NRC STAFF PERSPECTIVE ON PERFORMANCE OF VITRIFIED HLW AND HOW IT RELATES TO OTHER COMPONENTS

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ABSTRACT

At the present time, NRC staff does not know whether the borosilicate glass waste form will be compatible with the repository because compatibility has not been demonstrated. NRC staff identified what would be needed to assess the performance of the Savannah River Plant Defense Waste Processing Facility (DWPF) and the West Valley Demonstration Project (WVDP) waste forms. In order to reduce the risk of licensing delays NRC staff is willing to review the glass testing program. If the testing program is appropriate, NRC will so state.

INTRODUCTION

The regulation for disposal of High-Level Radioactive Wastes in Geologic Repositories (10 CFR Part 60) contains performance objectives for the waste package and the engineered barrier system. These performance objectives (§60.113) are (a) that containment of HLW within the waste packages will be substantially complete for a period of 300 to 1000 years after permanent closure of the repository and (b) the release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure. DOE has not identified whether any credit will be taken for the borosilicate glass waste form. NRC staff, however, for purposes of developing its review capability, has assumed that DOE will use the borosilicate glass waste form to take some credit for meeting the release rate performance objective.

LICENSING CONSIDERATIONS

The DOE plans to produce borosilicate glass waste forms from high-level wastes (HLW) at DWPF and at the WVDP. These two projects are scheduled to begin production of radioactive waste glass in the timeframe of late 1988-1989. This is prior to selection of the first repository site and submission of the license application to the NRC. This schedule is a fundamental concern for NRC staff because all of the WVDP HLW and a significant fraction of the DHLW at the Savannah River Plant will be committed to waste forms before the first repository is licensed. In fact, it is likely that the product specifications and the production process will be completed before the waste package design(s) are finalized and before the repository sites are characterized. In order for the NRC staff to make a final assessment on the performance of the DWPF and WVDP waste forms, DOE will need to make its performance allocation, submit sufficient specific waste package and site-specific environmental data and assess the potential negative impacts on other components of the EBS.

At the present time, NRC staff does not know whether the waste form will be compatible with the repository. We also do not know that the waste form will <u>not</u> be compatible with the repository but compatibility has not been demonstrated.

In order to minimize the possibility of licensing delays, NRC staff is willing to review and where appropriate reach agreement on the testing program that DOE intends to pursue. The testing program should be designed to provide data that will support an assessment that demonstrates that the waste form will meet the performance allocated to it (the testing program should relate to or reference the analysis supporting the performance allocation). The performance allocated to the waste form will be part of the demonstration that the waste package and engineered barrier system are in compliance with the performance objectives of 10 CFR 60. NRC staff would need to know the rationale for the performance assessment and the supporting models in order to evaluate the testing plan. The testing program should also describe the glass testing strategy and proposed test methods. It should also reflect the process control programs (PCP), PCP qualification and applicable quality assurance requirements. Based on the waste acceptance process schedules presented in a technical meeting with DOE, the information identified is expected to be available prior to WVDP and DWPF production startup.

DISCUSSION

Waste Acceptance Process

DOE has developed the Waste Acceptance Process (WAP) to formalize the activities within the Office of Civilian Radioactive Waste Management to ensure that waste forms will be acceptable at any potential repository. The WAP is also intended to provide opportunity for coordination between the repository projects, DOE headquarters, and the waste form producers.

We understand that it is DOE's intent to design the WVDP and DWPF waste forms to perform satisfactorily at any of the sites under consideration for the first repository. NRC staff, in assessing the performance of the waste forms, would be looking for the following kinds of information:

1. A Quality Assurance Program.

2. A performance allocation that specifies the design objectives of the waste package and its component parts. The design objectives should include the environmental conditions that the waste package will experience and the design degradation rates of the

individual components. Performance allocation is essential for aiding the design of the waste package because it defines the performance objective of each component. This is the most efficient way to avoid underdesign, which could result in delays in licensing the repository.

Quality assurance and performance allocation are interrelated in that the level of quality assurance (i.e., the required extent and nature of activities such as sampling and process control) required for waste form production would be dependent on the waste form's role in the overall system performance. For example, if the DOE were to take no credit for the waste form for containment or for controlling the release of radionuclides during the 10,000-year disposal period, the level of quality assurance required of the waste form would be very low. Alternate strategies, in which some fraction of the waste packages is considered breached and some credit is taken for control of radionuclide release by the waste form would require varying higher levels of quality assurance during waste form production.

3. A design reliability target for the waste package and its component parts. This should be supported by an analysis of the consequences of excessive rates of degradation from some fraction of the waste packages.

4. A method for assessing the performance of the waste package and its component parts.

5. Identification of the data base required to support the performance assessment and the data base that exists.

6. Identification of a plan and a schedule for acquiring additional data that may be needed. This plan should clearly identify which DOE organization is responsible for the acquisition of the data.

The NRC staff cannot make a final assessment on the extent to which the performance objectives specified in 10 CFR 60.113 are met until sufficient specific waste package data and site-specific environmental data are submitted.

Process Control Program

NRC considers that the basic elements of an adequate process control program include qualification testing, production feed sampling, process control, sample testing of the production waste form and administrative control. These five items are discussed briefly below.

1. Qualification testing includes identifying bounding parameters, performing qualification tests on the envelope of those bounding parameters and correlating test data from laboratory-size monoliths with that from full-size monoliths.

2. Production feed sampling consists of sampling the feed stream and verifying that feed stream parameters are within the qualified envelope.

3. Process control includes identifying critical process control parameters, designing the process equipment and implementing procedures to monitor and control critical parameters.

4. Sample testing of the production waste form consists of identifying final waste form specifications, sampling the production waste form and verifying that it meets specifications.

5. Administrative control includes defining organizational responsibilities and specifying and implementing requirements for document control, QA, recordkeeping and training programs.

The set of circumstances described above assumes that there is an adequate base of data for rates of degradation of the pour canister and the borosilicate waste glass at the upper bounds of each significant environmental parameter. It is then necessary to demonstrate that the simulated waste glass on which the degradation data are based is representative of the production waste forms. This should be done by documenting the fabrication process, fabricating some actual waste forms and canisters by that process and thoroughly characterizing these "qualification items." The documented fabrication process should include the ranges of values of process parameters that must be controlled and the methods of control. Characterization should include chemical, physical and nuclear properties of the qualification waste forms (e.g., homogeneity) and degradation rates at test conditions that conservatively bound the expected environment. If the process control measurements during production are to be performed on samples taken from the melt or the pour, the process development program should qualify the samples as being representative of the product.

The basic elements listed above could be applied in the sequential actions listed below.

1. Document the reference process.

2. Identify the significant attributes of the product that the process is designed to produce and the acceptable ranges of values for each significant attribute. The methods of test or measurement should be specified for each attribute.

3. Identify the significant process parameters and the acceptable range of values for each significant process parameter.

4. Specify the method of measurement and frequency of measurement for each significant process parameter.

5. Use the production process to produce sample product for evaluation.

6. The sample product must be evaluated in accordance with step 1 and found to meet the product specification.

The above steps are expected to demonstrate that the process control program is adequate and that waste form produced by the reference process is likely to meet waste form specifications.

Qualification Testing

NRC would expect the waste form producer to conduct the tests necessary to demonstrate that the sample product meets the waste form specification. This would entail showing that the significant attributes of the waste form that the process was designed to produce, and which were used in the performance assessment, fall within the specified ranges. Examples of attributes of the sample product that we would expect to see demonstrated by qualification testing are presented below:

1. Chemical and radionuclide composition and homogeneity, radially and vertically.

2. Surface area, i.e., the amount of cracking.

3. Leach test data on samples corresponding to locations where samples were taken to measure chemical and radionuclides composition. These tests should be conducted under conditions that bound the anticipated environments at the candidate sites or the results of the tests should be normalized to those conditions.

4. Physical structure of the glass and the homogeneity of the structure as a function of location, both radially and vertically. These tests should determine which radionuclides are in solution and which are present as inclusions or crystals. The tests should also show whether devitrification has occurred and should support quantitative estimates of each of the various types of crystalline structures that may be present.

Sampling

NRC staff considers that sampling of production glass is likely to be required in order to ensure that the production waste form will meet the desired specifications. The frequency of sampling of production glass should be based on the results of pre-operational and qualification testing programs. Sampling frequency also could be modified based on the results of initial production sampling.

The frequency of production sampling will depend upon the sensitivity of the degradation rate of the glass to composition (i.e., homogeneity), pour viscosity, pour temperature, furnace environment (i.e., oxidizing or reducing) and cooling rate. For example, if it can be shown that the rate of degradation of borosilicate glass waste form is relatively insensitive to broad variations in process parameters, sampling of the product or process stream could be less frequent. The term "broad variations" means ranges of values of process parameters that are broader than the limits to which the process parameters will be controlled in production.

Issues Raised by NRC Staff

At the time this paper was prepared, NRC and DOE staff had held two public meetings to discuss the production of borosilicate glass waste form. The first of these public meetings was held on July 31, 1986 and the purpose was to discuss the Waste Acceptance Process and the Waste Acceptance Preliminary Specifications for the Defense Waste Pilot Facility (DWPF) and the West Valley Demonstration Project (WVDP) waste form. The second public meeting was held December 9-10, 1986. The purpose was for the DOE to present information on the status of the DWPF and the glass technology program and to receive feedback from NRC staff.

The main issue raised by NRC staff in the first meeting was that the Waste Acceptance Preliminary Specifications did not address any key issues relative to the waste form. For example, the test procedures and acceptance criteria for the specification for radionuclide release properties were not available (these procedures are being developed along with each site characterization plan and depend upon the performance that DOE allocates to the waste form at each site). NRC staff considers that these procedures and criteria are the most important parts of the description of the waste form.

Agreements and issues raised by NRC staff in the second meeting are highlighted below:

1. DOE/DWPF plans to sample radioactive production glass as it is poured into the canister as part of the process control program. Initially, this sampling would occur frequently. The frequency would then be modified based on results of the initial sample testing. NRC staff agreed with this plan as presented. The detailed strategy for determining the frequency of sampling and testing would be provided in the DWPF Waste Qualification Report.

2. NRC staff identified the basic elements of a process control program and agreed that the DWPF Process Control Plan includes them.

3. DWPF plans to use process control and sampling as the basis for acceptance of the waste form. NRC staff considers that in order to do this, process variables and samples at various points in the process should be correlated with destructive testing of full-size non-radioactive monoliths. It would be necessary to demonstrate first that results of tests on nonradioactive glass are representative of those on radioactive waste glass.

4. NRC staff considers the site-specific leach tests should be performed under a suitably conservative range of repository conditions as defined in the SCPs because waste form production will begin before the sites are characterized. For example, leach rates should not be based on saturation but on a conservative flow regime. Also, it is possible that defense waste will be co-mingled with spent fuel; therefore, higher test temperatures should be considered.

5. Long-term testing of borosilicate waste glass should be considered in order to ensure that release mechanisms remain unchanged.

6. The in situ testing at WIPP will be helpful. The same types of tests should be considered in the SCPs.

7. If the DOE decides not to take credit for the waste form in controlling release of radionuclides, NRC staff considers that it still will be necessary to characterize the waste form. For example, a performance assessment of any failed waste packages should be based on supportable estimates of radionuclide release from the waste form. However, the sampling requirements may be lower than if the performance assessment were based on the waste form alone meeting the performance objectives.

SUMMARY

1. NRC staff identified what would be needed to assess the performance of DWPF and WVDP waste forms. At the present time, NRC staff does not know whether the waste form will be compatible with the repository. We also do not know that the waste form will not be compatible with the repository but compatibility has not been demonstrated.

2. The NRC staff cannot fully assess the acceptability of the repository waste package until sufficient site-specific environmental data are submitted.

3. In order to reduce the risk of licensing delays NRC staff is willing to review the glass testing program. This program would include the performance allocation, the planned performance assessment, the supporting models, the testing strategy and methods that DOE plans to pursue to support the performance

assessment, the PCP, PCP qualification and appropriate quality assurance. If the testing program is appropriate, NRC staff will so state.

4. NRC staff in assessing the performance of the waste forms would be looking for the following types of information: a quality assurance program, performance allocation, a design reliability target for the waste package and its component parts, a method for assessing performance of the waste package, identification of the data required to support the performance assessment, and a plan and schedule for acquiring additional data that may be needed. DOE has stated that it plans to address these issues in the site characterization plans.

5. The level of sampling and process control required for waste form production would be dependent on the waste form's role in the overall system performance. For example, if the DOE were to take no credit for the waste form for containment or for controlling the release of radionuclides during the 10,000-year disposal period, the level of sampling and process control required of the waste form would be very low. This assumes that variations in the waste form have no adverse effect on the release, i.e., no positive credit and no negative credit. Alternate strategies, in which containment of some fraction of the waste packages is considered breached and some credit is taken for control of radionuclide release by the waste form, would require varying higher levels of sampling and process control during waste form production.

6. NRC staff considers that sampling of production glass is likely to be required in order to ensure the production waste form will meet the desired specifications.

7. NRC staff has identified the basic elements of a process control program and agrees that the DWPF Process Control Plan includes them.

REFERENCES

1. Summary of the NRC/DOE Meeting on the DOE Waste Acceptance Process and Waste Acceptance Preliminary Specifications, James Kennedy (NRC), Timothy Johnson (NRC), and Mark Frei (DOE), August 1, 1986.

2. DWPF Technical Exchange with the NRC, Timothy Johnson (NRC), Ken Chacey (DOE-SR), and M. W. Frei (DOE-OGR), December 11, 1986.