Attachment 4

WORK PLAN FOR NRC/NMSS PROJECT #B0290: REVISION 2

LABORATORY EVALUATION OF DOE RADIONUCLIDE SOLUBILITY DATA AND SELECTED RETARDATION PARAMETERS, EXPERIMENTAL STRATEGIES, LABORATORY TECHNIQUES, AND PROCEDURES

Program Manager: A. G. Croff

Task Leader: A. D. Kelmers

Principal Investigators:
W. D. Arnold, C. S. Haase, G. K. Jacobs, J. H. Kessler, S. Y. Lee, and R. E. Meyer

Chemical Technology Division
Chemistry Division
Environmental Sciences Division

OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE 37831

Work sponsored by the Nuclear Regulatory Commission under contract with Union Carbide Corporation, Nuclear Division

CONTENTS

1. SUMMARY

This Work Plan describes radionuclide apparent concentration limit and retardation value measurements and the supporting geochemical modeling activities to be performed for the Nuclear Regulatory Commission (NRC). These activities will provide the NRC with an independent basis for evaluation of site-specific values determined by contractors for the Department of Energy (DOE) for use in high-level waste repository performance assessment. Such a data base is necessary so that NRC can independently establish the relevance, precision, and accuracy of radionuclide concentration limits, retardation values and data acquisition methods being used by DOE in site performance assessment modeling calculations. This will help assure that the nature of DOE radionuclide release predictions are conservative for groundwater transport scenarios and will, therefore, support the NRC licensing activities.

The initial work is being directed to evaluate data relevant to the Basalt Waste Isolation Project (BWIP) candidate site in basalt, since BWIP has already submitted a Site Characterization Report to the NRC and the NRC has responded with a draft Site Characterization Analysis. During FY 1984, work will also be started to evaluate data relevant to the Nevada Nuclear Waste Storage Investigation (NNWSI) candidate site in tuff. As other DOE sites advance in the licensing application process, attention will be directed toward evaluation of pertinent radionuclide concentration limit and retardation values.

The initial BWIP-related work involves radionuclide sorption/solubility measurements with neptunium and technetium. These radionuclides were selected based on their potential contribution to the radioactivity release hazard to the environment. The first tests were at room temperature under oxic conditions; however, the test parameters have been shifted to the expected repository conditions and/or other conditions being used by a DOE project. The work started with crushed basalt, but emphasis will be shifted to representative secondary minerals as they are acquired, since these are likely to dominate the release pathway. Synthetic groundwaters will be used and in some tests the groundwater composition will be altered to simulate the thermal and radiolysis effects anticipated in the near-field.

As the BWIP-related work is completed, similar measurements with neptunium and technetium will be initiated to evaluate data relevant to the tuff candidate site. At the same time, evaluation of uranium and plutonium sorption and concentration limit values under BWIP conditions will be initiated.

The experimental method will involve construction of sorption isotherms and extension of the isotherm to establish an apparent concentration limit. Both batch contact tests and column chromatographic experiments will be conducted to obtain data on sorption/concentration limit values. The column experiments will also provide information on possible multiple speciation of radionuclides. Geochemical modeling, employing established computer programs, will support the experimental effort and will evaluate the data base information and numerical modeling calculation methods being employed by the DOE.

This Work Plan contains a description of the scope and approach, detailed experimental method, a current status and future schedule including a milestone chart, and a discussion of possible additional future work.

2. INTRODUCTION

2.1 Project Objective and Justification

The objective of this project is to support the NRC staff analysis of geochemical information for DOE high-level waste repository candidate sites with a laboratory-oriented effort to evaluate key radionuclide data which may be employed by DOE in performance assessment calculations to show expected repository compliance with regulatory requirements. The results of this effort will help the NRC staff to independently review and evaluate the key data values employed in DOE site performance assessment analyses and the methods used to develop these values.

The laboratory analysis will concentrate on the geochemical processes expected to dominate predicted radionuclide retardation behavior and release rates at the candidate sites. The primary focus is on parameters which are relevant to the migration and retardation of radionuclides, namely, radionuclide concentration limits and radionuclide sorption on host rock constitutents and fracture filling minerals. In addition, the usefulness and limitations of geochemical models and computer codes which are used to predict the behavior and mobility of radionuclides in the repository far field will be assessed. The project activities will be undertaken on a site-specific basis, dependent on the site characterization schedule and importance to demonstration of site favorable or unfavorable features identified by DOE in the Site Characterization Plans.

2.2 Description of the Work Plan

This Work Plan includes a discussion of the background and scope of the proposed activities. The technical approach and experimental plans are discussed and expected results are identified. The DOE-developed data and information to be evaluated are identified, and possible areas of potential agreement or concern are discussed. A work reporting schedule is presented by which technical progress and significant results will be periodically reported. The Work Plan is considered to be a "living document," and will be periodically updated and revised following future DOE candidate repository site developments and NRC data evaluation needs. Potential work will be identified in future revisions.

3. WORK SCOPE AND APPROACH

3.1 Work to be Performed

3.1.1 Site Priorities

The work emphasis will parallel the DOE site development activities. Attention is first being directed toward evaluating values that quantify the behavior of radionuclides in basalt rock/groundwater systems. During FY 1984 work will also be initiated on quantifying radionuclide behavior in tuff rock/groundwater systems relevant to the tuff candidate site as representative tuff samples become available.

As the national waste repository program evolves in the future and NRC's data needs correspondingly change, the work emphasis for this project will similarly evolve. It is not possible to predict at this time which sites and site geochemical aspects will be of most importance to the NRC in the future, thus this Work Plan will remain a flexible "living" document. Planning for future work will be done in conjunction and coordination with the NRC.

3.1.2 Information to be Evaluated

Sorption distribution coefficient and isotherm data which exist for the basalt and tuff candidate repository sites will be experimentally evaluated using batch contact tests. In addition, column chromatographic experiments will be conducted to evaluate retardation factors and to obtain information on speciation on radionuclides in the site specific geologic media under controlled flowing conditions. Apparent limiting concentrations of key radionuclides under anticipated repository conditions will be experimentally determined for comparison with (a) the radionuclide solubilities obtained by computational methods and (b) results of experiments underway by some DOE projects. Virtually no experimental solubility measurements or verification of geochemical computer code calculations have been reported by the DOE projects up to the present time. The DOE projects have been using calculational approaches, using existing thermodynamic data bases and computer codes with minor extensions to handle the radionuclides not found in geochemical data bases, since determination of radionuclide solubility product constants by classical physical chemical techniques is time-consuming and expensive. The calculated radionuclide solubility values being employed and the calculation methods used to obtain them will also be evaluated by the geochemical modeling efforts.

3.1.3 Radionuclides to be Investigated

The evaluations will be restricted to "key" radionuclides. These are defined as those radionuclides which are most likely to dominate release hazard calculations, are less likely to be adsorbed by the host rock constituents under site specific conditions, or whose sorption or solubility values seem questionable in DOE site performance characterization information. Actinides, fission products, and activation products will be considered.

During the initial phase of this project, four criteria were established for the selection of radionuclides to be studied: (1) the radionuclide must have at least one isotope of major importance in the calculated release hazards, (2) a significant question or uncertainty concerning the measured or calculated value must exist, (3) the planned effort must be consistent with the project resources, and (4) adequate isotope availability and analytical methodology must exist.

Neptunium and technetium were initially selected as best satisfying these criteria and work this past year was started on confirming values that quantify the behavior of these radionuclides in basalt rock/groundwater systems found at the BWIP candidate site. It is planned to extend the neptunium and technetium studies to the other candidate sites such as the tuff rock/ground systems relevant to the Nevada Nuclear Waste Storage Investigations (NNWSI) candidate site in volcanic tuff beds at Yucca Mountain in the Nevada Test Site, and to salt rock/groundwater systems relevant to several bedded and domal salt sites being developed by the Office of Nuclear Waste Isolation (ONWI).

As evaluation of neptunium and technetium values in BWIP is completed, similar experiments are planned with plutonium and uranium. Both plutonium and uranium meet the above criteria for selection and uranium is a major constituent of spent fuel. Since there is a good data base for uranium, these experiments should provide comparison bases for our geochemical modeling activities.

3.1.4 Geochemical Modeling Activities

Geochemical modeling will be carried out both to support the radionuclide sorption and solubility measurements and to evaluate radionuclide solubilities calculated for candidate repository sites.

3.2 Experimental Facilities

The different radiologic hazards associated with fission products (which can be traced at low activity levels) and actinides (which have high-level alpha radiotoxicity values and/or emit low-level beta, gamma, and neutron radiations) require two separate experimental facilities in different ORNL buildings. A brief description of the facilities follows.

3.2.1 Alpha-Containment Laboratory

The Alpha Isolation Laboratory (Building 3508) is operated by the Chemical Technology Division. Five laboratories are equipped to handle large quantities of radioisotopes that have high-level alpha radiotoxicity values and/or emit low-level beta, gamma, and neutron radiations.

For the sorption/solubility work with actinides, two controlled-atmosphere glove boxes are set up in Building 3508. They are connected together, but have the capability of being isolated from each other. Each box is connected to the building offgas system and to a supply of argon. Additional equipment installed either in the glove boxes or adjacent to them include centrifuges for solid-solution separation after batch contact, temperature control equipment to maintain elevated test temperatures, and associated analytical apparatus. Automated sophisticated counting equipment is available in an adjacent building.

3.2.2 Radiochemical Laboratories

Lower levels of less radiotoxic radionuclides can be handled in conventional radiochemical laboratories. Work with fission products, which can be done with stable elements traced with low levels of gamma- or alpha-emitting isotope for analytical purposes, can be carried out in appropriate laboratory hoods or controlled-atmosphere glove boxes.

A controlled-atmosphere glove box equipped with a chemical oxygen-scavenger system has been installed in a laboratory in Building 4500N in the Chemistry Division for the batch sorption/solubility work. A shaking table and a high-speed centrifuge for the liquid-solids separation have been installed in the glove box.

Additional equipment utilized on this project includes a poteniostat for measuring/controlling redox conditions and an electrochemical cell for removing the remaining oxygen from solutions. Alpha and gamma counting equipment is available and other equipment and craft and support services will be utilized as necessary.

A laboratory in Building 3504 in the Environmental Sciences Division has been designated for the column chromatographic investigations. A high performance liquid chromatography system with a high-resolution gamma radiation detector has been procured and installed.

4. BATCH EXPERIMENTS

For details of initial work on neptunium and technetium sorption/solubility in basalt/groundwater systems, see the ORNL FY 1983 Annual Progress Report (Kelmers, 1983).

4.1 Experimental Materials

4.1.1 Solids

Initial tests will use McCoy Canyon basalt (obtained from a rock outcrop) which was carefully selected to minimize weathered rock or fractures containing secondary minerals. All the samples are crushed in an agate mortar so as to avoid contact with iron and screened to selected particle size ranges. Samples are prepared under oxic and anoxic conditions. In a few cases, the basalt size reduction has been carried out in an argon atmosphere box in order to prepare crushed basalt with surfaces which have not been exposed to air. Some samples are used "as is," while others are pre-equilibrated with site representative groundwater to more nearly simulate aged rock by diminishing possible reactivity of the freshly ground and exposed surfaces.

Secondary minerals may be of importance in radionuclide retardation in basalt flow flowtops and interbed regions and emphasis will be given to evaluation of secondary mineral information. Representative, well-characterized minerals will be purchased from commercial sources and used for this work since BWIP has not quantified the mineral content to be encountered in release pathways and samples of secondary minerals from the candidate repository horizons are not presently available. These secondary minerals may also be ground and screened under oxic and anoxic conditions.

It is anticipated that representative, well-characterized tuff minerals will be purchased or obtained from NNWSI and used in the continuation of the neptunium and technetium studies. Planning for this work will be done in coordination with the NRC contract manager. As site characterization at each site progresses, additional samples of basalt and tuff will be requested from BWIP and NNWSI.

4.1.2 Groundwater

To date, synthetic groundwater formulations GR-1 and GR-2 prepared by BWIP have been used in the batch tests. The GR-2 composition is reported to be representative of Grande Ronde groundwater and was used in many of the BWIP tests published prior to 1984. Due to stability problems with GR-2 and changes in BWIP methods, the recently described new groundwater GR-4 may be used in many of the future tests. However, it should be noted that radionuclide sorption and limiting concentration values in GR-3 and/or GR-4 have not been published by BWIP. In some future tests (to be developed later in the year), the groundwater composition may be systematically varied to determine the sensitivity of sorption and solubility values to groundwater composition. Altered groundwater compositions representative of the changes expected due to thermal and radiolytic reactions will also be used in the future.

The groundwater to be used to simulate conditions representative of Yucca Mountain will be selected as additional information on the site becomes available and in coordination with the NRC contract manager.

4.2 Experimental Plan

The initial objective will be to establish sorption isotherms and apparent concentration limits under site-specific geochemical parameters. Sorption isotherms will be constructed over a wide range of radionuclide concentrations; this will yield information on sorption ratios as a function of concentration and, if the solution can become saturated with the radionuclide under the test conditions, will also measure an apparent solubility limit. An example of such an isotherm is shown in Figure 1. Both sorption ratios and desorption ratios will be determined and related to the equilibrium distribution coefficient.

Initial tests were with crushed basalt under oxic conditions at room temperature. (These were completed in FY 1983 for Tc/Basalt and Np/Basalt.) As secondary minerals and other candidate site solids (e.g., tuff), temperature thermostats, and the controlled-atmosphere glove boxes become available, the work will shift to include these materials and conditions. Tests will explore the effects of altered groundwater composition, temperature, acidity, redox conditions, and radionuclide concentration.

4.2.1 Neptunium/Plutonium Batch Experiments

Batch contact sorption tests with crushed basalt under oxic conditions at room temperature have been initiated. Samples of crushed basalt, either "as is" or "pre-equilibrated" and groundwater are placed in a centrifuge tube, one radionuclide introduced, and the tubes (both samples and control blanks) capped and equilibrated for varying times on a rocking table. At the end of the equilibration time, the tubes are centrifuged and/or filtered and an aliquot of the supernate taken for radionuclide counting and the concentration in solution and on the solids is calculated.

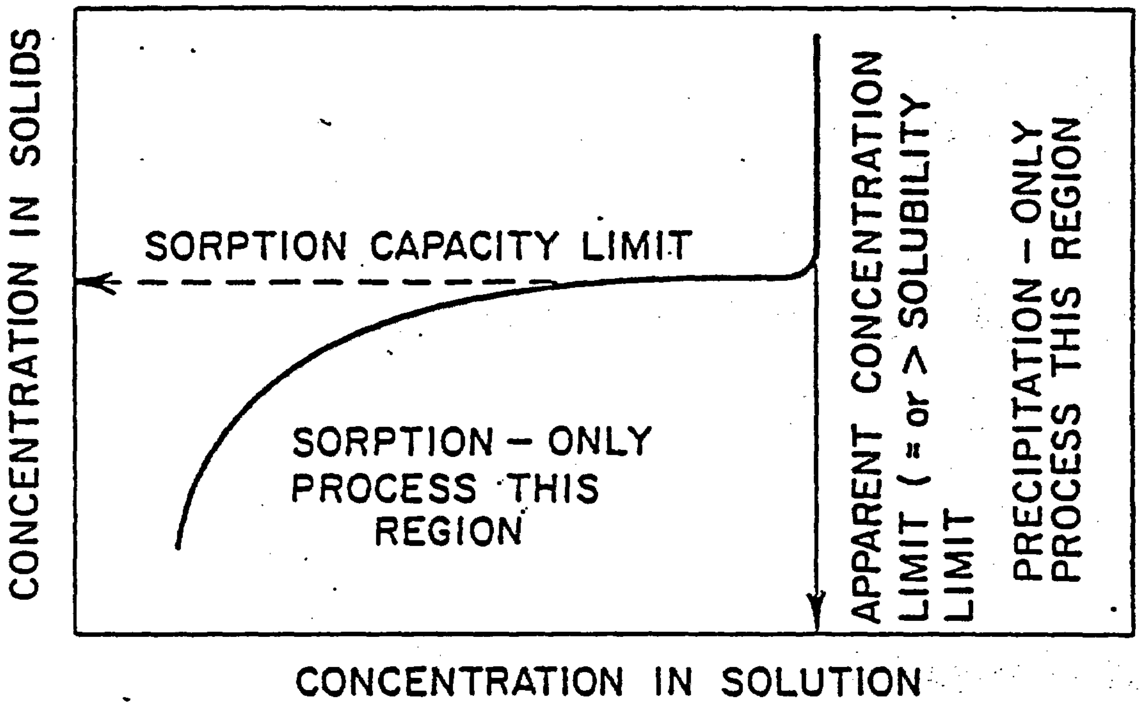

Figure 1 Idealized Radionuclide Sorption/Apparent Concentration Limit Isotherm - Batch Contact Method

Batch contact method employing rock and radionuclide-traced groundwater.

Geochemical parameters (rock, groundwater, temperature, redox conditions, etc.) must simulate actual conditions expected in situ; if this condition is met, then the apparent concentration-limit values are actual or conservative, never nonconservative.

Additional work under oxic conditions is planned to attempt to establish an apparent concentration limit in groundwater in the presence of the McCoy Canyon basalt used in the earlier tests. Then the major emphasis will be shifted to experiments under reducing and anoxic conditions relevant to the expected BWIP site far field redox conditions. In addition, the neptunium valence state in the tests will be characterized to determine the effectiveness of reducing agents such as hydrazine in order to evaluate experimental methods previously used by BWIP in determining sorption/solubility data.

Sorption/desorption tests will be conducted to explore the reversibility of the sorption reactions. If sorption/desorption disequilibrium does occur, sorption ratios would be conservative for retardation calculations.

As evaluation of BWIP neptunium values is rounded out, a similar experimental effort will be initiated to evaluate the BWIP values for plutonium solubility and sorption under oxic, anoxic, and reducing conditions. Representative well-characterized rock and mineral samples will be purchased for the tuff studies since samples from the repository horizon are not yet available. Similar batch contact tests will be conducted to evaluate NNWSI values for neptunium solubility and sorption under oxic and anoxic conditions. More detailed plans with tuff minerals and groundwater under conditions representative of Yucca Mountain will be coordinated with the NRC contract manager in the future as resources are available.

4.2.2 Technetium/Uranium Batch Experiments

Batch contact sorption/solubility tests with crushed basalt under oxic, reducing, and anoxic conditions are underway for uranium and have been completed for technetium. The experimental procedure is similar to that employed for neptunium (see Section 4.2.1), except no solids were used in the blank tests in order to explore technetium sorption by the test apparatus. Reducing conditions were established by the addition of hydrazine hydrate to the sample tube after the technetium addition. For anoxic conditions, basalt was pulverized in an argon inert atmosphere box and traced groundwater was deaerated by successive freeze-thaw cycles to 10 ppb residual oxygen. All rock and solution handling operations for the anoxic batch contact tests will be conducted in the argon box to eliminate contact with air, except selected samples given specific air treatments.

The preponderance of BWIP's experimental studies have been performed with hydrazine being introduced to simulate the expected reducing conditions in the repository. However, in our initial reducing condition experiments, hydrazine was observed to be interacting with the experimental system and it is not clear that the hydrazine is establishing relevant reducing conditions while not altering the behavior of the other system components. Therefore, limited additional experiments are planned to determine the quantities of technetium in different valence states using existing techniques.

In parallel, anoxic experiments to measure the sorption behavior and the apparent concentration limit of technetium under BWIP conditions will be conducted. The results of these experiments will be used to evaluate the methodological aspects of BWIP experiments (i.e., are anoxic results comparable to hydrazine results?) as well as to confirm the specific sorption and concentration values obtained by BWIP and in our earlier experiments.

Following this work, evaluation of uranium sorption and concentration limit values under BWIP conditions will be initiated. Concurrent with the uranium experiments, technetium sorption and concentration limit values under anticipated NNWSI conditions will also be performed. Detailed plans with tuff minerals and groundwaters under conditions representative of Yucca Mountain will be coordinated with the NRC contract manager as resources are available.

5. COLUMN EXPERIMENTS

A new experimental effort is being initiated which will employ high-pressure liquid chromatographic techniques to directly measure retardation factors for several radionuclides and to explore possible multiple speciation effects on radionuclide retardation. The retardation factor (a parameter for radionuclide transport modeling) of several radionuclides will be directly measured in the column tests by determining the velocity of the radionuclide with respect to the velocity of the groundwater. The apparent sorption ratio will be calculated from the column experiment data to compare with the batch sorption/desorption results.

5.1 Experimental Materials

5.1.1 Solids

Samples of crushed and sized repository mineral media will be placed in a column which is within a temperature controllable oven. The geologic media will include crushed and sized basalt (see Section 4.1.1), secondary minerals, and a mixture of reference materials (e.g., nontronite, zeolite, quartz).

5.1.2 Groundwater

Synthetic groundwaters described under Section 4.1.2 will be used in these experiments. As samples become available, actual groundwater from the specific sites will also be used.

5.1.3 Radionuclides

Initial experiments will be conducted using a mixture of technetium and neptunium. Later experiments will use mixtures of technetium, iodine, uranium, neptunium, plutonium, curium, selenium, tin, and radium.

5.2. Experimental Plan

Crushed and sized repository mineral media will be placed in a column which is within a temperature controllable oven; a "spike" of radioactive tracers will be added to the top of the column through an injection value, and then synthetic or actual repository groundwater will be pumped through the column. The column effluent will be collected in a fraction collector and the elution behavior of the radionuclides established by analyzing the activity in the collected samples. A multi-task analyzing system connected to a high resolution germanium detector will be used to quantitatively determine radioactivity concentrations. Tests will be performed under varying temperatures and flow rates.

The retardation factor and distribution coefficient values at different temperatures, with different geologic media, groundwater, and flow conditions will be determined. The distribution coefficient values from the column experiment will be used to confirm the values from the batch experiments. In addition the possible existence of multiple species of a given radionuclide and interaction among mixed radionuclides will be explored.

6. GEOCHEMICAL MODELING

Geochemical models and computer codes are likely to be used to predict the behavior and mobility of radionuclides in the repository far field as well as for simplification of groundwater data sets and to infer flow fields. Since it is expected that repository performance assessment will rely to some degree upon geochemical models, it is necessary that NRC be able to evaluate the applicability and limitations of model applications. A set of codes (e.g., PHREEQE, MINTEQ, EQ3/EQ6) for geochemical calculations is being assembled and applied to confirmatory analyses of site conditions.

The computer code PHREEQE has been adapted to the ORNL computers and calculations of equilibrium speciation and solubility indices for BWIP synthetic groundwaters have been made. Newer geochemical models with different and larger thermodynamic data bases will be implemented during the next year. MINTEQ has been adapted to the ORNL computers and the adapted version debugged so that the large internally consistent data base associated with that code can be used. In addition, arrangements for use of the most recent versions of EQ3/EQ6 are being made.

Future applications of geochemical modeling will include: (1) evaluation of BWIP radionuclide solubility calculations, and (2) calculational comparison of groundwaters from different rock types. The codes will also be used for comparisons with reported experimental plutonium speciation (Cleveland 1983) in groundwaters from basalt, granite, shale, and tuff using actual groundwaters collected from different rock types. Computations will be run using a range of provisional Pu-F reaction constants in order to determine if the fluoride increases the solubility of plutonium by a direct complex formation or if some more exotic explanation is required. Upon completion of uranium and plutonium concentration limit/sorption measurements on basalt, the experiments will be modeled and the calculated results compared to experimental data.

7. REPORTING METHOD AND SCHEDULE

Reporting to the NRC of work performed and progress achieved on this project will be by brief informal monthly progress letter reports and technical quarterly progress reports. The quarterly technical progress reports will be unedited ORNL/TM reports with a limited distribution for the first three quarters of the fiscal year. The year-end report will be an annual report summarizing the prior year's results in the form of a NUREG/CR report with a wide distribution.

Areas of agreement or disagreement between values developed on this project and relevant DOE-project data will be discussed and areas needing future attention by DOE or NRC will be identified. Topical reports for presentation at technical meetings and/or submission to technical journals will be prepared as appropriate.

Attachment A is the proposed near-term schedule of milestones for this project.

8. ADDITIONAL CONFIRMATORY WORK NEEDS

8.1 Stacked-Vessel Multistage Experimentation

In recent years there have been numerous experimental investigations dealing with radionuclide solubility and sorption in rock-water systems. However, most of the experimental data collected so far have been obtained under so-called "far-field" or "ambient repository" or laboratory ambient conditions, i.e., under geochemical conditions which are expected to prevail in the region surrounding a mined repository where the host rock and groundwater have not been significantly affected by thermal, radiolytic, or chemical events attributable to the construction of the repository and subsequent emplacement of high-level radioactive waste.

The lack of experimental data on the compositions of radionuclide-bearing groundwaters under disturbed zone presssure-temperature-radiation conditions precludes the assumption that a migrating radionuclide-bearing groundwater will not retain any significant chemical characteristics "inherited" from its earlier travel through the disturbed zone. Considering that so little is known about how heated radionuclide-bearing groundwaters evolve chemically as they flow toward the far field, it seems clear that future research on radionuclide solubility and sorption should be increasingly directed toward obtaining experimental data on the behavior of radionuclides under physicochemical conditions representative of the disturbed zone of a mined repository.

A plan will be developed for a stacked-vessel multistage experiment which can be employed to simulate and characterize hydrothermal process, waste-groundwater reactions, and aqueous transport of radionuclides in the disturbed zone of a mined repository containing high-level radioactive waste. The experiment is multistage in the sense that an aqueous fluid can be exposed to more than one set of solid starting materials during the course of a single run, i.e., stages could be designed to be analogous to the sequence of events: (1) groundwater approach toward, and entrance into, a mined repository containing high-level radioactive waste; (2) groundwater interaction with the waste package components and dissolution/mobilization or radionuclides via waste-groundwater reactions; and (3) flow of the contaminated groundwater from the engineered barrier facility through the disturbed zone and out into the far field. The apparatus would ultimately be designed specifically for experimentation at elevated presssure-temperature and should include typical radiation levels of the very near field/waste package to be simulated.

While it is conceivable that linked Dickson-type apparatus could be modified to simulate the stacked-vessel equipment proposed, the Dickson-type presssure vessels are not designed for multistage experimentation and would require a pressure gradient to force fluid flow from vessel to vessel. The stacked vessel apparatus consists mainly of a stack of pressure vessels that are very similar to conventional cold-seal pressure vessels and, due to the vertical arrangement of the vessels isothermal transfer of fluid from one vessel to the next is accomplished easily and efficiently. In addition, fluid flow could be restricted to brief periods between the various stages of an experiment (i.e., staged flow-through).

Attachment A

B0290

TITLE:

NO.	NEAR-TERM SCHEDULE	SUBTASK/MILESTONE SCHEDULE																	
SUBTASK/MILESTONE		FY 83				FY 84				FY 85				FY	FY	FY	FY	FY	BEYOND FY
		1	2	3	4	1	2	3	4	1	2	3	4						
1.	Tc/U Batch Experiments																		
	a. Tc/Basalt				—	—	—												
	b. Tc/Tuff (representative minerals)					—	—	—	—										
	c. U/Basalt						—	—	—										
2.	Np/Pu Batch Experiments																		
	a. Np/Basalt				—	—	—												
	b. Np/Tuff							—	—	—									
	c. Pu/Basalt							—	—	—	—								
3.	Column Experiments																		
	a. Preliminary Tc/Np experiments in basalt					—	—												
	b. Multiple-element tests for basalt						—	—	—										
	c. Multiple-element tests for tuff								—	—									
4.	Calculational Studies (PHREEQE, MINTEQ, EQ3/6)																		
	a. Comparisons with BWIP groundwater and radionuclide solubility values				—	—													
	b. Comparisons with NNWSI groundwater					—	—												
	c. Comparisons with Cleveland Pu results					—	—	—											
	d. Comparisons with column basalt results							—	—										
	e. Comparisons with column tuff results									—	—								
	f. Comparisons with batch U, Pu results								—	—									

ACTIVITY NO. ______

189A NO. ______ or FTP/A NO. ______

References

1. Cleveland 1983. J. M. Cleveland, T. F. Rees, and K. L. Nash, "Plutonium Speciation in Selected Basalt, Granite, Shale, and Tuff Groundwaters," Nucl. Tech. 62, 298-310 (September 1983).

2. Kelmers 1983. A. D. Kelmers, R. J. Clark, N. H. Cutshall, J. S. Johnson, and J. H. Kessler, "Evaluation of Radionuclide Geochemical Information Developed by DOE High-Level Nuclear Waste Repository Site Projects, Annual Progress Report: FY 1983," in preparation.