CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: SME 2004 Annual Meeting and Exhibit (20.06002.01.091)

DATE/PLACE: February 23–25, 2004; Denver, Colorado

AUTHORS: R. Fedors and S. Painter

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PERSONS PRESENT:

R. Fedors and S. Painter of the Center for Nuclear Waste Regulatory Analyses (CNWRA) and S. Green and D. Walter of Division 18 of Southwest Research Institute participated in Hydrology Session at the Society for Mining, Metallurgy, and Exploration (SME) 2004 Annual Meeting and Exhibit February 23–25, 2004 in Denver, Colorado. R. Fedors co-chaired a session. Members of the audience primarily consisted of mining engineers and geologists interested in underground ventilation of mines.

BACKGROUND AND PURPOSE OF TRIP:

The purposes of this trip were to present CNWRA research to the scientific community and to assess methods, tools, and conclusions presented by other researchers that could be useful to meet the objectives of CNWRA and NRC for evaluating any license application for Yucca Mountain as a high-level waste disposal facility. The primary reasons for attending the conference were to participate in the Hydrology Session titled "Hydrologic Conditions and Their Impacts In and Near Ventilated and Nonventilated Tunnels" and interact with researchers in the mining community to gain an additional perspective on environmental conditions in tunnels and drifts.

SUMMARY OF PERTINENT POINTS AND ACTIVITIES:

The session led off with three presentations that included the effects of forced and natural ventilation on environmental conditions in heated drifts and tunnels. The remaining four presentations focused on models and environmental conditions for a closed drift when only natural convection was occurring.

L. Allen (Environmental Evaluation Group, State of New Mexico) discussed the unexpected precipitation of salts on the monitoring system installed at the Waste Isolation Pilot Plant to verify compliance of air emanating from the drifts in the exhaust shafts. The title of the presentation was "The Effects of Brine Water Inflow on the Exhaust Shaft at the Waste Isolation Pilot Plant." Failure of the sensors was attributed to the physical buildup of salts. Of most interest to the audience was the pathway for the ions reaching the sensor. Liquid water was observed seeping into the exhaust shaft, but vapor phase transport to the sensors apparently also occurred. A drop in the temperature of the air mass rising in the shaft may have led to precipitation on the probes, in addition to of the water seeping into the shaft at the sensor horizon.

A model addressing in-drift forced and natural ventilation linked to a thermohydrological code for the potential repository at Yucca Mountain was presented by G. Danko (University of Nevada, Reno). This presentation, titled "Coupled Multi-scale Thermohydrologic-ventilation Modeling with MULTIFLUX," described lumped-parameter simulations of in-drift flow and heat transport coupled with the NUFT thermohydrological code. MULTIFLUX was previously developed for use by DOE to validate their simpler ANSYS model for ventilation. The State of Nevada is now supporting further development and use of MULTIFLUX. Self-consistent coupling between the in-drift model and the NUFT code was achieved by using linear response matrices that relate drift wall heat and mass fluxes and temperatures. The response matrices were calculated from numerous NUFT simulations. Once these matrices are calculated, they replace the NUFT simulations in a computationally efficient, self-consistent calculation. Both preclosure and postclosure conditions for a drift in repository panel 5 were considered. Panel 5 has a ventilation intake shaft on the west side and an outlet shaft on the east side. In the postclosure simulations, natural buoyancy-driven ventilation was assumed and the time-dependent calculated flow rates under these conditions were scaled by factors of 0.5–20 to account for uncertainties. Postclosure results show significant amount of condensation at the outlet end of the drift as peak temperatures were reached in the center of the drift. The edge of the repository would be cooler because of three-dimensional edge cooling effects. The zone of condensation was shown to expand inward with time as the thermal pulse dissipates. The spatial extent of the condensation depended on the assumed natural ventilation flow rate. Convection driven by temperature differences along drifts and by eccentric siting of waste packages were expected to lead to helical patterns along drifts. It was concluded that condensation would occur on drift walls and waste packages using the correct convective model for in-drift gas phase flow, and furthermore, that equivalent conductivity models (diffusive) for in-drift gas phase flow likely will fail to predict condensation.

S. Painter also presented a model and simulation results for forced and natural ventilation coupled self-consistently with a thermohydrological code. The presentation "Modeling Ventilation Effects in Three-dimensional Thermal Hydrological Simulations of a Potential Waste Repository at Yucca Mountain, Nevada" focused on forced ventilation during preclosure, which establishes initial conditions for the postclosure simulations. Coupling between the in-drift ventilation model and the thermohydrological code, however, was more direct than the approach described by G. Danko, with the in-drift model being called directly from MULTIFLO. The simulations demonstrate that it is feasible to directly couple in-drift lumped parameter models with thermohydrological codes; the computational requirements appear to be similar or smaller than to that of the entire response matrix approach used by G. Danko. Ventilation heat removal was shown to be highly dependent on time and position within the drift. In addition, it was shown that moisture transfer from the fractured tuff has a minor effect on calculated temperatures.

S. Webb (Sandia National Laboratories) presented estimates of heat transfer coefficients for in-drift forced and natural convection during the preclosure period. The presentation was titled "Natural Convection Effects on Forced Convection Cooling at Yucca Mountain." The complex interaction of forced and natural convection was referred to as mixed convection, for which there were no previous literature available pertinent to the Yucca Mountain potential repository configuration. Computational fluid dynamics modeling of a 25-percent scale experiment was used to estimate heat transfer coefficients for mixed convection. Although the heat transfer coefficients will be used to estimate isotropic effective thermal conductivity for in-drift cells of porous media continuum models, the 25-percent scale laboratory experiment and computational fluid dynamics modeling results suggest a heterogeneous temperature field will result at the waste package and drip shield because of the mixed convection. For example, the local heat transfer vertically upward is underestimated by a factor of 3 at the waste package and by a factor of 10 at the drip shield using the effective thermal conductivity approach. Conversely, the vertically downward heat transfer to the invert is overestimated using the effective thermal conductivity approach.

A series of three presentations by SwRI and CNWRA staff described the ongoing natural convection and cold-trap study for NRC. R. Fedors described the overall approach for linking thermohydrological models to in-drift models and focused on characterizing temperature gradients along drifts derived from either heat transfer or thermohydrological models. The presentation was titled "Evaluation of Large-Scale Temperature Gradients to Support Assessment of Convection and Cold-Trap Processes in Heated Drifts." Estimates of the areal extent along drifts of temperature gradients as a function of time were presented for the postclosure scenario of no degradation using a conduction-only model. The effects of drift degradation and thermohydrology were shown to have a prominent effect on temperature differences along drifts, and therefore should be considered when providing boundary conditions for computational fluid dynamics models of in-drift flow and heat transfer. A second presentation on the CNWRA and NRC approach was given by S. Green and was titled "A Model for Moisture Transport in a High-Level Radioactive Waste Repository Drift." The presentation described the validation of a moisture module linked to FLOW–3D, a computational fluid dynamics code. For either FLOW–3D or FLUENT (used by DOE), a user-developed module is needed to include moisture redistribution and latent heat transfer directly in the computational fluid dynamics simulations. The moisture module helped track changes in relative humidity and introduced the processes of evaporation, latent heat transfer, and condensation to the in-drift gas phase modeling. The third presentation on the CNWRA and NRC approach was the description of a prototype benchtop laboratory experiment and associated computational fluid dynamics modeling that focused on sensitivity analyses of parameters that were difficult to measure. The benchtop experiment (one-percent drift scale) provided the only data to support to in-drift numerical modeling studies at this session. Scaling uncertainties for the thermal processes (including temperature, flow rate, and heat transfer), however, appears to require larger scale models or in situ measurements at Yucca Mountain. In addition, axial convection was considered symmetrical about the long-axis of the drift, which differed from the G. Danko conceptualization of a helical pattern.

S. Webb (Sandia National Laboratories) ended the session with a presentation titled "A Summary of In-Drift Convection and Condensation Calculations Performed at Yucca Mountain." The approach used to estimate condensation was particularly of interest. Computational fluid dynamics models were used to estimate dispersion coefficients along a drift. Then, outside the computational fluid dynamics code, the dispersion coefficients were used in a one-dimensional diffusion-type equation to simulate moisture redistribution. Below the drip shield, the values of the dispersion coefficients were 300 to 450 times the coefficient for pure diffusion in air. Outside the drip shield, the dispersion coefficients were 1,400 to 1,500 times the coefficient for pure diffusion in air. Two drift scenarios were analyzed; the first one was a drift where both ends conducted heat to nonrepository areas and a second drift where one end abutted another panel of drifts. The latter scenario would lead to convection along the entire length of the drift, and disallow the use of symmetry to reduce the modeled drift length by half. The amount and distribution of condensation was generally consistent with the results presented by G. Danko.

CONCLUSIONS:

The presentations in the session indicate a range of alternative approaches were being taken for estimating temperature, relative humidity, and condensation in heated drifts. One model linked dual-permeability results using linear response matrices to a lumped-parameter model of in-drift flow and heat transfer. A second model used computational fluid dynamics simulations to define the temperature and flow field, and estimate effective dispersion coefficients that were later used in a one-dimensional diffusion-type equation to estimate moisture movement and condensation. A third model integrated a moisture model directly into the computational fluid dynamics simulations.

Discussions during and after the presentations led to the following observations (i) there is a lack of measured data to support in-drift modeling results for latent heat transfer and moisture redistribution; (ii) natural ventilation during the postclosure may reduce condensation; (iii) there are uncertainties about the type and shape of convection cells that may occur in drifts; and (iv) convection and condensation estimates did not account for the effect of potential drift degradation.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

None.

SIGNATURES:

GW for Randy Fedors — 4/2/2004

Randall Fedors — Date
Senior Research Engineer

Scott Painter — 4-1-04

Scott Painter — Date
Principal Research Scientist

CONCURRENCE:

Gordon Wittmeyer
Manager, Hydrogeology

3/29/2004
Date

Budhi Sagar
Technical Director

4/2/2004
Date