Basalt Waste Isolation Project Quarterly Report

**October 1, 1980
through
December 31, 1980**

MASTER

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Rockwell International

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February 1981

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ABSTRACT

This report addresses the technical progress for the Basalt Waste Isolation Project for the first quarter of fiscal year 1981. The organization of the report follows the current work breakdown structure for the technical areas of the project. The major highlights for the quarter are provided below.

In Systems Integration, significant progress was made toward the preparation of Technical Baseline documents. The Principal Criteria Document, System Specification (Draft), and three procedures were completed. Preparation of the End Function Technical Plans and design of the Index and Traceability System continued.

Analysis of data from Full-Scale Heater Tests #1 and #2 continued; experimental data were in good agreement with predictions. Planning for room-scale testing, including numerical modeling and analysis, also progressed during this quarter.

Preparation of environmental documents continued; three environmental evaluations were prepared and submitted to the U.S. Department of Energy during this quarter.

In the Geosciences activity, surface geology studies of the Columbia Plateau provided more information on the number of Pre-Wisconsinan floods in the Spokane area, revealed statistically significant differences in pebble deposits from the Columbia and Snake Rivers, and refined the stratigraphy of the post-basalt sediments in northern Oregon. Carbon isotope and gas ratio studies to evaluate resource potential in the Pasco Basin continued. Investigations related to the tectonic setting continued, including: magnetostratigraphy of the Ringold Formation sediments, Wanapum Basalt, and Saddle Mountains Basalt; installation of three of nine proposed geodetic monuments in the Pasco Basin; geophysical work in the Finley Quarry area; initiation of installation of a seismic network in the reference repository location (note: no microearthquake swarm activity occurred during the quarter). Structural geologic setting studies of the eastern Umtanum Ridge segment of the Umtanum Ridge-Gable Mountain structure indicate that the lower reverse fault dips to the south at an angle between 20 and 70 deg, and the maximum horizontal shortening produced by combined folding and faulting is 965 m or 25%. Drill core from DC-14 revealed a 0.3-m-wide breccia zone, interpreted to be of tectonic origin, in the Umtanum flow. A working hypothesis involving paleo-flooding during emplacement of flood basalt lava flows was developed to help explain the entablature/colonnade contact, an important feature of host rock lithology. Support was provided by Geosciences for the Exploratory Shaft Test Facility plan and for the cutter head development proposal.

Hydrologic modeling during this quarter focused on: improvement of the computer code structure; incorporation of refined descriptions of interbeds, interflows, and hydrologic discontinuities; and sensitivity

analysis. Remote sensing studies continued, and a subcontract was initiated to develop groundwater monitoring strategies.

Testing was directed at acquisition of hydraulic and hydrochemical data within new and existing boreholes on the Hanford Site. A distinct hydrochemical break between groundwaters in the upper Grande Ronde and Wanapum Basalts indicated lack of hydraulic communication across this boundary.

In support of Engineered Barrier activity, the Hanford Engineering Development Laboratory was requested to prepare 1 kg of simulated spent fuel for hydrothermal tests (spent fuel/groundwater interaction) conducted at Temple University. Advanced hydrothermal testing was initiated at Arizona State University, including on-line sampling to determine steady-state solution compositions. Initial results showed that the addition of basalt to simulated supercalcine and simulated Hanford groundwater causes a decrease in sodium, rubidium, molybdenum, and chromium.

In continuing studies scoped to define the sorption behavior of several cations in the presence of reference geologic materials, hydrazine was found to be an effective poisoning (buffering) agent for Eh control. Plutonium K_d values were found to decrease with increasing pH (to a pH of 8) under oxidizing and slightly reducing conditions in the presence of basalt. No definite trends were observed for Pu sorption as a function of Eh or, within the concentration range studied (6.81×10^{-14} to 1.96×10^{-4} mole/l), Pu concentration. Plutonium sorption on Umtanum and Flow E basalts increased significantly with increasing temperature and pressure, possibly as the result of secondary mineralization occurring at higher temperatures.

The first in a series of corrosion screening tests of candidate canister and overpack materials was completed, and post-exposure examination of the test specimens was initiated. Anoxic conditions were maintained during all tests.

Characterization of the recovered core and logging of the exploratory core holes for the shallow borehole plugging test adjacent to the Near-Surface Test Facility was completed. Results showed that several intervals are suitable for conducting the shallow borehole plugging test within the cored interval of 46 m. A laboratory test suitable for evaluating the effectiveness of grout for penetrating a fracture was developed.

Phase I construction for the Near-Surface Test Facility was completed except for several minor items. Phase II construction layout work was initiated. Drilling of Phase II test and instrument holes was completed.

In the Engineering Testing activity, operation of the full-scale heater tests is proceeding as planned. Preparations are well under way to start Jointed Block Test #1, including drilling, instrument and equipment procurement, software development, and heater/controller fabrication. Implementation of planned activities for the nuclear waste (Phase II) tests has started.

Kaiser Engineers/Parsons Brinckerhoff completed a study during the reporting period to augment the on-going nuclear waste repository in basalt conceptual design. The current design concept was based on the receipt and storage of commercial spent fuel. The new study evaluated the technical and economic impacts on repository conceptual design of the following waste receipt scenarios:

- Alternative 1: A repository which receives commercial spent fuel plus defense high-level waste
- Alternative 2: A repository which receives commercial high-level waste plus defense high-level waste.

During the quarter, work on the Exploratory Shaft Test Facility was limited to preparation for the National Waste Terminal Storage Program workshop on exploratory shafts held in St. Louis, Missouri, on December 16-17, 1980.

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INTRODUCTION

In February 1976, the U.S. Energy Research and Development Administration (currently the U.S. Department of Energy) expanded the commercial radioactive waste management programs and established the National Waste Terminal Storage Program. Its mission was to provide multiple facilities in various deep geologic formations within the United States. The Office of Waste Isolation was established within the Union Carbide Corporation-Nuclear Division to provide program management of the National Waste Terminal Storage Program. The overall program consisted of investigating a number of geologic rock types to determine their suitability for terminal storage of radioactive waste. Basalts, such as the Columbia Plateau basalts, which underlie a large portion of the Pacific Northwest and the Hanford Site, were selected for initial geologic reconnaissance. Atlantic Richfield Hanford Company was asked in May 1976, by the Office of Waste Isolation, to plan and execute a geologic exploration of Columbia Plateau basalts to determine the feasibility of utilizing those formations as a site for disposal of commercial nuclear waste.

In September 1977, the National Waste Terminal Storage Program was restructured. Additional funds were given to support investigations of two U.S. Department of Energy sites--Hanford and Nevada. The Hanford program is presently the responsibility of the U.S. Department of Energy-Richland Operations Office. Rockwell Hanford Operations (successor to Atlantic Richfield Hanford Company) is the prime contractor responsible for this work. The Basalt Waste Isolation Project within Rockwell Hanford Operations has been chartered with the responsibility of conducting these investigations. These investigations are part of a national program being integrated for the U.S. Department of Energy by the Office of Nuclear Waste Isolation of Battelle Memorial Institute.

The overall Basalt Waste Isolation Project is divided into the following principal work areas:

- Systems Integration
- Geosciences
- Hydrology
- Engineered Barriers
- Near-Surface Test Facility
- Engineering Testing
- Repository Studies.

Summaries of major accomplishments for each of these areas are reported in the following sections.

SYSTEMS INTEGRATION

The objective of Systems Integration is to integrate all research activities leading to the identification, characterization, and licensing of a site for potential use as a nuclear waste repository in basalt within the Hanford Site. The scope of work includes reviewing research, test, and design activities; providing thermomechanical computer models; conducting trade-off studies; performing data analyses and interpretation; and establishing the technical basis and criteria for site selection, licensing, and design of the repository and ancillary facilities.

The Systems Integration end function is divided into three major activities:

- Project Management
- Systems Integration
- Safety and Environmental Documentation.

During the first quarter of fiscal year 1981, work has progressed in all three activities.

PROJECT MANAGEMENT

The project management activity is concerned with the management of the Systems Integration end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of the technical activities.

SYSTEMS INTEGRATION

Technical Baseline

On September 8, 1980, the Basalt Waste Isolation Project proceeded with the implementation of the Basalt Waste Isolation Project Technical Baseline Control Plan as presented to the U.S. Department of Energy-Richland Operations Office.

The Technical Baseline operates according to the logic shown in Figure 1. The Principal Criteria document and System Specification define what has to be done to meet program objectives and the Basalt Waste Isolation Project Technical Plans identify how Rockwell Hanford Operations plans to perform the required work elements. An Index and Traceability System is used to ensure that control and traceability are maintained in the program.

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FIGURE 1. Basalt Waste Isolation Project Technical Logic Mechanism Network.

During the first quarter of fiscal year 1981, considerable progress was achieved toward implementation of the Basalt Waste Isolation Project Technical Baseline. Procedures were finalized and approved, principal criteria defined, and system specifications identified. In addition, End Function Technical Plans which included functional analysis, logic networks and detailed definitions of deliverable end items and work tasks were completed in draft form. Progress was also made on the identification and design of an Index and Traceability System.

Procedures. The following Technical Baseline procedures were completed and approved:

- Technical Baseline identification
- Change control processing
- Basalt Waste Isolation Project interface coordination group activities.

Principal Criteria. The Basalt Waste Isolation Project's Principal Criteria document was completed and submitted to the U.S. Department of Energy on October 21, 1980. Comments have been received from the U.S. Department of Energy-Richland Operations Office and incorporated, and a second draft will be issued on January 31, 1981, in agreement with Rockwell Hanford Operations' Award Fee Milestone 4.4.

System Specification. The Basalt Waste Isolation Project's System Specification draft was completed. Input from Rockwell Energy Systems Group and Kaiser Engineering/Parsons Brinckerhoff were incorporated; the document is presently in review and will be issued on January 31, 1981, in agreement with Rockwell Hanford Operations' Award Fee Milestone 4.4.

Technical Plans. Technical plans are being prepared for the following Basalt Waste Isolation Project end functions:

- Waste Package
- Site
- Repository
- Regulatory and Institutional
- Test Facilities.

From these End Function Technical Plans, a Basalt Waste Isolation Project Technical Plan will be prepared identifying the overall Basalt Waste Isolation Project end item deliverables and program logic required to meet program objectives.

The technical plans identify, through logic networks and functional analysis, the step-by-step approach being taken by the Basalt Waste Isolation Project to satisfy the principal criteria and the program objectives. The plans identify end item and intermediate deliverables and provide a basis for program control. All technical plans are scheduled to be completed by March 15, 1981.

Index and Traceability. The design of the Basalt Waste Isolation Project's Index and Traceability System for control and traceability of all criteria, requirements, specifications, end item deliverables, and work tasks is progressing satisfactorily. The system will initially be semi-automated and will have the capability of full automation as the Basalt Waste Isolation Project's demand for traceability increases.

In addition to the Technical Baseline, the Basalt Waste Isolation Project's Systems Department prepared a Verification Program Plan, which, when implemented, will guide the control of data acquisition and documentation necessary to support licensing of a nuclear waste repository in basalt. During this fiscal year, an overall Verification Plan will be completed and presented to the Basalt Waste Isolation Project management for review prior to implementation.

Systems and Test Analysis

The in situ testing program in basalt at the Near-Surface Test Facility is scheduled to progress in two phases: Phase I, using electric heaters; and Phase II, using nuclear materials. The initial thermo-mechanical tests in Phase I, Full-Scale Heater Tests #1 and #2, began in July 1980. Preliminary analysis of test data was conducted by Dames & Moore's Advanced Technology Group. There is general agreement in trends between predictions and measurements. Comparison of temperature contours within a plane indicates no evidence of gross anisotropy in thermal conductivity. Within a horizontal plane, minor differences between predictions and measurements occur, which may be caused by the presence of water at the start of the test, nonuniformity in temperature at the start of the test, and differences in laboratory-measured thermal conductivity used in the analysis and actual in situ thermal conductivity.

The next test to be conducted in the Near-Surface Test Facility is a Jointed Block Test. In this test, a 2-m x 2-m block of basalt is to be tested under controlled stress and temperature conditions. This will be accomplished by isolating the block, in place, by slot drilling and placing flat jacks in the slots to control stress. Electric heaters will be placed in drill holes within and around the block to control temperatures.

Scoping studies of the Jointed Block Test were conducted using analytical and numerical techniques to assess temperatures, displacements, and stresses. The scope of the analysis encompassed a test with a single slot and a second test with multiple slots. The analysis of the single-slot test included elastic and zero-tension material behavior over a range of stresses and temperatures from 0 to 20 MPa and from 150 to 200°C, respectively.

Execution of the various phases of the Jointed Block Test requires a capacity to introduce closely controlled increments of temperature in the rock. Analysis of various heating modes applied to the block was performed using the analytical computer code TEMP3D. It was assumed in the analysis that the tunnel wall at the block test site represents an isothermal surface. A uniform temperature field is required for thermal expansion measurements. Temperature gradient conditions are required for measurement of thermal conductivity.

Engineering Model Development

During fiscal year 1980, Dames & Moore's Advanced Technology Group initiated documentation activities for the models developed or modified for Rockwell Hanford Operations under previous subcontracts. Users' manuals for DAMSWEL and FINEL were prepared, and both were used in the analysis of the full-scale heater tests at the Near-Surface Test Facility.

DAMSWEL is a finite element computer program developed to model the transient thermal stress behavior of basalt. It is a two-dimensional program with plane and axisymmetric capabilities. Although capable of modeling any anisotropic elasto-plastic material, it was specifically designed to simulate the expected behavior of the basalt at the Near-Surface Test Facility. In particular, it incorporates nonlinear stress-strain relationships characteristic of basalt's locking behavior, variable thermal properties, thermal anisotropy, and free surfaces with convective, fixed temperature, or fixed-flux boundary conditions. Additionally, mass transfer at a free surface may be simulated. The last capability would be of importance if water boils off around the periphery of a hole containing a heater or waste canister.

The stress analysis routines of DAMSWEL may also be executed totally independently if required. Any nonlinear material law may be used, but the documented version contains an algorithm for treating locking materials. A feature of the algorithm is the calculation of residual forces at the end of each load increment and their application at the next load increment. This avoids the "drift" away from the true stress-strain curve, which is exhibited by codes based on a simpler initial stress approach. Other features of the stress analysis section of the code include treatment of basalt anisotropy, element removal, and definition of an initial field stress.

The FINEL computer program makes available to the user a wide variety of finite element analyses which vary from thermal stress analysis to general structural dynamics analysis. The code's ability to simulate complex three-dimensional geometries is among the thermal stress analysis capabilities of the code relevant to the Basalt Waste Isolation Project. Further, it has well-developed three-dimensional mesh generation and checking modules as well as extensive post-processing plotting facilities.

The thermal analysis capabilities of FINEL relevant to the modeling of basalt are: performs transient or steady-state analysis; accommodates anisotropic thermal conductivity; accepts convective, fixed-temperature and fixed-flux boundary conditions; and allows specification of heat generation within an element or along an element boundary in terms of a piecewise continuous curve with time. The stress analysis modules provide for one-, two-, or three-dimensional linear elastic analysis of an anisotropic material. Major features of particular relevance to the Basalt Waste Isolation Project include: anisotropic material properties, a comprehensive selection of boundary conditions, and initial loading conditions.

SAFETY AND ENVIRONMENTAL DOCUMENTATION

Three environmental evaluations for several boreholes were prepared and submitted to the U.S. Department of Energy-Richland Operations Office. Comments received from the U.S. Department of Energy were incorporated, and the environmental evaluations are now at the U.S. Department of Energy for final approval. The environmental assessments covering site screening and site characterization are being reviewed by the Environmental Group at the U.S. Department of Energy-Headquarters. A meeting is scheduled for January 26, 1981 to discuss their concerns.

Comments on the draft of the Basalt Waste Isolation Project Site Characterization Plan are being received from members of the National Waste Terminal Storage Program. The final version of the document is due for public release in May 1981.

GEOSCIENCES

The purpose of the Geosciences end function is to gather basic data on local and regional geology to support the identification of a reference repository site in basalt. The studies emphasize reconnaissance field investigations in that portion of the Columbia Plateau underlain by Columbia River basalt (Figure 2) and detailed field work within the Pasco Basin of the Columbia Plateau where the Hanford Site is located.

The Geosciences end function is divided into four major activities:

- Project Management
- Geology
- Geophysics
- Seismic Monitoring.

During the first quarter of fiscal year 1981, work has progressed in all four major activities.

PROJECT MANAGEMENT

The project management activity is concerned with the management of the Geosciences end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of the technical activities.

GEOLOGY

Integration of geologic data and communication of results to the scientific community represented a major portion of geologic efforts during the quarter. Results from the Basalt Waste Isolation Project's geological studies were formally presented at professional society meetings (seven abstracts), at the Office of Nuclear Waste Isolation annual meeting (one abstract), and at the Basalt Waste Isolation Project's annual meeting (five papers). Informal presentations on technical findings were made to the National Academy of Science, the U.S. Nuclear Regulatory Commission, and the Geology Overview Committee.

Site identification work continued during the quarter. "Identification of Candidate Sites Suitable for a Geologic Repository in Basalt within Hanford," a report describing the site identification process through February 1980, was issued as RHO-BWI-LD-24. Site A-H located in the western Cold Creek syncline area (Figure 3) continues to be the Reference Repository Location. Site J, located in the central Cold Creek syncline area, continues to be the alternate location. Geophysical surveys were begun in Site A-H (described in the Geophysics section of this

FIGURE 2. Index Map--Region.

FIGURE 3. Index Map--Northern Pasco Basin and Hanford Site.

report) to refine interpretations of the bedrock structure within its central part and to assist in selecting the location for an exploratory shaft now being considered. Six locations for boreholes were staked in the A-H area. Two of these boreholes are to be drilled to the Mabton interbed, and four are to be drilled only through the uppermost basalt unit. These boreholes will be used to determine the elevation of the bedrock surface and to calibrate geophysical surveys. Drilling of these holes was started and will resume next quarter.

Initial work on the geologic characterization section of the Detailed Site Characterization Plan was begun. A 1:24,000-scale base map for the Cold Creek syncline area was prepared. Important outcrops that are included within the map boundaries are portions of Yakima Ridge, Rattlesnake Hills, White Bluffs, and the entireties of Gable Mountain and Gable Butte. These outcrops will provide surface control for interpreting subsurface geology. The in-house data processing equipment for this work is nearly all operational, and the required software is being acquired either directly or on a time-share basis.

Work to assess the potential for geologic resources in the Pasco Basin continued. This work included carbon isotope and gas ratio studies in cooperation with the U.S. Geological Survey. Hydrocarbon gas samples are being studied in the context of the regional hydrologic regime to gain information on the origin and economic potential of hydrocarbons in the Pasco Basin. Arrangements have been made to conduct hydrogen isotope analyses on selected hydrocarbon gas samples. In cooperation with the U.S. Geological Survey, vitrinite reflectances are being measured for samples of coal-rich cuttings from hydrocarbon exploration hole, Rattlesnake Hills Well #1 (RSH-1), outside the southwest corner of the Hanford Site (Figure 3) in an effort to correlate the potential significance of the coal to generation of methane gas locally observed in selected hydrologic test wells. Results of carbon isotope and gas ratio analyses completed to date suggest a need for collection of additional, spatially separated samples.

Work related to the tectonic setting included: (1) installation of geodetic survey monuments, (2) a continuation of work to interpret the tectonic history and deformation rates in the Pasco Basin, and (3) a paleomagnetic analysis of Ringold core. Sites suitable for the installation of permanent geodetic survey monuments were selected in the southwestern portion of the Hanford Site where numerous surface fissures in colluvium in the Snively Basin were discovered by geologic mapping during fiscal year 1980. These fissures appear, in part, to reflect recent movement within the last 5 yr, but their cause--whether tectonic or nontectonic--is not presently known. Six monument sites in two triangular arrays within the Snively Basin were selected to provide the means for high-precision, laser-interferometer distance measurements across the mapped surface ruptures and known faults. Additional survey monument sites were selected on Gable Butte, within the Cold Creek valley, and on the eastern terminus of Yakima Ridge. Long-term distance measurements from these sites across the Cold Creek valley to Snively Basin monuments to the south, and between monuments within Snively Basin, will provide information on possible surface movements bordering or within the Cold

Creek syncline. Three of nine proposed monuments were installed. Completion of monumenting in this area is scheduled for the second quarter of fiscal year 1981, pending suitable weather conditions and availability of helicopter support.

Continuing studies on the distribution of basalt flows indicate that other Yakima Ridges, including the Saddle Mountains, were growing during the eruption of the Wanapum Basalt and Saddle Mountains Basalt flows. Previous studies suggested that the Saddle Mountains was the oldest ridge and that ridges to the south were progressively younger. The present study suggests that all ridges were growing at the same time. Deformation rates were low (40 to 70 m/million yr) which obscures evidence for ridge development in the Grande Ronde Basalt. Since over 85% by volume of the Grande Ronde Basalt was erupted in 1.5 million yr, any evidence of deformation would have been quickly covered in Grande Ronde time. Thus, to place a limit on the beginning of deformation of Yakima Folds is very difficult now. Evidence such as thinning of the Sentinel Bluffs sequence across Sentinel Gap to the west suggests that the Hog Ranch structure (Figure 2) may have been active, but at a much greater rate of uplift than measured in the Yakima Folds.

The paleomagnetic analysis of three Ringold core holes (DH-18, -19, and 699-40-12B), Figure 3, has extended the magnetostratigraphic data for the Ringold Formation both above and below the Parsons Canyon/Ringold Flat section data reported previously. These additional data are best shown in DH-19 where a normal polarity section, ~24 m thick, overlies the previously determined reversed polarity upper section of the Parsons Canyon/Ringold Flat section. Additional paleomagnetic stratigraphy below the Parsons Canyon/Ringold Flat section is difficult to correlate from core hole to core hole because of the presence of middle conglomerate facies in DH-18 and 699-40-12B. A reverse-to-normal sequence in the fine sediments of the lower portion of the Ringold Formation in DH-18 and 699-40-12B offers a high potential for time stratigraphic correlations in the Cold Creek syncline where there is a thick sequence of the fine lower Ringold sediments. No core holes have been completed yet in this locality to test this correlation. The preliminary interpretation of DH-19 indicates that the upper normal is lower Gauss Epoch (~3.5 million yr) or the uppermost normal of the Gilbert Epoch (Cochiti, ~3.8 million yr) and spans >2 million yr.

Ongoing regional geologic investigations of the sediment and volcanic deposits in the Columbia Plateau have produced new information. The status of the stratigraphy and correlations currently being used in the state of Idaho has been documented. Field studies in the state of Washington concentrated on the Pleistocene flood history of the Channeled Scabland, which is located in the east-central part of the state, and the Okanogan Highlands (see Figure 2). Results indicate evidence for at least three pre-Wisconsinan floods and three major late-Wisconsinan floods in the Spokane area. Studies in the Omak Trench, Okanogan Valley, and Columbia River valley areas give evidence for early or pre-Wisconsinan

flooding and at least seven mid- to late-Wisconsinan floods. These data are supported by carbon-14 dates on organics and thorium/uranium dates on caliche. The number and size of Pleistocene catastrophic floods are significant to long-term risk assessment for a repository sited in basalt underlying the Hanford Site. Gravels associated with the Yakima and Snake Rivers have been studied using pebble-cobble counts to determine paleo-drainage from late Miocene to present. The data base acquired is also helpful in identifying unknown gravel units. These data indicated that Yakima and Columbia River gravels are statistically different and can be used to identify drainage networks. Mapping of sediment and volcanic deposits overlying Columbia River basalts in the state of Oregon is continuing. Last quarter, the Deschutes Formation sediments of the Madras Basin were added to the Tygh Valley, Chenoweth, Alkali, and McKay formations of the proposed Dalles Group. Sediments in other basins in the eastern and southern parts of the study area are being designated with informal names until their genesis and character are further understood.

Work related to the structural geologic setting of the Hanford Site included a continuation of the detailed structural study of the Umtanum Ridge, geophysical surveys in the Cold Creek syncline (described under Geophysics), and a study of results from deep core holes currently being drilled. Structural features within the Umtanum Ridge in the Yakima River canyon north of Yakima were analyzed for a comparison with structural features measured in Umtanum Ridge at Priest Rapids Dam. The structural geometry and strain distribution within the anticline at the two widely separated locations are very similar. This finding provides increased confidence in projecting the strain distribution observed in surface outcrops in Yakima Folds into the subsurface of the Pasco Basin. A cross section of eastern Umtanum Ridge near Priest Rapids Dam has been constructed (Figure 4) by incorporating data from field mapping and new data acquired from two core holes at Priest Rapids Dam: PRR-6 drilled by the Grant County Public Utility District in 1955 and UR-1 drilled by Golder Associates in 1980. The lower reverse fault was penetrated by PRR-6, but UR-1 did not penetrate the fault and is interpreted to be entirely within the footwall. These core holes constrain the dip of the fault to between 20 and 70 deg to the south. A fault dip between 20 and 45 deg indicates a greater amount of displacement at depth than near the surface, which is characteristic of concentric folds such as the Umtanum anticline. If the fault dips 45 deg, then displacement is equal at depth and at surface. This would imply that faulting took place after flow layering had reached its present folded orientation. A fault dip >45 deg indicates that there has been a greater amount of horizontal displacement at the surface than at depth, suggesting that faulting is related to a much deeper discontinuity than strain within the concentric fold core would imply. The maximum amount of horizontal shortening within the eastern Umtanum structure is the result of horizontal shortening along the lower reverse fault, upper reverse fault, and the Umtanum anticline. The maximum horizontal shortening calculated from the cross sections is ~965 m or 25%.

FIGURE 4. Cross Section of Eastern Umtanum Ridge near Priest Rapids Dam Showing the Minimum Possible Dip of the Priest Rapids Fault (~ 20 deg S).

Three deep core holes are currently being drilled in the Pasco Basin. Predicted versus observed stratigraphic columns were prepared for each of these core holes. Monitoring of drilling progress and comparison to these predictions are serving as a basis for revising and updating isopach maps and structure contour maps.

Preliminary analysis of core samples by the energy dispersive X-ray unit indicates that two of the core holes, DC-12 and -14, have penetrated into the Umtanum flow. A 0.3-m zone of tectonic breccia with a few slickensides was cored in the flow above the Umtanum in DC-14. This breccia appears to be tectonic in origin and is similar to that recently observed in Grande Ronde Basalts on gently dipping limbs of the Yakima Folds. Breccia zones logged in previously drilled core holes are being reevaluated to interpret their origin. Improved core recovery techniques have resulted in recovering core that is more representative of in situ conditions.

Continued progress was made in the area of lithologic studies of the Umtanum flow, especially its intraflow structures. Petrographic parameters to aid in recognition of the entablature-colonnade contact in Grande Ronde Basalt flows continue to be studied. This work has also aided in developing a working hypothesis for the origin of entablature-colonnade in basalt flows. The higher glass content and the more dendritic morphology of titaniferous magnetite grains in the entablature strongly indicate that the entablature cooled at a more rapid rate than

the colonnade, in spite of the entablature's central position in the flow. Conductive cooling models do not adequately explain this phenomenon, implying that flows exhibiting entablature and colonnade might have had their normal cooling history perturbed by external conditions. If such is the case, these external conditions apparently occurred repeatedly during the emplacement and cooling of Grande Ronde Basalt flows. One reasonable possibility, which constitutes a working hypothesis, is that these flows blocked major drainages during eruption and emplacement in low-lying areas. Cooling of the flows then proceeded simultaneously with draining of water upstream from the blocked area until water poured over the flow and effectively chilled the unsolidified, internal part of the flow. Water pouring out over the top of the flow is thus the external perturbation that disrupted the "normal" cooling history of the flow. The entablature-colonnade contact represents the position of the solidification front within the flow at the time during its cooling history when the flow was chilled from above by water.

This hypothesis can be used to explain many of the features observed in surface outcrops of Grande Ronde Basalt flows, including the Umtanum flow, and provides additional input to interpreting the paleogeography of the Pasco Basin and Cold Creek syncline. This information aids in the prediction of intraflow structures at depth within candidate host rock such as the Umtanum.

During this quarter, a paleomagnetic study of surface exposures of Saddle Mountains, Wanapum, and upper Grande Ronde Basalts and subsurface core of Wanapum and Grande Ronde Basalts was completed by Sierra Geophysics, Inc., Arcadia, California. These new data have been combined with that of previous paleomagnetic studies to produce a comprehensive, statistically valid data set. The investigators developed two improvements in laboratory procedures: a means to recognize and to remove drilling-induced remagnetization of core and utilization of a new statistical method that makes it possible to apply Fisherean statistics to all data, including core data where only inclination can be determined. These improvements resulted in a statistically homogeneous data set for both surface and subsurface data. Paleomagnetic analysis of the Saddle Mountains and Wanapum Basalts produced the following results: (1) the Pomona Member of the Saddle Mountains Basalt yielded some of the best grouping of paleomagnetic directions of any Columbia River basalts; (2) this supports previous interpretations that the Umatilla and the Sillusi flows of the Saddle Mountains Basalt cooled at about the same time; (3) the Roza Member of the Wanapum Basalt has the shallowest inclination of any sampled flow in all three formations; (4) in the lower part of the Frenchman Springs Member of the Wanapum Basalt, the Sand Hollow and Ginkgo flows display nearly identical characteristic magnetic properties, which suggests they probably cooled within 100 yr of each other; and (5) since the directions of the lower part of the Frenchman Springs is ~ 90 deg from the Miocene axial dipole field direction, these flows are interpreted as recording part of a geomagnetic reversal of excursion. Results from the paleomagnetic study of Grande Ronde Basalt are currently being evaluated. Findings will be reported next quarter. Paleomagnetic

analysis of upper Grande Ronde Basalt was designed to increase the resolution and expand the Grande Ronde magnetostratigraphic correlations. Magnetostratigraphic correlations of Grande Ronde Basalt below the Vantage and above 1,526-m depth are now defined by six horizons. Only one of these horizons exhibits reverse polarity; it is designated horizon W and occurs ~460 m below the Vantage sandstone horizon of the Ellensburg formation. The five other horizons designated S, U, V, X, and Y are defined by fluctuations of inclination which recorded secular variations of the geomagnetic field. Surface sampling of Grande Ronde Basalt in the Crescent Bar area has reinforced confidence in the recognition of secular variation horizons U and V. The flow underlying the MgO horizon at Crescent Bar shows a characteristic shallow inclination (~40 deg), indicating it cooled at about the same time as the Umtanum. Paleomagnetic analysis core obtained by deepening core hole DC-7 was completed. Polarity reversal horizon W has been found in DC-7. Proposed polarity reversal horizon X is not interpreted as being a function of drilling-induced remagnetization and shall be reanalyzed using a more critical laboratory procedure. Two additional secular variation horizons, X and Y, have been recognized in DC-7. This makes a total of six useful magnetostratigraphic horizons in Grande Ronde Basalt.

Geosciences provided engineering and mining geology support to other components of the Basalt Waste Isolation Project. This support included completing a geologic site characterization report for the Near-Surface Test Facility (issued as RHO-BWI-ST-8), completing input for a drilling equipment development proposal, and completing input for a proposal to design and construct an exploratory shaft. The Near-Surface Test Facility report provided detailed characterization of the Pomona entablature and a rock mass characterization for the thermomechanical testing. Geologic support for the Exploratory Shaft Test Facility consisted of providing assistance in preparation of options for Exploratory Shaft Test Facility development. These options included evaluation of the possibility of expanding the Exploratory Shaft Test Facility for emplacement of from 40 to 1,000 nuclear waste canisters, incorporation of the equipment development facility into the Exploratory Shaft Test Facility planning schedule, and modification of the scope of the Exploratory Shaft Test Facility. The present emphasis in the Exploratory Shaft Test Facility is to site the facility using information obtained from the reference repository location drilling program and from reanalysis of reflection seismic data. Incorporation of these data with the present top-of-basalt map information should be sufficient to select a satisfactory site in the reference repository location.

GEOPHYSICS

The main geophysical effort during the quarter centered around intensive data analysis and interpretation of specific areas in the Pasco Basin. As a secondary effort, data collection in the reference repository location area continued along with preparing for subcontract efforts to be conducted later in the year.

In support of the Cold Creek syncline study, compilation, analysis and interpretation of seismic reflection surveys, multilevel aeromagnetics, and in-house surveys (magnetics and gravity) have led to new interpretations of the bedrock structure. This effort included the use of geologic and borehole data to begin revision of the top-of-basalt map and to prepare a geophysical features map.

Surveys conducted in the Finley Quarry area were finalized during the quarter with the completion of a report that describes the work conducted and details the resultant interpretation of structures in the area. An internal review of the report is currently under way.

Gravity surveying in the reference repository location area of the Cold Creek syncline was started during the quarter. This work supports the gridded gravity surveying in the Cold Creek syncline. Approximately 200 stations were occupied in the grid along specific baselines. Analysis of the data is currently under way along with continued data collection.

SEISMIC MONITORING

Regional seismic monitoring by the University of Washington continued during the quarter. A magnitude 3.5 earthquake occurred at 1444 PST on December 18, 1980 near Alderdale, Washington (lat. 45°49.3' N., long. 119°58.9' W.). Data from this event are currently being analyzed. No earthquake swarm activity has occurred during this quarter.

The configuration of the portable seismic network was modified to include three stations in the vicinity of Wooded Island where past swarm activity occurred in 1969-1970 and in 1975. Stations at Rattlesnake Ridge and the Saddle Mountains remain.

A four station, single-component, seismic network is presently being installed in the reference repository location area. Data from this network will be simultaneously recorded in the 200 West Area and in Richland, Washington, the former to verify any events that might trip accelerometers in facilities equipped with such instruments.

The borehole seismometer is no longer operational. High temperatures and a sealant used in the package produced an acidic environment which corroded the electronics. A newly designed seismometer package is presently on order and will be installed in borehole DC-3 (Figure 3) upon arrival.

A digital recording system similar to that at the University of Washington is being designed to record data from the Rockwell Hanford Operations' seismic network. This system will improve the quality of records and facilitate analysis of the data.

HYDROLOGY

The Hydrology end function provides criteria and evaluation techniques for hydrologic assessment of potential repository sites. Study of the groundwater regime underlying the Columbia Plateau is important, since the groundwater pathway affords the most likely avenue of contact between repository-stored wastes and the biosphere. Hydrologic studies have emphasized the development of a data base to characterize the groundwater system underlying the plateau and modeling of the flow system to evaluate the potential for radionuclide transport to the biosphere. The hydrologic studies include reconnaissance regional studies over the Columbia Plateau and intensive local studies within the Pasco Basin where the Hanford Site is located.

The Hydrology end function is divided into four major activities:

- Project Management
- Hydrology
- Testing Support
- Drilling Support.

During the first quarter of fiscal year 1981, work has progressed in all four activities.

PROJECT MANAGEMENT

The project management activity is concerned with the management of the Hydrology end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of the technical activities.

HYDROLOGY

During this quarter, in a cooperative effort between Rockwell Hanford Operations and a subcontractor, far-field (Pasco Basin) modeling work focused on: (1) use of finer vertical detail to include some significant, individual, interbed and interflow zones; (2) incorporation of some hydrologic discontinuities in the modeling process; (3) application of a three-dimensional version of the SEMTRA code (without the transport features) to take advantage of some of its superior code structure and portability, compared to the RHAF code that was used previously; and (4) parameter and sensitivity analysis (including the impact of disruptive events).

A near-field parameter and sensitivity analysis which focused on repository and near-vicinity scale was completed (see RHO-BWI-80-100 for a summary of results). A joint near-field modeling effort between the Hydrology Group and a subcontractor is under way concerning a sensitivity and parametric analysis. The analysis is focusing on the room to repository scale.

Another Rockwell Hanford Operations/subcontractor joint effort was initiated to verify the Basalt Waste Isolation Project hydrologic models with existing data and to prepare complete model documentation.

Work is under way to continue the remote-sensing studies. Specifically, the work integrates a number of data bases, such as digital terrain data, irrigation well locations and depths, soil arability, irrigation project boundaries, canals, etc., with LANDSAT data. This integration is expected to facilitate both the estimation of current effects of irrigation on the groundwater system and the prediction of likely development potential and scenarios. The products generated are expected to provide substantial input to the regional groundwater dynamics study targeted for completion in fiscal year 1981.

A subcontract was placed with Brown and Caldwell Consulting Engineers, Seattle, Washington for the purpose of identifying alternative groundwater monitoring strategies for the site/repository system. Deliverable items include a compilation of relevant regulatory criteria, an annotated bibliography on groundwater monitoring, and a final report presenting alternatives for various site/repository groundwater monitoring needs (e.g., baseline, model validation, long-term impact assessment, etc.).

TESTING SUPPORT

During this quarter, emphasis was focused on acquiring new downhole hydraulic parameter and hydrochemical data for groundwater horizons within new and existing boreholes on the Hanford Site.

Table 1 lists stratigraphic intervals and transmissivity values determined during this quarter for selected interbed and interflow zones. Eleven geologic intervals were hydrologically tested in boreholes now under construction: DC-12, -14, and -15 (see Figure 5 for locations). Two additional horizons were tested at existing boreholes, DC-6 and -7. Transmissivity values shown in Table 1 fall within the range previously reported for these types of rock intervals.

TABLE 1. Transmissivity Values for Selected Interflow Zones
Tested between October 1, 1980 and December 31, 1980.

Borehole number	Stratigraphic interval	Test interval (mBGS)	Transmissivity (m^2/d)
DC-6	Grande Ronde	688.5 - 881.5	$10^1 - 10^2$
DC-7	Grande Ronde	1,254.9 - 1,297.2	$10^{-4} - 10^{-3}$
DC-12	Grande Ronde	865.0 - 872.6	10^2
	Grande Ronde	892.5 - 907.7	
	Grande Ronde	907.7 - 961.2	$10^{-2} - 10^{-1}$
	Grande Ronde	934.8 - 961.2	$10^{-4} - 10^{-2}$
DC-14	Grande Ronde	809.9 - 876.0	$10^{-2} - 10^{-1}$
	Grande Ronde	841.2 - 876.0	$10^{-3} - 10^{-2}$
	Grande Ronde	877.8 - 906.8	$10^{-2} - 10^{-1}$
DC-15	Grande Ronde	639.8 - 670.0	$10^{-1} - 10^0$
	Grande Ronde	678.8 - 714.1	10^2
	Grande Ronde	723.0 - 758.0	$10^{-1} - 10^0$
	Grande Ronde	759.6 - 776.6	10^1

Vertical hydraulic head measurements within the Grande Ronde Basalt obtained from boreholes DC-12, -14, and -15 generally display a uniform pattern with depth, which is characteristic of an area of lateral groundwater movement. This is a continuation of the pattern which was determined for the overlying Wanapum Basalt at each of the sites. For example, Figure 6 shows the distribution of hydraulic head with depth at DC-15, which is located in the southeastern part of the Hanford Site adjacent to the Columbia River.

Vertical hydrochemical data obtained during this quarter indicate the presence of a significant hydrochemical break in the upper Grande Ronde Basalt at DC-14 and -15. Figure 7 shows the vertical hydrochemical pattern at DC-14. The sharp break in hydrochemical type in the upper Grande Ronde Basalt suggests a lack of hydraulic communication and mixing of groundwater across the Grande Ronde/Wanapum Basalt boundary. For boreholes within the Cold Creek structural area (e.g., DB-15 and DC-12), a similar hydrochemical break was evident between the Wanapum and Saddle Mountains Basalts.

FIGURE 5. Pasco Basin and Vicinity Boreholes.

RCP8103-17

FIGURE 6. Preliminary Hydraulic Head Measurements within the Saddle Mountains, Wanapum, and Grande Ronde Basalts at Borehole DC-15.

RCP8103-18

FIGURE 7. Preliminary Hydrochemical Data at Borehole DC-14.

DRILLING SUPPORT

Drilling accomplished during this quarter is shown in Table 2 (see Figure 5 for borehole locations).

TABLE 2. Status of Borehole Drilling--End
of First Quarter, Fiscal Year 1981

Borehole number	Actual depth (m)	Percent completion	Depth at completion (m)
DC-12	1,000	75	1,326
DC-14	958	70	1,371
DC-15	842	63	1,326

ENGINEERED BARRIERS

The objective of the Engineered Barriers end function is to specify the engineered and natural barriers that will ensure that nuclear and nonradioactive hazardous materials emplaced in a repository in basalt do not exceed acceptable rates of release to the biosphere. Key activities are the definition of repository conditions under planned operating and potential accident scenarios, review and development of information relevant to radionuclide transport, development and engineering of barrier materials and assemblages, and the acquisition of data necessary to define safe disposal of wastes in a repository in basalt. Program activities have concentrated on specifying and testing natural and man-made materials that can be used to plug boreholes in basalt and that can be used as multiple barriers to surround nuclear waste forms and containers.

The Engineered Barriers end function is divided into three major activities:

- Project Management
- Multiple Barrier Studies
- Borehole Plugging.

During the first quarter of fiscal year 1981, work has progressed in all three activities.

PROJECT MANAGEMENT

The project management activity is concerned with the management of the Engineered Barriers end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of the technical activities.

MULTIPLE BARRIER STUDIES

Emplacement of nuclear wastes in a deep geologic repository may cause both physical and chemical changes in the existing geologic environment. These changes may, in turn, promote detrimental reactions between engineered barrier components, repository host minerals, and the groundwater. Studies of potential interactions between candidate waste forms, canister, overpack, backfill materials, and the basalt in contact with groundwater have continued to meet the objective of designing and developing engineered barrier systems for emplacement in a repository located in basalt. These studies deal with potential chemical reactions both in the near-field zone (phase transformations, dissolution) and in the far-field zone (solution/precipitation).

Waste Form

The number and types of components required for the design of effective waste packages will be strongly dependent on the chemical and physical properties of the waste form. Consequently, an objective of this subactivity is to integrate currently available data on the properties of candidate waste forms and provide this data base to other Waste Package Studies activities. This integration of data will provide the basis for developing simulated waste forms for use in waste/barrier/rock interaction hydrothermal experiments. Nonradioactive materials, substituting stable isotopes of elements for the radioactive varieties present in actual waste, will be used to simulate the chemical properties of actual waste forms. Some radionuclides (plutonium, americium, technetium) have no stable isotope. Analogues for these elements will be substituted on the basis of their similar chemical properties (for example, rhenium for technetium, thorium and uranium for americium and plutonium). Using the composition shown in Table 3, 1 kg of simulated spent fuel is being prepared by the Hanford Engineering Development Laboratory. The first delivery of material is scheduled for January 31, 1981 and will provide required material for investigators at Temple University, who are conducting hydrothermal testing in support of the Basalt Waste Isolation Project's waste package development.

TABLE 3. Composition of Simulated Spent Fuel.

Compound	Weight (g/kg of fuel)
UO ₂	960.860
ThO ₂	9.520
Y ₂ O ₃	0.513
CeO ₂	2.585
Pr ₆ O ₁₁	1.197
Sm ₂ O ₃	6.551
ZrO ₂	2.965
Mo	1.473
MoO ₂	1.337
SrO	0.806
BaZrO ₃	3.076
Cs ₂ MoO ₄	2.088
CsI	0.488
Cs ₂ Te	1.568
Pd	3.674
Re	<u>1.299</u>
Sum	1,000.000

Hydrothermal Chemistry

The objective of the Basalt Waste Isolation Project's hydrothermal chemistry studies is to assess the performance of selected waste forms and candidate barrier materials under conditions appropriate to a repository constructed in basalt at the Hanford Site. Toward this end, qualitative screening tests began in 1977. These early tests were intended to give a preliminary assessment of waste form performance and to target areas for detailed, quantitative, hydrothermal experiments. This phase of the program has been completed.

In the advanced hydrothermal testing initiated this quarter, emphasis has been placed on accurate determination of steady-state solution composition. Data from these tests will provide the basis for detailed conceptual designs of engineered barrier waste packages. These experiments differ from the screening studies in that more sophisticated equipment and techniques are being used. The use of Dickson-type autoclaves allows on-line sampling of the test solution and thus minimizes the disturbance created by interrupting the test necessitated when using less-sophisticated equipment.

During this quarter, two sets of experiments have been completed. The first was the hydrothermal reaction of supercaline waste form (SPC-4) with a synthetic Hanford basalt groundwater. The second experiment measured the hydrothermal reaction of supercaline waste form (SPC-4) with a synthetic groundwater in the presence of Hanford basalt. Solution compositions were profiled for the duration of the experiments. These profiles are presented in Figures 8 and 9. Comparison of the figures indicates that the addition of basalt to the supercaline decreases the solution concentrations of sodium, rubidium, molybdenum, and chromium, while the concentration of silicon increases. The decrease in solution concentration of chromium, is the most dramatic and results from strong reaction with the basalt component.

In addition to profiling the solution compositions, the experiments identified solid alteration phases. The presence of euhedral crystals of pollucite ($\text{CsAlSi}_2\text{O}_6 \cdot n\text{H}_2\text{O}$) was observed (Figure 10) in the supercaline plus groundwater experiments. Ruthenium chloride (RuCl_3) has also been identified as a stable alteration phase in this experiment. When basalt is added as a component of the experimental system, the solid alteration phases include pollucite, as noted above, a rare earth element-zirconia phase, and a uranium silicate phase. Further study is under way to characterize these last two phases more precisely. The Geology Department of Temple University has been awarded a contract to conduct hydrothermal testing of the simulated spent fuel/basalt/groundwater system. In addition, techniques will be developed for more effective control and monitoring of the Eh and pH during experiments.

FIGURE 8. Selected Major Cation Concentration in Solutions Taken from SPCW 1-1 (SPC-4 + Groundwater) Plotted as a Function of Time. Uncertainty is approximately the size of the symbol.

FIGURE 9. Selected Major Cation Concentrations in Solutions Taken from BSPW 1-1 (Basalt + SPC-4 + Groundwater) Plotted as a Function of Time. Uncertainty is approximately the size of the symbol.

FIGURE 10. Cluster of Euhedral Pollucite Crystals from SPCW 1-1. Magnification is 4,800X.

To properly evaluate experimental data obtained with waste simulants, some tests using actual (radioactive) waste forms must be performed. Because tests with radioactive waste forms present both radiological and containment hazards, these experiments must be done at hot cell facilities. After evaluating several potential sites, the hot cell facility at Atomics International, Canoga Park, California was selected as the facility best able to provide support for the design and development of waste packages for emplacement in a repository on the Hanford Site.

Sorption Chemistry

The objective of the sorption chemistry studies is to obtain distribution coefficients for the key radionuclides under conditions which simulate those that exist in the groundwater flowpath to the biosphere from a repository constructed in basalt. The distribution coefficient (K_d) is defined as the ratio of the activity sorbed onto the solid

phase to the activity in the aqueous phase. These K_d s along with other relevant chemical and physical data, will be used to evaluate the ability of the geohydrologic system and the candidate engineered barriers materials to prevent the transport of radionuclides to the biosphere.

Radionuclide K_d s between representative Hanford Site geologic materials and synthetic, simulated, Hanford groundwaters have been determined using an equilibrium batch technique, as a function of solution composition, solid composition, radionuclide species, and Eh, pH, temperature, and pressure. The geologic materials include Umtanum, Flow E, and Pomona basalts, and a secondary mineralization from the Pomona basalt. The groundwater formulations used in the sorption experiments were presented previously (RHO-BWI-80-100 4Q).

The need for data on radionuclide sorption under the strongly reducing Eh and high pH conditions expected for a repository in basalt has prompted the investigation of several Eh-pH control systems. Repository conditions in basalt are expected to vary in pH from ~6 to 10 and in Eh from ~-0.5 V (10^{-68} atm O_2) to +0.5 V ($10^{-0.7}$ atm O_2). Ferrocyanide, quinhydrone, sodium sulfite, hydrazine, and sodium dithionite have been investigated as possible Eh-poising (buffering) agents for the basalt groundwater system. Experimental results indicate that hydrazine is the most promising Eh-poising agent for the basalt system. Preliminary experiments have shown that a 0.1M hydrazine solution can poise the basalt system at ~-0.44 V. In addition, the hydrazine appears to act as a pH buffer. The hydrazine buffers the basalt system at a pH of ~10. However, it is somewhat less efficient at buffering the secondary mineralization. This is probably due to the greater reactive surface area of the secondary mineralization. The results of the preliminary hydrazine-buffered, low-Eh-sorption experiments for plutonium are given in Table 4 for the basalts and secondary mineralization.

A comparison of plutonium K_d values determined under varying experimental conditions is presented in Table 5. Several general trends in plutonium sorption behavior are evident from these data. Plutonium K_d values decrease with increasing pH under oxidizing and slightly reducing conditions for the basalts. This is probably due to changes in plutonium speciation. At pH values >8 and in the presence of CO_3^{2-} , plutonium is probably present as the anionic $PuO_2CO_3OH^-$ species. Plutonium also can be present as negatively charged simple and polymeric hydroxides ($PuO_2OH_3^-$). At lower pH values, between 6 and 8, plutonium can be present as several different cationic and anionic species, depending upon solution composition; at pH values <6, plutonium is thought to be present as PuO_2^+ . Anionic species are not strongly sorbed by the basalts and, therefore, above pH 8, plutonium would not be expected to sorb strongly to the basalts.

TABLE 4. Low Eh ^{237}Pu Sorption Results. Solid to solution ratio was 1 g/10 ml at 23°C in a 0.1M hydrazine solution.

Media	Final pH	Final Eh (mV)	Corrected $K_d \pm 1\sigma$ (ml/g)	Average tubewall sorption (%)	C_I^a (moles/l)	C_f^b (moles/l)	x/m^c (moles/g)
14-d contact							
Solution only	10.30	-450	--	22.0	2.51×10^{-14}	--	--
Umtanum basalt	10.10	-440	39 ± 2	2.3	--	5.16×10^{-15}	1.99×10^{-16}
Flow E basalt	10.05	-440	34 ± 2	1.1	--	5.69×10^{-15}	1.94×10^{-16}
Pomona basalt	10.00	-430	41 ± 13	3.0	--	5.10×10^{-15}	2.00×10^{-16}
Fracture mineralization	8.75	-375	104 ± 19	1.7	--	2.75×10^{-15}	2.29×10^{-16}
28-d contact							
Solution only	10.20	-435	--	22.0	2.51×10^{-14}	--	--
Umtanum basalt	10.10	-430	42 ± 5	2.3	--	3.87×10^{-15}	1.59×10^{-16}
Flow E basalt	9.90	-440	37 ± 5	1.1	--	4.23×10^{-15}	1.57×10^{-16}
Pomona basalt	9.95	-440	47 ± 5	3.0	--	3.46×10^{-15}	1.62×10^{-16}
Fracture mineralization	8.85	-335	97 ± 25	1.7	--	1.06×10^{-15}	1.80×10^{-16}

aC_I = initial tracer concentration.

bC_f = final tracer concentration.

$^c x/m$ = plutonium loading onto the substrate.

TABLE 5. Comparison of Plutonium K_d Values.^a

Ground-water ^b	Temperature (°C)	Redox condition ^c	Initial tracer concentration (M)	K_d (ml/g)			
				Umtanum basalt	Flow E basalt	Pomona basalt	Secondary mineralization
#1, pH 8.0	25	0	10 ⁻¹¹	102 + 97 (7.4) ^d	165 + 16 (7.4)	267 + 18 (7.8)	2,572 + 341 (8.5)
#2, pH 10.0	25	0	10 ⁻¹⁴	20 + 3 (9.9)	--	--	1,706 + 671 (8.0)
#1, pH 8.0	25	SA	10 ⁻¹¹	5,190 ± 3,290	52 ± 14	71 ± 51	415 ± 178
#2, pH 10.0	25	SA	10 ⁻¹¹	5.6 ± 0.3	3.1 ± 1.1	5.7 ± 0.6	8,264 ± 12,166 ^e
0.1M hydrazine	25	A	10 ⁻¹⁴	42 + 5 (10)	37 + 5 (10)	47 + 5 (10)	97 + 25 (8.8)

^aAverage of observed values ± one standard deviation.^bGroundwater compositions are reported in RHO-BWI-80-100 4Q.^c0 = oxidizing (0.2 atm O₂).SA = slightly anoxic (7.9 × 10⁻⁷ atm O₂) (inert atmosphere glovebox).A = anoxic (10⁻⁶⁵ atm O₂) (hydrazine Eh-poising agent).^dNumbers in parentheses are the final pH values for the solutions.^eNearly complete removal of plutonium from solution.

There are no definite trends in plutonium sorption as a function of Eh. At a pH of 8, the plutonium K_d value appears to decrease slightly with decreasing Eh. This is inconsistent with thermodynamic considerations which predict that plutonium sorption should increase with decreasing system Eh due to the reduction of plutonium to the +4 or +3 state. No final solution pH values are available for the slightly anoxic plutonium K_d values. Theoretically, the pH of the solution should increase (assuming no available, solid, carbonate phases) when the carbonate equilibria shift due to removal of the system from atmospheric CO_2 contact and when the groundwater reacts with the basalt. If a significant pH shift occurs, plutonium could be stabilized as the $\text{PuO}_2\text{CO}_3\text{OH}^-$ complex, and a reduction in plutonium sorption would occur. The Eh conditions at 7.9×10^{-7} atm O_2 would not be sufficiently low to reduce the plutonium carbonate species. At a pH of 10, plutonium K_d values also appear to decrease with decreasing Eh for basalt. However, the decrease in K_d is slight and probably due to the difference in initial tracer concentration used in the experiments; K_d values often increase with decreasing radionuclide concentration. The K_d values for the secondary mineralization at a pH of 10 increase with decreasing Eh; however, the almost complete removal of plutonium in this experiment suggests that precipitation rather than sorption of plutonium is occurring.

The experiments conducted with hydrazine cannot be compared to the experiments using simulated groundwater due to solution composition effects (complexation, competing ion effects, etc.) on K_d values. However low-plutonium K_d values, even under highly reducing conditions and without the presence of interfering ligands, would suggest the presence of stable neutral or anionic Pu^{+4} and Pu^{+3} hydroxyoxides. Redox kinetics may also be a factor. Future sorption experiments will use a hydrazine-simulated groundwater solution so that K_d values may be determined with a more realistic solution composition.

Radionuclide K_d values have been shown to be sensitive to changes in the initial concentration of radionuclides present. The concentrations of the radionuclides in groundwater can be expected to vary with time because of changes in the thermal and physiochemical conditions in and near the repository. Experiments have been conducted to determine K_d values over a radionuclide concentration range determined by factors such as radionuclide solubility, specific activity, and the lower analytical detection limit. The results of the first of these experiments to determine the influence of the plutonium concentration on plutonium sorption are presented in Table 6. Over the small concentration range studied (due to high-specific activity of ^{237}Pu), there is no significant K_d dependence on plutonium concentration. The average plutonium K_d for Umtanum basalt at 23°C is 20 ± 3 mL/g. The plutonium K_d for secondary mineralization is about two orders of magnitude greater; the difference in K_d values is probably related to the greater surface area of the secondary mineralization, which is two orders of magnitude larger than the surface area of the basalt sample.

TABLE 6. Plutonium-237 Sorption Data from Groundwater #2 at a Contact Time of 60 d and a Solid Weight to Solution Volume of 1 g/10 mL. An average dissolved O₂ content of 8.3 mg/L at 23°C and 5.3 mg/L at 60°C was measured.

Solid	C _I ^a (moles/l)	C _f ^b (moles/l)	x/m ^c (moles/g)	Final pH	K _d ^d (ml/g)	Average K _d + 1σ (ml/g)
23°C						
Umtanum basalt	1.96 x 10 ⁻¹⁴	6.65 x 10 ⁻¹⁵	1.30 x 10 ⁻¹⁶	9.95	120	20 ± 3
	3.69 x 10 ⁻¹⁴	1.10 x 10 ⁻¹⁴	2.69 x 10 ⁻¹⁶	9.90	24	
	5.30 x 10 ⁻¹⁴	1.91 x 10 ⁻¹⁴	3.39 x 10 ⁻¹⁶	9.95	18	
	6.81 x 10 ⁻¹⁴	2.48 x 10 ⁻¹⁴	4.43 x 10 ⁻¹⁶	9.90	18	
Fracture mineralization	1.96 x 10 ⁻¹⁴	1.40 x 10 ⁻¹⁶	1.95 x 10 ⁻¹⁶	7.90	1,393	1,706 ± 671
	3.69 x 10 ⁻¹⁴	1.40 x 10 ⁻¹⁶	3.68 x 10 ⁻¹⁶	7.95	2,628	
	5.30 x 10 ⁻¹⁴	3.04 x 10 ⁻¹⁶	5.27 x 10 ⁻¹⁶	8.00	1,734	
	6.81 x 10 ⁻¹⁴	6.30 x 10 ⁻¹⁶	6.75 x 10 ⁻¹⁶	7.95	1,071	
60°C						
Umtanum basalt	1.96 x 10 ⁻¹⁴	6.93 x 10 ⁻¹⁵	1.26 x 10 ⁻¹⁶	9.25	18	24 ± 5
	3.96 x 10 ⁻¹⁴	9.02 x 10 ⁻¹⁵	2.79 x 10 ⁻¹⁶	9.27	31	
	5.30 x 10 ⁻¹⁴	1.62 x 10 ⁻¹⁴	3.68 x 10 ⁻¹⁶	9.45	23	
	6.81 x 10 ⁻¹⁴	1.95 x 10 ⁻¹⁴	4.86 x 10 ⁻¹⁶	9.40	25	
Fracture mineralization	1.96 x 10 ⁻¹⁴	1.79 x 10 ⁻¹⁶	1.94 x 10 ⁻¹⁶	8.15	1,084	964 ± 198
	3.69 x 10 ⁻¹⁴	4.41 x 10 ⁻¹⁶	3.65 x 10 ⁻¹⁶	8.15	828	
	5.30 x 10 ⁻¹⁴	4.47 x 10 ⁻¹⁶	5.26 x 10 ⁻¹⁶	8.10	1,177	
	6.81 x 10 ⁻¹⁴	8.78 x 10 ⁻¹⁶	6.72 x 10 ⁻¹⁶	8.20	765	

^aC_I = initial tracer concentration.

^bC_f = final tracer concentration.

^cx/m = plutonium loading onto the substrate.

^dCalculated by dividing x/m by C_f and multiplying by 10³.

The greater plutonium sorption onto the secondary mineralization may also result from the differences in final solution pH between the secondary mineralization and the Umtanum basalt. Carbonate and/or hydroxide could be complexing the plutonium and forming stable neutral or anionic species at the higher pH. As discussed previously, this would result in reduced plutonium sorption.

The effects of temperature and pressure on radionuclide sorption are also being investigated. Initial work on the temperature dependence of K_d for plutonium indicates there is no significant temperature dependence between 25°C and 60°C. This is shown in Table 6 and is consistent with previously reported results for plutonium and other nuclides. However, at higher temperatures and pressures (150°C, 6.89 MPa), the K_d for plutonium increases significantly (Table 7) for Umtanum and Flow E basalts. After 38 d, there was complete removal of plutonium from solution. The initial plutonium concentration is low enough to eliminate precipitation as a possible mechanism. It is possible that plutonium is being incorporated into newly formed secondary mineralization and/or that it is sorbing onto the higher surface area secondary minerals formed at higher temperatures.

In addition to the sorption experiments on the basalts and secondary mineralization, a second interbed reference material has been prepared for sorption studies. A sandstone from Sentinel Gap has been chosen as an interbed reference material. Preliminary kinetic sorption experiments are now in progress with the sandstone. The radionuclides americium, cesium, neptunium, radium, selenium, strontium, and tellurium are being studied to establish the time required for near equilibrium to be reached. This information will be used in the design of future sorption experiments with the sandstone.

Canister/Overpack Materials Evaluation

The objective of the canister/overpack materials evaluation task is to identify and characterize, by corrosion and mechanical property testing, materials that would be suitable candidates for long-lived engineered barrier system components for emplacement in a repository located in basalt.

The first in a series of corrosion screening tests of candidate canister and overpack materials has been completed. Specimens, both stressed and unstressed, were exposed for 60 d to simulated Grande Ronde groundwater at 250°C and a pH of 9.92 (measured at 25°C). The alloys represented by the test specimens are listed in Table 8. Anoxic conditions (10^{-50} atm O_2) were maintained by slowly purging the pressure vessels with an argon-0.19% hydrogen gas mixture. Periodic sampling of the cover gas during the test period confirmed that oxygen control was maintained.

TABLE 7. Plutonium K_d Values for Umtanum and Flow E Basalts at 6.9 MPa Ar and 150°C (basalt to groundwater ratio = 1 g/10 mL; initial plutonium concentration = $1.23 \times 10^{-14}M$).

Contact time (d)	Final pH measured at 23°C	Pu K_d (mL/g)	Contact time (d)	Final pH measured at 23°C	Pu K_d (mL/g)
Umtanum basalt			Flow E basalt		
1		26	1		4
4	7.55	22	4	7.60	7
8		61	8		6
11		66	11		30
15	7.60	70	15	7.60	34
18		72	18		109
23		89	23	7.95	113
31		119	31		189
38	7.75	292	38		Complete removal
45		Complete removal	45	8.55	Complete removal
52		Complete removal	52		Complete removal

TABLE 8. Test Specimen Alloys.

Vessel #1	Vessel #2
Inconel 600	Incoloy 800
Hastelloy G	Incoloy 825
Titanium, Gr. 2	Hastelloy G
Titanium, Gr. 12	Inconel 625
Ferrallium 25-5	Titanium, Gr. 2
Hastelloy C-276	Ferrallium 25-5
	90-10 Cupronickel
	Zircaloy-4

Samples of the test solution were taken after 1, 7, 14, 30, and 60 exposure days for analysis. Initial analytical results show that the original composition of the test solution remained reasonably constant during the test period. Post-exposure examination of the test specimens and analyses of the test solution samples for corrosion products were initiated.

BOREHOLE PLUGGING

The objective of the repository sealing activity (borehole plugging) is to develop seal systems for boreholes, shafts, and tunnels and for room backfill. Several types of seal materials, seal emplacement equipment and techniques, seal configurations, and seal testing instrumentation are undergoing study. An integrated series of field tests to support licensing of a repository in basalt is being planned.

The first of the planned field tests is the shallow borehole plugging test. As previously reported (RHO-BWI-80-100 4Q), a site adjacent to the Near-Surface Test Facility has been selected for this test. Five small-diameter (NX) core holes have been drilled to a depth of 46 m to characterize the candidate area. During this quarter, the characterization of the recovered core and logging of the core holes have been completed. Results indicate that several intervals are suitable for conducting the shallow borehole plugging test.

A study to evaluate the use of silica grouts in repository seals has been initiated. This study will evaluate the use of silica grouts as a binder for plugs composed of basalt aggregate and as a fracture-filling chemical grout.

Physical property testing of candidate seal materials continued during the quarter. Work elements completed were:

- Bentonite mixes-pumpability test marsh cone
- High-temperature grout mix/basalt bond tests
- Candidate earthen materials/basalt bore tests.

A study to determine the effects of host rock fracturing and its effect on seal performance has been initiated. A laboratory test to evaluate the effectiveness of grout in penetrating a fracture has been developed. Grout will be injected between two plastic plates held apart at a uniform distance by inert spacers to simulate two faces of a rock fracture. Separation distance and grout mixes will be varied so the penetration of specific grouts at varying separations may be observed.

NEAR-SURFACE TEST FACILITY

The Near-Surface Test Facility is a multipurpose test facility for in situ testing in basalt. The Phase I (electric heater) and Phase II (nuclear waste) tests to be conducted in the facility are designed to:

- Qualify basalt as a repository medium
- Provide the basis of design for key repository elements
- Demonstrate placement, storage, and retrieval of canisters containing radioactive material in an underground basalt environment.

The Near-Surface Test Facility is located on the west end of Gable Mountain on the Hanford Site. The facility consists of a computer room and ~1,000 m of underground workings, including access tunnels and test rooms. Work under Phase I developed the electric heater test portion of the facility so that testing will begin in fiscal year 1980. Work in preparation for Phase II testing is scheduled for completion in fiscal year 1982.

The Near-Surface Test Facility Design and Construction end function is divided into nine major activities:

- Project Management
- Design--Phase I
- Construction--Phase I
- Safety and Environmental Analysis--Phase I
- Decommissioning--Phase I
- Design--Phase II
- Construction--Phase II
- Safety and Environmental Analysis--Phase II
- Decommissioning--Phase II.

During the first quarter of fiscal year 1981, work progressed in Project Management, and in Phase I and Phase II construction.

PROJECT MANAGEMENT

The project management activity is concerned with the management of the Near-Surface Test Facility end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of the technical activities.

CONSTRUCTION--PHASE I AND PHASE II

Phase I construction was completed, except for several minor items. Redesign of the heating, ventilating, and air conditioning system for the uninterrupted power supply room is in process, since existing capacity is not adequate to maintain the required temperature.

The contract for the Phase II facility construction was awarded. The contractor started mobilization and layout work.

Grading for upgrade of the Gable Mountain road was completed. The remainder of the work will be done in the spring of 1981.

Drilling of the Phase II test and instrument holes was completed in November 1980.

The Phase II facility installation in the block test interface area will be completed in January 1981.

ENGINEERING TESTING

The objectives of the Engineering Testing end function are to design, procure, fabricate, and install equipment and instrumentation to obtain in situ test data during the Near-Surface Test Facility operations. Phase I tests consist of Full-Scale Heater Tests #1 and #2 and Jointed Block Tests #1 and #2. Phase II (nuclear waste) tests consist of Spent Fuel Tests #1 and #2 and a Vitrified Waste Form Test. The test data will be used to establish the engineering feasibility of constructing a repository in basalt and repository design. Rock testing and other miscellaneous special studies are also included as part of this program to assist in meeting the Near-Surface Test Facility objectives.

The Engineering Testing end function is divided into four major activities:

- Project Management
- Engineering Studies
- Phase I
- Phase II.

During the first quarter of fiscal year 1981, work has progressed in Project Management, and in Phase I and Phase II activities.

PROJECT MANAGEMENT

The project management activity is responsible for the management of the Engineering Testing end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program cost, and overall guidance of the technical activities.

PHASE I

The Phase I tests provide the design, procurement, fabrication, calibration, installation, checkout, operation, and analysis of heater test equipment in the Near-Surface Test Facility.

The Phase I tests are subdivided into the following subactivities:

- Heaters and Controllers
- Rock Instrumentation
- Data Acquisition System
- Site Characterization

- Test Engineering Support
- Equipment Installation
- Operation.

Work progressed in each of these subactivities, except equipment installation. Site characterization was completed and documented in "Near-Surface Test Facility Phase I Geologic Site Characterization Report" (RHO-BWI-ST-8). The equipment for the full-scale heater tests was installed in the third quarter of fiscal year 1980; the next planned equipment installation activity will be associated with the Jointed Block Test in the second quarter of fiscal year 1981.

Heaters and Controllers

Eighteen of the 29 heaters for Jointed Block Test #1 have been fabricated, assembled, tested, and staged at the Near-Surface Test Facility ready for installation. The 1.5-kW heaters are equipped with three E-type thermocouples located at the top, midplane, and bottom of the heated length. An additional 18 heaters (including seven spares) will be delivered to the Near-Surface Test Facility in the second quarter of fiscal year 1981.

Fabrication has started on seven (one spare) heater controllers for Jointed Block Test #1. Five heaters which are located within the block will each be controlled by one controller (units currently available at the Near-Surface Test Facility) to provide flexibility in controlling the block temperature. The 24 heaters located outside the block will be installed in groups of four to allow needed flexibility while minimizing cost.

Design activities for the heater controller cabinets were initiated, with completion scheduled for early in the second quarter of fiscal year 1981.

Rock Instrumentation

The rock instrumentation specification for Jointed Block Test #1 was prepared and requires the following:

- Four borehole deformation gauges
- Two hollow inclusion stress cells
- Two thermocouple assemblies consisting of five thermocouples per assembly.

Testing, quality assurance, and documentation requirements are similar to those specified for the full-scale heater tests. Design, fabrication, assembly, and testing is under way.

The eight flat jacks required for Jointed Block Test #1 (two per side) plus two spares are being fabricated. The 1-m by 2-m jacks are designed to exert a pressure of up to 20 MPa. The jacks are designed to fit into metal boxes which are grouted into the slots surrounding the block; this allows easy jack replacement if a failure occurs.

The hydraulic support system to control and maintain the flat jack pressure at the desired level is being fabricated. The design provides a packaged, modular system which contains all components in a single unit. The interface with the flat jacks will simply be the hydraulic lines themselves. Two different pressure levels will be possible (i.e., the two opposing sides of the block can be maintained at two different pressure levels), which allows greater flexibility in controlling test parameters.

Measuring overall block deformation presented a unique engineering problem: how to measure small deformations (as little as 1 μm) at temperatures as high as 200°C with little or no instrument drift over several months. The design approach uses an optical system which employs:

- Four boreholes near each corner of the block
- Active or passive targets in the boreholes located in the centerline plane of the flat jacks
- An optical bench located adjacent to the block, but beyond the area influenced by the heaters.

A performance specification has been prepared for the optical system, and detailed design will begin in the second quarter of fiscal year 1981.

Data Acquisition System

There are currently three different automated systems either being operated or developed to support the Near-Surface Test Facility. These are:

- Data acquisition system--The data acquisition system is a fully operational system which records and processes Near-Surface Test Facility test instrument responses and predicted data. The system has been operational for 6 mo and has functioned in a very reliable and stable manner.

The data acquisition system is depicted in Figure 11. Data loggers (block 1) receive analog signals from U.S. Bureau of Mines' gauges, extensometers, and thermocouples, and digital signals from IRAD gauges via a scanner (block 2). The sensor responses are read at 1/2-hr intervals and these data are written to magnetic tapes (block 3) and input through data transmission channels (block 4) to the computer (block 5). The computer processes the data to provide plots on the graphics terminals (block 6), data on magnetic tapes (block 7), and produces other hard-copy and video output (block 8).

The data acquisition system has been fully described in previous quarterly and annual reports. The system has been modified only slightly to correct errors and to accommodate changing user and test requirements.

- Data collection and retrieval system--The data collection and retrieval system is the set of computer software and hardware designed and configured to support Jointed Block Test #1. The existing data acquisition system which supports Full-Scale Heater Tests #1 and #2 cannot be used to support Jointed Block Test #1 because of these major differences in requirements:

- Variable scan/scan on demand
- On-line access to large numbers of scans
- Quick access to raw and converted data.

Major features of the data collection and retrieval system are:

- On-line, real-time data collection
- Relatively simple system
- Fast response
- Variable scan
- Digital data in sequential files
- Real-time conversion to engineering units
- Cathode-ray tube and/or hardcopy output
- Archived data.

To keep the system relatively simple, it will not contain predictive or smoothed data or provide graphic output. Other major design attributes include the capacity to be applied to more than one specific test. It is being written to accept any "N" occurrences of "J" types of instruments.

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FIGURE 11. Simplified Diagram of the Data Acquisition System.

- Tests automated support system--The tests automated support system is being considered as the final, follow-on system for Near-Surface Test Facility application. It is currently in the planning and preliminary design stage. This system would incorporate the best features of both data acquisition and data collection and retrieval systems, including:
 - Variable scan
 - Access to on-line raw data
 - Multiple algorithm options
 - Multiple initialization constants and values
 - Interactive graphics
 - Accept "N" frequency of "J" instrument types.

Site Characterization

Kaiser Engineers/Parsons Brinckerhoff, Oakland, California was contracted to review the series of reports dealing with the thermal and mechanical behavior of basalt. The objectives of this study were to consolidate pertinent basalt thermal/mechanical properties into a single reference document, to support the underground facilities design and to identify any limitations in the available laboratory data base which might indicate the need for additional laboratory investigations in support of the repository conceptual design effort.

Table 9 presents a summary of the findings of this analysis as reported in a document on the thermal and mechanical properties of Hanford basalts which will be released during the second quarter of fiscal year 1981. These results indicate that the bulk density of the Umtanum basalt is less than that of the Pomona basalt, which agrees with a lower measured uniaxial compressive strength and Young's modulus for Umtanum basalt. These values are subject to change as the data base is updated. Further data from tests being conducted by Foundation Sciences, Inc., Portland, Oregon will be incorporated in the data base in the near future.

Foundation Sciences, Inc. completed comparative triaxial confinement tests on Pomona and Umtanum core at elevated temperature and pressure conditions and are presently analyzing all data that have been accumulated to date. This includes data on cores from the entablature zone of the Umtanum basalt, as well as from the time-scale test area. The conflicting porosity test results reported earlier have been resolved and indicate that the variations are inherent to the basalt itself instead of to a sample-size phenomenon. A full analysis of all of the test areas will be completed in fiscal year 1981. Additional study is needed; however, it is felt that there is no significant programmatic impact at this time.

TABLE 9. Summary of Umtanum and Pomona Thermomechanical Properties as of November 1980.

Parameter	Umtanum	Pomona
Physical properties		
Grain density (g/cc)	(3.0)	3.0
Bulk density (g/cc)	2.78	2.85
Total porosity (%)	7.3	5.0
Apparent porosity (%)	(1.8)	1.1
Mechanical properties		
Unconfined compressive strength (MPa (ksi))	189 (27.5)	302 (43.7)
Triaxial friction angle (deg)	45	53
Joint friction angle (deg)	51	--
Tensile strength (MPa (ksi))	14.8 (2.15)	20.1 (2.91)
Modulus of rupture (MPa (ksi))	22.3 (3.24)	35.3 (5.12)
Young's modulus (MPa (ksi))	67,600 (9,800)	78,830 (11,430)
Poisson's ratio	0.25	0.25
Scleroscope hardness	70	(85)
Thermal properties		
Thermal expansion coefficient (microstrain/ $^{\circ}\text{C}$)	7.5	5.6
Specific heat (cal/g $^{\circ}\text{C}$)	0.22	0.22
Thermal conductivity (W/m $^{\circ}\text{C}$)	1.16	1.20
Thermal diffusivity (cm 2 /s)	0.0065	0.0065

NOTE: Values in parentheses are inferred or extrapolated. Data are representative of entablature and colonnade basalts only. The value for Pomona unconfined compressive strength is derived from intact and jointed samples; the intact samples yielded at 357 MPa (51.7 ksi).

Test Engineering Support

Data obtained from the full-scale heater tests were validated and verified in accordance with the data verification plan. Data validation and verification continued on a daily basis to ensure that data used for test analysis were representative of actual rock response.

The data validation confirms proper instrument function, and data verification ensures that converted data are representative of actual rock response. When rock mass material properties were required for data conversion, data verification was possible only when valid in situ values were available.

The data validation and verification process included:

- Evaluation of raw and converted data
- Identification and explanation of anomalous data
- Instrument performance monitoring and troubleshooting
- Description of test conditions
- Compensation for instrument drift by recalibration and statistical techniques
- Algorithm and input parameter studies.

Visual inspections of the main heater borehole walls for Full-Scale Heater Tests #1 and #2 were conducted in October and November 1980. No visible changes of the wall surfaces were observed. The borescope was returned to the manufacturer for repairs, and no observations were made during December 1980.

The following rock instrumentation was used to monitor the rock response during the tests:

- Temperature --Thermocouples
- Stress --U.S. Bureau of Mines' borehole deformation gauges
 --IRAD vibrating wire stressmeters
- Displacement--Multiple-position borehole extensometer.

Thermocouple Performance Status. All full-scale heater test thermocouples performed satisfactorily during this report period, with the exception of one Full-Scale Heater Test #1 peripheral heater thermocouple as reported last quarter.

During this reporting period, several thermocouples exhibited erratic behavior due to the presence of water after the temperature reached 100°C. Figure 12 shows the effects of water on Full-Scale Heater Test #1 thermocouple 1T01T02 between October 2 and November 15, 1980; note the flat portion of the curve at 100°C. Figure 13 shows data fluctuations recorded by the same thermocouple over a 24-hr period. Steam decreased the temperature at the thermocouple for much of the 24 hr. If water had not been present, the temperature would have been ~120.5°C on this day.

FIGURE 12. Erratic Behavior of Thermocouple 1T01T02 Due to Presence of Water (between October 2 and November 15, 1980).

Temperature Data. Temperatures are plotted as a function of time in Figure 14 for peripheral heater thermocouples 1H02T01 and 1H07T01. The increase in slope on day 95 corresponds to the increase in heater power levels on September 29, 1980. The subsequent decrease in temperature resulted from water infiltration. A sharp increase in temperature occurred on day 117 and may be due to water migration away from Full-Scale Heater Tests #1 and #2 as a result of the water pumping program in the time-scale test area adjacent to the heater test area.

FIGURE 13. Example of Erratic Behavior of Thermocouple 1T01T02 Due to Water (over a 24-hr period).

FIGURE 14. Actual Temperatures Versus Time for Full-Scale Heater Test #1 Peripheral Heaters.

A submersible pump is being used to periodically dewater borehole 3H01 in the time-scale test area. This pumping program has decreased the water levels in all time-scale test area boreholes and instrument and heater boreholes for Full-Scale Heater Tests #1 and #2 (Figure 15).

For Full-Scale Heater Test #1, temperature versus depth in borehole 1T07 is plotted in Figure 16. Predicted data are compared with actual data for December 14, 1980. Actual data are $\sim 25^{\circ}\text{C}$ lower than predicted at the heater midplane. Deviations between actual and predicted may be due to heat conduction away from the rock at the tunnel floor and/or by the presence of water reducing the actual temperatures. A detailed quantitative analysis of the first 90 d of thermal data was initiated during this quarter and will provide the basis for assessing the ability to successfully predict the thermal response of the rock.

Temperature is shown as a function of radial distance from the Full-Scale Heater Test #2 main heater at a depth of 4.25 m (heater midplane) in Figure 17. Actual temperatures are lower than predicted near the heater and correspond to predicted at a distance of 4.5 to 5 m. Actual temperatures slightly exceeded predicted at 8.5 m from the heater. Again, differences between actual and predicted may be attributed to the difficulties in modeling temperature due to the rock/tunnel interface and the presence of water near the heater.

Performance Status of U.S. Bureau of Mines' Borehole Deformation Gauges. At this time, 75% of the U.S. Bureau of Mines' gauges in the full-scale heater tests are producing valid data from all three gauge axes (87% of the individual axes are producing valid data); 25% of the gauges have one or more axes malfunctioning. One Full-Scale Heater Test #1 gauge was replaced during the reporting period. Table 10 shows in detail the performance status of the U.S. Bureau of Mines' gauges as of December 31, 1980 for Full-Scale Heater Tests #1 and #2, and combined. Gauges are divided into four performance categories, and both numbers and percentages are given for gauges (all three axes) and individual sensors (axis).

Data presently classified as valid include: (1) "acceptable" performance data from gauges producing consistent data trends and (2) "suspect" performance data from gauges in which output has exceeded 1 mV/wk or in which a trend reversal has occurred. Gauges classified "suspect" are considered to be operating properly, but are flagged for close observation. Gauges giving invalid data include: (1) those possibly in need of replacement based on data output showing extreme variation indicative of failure, but within the operating range of the instrument (see Figure 18); and (2) gauges in need of replacement based on out-of-limits data.

U.S. Bureau of Mines' Gauge Data. Verified U.S. Bureau of Mines' gauge data are not yet available as problems still exist with the conversion algorithms. However, U.S. Bureau of Mines' gauge data show good correlation with increases in thermal loading.

FIGURE 15. Near-Surface Test Facility Dewatering History for Full-Scale Heater Tests #1 and #2 Instrument Boreholes.

FIGURE 16. Temperature Versus Depth for Full-Scale Heater Test #1 Vertical Borehole 1T07 at a Radial Distance of 0.56 m.

FIGURE 17. Midplane Plot for Full-Scale Heater Test #2.

FIGURE 18. Example of U.S. Bureau of Mines' Gauge Indicating Incipient Failure.

TABLE 10. U.S. Bureau of Mines' Gauge Performance Status (December 31, 1980).

		Full-Scale Heater Test #1				Full-Scale Heater Test #2				Combined			
		Number		Percent		Number		Percent		Number		Percent	
		Gauges	Sensors	Gauges	Sensors	Gauges	Sensors	Gauges	Sensors	Gauges	Sensors	Gauges	Sensors
Data status	Performance status	12	36	100		16	48	100		28	84	100	
Valid	Acceptable ^a	4	22	33	61	8	32	50	67	12	54	43	64
	Suspect ^b	6	12	50	33	3	7	90	15	9	19	32	23
Invalid	Possible replacement ^c	2	2	17	6	3	6	19	12	5	8	18	10
	Need replacement ^d	0		0		2	3	12	6	2	3	7	3

^aPerforming satisfactorily.^bLarge change in output (0.1 mV/wk) or trend reversal.^cExtreme variation indicative of failure (within operating range).^dOut of limits (impossible readings) (one Full-Scale Heater Test #1 and one Full-Scale Heater Test #2 gauge already replaced).

Performance Status, IRAD Vibrating Wire Stressmeters (IRAD Gauge).

Thirty-three percent of Full-Scale Heater Test #1 IRAD gauges and 55% of Full-Scale Heater Test #2 gauges are performing satisfactorily. One Full-Scale Heater Test #1 gauge was replaced during the reporting period, and a subsequent failure analysis showed the cause to be water vapor which produced corrosion within the instrument. Full-Scale Heater Test #2 gauges probably are more reliable because of additional modifications made at the factory.

Table 11 shows the performance status of the IRAD gauges for Full-Scale Heater Tests #1 and #2, and combined as of December 31, 1980. Gauges are divided into the following categories according to performance:

- Gauges yielding valid data are producing consistent data trends.
- Gauges are considered to be producing questionable data when a wide range of readings is obtained over a short time. However, suspect gauges may be producing valid data as illustrated in Figures 19 and 20. Figure 19 shows similar raw output trends from two Full-Scale Heater Test #1 gauges located in bore-hole 1C02 in close proximity and in the same orientation: 1C02C01 is a suspect gauge and 1C02C01A is producing valid data. For the same time period, the change in gauge wire stress for the same two gauges, plotted in Figure 20, indicates that good correlation exists until after day 150, when gauge 1C02C01 began malfunctioning.
- Gauges in need of replacement are producing no data at this time.

TABLE 11. IRAD Gauge Performance Status (December 31, 1980).

		Full-Scale Heater Test #1		Full-Scale Heater Test #2		Combined	
		Number	Percent	Number	Percent	Number	Percent
Data status	Performance status	18	100	22	100	40	100
Valid	Acceptable ^a	6	33	12	55	18	45
Questionable	Suspect ^b	1	6	5 ^c	23	6	15
Invalid	Need replacement ^d	11	61	5	23	16	40

^aperforming satisfactorily.

^bWide range.

^cThree gauges, possible scanner problems.

^dNo readings.

FIGURE 19. Two IRAD Gauges in Same Orientation and Close Proximity; Change in Raw Output.

FIGURE 20. Change in Gauge Wire Stress for Two IRAD Gauges in Same Orientation and Close Proximity.

IRAD Gauge Data. Verified IRAD gauge stress data are not available because of uncertainties in the conversion algorithms.

Performance Status, Multiple-Position Borehole Extensometer. At this time, all multiple-position borehole extensometer measuring sensors are operating satisfactorily; however, 25% of the multiple-position borehole extensometer anchors are no longer capable of maintaining pressure. Table 12 shows the number and percentages of anchor failures in Full-Scale Heater Tests #1 and #2, and combined.

TABLE 12. Extensometer Anchor Performance Status (December 31, 1980).

		Full-Scale Heater Test #1		Full-Scale Heater Test #2		Combined	
		Number	Percent	Number	Percent	Number	Percent
Data status	Performance status	75	100	99	100	174	100
Valid	Acceptable	48	64	83	84	131	75
	Incapable of maintaining pressure	27	36	16	16	43	25

An investigation to study the effect of reduced anchor pressure on data was conducted in November and December 1980. Anchor failure was found to correlate with pressure adjustments, and a decreased operating range was prescribed based on the results of this study. Preliminary findings suggest that, in general, the loss of anchor pressure does not adversely affect data. Figure 21 is a plot of raw voltage versus time for a multiple-position borehole extensometer; anchor failure occurred on day 106, and the data trend remained consistent.

Multiple-Position Borehole Extensometer Data. Extensometer anchor displacement versus time for Full-Scale Heater Test #1 anchor 1E01E02, located in a vertical borehole is shown in Figure 22. Relative displacements are negative, meaning the distance between the anchor and the extensometer head is increasing.

A maximum error band is plotted about the displacement curve. The changes in slope of the displacement trend correspond to increases in thermal loading at days 30 and 90.

FIGURE 21. Example of Extensometer Yielding Valid Data Despite Anchor Failure.

FIGURE 22. Actual Relative Vertical Displacement Versus Time for Full-Scale Heater Test #1 Extensometer 1E01E02.

Operation

Full-Scale Heater Tests #1 and #2 were operating as planned in accordance with approved test procedures. No power level changes were made during this quarter. The Full-Scale Heater Test #1 main heater is operating at 1.0 kW, with the eight peripheral heaters at 0.5 kW each. The Full-Scale Heater Test #2 main heater is operating at 3.0 kW. The next scheduled power change will occur on January 27, 1981, when the Full-Scale Heater Test #1 main heater power will be increased to 2.0 kW and peripheral heaters increased to 1.0 kW each. Also, on January 27, the Full-Scale Heater Test #2 main heater will be increased to 5.0 kW.

Some influx of water has occurred in the boreholes due to residual drilling water and from perched water in the interbed above the Pomona flow. Initially, some boreholes contained as much as 750 mℓ, but, by dewatering the boreholes, the water volume has been substantially reduced. Some boreholes produce 10 to 30 mℓ of water per week. Because the boreholes are routinely monitored and dewatered, the effect on overall test operations has been minimal.

Several extensometer anchors have failed to maintain hydraulic pressure. The extensometer rods are held in tension by springs in the instrumentation head. When the hydraulic pressure in the metal bladder which forms the anchor is reduced to zero, data could be suspect. A failure analysis revealed that no shift in the rod occurred upon loss of hydraulic pressure, and recorded data appeared consistent with predictive data. The thin metal in the anchor bladder has apparently molded itself tightly to the borehole wall. Since the basalt is in the heat-up/expansion phase, any slip in anchor position would be readily apparent. However, during a cool-down phase, the rock will be aiding the spring tension, and an anchor shift in position could occur more easily.

Two U.S. Bureau of Mines' gauges and several IRAD gauges have failed. An error analysis is in progress; results will be available in the second quarter of fiscal year 1981.

PHASE II

The Phase II test program consists of placing three nuclear waste canisters in the Near-Surface Test Facility to demonstrate placement and to compare the thermomechanical response data collected to the full-scale heater test data. The Phase II tests are divided into the same activities as listed under Phase I plus an additional subactivity: spent fuel preparation. Activity has occurred in each area except heaters and controllers (there are no plans to use heaters in the Phase II tests), test engineering support, and equipment installation.

Rock Instrumentation

The rock instrumentation specification for the Phase II tests was prepared; the requirements for each test are as follows:

- Six multiple-position borehole extensometer assemblies
- Three U.S. Bureau of Mines' borehole deformation gauge/vibrating wire stressmeter assemblies
- Three thermocouple assemblies (consists of five thermocouples per assembly)
- Three radiation monitoring assemblies.

Testing, quality assurance and documentation requirements are similar to those specified for the full-scale heater tests. Delivery will occur in the fourth quarter of fiscal year 1981.

Data Acquisition System

The software concepts to collect, process, and assess the Phase II data started this quarter. The approach and logic will be documented in the next quarter. The major elements of the system were described in the discussion of Phase I testing.

Site Characterization

Pretest geologic site characterization is required to provide details on the structural and physical composition of the rock mass before testing. Changes resulting from the testing can be identified and utilized as a basis for estimating changes that would occur at the site selected for a repository in basalt.

The characterization is being accomplished by detail line mapping, lithological and geomechanical core logging, borehole television logging, and borehole photography.

Detail line maps of the Spent Fuel Test area and lithologic logs of the core have been completed. Geomechanical logs, with detailed descriptions of each discrete joint, will be completed in mid-January 1981. A preliminary review of this data indicates that the spent fuel test holes begin in the entablature of the Pomona flow and end in the basal colonnade. The entablature and colonnade are chemically alike, but petrographic and jointing characteristics differ. This should not adversely affect the testing or thermomechanical modeling efforts.

The information obtained through this characterization will be presented in the Near-Surface Test Facility, Phase II Geologic Site Characterization Report.

Operation

Phase II operations personnel have started planning activities for loading nuclear waste canisters, including identifying trained work crews, outlining procedure requirements, and establishing interfaces and responsibilities with required support agencies.

Planning calls for having trained crews and operating procedures in place by November 1, 1981 to conduct dry runs with a shipping cask and a dummy canister. The dry runs will assist in preparing the Near-Surface Test Facility and staff for the safe conduct of actual canister loading.

Spent Fuel Preparation

The Office of Nuclear Waste Isolation has project responsibility for coordinating the packaging and shipping of the spent fuel and vitrified waste to the Near-Surface Test Facility. These activities include:

- Arranging for and acquiring the 5-yr-old spent fuel assembly from Lawrence Livermore Laboratory (Climax Test Facility) and the 2-yr-old spent fuel assembly from the Florida Power and Light Company.
- Arranging for shipping the spent fuel assemblies and vitrified waste in a licensed spent fuel shipping cask. Shipments to the Near-Surface Test Facility will be in a radiologically clean cask, while shipments to the Nevada Test Site will be in a used, or potentially contaminated, shipping cask.
- Providing the necessary data to the cask vendor for a shipping license modification. These modifications include shipping the vitrified waste to Nevada Test Site and shipping the packaged spent fuel and vitrified waste to Near-Surface Test Facility.
- Determining the heat output by calorimetry for both spent fuel assemblies, and for the vitrified waste, and physically characterize the spent fuel assemblies before packaging.
- Packaging the spent fuel assemblies and vitrified waste, and performing ultrasonic inspection of the canister closure weld at the Nevada Test Site facility.
- Providing Near-Surface Test Facility with practice equipment (shipping cask and dummy canister) for personnel training prior to receipt of the spent fuel and vitrified waste.

REPOSITORY STUDIES

The objective of Repository Studies is to design a repository in Columbia River basalt for the disposal of nuclear waste. A supporting goal is to design and construct an Exploratory Shaft Test Facility on the repository site for detailed site characterization.

The Repository Studies end function is divided into seven major activities:

- Project Management
- Engineering Support
- Repository Design
- Long-Lead Procurement Support
- Construction Manager Selection Support
- Construction
- Site-Specific Tests.

During the first quarter of fiscal year 1981, work has progressed in three of these activities: Project Management; Repository Design; and Site-Specific Tests.

PROJECT MANAGEMENT

The project management activity is responsible for the management of the Repository Studies end function; specifically in the preparation and control of schedules, preparation of budgets and work packages, control of program costs, and overall guidance of the technical activities.

A quarterly repository conceptual design review meeting was conducted with the U.S. Department of Energy, Office of Nuclear Waste Isolation, Rockwell Hanford Operations, and Kaiser Engineers/Parsons Brinckerhoff during October 1980.

REPOSITORY DESIGN

During this quarter, Kaiser Engineers/Parsons Brinckerhoff completed a study of several alternatives to the current design concept based on the receipt and storage of commercial spent fuel. The new study was conducted to evaluate the technical and economic impacts on repository conceptual design of the following waste receipt scenarios:

- Alternative 1: A repository which receives commercial spent fuel plus defense high-level waste.

- Alternative 2: A repository which receives commercial high-level waste plus defense high-level waste. Highlights of the study are summarized in the following sections.

Radioactive Waste Characteristics

Three types of radioactive wastes were considered in this study:

- Commercial spent fuel
- Commercial high-level waste
- Hanford defense high-level waste.

The nuclear waste repository in basalt is also being designed to receive and store $\sim 1,600$ drums (0.21 m^3)/yr of solidified, low-level, transuranic waste. It was assumed that the alternate repositories would receive the same quantity of low-level transuranic waste, and, therefore, the low-level transuranic waste was not considered further since the cost will be essentially the same for the nuclear waste repository in basalt and for Alternatives 1 and 2.

The spent fuel canister will contain disassembled spent fuel rods in bundles equivalent to either three pressurized water reactor or seven boiling water reactor fuel assemblies. The canister will be constructed of carbon steel nominally 30.5 cm ID and 2.47 to 4.57 m long overall. The repository design (i.e., package and tunnel spacing) was based on a decay heat rate of 1,740 W/canister, characteristic of 10-yr-old pressurized water reactor fuel. The design basis receipt rate is 1,750 canisters/yr, or a total of 35,000 canisters over the 20-yr campaign.

The Hanford defense high-level waste inventory figures used in this study were obtained from "Alternatives for Long-Term Management of Defense High-Level Radioactive Waste" (ERDA 77-44). There are two types of defense high-level waste canisters: one having low- and the other having high-heating rates. This represents a conservative approach, since boiling water reactor canisters emit only 1.3 kW. The low-heating-rate canister contains waste immobilized in a monolithic, borosilicate glass cast in a carbon steel canister nominally 30.5 cm ID and 3.66 m long overall. If all Hanford high-level waste is assumed to be designated for disposal in the repository, a total of 66,130 canisters of low-heat glass waste will be processed. Each carbon steel canister will contain $\sim 0.20 \text{ m}^3$ of glass product and have a heat generation rate of 7 W. The high-heating-rate canister contains in-can-melted vitrified waste assumed to have been converted from encapsulated SrF_2 and CsCl (strontium and cesium glass canisters). A total of 329 canisters of glass waste will be stored. Each canister (stainless steel) contains an average of 480 kCi of ^{90}Sr and ^{137}Cs and has an average heat generation rate of 2,700 W.

The commercial high-level waste will be monolithic, borosilicate glass cast in nominally 30.5 cm ID and 3.66 m overall length carbon steel canisters. The annual number of commercial high-level waste canisters received will be 968, the reprocessed equivalent of the spent fuel currently planned for the nuclear waste repository in basalt (1,750 canisters/yr). A canister heating rate of as much as 3,800 W/canister can be achieved based on a specific volume of reprocessed waste of 0.06 m³/MTU for 10-yr-old spent fuel. However, a heating rate of 2,700 W/canister has been conservatively selected to limit the carbon steel canister temperature to <371°C with a basalt temperature rise of 236°C. The selected canister temperature limit precludes several degradation mechanisms identified for the canister and for CsCl. The 2,700-W/canister heating rate is identical to the defense high-level waste using glass from strontium and cesium capsules.

The quantities and physical characteristics of the three waste forms considered for storage are shown in Table 13. The data shown in Table 13 result from the following assumptions which formed the basis of the study:

- Commercial high-level waste to be stored in Alternative 2 was based on the same amount of heavy metal as for the spent fuel in the base case and Alternative 1.
- Commercial high-level waste canister temperature limit was assumed to be 371°C.
- Defense high-level waste volumes, ready for the repository, were estimated to be the minimum practicable by separation of the radionuclides from the inert chemical salts. Disposition of inert chemical salts is not included. Actual process development might increase or decrease these volumes.
- Defense and commercial high-level waste will be received over the same time span (20 yr) as currently planned for the nuclear waste repository in basalt, with the exception that the strontium and cesium glass canisters are received over the first 5 yr.
- Retrievability will be the same as used for the nuclear waste repository in basalt (25 yr).
- Commercial and defense high-level waste canisters will be overpacked and emplaced in the same waste packages and storage sleeve assemblies as employed for spent fuel canisters.

TABLE 13. Quantities and Physical Characteristics of Waste Forms.

Design Data	Spent Fuel	Defense High-Level Waste		Commercial High-Level Waste
		Glass with RRA ^a	Glass from Sr and Cs Capsules	
Canister material	Carbon steel	Carbon steel with insulation liner	Stainless steel	Carbon steel with insulation liner
Canister size	30.5 cm ID x 4.27 m and 4.57 m overall length	28.8 cm ID x 3.66 m overall length	30.5 cm ID x 3.66 m overall length	28.8 cm ID x 3.66 m overall length
Canister waste volume (m ³)	NA	0.20	0.21	0.20
Canister decay heat at receipt (W)	1,740	7	2,700	2,700
Number of canisters	35,000	66,130	329	19,360
Yearly canister receipt rate	1,750 (based on 20 yr of operation)	3,310 (based on 20 yr of operation)	66 (based on 5 yr of operation)	968 (based on 20 yr of operation)
Equivalent MTU/canister	1.38 (0.461 MTU x 3 PWRs)	NA	NA	2.5

^aRR = radionuclide removal is defined as removal and concentration of the radionuclides from the radioactive salts currently in the underground storage tanks at Hanford. Following the radionuclide removal process, the concentrated radionuclides are assumed to be incorporated into a monothitic borosilicate glass matrix.

Description of Repositories

Table 14 is a comparison of various characteristics of the nuclear waste repository in basalt and the alternative repositories. The significant differences are discussed in this section.

The Alternative 1 repository (spent fuel and defense high-level waste repository) would have the following storage and receipt rate capabilities:

- Storage capacity--35,000 canisters of spent fuel at 1,740 W/canister plus 66,130 canisters of glass-encapsulated defense high-level waste at 7 W/canister and 329 canisters of glass from strontium and cesium capsules at 2,700 W/canister.
- Receipt and emplacement rate--5,122 canisters/yr, which is 20.5 canisters/working day based on 20-yr campaign and 250 d/yr with the exception of only a 5-yr campaign for the strontium and cesium glass canisters.

Spent fuel canisters would be received in tiltable, rail-shipped casks, 7 canisters/cask, except for minor quantities to be received in smaller, truck-shipped casks as planned for the nuclear waste repository in basalt. Defense high-level waste canisters, since they are shorter, could be received in upright, railroad-car casks, 7 canisters/cask, or heavy, off-road trailer casks. The defense high-level waste shipments would originate on the Hanford Site, with sufficient casks provided to serve as mobile lag storage container so as to ensure a generally steady and reliable flow to the repository with some surge capacity.

The canisters would be overpacked within the nuclear waste repository in basalt shielded hot cell, which would contain multiple welding stations and other miscellaneous equipment, and delivered into the mine in a shielded transfer cask. The waste packages would then be emplaced in storage sleeve assembly units, previously installed in holes in the storage room floors, by means of shielded transport-emplacement vehicles called transporters.

Since the defense high-level waste canisters are 30.5 to 1.0 cm shorter than the spent fuel canisters, the storage rooms are of lesser height than for spent fuel. With the exception of the strontium and cesium glass canisters, the defense high-level waste canisters would require less shielding than spent fuel, so separate transfer casks and transporters could be considered. The strontium and cesium glass canisters could be transported safely in the spent fuel transfer cask.

TABLE 14. Summary of Repository Characteristics.

Characteristic	Nuclear waste repository in basalt	Alternative 1	Alternative 2
Spent fuel Number of canisters W/canister	35,000 1,740	35,000 1,740	NA NA
Commercial high-level waste Number of canisters W/canister	NA NA	NA NA	19,360 2,700
Defense high-level waste Number of canisters W/canister	NA NA	66,130 7	66,130 7
Sr and Cs glass canisters Number of canisters W/canister	NA NA	329 2,700	329 2,700
Canister throughput/d	7	20.5	17.4
Canister pitch (m) Spent fuel	3.66 (single row)	3.66 (single row)	NA
Commercial high-level waste	NA	NA	3.66 (single row)
Defense high-level waste	NA	2.44 (double row)	2.44 (double row)
Sr and Cs glass canisters	NA	3.66 (single row)	3.66 (single row)
Pillar width (m) Spent fuel	32.3	32.3	NA
Commercial high-level waste	NA	NA	52.43
Defense high-level waste	NA	11.58	11.35
Sr and Cs glass canisters	NA	52.43	52.43
Room dimensions (m) (height x width) Spent fuel	6.1 x 4.27	6.1 x 4.27	5.49 x 4.27
Commercial high-level waste	NA	NA	5.49 x 4.27
Defense high-level waste	NA	5.49 x 5.79	5.49 x 5.79
Sr and Cs glass canisters	NA	5.49 x 4.2	5.49 x 4.27
Mine areas (ha)	762.5	926.8	850
Basalt excavation (t/yr)	607,800	1,093,150	860,914

The shaft pillar and experimental chamber remain the same as the nuclear waste repository in basalt. The spent fuel panels are also the same in size and number as the nuclear waste repository in basalt, but they have been moved away from the shaft pillar to make room for the defense high-level waste panels. The defense high-level waste panels are placed adjacent to the shaft pillar to economize transport of excavated basalt, minimize the distance the waste canisters must be transported underground, and minimize ventilation power requirements. There are approximately twice as many defense high-level waste canisters as there are spent fuel canisters, and the defense high-level waste canisters (with exception of the strontium and cesium glass canisters) can be more closely packed than can the spent fuel canisters because of their lower decay heat rate. Since the defense high-level waste decay heat rate is negligible, the size of the pillar between storage rooms and the web between emplacement holes in the floor of the room need be sufficient only to maintain opening stability. For the purpose of this study, this is estimated to be as follows: rooms 5.5 m high by 5.8 m wide, with pillar width 11.6 m, and with a double row of emplacement holes in the floor spaced 2.44 m center-to-center both ways. The defense high-level waste transporter would straddle one row of holes at a time with the tires running on solid rock. An alternative scheme with a long trench replacing the individual floor holes for economy of space and construction may be attractive.

The storage sleeve assemblies would be pre-placed and bedded in the holes drilled in the floor, in advance of waste package emplacement. With the plugs in place, the area would be safe for transporter movement without risk of driving into a hole, and the plugs would preclude any slant-streaming of radiation from adjacent canister-filled holes into the room.

The strontium and cesium glass canisters would be emplaced in rooms with approximately 52.4 m pillar width, and with a single row of emplacement holes in the floor at a 3.66-m pitch. This is necessitated by the higher heat loading of these few canisters. Room size would be 6.1 m high by 4.27 m wide to utilize the spent-fuel transporter and its longer transfer cask.

The underground mine area is 926.8 ha, whereas the area for the nuclear waste repository in basalt is 762.5 ha. The basalt excavation rate would have to increase from 607,800 t/yr for the nuclear waste repository in basalt to 1,093,150 t/yr for Alternative 1. The hoists for the nuclear waste repository in basalt will be capable of handling the increased tonnage, so capital costs will not increase. However, operating costs will increase in direct proportion to tonnage handled. The ventilation system must be resized to handle the increase necessitated by the addition of more mining and storage hole drilling machinery and manpower for operations. The confinement side of the repository is not expected to increase in ventilation load due to the low heat output of the defense high-level waste. The increased amount of ventilation would require an increase in diameters of the service shaft and the basalt handling shaft.

The Alternative 2 repository (commercial and defense high-level waste repository) would have the following storage and receipt rate capabilities:

- Storage capacity--19,360 canisters of glass-encapsulated, commercial reprocessed, high-level waste at 2,700 W/canister plus 66,130 canisters of glass-encapsulated, defense, high-level waste at 7 W/canister and 329 canisters of glass from strontium and cesium capsules at 2,700 W/canister.
- Receipt and emplacement rate--4,340 canisters/yr, which is 17.4 canisters/working day based on 20-yr campaign and 250 d/yr (except a 5-yr campaign for the strontium and cesium capsule waste).

The commercial high-level waste canisters which are shorter could be shipped in upright shipping casks on or integral with special railroad cars, whereas the defense high-level waste cask transporters would probably be pneumatic-tire, off-road, trailer-type vehicles. The defense high-level waste shipments would originate on the Hanford Site, with sufficient casks provided to serve as mobile lag storage containers so as to ensure a generally steady and reliable flow to the repository with some surge capacity. All of the canisters would be 3.66 m long, with correspondingly shorter shipping casks. The canister would be overpacked within a shielded hot cell and would be delivered into the mine in a shielded transfer cask. The canisters would then be emplaced in engineered barrier units in holes in the storage room floors, by means of transporter-emplacement vehicles, which carry the shielded transfer casks.

A single design of subsurface transporter and transfer cask would be used for both the commercial high-level waste and the defense high-level waste, since the canister package sizes and room heights would be the same for both waste types. The shielding and thermal designs would accommodate the hotter, commercial high-level waste.

The storage rooms for the commercial high-level waste and also for the strontium and cesium glass canisters would be 5.49 m high by 4.27 m wide, with pillar net width about 52.4 m and with a single row of emplacement holes in the floor at a 3.66 m-pitch. The wide pillars are estimated to be required to keep rock stresses at depth within safe bounds with the relatively high decay heat from these canisters. This results in a repository loading of 53 kW/0.405 ha, which equals the nuclear waste repository in basalt loading. The two repositories, therefore, have comparable rock stresses. The storage rooms for the defense high-level waste, the emplacement holes in the floors, the waste packages, and storage sleeve assemblies would be as described for Alternative 1.

The overall area of the underground mine is 850.5 ha. The repository's yearly mined tonnage will total 861,000 t. This increased tonnage and the additional storage holes to be drilled will require an increase in ventilation on the mining side of the repository. The ventilation load for the confinement side of the repository is not expected to increase. As in Alternative 1, the increased ventilation will require an increase in the diameters of the service shaft and the basalt transport shaft.

Major changes to the nuclear waste repository in basalt for Alternatives 1 and 2 are summarized in Table 15.

Potential Investigations

During the preparation of this study, it was recognized that changes in certain bases could result in lower repository costs. The following discussion outlines five potential changes that could be the subject of future studies.

Alternative Defense High-Level Waste Emplacement. The heat produced by the low-decay-heat defense high-level waste canisters is so low (7 W/canister) that many could be placed immediately adjacent to each other without exceeding any temperature limitations. Placement in a long trench or vault excavated by explosive methods rather than in more expensive drilled holes would significantly reduce preparation cost, storage room length, and mine ventilation requirements.

Dilution of Commercial High-Level Waste. Due to the anticipated high cost of the canister/waste package/storage sleeve assembly system, it is estimated that repository costs will be at a minimum when the decay heat per canister is maximized. For this study, the commercial high-level waste canister decay heat loading was established at 2,700 W/canister to match the strontium and cesium glass canister heat rate and to avoid exceeding a 371°C temperature for the canister. The 371°C temperature limit appears to be too conservative. Additional studies should be performed to determine the feasibility of storing canisters generating up to ~3,800 W of decay heat, the estimated attainable, undiluted value for 10-yr-old waste, without exceeding reasonable canister, basalt, or glass media temperature limits.

Defense High-Level Waste Concentration Ratio. Further study of the feasibility and economics of various concentration ratios of radionuclide removal appears to be important to defense high-level waste studies. Lesser concentrations than assumed in this study could greatly increase the defense high-level waste repository costs, while greater concentration could affect large economies.

TABLE 15. Changes to Nuclear Waste Repository in Basalt for Alternatives 1 and 2.

Item	Base case--nuclear waste repository in basalt-spent fuel only	Spent fuel	Defense high-level waste	Increase over base case (%)	Commercial high-level waste	Defense high-level waste	Increase over base case (%)
		Alternative 1			Alternative 2		
Overpack weld test stations	2	2	3	150	2	3	150
Number of canister, waste package, storage sleeve assembly, storage hole (sets)	35,000	35,000	66,459	190	19,360	66,459	140
Basalt storage pile (m ³)	764,500	13,761,000			10,703,000		
Ventilation and mine cooling equipment (tons of refrigeration)	28,000	63,000			52,000		
Basalt excavation (t/yr)	607,800	1,093,150			860,914		
Diameter of basalt handling/service shafts (m)	4.27/4.88	5.8/6.71			5.49/6.4		
Number of underground waste transporters	2	2	2	100	1	2	50
Number of underground transfer casks	3	3	3	100	2	3	70
Electric power and distribution system (kVA)	25,000	35,000			32,000		

Engineered Barriers for Defense High-Level Waste. Defense high-level waste may warrant less costly engineered barriers than for spent fuel because it is encapsulated in glass, and the radionuclide quantities are lower by several orders of magnitude.

Commercial and Defense High-Level Waste Canister Length. A preliminary evaluation indicates that a 2.54-cm decrease in the canister length, and thus the storage room height, would save \$1 million in basalt excavation costs. Therefore, the canister length should be optimized, taking into account excavation costs and also waste package and storage sleeve assembly costs.

SITE-SPECIFIC TESTS

During the quarter, work on the Exploratory Shaft Test Facility was limited to preparation for the National Waste Terminal Storage Program workshop on exploratory shafts held in St. Louis, Missouri on December 16-17, 1980. Following the meeting, preparation of a final Exploratory Shaft Test Facility test plan for detailed site characterization was initiated. The test plan will be completed during the second quarter of fiscal year 1980.

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