MATERIALS PERFORMANCE THRUST

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Background

The Yucca Mountain site was recommended by the President to be a geological repository for commercial spent nuclear fuel and high-level radioactive waste. The site was then selected by Congress and signed into law by the President. The multi-barrier approach was adopted for assessing and predicting system behavior, including both natural barriers and engineered barriers. A major component of the long-term strategy for safe disposal of nuclear waste is first, to completely isolate the radionuclides in waste packages for long times, and then, to greatly retard the egress and transport of radionuclides from penetrated packages.

The goal of the Materials Performance Thrust program is to further enhance the understanding of the role of engineered barriers in waste isolation. In addition, the thrust will explore technical enhancements and seek to offer improvements in materials cost and reliability.

Opportunities for Performance and Technical Advances

The materials used for isolating waste in the proposed repository are an important component of the overall approach to the design of the repository system. The proposed emplacement drift is shown in Figure 1. Opportunities exist to enhance the understanding of material performance and to probe technical enhancements. These enhancements may include optimizing the performance of waste packages and drip shields for increased reliability and cost effectiveness.

Corrosion is a primary determinant of waste package performance at the proposed Yucca Mountain repository and will control the delay time for radionuclide transport from the waste package. Intact waste packages fully contain and isolate radionuclides at the proposed repository. Corrosion is the most likely degradation process that will determine when packages will be penetrated and the shape, size, and distribution of those penetrations. This thrust program strives for increased scientific understanding, enhanced

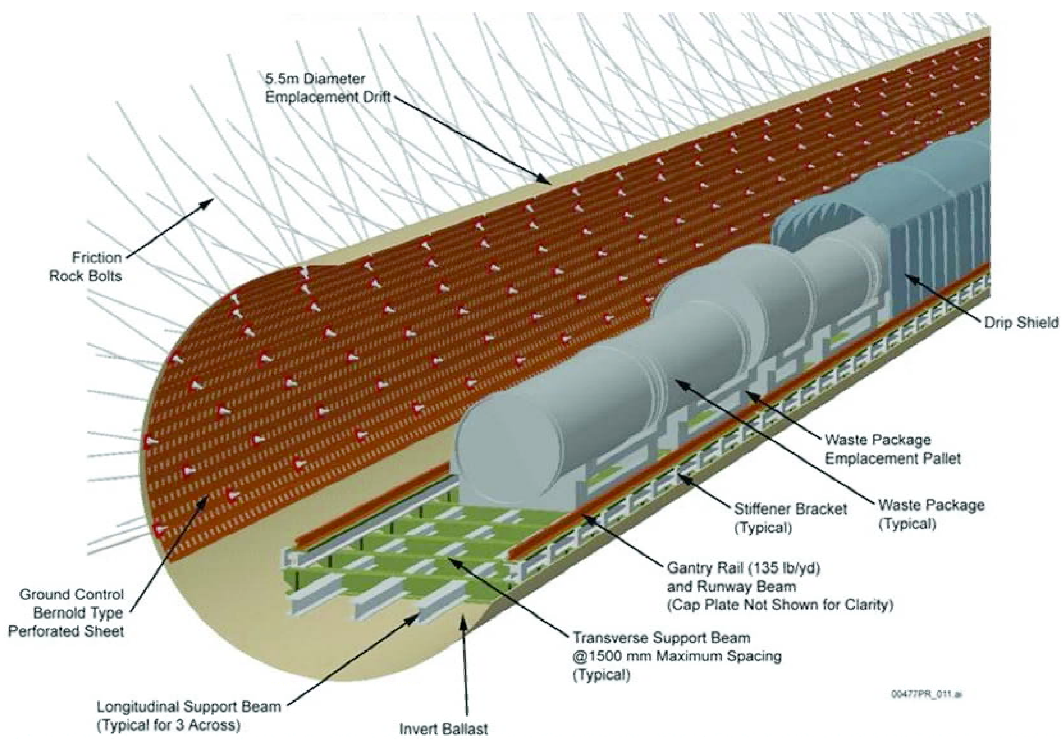


Figure 1. The proposed emplacement drift with waste packages and drip shield

process models, and advanced technologies for long-term corrosion performance.

Thus, corrosion resistance is important to the long-term performance of waste packages. The waste packages are manufactured from highly corrosion-resistant metals, and the surface of these metals is protected by the formation of a self-healing, passive layer. The metals for waste packages and drip shields have excellent corrosion resistance over a wide range of aqueous solution compositions and temperatures. Based upon previous measurements of corrosion rates of passive metals, if the passive film remains stable, the waste packages can remain intact with no penetrations resulting from corrosion for durations of tens of thousands and even hundreds of thousands of years.

Approach

Materials optimization is realized through a coordinated program of targeted, applied research projects. The program comprises directed technical goals and thrusts. A team of leading scientists/engineers from major universities, national laboratories, and other participants is working together to meet the program objectives. This group brings expertise and specialized facilities in important disciplines, including corrosion science, materials science, electrochemistry, physical chemistry, and geochemistry. The team is organized among collaborative technical thrusts focused on important topics:

- Long-term behavior of protective, passive films
- Composition and properties of moisture in contact with metal surfaces
- Rate of penetration and extent of corrosion damage over extremely long times.

Each technical thrust has a set of coordinated projects. As the program evolves, there will be additional technical thrusts, and the collaborative effort will be expanded to include other participants. The Materials Performance Thrust is coordinated with the Yucca Mountain Project through cooperative projects, technical exchanges, and program reviews.

Targeted Technical Thrusts

There are currently three multi-investigator projects within the Materials Performance Thrust. Each of these is a coordinated set of collaborative efforts.

Corrosion of Metal Surfaces Covered with Particulate and Deposits

The waste packages are supported in air, and they will never be fully immersed in water. Rather, the metal surfaces may be covered with dust, particulate, and moisture from the surrounding rock and humidity. This technical thrust examines corrosion in thin moisture films and layers of particulate and deposits. (See pp. 57–72 for an overview and the individual projects.)

Evolution of Corrosion Damage by Localized Corrosion

Understanding of localized corrosion processes, and particularly crevice corrosion, is a high priority. This technical thrust examines the rate of penetration and extent of corrosion damage by factors that determine localized corrosion over extremely long times. (See pp. 73–96 for an overview and the individual projects.)

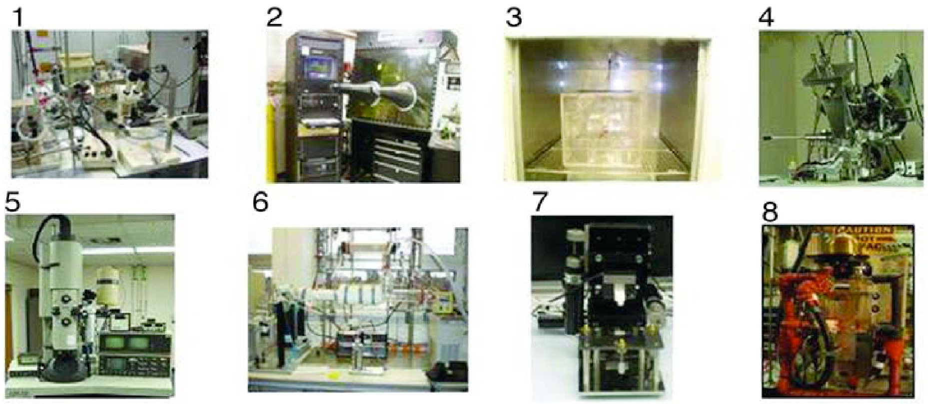
Evolution of Moisture Environment on Metal Surfaces

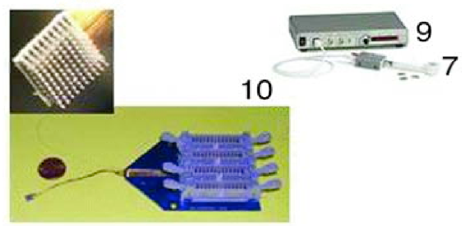
The corrosion performance of a metal is determined by the inherent corrosion resistance of the metal and the corrosivity of the environment to which the metal is exposed. The amount, distribution, and chemical composition of the moisture on waste packages are important. (See pp. 97-115 for an overview and the individual projects.)

In addition to the multi-investigator projects, there are bridging projects that coordinate and integrate process-modeling activities in the Materials Performance Thrust to those in the Natural Barriers Thrust and the Source Term Thrust. The Materials Performance Thrust has been an incubator for work that transitioned to full development projects in the Office of Science and Technology and Internatonal (OST&I) Advanced Technologies Thrust, e.g., advanced welding techniques and high-performance amorphous metal coatings.

Materials Performance Thrust Program Team

A team of experts from universities was formed under a DOE/OST&I Corrosion Cooperative (CorrCoOp), and they work closely with scientists and engineers at several national laboratories and other participants. The CorrCoOp is based at Case Western Reserve University and includes investigators at Arizona State, Ohio State, Pennsylvania State, University of California-Berkeley, University of Minnesota, University of Toronto, University of Western Ontario and University of Virginia. National





1. Kelvin Probe and Scanning Kelvin Probe
2. Laser-directed powder deposition for graded Ni-Cr-Mo compositions
3. Experimental apparatus for thin-layer electrochemical studies of stability of corrosion sites
4. X-ray Photo-Electron Spectrometry
5. 200KV Transmission Electron Microscope
6. Salt Particle Deposition System
7. Scanning Electrochemical Microscope
8. Thermogravimetric Analysis System at LLNL
9. Electrochemical Quartz Crystal Microbalance
10. Microelectrode Array

Figure 2. A sampling of the specialized capabilities and facilities in the Materials Performance Thrust

laboratory participants include Argonne (ANL), Lawrence Livermore (LLNL), Oak Ridge (ORNL), Pacific Northwest (PNNL), and Lawrence Berkeley (LBNL). Other participants include the Atomic Energy of Canada Limited (AECL).

The Director of the Materials Performance Thrust is Dr. Joe H. Payer at Case Western Reserve University. He is supported by an executive committee, a technology/research committee comprised of all program principal investigators, an external review panel, and several international affiliates.

The investigators in the Materials Performance Thrust bring expertise and specialized facilities in important disciplines, including corrosion science, materials science, electrochemistry, physical chemistry, and geochemistry. A sampling of the specialized capabilities and facilities is shown in Figure 2.

Programmatic Milestones

The Materials Performance Thrust was established as the Corrosion Thrust in FY2004 and renamed in FY2005 to reflect a broader materials perspective and technical scope. The thrust was initiated by the identification and grouping of start-up projects from the OST&I project portfolio. Two major program milestones are:

- Corrosion Cooperative established June 1, 2004
- Defense Advanced Research Projects Agency (DARPA)/DOE High Performance Corrosion Resistant Metals project transferred from the Materials Performance Thrust to Advanced Technologies in FY2005.

The former started the major, multi-university effort to address key technical areas for corrosion of waste packages and other engineered structures. The latter illustrates an effective transition from science-based development to engineering-based technology implementation.

During the fiscal year, progress and directions of thrust projects were presented at meetings of the principal investigators. The thrust was critically reviewed and received meritorious evaluations by a thrust External Review Panel and an OST&I Programmatic Evaluation Panel.

Acknowledgments

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