UNDERGROUND TESTING FOR CHARACTERIZATION

OF A SALT SITE FOR THE REPOSITORY

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ABSTRACT

Salt Repository Project (SRP) of the cepartment of Energy is required to characterize a salt site for the development of a repository for the permanent disposal of high level radioactive waste. This paper presents the rationale used in preparing an Underground Test Plan (UTP) for the characterization activities and a brief description of key tests.

INTRODUCTION

Site characterization is defined as activities (whether in the laboratory or in the field) undertaken to establish the geologic conditions and ranges of the parameters of a candidate site relevant to the location of a repository. This includes borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not the preliminary borings or geophysical testing needed to assess whether site characterization should be undertaken.

This paper primarily addresses some aspects of the underground testing (in situ testing) in characterizing the candidate salt site for salt repository. Underground testing is defined as the testing or characterization activities performed in the exploratory shafts (ES) and below ground at the repository horizon in the exploratory shaft facility. The primary purpose of underground testing is to obtain data for the purposes of assessing the design performance of the proposed repository, obtain data to assess the environmental impact on the site after radioactive waste has been placed in the repository, and obtain data for the preparation of the License Application (LA) for the disposal of radioactive waste at the salt site recommended by the President.

During detailed site characterization, the Salt Repository Project must obtain data to satisfy four key issues identified in the Mission Plan (1) and presented here in Table I. The site characterization activities are to be guided by a Site Characterization Plan (SCP). The hierarchy of documents as it relates to underground testing is presented in Fig. 1. This paper presents a methodology that has been used to develop the Salt Repository Project (SRP) Underground Test Plan (UTP), which presents a tentative list of tests and objectives of some of the key tests.

TABLE I

Four Key Mission Plan Issues

Key Issue 1

Will the geologic repository, consisting of multiple natural and engineered barriers, isolate the radioactive waste from the accessible environment after closure in accordance with the requirements set forth in 10 CFR Part 60 and the US Environmental Protection Agency (EPA) rule as codified in 40 CFR Part 191?

Key Issue 2

Will projected radiological exposures of the general public and projected releases of radioactive material to restricted and unrestricted areas during repository operation and closure meet applicable safety requirements in 10 CFR Part 10, 10 CFR Part 60, and 40 CFR 191, Subpart A?

Key Issue 3

Can the repository and its support facilities be sited, constructed, operated, closed and decommissioned so that the quality of the environment will be protected and waste transportation operations can be conducted without causing unacceptable risks to public health and safety?

Key Issue 4

Are repository construction, operation, closure and decommissioning feasible on the basis of reasonably available technology, and are the associated costs reasonable?

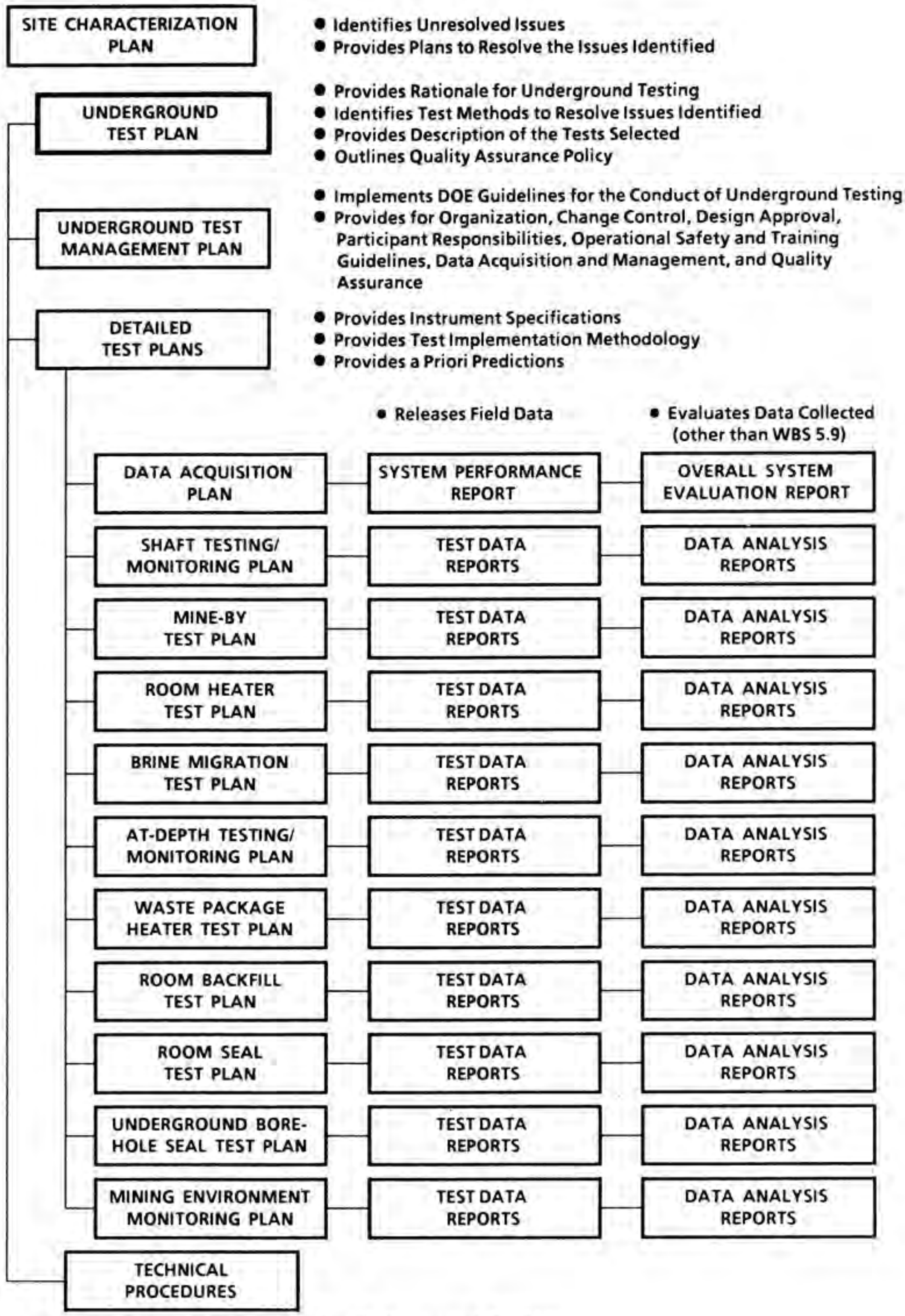


Fig. 1. Hierarchy of Documents for Underground Testing.

Underground Testing

For the project to progress on a timetable consistent with the NWPA, it has been necessary to develop the initial test planning in parallel with regulatory activities that are identifying regulatory issues and developing proposed strategies for addressing them. The underground test plan must present a testing strategy that applies the information needed to resolve the regulatory issues. Because the two activities are being conducted in parallel, some minor adjustments to the test plans may be necessary to fully integrate the testing and licensing strategies. In the interim, information requirements and data needs have been developed which are based on the four key issues presented in Table I, and on the regulatory requirements such as National Waste Policy Act (NWPA) NRC Rule 10 CFR 60, EPA Standard 40 CFR 191, DOE Siting Guidelines 10 CFR 960, 10 CFR 20 and Mining Rules and Regulation 30 CFR 57. The methodology used in developing underground tests is presented in Figs. 2 and 3.

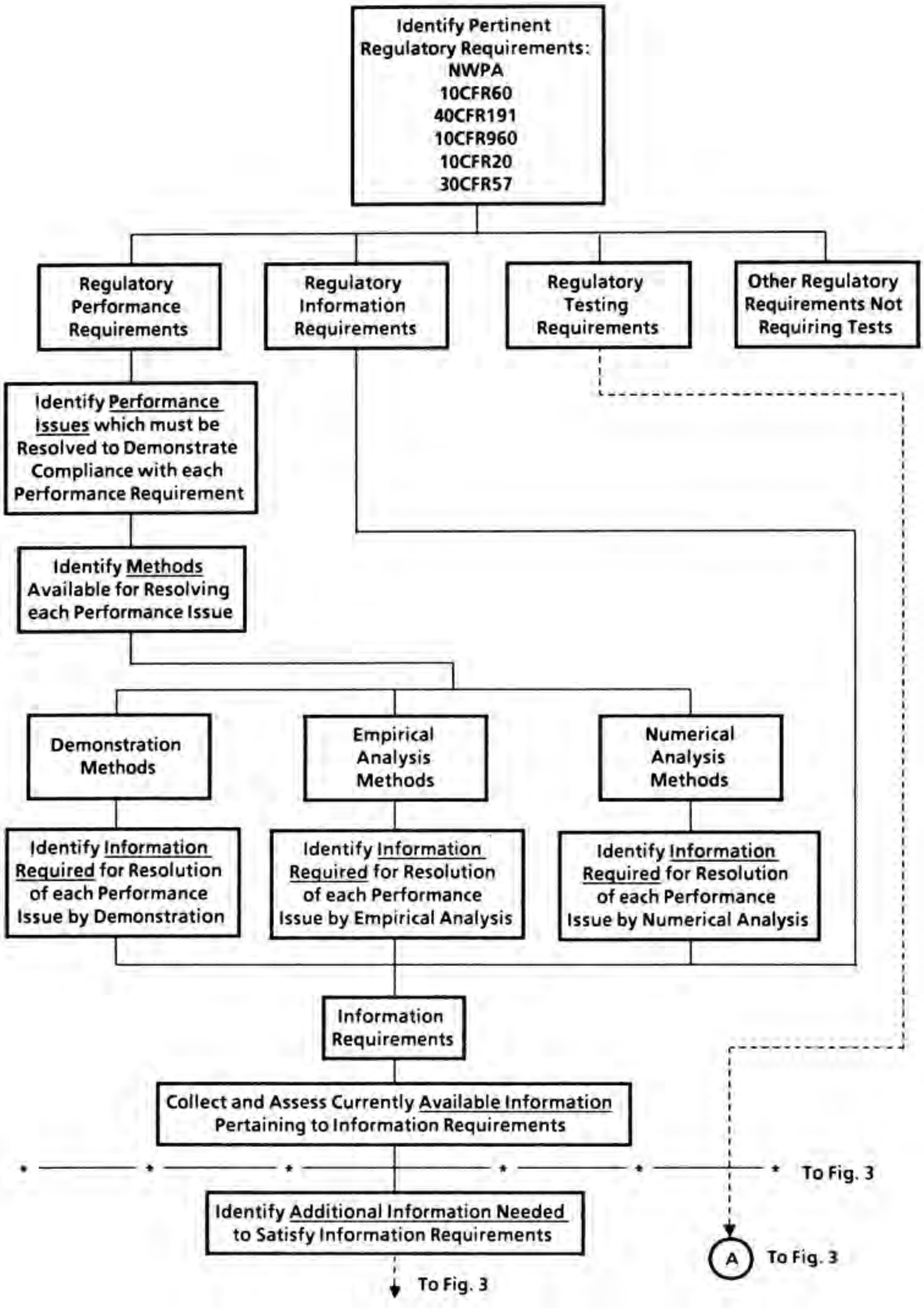


Fig. 2. Approach to Identifying Information Needs.

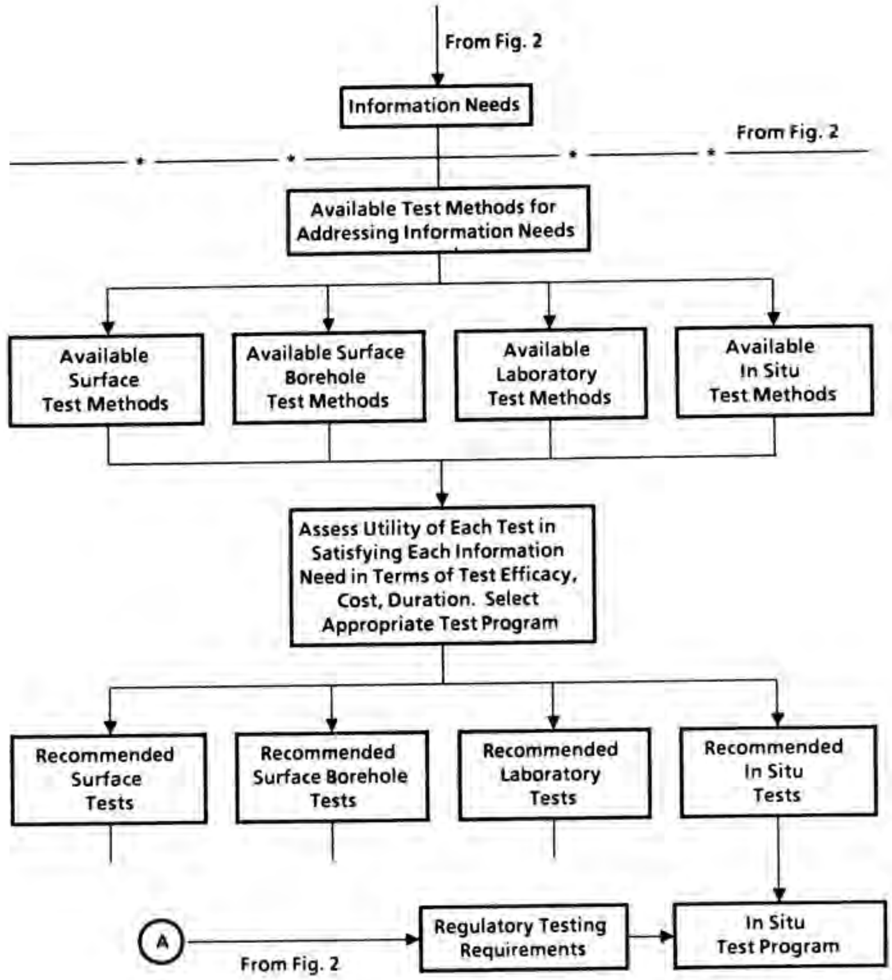


Fig. 3. Approach to Identifying In Situ Test Program.

The regulatory requirements are used to develop information needs to be addressed by testing. These needs include both regulatory performance types and regulatory information requirements. The regulatory performance requirements are initially restated in terms of performance issues which must be addressed in order to demonstrate compliance with the regulations. The information required to address the performance issues will depend, in part, on the methods of resolving issues. Methods for resolving performance issues are:

Demonstrations, where a component of the repository is physically constructed, and the performance is measured or observed. The results are used directly to predict repository performance (without determining parameter values or developing models). Construction and short-term performance aspects of borehole seals, for example, might best be resolved by such methods. Uncertainty with demonstration methods derives primarily from how well the test actually simulates the process.

Empirical Analyses, where past experience under similar conditions is quantified and transferred to the repository performance context through classification indices, etc.; this does not refer to the empirical derivation of input parameters, but to the performance equation itself. Design of underground opening support, for example, might best be done empirically. Uncertainty with empirical analysis methods derives primarily from the relevance of the data or the competence of the experience base.

Numerical Analyses, where conceptual and then numerical models which represent the perceived physical processes are developed, input parameters addresses, and performance predictions calculated. Most of the containment and isolation regulations must be addressed using numerical analyses because the time scale of interest are too long to be usable. The numerical analyses of system and component performance use the test results to address the regulations. The issue of radionuclide transport by groundwater flow, for example, can only be resolved by numerical analyses. When numerical modeling is used, uncertainties in the modeling must also be considered. Uncertainties will depend on how well the conceptual models represent reality, how well the numerical model represents the conceptual model, and how well the model input parameters are known.

The information needs can be directly related to the regulatory requirements. The regulatory performance requirements relate to the corresponding information needs through performance issues, performance assessment methodologies, and currently available information. The regulatory information requirements relate to the corresponding information needs through currently available information.

Based on the identified information needs, a variety of testing strategies can be applied to obtain the data required. The tests to be performed can be from the surface described under the Surface Based Test Plan, or from below ground addressed in the UTP. Generally speaking, surface testing, surface borehole testing, and laboratory testing, with some exception, do not fully address either model validation or design evaluation needs. consequently, underground testing is required to obtain these types of required data.

Preliminary List of Underground Tests

The information and data needs have been used to develop a preliminary list of underground tests. Several tests provide data for each information need. This is required to assess scale effect, calibrate the results of simpler tests, and to study responses under a variety of underground environmental conditions.

In the selection of the suite of tests, interactive effects (coupled testing) were also considered; i.e., the efficacy of a combination of tests in satisfying an information need and the satisfaction of different information needs by a single test. Currently, because the information needs are qualitative in nature, the evaluations have been qualitative and the selection of tests necessarily based on subjective assessments. However, once the information needs have been quantified, then the selection of tests can be undertaken in a more objective manner. Hence, the list of proposed tests is expected to change when the site is prepared. A tentative list of the tests to be performed is presented in Table II as categorized according to the primary type of information provided, e.g., geomechanical, geological, etc.

TABLE II

Proposed Underground Site Characterization and Testing Program

Geology

Geologic Mapping
Drilling (Core Sampling/Field Logging)
Geophysical Borehole Logging
Seismic Surveys
Seismic Monitoring
Electrical Surveys
Gravity Surveys

Geomechanics

Stress Measurement
Borehole Pressuremeter/Jacking Test
Borehole Condition/Convergence Monitoring
Torsional Shear Test
Mine-by Test
Rock Bolt Pullout Test
Facility Mechanical Response Monitoring

Thermomechanics

Thermal Conductivity Probe Testing
Waste Package Heater Test
Room Heater Test
Room Backfill Test
Facility Thermal Response Monitoring

Geochemistry

Formation Fluid Sampling
Formation Material Analysis

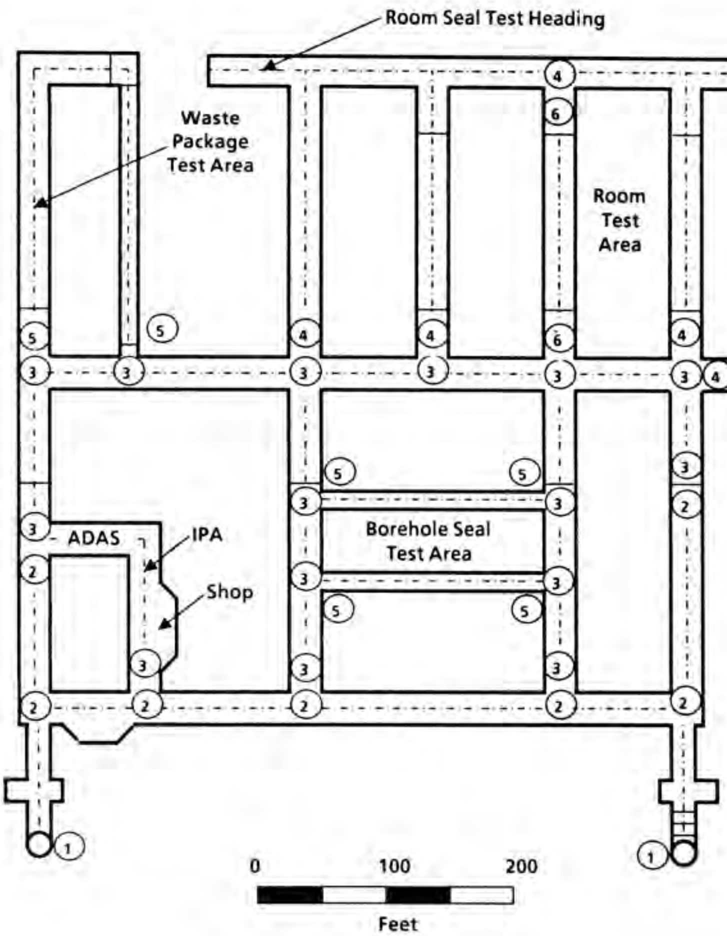
Geohydrology

Single Borehole Hydraulic Conductivity Test
Cross-Hole Hydraulic Conductivity Test
Cross-Hole Tracer Test
Tracer Diffusion Test
Underground Borehole Seal Test
Room Seal Test
Brine Migration Test
Grout Injection Test
Facility Hydrological Response Monitoring

Underground Testing Strategy

Underground testing will be performed in three inter-related phases: The first phase consists of testing during the excavation of the shaft; the second phase consists of tests during the construction of the underground facility and connecting of the two shafts; phase 3 consists of tests installed during and after the construction of the test facility. The test facility, as currently designed, will consist of two 12-foot diameter mined shafts and approximately 5,000 linear feet of underground excavations. Figure 4.

A tentative list of major tests identified is presented in Table III. Primary objectives of the key tests follows:



CONSTRUCTION DETAILS

STAGE	SHOWN	DURATION
1. Shaft Construction	(1)	18 Months
2. Connecting Airway	(2)	Three (3) Months
3. ADAS, IPA, Shop and Airway	(3)	Two (2) Months
4. Room Test Area Development	(4)	Two (2) Months
5. Waste Package Test Area Development	(5)	One (1)Month
6. Mine-by Test Construction	(6)	One (1) Month

ADAS = Automatic Data Acquisition System
IPA = Instrument Preparation Area
Shop = Equipment Maintenance and Repair Shop

Fig. 4. ESF Underground Layout.

TABLE III

Tentative List of Major Tests to be Performed to Characterize Salt Site Recommended by the President

Mine-by Test	Obtain early time salt response
Room Scale Heater Test	Obtain behavior of salt under simulated repository thermal environment
Facility Mechanical Response Monitoring	Obtain stress/deformation behavior of the ESF under ambient conditions
Thermal and Thermal Mechanical Characterization	Obtain thermal and thermomechanical characteristics of the site
Room Backfill Performance Test	Obtain data on reconsolidation of the crushed salt backfill
Canister Scale Heater Test	Obtain behavior of simulated waste package near field environment
Brine Migration Test	Obtain information on migration of brine under thermal gradient
Room Seal Performance Test	Evaluate seals placed in horizontal openings

OBJECTIVES OF THE KEY TESTS

Mine-by Test

The Mine-by Test will evaluate the excavation, support, stability and pre-waste emplacement mechanical performance of a waste disposal room, which is a major element of the repository system. An extensive data base will be developed by monitoring the performance of the test facility excavations in general, but early time data will be lost because it is usually not possible to pre-instrument these areas. The Mine-by Test will include pre-instrumentation of the test area and will therefore provide the opportunity for base-lining the more extensive but less complete information obtained elsewhere.

When sufficient information on the ambient temperature response of the test room has been obtained from the first phase Mine-by Test, the heaters will be activated to raise the temperature around the room. The previously installed instrumentation will be used to monitor the thermal, thermomechanical and hydrological response of the test area.

In addition to addressing room stability (i.e., safety) issues, a major objective of the Mine-by test will be to provide data for the validation of geomechanical models necessary for predicting performance related issues such as long-term closure behavior of the rooms (e.g., impacts backfill consolidation, strata disturbances, waste retrievability, etc.). The full-scale test room will enable a realistic evaluation of the effects of geologic structure on room behavior and of the relevance of the simplified geomechanical performance models. The Mine-by Test will comprise the first phase (i.e., ambient temperature conditions) of room-scale model validation testing. The second phase will involve the addition of thermal loading (see Room Scale Heater Test).

Room Scale Heater Test

The Room Scale Heater Test is an extension of the Mine-by Test and will be used to evaluate the stability and post-waste emplacement thermal/thermomechanical performance of a waste disposal room. Two time periods are of interest; the operational period during which waste retrieval may be required, and the post-decommissioning period. During the operational period, room closure might not be sufficient to derive substantial support from the backfill. A requirement for retrievability would involve re-entry to the waste disposal rooms and it is necessary to evaluate the structural integrity of these rooms following deformations of the magnitude likely to be experienced before decommissioning. In order to induce such a deformational response within the time available for testing, it will be necessary to accelerate the test. Thermomechanical model validation for room-scale behavior is therefore an important objective as such models will be required to relate the accelerated test performance to expected waste repository room performance.

Following decommissioning, the thermomechanical performance of repository rooms will impact repository horizon disturbance, backfill consolidation etc., which are important to the performance of the repository in isolating the waste. The Room Scale-Heater Test, in conjunction with the scaled-down Room Backfill Test, will provide data for validating the thermal/thermomechanical models used to evaluate post decommissioning behavior of the repository.

Facility Mechanical Response Monitoring

Mechanical Response Monitoring (i.e., stress-deformational response) of the test facility shafts and repository level excavations will be used to gather data in support of evaluating the excavation, stability and safety of the workings during the operational phase, the design of underground openings (layout, dimensions, room profiles), and the design of shaft linings and underground opening support. In addition, monitoring of the mechanical disturbance to the ground as a result of construction will provide input to estimates of the long-term performance of the repository in isolating the radioactive waste.

The test facility shafts and room excavations will comprise essentially full-scale simulations of the actual repository openings (although shaft diameters will be smaller in the test facility), and will therefore provide data for validating repository design and performance models. Whereas the Mine-by Test will provide the complete mechanical response (by pre-instrumentation) at a single location, monitoring within the facility at large will provide a spatially more comprehensive set of data, correlations between mechanical performance and geology, and identification of critical design/performance conditions.

Thermal/Thermomechanical Characterization

The site thermal and thermomechanical characteristics to be evaluated are in situ temperature and properties related to heat transfer (thermal conductivity and specific heat) and thermal expansion. In situ temperature and the distributions of the thermal and thermomechanical properties will be required in order to predict the waste induced temperature distributions and the resulting thermally induced stress/deformations, and their effects on repository performance.

Laboratory testing of samples from the test facility will also provide a major part of the thermal/thermomechanical data base.

Site thermal/thermomechanical characteristics will generally be evaluated throughout the ESF, following the completion of the construction Testing phase. In addition, large-scale testing will be performed for evaluating specific repository design features and for validating predictive thermomechanical design and performance models in the elevated temperature regime. In particular, the Canister and Room Scale Heater Tests will examine the responses of two of the major repository subsystems at representative thermal and mechanical loadings. This information will contribute to evaluations of the containment and isolation potential of the repository. The Room Backfill test will study the interactions of crushed salt backfill with the host repository rock and allow a determination of the level of long-term isolation which can be achieved by using salt backfill.

Room Backfill Performance Test

The Room Backfill Test will provide information which relates to the long-term performance of crushed salt backfill placed in repository waste disposal rooms. The functions of such backfill are to control deformations of the repository horizon strata and to ultimately encapsulate the waste so as to enhance long-term isolation. A desirable end point would be to return the repository horizon to an essentially virgin undisturbed condition. An in situ demonstration of the relithification of salt backfill and of the final condition of the backfill/rock salt interface will add significantly to the confidence which can be placed in the ability of the backfill to encapsulate and hydraulically isolate the radioactive waste.

Since the demonstration cannot be carried out at full scale because of time constraints (seven years might be required), a scaled-down overtest will be performed. It will therefore be necessary to extrapolate test results to the repository scale using appropriately validate thermomechanical models.

Canister Scale Heater Test

The Canister Scale Heater Test will evaluate the performance of one of the major elements of the repository system, the waste package, together with the thermomechanical interactions between the package and the surrounding salt. Thermal and thermomechanical response in the very near field relates to the maximum allowable temperatures of the waste, and mechanical loadings applied to the waste packages. The latter effect is important to the waste containment performance criterion. The test will therefore provide data which are important to waste package design, waste package life, and to the retrievability evaluation. In addition, waste package emplacement hole preparation procedures will be evaluated, and corrosion performance of both the heater assembly casing and of sample waste package material coupons will be assessed. The test data will also be used to validate thermal, thermomechanical and corrosion models which are required to predict the long-term performance of the waste package under repository conditions. Since thermomechanical loads on a waste disposal package are expected to be a maximum within a relatively short period, this aspect of waste package behavior will be directly simulated by the test.

Brine Migration Test

The Brine Migration Test will evaluate the phenomenon of fluid migration under thermal gradient in the very near vicinity of a heat source representative of a waste package. The quantity and chemistry of such fluids are important to considerations of waste package corrosion and waste containment, waste form solubility, and the performance of emplacement hole backfill. The test will therefore provide data necessary for waste package design, together with information which relates to the preparation of waste emplacement holes and which impacts on considerations of waste package retrievability. The test data will also be used to validate predictive models necessary for determining behavior over time periods which substantially exceed the period of the test. Because of the relatively complex synergistic effects and uncertainties about the exact mechanisms of thermally induced brine migration, the test will be designed to closely simulate representative repository conditions (i.e., geology, geometry, thermal loading, temperatures and temperature gradients).

Room Seal Performance Test

The Room Seal Performance Test will study the performance of hydraulic seals placed in horizontal openings within the repository. The repository excavations constitute a potential preferential pathway for the migration of groundwater into and radionuclides out of the repository horizon. Room seals will therefore be required initially to control the rate of fluid ingress to the repository in the period immediately following decommissioning, i.e., to inhibit saturation. Following repository saturation, the seals may also be required to control the migration of radionuclides to the accessible environment. This will depend on the rate and degree of consolidation achieved by the crushed salt backfill.

The Room Seal Performance Test will therefore be used to evaluate the seal design, construction and relatively short-term performance in controlling fluid migration.

SUMMARY

In order to characterize a salt site an Underground Test Plan has been developed. This UTP is primarily driven by the information needs identified from various regulatory requirements. This approach has resulted in developing a preliminary list of tests required to characterize the site. It is expected that testing requirements will change after a Site Characterization Plan has been prepared and again as site characterization progresses. The Site characterization Plan is to be prepared following the Department of Energy Secretary's recommendation of the site and Presidential approval.