See Pocket 6 for encl.

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Type

WM DOCKET CONTROL CENTER

~~WM Record File~~ 102

WM Project 11
Docket No.
PDR ✓
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Distribution:
Stablein
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(Return to WM, 623-SS)

Reply to:
U.S. Nuclear Regulatory Commission
Suite #319
1050 Flamingo Road
Las Vegas, NV 89119

M E M O R A N D U M

DATE: August 1, 1985

FOR: King Stablein, WMRP

FROM: Paul T. Prestholt, Sr. OR-NNWSI

SUBJECT: Documents for your information and review:

1. Lawrence Livermore Ntl Lab Quarterly report ending 9-30-84
2. LLNL Monthly report 9-84
3. LLNL Project Statis report for 10-84
4. LLNL Monthly report 1-85
5. LLNL Monthly report 7-84
6. LLNL Monthly report 8-84

We have kept NO copies of these reports in the LV office.

PTP/brm

enc.

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PDR WASTE
WM-11 PDR

102/85/13

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102 Encl. To memo to [illegible] from Prestholt - 8/1/85

Lawrence Livermore National Laboratory

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4 September 1984
NWM:84/5883C

Donald L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

SUBJECT: August 1984 Montnly Report - LLNL

Attached are LLNL's Project Status Reports for the month of August. A "Project Status Report" has been completed for each WBS.

for Wesley G. Patrick
L. Ramspott
LLNL Technical Project Officer
for NNWSI

Attachment

DXN → JRLaRiv.

(2) File

FILE NO.

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WM-11 PDR

PROJECT STATUS REPORT

10 September 1984
Report Period 1 - 31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2 - WASTE PACKAGE
L. Ballou, P.I.

SUMMARY

A number of long and intermediate-duration interaction experiments between Topopah Spring tuff (Tpt) and J-13 water are continuing, with water samples being collected periodically from these interaction systems according to the experimental plan.

Work continued on a fully three-dimensional model with which the stability of rock blocks adjacent to waste canister emplacement holes in the Yucca Mountain repository can be analyzed.

Initial results from the spent fuel cladding containment tests indicate that uranium is significantly more soluble in J-13 water than in deionized water (possibly due to the formation of carbonate complexes). The electrochemical Zircaloy corrosion scoping experiment (spent fuel cladding wrapped with a strip of stainless steel and partially immersed in J-13 water in contact with crushed Tpt) is continuing according to schedule.

A number of on-going leaching experiments on doped and undoped borosilicate glass formulations are continuing uneventfully according to the respective experimental plans. Electrochemical potential determinations have been used to estimate the effect of a radiation field on the corrosion rate of stainless steel exposed to J-13 water. Results indicate the presence of relatively persistent radiolysis products in solution (such as H_2O_2). Other experimental results suggest that stainless steel is no more susceptible to pitting attack with gamma irradiation then without.

Stress corrosion susceptiblity tests of a number of stainless steels (candidate structural materials for waste package canisters/overpacks) are continuing according to the planned experimental schedule.

Cost estimates are being obtained for spent fuel canister space frames. Also, a structural analysis of a waste canister drop test (horizontal canister dropped 40 inches onto a 6-inch diameter steel post) is being carried out.

Model verification and development continued in support of the waste package system performance analysis code (WAPPA). During the past month, these efforts have focused on review of the thermal submodel, the mechanical submodel, and development of an unsaturated flow model.

Analysis of the results from the high frequency electromagnetic geotomograpny experiment carried out in G-Tunnel (NTS) is continuing.

Wesley Patrick

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1 - 31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.1.L WASTE PACKAGE ENVIRONMENT
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the characterization of the variability in the properties of Topopah Spring tuff (Tpt) in that volume of Yucca Mountain in which a waste repository is to be located. Also included is the study of hydrothermal reactions between Tpt and J-13 water. These reactions provide a baseline for the multi-component testing carried out in WBS 1.2.2 involving waste forms and metals.

The data obtained in this sub-task also will be used to verify and extend the capabilities of EQ3/6. This applications objective supports site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

This sub-task also includes experimental work to determine the rates and mechanisms of dehydration and rehydration of repository near-field rock in response to the thermal field generated by emplaced waste. These data will aid in estimating the water flux past waste packages. Activities related to the stability of borehole openings which are part of this sub-task will aid in determining whether borehole liners will be necessary, and in determining the stresses on waste packages.

ACTIVITIES

A. Yucca Mountain Tuff and Groundwater - Interaction Experiments and Results

The experiments currently in progress in the gold cell rocking autoclaves continued normally. Summary status at the end of August was:

DB12 = G-1 core wafer, J-13 water, 90°C, plan 365 d, currently at day 118

DB13 = G-1 core wafer, J-13 water, 150°C, plan 365 d, currently at day 118

DB14 = G-1 wafer, J-13 water, 90°C, plan 64 d, terminated at day 49

DB15 = G-1 crushed, J-13 water, 90°C, plan 64 d, currently at day 68

The DB14 experiment was terminated prematurely due to error. The technician inadvertently neglected to reattach the furnace power cord plug to the base of the canister when he completed repairs to the unit and by the time the error was discovered the next morning the internal vessel temperature had cooled to 50°C. Fortunately, a sample had been taken on the previous day

(day 48) prior to making repairs, so the net effect was a normal termination on day 48 (instead of day 64, as originally planned).

The single mineral dissolution kinetics experiments using quartz was terminated at the end of the month. Solutions are being analyzed for Si only by colorimetry and ICP. Solid phase observations by SEM will commence shortly. The experiments spanned the range pH 1 through 13 and were run at 70°C for 60 days. Several of the experiments will have to be repeated due to leaking flow-through cells caused by cell plugging.

The report entitled "Report on static hydrothermal alteration studies of Topopah Spring tuff core wafers in J-13 water at 150°C" by Knauss and Beiriger was completed, passed QA peer review and was forwarded to WMPO for review.

The paper entitled "Hydrothermal interaction of Topopah Spring tuff with J-13 water as a function of temperature" by Knauss, Delany, Beiriger and Peifer was accepted for presentation at the Symposium on the Scientific Basis for Nuclear Waste Management in the 1984 MRS National meeting in Boston this fall. This report focuses on the results of drill core samples run in the gold-cell rocking autoclaves.

The report "Reaction of Topopah Spring Tuff with J-13 Water at 120°C" was reviewed at LLNL, revised, and forwarded to NV for policy review.

B. Stability of Borehole Openings

Work continued in August on a fully three-dimensional model with which the stability of rock blocks adjacent to emplacement holes can be analyzed. The model takes into account geometric parameters and rock mass properties that influence block behavior, and uses a closed form solution for an arbitrary three-dimensional stress field surrounding the underground excavation. Thermally induced stress changes will be incorporated in the model after the current phase of work is done. Once completed, the model will be evaluated by back-calculating the stability of blocks that have been measured in the field.

Translation of computer programs to identify and draw individual rock blocks also continued this month. These codes will be used to identify potentially unstable rock blocks in the emplacement holes from structural geology data. The stability models will be used to assess the stability of identified blocks.

C. Dehydration and Rehydration of Topopah Spring Tuff

During the month of August, 1984, a report entitled "Laboratory determined transport properties of Topopah Spring Tuff" was drafted. This report summarizes our experimental results of the dehydration and rehydration of the three 2.54 cm diameter Topopah Spring tuff samples. This manuscript will be ready for technical review shortly.

The larger (8.23 cm dia) Topopah Spring tuff sample has been prepared for testing. However, we have spent almost the entire month repairing the pressure vessel which we planned to use for the tests. Early in the next month we hope to have the test going.

PLANNED WORK

Tuff-water interaction experiments in rocking autoclaves will continue. Following completion of the two experiments planned for 64 day duration, some short term runs with J-13 water alone and runs using tuff plus distilled water at 90°C and 150°C will be undertaken.

Development of the three dimensional rock stability model will continue. Following completion of the model development, the model will be used to analyze emplacement hole stability for the waste package environment.

Measurements of dehydration behavior for the larger core sample (8.23 cm dia) will begin.

PROBLEM AREAS

None.

MILESTONE PROGRESS

1.2.1-84-III-6 (W278) Report on Topopah Spring Crushed Tuff Reacted with J-13 Water at 120°C

This report was transmitted to DOE/NV on August 16, 1984.

1.2.1-84-II-1 (M205) Report on Static Hydrothermal Alteration Studies of Topopah Spring Tuff Core Wafers in J-13 Water at 150°C

This report was transmitted to DOE/NV on August 24, 1984.

1.2.1-84-II-2 (M206) Report on the reaction of Topopah Spring tuff drill cores G-1, GU-3, G-4, and UE25h#1 with J-13 water at 150°C

A request has been submitted to the Change Control Board to request a revised submission date of 12/31/84.

1.2.1-84-III-7 (W279) Report on Geochemical Modeling of the Reaction of Topopah Spring Tuff with J-13 Water

This report has been rescheduled for delivery on 12/31/84.

for Wesley G. Patrick
L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1-31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.1.L WASTE FORM TESTING
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task involves the measurement of the radionuclide release rate from spent fuel and from borosilicate glass (containing DHLW or CHLW); these data are to be used as input for performance modeling of long-term radionuclide release rates from the waste package. Radionuclide release rate information will also determine whether or not a packing material must be incorporated in the waste package designs in order to meet NRC performance objectives.

ACTIVITIES

A. Spent Fuel Cladding Containment Credit Tests

Series 1 Cladding Containment Credit Tests, which had been terminated in March and restarted with fresh deionized water, were again terminated with 128 days on the second run. Results on the restart run were similar to the first run except that suspended colloids over the bare fuel specimen settled out sooner in the second run and peak Cs activity in solution was lower by a factor of about 3.

Initial data from Series 2A tests (H. B. Robinson fuel in J-13 well water) indicated that uranium solubility is much greater (3 ppm vs 1 ppb) in the J-13 water than in the deionized water used in Series 1 tests. The colloid phase observed in Series 1 has not been observed in Series 2A and all of the uranium in the J-13 water passes through an 18A filter. Stabilization of uranium in solution by carbonate in the J-13 well water may explain the observed solubility difference relative to the Series 1 deionized water tests.

Series 2B tests using Turkey Point fuel in J-13 well water were started. The Series 2B test purpose is to correlate Series 1 tests (Turkey Point fuel in deionized water) with Series 2A tests (H. B. Robinson fuel in J-13 water).

B. Zircaloy Cladding Corrosion

The electrochemical corrosion scoping experiment, in progress, consists of bundles of spent fuel cladding wrapped with a strip of 304L stainless steel sheet and submerged halfway in J-13 well water that is equilibrated with crushed tuff at 90°C. Two, 6 and 12 month experiments are running with the 2-month experiment scheduled for shutdown the first week in September. Evaluation of the spent fuel cladding from the two month experiment should be complete about the first of November. To date the experiment is operating as expected. No obvious signs of cladding corrosion have been observed.

Preparation of a sample of the oxide-metal interface region on the O.D. of a typical spent fuel cladding for scanning transmission electron microscopy (STEM) is almost complete. This sample chosen for comparison with material from the scoping experiment described above will be examined via STEM this next month.

An expanded draft of "Zircaloy Cladding Corrosion in a Tuff Repository, Initial Experimental Plan," HEDL-7455 (formerly HEDL-2843), is expected to be ready for LLNL review by the end of September.

C. Spent Fuel Oxidation

Initial results with the HEDL TGA system to determine its usefulness in low temperature oxidation studies of spent LWR fuel look promising. Two TGA runs were conducted at 225°C in air with a 14°C dew point on one sample of crushed fuel and one fuel fragment. The TGA system was relatively stable for a test period of over 20 days. Preliminary results indicate that oxidation rate is not simply directly proportional to sample area.

D. Parametric Testing

The manuscript entitled "Parametric Testing of a DWPF Glass" by F. Bazan and J. Rego was completed and distributed for technical review.

Parametric testing of uranium-doped and actinide-doped PNL 76-68 glass is progressing on schedule.

Testing of DWPF and PNL 76-68 glass in a gamma radiation field is continuing on schedule.

E. Testing in Rock Reaction Vessels

A series of tests reacting actinide-doped PNL 76-68 glass with J-13 water in tuff reaction vessels were started in July. Reaction times of 30, 90, and 180 days are planned at 90°C. All runs are being conducted in duplicate. Some tests are using glass on teflon supports while others use stainless steel supports. The 30 day tests were terminated on July 30; solution analyses are in progress.

F. Unsaturated Test Method Development

The test matrix being conducted to determine the reproducibility of the unsaturated test method is continuing. All indications were that everything was proceeding as expected.

G. Analog Test

The rock core was opened and examined during August. The waste package sample showed physical characteristics similar to those observed in the unsaturated test method.

PLANNED WORK

Long term testing of spent fuel in J-13 water will continue to investigate the release rate of radionuclides from bare spent fuel and from pin segments that contain defects in the cladding.

Testing of irradiated Zircaloy cladding material in J-13 water and Topopah Spring tuff will continue. The 2 month exposure sample will be removed during September.

Testing of glass waste forms in a gamma radiation field will continue, as will the testing of actinide-doped PNL 76-68 glass in rock reaction vessels.

Further experiments will be conducted to determine the oxidation rates of UO_2 in spent fuel using thermogravimetric analysis.

PROBLEM AREAS

The corrected version of the final report from PNL for FY 83 contract work (95% complete) was received at the end of August. It will be reviewed for technical accuracy in September.

MILESTONE PROGRESS

All level 1 and 2 milestones remaining for FY84 are presently on schedule.

Wesley Patrick

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1-31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.2.L METALS SELECTION/TESTING
L. Ballou/D. McCright, P.I.

OBJECTIVE

This sub-task includes the selection of the metals for the fabrication of canisters and of borehole liners, as well as the characterization of the corrosion rates of these metals under expected repository conditions. The corrosion data will be used in performance assessment modeling and predictions of long-term canister behavior needed for NRC repository licensing.

ACTIVITIES

A. Electrochemical Potential Determinations

During the past month, the electrochemical corrosion potential was measured for different candidate stainless steels in J-13 water in a high-intensity gamma irradiation field. We were particularly interested in determining the corrosion potential shifts due to the production of a more oxidizing environment under gamma irradiation, and whether such potential shifts could induce localized pitting attack because of the relative placements of the corrosion potentials and the pitting potentials of the different stainless steels.

Typical behavior for 304L stainless steel in J-13 well water under gamma irradiation at room temperature is described as follows: Upon initiation of the gamma irradiation (3.3 Mrads/hr), the corrosion potential shifts positive (more oxidizing direction) by about 150 mV. [These potentials were all measured relative to a saturated calomel electrode (SCE).] When the gamma source is "switched off" (by moving the vessel containing the test specimen four to six feet above the cobalt-60 source in the gamma pit), the potential again increases. When the specimen is re-exposed to the source, the potential drops. This cycle is then repeated (note that steady-state was not allowed to be obtained). The increase in the corrosion potential (E_{corr}) is thought to be due to the production of hydrogen peroxide (a strong oxidant) under gamma radiolysis of the water. Although the exact mechanisms occurring in the "on-off" cycle are still under investigation, when the source is "turned off", the further rise in potential may be due to "turning off the valve" for H_2 (a reducing agent) production, which is also a reaction product of gamma radiolysis of water. The net effect may be a further increase in potential due to accumulation of metastable hydrogen peroxide (H_2O_2) and a depletion (escape from solution) of H_2. As H_2O_2 is a relatively stable molecular product, once it is generated in solution, the corrosion potential of 304L remains positive when the source is "turned off".

Results similar to those for 304L were also obtained for 316L stainless steel. Again, a positive shift in the corrosion potential is observed for the 316L in room temperature J-13 water. After about 390 minutes, the experiment was terminated. The 316L electrode was removed and re-immersed in fresh, unirradiated J-13 water; E_{corr} was found to drop immediately. This experiment shows that the shift in E_{corr} found under irradiation is due to the formation of relatively stable radiolysis products which remain in solution.

After about 50 minutes at E_{corr} in the unirradiated J-13 water, one drop of concentrated 30% H_2O_2 was added and the potential was observed to shift in the oxidizing direction. The similarity between this shift and that observed under gamma irradiation suggests that radiolytic formation of hydrogen peroxide from water may account for the shift in corrosion potential. A concentration of 1.4×10^{-4} M hydrogen peroxide caused the potential shift.

Potentiostatic anodic polarization potentials in the gamma field were also obtained, as we are also interested in the effects of gamma radiolysis on pitting potentials. Polarization potentials for 316L were measured in 650 ppm chloride solution both under gamma irradiation and out of the gamma field. This Cl^- solution was chosen as it represents a solution 100 times more concentrated (in chloride only) than is J-13 and the pitting potentials in this environment are clearly defined. Under gamma irradiation, the E_{corr} and E_{pit} values are 50 mV and 390 mV, respectively. This represents a separation of 340 mV. In the polarization curve determined outside the gamma field, the corresponding values are -110 mV and +220 mV, which is a separation of 330 mV. The influence of the gamma field is therefore to shift both the corrosion potential and the pitting potential in the positive (oxidizing) direction with the same magnitude of separation between them. The similarity in the magnitude of the shift is interpreted to mean that the stainless steel is no more susceptible to pitting attack with gamma irradiation than without.

Further work is underway to understand the nature of this effect and the influence of gamma irradiation on solutions more concentrated than J-13, both in chloride ion as well as the other principal anions: nitrate, sulfate, and bicarbonate. Also, the effect at higher temperatures will be investigated.

B. Development of a More Concentrated Electrolyte

Use of stainless steels as container materials for nuclear waste in a tuff repository may be limited if the containers are contacted by a water much more concentrated in electrolyte than is J-13. An unlikely sequence of events is required for this concentration to occur. However, the performance of the material in such a circumstance should be investigated to determine the extent of degradation which would occur. Repeated episodes of water entering the repository environment and dripping onto the container with boiling and concentration of ionic species during the containment period could create this more concentrated ionic environment.

In order to investigate the corrosion behavior in the more concentrated electrolyte solutions, J-13 water was boiled down to approximately 10 times (10x) and 100 times (100x) its initial ionic concentration. Tables 1 and 2 indicate the results for anion analyses on the 10x and 100x concentrated

solutions, respectively. The initial analyses of the make-up J-13 water are also given. It is observed that the 10x solution results in anion concentrations that are roughly 10x more concentrated. The 100x solution yields high results for every anion except fluoride (fluorides are generally less soluble than other salts). These results are being repeated by analytical chemistry personnel. Copious precipitation is observed when J-13 is boiled down to 100x concentration. Analysis revealed this precipitate to consist mostly of calcium silicates. The pH of the 100x boil-down solution rises to about 9.8 (J-13 water is nearly neutral). This pH change may actually be beneficial to the localized corrosion performance of the stainless steel as the more alkaline environment may counter the effect of an increase in chloride ion content. A more complete analysis of the concentrated solutions to include all of the anions and cations will be performed to enable us to prepare reasonable synthesized solutions in the laboratory, as the time and water volumes required to prepare quantities of the boiled down water would be prohibitive.

Exposure of stainless steel specimens to the more concentrated electrolytes will be performed in future months to determine whether the metallic corrosion is affected by the beneficial effect of the pH increase or by the potentially harmful effect of the chloride ion increase.

TABLE 1: ANION CONCENTRATIONS IN BOILED DOWN J-13 WATER (ION CHROMATOGRAPHY ANALYSES)

	Concentration, ppm			
Sample	Fluoride	Chloride	Nitrate	Sulfate
J-13	2.5	7.7	5.9	19.2
"10x"	28.0	72.8	88.1	181.9

TABLE 2: ANION CONCENTRATIONS IN BOILED DOWN J-13 WATER (IC ANALYSES)

	Concentration, ppm			
Sample	Fluoride	Chloride	Nitrate	Sulfate
J-13	2.6	7.3	7.8	18.5
"100x"	262.	1040.	1150.	2190.

C. Stress Corrosion Susceptibility of Candidate Stainless Steels

Four-point load bent-beam specimens are exposed to 100°C J-13 water and to the saturated steam phase above the water. Specimens are stressed to 90% of their respective test temperature yield stress (ASTM G-39 test procedure). The matrix study of Types 304, 304L, 316L, and 321 stainless steel specimens in the welded, furnace-sensitized and cold-worked condition will attain 4000 exposure hours in September. No cracked specimens have been observed to date. A similar set of specimens, but without furnace sensitization, will attain 2000 exposure hours. A third set of specimens, of the same four alloys, is planned for thermally cycling and straining on the Gleeble. Each quarter inch plate stock of the alloy was cold-worked and then machined into one-inch by three-inch specimens for heat treating on the Gleeble.

A summer student, Debbie Hagen, completed her assignment and returned to school (New Mexico Tech). A detailed account of her work is being prepared in a final report. The following is a summary of the main points of her experiments:

Part A: The four alloys were heat treated to produce a strongly sensitized microstructure after being severely cold-worked (20% reduction). The purpose of this part of the work was designed to compare the relative amounts of sensitization produced in each of the four alloys. Metallographic analysis was performed in the as-received condition as well as after cold-working and again after the sensitizing heat treatment. Each plate was held at 700°C for one week in an argon atmosphere (to prevent excessive surface tarnishing) and water quenched. Samples were also prepared for electrochemical determination of the localized corrosion susceptibility.

Part B: This part was limited to 316L stainless steel in both the cold-worked and the as-received condition. Four different heat treatments were performed to produce a microstructure similar to that which might be expected to result from long-term, low-temperature sensitization during decades at the expected storage temperatures in a tuff repository. Since the low-temperature sensitization develops from initiation of microstructural features produced at a higher temperatures, these heat treatments involve two steps.

15 minutes @ 1000°C, water quenched + 1 day @ 250°C, water quenched
15 minutes @ 1000°C, water quenched + 1 week @ 250°C, water quenched
15 minutes @ 1000°C, air cooled + 1 day @ 250°C, water quenched
15 minutes @ 1000°C, air cooled + 1 week @ 250°C, water quenched

Metallography of specimens undergoing the above treatments was performed.

Part C: This part is also limited to 316L in the cold-worked and as-received condition. The objective of this heat treatment was to simulate the effect of waste emplacement on the canister, followed by the closure weld.

17 hours @ 800°C, air cooled for 2 hours, then 15 minutes @ 1000°C, air cooled
17 hours @ 800°C, air cooled for 2 hours, then 15 minutes @ 1000°C, then 1 week @ 250°C, water quenched

Metallography was also performed on this group of specimens.

Part D: The objective of this part was to determine the susceptibility of 316L and 321 to sigma phase formation. The following heat treatments were used:

1 week @ 800°C then 1 day @ 700°C, water quenched
1 week @ 800°C then 1 week @ 700°C, water quenched
1 week @ 800°C then 2+ weeks @ 700°C, water quenched

Metallography and transmission electron microscopy were used to characterize the microstructures.

Four-point load bent-beam stress specimens will be machined from the above treated plates and exposed to the 100°C J-13 water and steam test environments to determine the stress corrosion susceptibilities of the different microstructures produced by these various thermal and mechanical treatments.

PLANNED WORK

This has been appropriately discussed along with the affected activities.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All deliverables for this sub-task are on schedule.

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1-31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.3.L OTHER MATERIALS
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the development and testing of packing materials fabricated from crushed tuff plus additives to enhance the properties of the finished products (where necessary). Other activities under this sub-task include the assessment of the chemical effects of grouts and concrete on the performance of waste package components. (The second activity is not funded for FY84).

ACTIVITIES

Work is continuing at the USGS (Menlo Park) on measurements of the permeability of Topopah Spring tuff in a temperature gradient. They are investigating the effects of pore pressure, sample orientation, and flow direction on the permeability of the tuff and the fluid chemistry of the water. The temperatures and pressures of the experiments were chosen to approximate those expected at the repository level. To date, the permeability experiments and the chemical analyses of the discharged fluids have been completed. The analysis and interpretation of the chemical data is in progress.

PLANNED WORK

Samples will be prepared to investigate the effect of mixtures of silica gel of various grain sizes on the properties of packing material based on crushed tuff. Initial tests will be done using various proportions of gel (5, 10, and 15%) and a single compression pressure (probably 20,000 psi). If any of the mixtures give promising results, a full pressure-density test will be done and a specimen prepared for thermal conductivity measurements.

PROBLEM AREAS

Lack of staff is still restricting the progress of this sub-task. Interviews have been conducted with a view to hiring a petrologist or geochemist to take over responsibility for this section of work. We anticipate filling the position in the near future.

MILESTONE PROGRESS

All FY84 deliverables for this sub-task have been completed and forwarded to DOE/NV.

Wesley Patrick
for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1-31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.L PACKAGE DESIGN
L. Ballou/W. O'Neal, P.I.

OBJECTIVE

The objective for package design is to develop and analyze waste package designs which incorporate NNWSI qualified materials and which are compatible with the repository design. The designs and analyses are needed to support license application by documenting conformance with NRC requirements for safe handling, transportation, emplacement, retrieval, containment and release rate.

ACTIVITIES

A. Design

In order to obtain commercial cost estimates for spent fuel canister space frames, detailed drawings were prepared for BWR and PWR space frames. The PWR drawing was sent to fabricators for detailed cost estimates for quantities of 200 per year each of 3 lengths (total 600/yr).

B. Structural Analysis

Using DYNA3D, a three-dimensional analysis is underway on a spent fuel canister dropped 40 inches horizontally onto a 6 inch diameter vertical steel post. The problem is running nights and week-ends at low priority on a Cray computer.

The report "Structural Analysis of Conceptual Waste Package Designs for a Tuff Repository" is undergoing peer review and revisions.

PLANNED WORK

See activities mentioned above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

1.2.3-84-I-1 (M251) Report on Pre-Closure Analysis of Selected Conceptual Waste Package Designs for a Nuclear Waste Repository in Tuff

This report has been issued for internal peer review and is expected to be transmitted to NVO on 9/14/84.

All level 1 and 2 milestones for this sub-task have been completed for FY84.

for Wesley Patrick

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1-31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.4.L PERFORMANCE ANALYSIS AND TESTING
L. Ballou/M. Revelli/J. Yow, P.I.

A. PERFORMANCE ANALYSIS

OBJECTIVE

This activity involves the development and validation of models that can be used to predict long-term package performance for comparison with NRC performance objectives.

ACTIVITIES

Model verification and development continued in support of the waste package system analysis code (WAPPA). During the past month these efforts focused on three primary areas: 1) Documentation of the thermal submodel (TMODEL) review, 2) Debug of the mechanical submodel (FMODEL), and 3) Development of an unsaturated flow model. A draft of the level III milestone (1.2.4-84-III-2) "Report on the Evaluation of the WAPPA Thermal Model" is in preparation and should be completed next month. Work continued to correct the logic and coding errors identified last month in FMODEL; stand-alone testing of FMODEL will resume once these errors are corrected. The WAFE code, developed at LANL by B. Travis, is now operational on the LLNL Cray computer system and a sample problem, supplied by LANL, has been successfully executed. Definition of a waste package problem, assuming porous flow through the region, is in progress. After the necessary data base has been assembled, this problem will test WAFE's ability to model hydrothermal flow within the waste package subsystem.

Work has been initiated to model the matrix diffusion of radionuclides through the Topopah Spring tuff reaction vessels used in the SRL-NNWSI saturated release tests of the DHLW waste form. Both the simulated and the fully active waste release tests will be modeled and the results compared to the nuclide distributions measured in the rock and solution analyses. The details of the work will be presented at the ORNL sponsored Workshop on "The Application of Geochemical Models to High-Level Nuclear Waste Repositories," scheduled for October 2-5, 1984.

Discussions continued with S. Pawah (INTERA) to develop an FY85 statement of work for the analysis of non-porous flow within the waste package. M. Revelli and K. Eggert (LLNL) met with INTERA staff in Houston on August 29, 1984 to define several generic falling fluid problems which could impact the performance of a waste package in the unsaturated zone. It was agreed that the first phase of this proposed subcontract should focus on a calculation of flow path, volume, and residence time along a non-porous cylinder.

M. Revelli and K. Eggert met with SNL staff in Albuquerque on August 30, 1984 to discuss the capabilities of the PETROS and NORIA codes for modeling unsaturated matrix/fracture flow. J. Braithwaite also reviewed the status of the LBL TOUGH calculations and briefed M. Revelli on NNWSI System Description.

PLANNED WORK

Evaluation and verification of WAPPA submodels will continue through this fiscal year. In FY85, these models will be organized into a waste package system model (with a flow/transport submodel and data bases for metal corrosion and waste form release rates) to predict the long-term performance of the NNWSI waste package subsystem.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones are progressing consistent with the current schedule.

B. PERFORMANCE TESTING

OBJECTIVES

This activity includes planning and implementation of an in situ test of the waste package environment. The results of this test will be used to aid in validation of the models used in the waste package performance analysis.

ACTIVITIES

Borescope surveys of the G-Tunnel post-experiment boreholes were performed this month to detect fractures in the plane of the high frequency electromagnetic (HFEM) geotomography measurements. The borescope logs and the geophysical results were used to infer paths of tracer flow during the HFEM experiments. Anomalies seen in the geotomographs appear to closely match the fractures present in the plane of the HFEM measurements. A model of the inferred flow paths was also developed with which synthetic tomographs were generated. This procedure confirmed that the inferred flow paths can produce the image anomalies observed in the real tomographs.

Preparations of the report describing the use of HFEM geotomography techniques in fractured, welded tuff continued in August. This report will describe the HFEM measurements made in G-Tunnel at NTS, and their analysis and interpretation.

PLANNED WORK

The report describing the suitability of HFEM techniques for monitoring saturation changes in fractured, welded tuff will be completed in September. In addition, review of other types of instrumentation, measurement, and sampling techniques will continue. These fall into the general areas of subsurface hydrology and geomechanics, in keeping with the broad scope of the Waste Package Environment Tests. Scoping calculations for experiment design

will be commenced within the next months; this work is closely related to the numerical modeling being planned in the Waste Package Performance Analysis sub-task.

PROBLEM AREAS

None.

MILESTONE PROGRESS

Level 1 and 2 milestones for this subtask are complete for FY84.

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 September 1984
Report Period 1 - 31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.3.1.9 - GEOCHEMICAL MODELING CODE EQ3/6
D. Emerson/T. Wolery, P.I.

OBJECTIVE

This task is the development of advanced calculational capabilities for modeling geochemical processes in the repository environment. The work is being carried out by extending the capabilities of the existing EQ3/6 software. The applications objective is to support site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

ACTIVITIES

Development of economy mode and super-economy mode, was completed and these options are up and running on the development version of EQ6. All computational anomalies involved with finite-difference step-sizes have been corrected.

New MCRT data files were completed for selenium, thorium, and tin. Updates were made to all data files to coincide with the SUPCRT database update from UC Berkeley collaborators. Output changes were made in the pre-random access MCRT code to increase user productivity. The conversion of all data files to the new random-access format is continuing.

While the code was down, numerous other unrelated bugs were fixed and the EQ6 code overhauled. The Subroutine which performs iterative improvement on the solution to matrix equations was substantially rewritten, and now gives much better performance. Changes were also made in a few options, resulting in some INPUT file changes.

PLANNED WORK

MCRT User's Manual is being drafted to contain full explanation of the random access package. The recent changes in the MCRT data files to the random access format will also be included in the manual, although they were not originally planned to be made until FY85.

PROBLEM AREAS

The computational anomalies observed in the finite-differences routines affected all runs on EQ6, and thus slowed progress this month until they could be corrected. Testing on the precipitation kinetics test cases was delayed by approximately three weeks.

NETWORK ACTIVITY/MILESTONE PROGRESS

2.3.1.9-84-II-2 Draft report of MCRT User's Manual will be transmitted to NV by 10/31/84.

2.3.1.9-84-III-2 Draft report of the EQ6 Precipitation Kinetics Capability has been rescheduled to 9/28/84.

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 September 1984
Report Period 1-31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.6.5.2.L EXPLORATORY SHAFT TEST PLAN
L. Ballou/J. Yow, P.I.

OBJECTIVE

This sub-task includes the preparation and certification of LLNL input to the Exploratory Shaft Test Plan (ESTP).

ACTIVITIES

Only limited revisions (resulting from the LLNL internal peer review) have been made in the current internal (LLNL) version of the plan. No revisions have yet been made in the version that is included in the ESTP. This work has been delayed by the delay in receiving review comments from the La Jolla WMPO/TPO/ESTP Committee review of the ESTP. The ESTP Committee met in Las Vegas on August 16 and 17.

PLANNED WORK

Revision of the Test Plan will proceed as soon as the remainder of the review comments from the March ESTP retreat are received. In the interim, the test accounting and scheduling will be revised to reflect changes in the project WBS structure.

PROBLEM AREAS

See above.

MILESTONE PROGRESS

Level 1 and 2 milestones are complete for this subtask in FY84.

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 September 1984
Report Period 1 - 31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.7.1.L - SPENT FUEL TEST-CLIMAX
W. Patrick, P.I.

OBJECTIVE

The objectives of the SFT-C are to demonstrate the feasibility of storage and retrieval of spent nuclear fuel and to acquire data pertinent to the design, construction, and operation of a repository in crystalline rock. Emphasis in late FY 1984 and FY 1985 is post-test characterization and documentation of thermal- and radiation-induced changes in the rock mass. The extensive data set collected during heating and cooling of the rock mass is being analyzed in light of pretest and post-test calculations.

ACTIVITIES AND ACCOMPLISHMENTS

Summary

Post-test laboratory calibrations of transducers deployed on the SFT-C were completed. Data analyses continue to be the dominant activity following completion of field activities. Three draft reports were completed which document the results of borehole jack and petite sismique rock mass modulus measurements. A report comparing measured and calculated radiation doses in the vicinity of canister emplacement boreholes was also completed.

Geological Investigations

Two techniques were used to obtain data on the deformability of the rock mass. The deformation modulus values obtained using these techniques are required to make calculations of rock response to changes in stresses which result from excavation, heating, and similar processes.

As noted last month, analysis of Goodman borehole jack data revealed a reduction in modulus associated with regions of the rock mass which were heated to about 60° to 65° for a three-year period. Most of the rock mass was heated moderately to about 30° to 35°C during the three-year period. Since the effect was small in comparison to the variability of the rock mass (even at 60° to 65°C) it was important to study possible effects of moderate heating with pretest and post-test data from the same region. Four borehole segments in the pillars were the site of pre-test and post-test measurements. However, the published pretest values were processed with a different data reduction scheme than is currently recommended. This required going back to the raw data and reanalyzing it. Comparisons of these data reveal no consistent change in the deformation modulus. A draft report on these studies was completed and is being peer reviewed.

The second technique is a seismic approach to modulus determination known as "petite sismique". The potential signal "aliasing" problem identified last month has been resolved. The signal roll-off characteristics at high frequencies are sufficient to alleviate the problem. Response of the transducer to impulse and shaker table tests were used to make this determination. The draft report was prepared, peer reviewed, and forwarded to NV.

The development of microfractures may be a valuable precursor for studying possible thermal and radiation damage in crystalline rocks. This technique has been previously applied to laboratory irradiated samples of Climax granite. The effects of in situ heating are now being studied using samples obtained at various positions radially outward from each of two heated boreholes. Because the effect is presumed to be slight and the variability of microfracturing is quite high, the samples were obtained from near the auxiliary heaters where temperatures were much higher than near the spent fuel canisters or electrical simulators. The results from these samples will be compared with pretest unheated samples from the same area.

The first set of SEM scans for the microfracture study were completed and processed through the image analyzer. Initial indications are that the database will need to be augmented with additional scans to facilitate statistical analysis.

In addition to the microfracture analyses, changes in the mineralogy and petrology caused by heating and/or irradiation are also being studied. Cursory examination of post-test geological samples obtained near auxiliary heater boreholes revealed no influence of heat on the rock mineralogy or petrography. Neither samples located in "dry" areas nor those near seeps showed discernable alteration. Examination of canister emplacement hole samples will begin next month.

Major revisions were completed to the report on the structural geology of the Climax stock in the vicinity of the SFT-C. Peer review of the report is in progress. Because of the extensive scope of the revisions, the report will be resubmitted to NV/WMPO for programmatic review prior to publication.

Radiation Studies

Comparisons between calculated and measured radiation doses in the vicinity of spent-fuel emplacement boreholes were completed. This study reveals that radiation doses can probably be calculated much better than they can be measured using currently available long-term dosimetry. Careful definition of the source term and "calibration" of the model using short-term dosimetry are important to obtaining good calculational results. A report documenting this study was submitted to NV/WMPO following peer review.

Instrumentation and Data Management

Post-test laboratory calibrations were completed this month at the EG&G-Las Vegas facility. Analysis of IRAD vibrating-wire stressmeter calibration data was initiated. Data acquired during the heating and cooling phases of the SFT-C are being related to the stressmeter overcoring and biaxial compression data sets.

Error analyses of the Watt transducers were also performed using pretest and post-test calibration results. A systemmatic, though slight, change in slope and offset of the calibration curves has been observed. Potential sources of these changes are being investigated at this time.

Fabrication was completed and preliminary testing was initiated with the USBM gauge calibration fixture. This device is being used to evaluate apparent hysteresis in gauge response which was observed during in situ stress measurements at the SFT-C. It will also be used to address a fundamental flaw in the currently recommended USBM gauge calibration procedure: the gauge is "calibrated" with a system which is at best two orders of magnitude less precise than the gauge.

The support electronics for the microadjuster has been repackaged in a more rugged, field-worthy rack. This, along with cabling changes, will provide a more reliable, directly shippable system. This device was used to field calibrate multiple point borehole extensometers.

The HP3455A digital multimeters were received from EG&G-Las Vegas following post-test calibration.

Post-Test Calculations

Work continued on modification of models used to calculate mechanical and thermal phenomena associated with the SFT-C. Additional analyses of the "mine-by" data were performed in conjunction with calculations of permanent displacements induced by high explosive shock loadings. Attempts to model the shock-induced permanent displacements associated with the top heading excavation of the SFT-C facility have been unsuccessful. The assumptions of the superposition technique are being closely reexamined to ascertain why close agreement between measured and calculated displacements occurred in the bench excavation but not in the top heading. Sources of data other than the SFT-C are also being considered. For example, recently available shock effects data from the Michigan Tech experimental mine (in basalt) was examined to determine its applicability to our reanalysis of the Climax mine-by experiment. However, the absence of displacement measurements in the Tech experiment greatly limits its usefulness to us.

Progress on post-test thermal calculations continued to be delayed this month because the staff scientists has been tasked to the LLNL groundwater contamination study. Additional analytical models of heat transfer within the SFT-C three-drift complex began to be studied.

Decommissioning and Equipment Utilization

C. Washington (USGS, Denver) requested use of a digital multimeter (DMM) and scanner chassis from the SFT-C data acquisition system. These two units were loaned to the USGS pending a determination that the equipment is compatible with their data acquisition activities at Yucca Mountain. The required equipment will be transferred to the REECo property management group for long-term loan to the USGS when the compatibility of the SFT-C equipment is established. As noted above, the DMM was just calibrated at EG&G.

Public Information

Production of the update to the SFT-C documentary film is in progress. Film sequences have been selected and merged and the narration was completed. Production of the soundtrack is in progress.

PLANNED WORK

Staff efforts will continue to concentrate on analysis of field data and compilation and analysis of post-test calibration results. Revisions to thermal and thermomechanical models will continue. The production of the SFT-C film update will be completed.

PROBLEM AREAS

None.

NETWORK ACTIVITIES

2.7.1-84-III-4 Radiation Doses in Granite Around Emplacement Holes in the Spent Fuel Test-Climax (Final Report

This report was sent to DOE/NV for programmatic review on August 7, 1984.

2.7.1-84-IV-4 Measurement of In Situ Deformability with NX Borehole Jack, Spent Fuel Test-Climax, Nevada Test Site.

This report was sent to DOE/NV for programmatic review on August 17, 1984.

2.7.1-84-IV-8 Petite Sismique Measurements at the Spent Fuel Test-Climax

This report was sent to DOE/NV for programmatic review on August 31, 1984.

Measurement of Displacements in Large Boreholes with a Strain-Gauged Proving Ring

This paper, not a deliverable, was requested in a letter of invitation, dated July 19, 1984, from Engineering Mechanics Department, Deere & Company Technical Center, and forwarded on August 7, 1984 for possible inclusion in EXPERIMENTAL TECHNIQUES.

for Wesley Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 September 1984
Report Period 1 - 31 August 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.9.4 - QUALITY ASSURANCE
J. Dronkers, P.I.

OBJECTIVE

Prepare QA plans and procedures, conduct internal QA surveillance, advise and assist LLNL staff assigned to NNWSI in the performance of their QA responsibilities, conduct audits of contractors, and generally carry out activities in Quality Assurance that will meet NRC requirements during licensing of a high-level waste repository under 10CFR60.

ACTIVITIES

Two representatives of SAI's Lynchburg, Virginia office met with NWMP personnel here on August 3, 1984. The purpose of the meeting was to clarify the requirements of NUREG-0856 as they apply to NNWSI projects.

Ms. Bonnie Jean Smith has joined the QA staff as administrative assistant. Her duties will include coordination with principal investigators in NWMP in establishing and maintaining the QA records archives. Ms. Smith assumes her duties on September 10, 1984.

Work on the overall QA plan for NWMP is continuing.

Work on the NWMP QA procedure for software is continuing.

MILESTONE PROGRESS

There are no level 1 or 2 milestones due for this subtask in FY84.

for L. Ramspott
LLNL Technical Project Officer
for NNWSI

Lawrence Livermore National Laboratory

MILT 10/84 KE XC

Fiore Jonson
Hoffman Mulvey
Alan

29 October 1984
NWM:84/5976C

Original
JRL

Donald L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

Enclosed is LLNL's Quarterly Report for the period 1 July - 30 September 1984.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

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NNWSI QUARTERLY REPORT

Date: 31 October 1984
Report Period: 1 July - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

SUB-TASK 2.2 - WASTE PACKAGE
L. Ballou, P.I.

SUMMARY

Interaction experiments between Topopah Spring tuff (Tpt) and J-13 water were continued under a large range of environmental conditions.

The first set of single mineral (quartz) dissolution kinetics experiments was completed. Another set to study feldspar will be started soon.

Development of an improved two-dimensional block stability model was completed, and work was begun on a fully three-dimensional model with which the stability of rock blocks adjacent to emplacement holes can be analyzed.

Dehydration/rehydration studies of Tpt are continuing; properties of a larger sample (8.29 cm diameter, 10.10 cm long) are being determined.

Spent fuel cladding containment credit tests are being conducted in J-13 water using spent fuel from the H. B. Robinson and Turkey Point reactors. Initial results indicate that uranium solubility is much greater in J-13 water than it is in deionized water. how much is this?

A Zircaloy electrochemical corrosion scoping experiment is continuing; in this experiment, bundles of Zircaloy cladding wrapped with a strip of 304L stainless steel are partially immersed in J-13 water (at 90°C) that is equilibrated with crushed Tpt. Changes in the appearance of the cladding surfaces next to the stainless steel have been visually observed. what kind of changes?

Parametric tests of DWPF 165-frit and PNL 76-68 (CHLW-type) borosilicate glass (uranium-doped and actinide plus technetium-doped) in a gamma field have been completed. It was noted that pH of the DWPF-water system decreases slowly with reaction time, but increases for the PNL 76-68-water system. The addition of Tpt to the systems appears to buffer them.

The unsaturated test method developed by J. K. Bates of ANL is being used for a one-year experiment involving DWPF 165-frit glass.

Analog tests of mini waste packages embedded in Tpt cores through which J-13 water vapor at 130°C is being passed have been initiated; testing times of up to one year are planned.

Electrochemical corrosion potentials have been measured for different candidate stainless steels in J-13 water in a high-intensity gamma field. Preliminary indications are that H_2O_2 is an important radiolysis product; also, apparently, stainless steels are no more susceptible to pitting attack with gamma radiation than without.

how high

at least with the field used?

Preliminary work has been started on a study of the effect of concentrated electrolytes on stainless steel corrosion rates.

Experiments to investigate the stress corrosion susceptibility of candidate canister materials are continuing.

Preliminary corrosion studies of copper and copper containing alloys in J-13 water and steam have been completed. Results based on one sample of each of the candidate metals indicate that the corrosion rates for copper-based alloys are intermediate to those for carbon steel and those for the stainless steels.

Work is continuing at the USGS (Menlo Park) on measurements of the permeability of Tpt in a temperature gradient.

The conceptual design for space frames for use in spent fuel canisters was revised to reduce weight (from 6000 lb to 2500 lb) and cost.

Thermal calculations were made for two different arrays (different package and drift spacings) of vertically-emplaced canisters containing ten-year-old spent fuel. In both cases, the maximum allowable waste temperature (350°C) was not exceeded.

A three-dimensional calculational structural analysis of a canister drop test (a horizontal fully-loaded spent fuel canister dropped 40 inches onto a 6-inch diameter vertical steel post) was started.

WAPPA review and verification studies continued to determine the applicability of the existing code to the performance analysis of waste packages emplaced in unsaturated tuff.

SUB-TASK 2.2 - WASTE PACKAGE

L. Ballou, P.I.

WBS 2.2.1.L WASTE PACKAGE ENVIRONMENT

A. Yucca Mountain Tuff and Groundwater - Interaction Experiments and Results

The two long-term (365d) experiments currently in progress in the Dickson-type, gold-cell, rocking autoclaves continued uneventfully. They are:

DB12 = USW G-1 core wafer, J-13 water, 90°C, plan 365d, currently at day 147.
DB13 = USW G-1 core wafer, J-13 water, 150°C, plan 365d, currently at day 147.

During September samples were taken at day 120.

A short-term (planned 64d) experiment was terminated normally at the beginning of September.

DB15 = USW G-1 crushed, J-13 water, 90°C, plan 64d, terminated at day 72.

Following termination of the run the crushed material was submitted for XRD analysis. The vessels used in DB14 and DB15 were prepared for the next set of experiments.

The DB14 experiment was terminated prematurely in August. The technician inadvertently neglected to reattach the furnace power cord plug to the base of the canister when he completed repairs to the unit and by the time the error was discovered the next morning the internal vessel temperature has cooled to 50°C. Fortunately, a sample had been taken on the previous day (day 48) prior to making repairs, so the net effect was a normal termination on day 48 (instead of day 64, as originally planned).

Two short-term (planned 64d) experiments were started at the end of September. These were:

DB16 = USW G-1 polished wafer, distilled water, 90°C, plan 64d, currently at day 11.

DB17 = USW G-1 polished wafer, distilled water, 150°C, plan 64d, currently at day 11.

SEM observation and electron microprobe (EMP) analysis of polished core wafer run in experiment DB14 (Tpt USW G-1, J-13 water, 90°C, 48d) were begun. Initial examination shows that the metastable illitic "clays" observed previously at 150°C and 250°C have formed at this low temperature.

The single mineral dissolution kinetics experiments using quartz was terminated at the end of August. Solutions are being analyzed for Si only by colorimetry and ICP. Solid phase observations by SEM will commence shortly. The experiments spanned the range pH 1 through 13 and were run at 70°C for 60 days. Several of the experiments will have to be repeated due to leaking flow-through cells caused by cell plugging.

Following completion of the single mineral dissolution kinetics experiments using quartz, the flow-through system was completely disassembled, cells acid-cleaned, lines replaced and preparations made for the next series of experiments. Two banks of peristaltic pumps were obtained to allow flow rates to be achieved in the next experiments. Some of these experiments will assess the effect of low flow rates on the apparent dissolution rate at temperatures below 70°C, while others will confirm results with feldspar obtained earlier or repeat quartz experiments, which failed due to cell leakage problems.

The abstract for a paper entitled "Dachiardite Formation by Hydrothermal Alteration of a Devitrified High-Silica Rhyolite" by Knauss and Beiriger was accepted for presentation at the 1984 GSA National Meeting. Precise cell constants for the Ca-rich zeolite were determined this month using the Guinier camera. Numerous SEM photos were taken this month illustrating crystal habit, twinning, and relationships with coexisting mordenite, clays and other secondary mineral produced in the experiments.

The report entitled "Report on Static Hydrothermal Alteration Studies of Topopah Spring Tuff Core Wafers in J-13 Water at 150°C" by Knauss and Beiriger was completed, passed QA peer review and was forwarded to WMPO for review.

The report "Reaction of Topopah Spring Tuff with J-13 Water at 120°C" was reviewed at LLNL, revised, and forwarded to NV for policy review in August.

The manuscript entitled "Hydrothermal Interaction of Topopah Spring Tuff with J-13 Water as a Function of Temperature" by Knauss, Delany, Beiriger and Peifer was prepared and sent to the session chairman for peer review prior to presentation at the Symposium on the Scientific Basis for Nuclear Waste Management in the 1984 MRS National meeting in Boston this fall. The paper will be published in a symposium proceedings volume. This report focuses on the results of drill core samples run in the Dickson-type, gold-cell rocking autoclaves.

B. Stability of Borehole Openings

Development of an improved two-dimensional block stability model was completed this quarter, and work was begun on a fully three-dimensional model with which the stability of rock blocks adjacent to emplacement holes can be analyzed. Parametric studies were then performed with the two-dimensional model in order to define its limitations. The completed models will be checked by back-calculating the stability of individual blocks that have been measured in the field. Once thermally induced stress changes are incorporated, the models will be used in assessing waste package emplacement hole stability.

While the two-dimensional parametric studies were being performed, work also focused on development of the fully three-dimensional numerical model. Detailed plans for the structure of the model and coding and testing of major parts of the model were completed late in the quarter. Finished portions of the model incorporate a solution for an arbitrary initial three-dimensional stress field around an emplacement hole.

The initial two-dimensional block stability parametric studies, which included over two hundred analyses, are the subject of an extended abstract being prepared for submittal to the organizers of the 26th U.S. Symposium on Rock Mechanics. The abstract is entitled "The Influence of Stress Magnitude and Lateral Stress Ratio on Keyblock Stability." This part of the work is significant because previous researchers have dealt with only a limited range of in situ stress magnitudes and lateral stress ratios, and because the two-dimensional model used for the calculations treats the effects of the stresses more accurately than do previous models.

Computer programs that were written in BASIC at the University of California to identify and draw individual rock blocks were implemented on a microcomputer at LLNL last quarter. Conversion of these programs into FORTRAN versions for use on th LLNL Octopus computer system began this quarter; six programs have now been translated. Once completed, the converted codes will be able to take advantage of the higher quality graphics capabilities available on the larger system.

C. Dehydration and Rehydration of Topopah Spring Tuff

A larger fractured Topopah tuff sample was prepared. The sample is 8.23 cm in diameter and 10.10 cm long. The dry bulk density of the sample is 2.316 g/cc. The effective porosity is 3.6%. 20 electrodes and four ultrasonic P-wave transducers were mounted on the sample. Eight of the electrodes are in pairs in the fracture plane (same as the previously studied smaller sample). The rest of the electrodes form a ring around the sample. The electrode ring will be used to test the application of an impedance camera. One pair of the transducers was mounted along the longitudinal axis of the sample (same as the smaller sample). The other pair was mounted in the middle of the sample transverse to the fracture plane. The P-wave velocity measured from the transverse transducers may be more sensitive to the movement of moisture along the fracture surface.

The experimental procedures for this sample will be the same as for the first smaller fractured sample (reported in October, 1983) so that the effect of sample size can be tested. The experiment was started in early September; however, a rupture disc failure in the high pressure system reduced tne confining pressure to less than the pore fluid pressure of the larger fractured Topopah Spring tuff sample. That caused the sample jacket to leak. We are trying to clean the sample so that it is free of pressure fluid contamination.

The pressure-temperature system designed to measure transport properties of rock samples in a two-phase flow system is being assembled.

A report entitled "Laboratory Determined Transport Properties of Topopah Spring Tuff" was drafted. This report summarizes our experimental results of the dehydration and rehydration of the three-2.54 cm diameter Topopah Spring tuff samples. This manuscript has been reviewed for technical content and is being revised to reflect review comments.

WBS 2.2.2.1.L WASTE FORM TESTING

A. Spent Fuel Leaching Dissolutions

Series I Cladding Containment Credit Tests, which had been terminated in March and restarted with fresh deionized water, were again terminated at 128 days on the second run. Results on the restart were similar to the first run except that suspended colloids over the bare fuel specimen settled out sooner in the second run and peak Cs activity in solution was lower by a factor of about 3.

Post test examination of the specimens showed that dried fuel particles from the bare fuel test were coated with a light colored reaction product. Fuel dissolution features were observed at grain boundaries near the particle surface. No apparent fuel surface corrosion was observed in a metallographic section from the laser punctured clad specimen.

Two new series of spent fuel dissolution tests are in progress. Series 2A (H. B. Robinson fuel in J-13 water) was started on June 19; Series 2B (Turkey Point fuel in J-13 water) was started on August 7. Both series consist of four test specimens: bare fuel, laser puncture in cladding, machined slit in cladding, and intact cladding control specimen. Samples have been taken after 1, 6, 15, and 30 days exposure for series 2B and 1, 6, 15, 30, and 62 days for Series 2A.

Initial data from Series 2A tests indicated that uranium solubility is much greater (3 ppm vs 1 ppb) in the J-13 water than in the deionized water used in Series 1 tests. The colloid phase observed in Series 1 has not been observed in Series 2A and all of the uranium in the J-13 water passes through an 18A filter. Stabilization of uranium in solution by carbonate in the J-13 well water may explain the observed solubility difference relative to the Series 1 deionized water tests.

B. Zircaloy Corrosion

The electrochemical corrosion scoping experiment, in progress, consists of bundles of spent fuel cladding wrapped with a strip of 304L stainless steel sheet and submerged halfway in J-13 well water that is equilibrated with crushed tuff at 90°C. Two, 6, and 12 month experiments were set up, with the 2-month experiment completed in September. Evaluation of the spent fuel cladding from the two month experiment should be complete about the first of November. To date the experiments are operating as expected. Preliminary observations of the cladding surface after 2 months of exposure suggest changes to the cladding surface next to the stainless steel.

C. Spent Fuel Oxidation

Initial results with the HEDL TGA system to determine its usefulness in low temperature oxidation studies of spent LWR fuel look promising. Two TGA runs were conducted at 225°C in air with a 14°C dew point on one sample of crushed fuel and one fuel fragment. The TGA system was relatively stable for a test period of over 20 days. Preliminary results indicate that oxide formation rate is not simply directly proportional to sample area.

Ceramographic examination of the pulverized fuel used in the 225°C test indicated grain boundary oxidation attack. Examination by electron microprobe and x-ray diffraction were not fruitful due to the high sample background. New sample preparation methods are being tried. An additional TGA run is in progress at 200°C with a fragment sample. A synthesized air mixture of N_2 + 20% $^{18}O_2$ is being used in hopes of enhancing post-test examination capabilities.

D. Parametric Testing

Parametric testing of DWPF 165-frit glass to determine the effects of changing glass surface area relative to solution volume were completed and showed that the glass obeyed the scaling law (SA/V)(time) in deionized water and J-13 well water. Release rates based on Li for the glass were similar in systems containing pre-equilibrated J-13 water regardless of whether tuff and/or stainless steel were present. Release rates in J-13 were about an order of magnitude lower than those found in deionized water. A manuscript "Parametric Testing of a DWPF Glass" was prepared by F. Bazan and J. Rego. An abbreviated version will be prepared for the Materials Research Society Meeting (November 1984).

The parametric test series involving DWPF and PNL 76-68 glasses (uranium-doped and actinide plus technetium-doped) in a gamma radiation field was completed. A paper summarizing the results will be presented at the Materials Research Society Meeting. Major trends noted in the data are

(1) For the DWPF glass the initial reaction with water is small and the mass loss of specimens is linear with reaction time out to 56 days. The pH of solutions decreases with reaction time from 7.1 to 6.5. This indicates that radiolytic production of nitric acid is slightly greater than the production of silica in solution due to glass dissolution.

(2) For PNL 76-68 glass there is greater initial reaction and the pH becomes more basic as reaction continues. In this case the glass dissolution dominates the pH in the early stages; however, nitric acid production moderates the pH increase for the 28 and 56 day samples and the rate of dissolution of the glass decreases.

(3) The addition of tuff to the system moderates the pH changes, indicating that the tuff is buffering the pH.

E. Unsaturated Zone Test Method

The NNWSI Waste Form Test Method for Unsaturated Disposal Conditions has been "finalized" and a technical report was prepared by J. K. Bates of ANL detailing the test procedure. The report also gives results of testing for 6.5 and 13 week tests using DWPF-165 frit glass. A test matrix is in progress that involves sampling of three ongoing tests at 6.5 week intervals for one year, and termination of duplicate parallel tests after 13, 26, 39, and 52 week exposure times. The two tests terminated after 13 weeks gave the following normalized mass losses in g/m^2 based on total weight loss, boron release and lithium release.

	Mass	Boron	Lithium
F-1	0.26	0.14	0.70
F-2	0.25	0.22	0.22

The agreement between results for the two tests and among the three measures of release rate is extremely good when the small changes that must be measured are considered (e.g., change in sample mass was 3 mg in 13 weeks for a 10 g initial glass weight).

A full size DWPF glass monolith has an external surface area of about 5 m^2 and a mass of about 1500 kg. Scaling the 13 week results to full size indicates a predicted mass loss of less than 1 part in 10^6 for a 13 week period.

F. Analog Test

The analog test utilizes a tuff rock core the shape of a right circular cylinder 5" in length and 2-1/2" in diameter, as a reaction vessel. The test was initiated by placing a mini waste package in the cavity machined in the center of the core and placing both sections of J-13 saturated tuff into a teflon sleeve. The input of water to the tuff core was supplied by a storage reservoir of water that was heated to ∿ 130°C. The inlet line was also heated. The goal was to supply the tuff core with an evenly distributed supply of water vapor. The rate of flow through the tuff core could be regulated by the temperature (pressure) of the storage reservoir. Water, after passing through the tuff core, was collected in a vented bottle for analysis of radionuclides, cations, and anions.

The results of the 90 day analog test are very similar to unsaturated test results for similar time periods. However, they are the results of only one test and may represent only a portion of possible materials interaction. Analog tests that will run for six months and one year duration are in progress. The results of these tests will be compared to unsaturated test method results.

WBS 2.2.2.2.L METALS SELECTION/TESTING

A. Electrochemical Potential Determinations

During the past quarter, the electrochemical corrosion potential was measured for different candidate stainless steels in J-13 water in a high-intensity gamma irradiation field. We were particularly interested in determining the corrosion potential shifts due to the production of a more oxidizing environment under gamma irradiation, and whether such potential shifts could induce localized pitting attack because of the relative magnitudes of the corrosion potentials and the pitting potentials of the different stainless steels.

Typical behavior for 304L stainless steel in J-13 well water under gamma irradiation at room temperature is described as follows: Upon initiation of the gamma irradiation (3.3 Mrads/hr), the corrosion potential shifts positive (more oxidizing direction) by about 150 mV. [These potentials were all

measured relative to a saturated calomel electrode (SCE).] When the gamma source is "switched off" (by moving the vessel containing the test specimen four to six feet above the cobalt-60 source in the gamma pit), the potential again increases. When the specimen is re-exposed to the source, the potential drops. This cycle is then repeated (note that steady-state was not allowed to obtain). The increase in the corrosion potential (E_{corr}) is thought to be due to the production of hydrogen peroxide (a strong oxidant) under gamma radiolysis of the water. Although the exact mechanisms occurring in the "on-off" cycle are still under investigation, when the source is "turned off", the further rise in potential may be due to "turning off the valve" for H_2 (a reducing agent) production, which is also a reaction product of gamma radiolysis of water. The net effect may be a further increase in potential due to accumulation of metastable hydrogen peroxide (H_2O_2) and a depletion (escape from solution) of H_2. As H_2O_2 is a relatively stable molecular product, once it is generated in solution, the corrosion potential of 304L remains positive when the source is "turned off".

Results similar to those for 304L were also obtained for 316L stainless steel. Again, a positive shift in the corrosion potential is observed for the 316L in room temperature J-13 water. After about 390 minutes, the experiment was terminated. The 316L electrode was removed and re-immersed in fresh, unirradiated J-13 water; E_{corr} was found to drop immediately. This experiment shows that the shift in E_{corr} found under irradiation is due to the formation of relatively stable radiolysis products which remain in solution.

After about 50 minutes at E_{corr} in the unirradiated J-13 water, one drop of concentrated 30% H_2O_2 was added and the potential was observed to shift in the oxidizing direction. The similarity between this shift and that observed under gamma irradiation suggests that radiolytic formation of hydrogen peroxide from water may account for the shift in corrosion potential. A concentration of 1.4×10^{-4} M hydrogen peroxide produced the same potential shift as was observed in the radiolysis experiment.

It appears that the production of H_2O_2 under gamma irradiation is likely the main determinate of the corrosion potential shifts observed. Successive additions of hydrogen peroxide were made to a non-irradiated J-13 in which a 316L specimen was immersed; the resulting positive potential shifts of the corrosion potential corresponded to what was observed in the irradiated J-13 environment. Experimental data indicates that while the corrosion potential of 316L is strongly affected by the addition of hydrogen peroxide to the solution, the corrosion potential is not much affected by H_2, which is also produced by gamma radiolysis of water.

Potentiostatic anodic polarization potentials in the gamma field were also obtained, as we are also interested in the effects of gamma radiolysis on pitting potentials. Polarization potentials for 316L were measured in 650 ppm chloride solution both under gamma irradiation and out of the gamma field. This Cl^- solution was chosen as it represents a solution 100x more concentrated (in chloride only) than is J-13 and the pitting potentials in this environment are clearly defined. Under gamma irradiation, the E_{corr} and E_{pit} values are 50 mV and 390 mV, respectively. This represents a separation of 340 mV. In the polarization curve determined outside the gamma

field, the corresponding values are -110 mV and +220 mV, which is a separation of 330 mV. The influence of the gamma field is therefore to shift both the corrosion potential and the pitting potential in the positive (oxidizing) direction with the same magnitude of separation between them. The similarity in the magnitude of the shift is interpreted to mean that the stainless steel is no more susceptible to pitting attack with gamma irradiation than without.

An access tube was installed in the LLNL gamma pit during the past quarter. Experiments can be conducted at elevated temperatures as the access tube allows insertion of heating elements which are isolated from the shielding water. In the coming months, the electrochemical corrosion potential and polarization behavior of candidate stainless steels will be determined over a range of temperatures.

B. Development of a More Concentrated Electrolyte

Use of stainless steels as container materials for nuclear waste in a tuff repository may be limited if the containers are contacted by a water much more concentrated in electrolyte than is J-13. An unlikely sequence of events is required for this concentration to occur. However, the performance of the material in such a circumstance should be investigated to determine the extent of degradation which would occur. Repeated episodes of water entering the repository environment and dripping onto the container with boiling and concentration of ionic species during the containment period could create this more concentrated ionic environment.

In order to investigate the corrosion behavior in the more concentrated electrolyte solutions, J-13 water was boiled down to approximately 10 times (10x) and 100 times (100x) its initial ionic concentration. Tables 1 and 2 indicate the results for anion analyses on the 10x and 100x concentrated solutions, respectively. The initial analyses of the make-up J-13 water are also given. It is observed that the 10x solution results in anion concentrations that are roughly concentrated by a fraction of ten. The 100x solution yields high results for every anion except fluoride (fluorides are generally less soluble than other salts). These results are being checked by analytical chemistry personnel. Copious precipitation is observed when J-13 is boiled down to 100x concentration. Analysis revealed this precipitate to consist mostly of calcium silicates. The pH of the 100x boil-down solution rises to about 9.8 (J-13 water is nearly neutral). This pH change may actually be beneficial to the localized corrosion performance of the stainless steel as the more alkaline environment may counter the effect of an increase in chloride ion content. A more complete analysis of the concentrated solutions to include all of the anions and cations will be performed to enable us to prepare reasonable synthesized solutions in the laboratory, as the time and water volumes required to prepare quantities of the boiled down water would be prohibitive.

Exposure of stainless steel specimens to the more concentrated electrolytes will be performed in future months to determine whether the metallic corrosion is affected by the beneficial effect of the pH increase or by the potentially harmful effect of the chloride ion increase.

TABLE 1: ANION CONCENTRATIONS IN BOILED DOWN J-13 WATER
(ION CHROMATOGRAPHY ANALYSES)

Sample	Concentration, ppm Fluoride	Chloride	Nitrate	Sulfate
J-13	2.5	7.7	5.9	19.2
"10x"	28.0	72.8	88.1	181.9

TABLE 2: ANION CONCENTRATIONS IN BOILED DOWN J-13 WATER (IC ANALYSES)

Sample	Concentration, ppm Fluoride	Chloride	Nitrate	Sulfate
J-13	2.6	7.3	7.8	18.5
"100x"	262.	1040.	1150.	2190.

C. Corrosion Performance of Stainless Steels in Wetting and Drying Situations

Work is being performed under sub-contract at Pacific Northwest Laboratory on the corrosion performance of stainless steels exposed to alternate wetting and drying conditions. These conditions create a potentially aggressive environment that could be attained by periodic dripping of vadose water onto a hot canister surface, subsequent evaporation of the water leaving an ionic salt residue, with repetition of this event many times during the containment period. In this particular test, an assembly of 40 U-bend stress corrosion specimens are exposed to J-13 water and crushed tuff rock in an autoclave maintained at 200°C and a pressure of 1000 psi. At weekly intervals, the autoclave pressure is reduced, allowing the autoclave to "boil dry". The temperature is maintained at 200°C during the "dry" cycle, as well. The autoclave is then refilled with water, and the cycle repeated. The assembly of U-bend specimens includes 304 and 304L stainless steel, all of which have been furnace heat-treated at different times and temperatures in the "sensitization" range. The U-bend assembly has now undergone 15 wet and dry cycles over the past four months. The autoclave was disassembled for examination of the test specimens. Results are summarized in Table 2.

TABLE 2 - Results of U-bend Specimens Exposed to Alternate Wetting and Drying Conditions at 200°C

Material	Heat Treatment	No. Specimens Cracked/No. Tested
304	24 Hours @ 600°C	9/10
304L	24 Hours @ 550°C	0/10
304L	24 Hours @ 700°C	0/10
304L	8 Hours @ 700°C	0/10

The carbon content of the 304 was 0.063%, while that of the 304L was 0.017%. The reason for inclusion of the heavily-sensitized, high-carbon 304 material was to induce an early failure and show the test validity in discerning sensitivity to the degree of sensitization. This is exactly what occurred in this test. The morphology of the stress corrosion cracks in the sensitized 304 will be examined, because the crack morphology is indicative of the causative mechanism. An intergranular pattern of crack formation indicates that the sensitized microstructure is the cause, while a transgranular pattern suggests that concentration of the electrolyte (especially chloride ion) is the causative agent.

A sample of the water was withdrawn for analysis. The results are given in Table 3.

TABLE 3 WATER ANALYSIS AFTER 15 CYCLES OF "BOIL DOWN" AT 200°C

Species	Concentration (ppm)	Species	Concentration (ppm)
F^-	9.4	Ca^{++}	32.8
Cl^-	47.6	K^+	3
NO_2^-	1.7	Li^+	0.27
NO_3^-	37.8	Na^+	269
$SO_4^=$	393	Sr^{++}	0.15
HCO_3^-	156	Si	64.8

The pH of the solution was 8.78 and the conductivity was 1360 micromhos.

The surface of the U-bend specimens appeared somewhat "chalky", but there were no salt deposits or encrustations present. From the results in the above table, it appears that most of the soluble ionic species - chloride, sodium, sulfate - have concentrated 6-7 times their starting concentration in J-13 well water. The more insoluble species - calcium, bicarbonate, fluoride - have evidently precipitated. Nitrate ion is likely reduced to nitrite (and other valence states of nitrogen) at cathodic sites on the stainless steel surfaces. The increase in pH is probably due to the relative increase in concentration of sodium and other alkali species over the concentrations of calcium and other alkaline earth species which undergo partial precipitation. The uncracked U-bend specimens were re-emplaced in the autoclave to attain additional exposure hours in the concentrating environment.

D. Stress Corrosion Susceptibility of Candidate Canister Materials -- Bent-Beam Specimens

The matrix study of four-point-loaded, bent-beam specimens (ASTM G-39 Test Procedure) on welded, furnace heat treated, and cold-worked alloys has reached 4000 hours of exposure in 100°C J-13 water and steam with no evidence of crack initiation in any of the specimens. The alloys include types 304, 304L, 316L, and 321 stainless steels. Parallel studies conducted on the same alloys in the cold-worked, welded, and unsensitized conditions have reached 2000 hours of exposure in the same environments with no sign of crack initiation in any of these specimens.

During the past quarter, additional sets of specimens were prepared. One set of specimens was prepared in which several different heat treatments were performed on previously cold-worked (cold-rolled) plate stock. The bent beam specimens will then be machined from this plate. Some of these heat treatments have involved rather long times at high temperatures in an attempt to sensitize the low-carbon grades of stainless. This has required times of a week at 700°C. Types 304, 304L, 316L, and 321 were given this heat treatment.

An additional plate of each of the above materials in the cold worked condition has been reserved for future use in preparing specimens for the Gleeble. The Gleeble is an instrument which resistance heats small metal coupons, usually to simulate a weld or weld heat-affected-zone (HAZ). Thermocouples are spot-welded to the specimen, which is usually of a geometry resembling a small tensile specimen. A computer program is used to establish temperature control. Temperature can be ramped up or down, stepwise, or at a constant rate. "Gleeble" specimens offer an alternative way of creating a time-temperature history in a specimen which will subsequently be exposed to the repository-relevant test environment. The "Gleeble" specimens simulate continuous cooling conditions as opposed to isothermal conditions obtained in a furnace heat treatment.

Specimens of 304L and 316L stainless steel have been heat treated to simulate conditions which a fabricated canister would experience during the waste form filling and storage operations. Cold worked material is given a 15 minute treatment at 1000°C (to simulate welding), followed by either a water or air quench, and this followed by a treatment at 250°C to produce a "low temperature sensitization". The purpose of this sequence of treatments is to effect a structure representing the combinations of cold work (fabricated canister for spent fuel), high-temperature exposure and cooling (closure weld) and low-temperature exposure (storage in the repository). Further, some additional specimens are given an 800°C treatment for 17 hours to simulate the glass casting operation for the vitrified waste forms. Another group of specimens has been given the same heat treatments, but without the prior cold work. Tests run on this group of specimens will determine the effect of cold work in nucleating sensitized (chromium-depleted) areas in the stainless steel.

In addition to considering the sensitization effects, formation of sigma phase is of concern. Sigma phase is an ordered solid solution whose fracture toughness is significantly less than that of austenite. Sigma phase formation is favored by high concentrations of chromium or molybdenum (the latter forms a similar chi phase) in steel exposed to relatively high temperatures (greater than 700°C) for long periods of time. Some specimens of 316L stainless steel have been heat treated at 750°C for up to two weeks in an attempt to produce a sigma phase and determine its influence on the stress corrosion susceptibility of the steel in the J-13 water test environment. Since optical metallography did not conclusively reveal the presence of sigma phase, transmission electron microscopic (TEM) examination of the specimens is underway. As in the different heat treatments used in attempting to effect a "sensitized" microstructure, rather extreme treatments are given to the specimens in an attempt to effect a sigma phase. These extreme treatments subject the specimen to higher temperatures and for longer times than the actual processes to which canister materials will be exposed. However, the lengthy time at moderately elevated temperatures (decades at 200-300°C in the repository after

emplacement) may effect these kinds of microstructure. In any event, the intent here is to produce these "extreme condition" microstructures and to determine the tendency of these different microstructures to initiate stress corrosion cracking.

A test matrix for preparing stress corrosion specimens on the Gleeble has been planned. Types 304, 304L, 316L, and 321 stainless steel specimens will be heated to 900°C and cooled at accurately controlled rates of 0.2, 0.5, and 1 °C/sec. The specimens will be simultaneously strained 2%. Literature references have indicated that this combination of thermal cycling and strain produces sensitization in high carbon 304 stainless steels. Type 304 stainless steel specimens are included in this stress corrosion study in an attempt to produce an early failure, thereby enabling the test sensitivity to be estimated. An interesting effect may be produced in the titanium-stabilized 321 stainless steel in that the proposed time and temperature in the Gleeble may favor formation of the microstructure that gives rise to "knife-line attack" - the corrosion occurring in a very narrow region adjacent to a weld when this material is exposed to oxidizing aqueous environments. Gleeble-prepared 321 specimens may show a much broader region of attack because the chromium carbide precipitation occurs over a much broader region than in conventional welded specimens.

E. Slow-Strain-Rate Stress Corrosion Susceptibility Tests

Five slow-strain-rate tests were recently completed. Emphasis is being place on a strain rate intermediate to those used in the past to determine whether such an intermediate strain rate will distinguish between sensitized and non-sensitized material as well as the slow strain rate used previously. The intermediate rate is 5×10^{-6}/sec, compared to the previously used rate of 2×10^{-7}/sec. If the intermediate strain rate proves useful, the 1-month test required at 2×10^{-7}/sec could be reduced to a test of a few days' duration. So far reference data has been obtained, i.e., data using air environments and non-sensitized steel in J-13 water. Heavily sensitized specimens (24 hours at 600°C) of high-carbon 304 stainless steel will be exposed to the J-13 test environment to indicate the sensitivity of this intermediate strain rate in indicating stress corrosion susceptibility.

F. Corrosion of Copper and Copper Containing Alloys in J-13 Water and Steam

Because of the recent interest generated in examining copper-base materials as possible nuclear waste containment materials, we began a survey experiment of their corrosion performance in the J-13 well water environment and in the saturated steam phase directly above the water at 100°C. For this preliminary experiment, we exposed three coupons each of CDA 110 (Electrolytic Tough Pitch Copper), CDA 706 (90/10 Cupronickel), CDA 715 (70/30 Cupronickel), and for comparison Monel 400, to the water and another three coupons each to the steam. We followed the same ASTM G-1 and G-31 test procedures for the copper-base material weight-loss coupons as we use for the stainless steel coupons. The copper-base coupons are exposed in a different cell from the stainless steel, because of possible cross-contamination of the different corrosion products from the dissimilar metals.

The copper weight-loss coupons were examined after 3000 hours of exposure to the water and steam environments. As expected, the coupons were covered by corrosion products which on the high-Cu materials was an opaque black oxide film. The Monel 400 specimens developed a thinner, transparent film during the same exposure period. Copper and copper alloys often show a decreasing rate of corrosion/oxidation with exposure time because of the protection given to the metal by formation of the oxide films. For this reason, we decided to leave two of the three specimens with the film intact, while we cleaned off the film on the third specimen and determined the corrosion rate by the weight loss.

The corrosion rates of the different materials in the water and in the steam are given in Table 4. The values given in Table 4 were determined for single coupons of each alloy in each environmental phase. As expected, the cupronickel coupons showed lower corrosion rates than the essentially pure tough pitch copper (CDA 110). The Monel specimen actually showed a weight gain. All of these coupons had been cleaned according to the ASTM G-1 procedure for copper and its alloys. The cupronickels are generally more corrosion resistant in oxidizing environments (such as J-13 water) than the pure coppers. Monel (a nickel-base alloy containing about 32% Cu) is quite resistant to corrosion in aggressive aqueous environments. The coupons which had been weighed were then re-emplaced in the test cells along with the other coupons which had not been examined. The next planned inspection will be after 6000 accumulated exposure hours in the test environments. During this inspection, the previously cleaned specimens can be compared to those which had never been cleaned so that the protective role of the black oxide film can be determined.

TABLE 4 Corrosion Rates of Copper-Based Materials Exposed to J-13 Well Water and Steam at 100°C. 3000 Hours of Exposure.

Alloy	Corrosion Rate (μm/yr)	
	J-13 Well Water	Saturated Steam
CDA 110	3.11	4.22
CDA 706	2.10	0.90
CDA 715	0.28	0.50
Monel 400	0.02	-0.64 (wt. gain)

The amount of localized corrosion was also determined for each alloy tested. As with the corrosion testing for stainless steels, slotted Teflon washers were used to create an intentionally creviced area on each coupon. The maximum localized penetrations were found in this creviced region during the 3000 hour exposure period. Expressing these localized penetrations on an annualized basis, the rates fall in the range of 40-150 μm/yr and are considerably in excess of the general corrosion rates given in Table 4. These results suggest that the principal degradation mechanism for the copper base materials would be a localized penetration which would eventually perforate the canister wall. Subsequent exposure and inspection of these coupons should indicate whether projections of these localized penetrations do indeed dominate the corrosion attack.

For comparison purposes, the general corrosion rates of carbon steels (1020 and A-36) are 27-30 μm/yr in J-13 water and 10-13 μm/yr in steam at 100°C with annualized localized corrosion rates on the order of 150-260 μm/yr in water and 160-185 μm/yr in steam. Austenitic stainless steels (304L, 316L, 317L, 321, and 347) show general corrosion rates of 0.025-0.380 μm/yr in J-13 water and 0.25-0.56 μm/yr in steam with annualized localized corrosion rates from none discernible to 0.045 μm/yr in water and from none discernible to 0.372 μm/yr in steam. As expected, the corrosion rates for the copper-based alloys fall intermediate between those for carbon steel and those for the stainless steels in the oxidizing J-13 water and steam environments. The copper-based materials containing substantial quantities of nickel, as well as the nickel-base material containing substantial copper (Monel 400), are significantly more corrosion resistant than unalloyed copper in these test environments, with the corrosion rates of the 70/30 cupronickel and Monel 400 approaching those of the austenitic stainless steels. It should be emphasized that the corrosion data for copper are based on results from single specimens, while those for the carbon steel and stainless steel are based on results from multiple specimens.

WBS 2.2.2.3.L OTHER MATERIALS

Work is continuing at the USGS (Menlo Park) on measurements of the permeability of Topopah Spring tuff in a temperature gradient. They are investigating the effects of pore pressure, sample orientation, and flow direction on the permeability of the tuff and the fluid chemistry of the water. The temperatures and pressures of the experiments were chosen to approximate those expected at the repository level. To date, the permeability experiments and the chemical analyses of the discharged fluids have been completed. The analysis and interpretation of the chemical data is in progress.

A mixture containing 95% crushed Topopah Spring tuff and 5% silica gel was prepared during September. Experiments will be conducted during October to determine whether the silica gel improves the quality of compressed samples.

WBS 2.2.3.L PACKAGE DESIGN

A. Design

The conceptual design for spent fuel space frames was revised to reduce weight and cost. Criticality control is provided by the use of neutron absorbing poison rods consisting of boron carbide slugs in 1/2 inch diameter Zircaloy tubes. Spaces around the square-holed space frame are left open to allow thermal radiation heat transfer, and to reduce weight and cost. Space frame weight has been reduced from about 6000 lb to 2500 lb. Weights vary for PWR/BWR and as a function of fuel rod length.

In order to obtain commercial cost estimates for spent fuel canister space frames, detailed drawings were prepared for BWR and PWR space frames. The PWR drawing was sent to fabricators for detailed cost estimates for quantities of 200 per year each of 3 lengths (total 600/yr). These estimates will be available in late October, 1984.

The report "Preclosure Analysis of Conceptual Waste Package Designs for a Nuclear Waste Repository in Tuff" was forwarded to DOE/NV on September 25.

B. Thermal Modeling

Two thermal calculations were made for the current vertical emplacement canister design configuration with 10 year-old PWR spent fuel. In each case, borehole and canister diameters were 76.2 cm and 70.0 respectively. One case considered the canisters emplaced with a package pitch of 8 meters and a drift pitch of 30.5 meters, and for the other case the package pitch was 5 meters and drift pitch was 46.9 meters. In both cases the maximum allowable waste temperature (350°C) was not exceeded.

The above calculations were made in two stages. The first stage was a calculation to determine the borehole wall temperature history using the three-dimensional computer code TACO3D. The computer model consisted of a spent-fuel-like heat source inside the borehole surrounded by tuff with appropriate symmetry planes between boreholes and between drifts. A linear analysis was made using dry tuff thermal properties and an initial tuff temperature of 25°C. The second stage of the calculation modeled the waste package inside the borehole and used the temperature history of stage 1 as a boundary condition at the borehole wall. A two-dimensional, variable property, infinite cylinder model using the computer code TACO2D was subsequently used to calculate the thermal history of the waste package canister walls.

A three-dimensional calculation utilizing the TACO3D code was begun for a vertically emplaced PWR spent fuel canister with very detailed mesh of the latest space frame configuration. When some inconsistent calculated values resulted, debugging efforts involving parameters in the mesh and calculating code input were undertaken. A consistent solution is expected in October.

C. Structural Analysis

Using DYNA3D, a three-dimensional analysis was begun on a horizontal fully-loaded spent fuel canister dropped 40 inches onto a 6 inch diameter vertical steel post. Inconsistencies in the results as compared to hand-calculations has resulted in debugging efforts, mainly involving the DYNA3D input deck.

The report "Structural Analysis of Conceptual Waste Package Designs for a Tuff Repository" draft has been revised and is currently undergoing QA review. Due to the peer reviews taking longer than anticipated, the final revision of this report will be finished and forwarded to DOE/NV in October.

D. Economic Analysis

A spread-sheet program has been completed which estimates waste package and related repository costs for the current reference and some alternative canister designs in vertical emplacement configuration. The program and a summary of calculations was published in the conceptual design report. Additional details of this program will be published in the economic analysis report which will be available in December.

E. SNLA/A-E Integration

Leo Scully and Robert Stinebaugh (SNLA) visited LLNL to discuss FY85 waste package design and integration with SNLA/A-E. Follow-up letters were exchanged to determine the distribution of tasks.

WBS 2.2.4.L PERFORMANCE ANALYSIS AND TESTING

A. PERFORMANCE ANALYSIS

WAPPA review and verification studies continued to determine the applicability of the previously developed code to the performance analysis of waste packages emplaced in unsaturated tuff. During the past quarter several changes and additions have been made to the mechanical submodel (FMODEL) to examine and extend its capabilities. First, the stress components are now calculated at the outer radius of a metal barrier as well as at the inner radius. The inner radius is the more critical for the primary load case expected in a salt repository (i.e., lithostatic pressure); however in the absence of such external pressures (i.e., expected NNWSI emplacement conditions), stresses at the outer radius must also be considered. Second, WAPPA's detailed system diagnostic printout was not operational. A small program change allowed this diagnostic information to be printed and examined. Third, the crack rupture and stress corrosion crack growth submodels were not originally activated because no provision existed to read the initial crack size; this input has since been added. Stand-alone tests of FMODEL and the crack-related failure modes have been completed. FMODEL now performs as described in the WAPPA Users Manual (ONWI-452), but some problems remain at the system level in tracking barrier property changes subsequent to an outer barrier crack failure. A draft report, documenting the results of this study, is now in preparation.

Several initial elements in the Waste Package Flow/Transport Modeling Work Plan have been completed. The WAFE code, developed at LANL by B. Travis, is now operational on the LLNL Cray computer system and a sample problem supplied by LANL, has been successfully executed. Initial test problems have been defined to exercise WAFE and will include the reanalysis of the preliminary 1-D waste package study completed in a joint LLNL/LANL effort. Successful execution of these two test problems will provide a starting point for future efforts to model porous flow within the waste package. In preparation for these analyses it will also be necessary to define the boundary conditions which characterize the waste package emplacement environment. LLNL will host a coordination meeting next month with LANL and LBL to define a common problem for modeling this near-field environment using NORIA, TOUGH, and WAFE. An FY84 progress report, in preparation, summarizes the status and plans for modeling porous, hydrothermal flow/transport on the waste package scale.

The analysis of non-porous flow within the waste package has been discussed with T. Pigford (UCB) and S. Pawah (INTERA). LLNL and INTERA staff met in Houston to define several generic falling fluid problems which could impact the performance of a waste package in the unsaturated zone. It was agreed that the first phase of this effort should focus on a calculation of flow path, volume, and residence time along a non-porous cylinder. A preliminary study of these mechanisms will be initiated in FY85.

The first phase of an effort to model matrix diffusion of radionuclides through Topopah Spring tuff has been completed. Solution concentration data for this analysis was obtained from the LLNL/SRL saturated release tests of the DHLW waste form. Preliminary results were presented in October at the ORNL Workshop on "The Application of Geochemical Models to High-Level Nuclear Waste Repositories" in an abstract entitled "Matrix Diffusion Coefficients for the NNWSI Waste Package Environment" by K. G. Eggert and M. A. Revelli. Further analyses are planned to determine the effect of highly soluble caliche material in the tuff sample.

Waste package staff prepared a presentation for the Performance Assessment National Review Group (PANRG) describing the experimental work and modeling being done at LLNL to determine the radionuclide source term for NNWSI Performance Assessment.

A pre-baseline review of the "Generic Requirements for a Mined Geologic Disposal System" document, Volume I, July 6, 1984 was completed. Comments were forwarded to SNL for inclusion in the NNWSI project response.

Members of the waste package technical and QA staff met with Ms. Nina Thomas and Ms. Betty Paul (SAI-Lynchburg) to outline the software QA plan being developed for NNWSI, review the documentation requirements identified in NUREG-856 and discuss how these categories of documentation should be applied to the various levels of software used within the project.

B. PERFORMANCE TESTING

M. Revelli, K. Eggert, and J. Yow met with Nancy Hayden (SNL) early in the quarter to discuss transport codes for near-field hydrologic and thermal calculations. Computer codes such as WAFE or TOUGH will be used in scoping calculations to make an initial estimate of the environment to be expected in the rock mass near an emplaced waste package. These estimates will in turn be used in developing Waste Package Environment Test geometry and design details.

Several activities this quarter were related to the high frequency electromagnetic (HFEM) geotomography measurements that were conducted earlier this year in G-Tunnel. Such techniques may be used in the Waste Package Environment Tests to monitor spatial changes in saturation of the rock. In this part of the work, borescope surveys of the post-experiment boreholes were performed to detect fractures in the plane of the HFEM geotomography measurements. Borescope logs and the experimental geophysical results were then used to infer paths of tracer flow during the HFEM field trials. Anomalies seen in the geotomographs appeared to closely match the fractures present in the plane of the HFEM measurements. A model of the inferred flow paths was also developed with which synthetic tomographs were generated. This confirmed that the inferred flow paths could produce the image anomalies observed in the real tomographs.

A draft report describing the use of HFEM geotomography techniques in fractured, welded tuff was completed and subjected to internal review this quarter. "Study of Waste FLow in Welded Tuff using Geophysical Tomography," by A. Ramirez and W. Daily, describes the HFEM measurements made in G-Tunnel at NTS and their analysis and interpretation. The report will be forwarded to WMPO for review in October.

Consideration of other types of instrumentation and sampling techniques continued during the fourth quarter of FY84. These techniques fall into the general areas of subsurface hydrology and geomechanics, in keeping with the broad scope of the Waste Package Environment Tests. This work will continue and scoping calculations for experiment design will be commenced in FY85; ;the latter is closely related to the numerical modeling being planned for the Waste Package Performance Analysis subtask.

WBS 2.3.1.9.L - GEOCHEMICAL MODELING CODE EQ3/6

D. Emerson/T. Wolery, P.I.

GENERAL

A back-up archival copy of the shared EQ3/6 development directory was created and will be updated monthly.

Code Development

A random-access (r/a) capability was added to the MCRT thermodynamic data-base preprocessor code. A unified master data file, MDAS, written in serial format has been created to incorporate and replace the existing individual data files that had been created element-by-element as the data base has been expanded over a period of several years. This data file contains all the necessary documentation to comply with Q.A. procedures. A new utility, BMDR, is used to convert MDAS to MDAR, the random-access format master data file. The user may edit the random access data file directly using the MDAP utility, and then write the file back to serial format using BMDS, to ensure consistency with all data files.

The MCRT code was modified to accept the random access data file in place of three previous data files that were needed to run the code in the old format. Additional changes were made to the code so that an OUTPUT file is generated that catalogs all data-base errors, and permits the user to correct all errors after one run. This represents a significant modification to the MCRT code which originally stopped after encountering an error.

All coding for the precipitation kinetics option was completed last quarter, yet completion of this module was significantly delayed by EQ6 problems described below. All test cases were generated, but not verified during this period.

An EQ6 option called "super economy" mode was installed.

Data Base Development

Data base documentation, revision and expansion activities for FY84 were completed and incorporated into the on-line EQ3/6 data base this period. Two separate data base projects were contributed to by two summer-hire employees. In one project, ion-pairs and complexes of the "major" geochemical species H^+, Na^+, K^+, Mg^{2+}, Al^{3+}, $SiO_2(aq)$, Cl^-, OH^-, SO_4^{2-}, CO_3^{2-}, and HCO_3^- were

the focus of effort and 20 species were added while the data for 17 more were revised. This work was especially important because the old data lacked documentation. In addition, 8 acetate and 8 phthalate species were added; this data is intended for use in modeling experiments using acetate and phthalate pH buffers. These data have been incorporated into the new random-access MCRT data file MDAS.3245S26. The new updated version of DATAO will be with the 3245 version of EQ3/6 which is expected to be ready for release in early FY85.

The second project involved constructing thermodynamic data bases for thorium, tin, selenium, chromium, cobalt, and nickel in order to support future work on the modeling of canister corrosion experiments. MCRT data files were generated at the University of Colorado, transmitted via remote link to the LLNL MFE Computer Network, and checked for internal consistency before being added to the master data file. Thus far, thermodynamic data for 129 aqueous species and 136 solid species have been incorporated into the random-access MCRT data file, with about half the total MCRT data remaining in element by element files, including the Colorado work.

Code Documentation

The EQGRAF User's Manual was completed this period.

All changes to the MCRT preprocessor code and its supporting data files have been documented and are being incorporated into the MCRT User's Manual, a deliverable for which work is continuing. The majority of the code maintenance problems that surfaced this period required the sole attention of T. Wolery, resulting in the delay of this document.

Code Maintenance

The EQ6 code was down for an extended period this quarter A summary of the major problems are outlined below:

1. Computational anomalies were suspected in the finite-differences coding in EQ6. Testing showed this was actually okay, and that the problem lay in the design of economy mode. This mode was then restructured and now operates well.

2. Some EQ3/6 convergence problems were traced to ITREF, the linear system iterative refinement routine in the EQLIB library. It was necessary to write a largely new routine called ITREFN to overcome the problems.

3. The pre-iteration optimizer, used mainly with the new "economy" mode, proved inadequate and was extensively overhauled. It now works satisfactorily.

These problems delayed all deliverables this period by putting all testing and application work on hold until the EQ6 code could be overhauled.

WBS 2.5.2.L ENVIRONMENTAL ASSESSMENT

LLNL waste package staff completed a review of Section 6.3.2 (Version 6-Sept-84/EA6C), "Postclosure System Guideline" and two reviews of Section 6.4.2 (Version 26-Aug-84/EA6C), "Preliminary Analysis of Postclosure Performance" of the August 1, 1984 draft of the NNWSI Environmental Assessment. D. Alexander (HQ) offered several comments to the waste package staff regarding Section 6.4.2; his comments and LLNL concerns were transmitted to WMPO/NV. In a separate review of Sections 6.3.2 and 6.4.2, requested by M. Spaeth (SAI), several technical, typographical and logical errors were identified; a summary of page-specific comments was forwarded to WMPO/NV.

WBS 2.6.5.2.L EXPLORATORY SHAFT TEST PLAN

Revision of the Waste Package Environment Test conceptual test plan continued at a low level of activity during the fourth quarter of FY84. The ESTP Committee met once this quarter, on August 16 and 17 in Las Vegas.

Only limited revisions (resulting from the LLNL internal peer review) have been made in the current internal (LLNL) version of the plan. No revisions have yet been made in the version that is included in the ESTP. This work has been delayed by a lack of complete review comments from the March, 1984 WMPO/TPO/ESTP Committee review of the ESTP.

Revision of the Waste Package Environment Test portion of the ESTP will proceed as soon as the remainder of the review comments from the March ESTP retreat are received. In the interim, the current internal version of the conceptual plan for the Waste Package Environment Tests will be revised and issued as an informal LLNL report.

WBS 2.7.1 - SPENT FUEL TEST-CLIMAX

W. Patrick, P.I.

SUMMARY

Following completion of field activities at the SFT-C late last quarter, staff efforts have been directed toward documentation and analysis of test results, transducer calibrations, and laboratory analyses of post-test samples. In situ stress and deformability data were analyzed and three draft reports were prepared. Two reports of radiation dose to granite measurements were completed. The radiation data was also analyzed in the context of pretest calculations of radiation dose and the results of this comparison were documented. A statistically designed test of the effect of intense gamma irradiation on the strength and deformability of Climax stock quartz monzonite was also completed. A new effort was initiated to compare the excavation-response data, which was obtained during the Climax mine-by, to the calculated permanent displacements which are produced by detonation of high explosives.

GEOLOGICAL CHARACTERIZATION

Post-test geological characterization aims to document changes which may have occurred as a result of spent fuel storage and extensive heating of the rock. It also acquires certain critical in situ stress data which were not obtained prior to initiation of heating because of the time constraints on the project.

In Situ Stress Measurements

The draft final contractor report on measurement of the in situ state of stress at the Climax stock was peer reviewed and approved for publication. This report documents an extensive campaign of in situ stress measurements which were conducted between June-September 1983 and February-April 1984. In addition to determining the "undisturbed" state of stress far from the underground openings, the measurements program also examined the influences of heating and the presence of nearby underground openings on the state of stress.

It became evident during the in situ stress measurements that data variability was quite high and, in general, was greater than could be attributed to experimental errors and such factors as anisotropy of deformation moduli (as measured on the overcored rock specimen). A study has been undertaken to determine the influence of nearby geological features on the measurements. Discussions were initiated with members of the University of Illinois faculty who are currently examining how alteration zones in a rock mass may influence the measurement of in situ stresses. Geological logging of borehole ISS-11 was completed in support of this study. If geological structures can be identified which are closely related to the observed variations, it may be possible to describe the rock mass as several "domains" in which different stress regimes exist.

In Situ Deformability

The deformability of a rock mass, in concert with the state of stress in that mass, determines the magnitude and orientation of displacements and stress changes which occur due to mining, heating, and related disturbances to the mass. Significant progress was made this quarter using the results of two different techniques to measure the rock mass deformability.

First, analysis of post-test borehole deformation modulus data was completed. The results of this study indicate that the deformation modulus is decreased in the vicinity of boreholes where the rock was heated to about 60° to $65^{o}C$ for a period of three years. This observation led to consideration of lower temperature effects on the rock mass. Most of the rock mass was heated moderately to about 30° to $35^{o}C$ during the three-year period. Since the effect was small in comparison to the variability of the rock mass (even at 60° to $65^{o}C$) it was important to study possible effects of moderate heating with pretest and post-test data from the same region. Four borehole segments in the pillars were the site of pre-test and post-test measurements. Since the published pretest values were processed with a different data reduction scheme than is currently recommended, it was necessary to go back to the raw data and reanalyze it. Comparisons of these

data reveal no consistent change in the deformation modulus due to moderate heating at 30° to 35°C. A draft report on these studies was completed and peer reviewed. Based on the results of the reviews, additional statistical analyses of the data have been undertaken.

The analysis of borehole jack data also raised questions concerning the validity of recommended data reduction procedures. The recommended procedures, which are contained in a proposed ASTM Standard, appear to severely bias the data to lower modulus values. While the Goodman jack has a long history of development and evaluations, these evaluations and associated "corrections" have, to date, been applied in a piece-wise manner rather than as a composite.

Given the importance of deformability data in the calculation and analysis of rock responses to excavation and heating, the original scope of the in situ deformability measurements was extended to include laboratory testing of the response of the jack. Initial evaluations will be made by testing the jack in a large cubical aluminum block. Procurement actions were completed late this quarter to obtain the block. Techniques for heat-treating the block and for boring and sequentially enlarging the test borehole were established. A test procedure is currently under development with a planned start of testing in late November to early December .

Second, analysis of seismic survey data is nearing completion. Spectral analyses of shear waves acquired during the "petite sismique" survey were completed. A potential "aliasing" problem was identified which required a frequency response calibration of the signal enhancement seismograph used for this field study. In addition, it was necessary to determine the transducer response to pure impulses and to shaker table tests at higher frequencies than were used during transducer calibration. The results of these tests established that signal aliasing was not a problem.

The results of the petite sismique survey indicate that several factors, which were not treated by previous investigators, influence the frequency content of the shear waves. Probably most significant, the shear wave source had a profound influence on both the frequency and energy content of the shear waves. In addition, shear wave dispersion was seen to be path-length dependent.

While the petite sismique technique operates in the frequency domain, the method of data collection facilitated calculation of the dynamic moduli of the rock mass in the time domain. The in situ dynamic moduli values were found to be similar to the laboratory static moduli values.

A draft report documenting the techniques employed and the results of this study was prepared, peer reviewed, and submitted to the WMPO/NV.

Geological Sampling and Mapping

Preparation of a complete database containing the results of post-test core logging was initiated. A database format was established and over 80% of the pertinent fracture characteristics and orientations have been entered into the database. These data will form the basis of a report on the post-test drilling and sampling activities.

Technical and project reviews of the revised draft report "Structural Geology of the SFT-C" by D. Wilder and J. L. Yow, Jr. were completed. Suggested technical changes have been incorporated in the draft and it is being edited prior to submittal to the WMPO/NV.

Thermal and Radiation Effects

A laboratory study was completed on the effects of gamma irradiation on the strength and elasticity of Climax granite. The results of this study are documented in "The Effect of Gamma Irradiation on the Strength and Elasticity of Climax stock and Westerly Granites" (W. Durham, J. Beiriger, M. Axelrod, and S. Trettenero). Radiation effects were not anticipated on the laboratory scale, but a study was conducted two years ago to confirm the expected null effect. Surprisingly, a statistically significant effect was observed. Because the data set was highly variable and because of the unexpected nature of the result, the experiment was repeated this year. The second study was statistically designed and included Westerly granite as a known low-variability rock type. No radiation effect was observed on strength or elastic moduli of either the Climax quartz monzonite or the Westerly granite.

The development of microfractures may be a valuable precursor for studying possible thermal and radiation damage in crystalline rocks. This technique has been applied to study drilling damage and the effects of laboratory irradiation on samples of Climax granite. The effects of in situ heating are now being studied using samples obtained at various positions radially outward from each of two heated boreholes. Because the effect is presumed to be slight and because the natural variability of microfracturing is quite high in the Climax quartz monzonite, the samples were obtained from near the auxiliary heaters where temperatures reached 300°C; much higher than near the spent fuel canisters and electrical simulators where temperatures did not exceed 85°C. The results from these samples will be compared with pretest unheated samples which were obtained immediately adjacent to the post-test samples.

The required SEM photographs of microfractures were obtained, processed with an image analyzer, and pertinent crack statistics were developed. Detailed statistical interpretation of the data has been undertaken to support the physical and logical arguments presented in the draft report. As notified above, previous microfracture studies of this rock have shown that rather sophisticated statistical treatment of the data is required because of the high natural variability of microfracturing.

In addition to the microfracture analyses, changes in the mineralogy and petrology caused by heating and/or irradiation are also being studied. Cursory examination of post-test geological samples obtained near auxiliary heater boreholes revealed no influence of heat on the rock mineralogy or petrography. Neither samples located in "dry" areas nor those near seeps showed discernable alteration. Examination of canister emplacement hole samples has just begun, following receipt of the first set of thin sections from the vendor late this quarter. Once again, adjacent pretest and post-test samples will be compared.

RADIATION DOSIMETRY

Documentation of the radiation dose received by the rock mass in the vicinity of spent fuel storage boreholes was completed with the final peer review, approval, and submittal for publication of two reports. These reports are titled "Climax Spent Fuel Dosimetry, Short Term Exposure" and "Climax Spent Fuel Dosimetry Progress Report, September 1982 - January 1984", both by W. Quam and T. Devore.

In addition to documenting the radiation absorbed dose for the particular configuration of the SFT-C, these data form the basis of comparisons with calculated radiation doses. This comparison reveals that radiation doses can probably be calculated much better than they can be measured using currently available long-term dosimetry. However, careful definition of the source term and "calibration" of the model using short-term dosimetry are important to obtaining good calculational results. A report documenting this study was submitted to NV/WMPO following peer review.

POST-TEST CALIBRATION AND INSTRUMENTATION EVALUATION

Calibration and evaluation of transducers deployed on the SFT-C is essential to confirming the quality of the data acquired during the test. The instrumentation evaluations will also form a basis for selection of instrumentation for future in situ testing.

Temperature and Power Transducers

Analysis of post-test calibration data was completed for three of four classes of temperature transducers which were deployed at the SFT-C. Resistance temperature devices (RTDs), thermistors, and the specially designed temperature sensors for the convergence wire extensometers were all found to have performed at the anticipated levels of accuracy and stability. Thermocouple data remains to be analyzed.

Analysis of pre-test and post-test calibrations of Watt transducers revealed that slight changes in slope and offset occurred during the three-year test period. The shunt resistors used in these calibrations (the only plausible source of calibration error) were themselves recalibrated. Based on these results, minor (insignificant) changes in the Watt transducers did occur.

Stress and Stress-Change Instrumentation

A new technique was utilized to calibrate IRAD vibrating-wire stressmeters. The stressmeters were retrieved by overcoring so that they could be calibrated in the laboratory while they were still located within the same section of rock. The recovery process was not totally successful because geological discontinuities resulted in stressmeter cables being broken and the cores splitting. Laboratory calibration of the six stressmeters which were successfully recovered was completed. The draft report was prepared and is being reviewed internally prior to submittal to the WMPO/NV.

Two extensive campaigns of in situ stress measurements were conducted at the SFT-C. An apparent hysteresis response was observed during field calibration of the subcontractor's USBM overcore cells which were used to make over half of the stress measurements (the other measurements were made with a different type of cell). In addition, the standard calibration procedure was determined to be inadequate. An investigation of these problems is in progress.

A device was fabricated to study the hysteresis response and to provide an adequate laboratory calibration of the USBM gauge. An initial set of data was obtained late this quarter using the calibration device. Analysis of these data is awaiting completion of the data processing software. In addition, a set of data was obtained using the standard calibration technique to confirm that the phenomena occurred in the overcore cell which will be used in the investigations. Hysteresis on the order of hundreds of microstrains was observed. This is of the same magnitude as the gauge response to overcoring and, therefore, is very significant.

Displacement Instrumentation

All displacement transducers and associated laboratory calibration data sheets were obtained from the subcontractor. This completes the actual calibrations and makes the data available for analysis of the reliability of these transducers.

A potential problem with the long-term stability of the MBI-series borehole extensometers was detected in the rod- and anchorage-integrity testing data. This data was obtained as part of the post-test instrumentation analyses. The reference plug which the instrument transducer contacts was found to slip, with respect to the connecting rod and anchor, under certain conditions. A test procedure was prepared to evaluate the stability of the reference plug in the laboratory. Necessary test components were obtained from the SFT-C and are being prepared for testing.

The support electronics for the microadjuster, which was used to field calibrate multiple-point borehole extensometers, has been repackaged in a more rugged, field-worthy rack. This, along with cabling changes, will provide a more reliable, directly shippable system.

POST-TEST CALCULATIONS

Several attempts have been made to model the complex rock responses which were observed during the "mine-by" experiment which was conducted at the SFT-C. Scoping calculations using the one-dimensional code SOC have indicated that the observed displacements may result from blast-induced permanent deformations of the rock mass. The displacements recorded by the horizontal extensometers agree very well with the calculated response to mining the "bench" of the canister drift.

Attempts to model the more complex geometry associated with mining the top heading have not yet been successful. The one-dimensional approach was judged to be inappropriate to use in this case, a judgment which was confirmed by gross disagreements between measured and calculated results. Numerical instabilities occur during attempted solution of the problem using the two-dimensional code TENSOR. A new approach has been identified which should avoid these instabilities. The approach will be evaluated next quarter.

DATA MANAGEMENT

Peer review and final comments have been received on the report titled "REVERT: A CDC 7600 Program for Converting SFT-C Data to Engineering Units, with Corrections" by G. Hage. Comments are being incorporated in the draft in preparation for publication as an LLNL informal report.

FIELD SYSTEMS AND DECOMMISSIONING

Components of the data acquisition system (DAS) were reconfigured and reracked to form two stand-alone systems. These systems will be used to analyze SFT-C data and for development work on this and other Earth Sciences Department projects.

C. Washington (USGS, Denver) requested use of a digital multimeter (DMM) and scanner chassis from the SFT-C data acquisition system. These two units were loaned to the USGS on August 7, 1984 pending a determination that the equipment is compatible with their data acquisition activities at Yucca Mountain. The required equipment will be transferred to the REECo property management group for long-term loan to the USGS when the compatibility of the SFT-C equipment is established.

Public Information

Transfer of responsibility for routine tour support to DOE/NV-OPA is complete. Briefing notes were revised and a "fact sheet" was developed and forwarded to OPA to assist in this transition.

The SFT-C documentary film was revised to include information obtained during storage, retrieval, and post-test evaluations at the site. At the request of DOE/NV-OPA, the script was revised to the standard "English" units of measure, rather than the previous international metric units. Production of the updated SFT-C documentary film was completed and a distribution list was established under advisement from DOE/NV. Copies of the film will be prepared and distributed next month.

WBS 2.9.4.L - QUALITY ASSURANCE
J. Dronkers, P.I.

The Quality Assurance Program Plan for NNWSI is progressing smoothly. A meeting was held with NNWSI project personnel to provide comments and suggestions. J. Dronkers has been working with NNWSI Task and Subtask Leaders on the generic portions of the plan for submittal to NNWSI by October 31.

Work continues on software QA procedures. Various types of software have been identified and procedures are being developed to cover these programs, as well as a level specific plan for the project. L. Trent will be leaving NWMP as Software Quality Engineer and his contributions will be sorely missed.

The development of the Records and Documents Procedure has begun to accelerate with the arrival of B. Smith. Her tasks are to begin the current records inventory and the acquisition of the INMAGIC software for the records filing system. INMAGIC uses an inverted filing system to hold information about the physical record and can generate reports, indexes, and searches on the file data. A first draft of the actual procedures will be submitted for project review on November 5. An initial test run of the software with a sample database was conducted with only minor bugs in the search demonstration.

Two representatives of SAI's Lynchburg, Virginia office met with NWMP personnel at LLNL on August 3. The purpose of the meeting was to clarify the requirements of NUREG-00856 as they apply to NNWSI projects.

J. Dronkers attended the Eleventh Annual National Energy Division Conference in Las Vegas from September 16-19. A report on this conference is available through the LLNL NWMP Project Leader's Office. J. Dronkers also attended the NNWSI Project Quality Assurance Committee (PQAC) Meeting in Las Vegas on September 20.

Meetings on the Records and Documents Procedures have been held with representatives of the LLNL Technical Information Department. The purpose of these meetings is to develop the filing and subject categories for the NWMP QA Records File.

RB
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Lawrence Livermore National Laboratory

MILT

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8 October 1984
NWM:84/5972C

Donald L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

SUBJECT: September 1984 Monthly Report - LLNL

Attached are LLNL's Project Status Reports for the month of September. A "Project Status Report" has been completed for each WBS.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

Attachments

XC
Jonsen
Mulloy
Hoffman
Fiore
LaPlante

Klein

Original
File

9.2.1.6.2.7

OCT 15 1984

Sept. 1984
Monthly Report

PROJECT STATUS REPORT

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2 - WASTE PACKAGE
L. Ballou, P.I.

SUMMARY

A number of long and intermediate-duration hydrothermal interaction experiments between Topopan Spring Tuff (Tpt) and J-13 water are continuing, with water samples being collected periodically from these interaction systems for subsequent chemical analysis.

Work continued on a three-dimensional numerical model with which the stability of rock blocks adjacent to emplacement holes can be analyzed.

Additional results from the spent fuel cladding containment tests showed that treatment of bare fuel with deionized water resulted in observable amounts of fuel dissolution at grain boundaries near the surface of the fuel particles. The amount of uranium dissolved during the one-year test corresponds to 0.1 micron of uniform dissolution from the fuel particle surfaces.

Preliminary results from the Zircaloy corrosion test suggest a visible change in the appearance of the cladding surface next to the stainless steel strap used to support the cladding specimens.

Parametric testing of a number of doped and undoped borosilicate glass formulations are continuing under a variety of experimental conditions (temperature, leachant composition, etc.). Tests under both saturated and unsaturated conditions are in progress.

Also continuing is the analog test of a "mini-waste package" emplaced in a Tpt core through which J-13 water is being passed.

In the metals selecting and testing subprogram, work is continuing in the effort to understand the nature of electrochemical changes produced by the gamma radiolysis of J-13 water and water vapor. Recent work indicates that radiolysis-produced H_2O_2 has a marked effect on corrosion potentials, while the H_2 formed at the same time has relatively little effect.

Stress corrosion testing of several candidate canister materials (austenitic stainless steels) is continuing according to the experimental plan. The testing of type 304 and 304L stainless steels with "boiled down" J-13 water (where electrolyte concentrations are much higher than in normal J-13 water) is also continuing.

Preliminary results from the corrosion testing of copper and copper alloys exposed to J-13 water or steam indicate that both generalized and localized penetrations occur at significantly greater rates than is the case with austenitic stainless steels.

Thermal calculations were completed for vertically emplaced waste canisters containing ten-year-old PWR spent fuel. Two similar repository configurations were assumed; for both geometries it was found that no temperature constraints (including the 350°C allowable waste temperature) were exceeded.

Model verification and development for the mechanical and flow/transport subroutines continued in support of the waste package system analysis code (WAPPA).

Joanne Clark
for L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.1.L WASTE PACKAGE ENVIRONMENT
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the characterization of the variability in the properties of Topopah Spring tuff (Tpt) in that volume of Yucca Mountain in which a waste repository is to be located. Also included is the study of hydrothermal reactions between Tpt and J-13 water. These reactions provide a baseline for the multi-component testing carried out in WBS 1.2.2 involving waste forms and metals.

The data obtained in this sub-task also will be used to verify and extend the capabilities of EQ3/6. This applications objective supports site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

This sub-task also includes experimental work to determine the rates and mechanisms of dehydration and resaturation of repository near-field rock in response to the thermal field generated by emplaced waste. These data will aid in estimating the water flux past waste packages. Activities related to the stability of borehole openings which are part of this sub-task will determine whether borehole liners will be necessary, and will aid in determining the state of stress of waste packages.

ACTIVITIES

A. Yucca Mountain Tuff and Groundwater - Interaction Experiments and Results

The two long term (365d) experiments currently in progress in the Dickson-type, gold-cell, rocking autoclaves continued uneventfully. To review:

DB12 = G-1 core wafer, J-13 water, 90°C, plan 365 d, currently at day 147.
DB13 = G-1 core wafer, J-13 water, 150°C, plan 365 d, currently at day 147.

During this month samples were taken at day 120.

A short-term (planned 64 d) experiment was terminated normally at the beginning of September.

DB15 = G-1 crushed, J-13 water, 90°C, plan 64 d, terminated at day 72.

Following termination of the run the crushed material was submitted for XRD analysis. The vessels used in DB14 and DB15 were prepared for tne next set of experiments.

Two short-term (planned 64 d) experiments were started at the end of September. These were:

DB16 = G-1 polished wafer, distilled water, 90°C, plan 64 d, currently at day 11.

DB17 = G-1 polished wafer, distilled water, 150°C, plan 64 d, currently at day 11.

SEM observation and EMP analysis of polished core wafer run in experiment DB14 (Tpt G1, J-13 water, 90°C, 48 d) were begun. Initial examination shows that the metastable illitic "clays" observed previously at 150°C and 250°C have formed even at this low temperature.

Following the completion at the end of last month of the single mineral dissolution kinetics experiments using quartz, the flow-through system was completely disassembled, cells acid-cleaned, lines replaced and preparations made for the next series of experiments. Two banks of peristaltic pumps were obtained to allow flow rates to be achieved in the next experiments. Some of these experiments will assess the effect of low flow rates on the apparent dissolution rate at temperatures below 70°C, while others will confirm results with feldspar obtained earlier or repeat quartz experiments which failed due to cell leakage problems.

The manuscript entitled "Hydrothermal Interaction of Topopah Spring Tuff with J-13 Water as a Function of Temperature" by Knauss, Delany, Beiriger and Peifer was prepared this month and sent to the session chairman for peer review prior to presentation at the Symposium on the Scientific Basis for Nuclear Waste Management in the 1984 MRS National meeting in Boston this fall. The paper will be published in a symposium proceedings volume. This report focuses on the results of drill core samples run in the Dickson-type, gold-cell rocking autoclaves.

B. Stability of Borehole Openings

Work continued in September on a fully three-dimensional numerical model with which the stability of rock blocks adjacent to emplacement holes can be analyzed. Detailed plans for the structure of the model, and coding and testing of major parts of the model were completed this month. Portions of the model that were completed incorporate a solution for an arbitrary initial three-dimensional stress field around an emplacement hole.

In other activities, translation of computer programs to identify individual rock blocks from structural data continued this month. The initial two-dimensional block stability parametric studies were the subject of an extended abstract prepared for submittal to the organizers of the 26th U.S. Symposium on Rock Mechanics. The abstract is entitled "The Influence of Stress Magnitude and Lateral Stress Ratio on Keyblock Stability."

C. Dehydration and Rehydration of Topopah Spring Tuff

During the month of September, 1984, the draft of a report entitled "Transport Properties of Topopah Spring Tuff" was completed. This report is now undergoing internal review.

A rupture disc failure in the high pressure system reduced the confining pressure to less than the pore fluid pressure of the larger fractured Topopah Spring tuff sample. That caused the sample jacket to leak. We are trying to clean the sample so that it is free of pressure fluid contamination.

The pressure-temperature system designed to measure transport properties of rock samples in a two-phase flow system is being assembled.

PLANNED WORK

Work on development of the three dimensional model to analyze the stability of borehole openings will continue. Thermally induced stress changes will be included in the model.

Experiments in the Dickson rocking autoclaves will continue, as will post test characterization of rock samples from DB14 and DB15.

A new series of flow-through experiments to study the dissolution rate of pure quartz and feldspar will begin. The test series will use 16 samples.

Following cleaning of the large fractured tuff sample, the dehydration-rehydration experiment will be restarted.

PROBLEM AREAS

The equipment failure described under item C above has caused a set-back in the schedule for the dehydration and rehydration testing of tuff. The equipment is being repaired and the sample is being cleaned so that the experiment may be restarted. The impact on milestone schedules will be assessed after the experiment is restarted.

MILESTONE PROGRESS

1.2.1-84-III-5 Report on Dehydration and Rehydration Studies of Intact and Fractured Topopah Spring Tuff.

This report has been completed and is undergoing technical and QA review. Delivery to WMPO in October is planned.

All other milestones for FY84 have been completed.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.1.L WASTE FORM TESTING
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task involves the measurement of the radionuclide release rate from spent fuel and from borosilicate glass (containing DHLW or CHLW); these data are to be used as input for performance modeling of long-term radionuclide release rates from the waste package. Radionuclide release rate information will also determine whether or not a packing material must be incorporated in the waste package designs in order to meet NRC performance objectives.

ACTIVITIES

A. Spent Fuel Leaching/Dissolution Tests

Post-test examination of the Series 1 "Cladding Containment Credit Test" specimens (Turkey Point fuel in deionized water) is nearly complete. Dried fuel particles from the bare fuel test were partially coated with a light colored reaction layer after approximately one year in deionized water. Metallographic examination of these fuel particles showed that easily observable amounts of fuel dissolution had occurred at grain boundaries near the fuel particle surface.. Total cumulative uranium measured in test and strip solution samples in this test was approximately 0.025% of the initial inventory. This quantity of uranium corresponds to about 0.1 microns of uniform dissolution from the fuel particle surfaces, which is consistent with the post-test metallographic specimen appearance.

No apparent fuel surface corrosion was observed in a metallographic specimen from the one year Series 1 laser-punctured clad specimen. Total cumulative released uranium measured in this test was $\sim 6 \times 10^{-5}$% of inventory, which is equivalent to only about 2 angstroms of uniform fuel particle surface dissolution. Preparation of the post-test slit defect metallographic specimen is in progress. Delivery to LLNL of the draft topical report on the Series 1 Tests will be delayed until November 30, 1984, in order to incorporate expanded radiometallurgical examination results into this report.

The testing of spent fuel in J-13 water is continuing on schedule.

B. Zircaloy Cladding Corrosion

The electrochemical corrosion scoping test to investigate corrosion behavior of Zircaloy is continuing. It consists of bundles of spent fuel cladding each wrapped with a strip of 304L SS and immersed in 90°C J-13 well water that is equilibrated with crushed tuff. Turkey Point defueled cladding is being used for the experiment. Separate test assemblies were prepared for 2, 6, and 12-month experiments. The 2-month test was completed this month and is presently being examined and samples prepared for metallographic and SEM examination. Visual observations suggest change on the cladding surface next to the stainless steel wrap. The 6 and 12-month experiments continue to run. A baseline cladding specimen has been sectioned and examined. In addition a "C-ring" stressing machine suitable for operating stress corrosion cracking tests in a hot cell has been designed and is being assembled.

C. Spent Fuel Oxidation

Ceramographic examination of the pulverized fuel used in the 225°C test indicated grain boundary oxidation attack. Examination by electron microprobe and x-ray diffraction were not fruitful due to the high sample background. New sample preparation methods are being tried. An additional TGA run is in progress at 200°C with a fragment sample. A synthesized air mixture of N_2 + 20% $^{18}O_2$ is being used in hopes of enhancing post-test examination capabilities.

D. Parametric Testing

Preparations were made for a full parametric testing of the ATM-8 (Actinide) glass. Four series of tests will be started in October. These are: glass with deionized water, glass with J-13 water, glass with J-13 water and crushed tuff, and glass with J-13 water, stainless steel, and crushed tuff. Crushed glass will be used with the first two tests and glass in the form of discs will be used with the third and fourth tests. All tests will be run at SA/V = 0.3 cm^{-1} for 7, 14, 28, 56, 91, and 182 days.

The parametric test series involving DWPF (SRL) and PNL 76-68 simulated and actinide doped glasses in a gamma radiation field was completed.

The SRL glass composition for the simulated and actinide doped samples are tne same except for the actinide elements and, as expected, values for pH and Δmass for each glass were within experimental error and the data for each glass type was combined. However, the PNL glass compositions were slightly different and the data for each glass type are distinguishable.

For SRL glass the initial reaction of the glass with the water is small, and the pH decreases from 7.1 to 6.5 after 56 days and the weight change is directly proportional to the reaction time.

For PNL simulated glass there is a greater initial reaction which drives tne pH more basic after 14 days. However, for the 28 and 56 day periods the pH is becoming more acidic as the rate of reaction, as measured by weight loss, declines.

When tuff is included in the system the same pH trends are evident although they are moderated, except for the 56 day pH for the PNL actinide-doped glass which shows a definite change to a more basic pH. Note that the solution pHs and weight changes for the two PNL glass types are extremely sensitive to the small changes in glass composition. The same trends as are noted for pH and mass are observed for the more leachable elements in the glass, B, Li, Na, and Mo.

E. Unsaturated Test Method Development

The procedure to be used for NNWSI waste form testing under unsaturated conditions was documented in a draft report.

A long-term series of tests using defense glass (165 black frit) doped with uranium, cesium, and strontium was started 6/14/84. This series of tests is using the "final" version of the test apparatus and procedure. Two tests were sampled at the 6.5 week interval on 7/30/84 and at the 13 week interval on 9/13. Two otner tests were terminated on 9/13/84. It was recently decided to add tests F-11 and F-12 (Blanks) to the matrix, and these were started 9/13/84.

A summary of the test procedure and results obtained to date will be presented at the November Materials Research Society Meeting.

F. Analog Test

The analog test utilizes a tuff rock core the shape of a right circular cylinder 5" in length and 2-1/2" in diameter, as a reaction vessel. The test was initiated by placing a mini waste package in the cavity machined in the center of the core and placing both sections of J-13 saturated tuff into a teflon sleeve. The input of water to the tuff core was supplied by a storage reservoir of water that was heated to $\sim$ 130°C. The inlet line was also heated. The goal was to supply the tuff core with an evenly distributed supply of water vapor. The rate of flow through the tuff core could be regulated by the temperature (pressure) of the storage reservoir. Water, after passing through the tuff core, was collected in a vented bottle for analysis of radionuclides, cations, and anions.

The results of the 90-day analog test are very similar to unsaturated test results for similar time periods. However, they are the results of only one test and may represent only a portion of possible materials interaction. Analog tests that will run for six months and one year duration are in progress. The results of these tests will be compared to unsaturated test method results.

PLANNED WORK

This has been discussed under the individual items above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

1.2.2.1-84-III-2 Final report on FY83 contract work from G. McVay to LLNL.

This report has been received and is undergoing review. Delivery to WMPO in October is planned.

1.2.2.1-84-III-3 Report on Cladding Containment Credit Testing of Spent Fuel in Deionized Water.

This report is being rescheduled to 12/15/84 delivery to WMPO in order to allow time to incorporate expanded experimental results. See section A above.

1.2.2.1-84-III-4 Report on results of Parametric Testing of DHLW 165-Frit Glass.

This report was delivered to WMPO on September 27.

1.2.2.1-84-II-2 Report on revised unsaturated test procedure with results from preliminary testing .

This milestone was met by submission of a draft report "NNWSI Phase II Materials Interaction Test Procedure and Preliminary Results" by J. Bates and T. Gerding to WMPO on October 1.

1.2.2.1-84-III-6 Progress report on corrosion testing of irradiated Zircaloy cladding.

This milestone was met by submission of a letter report from Westinghouse Hanford Co. to LLNL on September 26. A copy of the report was sent to WMPO on October 1.

There are no further milestones for FY84 for this sub-task.

for J. Clark

L. Ramspott
LLNL Technical Project Officer
for NNWSI

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.2.L METALS SELECTION/TESTING
L. Ballou/D. McCright, P.I.

OBJECTIVE

This sub-task includes the selection of the metals for the fabrication of canisters and of borehole liners, as well as the characterization of the corrosion rates of these metals under expected repository conditions. The corrosion data will be used in performance assessment modeling and predictions of long-term canister behavior needed for NRC repository licensing.

ACTIVITIES

Activities which are reported on this month are:

1. Electrochemical Corrosion Testing
2. Stress Corrosion Testing - Non-Irradiated Environmental Conditions
3. Specimen Preparation on the Gleeble
4. Corrosion Performance of Stainless Steels in Wetting and Drying
5. Corrosion Testing of Copper and Copper-Base Alloys

1. Electrochemical Corrosion Testing

Work is continuing in the effort to understand the nature of electrochemical changes produced by gamma radiolysis of J-13 water and water vapor. Some of our recent work has focused on "more concentrated" electrolytes, e.g., 10x and 100x concentrated J-13 water by boil down.

The effects of "on-off" gamma cycles (3.3 Mrads/hr) on the corrosion potential of 316L in 10x and 100x concentrated J-13 water are noted as follows. Application of the gamma source results in a positive corrosion potential shift generally on the order of 200 mV. Once a more oxidizing environment is created, the corrosion potential remains at the more positive value when the source is removed. Generally, within an hour under irradiated conditions, steady-state concentrations of metastable molecular species, such as hydrogen peroxide, are reached, and the corrosion potential adopts an effective constant value. Anodic polarization curves on 316L determined in more concentrated environments indicate that both the corrosion potential and the critical pitting potential are shifted positively and remain well separated. Thus, the positive shift of the corrosion potential in the irradiated aqueous environments does not appear to indicate any increased susceptibility to localized corrosion attack. This is a preliminary observation and more work is needed in this area, particularly with respect to subsequent changes of the corrosion potential with time in the irradiated environment.

It appears that the production of H_2O_2 under gamma irradiation is likely the main determinate of the corrosion potential shifts observed. Successive additions of hydrogen peroxide were made to a non-irradiated J-13 in which a 316L specimen was immersed; the resulting positive potential shifts of the corrosion potential corresponded to what was observed in the irradiated J-13 environment. Experimental data indicates that while the corrosion potential of 316L is strongly affected by the addition of hydrogen peroxide to the solution, the corrosion potential is not much affected by H_2, which is also produced by gamma radiolysis of water.

In contrast to the behavior observed for 316L, the open-circuit or "corrosion" potential of platinum responds dramatically to hydrogen saturation of the solution, even when hydrogen peroxide is present. Upon saturation of the solution with hydrogen, the platinum immediately responds as a normal hydrogen electrode and the value of the open-circuit potential drops to the equilibrium value corresponding to a pH of 7. Subsequent bubbling of solution with oxygen removes hydrogen from solution and the potential moves in the positive direction. Modeling of the effects of radiolytically generated species on the corrosion behavior of stainless steels is continuing.

An access tube was installed in the LLNL gamma pit during the past month. Experiments can be conducted at elevated temperatures as the access tube allows insertion of heating elements which are isolated from the radiation moderating water. In the coming months, the electrochemical corrosion potential and polarization behavior of candidate stainless steels will be determined over a range of temperatures. Further, the electrochemical corrosion behavior of copper-based alloys will be surveyed under irradiated environmental conditions.

2. Stress Corrosion Testing - Non-Irradiated Environmental Conditions

The matrix study of four-point loaded, bent-beam specimens (ASTM G-39) with specimens in the CSW (Cold-worked, furnace heat treated as a "Sensitizing" treatment, and Welded) condition has reached 4500 exposure hours in 100°C J-13 water and steam with no cracked specimens. Nine specimens each of Types 304, 304L, 316L, and 321 austenitic stainless steels in the above metallurgical condition are exposed in the J-13 water and another nine specimens each of these alloys are exposed in the steam.

A companion study of specimens in the COW condition (Cold-worked, nOt furnace "sensitized", and Welded) is conducted in the same environment. These specimens have reached 2500 exposure hours with no cracked specimens observed to date.

Additional sets of bent-beam specimens are being prepared, as described in the August monthly report. Slow-strain rate specimens are also being prepared from the same plate stock, so that we will be able to have specimens with the same alloy composition and same metallurgical processing and treatment for comparison of the different test results.

Planned activities for the coming month are microstructural examinations of the processed and heat treated plates. These will be examined under a high-resolution transmission electron microscope for evidence of chromium carbide formation. Also, we are investigating use of the EPR technique (Electrokinetic Polarization Reversal) for quantifying the degree of sensitization in a stainless steel by measuring the amount of coulombs needed to "activate" a passive stainless steel. The greater the degree of sensitization is in the steel, the fewer is the number of coulombs required to activate the stainless steel. The usual metallographic techniques (ASTM A262) used for discerning sensitization in stainless steels are qualitative, while the EPR technique yields a quantitative result. The EPR technique has been successfully used to assess the degree of sensitization in 304 stainless steel used in BWR piping. Further, the EPR technique will relate the stress corrosion susceptibility of the candidate stainless steels to the other activities using electrochemical corrosion measurement techniques.

3. Preparation of Test Specimens with the "Gleeble"

The Gleeble is an programmable instrument which can impart different time-temperature-strain histories on individual specimens. The specimens are heated by a high electrical current and are restrained between grips. The time-temperature profiles are programmed and measured by a series of attached thermocouples. The amount of strain is monitored by quartz transducers mounted along the specimen edge. The Gleeble is often used to produce simulated heat-affected-zones (HAZ) for studies on the welding characteristics of different metals and alloys. We are using the Gleeble to simulate HAZ conditions on the candidate stainless steels. The Gleeble specimens complement the specimens which have undergone furnace heat treatments to produce "sensitized" microstructures. There are two fundamental differences, however. Because the specimen is restrained during heating and cooling, the specimen is simultaneously stressed while undergoing the heat treatment. In the case of "sensitizing" stainless steels, the diffusion of carbon atoms to form chromium carbides may be enhanced. Secondly, the specimens are heated and cooled (at controlled rates) in a continuous method, as opposed to conventional furnace isothermal heat treatment. This is, of course, a better simulation of the experience of welded canister.

As a pilot study to determine the efficacity of preparing weld simulated test specimens, we prepared some stock material of 304, 304L, 316L, and 321 on the Gleeble. Each stock specimen is 1 inch by .125 inch in cross section and 4 inches long. These stock specimens will then be machined to provide three bent-beam stress corrosion test specimens and a specimen for metallographic analysis. Stock specimens are heated to a maximum 800°C and strained to a maximum 2% and then cooled to 400°C at three different rates: 1°C/sec, 0.5°C/sec, and 0.2°C/sec. On half the specimens, the heating and cooling cycle is performed three times. Following machining to bent beam specimen dimensions, the specimens will be exposed to the same 100°C J-13 water and steam environment discussed with Activity 2.

4. Corrosion Performance of Stainless Steels in Wetting and Drying Situations

Work is being performed under sub-contract at Pacific Northwest Laboratory on the corrosion performance of stainless steels exposed to alternate wetting and drying conditions. These conditions create a potentially aggressive environment that could be attained by periodic dripping of vadose water onto a hot canister surface, subsequent evaporation of the water leaving an ionic salt residue, with repetition of this event many times during the containment period. In this particular test, an assembly of 40 U-bend stress corrosion specimens are exposed to J-13 water and crushed tuff rock in an autoclave maintained at 200°C and a pressure of 1000 psi. At weekly intervals, the autoclave pressure is reduced, allowing the autoclave to "boil dry". The temperature is maintained at 200°C during the "dry" cycle, as well. The autoclave is then refilled with water, and the cycle repeated. The assembly of U-bends specimens includes 304 and 304L stainless steel, all of which have been furnace heat-treated at different times and temperatures in the "sensitization" range. The U-bend assembly has now undergone 15 wet and dry cycles over the past four months. The autoclave was disassembled for examination of the test specimens. Results are summarized in Table 1.

TABLE 1 - Results of U-bend Specimens Exposed to Alternate Wetting and Drying Conditions at 200°C

Material	Heat Treatment	No. Specimens Cracked/No. Tested
304	24 Hours @ 600°C	9/10
304L	24 Hours @ 550°C	0/10
304L	24 Hours @ 700°C	0/10
304L	8 Hours @ 700°C	0/10

The carbon content of the 304 was 0.063%, while that of the 304L was 0.017%. The reason for inclusion of the heavily-sensitized, high-carbon 304 material was to induce an early failure and show the test validity in discerning sensitivity to the degree of sensitization. This is exactly what occurred in this test. The morphology of the stress corrosion cracks in the sensitized 304 will be examined, because the crack morphology is indicative of the causative mechanism. An intergranular pattern of crack formation indicates that the sensitized microstructure is the cause, while a transgranular pattern suggests that concentration of the electrolyte (especially chloride ion) is the causative agent.

A sample of the water was withdrawn for analysis. The results are given in Table 2.

TABLE 2 WATER ANALYSIS AFTER 15 CYCLES OF "BOIL DOWN" AT 200°C

Species	Concentration (ppm)	Species	Concentration (ppm)
F^-	9.4	Ca^{++}	32.8
Cl^-	47.6	K^+	3
NO_2^-	1.7	Li^+	0.27
NO_3^-	37.8	Na^+	269
$SO_4^=$	393	Sr^{++}	0.15
HCO_3^-	156	Si	64.8

The pH of the solution was 8.78 and the conductivity was 1360 micromhos.

The surface of the U-bend specimens appeared somewhat "chalky", but there were no salt deposits or encrustations present. From the results in the above table, it appears that most of the soluble ionic species - chloride, sodium, sulfate - have concentrated 6-7 times their starting concentration in J-13 well water. The more insoluble species - calcium, bicarbonate, fluoride - have evidently precipitated. Nitrate ion is likely reduced to nitrite (and other valence states of nitrogen) at cathodic sites on the stainless steel surfaces. The increase in pH is probably due to the relative increase in concentration of sodium and other alkali species over the concentrations of calcium and other alkaline earth species which undergo partial precipitation. These data are comparable to those given in the August monthly report on concentrating J-13 water by boil-down in the laboratory.

The uncracked U-bend specimens were re-emplaced in the autoclave to attain additional exposure hours in the concentrating environment.

5. Corrosion of Copper and Copper Containing Alloys in J-13 Water and Steam

Because of the recent interest generated in examining copper-base materials as possible nuclear waste containment materials, we began a survey experiment of their corrosion performance in tne J-13 well water environment and in the saturated steam phase directly above the water at 100°C. For this preliminary experiment, we exposed three coupons each of CDA 110 (Electrolytic Tough Pitch Copper), CDA 706 (90/10 Cupronickel), CDA 715 (70/30 Cupronickel), and for comparison Monel 400, to the water and another three coupons each to the steam. We followed the same ASTM G-1 and G-31 test procedures for the copper-base material weight-loss coupons as we use for the stainless steel coupons. The copper-base coupons are exposed in a different cell from the stainless steel, because of possible cross-contamination of the different corrosion products from the dissimilar metals.

The copper weight-loss coupons were examined after 3000 hours of exposure to the water and steam environments. As expected, the coupons were covered by corrosion products which on the high-Cu materials was an opaque black oxide film. The Monel 400 specimens developed a thinner, transparent film during the same exposure period. Copper and copper alloys often show a decreasing rate of corrosion/oxidation with exposure time because of the protection given to the metal by formation of the oxide films. For this reason, we decided to leave two of the three specimens with the film intact, while we cleaned off the film on the third specimen and determined the corrosion rate by the weight loss.

The corrosion rates of the different materials in the water and in the steam are given in Table 3. The values given in Table 3 were determined for single coupons of each alloy in each environmental phase. As expected, the cupronickel coupons showed lower corrosion rates than the essentially pure tough pitch copper (CDA 110). The Monel specimen actually showed a weight gain. All of these coupons had been cleaned according to the ASTM G-1 procedure for copper and its alloys. The cupronickels are generally more corrosion resistant in oxidizing environments (such as J-13 water) than the pure coppers. Monel (a nickel-base alloy containing about 32% Cu) is quite

resistant to corrosion in aggressive aqueous environments. The coupons which had been weighed were then re-emplaced in the test cells along with the other coupons which had not been examined. The next planned inspection will be after 6000 accumulated exposure hours in the test environments. During this inspection, the previously cleaned specimens can be compared to those which had never been cleaned so that the protective role of the black oxide film can be determined.

TABLE 3 Corrosion Rates of Copper-Based Materials Exposed to J-13 Well Water and Steam at 100°C. 3000 Hours of Exposure.

Alloy	Corrosion Rate (μm/yr) J-13 Well Water	Saturated Steam
CDA 110	3.11	4.22
CDA 706	2.10	0.90
CDA 715	0.28	0.50
Monel 400	0.02	0.64 (wt. gain)

The amount of localized corrosion was also determined for each alloy tested. As with the corrosion testing for stainless steels, slotted Teflon washers were used to create an intentionally creviced area on each coupon. The maximum localized penetrations were found in this creviced region during the 3000 hour exposure period. Expressing these localized penetrations on an annualized basis, the rates fall in the range of 40-150 μm/yr and are considerably in excess of the general corrosion rates given in Table 3. These results suggest that the principal degradation mechanism for the copper base materials would be a localized penetration which would eventually perforate the canister wall. Subsequent exposure and inspection of these coupons should indicate whether projections of these localized penetrations do indeed dominate the corrosion attack.

For comparison purposes, the general corrosion rates of carbon steels (1020 and A-36) are 27-30 μm/yr in J-13 water and 10-13 μm/yr in steam at 100°C with annualized localized corrosion rates on the order of 150-260 μm/yr in water and 160-185 μm/yr in steam. Austenitic stainless steels (304L, 316L, 317L, 321, and 347) show general corrosion rates of 0.025-0.380 μm/yr in J-13 water and 0.25-0.56 μm/yr in steam with annualized localized corrosion rates from none discernible to 0.045 μm/yr in water and from none discernible to 0.372 μm/yr in steam. As expected, the corrosion rates for the copper-based alloys fall intermediate between those for carbon steel and those for the stainless steels in the oxidizing J-13 water and steam environments. The copper-based materials containing substantial quantities of nickel, as well as the nickel-base material containing substantial copper (Monel 400), are significantly more corrosion resistant than unalloyed copper in these test environments, with the corrosion rates of the 70/30 cupronickel and Monel 400 approaching those of the austenitic stainless steels. It should be emphasized that the corrosion data for copper are based on results from single specimens, while those for the carbon steel and stainless steel are based on results from multiple specimens.

PLANNED WORK

This is discussed in the appropriate areas in the Activities Section.

PROBLEM AREAS

None.

MILESTONE PROGRESS

Milestone 1.2.2.2.2-84-III-2 "Behavior of Stressed and Unstressed 304L Specimens in Tuff Repository Environmental Conditions" has been edited and is currently awaiting project review and is expected to be submitted shortly to NV for policy review. A presentation of this report is planned for the NACE Corrosion/85 Meeting in Boston in March, 1985.

A report "The Corrosion Behavior of Carbon Steels in Tuff Repository Environments" was prepared. This report summarizes all of the work to date on carbon steels, which are now the principal candidate materials for borehole liners. A presentation of this work is planned for the MRS Meeting in Boston in November, 1984. This work was not scheduled as a milestone activity. The report is now in peer review.

Other scheduled milestones are on schedule.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.3.L OTHER MATERIALS
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the development and testing of packing materials fabricated from crushed tuff plus additives to enhance the properties of the finished products (where necessary). Other activities under this sub-task include the assessment of the chemical effects of grouts and concrete on the performance of waste package components. (The second activity is not funded for FY84).

ACTIVITIES

Work is continuing at the USGS (Menlo Park) on measurements of the permeability of Topopah Spring tuff in a temperature gradient. They are investigating the effects of pore pressure, sample orientation, and flow direction on the permeability of the tuff and the fluid chemistry of the water. The temperatures and pressures of the experiments were chosen to approximate those expected at the repository level. To date, the permeability experiments and the chemical analyses of the discharged fluids have been completed. The analysis and interpretation of the chemical data is in progress.

PLANNED WORK

Samples will be prepared to investigate the effect of mixtures of silica gel of various grain sizes on the properties of packing material based on crushed tuff. Initial tests will be done using various proportions of gel (5, 10, and 15%) and a single compression pressure (probably 20,00 psi). If any of the mixtures give promising results, a full pressure-density test will be done and a specimen prepared for thermal conductivity measurements.

PROBLEM AREAS

Lack of staff is still restricting the progress of this sub-task. Interviews have been conducted with a view to hiring a petrologist or geochemist to take over responsibility for this section of work. We anticipate filling the position in the near future.

MILESTONE PROGRESS

All FY84 deliverables for this sub-task have been completed and forwarded to DOE/NV.

L. Ramspott
L. Ramspott
LLNL Technical Project Officer
for NNWSI

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.L PACKAGE DESIGN
L. Ballou/E. Russell, P.I.

OBJECTIVE

The objective for package design is to develop and analyze waste package designs which incorporate NNWSI qualified materials and which are compatible with the repository design. The designs and analyses are needed to support license application by documenting conformance with NRC requirements for safe handling, transportation, emplacement, retrieval, containment and release rate.

ACTIVITIES

A. Design

The Level I Milestone report "Preclosure Analysis of Conceptual Waste Package Designs for a Nuclear Waste Repository in Tuff" has been forwarded to DOE/NV.

B. Thermal Analysis

Two thermal calculations were made for the current vertical emplacement canister design configuration with 10 year-old PWR spent fuel. Each canister contained six pre-consolidated fuel assemblies with a total decay heat power of 3.3 kW at time of emplacement. In each case, borehole and canister diameters were 76.2 cm and 70.0 cm respectively. One case considered the canisters emplaced with a package pitch of 8 meters and a drift pitch of 30.5 meters, and the resulting peak fuel temperature was 299°C four years after emplacement. For the other case the package pitch was 5 meters and drift pitch was 46.9 meters, and a peak fuel temperature of 322°C was reached four years after emplacement. In neither case the maximum allowable waste temperature (350°C) was not exceeded.

The above calculations were made in two stages. The first stage was a calculation to determine the borehole wall temperature history using the three-dimensional computer code TACO3D. The computer model consisted of a spent-fuel-like heat source inside the borehole surrounded by tuff with appropriate symmetry planes between boreholes and between drifts. A linear analysis was made using dry tuff thermal properties and an initial tuff temperature of 25°C. The second stage of the calculation modeled the waste package inside the borehole and used the temperature history of stage 1 as a boundary condition at the borehole wall. A two-dimensional, variable property, infinite cylinder model using the computer code TACO2D was subsequently used to calculate the thermal history of the waste package canister walls.

C. Structural Analysis

The report "Structural Analysis of Conceptual Waste Package Designs for a Tuff Repository" draft has been completed and is currently undergoing revision. Due to the peer reviews taking longer than anticipated, the final revision of this report will be finished and forwarded to DOE/NV in October.

D. SNLA/A-E Integration

Leo Scully and Robert Stinebaugh (SNLA) visited LLNL to discuss FY85 waste package design integration with SNLA/A-E. Follow-up letters were exchanged between LLNL and SNLA, and discussions are currently underway to determine the exact distribution of tasks.

PLANNED WORK

See activities mentioned above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

1.2.3-84-I-1 (M251) Report on Preclosure Analysis of Selected Conceptual Designs for a Nuclear Waste Repository in Tuff

This report was forwarded to DOE/NV on September 25.

All other milestones are on schedule.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

5 October 1984
Report Period 1 - 30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.4.L PERFORMANCE ANALYSIS AND TESTING
L. Ballou/M. Revelli/J. Yow, P.I.

A. PERFORMANCE ANALYSIS

OBJECTIVE

This activity involves the development and validation of models that can be used to predict long-term package performance for comparison with NRC performance objectives.

ACTIVITIES

Model verification and development for the mechanical and flow/transport subroutines continued in support of the waste package system analysis code (WAPPA). During the past month the mechanical model (FMODEL) was modified to correct the previously identified logic and coding errors, and the stand-alone test of FMODEL was completed. FMODEL now performs as described in the WAPPA User's Manual, but some problems remain at the system level in tracking barrier property changes. A draft report documenting the results of this study is in preparation.

Initial test problems to exercise WAFE on the LLNL computer system will include the reanalysis of the preliminary 1-D waste package study completed in a joint LLNL/LANL effort. Successful execution of these two test problems will provide a starting point for future efforts to model flow within the waste package. In preparation for these analyses it will also be necessary to define the boundary conditions which characterize the waste package emplacement environment. LLNL will host a coordination meeting with LANL and SNLA on October 18, 1984 to define a common problem for modeling this near-field environment using NORIA, TOUGH, and WAFE.

The first phase of an effort to model matrix diffusion of radionuclides through Topopah Spring tuff has been completed. Solution concentration data for this analysis was obtained from the LLNL/SRL saturated release tests of the DHLW waste form. Preliminary results will be presented at the ORNL Workshop on "The Application of Geochemical Models to High-Level Nuclear Waste Repositories" (October 2-5, 1984). An abstract for this presentation entitled "Matrix Diffusion Coefficients for the NNWSI Waste Package Environment" by K. G. Eggert and M. A. Revelli has been sent to WMPO/NV for programmatic review. Further analyses are planned to determine the effect of highly soluble caliche material in the tuff sample.

PLANNED WORK

During the first quarter of FY85, documentation of the physical process submodel evaluations (TMODEL and FMODEL) will continue to meet the revised delivery dates for these milestones. Code development efforts will focus on implementation of an unsaturated flow/transport submodel for the WAPPA code and modification of the mechanical submodel to represent the expected emplacement stresses. Later in FY85 these physical process submodels will be combined with data bases for metal corrosion and waste form release rates into a waste package system model to predict the long-term performance of the NNWSI waste package subsystem.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones are progressing consistent with the current schedule.

B. PERFORMANCE TESTING

OBJECTIVE

This activity includes planning and implementation of an in situ test of the waste package environment. The results of this test will be used to aid in the validation of the models used in the waste package performance analysis.

ACTIVITIES

A draft report describing the use of high frequency electromagnetic (HFEM) geotomography techniques in fractured, welded tuff was completed and subjected to internal technical review in September. "Study of Water Flow in Welded Tuff using Geophysical Tomography," by A. Ramirez and W. Daily, describes the HFEM measurements made in G-Tunnel at NTS and their analysis and interpretation.

Other activities in September included FY85 planning, and administrative work associated with combining the Performance Testing and the Exploratory Shaft subtasks. Effective October 1, all effort in this activity will be reported under the 2.6 Exploratory Shaft category, consistent with the new program-wide WBS.

PLANNED WORK

The report describing the suitability of HFEM techniques for monitoring saturation changes in fractured, welded tuff will be forwarded to WMPO for review early in October. Review of other types of instrumentation, measurement, and sampling techniques will continue. These fall into the general areas of subsurface hydrology and geomechanics, in keeping with the broad scope of the Waste Package Environment Tests. Scoping calculations for experiment design will be commenced; this work is closely related to the numerical modeling being planned in the Waste Package Performance Analysis subtask.

PROBLEM AREAS

None.

MILESTONE PROGRESS

No project deliverables were forwarded to WMPO during September.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

Date: 3 October 1984
Report Period: 1-30 September 1984

IPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

3.1.9 - GEOCHEMICAL MODELING CODE EQ3/6
Emerson/T.Wolery, P.I.

IVE:

is task is the development of advanced calculational capabilities for ıg geochemical processes in the repository environment. The work is :arried out by extending the capabilities of the existing EQ3/6 ·e. The applications objective is to support site and performance nent through calculations of solubilities, rock/water interactions, leading to long-term predictions of geochemical behavior.

TIES:

v MCRT data files have been compiled for boron.

·k has begun to develop data files for some organic species like acetate thalate. These occur in the natural environment and are also important s in the laboratory experiments undertaken to provide necessary data.

limited-access archival file storage directory has been established to the shared development directory for EQ3/6. This new directory will be ed monthly to protect and document the changes installed during the

st cases have been successfully run on EQ6 using the newly installed itation kinetics. Acceptable fits to the experimental data of Rinstidt ·nes (1980) for silica and of Reddy et al. (1981) for calcite have been ed.

) WORK:

e draft MCRT User's Manual, which incorporates the recently added random file capability of the code, is in progress.

though the summer-hire has left, some additional work is in progress to :e additions to the thermodynamic data base.

M AREAS:

·ing the installation of the precipitation kinetics to EQ6, bugs ıed which had to be found and corrected before work could continue. :ogether with the September meetings at LANL and Oak Ridge as well as ırose Conference, has delayed the draft MCRT User's Manual one month.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

1 October 1984
Report Period: 1-30 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.3.3.6 - BOREHOLE MAGNETOMETER
R. Stager, P.I.

OBJECTIVE:

This sub-task is to develop a proton precession magnetometer suitable for making measurements in small bore exploratory holes and compatible with the existing Birdwell logging equipment.

ACTIVITIES AND ACCOMPLISHMENTS

Downhole tests have been completed which satisfactorily meet our specifications. Documentation will be completed next week. Two downhole runs were completed with the resulting data virtually identical, thereby satisfying the stability tests. The resolution is plus or minus two gammas.

The one final test remaining to be completed is to mate the tool with the Birdwell cablehead, and then complete a cursory test to verify that it is operable.

PLANNED WORK

This activity is essentially complete. This project has been funded in FY84, but will not be funded in FY85.

NETWORK ACTIVITIES

2.3.3.6-84-III-2 User's Manual for the Proton Precession Magnetometer

An internal review of this manual is in process.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

5 October 1984
1 - 30 September 1984

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STATUS REPORT

5 October 1984
Report Period 1 - 30 September 1984

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warded to WMPO during September.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

1 October 1984
Report Period 1 - 31 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.7.1.L - SPENT FUEL TEST-CLIMAX
W. Patrick, P.I.

OBJECTIVE

The objectives of the SFT-C are to demonstrate the feasibility of storage and retrieval of spent nuclear fuel and to acquire data pertinent to the design, construction, and operation of a repository in crystalline rock. Emphasis in late FY 1984 and FY 1985 is post-test characterization and documentation of thermal- and radiation-induced changes in the rock mass. The extensive data set collected during heating and cooling of the rock mass is being analyzed in light of pretest and post-test calculations.

ACTIVITIES AND ACCOMPLISHMENTS

Summary

Data analysis and reporting continue to be the dominant activities following completion of field work. Two draft topical reports were completed this month and are being peer reviewed prior to submittal to the WMPO/NV. An abstract which summarizes the results of in situ deformability measurements was submitted for possible inclusion in the 26th U.S. Symposium on Rock Mechanics. Analysis of instrumentation calibration data continues.

Geological Investigations

Analysis of borehole jack data obtained during post-test characterization of the SFT-C has raised questions concerning the validity of recommended data reduction procedures. The recommended procedures, which are contained in a proposed ASTM Standard, appear to severely bias the data to lower modulus values. The Goodman jack has a long history of development and evaluations which primarily relate to the complex manner in which it interacts with the borehole. The evaluations and associated "corrections" have, to date, been applied in a piece-wise manner rather than as a composite.

Given the importance of deformability data in the calculation and analysis of rock responses to excavation and heating, the original scope of the in situ deformability measurements is being extended to include laboratory testing of the response of the jack. Initial evaluations will be made by testing the jack in a large cubical aluminum block. Procurement actions were completed this month to obtain the block. Techniques for heat-treating the block and for boring and sequentially enlarging the test borehole were established. A test procedure is currently under development. Testing is planned for late November to early December.

Significant progress was made on two studies of thermal and radiation effects on Climax stock quartz monzonite. The first set of thin sections of rock obtained adjacent to the spent-fuel canister emplacement boreholes was prepared by the vendor and received at the LLNL. Mineralographic and petrographic analyses of these sections will be done to detect and document changes which may have occurred as a result of heating and irradiation. Comparisons will be made with pre-test unheated, unirradiated specimens which were obtained immediately adjacent to the post-test specimens. The second study measured key characteristics of microfractures in specimens obtained at various radial distances outward from electrical heaters. All necessary data have been collected, processed, and analyzed. Detailed statistical interpretation of the data has been undertaken to support the logical arguments presented in the draft report. Previous microfracture studies of this rock have shown that rather sophisticated statistical treatment of the data is required because of the high natural variability of microfracturing.

Preparation of a complete database containing the results of post-test core logging was initiated this month. A database format was established and over 80% of the pertinent fracture characteristics and orientations have been entered into the database. These data will form the basis of a report on the post-test drilling and sampling activities.

Technical and project reviews of the revised draft report "Structural Geology of the SFT-C" by D. Wilder and J. L. Yow, Jr. were completed. Suggested technical changes have been incorporated in the draft and it is bring edited prior to submittal to the WMPO/NV.

Instrumentation and Data Management

Analysis of post-test calibration data was completed for three of four classes of temperature transducers which were deployed at the SFT-C. Resistance temperature devices (RTDs), thermistors, and the specially designed temperature sensors for the convergence wire extensometers were all found to have performed at the anticipated levels of accuracy and stability. Thermocouple data remains to be analyzed.

Analysis of pre-test and post-test calibrations of Watt transducers revealed that slight changes in slope and offset occurred during the three-year test period. The shunt resistors used in these calibrations (the only plausible source of calibration error) were themselves recalibrated. Based on these results, minor (insignificant) changes in the Watt transducers did occur.

A new technique was utilized to calibrate IRAD vibrating-wire stressmeters. The stressmeters were retrieved by overcoring so that they could be calibrated in the laboratory while they were still located within the same section of rock. The recovery process was not totally successful because geological discontinuities resulted in stressmeter cables being broken and the cores splitting. Laboratory calibration of the stressmeters which were successfully recovered was completed this month. The draft report was prepared and is being reviewed internally prior to submittal to the WMPO/NV.

Two extensive campaigns of in situ stress measurements were conducted at the SFT-C. An apparent hysteresis response was observed during field calibration of the subcontractor's USBM overcore cells which were used to make over half of the stress measurements (the other measurements were made with a different type of cell). In addition, the standard calibration procedure was determined to be inadequate. An investigation of these problems is in progress. This month, a set of data was obtained using the standard calibration technique to confirm that the phenomena occurred in the overcore cell which will be used in the investigations. Hysteresis on the order of hundreds of microstrains was observed. This is of the same magnitude as the gauge response to overcoring and, therefore, is very significant. An initial set of data was also obtained using a recently completed laboratory calibration fixture. Analysis of these data is awaiting completion of the data processing software.

All displacement transducers and associated laboratory calibration data sheets were obtained from the subcontractor. This completes the actual calibrations and makes the data available for analysis of the reliability of these transducers.

A potential problem with the long-term stability of the MBI-series borehole extensometers was detected in the rod- and anchorage-integrity testing data. This data was obtained as part of the post-test instrumentation analyses. The reference plug which the instrument transducer contacts was found to slip under certain conditions. A test procedure was prepared to evaluate the stability of the reference plug in the laboratory. Necessary test components were obtained from the SFT-C and are being prepared for testing.

Quality assurance records for measurement and test equipment (M&TE) were compiled and evaluated for completeness. Copies of records not currently in the project files are being obtained from the laboratories that performed the calibrations.

A patent disclosure was filed for the strain-gauged proving-ring transducers which were utilized to measure deformations in the canister emplacement boreholes following spent-fuel retrieval.

Post-Test Calculations

Several attempts have been made to model the complex rock responses observed during the "mine-by" experiment which was conducted at the SFT-C. Scoping calculations have indicated that the observed displacements may result from blast-induced permanent deformations of the rock mass. Attempts to properly model the excavation process have been unsuccessful to date, but a new approach was identified late this month which may lead to a solution. The new approach should avoid the numerical instabilities which have made the problem unsolvable to date.

Public Information

Production of the updated SFT-C documentary film was completed. A distribution list was established under advisement from DOE/NV. Copies of the film will be prepared and distributed next month.

PLANNED WORK

Staff efforts will continue to concentrate on analysis of field data and compilation and analysis of post-test calibration results. Revisions to thermal and thermomechanical models will continue.

PROBLEM AREAS

None.

NETWORK ACTIVITIES

2.7.1-84-III-5 Physical and Chemical Changes to Heater Drift Rock at Spent Fuel Test-Climax

Draft in process of internal review and revisions. Anticipated delivery to the WMPO/NV is October 31, 1984.

2.7.1-84-III-7 Overcoring and Calibration of IRAD Gage Stressmeter at Spent Fuel Test in Climax Granite.

Draft in process of internal review and revisions. Anticipated delivery to the WMPO/NV is October 31, 1984.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

1 October 1984
Report Period 1 - 31 September 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.9.4 - QUALITY ASSURANCE
J. Dronkers, P.I.

OBJECTIVE

Prepare QA plans and procedures, conduct ;internal QA surveillance, advise and assist LLNL staff assigned to NNWSI in the performance of their QA responsibilities, conduct audits of contractors,and generally carry out activities in Quality Assurance that will meet NRC requirements during licensing of a high-level waste repository under 10CFR60.

ACTIVITIES

B. Smith, a new QA staff member, has begun work on setting up procedures for the NWMP QA records archival system. The system will be computerized using the "INMAGIC" software package with an IBM PC.

J. Dronkers, NWMP QA Task Leader, released guidelines for use in implementing the NWMP Management Assurance Plan to be used in conjunction with the NWMP overall QA plan.

L. Ramspott chaired a meeting for NWMP leaders to review QA procedures already written and provide comments so they can be revised for the final approval copy. A second purpose of the meeting was to decide how to get the remaining procedures written and approved by October 31.

J. Dronkers attended the NNWSI Project Quality Assurance Committee (PQAC) Meeting in Las Vegas on September 20. A report of this meeting is available through the LLNL NWMP Project Leader's Office.

J. Dronkers attended the Eleventh Annual National Energy Division Conference in Las Vegas September 16-19. A report on this conference is available through the LLNL NWMP Project Leader's Office.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

Lawrence Livermore National Laboratory

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14 November 1984
NWM:94/60690

SUMMARY

Donald L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

SUBJECT: October 1984 Monthly Report - LLNL

Attached are LLNL's Project Status Reports for the month of October. A "Project Status Report" has been completed for each WBS.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

Attachments

FILE NO:

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PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2 - WASTE PACKAGE INVESTIGATIONS
L. Ballou, P.I.

SUMMARY

Two long term and two intermediate term hydrothermal interaction experiments between Topopah Spring tuff (Tpt) and J-13 water are continuing, with water samples being collected periodically for chemical analysis. A series of single mineral dissolution kinetics experiments (quartz and feldspar run in a flow-through system at 70°C) were begun this month.

Coding of a fully three-dimensional numerical model for the stability of rock blocks adjacent to emplacement holes was completed.

Testing of spent fuel (from Turkey Point and H. B. Robinson reactors) in J-13 water is continuing. Although uranium appears to be more soluble in the J-13 water than it is in deionized water, results to date do not suggest greater radionuclide release rates from the spent fuel in J-13 water relative to deionized water.

A 670-hour spent fuel oxidation experiment was carried out at 200°C in a synthesized air mixture (80% N_2 + 20% $^{18}O_2$). Although initially the fuel gains weight at 200°C more slowly than it does at 225°C (as expected), after 220 hours the rate of weight gain is greater at 200°C than at 225°C. Work is continuing to interpret this result.

Testing of a sample matrix using actinide-doped PNL76-68 glass was initiated; the matrix includes samples exposed to deionized water, J-13 water, J-13 water + Tpt, and J-13 water + Tpt + stainless steel. All tests are being run at 90°C with SA/V = 0.3 cm^{-1}. Parametric testing of uranium-doped PNL76-68 glass is continuing. The test matrix is identical to that being used for the actinide-doped glass, except that SA/V = 0.5 cm^{-1}.

Tests of actinide-doped PNL76-68 glass in tuff reaction vessels are continuing, as are the series of tests that are being carried out using the unsaturated test protocol.

Corrosion potential measurements of different stainless steels in irradiated J-13 water environments are continuing. It appears that radiolysis in systems of this sort produce characteristic (presumably unique) concentrations of H_2O_2 in solution. Similar measurements are also being carried out on samples of copper and its alloys.

A special crevice cell has been designed and fabricated in which the crevice corrosion susceptibilities of candidate stainless steels are being

quantitatively determined. Also, stress corrosion testing of the candidate stainless steels is being continued; currently, three different kinds of stress corrosion test configurations are being used: U-bend, slow strain rate (SSR), and bent beam.

Weight loss corrosion tests of various steels are also being continued (total exposure time to date is over 7500 hours). An array of carbon, alloy and stainless steel specimens are being exposed to J-13 water and/or to the saturated steam above the water; the experiment is being conducted at a temperature of 100°C.

A revised FY85 and FY86 corrosion test plan for copper and copper-base alloys has been developed and submitted to WMPO/NV for review and comment.

Samples of a mixture of 95% crushed Tpt + 5% silica gel were pressed isostatically at pressures ranging from 15,000 to 35,000 psi. Density of samples pressed at 20,000 psi and greater were all about 1.65 Mg/m^3, or about the same as compressed samples of crushed Tpt alone.

A conceptual design study for spent fuel canister/space frame optimization by SNLA has been completed. A cost estimate has been received for fabrication of spent fuel space frames; this estimate from a commercial supplier is 36% higher than that developed from engineering studies.

Thermal calculations for the current reference canister design for storing consolidated PWR spent fuel have been completed. Results of the three-dimensional calculations (using TACO3D) show a peak fuel temperature of 316°C reached 5 years after emplacement. Results for the two-dimensional calculations (using TACO2D) indicate a peak fuel temperature of 306°C.

Model verification and development of the mechanical (FMODEL) and flow/transport subroutines continued in support of the waste package system analysis code (WAPPA). The approach to be used in modeling hydrothermal flow in and around the waste package is being coordinated with modelers at LANL, LBL, and SNLA.

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.L PACKAGE ENVIRONMENT
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the characterization of the variability in the properties of Topopah Spring tuff (Tpt) in that volume of Yucca Mountain in which a waste repository is to be located. Also included is the study of hydrothermal reactions between Tpt and J-13 water. These reactions provide a baseline for the multi-component testing carried out in WBS 2.2.3 involving waste forms and metals.

The data obtained in this sub-task also will be used to verify and extend the capabilities of EQ3/6. This applications objective supports site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

This sub-task also includes experimental work to determine the rates and mechanisms of dehydration and resaturation of repository near-field rock in response to the thermal field generated by emplaced waste. These data will aid in estimating the water flux past waste packages. Activities related to the stability of borehole openings which are part of this sub-task will determine whether borehole liners will be necessary, and will aid in determining the state of stress of waste packages.

ACTIVITIES

A. Yucca Mountain Tuff and Groundwater - Interaction Experiments and Results

The 2 long term (365d) experiments currently in progress in the Dickson-type, gold-cell, rocking autoclaves continued uneventfully. To review:

DB12 = USW G-1 core wafer, J-13 water, 90°C, plan 365 d, currently at day 179.
DB13 = USW G-1 core wafer, J-13 water, 150°C, plan 365 d, currently at day 179.

The two short-term (planned 64d) experiments currently in progress continued with no known problems:

DB16 = USW G-1 polished wafer, distilled water, 150°C, plan 64 d, currently at day 43.
DB17 = USW G-1 polished wafer, distilled water, 90°C, plan 64 d, currently at day 43.

We have arranged for Rick Whitfield (USGS) to sample UZ-6 for unsaturated zone samples taken from the air-drilled hole. Using the lithologs developed by Rick Spengler (USGS) a total of 7 depths were selected to represent the section above the proposed repository. These samples will be tested to determine whether any caliche material is present.

A series of 16 single mineral dissolution kinetics experiments using both quartz and feldspar run in the flow-through system at 70°C were begun this month. Some of these experiments will assess the effect of both low and high flow rates on the apparent dissolution rate at temperatures below 70°C, while others will confirm results with feldspar obtained earlier or repeat quartz experiments which failed due to cell leakage problems. Samples have been taken through day 21 in the planned 50 day experiments.

A paper entitled "Hydrothermal Interaction of Topopah Spring Tuff with J-13 Water as a Function of Temperature" was prepared by K. Knauss, J. Delany, W. Beiriger and D. Peifer, and was forwarded to WMPO for review. This paper will be published as part of the proceedings of the November 1984 Materials Research Society meeting.

B. Stability of Borehole Openings.

Coding of a fully three-dimensional numerical model for the stability of rock blocks adjacent to emplacement holes was completed in October. The model incorporates a solution for an arbitrary initial three-dimensional stress field around an emplacement hole. Equations to adjust discontinuity shear strengths to residual values have since been added, and the model is now being debugged. Graphics capabilities, variable discontinuity stiffnesses, and thermally induced stress changes will be included in the model after the current work is done.

The extended abstract, "The Influence of Stress Magnitude and Lateral Stress Ratio on Keyblock Stability," was submitted to the organizing committee of the 26th U.S. Symposium on Rock Mechanics. The status of the keyblock stability work was reviewed at a graduate seminar at the University of California, Berkeley on October 23.

C. Dehydration and Rehydration of Topopah Spring Tuff

During the month of October, 1984, we completed the internal review process of a report entitled "Transport Properties of Topopah Spring Tuff." This report has been submitted to WMPO for review.

The larger fractured Topopah Spring tuff sample, which was contaminated with pressure fluid (isopar) when the pressure system failed the last month, has been cleaned. Residual gas analysis detected no outgassing of isopar vapor at 60°C and 10^{-5} torr vacuum. The sample is now in J-13 water at a pressure of 0.7 MPa to be saturated. We expect to jacket the sample early next month.

We continued assembling the pressure-temperature system designed to measure the transport properties of a rock sample in a two-phase flow system. We will start testing and debugging the system next month.

PLANNED WORK

Experiments that are in progress will continue. Plans for new work areas are discussed under the sections above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

2.2.2-84-III-5 Report on Dehydration and Rehydration Studies of Intact and Fractured Topopah Spring Tuff

This milestone was completed on October 25, 1984, by transmission of a manuscript entitled "Transport Properties of Topopah Spring Tuff" to WMPO.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.1.L WASTE FORM TESTING
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task involves the measurement of the radionuclide release rate from spent fuel and from borosilicate glass (containing DHLW or CHLW); these data are to be used as input for performance modeling of long-term radionuclide release rates from the waste package. Radionuclide release rate information will also determine whether or not a packing material must be incorporated in the waste package designs in order to meet NRC performance objectives.

ACTIVITIES

A. Spent Fuel Leaching/Dissolution Tests

Testing of spent fuel in J-13 water is continuing on schedule. The 62 day samples were taken from the Turkey Point fuel tests on October 8 and the 120 day samples were taken from the H. B. Robinson fuel tests on October 17. The main difference in results from these tests relative to the previous deionized water tests continues to be that uranium in solution samples from the J-13 water tests passes through an 18 Å filter while uranium is removed by filtration in the deionized water tests. At 62 days, the fractional Cs-137 release from Turkey Point fuel in J-13 water is the same as in deionized water. However, the amount of plutonium in solution at 62 days is less in the J-13 water tests than in the previous deionized water tests. The amount of plutonium plated out on quartz rod samples is also less in the J-13 water tests. Although uranium appears to be more soluble in J-13 water, results to date do not suggest greater radionuclide release rates from spent fuel in J-13 water relative to deionized water.

B. Zircaloy Cladding Degradation

The design of the "C-ring" stress corrosion scoping test apparatus has been completed. Machining work has begun and is expected to be complete before the end of November. The device compresses the "C-ring" between fixed and movable anvils with that part of the system submerged in a J-13 water bath. The force to the movable anvil is generated by a weighted lever arm with a movable weight to change the stress generated in the ring as desired. The apparatus will be able to test five samples at a time using different stress levels if desired.

The microstructural examination of spent fuel cladding from the completed 2-month electrochemical corrosion scoping test of cladding wrapped in 304L

stainless steel and exposed in a J-13 bath at 90°C has been delayed while radiometallography has been shut down for cleaning and renovation. The evaluation of samples from this test should resume this next month. The 6 and 12 month tests continue to run smoothly at a temperature of 90 ± 1°C with the pH readings remaining in the 8.4-8.6 range.

C. Spent Fuel Oxidation

A 670-hour oxidation run at 200°C in a synthesized air mixture of N_2 + 20% $^{18}O_2$ was completed. The fuel initially gains weight more slowly at 200°C than at 225°C as expected, but after 220 hours the rate of weight gain of the sample is greater at 200°C. The sample from the 200°C run will be examined using ceramography, XRD, and ion microprobe. Methods of interpreting the weight gain curves are under investigation. The XRD results on the fragment in the 225°C test was less than satisfactory and other XRD methods are being investigated. An oxidation run on a single particle will be started at 225°C in "dry air" (i.e., dew point ∿-65°C) to get initial data on the effects of moisture on the oxidation rate.

D. Parametric Testing

A paper was prepared describing "The Behavior of Actinide Containing Glasses During Gamma Irradiation in a Saturated Tuff Environment." This paper will be published in the proceedings of the November 1984 Materials Research Society meeting.

The test matrix using actinide-doped PNL76-68 glass was begun during October. The matrix includes samples run for 7, 14, 28, 56, 91, and 182 days in deionized water, J-13 water, J-13 water + tuff, and J-13 + tuff + stainless steel. All tests are being run at 90°C with SA/V = 0.3 cm^{-1}. Samples for 7 and 14 days were completed in October.

Parameteric testing of the uranium-doped PNL76-68 glass is continuing. The test matrix was identical to that being used for the actinide-doped glass, except that SA/V = 0.5 cm^{-1} was used. The original matrix has been completed and repeat samples for 56, 91, and 182 day runs have been started. This was considered to be necessary because of relatively large evaporative loss in the first samples.

E. Testing in Rock Reaction Vessels

Solution analyses have been completed for the 3 month tests of PNL76-68 actinide-doped glass in tuff reaction vessels. The 6 month tests are due to end in January. These tests follow the test protocol used at Savannah River for testing DWPF glass in tuff reaction vessels.

F. Unsaturated Test Method

The series of unsaturated tests begun last fiscal year are continuing. A paper describing the test method and results from the first three months of testing was prepared by J. Bates and T. Gerding. This paper ("NNWSI Waste

Form Performance Test Development") will be published as part of the proceedings of the November 1984 Materials Research Society meeting.

Please note: In the NNWSI Quarterly Report - LLNL (NWM:84/5976C) dated 29 October 1984, the lithium release on page 8 was incorrectly printed. The correct release of lithium for F-1 should read 0.20.

PLANNED WORK

This has been discussed under the individual items above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

2.2.3.1-84-III-2 Final report on FY83 contract work from G. McVay to LLNL.

This milestone was completed by submission to WMPO on October 30 of a draft report (PNL-4897).

2.2.3.1-85-II-2 Report on Test Results from Simulated and Fully Active DHLW Glass in J-13 Water and Tuff Reaction Vessels

We have been informed by Savannah River Laboratory personnel that we should receive a finished draft of this manuscript in early November.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.2.L METAL BARRIERS TESTING
L. Ballou/D. McCright, P.I.

OBJECTIVE

This sub-task includes the selection of the metals for the fabrication of canisters and of borehole liners, as well as the characterization of the corrosion rates of these metals under expected repository conditions. The corrosion data will be used in performance assessment modeling and predictions of long-term canister behavior needed for NRC repository licensing. Two alloy systems, austenitic stainless steel and copper-base materials, are currently being investigated as canister materials. Carbon steels are under consideration as borehole liner materials.

ACTIVITIES

Activities which are reported on this month are:

1. Electrochemical Corrosion Testing of Stainless Steels.
2. Electrochemical Corrosion Testing of Copper.
3. Crevice Corrosion Testing of Stainless Steels.
4. Stress Corrosion Testing of Stainless Steels.
5. Weight Loss Corrosion Tests of Stainless Steels.
6. Corrosion Test Plan for Copper and Copper-Base Alloys.

1. Electrochemical Corrosion Testing of Stainless Steels.

As discussed in the September report, we are continuing with corrosion potential measurements of different stainless steels in irradiated J-13 water environments. The positive potential shifts observed under gamma irradiation are associated with the production of H_2O_2. The exact interfacial mechanism by which hydrogen peroxide includes such potential shifts is still under investigation. Sub-millimolar concentrations of H_2O_2 should be produced under radiolysis of oxygenated aqueous systems.

To study the behavior of H_2O_2 in the gamma-irradiated system consisting of a 316L electrode in J-13 water, two drops of 30% H_2O_2 were added to the J-13 water before the corrosion measurement experiment was started. This represented a 4.9 mM H_2O_2 solution and is more concentrated in H_2O_2 than is the solution produced by radiolysis. It was noted that the potential shifts positive by some 320 mV upon addition of the peroxide. This potential shift is roughly twice that observed under irradiation. When this "spiked" solution is then exposed to gamma radiation, the corrosion potential immediately shifts negative and reaches values (about 130 mV) that reflect the usual potential shifts from E_{corr} observed under gamma irradiation of J-13 without the prior addition of H_2O_2. It

therefore appears that gamma irradiation enforces the establishment of an equilibrium concentration of H_2O_2 which is at a lower value than that which was initially added in this particular experiment. The negative potential shifts observed reflects the decomposition of some of the initial H_2O_2 until a lower steady-state concentration (under radiolysis) is achieved. The corrosion potential of 316L is therefore a sensitive monitor of the H_2O_2 concentration.

2. Electrochemical Corrosion Testing of Copper

Candidate high-purity copper and copper alloys are being survey-tested by electrochemical techniques similar to those used for testing austenitic stainless steels. When immersed in J-13 water and subjected to gamma irradiation, the corrosion potentials of copper and its alloys are generally around 100-150 mV more positive than 316L. Upon imposition of the gamma source, the corrosion potential of CDA 102 (oxygen-free, high-conductivity copper) makes a positive swing, then decreases in value to about 10-20 mV above the initial potential. The imposed gamma flux was 3.3 Mrads/hr. Subsequent "on/off" cycles show little further response of the corrosion potential. It appears that the corrosion potential of CDA 102 is far less sensitive to the increased oxidizing nature of the environment under radiolysis than is the case for the stainless steel. The corrosion currents were not measured in this investigation; the change of corrosion current with "on/off" cycles will indicate the corrosion rate of response to the environmental changes. Measurements of corrosion currents require incorporation of an additional electrode in the system; these measurements are planned in future work.

Aluminum bronze (CDA 613) showed an electrochemical response to radiation which was rather similar to those observed for the austenitic stainless steels; the potential shift was about 140 mV upon irradiation. The differences between the behavior of CDA 102 and 613 may reflect differences in operative electrochemical mechanisms or structures of the oxide films. The data presented here are preliminary; much further work is needed to clarify the situation.

In the electrochemical experiments, for both CDA 102 and 613, some vapor-phase corrosion had occurred. The formation of HNO_3 may account for this and is being explored. The air/water interface appeared to be a preferred area of attack. In an experiment performed under gamma irradiation (3.3 Mrads/hr) where CDA 102 was exposed to both the liquid and vapor phases, significant tarnishing of the portion exposed to the vapor phase was noticed after 68 hours. The portion of the rod immersed in solution showed much less attack.

3. Crevice Corrosion Testing of Stainless Steels

A special crevice cell has been designed and fabricated in which the crevice corrosion susceptibility of the candidate stainless steels can be quantitatively determined. In this cell, a portion of a circular sample is masked by a silicone O-ring forming a creviced area. The remaining portion of the sample is left freely exposed to the test solution. The "free" area is potentiostated at values in the passive range and simultaneously the current flowing through the creviced electrode and a counter electrode is monitored. The onset of crevice corrosion under the O-ring is then indicated by a sudden

rise in current. This "time to activation" assesses the relative susceptibilities to crevice corrosion of different materials.

In a typical experiment involving 316 stainless steel in 0.5 M NaCl at 50°C, the free area of the sample was potentiostated at 100 mV; after approximately 80 minutes, the oxide film in the creviced area broke down and crevice corrosion was initiated.

Experiments of this type are used to assess the resistance of other austenitic stainless steels to this form of corrosion. In particular, the potential synergistic effects of N and Mo additions in 316LN stainless steels are being evaluated. In this regard, alloys both with higher and lower concentrations of N and Mo are also being examined. The extension of these experiments to in situ gamma irradiation testing is planned.

4. Stress Corrosion Testing of Stainless Steels

Specimens of candidate stainless steels are stressed and exposed simultaneously to the test environment. Currently, three different kinds of stress corrosion test configurations are used: U-bend; slow strain rates; and bent beam.

U-Bend Stress Corrosion Tests

Stressed U-bends of 304 and 304L stainless steels are exposed to irradiated J-13 water in the PNL gamma facility. Tests are currently being conducted at 90°C and 50°C in the water and in the vapor phase above it. Crushed Topopah Spring member tuff is added to the test vessel to condition the water. The stainless steel test specimens have previously undergone different heat treatments to simulate different fabrication/welding process microstructures. The 90°C, 3×10^5 rads/hr test was disassembled for specimen examination after 7 months of exposure. No specimens exhibited obvious cracking failures, so no specimens were removed from the test. All of the specimens from the rock/water region of the vessel appeared uncorroded. A number of specimens (∿10) from the vapor/rock and the vapor only regions, including some specimens of 304L, appeared on visual examination to exhibit the possibility of some incipient cracking (solid corrosion products were evident). These specimens were re-emplaced in the test vessel and will be watched carefully in the course of future specimen examinations. The 50°C, 6×10^5 rads/hr test has accumulated a sample exposure of 10 months.

A number of water analyses associated with these two irradiation-corrosion studies have been carried out; note that the tuff rock and water in the vessel were replaced at each specimen examination, with the analysis coming at the end of the rock/water usage period. The analytical results were found to be highly variable. Rock heterogeneity is an obvious possible cause of water chemistry variability. In the future, the rock chips will not be changed after each specimen examination.

Slow Strain Rate Tests

The stress corrosion susceptibility of 304 and 304L stainless steel in J-13 water is being determined by the slow strain rate technique. Different thermal treatments and process histories of the test materials are performed

on the stock from which the individual specimens are machined. All testing is currently being performed in 90°C unirradiated J-13 well water sparged with air.

The purpose of the present test series is the determination of the optimum strain rate at which stress corrosion cracking (SCC) susceptibility develops in the highly vulnerable heavily sensitized 304 stainless steel. From previous tests performed at strain rates of 2×10^{-7} sec^{-1} and 1×10^{-4} sec^{-1}, it was concluded that SCC occurred at the lower strain rate in J-13 water. Specimens tested at the higher strain rate in J-13 exhibited approximately the same ductility as those tested in air, and showed no fractographic signs of embrittlement. Recent tests indicate that the strain rate of 5×10^{-6} sec^{-1} is too high to be useful in detecting SCC susceptibility. It appears that a strain rate of 1×10^{-6} sec^{-1} is adequate; additional testing, including fractographic analysis, is underway to verify this statement.

The slow strain rate tests are conducted under sub-contract by Pacific Northwest Laboratory.

Bent Beam Stress Corrosion Tests

Four-point loaded bent beam stress corrosion tests on 304, 304L, 316L, and 321 stainless steels are continuing. Test materials have been heat treated for different times and temperatures; welded specimens have been fabricated. These specimens are exposed to 100°C non-irradiated J-13 water and the vapor above it. To date, no specimens have cracked after more than 5000 hours of exposure in some cases.

Plate stock material of these alloys which has been heavily cold-worked [redacted] from this stock to allow direct behavior comparisons. The different processing and heat treatment characteristics of these plate stocks were described in the October monthly report.

5. Weight Loss Corrosion Tests of Stainless Steels

An array of carbon, alloy, and stainless steel specimens has been exposed to J-13 water and the saturated steam phase above the water at 100°C. Specimens are withdrawn periodically for determination of the weight loss due to corrosion and to observe and document the corrosion attack pattern. Both carbon steels (principal borehole liner material) and stainless steels (candidate canister materials) are placed in the same cell for this test. Specimens of each kind of material are electrically insulated from one another. However, the corrosion products of one material could alter the environment in the liquid phase and conceivably influence the attack on another material. This effect is considered to be small as the solubility of metal ions in the J-13 water is small. This situation is, of course, what could develop between a carbon steel liner and stainless steel canister and was intentionally incorporated into this test design. This array of specimens has now attained 7500 exposure hours in the test environments.

For the stainless steels, the general corrosion rates are quite small in both the water and in the steam. The localized penetration rates are also very small and are best described as a tarnishing phenomenon. The corrosion rates show a decrease with exposure time, and expressed on an annualized basis the localized rates also shown a decrease with exposure time.

For the carbon steels, the corrosion rates have decreased rather sharply with time. This indicates that the corrosion products (oxides of iron) do offer some protection in the relatively benign environments used here.

The next planned inspection of these specimens will occur after 10,000 hours of exposure.

6. Corrosion Test Plan for Copper and Copper-Base Alloys

A test plan for evaluating copper and copper-base alloys as possible waste package container materials was re-submitted to DOE/NV to reflect the larger budget amounts directed toward this investigation area in FY85 and FY86. The principal items to be addressed in FY85 are:

(1) Initiate corrosion survey tests on the nature of corrosion attack and the rates, particularly under irradiated conditions. The oxidizing environmental conditions are expected to increase the corrosion rate of pure copper, but certain of the alloys may perform well in this type of environment. Efforts will focus on oxygen-free, high-conductivity copper (CDA 102), aluminum bronze (CDA 613), and 70/30 copper-nickel (CDA 715). The general, localized, and stress-assisted forms of corrosion will be surveyed. One particular form of corrosion to which some copper-base alloys are susceptible is selective leaching of the less-noble constituent of the alloy. Because information on the corrosion performance is needed quickly, the survey will include a considerable amount of electrochemical corrosion data.

(2) Begin determination of mechanical strength requirements and design analyses for copper and copper-base alloy canisters. Pure copper is a structurally weak but highly ductile material; its alloys show an increase in yield strength while retaining the high ductility. An increase in canister thickness to compensate for the lower mechanical strength attenuates the gamma radiation transmitted through the canister wall, and this may have the desirable effect of reducing the aggressivity of the environment.

(3) Work with the copper industry, notably the Copper Development Association (CDA) and the International Copper Research Association (INCRA), in establishing an industry task group to review test results and guide future test efforts. The task group will draw upon the resources of the industry in assessing fabrication concerns, welding concerns, and the economic concerns in using copper as a waste package container material.

(4) Prepare a report on preliminary evaluation of copper as a nuclear waste container material. This report is due to the Congress at the end of the fiscal year, hence the emphasis on gathering test data and information in as timely a way as possible.

(5) Plan activities in detail for a larger FY86 budget. It is expected that these activities will be particularly directed toward resolving localized

and stress-assisted forms of corrosion. Also, in FY86 work will entail some investigation of the fabrication and welding processes that may be used and the effects of these on long-term corrosion performance. The interaction between copper and other waste package components will be investigated. A report on the corrosion survey test results over a two-year period and recommendations on which copper candidates for further testing will compete the activities. Further, the overall schedule for the Metal Barriers sub-task calls for a selection of container material at the end of FY86 from either the stainless steel candidate list or the copper candidate list.

Some of these activities may be undertaken in cooperation with the Basalt Waste Isolation Project (BWIP). The activities which may be jointly investigated would deal with such items as fabrication/welding concerns and radiation shielding which are not site specific.

PLANNED WORK

This is discussed in the appropriate areas in the Activities Section.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All scheduled deliverables are on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.3.L OTHER MATERIALS
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the development and testing of packing materials fabricated from crushed tuff plus additives to enhance the properties of the finished products (where necessary). Other activities under this sub-task include the assessment of the chemical effects of grouts and concrete on the performance of waste package components. (The second activity is not funded for FY85).

ACTIVITIES

Samples of a mixture of 95% crushed tuff + 5% silica gel were pressed isostatically at 15, 20, 25, 30, and 35 thousand psi. Final density of samples was similar for pressures of 20,000 psi or greater, and averaged 1.65 g/cc. This is similar to the density of samples prepared from crushed tuff alone. A mixture of 90% crushed tuff + 10% silica gel resulted in samples of lower density.

PLANNED WORK

Two samples of a 95% tuff-5% SiO_2 mixture will be prepared and used for thermal conductivity and permeability measurements.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones are presently on schedule for this sub-task.

L. Ramspott
L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.4.L DESIGN, FABRICATE, AND PROTOTYPE TESTING
L. Ballou/E. Russell, P.I.

OBJECTIVE

The objective for package design is to develop and analyze waste package designs which incorporate NNWSI qualified materials and which are compatible with the repository design. The designs and analyses are needed to support license application by documenting conformance with NRC requirements for safe handling, transportation, emplacement, retrieval, containment and release rate.

ACTIVITIES

A. Design

A conceptual design study for spent fuel canister/space frame optimization by SNLA has been completed, and a meeting for discussion of the results will take place at LLNL on 7 November 84.

A cost estimate was received for fabrication of spent fuel space frames based on supplied detailed drawings at quantities of 200 per year each of 3 lengths (total 600/yr). The commercial cost estimate (from Special Tools and Machinery Co. of Vernon, CA) was $6.33/lb, including poison rods, as compared to $4.66/lb calculated with the LLNL economics analysis computer program. Additional breakdowns of costs were requested to further clarify this commercial cost estimate.

B. Thermal Modeling

Thermal calculations for the current reference canister design for storing consolidated PWR spent fuel have been completed. These calculations were made using a three dimensional model to obtain an accurate solution and to compare the results to the simpler two dimensional model. The computer codes, TACO3D and TACO2D were used for the 3-D and 2-D calculations, respectively.

The three dimensional model incorporated the effects of spent fuel orthotropic conductivity and fuel axial power peaking. The 70 cm diameter canister was vertically emplaced in a 76 cm diameter borehole with a 5 m spacing between boreholes and an 47 m spacing between drifts. The canister contained 10-year-old PWR spent fuel with a decay heat of 3300 watts at time of emplacement.

Results of the three-dimensional calculations show a peak fuel temperature of 316°C reached 5 years after emplacement. Results for the two-dimensional calculations, which do not account for power peaking and orthotropic fuel

conductivity, show a peak fuel temperature of 306°C. The three-dimensional results therefore show a 10°C higher fuel temperature than the two-dimensional calculations.

C. Structural Analysis

The report "Structural Analysis of Conceptual Waste Package Designs for a Tuff Repository" has been completed and will be forwarded to DOE/NV.

D. Economic Analysis

A draft of the report "Preliminary Economic Analysis of Conceptual and Alternative Waste Package Designs for a Repository in Tuff" has been completed. This report documents the spread-sheet computer program that is used to estimate waste packages and related repository costs for vertical emplacement of reference and alternative designs.

PLANNED WORK

See activities mentioned above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones for this sub-task are presently on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1934

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.5.L PERFORMANCE ASSESSMENT
L. Ballou/M. Revelli

A. PERFORMANCE ANALYSIS

OBJECTIVE

This activity involves the development and validation of models that can be used to predict long-term package performance for comparison with NRC performance objectives.

ACTIVITIES

Model verification and development for the mechanical (FMODEL) and flow/transport subroutines continued in support of the waste package system analysis code (WAPPA). A draft report, summarizing the status of FMODEL, has been completed and is currently under review. The report outlines the systems model approach for performance analysis of the waste package and focuses on the following aspects of the WAPPA mechanical submodel:

- Evaluation of its current capabilities and limitations,
- Documentation of errors identified during this review and the resulting code changes,
- Assessment of model assumptions and their applicability to the Yucca Mountain emplacement environment,
- Test problem results designed to study expected Yucca Mountain conditions,
- Code modifications implemented during the testing, and
- Recommendation for additional submodel capabilities.

This report will fulfill the scheduled level III deliverable 2.2.5-85-III-1.

Efforts continued to define the modeling requirements necessary to represent hydrothermal flow in and around the waste package. Three classes of problems have been identified: 1) porous media flow, 2) fracture flow, and 3) falling fluid flow. Studies are in progress to analyze regions of porous flow within the waste package subsystem and to assess the applicability of WAFE to these representations.

In conjunction with these analyses, it is necessary to define the boundary conditions which characterize the waste package emplacement environment. On October 18, representatives from LANL, LBL, and SNLA met with LLNL staff to coordinate hydrothermal modeling efforts. At this meeting a common problem

was defined for modeling the near-field environment of a waste package emplaced in the Topopah Spring unit of Yucca Mountain. Three codes currently exist within the NNWSI project which are capable of simulating 2-D hydrothermal flow on this scale--NORIA, TOUGH, and WAFE. The similarities and differences of these codes were discussed and it was agreed to model this common problem with these three codes. Results of the analysis are needed to support several WBS elements, including: 1) waste package performance assessment, 2) waste package exploratory shaft test designs, 3) engineered barrier system analysis, and 4) computer code validation.

M. Revelli (LLNL) and J. Braithwaite (SNLA) reviewed the HQ proposed Engineered Barrier System definition for WMPO/NV. A set of viewgraphs was prepared to document the rationale for the NNWSI assessment and this material was forwarded to WMPO/NV in preparation for the Program Managers/ teleconference on this subject.

At the request of WMPO/NV, the list of "Computer Codes Used in the NNWSI Waste Package and Design Task" was reviewed and revised. Only minor modifications were needed to update the compilation.

PLANNED WORK

Plans for work are discussed under the sections above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones for this subtask are presently on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

2 November 1984
Report Period: 1-31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.3.4.1.9 - GEOCHEMICAL MODELING CODE EQ3/6
D. Emerson/T. Wolery, P.I.

OBJECTIVE

This task is the development of advanced calculational capabilities for modeling geochemical processes in the repository environment. The work is being carried out by extending the capabilities of the existing EQ3/6 software. The applications objective is to support site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

ACTIVITIES

The document "EQ3/6 Status and Applications" was prepared by T. Wolery et al., for a report to be published by ORNL in connection with the workshop "The Application of Geochemical Models to High-Level Nuclear Waste Repository Assessment".

J. Delany supported the laboratory effort of K. Knauss with EQ3/6 calculations for the document "Interaction of Topopan Spring Tuff with J-13 Water as a Function of Temperature". This has been submitted to the Boston MRS meeting of November 26-30.

The pre-Newton-Raphson optimizing subroutine in the EQ3NR code was extensively modified to overcome some non-convergence problems in the 3245 (development) version which will be released in early 1985. These problems are related to recent code additions and changes and affect the development version only.

A random-access capability for managing the DATAO data file is being developed and is about 70 percent complete.

A large number of minor-to-moderate changes were made to the EQ3NR code due to problems that surfaced during pre-release testing. The COMMON and LEVEL statements in the FORTRAN codes were checked for consistency. A few errors found in the EQ6 source code were fixed.

PLANNED WORK

Work on random access capability for data management of the main EQ3/6 data file is in progress.

New experimental data has been prepared for use in another test of the silica precipitation kinetics of EQ6.

The draft report on the addition of precipitation kinetics to the EQ6 code will be completed early next month.

The draft MCRT User's Manual, which incorporates the recently added random access format, is in progress.

PROBLEM AREAS

Extensive code debugging due to the problems associated with the addition of precipitation kinetics to EQ6 has delayed the draft report and the draft MCRT manual several months.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.5.2.2.L SITE CHARACTERIZATION PLAN
L. Ballou/P.I.

OBJECTIVE

This sub-task includes preparation and certification of LLNL input to the NNWSI Site Characterization Plan (SCP) and reviews of other inputs to the reference document as requested by WMPO/NV.

ACTIVITIES

L. Ballou and L. Hansen attended the SCP meeting at SAIC/LV on October 12.

M. Revelli participated in the NNWSI/SCP Workshop at SAIC/LV on October 31. During this meeting a draft "NNWSI Position" was established for a number of topics related to the Site Characterization. SAIC also requested LLNL review and comment on the revised annotated outlines for Chapter 7 (Waste Form and Package) and Chapter 9 (Site Characterization Program) distributed at that meeting.

PLANNED WORK

Work is in progress on review of and comments on designated sections of the SCP (see above).

PROBLEM AREAS

None.

MILESTONE PROGRESS

No project deliverables were forwarded to WMPO during October.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 November 1984
Report Period 1 - 31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.6.9.1.L and 2.6.9.2.5 EXPLORATORY SHAFT TEST PLAN and ENGINEERED BARRIER DESIGN TESTING
L. Ballou/J. Yow, P.I.

OBJECTIVE

This sub-task includes planning and implementation of in situ tests of waste package environment. The results of these tests will be used to aid in the validation of the models used in the waste package performance analysis. This sub-task also includes the preparation and certification of LLNL input to the Exploratory Shaft Test Plan (ESTP).

ACTIVITIES

A draft report describing the use of high frequency electromagnetic (HFEM) geotomography techniques in fractured, welded tuff is being subjected to internal technical review. "Study of Water Flow in Welded Tuff using Geophysical Tomography," by A. Ramirez and W. Daily, describes the HFEM measurements made in G-Tunnel at NTS and their analysis and interpretation.

Scoping calculations for test design have been commenced; this work is related to the numerical modeling being planned in the Waste Package Performance Analysis sub-task. Two types of calculations are currently in progress: (1) relatively simple thermal calculations to define the necessary duration and power requirements of in situ tests; and (2) calculations to examine various possible borehole configurations for HFEM geotomography measurements in the Waste Package Environment Tests.

Only limited revisions (resulting from the LLNL internal peer review) have been made in the current internal (LLNL) version of the plan. No revisions have yet been made in the version that is included in the ESTP. This work has been delayed by incomplete review comments from the La Jolla WMPO/TPO/ESTP Committee meeting.

Several meetings were held during October that were related to aspects of the Waste Package Environment Tests. J. Yow and L. Hansen met with representatives of LANL and SAIC on October 4 to discuss scheduling, costs, and QA. M. Revelli, J. Yow, and K. Eggert met with SNL, LBL, and LANL representatives on October 18 to discuss the use of the WAFE, NORAH, and TOUGH transport codes to model a test problem representative of the Waste Package Environment Tests. J. Yow participated in the ESTP Committee meeting in Las Vegas on October 25.

PLANNED WORK

The report describing the status of HFEM techniques for monitoring saturation changes in fractured, welded tuff will be forwarded to WMPO for review early in November. Review of other types of instrumentation, measurement, and sampling techniques will continue. These fall into the general areas of subsurface hydrology and geomechanics, in keeping with the broad scope of the Waste Package Environment Tests.

Revision and development of the Test Plan will proceed as soon as the remainder of the review comments from the March ESTP retreat are received. The schedule of the Waste Package Environment Tests will also be refined as the results of the scoping calculations become available.

PROBLEM AREAS

See above.

MILESTONE PROGRESS

No project deliverables were forwarded to WMPO during October.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

2 November 1984
Report Period: 1-31 October 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.7.2.1 - SPENT FUEL TEST-CLIMAX
W. Patrick, P.I.

OBJECTIVE

The objectives of the SFT-C are to demonstrate the feasibility of storage and retrieval of spent nuclear fuel and to acquire data pertinent to the design, construction, and operation of a repository in crystalline rock. Emphasis in FY 1985 is analysis post-test characterization data, instrumentation evaluations, and documentation of thermal- and radiation-induced changes in the rock mass. The extensive data set collected during heating and cooling of the rock mass is being analyzed in light of pretest and post-test calculations.

ACTIVITIES AND ACCOMPLISHMENTS

Summary

Data analysis and reporting continue to be the dominant project activities following completion of field work. Analysis of instrumentation calibration and reliability data is also a major focus. Two project deliverable reports were completed and are undergoing internal review. The SFT-C documentary film was distributed to U.S. and foreign agencies in accordance with DOE/NV guidance. The SFT-C Technical Measurements Interim report was also distributed this month.

Geological Investigations

The database of post-test core logs is essentially complete. Fracture orientations, locations, and characteristics were entered for nearly 1000 ft. of core. Data pertaining to one in situ stress borehole remains to be entered. The pretest and post-test core logs are being merged into a single database which will be made available to other researchers. A code which was developed on another program is being evaluated and will be modified as necessary to generate pictorial logs from the numerical data base. This is anticipated to streamline the preparation of both the post-test core logging report and the database report.

Studies of the effects of heat and irradiation on the Climax stock quartz monzonite (CSQM) continued. The study of thermal effects was completed and a draft report was prepared and submitted to DOE/NV for programmatic review. Potential physical and chemical changes to the CSQM

were investigated by examining pretest unheated samples and post-test samples from near two auxiliary heater boreholes in the north and south heater drifts. The post-test borings were located to provide samples within 0 to 150 mm of the heated borehole as well as at 760 mm from the borehole. Temperatures were in excess of 300°C adjacent to the boreholes and decreased to about 60°C at a distance of 760 mm radially outward. Microfracture studies indicated no physical changes to the rock occurred. Petrographic and mineralogic investigations indicate no chemical changes.

The effects of radiation on the mineralogy and petrology of the CSQM is the subject of a second study now in progress. The study was delayed because the required thin sections were not prepared on schedule. About half the sections are now available and the remainder are being prepared and delivered by the vendor on a regular schedule. The optical microscopy and electron probe work is progressing well at this time.

Both internal and external review comments have been received on the report "Measurement of In Situ Deformability with NX Borehole Jack, Spent Fuel Test-Climax". The comments have been addressed, as appropriate, and the text is being revised in preparation for a final review. In response to reviewer comments, the data were further analyzed with statistical techniques. These analyses focused on testing the statistical significance of this highly variable data set. Anisotropy, thermal effects, and excavation-induced damage were determined to be statistically significant.

Preparations for a laboratory evaluation of the NX borehole jack are in progress. Procurement of the large aluminum block to be used in this study was delayed about one month. Testing is currently planned for mid-December.

Instrumentation and Data Management

Post-test instrumentation evaluations have progressed in several areas. First, an approach was developed for comparing pre- and post-test laboratory calibrations of displacement transducers. These transducers were deployed on convergence wire extensometers which had no provision in their design for in situ calibrations. The required calibration data has been entered into the database and is being analyzed for changes in slope and for other potential errors. Second, error analyses were completed for the ventilation system instrumentation. Turbine flowmeters and dewpoint cells are included in these analyses Discrepancies were identified in the subcontractor's dewpoint cell calibrations. These have now been addressed and the subcontractor is preparing the supporting documentation for our records. Third, data acceptance criteria were established for the canister emplacement borehole deformation gauges. These criteria are based on pretest and post-test calibrations and on the response of two "standards" which were deployed to measure gauge creep and drift characteristics. Availability of the acceptance criteria permits release of the data for analysis and reporting. Fourth, evaluation of the stability of the couplings which were used to join the transducers to the rods of the MBI-series borehole extensometers began this month. During post-test instrumentation studies, these couplings were found to slip under certain

loading conditions. The laboratory tests will provide an envelope of certainty for the extensometer field data. Fifth, a series of tests of the U.S. Bureau of Mines (USBM) overcore cell using the standard calibration fixture was completed. The tests indicate hysteresis on the scale of hundreds (about 100 to 500) microstrains. In addition to being large, the errors do not repeat. Several tests using a newly designed calibration fixture were also performed. These "shake down" tests resulted in modifications to the fixture. Hysteresis with the new calibration fixture is generally less than 150 microstrains.

Problems were encountered in final processing the backlog of SFT-C field data. The computer code REVERT was unable to successfully accommodate the changes in the coefficients database which accompanied the addition of new instruments. Necessary changes to the code and to the database have been completed and REVERT is again operational.

Post-Test Calculations

Development of a fully three-dimensional TRUMP model of the SFT-C was begun. As currently configured, the TRUMP mesh generator is not readily capable of producing the required finite difference mesh. Possible modifications to the code are being studied. This model is being developed to facilitate treatment of the boundary conditions which are a result of the finite length of the SFT-C. Calculations to data have assumed an infinite length with the result that no heat flow occurs out the ends of the model.

Revised calculations of the SFT-C mine-by and heated-phase have been delayed as a result of weapons program demand on the physicist's time.

Decommissioning

A request was received for use of the uninterruptible power supply (UPS) which was deployed on the surface at the SFT-C. The need arises in long-term laboratory studies of the tuff waste package environment, which are being conducted at the LLNL. The request is being evaluated in light of transportation and set-up costs and the availability of small UPS units.

The USGS is still evaluating the digital multimeter and scanner which they borrowed from the LLNL. Pending a decision by the USGS, the required equipment should be transferred from the LLNL to the REECo property management systems for ease of accounting.

Public Information

Copies of the SFT-C documentary film were received, quality checked, and distributed in accordance with DOE/NV guidance. F. Guinn, DOE-OPA, previewed the film prior to its distribution.

Peter Lang, Atomic Energy of Canada, Ltd. was provided a visit to the SFT-C and G-Tunnel facilities. Instrumentation selection, installation,

calibration, and reliability were the subjects of discussion. These interactions are part of a joint U.S./Canadian Cooperative Agreement administered by the Office of Crystalline Repository Development.

PLANNED WORK

Staff efforts will continue to concentrate on analysis of field data and compilation and analysis of post-test calibration results. Revisions to thermal and thermomechanical models will continue.

PROBLEM AREAS

None.

NETWORK ACTIVITIES

2.7.2.1-85-II-1 Documentary Film on the SFT-C.

Copies of the film in 16mm and U-Matic formats were distributed on 30 October 1984 in accordance with DOE/NV guidance.

2.7.2.1-84-III-5 Physical and Chemical Changes to Rock Near Electrically Heated Boreholes at SFT-C

Internal technical and project reviews were completed. The report was submitted for WMPO programmatic review on 1 November 1984.

2.7.2.1-84-III-7 Overcoring and Calibration of IRAD Gage Stressmeter at Spent Fuel Test in Climax Granite

Internal technical and project reviews were completed Revisions are in progress.

The following two reports are not scheduled deliverables, but document important work on the project.

a) Review and revisions were completed on the report "REVERT: A CDC 7600 Program for Converting SFT-C Data to Engineering Units, with Corrections", by G. L. Hage. The document was submitted for publication services.

b) Project review was completed of an article on the results of personnel dosimetry at the SFT-C. The article entitled "Radiation Safety Considerations for a Test of Deep Geologic Storage of Spent Nuclear Fuel" will be submitted for possible inclusion in the Nuclear Science and Engineering Journal.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

2 November 1984
Report Period: 1-31 October 1934

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.9.3. - QUALITY ASSURANCE
J. Dronkers, P.I.

OBJECTIVE

The objective of Quality Assurance is to develop, implement, and maintain an effective management system that can readily and functionally integrate requirements for procedural and planning controls into the working environment of NWMP's scientists and engineers assigned to the NNWSI tasks.

ACTIVITIES

Four draft procedures and nine draft requirements of the NNWSI Quality Assurance Program Plan (NNWSI-QAPP) were completed and submitted to DOE/NV for review on October 30th. The nine draft requirements constitute the complete generic part of the NNWSI-QAPP. What remains are the detailed implementing procedures, of which the four submitted are a beginning.

Work on the QA Records Procedures has continued with the submittal for review to John Dronkers of a Current Records Inventory Plan and a proposed system for document numbering and identification. Both are under review.

A first draft of the formal procedures will be submitted to J. Dronkers on November 5. The acquisition of the INMAGIC software is progressing smoothly and should be completed within a few weeks.

Recruiting action for an additional QA Engineer has opened.

MILESTONE PROGRESS

There are no Level 1 or 2 milestones due for this subtask in FY85.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

Lawrence Livermore National Laboratory

3 February 1985
NWM:84/6362C

Donald L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

SUBJECT: January 1985 Monthly Report - LLNL

Attached are LLNL's Project Status Reports for the month of January. A "Project Status Report" has been completed for each WBS.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

Attachments

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2 - WASTE PACKAGE
L. Ballou, P.I.

The two long-term (300 d) hydrothermal interaction experiments between Topopah Spring tuff (Tpt) and J-13 water are continuing. The two short-term (52 d) experiments to study the effect of heating J-13 water in Dickson-type autoclaves were completed this month, and samples are being analyzed.

A number of Tpt samples have been received and will be used in future hydrothermal interaction experiments and in pore water characterization measurements.

Analytical results from the mineral dissolution kinetics experiments on quartz and feldspar are being received.

The experiments to investigate the distribution of Li in the system Tpt (FR core wafer) + J-13 water (90°C) were completed and samples have been submitted for analysis.

The field observations of rock blocks in the Climax stock and at G-Tunnel have been successfully back-analyzed with the fully three-dimensional block stability model.

Documentation of techniques for identifying and evaluating potentially unstable rock blocks is continuing.

The study of the dehydration and rehydration of the large (8.23 cm diameter) fractured Tpt core sample is continuing.

Leaching/dissolution testing of spent fuel in J-13 water is continuing on schedule.

The 6-month Zircaloy cladding corrosion test was terminated on schedule in the second week in January.

Oxidation rate experiments on spent fuel fragments at elevated temperatures are continuing; the medium is controlled-humidity air.

The unsaturated test method is being used to evaluate the leaching/dissolution rates characteristic of sintered UO_2 pellets and various compositions of borosilicate glass samples.

The 180 day leaching/dissolution experiments involving DWPF glass immersed in J-13 water contained in Tpt reaction vessels was terminated on schedule and the leachates are being analyzed.

The following metal barrier testing activities are continuing:

- o Determination of general and localized corrosion rates of stainless steels, carbon steels, and alloy steels
- o Determination of general and localized corrosion rates of copper and copper-base alloys
- o Localized corrosion testing of austenitic stainless steels and copper in irradiated environments
- o Slow strain rate testing of austenitic stainless steels
- o Crack initiation and propagation studies in austenitic stainless steels

A metallographic examination of canister D-34 from the Climax Spent Fuel Test has been initiated.

Contractual arrangements have been completed between LLNL and the Copper Development Association (CDA) to support the activities of a copper industry task group in the investigation of the feasibility of using copper or copper-base alloys as nuclear waste containment materials in a tuff environment.

Planning for corrosion testing of copper and copper-base alloys under gamma irradiation (to be carried out at HEDL) is under way.

The thermal conductivity of a compacted mixture of crushed Tpt with silicic acid powder (5%) was measured to evaluate the suitability of this formulation to serve as a packing material.

Work is continuing on a feasibility evaluation of collocating contaminated spent fuel hardware in the same canister with spent fuel rods, utilizing a 7-module space frame manufactured from thin, spot-welded stainless steel sheet.

Thermal analyses were carried out on two canister designs proposed by SNL; future calculations will be undertaken to establish the upper limit for the canister decay heat power level that will yield peak fuel temperatures within allowable limits (below 350°C).

Work has begun utilizing the three-dimensional, large-deformation, finite element code NIKE3D for modeling the drop test of a fully-loaded spent fuel canister.

Efforts leading to the development and verification of a 1-D waste package system model are continuing.

Hydrological flow modeling efforts have focused on debugging WAFE for specific waste package near-field flow configurations; the work is being closely coordinated with LANL code developers.

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.1 MANAGEMENT AND INTEGRATION
L. Ballou, P.I.

OBJECTIVE

This subtask provides the overall management of the waste package development activities including planning, scheduling, budgeting and reporting; provides for the interaction with other program participants; and is responsible for implementing the quality achieving aspects of the QA program for waste package activities.

ACTIVITIES

A draft evaluation and recommendation on a proposed change to the Waste Package performance criteria in the GR-MGDS document was prepared and sent to WMPO on January 23.

M. Revelli participated in the NNWSI System Description Workshop at SNL-Albuquerque on January 25. LLNL staff are currently reviewing the Pre- and Post-Closure Waste Package Subsystems of the Mined Geologic Disposal System document.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.L WASTE PACKAGE ENVIRONMENT
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the characterization of the variability in the properties of Topopah Spring tuff (Tpt) in that volume of Yucca Mountain in which a waste repository is to be located. Also included is the study of hydrothermal reactions between Tpt and J-13 water. These reactions provide a baseline for the multi-component testing carried out in WBS 2.2.3 involving waste forms and metals.

The data obtained in this sub-task also will be used to verify and extend the capabilities of EQ3/6. This applications objective supports site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

This sub-task also includes experimental work to determine the rates and mechanisms of dehydration and rehydration of repository near-field rock in response to the thermal field generated by emplaced waste. These data will aid in estimating the water flux past waste packages. Activities related to the stability of borehole openings which are part of this sub-task will determine whether borehole liners will be necessary, and will aid in determining the state of stress of waste packages.

ACTIVITIES

A. Yucca Mountain Tuff and Groundwater - Interaction Experiments and Results

The 2 long term (300 d) experiments currently in progress in the Dickson-type, gold-cell, rocking autoclaves continued with no problems. These experiments are:

DB12 = USW G-1 core wafer, J-13 water, 90°C, plan 300 d, currently at day 272.
DB13 = USW G-1 core wafer, J-13 water, 150°C, plan 300 d, currently at day 272.

Note that the planned length of these long term experiments with densely welded Tpt from the repository horizon has been decreased to 300 d to allow the more rapid start up of hydrothermal interaction experiments with Tpt vitrophyre and J-13 water. The vitrophyre experiments are described below.

Two short-term (planned 32 d) experiments in the Dickson-type autoclaves were completed this month. These are:

DB18 = J-13 water, 90°C, plan 32 d, terminated normally at day 52.
DB19 = J-13 water, 150°C, plan 32 d, terminated normally at day 52.

During this month samples were taken at day 32 and 52. All solution samples have been submitted for analyses.

Samples of Tpt vitric tuff were received from Schon Levy and Dave Vaniman (LANL). The samples are:

USW GU-3 1226.8 = densely welded Tpt vitrophyre with slight natural alteration from the middle of lower Tpt vitrophyre.

USW G-4 1362.1 = moderately welded Tpt vitric tuff from below the lower Tpt vitrophyre.

UE-25a#1 1297.4 = altered Tpt vitrophyre with zeolite and smectite from near bottom of lower Tpt vitrophyre.

These samples will be used to prepare solid monoliths (wafers) of tuff to be run in hydrothermal interaction experiments in the Dickson-type gold-cell rocking autoclaves. Present plans call for experiments at 90°C and 150°C using J-13 water as the reacting fluid. Slabs of material from the face opposite that ultimately cut for each wafer will be returned to LANL for pre-test geochemical and petrographic characterization. Post-test solid phase analysis will be done at LLNL. This cooperative research effort will compliment previous field studies by Schon Levy (LA-UR 83-3402) to evaluate the susceptibility of vitrophyre to thermal alteration by emplacement of HLW in Yucca Mountain.

Twelve samples from air-drilled hole UZ-1 were received from Rick Whitfield (USGS). These samples will be used in a leaching experiment (a modified shake and bake cleaning procedure for outcrop samples) to characterize the pore water trapped in the unsaturated zone tuff at Yucca Mountain. These experiments will commence next month. Additional samples from air-drilled hole UZ-6 are expected in the near future. Similar experiments will be performed using these later samples.

The remaining fluid chemistry analyses from experiment DB15 were received at the end of this month (1/30/85) and will be incorporated in the report entitled "Hydrothermal Interaction of Crushed Topopah Spring Tuff and J-13 Water at 90°C, 150°C, and 250°C Using the Dickson-Type, Gold-Cell Rocking Autoclaves" by Knauss, Beiriger and Peifer. This report has been rescheduled for delivery to WMPO on 31 March 85.

Solution analyses for Si only by colorimetry were received at the end of this month for the single mineral dissolution kinetics experiments using both quartz and feldspar run in the flow-through system. Solution analyses for Na, Al and Si in the feldspar experiments via ICP-ES await the receipt and calibration of a special wide orifice nebulizer. SEM observation of the reacted quartz crystals has been completed. No secondary minerals were observed indicating conditions remained far from equilibrium, as planned.

Well-developed micron-sized etch pits were seen, indicating a surface-reaction controlled dissolution mechanism above pH 8 (Experiments at pH 10, 11, 12, and 13) while none were seen below pH 3, which differs as expected from the analogous feldspar experiments. Etch pit development and density were directly related to pH. A preliminary examination of the silica fluid concentration raw data is in accord with these solid phase observations. These experiments were completed last month.

The experiments to investigate the distribution of Li in the system: Tpt-FR core wafer + J-13 water at 90°C (TGLE-1, -2, and -3) which were begun last month were completed after 61 days. Fluid samples have been submitted for ICP-ES analysis. The reacted core wafers will be analyzed by SEM/EMP and the Li distribution will be mapped using the ion microprobe.

The accuracy and precision of the IR CO_2 analyzer were evaluated and the precise value for the CO_2 content of the lab supply of J-13 water was determined by a series of experiments this month. After generating a calibration curve that was completely linear (r^2 = 1.000) and essentially passed through the origin (y-intercept corresponding to 0.2 ppm HCO_3^-), 15 standard samples were run as unknowns and found to contain 99.33 +/- 1.47 µg C/ml. The standard contained 100.0 µg C/ml. A total of 13 J-13 analyses produced a value of 125.3 +/- 7.1 ppm HCO_3^-. This resolves problems encountered in obtaining good charge balance with previous analyses of J-13 water, where IC or Technicon Autoanalyzer values of CO_2 were used. Both of these other methods were producing values that tended to be too high and both had significantly less precision than the IR CO_2 analyzer.

B. Stability of Borehole Openings

The field observations of blocks in the Climax stock and at G-Tunnel were successfully back-analyzed this month with the fully three-dimensional block stability model. The back-analyses were successful in that blocks that were observed to have failed were indicated as unstable by the model, while blocks that were observed to be stable were indicated as stable by the model. In addition, a series of bench scale block stability experiments were successfully back-analyzed with the two-dimensional model. These experiments had been performed by researchers at the Imperial College in London using a plaster model of a wedge in the horizontal roof of a tabular underground excavation subjected to a horizontal stress field. Taken together, the back-analyses show that the approach used in the models to evaluate stresses and discontinuity behavior are essentially correct.

Documentation of techniques for identifying and evaluating potentially unstable rock blocks continued this month. Of the several techniques that were examined in December, four methods were found that are capable of identifying potential blocks. Only the Keyblock Method efficiently avoided undue restrictions on excavation geometry or data requirements. A number of approaches for calculating the stability of identified potential blocks have also been reviewed, but none include the capabilities that the LLNL models have for treating blocks and stress fields as fully three-dimensional, and for incorporating thermal stresses and non-linear discontinuity behavior. The LLNL models do, however, assume that potentially unstable blocks are adjacent to cylindrical excavations. This is quite appropriate for waste package emplacement holes, and represents a good approximation for other excavation shapes.

C. Dehydration and Rehydration of Topopah Spring Tuff

During the month of January 1985, we continued the study of dehydration and rehydration of a large (8.23 cm diameter) fractured Topopah Spring Tuff sample. The sample has gone through two dehydration-rehydration cycles at temperatures of about 140°C during dehydration, 90°C during the first rehydration and 138°C during the second rehydration. The confining pressure was 5.0 MPa. The sample is now in the third dehydration period.

Electrical resistance was measured continuously from 4 pairs of electrodes mounted along the sample axis almost on the fracture edge (the same way as for the smaller sample). In addition, we are also testing the impedance camera concept by measuring electrical resistance occasionally from 14 electrodes evenly distributed around the circumference of the sample (reported in the July, 1984, Monthly Report). Water permeability was measured at least daily when the sample was rehydrated. We also tried to measure travel time of ultransonic P-waves propagating parallel and perpendicular to the fracture, but the wave signal became so deteriorated that when the sample temperature was raised to 90°C, no reliable travel time could be determined.

The permeability of the tuff sample was measured as function of time. Each measurement represents the averaged permeability from three flow rate measurements. The standard deviation of the average is no more than 5%. A decrease of more than one order of magnitude in permeability occurred when the initially saturated sample was first heated to 90°C, and a further slight decrease was observed on heating to 140°C. This is consistent with our experimental result from the smaller sample. However, further dehydration and rehydration did not have significant effect on water permeability of the sample.

PLANNED WORK

Experiments that are in progress will continue. Plans for new work areas are discussed under the sections above.

PROBLEM AREAS

The solution analysis backlog reported last month has been cleared.

MILESTONE PROGRESS

2.2.2-85-III-1 (W279) Report on geochemical modeling of Topopah Spring tuff and J-13 water reactions.

During the process of modeling the core wafer experiments it was decided that porosity data for the rock wafers would improve the modeling. These data are now in hand and modeling is completed. A draft of the report is expected by late February, with expected delivery to WMPO in March.

Other milestones for this subtask are presently on schedule; however, milestones 2.2.2-85-III-3 (W281), 2.2.2-85-III-4 (W280), 2.2.2-85-III-5 (W209), and 2.2.2-85-III-6 (W210) may be impacted by the SCP production schedule.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.1.L WASTE FORM TESTING
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task involves the measurement of the radionuclide release rate from spent fuel and from borosilicate glass (containing DHLW or CHLW); these data are to be used as input for performance modeling of long-term radionuclide release rates from the waste package. Radionuclide release rate information will also determine whether or not a packing material must be incorporated in the waste package designs in order to meet NRC performance objectives.

ACTIVITIES

A. Spent Fuel Leaching/Dissolution Tests

Testing of spent fuel in J-13 water is continuing on schedule. Series 2A tests using H. B. Robinson fuel in J-13 water were terminated after 223 days and were restarted in fresh J-13 water. Approximately 0.2 g (0.25% of fuel weight) of fine material, which apparently spalled from the fuel particle surfaces, settled out of the bare fuel rinse water when the Series 2A bare fuel test was terminated. The 0.2 g corresponds to ∿1 μm of material from the bare fuel particle surfaces. Ceramographic examination of 3 fuel particles from this test did not reveal intergranular attack which was observed on bare fuel particles from the Series 1 deionized water tests. Series 2B tests using Turkey Point fuel in J-13 water are being terminated at 181 days and restarted in fresh J-13 water.

B. Zircaloy Cladding Degradation

The "C-ring" stress corrosion test apparatus has been assembled. Linear voltage displacement transducers that will sense deformation of the "C-ring" cladding specimens will be installed and calibrated next.

The 6-month cladding corrosion test was terminated the second week in January. The cladding bundle test assembly macroscopic appearance was very similar to that of the 2-month test, although the 410 stainless hex screw on the hose clamp holding the 304L SS wrap on the cladding bundle had begun to corrode. The test bundle was disassembled, photographed, and selected pieces of cladding are being prepared for optical microscope and SEM evaluation.

Organic carbon levels up to 60 ppm have been detected in the J-13 water of the 12-month test. The J-13 water was completely changed twice to lower the

carbon level. The organic carbon is being measured periodically to see if a different equilibrium will be established. This will indicate whether carbon originates from unreacted epoxy components or from radiolysis of the epoxy, which was used to secure end caps onto the cladding segments.

C. Spent Fuel Oxidation

Spent fuel fragments tested at 225°C and 14.5°C dew point air had the same weight gain characteristics as fragments tested in -70°C dew point air. A new TGA test was started at 140°C and 14.5°C dew point and is expected to run for three months; the purpose is to obtain data at the lower temperature as well as to determine if enough oxidation takes place in three months to obtain useful data from the TGA system.

A draft of "Technical Test Description of Experiments to Determine the Oxidation Potential of Spent Fuel in a Tuff Repository" by R. E. Einziger underwent internal WHC review and was transmitted to LLNL for review. The paper "Low Temperature Spent Fuel Oxidation Under Tuff Repository Conditions" by R. E. Einziger and R. E. Woodley for the Waste Management '85 meeting was written and sent to LLNL for review.

D. Fuel Testing Using the Unsaturated Test Method.

Scoping tests using sintered UO_2 pellets (unirradiated) gave solution concentrations of 100 to 400 ppb U. This indicates that uranium release from spent fuel should be well above detection limits using the unsaturated testing procedure. Samples with Zircaloy cladding will be tested next.

E. Unsaturated Test Method

Solution analyses for the 26 week samples have been completed. Results for Li release from the glass are consistent with glass degradation rates based on weight loss. The sum of degradation rates from four 6.5 week consecutive tests are consistent with the rate determined from a 26 week continuous test.

A crystalline phase containing U, Si, P, and Ca has been identified on the glass surface between the stainless steel and glass on the 26 week samples. There is more of the phase on the bottom surface where liquid adheres to a greater degree than on the top surface. No crystalline materials were found on 6.5 or 13 week samples.

F. Parametric Testing

The behavior of Tc relative to Mo has been studied in deionized water and J-13 water from the parametric testing of the ATM-8 (actinide-doped) glass. Excellent agreement exists in the release rates of these two elements in the deionized water samples. Results for the J-13 water are still being compiled. A report of this study is now in preparation.

G. Testing in Tuff Reaction Vessels

The 180 day experiments were terminated in January. The leachates are now being analyzed for all glass components.

PLANNED WORK

Tests that are in progress will continue. New work areas are discussed above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones for this subtask are presently on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.2.L METALS BARRIERS TESTING
L. Ballou/D. McCright, P.I.

OBJECTIVE

This sub-task includes the selection of the metals for the fabrication of canisters and of borehole liners, as well as the characterization of the corrosion rates of these metals under expected repository conditions. The corrosion data will be used in performance assessment modeling and predictions of long-term canister behavior needed for NRC repository licensing. Two alloy systems, austenitic stainless steel and copper-base materials, are currently being investigated as canister materials. Carbon steels are under consideration as borehole liner materials.

ACTIVITIES

Activities reported this month are:

1. General and Localized Corrosion of Stainless Steels, Carbon Steels and Alloy Steels
2. General and Localized Corrosion of Copper and Copper-Base Alloys
3. Localized Corrosion Testing of Austenitic Stainless Steels and Copper in Irradiated Environments
4. Slow Strain Rate Testing of Austenitic Stainless Steels
5. Crack Initiation and Propagation Studies in Austenitic Stainless Steels
6. Compilation of Mechanical Properties of Austenitic Stainless Steels
7. Evaluation of Stainless Steel Canister from the Climax Spent Fuel Test
8. Implementation of NNWSI Copper Test Plan

1. General and Localized Corrosion of Stainless Steels, Carbon Steels and Alloy Steels

EXPERIMENT 11: General corrosion rates and localized corrosion tendencies are being determined for 304L, 316L, 321, and I-825 in J-13 water at 50°C, 70°C, 80°C, 90°C, and 100°C.

The 10,000 hour examination has been finished and all results recorded. Next evaluation is scheduled for May, 1985, at 15,000 hours.

EXPERIMENT 22: General corrosion rates and localized corrosion tendencies of the ferrous alloys 1020, A36, 9 Cr-1 Mo, 409, 304, 316L, 317L, 321, 347, and I-825 in J-13 water and steam (100°C).

The 10,000 hour examination of these samples was finished this month and all results have been summarized. Six new samples of 304L will be added to this experiment in the first part of February. The 15,000 hour exam is scheduled for August 1985.

EXPERIMENT 27: This is a weight loss experiment in a controlled humidity testing chamber at 150°C. The alloys tested are 1020, A36, 9 Cr-1 Mo, 409, 304, 304L, 316L, 317L, 321, 347, and I-825.

A 3500 exposure hour test has been completed. Next examination is scheduled for June 1985 at 10,000 hours.

2. General and Localized Corrosion of Copper and Copper-Base Alloys

EXPERIMENT 31: General and localized corrosion of electrolytic tough pitch copper, 90/10 cupronickel, and 70/30 cupronickel in 100°C J-13 water and steam.

The most recent examination was scheduled for 6000 hours on 1/6/85. Samples were removed, cleaned and are being examined at present. The test cycle for this experiment is as follows:

Sample 1: 3000 hours
Sample 1 & 2: 6000 hours
Sample 1, 2, 3: 10,000 hours

EXPERIMENT 31-A: The determination of general corrosion rates and localized corrosion tendencies of copper based alloys: CDA-102, CDA-613, and CDA-715. Three coupons of each alloy are immersed in the 100°C J-13 water and three coupons are suspended in the steam created by that water.

EXPERIMENT 31-B: The determination of general corrosion rates and localized corrosion tendencies of copper based alloys: CDA-102, CDA-613, and CDA-715. Three coupons of each alloy will be exposed in the humidity chamber at 150°C.

EXPERIMENT 43: Corrosion study of the following copper alloys in J-13 water at 80°C: CDA-102, CDA-110, CDA-613, CDA-715, 70/30, 90/10, and M-400. The experiment began November 20, 1984 and first evaluation is set for 3/25/85 at 3000 hours.

3. Localized Corrosion Testing of Austenitic Stainless Steels and Copper in Irradiated Environments

We are continuing to investigate radiation effects and have begun to focus on localized corrosion (Experiments 30-A and 30-B) effects in irradiated environments. In some preliminary work, CDA-102, CDA-613 and 304L stainless steel (in both the sensitized and solution annealed conditions) were exposed to a "3-phase" environment (crevice, liquid, and vapor) under gamma irradiation. The samples were used in rod form and were placed in sealed glass tubes. Crevices were made by tightly imbedding glass wool around the bottom 1" of the rods. The tubes were filled with enough 100X concentrated J-13 water so as to leave a vapor phase of about one inch. The dose rate in these experiments was approximately 3 Mrad/h and the temperature was 30°C. The experiments ran for 215 hours.

Under the above test conditions, both CDA-102 and CDA-613 showed some crevice attack in the "glass wool section" of the tube. No particularly noticeable corrosion occurred in the "solution" section of the tube for either alloy. In the vapor phase, both of the alloys showed tarnishing. The corrosion films which formed were black and bluish-grey. The films were not characterized at this point but future work will do so. In contrast, neither the sensitized nor the solution annealed condition of 304L showed noticeable solution or vapor-phase attack. However, as with the copper alloys, crevice attack was evident for the 304L specimens.

It appears that the copper alloys are very susceptible to vapor-phase corrosion under radiolysis conditions. The formation of nitric acid in gamma-irradiated $N_2/O_2/H_2O$ systems probably accounts for this. Future work both here and at HEDL will concentrate on quantifying the degree and modes of attack. Also planned is in situ electrochemical monitoring and modeling of crevice attack in gamma-irradiated systems.

4. Slow Strain Rate Testing of Austenitic Stainless Steels

Work is continuing, sub-contracted to Pacific Northwest Laboratory, on slow strain rate (SSR) testing to determine the stress corrosion susceptibility of candidate austenitic stainless steels. The susceptibility is determined as a function of the environmental conditions, strain rate of the applied load, and metallurgical condition of the specimen. In the SSR tests, the environmental degradation of material properties is readily measurable and the effects of environmental components, including J-13 well water or steam, elevated temperature, and gamma irradiation can be studied.

While it is possible that the fabrication history, welding, and waste emplacement may introduce stresses in excess of the yield point, intermittent annealing or stress-relieving practices can be employed to remove any residual stresses of this nature. The important information to be gained from the SSR tests is the effect of environment on the decay in yield and ultimate stresses as well as elongation.

In January, Mary Juhas visited Pacific Northwest Laboratory and discussed with Dick Westerman and Stan Pitman plans for the next set of SSR tests. This set of tests will be run in gamma-irradiated, 95°C J-13 water with complimentary specimens run in a control environment. The first material to be tested will be heavily sensitized Type 304 in the cold-worked condition. Three specimens will be tested in the presence of a gamma field of 1×10^5 rad/hr and three in the absence of the gamma field. The severity of the material condition in these initial tests was selected with a "shake-down" test condition in mind. Cracking should occur quite readily at the strain rate of 1×10^{-6}. The second material condition to be tested will be Type 316L, 20% cold-worked receiving the following heat treatments: (1) 15 min at 1000°C, AC/ 1 day at 250°C, WQ and (2) 15 min at 1000°C, AC/1 week at 250°C, WQ. The third set of tests will also be Type 316L, cold-worked with the following heat treatments: (3) 15 min at 1000°C, WQ/1 day at 250°C, WQ and (4) 15 min at 1000°C, WQ/1 week at 250°C, WQ. In addition, twenty-one 316L SSR specimens in various other heat-treated conditions have been sent to PNL. All specimens are in the unwelded condition. They will be tested after the first three sets of specimens. The final schedule has not yet been established

because we are sharing capital equipment furnished by the other repository projects (BWIP, ONWI) for the irradiated environment tests.

5. Crack Initiation and Propagation Studies in Austenitic Stainless Steels

A fracture mechanics approach to cracking behavior under the expected repository conditions is necessary to determine a tolerable microcrack size. The susceptibility to crack initiation in the environment is an important issue. While the crack initiation rate is not expected to be high, long term storage environmental conditions may require long incubation times. Crack initiation studies can be complicated by the effect of microstructure on very short cracks. In addition, the delayed formation of brittle phases such as sigma phase could produce cracking via a mechanism different from cracks produced elsewhere in the austenite matrix. Low temperature sensitization (LTS), which may take years to become a serious threat, would pose a SCC concern. Crack initiation studies would complement existing work and are planned to begin in late FY 85.

A realistic assessment of the cracking behavior derives from crack growth rate determination. This approach is based on the assumption of existing cracks in the canister. Slow crack growth studies will be conducted to address this issue. The tests will be run at constant load, and therefore, increasing stress intensity (K) as crack growth proceeds. Because each test will last several weeks, multiple specimens (probably 4) will be linked together and tested in loads (to prevent the formation of a large plastic zone) and then the fatigue cracks will be extended a short distance in the test environment to ensure that initiation does not occur during the actual test.

Initial tests will be run on heavily sensitized Type 304 in 95°C J-13 water to produce stable, intergranular cracking. The slow crack growth tests are attractive because they provide quantitative information about crack growth rates. The addition of initiation studies, a natural complement to these tests, would provide a more complete picture of cracking behavior over a wide range of stress intensity levels. While the crack growth tests are run at constant load (increasing K), initiation studies would be run at constant displacement (decreasing K). The specimens would be bolt-loaded and an existing crack would run until it arrested, determining the lowest K at which cracking occurs.

6. Compilation of Mechanical Properties of Austenitic Stainless Steels

A contract has been placed with the Metals and Ceramics Information Center at Battelle Columbus Laboratories to collect and place in report form information on AISI 304, 304L, 321 and Incoloy 825. The data of interest will be yield and ultimate strength, elongation, and toughness. These data are to be related to grain size, temperature, and cold work. The delivery of this information is to be late February. This information will be useful to the Design sub-task for their evaluation of advanced conceptual designs, as well as to the Metal Barriers sub-task in their evaluation of the stress corrosion behavior of these candidate container materials.

7. Evaluation of Stainless Steel Canister from the Climax Spent Fuel Test

An examination of Canister D-34 from the Climax Spent Fuel Test that had been disassembled at E-MAD is underway. Sections containing welds, base metal and a possible corrosion site have been removed for metallographic examination. This particular canister had been partially immersed in Climax groundwater for approximately 8 months. Historical information is being collected on exposure times, fabrication history, and log data to incorporate into a final report.

8. Implementation of NNWSI Copper Test Plan

Different aspects of the NNWSI Copper Test Plan have been implemented in the past month. Contractual arrangements have been completed between LLNL and CDA to support the activities of the copper industry task group on nuclear waste containers. Stuart Lyman, CDA, and Dale Peters, INCRA, met with the LLNL Metal Barriers sub-task group in January to discuss details of the CDA-INCRA involvement and their part in preparation of the report on feasibility of using copper and copper-base alloys as nuclear waste containment materials in a tuff repository. A draft outline was discussed, areas of responsibilities assigned, and a tentative schedule agreed upon for preparing the report.

Bob Glass visited with Wayne Younker at HEDL to discuss the experimental details for irradiation corrosion testing of copper-base materials in the Hanford gamma pit. The irradiation vessel design has been completed and parts and materials are on order. Two experimental conditions will be used, although the gamma dose rates will be the same in both (2 to 5 x 10^5 rads/h). In one vessel we will have a two-phase system at 90°C consisting of J-13 water and a vapor phase. In the other vessel, a steam/air environment at 150°C is planned. Each vessel will contain replicate samples of general corrosion coupons, U-bend specimens, and crevice specimens (bolted coupons) for CDA-102, 613 and 715.

Tentatively, the HEDL experiments are planned to begin on April 1. Subsequently, analyses will be performed at intervals of one month. These will include Auger analyses of oxide films, U-bend sectioning, solution analysis, etc. Once samples are removed they will not be re-immersed. "Fresh" samples will take their place. In all other respects, ASTM standard test procedures will be applied to the extent possible. From these original samples we plan on getting at least 3-month and hopefully 6-month data. In September/October two more access tubes will become available for use in which we will plan dose-rate dependence studies. A complete set of 1-year data in at least one environment (probably the air/steam) is planned. These experiments should provide quantitative information on the modes of attack in high-temperature irradiated vapor phases (e.g., whether radiolytically formed NO_x or HNO_3 is of concern).

We are negotiating a contract with Bill Smyrl, University of Minnesota Chemical Engineering and Materials Science Department, to undertake work on the electrochemical corrosion measurement techniques in and out of gamma irradiated environments. The work at University of Minnesota would complement the work already underway at LLNL and that planned at Westinghouse HEDL.

PLANNED WORK

Discussed along with the appropriate activities.

PROBLEM AREAS

None, except that creation of a compensated 13-month year would be most helpful in meeting the imposed schedule.

MILESTONE PROGRESS

A report "Results of Testing Conceptual Design Metal Barrier Materials Under Relevant Environmental Conditions for a Tuff Repository" is in preparation with expected delivery to NV by February 28, 1985. This is milestone M235.

A report "Effects of Gamma Radiolysis on the Aqueous Corrosion Processes of Austenitic Stainless Steels" by R. S. Glass, G. E. Overturf, R. A. Van Konynenburg, and R. D. McCright is completed and in peer review and will be sent to NV for policy review. This report is a previously unscheduled Level IV milestone.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.3.3.L OTHER MATERIALS
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the development and testing of packing materials fabricated from crushed tuff plus additives to enhance the properties of the finished products (where necessary). Other activities under this sub-task include the assessment of the chemical effects of grouts and concrete on the performance of waste package components. (The second activity is not funded for FY85).

ACTIVITIES

Topopah Spring tuff crushed to less than 100 mesh was mixed with 5% by weight of 230-400 mesh silicic acid powder and compressed at 25,000 psi for 10 minutes. Thermal conductivity of the sample was measured at ambient temperature. Four measurements gave an average of 0.47 W/mK, about 1/4 of the conductivity of intact rock.

PLANNED WORK

A revised version of the report on functions of packing material in the unsaturated zone will be prepared.

PROBLEM AREAS

None.

MILESTONE PROGRESS

2.2.3.3-85-II-1 (M240) Report on Permeability of Topopah Spring Tuff in a Temperature Gradient.

This report was sent to WMPO on January 29.

This completes the FY85 milestones for this subtask.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.4.L DESIGN, FABRICATION, AND PROTOTYPE TESTING
L. Ballou/E. Russell, P.I.

OBJECTIVE

The objective for package design is to develop and analyze waste package designs which incorporate NNWSI qualified materials and which are compatible with the repository design. The designs and analyses are needed to support license application by documenting conformance with NRC requirements for safe handling, transportation, emplacement, retrieval, containment and release rate.

ACTIVITIES

A. Design

Work continues on a feasibility evaluation of collating contaminated spent fuel hardware in the same canister with spent fuel rods, utilizing a 7-module space frame (six spent fuel modules, one hardware module), manufactured from thin, spot-welded stainless steel sheet. This design will accommodate reactor-consolidated and repository-consolidated spent fuel assemblies. SNL is assessing the feasibility of a resistance welding process (and other methods), and is corresponding with a large welding company. Likewise SNL is evaluating various pintle and top/bottom canister head designs.

A draft outline of the report "Waste Package Advanced Conceptual Design Criteria" has been completed, and the report will include the waste package functional requirements for the preclosure and post closure periods.

B. Thermal Modeling

The reports, "Peak Container Wall Temperature Analysis for a NNWSI Conceptual PWR Waste Package Design" and "Three-Dimensional Thermal Analysis of a Conceptual Waste Package Design for the Disposal of Pressurized Water Reactor Spent Fuel," have been revised and are undergoing QA review.

Two canister designs proposed by SNL were analyzed; one design involves dividing the 26 inch OD canister into six spent fuel modules (see Section A above) while the other design involves using three spent fuel modules. The 10-year old PWR spent fuel was assumed to be repository-consolidated and the canister vertically emplaced with 8.0 m spacing between boreholes and 30.5 m spacing between drifts. The three-dimensional effects from orthotropic conductivity and fuel axial power peaking were approximated based on previous analyses.

For the six-module unit a total decay-heat of 5614 watts was assumed, and results indicate a peak fuel temperature of 388°C occurring five years after emplacement. Another calculation for this design was made based on revised rock mass properties (SNL Keystone Document, 6310-85-1, October 1984) which resulted in lowering the peak fuel temperature to 360°C. Both of the results yielded temperatures in excess of the 350°C allowable limit, and future calculations will establish the upper limit for the canister decay heat power level that will yield peak fuel temperatures within allowable limits.

For the three-module spent fuel design a total decay-heat of 6837 watts was assumed which resulted in a peak fuel temperature of 450°C, and in the future, upper limit power level calculations will likewise be done for this case to establish a peak fuel temperature below the 350°C limit.

C. Structural Analysis

Work has begun utilizing the three-dimensional, large-deformation, finite element code NIKE3D for modeling of a fully-loaded spent fuel canister dropped horizontally 8 feet onto an unyielding rail (4 inches high x 1/2 inch wide). All of the major features of the current 7-module design under investigation (see Section A above) are reflected in this model. Various preliminary calculations have been done to optimize input parameters which will be used for minimizing the run-time of this computer model on the LLNL CRAY computers. The first complete calculation, which will be run until canister peak stresses are achieved, will take place in early February.

PROBLEM AREAS

None.

MILESTONE PROGRESS

The level III milestone "Report on Economic Analysis of Reference and Alternative Conceptual Designs" (W241) has been rescheduled to 3/29/85.

Other milestones for this subtask are presently on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.5.L PERFORMANCE ASSESSMENT
L. Ballou/M. Revelli, P.I.

OBJECTIVE

This activity involves the development and validation of models that can be used to predict long-term package performance for comparison with NRC performance objectives.

ACTIVITIES

Efforts leading to the development and verification of a 1-D waste package system model continued in support of the Performance Assessment Subtask (WBS 2.2.5.L). Work is in progress to develop specifications and design of a driver routine to control process model coupling, data base access, and information transfer within the system model. The logic of this routine must be designed to track the degradation of waste package components under emplacement conditions unique to the Yucca Mountain repository environment.

Hydrological flow modeling efforts have focused on debugging WAFE for specific waste package near-field flow configurations. These consist of horizontal emplacement, with and without gravity. Both vented and non-vented boundary conditions at the rock-emplacement hole interface are also being tested. We are currently working with code developers at LANL to better adapt WAFE for long term simulation problems. Further, isothermal runs are being made to identify the unsaturated flow conditions at steady state. These runs will be used both to provide initial estimates of flow conditions, and to check WAFE with other simulation results for simple geometries.

Waste Management staff met with representatives from other LLNL departments and programs to discuss in-house Software Quality Assurance. The purpose of these discussions is to identify an approach to implementing NRC's NUREG-0856, "Final Technical Position on Documentation of Computer Codes for High-Level Waste Management." Work is now in progress to develop and review a model for the control of software development.

The draft report of the Performance Assessment National Review Group (PANRG) was reviewed by waste package staff members at LLNL. Review comments were forwarded to F. Bingham (SNLA) for inclusion in an NNWSI Project Response. F. Bingham and V. Oversby (LLNL) presented these comments to the PANRG committee at Weston on January 31.

Waste package staff completed a review of the "NRC Draft Technical Position on Waste Package Reliability" and comments were forwarded to V. Witherill at WMPO/NV on January 30.

PROBLEM AREAS

Re-assignment of waste package performance assessment staff to SCP related activities has resulted in some slippage in the completion dates of two performance assessment deliverables.

MILESTONE PROGRESS

Two Level III milestone documents, W246 and W247, currently scheduled for a 1/31/85 delivery, will be rescheduled so as not to conflict with SCP preparation.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

3 February 1985
Report Period: 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.3.4.1.9 - GEOCHEMICAL MODELING CODE EQ3/6
D. Emerson/T. Wolery, P.I.

OBJECTIVE

This task is the development of advanced calculational capabilities for modeling geochemical processes in the repository environment. The work is being carried out by extending the capabilities of the existing EQ3/6 software. The applications objective is to support site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

ACTIVITIES

The thermodynamic data preprocessor, MCRT, and the processing codes that are used with it have all been converted to meet FORTRAN 77 standards and tested on the MFE Computer Center DEC 10 system. This demonstrates their transportability to other computers.

Extended testing of EQ3NR revealed several problems that only occurred with specific data inputs for cases involving the presence of large aqueous complexes, most of which are new to the thermodynamic data base. These have been corrected.

The geochemical codes PHREEQE and two versions of WATEQ have been brought up on the LLNL computers. Comparisons have been made of the results of these codes and EQ3NR and the differences are being investigated.

D. Axtell of the University of Colorado spent two weeks at LLNL documenting work he did last summer on the thermodynamic data for aqueous species of aluminum.

To evaluate the suitability of using a mini-computer system instead of the large and increasingly inaccessible mainframes for our work a tape of EQ3/6, complete with test problems, was prepared for testing on the LLNL Seismology Group PRIME system.

PLANNED WORK

William Bourcier, a Penn State-trained geochemist who worked for NASA as a post-doctorate, joined our group. He will start working with EQ3/6 on the PRIME system to determine if that is the way to proceed to get away from our current lack of sufficient time and standard software on the mainframe computers.

PROBLEM AREAS

Because our allocation of time on the LLNL main computer system is being severely curtailed by larger weapons' programs and because the system lacks several features of standard FORTRAN 77, we must find a way to obtain a super-mini workstation dedicated to the development and utilization of the EQ3/6 modeling effort.

MILESTONE PROGRESS

2.3.4.1-85-III-1 Precipitation Kinetics Addition to EQ6

Revision of this report is still in progress. It will now be forwarded to NV in early February instead of January.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

7 February 1985
Report Period 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.6.9.1.L and 2.6.9.2.5 EXPLORATORY SHAFT TEST PLAN and ENGINEERED BARRIER DESIGN TESTING
L. Ballou/J. Yow, P.I.

OBJECTIVE

This activity includes planning and implementation of in situ tests of the waste package environment. The results of these tests will be used to aid in the validation of the models used in the waste package performance analysis. This subtask also includes the preparation and certification of LLNL input to the Exploratory Shaft Test Plan (ESTP).

ACTIVITIES

High frequency electromagnetic (HFEM) geotomography can potentially be used on a limited scale to measure distributions of water saturations within a rock mass. The technique is a candidate for application in the Exploratory Shaft (ES) Waste Package Environment Tests as we attempt to define near field water flow mechanisms around an emplacement hole. Experiments (described in previous months) have been conducted in G-Tunnel at NTS in order to evaluate the capabilities of the HFEM technique. Core drilling at the HFEM site in G-Tunnel for confirmation of experimental results has been planned, and tests at LLNL are being developed to further define the ability of the technique to resolve spatial contrasts in saturation. Scoping calculations completed this month compare various layouts of boreholes for use of the HFEM technique in the Waste Package Environment Tests, and a letter report that documents the results of the calculations is currently undergoing internal technical review. A paper is also being prepared for the 26th U.S. Symposium on Rock Mechanics to outline the G-Tunnel experiments with the HFEM technique.

A set of revised budget estimates for Fiscal Years 1986 through 1991 was prepared and sent to LANL in December. Several questions and concerns about the ESTP schedule and budget that were raised while the estimates were being formulated were sent to LANL along with the estimates. The budget estimates cannot be used realistically until these questions have been answered.

A data list was prepared for the Waste Package Environment Tests as required by the DOE-NRC Site Specific Agreement. The list was included as part of the data catalog sent to WMPO/NV by LLNL in mid January.

The ESTP Committee met on January 11 at SAIC offices in Las Vegas. Subsequently, L. Ramspott and J. Yow met on January 23 with D. Vieth to discuss his comments on the Waste Package Environment Tests. Revisions of the conceptual test plan will incorporate WMPO and TPO review comments.

Members of the geotechnical staff that support the Waste Package Environment Tests attended th 17th Congress of the International Association of Hydrologists, which was held in Tucson, AZ. The Congress included sessions that dealt with the hydrogeology of fractured rocks, such as will be encountered in the Yucca Mountain ES.

PLANNED WORK

Drilling and sampling planned for the G-Tunnel HFEM site will commence shortly. Instrumentation for the measurement of stress changes, rock mass deformation, and pore pressures will be reviewed for possible use in the Waste Package Environment Tests. These measurement techniques fall into the general areas of geomechanics and subsurface hydrology, in keeping with the scope of the tests.

Revision and development of the conceptual test plan for the Waste Package Environment Tests will proceed using all available review comments. An ESTP Committee meeting is to be held on February 1 to discuss revision of the entire conceptual Exploratory Shaft Test Plan. The budget estimates for the tests will also be refined when the related questions and concerns are resolved.

PROBLEM AREAS

See above regarding the test budget estimates.

MILESTONE PROGRESS

No milestones were submitted to WMPO this month.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

3 February 1985
Report Period: 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.7.2.1 - SPENT FUEL TEST-CLIMAX
W. Patrick, P.I.

OBJECTIVE

The objectives of the SFT-C are to demonstrate the feasibility of storage and retrieval of spent nuclear fuel and to acquire data pertinent to the design, construction, and operation of a repository in crystalline rock. Emphasis in FY 1985 is analysis of post-test characterization data, instrumentation evaluations, and documentation of thermal- and radiation-induced changes in the rock mass. The extensive data set collected during heating and cooling of the rock mass is being analyzed in light of pre-test and post-test calculations.

ACTIVITIES AND ACCOMPLISHMENTS

Summary

Instrumentation reliability and error analyses were completed and documented in a major project deliverable. Reviews of three other reports were also completed. Staff efforts continue to concentrate on post-test calculations.

Geological Investigations

Statistical analyses of the results of rock deformability measurements were performed in response to peer review requests for a more solid statistical basis for the data interpretations. Both pretest and post-test borehole modulus data are being analyzed. These data will be used in final calculations of the rock-mechanical response of the SFT-C facility to excavation and heating processes.

Statistical inferences were avoided in the initial draft report because the requirement of spacial independence of the data was known to be violated. A general 12-term linear model was developed this month which accounts for the various causes of spacial variations in the data. Eight terms of the model express the effects of single factors (such as load direction or heating) while the remaining four represent cross-products (for example, interaction of load direction in combination with heating). Examination of the residuals indicates that errors not explained by the model are random, as required if statistical inferences are to be made. This 12-term model was used to operate on the borehole modulus data set. Interpretation of the results and rewriting the report are in progress.

As part of a continuing effort to make the data which was obtained at the SFT-C facility available for other researchers, compilation of a data base of core logs was begun this month. The resulting database will be published in microfiche form in a brief report which explains the organization of the data base and references existing analyses of the data. It will document the orientations, spacial distributions, and pertinent characteristics of fractures observed in cores obtained at the SFT-C. This will be a companion document to "Geologic Structure Mapping Database, Spent Fuel Test-Climax, NTS" by J. L. Yow, Jr., which was distributed this month.

Peer review of the draft report "Structural Geology Report, Spent Fuel Test-Climax" by D. Wilder and J. L. Yow, Jr., was completed this month and final revisions are in progress. This report, which was a milestone in a previous year, has undergone extensive revision in preparation for publication as a formal LLNL report.

Post-Test Instrumentation Evaluation

The remaining post-test evaluations and analyses of instrumentation deployed on the Spent Fuel Test-Climax were completed and documented in a draft report. This month's efforts focused entirely on the borehole rod extensometers which were deployed on the test. Three error analyses were conducted for each of five subsets of extensometers. The first analysis examined errors which were measured during the pretest and post-test field calibrations. Maximum errors were calculated using a "terminal-point" presentation of the data. Both the second and third analyses treated errors arising from changes in transducer sensitivity which occurred during the nearly four-year period of data acquisition. The second analysis used laboratory data to determine the errors associated with the transducer, only, whereas the third used field data to determine errors associated with the extensometer "system".

Laboratory tests of the long-term stability of the rod-to-transducer couplings used on the mine-by series borehole extensometers were also completed. The net rate of displacement of the coupling was less than one micro-inch per day for the one month duration of the test. This is within acceptable limits for these instruments as deployed for a four-year period.

Mechanical drawings for the "microadjuster", a recently designed rod-extensometer calibration fixture, were completed and checked. Revisions are in progress. Electrical drawings are required to complete the design package. This calibrator provides a means to accurately and expeditiously calibrate borehole extensometers.

A study was initiated last month to examine, in the laboratory, the influence of borehole size on the results of deformability measurements obtained with the NX borehole jack. A 0.76-m cube of aluminum which will be used in these laboratory evaluations was delivered to the subcontractor for initial machining. A pilot borehole will be drilled through the center of the block. This provides an additional control surface for the heat treating process. Calculations indicate that the borehole surface in the Grade 6061 block will plastically deform unless it is heat treated per ASTM-T6 specifications. The borehole jack testing will be performed at the subcontractor machine shops, as opposed to at the LLNL shops as originally planned. Coordination of the off-site activities is in progress.

Post-Test Calculations

The role of shock-induced permanent displacements in the results obtained during the Climax "mine-by" experiment is being considered in a series of post-test calculations. One-dimensional SOC code calculations clearly show that the sense of motion observed during the "mine-by" can be produced by the high-explosive detonations which were used to excavate the facility. Attempts to properly model the complex geometry of the explosive-charges and the resulting excavation have to date been unsuccessful. The capabilities of another in-house codes are being evaluated at this time.

Planning for post-test calculations of the thermal phase of the SFT-C began late this month. The approach will be to drive the ADINA structural response code with temperature histories actually measured during the test rather than with ADINAT-calculated temperature histories. This will minimize the effect of temperature errors on the calculated rock-mechanical responses. Thus, the sources of differences between measured and calculated displacements can be more clearly understood.

Formal documentation of the heater test series which preceded the SFT-C has been completed as a draft report, "Heater Test No. 1, Climax Stock, Nevada", by D. Montan and W. Bradkin. While the heater test results were published and frequently used (for example, in design of the SFT-C), the methods of analyses used in determining gas permeabilities and thermal conductivity and diffusivity have, to date, eluded publication. Revisions are in process following a first round of peer reviews.

Public Information

W. Patrick provided a briefing at the Spent Fuel Test-Climax on January 18, 1985 for Barbara Fenster, Producer, James Compton, Reporter, and Kenneth S. Jones, Photographer, from KING-TV, Seattle, WA.

A script for the planned February 21-22, 1985 Atomic Industrial Forum documentary filming at the SFT-C was received from the Film Group, Inc. Revisions were made to the script so that it more accurately reflects the nature of the work done at Climax.

PLANNED WORK

Staff efforts will continue to focus on analysis of test data and preparation and review of project reports. The recently completed study of the U.S.B.M. stress-relief overcore gauge will be documented. Post-test rock-mechanical response and heat transfer calculations which explicitly treat the boundaries of the SFT-C will be made.

PROBLEM AREAS

None.

MILESTONE PROGRESS

2.7.2.1-85-IV-3 "Geologic Structure Mapping Database, Spent Fuel Test--Climax, Nevada Test Site"

This report was published and distributed.

2.7.2.1-85-IV-1 "Logging of Post-Test and CCH Record Core Samples for the Spent Fuel Test-Climax"

Peer review has been completed. This report was submitted to the WMPO-NV for programmatic review on January 24, 1985.

2.7.2.1.85-III-3 "Mineralogic and Petrologic Investigation of Post-Test Core Samples from the Spent Fuel Test-Climax"

Peer review has been completed. This report was submitted to the WMPO-NV for programmatic review on January 29, 1985.

2.7.2.1-85-III-2 "Instrumentation Report #3: Performance and Reliability of Instrumentation Deployed for the Spent Fuel Test-Climax"

The draft report has been completed and submitted to Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratory-Albuquerque personnel for peer review.

"Operational and Technical Results from the Spent Fuel Test-Climax"

The draft report by W. Patrick was completed, reviewed, and commented on by M. Kunich, DOE-NV. This paper will be presented at the Institute for Environmental Sciences Symposium on Nuclear Waste Disposal, Las Vegas on May 2, 1985.

L. Ramspott

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

5 February 1985
Report Period: 1-31 January 1985

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.9.3.- QUALITY ASSURANCE
J. Dronkers, P.I.

OBJECTIVE

The objective of Quality Assurance is to develop, implement, and maintain an effective management system that can readily and functionally integrate requirements for procedural and planning controls into the working environment of NWMP's scientists and engineers assigned to the NNWSI tasks.

ACTIVITIES

The development of a Software Quality Assurance Procedure continues. Another open meeting was held on January 3 with Lynn Lewis of the Laboratory's Laser Isotope Separation Program as guest speaker. His topic was Configuration Management Models.

The Nuclear Waste Management Project's own model has been submitted for project review. A series of meetings will take place to discuss the impact of the model on the several code development efforts currently in force. Detailed implementing procedures will be written for each code under development or revision. Anticipated completion date is March 29, 1985.

Procedure 033-NNWSI-P 17.0 Quality Assurance Records was hand carried to WMPO on January 9. This completes, for draft, all 18 traditional quality assurance elements and brings LLNL up-to-date in the development of a QAPP.

Interviews for the Quality Assurance Specialist were begun during this month and will continue into February.

Meetings

John Dronkers attended the NNWSI PQAC Meeting in Las Vegas on January 9.

MILESTONE PROGRESS

There are no Level 1 or 2 milestones due for this subtask in FY85.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

JMG :0 116/87

Lawrence Livermore National Laboratory

XC
Klein
Jenson
Mulderig
Flora
Hoffman

10 August 1984
NWM:84/5764C

Donald L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, NV 89114

Original
JRL

SUBJECT: July 1984 Monthly Report - LLNL

Attached are LLNL's Project Status Reports for the month of July. A "Project Status Report" has been completed for each WBS.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

Attachments

FILE NO. 10.4.2.3

AUG 1 6 1984

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PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2 - WASTE PACKAGE
L. Ballou, P.I.

SUMMARY

A number of long and intermediate-duration Topopah Spring tuff (Tpt) and J-13 water interaction experiments are continuing, with a number of water samples having been collected from the reaction vessels during the past month.

The evaluation of a number of block stability models is continuing; one or more of these models will be used to estimate the stability of borehole openings in the Yucca Mountain repository environment.

A large sample of fractured Tpt has been prepared and instrumented in order that the effects of dehydration-rehydration cycling can be measured.

Spent fuel cladding containment credit tests (using H. B. Robinson fuel and J-13 water) at the Westinghouse-Hanford Company are continuing, as is the corrosion testing of irradiated Zircaloy cladding in the presence of J-13 water and crushed Tpt.

Leach testing of DWPF and PNL 76-68 glass in a gamma radiation field is continuing; the effect of the presence of Tpt and/or stainless steel in the system is also being evaluated.

A number of intermediate-duration leach tests of actinide-doped PNL 76-68 glasses using J-13 water in Tpt reaction vessels were started during July.

The extensive program for the evaluation of the stress corrosion susceptiblity of candidate canister materials under expected repository conditions is continuing, with a number of specimens having already been exposed to J-13 water and/or steam (100°C) for over 3000 hours.

A series of electrochemical corrosion potential experiments have been initiated in the LLNL gamma pit facility to determine the changes in corrosion potential with sample irradiation.

A number of 304 and 304L stainless steel specimens are being subjected to groundwater boil-down corrosion tests to determine the effect of higher concentrations of the minerals contained in J-13 water on corrosion rates.

Several different copper alloys are being tested in 100°C J-13 water and steam to determine their corrosion properties.

Permeability measurements of Tpt in a temperature gradient are continuing at the USGS (Menlo Park).

The conceptual design for spent fuel space frames (to be used inside spent fuel canisters) has been revised to reduce weight and cost.

Review and modification of the WAPPA mechanical submodel is continuing. Discussions with other NNWSI participants are underway with regard to the intercomparison and coordination of performance analysis models and codes.

Preparation of a report of the results of a high frequency electromagnetic geotomography test (recently carried out at G-Tunnel, NTS) is underway.

J. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.1.L WASTE PACKAGE ENVIRONMENT
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the characterization of the variability in the properties of Topopah Spring tuff (Tpt) in that volume of Yucca Mountain in which a waste repository is to be located. Also included is the study of hydrothermal reactions between Tpt and J-13 water. These reactions provide a baseline for the multi-component testing carried out in WBS 1.2.2 involving waste forms and metals.

The data obtained in this sub-task also will be used to verify and extend the capabilities of EQ3/6. This applications objective supports site and performance assessment through calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

This sub-task also includes experimental work to determine the rates and mechanisms of dehydration and resaturation of repository near-field rock in response to the thermal field generated by emplaced waste. These data will aid in estimating the water flux past waste packages. Activities related to the stability of borehole openings which are part of this sub-task will aid in determining whether borehole liners will be necessary, and in determining the stresses on waste packages.

ACTIVITIES

A. Yucca Mountain Tuff and Groundwater - Interaction Experiments and Results

The experiments currently in progress in the gold cell, rocking autoclaves continued normally. Summary status at the end of July was:

DB12 = G-1 core wafer, J-13 water, 90°C, plan 365 d, currently at day 87

DB13 = G-1 core wafer, J-13 water, 150°C, plan 365 d, currently at day 87

DB14 = G-1 wafer, J-13 water, 90°C, plan 64 d, currently at day 23

DB15 = G-1 crushed, J-13 water, 90°C, plan 64 d, currently at day 37

The single mineral dissolution kinetics experiments using quartz in the flow-through cells (FTQ) have progressed past the 1/2 way point of the planned 60 days. The experiments span the pH range 1 through 13 and are being run at 70°C. Two of the cells have developed significant (probably fatal) leaks and will have to be repeated. The other experiments progressed normally.

The abstract for a paper entitled "Dachiardite formation by hydrothermal alteration of a devitrified high-silica rhyolite" by Knauss and Beiriger was accepted for presentation at the 1984 GSA National Meeting. Precise cell constants for the Ca-rich zeolite were determined this month using the Guinier camera. Numerous SEM photos were taken this month illustrating crystal habit, twinning, and relationships with coexisting mordenite, clays and other secondary minerals produced in the experiments.

A report entitled "Reaction of the Topopah Spring Tuff with J-13 Well Water at 120°C" by V. Oversby was completed during July and distributed for technical review.

The paper entitled "Hydrothermal Interaction of Topopah Spring Tuff with J-13 Water as a Function of Temperature" by Knauss, Delany, Beiriger and Peifer was accepted for presentation at the 1984 MRS annual meeting in November 1984.

B. Stability of Borehole Openings

Development of an improved two-dimensional block stability model was completed this month, and work continued on a fully three-dimensional model with which the stability of rock blocks adjacent to emplacement holes can be analyzed. Both models take into account several key parameters that influence block behavior. Parametric studies have since been started with the two-dimensional model in order to define its limitations. The completed models will be checked by back-calculating the stability of individual blocks that have been measured in the field. Once thermally induced stress changes are incorporated, the model will be used in assessing emplacement hole stability as part of the waste package environment.

Computer programs that were written in BASIC at the University of California to identify and draw individual rock blocks were implemented on a microcomputer at LLNL in May. Conversion of these programs into FORTRAN versions for use on the LLNL Octopus computer system began this month. Once completed, the converted codes will be able to take advantage of the higher quality graphics capabilities available on the larger system.

C. Dehydration and Rehydration of Topopah Spring Tuff

A larger fractured Topopah tuff sample has been prepared. The sample is 8.23 cm in diameter and 10.10 cm long. The dry bulk density of the sample is 2.316 g/cc. The effective porosity is 3.6%. 20 electrodes and four ultrasonic P-wave transducers have been mounted on the sample. Eight of the electrodes are in pairs in the fracture plane (same as the previously studied smaller sample). The rest of the electrodes form a ring around the sample. The electrode ring will be used to test the application of an impedance camera. One pair of the transducers was mounted along the longitudinal axis of the sample (same as the smaller sample). The other pair was mounted in the middle of the sample transverse to the fracture plane. The P-wave velocity measured from the transverse transducers may be more sensitive to the movement of moisture along the fracture surface.

The experimental procedures for this sample will be the same as for the first smaller fractured sample (reported in October, 1983) so that the effect of sample size can be tested.

PLANNED WORK

Tuff-water interaction experiments in rocking autoclaves will continue. Following completion of the two experiments planned for 64 day duration, some short term runs with J-13 water alone and runs using tuff plus distilled water at 90°C and 150°C will be undertaken.

Development of the three dimensional rock stability model will continue. Following completion of the model development, the model will be used to analyze emplacement hole stability for the waste package environment.

Measurements of dehydration behavior for the larger core sample described above will begin.

The quartz dissolution experiments will be finished during August; repeat experiments for cases where the cells leaked will be done later.

PROBLEM AREAS

None.

MILESTONE PROGRESS

1.2.1-84-III-6 Report on Topopah Spring Crushed Tuff Reacted with J-13 Water at 120°C

This report was finished during July and distributed for technical review. Transmission to DOE/NV during August is planned.

1.2.1-84-II-1 Report on Static Hydrothermal Alteration Studies of Topopah Spring Tuff Core Wafers in J-13 Water at 150°C

This report was 75% complete at the end of July. Completion during early August is planned. Depending on the time required for technical review, revision, and final QA review, delivery to NV will occur during late August or early September.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.1.L WASTE FORM TESTING
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task involves the measurement of the radionuclide release rate from spent fuel and from borosilicate glass (containing DHLW or CHLW); these data are to be used as input for performance modeling of long-term radionuclide release rates from the waste package. Radionuclide release rate information will also determine whether or not a packing material must be incorporated in the waste package designs in order to meet NRC performance objectives.

ACTIVITIES

A. Spent Fuel Cladding Containment Credit Tests

Sampling has been completed for the Series II tests using H.B. Robinson fuel and J-13 water out to thirty days of reaction time. Uranium in solution at 30 days is approximately 60 ppb in the case of bare fuel. All of the uranium is truly in solution, i.e., passes through an 18 Angstrom filter. The solutions from the deionized water Series I tests at 6 months duration showed that most of the uranium was colloidal. The difference observed between the 30 day J-13 results and the 6 month deionized water results for uranium speciation may be due to the difference in water chemistry or to the incubation period for colloid formation. Filtration samples for longer term J-13 samples will be taken to clarify the reason for the different behavior in the two systems. Uranium in solution from the slit and laser puncture defect samples is about an order of magnitude lower than that for the case of bare fuel. This is similar to the result found in deionized water.

B. Zircaloy Corrosion

Testing of irradiated Zircaloy in the presence of J-13 water and crushed Topopah Spring tuff continued. By the end of July the sample scheduled for a total exposure time of 2 months at 90°C had been in the test system for 34 days. The 6 and 12 month samples had been started a few days after the 2 month sample and had reached an exposure time of 31 days. All tests are proceeding according to plan. Measurements of pH during testing show that the pH is approximately 8.5, indicating the radiolysis effects from the radioactivity of activation products in the Zircaloy is not significant.

C. Spent Fuel Oxidation Studies

A series of thermogravimetric analyses of spent fuel particles was undertaken at 225°C. After 3 weeks of reaction the UO_2 had largely oxidized to U_3O_8 at 225°C.

D. Parametric Testing

Parametric testing of DWPF glass to determine the effects of solution volume relative to glass surface area have been completed. Results are being compiled for a final report on the DWPF parametric testing.

Testing of DWPF and PNL 76-68 glass in a gamma radiation field were completed out to 14 days. Results indicate that the DWPF glass is more durable than the PNL 76-68 glass. The pH of solutions in contact with the DWPF glass in the gamma field is becoming more acidic, while the pH of solutions in contact with the PNL 76-68 glass is becoming more basic. The presence of tuff and/or stainless steel in the system reduces the level of plutonium in solution.

E. Testing in Rock Reaction Vessels

A series of tests reacting actinide-doped PNL 76-68 glass with J-13 water in tuff reaction vessels were started in July. Reaction times of 30, 90, and 180 days are planned at 90°C. All runs are being conducted in duplicate. Some tests are using glass on teflon supports while others use stainless steel supports. The 30 day tests were terminated on July 30.

F. Unsaturated Test Method Development

The test matrix being conducted to determine the reproducibility of the unsaturated test method is continuing. The samples that had been reacted for 6.5 weeks were taken during July. All indications were that everything was proceeding as expected.

G. Analog Test

The rock core that is being used in the analog test (glass inside a rock cavity with partially saturated water flow) was equilibrated with J-13 water at 90°C flowing at the rate of 1.5 ml/day. Following equilibration, the core was cooled, opened, and examined. There was no detectable water release during cooling. Some water had accumulated in the cavity (intended to contain the glass sample). While it would be preferable not to collect any water in the cavity, the amount of water found will probably not affect the test results significantly. The system was reassembled with a heated input line for water, with a waste package sample placed in the cavity. The flow rate was lowered to 0.2 ml/day, which is closer to the expected flow rate for the repository case.

PLANNED WORK

Long term testing of spent fuel in J-13 water will continue to investigate the release rate of radionuclides from bare spent fuel and from pin segments that contain defects in the cladding.

Testing of irradiated Zircaloy cladding material in J-13 water and Topopah Spring tuff will continue. The 2 month exposure sample will be removed during August.

Testing of glass waste forms in a gamma radiation field will continue, as will the testing of actinide-doped PNL 76-68 glass in rock reaction vessels.

Further experiments will be conducted to determine the oxidation rates of UO_2 in spent fuel using thermogravimetric analysis.

PROBLEM AREAS

The corrected version of the final report from PNL for FY 83 contract work, most recently promised for delivery by mid-July, has still not been received.

MILESTONE PROGRESS

1.2.2.1-84-III-3 Report on Cladding Containment Credit Testing of Spent Fuel in Deionized Water.

Delivery of the final report on this series of experiments has been rescheduled to 9/28/84. This is due to extension of the restarted phase of the experiments from an initially planned 60 day period to 128 days. The extension was required due to results obtained during the first 60 days.

1.2.2.1-84-III-1 Report on Test Results from Simulated and Fully Active DHLW Glass in J-13 Water and Tuff Reaction Vessels.

This report is a joint effort between LLNL and SRL. The SRL portion of the report had not been received by LLNL as of the end of July. A draft of the SRL contribution to the report is currently expected by mid-September. Based on that information, delivery to NV would occur by the end of October.

1.2.2.1-84-IV-3 Report on Literature Review of Spent Fuel Oxidation Data and Recommendations of testing to verify or expand existing data.

This report has been received by LLNL. Following review and Westinghouse corporate clearance the report will be issued by HEDL with limited NNWSI distribution. Copies will be sent to TIC in order to make the document available for reference.

1.2.2.1-84-III-2 Final Report on FY84 work from G. McVay to LLNL - Report on Parametric Testing of PNL 76-68 Glass with J-13 Water, Topopah Spring Tuff and 304L Stainless Steel.

This report has still not been received. The most recently promised delivery date has passed and no further communication has been received from PNL on the subject.

1.2.2.1-84-III-4 Report on Parametric Testing of DHLW 165-frit Glass

This report is somewhat behind schedule due to other commitments on the part of the author. Delivery to NV before the end of September is anticipated.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.2.L METALS SELECTION/TESTING
L. Ballou/D. McCright, P.I.

OBJECTIVE

This sub-task includes the selection of the metals for the fabrication of canisters and of borehole liners, as well as the characterization of the corrosion rates of these metals under expected repository conditions. The corrosion data will be used in performance assessment modeling and predictions of long-term canister behavior needed for NRC repository licensing.

ACTIVITIES

A. Stress Corrosion Susceptibility of Candidate Canister Materials -- Bent-Beam Specimens

The matrix study of four-point-loaded, bent-beam specimens (ASTM G-39 Test Procedure) on welded, furnace heat treated, and cold-worked alloys has reached 3000 hours of exposure in 100°C J-13 water and steam with no evidence of crack initiation in any of the specimens. The alloys include types 304, 304L, 316L, and 321 stainless steels. Parallel studies conducted on the same alloys in the cold-worked, welded, and unsensitized conditions have reached 1000 hours of exposure in the same environments with no sign of crack initiation in any of these specimens. Details of specimen preparation for these studies have been discussed in previous monthly reports.

During the past month, additional sets of specimens were prepared. One set of specimens was prepared in which several different heat treatments were performed on previously cold-worked (cold-rolled) plate stock. The bent beam specimens will then be machined from this plate. Some of these heat treatments have involved rather long times at high temperatures in an attempt to sensitize the low-carbon grades of stainless. This has required times of a week at 700°C. Types 304, 304L, 316L, and 321 were given this heat treatment.

An additional plate of each of the above materials in the cold worked condition has been reserved for future use in preparing specimens for the Gleeble. The Gleeble is an instrument which resistance heats small metal coupons, usually to simulate a weld or weld heat-affected-zone (HAZ). Thermocouples are spot-welded to the specimen, which is usually of a geometry resembling a small tensile specimen. A computer program is used to establish

temperature control. Temperature can be ramped up or down, stepwise, or at a constant rate. "Gleeble" specimens offer an alternative way of creating a time-temperature history in a specimen which will subsequently be exposed to the repository-relevant test environment. The "Gleeble" specimens simulate continuous cooling conditions as opposed to isothermal conditions obtained in a furnace heat treatment.

Specimens of 316L stainless steel have been heat treated to simulate conditions which a fabricated canister would experience during the waste form filling and storage operations. Cold worked material is given a 15 minute treatment at 1000°C (to simulate welding), followed by either a water or air quench, and this followed by a treatment at 250°C to produce a "low temperature sensitization". The purpose of this sequence of treatments is to effect a structure representing the combinations of cold work (fabricated canister for spent fuel), high-temperature exposure and cooling (closure weld) low-temperature exposure (storage in the repository). Further, some additional specimens are given an 800°C treatment for 17 hours to simulate the glass casting operation for the vitrified waste forms. Another group of specimens has been given the same heat treatments, but without the prior cold work. Tests run on this group of specimens will determine the effect of cold work in nucleating sensitized (chromium-depleted) areas in the stainless steel.

In addition to considering the sensitization effects, formation of sigma phase is of concern. Sigma phase is an ordered solid solution whose fracture toughness is significantly less than that of austenite. Sigma phase formation is favored by high concentrations of chromium or molybdenum (the latter forms a similar chi phase) in steel exposed to relatively high temperatures (greater than 700°C) for long periods of time. Some specimens of 316L stainless steel have been heat treated at 750°C for up to two weeks in an attempt to produce a sigma phase and determine its influence on the stress corrosion susceptibility of the steel in the J-13 water test environment. Since optical metallography did not conclusively reveal the presence of sigma phase, transmission electron microscopic (TEM) examination of the specimens is underway. As in the different heat treatments used in attempting to effect a "sensitized" microstructure, rather extreme treatments are given to the specimens in an attempt to effect a sigma phase. These extreme treatments subject the specimen to higher temperatures and for longer times than the actual processes to which canister materials will be exposed. However, the lengthy time at moderately elevated temperatures (decades at 200-300°C in the repository after emplacement) may effect these kinds of microstructure. In any event, the intent here is to produce these "extreme condition" microstructures and to determine the tendency of these different microstructures to initiate stress corrosion cracking.

A test matrix for preparing stress corrosion specimens on the Gleeble has been planned. Types 316L and 321 stainless steel specimens will be heated to 900°C and cooled at accurately controlled rates of 0.2, 0.5, and 1 °C/sec. The specimens will be simultaneously strained 2%. Literature references have indicated that this combination of thermal cycling and strain produces sensitization in high carbon 304 stainless steels. Type 304 stainless steel specimens will also be prepared on the Gleeble for inclusion in this stress corrosion study in an attempt to produce an early failure, thereby enabling the test sensitivity to be estimated. An interesting effect may be produced

in the titanium-stabilized 321 stainless steel in that the proposed time and temperature in the Gleeble may favor formation of the microstructure that gives rise to "knife-line attack" - the corrosion occurring in a very narrow region adjacent to a weld when this material is exposed to oxidizing aqueous environments. Gleeble-prepared 321 specimens may show a much broader region of attack because the chromium carbide precipitation occurs over a much broader region than in conventional welded specimens.

B. Process Metallurgy Developments

A prototype DWPF Type 304L stainless steel canister lid was received from Savannah River Laboratory. The canister lid contained a plug and an upset resistance weld. The weld was radiographed and ultrasonically analyzed for soundness, but the geometry prevented an effective radiograph from being obtained. Ultrasonic pulse-echo tests indicated that one-third of the welded circumference responded differently from that of the remainder. The reason for this difference in response was not explored at the time, but metallographic sections of the affected area showed incomplete fusion, a heavily extruded microstructure, and sensitization along grain boundaries in the most heavily worked regions. We have attempted to cut specimens for four-point bent-beam stress corrosion tests from the plug-weld-canister lid assembly, but because of the incomplete fusion, these specimens separated readily during machining. An attempt is being made to repeat the machining operation and obtain viable specimens.

C. Electrochemical Polarization Investigations

In situ electrochemical corrosion potential measurements were begun in late July in the LLNL gamma pit facility to determine the changes in corrosion potential with irradiation. The first measurements concerned the stability of the saturated calomel electrode in the gamma radiation field (up to 3×10^6 rads/hr). It appears that the reference electrode is stable at least for relatively short exposures (a few hours) to this high field. Measurements of the corrosion potentials of the candidate stainless steel canister materials will follow. These measurements will be performed in J-13 water and in "concentrated J-13" water where "boil-down" has allowed the concentration of the different ionic species to increase by a factor of 100. Other electrochemical potentials - the "pitting" and the "protection" potentials - will then be determined in these environments under irradiated conditions.

Low-carbon, high-nitrogen austenitic stainless steels (the LN grades) are being evaluated for increase in resistance to localized (pitting and crevice) attack in aggressive environments. The nominal nitrogen content in 304L and 316L stainless steels is 0.05%. In the high-nitrogen grades, the nitrogen is raised to 0.11 and 0.16% for 316LN and 304LN, respectively. The solution chosen to compare the low and high nitrogen grades is 0.05 $\underline{M}$ H_2SO_4 + 0.5 $\underline{M}$ NaCl (pH = 1.15 at 25°C). This test solution represents a significant "overtest" condition when compared to J-13 well water, but it has been used successfully to make comparisons among different stainless steels for screening tests, and an acid chloride solution is representative of an extremely aggressive crevice environmental condition.

Test results obtained so far indicate that the LN grades should be much more resistant to localized corrosion attack, as the "pitting potentials" for these grades are more positive than those for the L grades. In addition, the passive current densities for the LN grades are lower, and the potential region where a passive state obtains is larger for the LN grades. These observations indicate that the LN materials form more stable passive films. The role of nitrogen in increasing the passive film stability is being explored through the use of Auger electron spectroscopy.

D. U-Bend Irradiation Corrosion Tests

U-bend specimens of 304 and 304L stainless steel in both the solution annealed and "sensitized" conditions are exposed to tuff-conditioned J-13 well water and vapor in the PNL gamma pit (cobalt 60 source). R. E. Westerman at PNL is the principal investigator of this part of the work. The 50°C, 6 x 10^5 rad/hr test and the 90°C, 3 x 10^5 rad/hr test were disassembled and the specimens examined after 7 months and 5 months of exposure, respectively. Both test yielded cracked U-bend specimens. To date, all of the cracked specimens have been sensitized 304, and the cracked specimens were exposed to the vapor plus rock region of the test vessel. The 90°C test has produced 5 failures; the 50°C test has produced 3 failures. The uncracked specimens will be returned to the test vessels for continued exposure to the irradiated environments.

E. Slow-Strain-Rate Stress Corrosion Susceptibility Tests

Five slow-strain-rate tests were recently completed. Emphasis is being place on a strain rate intermediate to those used in the past to determine whether it will distinguish between sensitized and non-sensitized material as well as the slow strain rate used previously. The intermediate rate is $5x10^{-6}$/sec, compared to the previously used rate of $2x10^{-7}$/sec. If the intermediate strain rate proves useful, the 1-month test required at $2x10^{-7}$/sec could be reduced to a test of a few days' duration. So far reference data has been obtained, i.e., data using air environments and non-sensitized steel in J-13 water. Heavily sensitized specimens (24 hours at 600°C) of high-carbon 304 stainless steel will be exposed to the J-13 test environment to indicate the sensitivity of this intermediate strain rate in indicating stress corrosion susceptibility. This work is also being performed under sub-contract to PNL with R. E. Westerman and S. G. Pitman as Principal Investigators.

F. Groundwater Boil-Down Corrosion Tests

An autoclave test was initiated in which an assembly of stressed U-bend specimens of 304 and 304L stainless steel of various thermal histories are exposed to an environment of crushed tuff rock and J-13 well water at 200°C. Once every 7 days, the water is allowed to boil off. After 24 hrs of dry operation at 200°C, the autoclave is refilled with fresh J-13 water. Between boil-downs, just enough water is pumped into the autoclave to insure that the system remains full. The autoclave system has been in operation for four weeks, and 3 boil-down cycles have been completed. A total of 40 U-bend specimens are embedded in the tuff rock. The 40 specimens represent 10 specimens of each of the following material/heat treatment conditions:

-- 304; solution annealed then sensitized for 24 hours at 600°C and air cooled
-- 304L; solution annealed then sensitized for 24 hours at 550°C and air cooled
-- 304L; solution annealed then sensitized for 24 hours at 700°C and water quenched
-- 304L; solution annealed then sensitized for 8 hours at 700°C and water quenched.

These specimens will be examined after 3 months of exposure to the cyclic operation. The weight loss experienced by the specimens will be determined (U-bends can double as weight loss coupons), and any observed crack formation will be documented.

G. Inspection of 304L Stainless Steel Canister from the Climax Spent Fuel Test

Sections of the canister containing the D-34 spent fuel assembly in the Climax test were received from Westinghouse EMAD. The sectioning of this canister was discussed in the June report. Samples cut from the bottom section of the canister were sufficiently decontaminated for ordinary handling. The canister surface condition will be examined and documented in detail during the next month.

H. Corrosion of Carbon Steel Under Tuff Repository Conditions.

Carbon steel is viewed as a candidate borehole liner material. Stress corrosion susceptibility tests of 1020 carbon steel weldments (as bent-beam specimens) have attained 9000 hours of exposure without any crack initiation of the carbon steel specimens. As reported in the June report, welded specimens of nodular cast iron and 9 Cr - 1 Mo alloy steel have cracked under the same exposure conditions (90°C J-13 water), probably by a hydrogen embrittlement mechanism.

I. Corrosion Testing of Copper-Containing Materials

Coupons of CDA 110 (Electrolytic Pitch Copper), CDA 706 (90/10 Cupro-nickel), CDA 715 (70/30 Cupro-nickel), and Monel 400 (a nickel-base alloy containing about 30% copper) were exposed to 100°C J-13 water and steam. These tests have now accumulated nearly 3 months of exposure, and the coupons will be examined in August for weight loss and any indication of localized patterns of attack. The purpose of this experiment was to gather some background data on the corrosion of these copper-containing materials in the J-13 water environment (unirradiated). As reported last month, the copper research association has recommended a list of high-conductivity coppers and copper alloys to test as possible waste containment materials. Some of the alloys currently under test are on their recommended list.

PLANNED WORK

This has been appropriately discussed along with the affected activities.

PROBLEM AREAS

None.

MILESTONE PROGRESS

1.2.2.2.84-III-2 "Corrosion Behavior of Stressed and Unstressed 304L Stainless Steel under Tuff Repository Conditions"

Peer review and task leader approval of this report is completed, and the draft report will be sent to NV for policy review.

1.2.2.2.84-III-3 "Electrochemical Corrosion Behavior of Candidate Stainless Steels in J-13 Water"

This report was sent to NV for policy review in mid-July.

R. Stellar /for
R. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.2.3.L OTHER MATERIALS
L. Ballou/V. Oversby, P.I.

OBJECTIVE

This sub-task includes the development and testing of packing materials fabricated from crushed tuff plus additives to enhance the properties of the finished products (where necessary). Other activities under this sub-task include the assessment of the chemical effects of grouts and concrete on the performance of waste package components. (The second activity is not funded for FY84).

ACTIVITIES

Work is continuing at the USGS (Menlo Park) on measurements of the permeability of Topopah Spring tuff in a temperature gradient. They are investigating the effects of pore pressure, sample orientation, and flow direction on the permeability of the tuff and the fluid chemistry of the water. The temperatures and pressures of the experiments were chosen to approximate those expected at the repository level. To date, the permeability experiments and the chemical analyses of the discharged fluids have been completed. The analysis and interpretation of the chemical data is in progress.

PLANNED WORK

Samples will be prepared to investigate the effect of mixtures of silica gel of various grain sizes on the properties of packing material based on crushed tuff. Initial tests will be done using various proportions of gel (5, 10, and 15%) and a single compression pressure (probably 20,000 psi). If any of the mixtures give promising results, a full pressure-density test will be done and a specimen prepared for thermal conductivity measurements.

PROBLEM AREAS

Lack of staff is still restricting the progress of this sub-task. Interviews are being conducted with a view to hiring a petrologist or geochemist to take over responsibility for this section of work.

MILESTONE PROGRESS

All FY84 deliverables for this sub-task have been completed and forwarded to DOE/NV.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer.

WBS 2.2.3.L PACKAGE DESIGN
L. Ballou/W. O'Neal, P.I.

OBJECTIVE

The objective for package design is to develop and analyze waste package designs which incorporate NNWSI qualified materials and which are compatible with the repository design. The designs and analyses are needed to support license application by documenting conformance with NRC requirements for safe handling, transportation, emplacement, retrieval, containment and release rate.

ACTIVITIES

A. Design

The conceptual design for spent fuel space frames was revised to reduce weight and cost. Criticality control is provided by the use of neutron absorbing poison rods consisting of boron carbide slugs in 1/2 inch diameter Zircaloy tubes. Spaces around the square-holed space frame are left open to allow thermal radiation heat transfer, and to reduce weight and cost. Space frame weight has been reduced from about 6000 lb to 2500 lb. Weights vary for PWR/BWR and as a function of fuel rod length. In order to obtain an improved cost estimate, detailed weldment drawings have been completed. These will be RFQ'ed to fabricators for cost estimates for quantity production.

The conceptual design preclosure analysis report was 95% completed. Figures are in preparation, and peer reviewers have been assigned.

B. Structural Analysis

The waste package structural analysis report was 90% completed. Peer reviewers have been assigned.

C. Thermal Analysis

When full 3D characteristics were inputted to TACO3D in a very detailed spent fuel canister mesh, some inconsistent calculated values resulted. We are searching for the "bug" in the meshing or calculating code.

D. Economic Analysis

A spread-sheet program has been completed which estimates waste package and related repository costs for the current reference and some alternative canister designs in vertical emplacement configuration. The program and a summary of calculations will be published in the conceptual design report.

PLANNED WORK

See activities mentioned above.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones for this sub-task are presently on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.2.4.L PERFORMANCE ANALYSIS AND TESTING
L. Ballou/M. Revelli/J. Yow, P.I.

A. PERFORMANCE ANALYSIS

OBJECTIVE

This activity involves the development and validation of models that can be used to predict long-term package performance for comparison with NRC performance objectives.

ACTIVITIES

Review and verification of the WAPPA mechanical submodel (FMODEL) continued. Several changes and additions to the code have been made to examine and extend its capabilities. First, the stress components are now calculated at the outer radius of a metal barrier as well as at the inner radius. The inner radius is the more critical for the primary load case expected in a salt repository (i.e., lithostatic pressure); however in the absence of such external pressures (i.e., expected NNWSI emplacement conditions), stresses at the outer radius must also be considered. Second, WAPPA's detailed system diagnostic printout was not operational. A small program change allowed this diagnostic information to be printed and examined. Third, the crack rupture and stress corrosion crack growth submodels are not currently activated because no provision exists to read the initial crack size. A modification to correct this omission should be completed next month.

Work is in progress to install the LANL WAFE code on the LLNL computer system. Efforts to compile and load the source code are nearly complete, and its successful installation will be verified using a sample problem supplied by LANL. Several conceptual models have been formulated, approximating porous flow through the waste package region and the necessary data base is being assembled to study WAFE's ability to model hydrothermal flow/transport on this scale. Non-porous flow/transport mechanisms will be examined in a later phase of this study.

Preliminary discussions with other NNWSI participants (i.e., LANL and SNLA) have identified a need and an interest in comparing codes (e.g., WAFE, TOUGH, and NORIA) which could be used to perform near-field hydrologic and thermal calculations. A benchmarking exercise has not yet been defined, but will be considered in FY85.

Waste package staff prepared a presentation for the Performance Assessment National Review Group (PANRG) describing the experimental work and modeling being done at LLNL to determine the radionuclide source term for NNWSI Performance Assessment.

A pre-baseline review of the "Generic Requirements for a Mined Geologic Disposal System" document, Volume I, July 6, 1984 was completed. Comments were forwarded to SNL for inclusion in the NNWSI project response.

PLANNED WORK

Evaluation and verification of WAPPA submodels will continue through this fiscal year. In FY85, these models will be incorporated into a waste package system model (with a flow/transport submodel and data bases for metal corrosion and waste for release rates) to predict the long term performance of the NNWSI waste package subsystem.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones for this sub-task are currently on schedule.

B. PERFORMANCE TESTING

This activity includes planning and implementation of an in situ test of the waste package environment. The results of this test will be used to aid in the validation of the models used in the waste package performance analysis.

ACTIVITIES

M. Revelli, K. Eggert, and J. Yow met with Nancy Hayden (SNL) to discuss vapor transport codes for near-field hydrologic and thermal calculations. Computer codes such as WAFE or TOUGH will be used in scoping calculations to make an initial estimate of the environment to be expected in the rock mass near an emplaced waste package. These estimates will in turn be used in developing Waste Package Environment Test design details.

Preparation of a report on high frequency electromagnetic (HFEM) geotomography techniques for monitoring saturation changes in fractured, welded tuff continued in July. This report will describe the HFEM measurements made in G-Tunnel at NTS, and their analysis and interpretation.

An overview of the conceptual test plan for the Waste Package Environment Test was presented on July 18 to familiarize scientific and technical staff with the test. Review of instrumentation and techniques available for making the necessary hydrologic and thermomechanical measurements in the test continued this month.

PLANNED WORK

Interpretation of the geotomographs resulting from the HFEM data will proceed. A first draft of the report describing the suitability of HFEM techniques for monitoring saturation changes in fractured, welded tuff will tentatively be completed in August. Review of other types of instrumentation and measurement techniques will continue.

PROBLEM AREAS

None.

MILESTONE PROGRESS

All milestones for this sub-task are currently on schedule.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

10 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.6.5.2.L EXPLORATORY SHAFT TEST PLAN
L. Ballou/J. Yow, P.I.

OBJECTIVE

This sub-task includes the preparation and certification of LLNL input to the Exploratory Shaft Test Plan (ESTP).

ACTIVITIES

Revision of the Waste Package Environment Test conceptual test plan continued at a low level of activity this month. Revisions resulting from the LLNL internal peer review have been made in the current internal (LLNL) version of the plan, but not yet in the version that is included in the ESTP. Cost estimates were provided to Don York (LANL) for use in ESTP development. The ESTP Committee did not meet in July.

PLANNED WORK

Revision of the Test Plan will proceed and will reflect both the input received from the March ESTP retreat and the comments of LLNL reviewers. The next ESTP Committee meeting is planned for August 16-17; the status of revisions and test plan development efforts should be discussed at that time.

PROBLEM AREAS

None.

MILESTONE PROGRESS

The sub-task is on schedule. No project deliverables were forwarded to NV during July.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

6 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.3.1.9. - GEOCHEMICAL MODELING CODE EQ3/6
D. Emerson/T. Wolery, P.I.

OBJECTIVE

This task is the development of advanced calculational capabilities for modeling geochemical processes in the repository environment. The work is being carried out by extending the capabilities of the existing EQ3/6 software. The applications objective is to support site and performance assessment though calculations of solubilities, rock/water interactions, etc., leading to long-term predictions of geochemical behavior.

ACTIVITIES

Work on the precipitation kinetics capability for EQ6 is continuing. The first test case, involving precipitation of calcite from initially supersaturated solution, was run.

Data base updating has continued for the aqueous complexes appearing in the system Na-K-Mg-Ca-Al-H-OH-Cl-HCO_3-CO_3-SO_4-H_2O. Thermodynamic data have also been compiled for acetate and phthalate complexes (these are needed to interpret dissolution rate experiments employing pH buffers). These data are being worked up on the new, unified MCRT data file.

MCRT data files for Co and Cr, produced by our University of Colorado subcontractor, were put onto the LLNL computer system. Once here, they required a fair amount of debugging to get them to run through the MCRT code, and the subcontractor was notified of the factors which caused problems. Additional files for Sn, Th, Ni, and Se are now being constructed.

The LLNL copy of the SUPCRT data base was revised according to the "SUPCRT Update Notice" of June 26, 1984. SUPCRT is a product of the Dept. of Geology and Geophysics, University of California, and is a major source of data for the EQ3/6 thermodynamic data base. We recalculated all of the SUPCRT data used in the MCRT and EQ3/6 data files. These new data have been incorporated into the MCRT data base, but not yet into the EQ3/6 data base.

Several improvements were made to the MCRT code to assist the current data base development activity. Repetitious output of data grids for individual species has been eliminated. The code no longer stops when it encounters an error in processing a reaction, but writes an appropriate error message and goes on to the next reaction. Error messages are now written on both the OUTPUT and DFILE files.

Work has begun on data base management functions to use with unified MCRT data file. These functions will permit manipulation of data on the random access form of the unified file.

PLANNED WORK

Current activities will continue. A strong effort will be made in the coming month to solve the problems reported below.

PROBLEM AREAS

A number of problems with the EQ6 have turned up lately. Diagnosis has shown that most of these are traceable to either an inadequacy of the pre-iteration optimizer, mainly when running the code in the new "economy" calculational mode, or difficulties with ITREF, a routine used for iterative improvement of linear equations calculations. In either case, the response of the code is to stop before the run has gone the desired distance. These problems have been delaying EQ6 testing and applications.

NETWORK ACTIVITY/MILESTONE PROGRESS

2.3.1.9.-84-III-3 EQGRAF: A Graphics Package for the EQ6 Geochemical Reaction Path Modeling Code

The draft report was submitted to DOE/NV for policy review on July 20, 1984.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

6 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.7.1.L - SPENT FUEL TEST-CLIMAX
W. Patrick, P.I.

OBJECTIVE

The objectives of the SFT-C are to demonstrate the feasibility of storage and retrieval of spent nuclear fuel and to acquire data pertinent to the design, construction, and operation of a repository in crystalline rock.

ACTIVITIES AND ACCOMPLISHMENTS

Summary

Research conducted during previous months culminated in preparation and/or approval of several reports this month. Included are a report on the in situ state of stress in the Climax stock, two reports documenting the radiation dose received by the rock in the vicinity of the spent-fuel emplacement boreholes, a report on radiation effects on the mechanical properties of Climax granite, and a user's guide of the SFT-C data-conversion code REVERT. Other reports are in progress as analysis of field data sets and laboratory testing of post-test samples are accomplished.

Geological Investigations

The draft final contractor report on measurement of the in situ state of stress at the Climax stock was peer reviewed and approved for publication. This report documents an extensive campaign of in situ stress measurements which were conducted between June-September 1983 and February-April 1984. In addition to determining the pretest "undisturbed" state of stress, the measurements program also examined the influence of heating and nearby underground openings on the state of stress.

It became evident during the in situ stress measurements that data variability was quite high and, in general, was greater than could be attributed to experimental errors and such factors as anisotropy of deformation moduli (as measured on the overcored rock specimen). A study has been undertaken to determine the influence of nearby geological features on the measurements. As a first step, discussions were initiated with members of the University of Illinois faculty who are currently examining how alteration zones in a rock mass may influence the measurement of in situ stresses. Geological logging of borehole ISS-11, which will support this study, was completed this month.

The deformability of a rock mass, in concert with the state of stress in that mass, determines the magnitude and orientation of displacements and stress changes which occur due to mining, heating, and related disturbances to the mass. Significant progress was made this month using two different techniques to measure the rock mass deformability.

First, analysis of post-test borehole deformation modulus data was completed. The results of this study indicate that the deformation modulus is markedly decreased in the vicinity of boreholes where the rock was heated to about 60° to 65°C for a period of three years. This observation has led to consideration of lower temperature effects on the rock mass. The pillars between the heater drifts and the canister storage drift were heated to 30° to 35°C during the test. They were also the site of earlier deformability measurements so data is available to be analyzed for a possible thermal effect. This analysis is planned for August.

Second, analysis of seismic survey data is nearing completion. Spectral analyses of shear waves acquired during the "petite sismique" survey were completed. A potential "aliasing" problem was identified which required a frequency response calibration of the signal enhancement seismograph used for this field study. Preliminary analyses indicate that the problem is not significant. The seismic survey has also indicated a path-length dependence on shear wave dispersion.

While the petite sismique technique operates in the frequency domain, the method of data collection facilitated calculation of the dynamic moduli of the rock mass in the time domain. The in situ dynamic moduli values were found to be very similar to the laboratory static moduli values. A draft report on the findings of the seismic survey is in progress.

Radiation Studies

Documentation of the radiation dose received by the rock mass in the vicinity of spent fuel storage boreholes was completed with the final peer review, approval, and submittal for publication of two reports. These reports are titled "Climax Spent Fuel Dosimetry, Short Term Exposure" and "Climax Spent Fuel Dosimetry Progress Report, September 1982 - January 1984", both by W. Quam and T. Devore. In addition to documenting the radiation absorbed dose for the particular configuration of the SFT-C, these data will be used in comparisons with calculated radiation doses; thus providing a validation of the code against this data set.

A laboratory study was completed on the effects of gamma irradiation on the strength and elasticity of Climax granite. The results of this study are documented in "The Effect of Gamma Irradiation on the Strength and Elasticity of Climax stock and Westerly Granites" (W. Durham, J. Beiriger, M. Axelrod, and S. Trettenero. Radiation effects were not anticipated on the laboratory scale, but a study was conducted two years ago to confirm the expected null effect. Surprisingly, a statistically significant effect was observed. Because the data set was highly variable and because of the

unexpected nature of the result, the experiment was repeated. The second study was statistically designed and included Westerly granite as a known low-variability rock type. No radiation effect was observed on strength or elastic moduli of either the Climax or the Westerly granites.

Instrumentation and Data Management

Post-test calibration data are being processed for analysis on personal computers and the LLNL OCTOPUS computer network. The extensometer anchorage and rod integrity data was transferred to Hewlett-Packard "microfloppy" discs and the Watt transducer calibration files were keyed into a PC data file. Transfer of other calibration files is in progress.

With the exception of 12 KAMAN Sciences electromagnetic proximeters, all laboratory calibrations have been completed. These will be completed by EG&G-Las Vegas in early August.

Peer review and final comments have been received on the report titled "REVERT: A CDC 7600 Program for Converting SFT-C Data to Engineering Units, with Corrections" by G. Hage. Comments are being incorporated in the draft in preparation for publication as an LLNL informal report.

Post-Test Calculations

Post-test calculations were undertaken to incorporate recently acquired material properties and state-of-stress data and to evaluate the ability of new models to calculate thermal and thermomechanical responses of the rock mass to simulated repository conditions.

Several attempts have been made to calculate the excavation response experiment (mine-by) which was conducted during construction of the SFT-C. Attempts using continuum, ubiquitous-joint, and discrete-joint models have been largely unsuccessful. A new approach has been taken: the permanent displacements resulting from detonation of explosive charges used in excavation are being calculated. The complex test geometry favored a two-dimensional analysis. Efforts to apply the TENSOR code to solving this problem have been unsuccessful because of numerical instabilities which develop during the solution. An approach using superposition of one-dimensional SOC calculations was employed this month. Calculated rock response during excavation of the bench agrees favorably with measured displacements. Formulation and solution of the problem for excavation of the top heading of the canister drift is much more difficult. This task is in progress.

Decommissioning and Equipment Utilization

Components of the data acquisition system (DAS) were reconfigured and reracked to form a stand-alone system. This system will be used to analyze SFT-C data and for development work on this and other Earth Sciences Department projects.

Other SFT-C components are also being deployed on other projects. The four-pen plotter has been interfaced to the CAMECA ion probe for waste-package research. The continuous air monitor (CAM) chambers have been loaned to the LLNL Hazards Control group for a period of six to nine months.

C. Washington and P. Montazer (USGS) have expressed interest in using the SFT-C digital voltmeters and scanner units. Procedures for transferring one DVM and one scanner to the USGS for trial application are being investigated at this time.

Transfer of responsibility for routine tour support to DOE/NV-OPA is complete. Briefing notes were revised and a "fact sheet" was developed and forwarded to OPA to assist in this transition.

The SFT-C documentary film is being revised to include information obtained during storage, retrieval, and post-test evaluations at the site. At the request of DOE/NV-OPA, the script has been revised to the standard "English" units of measure, rather than the previous international metric units.

PLANNED WORK

Staff efforts will continue to concentrate on analysis of field data and compilation and analysis of post-test calibration results. Calculations of the "mine-by" excavation response experiment will be completed. Investigation of radiation and thermal effects on the mineralogy, petrology, and microfracture characteristics of Climax quartz monzonite will continue.

PROBLEM AREAS

None.

NETWORK ACTIVITIES

2.7.1.-84-III-6 The Effect of Gamma Irradiation on the Strength and Elasticity of Climax Stock and Westerly Granites.

This report was sent to DOE/NV for programmatic review on July 31, 1984.

REVERT: A CDC 7600 Program for Converting SFT-C Data to Engineering Units, with Corrections.

This report, although not a deliverable, documents important work accomplished on the SFT-C project and was sent to DOE/NV for programmatic review on July 20, 1984.

L. Ramspott
LLNL Technical Project Officer
for NNWSI

PROJECT STATUS REPORT

6 August 1984
Report Period 1 - 31 July 1984

PARTICIPANT'S NAME: LAWRENCE LIVERMORE NATIONAL LABORATORY
L. Ramspott, Technical Project Officer

WBS 2.9.4 - QUALITY ASSURANCE
J. Dronkers, P.I.

OBJECTIVE

Prepare QA plans and procedures, conduct internal QA surveillance, advise and assist LLNL staff assigned to NNWSI in the performance of their QA responsibilities, conduct audits of contractors, and generally carry out activities in Quality Assurance that will meet NRC requirements during licensing of a high-level waste repository under 10CFR60.

ACTIVITIES

Work is continuing on the computerization of the NWMP QA Records Library.

A project-wide software QA Plan is being written for work done here on NNWSI contract(s). The plan will be level specific and tied closely to NUREG-0856.

Work is continuing on the NWMP QA "umbrella" Plan (QP-033-06) for software generated and/or utilized within NWMP.

LLNL-NWMP is joining with SAI and eight other facilities within the Waste management community in formulating an overall software QA Plan that will be used throughout the NNWSI community.

L. Ramspott
LLNL Technical Project Officer
for NNWSI