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Second Generation Waste Package Design Study

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1. Research Merit Relevant to YMP

The design of waste packages currently proposed for YMP is highly conservative. The candidate materials of construction of the waste packages and drip shields while highly corrosion resistant are extremely expensive and components made from these materials will require complex and expensive fabrication methods to assure their integrity. A proposed, second generation operating concept and waste package design, is intended to permit more efficient and less costly operation of the repository while maintaining waste package integrity. Major reductions in waste package costs can be realized by increasing the number of fuel assemblies stored in each waste package, eliminating the reference titanium drip shield and fabricating the outer container from low alloy "weathering" steels. These steels have outstanding resistance to general corrosion and are localized corrosion.

The second generation waste package is proposed for implementation after the initial licensing and operation of the reference Yucca Mountain design. Implementation would follow a regulatory process analogous to that used to implement plant life extensions and power uprates of commercial light water nuclear reactors. The proposed concept capitalizes on the benefits of hot, dry storage to minimize potential for contact and corrosion of the waste package metallic surface by liquid electrolytes. The merits and feasibility of this approach have been investigated analytically at UNR [1, 2] and testing of the materials of interest is required to demonstrate the phenomena involved and the corrosion resistance of the proposed alternate material.

2. Objectives

The objectives of the proposed research are:

- To review the current YMP baseline environment and establish corrosion test environments representative of the range of dry to intermittently wet conditions expected in the drifts as a function of time.
- To demonstrate the oxidation and corrosion resistance of A588 weathering steel and reference Alloy 22 samples in the representative dry to intermittently dry conditions.
- To evaluate backfill and design features to improve the thermal performance analyses of the proposed second generation waste packages using existing models developed at UNR.

3. Approach

Task 1. Definition of expected worst case environments (humidity, liquid composition and temperature) at waste package outer surfaces as a function of time, and comparison with environments defined in the YMP baseline.

- Review assumptions in current YMP analytical models that define the chemistries and quantities of liquid phases that can contact the waste package outer surface during post closure.
- Meet with Office of Chief Scientist staff to discuss the "Environmental Conditions" report prepared by the Materials Thrust Team
- Work with project or national laboratory staffs to determine the realism of the assumptions. The primary environments that will be evaluated are:
    - Electrolytes formed at surfaces from the interaction of mineral dust and condensing water at the package cools.
    - Electrolytes that drip on the waste package surface.
- Define the expected worst case (as opposed to hypothetical worst case) environments to be used in oxidation and corrosion tests to be performed in Task 2.

Task 2. Oxidation and corrosion tests of proposed second generation outer container material.

- Verify the predicted oxidation and corrosion resistance of A588 steel in expected worst case Yucca Mountain environments established in Task 1. Tests will be performed in dry, humid and dripping environments over a range of temperatures and will be performed using methods and procedures which allow for direct comparison with other OCRWM studies being directed by the Office of the Chief Scientist.
- The selected environments and test plan will be submitted to DOE/OCRWM prior to initiation of Task 2.
- Testing will be performed over temperature ranges from 100 to 600 °C and relative humidity from 50% to 100% as well as under intermittent dripping (wet/dry) conditions.
- Testing will be performed under simulated deliquescent brine environments defined in Task 1.
- A588 will be tested in the as forged and as welded conditions. Samples of Alloy 22 will be included in the test program for comparison purposes. Focus of the testing will be to verify the resistance of the alternate material to localized attack and to confirm general oxidation and corrosion kinetics and mechanisms.

Task 3. Second Generation waste package thermal analyses.

- Extend the evaluation of the thermal performance of proposed high temperature waste packages to determine the highest surface temperatures that can be sustained without exceeding a peak fuel cladding temperatures of 400C. Evaluate design features such as aluminum shunts and helium pressurization to minimize the temperature difference between fuel cladding and waste package surface temperature.
- Thermal analyses will be performed using existing UNR models as well as YMP models (working with YMP staff) and will address both pre closure and post closure periods. The analyses will focus on the use of mineral backfill during the post closure period to maximize the duration of dry storage.
- Evaluate the influence of the proposed high temperature storage mode on the duration of the dry period as defined by temperature and relative humidity.

4. Collaboration

This work will be carried out in collaboration with National Laboratory personnel designated by DOE Science and Technology management and the Office of the Chief Scientist.

5. Qualification of the Research Team

The Center for Material Reliability, headed by Dr. Misra UNR has a well established Electrochemical and Corrosion Laboratory. Currently several YMP research projects are in progress at UNR. Dr. Sam Armijo, a lead investigator of this research, is one of the top nuclear technologists in the country with more than 40 years of experience in the design and development of nuclear power systems, nuclear fuels and fuel claddings. Preliminary investigations of the proposed design at UNR have shown promising results. Based on these preliminary investigations, peer-reviewed papers have been published in reputable nuclear engineering journals [1, 2].

6. Total Duration of the Project

There will be three subtasks in the project including long-term wet/dry corrosion tests. The total duration of the project will be 2 years.

7. The Estimated Annual Cost

In accordance with preliminary discussions between UNR and DOE, this budget assumes that the work and results will not be quality affecting. However, at the discretion of DOE, this work can be conducted in accordance with the approved NSHE Nuclear Quality Assurance Program, at an increased cost.

8. References

1. J.S. Armijo, P. Kar and M.Misra, "Second Generation Waste Package Design and Storage Concept for the Yucca Mountain Repository", Nuclear Engineering and Design, article in press, accepted for publication March 9, 2006.

2. P. Kar, G. Danko, J. S. Armijo, M. Misra and D. Bahrami, "Thermal Design of an Alternative Boiling Water Reactor Spent Nuclear Fuel Package for the Proposed Yucca Mountain Repository", Nuclear Technology (in print to appear in the July'2006 issue).