SPECIFICATIONS FOR ACCEPTANCE OF NUCLEAR HIGH-LEVEL WASTE FORMS BY A GEOLOGIC REPOSITORY

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ABSTRACT

To receive nuclear waste forms for disposal in a mined geologic repository, acceptance specifications must be established for each reference waste form and canister, if used. Such specifications provide the requirements that must be met and the respective compliance tests to use in determining whether the requirements have been satisfied. The Basalt Waste Isolation Project (BWIP) has begun the development of the site-specific acceptance specifications relative to U.S. Department of Energy (DOE) reference waste forms and canisters for commercial light-water reactor spent fuel and for commercial and defense high-level nuclear wastes from reprocessing. Acceptance requirements have been drafted and are being refined, and the programs to develop the associated compliance tests and/or procedures are being planned. The first site-specific compliance test being developed is a simplified hydrothermal experiment that would test a combination of simulated groundwater, basalt, waste form, and other components of the waste package, if necessary. The objective will be to determine what the maximum steady-state concentrations are for selected radionuclides found in the resulting fluid and then determine if these values exceed the respective acceptable limits listed in the acceptance specifications for the BWIP. The acceptable concentration limits for such radionuclides will be established by the BWIP site characterization program data base.

INTRODUCTION

The BWIP, conducted by Rockwell Hanford Operations (Rockwell) under contract to the DOE, is responsible for investigating the feasibility of siting a licensable repository for the disposal of nuclear waste in the basalt formations underlying the Hanford Site in south-central Washington State. This assignment includes producing preliminary designs for the repository system (i.e., all surface and subsurface facilities) and the waste packages to be emplaced. In order to license such a repository system, acceptance specifications must be established for each reference design case of nuclear waste type, form and canister proposed for receipt and disposal. The term "waste form" refers to the combination of nuclear waste, waste form matrix, and, for spent fuel, includes the cladding. A canister is the first material (e.g., metal) envelope surrounding the waste form and would typically be installed by the waste form producer/shipper.

The DOE and the three lead candidates for the first repository are working to develop preliminary versions of site-specific acceptance specifications prior to final site selection. The objective of this paper is to overview and status the BWIP program to establish such acceptance specifications. This will be done by discussing the development of the two major components of each acceptance specification: (1) the acceptance requirement and (2) the associated compliance test(s).

ACCEPTANCE SPECIFICATIONS

The acceptance specifications for nuclear waste form and canister combinations are written statements that establish all requirements to be met and specify all compliance tests or other means that must be used in determining whether the respective requirements have been satisfied. The major sources and types of information that input into this process are the characteristics and requirements of the BWIP mined geologic disposal system, the reference waste system and transportation system and the limitations imposed by Federal regulations.

The acceptance specifications are, in effect, a form of quality control imposed upon the producer (shipper). However, the specifications for a given reference case (i.e., waste form and canister) do not form an independent recipe that a prospective producer can simply apply to develop (1) either a major variation of an approved-for-disposal reference design case or (2) a whole new reference case for a similar type of waste and assume that the proposed product will be acceptable for receipt and disposal by the repository. Although some specifications will provide generic guidance, others do not and can only be established after the new candidate for a reference case has been considered by the receiver's site-specific testing, analysis, and design programs. The process of qualifying a new reference case or a major revision of an existing reference case and thus developing an applicable set of waste acceptance specifications will always require close interfacing between the producer (shipper) and the receiver (repository) to ensure compliance with the license to operate the repository.

ACCEPTANCE REQUIREMENTS

The acceptance requirements must establish which material parameters and characteristics (i.e., physical, chemical, thermal, radiation, etc.) must be controlled and within what values, what information must be provided on them, as well as any administrative requirements on topics such as documentation and quality assurance. The BWIP has drafted waste acceptance requirements for the following reference waste forms[1]: 1) commercial light-water reactor spent nuclear fuel, (2) commercial high-level waste (CHLW), and (3) defense high-level waste (DHLW)[2]. The DHLW and CHLW reference cases were based, respectively, on the design information available for the Defense Waste Processing Facility (DWPF) under construction by the DOE at the Savannah River Plant in South Carolina and for the now defunct Barnwell commercial nuclear spent fuel reprocessing plant also in South Carolina. The acceptance requirements for the high-level waste form

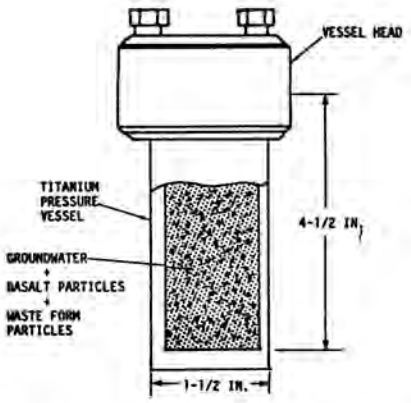

Fig. 1 A schematic of the proposed test vessel system for the MCC 14.4 compliance test.

and evaluation, the laboratory work has progressed into the testing of mixtures of simulated groundwater, basalt, and a simulated high-level waste form. The simulated waste form is a borosilicate glass matrix containing a nonradioactive simulation of a nuclear waste plus selected radionuclides. A listing of the primary conditions being used in this series of evaluation tests is as follows:

Temperature (150°C)
Pressure (Vapor pressure)
Basalt particle size (60 to 120 mesh)
Waste form particle size (120 to 230 mesh)
Mass ratio of solids (1:1)
Solution/solid ratio (10:1 mL/g)
Test duration (3-, 6-, 9-, 12-wk and 1 set of vessels run to a longer time, up to 6 mo, if needed)
Waste form replication [Two vessels (MCC-14.4 procedures will call for three)]
Waste form (MCC 76-68 borosilicate glass)
- ATM-3 (Np) doped
- ATM-4 (Pu) doped

The test vessels are loaded and started together as a group for each run. At each sampling time, a set of vessels are permanently removed from the group, disassembled and the fluid sampled for analyses. Results from the analysis of fluids taken for run times up to 12 wk are available and are being evaluated, and the 26-wk run will be sampled soon (March 1985).

Solution analyses results from these tests are being evaluated against data from tests using the same types of materials and conditions in the Dickson rocker-type autoclave system currently being used in the BWIP hydrothermal testing program. The latter system uses a gold bag chamber, and the fluid is sampled at pressure and temperature at designated times during the run. So far, the evaluation studies indicate that the test vessel system and the proposed procedures are performing satisfactorily and that only minor modifications to the equipment and the proposed procedures are needed. There are still some concerns to be resolved about possible quench effects. Evaluation studies of the proposed MCC test method and procedure will continue for at least another year with both simulated waste forms doped with radionuclides and actual waste forms such as spent fuel.

The BWIP hydrothermal testing program is also evaluating possible usage of the same type of pressure vessel system being used in the MCC 14.4 testing. As part of this effort, another version of the vessel system is also being evaluated. It is slightly larger and contains a device to permit sampling at pressure and temperature and should also permit more than one sampling time during the run. If needed, the proposed MCC 14.4 test method will be revised to use this vessel system.

A written description of the MCC 14.4 test system and procedure was submitted for an executive review by the DOE/Materials Review Board (MRB). The writeup of MCC 14.4 is being revised and will be submitted later in FY 1985 for a full MRB review.

Other Compliance Tests/Procedures

The BWIP is interfacing with several DOE and producer programs to plan the development of the respective compliance tests and procedures needed for the remaining acceptance requirements. A few of the proposed acceptance requirements deal with administrative topics (e.g., documentation, quality assurance, etc.) and should not pose much difficulty in defining appropriate compliance tests and procedures. Several requirements deal with providing information on the characteristics for given reference cases of waste forms and canisters and their expected ranges of variation during production. Information to comply with these requirements is expected to be provided by the producer's reference design, process demonstration testing, process control program, and especially for spent fuel, the records on operating history and the codes that predict such characteristics as radionuclide inventory and decay heat. For CHLW or DHLW forms cases, development of compliance tests will be heavily influenced by the extent to which the producers can provide the needed information via their process control programs. This will in turn help decide what types, extent, and frequency of direct sampling of the process may still be necessary in order to confirm whether or not certain acceptance requirements are being satisfied. The BWIP and the prospective producer programs are in the early stages of discussion on this important topic, and the next stage will be to review the producer's plans for process control, demonstration testing, and other aspects of compliance test development. An important part of all the compliance test/procedure development work will be to ensure that any predictive codes proposed by waste form producers for such use are properly verified and validated over the full range of parameters associated with the given waste form reference cases.

Two of the proposed requirements for CHLW and DHLW cases deal with demonstrating that the waste form and canister unit can withstand certain accident conditions, i.e., a fall and impact situation and a fire situation. These requirements are still being refined by the BWIP, and although the BWIP has not directly initiated such compliance test development, the DOE has sponsored some development work on such tests (e.g., the MCC 15 test). It is expected that, for other acceptance requirements generic to two or more of the three candidate repository programs, the development of the associated compliance tests and procedures will, likewise, be consolidated into a single program effort.

CONCLUSION

This paper has provided an overview of the BWIP efforts to develop waste acceptance requirements and associated compliance tests. The BWIP has produced draft waste acceptance requirements for three high-level nuclear waste reference cases: a CHLW, a DHLW, and a commercial spent fuel case. The BWIP is currently working on revising these requirements for reissue later in FY 1985.

The BWIP is working with the DOE and prospective waste form producers to plan the development of the

product from the West Valley Demonstration Plant (WVDP) in New York, which the DOE defines as a CHLW system, were not specifically addressed, pending receipt of more reference design information. However, the WVDP reference case is expected to be very similar to that for the DHLW case for the DWPF and, thus, so will the acceptance requirements. Commercial transuranic wastes were also not addressed, pending completion of further DOE work on defining the reference cases to be considered.

The topical categories of acceptance requirements are defined for the CHLW, DHLW, and commercial spent fuel references cases as follows:

- o Waste form requirements
  - Chemical
  - Physical
  - Thermal
  - Radionuclide inventory
  - Limits on radionuclide concentrations in near-field fluid
  - Control of conditions affecting limits on radionuclide concentrations in near-field fluid
  - Criticality
  - Properties
- o Canister requirements*
  - Chemical
  - Physical
  - Thermal
  - Handling
  - External contamination
  - Criticality
  - Noncompliance
  - Properties
  - Identification, labelling
- o Document requirements
- o Quality assurance requirements

*Incomplete for spent fuel case.

Completion of the requirements for spent fuel consolidated offsite (i.e., received in canisters) is awaiting further definition of the reference case(s). The draft waste acceptance requirements are being revised, and interim acceptance requirements are scheduled to be issued during the last quarter of FY 1985. The effort to refine the acceptance requirements will continue up through the advanced conceptual design tasks and preparation of the preliminary version of the acceptance specifications.

COMPLIANCE TESTS/PROCEDURES

The purpose of the compliance tests is to provide a means for determining whether or not the units of waste form prepared by a producer (shipper) conform within the limits of the requirements and, thus, the receiver's license to operate the repository. In establishing the compliance tests for the proposed acceptance requirements, the BWIP is, with one major exception, still in the first stage of development, namely identifying candidate approaches and planning the development program. The effort has focused on the requirements considered expecially important and specific to the BWIP.

MCC 14.4 Test

The BWIP has proceeded into the full development of the compliance test for one of the proposed site-specific waste form acceptance requirements. The Subject requirement specifies the acceptable BWIP limits for the maximum steady-state concentrations of radionuclides in fluid (i.e., conditioned groundwater) assumed to be located in the waste package at the waste form/packing (basalt + bentonite) interface, following breach of the container and the ingress of groundwater. The approach taken in defining this requirement is in turn based upon the approach the BWIP is using in characterizing waste and waste form constituent behavior as part of the study of isolation performance under site-specific conditions. Consideration of the hydrology and geochemistry of the Hanford Site has resulted in the BWIP placing the emphasis on determining the fate of radionuclides released from the waste form into the surrounding geochemical environment rather than an emphasis on determining the kinetics of radionuclide release (i.e., leach rate) from the waste form [3].

The radionuclides specified in the proposed requirement will be those that the BWIP determine to be potential problem radionuclides relative to conservatively meeting the radionuclide isolation performance assigned to the waste package. At present, a simple one-dimensional, two-media transport analysis has been derived to model radionuclide transport across the waste package packing [4]. By allocating a specific performance to the waste package (i.e., at the packing/host rock interface) and putting in conservative values for the parameters controlling transport across the packing, the model has been used to predict what the acceptable limits would be for the maximum concentrations of radionuclides in the near-field fluid at the waste form/packing interface and identify the potential problem radionuclides. The BWIP has completed such analyses for several high-level waste reference cases (i.e., a commercial spent fuel, a CHLW form and a DHLW form) [4]. If this proposed requirement becomes part of the final waste acceptance specifications, the acceptable maximum concentration limits for any radionuclides specified in the requirement would be established using the test data and performance analysis results used in the licensing process.

The BWIP has contracted with the Materials Characterization Center (MCC) at the Pacific Northwest Laboratory (PNL) to do the initial development on test devices and procedures for the MCC 14.4 compliance test. The primary objective is to develop a compliance test that will reliably yield data that can be satisfactorily related to the extensive data base being obtained by the BWIP hydrothermal testing program for licensing. The proposed MCC 14.4 test is, in effect, a waste form/near-field fluid interactions test. The test would use simulated groundwater, waste form, basalt, and any additional waste package constituents that are needed to obtain the data required. A subordinate objective is to develop a test method that is smaller, simpler to operate, and less costly than the autoclave system (Dickson rocker-type) currently used for such work in the BWIP hydrothermal testing program.

The current status of the effort is that a test method has been proposed, a pressure vessel system selected, a test procedure written, and laboratory demonstration testing begun. A schematic of the proposed pressure vessel system is shown in Figure 1. Titanium (non alloyed) was selected as the material for the pressure vessel body and lid. Initial test evaluations were devoted to determining whether or not the vessel system would be sufficiently nonreactive, the sealing system would be adequate, and the vessel could be satisfactorily decontaminated to allow reuse of the vessel. The testing program has produced affirmative answers for each of these questions. Currently, the material being used for the gasket in the seal system is Teflon (a registered trademark of DuPont). Further tests will be run soon to evaluate titanium as a seal material. After considerable developmental testing

compliance tests and procedures. The compliance test for a requirement concerning the acceptable limits for the maximum steady-state concentrations of radionuclides in near-field fluid (i.e., conditioned groundwater), MCC 14.4, is under full development. A test approach and the hardware needed have been selected, a procedure has been proposed, and laboratory testing and evaluation are underway. The effort has progressed into testing with radioactive waste form materials and evaluation of the results against those from the baseline hydrothermal testing program of the BWIP. To date the results of this development program have been favorable and indicate that work should continue on refining and evaluating the proposed compliance tests.

The development of compliance tests and procedures for the other proposed acceptance requirements is primarily in the conceptual stage of identifying candidate test approaches and planning the development programs.

ACKNOWLEDGEMENTS

Technical support was provided by R. G. Strickert and D. G. Coles of PNL and M. I. Wood and W. J. Anderson of Rockwell. Valuable review comments were provided by T. B. McCall, M. J. Smith, P. F. Salter, and L. C. Preston of Rockwell and P. E. Lamont of DOE. C. M. Allender and D. B. Mill of Rockwell prepared the manuscript and illustration, respectively.

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