RECEIVED

FEB 22 1996

OSTI

THERMAL MANAGEMENT WITH VENTILATION

George Danko
Mackay School of Mines
University of Nevada, Reno
Reno, NV 89557
(702) 784-4284

Thomas A. Buscheck and
John J. Nitao
P.O. Box 808
Lawrence Livermore
National Laboratory
Livermore, CA 94551
(510) 423-9390
(510) 423-0297

Steven Saterlie
TRW
101 Convention C. Dr.
Las Vegas, NV 89109
(702) 794-7534

ABSTRACT

Ventilation as a thermal management tool could provide (1) enhanced flexibility in design, (2) increased safety of operations, and/or (3) mitigation of risk for a potential repository. This paper describes calculations using a new ventilation code coupled with a hydrothermal code. The results and conclusions could be used to support the design activities for the Viability Assessment and Licensing efforts for the proposed repository at Yucca Mountain.

INTRODUCTION

Realistic calculations of the psychrometric environment in a potential repository require an understanding of the amount of heat and moisture that are removed from the emplacement drifts and the near-field rock by ventilation. To achieve this, a coupled simulation procedure was developed using the Lawrence Livermore National Laboratory (LLNL) Nonisothermal Unsaturated-Saturated Flow and Transport (NUFT) code for the hydrothermal calculations in the near-field (Nitao, 1995) and the Mackay Thermal Enhancement and Climate Simulation (MTECS) model (Danko, 1992; Danko and Mousset-Jones, 1992; Danko and Mousset-Jones, 1993; and Danko, 1994) for the heat and mass transport calculations in the air. The coupled codes, using projected site properties, produce three-dimensional calculations of the hydrothermal behavior of the near-field rock mass, including heat and moisture transport, the behavior at the rock-air interface, and the dilution of water vapor in the drift air flow and subsequent transport out of the system.

RESULTS AND DISCUSSION

Ventilation calculations were made for a single, 1232-m drift in the center of a potential repository with 5-m diameter emplacement drifts and waste packages emplaced in the drift at a spacing of 16 m. Large waste packages (21 PWR capacity) filled with PWR fuel that had oldest fuel first characteristics with an average age of about 26 years were assumed. The emplacement drift was divided into sixteen-meter calculation segments. Within a particular segment the hydrothermal parameters were calculated for 1-m long segments in order to determine the averages of the sixteen temperature and moisture fluxes. Further details of the boundary conditions and model parameters can be found in Danko, Buscheck, Nitao, and Saterlie (1995).

Airflow rates of 0 (base case of no ventilation) and $10 \text{ m}^3/\text{s}$ were calculated. The $10 \text{ m}^3/\text{s}$ flow corresponds to about 0.5 m/s air speed which is typically borderline between forced and natural convection or ventilation in underground mines and should be easy to achieve. The inlet air temperature and the partial vapor pressure were 26°C and 1024 Pa, respectively, corresponding to 30% relative humidity of the entering air. Calculations were done over 100 years after emplacement and an area mass loading (AML) of spent nuclear fuel of $20.6 \text{ kgU}/\text{m}^2$ was used.

In the zero air flow case the drift wall temperatures reach about 160°C at times less than 100 years (Saterlie and Thomson, 1994). With no sealing of the drifts, natural ventilation of 0.6 to $0.8 \text{ m}^3/\text{s}$ may occur as predicted by Danko and Saterlie (1996). This small

amount of air flow was found to keep drift wall temperatures at about 110°C (although moisture effects were not considered). This is on the low end of natural ventilation but is based on the selection of a large air flow resistance by the filters.

Coupled ventilation calculations at an air flow of $10 \text{ m}^3/\text{s}$ show that substantial reductions in temperature can be obtained. Figure 1 shows estimates of the wall temperature as a function of time for five different distances along the emplacement drift. The temperature steadily increases as the air moves down the tunnel and picks up heat from the waste packages and the wall. The wall temperature tends to peak between ten and thirty years after emplacement but the largest temperatures calculated do not exceed about 42°C. The air temperature is somewhat cooler than the wall temperature and with this ventilation rate stays below 40°C at all times. This would provide an environment where machines could operate since the current requirement for retrieval operations in emplacement drifts is 50°C (M&O, 1995). Calculations which only calculate sensible heat and do not include moisture (Yang, et. al., 1996 and McKenzie, 1995) indicate somewhat higher temperatures in the drift. Thus, including moisture vaporization in the calculations

indicates temperatures will be from a few degrees to as much as 20°C cooler than estimates made with models without moisture transport.

The calculations which include moisture also show a delay of about ten years in the time to reach peak temperature in the drift over calculations with dry air (Yang, et. al., 1996). The agreement between models improves as the tunnel walls dry out and moisture flux decreases. Estimates show that 60% additional heat could be removed as latent heat (75 kW) over and above what is removed as sensible heat (130 kW).

The total amount of water removed from the system by ventilation over 100 years was calculated by integrating moisture fluxes over time and the length of the tunnel. The results show that a significant amount of water, about $4.4 \times 10^7 \text{ kg}$, is removed from the rock surrounding the emplacement drift. To put this in perspective, calculations indicate a possible recharge around the drift (a distance that extends halfway to the next drift on either side) of about $2.8 \times 10^7 \text{ kg}$ during this 100 years for an infiltration of 10 mm/year. If the infiltration is only 1 mm/year then the recharge would be a factor of 10 smaller.

Figure 1. Maximum Wall Temperature as a Function of Time at Distances along the Emplacement Drift for a $10 \text{ m}^3/\text{s}$ Ventilation Rate at an AML of $20.6 \text{ kgU}/\text{m}^2$.

CONCLUSIONS

In summary, a significant capability to calculate ventilation effects which include both heat and moisture has been developed for the program. The calculation shows that a ventilation rate of 10 m³/s can keep drift temperatures (air and wall) around or below 40°C during preclosure for a high AML and can remove substantial amounts of water from the host rock. The coupled code predicts temperatures that are slightly lower than codes which do not include moisture. Calculations also show that ventilation significantly smears the local hot-spots along a drift length, thus, mitigates the local effects of large waste packages for 100 years. It is recommended that these results and the coupled code should be used in design analysis to support the Viability Assessment and License Application efforts.

ACKNOWLEDGMENTS

The research was supported by a grant from the Lawrence Livermore National Laboratory under subcontract B319792. The project was co-supported by a grant from the DOE Yucca Mountain Project Office under Block Grant Contract DE-FG08-90NV10891. The contribution of Mr. Csaba Mezei in computer programming and simulation work at the Mackay School of Mines is gratefully acknowledged.

REFERENCES

1. Danko, G., 1994: Ventilation and Cooling Enhancement for High-Level Waste Repositories, University of Nevada, Reno Semi-Annual Research Report to DOE.
2. Danko, G., 1992: "Modeling of the Ventilation for Emplacement Drift Re-entry and Rock Drying," University of Nevada, Reno research report submitted to M&O/MK/DOE, June 1992.
3. Danko, G. and P. Mousset-Jones, 1993: "Modeling of the Ventilation for Emplacement Drift Reentry and Rock Drying," Proceedings of the International High-Level Radioactive Waste Management Conference, Las Vegas, NV, April, 590-599.
4. Danko, G. and P. Mousset-Jones, 1992: "Coupled Heat and Moisture Transport Model for Underground Climate Prediction," Proceedings of the International High-Level Radioactive Waste Management Conference, Las Vegas, NV, April, 790-798.
5. Danko, G. and S. Saterlie, 1996: "Natural Ventilation of a Potential Exothermic Waste Repository," Proceedings of the International High-Level Radioactive Waste Management Conference, Las Vegas, NV, April. (planned for publication)
6. Danko, G., T. Buscheck, J. Nitao, and S. Saterlie, 1995: "Analysis of Near-Field Thermal and Psychrometric Waste Package Environment Using Ventilation," Proceedings of the International High-Level Radioactive Waste Management Conference, Las Vegas, NV, April, 30-May 5, 323-330.
7. McKenzie III, D. G., 1995: Waste Emplacement Management Evaluation Report, BC0000000-0171705705-00011, Rev 00, CRWMS M&O prepared for DOE under Contract Number DE-AC01-91RW00134, Las Vegas, NV, June 12, 1995.
8. 1995: Controlled Design Assumption Document, Report B00000000-01717-4600-00032, Rev 01, CRWMS M&O prepared for DOE under Contract Number DE-AC01-91RW00134, Las Vegas, NV, April 28, 1995.
9. Nitao, J., 1995: "Reference Manual for the NUFT Flow and Transport Code, Version 1.0," UCRL-ID-113520, prepared by Lawrence Livermore National Laboratory for the U.S. Department of Energy, Las Vegas, NV.
10. Saterlie, S. and B. Thomson, 1994: FY93 Thermal Loading Systems Study Final Report, B00000000-01717-5705-00013, Rev 01, CRWMS M&O prepared for DOE under Contract Number DE-AC01-91RW00134, Las Vegas, NV, August 29, 1994. (NNA.940329.0001)
11. Yang, H., Y. Sun, D. McKenzie, and K. Bhattacharyya, 1996: "Effect of Repository Underground Ventilation on Emplacement Drift Temperature Control," Proceedings of the International High-Level Radioactive Waste Management Conference, Las Vegas, NV, April. (planned for publication)

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.