Basalt Waste Isolation Project Quarterly Report

July 1, 1979

through

September 30, 1979

MASTER

R. A. Deju

**Director, Basalt Waste
Isolation Project**

October 1979

**Prepared for the United States
Department of Energy
Under Contract DE-AC06-77RL01030**

Rockwell International

**Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Rockwell International

**Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352**

NOTICE

This Report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their Employees, nor any of their Contractors, Subcontractors, or their Employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

BASALT WASTE ISOLATION PROJECT
QUARTERLY REPORT

JULY 1, 1979
THROUGH
SEPTEMBER 30, 1979

R. A. Deju
Director, Basalt Waste
Isolation Project

October 1979

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof nor any of their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Rockwell International
Rockwell Hanford Operations
Energy Systems Group
Richland, Washington 99352

DISTRIBUTION OF THIS DOCUMENT IS LIMITED

ABSTRACT

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

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

During the quarter, progress was made in all areas of the Basalt Waste Isolation Project. A summary of major accomplishments during the reporting period follows.

In the systems integration area, the technical requirements for a site suitability assessment of a potential nuclear waste repository in basalt were developed in preliminary form. The test program for the Near-Surface Test Facility was extensively reviewed and work was undertaken to revise the existing test plans. The test program was divided into two phases; qualification tests and demonstration tests. One candidate site of approximately 70 square miles was identified.

The Office of Licensing developed a detailed schedule to identify specific personnel who will be supporting the Site Characterization Report in fiscal year 1980.

In the geosciences group, integration of the results of geologic activities conducted through fiscal year 1979 by the Basalt Waste Isolation Project was completed. This integration effort was documented in a report entitled "Geologic Studies of the Columbia Plateau - A Status Report." The report included chapters on regional geology, Pasco Basin geology, and seismicity and tectonics. It also included plates that show surface geologic and photolineament analysis in the region, and surface geology, subsurface geology, and aeromagnetic survey results in the Pasco Basin. The emphasis of the report was on the basalt geology of the Pasco Basin, the main focus of geologic activities by the Basalt Waste Isolation Project to date. Seismic monitoring by the University of Washington continued during the fourth quarter with no unusual activity reported.

A report on the surface-water hydrology of the Washington State portion of the Columbia Plateau was completed during the quarter. The report provides an overview of regional surface conditions related to

site characterization. The initial finite element network for the Pasco Basin groundwater flow system was established for use in the Rockwell Hanford Finite Element computational model.

Science Applications, Inc., Albuquerque, New Mexico, conducted 23 water pressure measurement and 9 fluid injection-withdrawal tests within interflows of Grande Ronde Basalt in boreholes DC-2-A2, DC-6, and the dual borehole site DC-7/DC-8. Results are currently being evaluated.

Exploration Data Consultants, Inc., Denver, Colorado, conducted geophysical logging in borehole DC-4. The suite of logs run was: sonic; density; neutron; 3-arm caliper; induced polarization; and, magnetic susceptibility.

In the engineered barriers area, candidate borehole plugging materials were selected and are undergoing geochemical and physical testing. The testing program was designed to simulate the conditions in basalt in which a borehole plugging material might be expected to endure. Changes in thermal, hydrostatic pressure, and ion concentration gradients are being considered. Materials that are currently being tested in this effort include basalt, smectite clay (bentonite), Oregon clinoptilolite, portland cements, Hanford gravel, and sand and silt aggregate.

At the Near-Surface Test Facility, underground construction and core drilling is 100% complete. At the end of the quarter, facilities construction was 22% complete against a scheduled 26%. Final assembly and testing of all full-scale heaters was completed, followed by a simulation of an in situ heater installation. Coordination efforts continued for occupancy of the Near-Surface Test Facility Gable Mountain trailer village during the fourth quarter testing, and some support functions were scheduled to move to trailer village on October 26, 1979.

In engineering testing, the spent fuel canister preliminary design was completed. The preliminary design review of the canister was held on September 26, 1979 at Westinghouse-Advanced Energy Systems Division, the canister designer, in Pittsburgh, Pennsylvania. The review topics included canister design and weld development, weld inspection program, drop testing, seismic testing, and cask/canister thermal interference study.

The architect-engineer evaluation board completed the selection process directed to the award of a contract for architect-engineer services for repository conceptual design with an option for follow-on Title I (preliminary) design, Title II (detailed) design, and Title III engineering services. The architect-engineer contract was scheduled to be in place by October 31, 1979.

CONTENTS

Introduction	6
Systems Integration.	8
Project Management	8
Systems Integration.	8
Safety and Environmental Documentation	12
Geosciences.	13
Project Management	13
Geology.	13
Geophysics	16
Seismic Monitoring	16
Hydrology.	18
Project Management	18
Hydrology.	18
Testing Support.	22
Drilling Support	22
Engineered Barriers.	24
Project Management	24
Multiple Barrier Studies	24
Borehole Plugging.	26
Near-Surface Test Facility	28
Project Management	28
Design--Phase I.	29
Design--Phase II	29
Construction--Phase I and Phase II	29

Contents (continued)

Engineering Testing.	31
Project Management	31
Engineering Studies.	31
Phase I--Electric Heater Tests	32
Phase II--Nuclear Materials Tests.	38
Repository Studies	44
Project Management	44
Engineering Support.	44
Repository Design.	45
Documents Issued	46
Distribution	48

Figures

1. The Columbia Plateau	14
2. Basalt Waste Isolation Project Boreholes	23
3. Tentative Layout of Near-Surface Test Facility Tests	37
4. Plan of Jointed Block Test	39
5. Accelerated Room-Scale Tests	40
6. Spent Fuel Canister Assembly	42
7. Lifting Pintle Detail.	43

Tables

1. Current Computer Models--University of Minnesota and Dames & Moore.	11
---	----

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 terminal storage of commercial nuclear waste.

In September 1977, the National Waste Terminal Storage Program was restructured. While emphasis was still on a salt repository, 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. The investigations are presently aimed at assessing the feasibility of utilizing basalts as a possible rock type for nuclear waste storage. 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, Columbus, Ohio. As recently noted in a report by the Interagency Review Group (Report to the President by the Interagency Review Group on Nuclear Waste Management, October 1978, TID-28817 [Draft]), once feasibility is established at various sites, the U.S. Department of Energy will select a site for construction of a repository. The present basalt studies are not to imply that a commitment has been made to select a basalt site as a repository location.

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

- Systems Integration;
- Geosciences;
- Hydrology;
- Engineered Barriers;
- Near-Surface Test Facility;

- Engineering Testing; and,
- Repository Studies.

A summary of major accomplishments during the reporting period follows.

SYSTEMS INTEGRATION

The objective of systems integration is to integrate all activities leading to the identification, qualification, and licensing of a site and a repository for nuclear waste within Columbia River basalt. The scope of work includes reviewing of research, test, and design activities, providing computer models, trade studies, data analyses and interpretation, and establishing the technical basis and criteria for site selection, licensing, and the design of the repository and ancillary facilities and functions. The systems integration program is divided into three major activities:

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

During the fourth quarter of fiscal year 1979, work 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 Criteria

The technical requirements for a site suitability assessment of a potential nuclear waste repository in basalt were developed in preliminary form. Several drafts were prepared and coordinated with the U.S. Department of Energy, Office of Nuclear Waste Isolation, and other National Waste Terminal Storage Program participants before release for Basalt Waste Isolation Project planning purposes. The principal requirements were categorized by discipline and presented in the following categories: radiological; engineering; hydrologic; geochemical; geologic; and, socioeconomic.

Staff of the Basalt Waste Isolation Project participated in several meetings and reviews of preliminary and draft criteria prepared by the U.S. Nuclear Regulatory Commission, the U.S. Environmental Protection Agency, and the Office of Nuclear Waste Isolation. These included site selection criteria, systems performance criteria, package acceptance criteria, spent fuel pricing criteria, and others.

Preliminary studies were initiated to:

- Establish programmatic reference repository conditions;
- Develop subsurface seismic criteria;
- Estimate a repository size for disposal of Hanford defense wastes;
- Review preconceptual design concepts;
- Develop test requirements for spent fuel;
- Provide code control measures for mathematical modeling; and,
- Plan required system and trade-off studies.

Through studies contracted by Vitro Engineering Corporation, preliminary data on subsurface seismic response spectra were estimated. The estimate was developed using the FLUSH computer code. This study marked the beginning of a series of studies that will be necessary to develop subsurface seismic criteria for a nuclear waste repository in basalt at Hanford.

Systems and Test Analysis

The work on developing a potential test program for assessing underground conditions in a deep horizon selected as a repository site continued. The objectives of the test program would be to:

- Allow verification of actual geologic and hydrologic thermal properties at the horizon of the repository; and,
- Verify construction operations such as shaft sinking, grouting, tunnel boring, and roof support.

The test program for the Near-Surface Test Facility was extensively reviewed and work was undertaken to revise the existing test plans. The test program is divided into two phases; electric heater tests and nuclear materials tests. The qualification tests are to be conducted as Phase I of the facility and the demonstration tests as Phase II. The full-scale electric heater tests in the existing Phase I test plan are to be conducted as proposed. The time-scale test would be replaced by an accelerated room test. This will examine repository-level temperatures and stresses on a room scale. Heated block tests are also proposed for measurement of rock mass properties of the jointed blocks. These blocks would be approximately 2 meters square.

Site Identification

The goal of the siting study is to identify suitable repository sites within the Hanford Site. The last quarter's work relating to the identification of a repository site included the following:

- One candidate site of approximately 70 square miles was identified;
- Documentation of the status to date of all site identification activities was prepared and transmitted to the U.S. Department of Energy.

Engineering Model Development

This activity supports three areas within systems integration:

- Computer code development;
- Conceptual repository design; and,
- The Near-Surface Test Facility.

Work has been accomplished in the following specific areas.

- Code documentation--The documentation requirements for the codes being developed or modified for use by the subcontractors for Rockwell Hanford Operations were established. Final documentation will include magnetic tape copies of the source code and sample input, microfiche copies of listing output cards, etc., and manuals (the user's guide, the program analyst guide, and model validation verification report). A documentation schedule is to be developed during the course of future work and is not part of the current activity.
- Current computer models--A variety of computer models is presently available within the University of Minnesota and Dames & Moore systems for use on the Rockwell Hanford Operations' subcontract work. They are summarized in Table 1.
- Coupled fluid flow and thermomechanical analysis--The computer codes STEALTH and HOTDAM/CONDAM were modified to include fluid flow calculations and necessary constitutive equations for fully coupled analysis. Development, however, has not proceeded to a stage where fully coupled analysis of a repository may be performed. When completed, the capability will be available so that approximations associated with decoupled analysis may be fully assessed. It is necessary that the fluid flow calculations account for buoyancy forces by temperature gradients and that the relationship between permeability, stress, and temperature be taken into account.
- Preconceptual repository design--A preconceptual repository design was completed by the repository design group within Rockwell Hanford Operations and a modeling analysis conducted. This preconceptual design resulted in the selection of horizontal emplacement of canisters as opposed to vertical placement. Some of the preliminary results of this analysis are:

TABLE 1. Current Computer Models--
University of Minnesota and
Dames & Moore.

<u>Name</u>	<u>Classification</u>	<u>Capability</u>	<u>Application</u>
SYM3D (U of M)	Analytical	3D thermal & stress linear elastic homo- geneous	Parametric Studies Conceptual Design
HEFF (U of M)	Boundary Element & Analytical	2D thermal & stress linear elastic homo- geneous	Parametric Studies Room Scale Conceptual Design
BEH2D (D&M)	Boundary Element & Analytical	2D thermal & stress linear elastic homo- geneous & slip on joints	Parametric Studies Room Scale Conceptual Design
SALTY (U of M)	Boundary Element & Analytical	2D thermal & stress linear elastic homo- geneous & slip on joints	Parametric Studies Room-Repository Scale
DAMBIT (D&M)	Boundary Element	2D & 3D stress analysis	Design Room-Repository Scale
DIFFUS2 (U of M)	Finite Difference (Explicit)	1D thermal	Parametric Studies Repository Scale
HOTDAM (D&M)	Finite Difference (Explicit)	2D thermal & stress dynamic or static	Design Studies All Scales
CONDAM (D&M)	Finite Difference (Explicit)	2D fluid flow & stress dynamic or static	Design Studies All Scales
STEALTH (U of M)	Finite Difference (Explicit)	2D thermal, stress & fluid flow, dynamic or static	Design Studies All Scales
SNEAKY (U of M)	Finite Difference (Explicit)	1D thermal & stress dynamic or static	Parametric Studies Design Studies Canister Scale
FINEL (D&M)	Finite Element (Implicit)	2D & 3D thermal stress & joints	Design Studies Predictive Data
DAMSWEL (D&M)	Finite Element (Implicit)	2D thermal stress	Design Studies Predictive Data
GWTherm (D&M)	Finite Difference (ADI)	2D thermal, fluid flow & contaminant transport	Parametric Studies Regional Scale
DUST (D&M)	Discontinuum (Explicit)	2D thermal stress discontinuum	Design Studies Predictive Data
HIPPO (D&M)	Finite Element (Implicit)	2 & 3D single phase fluid flow, thermal & contaminant trans- port (2 phase in 2D)	Parametric Studies Regional Scale

On the canister scale, the circumferential stresses around canister boreholes are slightly higher for vertical holes (140 MPa compared to 120 MPa). In both cases, however, there exists only a slight change in stress from 5 years to 25 years.

Temperature analysis on a room scale for vertically and horizontally oriented canisters was undertaken. For the case of vertical emplacement in unventilated rooms, the rock wall (and/or backfill) temperatures were found to be 115°C, 130°C, and 160°C for 5, 10, and 25 years, respectively. These temperatures were higher, by approximately 30°C, than those for the horizontal canisters.

On the regional scale, a series of scoping studies which evaluated horizontal and vertical configurations indicated that both geometries produced much the same results.

SAFETY AND ENVIRONMENTAL DOCUMENTATION

The objective of this activity is to provide licensing documentation (Site Characterization Report, Environment Report, and License Application) for site selection and construction authorization of a repository.

The Office of Licensing has developed a detailed schedule to identify specific personnel who will be supporting the Site Characterization Report in fiscal year 1980. A request for proposal was prepared and sent out for the Cost/Benefit Analysis and support of Chapter 15 of the Environmental Report Section of the Site Characterization Report. Planning meetings with Pacific Northwest Laboratory and the Human Affairs Research Center were conducted to determine costs and schedules for Site Characterization Report support efforts. The fiscal year 1980 contract option with Los Alamos Technical Associates concerning the Long-Term Risk Assessment was executed.

An analysis of land use of the Columbia Plateau utilizing remote imagery techniques has been completed by Pacific Northwest Laboratory. These land-use patterns will be utilized in the Site Characterization Report.

GEOSCIENCES

The geosciences group conducts geologic and geophysical studies that gather basic data on local and regional geology which aid in the identification and selection of candidate repository sites. The studies emphasize reconnaissance field work in that portion of the Columbia Plateau underlain by Columbia River basalt and detailed field work within the Pasco Basin of the Columbia Plateau where the Hanford Site is located (Figure 1).

Geosciences is divided into four major activities:

- Project Management;
- Geology;
- Geophysics; and,
- Seismic Monitoring.

During the fourth quarter of fiscal year 1979, work progressed in all four 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 the results of geologic activities conducted through fiscal year 1979 by the Basalt Waste Isolation Project was completed. This integration effort was documented in a report entitled "Geologic Studies of the Columbia Plateau - A Status Report." The report included chapters on regional geology, Pasco Basin geology, and seismicity and tectonics. It also included plates that show surface geologic and photolineament analysis in the region, and surface geology, subsurface geology, and aeromagnetic survey results in the Pasco Basin. The emphasis of the report was on the basalt geology of the Pasco Basin, the main focus of geologic activities by the Basalt Waste Isolation Project to date. Preparation of the text and diagrams was the highest priority item of work within the geosciences group during this quarter. The report is in final editing prior to printing.

FIGURE 1. The Columbia Plateau.

Regional geologic mapping (scale: 1:250,000) is being conducted to develop an understanding of the stratigraphic, structural, and tectonic setting of the Columbia Plateau. Geologic maps of the Columbia River Basalt Group, Washington State (east of the Cascade Mountains, Figure 1), were finalized by personnel of the U.S. Geological Survey. Mapping of the Columbia River Basalt Group within Idaho is 75% complete; mapping of the basalt within Oregon is 60% complete.

In addition, geologic maps of the late Cenozoic sediments overlying the Columbia River Basalt Group in Washington State were finalized by personnel of the Washington State Department of Natural Resources. A companion report containing a discussion of stratigraphic and structural data presented on the maps was also completed.

Regional geologic mapping is being supported by remote sensing studies under way by Pacific Northwest Laboratory personnel. As part of the remote sensing effort, photolineament maps covering the Washington State portion of the Columbia Plateau were completed. Compilation of the photolineament maps was based primarily on an analysis of Landsat and U-2 photography. Photolineaments recorded on the maps are coded as to imagery association and as to interpreted origin (i.e., topographic, drainage alignments, tonal discontinuities, cultural features).

Preparation of a compilation geologic map of the Pasco Basin has been completed. This map will be available as a colored, 12-sheet set. Results from the surface geologic mapping and geophysical surveys (described below) were combined with drilling results to produce basin-wide subsurface contour maps and structure cross sections. In addition, thickness distribution maps were made of several basalt and interbed units that underlie the Pasco Basin. Comparatively detailed stratigraphic cross sections have been made through the Grande Ronde Basalt in the Pasco Basin subsurface based on correlations between deep boreholes. Correlations were made using chemical composition, paleomagnetism, and borehole geophysical logs. Several units heretofore unknown were identified and rock-stratigraphic interpretations based on these correlations were made. The surface and subsurface maps and sections are being used to assess the stratigraphic sequence and structural attitude of candidate repository host rock throughout the Hanford Site subsurface.

Surface outcrop studies and core hole studies of intraflow variation in Grande Ronde Basalt are continuing. These studies include examination of both fracture pattern variations, and chemical composition variations. Studies to date have concentrated on the Umtanum flow, a candidate repository host rock, to check its overall internal homogeneity beneath the Hanford Site. Results indicate the Umtanum flow averages about 200 feet total thickness across the central Pasco Basin beneath the southern Hanford Site. The flow top is typically a 25- to 50-foot thick rubble, but locally a flow-top breccia is developed and has a much greater thickness. The dense interior of the Umtanum flow is typically 150 to 175 feet thick, with the lower 10 to 68 feet consisting of

colonnade and the central 100 to 150 feet consisting of entablature. Tiered colonnade and entablature have been observed.

Results of stratigraphic analysis across a brecciated, slickensided, gouge zone in core hole DB-10, located in the central Hanford Site, revealed a zone containing 2 reverse faults with about 160 feet combined throw. This is the first unambiguous tectonic fault recognized as having been penetrated by drilling on the Hanford Site. Identification of the fault was confirmed by identifying repeated sections within the Saddle Mountains Basalt. The fault is tentatively interpreted as being the subsurface extension of nearby structure(s) mapped in the basalt bedrock exposed on Gable Mountain.

GEOPHYSICS

Investigations by the Basalt Waste Isolation Project geophysical staff were completed in one of seven sites currently being surveyed. The completed survey was across the Saddle Mountains syncline and successfully relocated a syncline axis and fault beneath sediment cover. The survey was designed as a test of various geophysical survey methods, singly and in combination. Geophysical survey work is continuing on the other six sites.

The final report and field data from the fiscal year 1979 reflection seismic surveys were received in July from the subcontractor. Interpretation and checking of seismic data are under way. This work includes correlation of seismic data with geologic data, and some mapping of horizons based on check shot surveys, geophysical well log data, and synthetic seismograms.

Magnetotelluric survey data collected during fiscal year 1979 were interpreted. Results indicate the same five geoelectric units beneath the Pasco Basin that were discovered by the fiscal year 1978 magnetotelluric survey. Contour maps and isopach maps were drawn using depth and thicknesses of geoelectric units measured at each sounding station. Results suggested northeast-trending structures and crustal thinning beneath the Pasco Basin.

Aeromagnetic survey results were analyzed. These include total field maps, associated maps, and a final report including interpretation. The aeromagnetic results were interpreted by utilizing known geologic conditions in the Pasco Basin. Results of this interpretation were then used to help describe the bedrock structure of the sediment-covered central Pasco Basin. The aeromagnetic survey continues to prove a valuable aid for locating buried structures.

SEISMIC MONITORING

Seismic monitoring by the University of Washington continued during the fourth quarter with no unusual activity reported. The annual

technical report for 1979 was received and reviewed in August. The annual review meeting with Hanford contractors was held in August during which comments regarding the annual technical report and thoughts and suggestions for the University of Washington proposal for fiscal year 1980 were discussed. Eastern Washington earthquake monitoring will continue during fiscal year 1980.

Draft and final reports for the baseline seismic monitoring plan development were received from Woodward-Clyde Consultants. The generic plan for seismic monitoring entails recording of events at the surface and down boreholes before, during, and after construction of potential repository facilities. This generic plan is now being modified specifically to suit the tentative candidate sites.

Downhole seismic monitoring in borehole DC-3 is expected to resume shortly. A three-component geophone array will be placed at the bottom of borehole DC-3 by the University of Washington. Data from this instrument array will be recorded locally on digital cassette tape, as well as telemetered to the university. This arrangement should circumvent a number of recording problems encountered in the earlier downhole array.

HYDROLOGY

The hydrology program provides hydrologic criteria and evaluation techniques by which potential repository sites can be identified and evaluated. Study of the groundwater regime underlying the Columbia Plateau is important, since the groundwater pathway probably affords the fastest avenue of contact between repository-stored wastes and the biosphere. Thus, hydrologic studies have emphasized the development of a large data base in order to characterize the groundwater system underlying the plateau, and modeling of the flow system needed to evaluate the potential for radiocontaminant 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 Pasco Basin contains the greatest accumulation of basalt rock found on the Columbia Plateau.

The hydrology program is divided into four major activities:

- Project Management;
- Hydrology;
- Testing Support; and,
- Drilling Support.

During the fourth quarter of fiscal year 1979, 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 the overall project guidance of technical activities.

HYDROLOGY

During this quarter, major emphasis was placed upon assimilating and evaluating hydrochemical data collected earlier in the year and comparing these results with those reported by other investigators. Data indicate that the groundwater within the Saddle Mountains and upper Wanapum Basalts beneath the Hanford Site is hydrochemically similar and is of a sodium-bicarbonate chemical type. Near areas of natural recharge, the predominant cation is calcium rather than sodium. Groundwater samples from the Grande Ronde Basalt are of a sodium-chloride, bicarbonate chemical type and thus chemically distinct from the shallower basalts. The Grande Ronde Basalt groundwaters also contain higher dissolved solids concentrations particularly chloride, sulfate, fluoride, sodium, and silica compared to groundwater in the Saddle Mountains and upper Wanapum Basalts.

These distinct differences in chemical types suggest a lack of hydraulic communication between aquifers in these formations.

Trace element concentrations are normally at or below detection limits. Those trace elements frequently detected in groundwaters from the Saddle Mountains and upper Wanapum Basalts are aluminum, barium, boron, iron, and strontium. Groundwaters from the Grande Ronde Basalt contain those listed above plus bromine and zinc.

A general potentiometric map was completed for the Saddle Mountains Basalt beneath the Pasco Basin. This map is included in the hydrology integration report to be issued in fiscal year 1980. In addition, a potentiometric map was completed for the Mabton interbed of the Saddle Mountains Basalt beneath the Hanford Site. The groundwater flow trends for the Mabton interbed suggest that natural recharge from infiltration of precipitation occurs in the basalt outcrops just west of the Hanford Site. The generalized flow direction is eastward and southward toward areas of discharge. The areal distribution of total dissolved solids, ^{18}O and ^{14}C data, also from the Mabton interbed, supports this trend.

A hydrologic reconnaissance of spring sites was completed in a 182-square mile area centered in the Rattlesnake Hills west of the Hanford Site. One hundred and twenty-five spring or suspected spring locations were identified and field analyses (temperature, specific conductance, pH, and alkalinity) were completed at 73 of these sites. Detailed laboratory analyses were later completed on waters from 23 of these spring sites. These analyses included major cation and anion, tritium, deuterium/hydrogen, and ^{18}O concentrations. Sketch maps and geologic cross section were also completed for each spring site.

Preliminary conclusions of this study were:

- Spring hydrochemical data suggest an overall uniform composition of a calcium-bicarbonate chemical type. The waters possess low total dissolved solids and trace element concentrations that are low or below detection limits.
- Tritium, deuterium/hydrogen, and ^{18}O data suggest that the spring waters are of recent, meteoric origin with no major mixing with groundwater of different origins.
- Springs occur throughout the basalt sequence exposed in the Rattlesnake Hills. They issue from the basalt whenever a local decrease in the hydraulic conductivity of the rock forces water to the surface.

A report on the surface-water hydrology of the Washington State portion of the Columbia Plateau was completed during the quarter. The report provides an overview of regional surface conditions related to site characterization. Information presented included:

- Description of the Columbia Plateau and the surface hydrologic conditions of its six component basins;

- Preliminary surface-water budgets estimating surface-water/ground-water transfer between basins and surface-water/groundwater interaction within each basin; and,
- Analysis of flood potential within the Pasco Basin.

On the last item, it was concluded that, even under major dam-failure scenarios, flood risks to a repository sited within the Hanford Site could be reduced to acceptable levels by proper siting.

In support of the Pasco Basin hydrologic studies, the following data were obtained:

- Mr. R. E. Brown, consultant from Pasco, Washington, submitted geologic and hydrologic maps for the Cenozoic sediments of the unconfined aquifer across the eastern and southern portions of the Pasco Basin outside of the Hanford Site. These included maps of the local water table and transmissivity distribution for the unconfined aquifer (based upon specific capacity tests) as well as isopach and structural contour maps for individual units within the Hanford and Ringold Formations. Approximately 600 new well completion records were also supplied. These were added to the hydrologic data base of the Basalt Waste Isolation Project.

Other work completed which also expanded the data base locally within the Pasco Basin and regionally within the Columbia Plateau included:

- Pacific Northwest Laboratory, Richland, Washington, submittal of color composite 1975 Landsat scenes collectively showing the Washington State portion of the Columbia Plateau and an overlay locating irrigation wells within Benton and Franklin Counties. These data are for evaluating land classifications, irrigation trends, and groundwater budgets.
- Washington State University, Pullman, Washington, transmitted data on township/range locations for much of the Columbia Plateau digitized in longitude-latitude format. These data are being used in automatic computer conversion of well locations from township/range/section to the Lambert Projection Planar Format required for hydrologic modeling.
- Regional groundwater contour maps of the Columbia Basin (Big Bend) area were obtained from the U.S. Bureau of Reclamation, Ephrata, Washington. These maps have potential use in evaluating flow system dynamics in the areas specified.

Numerical modeling studies completed during this quarter included the following:

- Computer simulations of waste migration from a hypothetical repository in basalt were performed using the Sandia Waste Isolation Flow and Transport (SWIFT) code; this generalized code was originally developed for the U.S. Nuclear Regulatory Commission by Intera

Environmental Consultants. The hypothetical repository site was characterized using hydrologic data previously reported by the U.S. Geological Survey for the Columbia River basalts. The spent fuel inventory for the entire United States projected to the year 2000 was assumed. Various other conservative assumptions were made. Simulations for a 150,000-year period showed that contaminant plumes for long-lived fission (^{99}Tc , ^{129}I) and activation products (^{14}C) are contained within a relatively small zone around the repository. Nuclides reaching hypothetical aquifers were at levels significantly below maximum permissible concentrations.

- Baseline testing of computer simulation models was completed. Testing consisted of numerical experiments in which computer model simulations were compared against known solutions for flow and transport problems. Results of these tests will be incorporated in user manual documentation. The models tested were:

CHAINT--far-field model for decay chain transport;

PECTRA--near-field model for nuclide transport; and,

SWIFT--near-field model for flow, heat, and nuclide transport.

Numerical experiments for all three codes showed excellent agreement with the known mathematical solutions. With regard to the SWIFT computer code, however, routine applications to realistic problems are severely limited on the Boeing Computer Services Richland, Inc.'s Univac 1100/44 computer. Version I of the SWIFT code is memory limited on the Univac. Version II, which is multibanked, requires only half the memory requirements of Version I but requires nearly 5 times the execution time; as a result, this version is run time limited. Consequently, effective use of the SWIFT computer code will require access to a large mainframe computer such as a CRAY (or STAR) or a virtual memory computer such as a VAX 11/780. Similar computer resource problems are expected with other codes when applied to large-scale regions such as the Pasco Basin.

- A technical report was received from the consulting firm Resource Management Associates, Lafayette, California. The report describes the development of a specialized computer routine which computes fluid fluxes on a finite element network from hydraulic head distributions. This information is used as input to finite element transport models for nuclide migration calculations. The computer routine is interfaced with the Rockwell Hanford Finite Element, RHAFE, which generates head distributions in three dimensions for a confined or unconfined groundwater system. The technical report points out a key computational problem associated with sharp permeability contrasts, such as those that occur in the Columbia River basalts. Large changes in permeability (or hydraulic conductivity) between layers; i.e., columnar basalts and interflows, create extraordinarily large gradients. This results in a

requirement for a large number of finite elements at the layer interfaces to ensure proper flux calculations. This in turn can substantially increase the computer memory requirements for the computer simulations of groundwater flow.

- The initial finite element network for the Pasco Basin groundwater flow system was established for use in the Rockwell Hanford Finite Element computational model. A one-layer version of the model system was initially defined using actual well sites as model nodes where possible. This permits comparison of model input and results directly with field observations without the spatial interpolation usually required. Some runs were made with the one-layer model to debug the element network. A three-layer model to depict a multilayer basalt sequence as exists within the Columbia River basalts is currently under development.

TESTING SUPPORT

Science Applications, Inc., Albuquerque, New Mexico, conducted 23 water pressure measurement and 9 fluid injection-withdrawal tests within interflows of Grande Ronde Basalt in boreholes DC-2-A2, DC-6, and the dual borehole site DC-7/DC-8. Results are currently being evaluated.

Exploration Data Consultants, Inc., Denver, Colorado, conducted geophysical logging in borehole DC-4. The suite of logs run was: sonic; density; neutron; 3-arm caliper; induced polarization; and, magnetic susceptibility.

DRILLING SUPPORT

Drilling support provides the boreholes necessary to investigate the subsurface geologic, hydrologic, and engineering properties of the Columbia River basalts.

Drilling accomplished during this quarter was as follows (Figure 2):

- The entrance hole for borehole DC-15 was completed at a total depth of 207 feet;
- The entrance hole for borehole DC-14 was completed at a total depth of 370 feet;
- The entrance hole for borehole DH-18 was completed at a total depth of 112 feet; and,
- Borehole DB-15 reached a depth of 1,343 feet, which is 69% complete based upon a total depth of 1,950 feet.

FIGURE 2. Basalt Waste Isolation Project Boreholes.

ENGINEERED BARRIERS

The primary goal of the engineered barriers program is to specify a set of multiple barriers--engineered and natural--that will ensure that nuclear 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, and the development of data necessary to define safe disposal of wastes in a repository in basalt. Activities in the program concentrated on specifying and testing natural and man-made materials which can be used to plug boreholes in basalt and which can be used as multiple barriers to surround nuclear waste forms and containers.

The engineered barriers program is divided into three major activities:

- Project Management;
- Multiple Barrier Studies; and,
- Borehole Plugging.

During the fourth quarter of fiscal year 1979, 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

The emplacement of nuclear wastes in a deep geologic repository may cause both physical and chemical changes to the existing geologic environment. This activity attempted to identify the chemical and physical stability of the proposed barriers to the transport of radioactive contaminants. The activity examined the need for five potential barriers: the waste form; the rock; the container; the overpack; and, the backfill. To assess the effectiveness of such a multiple barrier system, the potential occurrence of chemical reactions both in the near field (phase transformations, dissolution) and in the far field (solution/precipitation and sorption/desorption) was examined.

Research aimed at understanding radionuclide sorption on basalt and basalt secondary minerals continued. Sorption experiments are being conducted on basalt samples from the Umtanum and Pomona flows and Flow E at 23°C, 60°C, 150°C, and 300°C in simulated Hanford groundwater

containing dissolved oxygen. In 107-day equilibrations, ^{137}Cs and ^{241}Am were the most strongly sorbed of the radionuclides tested. Both radionuclides appeared to be best sorbed by basalt of the Pomona flow. Plutonium also showed strong sorption on the basalts and exhibited K_d , the largest K_d (non-equilibrium radionuclide partition coefficient) values in equilibrations with basalt from the Umtanum flow. Strontium and radium were also well sorbed, but showed no distinct preferences for any of the flow types. Selenium, technetium, iodine, neptunium, and uranium were not strongly sorbed by basalt samples in general, although K_d' values of 12 ± 3 and 9 ± 1 milliliters per gram were observed for ^{99}Tc and ^{237}Np , respectively, on basalt from the Umtanum flow.

Additional experiments at 230°C with different solid to liquid ratios (1 gram/80 milliliters as opposed to 1 gram/10 milliliters) were conducted at several radionuclide concentrations. The results of these experiments suggest that sorption of the radionuclides is dependent upon the initial solution concentration at levels lower than previously thought possible. Further investigation of this phenomenon is under way.

Sorption values obtained for cesium after 59 days of equilibration at 600°C tended to be lower than those observed in the 230°C experiments, while values for strontium, selenium, radium, and uranium were somewhat higher. Values of K_d' for the remainder of the radionuclides were the same as those observed at 230°C . Sorption experiments at 600°C were also initiated on representative secondary mineralization specimens obtained from a large vug in the Near-Surface Test Facility.

Preparation of a reference secondary mineral sample obtained from the Near-Surface Test Facility for experimental use was also completed in this quarter. The material was homogenized and freeze dried. Characterization of the sample by X-ray diffraction and electron microprobe revealed the mineralization to be a smectite clay.

Hydrothermal interactions of basalt with simulated waste forms in groundwater solutions similar to those found in Columbia River basalt continued. The formation of stable mineral-like phases containing fission product elements from reactions with basalt during the thermal period of the repository was found to greatly reduce the transport of radionuclides from a potentially breached canister to the biosphere.

In hydrothermal reactions between simulated spent fuel and ground water alone, 100% of the cesium and rubidium and up to 80% of the molybdenum present were taken into solution at 200°C and 300 bars pressure. Similar experiments with supercaline-ceramic indicated only a minor release of cations into solution. When basalt is added to similar experimental changes, the bulk of the elements normally solubilized react with the basalt to produce insoluble mineral-like phases.

In the absence of basalt, the appearance of cesium, rubidium, and molybdenum in solution from simulated spent fuel was shown to be strongly temperature dependent. The solubility of these elements at 200°C was an order of magnitude larger than that seen at 100°C . Lanthanum, neodymium, and zirconium were shown to be insoluble in these experiments.

Estimated chemical formulas for "average" Hanford clinoptilolites and smectite clays were calculated using data obtained from core samples. The free energies of formation of these phases were estimated for inclusion into the EQ3/6 mass transfer code data base. The average formula for Hanford clinoptilolite, based on 72 oxygens, is:

A free energy of formation of -8353 kcal/mole was estimated for this phase. The average formula for Hanford smectite is:

The smectite was estimated to have a free energy of formation of -1240 kcal/mole.

Computer simulations of Hanford groundwater genesis were conducted. These simulations produced an accurate reproduction of groundwater chemistry at depths of 300 to 500 meters. Concentrations of calcium, silicon, potassium, magnesium, and iron produced by the simulations were similar to those observed in actual groundwaters, although the sodium and inorganic carbon concentrations were lower. Deep groundwater compositions were best simulated when plagioclase dissolution was assumed to be dominant, although the carbon content of the simulated waters was also low compared to that seen in actual groundwaters.

The code simulations were usually able to depict the secondary mineral precipitation sequence observed in cores recovered from existing boreholes. A typical mineral sequence generated by the simulations was iron oxide, gibbsite, kaolinite, smectite (or β -cristobalite), clinoptilolite, and calcite. The simulations were generally unsuccessful in duplicating the relative amounts of secondary minerals precipitated. When spent fuel dissolution was simulated, the minerals uranophane $[\text{Ca}(\text{UO}_2)_2(\text{SiO}_3\text{OH})_2]$ and coffinite (USiO_4) were precipitated. No cesium minerals were formed in the simulation, which is contrary to behavior observed in actual hydrothermal experiments.

BOREHOLE PLUGGING

The objective of the borehole plugging activity was to devise a plugging system to seal boreholes, shafts, and tunnels leading from a nuclear waste repository in basalt. The plugging system being developed consists of material, machines, placement techniques, and instrumentation.

Candidate borehole plugging materials were selected and are undergoing geochemical and physical testing. The testing program was designed to simulate the conditions in basalt in which a borehole plugging material might be expected to endure. Changes in thermal, hydrostatic pressure, and ion concentration gradients are being considered. Materials that are currently being tested in this effort include basalt, smectite clay (bentonite), Oregon clinoptilolite, portland cements, Hanford gravel, and sand and silt aggregate.

Samples of individual components and several component mixtures are being reacted hydrothermally at 250°C and up to 300 bars pressure. These tests will last three months, after which the solid and liquid reaction products will be thoroughly characterized. Similar samples will be tested at 150°C.

The engineering properties (permeability and bond strength) of the candidate borehole plugging materials are being examined as a part of the physical testing program. Preliminary results indicate that the addition of 30% silica flour to portland cements roughly doubles their compressive strengths. Natural compositions such as local clays or bentonites mixed with local sands yield model plugs which have high densities (130 to 140 pounds per cubic foot). When these materials were compacted in a prepared basalt plug, the resulting bond strengths have been very high, approximately 15,000 pounds per square foot. Tests to determine the permeability of these materials are planned. Slurry injections of grout or bentonite into dry, compacted aggregate will be completed.

The performance of borehole plugging materials is dependent upon the plugging technique employed. Several preconceptual plugging schemes, some of which employ existing techniques and some which may require further research and development, were selected and are under evaluation.

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 (radioactive material) 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 spent fuel canisters in an underground basalt environment; and,
- Demonstrate spent fuel monitoring capability in an underground basalt environment.

The Near-Surface Test Facility is located on the west end of Gable Mountain on the Hanford Site near Richland, Washington. When completed, the facility will consist of approximately 3,300 feet of underground workings including access tunnels, test rooms, and a computer room. Phase I is to develop the electric heater test portion of the facility so that testing may begin in fiscal year 1980. Work on Phase II is scheduled for completion in fiscal year 1981.

The program 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; and,
- Decommissioning--Phase II.

During the fourth quarter of fiscal year 1979, work has progressed in five of these activities.

PROJECT MANAGEMENT

The project management activity is concerned with the management of the Near-Surface Test Facility design and construction 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.

DESIGN--PHASE I

The previously reported Phase I redesign effort to relocate the computer outside the tunnel was completed. Title III support continues for Construction--Phase I activities.

DESIGN--PHASE II

The Title II facility design was placed on hold during this quarter by the U.S. Department of Energy-Richland Operations Office. The Title II design for this effort is scheduled to start in the next quarter.

The Bottom Loading Transporter Title I design was completed in the prior quarter. The Bottom Loading Transporter Title II effort continued and is 68% complete. Completion of the Bottom Loading Transporter Title II design is scheduled for the second quarter of fiscal year 1980.

CONSTRUCTION--PHASE I AND PHASE II

Underground construction and core drilling at the Near-Surface Test Facility is 100% complete. At the end of the quarter, facilities construction was 22% complete against a scheduled 26%.

The following achievements have been made this quarter.

<u>Description</u>	<u>Status Date</u>
Completed 870 feet of 8-inch electrical power bore holes	September 7, 1979
Completed 5,900 feet of test hole core drilling	September 18, 1979
Operation trailer delivered and set in place Completed modifications to automatic sprinkler system and sewage holding	September 21, 1979
Completed tunnel excavation	September 28, 1979
Completed Tunnel #3 and inlet air house	September 28, 1979
Completed concrete and masonry work for Phase I standby generator building	September 28, 1979
Installed 10,000 feet of above-surface electrical conduit	September 28, 1979

During this quarter, the onsite general contractor concentrated their efforts on facilities outside the tunnels and mobilized their forces for underground facility work.

ENGINEERING TESTING

The objectives of the engineering testing program are to design, procure, fabricate, and install equipment and instrumentation to obtain in situ test data during the Near-Surface Test Facility operations. Test articles will include electric heaters and spent fuel. The test data will be used to establish 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 program is divided into four major activities:

- Project Management;
- Engineering Studies;
- Phase I--Electric Heater Tests; and,
- Phase II--Nuclear Materials Tests.

During the fourth quarter of fiscal year 1979, work has progressed in all four of the 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 costs, and overall guidance of the technical activities.

ENGINEERING STUDIES

Laboratory testing proceeded at Colorado School of Mines on cores from boreholes DC-8 and DC-4. Samples from both boreholes originated in the Umtanum flow at depths of approximately 3,570 to 3,665 feet for DC-8 and 3,600 to 3,800 feet for DC-4.

Testing consisted of uniaxial compressive strength, Brazilian tensile strength, triaxial compressive strength, modulus of rupture, static elastic properties, dynamic wave velocity, density, and porosity. The thermal properties testing and creep testing have yet to be completed. Significant trends have become apparent in the completed testing. DC-8 showed markedly lower strengths than either DC-6 or DC-4. Colorado School of Mines estimates the compressive strength of DC-6 core to be 25 to 70% higher than DC-8 core.

Density is usually considered a good indicator of physical properties, but, although densities for DC-8 core were comparable to the other two boreholes, the compressive strengths, Young's modulus, and

joint strengths were lower than those of core from DC-6 and DC-4. In all three series, confining pressure was found to significantly improve the compressive strength. DC-4 core showed a very uniform decrease in Young's modulus with increasing temperature.

Pacific Northwest Laboratory has also conducted thermal testing, thermal conductivity, and specific heat and heat capacity for input to determine thermal diffusivity. The work was not able to progress substantially due to electrical malfunctions with the equipment. One conductivity run for DB-5 was completed, however. The data showed trends in the reverse of that found by Colorado School of Mines and Lawrence Berkeley Laboratory in their 1978 testing. Mr. R. L. Erikson of Pacific Northwest Laboratory theorized on the reason for this trend. Crystalline substances usually have thermal conductivity decreasing with increasing temperatures. Amorphous substances and low-conductivity minerals such as plagioclase, however, have conductivity increasing with increasing temperatures. Bulk chemistry and mineralogy of this section of the Pomona flow indicate a relatively high plagioclase, tachylyte, and opal content which would account for this reverse trend.

PHASE I--ELECTRIC HEATER TESTS

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

These tests are subdivided into the following subactivities:

- Heaters and Controllers;
- Rock Instrumentation;
- Data Acquisition System;
- Site Characterization;
- Test Engineering Support;
- Installation; and,
- Operation.

Heaters and Controllers

Final assembly and testing of all full-scale heaters were completed, followed by a simulation of an in situ heater installation. A video tape of the installation simulation will be used for future training purposes prior to actual heater installation into the boreholes.

The design for a dewatering/desteaming system was initiated. This system will provide a method for removing water from the boreholes and accounting for any calories of heat used in converting the water to steam.

Acceptance tests were conducted on the remaining 5 main and 4 peripheral controllers for Full-Scale Heater Tests #1 and #2. The tests were run at anticipated power levels for in situ operation to check the operability of the controllers. All 9 main and peripheral controllers (includes spares) are now ready for final calibration and installation.

The fabrication and assembly of the calibration box and load bank needed to calibrate the controllers were completed. Also completed were the assembly and wiring of the racks to hold the controllers and modification of the controller voltage regulators to fit into the controller racks.

The 19 time-scaled heater test controllers were fabricated and delivered. These controllers will now be used for Block Test #1.

Rock Instrumentation

The design of the rock instrumentation for Full-Scale Heater Tests #1 and #2 was modified in the following areas to minimize corrosion, operating life, and long-term stability.

- Thermocouples--For corrosion protection, the exposed wires at the measuring junction of all extensometer thermocouples will be potted with epoxy and leak-tested to ensure a water-tight junction. Thermocouples for the U.S. Bureau of Mines' gages and the IRAD gages will be mechanically grounded directly to the U.S. Bureau of Mines' gage body and the IRAD gage platen by means of an electrical ring terminal which is crimped to the thermocouple-measuring junction and screwed to the gage. The measuring junction, terminal, and screw will be coated with silicone rubber to keep the junction moisture free.
- IRAD gage--The IRAD gage company has modified their manufacturing process of the epoxy plugs to provide additional heat curing, to improve the reaction with the Viton O-rings, and eliminate water leakage.
- U.S. Bureau of Mines' gage--To improve the long-term stability at high temperatures, the following revisions were made to the gage:

Ensure that the maximum strain anywhere in the transducer is less than $2,000\mu$ inch per inch;

Provide an undercut on the transducer beam threads (to the root diameter) and torque the retainer nut at high temperature (200°C);

Trim the strain gage using a razor blade rather than scissors to avoid cracking the gage substrate; and,

Cure the strain gages as follows:

Heat the gage at 163°C for 2 hours, clamped;

Heat the gage at 240°C for 2 hours, unclamped;

Cover the gage with a thin layer of Micro-measurements' 610 adhesive, then heat the transducer beam assembly from ambient temperature to 200°C, 3 cycles; and,

Strain cycle the borehole gage assembly at full-scale deflection, 3 cycles at 220°C.

Balance the bridges by making the connecting wires for each bridge arm equal lengths; and,

Check to ensure the electrical resistance between the strain gages and the gage body is greater than 50,000 megohms.

The following tests were completed during the quarter:

- Thermocouple calibration verification tests for Full-Scale Heater Tests #1 and #2;
- Thermocouple X-ray examination tests for Full-Scale Heater Tests #1 and #2;
- Extensometer anchor subsystem inertia tests;
- Extensometer rod expansion tests;
- IRAD gage preload wire tests at ambient temperature;
- IRAD gage elevated-temperature tests;
- IRAD gage long-term stability testing;
- IRAD gage submergence tests; and,
- IRAD gage calibration test.

The following assemblies were completed during the quarter:

- Thermocouple assemblies for Full-Scale Heater Test #1;
- IRAD gage assemblies; and,
- Extensometer assemblies.

Partial shipment of the Full-Scale Heater Test #1 rock instrumentation assemblies which include the thermocouple assemblies, extensometer assemblies, and IRAD gage assemblies was completed.

The four algorithm documents for the thermocouple IRAD gage, extensometer, and U.S. Bureau of Mines' gage were completed.

Data Acquisition System

The Data Acquisition System for the Near-Surface Test Facility is composed of equipment and computer programs. Technical accomplishments were achieved in the development of the computer programs (software) and in equipment fabrication.

Rockwell Hanford Operations completed functional specifications for major elements of the software for Full-Scale Heater Tests #1 and #2, which allowed the preliminary design of five major subsystems of the software and the coding of the top-level control modules for these subsystems.

As part of the the functional specification activity, Rockwell Hanford Operations and one of its subcontractors developed a description of the method of transmitting predicted for Full-Scale Heater Tests #1 and #2. A tape produced by the subcontractor will be tested for conformance early in the first quarter of fiscal year 1980.

The software for Full-Scale Heater Tests #1 and #2 is composed of 5 major subsystems. DATAC is the top-level control module for the subsystem that reads data from the dataloggers, validates it, and reports alarms which occur while the data are being read. UPDATE is the top-level control module for the subsystem which converts the datalogger data to engineering units, reads predicted data, and creates the tables of data that are needed for creating plots on the graphics terminals in the Data Acquisition System. IAS is the top-level control module for the subsystem that responds to commands from operators and test engineers to plot graphs, print reports, and read and write data tapes. PRDDTA is the top-level control module for the subsystem that reads the predicted data tapes that are produced by the subcontractor and processes them to extract daily values for comparison with the in situ instrument readings. FIVAC is the top-level control module for the subsystem that aids the rock instrument subcontractor during initial calibration of the instruments and during validation of the conversion algorithms. These top-level control modules were coded, tested, and then integrated with the control software that was supplied by the computer manufacturer.

To support the development of the software for Full-Scale Heater Tests #1 and #2, Rockwell Hanford Operations instituted a software development status monitoring system. At the completion of preliminary software design, Rockwell Hanford Operations had identified 66 software modules that corresponded to the functions to be performed by the Data Acquisition System. The general steps to complete each module are: detailed designing; coding and testing of individual modules; integrating the individual modules into its subsystems; testing subsystems; and, testing the subsystems after they are integrated into the system. The amount of effort and the elapsed time for each step for each module were estimated and a report was prepared to summarize the completion estimates. The report of task milestones is reviewed weekly to determine

if all milestones scheduled for the week were reached and to correct the problems that caused milestones to be missed. Experience shows that estimates after preliminary design have generally been correct.

The Data Acquisition System Interface Cabinet for Full-Scale Heater Test #1 was assembled and the wiring was verified by a point-to-point circuit check within the cabinet. It will be installed at the Near-Surface Test Facility when the instrument enclosure #1 has been constructed. The interface cabinet for Full-Scale Heater Test #2 is in assembly.

Site Characterization

Pre-test geologic site characterization is required to characterize the structural and physical composition of the rock mass before testing, so that changes resulting from the heating and testing can easily be identified and to allow comparison of the Near-Surface Test Facility geologic conditions that prevail at a site selected for a repository.

This characterization is accomplished by detailed geologic mapping, instrument borehole core logging, impression packer mapping of selected boreholes, and laboratory testing of the physical properties of the rock.

Completed geologic mapping consists of maps at a scale of 1:20 and detailed line maps. The 1:20-scale maps describe the rock mass mineralogy, fabric, and structure in detail. The detailed line maps are taken at frequent intervals and provide statistical data for analysis of local joint patterns, joint aperture, and infilling materials.

The instrument borehole coring program was completed and field copies of lithologic and structural core logs were prepared for these holes. Geomechanical logs, with detailed descriptions of each discrete fracture, were also prepared for the horizontal 3-inch holes. A computer program will be written to reduce these data and that from selected vertical holes.

Impression packer mapping, providing 360-degree borehole wall impressions, was completed and 26 holes, totaling 630 feet of cored impressions, were tested. The sleeves will retain the impressions for an indefinite time as well as used as baseline data for the post-test site characterization.

Test Engineering Support

During the last quarter of fiscal year 1979, the test plan for the Phase I tests was extensively revised. Full-Scale Heater Tests #1 and #2 remain unchanged. The Time-Scaled Test was replaced by the Accelerated Room-Scale Test. Two new tests, Block Tests #1 and #2, were added to the Phase I tests. Figure 3 shows the tentative location of these tests (Full-Scale Heater Tests #1 and #2, Accelerated Room-Scale Test, and Block Tests #1 and #2).

FIGURE 3. Tentative Layout of Near-Surface Test Facility Tests.

The block tests are identical except for their location. Block Test #1 is in the floor, while Block Test #2 is in the wall. The tests consist of linedrilling a 2-meter- by 2-meter- by 4.5-meter-deep block of basalt. The blocks are heated with 15 small, 1-kilowatt heaters, and confining stresses can be created with flatjacks inserted in the slots. Figure 4 shows a plan view of the block tests. The tests are designed to measure rock mass deformability, rock mass thermal expansion, and rock mass thermal conductivity as a function of temperature, stress, and rock quality.

The Accelerated Room-Scale Test is designed to simulate repository conditions at time periods of 25 to 50 years after 2 years of operation. To accomplish this, 60 heaters, at approximately 1-kilowatt output each, are located in the floor and walls of the test room as shown in Figure 5. The test area is isolated from the rest of the tunnel with insulated walls so that the room air temperature will approach 200°C. The test will provide data on stress and deformation on a room scale close to the strength limits of the rock mass as well as provide data on the impact of local variations in rock mass quality on thermomechanical response.

Operation

Coordination efforts continued for occupancy of the Near-Surface Test Facility Gable Mountain trailer village during this report period. Personnel from the Near-Surface Test Facility project office, engineering testing, and some support functions were scheduled to move to trailer village on October 26, 1979.

The operating plan for the Near-Surface Test Facility is ready for approval. Comments from a wide variety of organizations were reviewed and incorporated in the plan. Forty-eight standard operating procedures for monitoring the critical alarm function panel boards located in the operations trailer and the 100 Area Central Fire Station have been drafted, reviewed, and are being typed for approval. Two administrative-type standard operating procedures have also been drafted and are being typed for the review cycle. A schedule was prepared for the start and completion of seven types of standard operating procedures to be used for Near-Surface Test Facility operation.

PHASE II--NUCLEAR MATERIALS TESTS

Phase II (nuclear materials) tests will employ canistered spent fuel to evaluate emplacement of spent fuel and the thermomechanical response of basalt. These tests are subdivided into the same activities as listed in the Phase I tests plus the spent fuel preparation activity. Efforts for this quarter were directed at test engineering support and spent fuel preparation.

FIGURE 4. Plan of Jointed Block Test.

FIGURE 5. Accelerated Room-Scale Tests.

Test Engineering Support

During the fourth quarter of fiscal year 1979, the test plan that described the Phase II tests was extensively revised. Presently, two tests are defined as Phase II tests; Spent Fuel Test #1 and Spent Fuel Test #2. Spent Fuel Test #1 consists of one 5-year-old spent unprocessed fuel assembly. Spent Fuel Test #2 consists of a younger (tentatively 3-year-old) spent unprocessed fuel assembly.

Spent Fuel Preparation

The spent fuel canister preliminary design was completed. The preliminary design review of the canister was held on September 26, 1979 at Westinghouse-Advanced Energy Systems Division, the canister designer, in Pittsburgh, Pennsylvania. The review topics included canister design and weld development program, weld inspection program, drop testing, seismic testing, and cask/canister thermal interference study.

The present canister design/configuration using ellipsoidal end caps top and bottom meets the structural criteria imposed on the canister. The canister configuration (Figure 6) allows for the encapsulation of 1 pressurized water reactor fuel assembly and will have a nominal diameter of 12.75 inches and a maximum overall length not to exceed 178 inches, including pintle.

The welding technique for the seal weld of the upper closure lid was selected after evaluation of several concepts. The selected concept is the remote plasma arc welding process. Figure 7 shows a pintle/welder adapter ring that clamps to the canister pintle and will allow alignment of the plasma arc welding head. This step in encapsulation will take place remotely in the hot cell area of the Engine-Maintenance Assembly and Disassembly Facility located in Nevada. At present, inspection of the seal weld will consist of helium leak check and ultrasonic testing.

Drop testing of the present canister design was undertaken by Westinghouse-Advanced Energy Systems Division with good results. Preliminary drop test data indicated that the canister can withstand the 30-foot vertical drop test intact and maintain end cap mushrooming within allowable limits for insertion into the shipping cask.

A cask/canister thermal interference study was completed in September by Westinghouse-Advanced Energy Systems Division for the preliminary canister design. Heat loads up to 1.5 kilowatts from the spent fuel canister can be accommodated by the shipping cask during transit without thermal interference problems developing between the cask/canister side wall. In addition, work began on the seismic testing program for the spent fuel canister. Seismic testing at 0.7g for the Engine-Maintenance Assembly and Disassembly Facility storage configuration is scheduled for completion in the first quarter of fiscal year 1980.

FIGURE 6. Spent Fuel Canister Assembly.

FIGURE 7. Lifting Pintle Detail.

REPOSITORY STUDIES

The initial objective of the repository studies is to design a repository in basalt for the storage and eventual disposal of nuclear wastes and spent fuel.

The repository project is divided into seven major activities:

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

During the fourth quarter of fiscal year 1979, work was conducted on only the first three activities.

PROJECT MANAGEMENT

The project management activity is responsible for the management of the repository 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.

ENGINEERING SUPPORT

The architect-engineer evaluation board completed the selection process directed to the award of a contract for architect-engineer services for repository conceptual design with an option for follow-on Title I (preliminary) design, Title II (detailed) design, and Title III engineering services. The architect-engineer contract was scheduled to be in place by October 31, 1979.

Engineering support and contract management assistance was furnished to Systems Integration and Near-Surface Test Facility design groups in work performed by J. F. T. Agapito and Associates, Inc. Work continued on the functional design criteria document. Comments were received from the U.S. Department of Energy-Richland Operations Office and Rockwell Hanford Operations. These comments will be resolved and the functional design criteria document will be issued about October 31, 1979.

Vitro Engineering Corporation and J. F. T. Agapito and Associates, Inc. contracts were completed for preconceptual design activities. Comments on design documentation were furnished to both subcontractors for incorporation into final fiscal year reports and documents. Rockwell Hanford Operations also furnished engineering support to both subcontractors for fair cost estimate and architect-engineer proposal efforts.

REPOSITORY DESIGN

The preconceptual design effort was divided into seven tasks to control expenditures and contracts. These tasks for fiscal year 1979 were:

- Task I--Overall Repository Preconceptual Design (Rockwell Hanford Operations);
- Task II--Surface Facilities (Vitro Engineering Corporation);
- Task III--Shafts (J. F. T. Agapito and Associates, Inc.);
- Task IV--Subsurface Facilities (J. F. T. Agapito and Associates, Inc.);
- Task V--Waste Handling System (Vitro Engineering Corporation);
- Task VI--Surface Systems (Vitro Engineering Corporation); and,
- Task VII--Subsurface Systems (J. F. T. Agapito and Associates, Inc.).

During the report period, the technical studies for Tasks II through VII were completed. The design that has evolved includes the following significant features: five access shafts; a central shaft pillar area separated from the canister storage rooms by the low-level waste and experimental chambers; horizontal canister storage holes with each hole containing six canisters; and, early backfill of canister storage rooms.

The repository preconceptual design report will be written by Rockwell Hanford Operations, and it will be based on this design.

DOCUMENTS ISSUED

RHO-BWI-C-13 (unclassified), June 1978, Fenix & Scisson, Inc., Hole History, Core Hole DC-6, Hanford, Washington"

RHO-BWI-C-29 (unclassified), October 1978, Fenix & Scisson, Inc., "Hole History, Core Hole DC-8, Hanford, Washington"

RHO-BWI-C-32 (unclassified), October 1, 1978, M. P. Hardy, University of Minnesota, and G. Hocking, Dames & Moore, "Numerical Modeling of Rock Stresses within a Basaltic Nuclear Waste Repository - Final Report"

RHO-BWI-C-42 (unclassified), May 1979, D. R. Packer and J. M. Johnston, Woodward-Clyde Consultants, "A Preliminary Investigation of the Magnetostratigraphy of the Ringold Formation"

RHO-BWI-C-50 (unclassified), March 26, 1979, R. J. Miller and R. C. Bishop, Colorado School of Mines, "Determination of Basalt Physical and Thermal Properties at Varying Temperatures, Pressures, and Moisture Contents, First Progress Report, Fiscal Year 1979"

RHO-BWI-CD-2 REV 1 (unclassified), June 1979, Staff, Basalt Waste Isolation Program, and Vitro Engineering Corporation, "Nuclear Waste Repository in Basalt, Preconceptual Design Guidelines"

RHO-BWI-CD-3 REV 1 (unclassified), June 1979, C. D. Acree, M. P. Board, R. W. Carlson, N. C. Dresser, G. L. Huber, A. D. Krug, H. D. McDonald, B. K. Schroeder, D. R. St. Laurent, S. D. Sharpe, V. H. Stiessberger, "Engineering Study - Spent Fuel Test Facility"

RHO-BWI-CD-21 REV 2 (unclassified), April 1979, C. D. Acree, M. P. Board, G. L. Huber, A. D. Kurg, D. R. St. Laurent, B. K. Schroeder, S. D. Sharpe, V. H. Stiessberger, "Design Description - Near-Surface Test Facility"

RHO-BWI-CD-22 REV 1 (unclassified), November 10, 1978, J. F. Marron, "Preconceptual Design Management Plan, Basalt Waste Isolation Program, Basalt Repository"

RHO-BWI-CD-31 (unclassified), December 1978, K. R. Fecht, Editor, "The Hanford Site as it Relates to an Alternative Site for the Waste Isolation Pilot Plant: An Environmental Description"

RHO-BWI-SA-4-A (unclassified), June 1979, C. W. Myers, R. K. Ledgerwood, P. E. Long, S. P. Reidel, R. C. Edwards, "Stratigraphy of the Grande Ronde Basalt in the Pasco Basin, South-Central Washington USA," to be presented at the Geological Society of America Annual Meeting, San Diego, California, November 1979

RHO-BWI-SA-20 (unclassified), M. P. Hardy and C. M. St. John, University of Minnesota, and G. Hocking, Dames & Moore, "Numerical Modeling of the Geomechanical Response of a Rock Mass to a Radioactive Waste Repository"

Documents Issued (continued)

RHO-BWI-SA-21 (unclassified), June 1979, A. D. Krug, "Basalt Near-Surface Test Facility Test Plans," to be presented at the DOE/ONWI/LLL Workshop on Thermomechanical Modeling for a Hard Rock Waste Repository, Berkeley, California, June 25-27, 1979

RHO-BWI-SA-22 (unclassified), June 1979, University of Minnesota, "Radioactive Waste Disposal"

RHO-BWI-SA-23 (unclassified), July 1979, R. A. Deju, "Testimony Before the Subcommittee on Energy Research and Production, U.S. House of Representatives"

RHO-BWI-SA-24 (unclassified), Staff, "Brochure, Basalt Waste Isolation Program"

RHO-BWI-SA-25 (unclassified), August 1979, R. A. Deju, "Status Report on Studies to Assess the Feasibility of Storing Nuclear Waste in Columbia Plateau Basalts"

RHO-BWI-SA-26 (unclassified), October 1979, A. C. Waters, C. W. Myers, D. J. Brown, and R. K. Ledgerwood, "Basalt Stratigraphy - Pasco Basin"

RHO-BWI-SA-27-A (unclassified), August 31, 1979, I. Remson, Stanford University, and S. J. Dreiss, University of California at Santa Cruz, "Radioactive Waste Disposal - An Application of Predictive Geology"

RHO-BWI-SA-29-A (unclassified), September 1979, S. P. Reidel, R. K. Ledgerwood, C. W. Myers, M. G. Jones, and R. D. Landon, "Rate of Deformation in the Pasco Basin during the Miocene as Determined by Distribution of Columbia River Basalt Flows"

DISTRIBUTION

Number of
Copies

1	<u>J. F. T. AGAPITO AND ASSOCIATES</u>
1	<u>ARGONNE NATIONAL LABORATORY</u> A. M. Friedman
10	<u>BATTELLE-OFFICE OF NUCLEAR WASTE ISOLATION</u> J. M. Batch N. E. Carter R. E. Heineman M. Kahnemuyi J. Mountain Library (5)
2	<u>BECHTEL INCORPORATED</u> R. A. Langley, Jr.
1	<u>BROOKHAVEN NATIONAL LABORATORY</u> P. W. Levy
1	<u>BROWN UNIVERSITY</u> B. Giletti
2	<u>CALIFORNIA ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION</u> W. Irving E. Varanini
2	<u>CENTRAL WASHINGTON UNIVERSITY</u> Department of Geology Library
1	<u>CORNING GLASS WORKS</u> M. G. Britton
1	<u>DAMES & MOORE</u> G. Hocking

Number of
Copies

1	<u>DARTMOUTH COLLEGE</u> J. Lyons
2	<u>EASTERN WASHINGTON UNIVERSITY</u> Department of Geology Library
1	<u>ELECTRIC POWER RESEARCH INSTITUTE</u> Library
2	<u>FOUNDATION SCIENCES, INC.</u> D. J. Dodds Library
5	<u>GEOLOGY OVERVIEW COMMITTEE</u> T. Livingston I. Remson H. Ross D. A. Swanson W. S. Twenhofel
1	<u>HARVARD UNIVERSITY</u> R. Siever
7	<u>HYDROLOGY OVERVIEW COMMITTEE</u> P. Domenico W. W. Dudley, Jr. R. A. Freeze P. M. Grimstad S. P. Newman F. L. Parker J. Pearson
2	<u>IDAHO BUREAU OF MINES AND GEOLOGY</u> M. M. Miller Library

Number of
Copies

3	<u>KAISER ENGINEERS, INC.</u> A. L. Lindsay J. F. Munro J. S. Ritchie																		
1	<u>KANSAS STATE GEOLOGICAL SURVEY</u> W. W. Hambleton																		
2	<u>LAWRENCE BERKELEY LABORATORY</u> L. V. Benson P. A. Witherspoon																		
1	<u>LAWRENCE LIVERMORE LABORATORY</u> L. D. Ramspott																		
2	<u>LOS ALAMOS SCIENTIFIC LABORATORY</u> M. L. Wheeler K. Wolfsberg																		
2	<u>LOS ALAMOS TECHNICAL ASSOCIATES</u> S. E. Logan																		
3	<u>NATIONAL ACADEMY OF SCIENCES</u> W. E. Berg D. Daley S. Stuen																		
18	<u>NATIONAL ACADEMY OF SCIENCES -</u> <u>COMMITTEE ON RADIOACTIVE WASTE MANAGEMENT</u> <table border="0" style="width: 100%;"> <tbody> <tr> <td>M. Baram</td> <td>H. L. James</td> </tr> <tr> <td>S. N. Davis</td> <td>R. E. Kasperson</td> </tr> <tr> <td>E. L. Draper</td> <td>K. B. Krauskopf</td> </tr> <tr> <td>P. W. Durbin</td> <td>T. R. LaPorte</td> </tr> <tr> <td>J. T. Edsall</td> <td>C. Mawson</td> </tr> <tr> <td>M. Eisenbud</td> <td>F. L. Parker</td> </tr> <tr> <td>J. A. Fay</td> <td>T. Pigford</td> </tr> <tr> <td>J. C. Frye</td> <td>R. Roy</td> </tr> <tr> <td>E. F. Gloyna</td> <td>E. Wenk, Jr.</td> </tr> </tbody> </table>	M. Baram	H. L. James	S. N. Davis	R. E. Kasperson	E. L. Draper	K. B. Krauskopf	P. W. Durbin	T. R. LaPorte	J. T. Edsall	C. Mawson	M. Eisenbud	F. L. Parker	J. A. Fay	T. Pigford	J. C. Frye	R. Roy	E. F. Gloyna	E. Wenk, Jr.
M. Baram	H. L. James																		
S. N. Davis	R. E. Kasperson																		
E. L. Draper	K. B. Krauskopf																		
P. W. Durbin	T. R. LaPorte																		
J. T. Edsall	C. Mawson																		
M. Eisenbud	F. L. Parker																		
J. A. Fay	T. Pigford																		
J. C. Frye	R. Roy																		
E. F. Gloyna	E. Wenk, Jr.																		

Number of
Copies

2	<u>OAK RIDGE NATIONAL LABORATORY</u> N. Vaughan Library
1	<u>OREGON STATE DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES</u> J. D. Beaulieu
2	<u>OREGON STATE UNIVERSITY</u> Department of Geology Library
5	<u>PACIFIC NORTHWEST LABORATORY</u> J. R. Eliason D. E. Olesen A. M. Platt (2) J. R. Raymond R. W. Wallace Library
1	<u>THE PENNSYLVANIA STATE UNIVERSITY</u> B. E. Scheetz
1	<u>PRINCETON UNIVERSITY</u> G. Pinder
5	<u>ROCK MECHANICS OVERVIEW COMMITTEE</u> N. G. Cook J. W. Corwine W. Hustrulid A. A. Mathews J. Russell
1	<u>S. B. RUBIN</u>
8	<u>SANDIA LABORATORIES</u> E. H. Beckner F. A. Donath O. E. Jones R. C. Lincoln R. W. Lynch A. E. Stephenson L. D. Tyler W. D. Weart

Number of
Copies

1	<u>SAVANNAH RIVER LABORATORIES</u> Library
1	<u>SEISMOGRAPH SERVICE CORPORATION</u> Library
1	<u>SENTURION SCIENCES, INC.</u> Library
1	<u>SWEDISH NUCLEAR FUEL SUPPLY COMPANY (KBS)</u> L. B. Nillson
1	<u>STATE OF IDAHO GOVERNOR'S OFFICE</u> C. Jones
1	<u>STATE OF OREGON GOVERNOR'S OFFICE</u> K. Woods
1	<u>STATE OF WASHINGTON GOVERNOR'S OFFICE</u> J. Wood
1	<u>TEXAS A & M UNIVERSITY</u> J. Handin
1	<u>TEXAS A & M UNIVERSITY</u> J. Handin
1	<u>UNION OF CONCERNED SCIENTISTS</u> R. Lipschutz
1	<u>UNC NUCLEAR INDUSTRIES</u> G. O. Amy
4	<u>U. S. ARMY CORPS OF ENGINEERS</u> Seattle District Geologist Seattle District Librarian Walla Walla District Geologist Walla Walla District Librarian

Number of
Copies

1	<u>U. S. ARMY-YAKIMA FIRING CENTER</u> W. R. Dietderich
2	<u>U. S. BUREAU OF RECLAMATION</u> B. H. Carter D. Newmann
2	<u>U. S. DEPARTMENT OF ENERGY-ALBUQUERQUE OPERATIONS OFFICE</u> D. T. Schueler
1	<u>U. S. DEPARTMENT OF ENERGY-COLUMBUS PROGRAM OFFICE</u> J. O. Neff
10	<u>U. S. DEPARTMENT OF ENERGY-HEADQUARTERS</u> R. H. Campbell D. B. LeClaire C. R. Cooley S. Meyers M. W. Frei R. G. Romatowski C. H. George R. Stein C. A. Heath D. L. Vieth
2	<u>U. S. DEPARTMENT OF ENERGY-NEVADA OPERATIONS OFFICE</u> D. G. Jackson R. M. Nelson
1	<u>U. S. DEPARTMENT OF ENERGY-OAK RIDGE OPERATIONS OFFICE</u> C. A. Keller
2	<u>U. S. DEPARTMENT OF ENERGY-PUBLIC READING ROOMS</u> Richland, Washington Seattle, Washington
11	<u>U. S. DEPARTMENT OF ENERGY-RICHLAND OPERATIONS OFFICE</u> L. J. Adams J. Murphy T. A. Bauman B. L. Nicoll J. C. Cummings D. J. Squires R. B. Goranson F. R. Standerfer P. G. Harris M. W. Tiernan A. G. Lassila
1	<u>U. S. DEPARTMENT OF ENERGY-SAN FRANCISCO OPERATIONS OFFICE</u> L. Lanni

Number of
Copies

4	<u>U. S. ENVIRONMENTAL PROTECTION AGENCY</u> R. Kaufman G. L. Meyers J. Sceva Region X Library
3	<u>U. S. GEOLOGICAL SURVEY</u> C. Collier G. D. DeBuchananne P. R. Steven
6	<u>U. S. NUCLEAR REGULATORY COMMISSION</u> R. R. Boyle J. O. Bunting, Jr. J. D'Ambrosia J. C. Malaro J. B. Martin E. P. Regnier
1	<u>UNIVERSITY OF ARIZONA</u> Library
2	<u>UNIVERSITY OF IDAHO</u> Department of Geology Library
2	<u>UNIVERSITY OF MINNESOTA</u> C. A. Fairhurst C. M. St. John
2	<u>UNIVERSITY OF OREGON</u> G. Goles Library
4	<u>UNIVERSITY OF WASHINGTON</u> S. D. Malone S. W. Smith Department of Geology Library
1	<u>WASHINGTON PUBLIC POWER SUPPLY SYSTEM, INC.</u> D. D. Tillson

Number of
Copies

1	<u>WASHINGTON STATE DEPARTMENT OF ECOLOGY</u> Library
1	<u>WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES</u> Library
1	<u>WASHINGTON STATE ENERGY FACILITY SITE EVALUATION COUNCIL</u> N. D. Lewis
2	<u>WASHINGTON STATE UNIVERSITY</u> Department of Geology Library
1	<u>A. C. WATERS</u>
2	<u>WESTERN WASHINGTON UNIVERSITY</u> Department of Geology Library
1	<u>WESTINGHOUSE ADVANCED ENERGY SYSTEMS</u> T. Hakl
1	<u>WESTINGHOUSE HANFORD COMPANY</u> A. G. Blasewitz
2	<u>WESTINGHOUSE WIPP PROJECT</u> R. C. Mairson
1	<u>WOODWARD-CLYDE CONSULTANTS</u> Library
91	<u>ROCKWELL HANFORD OPERATIONS</u> H. Babad D. C. Bartholomew M. Bellofatto R. L. Biggerstaff D. J. Brown J. M. Carey D. J. Cockeram

Number of
Copies

Rockwell Hanford Operations (continued)

T. A. Curran
 M. H. Curtis
 R. A. Deju
 H. B. Dietz
 J. W. Donahue
 R. A. Freeman
 P. J. Fritch
 R. J. Gimera
 R. D. Hammond
 A. R. Hawkins
 G. S. Hunt
 R. E. Isaacson
 J. E. Kinzer
 E. J. Kosiancic
 W. J. Kurzeka
 D. L. Martin
 R. Raphael
 R. C. Roal
 J. H. Roecker
 M. J. Smith
 J. S. Sprouse
 D. B. Stephens
 D. A. Turner
 C. T. Webster
 R. T. Wilde
 L. Wilhelmi
 D. D. Wodrich
 Basalt Waste Isolation Project Library (50)
 Document Control (4)
 Records Retention Center (2)