CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: 2006 International High-Level Radioactive Waste Management Conference
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DATE/PLACE: April 30–May 4, 2006
Las Vegas, Nevada

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BACKGROUND AND PURPOSE OF TRIP:

The International High-Level Radioactive Waste Management Conference provides a forum to discuss technical, programmatic, and regulatory topics related to the back end of the nuclear fuel cycle. Topics address handling, treatment, storage, and disposal aspects of waste management. This conference provides an excellent opportunity to exchange knowledge and ideas among the participants. Over the years, participation of international professionals working in the high-level waste program in their own countries has increased substantially. This year, approximately 40 percent of the papers were from countries other than the United States. This increased international participation provided a broader exposure of the progress made and problems encountered in the high-level waste programs of other countries.

The purposes of the trip were to (i) present technical papers, (ii) chair technical sessions, and (iii) manage the conference. Electronic proceedings of the conference are available from the American Nuclear Society.

SUMMARY OF ACTIVITIES AND PERTINENT POINTS:

Opening Plenary Session

The opening plenary session featured four speakers representing different perspectives on the U.S. High-Level Waste program.

J. Strosnider, Director of the Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission (NRC), summarized the statutory and regulatory framework for the NRC program. He then focused on how each of the NRC strategic goals was being implemented in the high-level waste program. Appropriately, his most extensive remarks were on safety, the first of the NRC strategic goals. His summary of NRC activities encompassed pre-licensing interactions related to the potential repository through the adjudicatory process and inspections. He made particular note that quality assurance remains a challenging area for the U.S. Department of Energy (DOE). The historically high safety record of radioactive materials transportation was emphasized. With respect to security, a rulemaking on Yucca Mountain is planned for September 2008. In the area of efficiency, effectiveness, and realism, comments focused on the systems, review tools, and other processes that NRC has either implemented or plans to implement. He closed by summarizing the range of means used by NRC to communicate with and involve stakeholders.

E. Cotsworth, Director of the Office of Radiation and Indoor Air, U.S. Environmental Protection Agency (EPA), summarized the historical background and statutory framework for the EPA standard, including a brief discussion of related court actions. Her comments were limited because the rulemaking is in progress. Interesting comments included (i) EPA emphasizes protection of public safety, with sound science being a subordinate or implementing goal; (ii) the higher dose limit of 350 mrem/yr is intended to address increasing uncertainty (a premise that was challenged from the audience); and (iii) the median dose is being used by EPA to emphasize reasonable values rather that extremes.

E. Knox, Associate Director for System Operation and External Radiation, DOE, provided very brief remarks. These included discussion of reorganization of the DOE waste management program, a focus on the nuclear culture, concerns about quality assurance, the DOE goal as an applicant, and the overall direction from the Secretary of Energy to implement a repository program that is simpler, safer, and more robust. Knox noted that DOE plans to provide a schedule later this summer for future activities, beginning with submittal of a license application and continuing through receipt of waste. He noted that DOE made no assumptions about the various legislative initiatives by Congress and the Administration. In response to questions, Knox stated that (i) the U.S. Geological Survey issue is considered to be closed, but some data and analyses are being replaced, (ii) DOE is engaging the cask vendors on fuel handling and packaging capabilities (in the context of the transportation, aging, and disposal container), (iii) the two major technical issues are finalization of the EPA standard and development of the transportation, aging, and disposal specifications, (iv) DOE is fairly comfortable with the underground design, but needs to do some more work regarding surface facilities, and (v) DOE is streamlining the license application to focus on critical elements first.

The plenary closed with a rather detailed presentation and discussion by H. McFarlane, President-elect of the American Nuclear Society, on Nuclear Energy: Poised for Expansion. He set the stage with a slide listing why nuclear energy is green, but not green enough. A very high growth rate in electricity demand is projected in China, India, and throughout Asia. In the United States, the impact of the Energy Policy Act of 2005 was noted; it was credited with much of the recent interest and movement toward new plant licensing. The act includes loan guarantees, risk insurance, extension of Price-Anderson, and research and development funding for new reactors and related technologies. McFarlane quoted a recent survey that showed a 70-percent favorable rating for nuclear power, but he did not identify the question underlying that statistic, which could be crucial to interpreting its meaning. Highly favorable

statistics were given regarding nuclear fuel costs and operating costs. Only the last figure in the sequence touched on the larger (and more relevant) picture of total production cost, which includes amortization of the large capital cost of nuclear facilities relative to other means of energy production.

Status of International Programs

Six papers were presented summarizing the programs of five nations, as well as an initiative in multinational and regional repositories. A common theme in the first three papers was the long and deliberative process being followed.

In her discussion of the Canadian program, J. Facella (Nuclear Waste Management Organization) described the Adaptive Phased Management approach, which has been adopted as both the technical method and management system for siting a geologic repository. This is a very long process that will play out over several decades. The process will take into consideration technical, social, ecological, economic, and other aspects.

P. Zuidema, NAGRA, described the phased approach being taken in Switzerland. Considering the time associated with reprocessing and waste-form cooling, a repository will not be needed until the middle of this century. Phase 1—Development of the Technical Basis, was said to be largely complete and the program has moved to Phase 2—Decision Making, which was described as a transparent societal process. Phase 3—Implementation, will follow.

A three-phase siting process is also planned in Japan, as described by M. Takeuchi of NUMO. This presentation focused on a communication initiative comprising a survey of perceived risk and importance of waste disposal. The data suggest a very small sample size (~100 people) and no follow up survey, which raises questions about the validity of the conclusion that public education had good effects.

C. McCombie, Arius Associates, posed strong arguments for multinational and regional repositories, a theme that he has promoted for more than a decade. Though broadly applicable to other regions, his arguments appeared most compelling with respect to Europe, where both ownership of electrical power generation companies and distribution of power spans borders. He also noted the very large number of repositories that would be required to meet needs at the national level. He concluded that, to be successful, any such initiative would need to meet technical, societal, and business and economic criteria.

S. Mayer, ANDRA, provided an overview of the French program with a technical presentation on the status of the clay program. The overall approach used in France is stagewise, using several analysis methods or programs. ANDRA began with a Functional Analysis of key features (using the features, events, and processes database), and progressed to a Phenomenological Analysis of Repository System, which breaks down the results of the preceding analysis into spatial and temporal domains. The Qualitative Safety Analysis builds on the functional analysis and phenomenological analysis of the repository system; quantitative analysis follows, using simulation techniques to manage and integrate the data into a model of the overall system.

International and Regional Science and Technology Cooperation–Panel

H. Issler, representing the 11-member EDRAM organization, summarized the role of the cooperative organization in coordinating research and development activities relevant to its members. Member organizations are promoters/developers of geologic repository programs; there are no regulators or other stakeholders represented in EDRAM.

C. Thegerstrom (Swedish Nuclear Fuel Company, SKB) highlighted the historical role of SKB in international cooperative efforts. These include the international STRIPA and DECOVALEX projects, and the ongoing research at the Äspö underground research laboratory. The reader is referred to specific presentations on Äspö.

K. Nash (Ontario Power Group) described the overall Canadian program implemented under the purview of the Nuclear Waste Management Organization. The reader is referred to specific presentations on this program.

The Belgian program was described by J-P. Minon of ONDRAF/NIRAS. Emphasis was placed on how smaller nations (both in terms of overall size and size of nuclear program) must rely on cooperative efforts to be able to develop the required disposal technologies.

M-C. Dupuis (ANDRA) provided a comprehensive summary of the French program. Of particular note is a recent federal law that prescribes a new schedule for their research program, leading to a license application in 2015 and waste receipt in 2025. She emphasized that, in France, there is no debate on whether a repository is required; it is needed just to address disposal of wastes from the existing program. France is forming two new commissions to study the various factors affecting repository development, including social factors.

E. Knox (DOE) expressed that DOE is in the near final stages of preparing a license application for the potential repository at Yucca Mountain. In addition, he stated that DOE is promoting legislation that would benefit the Yucca Mountain project, and noted that specific legislation will be required to withdraw the appropriate area of land (currently under the jurisdiction of several federal agencies) to meet NRC land ownership and control requirements. Little was said about international cooperation in this presentation.

This time representing the Swiss organization NAGRA, H. Issler returned to summarize the recent publication of a revised siting concept. It calls for identification of two sites for subsequent detailed characterization, a very open and public process, approval by both houses of parliament, and possibly a full public referendum.

Underground Facilities

W. Patrick [Center for Nuclear Waste Regulatory Analyses (CNWRA)] and J. Kemeny (University of Arizona) co-chaired the seven-paper session on Underground Facilities. The papers spanned conceptualization, experimentation, and numerical analyses.

S. Masuda (Obayashi Corporation) opened the session describing a new concept that is being promoted to the government as an alternative approach to the current disposal facility design in Japan. CARE would comprise a series of large parallel panels in which self-shielding packages would be emplaced. Long-term monitoring, inspection, and maintenance would be facilitated,

as would ongoing access for possible retrieval, if necessary. The caverns would be backfilled, sealed, and closed at the appropriate future time. CARE appears to be at a very early state; little was said about detailed analyses of the underground structures, hydrological implications, worker doses, or performance assessment.

K. Sjoland (SKB) provided a comprehensive update on the ongoing Äspö experimental program, and how research there is supporting the overall repository research and development effort in Sweden. A central theme was that everything in the proposed repository would be natural: the geological system, the bentonite backfill, and the copper container are all natural materials with well known stability over very long periods of time. He also expressed a recent shift to emphasize research on (and perhaps the role of) engineered barrier systems in the SKB concept.

Two presentations provided different perspectives on the potential for, timing of, and extent of rock falls in the potential repository at Yucca Mountain. Under contract to the Electric Power Research Institute, J. Kemeny and colleagues calculated relatively minor skin effects would result from prolonged heating of the disposal drifts. Effects of seismic events were also studied. Here again, the effects were said to be relatively minor (though rock falls were larger) and very limited in spatial extent (i.e., few waste packages would be affected). Although he asserted a stable shape would be quickly achieved (and showed a picture from the Canadian underground research laboratory in massive granite as an example), no supporting information beyond the calculations was provided on this topic.

G. Ofoegbu (CNWRA) presented a different perspective on rock falls at the potential repository at Yucca Mountain. These calculations suggest rock falls will be more likely, will occur earlier, and will be more spatially extensive than indicated by Kemeny. Readers are referred to the proceedings and a number of CNWRA reports on this subject.

Two papers addressed recent repository-related research at the University of Nevada. P. Kar (a student of G. Danko) conducted an extensive study aimed at optimizing the amount of waste that can be incorporated in large waste packages while meeting fuel temperature and other requirements. With few exceptions, denser fuel packing configurations were able to be achieved with no changes in external waste package dimensions; in a few cases, relatively minor increases in waste package diameter were required. Potential criticality concerns associated with the denser packing configurations were addressed by introducing neutron-absorbing materials within the packages. The authors concurred that the DOE move toward a transportable, aging, and disposal container concept would eliminate the possibility of implementing the configurations shown here.

G. Danko (University of Nevada) summarized an extensive study of the effects of preclosure ventilation on the environmental conditions in disposal drifts at the potential repository at Yucca Mountain. Results of the numerical simulations focused on temperature, humidity, and formation of condensate.

O. Povetko (CNWRA) closed the session with a presentation on independent analyses of worker doses in the vicinity of access drifts adjacent to disposal drifts. Two models were used, based on the current DOE configuration for the underground area of the potential repository at

Yucca Mountain. Results were shown to be very sensitive to one model simplification (i.e., representing the curved intersection with an angular drift-to-drift configuration).

Alternatives to Deep Disposal–Panel

B. Butterfield (HDR Engineering) and D. Bullen (Exponent) hosted a four-member panel on alternatives to deep disposal. Each panelist brought strong individual perspectives to the discussion. A. MacFarlane (MIT) expressed her themes about the insufficiency of understanding about the potential repository at Yucca Mountain, the inadequacies of performance assessment, and the general unacceptability of deep geologic disposal at Yucca Mountain. Her presentation and responses to questions were marked by unequivocal statements. P. Craig (University of California) expressed concern about the haste with which the United States program is proceeding, highlighted by the title of his presentation (from the Beatles): "Let it be, let it be, let it be, let it be; speaking words of wisdom, let it be." As a counterpoint, J. Malone (Exelon) provided pro-repository perspective. His emphasis was on making significant progress, doing so efficiently, and DOE completing what it was charged by Congress and paid by the utilities to do. J. Kessler (EPRI) spoke of the statutory and regulatory framework, the historical perspective on geologic disposal, and the basic scientific principles that have led all nations to adopt deep geologic disposal as the most appropriate means for dealing with high-level waste.

Interactions between the panel and the audience were quite vigorous. Several speakers from the floor sought to correct and/or clarify comments from the speakers. Some participants expressed concern over the apparent and seemingly fundamental problems (particularly comments by MacFarlane) associated with deep geologic disposal.

Studies in Underground Research Laboratories

A presentation by K. Lehto (Posiva Oy) on monitoring of the Underground Rock Characterization Facility (known as ONKALO) in Finland led the session on underground research laboratories. To date, the Underground Rock Characterization Facility has been developed with about 1 km (.62 mi) of excavated tunnel to a depth of nearly 100 m (328 ft). Development was preceded by installation of various monitoring systems to provide a baseline for assessing changes in the environment, hydrology, chemistry, and rock responses of the surrounding area. Although not discussed in the presentation, the study included a range of pre-test calculations of anticipated responses.

N. Bockgard (SKB) summarized hydrologic research at the Äspö facility in Sweden. The program began with descriptive hydrology, which divided the site into hydraulic soil, hydraulic rock, and hydraulic conductor (i.e., fracture) domains. The reader is referred to the paper for details on the numerous measurement programs, modeling efforts, and research/technology development activities at Äspö (e.g., development and implementation of adaptive grid generation).

International Repositories–Panel

The panel discussion on international repositories—moderated by L. Barrett—featured five speakers representing various national and international perspectives. The interactions were vigorous and rather rapid-fire, so only selected points are captured here.

Working from the assumption that the world must have more nuclear energy, T. Isaacs (Lawrence Livermore National Laboratory) stated that security concerns (e.g.,nuclear proliferation) were the greatest impediment. He offered an approach of controlling the fuel supply, beginning with enrichment and continuing through reprocessing and ultimate disposal of residual wastes.

H. Codee (COVRA, Netherlands) offered some simple and sobering arithmetic. Smaller nations have (or could be expected to have) on the order of 500 MW of generating capacity that over the life of the reactors would produce about 100 GW-hr of electricity. With an assumed repository cost of $1 billion, the burden of disposal would contribute 1 cent/KW-h produced: 1000 times greater than the planning factor used by most nations, including the United States. Furthermore, a very large number of repositories would be needed if each nuclear-generating nation was required to have its own. Codee contrasted the assumed nation-by-nation repository siting with the situation in Europe where electrical generation and distribution, fuel fabrication, reprocessing, and other parts of the nuclear fuel cycle are shared across national boundaries.

I. Rybalchenko (VNIPIET, Russia) provided an historical perspective on the Soviet era when sharing of electrical distribution, fuel fabrication, reprocessing, and disposal as he stated was successfully accomplished. He stated that most of the concepts required for international repositories to be implemented were used among the states comprising the Soviet Union and throughout Eastern Europe.

A speaker from the floor offered an assessment of the elements of an international program. These are (i) a mature understanding of democracy, (ii) a profound fairness during implementation, (iii) joint development of required technologies, (iv) understanding and acceptance of the relatively high cost of the program, including the need for basic research as a foundation to site characterization, design, and assessment, (v) the need to value safety the same everywhere (i.e., there should be no differentiation among nations), and (vi) the discussion must begin now.

Codee observed that nations are increasingly aware that the environment does not stop at the border. He called for extending this thinking because problems encountered in one nation reflect on and may directly affect others.

The International Training Center was mentioned in this panel session and a lunch keynote speech. This training center is located in Switzerland, sponsored by 50 international members and was promoted as a way to educate the next generation of scientists and engineers, and to bring a more common understanding among the current generation.

Preclosure and Environmental Impact Estimation

A presentation by S. Mayer (ANDRA) discussed how the French program addresses reversibility, and supports related decisions by active monitoring programs. The monitoring programs envisioned are comprehensive with respect to the features, events, and processes to be assessed; and extensive on spatial and temporal scales. Mayer emphasized that a viable retrievability option was central to the credibility of any claim to reversability of decision making. A video clip was used to show in animated fashion the planned construction, emplacement, and operation processes at a future repository; retrievability was also addressed. In response to a question, he stated that it was not certain, but was assumed there would be a physical demonstration of retrievability as the French repository program progressed.

J. Bruno (Enviros) described how consideration of retrievability influenced the Spanish repository program. As described, the Spanish approach is very flexible in comparison with many other nations. This led to vigorous interchange with a representative of the German repository program, which the Bruno presentation asserted was rather inflexible. J. Bruno indicated that including the retrievability option in the Spanish program, introduces the need to (i) extend the period of maintenance and (ii) consider a longer period during which water inflows an oxidizing environment persist, an enlarged excavation disturbed zone, greater potential for human intrusion, and other factors.

T. Ahn (NRC) closed the session with a presentation on preclosure safety analysis. The analysis was based on the proposed Dry Transfer Facility handling single bare spent fuel assemblies. Sensitivity studies were done for several parameters. The author noted that if DOE implements the transportation, aging, and disposal canister concept, the analyses would need to be revised.

Transport in Geological Barriers

Several presentations summarized studies with implications for more realistic analysis of geological barriers.

H.H. Liu (Lawrence Berkeley National Laboratory) presented a meta-analysis of field data on plume development in fractured rock. The meta-analysis suggests possible scale dependence in the matrix diffusion process. Matrix diffusion is an efficient process for slowing down-gradient movement of radionuclides; an increase in diffusion with travel distance would improve barrier performance.

P. Reimus (Los Alamos National Laboratory) summarized a different analysis of plume development in volcanic aquifers. That study focused on estimating transverse dispersivities and suggested that transverse dispersion may be greater than assumed in DOE and NRC saturated zone modeling. Greater dispersion would reduce groundwater concentrations. Several members of the audience pointed out that transverse dispersion is difficult to estimate because of uncertainties in source size and temporal changes in groundwater flow direction.

C. Scism (Los Alamos National Laboratory) described desorption experiments using uranium and neptunium and Yucca Mountain alluvium. The experiments showed evidence for kinetic limitations on sorption and desorption. Models with multiple sorption rates were needed to fit the

experimental data. The results suggest that short-duration sorption and desorption experiments may significantly underestimate distribution coefficients.

S. Painter (CNWRA) presented a new particle-based Monte Carlo approach for radionuclide transport simulation. The new method is designed specifically for performance assessment calculations and allows more realistic representations of matrix retention processes with fewer simplifications.

Subsurface Water Flow and Contaminant Transport

There were several presentations related to saturated zone flow and transport. W. Arnold (Sandia National Laboratories) presented an evaluation of the potential effects of a reducing geochemical environment in the saturated zone at Yucca Mountain. This analysis was prompted by previous work that suggested the transport flow path may encounter a narrow zone of reducing conditions. It was concluded that reducing conditions, if confirmed by additional data, could provide a significant barrier to migration of certain radionuclides by increasing their effective sorption coefficients by several orders of magnitude. Dr. Arnold noted, however, that there are presently no plans to take credit in a license application for reducing geochemical conditions in the saturated zone.

S. James (Sandia National Laboratories) explained the development of a new ghost-node method for integrating the Yucca Mountain site-scale saturated flow model with the larger Death Valley regional model. This approach will provide better integration between the two models and make boundary conditions for the site-scale model consistent with the regional model. Dr. James presentation suggested that significant refinements are being made to the Yucca Mountain saturated zone model. For example, the model grid is being refined to 250 m (820 ft) grid squares in the horizontal dimension, compared to the previous 500 m (1640 ft) grid scale. Additionally, the model will be updated to incorporate an updated hydrogeologic framework model.

Also related to saturated zone flow, A. Umari (U.S. Geological Survey) and P. Reimus (Los Alamos National Laboratory) gave separate presentations on results of recent tracer testing conducted in saturated alluvium at the Nye County EWDP–22 well complex. Depending on the analytical method and input assumptions, a wide range of effective porosities can be estimated from these tests. One of the tracer tests seemed to show the effects of matrix diffusion along the transport pathway, but other tests in the same wells did not show this affect. Results of these tests are currently considered preliminary, but may be used to provide support for parameter estimates used in the Yucca Mountain site-scale model.

G. Danko (University of Nevada) made a series of presentations related to his recent modeling work on heat-driven moisture vapor transport in a hypothetical repository drift. Previous models that did not account for the high permeability of the drift itself tended to predict that moisture vapor would be driven away from heated repository drifts where it could subsequently condense. His more recent results suggest that significant amounts of moisture vapor could be driven from the heated rock into the drift. In this model, the water vapor would move from the hotter drift center towards the relatively cooler drift ends, where the vapor could condense.

Volcanic Hazards and Consequences

C. Connor presented an alternative modeling approach for estimating volcanic hazards. The approach uses a random potential (as opposed to a constant or deterministic potential) and double stochastic process where results are driven more by observations (i.e., measured data) than the model selection. Probability modeling for volcanic hazards is relevant to NRC and CNWRA evaluations of DOE Identification of Events with Probabilities Greater Than 10^{-8} Per Year.

Three papers presented results from Electric Power Research Institute investigations on magma repository interactions and the disruption of waste packages by magma. In addition, Electric Power Research Institute investigations of volcanic consequences, including assumptions on human remediation actions and human-induced removal of tephra following the original fall deposit, were presented in the poster session. Electric Power Research Institute concluded that in the unlikely event of an igneous event at Yucca Mountain, it is very unlikely that waste packages will be breached by the actions of the magma or that radioactive material will be released from the repository. Two presentations summarized recent EPRI reports. M. Kozak (Monitor Scientific LLC) discussed consequences associated with igneous activity at Yucca Mountain, and M. Morrissey (Colorado School of Mines) presented the conceptual models for an igneous event at the Yucca Mountain repository. The Electric Power Research Institute project team concluded that (i) conditions at the drift level are less extreme than assumed previously by DOE and NRC, (ii) magma enters the drifts less violently than previously described in DOE and NRC analyses, (iii) magma entering drifts cools and solidifies rapidly so that it only flows a relatively short distance into an intersected drift, (iv) any magma entering the drifts would be expected to cool and solidify in a manner that isolates the remaining waste packages, and (v) the waste package provides a very significant barrier to release of radionuclides such that consideration of credible failure mechanisms leads to a reasonable expectation that no waste packages will fail during a postulated igneous event at Yucca Mountain. These conclusions by the Electric Power Research Institute team are based on the consideration of several key features of the repository system that are claimed to have not previously been considered, including the consideration of improved analogs and new data that suggest much lower eruption temperatures, a much less violent eruption style, and much higher magma viscosities than have been considered by other investigators. The Electric Power Research Institute team believes that present DOE and NRC assessments of repository performance are conservative, and more realistic scenarios and input data would demonstrate an even greater margin of compliance. The full Electric Power Research Institute reports are being reviewed by NRC and the CNWRA staff.

R. Benke (CNWRA) and D. Hooper (CNWRA) presented companion papers that described a new abstracted model for the fluvial redistribution of contaminated tephra in Fortymile Wash and discussed how process-level modeling supported the determination of parameter values for the abstracted model. The new abstracted model will improve realism and allow staff to investigate the significance of fluvial redistribution of contaminated tephra when estimating potential consequences and risk from an igneous eruption that intersects the repository.

Unsaturated-Zone Rock-Water Interactions

Presentations about Yucca Mountain groundwater geochemistry and rock-water interactions were divided among several technical sessions.

A presentation by K. Scofield (S.M. Stoller, U.S. Geological Survey) supported the characterization of porewater chemistry from Yucca Mountain samples. The reliability of such data is an important geochemical concern because most of the water in the unsaturated zone is porewater, which is difficult to sample. In many rocks and sediments (e.g., clay-bearing materials), the more easily removed fraction of porewater tends to be less saline than tightly held porewater, so the chemical data may vary arbitrarily depending on how hard the sample has been squeezed to remove the porewater. In this study of Yucca Mountain samples, the author contrasted the effectiveness of two extraction techniques, uniaxial compression and ultracentrifugation, and demonstrated that the porewater chemistry from the tuff samples did not vary significantly as a result of the extraction method used or as a function of the amount of squeezing (i.e., the proportion of porewater removed from the sample). Uniaxial compression worked best on nonwelded tuffs. The compression technique first removes the pore gas fraction, which can also be a source of useful data, and then the porewater is squeezed out. As might be expected, higher compression strengths remove more water from samples. In this study, the aliquots of water collected at different compression strengths nevertheless showed little variation in composition. Ultracentrifugation is a more recently developed extraction technique than compression, and it presently appears to be the only effective method of obtaining porewater samples from densely welded tuffs. Ultracentrifugation can remove about 40 percent of the water from welded tuffs, but it can only remove about 25 percent of the water from nonwelded tuffs because of capillary pressure effects. The aliquots of water collected from welded tuff samples at different centrifugation speeds and over increasingly longer time periods in this study were chemically similar to each other. For a nonwelded tuff, Scofield also compared porewater samples collected by uniaxial compression with porewaters collected from the same tuff by ultracentrifugation. The comparison indicated that no significant difference in porewater chemistry resulted from the difference in extraction methods.

Isotopic and chemical analyses of tunnel seepage water from the 2005 seepage event were presented by T. Oliver (S.M. Stoller) and J. Whelan (U.S. Geological Survey). The stable isotope data (oxygen and deuterium) were consistent with heavy isotope enrichment by evaporation of young shallow groundwater. The seepage samples overall were calcium-sulfate-chloride waters and, except for a higher carbonate concentration, they were similar in composition to the porewaters associated with overlying tuffs. Seepage around rock bolts had slightly different compositions corresponding to localized reduction, possibly promoted by microbiological activity.

Two U.S. Geological Survey presentations were based on uranium disequilibria studies involving rock-water interactions. J. Paces, L. Neymark (U.S. Geological Survey), T. Chezzehei, and P. Dobson (Lawrence Berkeley National Laboratory) examined four large lithophysae [cavity diameters 0.5–1.0 m (1.6–3.2 ft)] exposed in welded tuff in the walls of the Exploratory Studies Facility and ECRB. Based on a numerical simulation of drift shadow formation, they expected that cavities smaller than 0.5 m (1.6 ft) would not develop a drift shadow. They analyzed rock samples beneath and around the cavities to determine whether naturally occurring uranium in the rock below the openings had been protected from leaching by groundwater compared to the surrounding rock, an effect that may have persisted even if the drift shadow had only been present initially (~12 million years ago) and gradually disappeared. They also conducted U-series disequilibria studies of the rock samples, to determine if the area beneath the cavity had experienced less interaction with water within the past million years compared with the rocks above or beside the cavity walls. The data indicate that a drift shadow is associated with one of the two largest cavities. However, there was no clear evidence for a

drift shadow in the other large cavity or in the two smaller cavities studied. This result was not surprising given that the large cavity with no drift shadow had a thick 2–3 cm (.78–1.81 in) deposit of secondary calcite and opal on its floor, indicating that there had been substantial seepage into the cavity over time clearly indicating that no drift shadow had formed.

The other uranium isotope disequilibria study was presented by L. Neymark (U.S. Geological Survey). Because of the low permeability in the Calico Hills nonwelded zeolitic unit, water movement is assumed to occur as fracture flow. No credit is taken in the performance assessment for radionuclide sorption on zeolites in the rock matrix. However, this study reported evidence of isotopic disequilibria in the matrix of the Calico Hills nonwelded zeolitic tuff, indicating that water has preferentially leached U-234 from the rock matrix within the past several hundred thousand years. The data are inconclusive about whether the hydrogeological process was matrix flow or matrix diffusion, but in either case a substantial retardation of certain radionuclides could be attributed to water movement through the zeolitic unit as a natural barrier.

Geochemistry of Saturated-Zone Waters

K. Futa (U.S. Geological Survey) compared and contrasted data from two sites (borehole complex 19 and borehole complex 22) and from two wells (one drilled traditionally, with screened borehole intervals, and one sonic drilled to avoid contamination by drilling fluids) at each site. Both sites are located adjacent to southern Fortymile Wash, where the water table is in alluvium. Water samples were collected from the screened boreholes (in 19D and 22S) by pumping the discrete intervals and from sonic cores by ultracentrifugation (in 19PB and 22PC). The water samples collected by ultracentrifugation provided more detailed information on saturated-zone water chemistry than the boreholes completed by traditional methods. Strontium isotope data from the upper part of the saturated zone in boreholes 19PB and 22PC indicate an influx of local recharge water mixing with groundwater similar in composition to that beneath Yucca Mountain. Concentrations of Na, Ca, and Sr from the middle, high-flow part of borehole 19PB may correspond to cation exchanges processes on zeolites in the alluvium or upgradient in the tuff.

Another U.S. Geological Survey study presented by G. Patterson discussed additional geochemical data about water samples from boreholes 19PB and 22PC that also indicated a shallow mixing component of recharge water along Fortymile Wash, and cation exchange processes in deeper waters [below 200 m (656 ft)] that correlate more closely with Yucca Mountain porewaters. The authors proposed a layered conceptual model for the saturated zone in this area, with a layer of alluvial groundwater, mixed with recharge water, essentially sitting on top of older water flowing from the vicinity of Yucca Mountain.

The geochemistry papers included two Los Alamos National Laboratory studies of sorption of neptunium and uranium onto alluvium. In Uranium and Neptunium Desorption from Yucca Mountain Alluvium, C. Scism, P. Reimus, M. Ding, and S. Chipera studied uranium and neptunium desorption using a flow-through experimental method and groundwater and alluvium samples obtained from sonic-drilled boreholes along a potential groundwater flow path. The desorption results were modeled assuming that approximately 80 percent of the sorption sites in the alluvium were fast and 20 percent were slow. Batch sorption experiments and short-term batch desorption experiments typically have not detected the effects of the slow sorption sites, but their role over distance and time in a repository setting would increase their importance in

terms of retarding transport of radionuclides. A related study, Sorption Characteristics of Radionuclides on Clays in Yucca Mountain Alluvium, by M. Ding, P. Reimus, S. Chipera, and C. Scism, used natural alluvium and a sodium nitrate solution to examine the variation of pH and particle size on sorption. The smaller particles in the alluvium had greater proportions of smectite and clinoptilolite, which improved their overall sorption characteristics. Sorption also appeared to be enhanced, relative to sorption on pure phases, by a thin coating of iron oxide that appears to be present on many of the alluvium particles.

Regulatory Development

The DOE quality assurance requirements traceability database and its application were discussed in the conference. The purpose of this system is to assure that all applicable source quality assurance requirements (e.g., 10 CFR 63.142, Yucca Mountain Review Plan Section 2.5, etc.) are addressed in the DOE Quality Assurance Requirements and Description. The system allows for forward and backward traceability. In addition to its use in quality assurance requirements and description development, reports from this system are provided to NRC to facilitate their quality assurance requirements and description reviews.

In discussing the Swedish guidance for geologic disposal of nuclear waste, the speaker described how the best available techniques should be used to reduce uncertainty and how optimization should be used to reduce risk. A second Swedish presentation described prelicensing review activities and the review strategy as applied to their waste encapsulation and spent fuel facilities.

A presentation on EPA proposed amendments to the Yucca Mountain radiation standards elaborated on the general presentation made during the Opening Plenary Session by the EPA Director of the Office of Radiation Protection and Indoor Air. The types and sources of public comments were discussed, as was the logic (to a very limited degree) for the EPA approach.

Near-Field Processes

The session on near-field processes covered various aspects of high-level waste handling and disposal. One paper was devoted to discussing drop tests of spent nuclear fuel canisters made of austenitic stainless steels. Tests show that canisters can remain airtight after accidental drop events. Finite element simulations of plastic deformation produced results in good agreement with the experimental deformation, providing confidence that possible deformation states can be reliably simulated.

The session also addressed use of bentonite as buffer material in the high level waste programs of Japan and Sweden, such as the effect of gas accumulation on the permeability of the host rock. Bentonite is a material that expands when saturated with water, sealing the system and driving it towards anoxic conditions. One paper discussed a model to compute volume fractions during the transient bentonite expansion to possibly support contaminant transport models; this study was only partially successful in reproducing empirical trends. There is still a need to develop reliable models for bentonite transformation that can be used to support contaminant transport models for long periods. Two papers discussed gas migration tests for high-level waste programs in Japan and Sweden. It is envisioned that gas may be produced by corrosion of metals and microbial degradation of organic materials. Gas accumulation may affect the near field; correspondingly, one objective of the gas migration tests is to assess possible effects of

gas accumulation. Experiments to support the high-level waste program of Japan are being performed at the Nagra Grimsel Test Site in Switzerland. The data gathered were useful to understand potential paths of gas migration. To date, no increase in bentonite permeability has been detected. Lasgit is a full-scale demonstration experiment at the Äspö Hard Rock Laboratory at a depth of 420 m (1378 ft) to support the high-level waste program in Sweden. Lasgit will provide data for performance assessment models. Preliminary gas testing is scheduled to start in 2007. To date, only results of the hydration phase are available, including measurements on bentonite stresses, porewater pressures, and permeabilities.

Two talks were devoted to the implications of advanced spent fuel cycles in the United States and Belgium. Fast breeder reactors could produce spent fuel with lower actinide inventories. The design of the repository could be modified to take advantage of the lower thermal output and lower inventory density.

Waste Packages

Three technical sessions were related to waste package, including five papers for each session on waste package corrosion, waste package fabrication, and waste package materials.

The waste package corrosion session, co-chaired by F. King (Integrity Corrosion Consulting) and Y. Pan (CNWRA), included three presentations from the DOE Science and Technology Program on general and localized corrosion of Alloy 22. The information presented was consistent with that previously reported by DOE. In addition to the DOE papers, the presentation by F. King summarized the Engineered Barrier System Corrosion Model developed by EPRI. The model predicted that approximately 66 percent of drip shields and 15 percent of waste packages will fail within a period of one million years.

In the waste package fabrication session, three presentations discussed the DOE development of a full-scale waste package closure system at the Idaho National Laboratory. The primary operations included welding three closure lids, evacuating and backfilling the waste package, examining the welds nondestructively, and mitigating residual stresses in the outer lid weld. A demonstration of the closure system with a full-scale prototype waste package is currently scheduled by October 2008.

Papers in the waste package materials session included mechanical properties of Alloy 22 weldment, development of a Ni-Cr-Mo-Gd alloy as neutron absorbing structural material, and waste package performance during an igneous disruptive event. F. King presented an assessment of the potential impacts of igneous processes on the structural integrity and corrosion behavior of waste packages. Modeling and laboratory analyses indicated that few failures of the Alloy 22 waste packages are predicted to occur for either the extrusive or intrusive scenarios.

Waste Storage and Transportation Casks

There were two separate but closely related sessions on waste storage and transportation casks.

C. Parks gave an update on the status of the current and planned burnup credit activities at Oak Ridge National Laboratory. The Oak Ridge National Laboratory analyses indicate that if full

burnup credit is allowed in high-capacity (e.g., 32-assembly) transportation and storage casks, it would increase the allowable loading inventory up to 90 percent of the total projected spent nuclear fuel inventory. He emphasized that implementing a pressurized-water-reactor fission product burnup credit would save in the range of $150–$400M in transportation costs alone. Currently, Oak Ridge National Laboratory is working to obtain and make available to industry an experimental database that would ensure reliable and accurate estimations of biases and uncertainties in code predictions of neutron multiplication factors. Suitability of French proprietary criticality experiments for this purpose is being assessed now using the SCALE/TSUNAMI code.

R. Quinn from BNG Solutions, which provides a variety of services to DOE presented their view on the DOE transportable, aging, and disposal canister concept under development. He endorsed the concept, focusing mostly on benefits such as the reduced number of handling operations and reduced risk of fuel handling-related accidents.

Several talks were devoted to the proposed use of depleted uranium (i) as metal cast, (ii) in high-density concrete with ceramic aggregate based on depleted uranium dioxide, (iii) as ceramics component, and (iv) in uranium dioxide–steel CERMETs to construct spent nuclear fuel casks for storage, transportation, and disposal. C. Forsberg from Oak Ridge National Laboratory emphasized that CERMETs, which consist of ceramic particles embedded in contiguous steel, can incorporate brittle ceramics [DUO_2, aluminum oxide (Al_2O_3), etc.] with highly desirable properties into a strong ductile metal matrix with a high thermal conductivity, thus combining the best properties of both materials. Four presentations from different research organizations of the Russian Agency for Atomic Energy, Rosatom, (VNIIEF, VNIINM and VNIIKhT) emphasized that the CERMET composite material was developed jointly by the Rosatom Institutes and Oak Ridge National Laboratory. It is intended to be both an effective anti-radiation protection and structural material in the proposed casks. Their presentations covered detailed conceptual designs of the casks utilizing depleted uranium in CERMET, high-density concrete DUCRETE, and ceramics DUAGG materials, as well as the shielding properties, criticality safety, compliance with IAEA safety requirements, and comparison of similar Russian, German and U.S. conceptual cask designs.

L. Taylor from Idaho National Laboratory presented a poster documenting results of the criticality safety analyses for the DOE spent nuclear fuel intended for geologic disposal. The current DOE approach to fuel packaging proposes using a limited number of basket designs for the great variety of DOE spent nuclear fuel types. These fuel types were organized into nine major groups with respect to criticality safety, and detailed analyses were conducted for the bounding fuel types within each group. It was demonstrated that (i) the reactivities of the loaded casks increase with increased load of fissile materials, (ii) the limited fuel and moderator homogenization within the baskets would produce conservative reactivity results but significantly simplify criticality analysis, and (iii) some of the casks would require introduction of neutron absorber material within the casks in order to maintain subcriticality of the loaded fissile configurations.

CONCLUSIONS:

The conference was beneficial because it covers topics in many disciplinary areas related to high-level waste disposal and regulatory perspectives. In addition, the conference provides an excellent forum to exchange technical ideas, regulatory perspectives, and current

progress in addressing challenging issues related to the repository programs of the United States and other countries.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

Staff should continue to support this conference through active participation and submission of papers.

The International Training Center should be investigated as a possible way to educate the next generation of scientists and engineers, and to bring a more common understanding among the current generation of staff at the NRC and CNWRA.

SIGNATURE AND DATE:

R. Benke	6/8/06 Date
R. Brient	6/8/2006 Date
A. Chowdhury	6/8/2006 Date
J. Durham	6-8-06 Date
D. Hooper	6/8/2006 Date
S. Hsiung	6-8-06 Date
J. McMurry	6-8-06 Date

S. Mohanty — Date: 6/6/2006

G. Ofoegbu — Date: 6/8/2006

O. Osidele — Date: 6/8/06

S. Painter — Date: 6/8/06

Y. Pan — Date: 6/8/06

W. Patrick — Date: 06/08/2006

O. Pensado — Date: 6/8/06

O. Povetko — Date: 6/7/06

B. Sagar — Date: 6/8/06

P. Shukla — Date: 6/8/06

J. Winterle — Date: 6/7/06

CONCURRENCE:

Siddhanta Mohanty for
B. Sagar, President

6/8/2006
Date