

RESEARCH TO SUPPORT ENTOMBMENT RULEMAKING

Introduction

10 CFR 50.82a (3) requires that decommissioning of power plants be completed within 60 years of the permanent cessation of operations. This requirement effectively prohibits entombment as a decommissioning option unless NRC grants a case-specific exemption based on a health and safety need. Any significant extension of the time permitted for decommissioning has far reaching implications. SECY-99-187, "Information Paper on the Viability of Entombment as a Decommissioning Option," (July 19, 1999) discussed these issues and noted that absent inclusion of Greater Than Class C (GTCC) waste, an inadvertent intrusion after 130 years would not produce a significant radiation exposure. Assuming a time period of this length raises questions about the adequacy of existing financial assurance mechanisms to reliably support the facility and what type of institutional controls will be sufficient. Staff will also need to consider potential impacts from the inclusion of GTCC waste in the entombed structure when developing the proposed rule. Work being performed by the Electric Power Research Institute will be used to support development of the source term for cases with and without GTCC waste.

Developing a risk-informed, performance-based rule permitting entombment as a decommissioning option will require staff evaluation of a wide range of licensee options. The research in this plan is based on the assumption that one or more existing buildings are modified to serve as the outer structure of the entombed facility, and that backfills or infills are used to isolate and immobilize contaminated materials and equipment within the structure. Some modifications such as installation of a new roof or cap would most likely be needed to both cover the structure and prevent water entry.

In order to model the performance of such a structure under a performance based rule, the staff must be able to characterize, understand and simulate key features and effects of the structure over time. Research on long term effects of cracking on permeability of both the outer structure and the backfills is necessary to permit staff assessment of entombed facility capabilities. Non-destructive examination techniques will be needed to establish the condition of the outer structure at the time of closure and to monitor its degradation over time. Updated source term information will assist staff to identify and quantify the radionuclides available for release to the environment. Specific modifications to existing performance assessment codes will help the staff to customize such codes for the evaluation of entombed facilities. Evaluating the fundamental mechanisms involved and the tools for performance assessment will provide the staff with technical support for several rulemaking options. Much of this research will also be useful to support review of licensee proposals to use assured isolation or enhanced Safestor as part of their decommissioning plan.

By Staff Requirements Memorandum the Commission agreed to defer entombment rulemaking until completion of research studies on entombment viability issues. In view of the lack of immediate need and higher priority competing activities, the research described here will provide timely support for Office of Nuclear Material Safety and Safeguards (NMSS) licensing activities. If funded, research on entombment issues should be able to support resumption of rulemaking activities in 2005.

The discussion that follows details the research that will be undertaken prior to the commencement of rulemaking activities and some work that continues on to support staff capabilities to assess compliance with the rule. Where specific costs, milestones, and

schedules are available, they are provided. For research not yet undertaken, the plan provides preliminary descriptions of the work to be performed and estimates of schedules, milestones, and resources in terms of full time equivalents (FTEs), staff and contractor, that will be needed to accomplish this work.

1. Research in Progress

Research currently being undertaken by the National Institute for Standards and Technology (NIST) examines the performance of concrete-entombed structures and methods for assessing radionuclide transport through them. The estimated completion date for the project is March 2008. Results from Task 1 and part of Task 2 of the project are expected to be available in 2005, at which time the staff would begin rulemaking. The remaining research is not essential for initiation of a rulemaking, but will provide important information to the staff in the implementation of a final entombment rule. The following summary briefly outlines the statement of work for this research.

Project Title: Evaluation of Entombed Structures for Decommissioning Nuclear Facilities

Contractor:	National Institute of Standards and Technology (NIST)
NRC Project Manager:	Jacob Philip (301) 415-6211
Period of Performance:	February 2002 - March 2008
Estimated Total Cost:	\$552K

Task 1: Evaluation of strategies for the assessment of entombment structures prior to entombment

Results from this task will provide guidelines for assessing concrete entombment structures from a flow-and-transport perspective. This involves evaluating the chemical and physical condition of the structure. Given the size of the structure to be entombed, an effective sampling plan is needed to reliably estimate the actual chemical and structural condition of the concrete. Guidelines will be developed for applying a performance assessment code to evaluate the existing facility before entombment. Under this task the NIST will also assess non-destructive evaluation (NDE) techniques to characterize existing cracks and other transport pathways in the concrete.

Milestones:

- (1) A letter report outlining a plan for performing a condition assessment and service life prediction, and ranking crack parameters that most influence transport through the concrete. (January 2003)
- (2) A letter report that evaluates existing NDE techniques as candidates for characterizing cracks in concrete structures considered for entombment (September 2005)

Task 2: Evaluation of promising NDE techniques available for further evaluation as effective tools for entombment structure assessment.

There is no standard NDE test method for measuring the depth of surface opening cracks. Methods identified in Task 1 will be subjected to an in-depth analysis to evaluate their potential for application to heavily reinforced structures that may be characteristic of an entombed facility. NDE will be important during the surveillance and monitoring period for the entombed structure.

In addition, this task will include a study of the time-dependent behavior of cracks within the structure and assessment of conditions under which such cracks can heal. This is important because the expected future behavior of cracks over time will determine the required monitoring frequency. In a moist environment, cracks are avenues for the flow of water and transport of soluble and suspended materials through concrete. As such, the cracks are susceptible to leaching and further widening or, in some cases, precipitation which can cause cracks to close up. This study will provide a better understanding of the conditions that determine whether a crack will be either leached or healed.

Milestones:

- (1) A letter report on the time-dependent behavior of cracks in concrete and the conditions under which cracks can heal. (December 2003)
- (2) A letter report on the evaluation of an appropriate NDE technique for characterizing cracks in concrete structures. The technique should be applicable to both initial assessment and long-term monitoring of the entombed structure. (March 2007)

Task 3: Assessment strategies for surveillance and monitoring of entombed structures with a focus on obtaining data to confirm the performance modeling of the entombed structure.

This task involves the evaluation of sensors capable of monitoring the properties of entombed structures (e.g., corrosion of reinforcing bars, formation and growth of cracks etc.). It is anticipated that the models used and the predictions of performance will play an essential role in establishing the parameters that need to be monitored.

The first activity of Task 3 will be to identify what needs to be monitored. It is anticipated that some of the key parameters may include formation and growth of surface opening cracks, distribution of deleterious ionic species (such as chloride ions), depth of carbonation, and corrosion activity of embedded steel. The next step will be to determine how these parameters can be monitored. Since the entombed structure may need to be monitored for more than 100 years, it will be important to select techniques that will remain reliable over the time of surveillance. The frequency of evaluation of monitoring results will also be addressed. It is expected that monitoring will be more frequent at the start of the surveillance period. The objective is to combine quantitative monitoring with performance assessment calculations. The calculations will yield expectations that then can be compared to future monitoring measurements.

Milestones:

- (1) A letter report enumerating structural properties that require monitoring and the evaluation of existing sensors for each property. (February 2008)
- (2) A letter report on strategies for spatial and temporal distributions for long-term monitoring. The strategies must be comprehensive to enable timely response to changes in structure conditions and facilitate corrective action. (February 2008)
- (3) A NUREG/CR report on the entire project will be prepared. (June 2008)

2. Planned Research Activities

This section provides preliminary descriptions of new research that is needed to develop technical information sufficient to support rulemaking to permit entombment of a power reactor facility and to support technical evaluations of a proposal for entombment. These projects are currently not included in the FY 2003-2004 budget. The staff will use the add/shed process to determine whether other work can be delayed in order to initiate these tasks. They will also be considered in development of the FY 2005-2006 budget proposal.

Entombment Source Term Development

The staff plans to initiate research to characterize the source term and estimate inventories (volumes and radionuclide content). The staff estimates that the resources needed for this research will be the equivalent of 2 person-years of effort spread over 3 years. Staff will use the add/shed process to determine whether other work can be delayed in order to initiate these tasks in FY 2003.

This work will primarily involve updating existing source term estimates for entombment which were prepared to support the 1988 decommissioning rule. Much of what was reported from the earlier studies (NUREG/CR-0672, "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," and NUREG/CR-0130, "Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station") is likely to remain valid today; however, an update is warranted because this work was completed 20 years ago. The contractor will evaluate the impact of plant life extension and the use of higher burnup fuels as part of this update.

In addition, the staff will continue to follow ongoing activities of the Electric Power Research Institute (EPRI) on entombment source term characterization for typical boiling water reactors (BWRs) and pressurized water reactors (PWRs). EPRI indicates that much of this work has been completed and is currently under quality assurance (QA) review.

Milestones (based on initiating work in FY 03):

- (1) A letter report updating the source term estimates for a reference BWR and PWR. (December 2005)

Characterization of Infills and Backfills for Use at an Entombed Facility

The staff plans to initiate research to evaluate infills and backfills for the interior of the entombment structure. The staff estimates that the resources needed for this research will be the equivalent of 2 person-years of effort over 3 years. The staff will use the add/shed process to determine whether other work can be delayed in order to initiate these tasks in FY 2003.

Infill and backfill materials to be investigated will include cement grouts and soils (sand, clay and combinations of these materials). Research to be conducted for cement grouts will address the deformation properties of the grouts, testing and monitoring procedures, properties of materials and admixtures to be used, permeability and stability requirements, heat generation and abatement, and radionuclide sorption properties. For soil materials, research will evaluate ease of soil placement, adsorption, permeability, stability, and isolation capabilities.

Milestones (based on initiating work in FY 03):

- (1) A letter report on the flow properties of cement grouts as a function of its viscosity, permeability, material properties and water-cement ratio. (December 2004)
- (2) A letter report on the effects of admixtures in the grout, heat of hydration and abatement, and grout testing and stability, and radionuclide sorption properties. (April 2006)
- (3) A letter report on soil materials (sands, clays, and combinations) as infills or backfills for entombed structures. (December 2006)

Environment Effects of an Entombed Facility

This study is intended to evaluate existing models to characterize radionuclide dispersal into the environment, with a primary focus on shallow and surficial water pathways that might exist around an entombed facility. This work will assist the staff in assessing the potential dose from an entombed facility. The staff estimates that the resources needed for this research will be the equivalent of 2 person-years of effort spread over 3 years. Staff will use the add/shed process to determine whether other work can be delayed in order to initiate these tasks in FY 2004.

In the past the staff has conducted flow and transport modeling and performance assessment analyses using dose models such as RESRAD. This study will integrate these and other models with surface and ground water models to evaluate flow and transport for use in dose modeling for entombed facilities.

Milestones (based on initiating work in FY 04):

- (1) Review existing models for applicability to assessing performance at entombed facilities, including work performed by other Federal agencies and industry. This will assist staff in developing dose modeling tools sufficient to evaluate entombment performance over several hundred years. (August 2004)
- (2) Develop a tool that will be suitable for modeling entombment performance, taking into account the various conditions that may be present in the entombed facility. (August 2005)
- (3) Prepare a NUREG/CR report documenting the model's capabilities. (January 2006)