

TRIP REPORT
January 7-10, 1991

SUBJECT: Flow and Transport Through Unsaturated Fractured Rock--Related to High-Level Radioactive Waste Disposal--Workshop V

DATE AND PLACE: January 7-10, 1991 - Radisson Suite Hotel, Tucson, AZ.

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PERSONS PRESENT: See Attached List

BACKGROUND AND PURPOSE:

The Hydrology and Water Resources Department of the University of Arizona has held a series of workshops in conjunction with their ongoing NRC-sponsored project on flow and transport through unsaturated rock.

The purpose of the workshops has been to provide representatives of the NRC, the University and Arizona and the technical community an opportunity to have open and informal technical discussions concerning flow and transport through unsaturated fractured rock. This workshop is the fifth of this series that began in August, 1982.

The workshop was partially funded by the Center for Nuclear Waste Regulatory Analyses as part of Task 2, Develop Technical Interchange Opportunities, of the Overall Research Project. The funds were supplied for use in the organization and the operation of the workshop and the preparation of the workshop proceedings.

SUMMARY OF PERTINENT POINTS:

The workshop was divided into three categories of interactions: guided tours of the laboratory and field experiments; technical presentations with associated discussions; and open discussions on directed topics. The workshop agenda is included with this document.

Proceedings of the technical presentations are to be published in the future as a NUREG. Preprints of some of the presentations were available at the workshop. Copies of these preprints are located in the library at the CNWRA for reference.

SUMMARY OF ACTIVITIES:

Laboratory and Field Tours

The University of Arizona staff were available for presentation and

discussion of the laboratory experiments on the morning of Monday, January 7, 1991.

A field trip to the Apache Leap Site (APS) was conducted on Tuesday, January 8, 1991. Visited during the field trip were the site for cross borehole investigations, the associated series of boreholes for use in geophysical investigations, the watershed investigation, the knoll site for the proposed heater experiment, the discussion point for the geochemical investigations and the location of the USGS dry and wet borehole drilling and gas sampling investigations. The personnel associated with each of the various activities were available for presentation and discussion during the field trip.

Technical Presentations

There were four half-day sessions for technical presentations. The topics of these four sessions were: overview and general information presentations; flow and transport; nonisothermal multiphase flow and transport; and gas and aqueous tracers. The presentations and associated discussions were typically 30 minutes. The nature of the technical presentations was varied. Several presentations were general in nature, such as conceptual approaches to areas of technical concern or summaries of the state-of-knowledge on specified topics. However, most talks were directed toward presentation of progress-to-date on various technical issues of interest. Included in this latter category were the presentations of recently calculated or measured data sets. Several presentations also included results of numerical and analytical simulations.

Technical Discussions

Additional open discussions were held on areas of particular concern. Included in this category were discussions of travel times and release rates, the proposed heater test and areas of future research. Summaries of the these directed studies are included below.

Travel Times and Release Rates

The discussion was lead by R. Green who briefly summarized the groundwater travel time (GWTT) and release rate issue. The presentation commenced with a statement that the following summary was predicated on the assumption that the intent of the GWTT rule is to provide a measure of the performance of the geologic setting. As part of the introductory comments, four categories of alternatives to resolution of the GWTT issue were identified. These four categories are as follows:

- 1) Maintain the GWTT rule as stated in 10 CFR 60.113 (a)(2).
- 2) Maintain the GWTT rule as stated in 10 CFR 60.113 (a)(2), however, provide additional clarifying language.

- 3) Keep GWTT as the performance measure of the geologic setting but change the language of the rule.
- 4) Replace GWTT as the performance measure of the geologic setting.

A discussion participant made an initial comment regarding the GWTT rule as it was originally formulated. The rule was intended for horizontal, saturated, Darcian (Darcy velocity, not Darcian regime) flow and not seepage velocity. The compliance boundary of five km defining the accessible environment was totally arbitrary. The phrases "fastest path" and "likely radionuclide travel" were caveats added later by others. An additional comment was made that the rule was initially drafted for Hanford, a saturated site and not an unsaturated site such as Yucca Mt.

All the suggestions to resolve the travel time and release rate issue can be placed into categories 2) and 3) of the above mentioned categories. There was no support for the rule as stated (category 1) except for concerns that any change of the rule would lead to litigation and raise suspicions with the public. There were no suggestions in support of replacing GWTT with a distinctly alternative measure of performance for the geologic setting (category 4). Although several of the comments were those that supported the GWTT rule as stated but with additional clarifying language to resolve ambiguities (category 2), there were no suggestions for specific language that could clarify the rule as written. Most of the comments could be placed in category 3--retaining GWTT as the measure of performance of the geologic setting but changing the language.

There were a few suggestions for alternatives to the GWTT rule although none of the alternatives were stated with specific language. A proposal was made to use GWTT in a broad sense of the term as the performance standard but measure the travel time or the release rate in terms of dosages, cumulative release or cumulative release rates. A second suggestion was to use some sort of integrated measure of the performance of the geologic setting, similar to what is used with hazardous waste. There were several other general suggestions to use an integrated measure of release rates or groundwater, but without specific language. A suggestion for a more accurate description of measuring the uncertainty of GWTT was by estimating the dispersion of groundwater velocities.

General comments were offered that suggested that if groundwater velocity was retained as the measure of the performance of the geologic setting, then a statistical type of definition was required (e.g. 95% of the fastest groundwater velocities). There was no support of attempting to identify the exact fastest groundwater particle.

There was one recommendation to use the existence or nonexistence

of a fracture pathway through the mountain as a measure of the performance of the geologic setting. Although GWTT is not explicitly stated in this alternative, the ease with which groundwater can flow through the geologic medium is the essence of the performance measure, therefore, it is considered a variation of the GWTT rule. Additionally there were comments concerning the possibility of incorporating either the adsorptive characteristics of the medium into the performance measure of the geologic setting or the use of groundwater tracers as a technique to quantify GWTT.

There were additional comments that are not contained within the structured categories listed above. One comment addressed the concept of 'defense in depth' and 'multi-barriered system'. The suggestion was to include the performance of the engineered barrier system with the geologic setting and assign a single performance measure to both of them. Along this same approach, a suggestion was made to eliminate the requirement to meet the criteria stated in 10 CFR 60 and only be required to meet the EPA standard (40 CFR 191).

Apache Leap Site Proposed Heater Test

The phases of the proposed heater test were presented by D. Evans. A summary of the discussion of the test follows.

Initial and boundary conditions Use the installation of 1-3 early (FY91) boreholes around the perimeter of the knoll which are equipped with sensors to determine the baseline properties (moisture content, matric pressure, temperature, etc.) of the knoll. This may be completed prior to resolution of exactly how to proceed on subsequent tasks. It was suggested to continue collecting the data as baseline data even after the experiment had started if the locations are sufficiently far from the heater.

It was suggested to use dry drilling versus wet drilling, in light of the fact that the impact of dry drilling upon the subsurface will last a few weeks as compared to wet drilling whose impact could last for as long as a year.

There was discussion but no resolution on how to treat the upper boundary. The two prominent possibilities were to leave the surface as is and to treat the boundary as a constant flux (whatever it may be) or to cover the surface of the knoll with an impermeable material and treat the boundary as a no-flow boundary.

Should the heater borehole be vertical or horizontal? If the borehole is horizontal, it would be easier to intersect fractures. There was no resolution of this topic.

There was discussion as to if the heater should be located to

simulate probable failure mechanisms at Yucca Mt. It was subsequently suggested that their experiment should not be turned into an analog for Yucca Mt.

There was additional discussion given to the wind effect that could cause the knoll to breathe.

Heater test location The prospect of placing the heater in a tunnel rather than in a borehole was discussed. The benefit of return versus cost was discussed. There was also discussion of placing a tunnel or chamber underneath a heater emplaced in a borehole in the knoll for the purpose of providing a means to collect infiltrating water over a larger volume. It was stated that funding constraints would probably limit the selection choices to placing the heater in a borehole from the surface and not from a tunnel.

Source term, power and temperature The advantages and disadvantages of employing a source of constant power versus constant temperature were discussed. There were several suggestions to construct the source as a step-function and not as a constant. By using a stepped source, the possibility of irreversibly impacting the structure, geochemistry, etc. of the host geology will be reduced.

There were suggestions to emplace liquid and vapor tracers in the source region so as to more easily identify liquid and vapor flow paths.

There was also a suggestion to place samples of candidate metals for canisters at the source area to be able to assess the geochemical effect of the local liquid water and water vapor upon the metals. A concern that such metals could adversely affect geophysical measurements was raised.

Sensor locations The study site should be pre-modeled to provide the best estimate for sensor location.

Geophysical instrumentation Geophysical instrumentation was suggested for several applications. Included in these applications were the use of geophones and extensimeters for detecting micro-fracture generation and the use of electromagnetic methods to help monitor the heater experiment.

Concluding remarks The question of the accessibility of the DOE sponsored G-tunnel heater experiment data was raised. There was no definitive response to this question. Some of the Az personnel expressed an interest to visit LLNL to discuss the G-Tunnel experiment results prior to finalizing the plans for the proposed Apache Leap Site heater test.

There were several suggestions during the discussion to keep

the experiment as simple as possible. Additional discussion on this topic included comments to the effect that this opportunity should be used to include as much in this heater experiment as possible.

There was some concern expressed that the proposed field heater test would provide an insufficient amount of quantitatively significant data to allow definitive modeling.

There were comments that the test appeared to be a repetition of the G-tunnel heater experiment. A question was raised that if this is the case, what is the purpose of repeating the experiment. There was additional discussion that the G-tunnel experiment or at least portions of that experiment merited repetition. Additional discussion was directed to identifying those technical areas not addressed by the G-tunnel heater experiment that should be addressed in the proposed ALS field heater experiment.

Future Research

The discussion group was divided into six groups of eight to ten participants for the purpose of formulating lists of prioritized technical questions which could be answered through reasonable research endeavors to yield improved estimates of travel times and radionuclide releases for a high-level nuclear waste repository in unsaturated fractured rock. There were two groups assigned to each of the general topics of geochemistry, modeling and experimental methods, although the groups were not restricted to their particular topic. Each of the groups reported their list of ten prioritized research topics to the full discussion group. The finalized list of research topics will be included with the published proceedings of the workshop.

IMPRESSIONS/CONCLUSIONS:

The workshop presented a kaleidoscope view of the condition of the unsaturated flow and transport through unsaturated fractured rock research program: interesting and useful pure research; elegant theory; detective work and useful information. Difficulties remain with modeling theories and applications. Many of the difficulties lie in the fact that basic features and processes are not yet sufficiently understood. Some of these are matrix/fracture interactions, heterogeneities, channeling, boundary conditions and flux rates.

Although many technical questions remain, the understanding offered by the participants at Workshop V is much broader and greatly enhanced as compared to the basic understanding presented by the participants at the first workshop held in August, 1982. Given that the driving force of the efforts in 1982 was to begin to establish a preliminary data base and to lay the groundwork to

understand the physics behind unsaturated flow and transport, researchers at workshop V indicated that they were attempting to structure their research toward accommodating the goals set forth in the regulations (10 CFR 60 and 40 CFR 191). Various researchers commented that striving for this goal insured that their efforts would be relevant to the stated problem and not in pursuit of a heuristic, albeit related, academic goal.

PROBLEMS ENCOUNTERED:

None

PENDING ACTION:

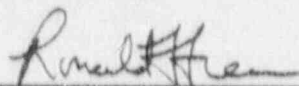
None

RECOMMENDATIONS:

Although the workshop started most days at 8:00 AM and often lasted until 10:00 PM with discussion groups at night, there was not sufficient time for discussion associated with the presentations. It is recommended that the number of talks be curtailed and that additional time be used for discussion. The presentations should be constrained to their current length of 25-30 minutes.

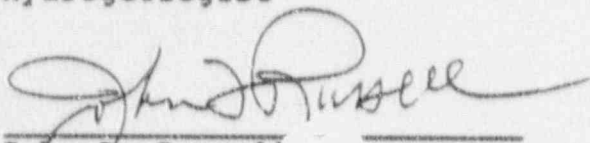
It is recommended to name the future workshops 'The Evans Workshop' in recognition of past efforts by D. Evans without whose efforts the first five workshops would not have been possible.

SIGNATURE:



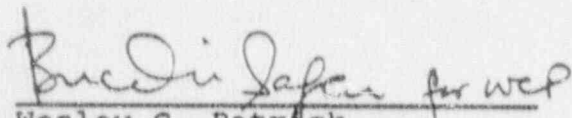
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WORKSHOP V

ORGANIZATION AND PROGRAM

- Workshop V - Flow and Transport Through Unsaturated Fractured Rock --
Related to High-Level Radioactive Waste Disposal
- Sponsored by - Nuclear Regulatory Commission
Center for Nuclear Waste Regulatory Analyses
University of Arizona
- Date and Place - January 7-10, 1991
Radisson Suite Hotel
5555 E. Speedway
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(602) 721-7100
(800) 333-3333
- Organizing - Thomas J. Nicholson, NRC-RES/WMB
Committee Donald L. Chery, NRC-NMSS/TR
John L. Russell, CNWRA
Al Yang, USGS/Denver
Daniel D. Evans, Coordinator
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- General Scope - Physical, chemical and coupled processes and relevant
parameters, experimental methods and results, modeling -
- as related to water flow and transport of contaminants
through unsaturated fractured rock
- Schedule -
- | | |
|--------|---|
| Jan 7 | Monday a.m. - Open House, Dept. of Hydrology and Water
Resources, University of Arizona
Monday p.m. - Technical Session, Radisson Suite Hotel |
| Jan 8 | Tuesday - Field Trip, Apache Leap Tuff Site |
| Jan 9 | Wednesday - Technical Sessions, Radisson Suite Hotel |
| Jan 10 | Thursday a.m. - Technical Session, Radisson Suite Hotel
Thursday p.m. - Future Research Session, Radisson Suite Hotel |
- Registration Fee - \$125.00

Tentative Program

Workshop V

(Some Titles are Tentative as of 12/19/90)

Monday Morning - 01/07/91

8:30 to noon Open House at the Department of Hydrology and Water Resources,
University of Arizona.

Monday Afternoon

12:30 Registration in Radisson Suite Hotel Foyer

General Chairperson: Tom Nicholson, RES/NRC, Salon B

1:00 Introductory remarks - Dan Evans, U of AZ

1:15 Performance assessment/hydrogeologic research -
Budhi Sagar, CNWRA

1:45 Hydrogeologic issues at Yucca Mountain: Findings of a DOE peer review
team - Alan Freeze, UBC

2:15 On the relationship between information content and model structure:
Advective travel (time) versus dispersion -
Shlomo Neuman, U of AZ

2:45 Break

3:00 Tracer transport in fracture systems - Yvonne Tsang, LBL

3:30 How does equilibrium continuum compare with fracture/matrix
interactions? - Tom Buscheck and John Nitao, LLNL

4:00 Update on INTRAVAL/Phase II Cases - Thomas Nicholson, NRC and
Charlie Voss, Golder and Associates

4:30 Does the wind blow through Yucca Mountain? - Ed Weeks, USGS, Denver

4:40 Discussion

5:00 Adjourn

5:30 Reception

Monday Evening

7:00-11:00 INTRAVAL Phase I Working Group. Charlie Voss, Leader, Rm 101

8:00-10:00 Travel times and release rates - Discussion: Ron Green, Leader, Salon B

FULL TEXT AT

Tuesday Morning and Afternoon - 01/08/91

Field discussions - Apache Leap Tuff Site - Leaders: Todd Rasmussen and Mike Sully

- 8:00 Leave hotel with box lunch
- 10:30 Arrive at field stations - subgroups rotate among sites
 1. Cross borehole testing/geophysics site - Mike Sully, U of AZ
 2. Geochemical site - Randy Bassett, U of AZ
 3. Watershed site - Ingrid Anderson, U of AZ
 4. Heater experiment site - Todd Rasmussen, U of AZ
 5. Gas sampling site - Al Yang, USGS
 6. Prototype drilling at Apache Leap - Roy C. Long, DOE
- 3:00 Leave field sites
- 5:15 Arrive at hotel

Tuesday Evening

- 7:00 Group Dinner, Hidden Valley Inn

Wednesday Morning - 01/09/91

Flow and Transport, Chairperson: John Russell, CNWRA, Salon B

- 9:00 Physical-chemical properties of thin water films - John Cushman, Purdue Univ.
- 9:30 Characterization of hydraulic rock properties and verification through modeling - Alan Flint, USGS/Las Vegas
- 9:00 Unsaturated flow Laboratory studies using welded and nonwelded tuff - Falah Thamiir, USGS Denver
- 10:00 Break
- 10:20 Issues related to modeling - Bill Ford, NRC/NMSS
- 10:50 Unsaturated flow and transport modeling - Rachid Ababou, CNWRA
- 11:20 Hysteresis Measurement - Lorraine Flint, Fenix & Scisson
- 11:50 Discussion
- 12:00 Group Lunch

Wednesday Afternoon

Nonisothermal multiphase flow and transport. Chairperson: Karsten Pruess, LBL, Salon B

- 1:15 Coupled processes - Chin Fu Tsang, LBL
- 1:45 Field heater test, G-tunnel - Tom Buscheck, LLNL
- 2:45 Break
- 3:00 Status of nonisothermal modeling at Yucca Mountain - Rex Wescott, NRC/NMSS
- 3:30 Nonisothermal laboratory experimental results - Ron Green, CNWRA
- 4:00 Modeling 2-phase nonisothermal flow - Karsten Pruess, LBL
- 4:30 Material heterogeneities and flow - Roger Eaton, Sandia
- 4:40 Discussion
- 5:00 Adjourn

Wednesday Evening

- 7:30 Proposed field heater experiment: Discussion - Dan Evans, U of AZ, Discussion Leader, Salon B

Thursday Morning - 01/10/91

Gas and aqueous tracers. Chairperson: Al Yang, USGS/Denver, Salon B

- 8:00 Evaluation of tracers for hydrologic studies at Yucca Mountain - Robert Bowman, New Mex. Tech.
- 8:30 The carbon dioxide and carbon isotopes of gases from borehole UZ-8 at Yucca Mountain - Donald C. Thorstenson, USGS/Reston
- 9:00 Flow and transport through unsaturated rock at Yucca Mountain: Preliminary stable- and radioactive-isotope analyses - Al Yang, USGS/Denver
- 9:30 Stable and tracer isotopic studies of hydrogenic deposits exposed at Trench 14, Nevada Test Site, Nevada - John S. Stuckless, USGS/Denver
- 10:00 Break
- 10:20 Isotopic tracer for water and solute movements in desert soils - Fred Phillips, New Mex. Tech.
- 10:50 Discussion
- 12:00 Group Lunch

Thursday Afternoon

- 1:15 Future Research Session
Co-Chairpersons: Don Chery, Jr., NRC; Den Evans, U of AZ, Salon B

Objective: To arrive at lists of prioritized technical questions which could be answered through reasonable research endeavors to yield improved estimates of travel times and radionuclide releases for a high-level nuclear waste repository in unsaturated fractured rock.

Procedure:

1. Participants are divided into subgroups with a designated group leader and reporter for each subgroup
2. Each participant independently prepares a list of 10 technical questions considered of highest priority (should be completed prior to the session)
3. Questions are presented to the subgroup, one list at a time with no discussion or elaboration
4. The lists of 10 questions are combined and edited for duplications to form a single list
5. Each participant selects the 20 most important questions and ranks them from 1 to 20, with 1 being of highest priority
6. The rankings are tallied and the 20 with the lowest scores are arranged in ascending order
7. Each of the 20 questions is written at the top of a separate pad of paper. Participants write brief statements of justification and research approaches on pad for each question in turn
8. Group leader leads discussion of products generated. The group summarizes its efforts for reporting to the complete group
9. Each subgroup gives a brief presentation to the entire group and each reporter prepares a written report for inclusion in the final workshop report.

Thursday Evening

- 7:30 INTRAVAL Working Group I meeting. (All participants are invited)
Group Chairman: Tom Nicholson, NRC/RES, Room 101

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