U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: THERMAL MANAGEMENT STRATEGY

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Thermal Management Strategy

- Overall strategy
- Thermal goals
- Testing
- Design and operational considerations
- Issues
- Summary

Thermal Loading Considerations

- **Definition**
  - Thermal loading is due to the mass loading of waste per unit area, usually measured in MTU/acre
- **Objective of the reference thermal loading range**
  - Use thermal loading to create a dry low-humidity drift that does not rewet until after Waste Package surface temperatures have fallen well below the water boiling temperature

Thermal Loading Considerations
(continued)

- **Impacts of thermal loading options**
  - Waste Package design, subsurface design, surface design, site characterization, and performance assessment are affected significantly by the choice of thermal options
- **Implementation approach**
  - Studies provided recommendations for requirements
  - Have developed a Thermal Loading Strategy
  - Progressing with designs and design evaluations
  - Initiated an integrated thermal testing program

Thermal Loading Strategy

- The repository design should accommodate at least the statutory maximum capacity of 70,000 MTU
- The reference thermal loading range is 80-100 MTU/acre
- Use testing and modeling to provide reasonable assurance that thermal loading aspects of the design meet performance objectives
- Retain flexibility to accommodate alternative thermal loads

Thermal Goals, Assumptions and Requirements

Goals

Initially defined in the Site Characterization Project

Updated in Systems Studies

Assumptions

Documented in the Controlled Design Assumptions Document

Requirements and Criteria

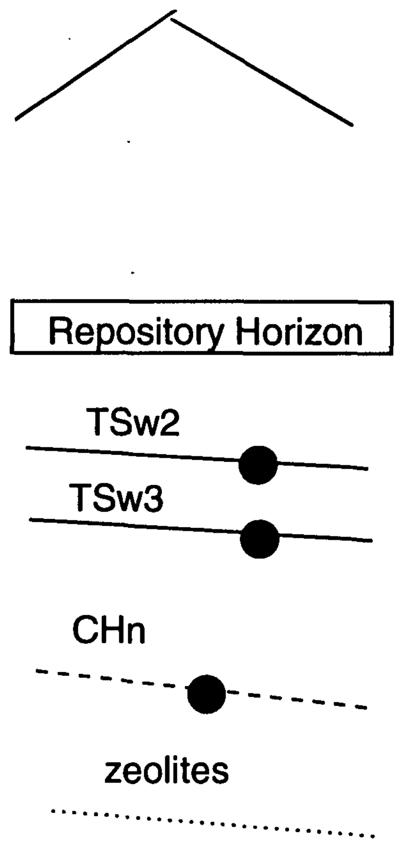
In the MGDS Requirements Document and System Description Documents

Thermal Goals

- The following goals are being reevaluated because they are currently identified as strong design drivers
- Cladding temperature limit (<350°C) retained due to potential performance benefit (1-2 orders of magnitude)
  - Related secondary goal for backfill, thermal conductivity >0.4 to 0.5 W/m·K for the ACD design, if the backfill is emplaced just before repository closure
- Drift wall temperature limit (<200°C) retained to limit ground support goals
  - Based on conservative calculations of thermal stress and rock expansion

Geochemistry Thermal Goals

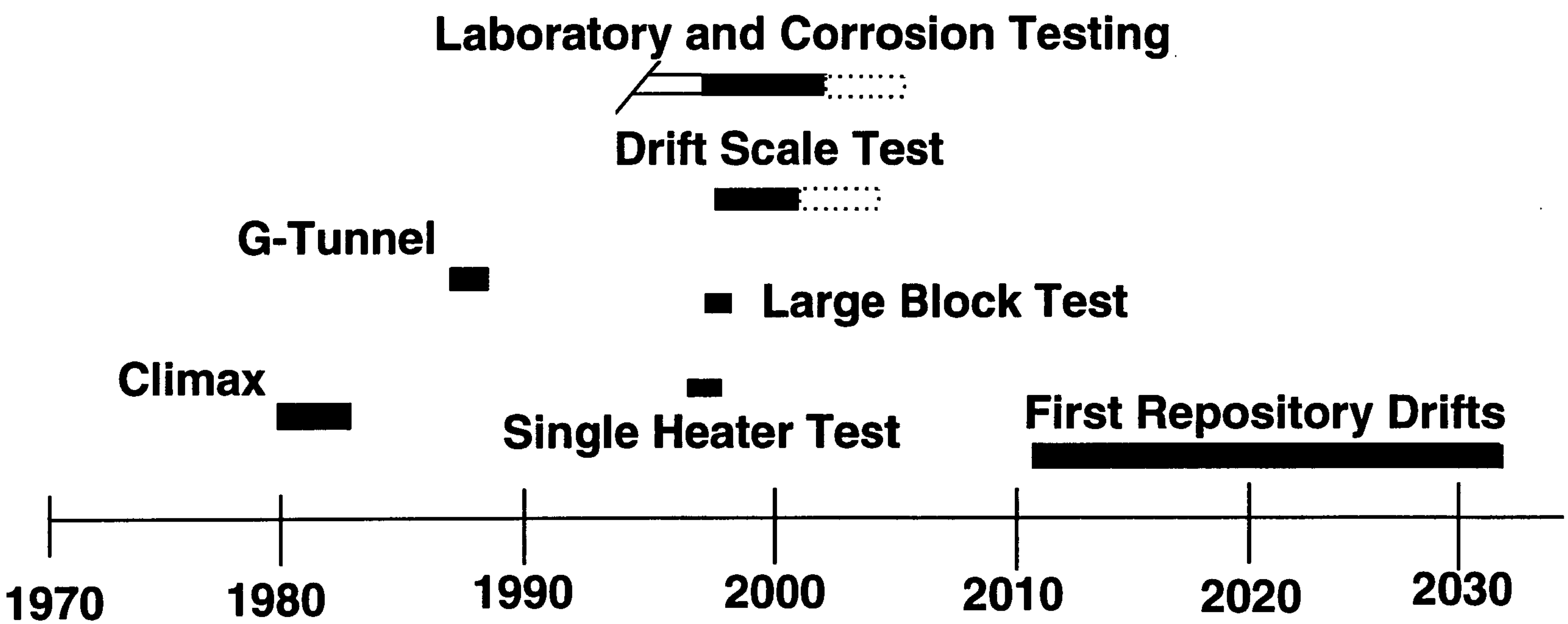
- **The goal of a 115°C limit at the TSw2/TSw3 interface will be deleted**
  - **No technical basis was found for the goal**
- **The goal of a 115°C limit in the CHn unit will be modified, as below, to protect the zeolites**
- **The new goal will be a 90°C limit 170 m below the repository horizon**
  - **This is the depth to most of the zeolite layer**
  - **About 10-15% of the area will have some zeolites above this layer**
  - **The goal is compatible with much of the reference thermal loading range**



Testing

- Laboratory tests
  - Thermal, mechanical, hydrological properties of the matrix and rock mass
  - Processes such as imbibition, mineral dehydration, and fracture closure
- Corrosion tests
  - Accelerated tests of multiple materials and environments in tanks
  - ThermoGravimetric Apparatus tests
  - Potentiostatic tests
- *In situ* coupled process tests
  - Accelerated to observe thermal phenomena

Thermal Test Timeline



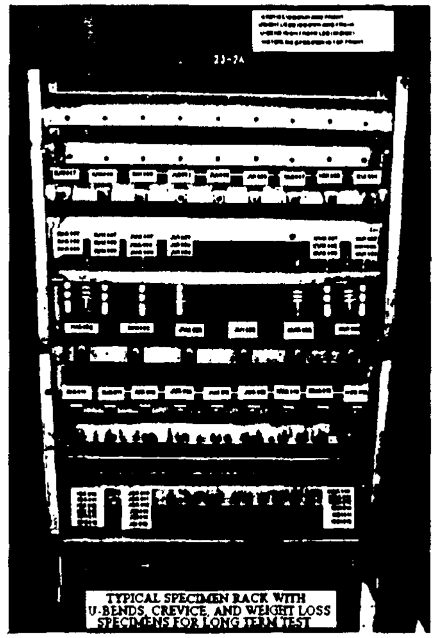
Single Heater Test

- First thermal test in the Exploratory Studies Facility
- Test instrumentation for the drift scale test
- Rock properties for geomechanical design
- Began on schedule August 26, 1996
- Approximately one year of heating
- 35 instrument holes, >600 instrument channels

Corrosion Test Facility

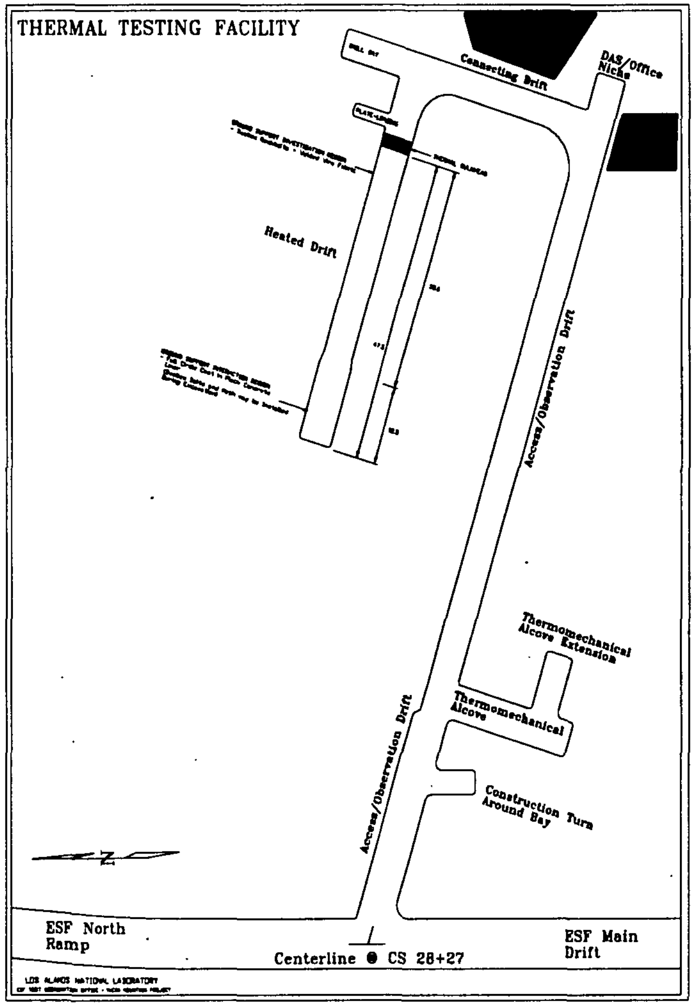
- Waste Package reference design materials (alloy 625, carbon and stainless steels) and alternate materials (e.g. hastelloys, titanium, copper alloys)
- Typical (J-13 water) and three bounding (acidic, alkaline, concentrated J-13) environments
- Includes galvanic (cathodic protection) tests
- Phased activation, Phase 1 began testing in September 1996


1 OF 5 SPECIMEN RACKS BEING LOWERED INTO TEST VESSEL ON 9-24-96


TYPICAL SPECIMEN RACK WITH U-BENDS, CREVICE, AND WEIGHT LOSS SPECIMENS FOR LONG TERM TEST

Drift Scale Test

- Coupled thermal-mechanical-hydrological-chemical processes
- Full diameter drift and canister heaters
- 47.5 m of drift with 12.5 m cast-in-place concrete liner section
- 2-4 years of heating, depending on processes that are observed in the first two years
- Heater activation scheduled for late calendar year 1997
- 144 instrument holes, ~6500 instrument channels



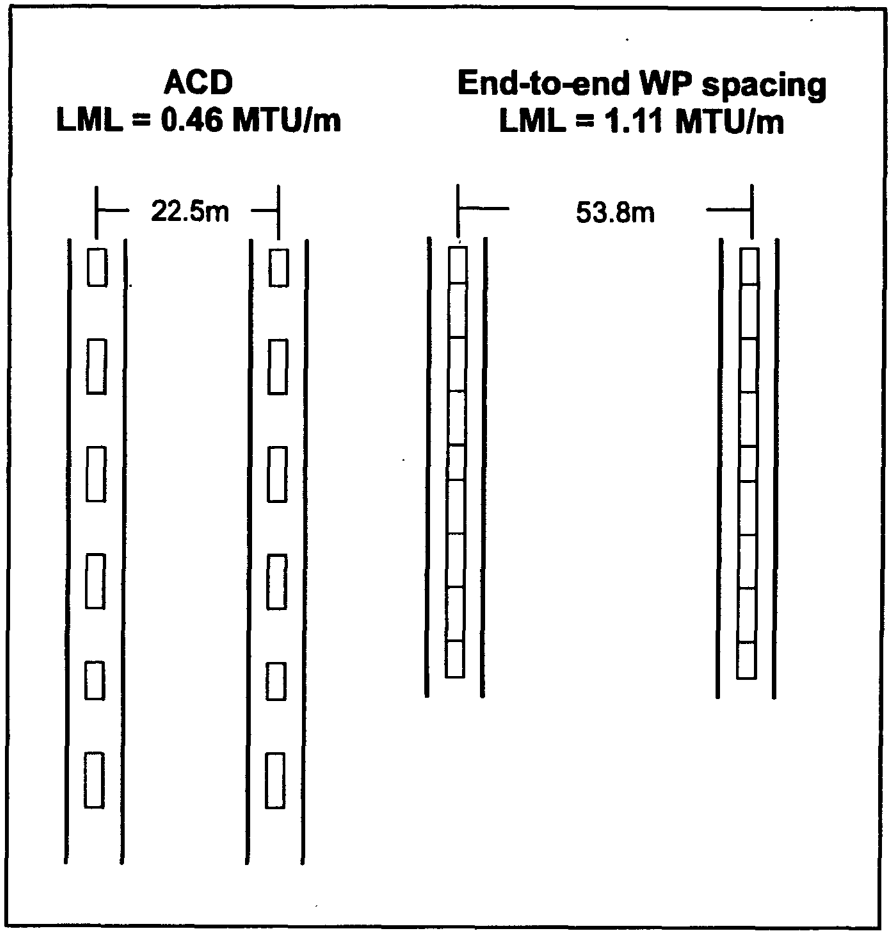
Thermal Management Operational Techniques Evaluated

- **Controlling emplacement sequence of Waste Packages or Spent Nuclear Fuel (SNF) assemblies**
  - Waste Package sequencing reduced power variation between Waste Packages by 4x (due to aging)
  - SNF assembly sequencing reduced power variation between Waste Packages by 10x
- **Higher thermal loading at repository edges**
  - The current design does not use enhanced edge loading because recent calculations do not indicate a large benefit. This issue will not be revisited during the VA design period
- **Ventilation**
  - The current design does not ventilate emplacement drifts because of increased cost and complexity

Thermal Management Operational Techniques Evaluated

(continued)

- For thermal loads below 100 MTU/acre, the Waste Packages can be spread as "points" in a "square" spacing, or concentrated in more widely spaced drifts (line loading)
- Line loading reduces the Waste Package to Waste Package temperature variation and drift construction costs, but generates somewhat higher temperatures for the hottest Waste Packages
- Line loading is an option under consideration for design implementation



Operational Considerations

- Some subsurface sequencing of sealed Waste Packages could be used to allow optimal sequencing of Waste Packages in drifts, particularly if the sequencing area is well ventilated
- Emplacement drifts could be either completely filled prior to moving to the next drift, or several drifts could be filled simultaneously
  - It will take two to three months to fill a drift, if that is the only drift being filled
  - Even one year is a small time when compared with the amount of time for heat to conduct across the pillar of rock between drifts
  - Having several drifts open could help in sequencing hot and cold Waste Packages, thereby reducing lag storage requirements

Issue: Effects of Higher Percolation Flux on Design

- Current designs and performance assessments are based on a percolation flux of 0 to 0.3 mm/yr
- Recent site characterization data indicate that a flux of 1 to 10 mm/yr may be more appropriate
- Preliminary calculations for an 83 MTU/acre indicate that at 1 to 5 mm/yr there is less dryout and relative humidity reduction

Issue: Effects of Higher Percolation Flux on Design

(continued)

- Design has several options
  - Increase thermal loading (to offset the flux)
  - Decrease the thermal loading and use more robust waste package materials
- This issue will be studied more during design development for VA

Summary: Thermal Management Decisions (Current Status)

- Decisions made
  - Established a design basis thermal loading range (80-100 MTU/acre)
  - Selected most thermal management options for VA
    - » Line loading is still being evaluated
  - Determined the initial thermal and corrosion testing program needed to support VA and LA