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TEST CONCEPT FOR WASTE PACKAGE ENVIRONMENT TESTS AT YUCCA MOUNTAIN

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Test Concept for Waste Package Environment Tests at Yucca Mountain*

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1 INTRODUCTION

The Nevada Nuclear Waste Storage Investigations Project is characterizing a tuffaceous rock unit at Yucca Mountain, Nevada to evaluate its suitability for a repository for high level radioactive waste. The candidate repository horizon is a welded, devitrified tuff bed located at a depth of about 300 m in the unsaturated zone, over 100 m above the water table. As part of the project, Lawrence Livermore National Laboratory is responsible for designing the waste packages and for assessing their expected performance in the repository environment.

The primary region of interest to package design and performance assessment is the portion of the rock mass within a few meters of waste emplacement holes. Hydrologic mechanisms active in this unsaturated near-field environment, along with thermal and mechanical phenomena that influence the hydrology, need to be understood well enough to confirm the basis of the waste package designs and performance assessment. Large scale in situ tests (called waste package environment tests) are being planned in order to develop this understanding and to provide data sets for performance assessment model validation (Yow, 1985). These tests will be conducted in an exploratory shaft test facility at Yucca Mountain. Planning for these tests is now in progress based on scoping calculations and on phased prototype experiments. Although the status and development of these tests are described below, this paper does not address the extrapolation of test results or the relationship between these site characterization activities and subsequent performance confirmation testing.

2 TEST CONCEPT AND OBJECTIVES

Exploratory shafts and limited underground facilities for in-situ testing will be constructed at Yucca Mountain during site characterization. Multiple waste package environment tests are being planned for execution in these facilities to represent horizontal and vertical waste emplacement configurations in the repository target horizon. These approximately half-scale tests are being designed to investigate rock mass hydrologic conditions during a cycle of thermal loading. In comparison to previous

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heater tests (e.g., Zimmerman et al., 1984), these tests focus on the cooling as well as heating portions of the thermal cycle. Thus, the tests are complex in that they address the interaction of thermal, hydrologic, mechanical, and (to a limited extent) chemical phenomena in the near-field environment.

Figure 1 illustrates schematically the layout of a single test intended to represent a horizontal waste package emplacement configuration. For this case, a 6 meter (20 feet) long heater is located in a 30 centimeter (12 inch) diameter emplacement hole at a depth from collar of 6 meters (20 feet). The heater hole itself is drilled so as to provide a separation of at least 6 meters (20 feet) between the horizontal heater and the adjacent drift surfaces. This separation will be maintained for the vertical emplacement case as well, except for the distance between the heater and the collar of the emplacement hole in the access drift invert. In both cases, small-diameter instrumentation holes will be drilled parallel and perpendicular to the heater holes to provide measurements in more than one dimension.

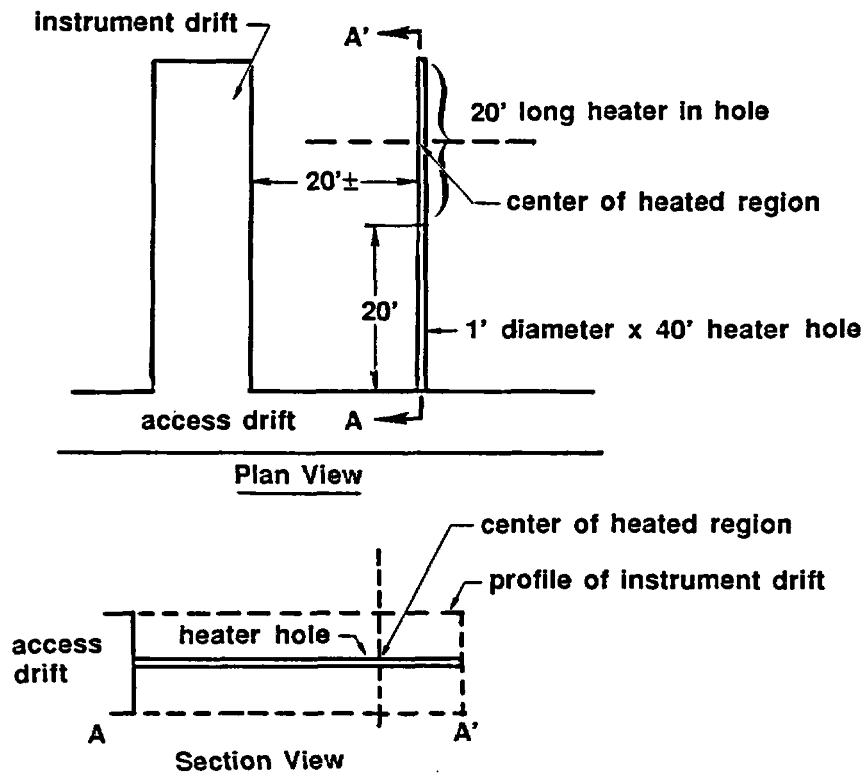

Figure 1. Schematic waste package environment test geometry to represent horizontal emplacement.

All borehole and transducer locations will be surveyed as each test is constructed. Boreholes and drift surfaces will be logged or mapped to record locations of major fractures, degree of fracturing, and noticeable variations in matrix properties. Boreholes will also be logged to measure gross moisture contents to help establish the initial conditions of each test.

Figure 2 shows conceptually the types of hydrologic phenomena that might occur during the thermal cycle in each test. Once the initial moisture conditions have been perturbed by the thermal loads, moisture migration will be driven by saturation, temperature, and pressure gradients, and by gravity. Evaporation and condensation are expected to occur in the rock mass around the heater, although the temperature at which boiling takes place is likely to be strongly affected on a localized basis by capillary effects.

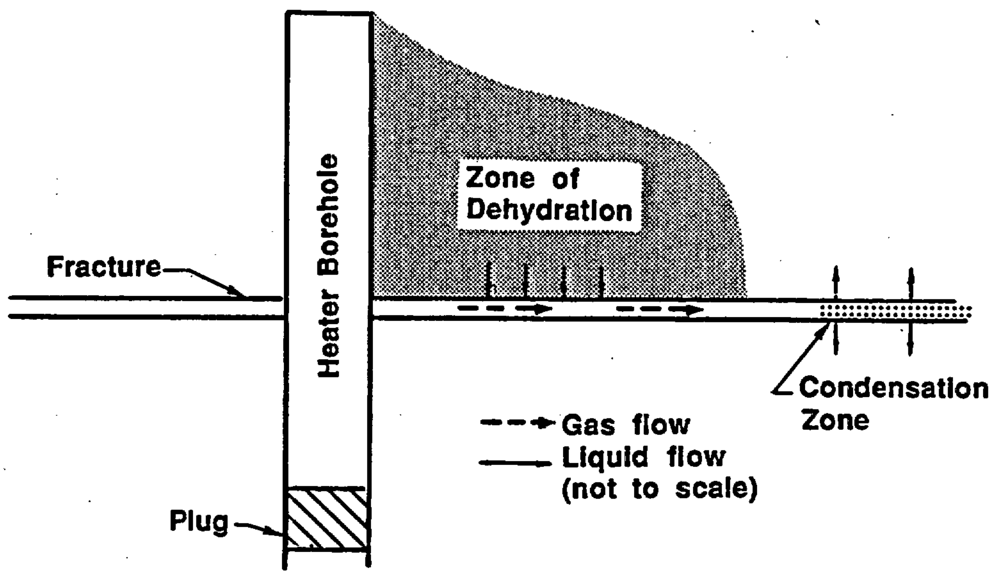

Figure 2. Schematic of hydrologic phenomena near emplaced heater (after Ramirez and Daily, 1985).

3 PROTOTYPE EXPERIMENTS

Prototype experiments in a similar rock in an existing tunnel at the Nevada Test Site are being used with scoping calculations to develop detailed plans for the tests that will be conducted at Yucca Mountain. In the prototype experiments (Ramirez and Daily, 1985 and 1987), high-frequency electromagnetic geotomography measurements have been used to evaluate moisture distributions in fractured, porous, partially saturated rock before, during, and after thermal loading, and to monitor fluid movement through the fractures and the matrix. Preliminary results indicate that these measurements have been successful in observing moisture migration patterns, although the time available for monitoring field conditions has been only three months.

Subsequent phases of the prototype experiments are being prepared to include other geophysical and geotechnical instrumentation in order to evaluate their performance in the in-situ test environment for realistic, if short, test durations. Techniques that will be used to provide redundant data sets include methods that characterize a volume of rock, such as neutron logging, as well as point measurement methods. Geotechnical instruments for monitoring mechanical responses will include modified borehole deformation gauges and extensometers.

In addition to allowing an evaluation of measurement system performance, the prototype experiments yield early, representative results for use with the scoping calculations in designing the exploratory shaft tests. The experiments also provide an essential shake-down experience for the use of the systems, before any Yucca Mountain site data are at stake, and allow quality assurance procedures to be developed for the various activities that will make up the tests.

4 SCOPING CALCULATIONS

Thermal, thermomechanical, and hydrothermal scoping calculations are supporting experiment and test planning, including instrument selection and location. These studies are used to evaluate the range of environmental conditions that instrument systems must withstand, to select transducers that have the required range and

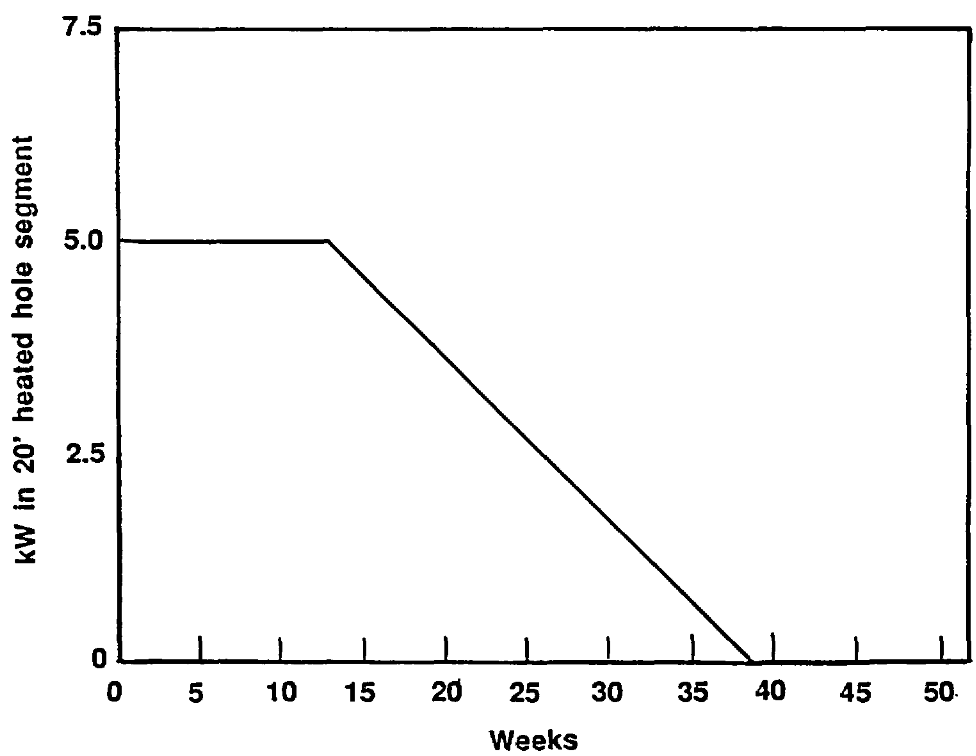

Figure 3. Typical thermal loading curve for waste package environment test (after Butkovich and Yow, 1986).

sensitivity (where options are available for choosing), and to anticipate the time and spatial scales of the phenomena to be encountered in situ. Figure 3 indicates a typical thermal loading curve used to drive the calculations.

Thermal studies (see Figures 4 and 5) indicate an expected maximum heater hole wall temperature of nearly 250°C in the exploratory shaft tests, with temperature gradients early in the test of up to 300°C/m (Montan, 1986). Thermomechanical continuum models estimate near field rock mass displacements of one to two millimeters, and stress changes of over 10 MPa (Butkovich and Yow, 1986). These values should be readily measurable if the instrument systems can withstand the elevated temperatures and humidity conditions in the test for extended periods.

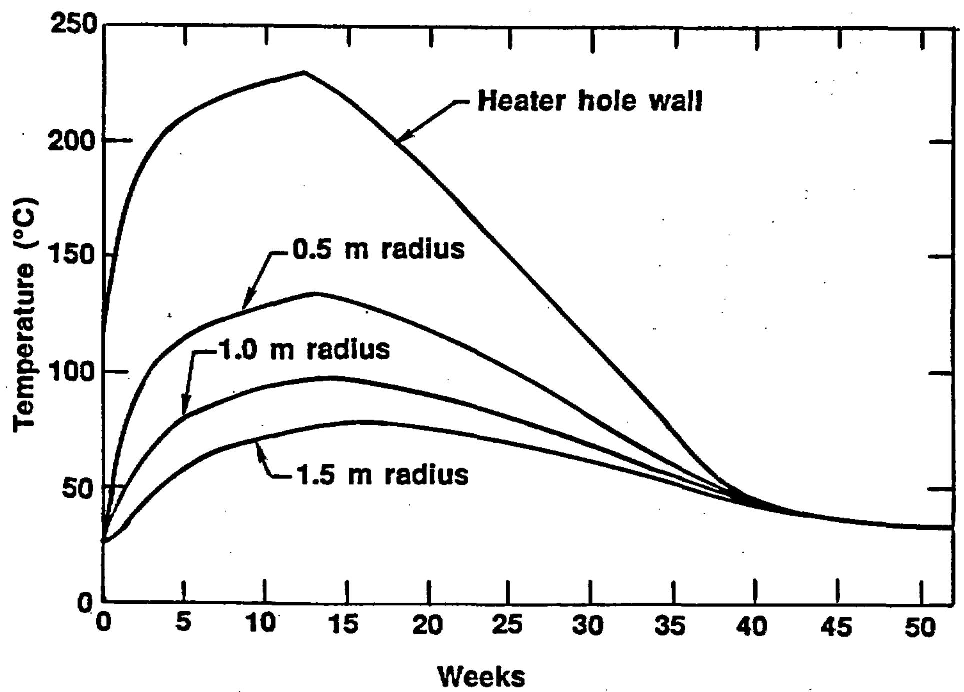

Figure 4. Temperature histories calculated from thermal loading (after Montan, 1986).

As described above, only the inner few meters of each hole will be heated in order to separate the heated test zone from humidity and temperature changes in the drifts. Thermal scoping calculations are being used to determine the minimum required separation of each test from the drift and from other tests; hydrothermal calculations will also be used to check the test layout.

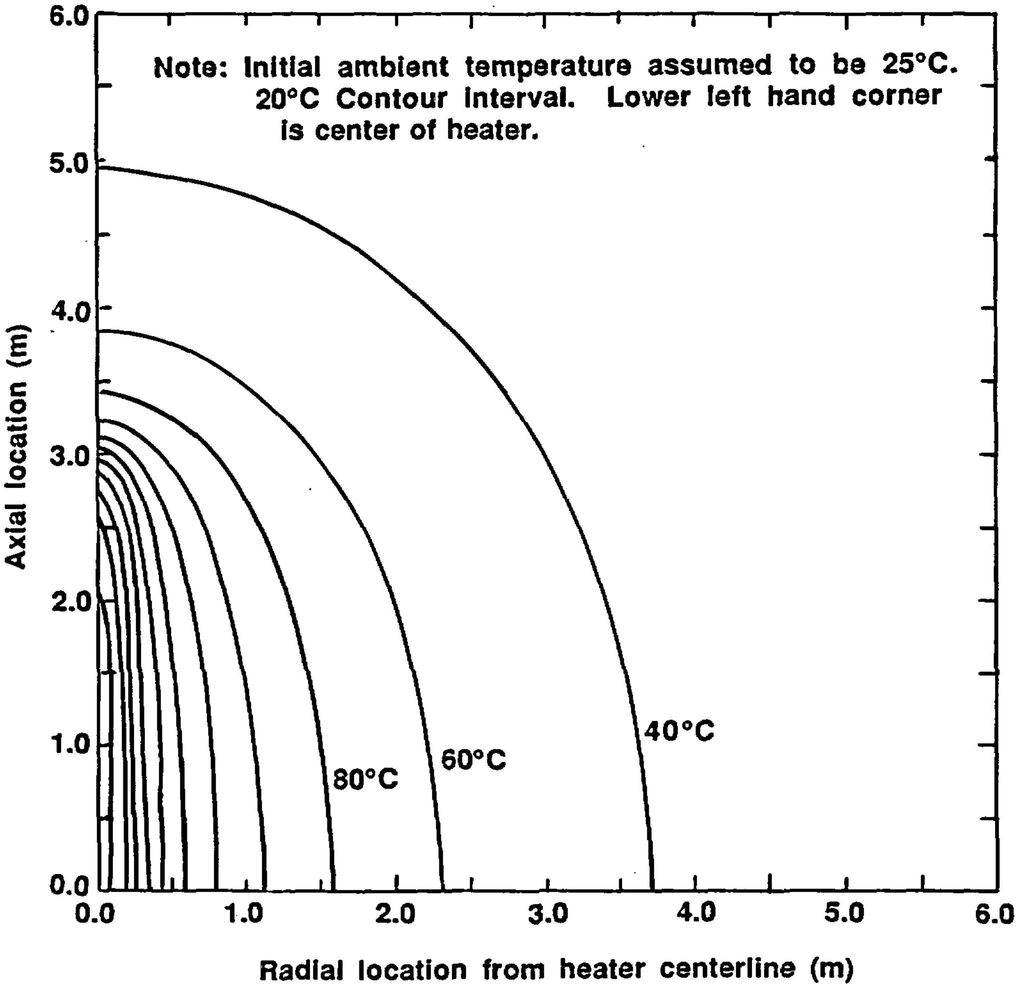

Figure 5. Temperature contours calculated for time of 13 weeks after start of thermal loading (after Montan, 1986).

5 SUMMARY

In summary, tests are being designed to examine the near field waste package environment during Yucca Mountain site characterization. Although the primary focus of the tests is the thermally perturbed hydrologic behavior of the rock mass, thermomechanical phenomena will also be examined for their influence on fluid flow. The general test layouts are based on anticipated waste emplacement configurations, but calculational and experimental work will be used to complete the design to the extent that is possible before the exploratory shaft test facilities are available. In these tests, preliminary spacings and locations of boreholes and transducers will be selected so that the rock mass is most heavily instrumented in zones which experience liquid-water vapor transitions. Final instrument locations will then be selected in the field as the test horizon geology is revealed in the test drifts.

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