A PUBLICATION OF THE AMERICAN NUCLEAR SOCIETY

Radwaste Solutions

THE MAGAZINE OF RADIOACTIVE WASTE MANAGEMENT AND FACILITY REMEDIATION
MARCH/APRIL 2007

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Radwaste Solutions

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Radwaste Solutions

Editorial correspondence: Nancy J. Zacha, *Radwaste Solutions*, 1004 Langhorne Rd., Lynchburg, VA 24503; 434/384-3305; fax 434/385-0751; e-mail: radwaste99@aol.com.

Advertising correspondence: Jeffery R. Mosses, Advertising Sales Manager, *Radwaste Solutions*, 555 N. Kensington Ave., La Grange Park, IL 60526; tel. 708/579-8225; fax 708/352-6464.

ANS Headquarters: all numbers are in the 708 area code; accounting, 579-8205; data processing, 579-8223; executive director, 579-8200; member services, 579-8266; officer and board services, 579-8284; procurement, 579-8207; public communications, 579-8265; scientific publications, 579-8216; standards, 579-8268.

ANS Headquarters–General Information
phone: 708/352-6611
fax: 708/352-0499 or 708/352-6464
e-mail: nucleus@ans.org
ANS Web Site: http://www.ans.org

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Radwaste Solutions

Volume 14, Number 2
March/April 2007

Wetlands management is now part of the continuing legacy of the old Fernald Feed Materials Production Center. The article beginning on page 54 looks at the role of public involvement in the Fernald site cleanup and restoration.

Features

Departments

On the Cover:

What can a three thousand-year-old Egyptian glass cosmetic bottle tell us about the potential performance of an underground nuclear waste repository? The article beginning on page 22 give us some clues. (Photo copyright: British Museum, London)

Next Issue:

Low-Level Waste

Comments on this issue ▼

Too Many Choices?

Shortly after the November U.S. elections, which put the Democratic Party in control of both houses of Congress for the first time in a dozen years, I asked a colleague what would be the impact of having Sen. Harry Reid of Nevada, the champion opponent of the U.S. Department of Energy's Yucca Mountain Project, serve as the Senate Majority Leader. My colleague replied that I was asking the wrong question.

The real threat to the Yucca Mountain Project, my colleague continued, was not a little high-level opposition at the congressional level. Rather, he said, it was the sudden increase in the number of alternatives to a high-level waste/spent fuel repository. He listed onsite spent fuel storage, centralized spent fuel storage, spent fuel reprocessing, and the Global Nuclear Energy Partnership (GNEP) project, among others. Are we going to store spent fuel for a while, or aren't we? Are we going to reprocess the backlog of spent fuel, or aren't we? Are we going to reprocess future spent fuel, or aren't we? It's these questions, and the uncertainties surrounding them, he concluded, that give those involved in the Yucca Mountain Project reason to fret.

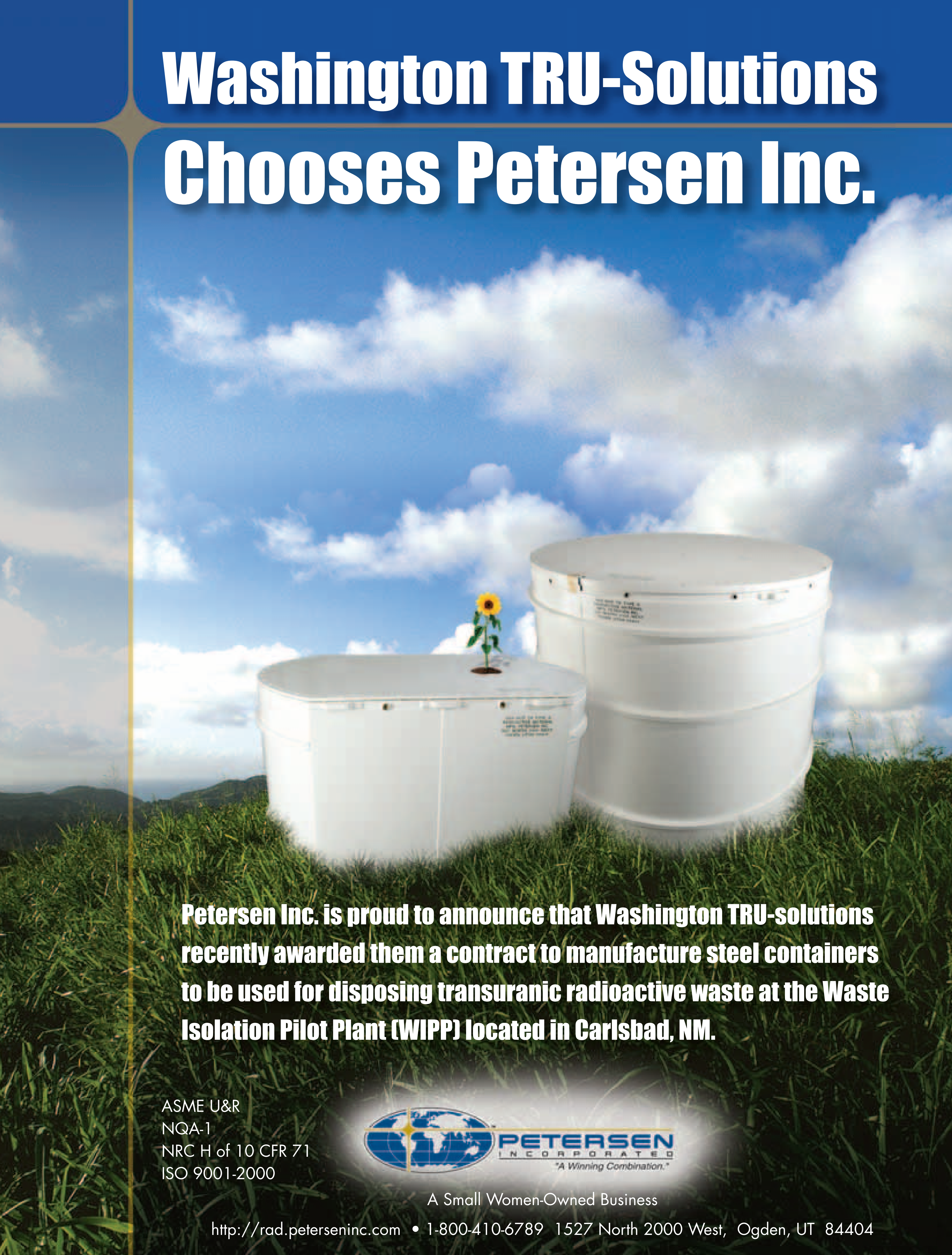
I have spent a great deal of time since November thinking about that brief exchange. *Can* one have too many choices, and therefore be unable to make a sensible decision? I remember stories told in the Cold War days, by defectors from Eastern Europe and the old Soviet Union, that they found living in the West to be very stressful. Why? Too many choices. Moving from a world where they had few options or choices, whether we are talking about career moves or food selections, to a world of almost infinite choices was unbearably stressful. Need a box of cereal for breakfast? The typical Western grocery store offers a whole *aisle* of cereal choices: corn flakes, oatmeal, shredded wheat, Wheaties, Chex, Cheerios, plain cereal, sugar-coated cereal, chocolate-flavored cold cereal, maple-flavored hot cereal. How does one used to dealing with one or two choices of cereal make a selection from so many offerings?

So, does the prospect of reprocessing, for example, take away from the need for a geologic high-level waste repository? The most sensible answer would be that, no, reprocessing doesn't remove the need for the repository, although it may delay that need. But in the case of Yucca Mountain, which has suffered from so many delays already, does the prospect of even more delays sound the death knell? Is that the fear of the people who have already given up to a quarter of a century to the project?

Editorial writers can seem unbearably smug, sounding as if they have all the answers, pretending to be the voice of reason amidst the din of chaos. In truth, we editorial writers *don't* have all the answers—in some cases not even a single proposal. I'd like to think that just because there appear to be more options out there today than were available, say, five or ten years ago, we haven't lost sight of the Holy Grail. I want to believe that our quest for a final disposal facility for HLW and spent fuel—or for the reprocessing leftovers of that spent fuel—is still a major focus of our nuclear energy program.

I guess the only way we can tell for sure if the Energy Department is still serious about Yucca Mountain is to track the license application. Ward Sproat, director of the Office of Civilian Radioactive Waste Management, says he is "100 percent confident" that the license application will be submitted to the U.S. Nuclear Regulatory Commission by June 2008 (see "Headlines," this issue, page 6). You can be sure that the companies, utilities, scientists, engineers, workers, other interested parties in the nuclear industry, and, yes, editorial writers, will be watching closely as that date approaches.—*Nancy J. Zacha, Editor*

Have We Lost Sight of Our Holy Grail?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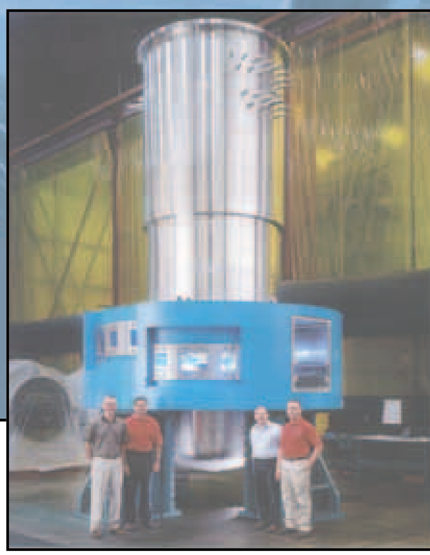
Sproat "100 Percent Confident" about License Application Submittal Date; Other Yucca Mountain Updates

OCRWM Director Ward Sproat is "100 percent confident" that the U.S. Department of Energy will have the Yucca Mountain high-level waste repository license application submitted to the U.S. Nuclear Regulatory Commission by June 2008. Sproat, head of the DOE's Office of Civilian Radioactive Waste Management, which oversees the Yucca Mountain project, was quoted in a *Nuclear News* interview published in January 2007.

Sproat was less confident that the repository will open in 2017, saying that all along, the 2017 date was considered the "best achievable" date the facility could become operational. For instance, he said, the most uncertainty lies in the time between the submittal of the license application and the time the DOE can proceed with construction. The best-achievable scenario allocates three years, but it could be as much as seven years, Sproat conceded. This would bring the repository start of operations date to around 2021.

In November 2006, Sproat told a National Academy of Sciences panel that the most likely starting date for the repository would be in 2020. He attributed the delay to the likelihood of lawsuits and other challenges.

- The U.S. Environmental Protection Agency is expected to release its final Yucca Mountain radiation protection standard in 2007, agency officials announced at the end of 2006. The standard had been expected to be released by the end of the year, but was held up by a review by the White House Office of Management and Budget. A draft standard was issued in 2005. The EPA declined to comment on whether the final standard contains any changes from the draft, which proposed radiation release levels over a million-year period.
- At the end of 2006, the state of Nevada filed a petition with the U.S. Nuclear Regulatory Commission to prohibit the U.S. Department of Energy's proposal for in-



definite interim storage of spent fuel at the Yucca Mountain repository site. According to the petition, federal law prohibits a large interim storage site in Nevada as long as the state is the proposed location of a repository.

- In late November, the U.S. Department of Energy issued performance specifications for the Transportation/Aging/Disposal (TAD) canisters that it plans to use for transporting spent nuclear fuel from commercial reactor site to a high-level waste geologic repository. The agency will use the specifications to contract with industry vendors for developing conceptual container designs. The specifications include a description of the TAD system, which includes the TAD canister, the transportation overpack, the transportation skid, ancillary equipment, the shielded transfer cask, the aging overpack, the site transporter, the waste package overpack, and the storage ovepack. The specifications can be found on the Internet at http://www.ocrwm.energy.gov/.
- Decommissioned plants will not have to repackage spent fuel now being stored in dry storage canisters at Independent Spent Fuel Storage Installations at the closed plant sites, according to Ward Sproat, director of the U.S. Department of Energy's Office of Civilian Radioactive Waste Management. In a *Nuclear News* interview published in the January 2007 issue of the magazine, Sproat said: "We are not going to force people to open canisters they have sitting on a pad after their plant has been closed down. I believe we can come up with an equitable and mutually agreeable solution to this issue."

Waste Acceptance Contract for New Plants Due in Early 2007

The U.S. Department of Energy plans to develop a new standard waste acceptance contract for new power reactors, OCRWM Director Edward Sproat announced in late November. The DOE will be working with industry on developing a model contract, and an applicant seeking a combined construction/operating license from the U.S.

Nuclear Regulatory Commission for a new reactor will have to have a signed contract in hand before the NRC can issue the license. Sproat did not say how the DOE will handle the contract provision specifying the date by which the DOE must begin taking possession and disposing of commercial plants' spent fuel. That provision in existing contracts with the nation's nuclear utilities specified that the DOE would begin disposing of spent fuel by January 31, 1998, which in turn has led to a rash of lawsuits by utilities against the DOE for failure to meet that deadline (see next story).

Court Awards $39.7 Million in Rancho Seco Spent Fuel Lawsuit

Put the Sacramento Municipal Utility District on the list of nuclear utilities to receive court awards compensating them for the U.S. Department of Energy's failure to take possession of spent fuel by the January 31, 1998, contract date. In early December, the U.S. Court of Federal Claims awarded SMUD around $39.7 million in damages. The utility had initially sought to recoup $78.5 million in spent fuel costs incurred between 1992 and 2003. The court pared the amount to around half the original request.

Under contracts the DOE signed with nuclear utilities, the DOE was to take possession of a utility's spent nuclear fuel in 1998, the date by which a federal high-level waste/spent fuel repository was supposed to be operations. Delays in the repository program mean that the most optimistic start of operations date has been pushed back by more than 20 years. SMUD is one of more than 60 nuclear utilities that have sued the federal government after the DOE failed to meet its contractual obligations. The nuclear industry has estimated that total damages could reach $56 billion.

The Rancho Seco plant shut down in 1989 as a result of a citizen referendum. The spent fuel was removed from the reactor and placed in onsite dry storage in 2002.

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KEYNOTE SPEAKER ANNOUNCED

DR. DALE KLEIN
CHAIRMAN
NUCLEAR REGULATORY COMMISSION

CANBERRA is pleased to announce the confirmation of Dr. Dale Klein, Chairman of the US Nuclear Regulatory Commission as Keynote Speaker for the upcoming Users' Meeting. Dr. Klein will be speaking on topics of general interest to the nuclear industry.

As the principal executive officer of and the official spokesman for the NRC, Dr. Klein is responsible for conducting the administrative, organizational, long-range planning, budgetary, and certain personnel functions of the agency. His participation in the CANBERRA Users' Meeting will certainly benefit attendees with his insights.

CANBERRA's Annual Users' Group Meeting provides a professional forum where CANBERRA users and CANBERRA personnel exchange valuable information on products, services and applications. *We also find ways to have some fun!*

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- Radiation Monitoring
- Health Physics
- Waste Assay
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Canberra Industries, Inc.
800 Research Parkway – Meriden, CT 06450 U.S.A.
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DOE Releases GNEP Strategic Plan; Selects 11 Sites for Potential GNEP Facilities

In early January, the U.S. Department of Energy released its strategic plan for the Global Nuclear Energy Partnership (GNEP), outlining the program's purpose, principles, and implementation strategy. According to the DOE, the plan outlines a path forward to enable worldwide increase in the use of safe, emissions-free nuclear energy without contributing to the spread of nuclear weapons capabilities in a manner that responsibly addresses the waste produced. GNEP is a major element of President Bush's Advanced Energy Initiative.

The plan lays out how the DOE will prepare for construction and operation of a nuclear fuel recycling center and an advanced recycling reactor, and for continuing an aggressive research and development program focused on advanced fuel cycle technology. It also identifies the technology, economic, and environmental information necessary to present a convincing case to the Secretary of Energy by June 2008 for his decision on a path forward regarding the design and construction of recycling facilities in support of GNEP. The plan can be found on the Internet at http://www.gnep.energy.gov/.

Several weeks earlier, in late November 2006, the DOE selected 11 commercial and public consortia sponsoring 11 sites to receive up to $16 million in grants to conduct detailed siting studies for integrated spent fuel recycling facilities to support the GNEP initiative.The 11 proposed sites and sponsors are as follows:

- Atomic City, Idaho (EnergySolutions LLC).
- Barnwell, S.C. (EnergySolutions LLC).
- Hanford Site, Richland, Wash. (Tri-City Industrial Development Council and the Columbia Basin Consulting Group).
- Hobbs, N.M. (Eddy Lea Energy Alliance).
- Idaho National Laboratory, Idaho Fall, Ida. (Eddy Lea Energy Alliance).
- Morris, Ill. (General Electric Co.).

Industry news

● Oak Ridge National Laboratory, Oak Ridge, Tenn. (Community Reuse Organization of East Tennessee).
● Paducah Gaseous Diffusion Plant, Paducah, Ky. (Paducah Uranium Plant Asset Utilization Inc.).
● Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio (Piketon Initiative for Nuclear Independence LLC).
● Roswell, N.M. (EnergySolutions LLC).
● Savannah River National Laboratory, Aiken, S.C. (Economic Development Partnership of Aiken and Edgefield Counties).

Six of the proposed sites are DOE-owned.

The DOE will award the grants in 2007 for the groups to conduct site characterization studies for facilities that support GNEP. The facilities would include the Consolidated Fuel Treatment Center or the Advanced Burner Reactor, or both. The Consolidated Fuel Treatment Center would contain facilities where usable uranium and transuranics are separated from spent reactor fuel for use in producing new fuel that can be reused in a power reactor. The Advanced Burner Reactor would be a fast reactor that would demonstrate the ability to reuse and consume materials recovered from spent fuel, including long-lived elements that would otherwise have to be disposed up in a geologic repository.

The studies will examine site and nearby land uses, demographics, animal and plant habitats, geology and seismology, weather and climate, and regulatory and permitting requirements. The DOE may use this information in the environmental impact statements for each proposed GNEP facility. The department would then decide whether to move ahead with the facilities and choose a location for them.

Fourteen applications were originally submitted, and 12 were selected to receive a comprehensive merit review. Two of the 12 (the Tri-City Industrial Development Council and the Columbia Basin Consulting Group) decided to collaborate and team, because they both had nominated the Hanford site.

Radwaste Solutions
Low-Level Waste
Also in this issue:
· D&D at NTS
Fernald:
From Weapons

D&D Updates

● In early January, Consumers Energy's Big Rock Point Restoration Project received approval from the U.S. Nuclear Regulatory Commission to release the majority of the former nuclear plant property for unrestricted use. The NRC action confirms that the site meets all regulatory requirements and allows any type of use—from parks to playgrounds to housing—on the property. The release applies to approximately 435 acres and 1.5 miles of Lake Michigan shoreline. The property is a mixture of shoreline, mature hardwoods, and wetlands. Activities associated with the operation of the Big Rock Point nuclear plant actually encompassed less than 20 acres of the property. The plant's dry fuel storage facility remains under NRC jurisdiction and is located on a separate parcel from the 435 acres released for unrestricted use.

● In early November 2006, the U.S. Department of Energy has announced the completion of the decontamination and decommissioning operations at the Ashtabula, Ohio, site where uranium extrusion operations were carried out for 26 years in support of the government's nuclear weapons program.

The Ashtabula project, which focused mainly on uranium contamination, was completed by Lata-Sharp Remediation Services LLC, which was hired by the DOE in September 2005 to take over soil, groundwater, and facility remediation. Over 10 months of operations, Lata-Sharp excavated more than 1 million cubic feet of low-level radioactive and mixed waste from the site, and demolished more than a dozen structures. The DOE must still evaluate the site to ensure it meets final decontamination standards, which call for the site to be handed back to the site's owner, RMI Titanium Co., for unrestricted use.

This marked the third nuclear weapons site in a year where the DOE has finished cleanup operations. Major cleanups were recently declared completed at the DOE's Fernald site in Ohio and the Rocky Flats site in Colorado.

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Volume, product line growth

The demand for Westerman products is growing rapidly in both U.S. and international markets. Although small, Westerman has both custom build and production run manufacturing capability, and thus is able to accommodate limited orders as well as large-quantity demands. The company's manufacturing and fabrication facilities have steadily grown in size and now exceeds 150,000 square feet…and is still growing.

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The scope and depth of Westerman's manufacturing experience combined with established quality assurance processes enable the company to meet stringent standards set by A.S.M.E and those of the Nuclear Regulatory Commission. The company likewise meets the most rigorous standards established by the U.S. Department of Energy, the U.S. Corps of Engineers, the U.S. Department of Defense, and numerous prime and secondary government contractors involved with the production and handling of nuclear material and products.

The overarching imperative: SAFETY

From the office to the production floor, decisions made at Westerman are informed and molded by a nuclear safety culture that is as powerful as it is pervasive.

A DOE celebration in mid-January in Ohio marked the successful conclusion of the Ashtabula, Columbus, and Fernald cleanup projects.

● Tired of what it termed "senseless delays," the state of New York filed suit in December to force the U.S. Department of Energy to spell out plans for decontamination and decommissioning of highly contaminated facilities and removal of residual high-level radioactive waste at the former commercial spent fuel reprocessing site in West Valley, N.Y. The suit was filed by the New York State Energy Research and Development Authority and the state's attorney general. It also seeks damages from the federal government for pollution that has leaked from West Valley and contaminated nearby land and groundwater.

The lawsuit follows extensive, though ultimately futile, negotiations between the state and the DOE on the division of cleanup responsibilities at the facility. The DOE is required by law to clean up the high-level radioactive contamination at the site, while the state is responsible for cleanup of low-level waste at West Valley landfills that have also leaked contamination into the soil and groundwater. The state is also concerned that the DOE, in at effort to cut costs, may decide to leave some residual contamination in place at the site, particularly the underground storage tanks that once contained high-level waste. The DOE is planning to bury (rather than remove) similar tanks at the Idaho National Laboratory and Savannah River Site.

● Waste retrieval began in late December on the ninth single-shell waste storage tank at the U.S. Department of Energy's Hanford Site. Tank C-108, built in 1946, is one of 16 single-shell tanks in Hanford's C tank Farm. The tank has a capacity of 530 000 gallons, and currently contains about 66 000 gallons of sludge waste that must be retrieved. Waste retrieval operations were recently completed on Hanford tank C-204, bringing to total number of single-shell tanks retrieved at Hanford to six. Waste retrieval operations remain under way on tanks S-112 and

40 Ft. Top-loader

Top Hat Box

B-25 Type Box

S-102, and were to begin soon on Tanks C-104 and C-109. The work is being carried out by tank farm contractor CH2M Hill Hanford Group.

- The Savannah River Site has achieved its first area closure, transforming T-Area, a former industrial area, into a grassy hill. T Area was chosen as the first area to close largely because of its location at the periphery of the site and its position on the Savannah River. By closing areas at the periphery first, the SRS footprint will eventually shrink into an operational area at the center of the site.

During SRS's production years, T Area, also known as TNX, served as the gateway to the site. Equipment was brought via the river to the site and unloaded in T Area, where it was tested and evaluated before being used in the production facilities. More recently, T Area was used to model and evaluate the vitrification process now used in the Defense Waste Processing Facility, where waste is immobilized in glass for final disposition in a national waste repository. Demolition work in T Area was initiated in 2002. Final remediation work was completed in August 2006, 48 months earlier than the original schedule. Groundwater remediation in the area will continue for several years, however.

- The U.S. Department of Energy's vitrification plant at Hanford has a new official cost estimate: $12.26 billion, more than double the official estimate in 2003. The estimate depends on a congressional appropriation of $690 million per year until the plant is fully operational in November 2019. If the appropriation is cut, costs could rise further, the DOE and contractor Bechtel National have warned. Costs for the plant have risen since late 2004, in part because of technical problems, including the need for upgraded seismic design features.

- At the end of November, Energy Secretary Samuel Bodman signed a "waste determination" declaring that residual high-level radioactive waste in 15 underground storage tanks at the Idaho National Laboratory can be buried in place, as long as the contamination levels in any possible future leakage will be so low as to present no significant long-term threat to public health or the environment. Lengthy reviews by the state of Idaho and the U.S. Nuclear Regulatory Commission determined that the U.S. Department of Energy had cleaned the tanks to the maximum extent practicable. The DOE is expected to close 11 of the tanks by October 2008 (three of the 30 000-gallon tanks were emptied in late November 2006 and filled with grout). The remaining four tanks are expected to be closed by December 2012. This represents the first time the DOE has completed a new regulatory review under a 2005 law that for the first times allows for disposal of high-level tank waste in shallow burial grounds at the Idaho laboratory and at South Carolina's Savannah River Site.

- The U.S. Department of Energy has emptied the first of several trenches filled with radioactive waste containers at the Hanford site, and completed the work a month ahead of an agreement deadline. Under an agreement with the DOE, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology, the DOE is removing transuranic waste containers from several trenches because of the heavily corroded condition of some of the buried drums. Once the drums are retrieved, workers will determine whether they contain TRU waste, which must be shipped to the Waste Isolation Pilot Plant in New Mexico, or low-level radioactive waste, which can be disposed of onsite at Hanford.

International Briefs

- The United Kingdom's four oldest reactors (Sizewell A 1 and 2 and Dungeness A 1 and 2) closed down at the end of 2006 after some 40 years of operation. These first-generation Magnox units were operated by British Nuclear Fuels plc's British Nuclear Group, under contract to the Nuclear Decommissioning Authority. The Oldbury 1 and

2 units are expected to be closed down at the end of 2008.

● In late November, Italy and France signed an agreement on the reprocessing of spent fuel now stored at Italy's decommissioned nuclear power plants. The fuel will be shipped to the La Hague reprocessing plant between 2007 and 2015, and the reprocessing waste will be returned to Italy between 2020 and 2025.

● Tests of robotic equipment that could be used to remove fire-damaged fuel and debris from the core of the Windscale Pile One reactor have been completed. The tests, at a facility in Colorado, involved a mockup of four full-size fuel channels from which simulated fuel and debris were removed remotely using grippers, scoops, and loosening tools. A 1957 fire at Windscale damaged some 20–25 percent of the core, and some 15 metric tons of fuel are thought to remain in the facility. The successful robotic tests will help the U.K. Atomic Energy Authority find the right technical solutions to clean up the reactor. The winner of the contract to manage the U.K.'s Sellafield complex will also direct the cleanup of the Windscale site and the Calder Hall Magnox station. That contract is expected to be awarded in mid-2008.

● Stabilization work on the Chernobyl-4 shelter (or "sarcophagus") was expected to be completed by the end of 2006. The work, which cost in the neighborhood of 45 million euros ($58 million), was performed by Atomstroyexpert. The stabilization work should extend the operational lifetime of the current shelter by some 10 or 15 years. During that time, a new shelter is to be constructed. The French-led Novarka consortium is considered to be the primary candidate for the new shelter contract.

● Russian expects to spend around $10 billion between 2008 and 2015 on decommissioning nuclear facilities built during the Soviet Union years. As elsewhere in the world, the cleanup work is being driven by the need to move forward with new nuclear facilities. Russia is planning to construct 40 new reactors by 2030. ■

ARTIFACT TO ANALOGUE

Archeology of Arid Environments Points to Management Options for Yucca Mountain

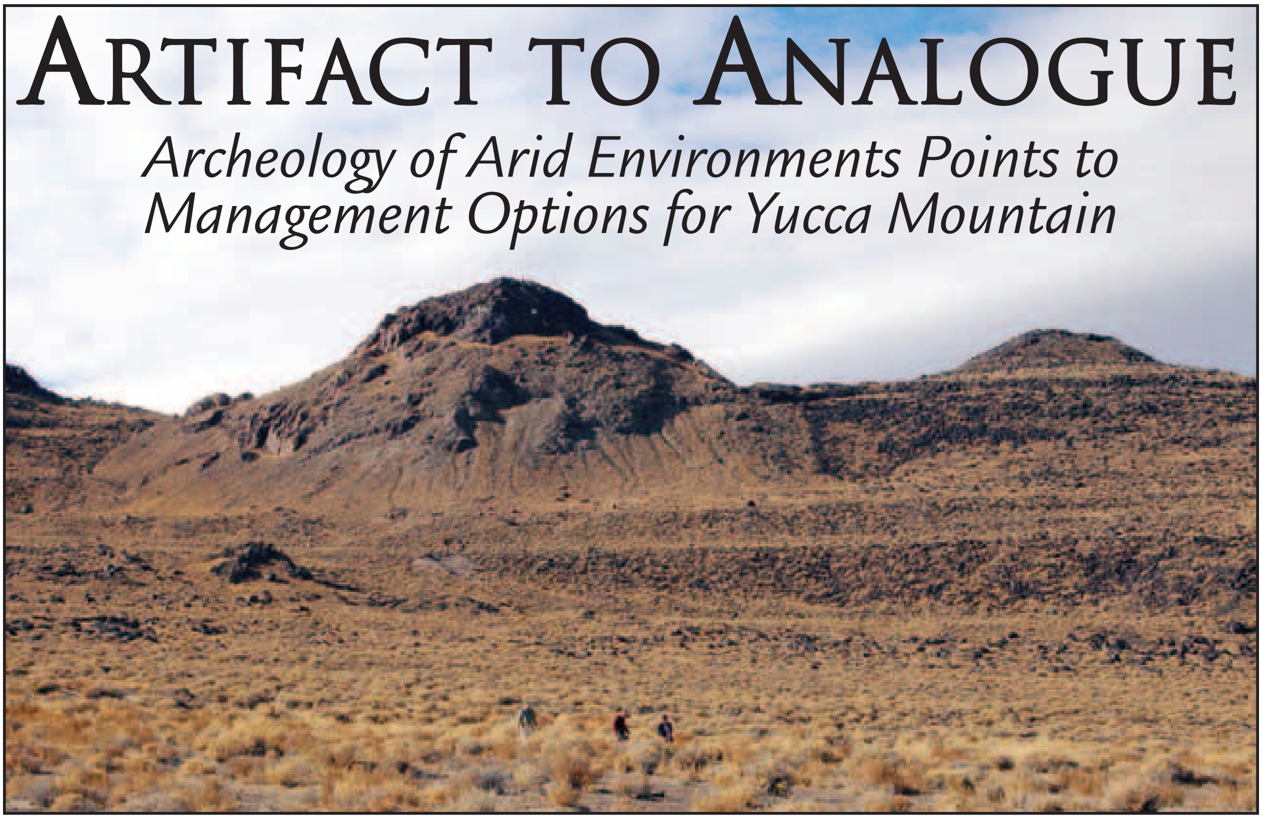

Fig. 1. Paleo-shorelines of ancient Lake Lahontan, northern Nevada.

Archeology has a lot to tell us about the potential behavior of materials and structures during a high-level waste repository's first 10 000 years.

By Neil Chapman, Amy Dansie, and Charles McCombie

As with all planned repositories for spent fuel, the critical period over which Yucca Mountain needs to provide isolation is the first hundreds to thousands of years after the fuel is emplaced, when it is at its most hazardous. Both the original and the proposed new U.S. Environmental Protection Agency standards highlight the central importance of this performance period by focusing on repository behavior during the first 10 000 years.

Archeology has a lot to tell us about the behavior of materials and structures over this time period. There have been numerous studies of archeological artifacts in conditions relevant to the groundwater-saturated environments that are a feature of most international geological disposal concepts but relatively few in arid environments like that of the Nevada desert. However, there is much information to be gleaned, not only from classic archeological areas in the Middle East and around the Mediterranean, but also, perhaps surprisingly to some, from Nevada itself.

Our recent study evaluated archeological materials from underground openings and shallow burial in arid environments relevant to Yucca Mountain, drawing conclusions about how their state and their environment of preservation could help to assess design and operational options for the high-level waste repository.

We compared materials from cultures in the arid regions of the ancient Middle East with the preservation of ancient materials in dry cave sites in the Great Basin desert area of Nevada. The specific reasons we studied objects from the Middle East are that the environments are similar to the Nevada sites and that these historical regions were home to cultures that used metals and glasses, whereas the ancient Nevada artifacts are mainly of organic materials. The preservation environments of materials that we considered are unsaturated and oxidizing; our emphasis has been on materials found in undisturbed underground openings such as caves and unbackfilled tombs.

In the Great Basin desert region of the United States, natural caves around the shoreline of the ancient (now long dried out) Lake Lahontan in northern Nevada (see Fig. 1) have been used as shelters or as burial sites for more than 10 000 years, with some containing almost perfectly preserved fabrics and textiles (e.g., Spirit Cave, Crypt Cave, and Horse Cave). Clearly, these predate the dawn of the ancient civilizations of the Middle East by many thousands of years (see Fig. 2). Detailed study of shelter caves also provides much information on how the interaction of natural ventilation, moisture ingress, and "natural backfill" (cave fill) affect materials preservation, as well as the overall stability of underground openings. The main timescales of interest in this study are from one to

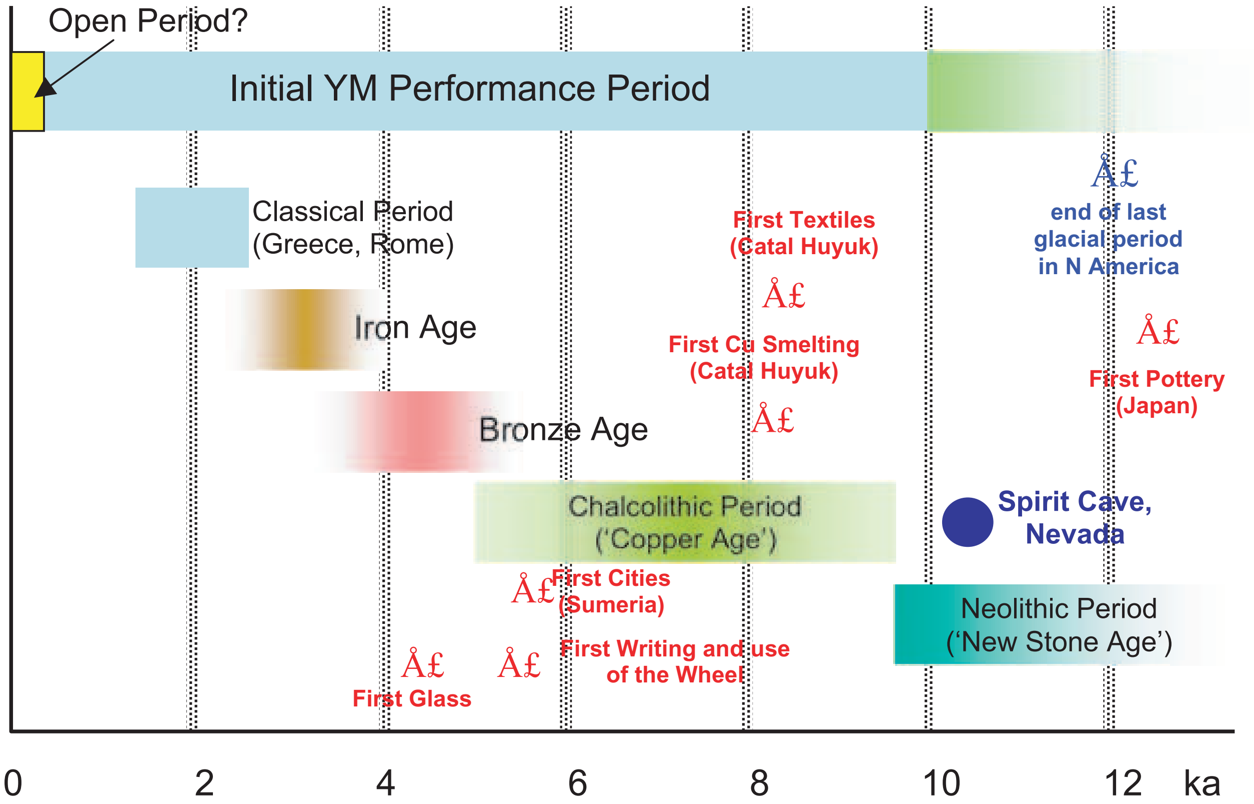

Fig. 2. Use of materials in past cultures in the Middle East and the Mediterranean area as a function of archeological time along with the age of one of the key dry cave sites in Nevada. The initial 10 000-year performance period for Yucca Mountain is shown on the same timescale.

several thousand years. However, combinations of archeological and paleontological evidence allow inferences to be drawn on preservation environments for the years back to 35 000 BP (before the present).

What Are We Looking For?

The Yucca Mountain repository is currently planned to remain in an open, unbackfilled state for at least 50 years after spent fuel and vitrified HLW are emplaced. It is envisaged that this open period could extend to around 300 years. The first few hundreds of years are the most critical period for isolation and containment of the waste as the activity and radiotoxicity are at their highest, although declining rapidly. The radioactivity (and radiotoxicity) of the fission products in both spent fuel and vitrified HLW declines by a factor of about 100 000 within the first thousand years. For spent fuel, this is shown on a standard log-log plot in Fig. 3.

After a few thousands of years, the total radiotoxicity of HLW is similar to that of the uranium ore from which its precursor fuel was manufactured—for spent fuel (see Fig. 3), this "natural crossover"

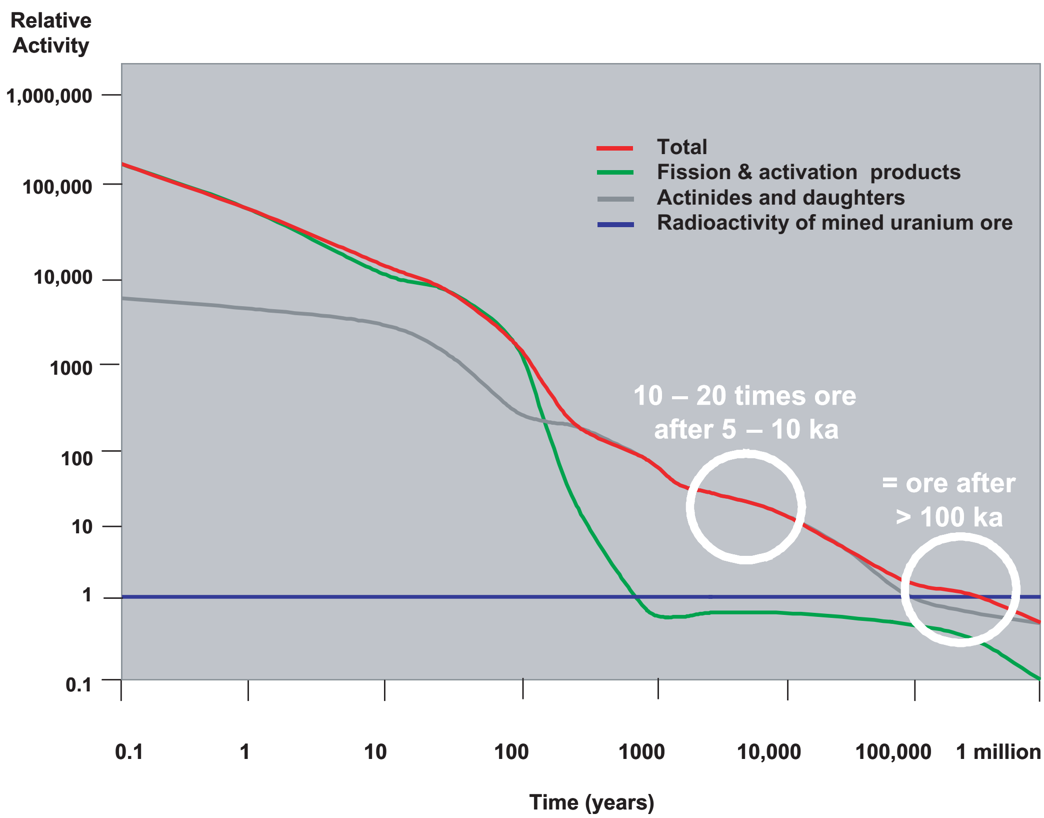

Fig. 3. Decline in radioactivity of spent fuel as a function of time out of the reactor, shown normalized to the activity of the uranium ore from which it was manufactured. Radiotoxicity follows approximately the same pattern.

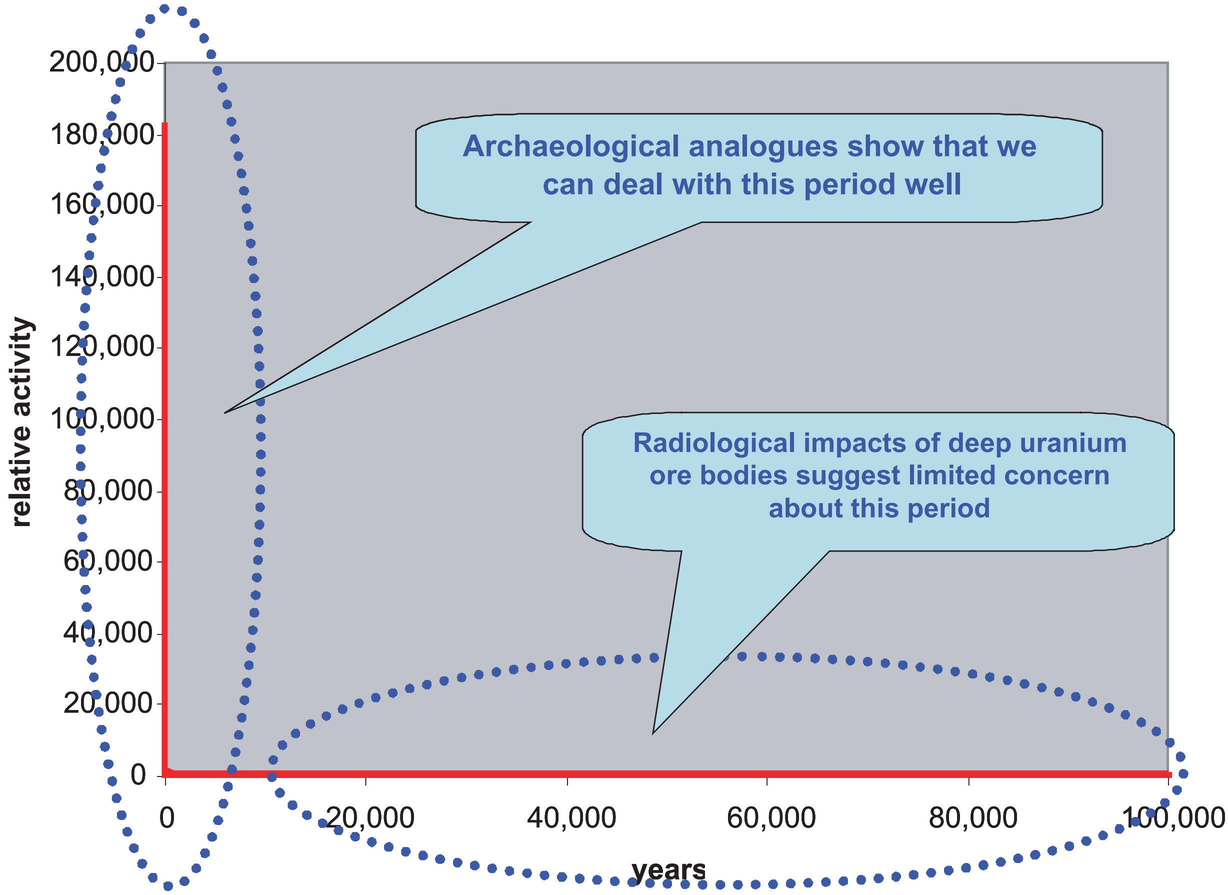

Fig. 4. Linear plot (red line) of the same relative activity decline for spent fuel as shown in Fig. 3.

time is longer—a few hundred thousand years. Nevertheless, at around the same time as the HLW crossover (a few thousand years), the radiotoxicity of spent fuel is only a few tens of times higher than that of the equivalent uranium ore.

The same information for spent fuel is shown on a linear plot in Fig. 4. The curve of Fig. 3 has been replaced by the two red lines clinging to the axes of the graph, and the dominance of the first few hundreds to thousands of years in reducing the hazard of the spent fuel is much more evident.

In terms of providing overall safety and isolation, we can see the following:

- Containment for around 1000 years brings immense benefits in terms of reduction in radiotoxicity for both waste forms.
- Containment for a few thousands of years brings both waste forms close to naturally occurring radioactive materials found in geological environments, and from natural analogues such as the Cigar Lake uranium deposit in Canada, we know that deeply buried ores can have essentially no radiological impact in some environments.

Consequently, having a high degree of confidence in the behavior of the engineered containment system over just a few thousands of years is an essential and valuable aspect of demonstrating repository safety.

This is where archeological materials and preservation environments offer the most direct and illustrative means of confidence building. Observations of materials preserved in parallel environments provide probably the most credible evidence that long-term containment is possible over these time periods (compared to predictions made from laboratory tests of materials).

Long-Term Repository Conditions

The key to any analogue, geological or archeological, is the relevance of the analogue materials and environment. Neither can ever be exact, but a good analogue has sufficiently close similarities to give strong indicators, or sometimes even direct quantitative information, about long-term repository performance.

In the case of the Yucca Mountain repository, focusing on the early containment period of a few thousand years, we can make the following observations on analogue relevance:

- There are clearly no direct archeological analogues of the sophisticated nickel-chromium-molybdenum-tungsten and titanium alloys that are foreseen to be used for engineered barriers in the U.S. program. However, given that these materials have been selected for their corrosion resistance, it is possible to study analogous processes in other archeological "corrosion resistant" (but not noble) metals (copper and bronze) as well as in materials known to be much less resistant, such as iron and simple steels. If these materials show stability in similar environmental conditions, then it gives a measure of confidence that the metals specially selected for engineered barriers should also perform well. Much the same can be said about the analogy between HLW glass and archeological glasses, even though the compositional differences are pronounced.
- The repository is currently planned to remain open for decades to hundreds of years, with a representative relative humidity being about 40 percent. Following closure, humidity will rise to much higher values.

The specific reasons we studied objects from the Middle East are that the environments are similar to the Nevada sites and that these historical regions were home to cultures that used metals and glasses, whereas the ancient Nevada artifacts are mainly of organic materials.

● There is thus interest in looking at the behavior of materials in both well-ventilated underground openings (such as shallow caves) as well as closed underground openings such as tombs, where relative humidity is high, even in arid external conditions. Consideration of materials behavior in these varying conditions may give an indicator of alternative modes in which the repository might be managed during an extended open period and beyond.

With these points in mind, we sought locations where ancient metals and glasses could be found in underground openings, both closed and well ventilated. Our guideline was to look for the oldest examples possible and to concentrate on preservation in arid, desert environments, although tombs and burials in less arid conditions have also yielded valuable examples. Regions of the world displaying long periods of aridity during the Holocene as well as the presence of ancient cultures are clearly of most relevance—this points the focus principally to the ancient Middle East. In this region, from around 11 000 through 7000 BP, the climate was cooler and somewhat wetter than today. Mediterranean woodland existed in the uplands of the Sahara, and grasslands were found on its fringes and around its central massifs. For the last 7000 years, there has been a trend to increasing aridity—from about 3500 BP, becoming extremely arid in North Africa. A period of sudden aridity developed about 4170 BP in Mesopotamia. It is thought to have contributed to the collapse of the Akkadian empire, and its impacts can be seen in the evidence of windborne sands of that period.[1]

The southwestern United States has seen a similar trend toward drier conditions in the Holocene. In this region, Nevada contains many archeological sites where pretechnological human occupation materials (even delicate organic items, such as feathers and basketry) can be found in a state of almost perfect preservation in underground openings (open caves). Consequently, to make a link with the preservation of technological materials, we have also looked for direct parallels in Middle Eastern culture: similar open caves containing organic materials of similar age but, also, alongside glass or metal objects.

Analogue Sites and Materials

The earliest use of metals and glass was in the ancient Middle East (e.g., Anatolia, Mesopotamia, Egypt, Kush, Syria, Palestine, Jordan, and Persia). In this region, exceptionally well-preserved glass, metal, and organic materials are found in the archeological record from sites that have been characterized by arid conditions for many thousands of years. Hoards of uncorroded copper objects as old as 5500 years BP (e.g., Nahal Mishmar) and an intact, 9-tonne (3.4- × 1.95- × 0.45-meter) block of more than 1000-year-old glass (Bet She'arim) are among some of the more remarkable items found concealed in natural or manmade underground openings in this region. Highly ornamental glass bottles survive intact from the earliest use of glass for containers across Mesopotamia and the eastern Mediterranean area from 3500 years BP. Iron and steel objects between 2500 and 3100 years old are also found in some locations.

In several cases, glass and metal artifacts are found together with well-preserved organic materials such as leather, bone, textiles, and matting. The preservation environments of materials considered in this study are unsaturated and oxidizing and include openings that have been either continuously open (caves) or sealed but not backfilled (tombs). Over periods of many thousands of years, glass and copper or bronze, sometimes also iron and steel, have been preserved in either extremely dry, well-ventilated conditions or in a humid atmosphere. Examples of the latter include ferrous metal objects preserved in periodically wetted sediments and copper and bronze objects from sealed Etruscan tombs, many excavated in volcanic tuffs.

Locations and Materials

Chalcolithic Hoards, Israel

Dry caves in the deserts of Israel contain some of the oldest copper objects, from around 5500 years ago, in the Chalcolithic Period (prior to the Bronze Age). A hoard of 429 artifacts was discovered in the so-called Cave of the Treasures at Nahal Mishmar in the 1970s.[2] These are mainly copper ceremonial items, plus a few objects of stone or ivory (see Fig. 5). The cave is extremely isolated, being located 50 m below the top of a cliff that drops 250 m to the bed of a canyon that descends through the Judean Desert to the Dead Sea.

The copper artifacts have highly variable levels of antimony and arsenic,[2] and a "natural alloy" of copper-arsenic-nickel also occurs in some artifacts. The hoard was found at a depth of approximately 2 m below the present cave floor, in a crevice in the cave wall. It was wrapped in a reed mat. Associated organic material, which provides a key link to the dry cave sites in Nevada with no metallic objects, in-

Fig. 5. Cooper objects, approximately 5500 years old, from a Judean desert treasure, Nahal Mishmar (Chalcolithic Period, second half of 4th millennium BCE). The white object in the background is ivory. Collection of Israel Antiquities Authority. (Photo copyright: The Israel Museum, Jerusalem.)

cludes artifacts of hippopotamus ivory, a wooden loom, pieces of woven linen and wool, wooden strainers, straw mats, ropes and basketry, and parts of a leather garment and a sandal.

Nahal Mishmar is not an isolated occurrence—a similar site was found recently at Peqi`in, in Upper Galilee.

Massive Bronze Objects

While small, delicate copper and bronze objects clearly testify to good preservation conditions, a more useful analogy to waste containers that weigh several tonnes is found in massive metal objects. The ancient world contains examples of measuring weights, sarcophagi, and other objects that may contain on the order of hundreds of kilograms of bronze such as the following:

- A large copper relief from the Ninhursaq temple at Tell al'-Ubaid, near Ur (modern Iraq) that dates from 4300 BP and is almost 3 m long. This is heavily corroded, which may be because it was buried in soil rather than in an opening (location: British Museum).
- Tin bronze weights in the shape of lions have been found in several locations. A typical example (see Fig. 6), from western Anatolia, weighs about 31 kilograms, is around 2500 years old, and represents a weight of one Babylonian talent (location: British Museum). A very similar Achaemenid (Persian) piece from Susa (Iran) is located in the Louvre Museum but is equivalent to 4 talents and weighs about 121 kg.
- A 2850-year-old massive bronze sarcophagus was found in 1989 at the ancient city of Nimrud (modern Iraq) within the inner chamber of a tomb located beneath the floors of a palace. Several tombs were untouched since the last burials took place. Hoards of gold, glass, and jewelry were found in some tombs. Some of the tomb chambers

Fig. 6. Persian (around 2500 BP) bronze lion weight (approx. 31 kg = 1 talent). A 121-kg (4-talent) equivalent also exists.

Fig. 7. Bronze and glass items found undisturbed in an Etruscan (2700 BP) tomb in central Italy.[3]

were found unfilled and "waterproof," apart from some soil that had seeped through gaps in the stonework. Presumably, the environment has had relatively high humidity for around 3000 years. A similar massive bronze coffin, dated at about 2350 BP, was found in Susa (Iran). It was found in a collapsed, brick-built vaulted tomb.

Etruscan Tombs, Central Italy

Undisturbed Etruscan tombs more than 2500 years old are found in parts of central Italy. Many of these, particularly those in Lazio and southern Toscana, have been constructed in volcanic tuff—partly hewn from the rock, partly constructed of worked masonry tuff blocks. The tombs were sealed, and bronze objects can be found as they were deposited[3] (see Fig. 7). These tombs also provide evidence that excavated underground openings can be stable, even in a region of Italy prone to significant earthquake activity, for thousands of years.

Iron and Steel

The earliest use of manufactured iron dates from about 3200 BP. Introducing carbon into the smelting process lowers the melting point to a temperature that was just about the limit of the temperature of ancient kilns (that could be used to melt copper). Iron with a low carbon content could be hammered but not melted completely (wrought iron). Semimolten carbon-rich iron can be cast (cast iron). Heat-treated steels (to remove impurities and some carbon) were made over much of the Old World from about 2500 BP.[4]

A set of well-preserved iron tools dating from the Assyrian occupation of Thebes (Egypt) in 667 BCE (before the Christian Era) was excavated by Sir Flinders Petrie from a brick chamber that may have been constructed in gravels close to the banks of the River Nile. Some of the tools contain small amounts of carbon and can be classed as steel.[5] One chisel with a fairly homogeneous composition consists of martensite, contains 0.2 percent carbon, and has been quench hardened. The preservation of iron in good condition for such a long period suggests that the burial location has remained essentially dry.

Somewhat older (about 3100 BP) steel anklets have been found in more closely relevant environments in cave burials in the Baq'ah Valley, Jordan.[6]

Core-Formed Glass Vessels

Core-formed potion bottles are the oldest known glass vessels, the earliest being found in Mesopotamia and dating from around 3500 BP. They are generally small (a few centimeters long) and highly colored, with some of the most beautiful pieces being produced in Egypt around 3300 BP. Residues of cosmetics and opium have been found in some samples. A bottle in the shape of a *bulti* fish (3350 BP), found in soil layers in the ancient Egyptian city of Tel el-Amarna, typifies the state of preservation of much early glass in these environments (see Fig. 8). Amarna was a center for glass production where current excavation and research is being undertaken on ancient glass technologies.

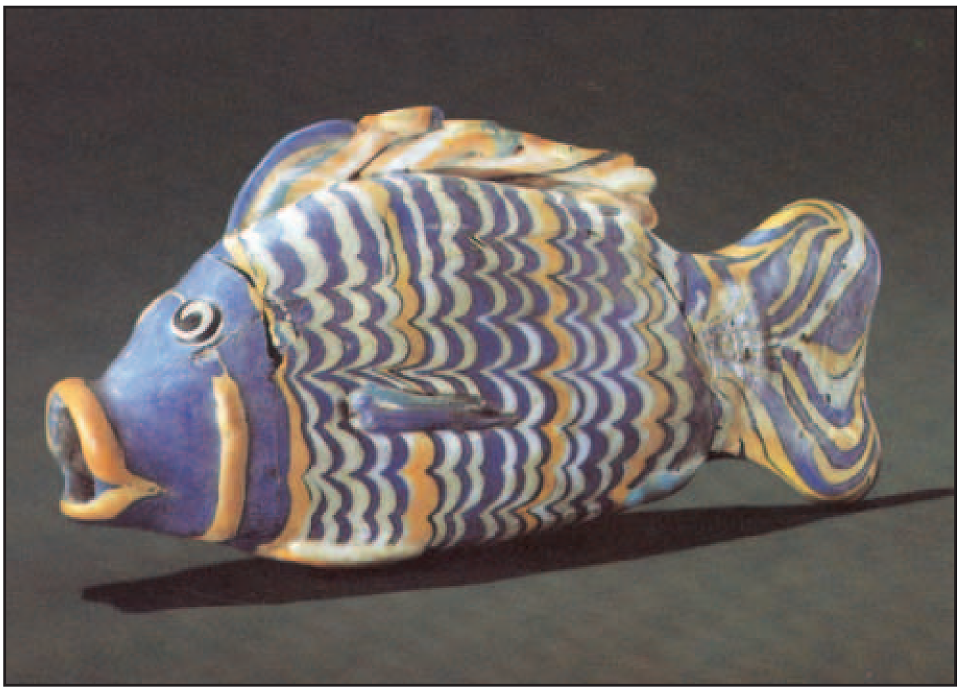

Fig. 8. Core-formed Egyptian glass cosmetic bottle from 3350 BP (Photo copyright: British Museum, London).

The Great Glass Slab

A massive, roughly 9-tonne (3.4- × 1.95- × 0.45-m) block of glass[7] (see Fig. 9) about 1100 years old was found in a cave at Bet She'arim in Israel. It is speculated[7] that it may have been cast underground as a secret compositional experiment that failed, as the calcium content was too high for glass working (high liquidus temperature). It was formed in a tank furnace, in situ in the cave, with about 11 tons of raw materials being heated to 1100°C and held at that temperature for 5 to 10 days. This block is considerably more massive than the vitrified HLW blocks intended for geological disposal.

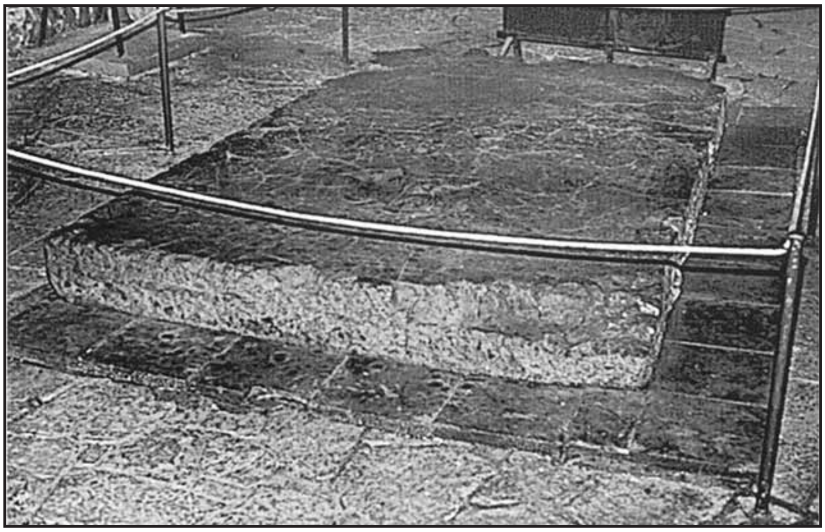

Fig. 9. The great glass slab (about 9 tonnes) of Bet She'arim—1100 BP, found in a cave in the desert.[7]

Organic Materials

As noted in the introduction, a special search was made for parallels to the dry caves of Nevada containing organic remains. Several examples are known where glass and metal artifacts are found together with well-preserved organic materials such as leather, bone, textiles, and matting. The copper hoard in the Cave of Treasures (described earlier) was wrapped in a Cyperus reed mat, bound with straw ropes. A contemporaneous grave (around 6000 years BP) in another dry cave site (the so-called Cave of the Warrior) contained well-preserved organic material but no metals.[8]. The grave objects include a plaited reed mat, textiles, a coiled basket-bowl, a wooden bowl, a bow and arrows, and leather sandals.

The Dry Caves of Nevada

More than a hundred dry cave sites that contain archeological remains are known of in Nevada. Most of these date back to about 6000 BP, a few back to 11 000 BP, and many contain packrat middens showing animal occupation back to 40 000 BP. No single archeological site is a direct analogue to Yucca Mountain, particularly because the archeological record does not include deep drifts, potentially affected by infiltration and seepage issues. All are shallow by comparison, but each has a suite of scientific data that when organized by repository variables can isolate a broad range of processes relevant to long-term preservation in a sheltered environment.

One of the best-documented sites contained a mummy burial that was discovered in 1940 but not dated until 1994. Originally thought to be about 1500 years old, the remains proved to be about 10 300 years old. Perfectly preserved textiles, leather, and other organic materials were found in a shallow burial in the cave floor, only a few meters from the cave entrance (a rock shelter rather than a deep cave). The textiles (see Fig. 10) were as pliable as if recently made.

Caves with burial materials of similar age (earlier than 10 000 BP) include Crypt Cave, Fishbone Cave, Hidden Cave, Chimney Cave, and Grimes Burial Shelter. Many of the burials are tightly wrapped in dry, absorbent textiles and placed under a thin layer of stones, soil, or sticks. Crypt Cave contained several human mummy burials and that of a dog (about 6300 BP), along with fine textiles including earlier than 9000 BP plain weave.

Many of the caves are in tufa or in tufa-cemented rock formations associated with the margins of pluvial Lake Lahontan. Tufa caves are extremely dry as they are generally protected from run-off permeation. Even caves that are less dry have sometimes provided high levels of preservation. For example, Smith Creek Cave contained wood shavings dated at earlier than 10 000 BP. However, moister conditions (e.g., caves with small openings and poor ventilation) generally have proved unfavorable to preservation of organic materials.

Fig. 10. Still pliable textile dated at earlier than 10 000 BP, from Spirit Cave, Nevada.

In the Nevada component of the study, we have sought evidence of the oldest cultural artifacts preserved in sheltered environments in the region of Yucca Mountain. Perishable artifacts greater than 10 000 years old are rare, and one of the questions is "Why are they so rare—is it poor material

Preservation is best in openings that have been well ventilated (open caves), but good preservation is also found in sealed openings, with the best being in the driest sites (e.g., Egypt). Even under high-humidity conditions, openings can provide preservation of glass and copper/bronze for about 3000 years. Burial in soils, probably with periodically high pore-space humidity, can also give excellent preservations of metals.

survival or infrequent use of the shelters that makes the ancient evidence so rare?" Differential preservation and changing human settlement patterns are compared throughout the archeological record to evaluate long-term repository performance. Climate history has affected the preservation in some of the sites, which may offer clues to possible future climate effects on long-term storage, and provides the dynamic backdrop for the human adaptations represented by the archeological data.

In addition to seeking examples of ancient soft perishables, our analysis expands the archeological analogue concept to those sites that do not preserve material analogues for repository variables, using differential survival and other archeological data to demonstrate poor preservation conditions over time. This approach attempts to address a key question posed by Stuckless[9] regarding the continuum of preserved artwork and other analogues. Are we seeing all originally present analogues or have some been destroyed by environmental forces in the sheltered setting? This is an important question because Yucca Mountain is not likely to be completely dry due to normal infiltration of seasonal precipitation. The archeological record can show how much variation there is in the degree of long-term preservation and, in some cases, what causes the variation.

Implications for the Proposed Yucca Mountain Repository

Future decisions concerning the management of any geological waste repository cannot be preempted completely by today's society. Although project managers and regulators may stipulate, as part of planning and licensing, how a repository is to be operated and closed, the multidecade length of disposal projects means that the actual decisions will be taken by future generations on the basis of whatever drivers are important at the time. A clear example of how a new driver can radically affect a program is the possible impact of the Global Nuclear Energy Partnership on the waste forms that might be assigned to Yucca Mountain and how they will be managed. For example, the amount of spent fuel to be managed may be very significantly reduced, and it is even debatable whether spent fuel would be disposed of or simply stored until it can be reprocessed.

Uncertainties such as these will affect all the plans we may have today concerning open periods, retrievability, backfilling, closure, and sealing. With respect to Yucca Mountain, it is quite reasonable to envisage a long period (decades to hundreds of years) during which the repository could be managed as any one or more (i.e., sequentially) of the following:

- An open, ventilated, and managed long-term store.
- An open, unventilated long-term store.
- A sealed, ventilated disposal facility without backfill.
- A sealed, unventilated disposal facility without backfill.
- A sealed and backfilled disposal facility.

In these scenarios, the behavior and condition of repository materials over time frames of hundreds or a few thousands of years will be an important aspect of future decision making. As noted at the beginning of this article, this is the most critical period for the provision of containment.

Over the longer term, the climatic environment of Yucca Mountain is expected to vary significantly. It seems reasonable to assume that Nevada will either remain arid or will slowly return to wetter conditions but not for many thousands to some tens of thousands of years. For the next few thousand years, conditions are expected to remain rather similar to those of today.

Prior to closure, ambient atmospheric conditions will be warm and oxidizing, with medium-to-low humidity, depending upon the use and scale of ventilation. Following closure, the facility will remain warm for several hundreds of years, with increasing humidity and continuing oxidizing conditions. One can also envisage a facility that is closed and sealed (to access by people) but nevertheless equipped with natural ventilation to maintain lower humidity. Over hundreds of years, unless a tunnel support system has been emplaced and maintained, some parts of the facility may suffer from roof collapse, affecting local atmospheric conditions. In a backfilled system, the waste packages would be surrounded by unsaturated rock/soil

It seems reasonable to assume that Nevada will either remain arid or will slowly return to wetter conditions but not for many thousands to some tens of thousands of years. For the next few thousand years, conditions are expected to remain rather similar to those of today.

but with relatively high-humidity air in the pore spaces.

It can be seen that the preservation environments of the archeological materials addressed in our study span all of these conditions. What, then, can be concluded with respect to the operation of Yucca Mountain?

Implications for Decisions

No analogue, natural or archeological, can match all aspects of the design, material, and future evolution of a waste repository. Nevertheless, it is possible to use our observations to draw conclusions of relevance to Yucca Mountain and to raise some interesting questions concerning the optimization of the design and the operational procedures.

Underground openings in arid regions are capable of providing exceptional preservation of glass and metals, like copper and bronze, for times that are *at least as long* as these materials have been known and used—their frequent perfect preservation suggests that they would actually survive very much longer.

Ventilated environments provide excellent preservation of delicate organic materials such as fabrics, basketry, leather, wood, and ivory—in the Middle East they are sometimes found with perfectly preserved copper items from 5500 BP, thus suggesting that the U.S. dry cave preservation of organics would also have preserved metals for at least 10 000 years.

Preservation is best in openings that have been well ventilated (open caves), but good preservation is also found in sealed openings, with the best being in the driest sites (e.g., Egypt). Even under high-humidity conditions, openings can provide preservation of glass and copper/bronze for around 3000 years. Burial in soils, probably with periodically high pore-space humidity, can also give excellent preservations of metals.

As well as small artifacts, massive and/or thick-walled glass and bronze/copper objects similar to waste blocks and waste containers also have well-preserved analogues. Archeological iron and steel artifacts are less well preserved in moist, oxidizing underground openings, although objects buried in tuff and in "dry" openings can maintain some integrity for about 2000 years.

Tombs excavated in native rock or built from stone and brick are generally in good structural condition, although some show soil and debris in-wash.

Analogues show that even a multicentury-scale interim storage/retrievable period is achievable without a need to repackage and possibly without a need for extensive repository refurbishment. The first centuries of interim, retrievable storage are of the most immediate importance, and the evidence from these analogues may indicate which materials are most demonstrably appropriate for retrievable waste packages.

Stuckless[9] observed that backfilling and sealing the Yucca Mountain repository "may not enhance its performance." If well-ventilated conditions would be valuable for management on a timescale of decades to hundreds of years, one can ask whether the repository can be designed so it can be sealed from human access but still have passive, very long term natural ventilation. This, in turn, has implications for decisions on drip shields and backfilling options. It also raises questions of how simpler container materials might perform under backfilled conditions (compared with C-22) with respect to releases occurring after about 10 000 years.

If preservation of generally corrosion-resistant materials over hundreds to thousands of years under the oxidizing conditions of the repository is considered important, then a well-ventilated system may enhance performance. If decade- or century-long retrievability is to be a feature of facility management, then a well-ventilated (forced or natural) design can be expected to keep corrosion-resistant materials in good condition—the analogous locations studied here have done this successfully for 6000 to 12 000 years, even for the most delicate organic materials.

Designs where good natural ventilation might be maintained even after closure and sealing (to prevent human access) may provide enhanced preservation well into the multithousand-year time frame, although this would obviously need to be evaluated in a full performance assessment. Information from closed tombs (e.g., Etruscan, Egyptian, and Assyrian) and artifacts buried in desert soils, where humidity has been elevated since burial, indicate that these conditions are less favorable; nevertheless, they show that bronze, and even iron, can remain extremely well-preserved for 2000 to 3000 years.

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Neil Chapman (neil.chapman@bluewin.ch) is a principal at MCM Consulting in Switzerland, Amy Dansie (ADansie@aol.com) retired in 2000 from the Nevada State Museum in Reno, and Charles McCombie (Charles.McCombie@mccombie.ch) is a principal at MCM Consulting. *Funding for this study was provided by the U.S. Department of Energy, Office of Civilian Radioactive Waste Management, in partnership with Booz Allen Hamilton. The authors would particularly like to thank Bob Murray for his support. This article is based on presentations made at the American Nuclear Society's 11th International High-Level Radioactive Waste Management Conference, held April 30–May 4, 2006, in Las Vegas, Nevada.*

Full Burnup Credit in Transport and Storage Casks—Benefits and Implementation

By C. V. Parks, J. C. Wagner, D. E. Mueller, and I. C. Gauld

Allowing for full burnup credit of spent nuclear fuel during transport can allow higher density packing of transport casks, leading to savings for high-capacity systems.

Safe, efficient, and effective management of spent nuclear fuel (SNF) from commercial nuclear power plants will require increasing attention to transport and, potentially, dry storage in casks. Historically, cask designs for transporting SNF have had to demonstrate criticality safety and structural integrity while meeting limits on weight, thermal loading, external dose, and containment. In the late 1980s, with the reduced thermal load and dose resulting from a required minimum five-year cooling time for transport of SNF, it became apparent that SNF cask capacity would often be limited by the conservative, yet simple, assumption of unirradiated fuel (i.e., no credit for the fuel burnup) used in criticality safety evaluations. For pressurized water reactor (PWR) SNF, burnup credit eliminates the need for the gapped basket structures (i.e., flux traps) used for separation and criticality control, thus offering an important degree of flexibility to cask designers. Elimination of the flux traps can provide additional space that allows high-density packing of the SNF for capacity increases of at least 30 percent in PWR casks.

Although crediting the reactivity reduction from burnup (i.e., burnup credit) is an important component of allowing SNF casks to have high capacity, the current regulatory guidance recommends credit only for the reactivity change due to major actinide. The current regulatory position for transport and storage is provided in the U.S. Nuclear Regulatory Commission Interim Staff Guidance 8, Rev. 2 (ISG-8R2), which was issued by the Spent Fuel Project Office in 2002. Adherence to this guidance will enable no more than approximately 30 percent of the domestic SNF inventory from PWRs to be loaded in high-capacity (approximately 32 PWR assemblies) casks that have been planned for transport. However, adding the reactivity changes due to fission products to the burnup credit equation would allow high-capacity casks to handle the bulk (up to 90 percent) of the domestic PWR SNF inventory.

In 2004, Oak Ridge National Laboratory (ORNL) prepared a road map for a project with a goal to develop and/or obtain the scientific and technical information necessary to support preparation and review of a safety evaluation for transportation cask designs that use full (actinide and fission product) burnup credit for PWR contents. Subsequently, ORNL worked cooperatively with the NRC, the Electric Power Research Institute (EPRI), and the U.S. Department of Energy Office of Logistics Management to execute the project plan. The plan called for existing critical experiments and assay measurement data to be assessed for technical value in developing an adequate safety evaluation that includes both actinide and fission product credit. New data would be acquired based on the needs identified following assessment of existing data.

The decision by the DOE Office of Civilian Radioactive Waste Management (OCRWM) to specify use of a relatively low capacity (e.g., 21 PWR assemblies) canister for transportation, aging, and disposal (TAD) means that criticality control for the TAD canister can likely be achieved without full burnup credit. Here we discuss cost benefits that were predicted prior to the decision on the TAD canister system and are applicable for a scenario where the goal is to minimize shipments through use of high-capacity casks. However, the technical information we discuss may still be needed for transport of SNF already loaded in high-capacity storage casks and may be beneficial for transport of a portion of the SNF inventory that may not be transported in the TAD canisters. In addition, the technical strategies we discuss are now being pursued to help facilitate the safety basis for permanent disposal, where criticality control by flux traps cannot always be assured because of the potential environment and/or events.

Assessment of Benefits for Full Burnup Credit

Inventory Accommodation for PWR SNF

During 2004, the DOE Energy Information Administration released a Microsoft Access™ database with an updated version of the RW-859 compilation submitted by U.S. commercial nuclear power plant licensees for PWR SNF through the end of 2002. The present study investigated six PWR fuel assembly types, which comprise about 94 percent of the 70 290 PWR SNF assemblies in the database, to assess the benefits that would be provided by full burnup credit for transport in a high-capacity cask.

A generic high-capacity (32-assembly) cask, designated GBC-32, was selected as the reference configuration to assess the benefits of full burnup credit for the RW-859 inventory. The GBC-32 cask is representative of burnup-credit rail casks currently being considered by U.S. industry and, prior to the issuance of the TAD specification, was judged a relevant and appropriate configuration for this evaluation. The loading curves (required burnup versus initial enrichment) were generated with basic assumptions (reactor operating conditions, bias and uncertainty process, axial profiles, etc.) consistent with ISG-8R2.

The acceptability of the SNF assemblies for the six fuel types is summarized in Table I. Consistent with the regulatory guidance, assemblies that require burnup greater than 50 gigawatt days per metric ton of uranium are classified as unacceptable. Also, the determination of acceptability does not account for burnup uncertainty, which would reduce the percentage of acceptable assemblies. The results indicate that while burnup credit with ISG-8R2 can allow loading a large percentage of the Combustion Engineering (CE) and the Westinghouse Electric (WE) 14 x 14 assemblies in high-capacity casks, the benefits of ISG-8R2 are minimal for the other assembly designs considered.

To evaluate the effect of selected calculational assumptions, Fig. 1 compares the reference case loading curve for the WE 17 × 17 assembly with loading curves for the following individual variations:

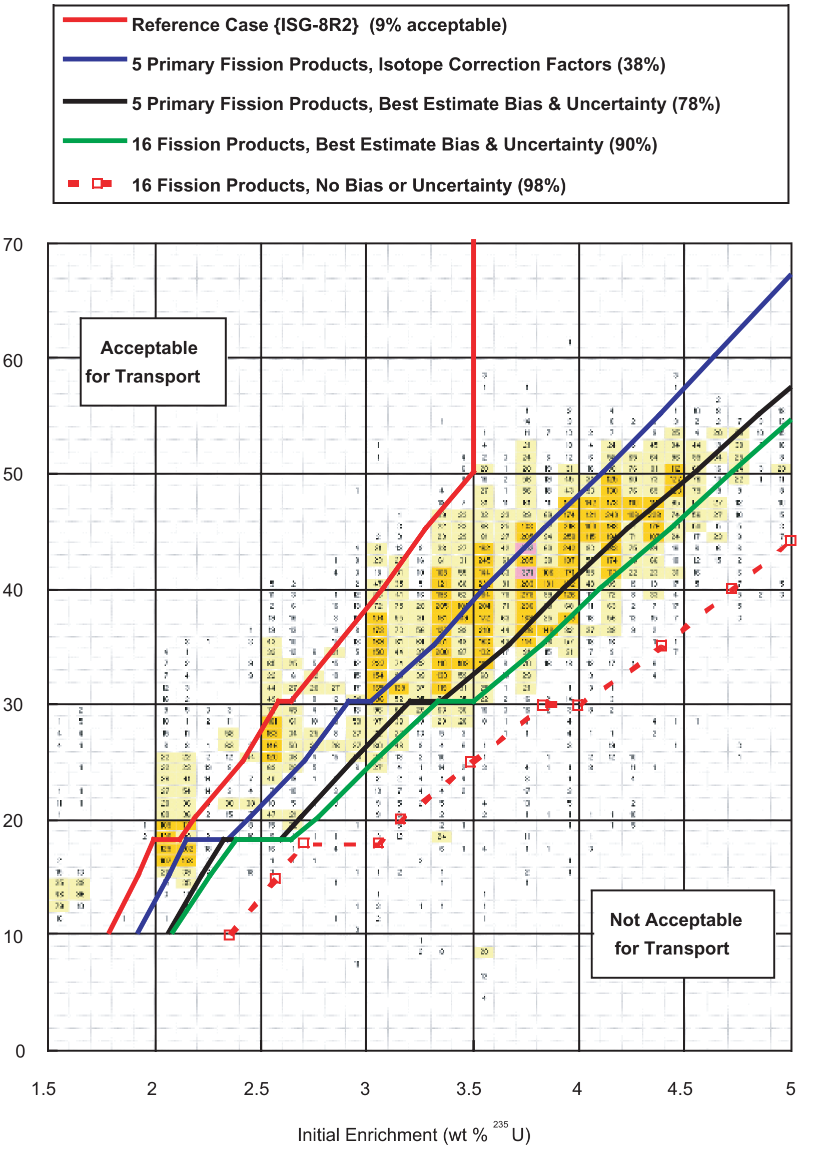

Fig. 1. Comparison of calculational assumptions for WE 17 x 17 fuel assemblies. Percentages of inventory acceptable for the GBC-32 cask are shown in parentheses.

- Inclusion of minor actinides (^{236}U, ^{237}Np, ^{243}Am) and five of the six principal fission products (^{149}Sm, ^{143}Nd, ^{151}Sm, ^{133}Cs, and ^{155}Gd), with isotopic correction factors determined in a bounding manner based on comparisons between predicted composition for each nuclide and available assay data for each nuclide.
- Inclusion of minor actinides and five principal fission products with spent fuel composition bias and uncertainty based on a more realistic,

Table I. Summary of SNF Acceptability in the GBC-32 Cask with Actinide-only Burnup Credit for the Six Assembly Types Considered

Assembly type	Total in discharge data	Number acceptable for loading	Number unacceptable for loading
CE 14 × 14	6972	4518 (65 %)	2454 (35 %)
CE 16 × 16	6828	1731 (25 %)	5097 (75 %)
B&W 15 × 15	7519	166 (2 %)	7353 (98 %)
WE 17 × 17	28 704	2448 (9 %)	26 256 (91 %)
WE 15 × 15	10 365	475 (5 %)	9890 (95 %)
WE 14 × 14	5448	4686 (86 %)	762 (14 %)
Total	65 836	14 024 (21 %)	51 812 (79 %)

best-estimate approach that conservatively propagates the bias and uncertainty for the composition prediction into an estimate of its impact on the neutron multiplication factor.

- Inclusion of sixteen fission products (^{95}Mo, ^{99}Tc, ^{101}Ru, ^{103}Rh, ^{109}Ag, ^{133}Cs, ^{147}Sm, ^{149}Sm, ^{150}Sm, ^{151}Sm, ^{152}Sm, ^{143}Nd, ^{145}Nd, ^{151}Eu, ^{153}Eu, ^{155}Gd) and minor actinides (^{236}U, ^{237}Np, ^{243}Am), with spent fuel composition bias and uncertainty incorporated using the best-estimate approach.
- Inclusion of the principal fission products and minor actinides without any correction for bias and uncertainty in the prediction of the SNF composition.

> The technical strategies we discuss are now being pursued to help facilitate the safety basis for permanent disposal, where criticality control by flux traps cannot always be assured because of the potential environment and/or events.

Note that for a few of the relevant fission products (e.g., ^{103}Rh), insufficient measured assay data are available to estimate bias and uncertainty. Thus, with the exception of the final case, no credit was taken for their presence in the SNF.

All the curves in Fig. 1 were prepared assuming a five-year cooling time. Extending the cooling time up to 20 years makes only a marginal increase in the allowed inventory. A more effective approach is shown in Fig. 1, where inclusion of fission products and/or the use of more realistic approaches to isotopic error and uncertainty offer significantly larger increases in allowed inventory. For the GBC-32 cask, the percentage of acceptable assemblies increases from 9 to 38 percent with the inclusion of the five primary fission products and minor actinides (both cases at five-year cooling) and from 38 to 78 percent with the use of the best-estimate approach for including error and uncertainty in the prediction of SNF compositions. The next case includes the remainder of the principal fission products and again uses the best-estimate approach for isotopic error and uncertainty. These assumptions allow the percentage of acceptable assemblies to increase to 90 percent. The final case shown in Fig. 1 corresponds to full credit for the calculated actinide and principal fission product compositions and, given the conditions considered, represents a limit in terms of the available negative reactivity that might potentially be credited.

Comparison of actinide-only-based loading curves for the GBC-32 cask with PWR SNF discharge data (through the end of 2002) leads to the conclusion that additional negative reactivity is necessary to accommodate the majority of PWR SNF assemblies in high-capacity casks. Relatively small shifts in a cask loading curve, which increase or decrease the minimum required burnup for a given enrichment, can have a significant impact on the number of SNF assemblies that are acceptable for loading. Thus, as the uncertainties and corresponding conservatisms in burnup credit analyses are better understood and reduced through acquisition of additional experimental data, the population of SNF acceptable for loading in high-capacity casks will increase. Figure 1 demonstrates that given appropriate data for validation, the inclusion of fission products should provide more realistic estimates of the subcritical condition and significantly enhance the utilization of burnup credit. This fact is valid for any high-density SNF system design.

Pre-TAD Cost-Benefit Assessment for PWR SNF

Assuming a scenario where shipments to a permanent repository use high-capacity casks, a relatively simple evaluation of the potential cost benefits for using full burnup credit was performed in 2004. This evaluation used the current capacity limit for the Yucca Mountain repository [70 000 metric tons of heavy metal (MTHM)], the percentage of total MTHM from PWRs at the end of 1998 (approximately 64 percent), and the average number of PWR assemblies per MTHM to predict that approximately 100 000 PWR assemblies will need to be transported to the repository. Using representative loading curves and assuming assemblies that cannot be accommodated in 32-assembly casks are transported in 24-assembly casks, the resulting estimate was that full burnup credit can reduce the number of shipments by approximately 22 percent (about 940 shipments) while actinide-only-based burnup credit merely reduces the number of shipments by approximately 8 percent (about 315 shipments). An ad hoc survey of industry experts suggested an estimated cost per rail cask shipment (freight and operational costs) ranging from $200 000 to $500 000. Although the majority of the experts supported the $500 000-per-shipment value, a conservative estimate of $250 000 was adopted. Using this per-shipment estimate [assuming shipments are reduced by 625 = (940 − 315)] results in cost savings of at least $156 million that can be realized from establishing full burnup credit for SNF transportation.

A significant simplifying assumption used in the preceding cost evaluation is that all assemblies would be loaded and transported in large (100- to 125-ton) rail-type casks. The initial cost estimate was updated in 2005 to remove this simplifying assumption and investigate the impact of using a cask fleet of varying sizes. Discharge data as a function of site cask capabilities (size of cask that could be handled) were obtained and estimates developed for (a) cost per cask shipment (varying from $150 000 for truck cask to $250 000 for 32-element rail cask), (b) cask design capacities with and without burnup credit (varying from 100 percent for a legal-weight truck cask to 30 percent for large rail casks), and (c) percentages of assemblies acceptable for loading with and without burnup credit (based on approximate loading curves for each cask using actinide-only and full burnup credit). Using this information, estimates of the cost savings associated with burnup credit for transportation are approximately $638 million. Of this total, around $235 million is attributable to credit for fission products. The cost estimates are higher than the preceding, simpler cost-benefit analysis because there is an increased shipment cost on a per-assembly basis associated with the use of smaller casks. Thus, even if the mix of casks as assumed is not correct, the $156 million figure—based solely on a rail cask—appears to be a minimal savings assuming that other cask design constraints (e.g., decay heat) do not limit the burnup credit benefits. These two cost-benefit estimates demonstrate the significant potential cost savings associated with establishing full burnup credit for the specified scenario (i.e., shipments minimized through the use of high-capacity casks).

Database of Critical Experiments for Full Burnup Credit

Background and Approach

To achieve the potential benefits discussed and demonstrated earlier, ORNL developed and initiated a plan to obtain the data needed for straightforward and effective preparation and review of a criticality safety evaluation with full burnup credit. NRC staff have noted that the rationale for restricting ISG-8R2 to actinide-only is based largely on the lack of clear, definitive experiments that can be used to estimate the bias and uncertainty for computational analyses associated with using burnup credit. Applicants and regulatory reviewers are constrained by both a scarcity of data and a lack of clear technical bases (e.g., criteria) for demonstrating applicability of the data.

The goal therefore is to obtain, and make available to industry, a well-qualified experimental database that can ensure reliable and accurate estimation of any bias and uncertainty resulting from the codes and data used to predict the system neutron multiplication factor, k_{eff}. Rather than an *a priori* decision on suitability of candidate experiments, ORNL sought to obtain and assess critical experiment data from the following sources:

- Critical experiments within the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (IHECSBE).
- Proprietary critical experiment data.
- Commercial reactor criticals (CRCs), i.e., critical state points from operating reactors.
- Proposed new critical experiments.

The applicability and value of this database of critical experiments is currently being assessed with the aid of sensitivity and uncertainty (S/U) analysis tools developed at ORNL and incorporated within Version 5 of ORNL's SCALE code system. The TSUNAMI-3D sequence within SCALE uses first-order linear perturbation theory to calculate the sensitivity of k_{eff} for systems (e.g., SNF casks) and/or critical experiments to variations in nuclear data. Energy-, nuclide-, reaction-, and position-dependent sensitivity profiles are generated and saved in sensitivity data files. The TSUNAMI-IP module of SCALE uses the sensitivity data file information and cross-section uncertainty data to evaluate the similarity of different systems. One of the products of this comparison is an integral index, referred to as c_k, which is a single-valued quantity used to assess the similarity of uncertainty-weighted sensitivity profiles for all nuclide reactions between a modeled system and a critical experiment. A c_k

> Test results indicate that while burnup credit with ISG-8R2 can allow loading a large percentage of the CE and the WE 14 × 14 assemblies in high-capacity casks, the benefits of ISG-8R2 are minimal for the other assembly designs considered.

index is similar to a correlation coefficient, and a value of 1 indicates that the compared systems have identical uncertainty-weighted sensitivities. A value of 0 indicates that the systems are completely dissimilar. The current ORNL guidance is that critical experiments with a c_k value of at least 0.9 are applicable for validation purposes and that c_k values between 0.8 and 0.9 indicate marginal applicability.

The SCALE S/U tools were used to analyze the GBC-32 prototypical high-capacity rail cask loaded with WE 17 × 17 fuel having accumulated burnups of 10 to 60 GWd/MTU. The results from this cask model serve as the initial reference for applicability comparisons with the sets of critical experiments under consideration.

Assessment of IHECSBE and French Proprietary Experiments

As part of this project, ORNL was able to negotiate a multioption contract with Cogema (now AREVA) to gain access to proprietary critical experiments performed by the French Institut de Radioprotection et de

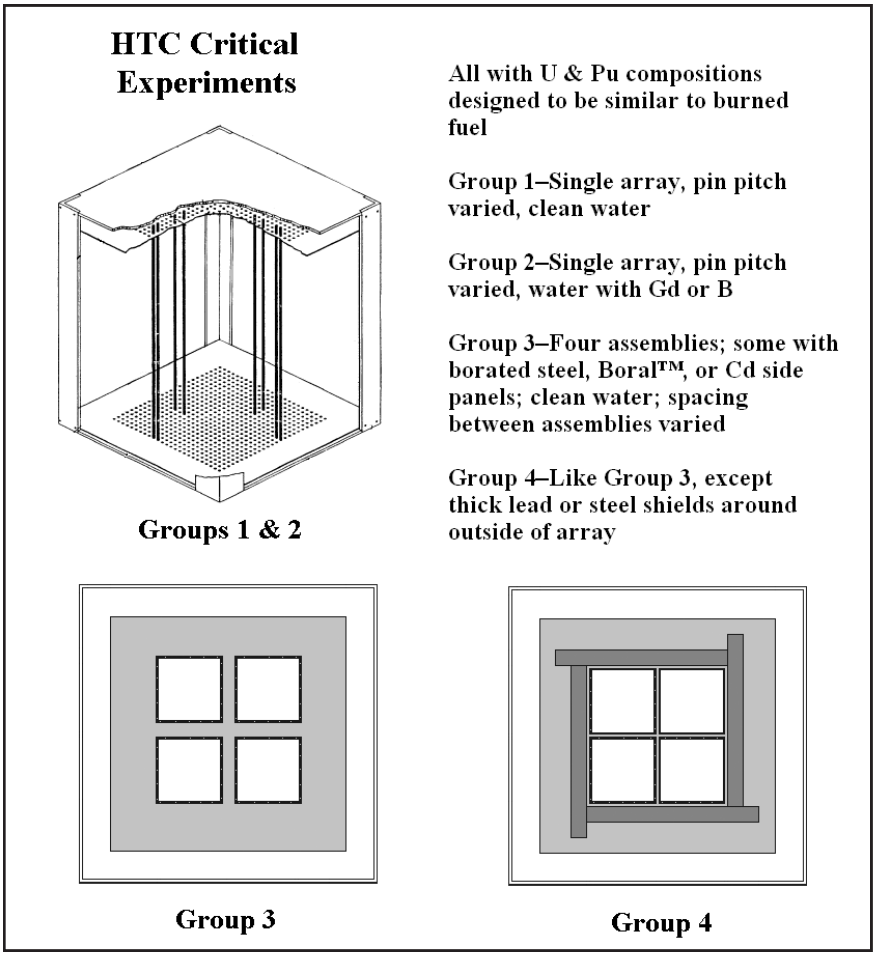

Fig. 2. French HTC critical experiments.

Sûreté Nucléaire (IRSN) at their Valduc critical experiment facility. These experiments are part of a larger French program to develop a technical basis for burnup credit. Subsequent to a positive evaluation and acquisition rights, the data obtained will be made available to industry for use in cask design and licensing activities.

ORNL has received the first set of critical experiment data documented using the format of the IHECSBE. The French institute had performed these experiments with rods having uranium and plutonium isotopic compositions similar to U(4.5 percent)O_2 fuel with a burnup of 37 500 MWd/MTU. The experimental series, referred to as the HTC experiments, investigated 156 configurations divided into four groups, as illustrated in Fig. 2. The first group is a single clean-water-moderated and water-reflected array of HTC rods with the pin pitch varied from 1.3 to 2.3 centimeters. The second group is similar to the first, except that boron or gadolinium is

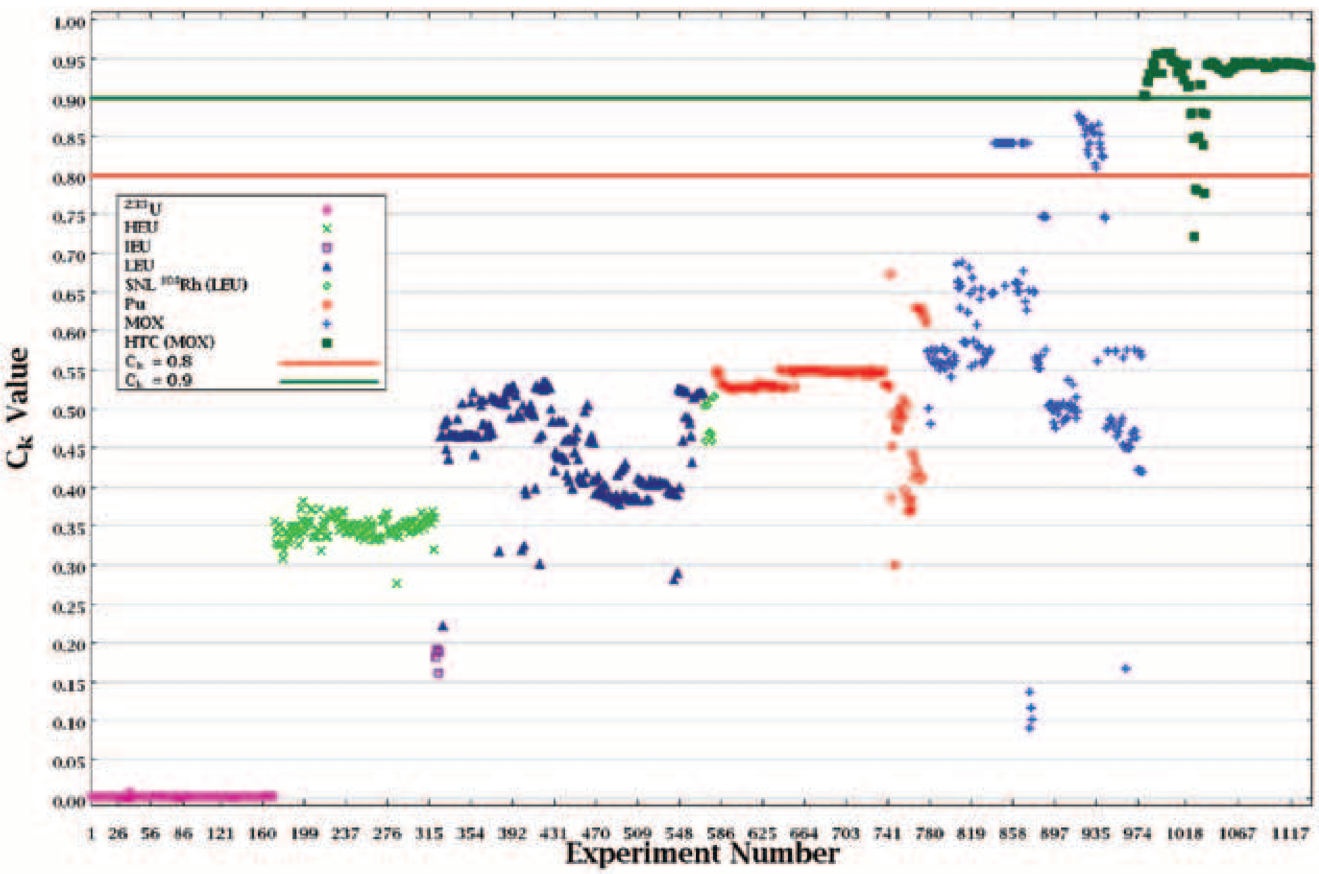

Fig 3. Critical experiment applicability to burnup credit, showing 1134 critical experiments compared with PWR model.

dissolved in the water in varying concentrations. The third group has four separate assemblies of HTC rods, separated by varying distances, and with borated steel, Boral™, or cadmium plates on the outsides of the assemblies in 11 of the critical configurations. The fourth group is similar to the third group, except that a thick lead or steel shield is placed around the outside of the four assemblies to simulate the type of reflector representative of a cask.

These 156 HTC critical experiments, together with nearly 1000 critical configurations from the IHECSBE, were analyzed with the TSUNAMI-IP sequence and the sensitivity data obtained compared with sensitivity data for the reference cask model loaded with assemblies burned to 40 GWd/MTU. Figure 3 shows the distribution of the c_k values for the 1134 critical configurations when compared with the reference burnup credit cask model. As shown in the figure, the 170 ^{233}U experiments, the 150 high-enrichment-uranium experiments, the 4 intermediate-enrichment-uranium experiments, the 197 plutonium-only configurations, and the 256 low-enrichment-uranium experiments all have c_k values of less than 0.8—an expected result given the difference in fissile material between these critical experiments and SNF. Only 45 of the 201 non-HTC mixed-oxide (MOX) configurations have c_k values greater than or equal to 0.8, with none having c_k values ≥ 0.9. Additional non-HTC MOX experiments continue to be assessed. However, the strong applicability of the HTC MOX experiments is demonstrated by 152 of the 156 configurations having c_k values ≧0.8, with 143 c_k values ≥ 0.9. The results of these studies confirm the significant value of the HTC experiments for criticality validation of the primary actinides and the weaker validation basis that exists without the HTC experiments.

Work has been initiated to assess two sets of critical experiments for validating the fission product component of SNF in a cask environment. The first set of experiments was performed in 2003 at Sandia National Laboratories (SNL) as part of a DOE Nuclear Energy Research Initiative (NERI). The set of experiments included thin ^{103}Rh foils stacked between fuel pellets in UO_2 rods placed in a hexagonal array. S/U analyses have been performed for the SNL ^{103}Rh critical experiments, and the results have been compared with S/U analyses results for the GBC-32 cask model. A comparison of the energy-dependent sensitivity profiles shows reasonably good agreement except in the 1- to 2-electron-volt neutron energy range. Further studies showed how a modified experiment design (use of thinner foils) could improve the applicability of the experiments. The design process of planned SNL experiments will employ the S/U tools to ensure maximum applicability.

The second series of experiments being assessed for their value in validation of the fission product burnup credit are IRSN's second set of critical experiments (included as part of the contract ORNL currently has with Cogema). IRSN sent ORNL preliminary reports that describe 147 critical configurations (referred to as the "PF" experiments), 74 of which contain fission products. ORNL will work to perform S/U analyses for these French fission product experiments using TSUNAMI-3D and TSUNAMI-IP. Upon completion of an evaluation that ensures these PF experiments can provide a reliable estimate of the bias and uncertainty for fission product burnup credit, ORNL will seek to acquire rights to use the data, which will be distributed for use by potential licensees.

Assessment of Commercial Reactor Critical Configurations

ORNL obtained reactor core configurations and material compositions for 33 Crystal River-3 state points from the Yucca Mountain Project (YMP) and performed S/U analyses to investigate the applicability of the CRC state points to burnup credit validation. The CRC state points require very large and complex computational models with the following information required for accuracy: fuel assembly locations during reactor cycles and 18-node fuel rod compositions; burnable poison rod assembly core locations and 17-node compositions; rod cluster control assembly and axial power shaping rod assembly core locations, compositions, and insertion heights; and a description of assembly hardware.

Preliminary results for the Crystal River CRC state points show c_k greater than 0.9 for 25 of the 33 cases with effective full-power days ranging from 0 to 515. In addition, comparisons of the sensitivity files show reasonable similarity for many of the key fission products. However, a major drawback to use of the CRC state points is the lack of specific information (exact component locations, spatially varying operating conditions, and isotopic com-

ORNL has also worked with SNL to pursue planning activities for additional experiments with the principal fission products. The planned experiments would be performed at SNL in a manner similar to the critical experiments with ^{103}Rh under the DOE/NERI project.

positions) for these measured critical systems, which leads to major difficulties in quantifying the "experiment" uncertainties such that the CRCs can be effectively used to establish the bias and uncertainty for the computational tools.

Proposed New Critical Experiments

In parallel with efforts to locate and evaluate existing critical experiment data, ORNL has also worked with SNL to pursue planning activities for performing additional experiments with the principal fission products. The planned experiments would be performed at SNL in a manner similar to the critical experiments with ^{103}Rh performed under the DOE/NERI project. The S/U analysis tools, which were not available when the ^{103}Rh critical experiments were designed, will be used to help guide the design of the critical configurations. The goal will be to address any technical needs that may not be adequately addressed with the data obtained from the French critical experiments. Initial planning activities are under way and, given sponsor support, critical experiments are expected to begin in 2008.

Database of Isotopic Assay Data for PWR Full Burnup Credit

Evaluated Assay Data for Fission Products

Just as there are limited benchmark critical experiments that can be used to estimate the bias and uncertainty due to the presence of fission products in SNF cask systems, the existing regulatory guidance of ISG-8R2 notes a definitive lack of measurements that can be applied to estimate the bias and uncertainty in the prediction of the fission product compositions in SNF.

Regardless of the burnup, the top six nongaseous fission products, accounting for approximately 75 percent of the total worth of all fission products, are ^{103}Rh, ^{133}Cs, ^{143}Nd, ^{149}Sm, ^{151}Sm, and ^{155}Gd. These six fission products have been the focus of ORNL's efforts to obtain and assess potential sources of measured data that can support a strengthened technical basis for fission product credit.

Although radiochemical assay measurements have been reported for a large number of spent fuel samples, most measurements include only the major actinides. Relatively few measurements include the largely stable fission products important to burnup credit (i.e., ^{95}Mo, ^{99}Tc, ^{101}Ru, ^{103}Rh, ^{109}Ag, ^{133}Cs, ^{143}Nd, ^{145}Nd, ^{147}Sm, ^{149}Sm, ^{151}Sm, ^{152}Sm, ^{155}Gd, and ^{153}Eu). Of the 56 PWR spent fuel samples that had been evaluated by ORNL prior to 2005, only 19 included measurements for any of these fission products, and many samples have measurements for only a small number of fission products. No measurements are available for three fission products (^{95}Mo, ^{101}Ru, and ^{109}Ag), and ^{103}Rh had just one measurement. Table II provides a summary of the total number of measurements assessed and used by ORNL for each fission product in general order of descending importance. The fission product assay measurements shown in Table II are from just two reactors: the Calvert Cliffs fuels [designated as approved testing materials (ATM)-103, ATM-104, and ATM-106 fuels], measured at Pacific Northwest National Laboratory (PNNL), and the V. G. Khlopin Radium Institute (St. Petersburg, Russia) and the Japanese Takahama-3 PWR fuel measurements, performed at the Japan Atomic Energy Research Institute.

In 2005, ORNL thoroughly reviewed existing information on measured assay data with the goals of (a) collecting all of the relevant data into a single database and (b) identifying measurement data that are not currently being utilized. ORNL used the calculated-to-experiment (C/E) ratios obtained for the measurements noted in Table II to investigate the potential improvement (additional negative reactivity that could be credited) that would be obtained with availability of similar quality measurements. At least 20 high-quality measured samples need to be available to provide a good statistical estimate of the isotopic uncertainty and avoid significant statistical penalties due to low sample size. Thus, the goal is to have this minimum number of measurements available for the validation of the principal fission product nuclides. The samples must also cover the range of spent fuel characteristics and variations. Additional samples may be required to evaluate trends identified in the isotopic bias.

Sources of Additional Assay Data—Proprietary

ORNL has explored potential foreign sources of isotopic assay data as a means to support code validation for burnup credit using fission products. The sources include existing proprietary programs, currently active programs, and opportunities to perform new measurements.

The Commissariat à l'Énergie Atomique (CEA) of France has established experimental programs to provide data for the validation of French computer codes. The programs include spent fuel assay measurements in support of fuel inventory and fuel cycle studies, including burnup credit. The data from these programs are proprietary. However, through the contract with Cogema (one of the optional purchases under the contract previously discussed), ORNL can obtain and distribute the data for use with burnup credit design and review activities. The available Bugey reactor assay measurements include only two SNF samples of 2.1 weight percent and 3.1 wt% enrichment, with burnup less than 38 GWd/MTU. The available Gravelines reactor assay measurements include three SNF

Table II. Number of PWR Assay Measurements and Relative Importance of Fission Products to Burnup Credit

(Higher Importance)														(Lower Importance)
^{149}Sm	^{143}Nd	^{103}Rh	^{151}Sm	^{133}Cs	^{155}Gd	^{152}Sm	^{99}Tc	^{145}Nd	^{153}Eu	^{147}Sm	^{109}Ag	^{95}Mo	^{150}Sm	^{101}Ru
9	14	1	9	3	4	9	9	14	4	9	0	0	9	0

samples with initial enrichments of 4.5 wt% and burnup values of 39.1, 51.6, and 61.2 GWd/MTU. All of these samples include measurements for the fission products of interest. If the CEA data are acquired, assay measurements for three boiling-water reactor (BWR) SNF samples from the German Gundremmingen reactor would also be provided.

The CEA fission product data are viewed as highly beneficial to strengthening the technical basis to support quantifying fission product uncertainty because of (a) the high-precision radiochemical analysis methods employed, (b) the range of enrichments and burnups (covering most commercial U.S. fuels), (c) the use of standard commercial fuel assemblies (nonrebuilt), and (d) the fuel, which is probably well characterized (because it was selected specifically to support code validation in France). However, the quantity of CEA fission product assay data is limited to five PWR samples, thus leaving the total number of measurements available for many nuclides well below the target value of 20.

Belgonucleaire is coordinating the international REBUS program to obtain worth measurements for SNF and the MALIBU program to obtain isotopic assay data for high-burnup spent fuel. Similarly, there has been a research program of the Spanish organizations CSN, ENUSA, and ENRESA to obtain comprehensive isotopic characterization on high-burnup PWR fuel. Through support from NRC and DOE, ORNL is participating in REBUS and MALIBU and collaborating with ENUSA to obtain high-quality fission product assay data. The REBUS program will provide fission product assay data for one PWR UO_2 SNF sample, the MALIBU program will provide fission product assay data for two PWR UO_2 SNF samples, and the Spanish program will provide fission product assay data for seven PWR SNF samples. ORNL will evaluate these data and distribute them as needed at the end of the proprietary period established by each program.

Sources of Additional Assay Data—Nonproprietary

In 2005, ORNL contracted with the PNNL to investigate and assess whether there are existing U.S.-origin SNF samples that can be retrieved and made available for expanding the database of radiochemical assay data for validation of fission product burnup credit. The Material Characterization Center at PNNL generated a large percentage of the existing U.S. fission product assay data as part of an OCRWM program conducted in the late 1980s and early 1990s. PNNL's investigation identified numerous well-characterized SNF samples that have the criteria (e.g., enrichment, burnup, and fuel type) needed to address shortages in the available assay database. Subject to sponsor funding, it is anticipated that radiochemical assay measurements will begin in 2007.

A major activity at ORNL has been a reassessment of reported measurements of Three Mile Island-1 (TMI-1) SNF that were performed circa 1999 to support the YMP. The TMI-1 measurements include 19 fuel samples with extensive fission product data. However, in an earlier assessment of the TMI-1 data, ORNL and staff at the YMP showed the C/E results to be highly discrepant compared with the results from the other samples that ORNL analyzed and those that the CEA and Belgonucleaire programs reported for SNF with similar characteristics. For example, differences of 30–40 percent between measured and calculated predictions for ^{239}Pu have been reported. Reanalysis performed by ORNL using state-of-the-art multidimensional lattice physics codes (both SCALE and HELIOS) still shows discrepancies of 10–20 percent as compared with typical C/E differences of plus or minus 5 percent for ^{239}Pu for other available assays.

The difficulty in obtaining the quantity and quality of measured assay data for fission product nuclides has led ORNL to reinvestigate these samples. Through the assistance of EPRI and AREVA, ORNL was able to obtain additional assembly design information including the location and composition of gadolinium rods and assembly pitch associated with the TMI-1 assay samples. With this additional information, ORNL reanalysis indicates that the eight high-precision TMI-1 samples measured at the GE-Vallecitos Nuclear Center provide C/E values consistent with those anticipated based on experience with a range of reactor types and radiochemical assay programs. However, the 11 other samples remain discrepant. Further review indicates that the measurement

To provide a basis for statistically meaningful bounding values, ORNL has initiated an effort to gather and organize operational parameter data using the CRC information documented by the YMP. The initial parameters investigated were soluble boron concentrations, maximum fuel temperature, and minimum moderator densities.

methods used for these particular samples involved relatively low-precision techniques that resulted in large experimental uncertainties, likely making these results of limited value for code validation purposes. Thus, once the new information on the TMI-1 samples are documented and released, there should be at least an additional eight PWR SNF samples having desirable initial enrichment (4.65 wt%) and burnup values (23–30 GWd/MTU) and providing high-quality measurements for many fission product nuclides. Measurements for the metallic fission products (Mo, Tc, Ru, Rh, and Ag) were not available for these eight samples.

Radiochemical assay data needed for estimating bias and uncertainties in predicted fission product nuclides continue to be a challenge. ORNL has investigated known sources of assay data and is working to ensure existing data are available for safety evaluations.

Nuclear Data Assessment, Measurement, and Evaluation

The technical rigor (physics measurements and evaluations to smoothly fit data over the entire energy range) for acquiring current fission product cross-section data is deficient relative to that for major actinides and can impact the uncertainty and credibility of the validation process. This discrepancy in technical rigor has long been a concern of NRC staff in their consideration of allowing fission product credit (albeit, a secondary concern, if sufficient integral assay and critical measurements with fission products are available). Similar interests exist in Europe, and ORNL is working with the Institute for Reference Materials and Measurement under a DOE-Euratom agreement to assess the quality of cross-section data (from domestic and international sources) for the key fission product nuclides (i.e., ^{103}Rh, ^{143}Nd, ^{149}Sm, ^{151}Sm, ^{133}Cs, and ^{155}Gd) and propose new measurements as justified. Work has already been initiated on new measurements and an updated evaluation for ^{103}Rh.

Other Activities

Data for Improved Safety Analyses

The reactor analysis used to predict the SNF composition for the burnup credit safety evaluation should assume operating history parameters that are realistically bounding in terms of the impact on the k_{eff} value. In an effort to provide a basis for statistically meaningful bounding values, ORNL has initiated an effort to gather and organize operational parameter data using the CRC information documented by the YMP. Soluble boron concentrations, maximum fuel temperature, and minimum moderator densities were the initial parameters investigated.

It is hoped that investigation of the range of data values obtained and the mean standard deviations will offer a technical basis for bounding assumption values that should be used in the safety analysis. Given a sufficiently large database, it is anticipated that there should be a reduction in the conservatism of the values recommended by ORNL in earlier reports. The reduction should allow a larger fraction of spent PWR fuel to be considered acceptable for loading.

Burnup Credit for BWR SNF

The potential data needs for effective utilization of burnup credit in BWR SNF systems are likely to be less than that for PWR SNF systems. Each BWR assembly is less reactive than a PWR assembly, and criticality control is more easily achieved without the use of full burnup credit. ORNL has performed analyses that confirm the need for relatively little burnup credit in a high-capacity BWR SNF rail transport cask. In addition, ORNL performed analyses to determine to what extent current high-capacity rail casks, which have a maximum initial enrichment limit of approximately 4.0 wt%, would need to be derated (capacity reduced) to accommodate maximum-enrichment (5.0-wt%) BWR assemblies without burnup credit. The analyses suggest that a reduction in capacity of a 68-assembly cask to 64 assemblies will enable loading 5.0-wt% BWR assemblies without credit for fuel burnup. Although the complexity of the reactor operation may be greater for BWR SNF than for PWR SNF, it is anticipated that the minimal amount of burnup credit that may be needed with BWR SNF systems can be readily achieved. The key need for any additional data would likely be for radiochemical assay data, but insufficient work has been done to address the specifics relative to transport and storage.

Simple and Straightforward

A simple, straightforward approach for quantifying the benefits of PWR fission product burnup credit indicates a savings in transport cost alone in the range of $150 million to $400 million.

The highest priority data for critical experiments have been obtained (with the HTC critical experiment data set in final form and the PF, or fission product, critical experiment data set in draft form) from a proprietary French program and are currently being evaluated for applicability to SNF transport and storage casks. The initial results indicate that the HTC data set will become a strong technical foundation for the actinide portion of burnup credit and enable more flexibility in the criteria with which credit for fission products is considered.

Radiochemical assay data needed for estimating bias and uncertainties in predicted fission product nuclides continue to be a challenge. ORNL has investigated known sources of assay data and is working to ensure existing data are available for safety evaluations.

The technical strategy has pursued a diverse path to help (a) provide flexibility in future safety analyses and (b) ensure that a solid technical basis consistent with cost and benefit is established. Thus, critical experiment data continue to be assessed for applicability to cask systems, efforts to improve the cross-section data for fission product nuclides have been initiated, and activities are ongoing to increase the database through domestic efforts (e.g., new critical experiments at SNL and assay data measurements at PNNL) or international activities (e.g., participation in international research programs). The results of these activities may give NRC the information needed to consider an update to ISG-8R2 that provides guidance for implementing fission product credit. ■

Cecil V. Parks is technical integration manager for Nuclear Systems Analysis, Design, and Safety in the Nuclear Science and Technology (NST) Division at ORNL (parkscv@ornl.gov); John C. Wagner is group leader for Radiation Transport and Criticality in the ORNL NST Division; Don E. Mueller is a senior Research and Development (R&D) staff member in the Radiation Transport and Criticality Group, ORNL NST Division; and Ian C. Gauld is a senior R&D staff member in the Reactor Physics Group, ORNL NST Division. This article is adapted and updated from a paper presented by the authors at the American Nuclear Society's 2006 International High-Level Radioactive Waste Management Conference, held April 30–May 4, 2006, in Las Vegas, Nev.

The Big Rock Point landmark will be dedicated in 2007 and located near the entrance to the former nuclear plant site.

Thank You

- We express our sincere thanks to the generous donors and project partners listed below who helped make the Big Rock Point permanent landmark possible
- The landmark will share the history of the plant, contain donor names and logos, and be a fitting testament to the many achievements of Big Rock Point and its employees
- The structure will use pieces of steel from the plant's containment sphere and is designed to blend into the pristine northern Michigan landscape

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A Dream Fulfilled, a Promise Kept

On Jan. 8, 2007, Consumers Energy received approval from the U.S. Nuclear Regulatory Commission to release for unrestricted use 435 acres of the Big Rock Point Nuclear Plant property. The plant's iconic containment sphere and red and white stack, along with all other structures, have been removed and the site restored to a natural state.

The Big Rock Point landmark will commemorate the realization of the dream that nuclear energy could safely and reliably produce electricity, and the fulfillment of the company's promise to return the site to a natural state after the plant was closed.

In addition to the landmark, the state of Michigan has approved a State Historical Plaque commemorating the plant and site, and the Charlevoix Historical Society has become the safekeeper of plant artifacts.

We salute all who played a part along the road to green and offer special thanks to those who so generously supported the Big Rock Point landmark.

Looking into the Yucca Mountain Controversy

UNCERTAINTY UNDERGROUND
Yucca Mountain and the Nation's High-Level Nuclear Waste
Edited by Allison M. Macfarlane and Rodney C. Ewing
The MIT Press, 416 pp., $72.00 (Cloth), $29.00 (Paper)

Reviewed by Steve Turner

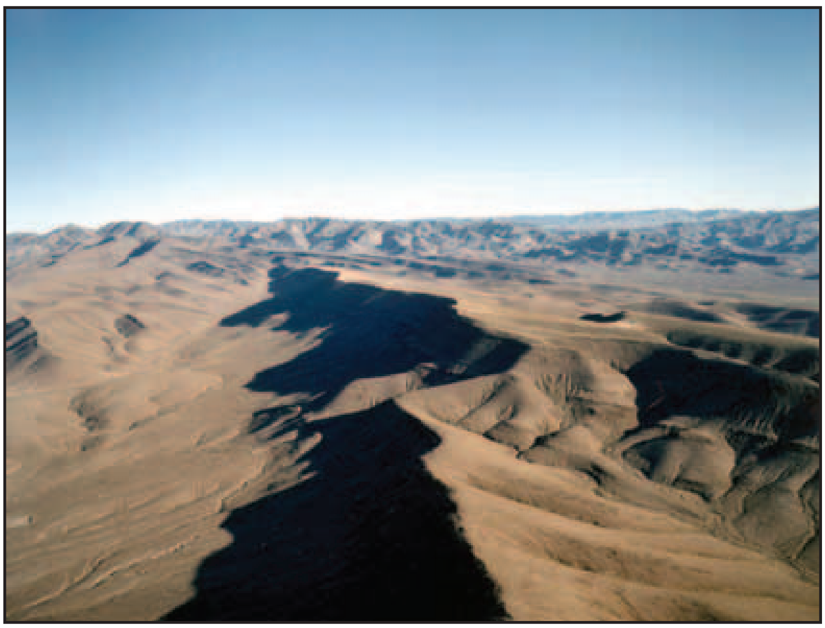
A comprehensive discussion of the uncertainty of making predictions one million years into the future.

For those with limited knowledge of the science and evaluation of the Yucca Mountain repository, this book is true to its title and comprehensively discusses the uncertainty of making predictions one million years into the future. For those uninitiated into the controversy and arguments surrounding Yucca Mountain, the book satisfactorily covers the historical and current scientific debates.

Policy, project descriptions, and historical information are provided, followed by chapters that focus on the issues involved in the scientific analyses of the repository as well as the arguments that support the licensing process. There are about 15 technical areas that cover the general science and technology subjects of earth science, hydrology, thermohydrology, waste package behavior, and waste forms. The historical context for the overall project, as well as the historical context for each chapter, is firm ground for understanding where the project has been and where it is going.

The language and content are appealing and effective to enhance understanding. Each chapter is developed such that it can stand alone, and the reader can focus on an issue of interest by reading the applicable chapter. The discussions of each technical area and the uncertain aspects are effectively a primer on the issue, making this a valuable reference book. For example, the complex earth science for Yucca Mountain—including seismology, volcanism, and climate change—is deftly covered in just 60 pages. While each chapter offers a quick reference and basic understanding of an issue, the full comprehension of the Yucca Mountain "problem" demands a cover-to-cover read.

The contributors do a balanced job of presenting all sides of the various arguments, and the editors deserve credit for even-handedness in the collection of issues and the point-counterpoint within each chapter. The reader is compelled to keep a scorecard of the plusses and minus-


Aerial view of the crest of Yucca Mountain.

> *While the chapters provide a quick reference and basic understanding of an issue, the full comprehension of the Yucca Mountain "problem" demands a cover-to-cover read.*

es, building an understanding of the uncertainty dilemmas. The reader quickly adopts the convention of thinking in terms of "features, events, and processes (FEPs)" and pondering if all the FEPs can be identified, along with the balance of knowns and unknowns of each.

The book is enlightening to nuclear proponents who believe that all the components in a decision process can be expressed using probabilistic analyses such as those in the Yucca Mountain performance assessment. The rather sobering message here is that these methods may not be suitable for many issues in geological processes and earth science. Strong arguments are presented that the ultimate result from using these methods is that many of the key aspects of the assessments and models for licensing cannot be verified or validated. One gets the feeling that the probabilistic approaches so familiar to reactor and nuclear facility assessments are misapplied for many of the Yucca Mountain evaluations. It appears the project made a misstep by selecting approaches that are most familiar to nuclear proponents and regulators while seeming to ignore the basic unpredictability of open geologic systems.

There are some disappointments in the book, such as the complaint that the possible sites were not adequately evaluated before the selection of Yucca Mountain in 1987. The text indicates that the decision was made for political expediency, but the observation seems weak, as there is no compelling evidence presented to substantiate that the technical evaluations in the 1980s were inadequate to select Yucca Mountain as the "best" alternative.

The concluding chapters reflect the sentiments of the editors, which have been expressed publicly on numerous occasions but do not seem too heavy handed. The editors recommend adjusting the approach to include other methods to show the adequacy of the repository. The adjustments include depending less on performance assessment, applying more qualitative technical judgment and comparative analysis (such as the sites and site selection methods in other countries), enhancing the oversight and making it clearly independent, and reducing the need for urgency in the current selection process.

In the end, the book falls a bit short by not clearly addressing the key point that the license decision for Yucca Mountain is based on the rule of law not on the rules of science and that uncertainty can be accommodated in that legal process, including implementing the closing recommendations suggested in the book. The law will rule out even if the law is viewed as a virtual endorsement for performance assessment prediction methods that may have arguable applicability. ■

Steve Turner is chief scientist with Terranear PMC in Oak Ridge, Tenn. He can be reached at stephen.L.turner@saic.com.

Planting a tree at the Big Rock Point site during the Greenfield Ceremony in August 2006.

A Decommissioning Wrapup

Commercial Reactor Decommissioning Status in 2006

The current status of the commercial reactor decommissioning projects in the United States and the major milestones achieved over the past 12 months.

By Edward C. Doubleday

For the past decade or so, a major facet of the commercial nuclear power plant industry in the United States has been the decommissioning of shutdown plants. At any given time, some 10 power plants have been in the process of decommissioning and/or demolition. Now, however, the current phase of commercial decommissioning work is winding down, and with most nuclear plants currently in service expecting to continue operation beyond their original 40-year licenses, the next era of plant decommissioning may be many years in the future.

The last 12 months, however, have been an extremely successful period for decommissioning and decontamination (D&D) professionals with the completion of physical decommissioning at a number of major projects. The myriad of unknowns that faced the industry 10 years ago with the unplanned shutdown of so many plants simultaneously challenged regulators, owners, and contractors alike. Working together, these separate entities resolved the issues such that the industry has successfully demonstrated that a large commercial nuclear power plant can be effectively decommissioned and the land returned to the community for economic development or other local use. This is an extremely important consideration, given the recent industry interest in new plants.

Here we take a look at the current status of the commercial decommissioning projects, presented in alphabetical order. It is based, in large part, on information that each plant provided in support of the American Nuclear Society's (ANS's) Decommissioning, Decontamination and Reutilization Division newsletter.

Big Rock Point

In late August 2006, Big Rock Point hosted a Greenfield Celebration, on the 44th anniversary of its receiving an operating license from the U.S. Atomic Energy Commission. This event marked the end of the Big Rock Point decommissioning process. Earlier in the year, in April, demolition of the containment interior concrete was completed and the steel containment sphere shell was removed.

Consumers Energy's Big Rock Point was a 67-MWe General Electric Co. boiling water reactor (BWR) located in northern Michigan. It began operation in 1962 and shut down on August 29, 1997, just three years shy of the end of its operating license, because improvements to meet future regulatory requirements were not considered cost-effective, given the small size of the plant.

After the celebration, there was still some status survey work being done at the plant site, as well as final grading and seeding. Once that is completed, all that will be left of the Big Rock Point plant site will be the independent spent fuel storage installation (ISFSI), which will hold the plant's spent fuel until it can be shipped to a national repository—and the Big Rock itself, just offshore in the shallow waters of coastal Lake Michigan, from which the plant took its name. License termination was expected from the U.S. Nuclear Regulatory Commission in the first quarter of 2007.

If the sale of Consumers Energy's other Michigan nuclear power plant, the Palisades plant, to Entergy Corp. is completed as expected in the first quarter of 2007, the deal will include Big Rock Point's ISFSI, marking the end of Consumers Energy's involvement in the nuclear industry.

The Big Rock Point plant before start of decommissioning.

Connecticut Yankee

Connecticut Yankee, a 590-MWe Westinghouse pressurized water reactor (PWR), began operation in 1968 and shut down in 1996. Decommissioning work began two years later.

In July 2006, the containment building was successfully demolished with the use of hydraulic hoe rams that broke up the structure from the bottom up. Pillars around 40 feet wide were created and then weakened one at a time to allow the containment to settle down on itself until the dome portion could be reached by the hoe rams. The process took approximately four months.

Demolition of the Connecticut Yankee containment building in summer 2006.

By August 2006, major demolition of the plant was completed, and physical decommissioning was expected to be completed by the end of the year. The plant shipped some 365 million pounds of decommissioning waste for offsite burial between 2003 and the end of 2006.

Final status surveys (FSSs) of miscellaneous land areas were scheduled for completion in early 2007, and license termination is expected this summer. Approximately 30 acres of the site, which will hold the ISFSI and a new administration building to support long-term fuel storage activities, will remain under NRC license.

Fermi-1

Detroit Edison's prototype sodium-cooled fast breeder reactor, the 94-MWe Fermi-1 unit, operated from 1963 to 1972. In October 1966, the plant suffered a partial nuclear meltdown. No radiation was released offsite, and no one was injured. The accident was attributed to a piece of zirconium that obstructed a flowguide in the sodium cooling system. Two of the 105 fuel assemblies melted during the incident, but no contami-

Dairyland Power Cooperative is in the process of removing the La Crosse BWR reactor vessel for packaging and shipment to the Barnwell LLW disposal site before it closes to out-of-compact waste in mid-2008.

nation was recorded outside the containment vessel. The plant continued to operate until September 1972. Fuel was removed from the plant in 1975. It shares a site with the Fermi-2 BWR.

During the past few years, the Fermi-1 Decommissioning Project has continued to make slow, but safe, progress. In December 2005, the plant staff safely reacted sodium residues in Primary Sodium Loop No. 1 after separating the loop from the reactor and building a processing system to perform the reaction in situ. Efforts are under way to set up Loops Nos. 2 and 3 for similar processing, as well as the reactor vessel itself.

Other recent actions include the removal of components from the top and inside the reactor that interfere with removal of the rotating plug graphite block layers. The control rod extensions will be the next components removed.

Currently, an enclosure is being built around the reactor in preparation for the removal of the graphite blocks. Efforts are complicated by the sodium residues remaining in the reactor vessel and possibly trapped inside components. The graphite blocks need to be removed so that the remaining sodium residues in the reactor vessel can be processed.

In early 2006, camera inspections and dose measurements were taken inside the reactor, and a Request for Proposals for the reactor vessel and large component removal portion of the project was issued.

La Crosse

Dairyland Power Cooperative's La Crosse BWR was built in 1967 and shut down and placed in SAFSTOR in 1987. The spent fuel is still being stored in the spent fuel pool at the reactor site.

However, Dairyland is in the process of removing the reactor vessel for packaging and shipment to the Barnwell, S.C., low-level waste disposal site before it closes to out-of-compact waste in mid-2008. This process is complicated by the location of the spent fuel pool directly adjacent to the reactor vessel.

In March 2006, the entire vessel was grouted. The utility plans to cut away enough of the biological shield around the reactor with a diamond wire saw to allow the vessel to be moved out laterally. A large hole will also be cut in the side of the reactor building to allow for the vessel removal.

All remaining Class B and C LLW was shipped to Barnwell in July 2006, leaving only Class A material onsite and allowing for the complete decommissioning of the site without any "greater-than-Class-C (GTCC)" issues.

In 2007, the utility plans to erect a large gantry crane (by March), package the vessel in a separate container, grout the container, and heavy haul the container to a rail spur on the site for shipment (by June).

Rigging holes being drilled in the La Crosse reactor building to support vessel removal.

Maine Yankee

In October 2005, the NRC notified Maine Yankee that its former plant site had been successfully decommissioned in accordance with NRC procedures, and the Maine Yankee license was amended to reduce the land under the license from approximately 179 acres to the 12-acre ISFSI site, located on Bailey Point peninsula.

Maine Yankee, an 860-MWe Combustion Engineering PWR, entered into service at the end of 1972. It was shut down in December 1996.

The Maine Yankee site after completion of decommissioning work.

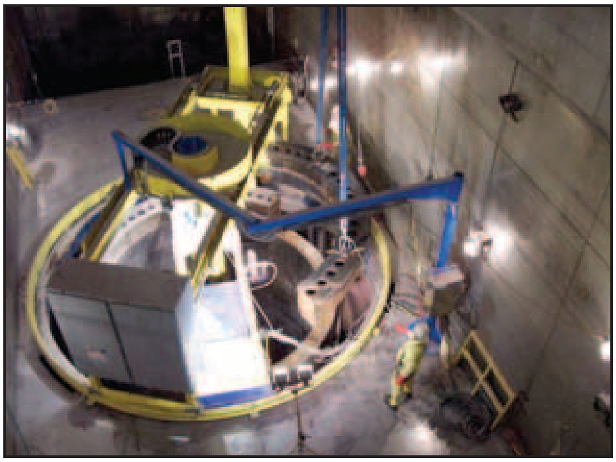
During its decommissioning process, Maine Yankee recorded the following key accomplishments:

- Zero lost time injuries over a period of more than three years.
- Completing decommissioning for less than half the NRC's radiological dose limit.
- Radiological cleanup of the site to a level significantly lower than the 10-millirem target.
- First-ever use of explosives to safely demolish a containment building.
- Approximately 400 million lb of waste safely removed from the site by rail, truck, and barge.
- Largest single campaign to move spent nuclear fuel from wet to dry storage.
- Creation of an upland marsh area.
- Donation of 200 acres of plant property for conservation and environmental education.
- Transfer of 400 acres of plant property now undergoing economic development.

Rancho Seco

The Sacramento Municipal Utility District's Rancho Seco plant, a 913-MWe Babcock & Wilcox PWR, began operation in 1975. It was shut down in 1989 as a result of a referendum. In 1995, the NRC approved a SAFSTOR plan for the plant, but a few years later, the utility owner opted to begin an incremental dismantlement approach to decommissioning.

In the spring of 2006, cutting and packaging of the reactor vessel internals was completed. Mechanical cutting and milling, not to mention brute force, were used to remove the internals underwater.



The Rancho Seco reactor vessel is currently being segmented for packaging and disposal.

Disposition of the concrete in the reactor building is currently under study, and negotiations with demolition and disposal bidders are under way. Self-performance and partial removal as an alternative is also under review.

At press time, the reactor vessel itself was being segmented for packaging and disposal, with robotically controlled high-pressure water/grit cutting (not underwater). All pieces except beltline pieces will be shipped in Sealand containers. The six beltline pieces will be placed in two boxes, grouted, and then shipped to the EnergySolutions disposal facility in Utah. Cutting was expected to be completed in January 2007.

Cleaning of embedded drain piping in the auxiliary building is nearing completion using a grit blast system that vacuums the debris and grit out from the end of the pipe. Similar work is complete in the reactor building, but piping remains to be cleaned in the spent fuel building and the turbine building. All contaminated underground pipe outside has been removed except for the liquid effluent line, which will be removed in 2007 along with the effluent basins.

Room decontamination is in progress in the auxiliary building and is expected to continue throughout 2007. All current decommissioning activities are expected to be completed by the end of 2008. At that time, a partial release of the site from the *Code of Federal Regulations,* Sec. 10, Part 50 license is expected. Decommissioning of the waste storage building will be completed once waste disposal is complete. The ISFSI is under a Part 72 license and will remain until the U.S. Department of Energy takes the fuel.

The License Termination Plan (LTP) was submitted to the NRC in April 2006. Requests for Additional Information were received in October, and those responses were being prepared at the end of the year. The LTP public meeting was held November 12. Derived concentration guideline levels have been determined using the industrial worker scenario, due to the ongoing use planned for the site. The FSSs are in progress, based on methodology submitted in the LTP.

San Onofre-1

San Onofre-1, owned by Southern California Edison Co., is a 436-MWe Westinghouse PWR. It began opera-

Phase I of the San Onofre-1 Decommissioning Project is approximately 68 percent complete and is forecast to be completed in 2008. The remainder of the decommissioning project will be completed concurrent with the decommissioning of the other two units on the site, which is projected to be many years into the future.

tion early in 1968 and shut down permanently at the end of 1992. The facility transitioned from SAFSTOR to active decommissioning in 1999.

Today, the project is nearing completion of its seventh year of decommissioning. Hydraulic pounding and torch cutting are bringing down remaining standing structures on the site, which include the containment sphere, portions of the sphere enclosure building wall, the spent fuel building (with the pool liner removed), and the radwaste building, empty of all equipment. Key decommissioning activities include dismantling the containment sphere and removing the fuel storage and radwaste buildings to approximately 12 feet below grade.

Since spring 2006, the project has focused its efforts on crushing, loading, and shipping debris from inside the containment. Some 112 million lb of demolition debris have been removed and shipped since the start of the project using various means, including lift liners (synthetic bags) and intermodal containers. The project expects to ship another 70 million lb of materials from the site by the end of 2008.

During 2007, the project will focus on completing the following decommissioning activities:

- Removing the radwaste building.
- Dismantling the Unit 1 spent fuel building.
- Clearing the area for the second ISFSI pad (for fuel from San Onofre-2 and -3, still operating on the site). The first pad of the ISFSI contains 31 advanced horizontal storage modules. Eighteen of these have been used to store San Onofre-1 spent fuel and GTCC waste. Beginning in 2007, the remaining 13 modules will be used to store spent fuel assemblies from the two operating units.

Phase I of the project is approximately 68 percent complete and is forecast to be completed in 2008. The remainder of the decommissioning project will be completed concurrent with the decommissioning of the other two units on the site, which is projected to be many years into the future.

Saxton

The Saxton Nuclear Experimental Corp. plant was a small (23.5-MWe) Westinghouse PWR that generated its first electricity in 1962. For 10 years, the plant served as a research and training facility for scientists, engineers, and nuclear plant operators worldwide. It was shut down in 1972 and placed in SAFSTOR in 1975. The fuel was shipped to the Savannah River Site.

Phased decommissioning work began in 1986, and full decommissioning began in 1998, when the reactor vessel, steam generator, and pressurizer were removed and shipped by train to the Barnwell LLW disposal site. Physical decommissioning was completed in 2005, with the site returned to its natural state.

The license for the facility was terminated in November 2005.

Trojan

Trojan, Portland General Electric's (PGE's) 1095-MWe Westinghouse PWR, began operation in 1976. It was shut down in 1992 for economic reasons. The large components (four steam generators and the pressurizer) were removed in 1995, and in 1996, the NRC approved the decommissioning plan.

In 1999, as a first-of-its-kind project in the United States, the reactor vessel and internals were removed intact and shipped up the Columbia River to an LLW burial site in Richland, Wash.

In 2001, the final survey began, and by 2003, all spent fuel had been transferred from the spent fuel pool to the ISFSI. PGE completed the final survey and submitted all results to the NRC in 2004; in 2005, the NRC and the Siting Council approved the site for release. In May 2006,

The Trojan cooling tower was imploded in May 2006

The Yankee Rowe plant before (above) and after decommissioning.

the cooling tower was safely and successfully imploded.

Yankee

The Yankee Rowe plant, a 167-MWe Westinghouse PWR, began operation in 1961 and was shut down 30 years later in 1991. The steam generators were shipped to Barnwell in 1993, the decommissioning plan was approved in 1995, and the reactor vessel was shipped to Barnwell in 1997.

Physical decommissioning of the plant was completed in September 2006, including the installation of additional groundwater monitoring wells. Decommissioning waste shipments were also completed in September, and grading and seeding of the site were completed by the end of the year. All FSS field activities were completed in September, and the FSS reports were completed and submitted to the NRC at the end of the year.

Work remaining at the site includes the completion of the extension of an adjacent dam onto Yankee property, and installation of a modular ISFSI administration building to support long-term spent fuel storage operations. Groundwater monitoring will continue until the Massachusetts closure criteria are achieved. License termination is scheduled for mid-2007. Approximately one acre will remain under NRC license.

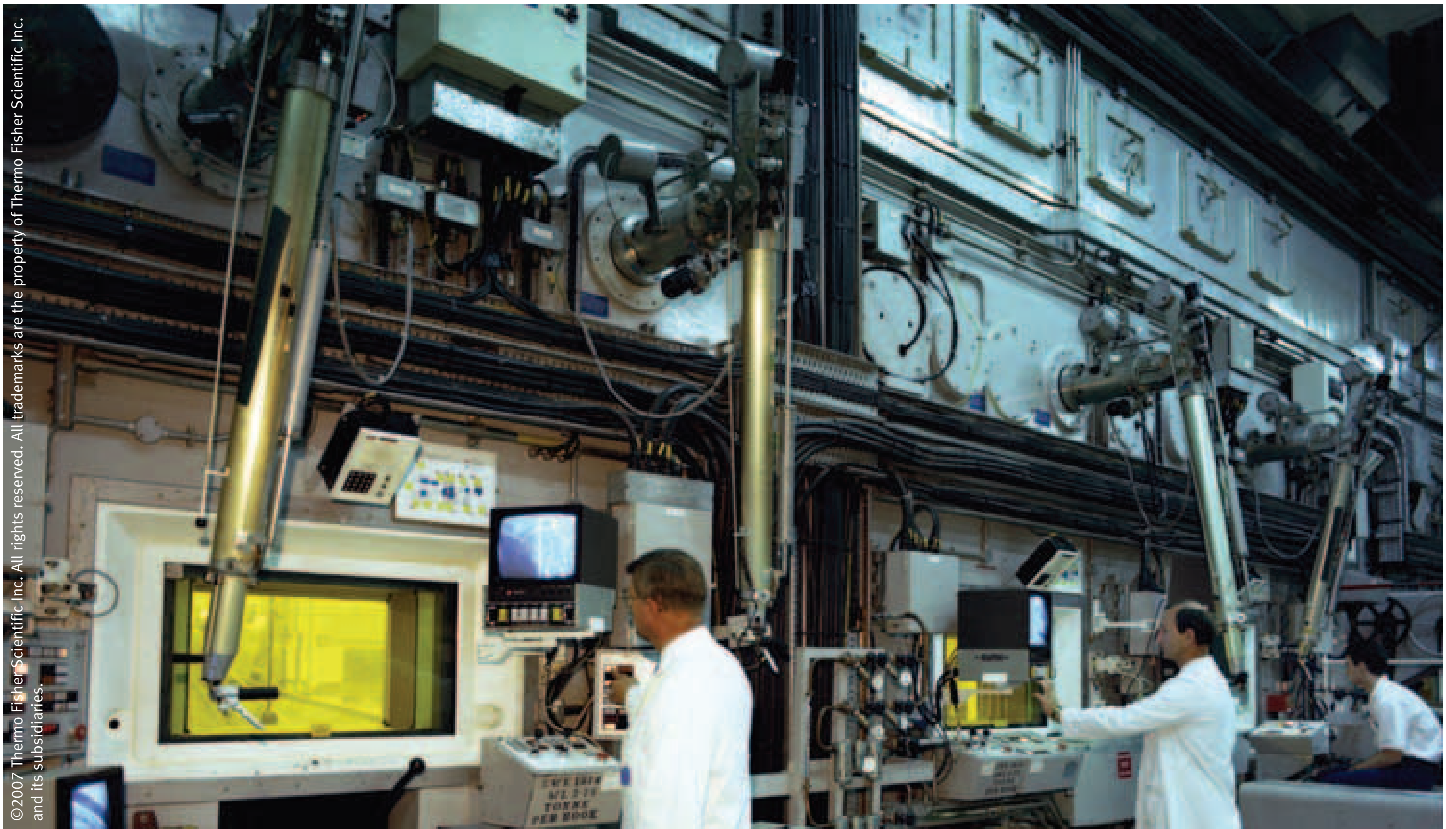
Work remaining at the Yankee site includes the completion of the extension of an adjacent dam onto Yankee property and installation of a modular ISFSI administration building to support long-term spent fuel storage operations. Groundwater monitoring will continue until the Massachusetts closure criteria are achieved. License termination is scheduled for mid-2007.

SAFSTOR

In addition to the previous plants, several plants have been shut down but are currently in either a SAFSTOR condition or are proceeding with limited decommissioning activities:

- Zion-1 and -2.
- Humboldt Bay.
- Three Mile Island-2 (actually in post-defueling monitored storage—see "Whatever Happened to TMI-2, and Other Nuclear Waste Issues," this issue, page 68).
- Indian Point-1.
- Dresden-1.
- Millstone-1.
- Peach Bottom-1. ■

Edward C. Doubleday is senior vice president, Commercial Decommissioning and Waste Management Services, for EnergySolutions LLC. He can be reached at 860/355-8194; e-mail edoubleday@energysolutions.com. This article is based on a presentation made at the 2006 ANS Winter Meeting, held November 12–17, 2006, in Albuquerque, N.M.



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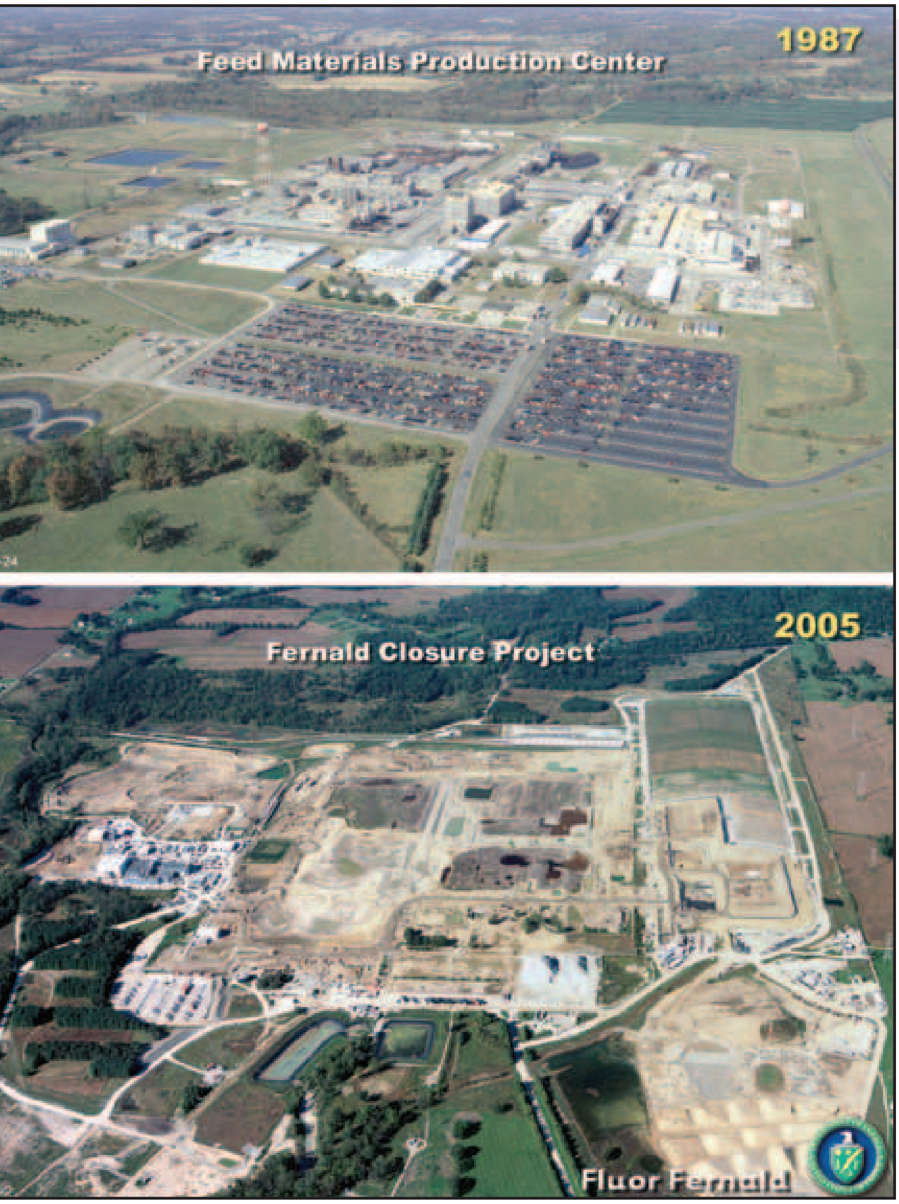
Changing Public Participation at Fernald

Not an Easy (or Popular) Task



Fernald "then" and at the end of 2005. The project landscape changed daily in 2006 as closure approached.

Fernald's transition to the Office of Legacy Management will likely be more difficult than at other cleanup sites, in part because area stakeholders have 20 years already committed to this project.

By Jeff Wagner

Public participation at a closure site evolves. In large part it's driven by the players—neighbors, U.S. Department of Energy, contractors, regulators, and, to some extent, the media. At Fernald, public participation became an integral part of the decision-making process in the late 1980s and early 1990s. At that time the DOE was really just beginning to understand the extent of environmental contamination caused by 40 years of producing uranium metal.

To give the public a single voice, the Fernald Citizens Advisory Board (FCAB) was formed. Its job was to make recommendations to the DOE regarding cleanup levels, the cleanup approach, and, ultimately, the final look and use of the site. Since 1994, the FCAB has had a tremendous influence in shaping the course to closure. The advisory board proposed the "balance approach" to waste management, a decision that will ultimately save nearly $3 billion in cleanup costs. This approach calls for onsite disposal of a majority of Fernald's contaminated waste (e.g., soil and building debris) while shipping legacy waste and other more concentrated waste streams offsite.

More recently, when Fernald needed to change its approach to treating silo waste, the FCAB was heavily involved in selecting a waste-stabilization technology. When concerns arose over the potential hazard of inhaling airborne contaminants associated

Stakeholders discuss how to make the Fernald property an asset to the community at a CAB Future of Fernald workshop held at the Crosby Township Senior Center.

with extracting, packaging, and shipping Silo 3 material, the FCAB urged Fluor Fernald to incorporate a chemical additive into the operation to agglomerate the powdery byproduct. This step added yet another level of safety into an already robust packaging and shipping design.

The Future of Fernald

In 1999 and 2000, the FCAB hosted a series of "Future of Fernald" workshops. The advisory board made a concerted effort to attract individuals and groups with backgrounds in nature, environment, and education. These groups were sought based on their potential interest in the site postclosure.

During these workshops, stakeholders had a chance to express their views on how the site would look and on possible uses for the 1050-acre property. Would the land be open for light industry? If the land were to be used as a park, what kind of park? Would there be trails through the restored areas? What kind of trails—bike or pedestrian? Will there be a fence around the property? These and many other questions, which included the need for establishing a multiuse education facility, were asked. From these workshops with the public came this vision statement:

A Stakeholder Vision for the Future of Fernald
(Adopted by Fernald stakeholders at the third Future of Fernald workshop, September 26, 2000)

Fernald stakeholders envision a future for the Fernald property that creates a federally owned regional destination for educating this and future generations about the rich and varied history of Fernald. We envision a community resource that serves the ongoing information needs of area residents, education needs of local academic institutions, and reinterment of Native American remains. We envision a safe, secure, and partially accessible site, integrated with the surrounding community, that effectively protects human health and the environment from all residual contamination and fully maintains all aspects of the ecological restoration.

What's unique about Fernald compared to some other DOE cleanup sites is the remedy for cleaning up the aquifer. Pumping and treating the contaminated aquifer on and off Fernald property could continue for another decade after the declaration of physical completion.

As cleanup nears an end, the FCAB and other key stakeholders stand at a crossroads. The DOE Office of Environmental Management (EM) is working with the Office of Legacy Management (LM) and its contractors as they prepare to take over stewardship and long-term maintenance of the site. In fact, for the past year LM has

Above: *The DOE's Ohio Field Office Manager Bob Warther congratulates FRESH President Lisa Crawford and FRESH members for 25 years of service to the Fernald community.*

Left: *John Homer (left) and Eric Woods (right) of Fluor Fernald's Environmental Restoration Section carefully monitor ponds and wetlands developed on the 1050-acre former uranium production plant, looking for signs of a budding ecosystem.*

been actively setting up shop. They are playing an equal role with EM in Fernald public meetings. The LM contractor, Stoller, has hired seasoned personnel from the project to bring continuity to key positions with public interaction.

The DOE is also chartering local stakeholder organizations (LSOs), made up of elected officials, to serve as the voice of the public. LSOs are being established to provide DOE guidance on postclosure issues. Township trustees from Ross, Crosby, and Morgan Townships in southwestern Ohio have been meeting with LM and stakeholders to determine if the postclosure and public involvement needs of the site warrant forming an LSO. Clearly the decisions surrounding remediated DOE sites are less "charged" than those associated with environmental contamination and public health. Fernald neighbors have confidence in the cleanup levels established early on under each Record of Decision. The core of the decision-making effort now really centers on how best to return the property as an asset for the community.

DOE Fernald Closure Project Director Johnny Reising (right) gives Fernald neighbors a tour of Silo 3 packaging operations before the system went online in April 2005.

In light of the changing mission, and the changing complexion of each site, the DOE is also looking to bring in members of the public who have a broader and, in some cases, more recognized constituency base than some current stakeholders. After several decades of active involvement by some stakeholders, the DOE wants to bring new faces and ideas into the process.

Two Decades of Public Involvement

The transition at Fernald will likely be more difficult than at other cleanup sites. Many area stakeholders have 20 years already committed to this project. For most, Fernald has been an emotional subject that affected their community and families. One group in particular, Fernald Residents for Environmental Safety and Health (FRESH), has been a fixture at Fernald public meetings for the past two decades. In 1984, FRESH President Lisa Crawford learned her family was drinking from a well contaminated with uranium. From that point on, Crawford and her neighbors organized an effort to find out more information on the extent of the contamination and its effects on public health. Crawford and FRESH members became the face of a public betrayed by their government.

With perseverance and commitment, the group became subject-matter experts on the effects of radiological contamination. Members of the FRESH core group are frequently asked to speak at local and regional conferences on their fight to clean up Fernald. They gradually began

An artist's rendering of how Fernald would look in the future as wetlands, ponds, woods, and prairie land mature. Today, this vision is a reality.

networking with stakeholder groups from other DOE sites to form a cohesive force that could not be ignored. With commitment, media savvy, and hard work came recognition by the DOE, local representatives, the media, and the public. When Lisa Crawford picked up the phone, congressmen, assistant secretaries, and reporters took the call.

> Decisions regarding Fernald's cleanup were made based on balanced information and in cooperation with all parties—the DOE, regulators, and stakeholders. The DOE is committed to open communications but realizes the decisions and the opinion leaders change as Fernald's new mission takes shape.

As the risk issues at Fernald have faded with the progress of cleanup, so has most of the fire that caused FRESH to mobilize in the beginning. Public involvement has moved from determining acceptable cleanup levels to looking for cleanup options, monitoring the progress of cleanup, and finally overseeing long-term monitoring and public access. While the issues have changed and are less emotional, FRESH is reticent to ease up on the throttle. What does a grass-roots organization do once their cause no longer exists? Change isn't easy.

Relief Ahead

For most members of the FCAB, site completion will bring welcome relief. Several members of the advisory board are near the end of their professional careers and are looking forward to retirement. Attending several FCAB and public meetings each month for the better part of 15 years is a considerable commitment. In addition to normal meetings, members spend even more time at home studying or preparing to discuss specific Fernald issues. Most members of the advisory board are willing to walk away from Fernald once the cleanup is complete. They are ready to spend their free time and energy in new pursuits. The Fernald public is fortunate to have had such a dedicated group of citizens looking out for their community.

Aside from the FCAB and FRESH, the general public's interest in Fernald has faded. Cleanup is a long process, even accelerated cleanup. Quarterly "Countdown to Closure" public meetings are lightly attended by the general public. Media interest in the site for the most part has waned. New inquiries about the status of the cleanup are often the result of a high school or middle school class project.

At Fernald, public participation has changed and will continue to change. Open communication has been a major factor in the success of the project. Decisions regarding Fernald's cleanup were made based on balanced information and in cooperation with all parties—the DOE, regulators, and stakeholders. The DOE is committed to open communications but realizes the decisions and the opinion leaders change as Fernald's new mission takes shape. While LM and EM are working hard to make a smooth transition, there aren't many examples the public can refer to of how a completed cleanup site is developed, managed, and utilized. Once some of these unknowns are answered, the need for public involvement will drop dramatically, probably after about one year of closure. By then, maintenance and management of the property will become routine.

What's unique about Fernald compared to some other DOE cleanup sites is the remedy for cleaning up the aquifer. Pumping and treating the contaminated aquifer on and off Fernald property could continue for another decade after the declaration of physical completion. The DOE will need to maintain some level of public involvement to keep the community informed of the cleanup progress. Over the years, for the most part, this issue has taken a back seat to other more pressing risks. The general public has confidence in the aquifer treatment operations and the people responsible for those operations. Both the system and the staff will remain intact after 2006.

If the Multi-Use Education Facility comes to fruition, curricula will be developed and LM will have the opportunity to bring kids to the site as well as Fernald education programs to area schools. What has yet to be determined is how readily local educators will take advantage of the rich history of Fernald both during the Cold War and later in the cleanup era. Will an educational facility be a sustainable part of Fernald's future?

Once the education and maintenance elements of the site become routine, public confidence in the remedy and use of the property will forgo the need for formal public involvement. Fernald will then be added to the growing list of successful DOE EM cleanup projects. ■

Jeff Wagner is Public Affairs director for Fluor Fernald. He can be reached at Jeffrey.Wagner@fernald.gov. This article is adapted from a presentation at Waste Management 2006, held February 26–March 2, 2006, in Tucson, Ariz. The presentation won the Best Oral Paper Award for that meeting.

Best Poster Paper
Waste Management 2006

Science, Technology, and Workforce Innovations

Keys to a Successful D&D of Hanford's Plutonium Finishing Plant

D&D work at PFP is met with innovative approaches based on new science and technology and also on the creativity and motivation of the workforce.

By Stacy Charboneau, Andrea Hopkins, Bruce Klos, Robert Heineman, and Brian Skeels

The Plutonium Finishing Plant (PFP) at the U.S. Department of Energy's Hanford reservation consists of a number of process and support buildings for handling plutonium. Building construction began in the late 1940s, and the facility became operational in 1950, producing refined plutonium salts and metal for the U.S. nuclear weapons program. The primary mission of the PFP was to provide plutonium used as special nuclear material for fabrication into a nuclear device for the war effort. After the end of World War II, the PFP's mission expanded to support the Cold War effort through plutonium production during the nuclear arms race. PFP has now completed its mission and is fully engaged in deactivation, decontamination, and decommissioning (D&D). At this time the plan is to reduce PFP buildings to ground level (slab-on-grade) and remediate the site to satisfy national, DOE, and Washington State requirements.

The D&D of a highly contaminated plutonium processing facility presents a plethora of challenges. PFP personnel approached the D&D mission with a can-do attitude. They went into D&D knowing they were facing a lot of potential problems and unknowns. There were concerns about the configuration control associated with drawings of these old process facilities. There were unknowns regarding the location of electrical lines and the condition and contents of process piping containing chemical residues such as strong acids and caustics. The gloveboxes were highly contaminated with plutonium and chemical residues, and most of the glovebox windows were opaque with splashed process chemicals that coated the windows or etched them, reducing visibility to near zero. Visibility into the glovebox was a serious worker concern. In addition, all the gloves in the gloveboxes were degraded and unusable. Replacing gloves in gloveboxes was necessary before glovebox cleanout could even begin. The sheer volume of breathing air needed was also an issue.

Throughout the course of the D&D, personnel at PFP applied innovative work practices, invented new ways of performing work, created new work tools, and applied lessons learned from other D&D sites. The decontamination of plutonium-contaminated gloveboxes, process equipment and product transfer piping, ventilation hoods and ductwork, and buildings can lead to risk of injury to workers and the environment. Workforce ingenuity combined with the creative inventions and approaches to the D&D work not only made the work safer, but also more efficient.

These innovations were developed mutually by PFP management and workers. They have resulted in productivity improvements, enhanced safety, and improved contamination control.

Workforce Innovations

Over a period of time, chemical processing inside gloveboxes has caused poor visibility through glovebox windows and panels. Historically, temporary improvement in clarity has been gained by wetting the inside surface of the windows with water or Vaseline and sometimes cleaning with nitric acid wipes. When severe visibility impairment precluded necessary operations, the glovebox panels or windows were replaced with new ones. This task required breaking the glovebox containment, which is time consuming, costly, and hazardous. Major contamination spreads have occurred during glovebox panel change out.

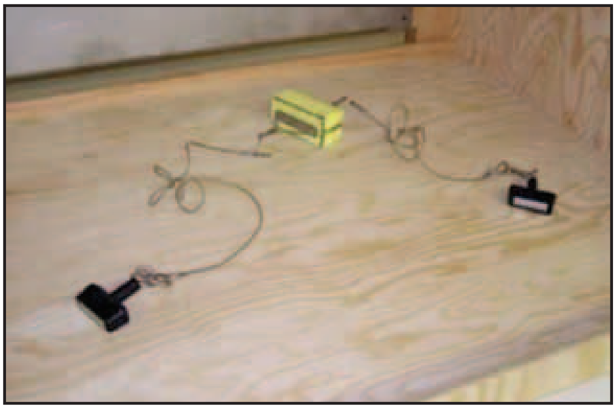
Unimpeded vision into the gloveboxes was necessary to perform the clean-out work safely and efficiently. To avoid the cost and negative consequences of the panel change, several window cleaning methods were applied with significant success. Because the origin of the visibility impairment is generally unknown due to the age of the system, one or more of the window cleaning methods were required, chosen by trial and error. Window cleaning processes used during PFP D&D include commercial degreasers, T.C.G's Novus™ plastic cleaning system using rubbing compounds, and the 3M Trizact™ abrasive disk and orbital sander system.

The orbital sander system had been developed to restore vision through aircraft canopies, using a series of graded abrasive disks. Using these disks, it was possible to restore visibility sufficiently to allow D&D operations to proceed when visibility through the glovebox was problematic. It was important to use an efficient system to clean the glovebox windows because more time required for cleaning, especially for severely damaged window panels, results in additional radiation exposure to the worker. In addition, the installation of remote cameras also helped reduce the time associated with glovebox cleanout.

The keel haul tool, also known as "Sponge Bob" after its resemblance to the cartoon character, was invented at PFP to assist in the nondestructive assay (NDA) of objects encountered during the D&D process. (NDA is used to determine the level of contamination of an object.)

To complete the surface-contaminated object (SCO) process on the reflux hoods located within the PFP, the backside of the hood's baffle plate had to be accessible for a direct radiological survey. Cutting or removing the hood baffle plate was required to allow access for the SCO survey probe and completion of the SCO process. A concern over the buildup of lint and the potential for chemical and radiological contamination in removing these baffles led the D&D team to identify ways to mitigate these potential hazards. Subsequently the team developed a tool called the keel haul tool, which allows the backside of the baffle plate to be cleaned by pulling a sponge attached to cables. This tool reduces contamination risks and enhances as-low-as-reasonably-achievable (ALARA) practices in the decommissioning of the PFP's open-faced hoods.

Also used to assist in wipe downs of inaccessible areas are magnets. Neodymium magnets are extremely powerful for their size, and for this reason they were selected for use in ventilation duct cleanout work. Where ducts are readily accessible, magnets outside the duct can be magnetically coupled to magnets on tools inside the duct, making it possible to manipulate the clean-out tools from outside the duct.



"Sponge Bob" and magnets arrangement for D&D.

There are cautions to be considered with the use of magnets, however. There is concern that the extremely strong magnetic fields from the magnets may set off CAM and criticality alarms. The manufacturer warns that the magnets should be kept away from any magnetic-based storage devices, such as tapes, hard drives, and credit cards, with the warning to keep the magnets at least one foot away from these items at all times. There is a special warning regarding pacemakers.

The strength of even the strongest magnets drops off exponentially with distance from the magnet. A Neodymium magnet with a 90.7-kilogram (200-pound) lifting strength (at zero distance) was tested using a compass to determine how far away from the magnet the compass needle would be affected. At an 81.3-cm (32-in.) distance east of the compass the needle deflection was barely perceptible. At a 91.4-cm (36-in.) distance east of the compass needle, there was no perceptible needle movement. Magnet location either east or west of the compass needle was determined to have the greatest effect on the compass needle.

Glovebox decontamination at PFP is facilitated by the use of decontamination systems using cerium nitrate and certain proprietary chemical decontamination processes. Most of the process equipment and gloveboxes at PFP are

Glovebox decontamination at PFP.

Because of the plastic sleeves in gloveboxes, each piece of contaminated equipment from a glovebox had to be thoroughly padded and taped inside the glovebox, then slowly and carefully brought out through the plastic sleeve to avoid tearing the sleeve. A tear in the sleeve meant contamination spread with undesirable consequences: worker exposure, lost productivity, and the need to decontaminate and clean up the area.

contaminated with transuranic (TRU) waste. If the equipment is not decontaminated, it must all be disposed of at the Waste Isolation Pilot Plant (WIPP) as TRU waste. This is not advantageous from a cost and waste minimization standpoint. PFP scientists and management determined that a more practical and efficient method for the D&D of this equipment would be to decontaminate the equipment from a TRU level to a low level and dispose of the equipment as low-level waste. Wet and dry methods of decontamination technology were investigated at PFP by PFP and Pacific Northwest National Laboratory (PNNL) chemists and technicians.

Four candidate chemical decontamination technologies were investigated for decontaminating plutonium-contaminated gloveboxes at Hanford's PFP. Treatability studies under the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) were conducted.[1,2] These technologies are cerium nitrate/nitric acid, AET Inc.'s RadPro™ (wet method decontamination) process, STMI's Glygel™ decontamination process, and CEA/COGEMA's ASPIGEL 100™ (dry method decontamination) process. PFP and PNNL personnel investigated chemical reactivity hazards of wastes arising from these technologies as they are applied in the field. PFP is the only facility in the DOE complex to perform these studies to ensure the safety of the decontamination chemicals both in use and as residual stored in waste drums.[3]

HEPA Filter Exchange

There are hundreds of high-efficiency particulate air (HEPA) filters in the PFP, which all have to be changed periodically. The use of glove bags for the exchange of HEPA filters is difficult. A typical HEPA filter exchange would generally cause the containment tent to become highly contaminated and induce high airborne conditions. Planning for changing HEPA filters at PFP identified a need to control contamination and airborne activity. A rigid double barrier was conceived, tested, and practiced on a mockup and is now in use throughout the plant. This innovation has resulted in the confinement of plutonium particulate; consequently, there is only a small risk of the spread and generation of airborne contamination during filter exchange.

Passive aerosol generation (PAG) was used to transform the Plutonium Reclamation Facility (PRF) main airlock from an airborne radioactivity area to a radiological buffer area. PAG was determined to be the best technology to reduce the time and resources required to decontaminate and decommission the PRF canyon. The PRF main airlock was remotely fogged with a PAG using a commercial product capture coating. The PAG uses patented technology to create a very fine aerosol to disperse the capture coating throughout the entire volume of the airlock. After several hours, the aerosol forms an encapsulating film over all the surfaces. As the aerosol settles, it adheres to and removes airborne particulates in the area, which eliminates airborne radioactivity. After the airborne radioactivity had been controlled, workers made a number of entries into the airlock to remove gross and wet debris and thick piles of dirt and dust.

To perform work in the airlock, however, workers needed a fixative to ensure contaminants were contained on the surface of the airlock. Therefore, a lead-free, waterborne, acrylic enamel coating was applied with a common airless spray system. The capture coating was applied to a dry film thickness of approximately 6 mm. This coating was engineered to absorb the capture coating from the fogging process and still adhere to the various substrates in the area. This spray fixative adheres to steel, concrete, drywall, plastic, glass, and various other materials within the area.

To ensure that the fixative is not disturbed or abraded through worker ingress and egress, a layer of self-leveling floor coating was applied to the floor and first 1.8 m (6 ft) of the walls. This floor coating system is a two-part, zero-VOC epoxy system composed of 100 percent solids formulated to yield an abrasion- and chemical-resistant floor surface. This methodology ensures that the ensuing work in the airlock will not chip or abrade the encapsulating spray fixative.

Modifying Glovebox Port Rings for D&D

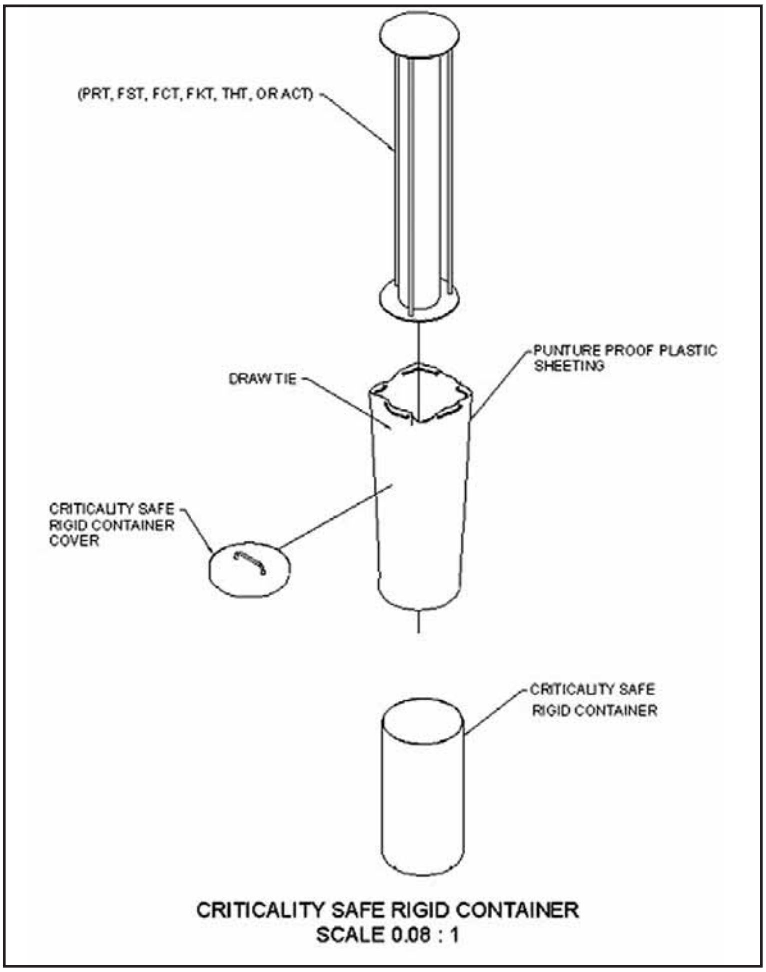
During processing of plutonium at PFP, glovebox port rings and port covers had been used when necessary to gain access to the glovebox using gloves, for equipment and waste seal in and seal out, and for viewing ports through clear port covers. D&D operations required new uses for port rings and covers. Several useful modifications were made to both port rings and covers to meet specific needs of the D&D worker that have increased productivity and safety while reducing costs and increasing efficiency. Port covers have been modified to provide routing for 110-volt electrical power, SCO detector wiring, and remote camera wiring into the glovebox.

Port rings of various sizes were mounted on port covers to provide a new uncontaminated port ring for seal out, which greatly reduces the chances of contamination spread. Port rings of smaller size were mounted on port covers to reduce the size of the seal-out bag. The smaller the seal-out bag, the easier it is to perform the seal-out operation, which increases the safety of the operation.

PFP's special augers, machined out of Teflon™ blocks and mounted on stainless steel cores, were used with "quick connect" extension rods to clean out legacy plutonium-bearing materials held up in piping. The extension rods can be added as needed to reach legacy material in the lines. The auger is simply pushed into a pipe, rotated, and pulled out, with the heldup material dropping into staged, critically safe containers through a transparent "tee" (short branch) attached to a line flange. Larger versions of the auger were used to clean out the mercury vacuum headers in PFP's duct level between the first and third floors. In many cases, the augers allowed holdup removal to proceed without pipe removal, thus saving time. PFP D&D teams also developed special scrapers, brushes, and core drill bits to aid in this work.

Demonstration of PFP's special augers.

Removal of old process system glass tanks that were used in converting plutonium solutions to plutonium metal presented a potential hazard to D&D workers, e.g., breached gloves. Operators developed an innovative collapsible sleeve that can be fitted over glass tanks that hang on flanges and rod assemblies inside the gloveboxes. The sleeve is made of heavy rubberlike material and can fit over tanks up to 1.8 m (6 ft) long. The sleeve is an open cylinder. The lower end fits inside a critically safe metal container, sized to be able to contain all of the broken glass tank pieces. Once the sleeve is installed around the glass tank and the lower end is fit inside the metal container, operators reach into the glovebox and break the tank inside the sleeve device. Pieces of glass fall into the container. The sleeve is then collapsed into the metal container and sealed out as a waste package. With this innovation productivity has improved, and operators never touch the contaminated glass, thereby reducing the probability of puncturing a glove.



PFP's collapsible sleeve.

Rigid Port Bag and Lazy Susan

Because of the plastic sleeves in gloveboxes, each piece of contaminated equipment from a glovebox had to be thoroughly padded and taped inside the glovebox, then slowly and carefully brought out through the plastic sleeve to avoid tearing the sleeve. A tear in the sleeve meant contamination spread with undesirable consequences: worker exposure, lost productivity, and the need to decontaminate and clean up the area. The rigid port bag, or "turkey fryer," was a new approach that enabled operators to seal out as much as four times the contaminated equipment from gloveboxes per shift as achieved with traditional equipment. The device looks like a turkey fryer, consisting of a stainless steel can with han-

The "turkey fryer" in use.

dles on each side, near the top, and a seal-out bag that fits around the outer rim. It then connects to the glovebox port with a large elastic band similar to a bungee cord. With this approach glovebox cleanout progresses more quickly and radiation dose exposure, time, and costs are reduced while ergonomic conditions are improved.

The 232-Z Incinerator Facility personnel recommended that sealed-out waste packages be place on a lazy susan–style turntable for dose rating and portable NDA. Operators placed each waste package on the lazy susan after seal out and contamination survey. This allowed for changing the position of the package with minimal handling, thereby reducing dose to the fissile material handler. This approach also reduced the risk of breaching plastic layers by abrasion or puncturing from multiple lifting and movements required to obtain adequate dose rates and NDA measurements of the package.

Hanford Personnel Have a Better Idea

Forty-four assemblies of pencil tanks and processing columns ranging from 1.2 to 10.4 m (4 to 34 ft) long had been used during plutonium purification operations in the canyon portion of the PRF. The original, baseline plan was to move the pencil tank assemblies into the south canyon airlock for size reduction and disposition. This approach was changed to utilize the maintenance cell at the north end of the PRF canyon for the following reasons:

- The hazards analysis revealed many complications associated with performing this work in the south canyon airlock.
- Worker input during the planning phase showed a preference for performing this work in the maintenance cell. Analysis indicated that size reduction and removal would be equally efficient at this location.
- Workers pointed out that pencil tank size reduction and removal at the maintenance cell had been successfully performed in the past.
- Using the maintenance cell instead of the south canyon airlock allows introduction of equipment to clean the canyon floor through the south canyon airlock.

The current concept is to move pencil tank assemblies into the existing maintenance cell. Each assembly will undergo NDA. The pencil tanks and the top dunnage will be size-reduced and lowered to the bottom of the cell. There they will be bundled and moved to the canyon mezzanine where each bundle will be analyzed for contami-

The "lazy susan" allows the position of the waste package to be changed with minimal handling, thereby reducing dose to the fissile material handler.

nation and then sealed out through the existing 50.8-cm (20-in.) port into a waste container. Six of these containers can be loaded into a solid waste box and removed from PRF for disposition. The support dunnage will be returned to the canyon wall to be removed with the final canyon D&D.

Benefiting from D&D Lessons Learned

Part of the PFP Closure Project requires the demolition of 61 buildings. To expedite physical demolition of these facilities, PFP plant management brought in project management and D&D workers who had been involved with the recent open-air demolition of the 233-S Plutonium Extraction Facility on the Hanford Site. Their knowledge, experience, training, and numerous lessons learned are instrumental in the accelerated progress of this activity.

During PFP decommissioning planning in 2004, one of the issues identified was the increased work requiring supplied air during D&D. Many of the areas are difficult to access, and the number of air bottles required to be handled daily was going to be very difficult to manage without delaying work. During the investigation of alternatives to solve the bottle handling issue, Rocky Flats personnel recently transferred to PFP noted they had the same issue. They had resolved the issue of providing large volumes of breathing air by taking trailer-mounted compressors and distribution piping to needed locations. In addition, the compressors had enough volume to provide cooling air, using commercially available "vortex tubes," to individuals wearing several layers of protective clothing, solving another persistent issue of heat stress.

Heat stress while wearing protective clothing has been a significant issue at Hanford from both safety and productivity standpoints. Initial demonstrations at PFP have been very positive. PFP engineers adopted this demonstrated approach, and the system is now being installed in PFP to support the PFP decommissioning efforts. The DOE will benefit from using a system already proven effective at Rocky Flats (positive lessons learned) and will save money by reusing equipment already owned by the DOE to reduce heat stress on workers and improve productivity at Hanford.

Part of the PFP D&D Project includes the D&D of the highly contaminated 232-Z facility that was previously operated to recover plutonium scrap material. The 232-Z glovebox has been decontaminated as much as practicable and cocooned for shipment to T Plant, where it will be size-reduced for ultimate disposal at the WIPP facility in Carlsbad, N.M. The successful removal of the glovebox from the facility was the result of outstanding teamwork in the planning and execution of the work from nearly every craft on the Hanford Site beginning with glovebox cleanout to decontamination and subsequent shrink wrapping and removal from the facility. [Editor's note: For more information on the 232-Z demolition, see "Hanford Scores Another Successful Open-Air Demolition: 232-Z Plutonium Incinerator Facility Demolished in July," *Radwaste Solutions*, Jan./Feb. 2007, p. 31.]

The ALARA Center

The ALARA Center is a resource provided by the DOE's Richland Operations Office, through Fluor Hanford. It has been a valuable asset for the PFP workforce. The center sponsors vendor demonstrations on a frequent basis to bring potential buyers and sellers of safety technology together. The PFP has benefited from this service in purchasing HEPA-filtered vacuum cleaners, improving glovebox window visibility for D&D. Personnel have also used the ALARA Center gloveboxes for training prior to executing a work evolution in the field.

Workforce Ingenuity and Inventions

The management and workforce at PFP have gained efficiency and increased safety through the development of special tools and devices to assist in the D&D effort. During the course of the D&D of the PFP, workforce personnel have applied innovative work practices, invented new ways of performing work, created new work tools, and applied lessons learned from other D&D sites. These innovations were developed mutually by PFP management and workers and have resulted in productivity improvements, enhanced safety, and improved contamination control.

The decontamination of plutonium-contaminated gloveboxes, process equipment and product transfer piping, ventilation hoods and ductwork, and buildings can lead to risk of injury to workers and the environment. Workforce ingenuity combined with creative inventions and approaches to the D&D work not only made the work safer, but also made the work more efficient.

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Stacy Charboneau is director of Federal Projects with the DOE's Richland Operations Office. Andrea Hopkins is project manager; Bruce Klos is vice president, PFP Closure Project; Robert Heineman is director, Special Projects; and Brian Skeels is manager, Ancillary Facilities Decommissioning, all with Fluor Hanford Inc. The authors can be reached through Andrea_M_Hopkins@RL.gov.

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The decontamination of plutonium process equipment, product transfer piping, ventilation hoods, and ductwork led to a safer and more efficient demolition process.

A Report from the American Nuclear Society's Winter Meeting in Albuquerque, N.M.

Whatever Happened to TMI-2, and Other Nuclear Waste Issues

It's been nearly 28 years since the 1979 accident at the Three Mile Island-2 (TMI-2) plant in Pennsylvania. An update on the plant's current status was provided by Jim Byrne, recently retired from FirstEnergy and now an independent consultant, at the American Nuclear Society's (ANS's) Winter Meeting in Albuquerque, N.M., during a paper/panel session on Project Status of Decommissioning and Reutilization. The session was sponsored by the ANS Decommissioning, Decontamination and Reutilization (DD&R) Division.

Today, Byrne said, although the plant is officially in postdefueling monitored storage (PDMS) status, the TMI-2 control room is staffed from nine to five weekdays. There are still some sumps working, and ventilation is still flowing, he said. In addition, Operations, Rad Con, and Security departments maintain their daily rounds at the facility, and staff performs regular maintenance. Also, minor modifications have been made to the facility, including upgrading of circuit breakers, replacement of air compressors, and repair and/or replacement of emergency exit lights. This work is done in an effort to keep the unit similar to the operating TMI-1 unit, for maintenance purposes. A new roof is scheduled to be installed in 2007.

The plant will maintain PDMS status at least until 2014, Byrne reported. Between 2012 and 2014, the decommissioning of the plant will be planned. The timing of the actual de-

The Three Mile Island nuclear plant. Unit 2 is currently in postdefueling monitored storage status. Decommissioning of the damaged unit will take place concurrently with the decommissioning of Unit 1, sometime in the future.

Although the TMI-2 plant is officially in postdefueling monitored storage status, the control room is staffed from nine to five weekdays.

commissioning will depend on whether TMI-1 renews its operating license. Therefore, decommissioning will take place some time between 2014 and 2036, Byrne said, and both units will be decommissioned together.

There are many unique challenges that will have to be overcome in the TMI-2 decommissioning, Byrne pointed out:

- Alphas from damaged fuel throughout the plant.
- Many criticality issues.
- Some 1000 kilograms of fuel left in the plant, about 900 kg of that in the reactor vessel.
- High radiation contamination areas in the plant.
- High levels of strontium-90 contamination (which has high-energy betas).
- The dispersal of the former staff, resulting in a loss of the knowledge base from plant workers.

To help compensate for the loss of the knowledge base, plant personnel have already written the historical site assessment of the plant, converted VHS videos of all cubicles, taken during plant closeout, to DVD format, and developed an electronic records database. In addition, Byrne said, the Safety Analysis Report is more detailed than it needed to be.

GNEP

The Global Nuclear Energy Partnership (GNEP) was the subject of the ANS President's Special Session on Monday afternoon during the ANS Winter Meeting. ANS President Harold McFarlane, in his opening remarks, pointed out that GNEP is a program that will be realized in the second half of the 21st century—a program taking nuclear "from clean to green" by creating a truly sustainable energy source.

Dennis Spurgeon, introduced as "the first assistant secretary for nuclear energy at the U.S. Department of Energy in more than a decade," also serves as the program manager for GNEP. And GNEP, he noted, is not just a nuclear energy program. It reaches into many other sections of the DOE, so it is truly a department-wide program.

Because at meeting time there was no fiscal 2007 appropriations bill (nor one at the end of the year, most departments being funded by continuing resolutions, leaving the fiscal 2007 budget to the next Congress), Spurgeon said, the DOE has proposed where it wants to go in 2007 with GNEP, but others (meaning Congress) may decide what they can actually do.

Addressing the centerpiece of

GNEP, reprocessing of nuclear fuel, Spurgeon explained that there have been advances in reprocessing technology to reduce the proliferation risk, but he acknowledged that there is "no silver bullet" that can prevent misuse of an enrichment plant or a reprocessing facility. The virtue of GNEP, he said, is that the program will be able to supply fuel more cheaply and more reliably than a country could provide on its own, making participation attractive and lessening the attraction of a country's building its own enrichment or reprocessing facility.

But GNEP is more than just a reprocessing and fuel take-back program, Spurgeon continued. The DOE is also looking at partitioning objectives as well, for example, removing some fission products from the waste stream. It is "reasonable to believe" that we can develop minor actinide removal in the decade it will take to develop facilities, he said.

In addition, GNEP is more than just a research and development (R&D) program, Spurgeon said. Rather, GNEP must build facilities as well. Initially, three facilities are planned: a separations plant, an advanced burner reactor, and an advanced fuel cycle facility. The separations plant and the advanced burner reactor will be built through a government/private sector/national laboratory/university partnership, while the fuel cycle facility will be government funded and built on a government site.

In the future, Spurgeon said, GNEP will have an industry component as well, and industry must be engaged now, he said, as to potential participation. Several companies have expressed interest but have made no commitments, he said. Federal investment in R&D is needed, he acknowledged, but commercial-scale facilities funded by the private sector are needed as well.

The next steps to be taken, Spurgeon said in conclusion, include the following:

- Obtain input from U.S. and international industries on the best path forward—with commercial money and government guarantees.
- Develop a detailed road map.
- Pursue industry participation, with industry designs that show how they meet program goals.
- Prepare the programmatic GNEP Environmental Impact Statement.
- Prepare the decision package for the DOE secretary—by no later than June 2008.

Risk Issues

A session on risk issues in environmental cleanup, organized by S. Y. Chen from Argonne National Laboratory and sponsored by the ANS Environmental Sciences Division, looked at environmental cleanup from both federal and state viewpoints.

Stuart Walker, from the U.S. Environmental Protection Agency's (EPA's) Office of Superfund Remediation and Technology Innovation, noted that the Comprehensive Environmental Response, Compensation, and Liability Act (otherwise known as the Superfund Act) radiation risk assessments set cleanup levels based on cancer rates; as such, cleanup levels are not based on either U.S. Nuclear Regulatory Commission decommissioning requirements nor on guidance outside the risk range. Radiation cleanup levels thus are based on risk levels not on millirems. Furthermore, he stressed, cancer risks from radiation and from chemicals are *summed.*

Phil Egidi, from the Colorado Department of Health, pointed out that states and licensees often have limited resources. Thus, he said, "ALARA [as-low-as-reasonably-achievable] levels depend on the depth of the pocket you are picking." In the wake of facts such as this, decisions tend to be "pragmatic," he said.

From a state point of view, Egidi continued, states are the ones that really handle the bulk of the cleanups; therefore, he said, it would have been nice had the EPA and the NRC included the states more in their discussions and negotiations and cleanup criteria. In addition, he noted, it's not unusual for a licensee to have multiple regulations to meet, especially if you are talking about groundwater.

Describing his personal opinions on the issue, Egidi listed the following:

- Uncertainties limit the value of a risk-based approach over long time frames, so reasonable and prudent *precautions* should be considered when uncertainties render risk data meaningless. This opinion, he continued, can generally be considered as the European approach to cleanup, but it makes businesses in the United States "bristle."
- Reliance on institutional controls remains problematic.
- The lack of consideration of end points other than cancer remains a problem. For example, he said, radon might be considered a cofounder for cardiovascular disease (although Daniel Strom, a later speaker, noted that many people don't find that credible).

In conclusion, Egidi suggested using a "pragmatic approach" to cleanup, pointing out that we cannot predict land use many years out: Old ghost towns become resorts, old uranium mining roads become mountain bike trails, old blighted areas become gentrified. Egidi also noted that after the terrorist attacks of 9/11, "you can't buy surety." You used to be able to get it for 5 or 10 cents on the dollar, but now it's a dollar on the dollar, he explained.

Daniel Strom, from the Pacific Northwest National Laboratory, explained the EPA's lifetime cancer risk approach to cleanup, noting that the agency *must* use this approach because lead, arsenic, and chemicals "don't *have* millirems." Therefore, you have to use a risk-based approach, he said. He added that both the EPA and the NRC in their risk assessments assume *no* medical improvements in the next 1000 years, and no climate change.

In discussing the National Council on Radiation Protection and Measurements' (NCRP's) recent NCRP Report 146, Strom said that the report concluded that in the end, either the NRC dose-based approach or the EPA's risk-based approach can protect public health. In addition, the report expresses the opinion that EPA involvement should not impede NRC license terminations. (The EPA and the NRC "have turned down the volume" on their exchanges in recent years, Strom noted in an aside.) A lot of people have looked at 25 mrem (the NRC decommissioning cleanup level) and 15 mrem (essentially, the EPA's cleanup level) and have concluded that they are the same thing, Strom said.

New Technologies

Concrete is the number one building material we deal with in decommissioning, according to Kevin Taylor, from EnergySolutions, during a session on updates on new technologies (sponsored by the DD&R Division). All concrete is different, so activation of various concretes will be different as well. Two methods of dealing with concrete that Taylor discussed were diamond wire cutting (which brings the advantages of less vibration and less dust) and controlled explosives.

Diamond wire cutting, while expensive, allows a job to be completed in less time and with less manpower. The DOE considered it an "emerging technology" as recently as the year 2000, Taylor said. It has been used successfully at Trojan, at the Tokamak Fusion Test Facility, at West Valley, at Quehanna, and at the Cornell TRIGA reactor, among others.

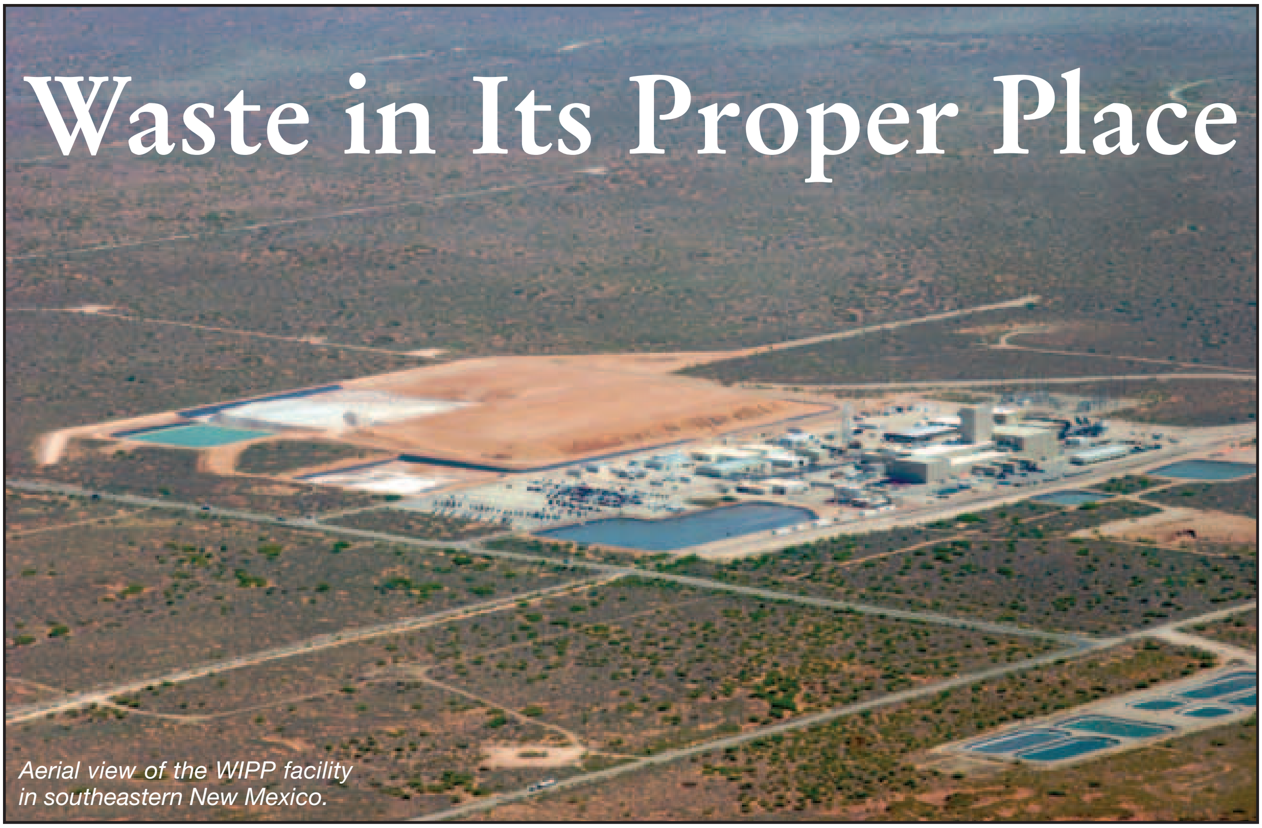
Controlled explosives are useful for smaller jobs, particularly in tight spaces where you can't go in with large equipment.

Controlled explosives are not necessarily a new technique, Taylor admitted. Recently, Maine Yankee (containment building demolition), Big Rock Point (containment demolition), and Trojan (cooling tower) used controlled explosives for building demolition. But controlled explosives are also useful for smaller jobs, particularly in tight spaces where you can't go in with large equipment, he said.

Joe Shonka, from Shonka Research Associates Inc., commented on a segmented gate system sorter, which was used to sort plutonium particles from sand at Johnston Atoll in the South Pacific. The technology was brought to the mainland for DOE work and tested at seven sites, but it turned out not to work as well on the clay soils at the DOE sites. About all that was achieved was mixing the contaminants into the soil so thoroughly that they could not be sorted out. Because of equipment costs, schedules, etc., any sorting solution has to move between 200 and 400 tons per hour, and one must virtually "move a whole laboratory onto the yellow iron," Shonka said.

Still, Shonka concluded, sometimes sorting is more cost-effective than characterizing, treating, and final survey. So it's up to the customer to decide if the technology is worth using.—*Nancy J. Zacha, Editor*

Waste in Its Proper Place



Aerial view of the WIPP facility in southeastern New Mexico.

A Report from the American Nuclear Society's Winter Meeting in Albuquerque, N.M.

A Tuesday afternoon session at the American Nuclear Society's Winter Meeting in Albuquerque focused solely on the Waste Isolation Pilot Plant (WIPP) in New Mexico, the world's only operating engineered deep geologic waste repository, located in a 250-million-year-old salt bed. The WIPP session was organized by Thomas Hirons, from Los Alamos National Laboratory, and Ruth Weiner, from Sandia National Laboratories, and chaired by Hirons.

The WIPP received a permit to dispose of remote-handled (RH) transuranic (TRU) waste in October. The permit went into effect in mid-November, and the facility expected to begin receiving RH waste in early 2007. Dave Raaz, from Washington TRU Solutions, the contractor operating the facility for the U.S. Department of Energy, noted that the eight years of operations since WIPP opened in March 1999 have seen a record of safety that should be the envy of nuclear and industrial facilities around the world. For example, he said, WIPP has never had a release to the environment during transportation or disposal operations and has never had a transportation accident in which a driver or a member of the public was seriously injured. The industrial safety record is outstanding as well, Raaz said; for example, more than 50 percent of recordable events are merely flying insect bites.

In addition to allowing the disposal of RH waste, Raaz continued, the new permit from the New Mexico Environment Department does the following:

- Reduces the amount of sampling that shipping sites must do before waste can be shipped to WIPP.
- Eliminates redundant data reviews.
- Allows "acceptable knowledge" as a sole characterizing method in some cases.
- Increases the disposal capacity in each panel and, therefore, total site capacity.
- Mandates more public notification of WIPP activities. As far as this last point goes, Raaz said they are "willing to notify anyone who is interested" of site activities.

Raaz also presented some WIPP data as of meeting time in mid-November:

- 198 shipments received.
- 5.8 million loaded miles traveled.

What's in a Name?

"WIPP" is an ideal acronym, Dave Raaz, from Washington TRU Solutions, noted during his presentation at the ANS Winter Meeting in Albuquerque. It has a vowel, which makes it pronounceable, and it has not changed since it was first created in the early 1970s. In fact, he said, the WIPP acronym is older than the DOE abbreviation by a few years.

But Roger Nelson, from the Carlsbad Field Office, stated later in the session that, indeed, perhaps the WIPP acronym has changed. It no longer just stands for "Waste Isolation Pilot Plant," he said, but could also be an acronym for "Waste in Its Proper Place," or "Waste Interred Permanently, in Perpetuity."

In a simulation exercise, workers at the control panel watch an RH waste cask being loaded into the facility cask, which will then be emplaced into a horizontal borehole in the underground WIPP burial facility.

- 13 810 TRUPACTS and half-PACTS disposed of.
- 43 305 cubic meters disposed of.
- 84 179 waste containers disposed of.
- 31 862 drums certified.
- 13 sites where all legacy TRU has been removed.

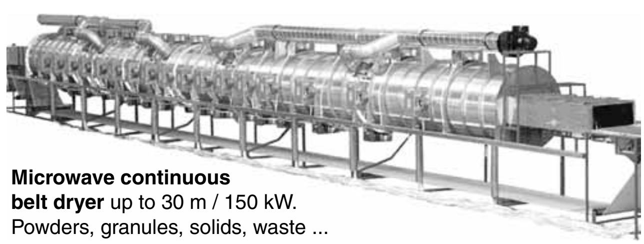
Panels 1 and 2 at the facility have been filled and closed; waste emplacement is ongoing in Panel 3, Panel 4 is mined and ready to begin emplacements, and Panel 5 is under construction. (Each panel holds around 18 000 m^3 of waste, or around 86 500 drum equivalents.) The facility will have a total of eight panels. Because RH waste is emplaced in the walls of the panels, it must be disposed of before regular waste can be stacked in the centers of the panel rooms. That is why facility operators are eager to begin RH waste operations.

In the future, Raaz concluded, the facility wants to expand the work scope to include the following:

- Small *and* large TRU waste containers.
- Legacy *and* newly generated TRU waste.
- Contact-handled and RH waste disposed of simultaneously.

During the subsequent question-and-answer period, Raaz was asked if WIPP will be able to hold the entire TRU inventory in the United States. Yes, he answered. The total capacity of WIPP is around 175 000 m^3, while the U.S. inventory is around 150 000 m^3.

Phil Gregory, packaging manager at Washington TRU Solutions, described the new TRUPACT-III container, which is designed to ship large waste boxes. Testing of the container was completed in early November, he said, and he expected to be able to submit the license applications for the container to the U.S. Nuclear Regulatory Commission in early 2007. With luck, he concluded, NRC approval could be granted by fall 2007.



The WIPP is regulated by the U.S. Environmental Protection Agency (EPA), and every five years the facility must submit an application for recertification. The first compliance recertification application was submitted in 2004 (five years after the 1999 start of operations), and the next is due in March 2009. Russ Patterson, compliance certification manager for the DOE's Carlsbad Field Office, stated that there will be a change in the recertification process for 2009.

Patterson noted that the previous recertification application contained more than 8000 pages, and with the next recertification application, he is hoping to streamline the document and submit it directly in EPA format, instead of in its old chapter format. The document will be submitted electronically (although the electronic format has not been identified—the field office is waiting until the last minute so the most advanced format can be used).

It is hoped that this change will decrease the effort level for the applicant, the EPA, and stakeholders and speed the recertification decision (the most recent recertification process took two years, Patterson said).

The field office has already had one teleconference with stakeholders and was planning to meet with the EPA in December, Patterson said in conclusion.

Because RH waste is emplaced in the walls of the panels, it must be disposed of before regular waste can be stacked in the centers of the panel rooms. That is why facility operators are eager to begin RH waste operations.

Roger Nelson, chief scientist with the Carlsbad Field Office, pointed out that plutonium-239 dominates the emplaced mass and TRU radioactivity inventory at WIPP. Most of the uranium present in the inventory is depleted uranium, and there are very few fission products. The bulk of the Pu-239 content came from the Rocky Flats site, he said.

Prior to shipment to WIPP, waste containers are examined by nondestructive assay, nondestructive examination, and headspace gas sampling and analysis, Nelson said. He pointed out that waste characterization costs to date have just about equaled the costs for transportation and disposal: At an average of $3900 per drum for characterization, some $200 million was spent in fiscal 2006 for characterization work, while another $200 million was spent for WIPP transportation and disposal.—*Nancy J. Zacha, Editor* ■

People in the news

The Electric Power Research Institute appointed **Bryan Hannegan** as vice president for Environmental Research and Development, effective January 1. Hannegan joined EPRI in September 2006, serving as managing director for Environmental R&D. Prior to joining EPRI, Hannegan served in the dual capacity of chief of staff at the White House Council on Environmental Quality and as an acting special assistant to the President for Economic Policy. He also served for a time as staff scientist to the U.S. Senate Committee on Energy and Natural Resources, where he handled energy efficiency, renewable energy, alternative fuels, and environmental aspects of energy production and use.

CH2M Hill has rehired **Mark Fallon** as senior vice president of Client Development and Marketing for the Federal Client Group. In this new role, Fallon will be responsible for leading the business development and marketing teams of the Federal Client Group to help the group achieve its strategic goals. Prior to rejoining CH2M Hill, Fallon was president of Bartlett Services Inc., a nuclear services company, where he was responsible for all aspects of safety, operations, human capital, and financial performance. Previously at CH2M Hill, Fallon served as a vice president within the Nuclear Business Group, focusing on business development and operations of international and commercial decommissioning markets.

Alan Parker has joined EnergySolutions as executive vice president and chief operating officer, with responsibility for all commercial and federal contracting operations in North America. Parker most recently served as president of CH2M Hill's Federal Group. Prior to that, he had served as CEO of Kaiser Hill LLC, leading the recently concluded cleanup effort at the U.S. Department of Energy's Rocky Flats Environmental Technology Project. Kaiser Hill, half-owned by CH2M Hill, pioneered several innovative cleanup techniques for the plutonium-contaminated buildings at Rocky Flats, significantly reducing the remediation time at the Colorado facility.

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Mark Walker
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Andy Smith
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Kevin Tuite
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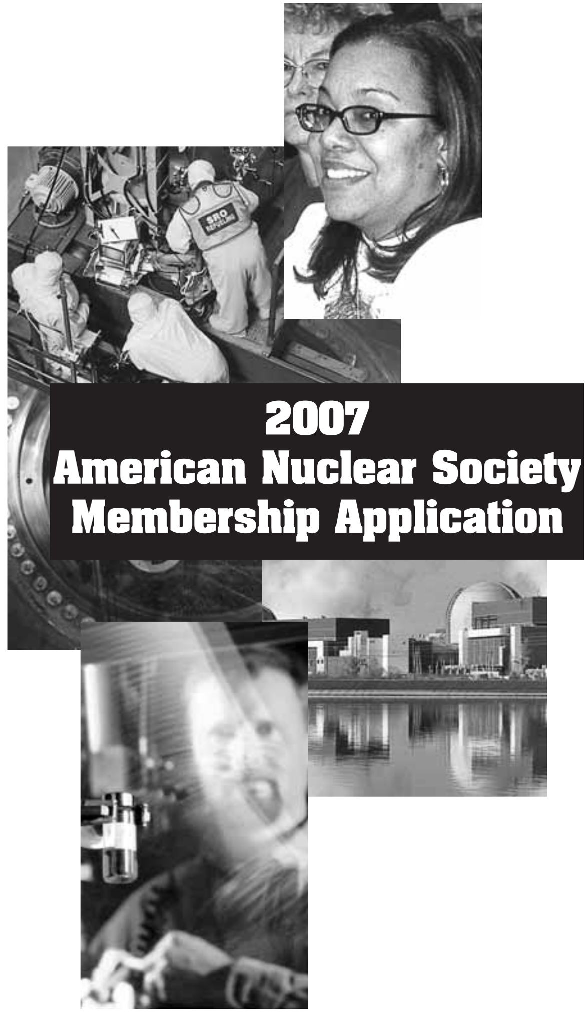

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City ____________ State/Province ____________

Zip/Postal Code ____________ Country ____________

Phone ____________ Fax ____________

Cell Phone ____________

E-Mail ____________

Company/Organization ____________

Nature of Business ____________

Address ____________

City ____________ State/Province ____________

Zip/Postal Code ____________ Country ____________

Phone ____________ Fax ____________

E-Mail ____________

Dates from/to ____________ Title ____________

Indicate any member grade previously held in ANS:
☐ Student Member ☐ Member
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☐ DO NOT include my name in the Membership Directory
☐ I pay ☐ My company pays/reimburses me for membership dues
☐ I am a licensed Professional Engineer (P.E.) ☐ Local Section Member

I wish to receive *ANS News*: ☐ By mail only
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LaGrange Park, IL 60526
Phone 800-323-3044 or 708-352-6611
Fax 708-579-8295
E-Mail: members@ans.org

20NN

Education

Year formal education completed ____________

Please list post-secondary education beginning with most recent.

College/University ____________

Major ____________ Degree Received ____________

College/University ____________

Major ____________ Degree Received ____________

Professional Background

Previous Employer ____________

Address ____________

City/State/Zip ____________

Dates from/to ____________ Title ____________

Professional Divisions

Dues cover membership in TWO technical divisions – please indicate your selections as primary, secondary, etc. (Ex. 1 – Human Factors, 2 – Reactor Physics, etc.); additional divisions are $8.50 each.
Note - The Young Members Group (YMG) works to meet the needs of young professionals. If you're under age 36, you're automatically a member of the YMG in addition to two divisions. Others may join YMG for $8.50. YMG may not be substituted for the two divisions included with membership.

__ Accelerator Applications
__ Biology & Medicine [2]
__ Decommissioning, Decontamination & Reutilization
__ Education & Training
__ Environmental Sciences[1]
__ Fuel Cycle & Waste Management
__ Fusion Energy
__ Human Factors
__ Isotopes & Radiation
__ Materials Science & Technology
__ Mathematics & Computation [1]
__ Nuclear Criticality Safety
__ Nuclear Installations Safety
__ Operations and Power
__ Radiation Protection & Shielding
__ Reactor Physics
__ Robotics and Remote Systems
__ Thermal Hydraulics
__ Aerospace Nuclear Science & Technology Technical Group
__ Young Members Group

[1] Includes Nuclear Production of Hydrogen working group
[2] Includes Computational Medical Physics working group

To the Board of Directors

I hereby apply for admission to the American Nuclear Society. I certify that the record of my training and professional experience is correct, and agree that if accepted, I will be governed by the Society's Code of Ethics (www.ans.org/about/coe) and Bylaws and Rules (www.ans.org/about/br) as long as I remain a member.

Signature ____________ Date ____________

Position

Please indicate the position which most nearly matches your own *(check one only)*.

☐ President (11)
☐ Vice President (12)
☐ Director (13)
☐ Owner (14)
☐ other official (19)
☐ Superintendent (21)
☐ Supervisor (22)
☐ Manager (23)
☐ Chief Engineer (24)
☐ Department Head (25)
☐ other managerial title (29)
☐ Nuclear Engineer (31)
☐ Electrical Engineer (32)
☐ Mechanical Engineer (33)
☐ Chemical Engineer (34)
☐ other engineering title (39)
☐ Health Physicist (41)
☐ Chemist (42)
☐ Technician (43)
☐ Analyst (44)
☐ Consultant (45)
☐ Scientist (46)
☐ other specialist (49)
☐ Professor (51)
☐ Instructor (52)
☐ Trainer (53)
☐ other educational title (59)
☐ Reactor Operator or Senior Reactor Operator (71)
☐ Reactor Operations Supervisor (72)
☐ other (69) ____________

Industry

Please indicate the industry which most nearly matches your own *(check one only)*.

☐ Manufacturer (11)
☐ Supplier (12)
☐ Private Research Lab (21)
☐ Test Lab (22)
☐ National Lab (31)
☐ Government Agency (32)
☐ Architect/Engineer Company (41)
☐ Construction Company (42)
☐ Educational Institution (51)
☐ Medical Institution (61)
☐ Consulting Company (71)
☐ Service Company (72)
☐ Utility (81)
☐ other (69)

For Office Use Only

Date Received ____________ ID# ____________
Amount Received ____________
Dues ____________ NN ____________
Entrance Fee ____________ Extra Divisions ____________
NT ____________ NS&E ____________
TRANS. ____________ PROC. ____________
FS&T ____________ RWS ____________
PI ____________ NEED ____________
Schol ____________
Sub Total ____________ Balance ____________

Hanford

In late November 2006, the U.S. Department of Energy issued three draft contract proposals for the Hanford site, including one plan for selecting a new contractor to conduct the decontamination and decommissioning of the site's old nuclear processing facilities and burial grounds, and another to remove the millions of gallons of highly radioactive waste from underground storage tanks. The three new contracts would replace the two contracts currently existing, under which **Fluor Hanford Inc.** is responsible for the D&D work and site support operations and **CH2M Hill Hanford Group** manages the underground storage tanks. The contracts, expected to be awarded in 2008, include:

- The Plateau Remediation Contract, to be managed by the DOE's Richland Operations Office (ROO), to complete the cleanup of the Plutonium Finishing Plant, excavate and dispose of buried waste, transfer cesium and strontium capsules from wet to dry storage, remove and dispose of sodium waste materials from the Fast Flux Test Facility, monitor groundwater and operate pump-and-treat facilities, and maintain and/or remediate dozens of facilities and waste sites.
- The Tank Operations Contract, to be managed by the DOE's Office of River Protection, to manage the site's 177 underground storage tanks and transfer waste from the older, leaking single-shell tanks to the double-shell tanks. The contract also covers closure of the single-shell tanks and preparation of tank waste for the vitrification plant being built at the site.
- The Mission Support Contract, to be managed by the ROO, to cover cross-cutting services for the Hanford site, such as safety and security, infrastructure, information technology, and integrated life-cycle planning.

The new contracts would not affect the contract held by **Bechtel National Inc.** to construct the vitrification facilities, nor the river corridor contract, held by a consortium led by **Washington Group International Inc.** and CH2M Hill to clean up soil and groundwater contamination and to "cocoon" the obsolete reactors and clean up other facilities along the Columbia River.

Under conflict-of-interest clauses in the contracts, companies bidding for the tank farm contract cannot be involved in the vitrification plant project, and companies bidding for the mission support contract cannot participate in any of the four other major contracts at the site because of interactions with other contractors and assessments that the mission contractor will be required to perform for the DOE on life-cycle planning for site operations, among other issues.

The DOE did not provide cost estimates for any of the three draft contracts. All three will have an initial five-year term, with the option for a five-year extension. The DOE plans to have the new contractors start at the beginning of fiscal year 2009 (October 1, 2008).

Contracts, business news, etc. ▼

Mergers and Acquisitions

EnergySolutions LLC has acquired **Safeguard International Solutions Ltd.,** a United Kingdom–based company that provides turnkey services for the disposition of radioactive materials, including waste, from non-nuclear power generating facilities such as hospital, universities, industry, and government. The acquisition is considered a demonstration of EnergySolutions's commitment to work in the United Kingdom and to grow its business there. The company has already assembled a team to bid for the U.K. Nuclear Decommissioning Authority's contract to manage the country's low-level nuclear waste facility at Drigg.

In early December, **Studsvik** announced that it was selling its **Stensand** subsidiary, which provides radiation protection services to the nuclear industry, to Sweden-based company **Coor Service Management.** Studsvike said it was selling the subsidiary because it wants to concentrate on nuclear waste management and decommissioning services. The sale price was undisclosed.

British Nuclear Fuels plc announced in December that it has put its United Kingdom reactor sites management business up for sale. The business includes operation of two Magnox reactors, which are scheduled to cease generation in the next few years, and the decommissioning of eight plants that closed at the end of 2006. The purchaser will manage the sites on behalf of the U.K. Nuclear Decommissioning Authority, the government agency that oversees cleanup of U.K. nuclear sites.

New Facilities

Flowserve Corp. has opened new administration headquarters for its Flow Solutions Europe, Middle East, and Africa operations. The new facility, located in Essen, Germany, houses a quick response center to provide product support and a learning resource center that offers best-practices maintenance training programs for pumps and seals for employees and customers.

Reorganizations

The **Nukem Group** has been restructured. **Nukem GmbH,** based in Alzenau, Germany, will continue to offer products and services in the nuclear fuel cycle, including fuel trading for power and research reactors, as well as the isotope business. **Nukem Technologies GmbH,** a 100 percent subsidiary of Nukem GmbH, will handle all business activities in the areas of decommissioning, management of radioactive waste, and consulting. The holding company of the Nukem Group will be **Nukem International GmbH,** founded on September 1, 2006. ■

February

Feb. 25–Mar. 1 **Waste Management 2007 (WM2007),** Tucson Convention Center, Tucson, Ariz. Sponsored by WM Symposia Inc. Contact: James Voss, general chair, WM Symposia Inc., P.O. Box 35340, Tucson, AZ 85740; phone 520/292-5652; e-mail jamesvoss@1tvg.com.

March

Mar. 26–29 **Training Course on Facility Decommissioning,** Las Vegas, Nev. Sponsored by Argonne National Laboratory. Contact: Course Director Lawrence E. Boing, Argonne National Laboratory, phone 630/252-6729; fax 630/252-7577; e-mail lboing@anl.gov; Internet www.dd.anl.gov/ddtraining/index.html.

April

Apr. 9–12 **40th JAIF Annual Conference,** Hotel Aomori, Aomori, Japan. Sponsored by the Japan Atomic Industrial Forum. Contact: Department of Policy Making and Promotion, Japan Atomic Industrial Forum Inc., 2-1-3, Shimbashi, Minato-ku, Tokyo 105-8605, Japan; phone +81 3 6812 7101; fax +81 3 9812 7110; e-mail 40th-annual@jaif.or.jp.

April 30–May 3 **43rd Semiannual Nuclear Fuel Management Seminar,** DoubleTree Hotel, Atlanta, Ga. Sponsored by NAC International. Contact: Chris DeLance, phone 678/328-1281; fax 678/328-1481; e-mail cdelance@nacintl.com.

May

May 2–5 **Prevention, Detection, and Response to Nuclear and Radiological Threat,** Yerevan, Armenia. Organized by the North Atlantic Treaty Organization. Contact: The Advanced Science and Technology Center of Armenia, Internet www.astec.am.

May 21–22 **Decommissioning and Waste Cooperation in Nuclear—A Joint Conference on Strategic, Technical and Social Experiences and Solutions,** Vilnius, Lithuania. Sponsored by IBC Global International. Contact: Dan Claassen, IBC Global Conferences, e-mail daniel.claassen@informa.com.

May 22–24 **Annual Meeting on Nuclear Technology 2007,** Karlsruhe, Germany. Organized by the Ger-

Meetings of interest

man Atomic Forum and the German Nuclear Society. Contact: Congress Office, dbcm GmbH, Kamillenweg 16-18, 53757 Sankt Augustin, Germany; phone +49 0 2241 93897-23; fax +49 0 2241 93897-12; e-mail jk@dbcm.de.

June

June 24–28 **ANS Annual Meeting,** Boston Marriott Copley, Boston, Mass. Sponsored by the American Nuclear Society. Contact: J. Art Stall, general chair, Florida Power & Light Co., 700 Universe Blvd., P.O. Box 14000, Juno Beach, Fla. 33408-0420; phone 516/694-4220; fax 561/694-3237; e-mail stall@fpl.com; or Richard F. Gil, Shaw Stone & Webster Nuclear, 4171 Essen Lane, Baton Rouge, La. 70809; Internet www.ans.org/meetings.

August

Aug. 5–8 **Utility Working Conference and Vendor Expo,** Amelia Island Plantation, Amelia Island, Fla. Sponsored by the ANS Operations and Power Division. Contact: Jeffrey T. Gasser, Southern Nuclear Operating Company, 40 Inverness Center Parkway, Birmingham, AL 35242; phone 205/992-7721; fax 205/992-6165; e-mail jtgasser@southernco.com.

And coming up . . .

Global '07, Sept. 9–12, 2007, Boise Convention Center, Boise, Idaho.

Decommissioning, Decontamination and Reutilization (DD&R) Topical Meeting, Sept. 16–19, 2007, The Chattanoogan Hotel, Chattanooga, Tenn.

2007 ANS/ENS International Meeting, November 11–15, 2007, Omni Shoreham Hotel, Washington, D.C.

2nd Joint Emergency Preparedness and Response and Robotics and Remote Systems Topical Meeting, March 9–12, 2008, Hotel Albuquerque at Old Town, Albuquerque, N.M.

2008 ANS Annual Meeting, June 8–12, 2008, Disneyland Resort, Anaheim, Calif.

2008 Winter Meeting, Nov. 9–13, 2008, Reno Hilton Hotel, Reno, Nev.


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