UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE AND MATERIALS
WASHINGTON, D.C. 20555-0001

February 29, 2008

The Honorable Dale E. Klein
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: WASTE PACKAGE AND DRIP SHIELD CORROSION, JUVENILE FAILURE OF WASTE PACKAGES, AND SPENT FUEL DISSOLUTION

Dear Chairman Klein:

At its 182nd meeting on September 18–20, 2007, the Advisory Committee on Nuclear Waste and Materials (ACNW&M or the Committee) heard presentations from the Office of Nuclear Materials Safety and Safeguards, Division of High-Level Waste Repository Safety. The presentations covered issues including the following:

- corrosion of waste package and drip shield materials in a repository environment
- mechanisms for estimating juvenile waste package failures
- dissolution processes for commercial spent nuclear fuel (SNF) in a repository environment

At its 186th meeting on February 12–14, 2008, the Committee received an additional briefing by NRC staff on corrosion of the waste package and SNF dissolution. This briefing was in response to a series of questions supplied by the Committee to the staff. An enclosure, "ACNW&M Questions on Corrosion of the Waste Package and Spent Fuel Dissolution," presents questions from the Committee.

BACKGROUND

Radionuclides from SNF disposed of in the high-level waste repository could reach the accessible environment if they are released from the waste package by either advection or diffusion. The release rate of any radionuclide depends on the condition of the fuel rods (gap and grain boundary inventory), the radionuclide solubility in vadose zone water, and on the flow of water through perforations or cracks in the waste package and any containers inside the waste package. The waste package is partly protected from water damage by the drip shields. The waste package and drip shield together are thus important components of the engineered barrier system that prevents or mitigates release of radionuclides to the accessible environment.

The waste package and drip shield will experience a wide range of environmental conditions in the repository, many of which had been thought to enhance corrosion and destabilize the passive oxide film. Waste package performance relies on a very slow general corrosion rate, which in turn depends on the persistence of a protective passive film. The NRC staff has investigated a number of chemical mechanisms that can result in corrosion of the waste package, and/or the drip shield, including surface corrosion by brine, dust deliquescence corrosion, juvenile failure of the waste package, damage from rockfall, crevice corrosion, microbial corrosion, and hydrogen-induced embrittlement of titanium.

OBSERVATIONS

- The NRC staff's understanding of corrosion mechanisms and their risk significance has evolved considerably since earlier meetings (see transcripts from the 100th, 123rd, 135th, and 151st meetings) with the Committee as a result of laboratory experimentation and a thorough study of corrosion literature. The Committee commends the staff for this effort.

- Topics investigated include general corrosion, seepage groundwater corrosion, dust deliquescence corrosion, stress-corrosion cracking, microbial corrosion, and the effects of fabrication processes. Of these mechanisms, only general surface corrosion appears to be involved in damaging the waste package sufficiently to enable radionuclide release.

- The staff has studied the persistence and stability of the chromium-rich oxide film that can protect the surface of the waste package. Alpha radiation has a limited effect on the film, because there is no significant alpha source in contact with it. The drift environment influences the long-term chemical or structural changes in passive film stability. For example, accumulation of sulfur impurities at the interface may cause breakdown of passive film.

- Dust may form deliquescent brines at elevated temperature, and some deliquescent brines could induce crevice corrosion. Current information from experiments indicates that crevice corrosion by dust deliquescence does not affect waste package performance significantly, because the surface tension of the deliquescent droplets can reduce the amount of brine that contacts a metal surface.

- Stress-corrosion cracking requires carbonate and bicarbonate concentrations that are not expected in the high-level waste repository. Thus, initiation of waste package damage by stress-corrosion cracking appears unlikely.

- Microbially influenced corrosion does not appear to affect performance of the repository.

- Juvenile failures have been conservatively estimated to occur at the start of the postclosure period. There is a lack of direct experimental evidence for juvenile failure in Alloy 22.

- The staff reported that dissolution rates of SNF, unirradiated uranium dioxide (UO_2), and simulated fuel (SIMFUEL) are indistinguishable under similar environmental conditions.

- All release mechanisms studied have inherent uncertainties, which are reflected in input parameters for NRC's Total-System Performance Assessment (TPA) code, version 5.1. The staff reported that the risk significance of corrosion mechanisms has not changed since documented in the NRC's, "Risk Insights Baseline Report," issued 2004.

CONCLUSION

The staff appears to be adequately prepared to review those aspects of the repository license application that deal with corrosion and waste dissolution.

Sincerely,

/RA/

Michael T. Ryan
Chairman

Enclosure:
Questions on Corrosion Waste Package
and Spent Fuel Dissolution

REFERENCE

U.S. Nuclear Regulatory Commission Report, "Risk Insights Baseline Report," 2004, ML040560162.

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ACNW&M Questions on Corrosion of the Waste Package and Spent Fuel Dissolution

The most important considerations in any corrosion discussions with the Advisory Committee on Nuclear Waste and Materials (ACNW&M or the Committee) are (1) what radionuclides (at what activity) are released from the waste package, and (2) how are they released? The following questions are directed towards these considerations:

(Q1) Explain the use of temperature as a time surrogate and discuss the type of results the staff expects.

During the September briefing, the staff mentioned that one of the Center's [Center for Nuclear Waste Regulatory Analyses] reports notes the use of temperature as a time surrogate to try to reproduce what would happen at lower temperatures over longer periods of time by accelerating the process by heating. In addition, the staff indicated that this would be discussed further during the total-system performance assessment presentation, but that presentation did not address the subject. (Refer to ACNW&M transcript, Tuesday, September 18, 2007.)

(Q2) Explain how the corrosion experiments that the Center has been performing since 2003 are going to be used (a) in the License Application review and (b) in the performance assessment.

(Q3) What results have studies of passivation yielded, and how do these results apply to corrosion studies on the waste package?

The response should discuss the experimental work of the U.S. Nuclear Regulatory Commission (NRC) with respect to formation and stability of a passive film and sources of sulfur in the repository that would enhance chemical breakdown of a passive film. Note that alpha bombardment can alter the passive oxide film and may produce localized destruction of the film.

(Q4) Why do studies continue on dust deliquescence, especially since it has no impact? Is the staff assuming that the water will actually be more likely to come in contact with the waste package than with the dust? Furthermore, discuss the experimental evidence that crevice corrosion by dust deliquescence does not affect waste package performance.

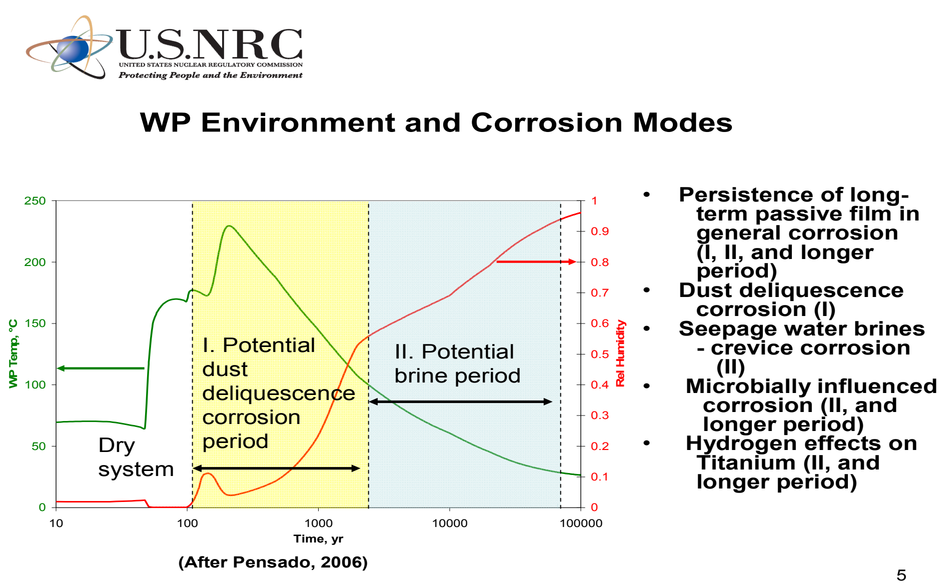
The Nuclear Waste Technical Review Board (NWTRB) has questioned the stifling of crevice corrosion. The response should consider the relevance of the statement. Note that current information from Center experiments indicates that crevice corrosion by dust deliquescence does not affect waste package performance significantly.

The staff response in September was not clear. The transcript from the meeting stated the following:

> Actually, that's a very good point. Yes. Actually, the deliquescence period will continue to this area, too. However, the dominant corrosion failure is from seepage water. That's why we made distinction. You are absolutely right, this will go on continuously here, but it will be dominated by seepage water. Again, here, yes, the deliquescence—you could assume several different assumption of capillary holding of water, either dust or on to the metals.
>
> (Refer to ACNW&M transcript, Tuesday, September 18, 2007.)

(Q5) What is the role of brine? What rate of water flow would be needed to get to the brine period?

The NRC has done much work on the formation of humidity deliquescence and corrosion induced by deliquescence on the waste package surface. The graph below shows two regions of potential corrosion, the dust deliquescence period and the brine period. However, a concentrated solution deliquescing on the surface (the dust deliquescence period) will have a high surface tension and thus only minimal contact with the surface, while a dilute solution (the brine period) that can spread over the surface will be minimally corrosive. It would appear that there would be little corrosion during either period.



(Q6) Defend the statement made by the staff during the September 2007 meeting, "Dust may form brines for deliquescence at elevated temperature and some deliquescence brines can induce general or crevice corrosion."

Note that concentrated brines have high surface tension and stick to the dust, and dilute brines can spread over the surface and are dilute. Hence, corrosion cannot be initiated with either one.

(Q7) What, if any, is the role of stress-corrosion cracking? How does experimental work support this?

The initiation of stress-corrosion cracking of Alloy 22 has been observed only in tests using either cyclic loading or constant straining with high applied potentials (Andresen, et al., 2004; King, et al., 2002). No stress-corrosion cracking of Alloy 22 has been observed for constant deflection conditions in simulated groundwater under acidic and alkaline conditions (Fix, et al., 2004). The U.S. Department of Energy indicated that the drip shield would be emplaced in a stress-mitigated condition.

(Q8) Explain the chemical mechanism for waste package destruction. How is this mechanism initiated? What conditions must be maintained for this mechanism to function? What is the degradation rate for this mechanism?

(Q9) What are the sources of nitrates in the repository? Explain how this has been confirmed.

Studies done by the Electric Power Research Institute appear to show that nitrate solutions inhibit localized corrosion.

(Q10) Compare dissolution rates for low-burnup and high-burnup fuel.

Dissolution studies need to gather data on high-burnup fuel characteristics (i.e., excess hydrides, oxides and fission products, and oxidation of high-burnup fuel).

(Q11) Explain why the results from the testing of SIMFUEL are acceptable to the staff.

The Center still bases its conclusions on experiments done with simulated fuel doped with stable isotopes of important fission products like cesium and strontium. Simulated fuel behaves differently from spent nuclear fuel primarily because the dopants are not bound to the uranium oxide in the same way that fission products are bound. Moreover, the radiation damage done by alpha emissions from actinides in spent fuel is not duplicated in simulated fuel.

(Q12) How does irradiated (spent) fuel behave under repository conditions and over long periods of time? How stable is the cladding? What is the physical degradation rate of irradiated fuel in the intact waste package? What is the role of hydriding in fuel degradation?

The response should consider that the waste package has undergone some corrosion and high-burnup fuel effects.

(Q13) Please provide the risk insights regarding how any new thinking on corrosion influences the release of radioactive material from waste packages over time with availability for transport into the near-field environment.