UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

February 5, 1988

Mr. Charles Peterson
Technical Review Branch
Division of High-Level Waste Management
Office of Nuclear Materials Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Peterson:

Enclosed are NNWSI CDSCP Point Papers for the Yucca Mountain CDSCP. Also enclosed is one floppy disk in DisplayWrite 3 format, which was requested. If you have any questions, please give me a call.

Sincerely,

Charles G. Interrante

Charles G. Interrante
Program Manager
Corrosion Group
Metallurgy Division

Enclosures (2)

NNWSI CDSCP Point Paper for the Yucca Mountain CDSCP

Section 7.4.5.6 Corrosion Model

Comment

Corrosion models should be specific and/or be adaptable to given metals, environmental conditions, and forms of corrosion.

Basis

- The electrode potential of a metal or a phase within an alloy and the repository environment will control initiation or absence of corrosion. Electrode potentials should be known for varying conditions and times of exposure.

- Changes in water chemistry such as pH and/or ionic content will affect the electrode potential of the exposed metal.

- Surface film formation on a given metal as related to composition, electrode potential and corrosion rate must be established.

- Localized stresses, brittle phases, precipitates, different phases and other microstructural variations will result in variations in electrode potential and corrosion processes.

- Corrosion processes expected should be correlated with the material and environment.

Recommendations

- Use standard testing methods to determine and verify corrosion behavior of candidate repository materials in repository environments.

- Measure electrode potentials associated with given corrosion reactions in the repository environment.

- Set up corrosion data base for each material, environment, temperature and condition.

- Set up corrosion data base for previously determined corrosion data that will be used as a basis for projecting corrosion rates or behavior. (Note: There is a lot of scatter in some corrosion data, and this must be dealt with for modeling or predicting.)

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Section 8.3.4.2.1.3 Composition of Vadose Water from the Waste Package Environment

Comment

Evaporation of vadose water will be responsible for salt transport to the canister area during the period in which the temperature exceeds about 95°C. The composition of vadose water may differ from the reference J-13 groundwater.

Basis

- Corrosion of the canister and dissolution of the waste form may be strongly dependent on groundwater chemistry.

Recommendations

- Theoretical models for comparison of vadose water composition should be described.
- Criteria indicating "contaminated water" should be explained.
- Plans for characterization of corrosivity of the vadose water in relation to the candidate canister material must be made.

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Section 8.3.5.9.1 Information Need 1.4.1: Waste Package Design Features that Affect the Performance of the Container.

Comment

There is no description of the development and use of standardized test methods which have undergone peer review.

Basis

- These test methods are needed for determining the stability and durability of the nuclear waste and the waste package materials.
- The tests must be acceptable in terms of reliability and reproducibility.

Recommendations

- Make use of the Materials Characterization Center (MCC), which was established by the DOE in 1980, to ensure that qualified materials data are available on nuclear waste and waste package materials. Meeting this goal must include development of acceptable standardized test methods.
- Use MCC test method development and approval procedures as a first step in obtaining acceptable compliance data.
- The site characterization plan should contain a section describing test method development and test method approval, and data reliability, precision and accuracy.

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Section 8.3.5.9.1.1.2 Microstructural Characterization

Comment

Metallographic and microscopic characterization techniques given in this section for copper, copper-based alloys, and austenitic stainless steels are inadequate.

Basis

- Chemical etchants are selected to show a specific feature of a microstructure, but may not show other critical characteristics.

- Some microstructures cannot be observed using conventional metallographic techniques.

- Grain boundary structure, precipitate formation, and dislocation structures affect material properties and stability, and these features should be viewed at high magnifications of transmission electron microscopy.

- Chemical analysis, x-ray analysis, hardness measurements and other techniques would be needed to analyze for oxygen, hydrogen, or other elemental diffusion into metals.

Recommendations

- Establish standard procedures for studying microstructures of materials being considered for use in nuclear waste storage.

- Establish necessary specific methods for characterizing microstructures of a given material.

- Methods should be specified for the material and microstructural considerations in question.

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Section 8.3.5.9.1.1.2 Phase stability in austenitic stainless steels

Comment

Microstructures of austenitic stainless steels are unstable in terms of transformation to martensite, precipitation of sigma or other embrittling phases and sensitization, and data are not available to show effects of prolonged exposure to 100 to 400°C temperatures expected in the repository.

Basis

- Small amounts of martensite increase the steel's susceptibility to stress corrosion cracking.

- Embrittling phases provide initiation sites for cracking and increase susceptibility to cracking.

- Sensitization or carbide formation may be enhanced by initial high temperatures and by extended elevated temperatures of the repository. Beneficial effects of carbide forming alloying elements such as titanium and of specified cooling rates during manufacture could be negated by the extended time at temperature after emplacement.

- Phase precipitation causes chemical changes in the microstructure which will result in decreased resistance to localized corrosion such as pitting and stress corrosion cracking.

Recommendations

- The microstructure and associated properties should be established to be stable in given repository conditions before selecting the material for use in the repository. Any metastability should be characterized and demonstrated to not adversely affect predicted performance.

- Data should be collected under simulated repository conditions to show microstructural changes which will and will not occur.

- Effects on sensitization of alloy composition and time at repository temperatures should be studied.

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Section 8.3.5.9.1.1.4 Subactivity 1.4.11.4. State of Stress in the Container

Comment

The analyses of the state of stress at various locations should include analyses of fabrication and handling flaws which will not be detected by non-destructive evaluation (NDE) and inspection procedures.

Basis

- This section states that changes in the state of stress with time and temperature will be evaluated at a number of locations, but it does not specifically state that fabrication and handling flaws are considered in these analysis.

- Pores, inclusions, stringers, etc. can occur during fabrication of the container and the presence of these can alter the stress state.

- Mishandling of the container can result in alterations in the residual stress pattern and the size and shape of surface flaws.

Recommendations

- The evaluation should take into account fabrication and handling flaws, and should identify limiting flaw sizes for different geometries.

- The limiting flaw sizes and geometries should then be used as design parameters for the development of fabrication procedures and the establishment of non-destructive testing techniques and practices to be used at the site.

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Section 8.3.5.9.1.1.4 Subactivity 1.4.11.4. State of Stress in the Container

Comment

The plan should take into account temporal changes in the state of stress due to corrosion of the container.

Basis

- This section states that changes in the state of stress with time and temperature will be evaluated at a number of locations, but it does not specifically state that corrosion damage is included in this evaluation.

- Wall thinning due to corrosion processes with alter the stress state.

- If localized corrosion (pitting, crevice corrosion, etc.) occurs, it will result in the formation and growth of flaws which act as stress concentrators.

Recommendations

- Analysis of the state of stress at various locations in the container and changes in the state of stress with time should account for the influence of corrosion as well as temperature.

- Corrosion processes can alter the geometry of the wall by reducing the wall thickness and by promoting the formation and growth of stress concentrating flaws.

- The probability of formation of stress concentrating flaws and the expected rate of growth of these flaws should be accounted for in the analyses.

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Section 8.3.5.9.1.1.5 Weld Inspection

Comment

Metallurgical characterization of prototype welds should be made to characterize microstructures and chemistry and to determinate their effects on weld integrity.

Basis

- Welds are areas of chemical inhomogeneity, and effects of this inhomogeneity under repository conditions should be established.
- Welds of austenitic stainless steels are areas subject to sensitization that may lead to failure.
- Weld solidification shrinkage can result in localized increases in stress that can promote stress corrosion cracking and other cracking.
- Weldments have the potential for contamination and local segregation, either of which may promote premature failure.
- Welded areas are potential sites for galvanic corrosion and localized corrosion.

Recommendations

- Establish, for each material considered for repository storage, the metallurgical and microstructural properties which result after welding.
- Conduct studies, of the metallurgical aspects of weldments, that involve exposure of weldments to simulated repository conditions.
- Evaluate data in terms of long term stability and durability.
- Conduct tests to determine effects of welded microstructures and weldment chemistry on corrosion behavior.
- Effects of composition, welding conditions and repository environment should be established.

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Section 8.3.5.9.2.2.1 Assessment of Degradation Modes Affecting Candidate Copper-Based Container Materials

Comment

The scientific basis for degradation modes of copper-base alloys in the CDSCP is not in agreement with scientific literature. This causes concern that future plans may be improperly drawn.

Basis

- Only T-SCC (trangranular stress corrosion cracking) is being considered. However, I-SCC (intergranular SCC) is known to occur for many copper-base alloys, in particular α-brass in the presence of an oxide film, in aqueous NH_3 solutions.

- The role of NH_3 in the electrolyte is assumed to be that of dissolving a protective film. However, T-SCC in pure copper, for instance, requires the presence of a film.

- Since T-SCC in some copper-base alloys has been observed in conditions where copper was not being dissolved, the existence for critical electrical potentials for SCC prevention seems rather doubtful.

- There is no convincing evidence that selective leaching (dealloying) occurs exclusively through a dissolution-precipitation mechanism

Recommendations

- The section (p. 59-79) should be rewritten so as to reflect a better understanding of the scientific literature.

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Section 8.3.5.9.2.2 Degradation Modes Affecting Candidate Copper-Based Container Materials

Comment

There is no indication of the reasons for choosing three specific copper-base alloys as candidate container materials.

Basis

- 3 materials CDA 102, CDA 613, and CDA 715 are going to be tested
- Other copper-based alloys could perform as well or better than the three listed.
- Except for these 3 materials, no tests, not even scoping tests, have been performed on other potential, or candidate copper-base alloys.

Recommendations

- A program for preliminary testing of other copper-base alloys should be initiated, and
- A more detailed and convincing argument should be made to justify the selection of certain copper-base alloys as candidate materials.

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Section 8.3.5.9.2.3.2 Subactivities 1.4.2.3.2. - 1.4.2.3.9. Laboratory Test Plan for Austenitic Materials

Comment

The experimental approach for each possible degradation mode should be designed and evaluated prior to testing. How will "more severe" environments be identified and proven to be "more severe" for a given failure mode?

Basis

- The design of an experiment can determine the outcome. Therefore, it is important that each experiment be thoroughly evaluated as to its appropriateness to test a possible failure mode or to yield information for use in a given model.

- Various investigators will disagree as to the value of experimental designs, and their differences need to be considered and then resolved or accommodated.

- The relative severities of environments can be difficult to evaluate and quantify. Proving that a given environment is "more severe" may become difficult.

Recommendations

- A procedure should be established to evaluate the appropriateness, so as to establish whether it can be used in (1) evaluation of a possible failure mode, or (2) providing information to be used in a model.

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Section 8.3.5.9.2.3.2 Subactivities 1.4.2.3.2. - 1.4.2.3.9. Laboratory Test Plan for Austenitic Materials

Comment

The possibility that the container may come into contact with dissimilar metals is not addressed in this section.

Basis

- The container may come into contact with various alloys in the repository (spacers and bare plates, etc.) or with the fuel rods inside the container.

Recommendations

- The possibility of galvanic coupling should be identified as an area of concern.

- Potential couples and procedures to avoid galvanic coupling should be identified.

- Where galvanic coupling cannot be avoided, experimental and modeling programs should be established to address this possibility and the expected results of the various conceivable couplings.

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Section 8.3.5.9.2.3.2 Subactivities 1.4.2.3.2. - 1.4.2.3.9. Laboratory Test Plan for Austenitic Materials

Comment

The effects, on the corrosion behavior of the containers, that may result from any metallurgical changes associated with fabrication in large sections is not identified as a specific topic of a test program.

Basis

- Metallurgical conditions associated with large sections can differ considerably from those of small laboratory samples. As a result, the corrosion behavior can be considerably different.
- The size of the section and the welding procedures govern metallurgical conditions and, thus, they alter the corrosion behavior.
- Other fabrication processes and procedures (such as shot peenig [1]) may alter the surface and metallurgical condition of the container and thereby alter the corrosion behavior of the container.

Recommendations

- The impact of fabrication procedures on the corrosion behavior of full size containers should be evaluated.

References

- CDSCP Section 8.3.5.9.1.1.4 State of Stress in the Container

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Section 8.3.5.9.3.2.1 Subactivities 1.4.3.2.1 Metallurgical Aging and Phase Transformations

Comment

The resistance of an alloy to corrosion, intergranular corrosion, and stress-corrosion cracking is a function of the combined effects of radiation, temperature, stress, and time on the metallurgical stability of the alloy

Basis

- Changes in the metallurgical condition of austenitic materials can have dramatic effects on the resistance of these materials to degradation by chemical as well as mechanical processes.

Recommendations

- This section should address the effect of metastability of austenitic materials on the resistance of these materials to degradation by chemical (corrosion), and combined chemical and mechanical (stress-corrosion) processes, as well as purely mechanical processes.

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Section 8.3.5.10 Corrosion of Zircaloy

Comment

Corrosion of Zircaloy depends on the repository environment, composition and metallurgical condition, and the previous history in service and storage.

Basis

- The type of reactor exposure, the composition of the residue that collects on the fuel rods, and the manner in which the fuel rods were cleaned will affect corrosion of Zircaloy.
- Residue deposits that contain copper have especially destructive effects on Zircaloy's protective oxide film, and local corrosion or pitting may result.
- Zircaloy, in reactor service, is subject to stress corrosion cracking from the fuel side of the cladding due to fission products such as iodides.
- Liquid metal embrittlement has been reported for Zircaloy in contact with molten cesium, liquid sodium or cadmium.
- Examples of hydrogen embrittlement failures in Zircaloy cladding have been reported.
- Zircaloy is not immune to pitting corrosion and pitting can occur in hydrochloric acid which contains ferric or cupric ions and in the presence of all the halogens either in liquid or gaseous form.

Recommendations

- Conduct corrosion studies to measure electrode potentials for Zircaloy in the repository environment, and to determine effects of varying temperature, ions present, water and oxygen.
- Use standardized tests to determine the susceptibility of Zircaloy to stress corrosion cracking in the repository environment.
- Study structural formation of the oxide film, and determine effects of wetting, drying and other conditions of the repository.
- Use standard tests to determine susceptibility to hydrogen embrittlement and cracking.
- Conduct standard tests to determine pitting susceptibility of Zircaloy.
- Study effects of welding on the corrosion behavior of Zircaloy.

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Section 8.3.5.10 Issue Resolution Strategy for Issue 1.5. Will the Waste Package and Repository Engineered Barrier Systems Meet the Performance Objective for Radionuclide Release Rates as Required by 10 CFR 60.113?

Comment

The leaching of spent fuel may be an important factor in meeting the performance objective for radionuclide release.

Basis

- The solubility or leachability of spent fuel will be enhanced if it is oxidized in the repository environment.

Recommendations

- Define an alternate strategy for prediction of spent fuel oxidation and dissolution.

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