Summary of the Interim Report of Waste Package Materials Performance Peer Review Panel

Presented by

Joe H. Payer
Chairman, Peer Panel on Waste Package Materials Performance

Presented to

U.S. Nuclear Waste Technical Review Board

Fall 2001Board Meeting
September 10, 2001
Las Vegas, NV

Peer Review of Waste Package Materials Performance

The U.S. Department of Energy (DOE) has requested Bechtel SAIC Company, LLC (BSC) to conduct a consensus peer review of the waste package materials performance.

Prediction of the long-term performance of waste package materials

- Review the current technical basis for prediction
- Assess the planned experimental and modeling program
- Focus on corrosion performance of Alloy 22 waste package and Ti Gr 7 drip shield materials

Panel recommendations will be provided to the DOE

Peer Review Panel Members

Chairperson - Dr. Joe H. Payer, Case Western Reserve University
Dr. John A. Beavers, CC Technologies Laboratories, Inc.
Dr. Thomas M. Devine, Jr., University of California, Berkeley
Dr. Gerald S. Frankel, Ohio State University
Dr. Russell H. Jones, Battelle-Northwest
Dr. Robert G. Kelly, University of Virginia
Dr. Ronald M. Latanision, Massachusetts Institute of Technology

Panel member expertise in the materials science and engineering, corrosion, and prediction of materials performance

Subject Matter Experts:

- *~15 U.S. & International to assist the Panel*
- *Expertise includes passivity, localized corrosion, geochemistry, hydrogeology, physical metallurgy, welding, oxidation*

Noteworthy Technical Exchanges

Waste Package Materials Performance Peer Review Kickoff Meeting, Las Vegas, Nevada, May 23, 2001

International Workshop on Long-Term Extrapolation of Passive Behavior, conducted by the U.S. Nuclear Waste Technical Review Board, Arlington, Virginia, July 19-20, 2001

Panel Sub-Group Meeting on Localized Corrosion, conducted by the Panel, Arlington, Virginia, July 21, 2001

State of Nevada and Nuclear Regulatory Commission Presentations to the Panel, conducted by the Panel, Cleveland, Ohio, July 24, 2001

Panel Sub-Group on Waste Package Fabrication, conducted by the Panel, Livermore, California, August 10, 2001

Review Schedule

February-April 2001

Select Peer Review Panel and Subject Matter Experts, Develop Peer Review Plan including specific objectives

May 2001

Peer Review Introductory Meeting (May 23) to include presentations by the Project;

Open meeting on May 23 in Las Vegas, NV

June-August 2001

Conduct Peer Review

September 2001

September 4, 2001 Interim Report submitted to DOE/Contractor;

Open meeting on September 25 in Las Vegas, NV

October-January 2001

Complete Peer Review

February 2002

Issue Final Report and present Final Report Findings to DOE/Contractor

Open meeting in Las Vegas, NV

March/April 2002

Prepare and issue Peer Review Evaluation Report (Contractor)

Preliminary Findings
General Findings

The Panel has not found a technical basis for concluding that the waste package materials being considered are unsuitable for long-term containment

- Significant technical issues remain to be settled
- Likelihood is great that uncertainty about long-term performance can be substantially reduced through further experiments and analysis
- Much experimental and analytical work to support performance assessments is underway, a large amount of necessary work is included in Project plans and remains to be completed

Preliminary Findings
General Findings

The effective control of corrosion of waste package materials is essential to the long-term performance of a Yucca Mountain repository

The Project is taking a sound approach to corrosion control

(a) the determination of the realistic range of aqueous environments that can contact the material surfaces

(b) the use of materials that are resistant to corrosion in those aqueous environments

Nickel-base Alloy 22 and titanium Grade 7 have excellent corrosion resistance over a wide range of aqueous solution compositions and temperature

Preliminary Findings

Potential Degradation Modes and Contributing Factors

Proper identification and control of degradation modes are essential to waste package design

Corrosion is the most significant potential degradation mode

The Panel identified three metallurgical processes that can affect corrosion resistance and mechanical properties

The Panel notes that the design and fabrication details can have a great effect upon corrosion and mechanical behavior

Other degradation modes (mechanical failure and hydrogen embrittlement) and contributing factors (radiation effects, microbiological activity and fabrication issues)

The Panel is reviewing Project plans in these areas for the adequacy of the necessary experimental and analytical work.

Preliminary Findings

Composition of Aqueous Environments

Water composition in Yucca Mountain

Two distinct water types moving through Yucca Mountain

- **Mildly-alkaline, sodium-carbonate waters**
- **Near-neutral, calcium-chloride/sulfate waters**
- **All waters are ensemble of mixed anions**

Project has focused work on evaporative concentration of solutions

- **two general solution compositions described above**
- **solution pH ranging from 6 to 12 or 13**

The Panel finds this treatment consistent with the current state of scientific understanding

Preliminary Findings

Composition of Aqueous Environments

Aqueous environments on metal surfaces

The Panel concludes three conditions describe the metal surfaces subject to corrosion in the proposed repository

(a) moist dust on the metal surface,

(b) scale and deposits on the metal surface,

(c) crevice areas at metal-to-metal contact surfaces

Full immersion of metal surfaces is a highly unlikely condition in the repository

The Panel recommends that the Project undertake a comprehensive experimental and analytical modeling program for all three environmental conditions

The Panel recommends the formation of a task group of technical experts to work on both the experimental determination and analytical modeling of the environment.

Preliminary Findings

Long-Term Behavior of Corrosion Resistant Metals (Passive Metals)

International Workshop on Long-Term Extrapolation of Passive Behavior," conducted by the U.S. Nuclear Waste Technical Review Board, July 2001

The perception of the Peer Panel members who attended this workshop was that passive corrosion rates of alloys such as titanium Grade 7 and Alloy 22 could, in principle, remain low enough for waste packages to survive for thousands of years.

Preliminary Findings

Long-Term Behavior of Corrosion Resistant Metals (Passive Metals)

The Project has concluded that the rates of uniform penetration of the passive alloys are quite low

- The crucial issue is whether these low penetration rates will persist

The Panel has identified changes in the intrinsic nature of the film, changes in the environment, and changes in the alloy itself to be considered

Need additional experiments and analysis to confirm the corrosion resistances over the range of possible environmental conditions

Effect of long-term metallurgical processes on the corrosion behavior of the passive metal needs to be considered

The Panel recommends that a back-up alloy and a comparison alloy be included in the experiments and analysis.

Preliminary Findings
Localized Corrosion

Nickel-base Alloy 22 and titanium Grade 7 are extremely resistant to localized corrosion

- exhibited no evidence of pitting or crevice corrosion after four-year exposures
- Nevertheless, these alloys are susceptible to crevice corrosion under extreme conditions of environment and potential.

The framework used by the Project for the evaluation of resistance to crevice corrosion is appropriate

Panel recommends a more rigorous approach for determination of the critical potentials

Panel recommends that experiments be performed under conditions beyond those thought to pertain to examine margins of safety

Preliminary Findings
Localized Corrosion

Issues to be addressed

- higher temperatures
- propagation and arrest of localized corrosion
- effects of metal surface condition
- environments containing possible oxidizing agents
- Analysis of initiation, propagation and arrest for the three most relevant conditions in contact with metal surfaces
  - moist dust on the metal surface
  - scale and deposits on the metal surface
  - crevices at metal-to-metal contact surfaces

Preliminary Findings
Stress Corrosion Cracking

Research to date shows that nickel base Alloy 22 is highly resistant to stress corrosion cracking in the environments expected in the repository

The mitigation method, experimental approach, and modeling efforts for stress corrosion cracking are consistent with the state-of-the-art

The Panel recommends additional work to address some deficiencies in the current program

The Panel recommends that alternative models for stress corrosion cracking be considered by the Project

- To provide validation and support for the Project approach
- To be an alternative should current models be found deficient

Preliminary Findings
Level of Effort and Organization/Structure

The Panel is concerned that adequate resources will not be allocated to complete the work necessary for evaluating the long-term performance of waste package materials.

- Much of the experimental and analytical work to support performance assessments is complete or underway
- However, a large amount of necessary work is still only included in Project plans and remains to be completed.

The Panel's perception is that a more substantial effort in manpower and resources is required to accomplish the needed work, meet the current schedule, and provide support for targeted decision points.

Preliminary Findings
Level of Effort and Organization/Structure

The Panel recommends the direct, collaborative participation of technical experts in corrosion, materials science, geochemistry and hydrology to determine the realistic range of aqueous environments on waste package surfaces.

The Panel recommends closer integration between the design and fabrication engineers and the corrosion and materials experts working on performance assessment.

Peer Review Plans

The Panel has identified three categories of issues concerning waste package materials performance:

(a) Corrosion Processes

(b) Environment

(c) Other waste package degradation modes and issues

The Panel plans to address the status of these issues and the Project's plans to resolve them.

The Panel will suggest approaches to increase understanding and reduce uncertainty in these areas.