
- surface concentration of radionuclides on a canister
- permeability of canister weldment
- dimension.

These characteristics are given values that become the numerical standard with which the mean and standard deviation of the actual characteristics are to be compared for quality of conformance. Therefore, quality of product design must be established in terms of these characteristics in order to link acceptability to quality of conformance. This linkage is accomplished by use of a product model (Figure 2).

The product characteristics must in turn be related to **process variables** (process control settings and operating procedures) that can be controlled during the operation of the process to show that it will result in the intended product, thereby establishing the quality of process design. That is, the product characteristics must be linked to controllable (measurable) process variables, such as:

- temperature
- flow rate
- time and position
- mass and volume
- composition.

The intended values of process variables must be established to define process control requirements, which in turn must be established to complete process design, process control settings, and standard operating procedures.

Quality of conformance is established by acquiring data on the actual operation of the process in terms of the process variables defined previously. The same model that was used to establish quality of process design is used to establish quality of conformance. This model, called the process model, is shown as part of Figure 2. The process model not only propagates uncertainty from the standard deviation of the process records, but also adds uncertainty associated with the level of confidence in the model (this is indicated in Figure 2 by the standard deviation symbol). Comparing the mean and standard deviation of the actual product characteristics establishes quality of conformance.

Acceptability of the actual product is established by inferring from the product description the mean and standard deviation of the quality description

for the actual product, using the same product model that established the intended product characteristics from required quality characteristics.

The acceptability of the actual product determined in this way is documented and asserted to the receivers of the actual product. Because the mean and standard deviations of the quality characteristics for the actual product are established on an individual-canister basis, the standard deviation of a given quality characteristic, such as leach rate for a large number of canisters in a repository, is much smaller than for the individual canisters, thus greatly increasing confidence in the acceptability of the canisters. The greater confidence should improve the general public's willingness to accept the proposed disposal system.

IMPLEMENTATION OF APPROACH

To obtain approval for plant startup, the waste form producer must demonstrate that his process is capable of consistently producing high-quality products that are acceptable for disposal. To dispose of these products during production, the producer must then provide evidence that they meet the repository waste form acceptance specifications. If the process and waste form performance are well understood as a function of the possible variations that can occur, then defining the process control limits and demonstrating compliance to acceptance specifications becomes a relatively simple task. To achieve this understanding, the producer must define the specific range of process and product parameters for which acceptable glass-filled canisters are produced. In doing this, the producer establishes what are commonly referred to as product and processing acceptance envelopes. Through equipment design and process control within these envelopes, the product quality can be controlled and demonstrated to comply with the disposal specifications.

Establishing these envelopes involves characterizing an extensive range of laboratory glasses and correlating the results with selected glasses made in larger-scale prototype equipment under conditions representing potential variations in the actual process parameters. Figure 3 is a simple representation of the acceptance envelope obtained from testing and how it relates to product quality control and qualification. The area inside the largest circle

FIGURE 3. Product Acceptance Envelope

represents the range of glasses studied. Some of these glasses will be unacceptable from a quality standpoint, and thus the next smaller circle establishing the glasses of acceptable quality for disposal is defined. The innermost circle defines the zone of glass produced due to normal process variation that results from operating within the established control parameters. Prototype tests are conducted on a range of conditions greater than this normal control range to establish confidence that the control parameters are appropriately narrow and can ensure an acceptable product with a high degree of confidence. If the process parameters vary outside the normal control range during off-normal conditions, data and models will exist from prototype testing to predict the product quality. Once the control parameters are established in

this manner, it is expected that the waste producers will have no problem demonstrating that they can consistently make a high-quality product.

The test program must also establish scale-up to the full-scale equipment as well as nonradioactive to radioactive correlations so that the data can be related to the actual waste forms generated during production. Prior to plant startup, it must be proven that these relationships exist with sufficient confidence for the specific waste composition, treatment flowsheet, and equipment design to demonstrate that the products will be acceptable for disposal. This is best done by conducting confirmatory radioactive tests at a large scale to validate the use of simulated waste in the test programs that defined the acceptance envelope.

Adequate control of the vitrification process is also required to maintain safe, efficient operation. Common processing problems observed in pilot-scale testing such as foaming in feed tanks, plugging of transfer lines, reboil of the glass, secondary phase formation in the melter, and glass nesting in the discharge and canister regions can lead to major equipment failures with extensive maintenance time and costs. The processing acceptance envelope is established in the same manner as the product acceptance envelope, using laboratory and prototype tests. In many cases, it is expected that the process control parameters will be defined by processing considerations rather than by product quality. This is particularly true of melting behavior, where experience with some simulated HLWs has shown that relatively small variations in melter feed composition can lead to serious secondary phase formation, high melt viscosity, and glass foaming problems well before they would impact product quality. The overlap between these two envelopes defines the process control region. Ideally, the reference glass composition should be near the centroid of this overlap region to provide for maximum flexibility in the process control.

For the acceptance envelope presented in Figure 3 we assume that the regions of acceptability can be defined as two-dimensional circles. In reality, these product acceptance and processing acceptance envelopes will be multidimensional, complex in shape, and may require an unmanageable number of tests to be fully defined. However, simplifying assumptions and theoretical models can be developed to decrease the number of tests required to relate

product and processing characteristics to controllable parameters. Test data will help to guide the theoretical model development, provide verification of these models, and establish empirical correlations where a model based on first principles is not appropriate.

The next two sections give further details on the use of the process and product models, and on their current status of development by the NWTP.

Development of the Product Model

The product model is a collection of correlations relating quality characteristics (e.g., release rates) to product characteristics (e.g., composition of the glass). It is provided through statistically designed testing of the product, where varying quality characteristics are correlated with varying product characteristics, or where acceptable values of quality characteristics are translated into limits for product characteristics. Given the product model, the mean and standard deviation of quality characteristics (i.e., the probability that they are in an acceptable range) can be established if the product characteristics are quantitatively known.

A major part of the product model will be the empirical models used for designing a glass composition. These empirical models are currently being generated to choose, a priori, a first-approximation glass composition and then to refine it through a well-defined test program. The statistical design approach to address such an effort has been developed and applied to the West Valley waste (Chick et al. 1984) and will serve as the model for future improvements.

To support further development of the product model, leach tests on the glass will be performed to determine the predicted rate of release of radionuclides in reference repository environments. Release is one of the most technically and politically important quality characteristics. Although the repository sites are assumed to provide most of the data in this area, some tests will be conducted in parallel with the extensive tests being performed by repository site projects. The NWTP, representing the future waste form producer, will emphasize investigation of the effects of variation in the waste on the predicted radionuclide release rate from the glass. The repository site

programs will in turn need to emphasize investigating the effects of variation in the site environment on the predicted release rate. The NWTP, in combination with current producers, will develop data on the performance of the full-scale glass-filled canister during accidents. Complementing this effort, the repository site programs are developing models of the performance of a waste package after closure of the repository.

Leach tests will be done on a range of glass compositions that represent the best guess of future variations in the expected composition. Long-term tests are planned, designed to show that the leach rate reduces with time due to changes at the glass surface. Saturation leach tests, where the ratio of glass surface area to solution volume is large, may be used to predict release rates and solubilities in a repository environment, and determine the extent to which the glass can meet regulation 10 CFR 60 (radionuclide release from a repository).

While glass composition is expected to be the most important product characteristic in a product model, the dependence of leach rate on crystallinity in the glass and on any other microscopic product characteristics, such as porosity, will also be determined.

Canister filled with glass also need to be tested in several respects. Samples of glass taken from nonradioactive full-scale canisters are being subjected to leach tests and analyzed for microscopic product characteristics, such as composition and devitrification. This glass is compared to the glass produced in the laboratory to validate the use of extensive data obtained from laboratory testing. Samples taken from a smaller number of developmental, radioactive canisters of glass will be subjected to similar analyses to provide confidence that the product produced during remote operation is well enough understood to forgo testing of actual glass produced during radioactive operations.

Data from drop and impact tests using canisters filled with glass will be used to relate drop and impact resistance to such macroscopic product characteristics as particle size.

Development of the Process Model

The process model relates the product characteristics (e.g., composition of the glass) to the process variables (e.g., flow rates, temperatures). The model is created by statistically designed testing of the process, where varying product characteristics are correlated with varying process variables, or where acceptable values of product characteristics are translated into limits on process variables. Using the process model, the mean and standard deviation of the product characteristics (the probability that they are in an acceptable range) can be established from known process variables.

The process model comprises three principal submodels that are discussed in the following sections:

- mass balance
- canister thermal history
- canister closure and decontamination.

Mass Balance

The mass-balance submodel is a collection of correlations relating the composition of the HLW feed, as determined through sampling, to the composition of the actual glass product. This is a mathematically simple model but requires an accurate and carefully documented data base for its validation. The principal technical issues and required testing for this model are discussed next.

Product quality control will depend largely on two criteria: 1) the ability of equipment to accurately sample a feed slurry and measure the slurry level in tanks to determine the chemical and glass former additions to the waste; and 2) the ability of the chemical makeup and transfer systems, including tank designs and chemical addition procedures, to produce and maintain a known homogeneous melter feed. Bench-scale mixing tests with prototype tank designs have been completed. A large-scale system is currently being designed and will be tested late in fiscal year 1986. Verification of scale-up correlations and characteristics of feed homogeneity with a range of feed compositions is planned.

The homogeneity of the slurry in process tanks is being studied in terms of the rates and interruptions of agitation. The accuracy of sampling (in terms of composition) is being studied in terms of sampling variables, such as the flow rate of a sample stream and the point of sampling in a tank.

The required testing includes measuring sampled compositions of simulated HLW feeds in a representative feed system, while varying the process variables such as tank volumes, sampling flow rates, agitation rates, times without agitation or transfer, and feed chemistry.

Settling and resuspension of solids in tanks and transfer lines are also being evaluated. The required testing includes sampling throughout the set of tanks in a representative feed system, while the varying feed transfer rates, the duration of periods without transfer or agitation, the feed chemistry, and the feed particle sizes.

The feed and glass residence time in the melter is being studied to predict the composition of the exiting glass as a function of time in terms of the composition of the entering feed as a function of time. Related testing includes sampling and pouring glass while varying the feed composition and feed rate in a known manner, and while varying the rate of glass convection in the melter.

In addition, researchers are studying the loss of radionuclides through the off-gas system to predict the inventories of radionuclides in the product canisters.

Canister Thermal History

Canister fill quality, including devitrification (cracking) and void area, is a function of glass thermal history, fill rate and temperature, chemical composition, and canister configuration. Development of a canister-filling model is under way.

Testing required to validate the heat transfer code includes measuring temperatures in full-scale canisters of glass as they fill with simulated waste glass and cool. The filling rate, filling sequence, and the cooling boundary conditions are varied during testing. Heat transfer models developed to

predict thermal histories of canisters during filling and cooling are currently undergoing verification using data collected during nonradioactive testing.

Data that will relate thermal history to cracking are also being assembled. Testing includes measuring the extent of cracking in the glass that happens during cooling at different rates and with different filling sequences. Appropriate tests still need to be developed for testing how cracking is affected by heat generation in a canister, which causes a significant steady-state temperature profile in actual radioactive canisters. Cracking is a complex, stochastic process; hence, an empirical model with only some theoretical basis is expected.

Devitrification kinetics are being studied as a function of composition and temperature. Current test programs include measuring the extent of devitrification in full-scale canisters of simulated glass that used various glass compositions and temperature histories. Samples of product glass are analyzed for devitrification and submitted to the laboratory for remelting and cooling according to the recorded or predicted temperature history of that glass while in the canister.

Canister Closure and Decontamination

In addition to control and verification of the glass product, design of the canister and welding of the final closure must be controlled to assure overall waste package integrity through interim handling, storage, and repository closure. Canister drop tests being conducted for the Savannah River Laboratory (SRL) are supporting the verification of the overall canister design. The canister closure integrity is being studied extensively by SRL. Work under way is demonstrating methods for assuring that a high-quality weld results from the upset welding process to be used for the DWPF. An alternative canister welding system that uses inertia welding could be used for future plants. If this latter welding process is selected, similar verification testing will be required. The correlation and qualification procedures developed for the upset welding process would greatly simplify this task but would probably not eliminate the need for testing.

Based on recorded process variables that pertain to the decontamination process, correlations are being developed and validated to predict the residual surface contamination on the canister after decontamination. Related testing includes measuring the extent of decontamination attained on radioactive canisters while varying the decontamination process. Work in this area with nonradioactive canisters is under way at SRL for the reference DWPF decontamination process and will be validated by radioactive data later. Decontamination studies using radioactive canisters are planned as part of the pilot-scale radioactive melter demonstration at PNL.

REFERENCES

- Chick, L. A., et al. 1984. West Valley High-Level Nuclear Waste Glass Development: A Statistically Designed Mixture Study, PNL-4992. Pacific Northwest Laboratory, Richland, Washington.
- Kuhn, W. L., and S. C. Slate. 1983. "Using Process Instrumentation to Obviate Destructive Examination of Canisters of HLW Glass." In Waste Management 1983, Vol. 1, pp. 121-126, University of Arizona, Tucson, Arizona.
- U.S. Department of Energy. 1981. Environmental Protection, Safety, and Health Protection Program for DOE Operations. DOE 5480.1A, Washington, D.C.
- U.S. Department of Energy, Richland Operations Office. 1982. Environmental Protection, Safety, and Health Protection Program for Richland Operations. DOE 5480.1, Washington, D.C.
- U.S. Department of Transportation. 1984. Code of Federal Regulations. Title 49, Transportation; Part 173, Shippers General Requirements for Shipments and Packaging. Washington, D.C.
- U.S. Environmental Protection Agency. 1985. Code of Federal Regulations. Title 40, Protection of Environment; Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes. Washington, D.C.
- U.S. Nuclear Regulatory Commission. 1984a. Code of Federal Regulations. Title 10, Energy; Part 20, Standards for Protection Against Radiation. Washington, D.C.
- U.S. Nuclear Regulatory Commission. 1984b. Code of Federal Regulations. Title 10, Energy; Part 50, Licensing of Production and Utilization Facilities; Appendix B, QA Criteria for Nuclear Power Plants and Fuel Reprocessing Plants. Washington, D.C.
- U.S. Nuclear Regulatory Commission. 1984c. Code of Federal Regulations. Title 10, Energy; Part 71, Packaging and Transportation of Radioactive Material. Washington, D.C.
- U.S. Nuclear Regulatory Commission. 1984d. Code of Federal Regulations. Title 10, Energy; Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories. Washington, D.C.

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

30 DOE Technical Information
Center

6 DOE Office of Civilian
Radioactive Waste Management
Forrestal Building
Washington, DC 20585
ATTN: L. H. Barrett, RW-33
C. R. Cooley, RW-4
J. R. Hilley, RW-30
S. Kale, RW-20
D. E. Shelor
R. Stein, RW-23

3 DOE Office of Defense Waste &
Transportation Management
GTN
Washington, DC 20545
ATTN: T. C. Chee, DP-123
G. H. Daly, DP-124
J. E. Lytle, DP-12

5 DOE Office of Remedial Action
and Waste Technology
GTN
Washington, DC 20545
ATTN: J. A. Coleman, NE-24
T. W. McIntosh, NE-24
H. E. Stelling, NE-24
W. R. Voigt, NE-20
H. F. Walter, NE-24

A. T. Clark
Division of Fuel Material
Safety
Nuclear Regulatory Commission
Washington, DC 20555

V. Stello
Office of the Executive
Director for Operations
Mail Station 6209
Nuclear Regulatory Commission
Washington, DC 20555

G. L. Sjoblom
Environmental Protection Agency
Office of Radiation Programs
401 M Street, S.W.
Washington, DC 20460

J. M. McGough
DOE Albuquerque Operations
Office
P.O. Box 5400
Albuquerque, NM 87185

P. G. Hagen
Joint Integration Office
Bldg. 3, 2nd Floor
2201 San Pedro N.E.
Albuquerque, NM 87110

E. Maestas
DOE West Valley Operations
Office
P.O. Box 191
West Valley, NY 14171

2 DOE Idaho Operations Office
550 Second Street
Idaho Falls, ID 83401
ATTN: J. P. Hamric
S. T. Hinschberge

F. T. Fong
DOE San Francisco Operations
1333 Broadway
Oakland, CA 94612

No. of
Copies

- M. R. Jugan
DOE Oak Ridge Operations Office
P.O. Box E
Oak Ridge, TN 37830
- W. J. Brumley
DOE Savannah River Operations
Office
P.O. Box A
Aiken, SC 29801
- M. J. Steindler
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
- C. S. Abrams
Argonne National Laboratory
P.O. Box 2528
Idaho Falls, ID 83401
- 3 Battelle Memorial Institute
Project Management Division
505 King Avenue
Columbus, OH 43201
ATTN: W. A. Carbeiner
W. S. Madia
B. Rawles
- L. D. Ramspott
Lawrence Livermore National
Laboratory
University of California
P.O. Box 808
Livermore, CA 94550
- D. T. Oakley, MS 671
Los Alamos Scientific
Laboratory
P.O. Box 1663
Los Alamos, NM 87544
- 4 Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830
ATTN: J. O. Blomeke
W. D. Burch

No. of
Copies

- Oak Ridge National Laboratory
(contd)
ATTN: R. T. Jubin
L. J. Mezga
- Sandia Laboratories
P.O. Box 5800
Albuquerque, NM 87185
ATTN: Technical Library
- J. R. Berreth
Westinghouse Idaho Nuclear Co.,
Inc.
P.O. Box 4000
Idaho Falls, ID 83401
- 6 E. I. du Pont de Nemours
Company
Savannah River Laboratory
Aiken, SC 29801
ATTN: M. D. Boersma
J. G. Glasscock
E. J. Hennelly
J. R. Knight
M. J. Plodinec
C. T. Randall
- E. A. Jennrich
EG&G Idaho
P.O. Box 1625
Idaho Falls, ID 83415
- R. Shaw
Electric Power Research
Institute
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA 94304
- 5 West Valley Nuclear Services
Company
P.O. Box 191
West Valley, NY 14171
ATTN: S. M. Barnes
C. C. Chapman
J. E. Krauss
S. J. Marchette
J. M. Pope

No. of
Copies

J. L. White
Energy Research & Development
Authority
Empire State Plaza
Albany, NY 12223

A. K. Postma
Rt. 1, Box 46A
Halfway, OR 97834

ONSITE

9 DOE Richland Operations Office

J. H. Anttonen
E. A. Bracken
G. J. Bracken
C. E. Collantes
C. R. DeLannoy
R. D. Izatt
J. L. Rhoades
M. W. Shupe
J. D. White

10 Rockwell Hanford Operations

T. D. Anderson
R. N. Gurley
J. M. Henderson
H. E. McGuire
R. D. Prosser
J. L. Scott
D. A. Turner
D. D. Wodrich
R. D. Wojtasek
File Copy

UNC United Nuclear Industries

T. E. Dabrowski/W. J. Kyriazia

2 Westinghouse Hanford Company

R. E. Lerch
J. D. Watrous

No. of
Copies

61 Pacific Northwest Laboratory

C. R. Allen
W. W. Ballard
S. O. Bates
W. F. Bonner
D. J. Bradley
R. A. Brouns (10)
H. C. Burkholder
J. R. Carrell
D. G. Coles
L. J. Ethridge
D. W. Faletti
M. S. Hanson
L. K. Holton
J. H. Jarrett
D. E. Knowlton
M. R. Kreiter
W. L. Kuhn (10)
L. T. Lakey
D. E. Larson
J. M. Latkovich
J. L. McElroy
A. H. McMakin
G. B. Mellinger
J. E. Mendel
J. E. Minor
R. N. Nakaoka
J. M. Perez, Jr.
R. D. Peters
M. E. Peterson
P. W. Reimus
W. A. Ross
K. J. Schneider
P. A. Scott
S. C. Slate
J. L. Straalsund
J. H. Westsik, Jr.
Publishing Coordination (2)
Technical Information (5)