



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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DEC 14 1992

MEMORANDUM FOR: Ronald L. Ballard, Chief
Geology and Engineering Branch
Division of High-Level Waste Management/NMSS

FROM: Mysore S. Nataraja, Section Leader
Geotechnical Engineering Section
Division of High-Level Waste Management/NMSS

Richard A. Weller, Section Leader
Materials Section
Division of High-Level Waste Management/NMSS

SUBJECT: TRIP REPORT OF NRC STAFF VISIT TO CANADA'S WHITESHELL
NUCLEAR RESEARCH LABORATORIES AND UNDERGROUND RESEARCH
LABORATORY

On November 3 and 4, 1992, the undersigned visited the Atomic Energy of Canada Limited (AECL) Whiteshell Nuclear Research Laboratories and Underground Research Laboratory (URL) to conduct a technical exchange on repository engineered barrier system (EBS) and geotechnical engineering issues of mutual interest. The agenda for the technical exchange is enclosed.

WHITESHELL LABORATORIES

The focus of the meeting at the Whiteshell Laboratories was directed at AECL's ongoing research program on spent fuel. Mr. Lawrence Johnson (Manager, Fuel Waste Technology Branch) initiated the meeting with an overview of the Canadian spent fuel waste management program and the current concept for disposal. The primary objective of the spent fuel waste management program is to develop and demonstrate the technology for spent fuel disposal deep in the granite rock of the Canadian Shield. The current reference design concept for the EBS includes a relatively thin walled container of corrosion resistant copper or titanium capable of holding 72 spent fuel bundles. Glass beads would be packed in the spaces around the bundles inside the container to prevent the walls of the container from collapsing under underground pressure in the disposal drifts. The containers would be emplaced vertically in boreholes drilled in the disposal drifts and backfilled with a clay/sand mixture to further retard any migration of radioactive material. The containers would be designed to last at least 500 years in the kind of groundwater found in the Canadian Shield.

Following the overview of the Canadian EBS concept, Dave Shoemith (Head, Corrosion and Electrochemistry Section, Fuel Waste Technology Branch) gave a presentation on the electrochemical basis for fuel (UO_2) oxidation. Understanding of the mechanism for, and kinetics of, oxidation of spent fuel in the repository environment is important because of the potential adverse consequences of oxidation to higher states.

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Oxidation of UO_2 to U_3O_8 would result in a 30% volume increase that, in the process, would turn the fuel matrix to powder and rupture the cladding.

Next, John Tait (Head, Wasteforms Section, Geochemistry Research Branch) described the research in progress on spent fuel dissolution. The overall purpose of this work is to develop the methodology for estimating the source terms for radionuclide release from fuel in contact with groundwater. The research has focused on three release mechanisms; (1) rapid release of a small fraction of the total fission product inventory from the fuel/cladding gap; (2) gradual release of fission products from the UO_2 grain boundaries and (3) slow, UO_2 - solubility controlled congruent release of radionuclides as a result of UO_2 matrix dissolution. The matrix dissolution studies include both static and flow-through tests with some of the static tests planned for as long as 15 years. Measured values from these studies will be compared with analytical models.

Next, Peter Taylor (Research Chemistry Branch) gave an overview of the ongoing research on the oxidation of UO_2 fuel. The purpose of this work is to improve the understanding of the mechanisms for fuel oxidation in dry or moist air and in aerated water, recognizing the damage (swelling, powdering) that can occur on oxidation of UO_2 fuel to higher states. The research includes tests on both spent and unirradiated fuels to determine if any differences exist in oxidation behavior as a result of the fission products present.

The presentations by AECL staff were followed by a tour of the hot cell and laboratory facilities where the fuel oxidation and dissolution studies were in progress. The facilities were extensive and comparable to those at Pacific Northwest Laboratories (PNL, Hanford, Washington) where the Department of Energy (DOE) spent fuel research is conducted.

Following the tour, Richard Weller gave an overview of NRC staff interest in spent fuel research. The discussion was initiated with an explanation of 10 CFR Part 60 performance requirements and the staff's efforts to develop independent assessment capability (multiple codes) to determine DOE compliance with those performance requirements. With a focus on the Part 60 subsystem performance requirements for the waste package and EBS, NRC interest in spent fuel research is related to two factors. First, the waste form (e.g. spent fuel) is an important component in the waste package/EBS design and it will be necessary to predict its expected behavior in the repository environment. Secondly, spent fuel will constitute roughly 97% of the Curie inventory in the repository by the year 2020 and will likely dominate the source term from the EBS. The staff anticipates that ongoing and future research on the spent fuel waste form will contribute to the development of models for predicting spent fuel behavior and performance in the repository environment. In this regard, while the staff has identified technical issues (e.g. potential for colloid formation on waste form dissolution, High-Level Waste Management Research Need 101) in need of resolution through research, the staff has no spent fuel research program, per se, because of resource limitations. Accordingly, the staff's efforts to date have been limited to following the spent fuel research activities of others (PNL, AECL) through literature surveys and technical exchanges. With respect to the ongoing research at AECL, Richard Weller noted

that, notwithstanding significant differences in CANDU reactor and fuel assembly design in comparison with U.S. designs, the dominant spent fuel technical issues (i.e. spent fuel oxidation and dissolution) are the same in our respective programs. With this in mind, one of the purposes in the technical exchange with AECL staff was to explore possible future areas of cooperation or information exchange between our respective organizations. Richard Weller noted the attractiveness of the established program and facilities at AECL and the fact that direct involvement of NRC at any DOE laboratories would pose difficulties related to conflict of interest concerns. No problems or conflicts were identified that would preclude involvement with the Canadians with the possible exception that there is an existing DOE (Office of Civilian Radioactive Waste Management)/ Canadian cooperative testing program on eight different technical tasks, one of which involves spent fuel research (Spent Fuel Dissolution Modeling). Lawrence Johnson indicated that he would provide additional information to us about this cooperative program so that we could further assess whether it poses any problems with respect to our interest in the AECL spent fuel research.

UNDERGROUND RESEARCH LABORATORY

AECL made several presentations starting with an overview on the Disposal Vault Engineering and the URL. The URL is located in eastern Manitoba in previously undisturbed granite in the Canadian Shield. A shaft has been sunk to 445 meters below the surface and experimental rooms have been built at the 240 meter level. The URL is being used to study the physical and chemical effects of excavation in granite and to demonstrate the technology necessary for safe disposal of nuclear waste. Hydrogeological testing and monitoring have been carried out to a depth of 1200 meters in boreholes of selected research areas in the Canadian Shield. Groundwater conditions at the URL before shaft excavation and after shaft sinking have been studied and documented.

AECL is studying the thermal, mechanical and thermo-mechanical modeling aspects of the disposal vault engineering. In situ experiments are being conducted underground to validate the models and the assumptions used in developing these models. The following experiments have been performed or in progress at the URL.

Grouting Experiment: An engineering demonstration of the grouting of a fractured rock and a demonstration of methods for grout application.

Buffer/Container Experiment: A demonstration of the engineering aspects of borehole emplacement, and a field test to collect a database for development and improvement of models of the coupled processes that will occur in the buffer and the rock mass surrounding a container as a result of moisture movement and heat transport.

Shaft Sealing Experiment: A study of materials and emplacement methods for a shaft seal, and of the performance of components of a high-quality sealing system.

Mine-by Experiment: A study of the material properties and in situ behavior of rock to develop and evaluate models for use in the design and optimization studies of a vault, and to develop instrumentation, monitoring and analysis methodologies.

Multicomponent Experiment: A study of many aspects of the disposal concept, including buffer experiment and room backfilling and sealing, and to gather a database on performance of a fully backfilled room, representing the borehole emplacement concept, under the influence of in situ moisture conditions and heating.

URL Characterization Program: A study to develop and demonstrate a methodology for underground characterization, to apply the geological, hydrogeological, hydrogeochemical and rock mechanics knowledge to the siting and analysis of URL experiments, and to contribute to the geological studies of the Lac du Bonnet batholith.

In Situ Stress Program: A study of in situ stress to develop and demonstrate tools and equipment for determining stress, to improve the analysis methods used to calculate stress from field measurements, and to determine the influence of various physical factors on the calculated stress.

After the AECL presentations Dr. Mysore Nataraja made a brief presentation to the technical staff at the URL. The presentation covered the current activities at the NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) in the area of geotechnical engineering. These included reactive (review of DOE's work), proactive (guidance development and rulemaking activities), and research.

Following the presentations, there was a tour of the URL. Sites of most of the experiments mentioned earlier during the AECL presentations were visited during the tour along with their core storage facility. The controlled blasting accomplished at the URL is a fine example of high-quality work. There was very little overbreak in the openings. This was possible because of the high-quality rock and tight specifications and continuous oversight over the contractor. The failure patterns around the openings in locations of high horizontal stresses and unfavorable orientation were directly comparable to text book examples! The massive granite at the URL has considerably different properties in comparison to the jointed tuff at the Yucca mountain project site. Nevertheless, the knowledge gained at the URL has ample application to the U.S. program in the areas of underground facility design, geotechnical instrumentation, and general techniques of site characterization.

Ronald L. Ballard

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SUMMARY

In summary, the trip by the NRC staff to the Whiteshell Laboratories and the URL was worthwhile, in that it gave us an opportunity to establish some personal contacts at the AECL and for a first-hand observation of their technical activities which may lead to possible future cooperation or information exchange. We recommend that such technical exchanges be permitted as often as budget and other work priorities allow.

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Enclosure: As stated

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USNRC Staff Visit

November 3 - Whiteshell Laboratories

09:00	Overview of Engineered Barriers	L.H. Johnson
09:30	UO ₂ Studies	D.W. Shoesmith, Head Corrosion and Electrochemistry Section Fuel Waste Technology Branch
10:30	Spent Fuel Studies	J.C. Tait, Head Wasteforms Section Geochemistry Research Branch
11:30	UO ₂ Fuel Air Oxidation Studies	P. Taylor Research Chemistry Branch
12:00	Lunch	
13:00	Laboratory Visits	IFTF and Corrosion Labs
14:00	USNRC Program	R. Weller, Head Materials Section Geology and Engineering Branch
15:00	General Discussion	

UNITED STATES NUCLEAR REGULATORY COMMISSION STAFF VISIT
1992 November 04

Tentative Program for 3-5 visitors (if there are any changes a revised agenda will be issued)

- 08:20 Arrive at URL, Introductions
- 08:30 Overview of Disposal Vault Engineering and the URL
- G.R. Simmons
- 09:15 Thermal, Mechanical and Thermal-Mechanical Modelling for Disposal Vault
Engineering - P. Baumgartner
- 09:45 Presentations on Specific URL Activities
(20 mins. each with emphasis on modelling where appropriate and 10 mins. for
questions)
- Excavation disturbed Zone Studies - C.D. Martin
 - Buffer/Container Experiment - B.H. Kjartansson
 - Mine-by Experiment - R.S. Read
- 11:30 Presentation of USNRC Geotechnical Activities
- LUNCH
- 13 30 Tour of URL Surface Facilities (Hydrogeological and Geomechanical
Instrumentation and Core Examination) - P.M. Thompson/R.A. Everitt
- 14:30 Tour of URL Underground - R.S. Read/G.W. Kuzyk
- 16:30 Discussion
- 17:00 Depart URL