UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
[formerly National Bureau of Standards]
Gaithersburg, Maryland 20899

May 17, 1989

Mr. Charles H. Peterson
Engineering 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:

As required under Task 1 of the current Statement of Work for FIN A-4171-9, enclosed are outlines of interpretive papers on selected topics. The three attached outlines cover the following subjects:

1. Mechanisms of Environmental Induced Fracture and their Relevance to HLW Containers in the Tuff Environment

2. Mechanisms of Internal Corrosion of Spent Fuel Rods

3. Mechanisms of Localized Aqueous Corrosion of Copper and its Alloys

Every effort will be made to furnish the first drafts to the NRC by June 30, 1989 as requested.

Sincerely,
Charles G. Interrante

Charles G. Interrante
Program Manager
Corrosion Group
Metallurgy Division

Enclosures

cc: R. Ricker
U. Bertocci
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WM-11
NH14
A4171

Anna Fraker

OUTLINE

MECHANISMS OF INTERNAL CORROSION OF SPENT FUEL RODS

I. Introduction

A. Most failures of Zircaloy nuclear fuel cladding until now have been internal resulted from mechanical, chemical and nuclear reactions.
B. Considerations of spent fuel cladding for radionuclide containment may be included in determinations to assess whether the engineered barrier will meet release requirements.

II. Purpose

This paper will provide a review of information on mechanisms of previous failures, and it is intended to be useful for assessing corrosion and making long term durability predictions of Zircaloy cladding in a tuff repository.

III. Scope

This paper includes information on radionuclide containment requirements, previous cladding failures, causes of the failures, corrective measures taken by the nuclear industry and discussions of potential modes of internal failures that should be considered for long term repository storage.

IV. Body of the report

A. Materials
1. Metallurgical aspects of Zircaloy-2 and Zircaloy-4
2. Stainless steel nuclear fuel cladding

B. Environments
1. Environments of previous failures
2. Anticipated repository environments

C. Failure modes and mechanisms
1. Cladding collapse
2. Pellet cladding interactions
3. Hydride formation
4. Fretting corrosion

D. Effects on corrosion
1. Temperature
2. Ions
3. Hydrogen
4. Stress
5. Oxidation, passivation

V. Summary
VI. Conclusions
VII. References

Ugo Bertocci

OUTLINE OF THE INTERPRETIVE PAPER MECHANISMS OF LOCALIZED AQUEOUS CORROSION OF COPPER AND ITS ALLOYS

Introduction

Copper-base metals have been proposed as alternative materials for the high-level waste containers at Yucca Mountain. Although it is reasonable to assume that these materials will perform satisfactorily, there are major uncertainties as to the environment that they will have to withstand, as well as to their behavior in certain circumstances. In particular, the possibility that copper-base containers may fail because of some form of localized attack, mainly stress corrosion cracking (SCC), cannot be easily discounted.

An additional cause of concern is that, in discussing the mechanisms and conditions leading to this kind of failure, the DoE Site Characterization Plan seems to be significantly at variance with the prevailing opinions among experts in the field.

Purpose

It seems appropriate, therefore, to undertake a review of what is currently known about localized corrosion of copper and its alloys, with particular emphasis on stress corrosion cracking, in order to put the problems into sharper focus, taking into account the Yucça Mountain repository environment and its uncertainties.

Scope

The environmental conditions in the repository, because of the heat generated by radioactive decay, are expected to lead to dry oxidation of the metal containers for very long times. However, aqueous corrosion is a significant possibility, particularly if the conditions deviate somewhat from those anticipated. The present paper will not concern itself with dry oxidation, but will consider aqueous corrosion, whether due to liquid water percolating through the rock or moisture condensing on the metal surface.

Body of the report

The proposed interpretive paper will be a review of localized corrosion in copper and copper alloys. The topics to be covered are:

A) Pitting
B) Stress Corrosion Cracking
C) Intergranular Attack
D) Crevice Corrosion

It is suggested that topic B will be the first to be addressed. A tentative scheme of the organization of the paper is as follows:

1) A description of the environments in which SCC has been observed
2) A list of the mechanisms which have been advanced for its explanation
3) A discussion of their relevance for the repository conditions.

Although the work will concentrate on the three Cu-base materials which have been selected by DoE, namely pure copper, Aluminum bronze and Copper-Nickel alloys, other materials, such as brass, will be included in the paper, since a great deal of the mechanistic work published has been carried out on brass.

This review will allow an assessment of the likelihood of container failure by SCC at the repository on the basis of what is already known, and will contribute to determining which information and data must be obtained before Cu-base alloys can be accepted or rejected as container material for high level waste.

Summary

Conclusions

References

Outline for a Paper to be Entitled

"Mechanisms of Environmental Induced Fracture and their Relevance to HLW Containers in the Tuff Environment"

by

R.E. Ricker

I. Introduction

A. Purpose

B. Scope

C. What is Environmental Induced Fracture (EIF)

1. SCC
2. HE
3. LME
4. CF

D. What causes EIF

1. Environmental Factors
2. Stress Factors
   - what kinds of stress
   - how much stress
   - sources of stress in HLW containers

E. Quantifications

Since the mechanism of SCC is not known and since we don't even know if there is only one common mechanism or a host of different mechanisms, we have to discuss and evaluate what is known based on the types of experiments that have been conducted. As a result, we must discuss the techniques used to evaluate and quantify environmental induced fractures.

II. Environments Known to Cause SCC of Candidate Stainless Steels

A. Halide Containing Environments

B. Other types of Environments

C. Tuff Environment
- Review environmental species available in Tuff
- JI3 Concentration
- Concentrated Solns.
- Temperature Effects

III. Mechanism(s) of EIF

The mechanisms which have been proposed to explain EIF will be reviewed and evaluated with respect to their possibility of occurring in the Tuff environment. Only these mechanism which are still considered to be viable possibilities by the EIF research community will be discussed.

IV. Avoiding SCC

A review of the techniques that can be used to avoid SCC will be presented.

A. Stress Control

B. Control of Environment

C. Modeling
1. Empirical modeling
2. Mechanistic modeling

V. Summary

VI. Conclusions

VII. References