WASTE FORM PERFORMANCE ALLOCATION, FUNCTIONAL REQUIREMENTS, AND TESTING PROGRAMS OF THE SALT REPOSITORY PROJECT RELATIVE TO WASTE ACCEPTANCE SPECIFICATIONS FOR GLASS HIGH-LEVEL WASTE FORMS

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ABSTRACT

The Salt Repository Project is one of the four U.S. Department of Energy (DOE) projects associated with the deep geologic disposal of high-level nuclear waste. Concurrent with these project activities directed toward the final selection and licensing of a geologic repository, other nonrepository DOE projects are proceeding with activities directed toward vitrification of liquid wastes, particularly those stored at the West Valley and Savannah River Laboratory facilities. Waste acceptance specifications have been jointly developed by both the repository projects and the waste form producers to allow both groups to proceed with their respective activities with a high degree of assurance that the waste forms thus produced can be received, packaged, and disposed of by the repositories in a manner that will meet applicable regulations. The bases for these acceptance specifications are the performance allocations and the functional requirements assigned to the waste form by the repository projects as well as recognition of the additional attendant testing to be performed by the repository projects in developing a testing data base to support licensing of the repository.

INTRODUCTION

The U.S. Department of Energy (DOE) has selected deep geologic isolation as the method for permanent disposal of high-level nuclear waste. Disposal of these wastes is to be in accordance with Federal legislation (e.g., Nuclear Waste Policy Act of 1982) and regulatory requirements (e.g., 10 CFR Part 60).

Several types of high-level nuclear waste have been identified for such disposal. The principal types identified so far are spent fuel from commercial power reactors, vitrified commercial high-level waste from West Valley, New York, and defense high-level waste from DOE sites such as Savannah River, South Carolina, and Hanford, Washington.

The 10 CFR Part 60 regulation places specific performance requirements on the waste package following emplacement in the repository (e.g., containment and controlled release of the radionuclides). In addition, the repository facilities are responsible for the requirements regarding the safe receipt, handling, packaging, and emplacement operations. These requirements may impose secondary performance requirements on the waste package and its components, one of which is the waste form.

Waste acceptance (preliminary) specifications for the vitrified high-level wastes from the West Valley and Savannah River Laboratory (SRL) facilities have recently been prepared as part of the preparation for startup of the two waste form facilities and so that work can proceed in parallel with waste package and repository design, testing, and analysis work supporting the repository site characterization programs.

The waste acceptance specifications are, to a large degree, the result of performance allocations and subsequent functional requirements that are placed on the waste form that, in conjunction with requirements on other waste package components, the remainder of the engineered barrier system, and the geologic site, will result in the repository system meeting applicable licensing regulations.

Although it is noted that many of the waste acceptance specifications are primarily directed toward receipt, handling, and other preclosure operations at the repository, this paper only addresses salt repository project postclosure allocations, requirements, and testing. An additional set of allocations, requirements, and testing is associated with these preclosure activities.

PERFORMANCE ALLOCATION

The U.S. Nuclear Regulatory Commission (NRC) has established regulatory requirements for the geologic disposal system in 10 CFR 60.113. The NRC has set minimum performance objectives for the overall disposal system as well as for the engineered subsystems of which the waste package (which includes the waste form) is a part.

The performance objectives related to containment of waste within waste packages, and subsequently the slow release of radionuclides from the engineered barrier system, are of direct relevance to the waste package, and hence the waste form.[a]

Waste Form Allocation - Containment

The Salt Repository Project (SRP) places major reliance in meeting the containment performance objective by showing that, for a large number of the waste packages, the container component of the waste package does not develop a breach or pathway by which radionuclides can travel to the exterior of the package. The allocation of functional requirements to the waste form during this containment period, which is from 300 to 1,000 years following closure of the repository, is directed toward:

(1) Ensuring that there is minimal degradation of the canister and inner surface of the container from actions directly attributable to the waste.

(2) Setting limits to and requiring quantification of parameters that could influence processes that are operable on the exterior of the container or canister.

For the first functional requirement, the SRP is proceeding with the intention of showing that the canister material[b], which is specified in the acceptance specification and is hence controlled, does not react with the container material and degrade its isolation performance. Additionally, a specification on chemical compatibility ensures that the waste form will not adversely react with the canister to cause it to breach through internal corrosion reactions.

For the second functional requirement, control of the upper values of heat production and radiation level are required so that package components can be designed to accommodate the effects of these parameter processes that affect the external surface of the container and other package components. For example, testing has shown that both temperature and radiation effects can influence general corrosion rates of the container. Although the values for heat generation (that directly influence package temperatures) and radiation levels are not absolute upper limits, they are established so the other waste package components can be designed, taking into account the effect of these parameters, assuring that the upper values for the subject waste forms are not exceeded.

Waste Form Allocation - Slow Release

The NRC in 10 CFR 60.113 requires that

> The release rate of any radionuclide from the total inventory of waste packages placed in the repository shall, following the containment period, 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. This requirement does not apply to any radionuclide which is released at a rate less than 0.1 percent of the calculated total release rate limit which shall be taken to be one part in 100,000 of the total emplaced inventory that remains after 1,000 years of radioactive decay.

At the present time three waste types have been identified for disposal in the repository. They are spent fuel from commercial nuclear reactors, glassified high-level defense waste from the Savannah River Plant, and glassified reprocessed high-level waste from West Valley. These wastes contain many common radionuclides. Since the release requirement is placed on the total inventory in the repository, a possible allocation strategy would be to develop separate and different release requirements for each waste type or to take advantage of the lower release performance of one waste type to offset higher release performance of another.

It has initially been decided to apply the same release requirement to each waste type for two reasons: (1) The only basis for a difference would be that one waste type was expected to result in significantly different release performance. There is no large data base to definitely establish release performance of a package of a given waste type. (2) A strategy of differing release rate requirements would depend upon maintaining a predetermined established ratio of waste quantities of each type to be emplaced in the repository.

If, in the future, additional waste types are identified for disposal, the release requirement for each will be developed on a case-by-case basis.

As data are obtained on release performance of the various waste-type packages, it may become apparent that one type of waste has a greater probability of meeting or exceeding the release requirement than another. It is possible that a new waste type, particularly if it is a small quantity, could be accepted and disposed of at a repository with a different release-rate requirement but only if data and analysis of the performance of other waste-type package releases available at that time indicate that such an approach would still meet release requirements. Under these conditions an integrated release performance analysis could be used in demonstrating that the total repository waste package release requirement will be met.

A possible strategy for showing that the waste package release requirement will be met is to demonstrate that for the release period, loss of containment does not occur for a very large fraction of the waste packages emplaced in the repository. Since the release period of concern is for 10,000 years following emplacement, this allocation strategy would require demonstration that a large number of packages do not develop a pathway between the waste form and the package exterior for 10,000 years. For this strategy to be viable, present waste package design concepts must be significantly modified by adding barriers and making changes in materials.

Another strategy for meeting the release requirement is to demonstrate that the waste form will not release radionuclides at a rate greater than the maximum allowable release under all anticipated conditions. This would be done either over the range of anticipated conditions or at a possible condition that has been shown to result in the greatest rate of release.

Results of preliminary testing and analysis indicate that dissolution of the waste form may not of itself control the rate of radionuclide release to values below those required of the engineered barrier system by the NRC, particularly over the range of environments

a. The DOE has set as a program goal meeting the radionuclide release requirement at the boundary of the waste package rather than at the boundary of the engineered barrier system.

b. Because both the West Valley and SRL waste forms are provided by pouring molten glass into canisters, the canisters are considered as part of the acceptance specification.

presently considered possible during the release period. For example, the rate of dissolution of the waste form is increased in the presence of the carbon steel container material due to the formation of colloids and precipitates that prevent the solution saturation of chemical species affecting the dissolution rate.

It is possible that package components (additions/modifications), their materials of construction, and engineered barrier system design could be altered in a manner that would change the waste form dissolution rate to a level that is smaller than the required release values.

If the dissolution rate of the waste form will not, of itself, meet the required release value, it becomes necessary to adopt an allocation strategy to demonstrate that some quantity of radionuclides (the difference between the release requirement and the radionuclides dissolved from the waste form) is not transported to the exterior of the waste package but continues to reside within the package as colloids or precipitates. It must be demonstrated that the radionuclide concentration in the transport medium times its rate of movement in or with the transport medium exiting across the exterior boundary of the package is less than the required release value.

The radionuclide concentration in the transport medium consists of radionuclides that are in solution and those that are in suspension in the form of colloids. Even with a brine chemistry, which tends to minimize radionuclides in solution, it is likely that the radionuclide content (in-solution radionuclides plus colloids) would exceed the allowable release value if the transportable medium were to cross the package boundary at a significant rate.

The transport velocity of the radionuclides from the waste form to the exterior of the package will be significantly reduced when the package contains a packing material component with a predictable low porosity, thus limiting transport velocities to values typical of diffusion-controlled processes. Additionally, this low porosity will act to effectively filter colloids and prevent their movement to the package exterior. A packing material that retards radionuclide migration through adsorption could also be beneficial.

Given the above allocation strategy for the waste forms from West Valley and SRL, it can be seen that an acceptance specification requiring that the waste forms be shown to have a dissolution rate below some value is unnecessary. It is also not realistic to require the waste form producer to demonstrate acceptance by requiring the waste form to directly limit the solubility of radionuclides. The radionuclide solubilities are strongly influenced by factors (such as brine composition, brine chemistry, and other package material interactions) that are not within the direct control of the producers.

The acceptance specification related to repository postclosure performance therefore is limited to requiring that the waste form producer provide the following:

(1) Data about the chemical and radionuclide composition of the waste form over the range of products that are likely to be produced.

(2) Data to demonstrate the chemical and phase stability of the waste form so that testing by the repositories will be representative of product condition after the 300- to 1,000-year containment period.

(3) Data on the release characteristics of the waste form over its product range under conditions representative of those expected in the repositories.

Item (3) above relates to acceptance specification 1.3 (radionuclide release property specification). It should be noted that this is not a pass/fail type of specification for the SRP but rather a requirement to generate release-relevant-test data over the product range of the producers' process so that the SRP, in its testing program, can take this variability into account.

REPOSITORY WASTE FORM TESTING PROGRAM

Based upon the previous discussion of waste form performance allocation and the waste acceptance specifications, it is the responsibility of the repository program to develop, through testing and analysis, the necessary data base to support licensing actions regarding conformance to 10 CFR Part 60 postclosure performance objectives. This testing will fall into the following categories:

(1) Testing to determine and bound the environmental conditions existing within the waste package following loss of containment and through the release period, particularly those conditions that influence radionuclide solubility and transport.

(2) Testing to determine radionuclide solubilities of relevant nuclides over the range of possible environmental conditions.

(3) Testing to characterize the properties of colloids that may form in conjunction with waste form dissolution.

(4) Testing to determine transport rates of radionuclides to the exterior of the package. This includes consideration of mechanisms of liquid movement and long-term properties of the packing material relevant to the transport of radionuclides.

The waste acceptance specifications and attendant waste form qualification report that demonstrate the waste forms' compliance to the acceptance specifications are and will be utilized by the repository SRP in planning and implementing its testing program in the areas previously mentioned. By setting acceptance limits on the waste form product, the repository projects can bound their test conditions. By requiring that the waste form producers provide data on the dissolution behavior of their waste form over its range of product variability, the repository projects can determine the number of tests involving the various waste form compositions that will be necessary to develop an adequate data base.

CONCLUSION

The waste acceptance specifications developed for the West Valley and SRL waste forms are intended to establish a set of requirements and data needs from which the repository projects can, through testing, proceed to develop the necessary data base and analysis to show conformance to licensing requirement performance objectives. The specifications are directly related to the performance allocation strategies adopted by the repository projects for the waste form as a component of the waste package and the engineered barrier system. The testing to be performed by the waste form producers to show conformance to the specifications is not a substitute for testing by the repository projects. The repository projects will have to conduct an extensive testing program to develop licensing data. The data

from the producers are intended to allow the repository projects to place bounds or limits on parameters used in their testing, with assurance that testing outside these limits is unnecessary.