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MEMORANDUM FOR: Michael J. Bell, Chief
High-Level Waste Licensing
Management Branch
Division of Waste Management

FROM: Kien C. Chang
High-Level Waste Licensing
Management Branch
Division of Waste Management

SUBJECT: REPORT OF WASTE PACKAGE TEAM MEETING

Attendees: F. R. Cook, NRC
E. A. Wick, NRC
K. C. Chang, NRC
M. McNeil, NRC
M. Siegel, SLA
K. Swyler, BNL
R. Talbot, GAI

Date: September 13-14, 1982

Purpose: To prepare waste package portion of Site Characterization Analysis and three appendices

Summary:

September 13, 9:00 AM - 5:00

1. The NRC's BWIP Team has previously agreed to the use of a common format to present all BWIP SCR issues. The BWIP Team has also assigned Waste Package Team the write-up of three issues on waste form/waste package. A copy of each of the issue format (enclosure 1) and the three issues (enclosure 2) were given to each attendee.

2. The constraints imposed by the format and the three issues were discussed in the meeting. In order to address all areas related to

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the waste form/waste package portion of the SCR, many specific sub-issues must be brought out and examined in the site issue analysis.

3. An outline for the write-up of issue number 1 of Enclosure 2 was discussed. This outline is presented in Enclosure 3 and was used by the attendees to prepare similar outlines for the second and third issues.

September 14, 8:30 AM - 5:00 PM

4. The team was divided into two groups to work on issues number 2 and number 3. Outlines for these issues are presented in Enclosures 4 and 5.

5. An open discussion was held to identify the interactions of 19 sub-issues generated in the outlines. Each sub-issue was identified to be part of the three general issues of Enclosure 2. These interactions are presented in the form of a chart in Enclosure 6. This chart will be used by F. R. Cook (Waste Package Team Coordinator) to report to NRC's BWIP Team for further development in the waste package issue write-up for SCA.

6. Team members will be notified by F. R. Cook on future write-up assignments.

ORIGINAL SIGNED BY

Kien C. Chang
High-Level Waste Licensing
Management Branch
Division of Waste Management

Enclosures:
As stated

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Enclosure 1

SITE ISSUE ANALYSIS

(1) Name of the site:

(2) Statement of the issue (in form of a question):

(3) Importance of the issue to repository performance:

(4) Portions of 10 CFR 60 that are directly connected to the issue:

(5) Summary of the present state of knowledge, with analysis of uncertainties:

(6) Summary of the information needed to close out the issue by the time of construction authorization application:

Enclosure 2

2. Waste Form/Waste Package

What is the relative importance of waste form-leach rates versus solubility (steady-state) of key radionuclides in the near-field environment for controlling release?

*Does the near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance?

*How can very near-field waste/barrier/rock-material interaction data as measured experimentally, be extrapolated over time to reasonably assure overall waste package and repository performance meets regulatory criteria?

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*This issue embraces responsibilities of both team 2 and team 4.

Enclosure 3

What is the relative importance of waste form - leach rates vs. solubility (steady-state) of key radionuclides in the near-field environment for controlling release?

1. Name of the Site.

   Hanford, Washington (BWIP)

2. Statement of the Issue.

   a. Economics
   b. Leach vs. solubility/flow
   c. Variable flow conditions
   d. Particles or colloidal transport in parallel with flow conditions
   e. Oxygen consumption rate

3. Importance of the Issue.

   a. Economics
   b. Ease of data collection
   c. Less dependence on waste form degradation process (except particle or colloid)
   d. Reliability of overall system

4. Applicable Part of 10 CFR 60.

The specific parts of 10 CFR 60 will be stated including the requirement of 1000 year life for the container and 10^{-5} release rate from 1000 year to 10,000 years.

5. Summary of Present State of Knowledge, with Analysis of Uncertainties.

   a. The experimental studies of basalt/sea water at high temperatures.

   b. Conditions in engineered system from time 0 to 10^4 year

      (i) Flow hydraulics/thermal, or range of pressure change on boundary and range of velocities.

      (ii) Chemistry, i.e., solubility, Eh, T.

   c. Particles or colloid formation and transport. All the potentials involved in the diffusion effects, particularly temperature gradients.

6. Summary of information needed to close out the issues by the time of construction authorization application.

   a. Knowledge and understanding of the function and interaction of a given system.

      (i) Knowledge to apply accelerated test data to real time.

(ii) A mechanism to extrapolate leach rates and solubilities to obtain bounds on the behavior of real systems, including canister life and controlled release.

b. Data or engineering analysis (info) needed to demonstrate solubility limit of glass.

Mineral assemblage under reasonable expected conditions (flow).

(i) Criteria for extrapolation of accelerated test to long term behavior of system.

(ii) Differences between behaviors of fresh and aged glass (devitrified, radiation damage) in hydrothermal systems.

(iii) Characterization of colloids produced during degradation of glass and formation of metastable secondary minerals.

(iv) Flow condition boundary between leach rate limited and solubility limited release regimes.

(v) Speciation/solubility at elevated temps.

(vi) Radiation effects on the dissolution of waste glass (solubility behavior).

(vii) Long term stability of high temperature secondary phase at ambient conditions.

(viii) Hydrothermal conditions as a function of time, also pH and (O_2 conc or pH).

Separate Issues.

1. Hydrothermal leach rates of glass. Effect of microbial action on leaching (subordinate issue).

2. Oxygen reduction rates.

3. Backfill emplacement - reliability of technology/method.

Enclosure 4

1. Name of the Site.

Hanford, Washington (BWIP)

2. Statement of the Issue.

Does interaction between the waste packages (and its components), the underground facility and the geologic setting compromise the performance of the waste package or the engineered system performance?

Possible Interactions (Issue II)

	Cann	WF	Bentonite	Basalt	Geology
Can		I, II	III	IV	VIII
WF			V	VI	IX
Bentonite				VII	X
Basalt					
Geology					

I. Canister - Waste Glass

A. Release of helium in the metal as a result of the neutron-alpha particle reaction. The helium becomes entrapped in the metal and this causes embrittlement of the metal.

B. Change in corrosion process due to radiolysis of water which produces hydrogen and OH-ions.

C. Volume increase in waste form as a result of radiation.
- radiation induced
- devitrification

D. Glass degradation related to metal-glass interaction.

*E. Plastic deformation and thinning of canister due to hydrostatic pressure.

II. Canister - Spent Fuel

A. Fission gas release after failure of zirconium jackets leading to pressure buildup in container.

B. (A, B, E from I above).

III. Canisters - Bentonite

A. Swelling pressure of bentonite and stress on canister.

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* = secondary concern.

B. Change in corrosion of metal due to presence of bentonite.

C. Ability of bentonite to buffer composition of water w.r.t. corrosion.

D. Contribution of can. to O_2 consumption and creation of anoxic retard. in bentonite

BF = 75% Basalt
25% Bentonite

IV. Canister - Basalt (BF)

A. Oxygen consumption by basalt to reduce oxic corrosion of canister.

B. Microbes related to SO_4^{2-} - $S_2^{=}$ couple in pyrite in basalt.

C. Enhancement of localized corrosion due to presence of particulate basalt.

V. Waste Form - Bentonite

A. Bentonite - illite thermal transformation.

B. Dehydration of bentonite leading to increase of permeability (crack formation).

C. Enhanced leaching of waste glass due to presence of bentonite.

D. Retardation of radionuclides in bentonite.

E. Radiation effects on bentonite properties - gas creation in interlayer water.

F. Filtration of colloids* by bentonite as they leave the waste package.
(*formed by glass degradation).

G. Ability of bentonite to retard radionuclides by adsorbing them.

H. Thermal conductivity of bentonite and effect on temperature field and leach rate/solubility of waste form.

VI. Waste Form - Basalt

A. Rate of leaching of waste form due to presence of basalt/solubility.

1. pH or carbon effects or Eh effects.
2. particulate presence

B. Effect of radiation on O_2 consumption by basalt.

C. Effect of thermal field on O_2 consumption.

D. Effect of basalt on thermal conductivity of backfill and thermal field.

E. Sorption of radionuclides by basalt.

F. Creation of anoxic environment and effects on radionuclide sorption by bentonite.

G. Effect of radiation on sorptive capacity of basalt.

H. Effect of heat on sorptive capacity of basalt.

VII. Bentonite - BF Basalt Interactions

A. Effect of basalt on thermal conductivity of backfill and decrease in temperature (may prevent bent - illite or bent. dehydration from occurring).

B. Reduced cost of backfill due to use of crushed basalt in place of pure bentonite backfill.

C. Homogeneity of basalt-bent. mixture after emplacement and effect on (III, IV, V, VI).

VIII. Geology - Canister

A. Mechanical loading of container.

B. Precondition of water.

C. Flow rate of water and effect on corrosion rate.

D. Creation of potential resource by emplacement of metal.

- magnetic, electr. anomaly
- gravity anomaly

IX. Geology - Waste Form

A. (VIII - B)

B. (VII - C)

C. Effect of basalt thermal conductivity on temeprature of WF and effect on leach rate and solubility.

X. Geology - Backfill

A. (VIII - A)

B. (VII - B)

C. Water flow rate and erosion of bentonite.

XI. WF - Bentonite - Canister

A. Effect of bentonite on thermal field, and corresponding effect on canister corrosion rate.

XII. WF - Basalt - Canister

A. (XI - A)

XIII. WF - Geology - Canister

A. Effect of geology on thermal field and corresponding effect on waste form leach rate and solubility.

XIV. Geology - Bentonite - Can

A. Effect of bentonite on flow rate and corr. effect on corrosion.

B. Ability of bentonite to relieve lithos stress.

XV. WF - Geology - Backfill

A. Effect of geology thermal conduct. on temp. in bentonite and effect on dehyrdation, min. transf. of bentonite.

XVI. Basalt - Basalt/Bentonite - Geology

A. Mechanical stability of BF mixture with respect to "removal" by groundwaters.

Enclosure 5

How can very near field waste/barrier/rock material interaction data, as measured experimentally, be extrapolated over time to reasonably assure overall waste package and repository performance meets regulatory criteria?

1. Name of the Site.

   Hanford, Washington (BWIP)

2. Statement of the Issue.

   a. How do we use short-term data to predict repository behavior in the distant future?

      (i) Rate processes in barrier penetration:
      Corrosion rates
      Transport rates through breached container
      Transport rates through backfill

      (ii) Release from the waste form
      Leach rates
      Solubility

   b. How do we project the conditions under which these rate processes will operate in the future?

3. Importance of the Issue to Repository Performance.

   a. Engineered barriers must retain all radionuclides for 1000 years.

   b. Radionuclide escape in the 10^3-10^4 year period is limited to 10^{-5} of the inventory at 10^3 years.

   Key issue is reliability of the performance assessment, which will involve extrapolations of rate processes. NRC must judge accuracy of extrapolations. The more accurate the bounds are which can be placed on corrosion rates, the less overdesigned the repository must be. Reductions in overdesign can lead to significant reductions in cost.

4. Just cite elements.

5. Summary of Present State of Knowledge.

   See Table 1.

6. Summary of Information Needed to Close Out the Issue.

   See Table 1.

Table 1

Summary of Present State Knowledge

Summary of Information Needed to Closeout the Issue

KNOWLEDGE	STATUS	INFORMATION NEEDED TO CLOSE THE ISSUES
(A) Knowledge of Modification on Materials Properties		
i) Devitrification	i) Moderately extensive data available may be needed in thermal gradient	i) Effects of temperature dependent visocosity and grain size, phases produced
ii) Radiation damage	ii) Some data available. Some support for extrapolation from accelerated tests.	ii) Dose rate effects
iii) Phase separation and segregation of radionuclides	iii) Little known. Maybe important.	iii) Low-temperature diffusion data, especially those associated with grain boundaries.
iv) Transmutations	iv) Little known. Probably not important.	iv) Significance?
v) Water-connected alteration	v) Some data available. Data needed on aged glasses.	v) Morphology of new phases

KNOWLEDGE	STATUS	INFORMATION NEEDED TO CLOSE THE ISSUE
(B) Change in container properties		
i) Chemical interactions with waste froms	i) Important effects are predictable	i) Probably none
ii) Radiation damage	ii) Bounds are predictable	ii) Probably none
iii) Dry interaction with backfill	iii) Probably boundable except possibly for Ti.	iii) Probably none
iv) Hydrogen embrittlement	iv) Probably boundable but experimental data for prediction may not exist	iv) Rates of uptake and effects on fracture properties
v) Mechanical stress effects	v) Predictable	v) Probably none
vi) Mechanical stress due to waste form	vi) Predictable	vi) data may be needed
(C) Change in backfill properties		
i) Hydrothermal and thermal alteration (including dehydration)	i) Short-term stability data are available, not clear how to project long-term stability	i) Long-term low-temperature data and information under wet/dry cycling.

KNOWLEDGE	STATUS	INFORMATION NEEDED TO CLOSE THE ISSUES
ii) Radiation effects	ii) Not a conceptual problem but are lacking	ii) Whether effect is important; rate data; radiation effects on sorption.
iii) Interaction with corrosion products	iii) Data are lacking	iii) Effect of ions from canister. Possibly of colloid formation.
iv) Interaction with leaching products	iv) Data are lacking	iv) Effect of ions from waste form. Possibly of colloid formation
v) Geothermal conductivity	v) Boundable but data lacking	v) Good data on thermal conductivity, especially for backfill undergoing thermal cyclying
vi) Porosity and presence of fissues	vi) no data. Very difficult.	vi) Need the capability for predicting the presence of fissues and theortical analyses capable of accommendation pores and fissues.
(D) Knowledge of Processes Affecting Release Rate		
1) Barrier Penetration		
a) Mechanical failure		
i) H_2 effects	i) Boundable	i) See B-iv
ii) Stress corrosion cracking	ii) No good basis for extrapolation, but most container materials under consideration are not much affected	ii) Results of slow train rate experiments in radiolytic environment

KNOWLEDGE	STATUS	INFORMATION NEEDED TO CLOSE THE ISSUES
iii) Corrosion induced mechanical failure	iii) Depends on predictions of corrosion	iii) Results of corrosion; fracture toughness of containers (e.g., effects of pits as stress-risers)
iv) Weld failures	iv) Difficult to predict	iv) Test on welds, especially for pitting corrosion.
v) Simple crushing	v) Predictable, if stress field in known	v) No data needed
2) Corrosion		
i) Uniform corrosion	i) Boundable. For iron, long-term test data may be usable to give less conservative bound	i) Data on specific container alloys as a function of temperature. Data needed to estimate radiation effects at realistic dose rate and possiblity of occluded cell corrosion associated with oxide layer.
ii) Pitting corrosion	ii) No reasonable theortical basis for extrapolation. very limited data	ii) Data on pitting rates and electrochemical data on incipient pitting in container materials. Radiation effects at realistic dose rates.
iii) Crevice corrosion	iii) No resonable theoretical basis for extrapolation. Very limited data	iii) Data on crevice corrosion rates, especially with radiation effects at realistic dose rates.
iv) Grain boundary corrosion	iv) Predictable, but experimental data lacking except for iron	iv) Data margin boundary corrosion, especially with radiation effects at realistic doses
v) bimetallic (galvanic) effects	v) There are two ways of predicting barrier penetration by corrosion, project by a rate, or	v) Whether there is opportunity for it; if so, data as in (i)-(iv) with E_H offset artificially

KNOWLEDGE	STATUS	INFORMATION NEEDED TO CLOSE THE ISSUE
	assume corrosion is limited by consumptions of hostile species.	
b) <u>Release</u> of radionuclides for waste form		
i) leach rate controlled escape	i) Many data available. Boundable by initial data. Long-term data to develop congruent dissolution bounds not readily available. Effect of spalling uncertain. Little data available on artifically aged waste forms. Total release sensitive to surface/volume ratios, etc.	i) Long-term data to estimate congruent dissolution rates, especially on articially aged waste forms, (s/v ratio, etc).
ii) solubility controlled escape	ii) Very few data available. Theortical basis for extrapolation straight forward.	ii) Dynamical studies on the evolution of "solubility limited" radionuclides concentration i.e. evalution of these with time under conditions of changing T, etc; object to establish intergrated release behavior.

KNOWLEDGE	STATUS	INFORMATION NEEDED TO CLOSE TO ISSUE
c) Transport processes		
i) Rate of escape from breached canisters	i) Boundable.	i) No information needed.
ii) Flow pattern in failed system	ii) Solvable in principle, information needed for solution does not exist.	ii) Flow pattern in failed system; no knowledge information needs, need data on failure mod--
iii) Diffusion through sorptive barrier	iii) Many K_d data available for isolated species on special backfills. K_D measurements not been shown to be usable for prediction.	iii) Demonstration that models have predictive capability in thin layers.
iv) Flow transport through sorptive barrier	iv) Useful data not available.	iv) See (iii) above-little data for systems other than diffusion limited behavior.
v) Flow through channels and cracks	v) Information on channels and cracks not available.	v) Direct tests needed to determine extent of fracture etc. depending both on emplacement tech. and resaturation scenario.

Enclosure 6

Relationship of Sub-Issues to Main Issues

	Waste Form/Waste Package Issues		
Sub-issues	I	II	III
1. What is solubility of radionuclides vs. time in near field?	X	X	X
2. What is solubility of radionuclides vs. temperature in near field?	X	X	X
3. What are the ranges of resistance times of a unit volume of water in contact with a unit areas of W/F?	X		X
4. What is effect of residence times on leach rates?	X		X

Sub-Issues	I	II	III
5. What is the production of particles and colloids which can hold or transport radionuclides vs. time?	X	X	X
6. How do E_h, pH, A_{O2}, T&P change with time in near field?	X		X
7. How do the waste form chemical and crystallographic properties change with time?	X	X	X
8. What are the chemical and physical property changes of container metals?		X	X
9. What are changes in chemical and physical properties of backfill?	X	X	X
10. What are the possible mechanical failure modes for the container?		X	X
11. What are the possible corrosion failiure modes for the container?		X	X

Sub-Issues	I	II	III
12. What are the transport processes and their range of release times in backfill?		X	X
13. What is effect of backfill on leach rate of glass and corrosion rate of container?		X	X
14. What is the radiolytic generation of hydrogen, oxygen and other species due to gamma radiation?	X	X	X
15. What is dependence of the oxygen removal rate upon temp., P, radiolysis, particle size of backfill, groundwater flow rates and composition, time?	X	X	
16. What is resaturation scenario?	X	X	X
17. What is effect of homogeneity and mechanical stability of B/F backfill erosion by groundwater?		X	X

Sub-Issues	I	II	III
18. Creation of potential resource by emplacement of waste.			X
19. Microbial attack on engineered system.			X