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Lawrence Livermore National Laboratory

NUCLEAR WASTE MANAGEMENT PROGRAM

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# NUCLEAR WASTE MANAGEMENT PROGRAM
# NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS PROJECT
# TEST PLAN:
# PROTOTYPE ENGINEERED BARRIER DESIGN TESTING - HORIZONTAL EMPLACEMENT

WBS 1.2.6.9.4.5.L

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# 1.0 INTRODUCTION

## 1.1 Purpose

The Nevada Nuclear Waste Storage Investigations (NNWSI) project is studying a tuffaceous rock unit located at Yucca Mountain on the western boundary of the Nevada Test Site, Nye County, Nevada. The objective is to evaluate the suitability of the volcanic rocks located above the water table at Yucca Mountain as a potential location for a repository for high level radioactive waste. As part of the NNWSI project, Lawrence Livermore National Laboratory (LLNL) is responsible for the design of the waste package and for assessing the expected performance of the waste package in the repository environment.

The mechanisms by which liquid water is driven off and subsequently returns to the waste package must be established to complete the waste package design for the unsaturated emplacement environment. Also, consideration must be given to the potential for these mechanisms to impact the water chemistry. Development of models of the hydrologic behavior is necessary to allow prediction of container corrosion modes and rates, and the rates of waste form dissolution. Therefore, tests known as "In Situ Engineered Barrier Design Tests" - WBS 1.2.6.9.2.5.L- are being designed for the in situ phase of Exploratory Shaft testing. These tests emphasize measurement techniques that offer the possibility of characterizing the movement of water into and through the pores and fractures of the densely welded Topopah Spring Member. Other measurement techniques will be used to examine the interactions between moisture migration, geochemistry, and the thermomechanical rock mass behavior. Yow (1985) provides additional information on the concept of these tests.

## 1.2 Test Objectives

In order to assure the effectiveness of the In Situ Engineered Barrier Design Tests a group of Prototype Engineered Barrier - Design Tests (PEBDT) - WBS 1.2.6.9.4.5.L tests will be conducted prior to the In Situ Engineered Barrier - Design Tests. These tests are part of Activity S-20-1 "Evaluate Test Component in Support of Component Selections" described in the Scientific Investigation Plan "NNWSI Exploratory Shaft Investigations: Engineered Barrier System testing - Waste Package Environment Tests" (see sections 3.1, 3.2 and Appendix for further details). The knowledge and experience gained during prototype testing will be used in the detailed design of the "In Situ Engineered Barrier Design Tests" which are part of Exploratory Shaft testing in Yucca Mountain. The primary purpose of the Prototype Engineered Barrier Design Tests is to evaluate the technical feasibility of defining the hydrologic and thermomechanical behaviour of the near field rock mass during a heating and cooling cycle. Evaluating the effectiveness of various measurement techniques for monitoring the hydrologic and thermomechanical response under realistic conditions is the major objective of the prototype tests. Additional objectives of these tests are: a) to provide data that can be used to improve understanding of the thermomechanical and hydrologic response of welded tuff around a heater, and b) to develop and evaluate technical procedures under realistic conditions so that final procedures can be prepared for Exploratory Shaft testing.

The PEBOT will consist of a series of tests to be conducted at G-tunnel, which is located within the Nevada Test Site (NTS). Welded tuffs with similar properties to tuffs in Yucca Mountain are located in a portion of G-tunnel (Zimmerman et al, 1986). An underground facility called the G-tunnel Underground Facility (GTUF) has been constructed by the Sandia National Laboratories for the NNWSI project.

1.3 Scope

This test plan covers the activities for the first test of the PEBOT including its preparation, execution and documentation. Other test plans will be prepared for additional tests. Yow (1985) provides additional information on the overall testing concept. The work includes the preparation and execution of field tests to evaluate draft technical procedures, methods, equipment and designs under conditions which approximate those expected to be encountered during the Exploratory Shaft Testing in Yucca Mountain.

Due to the developmental nature of the test, as well as the variability of geologic materials, it is expected that the activities described in this test plan may need to be modified in the field to accomodate unexpected situations. These changes will be based on the professional judgement of the scientists conducting the test. The documentation and approval of these changes is described in Section 4.8.

One of the objectives of prototype testing is the evaluation of procedures and test plans (as well as techniques and instruments). This Test Plan may offer a different level of detail than the plan for Yucca Mountain tests. One of the expected results of prototype testing will be to define what is the adequate level of detailed specification vs. flexibility in a test plan to allow professional judgement but assure successful and well documented testing.

"Technical Procedures" and "Criteria Letters" supplement test plan information by providing further details about various activities. The "Technical Procedures" specify preliminary methods to be followed by Lawrence Livermore National Laboratory employees while implementing test-related activities. The preliminary nature of these procedures and the documentation describing changes to the procedures are specified in sections 4.6 and 4.8. The "Criteria Letters" list the requirements and specifications to be used by supporting organizations (e.g., Reynolds Electrical & Engineering Company (REECo) and Holmes and Narver (H&N)) while performing various activities associated with this test.

1.4 Test Elements

(A) Perform scoping calculations in support of test plan development

(B) Develop specifications and preliminary procedures for calibration, installation and operation of test components. These draft procedures will be compared against actual field efforts so that the procedures can be evaluated and changed as necessary in preparation for Exploratory Shaft testing.

(C) Fabricate or procure test components.

(D) Calibrate sensors and equipment prior to installation.

(E) Install test components. The test components will probably include:

a) a heater to thermally perturb the rock,
b) psychrometers and resonant circuits to measure air humidity in the rock,
c) thermocouples for temperature measurements,
d) neutron logger for moisture content measurements and gamma-gamma density logging,
e) electromagnetic measurement system to monitor moisture content between measurement boreholes,
f) pressure transducers to monitor air pressure inside sealed boreholes,
g) data acquisition and recording equipment,
h) inflatable packers, flow meters and pressure transducers for air permeability measurements,
i) a moisture condensation trap to collect, condense, and measure the water vapor invading the heater borehole,
j) a barometric pressure sensor that monitors changes in atmospheric pressure that could influence hydrologic behaviour.

(F) Conduct pre-test air permeability measurements and begin collecting pre-heating baseline data from all measurement systems.

(G) Conduct the test. The instrumentation listed above will be used before, during, and after heating the rock mass with a heater

(H) Conduct air permeability measurements along the heater emplacement borehole after the heater is removed to compare pre and post-test gas permeabilities.

(I) Evaluate instrumentation performance based on recorded data, visual inspection and when deemed necessary, post test calibration. Interpret the measured data to reconstruct the hydrologic and thermal environment around the heater emplacement borehole to assist in model development.

(J) Overcore two of the grouted/sealed boreholes to visually inspect the condition of the seals.

# 2.0 DESCRIPTION OF WORK

## 2.1 Management

The prototype test described herein is a precursor to the tests that support model development and validation efforts designed to address Information Need 1.10.4 and indirectly Information Needs 1.4.3 and 1.5.3 (NNWSI Issues Hierarchy of July 10, 1986). This testing involves the planning and implementation of a prototype test to field test procedures and evaluate, calibrate and prepare geophysical, geotechnical and thermal measurement techniques for future use in the NNWSI Exploratory Shaft Testing Program (WBS 1.2.6).

The management organization in charge of this prototype testing is shown in Figure 5.L-1. D. Wilder is the Task Leader for "In Situ Engineered Barrier Design Testing." Additional information describing the Nuclear Waste Management Project (NWMP) organizational structure is available in LLNL's Quality Assurance Program Plan - 033-NWMP-P. 1.0 - Organization.

## 2.2 Test Concept and Borehole Configuration

This prototype test for the "In Situ Engineered Barrier Testing" has evolved from scoping calculations, laboratory tests and field testing efforts in GTUF. The test will measure several parameters as a function of location and time in the near field (within a few meters) of a heater emplaced in welded tuff. The test includes an accelerated thermal cycle to examine the efforts of the heating and cooling sides of a thermal pulse.

Figure 5.L-2 shows the thermal loading history to be used during the test. The initial thermal loading for the 3m heater is 3 Kw (1 Kw/meter). It is higher than the loading planned for the Exploratory Shaft Test (0.82 Kw/meter) in an attempt to increase the volume of rock to be disturbed in the shorter time period available for prototype testing. The duration of heating is based on the criteria of heating the rock mass such that the boiling point isotherm extends approximately 0.6-0.7m from the heater borehole wall, as discussed in section 2.2.1. The duration of the test will be determined based on temperature measurements in holes P-1, P-2, and P-3. The parameters to be measured or derived include temperature, moisture content, pore water pressure and air pressure. Temperatures and pore pressures will be used directly with the moisture content to define the spatial distribution of moisture with time around the heater borehole (H-1).

Figures 5.L-3, -4, and -5 shows an approximation of the borehole layout to be used for this test. The final borehole layout will depend on the drilling accuracy, and the presence of localized obstacles such as rock bolts. The test location within G-tunnel is bounded by the "Small Diameter Heater Alcove" and the "Rock Mechanics Incline" as shown in Figure 5.L-3.

The heater borehole will be drilled slightly inclined upward (elevation increases from the collar to the end of the borehole) from the "Rock Mechanics Incline" as shown in Figure 5.L-4. The diameter of the heater borehole will be 30.5 cm (12 in).

The remaining twelve boreholes will be used to monitor the rock response. All of these will be inclined downward (collar elevation is greater than bottom elevation). Table I describes the approximate length, diameter, approximate inclination, and usage for each borehole. The majority of the boreholes will be drilled orthogonal to the emplacement hole axis. This arrangement provides better coverage of the spatial variations in response occuring parallel to the radius of the emplacement borehole. Three boreholes will be drilled parallel to the heater borehole axis to monitor rock response parallel to the heater axis, beyond the ends of the heater. Boreholes P-1, P-2, and P-3 will contain thermocouple psychrometers and one microwave resonator to measure pore pressure, pressure transducers to measure total air pressure and thermocouples.

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......................Principal Investigators For......................

| Geochemical Measurements | Modeling To Be | Hydrologic Measurements | Geotechnical Measurements | Data Acquisition | Geophysical Measurements |
| --- | --- | --- | --- | --- | --- |
| D. Emerson | Determined | W. Lin | T. Ueng | D. Watwood | A. Ramirez |

Figure 5.L-1 Management organization supporting the test.

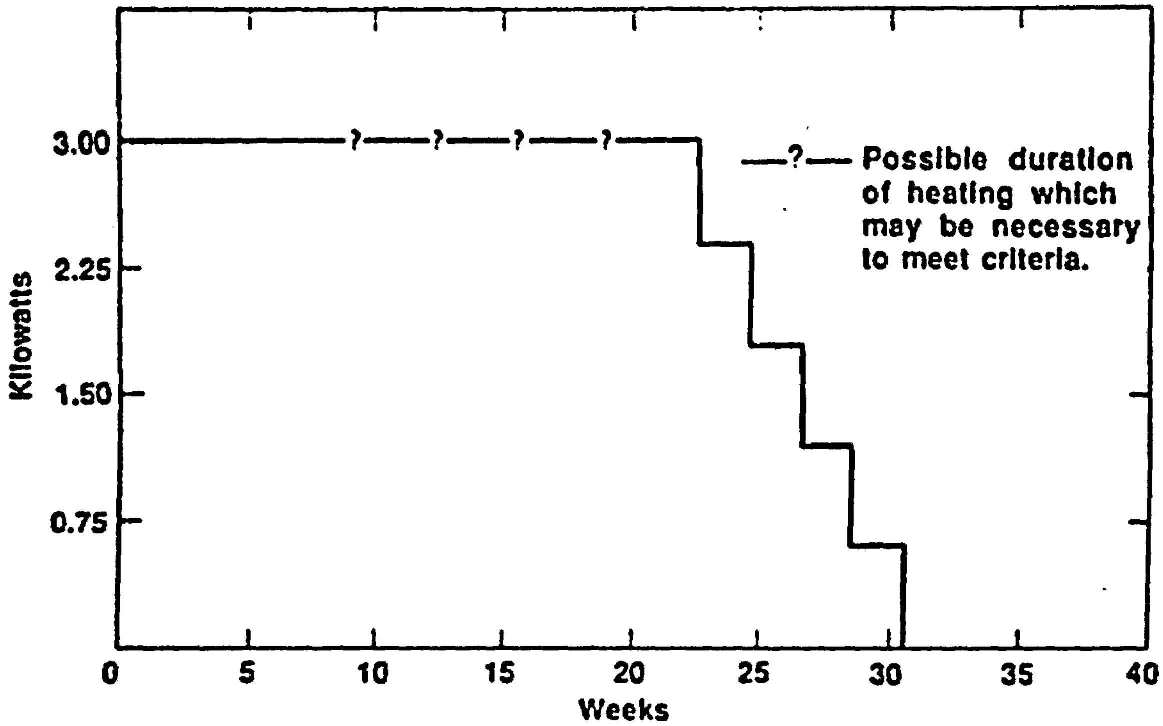


Figure 5.L-2. Thermal loading history planned for the test.

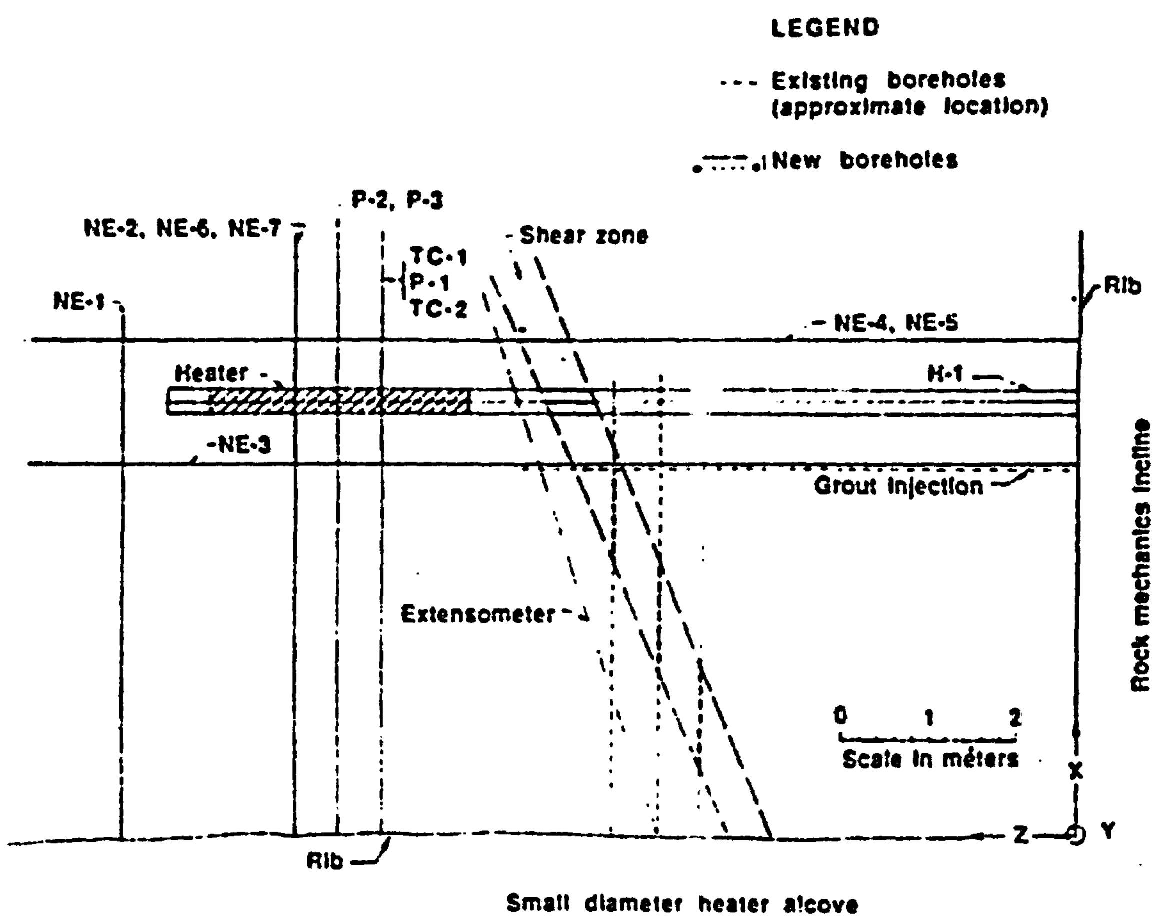


Figure 5.L-3. Plan view of the planned borehole layout. The location of the "Rock Mechanics Incline" and the "Small Diameter Heater Alcove" in G-tunnel are shown for reference.

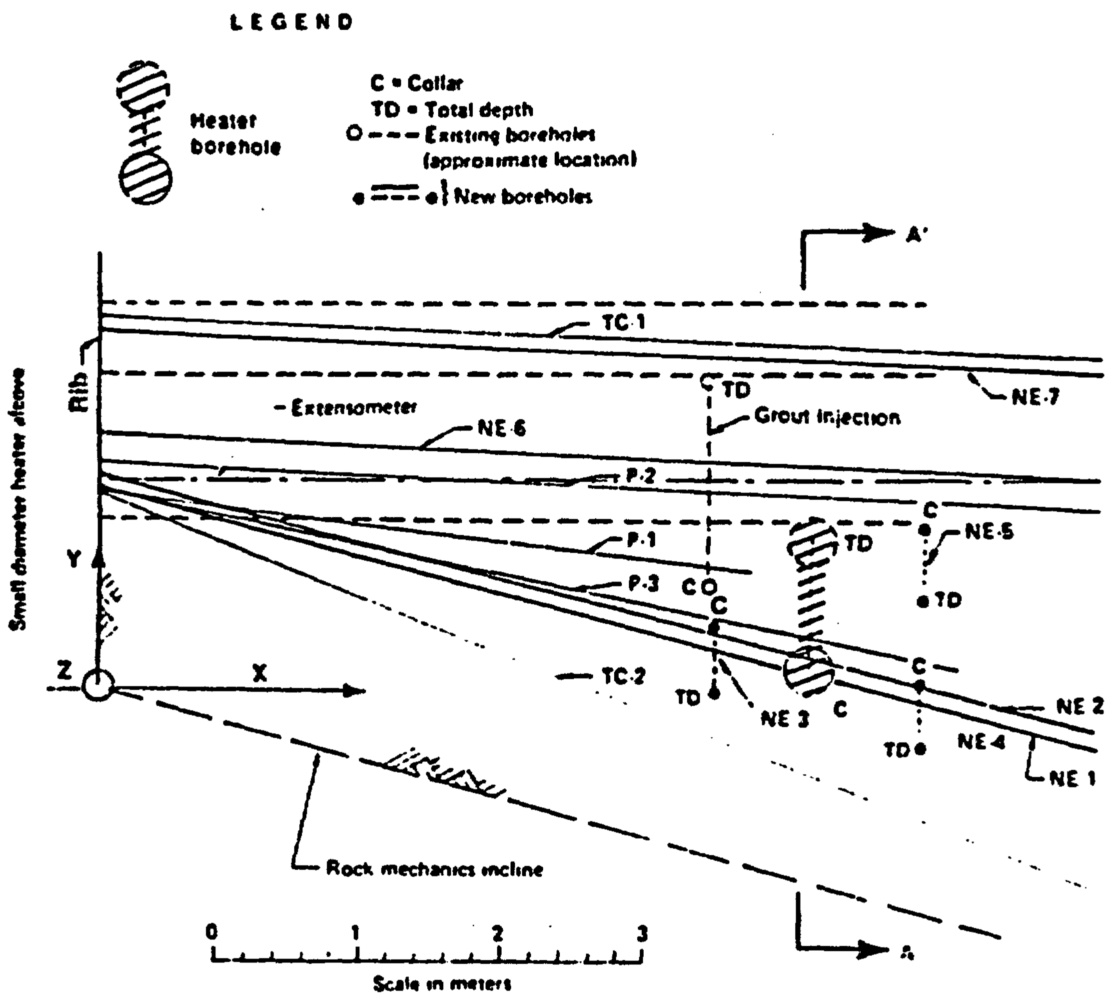


Figure 5.L-4. Cross section view of the planned borehole layout. This view is parallel to the azimuth of the "Rock Mechanics Incline."

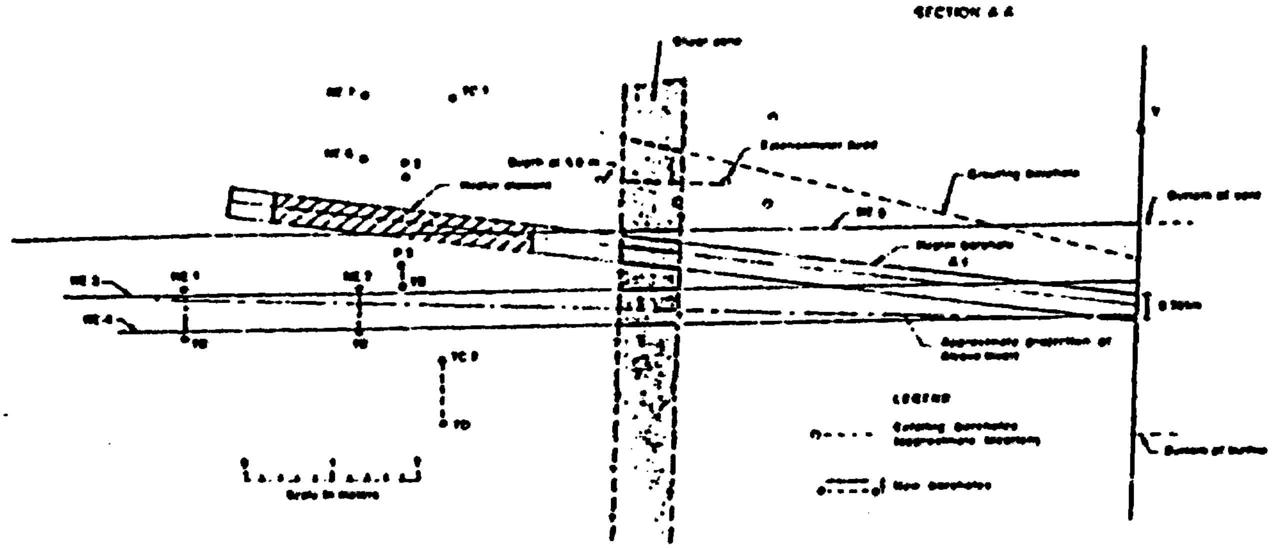

Figure 5.L-5. Cross-section view of the planned borehole layout parallel to the "Small Diameter Heater Alcove" along section line. The view is from the rib of the alcove towards the rock mass A-A1 defined in Figure 5.L-4.

The remaining boreholes (NE-1, NE-2, NE-3, NE-4, NE-5, NE-6, NE-7) will be used for electromagnetic and neutron probe measurements to monitor moisture content. These measurements may, on occasion, be supplemented by gamma-gamma density surveys to detect the slight variations in bulk density caused by changes in moisture content. Boreholes NE-1, NE-2, NE-3, and NE-4 are to be constructed such that a roughly planar surface is defined by the four boreholes. The borehole layout has been designed to maintain a minimum separation of 20 cm at the closest point of approach between boreholes NE-1 to NE-3, NE-1 to NE-4, NE-2 to NE-3 and, NE-2 to NE-4. Figure 5.L-5 shows these boreholes at their closest point of approach. Note that the 20 cm distance is measured from the borehole centerlines. Thus, the minimum distance between the borehole walls should be 20 cm less one borehole diameter (7 cm) or about 13 cm. Borehole NE-5 is to be drilled approximately 2.7 m above the floor of the Rock Mechanics Incline. The ventilation duct may need to be moved at this location to allow sufficient clearance for the drilling rig.

Borehole H-1 is expected to penetrate a highly fractured section of rock identified in Figure 5.L-5 as "shear zone". Existing boreholes which intersect this zone suggests that borehole wall instability is likely due to the high degree of fracturing. Grouting of that portion of the fracture zone to be intercepted by borehole H-1 is planned to improve borehole stability and achieve smooth walls in this region. A criteria letter describing the specifications for borehole grouting has been prepared. Boreholes NE-3, NE-4 and NE-5 will be drilled before borehole H-1 so that the location and width of the shear zone shown in Figure 5 can be determined. This information will then be used to finalize the drilling and grouting plans for borehole H-1.

Table I

| Borehole | Instrumentation | Borehole Depth*(m) | Borehole Diameter | Core Required | Borehole Inclination* |
|---|---|---|---|---|---|
| TC-1 | Thermocouples | 7.0 | NX (75.6 mm) | No | - 2.0° |
| TC-2 | Thermocouples | 7.5 | NX (75.6 mm) | No | -22.0° |
| P-1 | Psychrometer, air pressure transducer, thermocouples | 4.6 | NX (75.6 mm) | Yes | - 7.5° |
| P-2 | Psychrometer, air pressure transducer, thermocouples | 7.0 | NX (75.6 mm) | Yes | - 2.0° |
| P-3 | Psychrometer, air pressure, transducer, thermocouples | 6.1 | NX (75.6 mm) | Yes | -12.0° |
| NE-1 | Neutron, gamma density and electromagnetic surveys | 7.2 | NX (75.6 mm) | No | -15.0° |
| NE-2 | Neutron, gamma density and electromagnetic surveys | 7.2 | NX (75.6 mm) | No | -15.0° |
| NE-3 | Neutron, gamma density and electromagnetic surveys | 13.0 | BX (60.3 mm) | Yes** | - 2.0° |
| NE-4 | Neutron, gamma density and electromagnetic surveys | 13.0 | BX (60.3 mm) | Yes** | - 2.0° |
| NE-5 | Neutron, gamma density and electromagnetic surveys | 13.0 | BX (60.3 mm) | Yes** | - 2.0° |
| NE-6 | Neutron, gamma density and electromagnetic surveys | 7.0 | NX (75.6 mm) | No | - 2.0° |
| NE-7 | Neutron, gamma density and electromagnetic surveys | 7.0 | NX (75.6 mm) | No | - 2.0° |
| H-1 | Heater, thermocouples, moisture trap, microwave resonator | 10.5 | 305 mm(12in) | Yes*** | (+)5.0° |

* All borehole depths and inclinations are approximate. The final depths and inclinations will be determined by the LLNL representative in the field. All boreholes except H-1 are inclined such that the collar elevation is greater than the elevation at the end of boreholes. Borehole H-1 is inclined in the opposite sense.

** Core required only for depths between 4.5 and 6.5 m.

*** The diameter of the core obtained from H-1 can range from 76 mm to 280 mm depending on the drilling method chosen by REECo.

- All other boreholes will be diamond drilled using a 60 mm (BX) or a 75.6 mm (NX) core barrel at the prescribed location and to the prescribed depths in Table 1 and Figures 5.L-3, -4, -5. The location of all boreholes should be established by survey prior to drilling and should include fore and backsight spad points. The driller should establish the alignment of the drill rig using the spad points as references in accordance with criteria established in criteria letters. As-built surveys of the boreholes will also be performed to establish the location and orientation of the boreholes.

### 2.2.1 Comparison of Prototype Engineered Barrier Design Test (WBS 1.2.6.9.4.5.L) and Waste Package Environment Tests (WBS 1.2.6.9.2.5.L)

The Waste Package Environment Test Concept (WPETC) as defined by Yow (1985) calls for the 100°C isotherm to reach a radial distance of about 1m in three months. The prototype test concept described herein will be performed such that the boiling point isotherm (assumed to be in the range of 100-150°C) has extended to 0.6 - 0.75 meters in 7-23 weeks. The duration of heating in the prototype test as estimated by scoping calculations (section 2.6.1) has been estimated to range from 20 to 36 weeks. The heater will be turned off in decrements to depict gradual cooldown of waste. The ramping down will take approximately 8 weeks and thus the prototype test will last at least 15 weeks, while the WPETC test duration will be at least 39 weeks.

Six new measurements have been included in the prototype test that were not listed in the WPETC. Gas pressure will be monitored in sealed boreholes. Air permeability measurements will be made along the emplacement borehole before and after heating. The bulk rock density will be monitored along some boreholes. The water vapor invading the emplacement borehole will be collected, condensed, and its volume measured with time. Microwave resonators will be used to measure air humidity in boreholes. Also, a barometer will be used to monitor changes in atmospheric pressure at the experiment location. The prototype test concept requires separations between the emplacement and measurement boreholes which range along the vertical from 0.5m to 1.5m. The WPETC did not specify a range of borehole separations; however, it is expected that the prototype borehole separations approximate those that will be used for Exploratory Shaft Testing. The emplacement configuration of this first prototype test requires a horizontal emplacement borehole whereas the WPET as currently planned requires both horizontal and vertical emplacement tests.

## 2.3 Test Methods

The actual test methods will be fully developed in individual technical procedures.

### 2.3.1 Control Equipment

The control systems for this test consist of:

1). A power controller and heater operating at a controlled wattage. Heater wattage is to be normally set to the levels shown in Figure 5.L-2 and each wattage level will be kept constant over the time period shown.

2). An uninterruptible power source (UPS) will control the power levels going into the monitoring instrumentation and the recording system. This system will remove any power surges present in the G-tunnel power grid and will insure that instrumentation will continue to function during short power outages (up to 15 minutes).

All other boreholes will be diamond drilled using a 60 mm (BX) or a 75.6 mm (NX) core barrel at the prescribed location and to the prescribed depths in Table 1 and Figures 5.L-3, -4, -5. The location of all boreholes should be established by survey prior to drilling and should include fore and backsight spad points. The driller should establish the alignment of the drill rig using the spad points as references in accordance with criteria established in criteria letters. As-built surveys of the boreholes will also be performed to establish the location and orientation of the boreholes.

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2). An uninterruptible power source (UPS) will control the power levels going into the monitoring instrumentation and the recording system. This system will remove any power surges present in the G-tunnel power grid and will insure that instrumentation will continue to function during short power outages (up to 15 minutes).

3). The control systems for the air permeability measurements will consist of: a) set of packers to isolate sections of the emplacement borehole, b) a pressure regulator with operating pressure of 0-100 psi (0-0.7 MPa) and a precision of 0.2 psi (± 1380 Pa) and, c) a flow regulator with operating range of 0-200 standard cubic feet/min (0-9.44 x $10^2 M^3$/min). 4) A grout/liner system that will be emplaced within the measurement boreholes to prevent boreholes from acting as pressure sinks that would change the hydrologic response of the rock. The materials and emplacement procedures used are described in Technical Procedure - "Grouting of Measurement Boreholes".

### 2.3.2 Measurement Parameters

The following types of data are required:

- a) temperature
- b) gas pressures
- c) complex dielectric constant
- d) thermal neutron and gamma counts
- e) air humidity
- f) air permeability of the rock near the emplacement borehole
- g) heater wattage
- h) time
- i) fracture location and orientation
- j) volume of water vapor in the heater borehole
- k) atmospheric pressure

- o Temperatures are needed to reconstruct the thermomechanical response of the rock and to evaluate the performance of the test equipment during the heating.
- o Gas pressure and atmospheric pressure are needed to reconstruct the flow regime of the air and water vapor in the rock mass.
- o The complex dielectric constant of the rock, thermal neutron and gamma density counts will be used to infer the spatial and temporal changes in the moisture content of the rock mass.
- o The air humidity measurements are used to calculate the pore pressure gradients which drive the movement of liquid water within the rock mass.
- o The inferred moisture content and pore pressure information are used to reconstruct the flow regime of liquid water in the rock mass. The spatial variations in moisture content will be used to infer the flow paths of the liquid water.
- o The air permeability measurements will be used to detect any changes in the rock surrounding the emplacement borehole caused by the heat cycle imposed on the rock. These measurements will be made along the heater borehole as soon as all the other boreholes have been drilled and grouted. The measurements will again be repeated after the heating sequence is completed and the heater is removed from the borehole.
- o Heater wattage will be monitored to document the thermal loading history of the test.
- o Time is needed as a reference for all measurements.
- o Fracture locations and orientations will be measured by borescope and/or borehole TV surveys performed in all the boreholes before the heater is energized and along the emplacement borehole after the test is completed. This information is needed to understand the effects of heating on the stability of the emplacement borehole walls, and to establish the changes in fracture permeability caused by the heating and cooling cycle. It will also aid in the interpretation of the flow regime of vapor and liquid water in the rock mass.
- o The volume of water vapor invading the heater borehole will be measured to obtain estimates of how much vapor flows towards the heater borehole.

## 2.4 Operational and Measurement Equipment

### 2.4.1 Operational Equipment

(a) Heaters - The heater assembly will consist of a 3.0m long heating element and a variable power transformer. The heater assembly will be rated to at least 3000 watts and operate at 220v. The heater rods will be kept separated by metal spacers and centralizers inside a 20.32 cm stainless steel can.

### 2.4.2 Measuring Equipment

#### 2.4.2.1 Instrumentation Requirements

The design requirements for instrumentation are as follows:

a) Maintain operational status under the maximum temperature conditions which develop at the measurement location of the instrument. Figure 5.L-6 shows the results of scoping calculations which show the predicted maximum temperature for various radii away from the centerline of the emplacement borehole.

b) The design requirements also address the high air humidity conditions that are likely to exist in the instrumentation boreholes due to the pressure of steam in the rock mass.

#### 2.4.2.2 Sensors Required

a) Thermocouples - Type K Chromel - Alumel with Inconel sheaths.

b) Gas pressure transducers - Silicon and sapphire sensors.

c) High frequency network analyzer - Operating frequency range 0.5 to at least 1,000 MHz.

d) Thermal neutron and gamma (density) probes. Neutron and gamma source strengths of at least 10mCi.

e) Thermocouple psychrometer

f) Borescope and borehole TV camera - the depth range of the instruments should be 12M or more.

g) Wattage transducer - The power driving the heater will be monitored by the Data Acquisition System.

h) Pressure transducers - (air permeability measurements).

i) Flowmeter - (air permeability measurments)

j) Thermocouples - Type E.

k) Liquid level gauge - operating range from 0" to 60", with a accuracy of ± 0.001", and a repeatability of 0.001% of full scale.

l) Microwave resonator - with a resonant frequency between 0.1 and 3.0 GHz.

m) Barometer sensor - operating range from 0.74 to 1.07 bars.

2.4.2.3 Calibration requirements

a) Thermocouples - Laboratory calibration will be performed on all thermocouples to be used. The electromagnetic force generated by each thermocouple will be measured at 0°, 25°, 100°, 250°, and 20°C. Additional details on calibration can be found in "Technical Procedure for Temperature Measurements".

b) Thermocouple psychrometers - The sensors will be calibrated inside sample chambers where known vapor pressures are generated. The range of temperatures for calibration will be 20°-80°C. Additional details on calibration are presented in "Technical Procedure for Measurement of Suction Potential via Relative Humidity in Unsaturated Rock".

c) Network analyzer - The instrument will be calibrated by the manufacturer using manufacturer developed procedures and NBS traceable standards. Phase shifts caused by other test components (e.g., cables antennas and power amplifier) will be nulled in the field as described in the "Technical Procedure for Installation and Operation of the Electromagnetic Measurement System". Certificates of calibration will be obtained from the manufacturer.

d) Neutron and density probes - The neutron and density probes need to be calibrated in the laboratory using a welded tuff volume at various water saturation levels. At present, a laboratory facility in which to perform this calibration is not available. As a result, the neutron counts will be used to monitor <u>changes</u> in absolute moisture content throughout the test, and will not be used to infer absolute moisture content. A one point calibration (for 100% moisture content) will be performed by the manufacturer to calibrate for source strength and detector efficiency.

e) Borescope and borehole TV camera - The graduated scale within the eyepiece of the borescope will be calibrated by inserting a sheet of quadrille paper inside the borehole of interest to calibrate the distance measured. The quadrille paper should have at least four squares per 2.5 cm x 2.5 cm area. The Technical Procedure - "Borescope Surveys to Map Fractures Intercepting Boreholes" provides additional details on the calibration. The Technical Procedure - "Borehole Television Surveys to Map Fractures Along Horizontal or Subhorizontal Boreholes" describes the calibration of the TV system.

f) Wattmeter - A wattmeter will be calibrated by LLNL Instrument Services following a procedure developed by the Instrument Services Group of the Department of Electrical Engineering at LLNL.

g) Gas pressure transducers and barometer will be calibrated at LLNL High Pressure Calibration Shop using internal procedures. The flowmeters will be calibrated by the manufacturer according to their own procedures.

h) Microwave resonators will be calibrated inside environmental chambers at LLNL where temperature and relative humidity can be controlled. The calibration process is described in the Technical Procedure - "Microwave Resonator Humidity Measurements."

## 2.5 Field Preparations

Field preparations for this test and the organizations reponsible for the various activities are:

a) Surveying of fore and backsight spad points for 13 boreholes of specified locations and orientations (H&N). The borehole locations are as shown in Figures 5.L-3, -4, and -5. The borehole spad points will be surveyed after the surveyors meet with an LLNL appointed representative. A criteria letter specifying the surveying requirements has been prepared. As built surveys of the boreholes will also be performed.

b) All boreholes will be drilled with borehole dimensions as specified in Table I (REECo). A criteria letter detailing the drilling requirements has been provided. After borehole completion the boreholes can be flushed clean with water if needed or air in preparation for borescope mapping.

c) All boreholes will be examined with a borescope and/or a borehole TV camera (LLNL) to map the location and approximate orientations of fractures. The Technical Procedure - "Borescope Surveys To Map Fractures Intercepting Boreholes" and the Technical Procedure - "Borehole Television Surveys to Map Fractures Along Horizontal and Subhorizontal Boreholes" describe the manner in which the survey will be executed.

d) Installation of instrumentation, grout/liners and emplacement borehole seals will be performed upon completion of the borescope surveys. The installations of the thermocouples, thermocouple psychrometers, microwave resonator, and air pressure transducers (LLNL) are covered by the "Technical Procedure for Temperature Measurements," Technical Procedure - "Measurement of Suction Potential Via Relative Humidity in Unsaturated Rock", and Technical Procedure - "Air Pressure Measurements." The installation of the grout (REECo and LLNL) is covered by Technical Procedure - "Grouting of Measurement Boreholes" and by criteria letters.

e) Provisions for a 220v, 30 amp circuit should be available at test region (REECo).

f) Installation of the air permeability packer assembly, and of the moisture collection system are described in Technical Procedure - "Installation and Operation of Heater Assembly and Moisture Collection System."

## 2.6 Related Analyses and Experiments

### 2.6.1 Numerical Analyses

a) Scoping calculations - Thermal scoping calculations are used to plan the test. Important issues are a) to establish the maximum temperatures to which the various sensors will be subjected and b) estimate the maximum distance to the boiling isotherm in the rock. Figure 5.L-6 shows the results of scoping calculations which provide estimates of the spatial and temporal temperature distributions in the rock around the heater. In these calculations, the thermal loading history shown in Figure 5.L-2 was assumed. Pruess and Wang (1984) describe the algorithm used for these calculations. Figure 5.L-6 can be used to estimate the maximum temperatures that sensors will be subjected to and the location of the boiling isotherm as a function of time and distance from the heater. This information was used in defining the borehole layout shown in Figures 5.L-3, -4, and -5, and the location of instruments.

b) Numerical Model Evaluations: The test will provide data which will be used to interpret the hydrologic and thermal environment around the heater emplacement borehole. The interpreted rock response will be one of the inputs to the conceptual model development ongoing at present. The data will also be compared with numerical model predictions in order to check the extent of agreement. It is expected that models and/or test procedures will be adjusted in future testing as a result of these comparisons.

# 3.0 QUALITY ASSURANCE

## 3.1 Scientific Investigation Plan (SIP)

The prototype testing described in this document is described by the SIP for NNWSI Element 1.2.6.9. The title of the SIP is "NNWSI Exploratory Shaft Investigations: Engineered Barrier System Testing Waste Package Environments Tests." This SIP was approved on October 30, 1986.

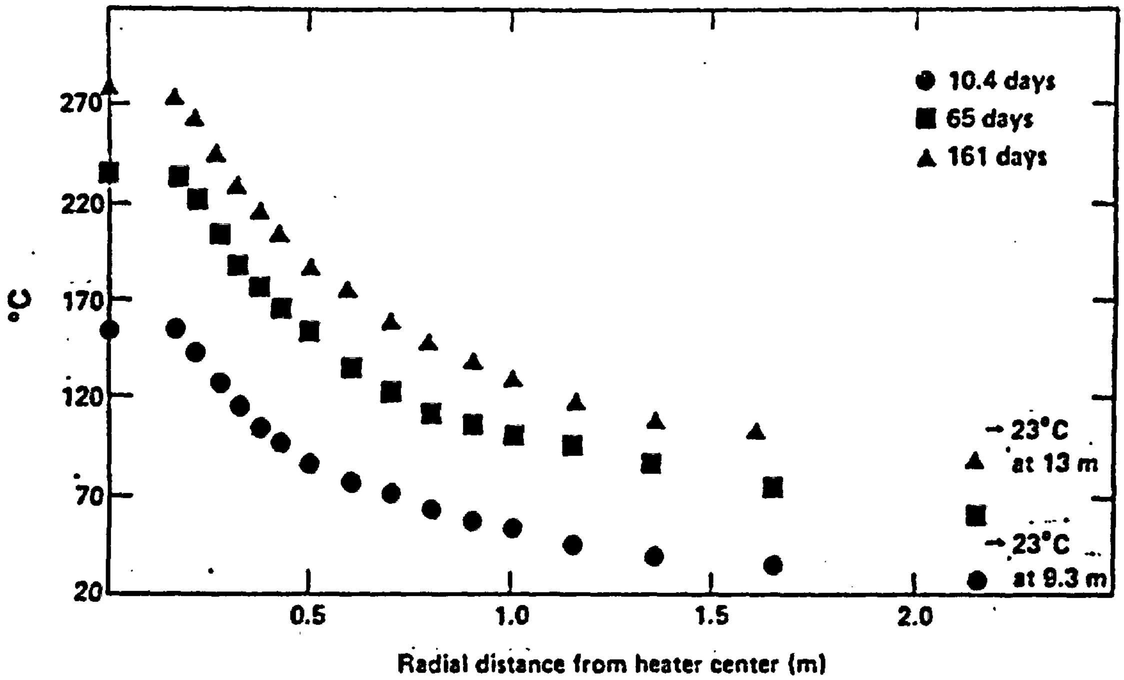


Figure 5.L-6: Scoping calculations showing the spatial and temporal distributions of temperature around the heater.

### 3.2 Quality Assurance Level

This work was assigned a Quality Assurance (QA) level III in accordance with 033-NNWSI-P-20.0 Rev. 0. A copy of the Quality Level Approval Sheet for Activity S-20-1 "Evaluate Test Components in Support of Component Selections" is included in Appendix A.

## 4.0 OPERATIONS

### 4.1 Operational Stages

The prototype test described herein will involve laboratory and field testing. Laboratory testing is used to investigate various grouting materials and to calibrate instruments and for instrumentation shake-down prior to field deployment.

The field portion of this prototype test will be conducted in four phases. A) The ambient temperature phase consists of the measurement of baseline conditions at ambient temperatures. B) The heating phase consists of heating the rock according to the thermal loading history shown in Figure 5.L-2 for the initial 7-23 weeks of heating. The objective of this phase is to monitor the various parameters of interest as the temperatures in the rock mass increase. C) The cool-down phase involves a stepped heater-ramp-down period lasting about 8 weeks. Of particular significance will be the measurements obtained when the maximum drying occurs at the end of the heat phase and when the rock mass temperatures subsequently begin to drop below the boiling point of water. D) The post-thermal stage involves the monitoring of the rock mass over a period of about five weeks after the heater is deenergized.

### 4.2 Measurement Schedule

Borescope and/or a borehole TV camera surveys will be made soon after completion of all boreholes. In addition, surveys of the heater borehole will be performed when the "Post Thermal" (see Section 4.2) stage is completed. Air permeability measurements will be made within emplacement borehole H-1 when all other boreholes are drilled and sealed with grout and liners but before heating starts. These measurements will be repeated after completion of the post-thermal stage when the heater has been removed from the emplacement boreholes.

The sampling frequency to be used during the test is determined by the test conditions expected to be encountered and the need (or lack of) to move the sensors along the boreholes to make the measurement. Immobile sensors such as the thermocouple psychrometers, the thermocouples and the air pressure sensors will be grouted in-place. The barometer will also be an immobile sensor installed within the small diameter heater alcove. These sensors will be automatically monitored on an hourly basis by the Data Acquisition System throughout all the four tests stages described in Section 4.1. The frequency of measurements may be adjusted if test conditions deviate from expectations. One exception to this schedule is the monitoring of the microwave resonators. These sensors will be monitored manually rather than automatically according to the schedule shown in Figure 5.L.7.

The electromagnetic and the neutron probe measurements require that the probes be manually moved along the boreholes. Thus, these measurements require direct field personnel involvement. Two sets of baseline measurements will be made to obtain the reference conditions and verify instrument stability. The measurement schedule to be followed during the test is shown in Figure 5.L-7. This schedule maybe changed as test conditions dictate. The rationale used in determining this schedule is that at times of changing temperatures more frequent sampling is to be performed to monitor the accompanying hydrologic changes. As the rate of temperature change decreases the sampling frequency is decreased. It is estimated that a full set of electromagnetic and neutron measurements can be completed in 0.3 weeks (2 working days). This sets the minimum time step between sets of measurements. It is anticipated that a complete set of measurements will be made before and after each heater power adjustment. Thus, the heater power adjustments are scheduled for mid-week to allow time for "before" and "after" monitoring.

The measurement schedule to be followed with the gamma density measurements will be determined in the field. It is anticipated that these measurements will be made less frequently than the neutron or electromagnetic measurments due to the relatively small changes expected in bulk density.

4.3 Prerequisites

a) Equipment and Instrumentation. The test begins with the mapping of the fractures along the boreholes. The baseline measurements obtained at ambient temperature can start when the instrumentation is in position, has been checked, and the necessary grouting and lining of the boreholes is completed. The instrumentation checkout includes continuity checks, evaluation of signal stability and field calibration (electromagnetic system and neutron probe). The Data Acquisition System checkout will verify that all software is functioning properly and that the data recording peripherals are functioning adequately. This is followed by the measurement of gas permeability, and by the installation and checkout of the heater and monitoring instrumentation. The heater checkout includes a continuity check and verification that the wattage meter is functioning. Entries will be made on the scientific notebook to document all the field checks performed on the hardware. The heating stage can begin when all the hardware checks are completed.

4.4 Test Requisites

a) The ambient temperature testing will be completed when a full set of data from all the emplaced sensors has been obtained. The heating phase will be completed when the boiling point isotherm (assumed to be somewhere between 100°-150°C) is approximately 0.6-0.74 meters away from the centerline of the heater as determined by measurements. Scoping calculations suggest that this condition may be reached after approximately 7-23 weeks of heating at full power. The cool-down phase will be completed in approximately 8 weeks when the energy output of the heater is 0 Kilowatts. The post thermal stage (and the overall test) will end when the hottest rock temperatures are within 20° of original ambient temperatures. It is estimated that this condition will occur 2-3 weeks after the heater is turned off. An additional measurement may be made six weeks after the end of heating.

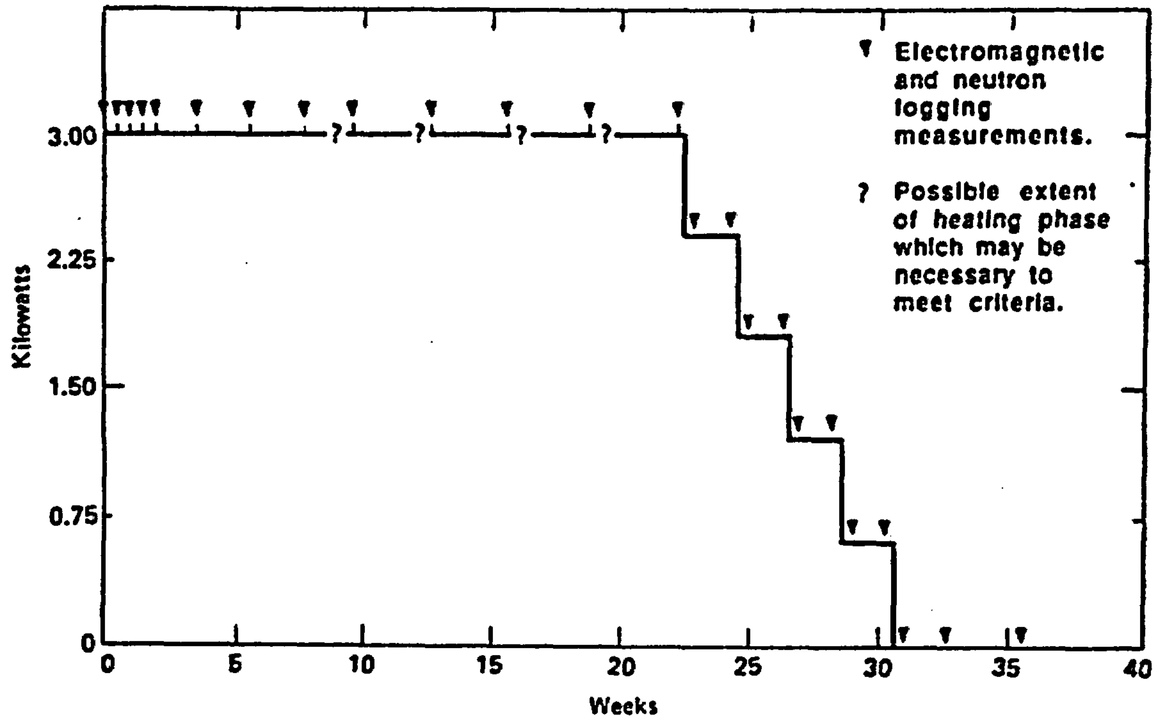


Figure 5.1-7: Measurement schedule for the electromagnetic measurements and neutron logging.

### 4.5 Duration of Field Activities

The time required to complete the field portion of the test is estimated to be approximately 9.9 - 13.6 months (45-61 weeks). The time breakdown is as follows:

| | Activity | Time (weeks) |
| --- | --- | --- |
| a) | Drilling | 6 |
| b) | Grouting, Instrument Installation | 6 |
| c) | Prototype Testing Phase | 20-36 |
| d) | Borescope survey Emplacement Borehole, and overcoring of two grouted boreholes | 3 |
| | | 35-51 (field phase subtotal) |
| e) | Contingency | 10 |
| f) | Data Analysis and Reporting | 13 |
| | TOTAL | 58-74 |

### 4.6 Technical Procedures

Formal technical procedures are not required for QA Level III work. However, two of the goals of this prototype test are a) to prepare technical procedures on a best judgment basis to specify quality controls for the calibration, installation and operation of test components, and b) field test these draft procedures against actual field practices so that their adequacy can be assessed. The procedures have been prepared following 033-NWMP-P5.1. The intended use of these procedures is for field evaluation to check for completeness and validity. These procedures will be reviewed and approved following 033-NWMP-P5.1- "Review and Approval of Technical Procedures".

The following technical procedures have been or will be prepared:

a) Technical Procedure - Borescope Surveys to Map Fractures Intercepting Boreholes
b) Technical Procedure - Neutron and Gamma (Density) Logging in Welded Tuff
c) Technical Procedure - Installation and Operation of the Electromagnetic Measurement System
d) Technical Procedure - Measurement of Suction Potential via Relative Humidity in Unsaturated Rock
e) Technical Procedure - Temperature Measurements
f) Technical Procedure - Air Pressure Measurements
g) Technical Procedure - Installation and Operation of the Data Acquisition System
h) Technical Procedure - Air Permeability Measurements
i) Technical Procedure - Grouting of Measurement Boreholes
j) Technical Procedure - Installation and Operation of Heater Assembly and Moisture Collection System
k) Technical Procedure - Borehole Television Surveys to Map Fractures Along Horizontal and Subhorzontal Boreholes
l) Technical Procedure - Microwave Resonator Humidity Measurements

### 4.7 Criteria for NTS Support

Criteria Letters have been and will be generated by LLNL to request NTS contractor support at G-Tunnel. These criteria letters will specify the support needed and will be submitted through the chain of command indicated by WMPO.

### 4.8 Changes in Prototype Test Plan

This test plan has been written in accordance with 033-NNWSI-R. 11.0 - Test Control. The initial issue is Revision 0. The approval sheet identifies the persons who review and approve the current revision. Changes to this document can be made in the field. The documentation and approval process for these changes is as follows. Scientists supporting the test initiate the process by handwriting the proposed change in carbon-copy memorandum forms consisting of one original and two copies. The memorandum will identify the initiator of the proposed change and the person (Task Leader or Subtask Leader) who gave authorization to implement the change. The original sheet of the form will be attached to the field copy of the test plan and a notation made on the margin of the test plan referring the user to the memorandum. The changes made will be considered when test plan(s) for future test(s) are prepared.

One of the carbon copies will be pasted on the scientific notebooks and the third copy will be returned to the Subtask Leader and filed. Section 8.0 "Documentation" describes the use of scientific notebooks.

### 4.9 Changes in Technical Procedures

The prototype test described herein is a developmental effort where unanticipated events are likely to occur during field activities. The technical procedures prepared for this test will be evaluated in the field and changed as necessary based on the technical judgement of the scientists implementing the procedure. This process of procedure preparation, field evaluation and change is expected to result in the technical procedures that will be used during Exploratory Shaft Testing.

The process to change a procedure is dependent upon the section of the procedure which has to be changed. Changes to procedures sections titled: "Purpose", "Scope", "Responsibilities", "Records", "Personnel Qualifications", and "Safety" are described using carbon copy memorandum forms. The review and approval process for these changes begins when the initiator of the changes writes the proposed changes on the memorandum form. The memorandum identifies the initiator of the proposed changes. The Principal Investigator responsible for the activity will review the proposed change and authorize it by signing the memorandum. The original sheet of the form will be attached to the field copy of the technical procedure and a notation made on the margin of the procedure referring the reader to the memorandum. One of the carbon copies will be pasted in the scientific notebook assigned to the activity and the third copy will be returned to the Subtask Leader and filed.

Documentation of the methods or procedures used to perform the test/activity will be provided by the scientific notebook approach. In contrast to the requirement for documentation of changes to other sections of this procedure, there is no requirement to note deviations from the typical approach in those sections of this procedure that address methods or procedures only. Rather, the method or approach used will be determined by the Principal Investigator or the person assigned by the Principal Investigator to do the work, and the documentation will be provided in the scientific notebook assigned to the activity in accordance with 033-NWMP-R 11.0, Revision 1 (approval pending). As such, deviations from the suggested or typical approaches outlined in this procedure are allowed based on the technical judgment of the scientist responsible for this activity. Revised procedures will then be prepared upon completion of the test using the original technical procedures, memorandum forms and scientific notebooks in accordance with revision procedures outlined in Section 8.2.

## 5.0 DATA ACQUISITION SYSTEM

### 5.1 Data Acquisition System Description

#### 5.1.1 Introduction

The Data Acquisition System described will automatically monitor and record data from all stationary sensors (thermocouples, air pressure transducers and wattmeter). The data from the electromagnetic measurement system and thermocouple psychrometers will be collected and recorded by separate data acquisition systems.

#### 5.1.2. Block Diagram

Figure 5.L-8 is a block diagram showing the major components of the DAS. The separate data acquisition systems for the electromagnetic and thermocouple measurement systems are described in the corresponding technical procedures for both measurement systems.

5.1.3 Hardware

Equipment for the DAS exists as a result of other LLNL testing efforts. The following equipment will be used:

a) Hewlett Packard (HP) 216, Series 200 digital computer with monitor, and line printer
b) Hewlett Packard 3498 Input/Output Expander

c) Hewlett Packard 9133 Hard Disk Storage and Diskette Drive

d) Hewlett Packard 3497A DVM Scanner

5.1.4. Software

Software will consist of data acquisition program prepared at LLNL using the Hewlett Packard DACQ-300 package for instrument control and data acquisition as a basis. The computer will automatically access the scanner to sample the data. Raw data is then recorded on hard disk until transferred to floppy diskettes, the raw data from hard disk will be processed, and the processed data will also be stored in diskette form and also as line printer listings. This information is printed out on the line printer to signify completion of a scan. One option being considered is to turn off the hard disk during periods when excessive vibrations (caused by underground blasting, or nuclear events) are anticipated. Another option considered is to shock-mount the hard disk to dampen any excessive vibrations.

5.1.5 Data Collection Rate

Data will be sampled at one hour intervals with the DAS. This sampling rate may be adjusted as test conditions dictate. At present, it is expected that the one hour sampling rate will provide adequate coverage of the changes to be monitored.

5.2 Data Storage

5.2.1 Manual Data

Data obtained with the neutron probe, gamma density probe, microwave resonator and flow meters (air permeability system) will be manually recorded in the scientific notebooks. Borescope survey data will also be manually recorded in scientific notebooks. These records will be archived in the Records Management System (RMS) of the NWMP upon completion of final reports for the test.

5.2.2 DAS Recorded Data

Data from the monitoring channel of the DAS will be stored on hard disk and transferred to floppy diskettes and line printer listings. Similarly, data from the electromagnetic measurement system will be stored and transferred to floppy diskettes and in line printer listings. Periodically these data on floppy disks will be manually transferred to Livermore for data analysis. When data confirmation has been completed at Livermore, that data will be purged from hard disk to free up space for additional data. These data will be transferred to the RMS for archival purposes after completion of final reports. Data from the thermocouple psychrometers will be stored on floppy diskettes.

### 5.2.3 Data Identification

All the data recorded manually, recorded by the electromagnetic system, recorded by the psychrometer system or recorded by the DAS will be identified by type of measurement, sensor identification and recording time.

## 6.0 PERSONNEL QUALIFICATIONS

Quality Level III work does not require formal certification of project personnel. However, the technical competence and experience of the personnel involved in this test will be documented by submission of resumes showing relevant training and experience.

## 7.0 NONCONFORMANCE ACTIONS

Nonconformance of Quality Level III items activities, or processes will be documented according to 033-NWMP-P 15.0. Corrective Actions will be documented according to 033-NWMP-P 16.0.

## 8.0 DOCUMENTATION

Scientific notebooks will be assigned to the following activities: borehole television, borescope, electromagnetic, resonator, neutron, air permeability and psychrometer measurements. An additional scientific notebook will be kept with general information pertaining to the test as a whole. These scientific notebooks will be archived in the Record Management System after all test data is analyzed and the reports are completed. These notebooks will contain all information required by procedure 033-NWMP-R 11.0, Revision 1, (approval pending) and will be controlled according to the same procedure.

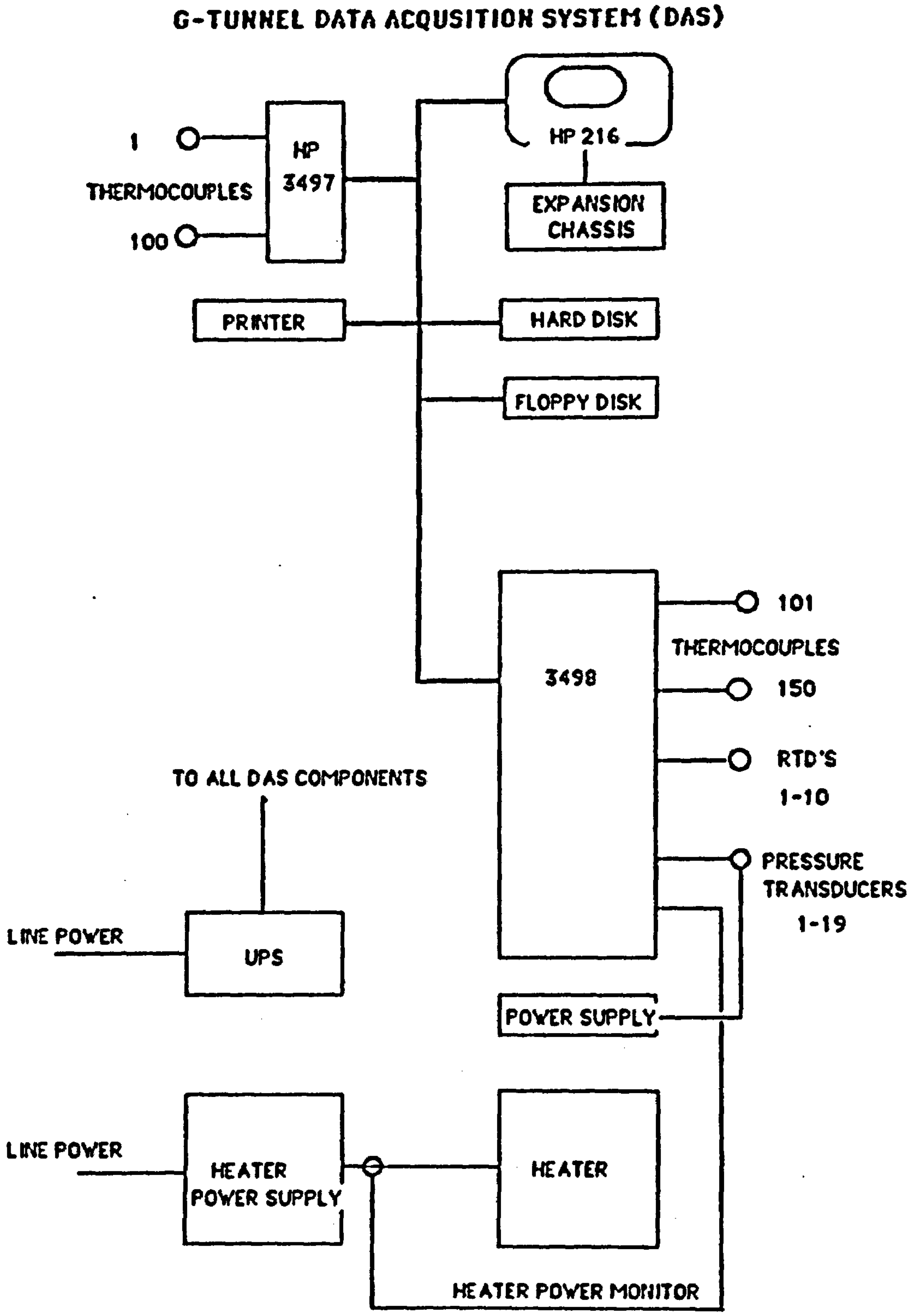


Figure 5.L-8. Diagram showing major components of the Data Acquisition System.

## 9.0 SAFETY

Safety of LLNL activities are the responsibility of LLNL line and project managers as well as the responsibility of the individuals involved. To assist in providing for safety of activities, an organization structure and operating procedures have been established. This, however, does not relieve the individual of responsibility for safe practices and alertness while involved in any activities. Any practices which are observed which appear to be unsafe should be called to the attention of either project management, line management, or safety people as outlined below.

The Earth Science Department (ESD) management has responsibility for safety of ESD personnel and activities. They have issued an Operational Safety Procedure (OSP) which is to be followed by all ESD Personnel. This procedure (OSP No 0-106, "Geologic and Geophysical Field Operations") gives overall guidelines on safety. This OSP is augumented by additional procedures and safety groups as appropriate. The Hazards Control (HC) Department has been delegated responsibility for safety for activities which take place at LLNL's facilities in Livermore. All technical procedures covering work at Livermore will be submitted to HC for review. The designate responsibility for LLNL activities at the Nevada Test Site is given to the Nuclear Test Operations Department (NTOD) Head. The safety aspects are coordinated by NTOD Health and Safety Group. All technical procedures for activities at NTS will be submitted to NTOD-H&S for review. Specific safety hazards that have been identified are discussed below.

There are four potential hazards associated with this testing. The first is the use of electrical resistance heaters that will become hot when energized and represent potential electrical shock. The second potential hazard pertains to the handling and operation of neutron and gamma ray probes containing radioactive sources and also, to the tritium vapor present within G-tunnel which will be inhaled by workers. The third potential hazard is that associated with normal underground activities and construction equipment. A fourth potential hazard is associated with the compressed air lines and pressurized packers used for air permeability testing.

The heaters can generate temperatures higher than 300°C and need special handling precautions. The heater will only be energized when it is in position within the emplacement boreholes. An exception to this will be when the heater is briefly energized (for a period of less than a minute) for check out purposes prior to emplacement. The heater temperatures will not present a significant hazard during this short check out and access will be restricted at this time. Once in the emplacement borehole the heater will be energized for the duration of the test. The heater will be removed from the emplacement borehole at the completion of the test after being deenergized for a period of two to three weeks. Heater temperatures at this time are expected to be within a few degrees of ambient conditions and no significant hazard is expected.

The neutron and gamma ray probes each contain a radioactive source which requires special handling and operating precautions. Responsibility for the tool is assigned to one person who insures that the tool is stored, transported and used in a safe manner as prescribed in technical procedures. This person will also insure that access to the neutron tool is controlled and documented. The tool is to be stored in a locked container and a log book will be kept with the tool indicating the people that have opened the locked container and used the tools. The Technical Procedure - "Neutron and Gamma (Density) Logging in Welded Tuff" provides specific handling safety procedures. In addition, the Nevada Test Site Safe Operating Procedures: NTS-230: "On-site Handling, Transportation and Storage of Radioactive Materials" and NTS-231: "Source Control" will be followed.

The tritium present in the air within G-tunnel exposes underground workers to another source of radioactivity. Workers within G-tunnel will be monitored in accordance with instructions from an LLNL Health Physicist to insure that exposure to tritium of all workers implementing this test plan falls within acceptable limits. Appendix B contains pertinent information regarding tritium exposure within G-tunnel.

The third potential hazard is that associated with normal underground activities and construction equipment including potential electrical shock as well as working at NTS. Reynolds Electrical & Engineering Company is in charge of tunnel safety at NTS. Their procedures and instructions will be followed. LLNL's safety procedures are coordinated through LLNL-NTOD Health and Safety Group, which will receive copies of all procedures. The LLNL NTOD Health and Safety Manual will be followed. (An additional safety procedure to be followed is LLNL's Earth Science Department Operations Safety Procedure No. O-106, "Geologic and Geophysical Field Operations.")

The fourth potential hazard is that associated with the pressurized gases used for air permeability testing. The maximum compressed air pressure to be used is 95 PSI (0.65 MPa), which is the compressed air line pressure at G-tunnel. Every time the packer assembly is inflated within the borehole, a restraint consisting of two rock bolts and steel rope or chain will be used to prevent ejection of the assembly from the borehole. The compressed air lines and gauges which remain outside the borehole will be secured against the steel mesh covering the tunnel walks to limit the travel distance of the line in the event of a rupture or a blowout.

## 10. REPORTS

The planning of this test effort is covered by this test plan and in the associated technical procedures. Preliminary data output and analysis may be reported in at least one LLNL UCID report. Final data interpretation and analysis will be reported in at least one LLNL UCRL report. Results from laboratory testing and numerical analysis will be reported in several UCID's with the possibility of upgrading to UCRL reports. It is expected that these results will also be included in papers submitted to technical conferences and to scientific/engineering journals.

One of the important outputs of this testing will be the development of field tested technical procedures as listed in section 4.6.

## 11.0 REFERENCES

### 11.1 LLNL References

a) Yow, J. L. (1985), "Concept of Waste Package Environment tests in the Yucca Mountain Exploratory Shaft," Lawrence Livermore National Laboratory, UCID-20450.

### 11.2 Nuclear Waste Management Program Quality Assurance Program Plan References

033-NWMP-P.1.0 - Organizations
033-NWMP-P.5.0 - Instructions, Procedures and Drawings
033-NWMP-P.5.1 - Preparation of Technical Procedures
033-NWMP-P.5.2 - Review and Approval of Technical Procedures
033-NWMP-R.11.0 - Test Control
033-NWMP-P.15.0 - Nonconformances
033-NWMP-P.16.0 - Corrective Action

### 11.3 Nevada Test Site (LLNL) References

On-site handling, transportation and storage of Radioactive Materials, Procedure Number NTS-230, Lawrence Livermore National Laboratory, Nevada Test Site.

Source Control, Procedure No. 231, Lawrence Livermore National Laboratory, Nevada Test Site.

### 11.4 External References

Pruess, K. and J. Y. Wang (1984), "Tough-A Numerical Model for Nonisothermal Unsaturated Flow to Study Waste Canister Heating Effects," Mat. Res. Soc. Symp. Proc. Vol 26, pp. 1031, Elsenor Science Publishing.

Zimmerman, R.M. & M.B. Blanford (1986), Expected thermal and hydrothermal environments for waste emplacement holes based on G-Tunnel heater experiments. Proc. 27th Symposium on Rock Mechanics, Chapter 125, p.874-882.

# Appendix A

## Quality Level Approval Sheets

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: 7-31-86

Meeting Attendees: J. Yow, L. Ballou, J. Dronkers

Name(s) and number(s) of Activity: S-20-1/WBS 2.6.9.4.5
Evaluate test components in support of component selection

S.I.P. Identification: Engineered Barrier System Testing

Additional Comments:

This includes laboratory and field trials of components and techniques leading to selection of components and development of procedures. This includes prototype testing.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF III

10-6-86
Task or Subtask Leader Date

10-21-86
Deputy Leader for QA Date

10-16-86
NWMP Deputy Leader Date

10-20-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

10-21-86
Project Sponsor Date

10/20/86
Project Sponsor Quality Manager

RETURN TO LLNL NNWSI QA FILE

# Appendix B

## G-Tunnel Tritium Levels

**Nuclear Test Operations**

*Interdepartmental letterhead*

Mail Station L 777

Ext 6347

EMO-21-87

February 4, 1987

MEMORANDUM

TO: Lyn Ballou, L-206

FROM: K. M. Oswald

SUBJECT: RADIOACTIVITY INFORMATION, U12g

Per your telecon February 3, 1987, here is the information requested:

1. The results of the quarterly sampling done by REECo Environmental Services indicates the peak concentration of H-3 was found near the Rock Mechanic Incline - $6x10^{-7}$ µCi/cc.

2. The Maximum Permissible Concentration for monitored workers, based on an eight-hour day, forty-hour week exposure is $5x10^{-6}$ µCi/cc. This is about eight times the peak levels found in U12g.

3. The Maximum Permissible Concentration for uncontrolled areas is $2x10^{-7}$ µCi/cc. This is based on a 168-hour week of continuous exposure.

University of California
Lawrence Livermore National Laboratory