CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Attend the U.S. Geological Survey (USGS) Committee for the Advancement of Science in the Yucca Mountain Project (CASY) Symposium (20-5704-023)

DATE AND PLACE: March 24-25, 1993
Golden, Colorado

AUTHOR: Randall D. Manteufel

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PERSONS PRESENT: Randall D. Manteufel, (CNWRA)
John W. Bradbury, (NRC)
Attendance list not published, but over 100 attendees

BACKGROUND AND PURPOSE OF TRIP:

The CASY symposium is sponsored by the USGS and draws a spectrum of technical persons from many different organizations [USGS, Sandia National Laboratories (SNL), Lawrence Livermore National Laboratory (LLNL), Science Applications International Corporation (SAIC), Los Alamos National Laboratory (LANL), Lawrence Berkeley Laboratory (LBL), U.S. Nuclear Regulatory Commission (NRC), Center for Nuclear Waste Regulatory Analyses (CNWRA), etc.]. The topic of the meeting was "Effects of Repository Thermal Loading on Fluid Movement and Geochemistry at Yucca Mountain." The USGS sponsors continually stressed the technical aspects of the subject and moderated questions and/or comments in order keep the focus on technical issues (with the encouragement and support of the attendees).

SUMMARY OF PERTINENT POINTS:

The two day symposium was divided into four half day sessions. The agenda is provided in attachment A. The sessions were organized along the following topics:

- Introduction/Review of Thermal Loading Options
- Thermal effects on Geochemistry
- Thermal effects on Hydrology
- Panel Discussion

Due to illness, I was able to attend only the first and third sessions. John Bradbury, (NRC) was able to attend all of the sessions.

The major observations from the talks are summarized here:

- Everyone was very collegial, engaging in open comments which stressed how different organizations (eg., SNL, LBL, LLNL) were contributing in a complementary manner to the overall Yucca Mountain Project (YMP).

- Horizontal drift emplacement has essentially replaced the vertical borehole emplacement for many analyses/discussions.

- The "hot" repository concept is now called the "extended-dry" concept.

- The term "cool" repository is now called the "SCP design thermal load repository".

- Many calculations with 30 year old spent fuel (versus 10 year old) were presented. There appears to be an assumption that older fuel (which has a different temporal decay heat profile than younger fuel) will be emplaced in the repository.

- There was a broad consensus regarding the need for better characterization of thermal/hydrologic/chemical properties of the geologic medium.

- LLNL people stressed the importance of the planned block-heater test ($4.5 \times 3 \times 3$ m), and a proposed field heater test.

- Numerous discussions took place on the anticipated buoyancy-driven gas flow above the water table, and potential buoyancy-driven liquid flow below the water table.

- Discussion occurred on the potential "heat-pipe" effect, although this was always caveated to be dependent on the assumed values of the effective properties (e.g., permeability and characteristic curves) and also dependent on the assumption of equivalent continuum models (while heterogeneities are expected to be important).

The highlights of many of the talks are summarized below.

Bill Dudley, (USGS) gave opening comments for the symposium. He stated that the USGS has always encouraged that the geologic repository design minimize the magnitude of the thermal loading, hence minimize the thermal effects. He noted that LLNL is proposing that an intense and sustained thermal loading be incorporated in the design, and that this would be discussed at the symposium. He also stressed that everyone should identify what data is known and what data is needed in order to characterize the thermal-hydrologic and the thermal-chemical interactions.

Dick Morissette, (SAIC) gave a historical overview of thermal loading considerations from 1980 - present. This talk was also given to the NWTRB in October 1991 by Mike Voegele, SAIC. Very early in the program, it was recommended that the temperature at 15 percent of the distance from the repository to the ground surface not exceed 100 C. For Yucca Mountain, this is ~ 50 meters above and ~ 50 meters below the repository for the maximum extend of the 100 C isotherm. In 1982/3, the Early Site Design Criteria (NWTS-33) specified design requirements with respect to containment and isolation of the repository. Here, the initial thermal load was set to 12-15 W/m^2 so that the thermal by induced alterations were minimized in the far field. Dick also discussed SAND85-2509, SAND83-0372, and

SAND86-1955 as these reports continued to quantify the favorable and unfavorable effects of thermal loads on the preclosure mechanical and postclosure geochemistry and hydrology. He concluded that geologic disposal would be a much simpler problem without the effects of heat.

Larry Ramspott, (LLNL) discussed thermal loading options. Larry stressed the need for: (i) simple safety strategies such as the choice of an arid repository site; and (ii) need for improving the state-of-understanding of thermal loads for both the "SCP design" and "extended dry" concepts. He stressed that field heater tests are very important in helping us understand the physics. Larry summarized the extended dry concept being based on "No water, no dissolution, no transport." He also made the distinction between "prevention" barriers and "mitigation" barriers. A prevention barrier would be one that (for example) keeps water from the containers. A mitigation barrier would be (for example) Calico hills which is expected to sorb radionuclides. Overall, Larry stressed the need for field heater tests, such as those being planned and proposed by his group.

Dale Wilder, (LLNL) gave an overview of the LLNL extended dry concept in contrast with the SCP conceptual design for thermal loads. The SCP is based primarily on the capillary barrier due to open boreholes which keep waste packages dry. The extended dry concept uses heat to dryout the nearby rock and elevate temperatures to keep the containers dry. He stressed that the unsaturated site is intuitively a good site, the problem is demonstrating that it is good. For a saturated site, the thermal effects on hydrology are not good for performance, but are easier to characterize. He noted that Lin and Daily, LLNL, have performed laboratory experiments which indicate that the extended dry concept will form very sorptive minerals which is good for geochemistry, but this was a passing comment instead of a main point in this talk.

Tom Buscheck, (LLNL) talked about the impact of thermal loads on hydrothermal flows, primarily as proposed in the extended dry concept. He addressed three main topics:

- Can the thermal load limit hydrologic effects to waste containers?
- Will the SCP design meet regulatory requirements?
- Will higher thermal loadings help demonstrate compliance with regulatory requirements?

The major points of Tom's talk are summarized here. Numerous numerical calculations were performed with bulk saturated permeabilities ranging from millidarcy up to 840 darcy. Heterogeneities were not simulated, but the layering characteristics were accounted for. Calculations show that buoyancy driven flow set up convection cells (gas phase above the water table, and liquid phase below the water table), and these need ~ 1000 years to develop yet may persist for tens of thousands of years. Buoyant gas flow results in a buildup of saturation above the edge of the repository, which was noted to be important in wetting containers located at the edge. The importance of buoyancy, however, is highly dependent on the bulk permeabilities which remains difficult to characterize. The extended dry concept was noted to have the benefits of: (i) knowing the extent of the 95 C boiling isotherm; (ii) retardation of episodic infiltration due to a large dry-out zone; and (iii) retardation of condensate dripping due to a large dry-out zone. The extended dry concept keeps the groundwater boiling and flowing away from the repository for up to 1000 years. Hence, the system is dominated by boiling/condensation instead of buoyancy. Sensitivity studies for the extended dry concept were performed, where if the bulk permeability is above 1 millidarcy (which is considered very low, and safe to assume), then the dryout zone is dominated by fractures so that the extent of the dryout can be calculated with confidence. Tom repeatedly emphasized

the importance of the planned LLNL block heater test (4.5 × 3 × 3 m). The block heater tests would include one-dimensional (1D) heat transfer which would be primarily conduction dominated. The test would investigate (among other things) the "heat pipe" effect to show when convection affects the heat transfer and when the conduction-dominated assumption is not valid. Field scale heater tests were briefly mentioned, where a "gallery" is proposed below the heaters in order to collect and analyze dripping condensate water.

Larry Constin, (SNL) discussed thermomechanical effects and laboratory experiments being conducted at SNL to characterize jointed rocks. He noted the joints account for much of the thermal expansion of the rock mass. In laboratory experiments conducted at SNL, it was found that normal loads change fracture flow by a factor of at most 2-3, while shear loads change fracture flows by orders of magnitude. The effects could be either to increase or decrease fracture permeabilities, depending on initial load conditions, initial seating conditions, soft/hard fracture coatings, etc.

Ben Ross, (Safety Disposal consultant to SNL) gave a talk which summarized his earlier papers presented at the International High-Level Radioactive Waste Management Conference (HLRWM) in Las Vegas, NV. His topics were:

- Classification of potential heat transfer regimes, and
- Benard-type buoyancy stability analysis.

The potential heat transfer regimes include: (i) conduction dominated; (ii) buoyant flows; and (iii) heat pipe. Conduction dominated conditions appear to be most prominent as observed by many other researchers. Similar to the calculations presented by Tom Buscheck, (LLNL) buoyant flow requires about 1000 years to develop and are more important at large distances and long times. Heterogeneities are expected to be very important, yet have been neglected in the calculations due to poor characterization of the site. A Benard-type stability analysis was presented where it was shown that the water vapor has an effect of reducing the critical Rayleigh number from ~ 40 to ~ 0.1. The lower Rayleigh number increases the importance of convection heat transfer which has typically been neglected. Ben suggested that bulk permeabilities of ~ 10 darcy appear realistic for Yucca Mountain.

Ed Kwickless, (USGS) presented a numerical comparison between the dual-porosity and the effective-continuum models for hydrologic calculations. A 1D Yucca Mountain model was developed for liquid and vapor flow, and the thermal load was included as the primary driving force for fluid redistribution. The calculations were based on best estimates and/or measurements of material properties. A very surprising conclusion was that both models gave essentially the same solution. Many people in the room (as well as Ed) found these results surprising. Ed commented that "there is just enough difference (in the 1D saturation profiles at 100 years) that I know I didn't plot the same results file twice." Some of the other conclusions were equally startling such as: (i) the thermal effects on hydrology appear negligible if the maximum repository temperature stays below the boiling temperature; (ii) flow above the repository is primarily in the matrix while flow below the repository (in the unsaturated zone) is primarily in the fractures. Ed concluded that the hydrologic diffusivity (D) of the rock matrix and the length scale (L) for the rock blocks is such that the matrix and fracture are in hydrologic equilibrium for the slowly evolving system at Yucca Mountain, (recall: $t \sim L^2/D$) hence the good agreement between the dual-porosity and effective-continuum models.

IMPRESSIONS/CONCLUSIONS:

This was a very informative meeting and I was able to benefit from much of the discussion. The last meeting of this nature that I attended was the NRC/Department of Energy (DOE) technical exchange on liquid/vapor flow in late 1991. I was impressed with the improvements in the models and calculations over the last year. One common theme in both meetings in the need for data on effective properties at the site, which is expected through site characterization.

PROBLEMS ENCOUNTERED:

I became very ill with a flu/sore-throat during the meeting which resulted in my not attending portions of the meeting.

PENDING ACTIONS:

None

RECOMMENDATIONS:

None

ATTACHMENTS:

1. Meeting Agenda

SIGNATURES:

Randall D. Manteufel
Research Engineer

4/8/93
Date

CONCURRENCE SIGNATURES AND DATE:

Robert G. Baca
Manager, Performance Assessment
& Hydrologic Transport

4/8/93
Date

Budhi Sagar
Technical Director

4/8/93
Date

USGS COMMITTEE FOR THE ADVANCEMENT OF SCIENCE
IN THE YUCCA MOUNTAIN PROJECT

CASY SYMPOSIUM
March 24-25, 1993
Holiday Inn West
14707 West Colfax Avenue
Golden, Colorado
(303) 279-7611

EFFECTS OF REPOSITORY THERMAL LOADING ON FLUID MOVEMENT AND GEOCHEMISTRY AT YUCCA MOUNTAIN

Wednesday, March 24

MORNING CHAIR - Bill Dudley (USGS)

8:30 WELCOME AND INTRODUCTION - Larry Hayes and Bill Dudley (USGS)

8:45 HISTORICAL PERSPECTIVE ON THERMAL LOADING CONSIDERATIONS - Mike Voegele (SAIC)

9:15 OVERVIEW OF THERMAL LOADING OPTIONS AND THE EXTENDED DRY CONCEPT - Larry Ramspott (LLNL)

9:45 ***BREAK***

10:00 IMPACT OF REPOSITORY THERMAL LOAD ON HYDROTHERMAL FLOW - Tom Buscheck (LLNL)

12:00 ***LUNCH***

AFTERNOON CHAIR - Zell Peterman (USGS)

1:30 HISTORICAL DEVELOPMENT OF THE EXTENDED DRY CONCEPT - Dale Wilder (LLNL)

1:45 TRADITIONAL AND PERSISTENT FACTORS FAVORING LOW THERMAL LOADING - Gene Roseboom (USGS)

2:15 HYDROTHERMAL ANALOGS AT YUCCA MOUNTAIN - Schon Levy (LANL)

2:45 ***BREAK***

3:00 EFFECTS OF HEATING ON ZEOLITES AND SMECTITES - David Bish (LANL)

3:30 EFFECTS OF HEAT ON HYDROLOGIC PROPERTIES - Alan Flint (USGS)

4:00 CONSIDERATIONS OF GEOCHEMICAL AND PHYSICAL EFFECTS - Bill Glassley (LLNL)

4:30 Announcements and discussion of Day 1

Thursday, March 25

MORNING CHAIR - Dick Luckey (USGS)

8:00 GEOMECHANICAL EFFECTS OF HEAT ON FRACTURE SYSTEMS - Larry Costin (SNL)

8:30 PHYSICAL PROCESSES AFFECTING TEMPERATURES AT YUCCA MOUNTAIN - Ben Ross (Disposal Safety, Inc.)

9:00 COMPARISON OF DUAL-POROSITY AND EFFECTIVE-CONTINUUM APPROACHES TO THERMAL MODELING - Ed Kwickless (USGS) and Bo Bodvarsson (LBL)

9:30 ***BREAK***

10:00 PERFORMANCE ASSESSMENT PERSPECTIVE - George Barr (SNL)

10:30 POSSIBLE IMPACTS ON NATURAL BARRIER SYSTEM - Dwight Hoxie (USGS)

11:30 ***LUNCH***

AFTERNOON CHAIR - Bill Dudley (USGS)

1:00 PANEL DISCUSSION - Panelists: Bo Bodvarsson (LBL)
Phil Bethke (USGS)
John Bredehoeft (USGS)
Clarence Duffy (LANL)
Eric Ryder (SNL)
Ed Taylor (M&O/TRW)
Dale Wilder (LLNL)
Ike Winograd (USGS)

Charge to the Panel: By personal observations on the symposium and related topics and by questions directed to the speakers or others in the audience, lead the group in examining such questions as:

- strengths and weaknesses of models and concepts presented, particularly as to thoroughness in representing the important processes and hydrogeologic and mineralogic frameworks

- possible beneficial and adverse mineralogic changes resulting from a large heat load

- effects of thermal loading on difficulty of predicting flow and transport in both liquid and gaseous states

- ramifications of thermal loading scenarios from warm to very hot

3:00 Adjourn

ATTACHMENT A
MEETING AGENDA