Spring 2016

Radwaste SOLUTIONS

HLW/LLW Management
Environmental Remediation

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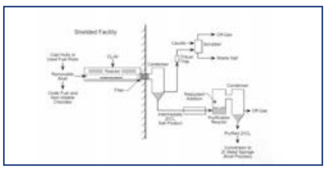
Volume 23, Number 1

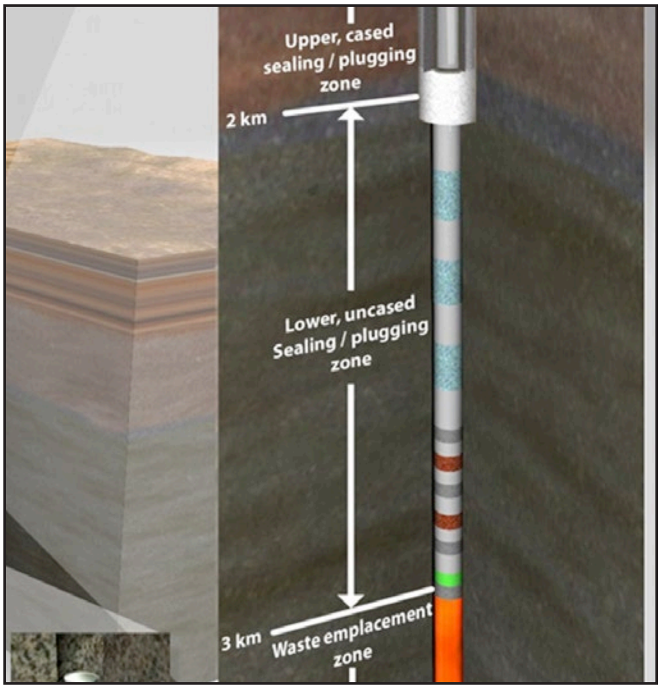
Spring 2016

High-Level Waste Management



Low-Level Waste Management

Environmental Remediation



Research into the disposal of nuclear waste in deep boreholes is being conducted by Sandia National Laboratories. For more, turn to page 30.

Meeting Reports

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On the Cover:

The National Nuclear Laboratory in the U.K. is conducting research on plutonium and actinides as the country deliberates moving from a closed to an open fuel cycle. For more, turn to page 48.

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- *Decontamination and Decommissioning*
- *2016 Buyers Guide*

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Editor's Note

Comments on this issue

Depth of experience

Welcome to the new *Radwaste Solutions*. Well, the new *look* of *Radwaste Solutions*. The magazine is still dedicated to the current, in-depth, and insightful coverage of all things waste management. We just updated our look in an effort to improve readability and make the magazine more contemporary and attractive. Everyone needs to update his or her wardrobe once in a while. And yes, I will admit, it is a bit about "branding," to use an overworked buzzword.

A book should not be judged by its cover, but being stylish does not exclude being substantive.

Outside of marketing circles, the idea of branding is often seen as somewhat suspect. I would hazard to guess that for many people it connotes the idea of image over substance, a ploy of the shameless shill. Yet the importance of image should not be overlooked, particularly when a strong, quality product (such as the magazine you are holding) backs up that image. We do not have to look far to see how nuclear energy, which contributes so much to our well-being, struggles with an image problem. Struggles unfairly, I should add.

This has real consequences for our ability to safely and securely manage our radioactive wastes, in ways that sometimes defy logic. I'm thinking now about North Dakota, where the Department of Energy is planning to conduct tests related to the disposal of radioactive waste in deep boreholes. (You will find extensive coverage of the DOE's investigation into deep boreholes in the feature article, "Field Test to Evaluate Deep Borehole Disposal," beginning on page 30.) Even as planning begins on this project, a petition in opposition is circling among local residents and state officials are putting up red flags. Never mind that no radioactive material will be used during the tests and the holes will never be used to dispose of waste; simply the specter of radioactive waste is enough to curtail progress. It is somewhat ironic that this is the same state that just last year approved legislation to raise by 10 times the allowable concentrations of naturally occurring radioactive material, a by-product of oil and gas drilling, to be disposed of in its landfills. For what it is worth, however, North Dakota is, of course, a big oil-producing state.

The idea of deep borehole disposal is nothing new. The concept was considered as early as the 1950s and studied in the United States during the 1980s. The DOE's latest investigations into borehole disposal, however, are encouraging and may pave the way for the disposition of some smaller-sized defense-related waste, such as Hanford's cesium/strontium capsules. Coincidentally, this issue of the magazine also contains a brief article on progress the International Atomic Energy Agency is making on methods for disposing of sealed-source low-level radioactive waste in boreholes (page 56). Following the idea that success builds upon itself, the ability to safely dispose of even a small amount of defense-related waste and sealed-source packages just may clear a path to the disposition of greater quantities of waste, including commercial spent nuclear fuel.

Deep borehole disposal, however, is just one option being explored for managing our most problematic waste. In the absence of a permanent repository program in the United States practical steps are being taken to ensure that spent fuel and HLW are managed in such a way as to protect the public and the environment. This includes the safe storage of HLW awaiting a path to disposal. Starting on page 41, researchers from the University of Utah and the University of Nevada describe tests done on anchors designed to limit damage to spent fuel casks and their contents during earthquakes, a real concern as more spent fuel is moved to storage pads for extended periods of time. It also means looking at ways to reduce the volume of HLW that must be shipped to a deep geologic repository. At Oak Ridge, research is being done on the recovery and possible recycling of zirconium from spent fuel cladding (page 52), which could reduce the amount of material needing to be disposed of as HLW by as much as 25 percent.

In addition to the articles on HLW and LLW management, you will find in this issue two informative pieces on environmental remediation efforts at DOE sites and a report from the 2015 RadWaste Summit in Las Vegas, along with the usual news items and other pertinent information. As you can see, *Radwaste Solutions* still provides coverage of the important, complex, and interesting work being done in waste management, environmental management, decontamination and decommissioning, and other areas. Only now we have the updated looks to match our worthwhile content. —*Tim Gregoire, Editor*

Consent-based siting

As part of its strategy for the long-term storage and disposal of spent nuclear fuel and high-level radioactive waste, the Department of Energy has launched a consent-based siting initiative for future nuclear waste management facilities. The DOE also stated that it intends to move forward with the development of a separate repository for defense-related nuclear waste, as announced by Energy Secretary Ernest Moniz in March 2015.

The DOE's consent-based siting initiative was announced in a December 21 blog post on the DOE's website, at www.energy.gov, by Franklin "Lynn" Orr, undersecretary for science and energy. According to Orr, the initiative "represents an important step toward addressing this nuclear waste management challenge, so that we can continue to benefit from nuclear technologies."

Aided by public input, the DOE intends to develop a detailed plan by the end of the year for a process that will ensure that communities, tribes, and states "are comfortable with the location of future storage and disposal facilities before they are constructed," Orr said. In developing its plan, the DOE will draw on extensive experience in storage, transportation, siting, policy, legislative, and regulatory issues both in the United States and elsewhere.

The DOE's goals for the management of both commercial and defense-related spent nuclear fuel and HLW was outlined in a January 2013 strategy document that called for a pilot interim storage facility, a larger interim storage facility, and long-term geologic repositories. The DOE strategy is based on the recommendations of President Obama's Blue Ribbon Commission on America's Nuclear Future, which was formed following the administration's 2010 abandonment of the HLW repository project at Yucca Mountain, in Nevada.

The DOE has requested public input regarding the development of its consent-based siting plan, publishing a notice of invitation for public comment (IPC) in the December 23 *Federal Register*. Concurring with the Blue Ribbon Commission's recommendation for a phased, adaptive, consent-based approach to siting nuclear waste facilities, the DOE said that it is requesting input about what considerations are important when designing a fair and effective process for consent-based siting. According to the DOE, a top priority is to build on and improve existing relationships with states, tribes, communities, and stakeholders to help identify important considerations, challenges, and opportunities for discussion.

Comments are being accepted through June 15 and can be submitted by e-mail to consentbasedsiting@hq.doe.gov, with the inclusion of "Response to IPC" in the subject line; by mail to U.S. Department of Energy, Office of Nuclear Energy, Response to IPC, 1000 Independence Ave. SW, Washington, DC 20585; by fax to 202/586–0544, with "Response to IPC" on the fax cover page; or online at www.regulations.gov.

In addition, the DOE is hosting a series of public meetings to engage communities and discuss the development of a consent-based approach to managing the nation's nuclear waste.

EnergySolutions to buy WCS

EnergySolutions announced in November that it will acquire Waste Control Specialists (WCS) of Texas for $367 million. The Utah-based company said it signed a definitive agreement in which it will pay $270 million in cash and $20 million face amount in Series A preferred stock and assume approximately $77 million of debt of WCS, a subsidiary of Valhi. EnergySolutions said that it will also assume all financial assurance obligations related to the WCS business. WCS, which operates a low-level radioactive waste disposal facility in Andrews County, Texas, announced in February 2015 that it intends to apply with the Nuclear Regulatory Commission for a license for an interim spent nuclear fuel storage facility at the site. David Lockwood, president and chief executive officer of EnergySolutions, said that the acquisition will improve the company's operational efficiencies and provide a seamless supply chain.

On November 17, two days before announcing its acquisition of WCS, EnergySolutions announced that it has agreed to sell its projects, products, and technology business—which comprises the company's North American government, Europe, and Asia

Valhi agreed in November to sell its Waste Control Specialists subsidiary to the parent company of EnergySolutions. Photo: WCS

businesses—to WS Atkins, a global design, engineering, and project management consultancy firm based in the United Kingdom, for $318 million. Pursuant to the agreement, Atkins will hire approximately 650 EnergySolutions employees. EnergySolutions will retain its logistics, processing, and disposal business; its reactor decommissioning business, including the current projects at Zion, Ill., and LaCrosse, Wis.; and its North American utility services, including liquid waste processing, fuel pool services, and other projects. The sale is expected to close in the first quarter of 2016.

WIPP Updates

Settlement agreements related to the February 2014 incidents at the Waste Isolation Pilot Plant near Carlsbad, N.M., have been signed by the New Mexico Environment Department (NMED) and the Department of Energy and its contractors, the DOE announced on January 22. The settlement agreements resolve NMED's claims against the DOE and its contractors related to incidents at WIPP and the associated waste packaging issues at Los Alamos National Laboratory. The agreements provide funding and scheduling parameters for environmental projects and infrastructure improvements in the Carlsbad and Los Alamos communities. Included in the $74-million settlement is $34 million to help the N.M. Department of Transportation make repairs to state roads used for the transportation of transuranic waste to WIPP. Improvements to WIPP's emergency response capabilities will also be made. The finalized settlement agreements are based on the general principles of agreement signed by the state of New Mexico and the DOE in April 2015.

● The Department of Energy announced on January 21 that its Carlsbad Field Office has approved a new integrated performance measurement baseline for WIPP that puts the initial resumption of waste emplacement operations in December 2016. According to the DOE, the new performance measurement baseline considers potential risks that could have an impact on the project and adds appropriate contingency to the schedule to help ensure that activities can be conducted safely.

● Respiratory protection requirements were lifted for a significant portion of the WIPP underground as a result of radiological risk mitigation efforts by WIPP radiological control teams, it was announced on January 29. The change in respiratory protection requirements applies to all areas south of S-2520 and represents a milestone in the contamination mitigation efforts, according to the DOE. While the use of protective clothing, booties, and gloves will still be required in the decontaminated areas, eliminating the need for powered air-purifying respirators is expected to reduce physical stress on employees working there and will make performance of work activities easier and safer.

Airborne radioactivity levels in the south end of the

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underground were mitigated through the use of a fresh-water spray applied to the walls and floors of the common access drifts. Panel 7, its associated exhaust drift, and the exhaust shaft currently are the only areas of the underground where respiratory protection is required to be used.

Utilities

The Nuclear Regulatory Commission has granted Entergy Nuclear Operations' request for exemptions from certain emergency planning (EP) requirements under 10 CFR Part 50, allowing the company to alter the emergency preparedness plan for the closed Vermont Yankee nuclear power plant in Vernon, Vt. The exemptions will reflect the plant's decommissioning status and become effective on April 15. The NRC issued the exemption package, including a safety evaluation, on December 10, 2015.

According to the NRC, once Entergy implements the exemptions, state and local governments may rely on comprehensive emergency management ("all-hazard") planning for off-site emergency response to events at Vermont Yankee, rather than having a dedicated off-site radiological emergency response plan approved by the Federal Emergency Management Agency. As a result, there will not be a 10-mile emergency planning zone identified in Vermont Yankee's license. The plant will maintain an on-site emergency plan and response capabilities, including the continued notification of state government officials of an emergency declaration.

Entergy announced in December that the transfer of Vermont Yankee's spent nuclear fuel from wet to dry storage will begin in 2017, two years earlier than originally planned. According to the company, the change will provide a high level of confidence that the transfer of all spent fuel from the plant's spent fuel pool to dry cask storage will be completed by the end of 2020. The ability to transfer all spent fuel to two independent spent fuel storage installation pads by then depends on the issuance by the Vermont Public Service Board of a Certificate of Public Good authorizing Entergy to begin constructing the second storage pad in early 2016.

● Dominion Generation is seeking to amend its license to store spent nuclear fuel at its North Anna nuclear power plant as part of research into the effects of long-term dry storage of high-burnup nuclear fuel assemblies. Located near Mineral, Va., North Anna houses two pressurized water reactors with a combined capacity of 1,946 MWe.

In August of last year, Dominion requested that the Nuclear Regulatory Commission revise the technical specifications for its license for the North Anna independent spent fuel storage installation (ISFSI). The proposed changes would allow for the storage of high-burnup spent fuel in a modified Areva TN–32B bolted-lid cask as part of the High-Burnup Dry Storage Cask

Research and Development Project, sponsored by the Department of Energy and the Electric Power Research Institute (EPRI). According to EPRI's test plan for the high-burnup dry storage project, a TN-32B cask will be loaded with intact high-burnup spent nuclear fuel (greater than 45 gigawatt-days per metric ton of uranium) with four different types of cladding: standard Zircaloy-4, low-tin Zircaloy-4, Zirlo, and M5. All of the spent fuel to be loaded into the cask is in the North Anna spent fuel pool.

Dominion's application to amend its ISFSI license was found to be acceptable for technical review by the NRC, which will document its findings in a safety evaluation report and an environmental assessment. In the October 13, 2015, *Federal Register*, the NRC published notice of Dominion's license amendment request and provided an opportunity to request a hearing or file a petition to intervene in the proceeding, with a deadline of December 14, 2015.

● The Nuclear Regulatory Commission on December 9 approved a 40-year license renewal for Northern States Power Company's independent spent fuel storage installation at the Prairie Island nuclear power plant in Red Wing, Minn. Notice of the license renewal was published in the December 16, 2015, *Federal Register*. The renewed license expires on October 31, 2053.

Northern States Power applied to the NRC in October 2011 to renew the site-specific license for the Prairie Island ISFSI. The original 20-year license for the Prairie Island ISFSI issued by the NRC in 1993 expired in October 2013. Under the NRC's timely renewal policy, Northern States Power was able to continue to operate the ISFSI while NRC staff was reviewing the license renewal request.

The application to renew the license was contested by the Prairie Island Indian Community (PIIC). Most of the PIIC's contentions were dismissed, however, and Northern States Power reached a settlement agreement with the PIIC on the last remaining contention in October 2015. The NRC published the final environmental assessment for the 40-year ISFSI license renewal in July 2015 and documented the safety review in a final safety evaluation report, issued on December 9.

Canada

Canada's Nuclear Waste Management Organization (NWMO), which is conducting a multiyear selection process to find a community willing to host a repository for the country's high-level radioactive waste, has determined that Central Huron, Ontario, is worthy of further study as a potential repository site.

In an October 29, 2015, press release announcing that it has completed the first phase of a preliminary assessment for the municipality, the NWMO said that based on the work it has completed, "Central Huron is assessed as having potential to meet site selection requirements for a deep geological repository

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Central Huron, located along Ontario’s West Coast on the shore of Lake Huron in Huron County, is one of 21 Canadian municipalities that expressed an interest in learning about the government’s repository plan and have undergone Phase 1 preliminary assessments. Of those, Central Huron and eight other Ontario municipalities have been identified as potential sites warranting further study. According to the NWMO, the preliminary findings do not confirm the technical suitability and safety of any site, and no community is being asked to confirm its willingness to host the project at this point. Under Canada’s “adaptive phased management” approach to siting a deep geological repository, the preliminary assessment is the initial phase of study in a nine-step selection process.

● A decision on a repository for low- and intermediate-level radioactive waste in Canada was delayed until March 1 by Canada’s Minister of Environment and Climate Change, Catherine McKenna, it was announced on November 27, 2015. The Canadian government was to make a decision on Ontario Power Generation’s (OPG) proposed repository by early December 2015. The facility would be located about 1.2 kilometers from Lake Huron, near OPG’s Bruce nuclear power plant in Kincardine, Ontario, and would accept LLW and ILW from the company’s Bruce, Pickering, and Darlington plants. In a statement, OPG said that it respects McKenna’s need for more time to review a joint review panel’s

Central Huron, in Ontario on the shore of Lake Huron, will be assessed as a possible site for a spent nuclear fuel repository.

May 2015 recommendation for the approval of the repository. The *Detroit News* reported on November 28 that the project, which has advanced under former Prime Minister Stephen Harper's Conservative Party, may be getting a new look following the October 2015 election of Justin Trudeau as prime minister.

United Kingdom

The Nuclear Decommissioning Authority (NDA) announced on October 5, 2015, that the last of the spent nuclear fuel has been removed from the reactors at the Oldbury nuclear power plant. Located in South Gloucestershire, England, Oldbury houses two Magnox reactors. Unit 2 was shut down in June 2011, followed by Unit 1 in February 2012. Defueling began in early 2013.

According to the NDA, more than 52,000 fuel elements were removed from the reactors during defueling, with the last element being removed from Unit 2 on October 4. The spent fuel was shipped over the following month to the Sellafield site in West Cumbria for reprocessing, with the final shipment of spent fuel due to leave the Oldbury site in early 2016. Once all of the spent fuel has been shipped to Sellafield, 99 percent of Oldbury's radioactive inventory will have been removed, and the plant will move into its decommissioning phase.

● International Nuclear Services (INS), a subsidiary of the NDA, announced on September 19, 2015, that it has delivered the first of two planned shipments of high-level radioactive waste from the Sellafield site to Switzerland. Three casks, each containing 28 containers of HLW in the form of vitrified residues, arrived at the Zwilag storage facility in northern Switzerland on September 18.

The HLW, the result of the reprocessing of spent nuclear fuel from Swiss electric utilities, was transported by ship to the port of Cherbourg in France and then by rail to Switzerland. INS said that it had contracted with Areva to safely manage the overland transport across France. The United Kingdom's Vitrified Residue Returns program, a partnership between Sellafield Ltd. and INS, is part of the NDA's strategy to repatriate HLW from the United Kingdom, fulfill overseas contracts, and deliver U.K. government policy.

● Sellafield Ltd., the cleanup contractor for the United Kingdom's Sellafield nuclear site, announced on October 28, 2015, that one of the site's biggest tasks is halfway to completion, with 50 percent of the radioactivity having been removed from the site's oldest nuclear fuel pond.

According to the company, the milestone was achieved in October when the final "canned fuel" was transferred from the Pile Fuel Storage Pond at Sellafield to a modern handling plant operated by the National Nuclear Laboratory (NNL). The storage pond, one of four high-hazard facilities on the site that were prioritized for cleanup by the Nuclear Decommissioning Authority, is a relic from the Cold War, when Sellafield produced

material for the U.K.'s nuclear arsenal. The pond will be drained and demolished after its contents, which include spent nuclear fuel, equipment, and sludge, have been removed.

The canned fuel consists of stainless steel cans containing fuel pins, pellets, and cladding waste from the Windscale advanced gas-cooled reactor. According to Sellafield Ltd., 191 cans containing 2.5 tons of fuel were removed from the pond and transferred to the NNL handling plant. Work is under way to remove the remaining contents of the pond, including metal fuel, which is expected to be cleared by April.

● The National Nuclear Laboratory and the Irvine, Calif.–based waste technology company Kurion announced on November 17, 2015, that they have completed the nonradioactive testing phase for a vitrification plant at the Sellafield nuclear site. NNL and Kurion formed a joint partnership in January 2014 to deploy a full-scale, in-container vitrification plant based on Kurion's GeoMelt technology at NNL's flagship Central Laboratory on the Sellafield site.

The testing phase of the commissioning program was capped off with a paid demonstration for the U.K. Nuclear Decommissioning Authority at the NNL Workington Laboratory nonradioactive test rig facility using simulated Sellafield waste. With testing complete, the system will be disassembled and moved to the Central Laboratory for final commissioning, followed by commercial operation.

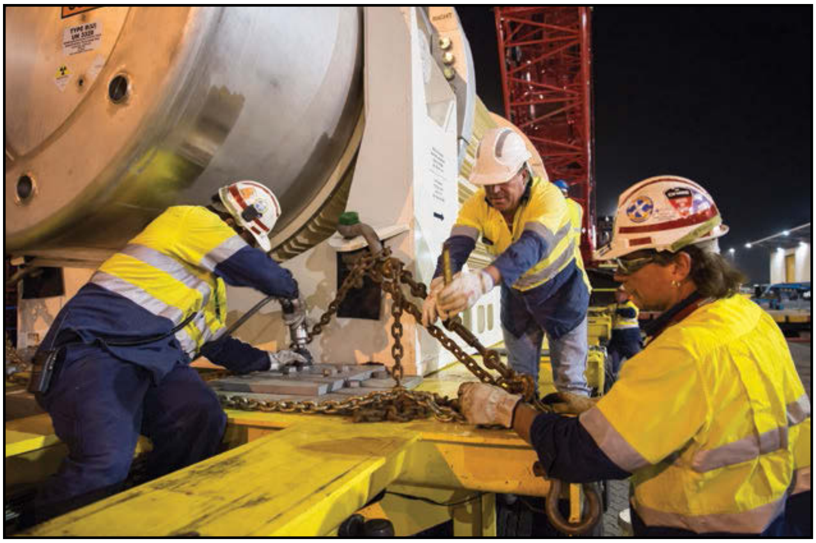
According to NNL, the United Kingdom has more than 300,000 t of intermediate- and low-level radioactive waste in its inventory that may be suitable for thermal treatment with GeoMelt. In 2016, Kurion and NNL plan to increase the total throughput of the system to a maximum annualized processing capacity of more than 200 t and evaluate the installation of additional systems.

Australia

The Australian Nuclear Science and Technology Organization (ANSTO) announced on December 6, 2015, that the first phase of its radioactive waste repatriation project has been completed with the return of Australian waste from France.

Hef Griffiths, ANSTO's head of nuclear services, said that the shipment of repatriated waste left France on October 15 aboard the nuclear-rated ship *BBC Shanghai* and arrived in Port Kembla, New South Wales, on December 5. The intermediate-level radioactive waste was transported the following day to an interim storage facility at Lucas Heights, where it will remain until it can be moved to the yet to be built National Radioactive Waste Management Facility. Australia is in the process of siting a permanent repository for radioactive waste.

With a single national facility yet to be established, radioactive waste generated by the country's medical, industrial, and nuclear research activities is currently stored at more than 100 locations across Australia, including hospitals, mining sites,



A transport canister containing repatriated waste is secured on a vehicle for shipment to Australia's Lucas Heights facility for temporary storage. Photo: ANSTO

and research centers. The Australian government has initiated a community consultation process to identify suitable sites for the proposed National Radioactive Waste Management Facility. On November 13, 2015, the government shortlisted six sites for further evaluation and public consultation. The six sites are at locations near Sally's Flat in New South Wales; Hale in the Northern Territory; Cortlinye, Pinkawillinie, and Barndioota in South Australia; and Oman Ama in Queensland.

According to the government, each nominated site was subject to an objective and evidence-based assessment by the Department of Industry, Innovation and Science, with the assistance of an independent advisory panel and Geoscience Australia. The department will consult until March 12 with local stakeholders that have an interest in the sites and a final site is expected to be identified before the end of the year.

NRC

An audit by the Nuclear Regulatory Commission's Office of the Inspector General has found that there are varying definitions of the term "long-term storage" relative to low-level radioactive waste. Without a formal definition of the term "long-term storage," NRC staff and external stakeholders are left to interpret its meaning, which could lead to inconsistency in inspections, according to the OIG.

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The findings were released in a September 23, 2015, report, *Audit of NRC's Oversight of Low-Level Radioactive Waste* (OIG-15-A-20). The audit found that the NRC has the requisite processes in place for overseeing LLW stored at operating commercial nuclear power plants, but that improvements could be made. Finding that NRC staff, inspectors, and management had widely varying definitions for "long-term storage," the OIG recommended that the agency's executive director for operations define the term in all future NRC documents or eliminate the term altogether.

According to the OIG, the lack of a cohesive understanding regarding the meaning of "long-term storage" stems from changing NRC policy. Previously, the NRC had a five-year limit on the length of time that LLW could be stored at a nuclear power plant before it had to be shipped to a disposal facility. At that time, NRC guidance documents defined "long-term" as meaning the life of the plant. The NRC lifted the five-year time limit in 1994 but continued to use the term "long-term storage."

The OIG audit also found a lack of communication among NRC internal offices and regional offices pertaining to transportation regulations, and that the agency's established mechanism for informing regional offices of updates to transportation regulations is being circumvented. To prevent inspectors from conducting inspections based on outdated transportation regulations, the OIG recommended that the NRC develop a mechanism to inform the regional offices of updates. This could be done through refresher training, monthly calls, or webinars, the OIG said.

The OIG's report can be accessed through the NRC's website at www.nrc.gov/reading-rm/doc-collections/insp-gen/.

EPA

The Environmental Protection Agency announced on October 1, 2015, that it has completed a record of decision (ROD) outlining a detailed plan for cleaning up the Nuclear Metals Inc. site in Concord, Mass. The cost of the cleanup is estimated at about $125 million.

Nuclear Metals produced depleted uranium products, primarily as penetrators for armor-piercing ammunition, and specialty metal products at the site, beginning in 1958. The operations resulted in contaminated soil, sediment, and groundwater, according to the EPA. The ROD explains the various cleanup options chosen by the EPA for the site. The EPA selected a cleanup plan that includes the excavation and off-site disposal of sediments and soil located outside of the site's holding basin, the stabilization of holding basin soils, and the containment of those soils with a vertical wall and a horizontal cover. The ROD also includes the treatment and monitoring of groundwater at the site.

● In a settlement with the Environmental Protection Agency, Energy Future Holdings has agreed to pay $2 million to clean up uranium mines in northwest New Mexico, it was reported by

the *Dallas Morning News* on December 2, 2015. Energy Future Holdings settlement with the EPA comes as part of a settlement with the U.S. Justice Department, which filed an objection to the company's bankruptcy plans last summer claiming that Energy Future Holdings was trying to skirt its environmental responsibilities, according to the news report. An Energy Future Holdings subsidiary that has since closed extracted uranium from four mines in McKinley County, N.M., in the 1970s and 1980s. The EPA, which estimates the cost of cleanup at $23 million, found uranium contamination was still present at the mine sites decades later.

● The Environmental Protection Agency announced on December 31, 2015, that an isolation barrier at the West Lake Landfill near St. Louis, Mo., will be installed to prevent subsurface smoldering from reaching radiologically contaminated areas of the Superfund site. The construction of the physical isolation barrier will be carried out under the direction and oversight of the EPA with support from the Army Corps of Engineers. According to the EPA, additional engineering controls will be used at the site, where a subsurface fire was detected in 2010. Additional controls include the installation of cooling loops to prevent potential impacts that could result if the smoldering were to come into contact with the radioactive materials contained in the landfill. The EPA said that it will release additional information, such as the location of the barrier, once plans are finalized.

On February 2, the U.S. Senate passed a bill that would transfer remediation authority over the West Lake Landfill from the EPA to the Army Corps of Engineers, putting the site in the Corps' Formerly Utilized Sites Remedial Action Program. U.S. Sens. Claire McCaskill (D., Mo.) and Roy Blunt (R., Mo.) introduced the bill, while companion legislation was introduced in the House by U.S. Reps. Lacy Clay (D., Mo.) and Ann Wagner (R., Mo.). Residents near the landfill and state officials have long sought to move oversight of the landfill cleanup away from the EPA.

DOE

Hoping to conduct a deep borehole field test in North Dakota, the Department of Energy announced on January 5 that it has selected a Battelle-led team to drill a test borehole more than 16,000 feet deep into a crystalline basement rock formation near Rugby, N.D. The DOE is conducting research into the potential use of deep boreholes for the disposal of certain types of high-level radioactive waste. According to the DOE, the field test will provide insights into crosscutting subsurface science and engineering challenges such as drilling techniques, wellbore stability and sealing, and subsurface characterization. Determining the feasibility of deep borehole disposal is the goal of the DOE's estimated $35-million, five-year project on approximately 20 acres of state-owned land. The research will examine the

hydrogeological, geochemical, and geo-mechanical characteristics of the host rock at a considerable depth. No radioactive material will be used during any of the testing for the borehole project.

● Unable to reach an agreement with the state over a waiver of a 1995 settlement agreement, the Department of Energy has canceled a shipment of spent nuclear fuel to Idaho National Laboratory, it was reported on October 23, 2015. The shipment was one of two deliveries of 25 spent fuel rods the DOE was proposing to send to INL as part of a research project on the characteristics and storage of spent fuel. Former Idaho governors Cecil Andrus and Phil Batt, architects of the 1995 Batt Agreement prohibiting the transfer of commercial spent nuclear fuel to INL, had opposed the shipments.

In December 2014, the DOE requested a waiver of the Batt Agreement. Idaho Gov. C. L. "Butch" Otter and Attorney General Lawrence Wasden indicated that the state would be willing to grant a conditional waiver if the DOE would take steps to resolve current noncompliance issues with the agreement. Those issues stem from the delay in the construction and operation of the site's Integrated Waste Treatment Unit (IWTU), which was supposed to begin treating nearly 900,000 gallons of liquid sodium–bearing waste in 2012.

A shipment of mixed, low-level waste from Hanford is secured for treatment and disposal. The DOE is researching the use of plasma mass filtering to separate and treat radioactive waste. Photo: DOE

The delay in the construction of the IWTU has resulted in the DOE's missing deadlines set by the settlement agreement with the state. Wasden had said that he would not consider granting a waiver to allow the shipments of spent fuel, the first of which was to come from Dominion's North Anna nuclear power plant, until the IWTU was operational and the DOE entered into an enforceable agreement to resolve the missed deadlines.

● Physicists at the Department of Energy's Princeton Plasma Physics Laboratory are proposing the use of a plasma-based centrifuge method to separate nonradioactive elements from radioactive waste in an effort to reduce the volume of nuclear waste and the costs associated with treating it. Known as plasma mass filtering, the new separation technique would supplement chemical techniques. Announced by PPPL on December 2, the research results first appeared in the paper "Plasma Filtering Techniques for Nuclear Waste Remediation," which was published in the October 2015 issue of the *Journal of Hazardous Materials* (Vol. 297).

Noting the challenge of safely treating radioactive waste, Renaud Gueroult, PPPL staff physicist and the paper's lead author, said that supplementing existing chemical separation techniques with plasma separation techniques "could be economically attractive, ideally leading to a reevaluation of how nuclear waste is processed."

According to PPPL, the high-throughput plasma-based mass separation techniques advanced at the laboratory offer the possibility of reducing the volume of waste that needs to be immobilized through vitrification. Plasma mass filtering begins by atomizing and ionizing the hazardous waste and injecting it into a rotating filter so that the individual elements can be influenced by electric and magnetic fields. The filter then separates the lighter, less active elements from the heavier ones by using centrifugal and magnetic forces. As the lighter elements often do not need to be vitrified, processing the HLW would require fewer high-level glass canisters overall. The less-radioactive material then could be immobilized in a less costly waste form, such as concrete or bitumen, according to PPPL.

● The Department of Energy is seeking a 17-year delay in opening the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site near Richland, Wash. In response to a request by the U.S. District Court for the Eastern District of Washington, the DOE and the state of Washington filed new deadlines for the WTP, it was reported in *Tri-City Herald* on November 14, 2015. Technical issues have delayed the construction of the WTP, otherwise referred to as the Vit Plant, which is being built to treat and vitrify Hanford's approximately 56 million gallons of radioactive liquid waste. The DOE, which has been reluctant to set a deadline for completing the WTP, has proposed bringing the plant into full operation by 2039. The state, however, has proposed a start-up date of 2034. Under a 2010 consent decree, which set certain milestones for the treatment of Hanford's waste, the plant was to be fully operational by 2022. The DOE and the state went to the federal court in late 2014 seeking new deadlines in the consent decree after the DOE determined it would be unable to meet the current deadlines.

In response to the DOE's new deadline, the watchdog group Hanford Challenge called on the Obama Administration on November 23 to stop work at the WTP and immediately begin the construction of 12 new underground nuclear waste storage tanks. The state also is asking the court to require the DOE to start planning and permitting work on new double-shell waste tanks.

● The final pouring of grout into Tank 16 at the Savannah River Site was completed on September 22, 2015, more than a month ahead of schedule, according to the Department of Energy. Beginning on June 2 of last year, contractors at the DOE's Savannah River Site poured nearly 6,300 cubic yards of grout into the underground high-level radioactive waste tank as part of the process for closing the tank. Tank 16, which has a capacity of approximately 1 million gallons, is the seventh waste storage tank to be operationally closed at the site, and the fifth tank closed since 2012. Closure is the culmination of several extensive preparation and isolation activities, and the placement of grout to fill up the entire tank and all internal tank components is the final step. Tank 12 is the next older-style tank that will be operationally closed at SRS. Preparations for grouting Tank 12 were completed in September of last year and contractors began pouring grout into the tank on January 19, according to the DOE. ■

On January 19, cement trucks hauling specially formulated grout began filling Tank 12, an underground radioactive waste tank at the Savannah River Site. Photo: DOE

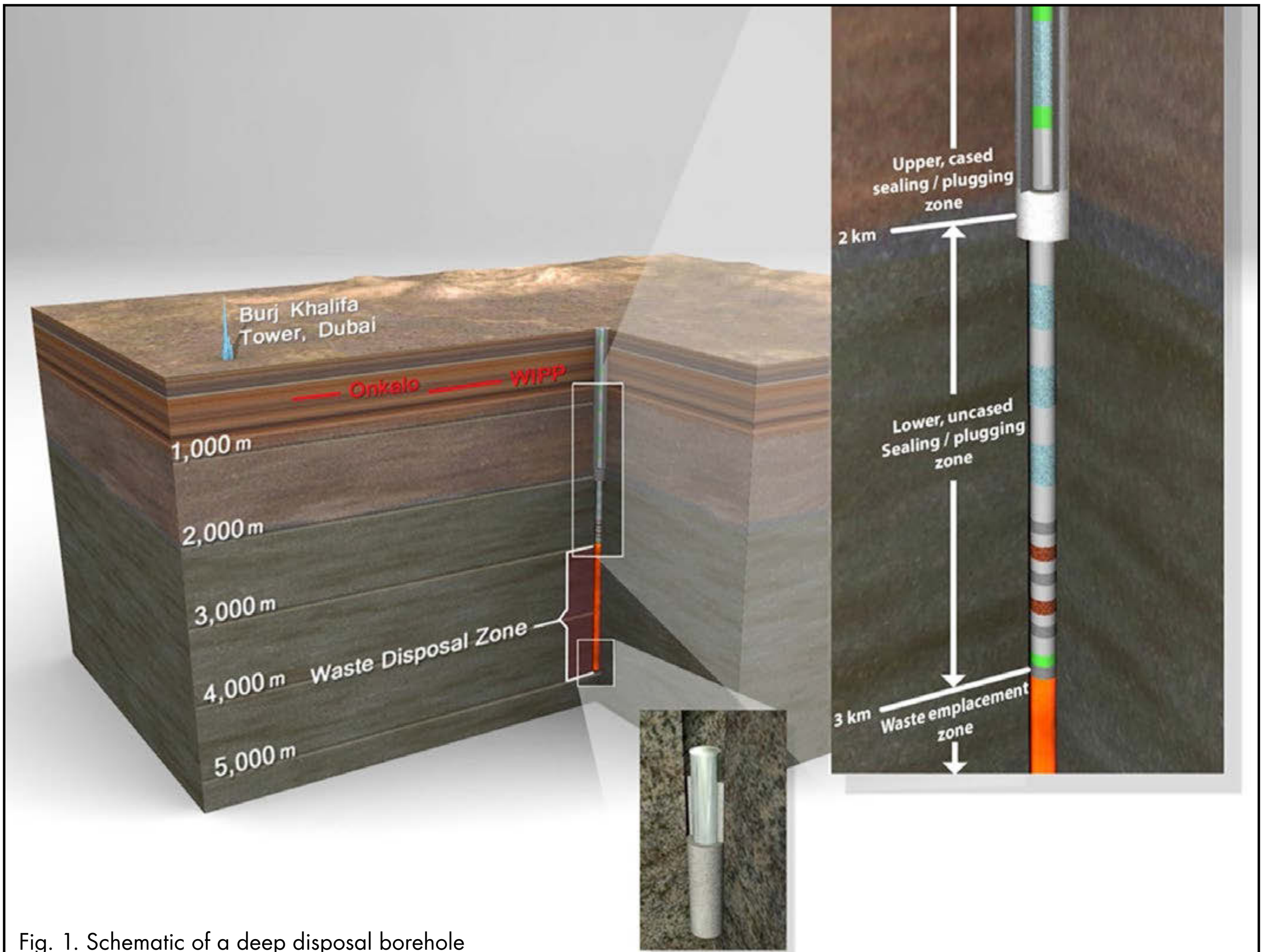

Fig. 1. Schematic of a deep disposal borehole depicting sealing and plugging.

Field Test to Evaluate Deep Borehole Disposal

Sandia National Laboratories has begun research on the potential use of deep boreholes for the disposal of radioactive waste.

The U.S. Department of Energy has embarked on the Deep Borehole Field Test (DBFT), which will investigate whether conditions suitable for disposal of radioactive waste can be found at a depth of up to 5 kilometers in the earth's crust. As planned, the DBFT will demonstrate drilling and construction of two boreholes, one for initial scientific characterization and the other at a larger diameter appropriate for potential waste disposal (the DBFT will not involve radioactive waste). A wide range of geoscience activities is planned for the characterization borehole, and an engineering demonstration of test package emplacement and retrieval is planned for the larger field test borehole. Characterization activities will focus on measurements and samples that are important for evaluating the long-term isolation capability of the deep borehole disposal (DBD) concept. Engineering demonstration activities will focus on providing data to evaluate the concept's operational safety and practicality. Procurement of a scientifically acceptable DBFT site and a site management contractor is now under way.

The concept of DBD for radioactive wastes is not new. It was considered by the National Academy of Science [1] for liquid waste, studied in the 1980s in the U.S. [2], and has been evaluated by European waste disposal research and development (R&D) programs in the past few decades (e.g., [3, 4]). Deep injection of wastewater, including hazardous wastes, is ongoing in the U.S. and regulated by the Environmental Protection Agency [5]. The DBFT is being conducted with a view to use the DBD concept for future disposal of smaller-quantity, DOE-managed wastes from nuclear weapons production (i.e., cesium/strontium capsules and granular solid wastes). However, the concept may also have broader applicability for nations that have a need to dispose of limited amounts of spent fuel from nuclear power reactors. For such nations, the cost for disposing of volumetrically limited waste streams could be lower than mined geologic repositories.

Deep Borehole Disposal Concept

DBD safety relies on emplacing wastes in competent crystalline rock well below the extent of naturally circulating groundwater. Whereas movement in groundwater is practically the only means for migration of radionuclides, if the groundwater has not moved for millions of years, then transport is limited to the mechanism of aqueous diffusion, a slow process. Diffusion-limited transport is the principle of isolation for mined repositories proposed at depths of 500 meters in clay or shale, and salt. However, DBD would be situated at a 3- to 5-km depth (Fig. 1) in low-permeability granite or schist, and therefore the radionuclide migration path distance would be at least an order of magnitude greater than for mined repositories (e.g., 1,000 m in the crystalline basement vs. 150 m in clay or shale). Hence, DBD offers the potential for exceptional waste isolation, because the time for diffusive release to the biosphere is proportional to the square of distance.

The key to proving the potential effectiveness of DBD is to carefully analyze the environment at depth, to determine the origin and residence time of deep groundwater, and to understand why it has remained isolated. Natural cosmogenic tracers with long half-lives such as argon isotopes and krypton-81 could be helpful because they can be used to estimate or bound the average time since a groundwater sample was at the earth's surface. Other tracers originate in the solid earth: accumulation of radiogenic helium, and uranium-series equilibria, are indicators of long groundwater residence time. The characterization borehole will use state-of-the-art methods to characterize chemical and isotopic tracer signatures for interpretation of groundwater provenance and apparent age [6].

Another aspect of deep groundwater isolation pertains to the chemical composition of such waters, which are typically concentrated chloride brines with density from 2.5 percent (seawater) to more than 30 percent greater than pure water. Types of brine range from sodium chloride to calcium and magnesium chloride at higher density. The density gradient (fresh near the surface, concentrated at depth) is stabilizing and inhibits vertical flow or mixing. The inhibitive effect is well-known where seawater invades near-surface groundwater aquifers. Density stratification would tend to limit the effects from future perturbations to hydrologic conditions such as climate change or from early borehole heating by the waste. For example, ancient brines have been found in crystalline basement rock over a large area of the northern plains of North America, an area subjected to glaciation during the Pleistocene epoch.

Several causes have been proposed for deep brines: water-rock interaction (leaching), infiltration of cryogenic brines from large-scale freezing of seawater, and dissolution of evaporites (where present). The cause and age for specific occurrences may be inferred from their composition (e.g., [7]) or they may be undetermined. The simple existence of concentrated chloride brines in the crystalline basement is a general indicator of great age, especially when no evaporites are present in the geologic setting.

The presence of ancient, saline water in the basement suggests that waste isolation in deep boreholes may not depend critically on borehole seals above the waste disposal interval. Within the borehole and the disturbed rock zone (DRZ) within a few feet of the borehole, the permeability will be low and the potential radionuclide pathway will be long, limiting the rate of diffusion-dominated transport to the biosphere above. During the thermal period (a few decades to hundreds of years, depending on waste type) there is the possibility for thermally driven buoyant convection, which seals could help to mitigate. After cooling, with fluid of similar composition in the borehole and formation reestablishing density stratification, the upward hydraulic gradient is likely to be very small or nonexistent regardless of the seals. Radionuclide transport under such conditions would be diffusion-dominated and limited to long pathways and low permeability.

The DBFT will evaluate methods for sampling and testing in the characterization borehole to determine groundwater provenance and apparent age at the test site. The capability for safe handling and emplacement of waste in deep boreholes will be demonstrated, and borehole sealing materials and technologies will be evaluated.

Deep Borehole Field Test

Previous Investigations

The National Academy of Sciences [1] identified deep injection as a promising method for disposal of liquid radioactive or mixed wastes. This was followed in the 1960s by a campaign of injection of cementitious waste slurries into shale, near Oak Ridge, Tenn. The Oak Ridge disposal site was shallower (about 300 m) than proposed for deep boreholes. It was discontinued in the 1980s but continues to be monitored [8].

A number of disposal options for radioactive waste were investigated in the 1980s in the U.S., including deep borehole disposal of commercial spent nuclear fuel [2]. That study was the first to propose a means for emplacing strings of waste packages, threaded together, using a drill rig (drill-string emplacement). Later studies evaluated drill-string emplacement for the Swedish waste program [9]. R&D programs for deep borehole disposal have been ongoing for several years in the U.S. and the United Kingdom [10, 11]. Technical leadership for the DBFT is provided by Sandia National Laboratories for the DOE and builds on Sandia's DBD R&D activities started in 2009 [12].

There have been hundreds of deep-injection wells for wastewater and liquid hazardous waste in the U.S., licensed by the EPA [5]. Approximately 500 to 600 wells have been put into service, with depths from 3,000 to 12,000 feet. The injection intervals are typically separated from underground sources of groundwater by multiple low-permeability confining units. Injection wells have double

Table 1. Summary of selected deep scientific drilling projects conducted internationally

Site	Location	Years	Depth [km]	Diam * [in]	Purpose
Kola SG-3	NW USSR	1970-1992	12.2	8 1/2	Geologic Exploration + Tech. Development
Fenton Hill	New Mexico	1975-1987	4.6	9 7/8	Enhanced Geothermal
Urach-3	SW Germany	1978-1992	4.4	5 1/2	Enhanced Geothermal
Gravberg	Sweden	1986-1987	6.6	6 1/2	Gas Wildcat
Cajon Pass	S California	1987-1988	3.5	6 1/2	Geologic Exploration
KTB	SE Germany	1987-1994	9.1	6 1/2	Geologic Exploration + Tech. Development
Soultz-sous-Forets GPK	NE France	1995-2003	5.3	9 5/8	Enhanced Geothermal
SAFOD	Central California	2002-2007	4(3)#	8 3/4	Geology Exploration
Basel-1	Switzerland	2006	5	8 1/2	Enhanced Geothermal

* borehole diameter at total depth
#true vertical depth

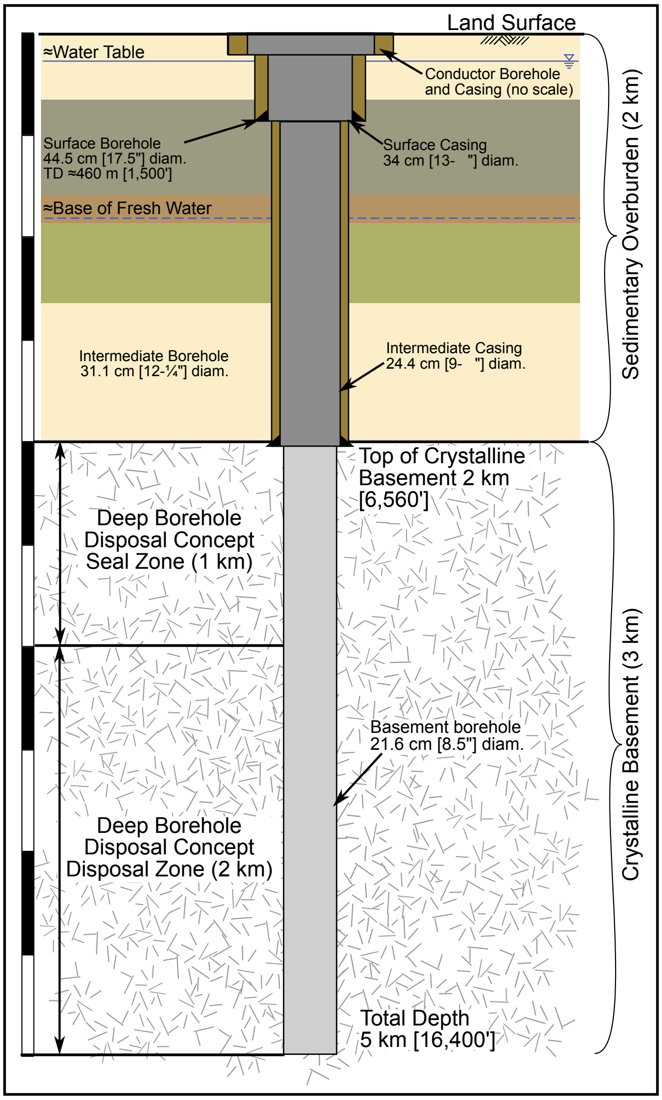

Fig. 2. Deep Borehole Field Test characterization borehole diameter and casing plan.

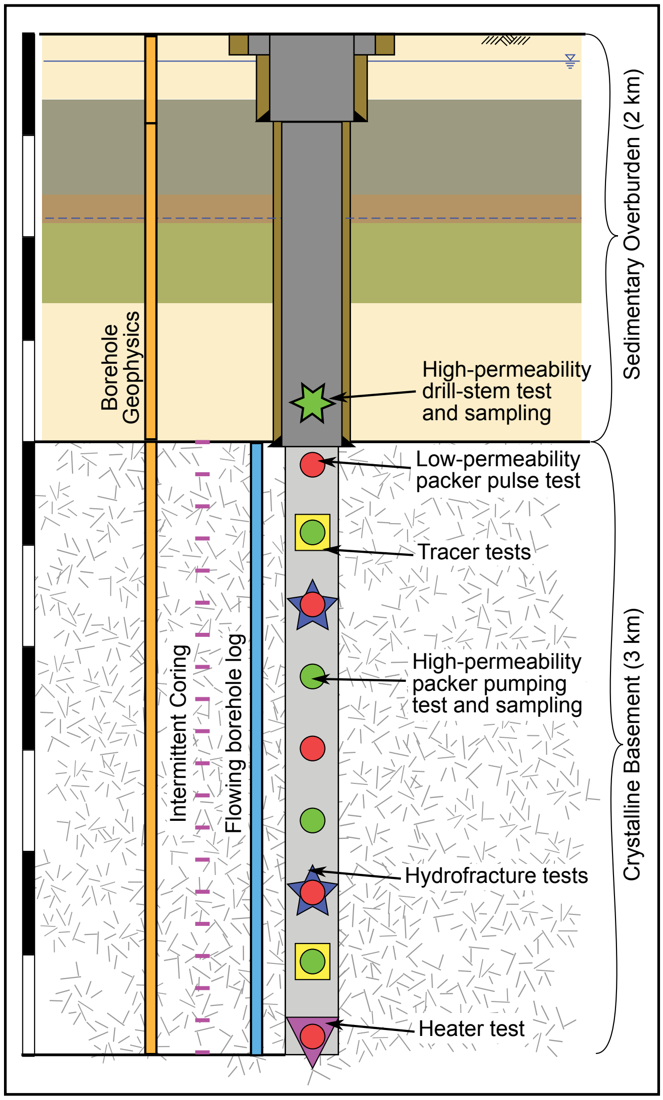

Fig. 3. Schematic of sampling and measurement locations planned for the characterization borehole.

casings (double-cemented) to isolate the waste path from overlying units. Final sealing and plugging of these wells follow established procedures for oil and gas wells.

The characterization borehole, discussed below, resembles boreholes drilled for scientific research. Whereas oil/gas wells are nearly always drilled in sedimentary rock and may penetrate to 6 km or deeper, deep boreholes in crystalline rock are far fewer and are drilled for scientific R&D. Several of these deep boreholes drilled for scientific research are listed in Table 1. They are instructive for the DBFT because of the drilling and completion methods used, the states of *in situ* stress encountered, the frequency of borehole breakouts, the rock permeability encountered, production of hydrogen gas, and many other aspects.

Site Activities

Site activities for the DBFT are scheduled to begin in early 2016 after selection of a site and a site management contractor [13]. Site-specific activities will begin with a phase in which drilling engineers, geoscientists, and support personnel plan the details of the initial characterization borehole. This vertical borehole will be drilled to approximately 16,400 ft (5 km), at a relatively small diameter (8.5 inches) to characterize the crystalline basement (Fig. 2). The drilling phase (approximately seven months) will include initial testing such as stem tests, hydraulic fracturing stress measurements, wireline logs, etc. Core will be obtained for 5 percent of the borehole length, in selected intervals emphasizing the crystalline basement and the contact with overlying strata, if one exists. The characterization borehole will be lined with steel casing from the surface to a depth of approximately 2 km, and open hole below that for testing.

The testing phase (approximately seven months) will follow, involving wireline logs while pumping, specialized low-permeability packer tests, tracer tests, and formation fluid sampling [6] (Fig. 3). The actual scope of testing will depend on borehole observations such as the distribution of permeability and the extent of borehole breakouts. Other tests may be performed later, such as a borehole heater test at depth to characterize the potential for thermally convective flow in and around the borehole.

When sufficient experience has been acquired with drilling and testing in the characterization borehole in the crystalline basement, a decision will be made whether to proceed with planning and drilling a larger-diameter field test borehole, or whether the characterization borehole can be used for the remaining DBFT activities. The primary purpose of the larger borehole will be to demonstrate drilling and construction methods that could be used for future waste disposal (at a different site). The combination of 17-in. diameter and total depth of 16,400 ft in crystalline rock is at the margin of the envelope representing worldwide drilling accomplishments.

The field test borehole will have a guidance casing at constant diameter (nominally 13 3/8 in.) from top to bottom to provide a secure path for emplacing test packages [14]. The upper 3 km of guidance casing, and the liner between 2 km and 3 km depth, will be removable as they would in a disposal borehole for installation of seals directly against rock. Selected logs and tests in the field test borehole will be used to test predictions based on characterization borehole data. The hole will then be available for demonstration of emplacement and retrieval of test packages.

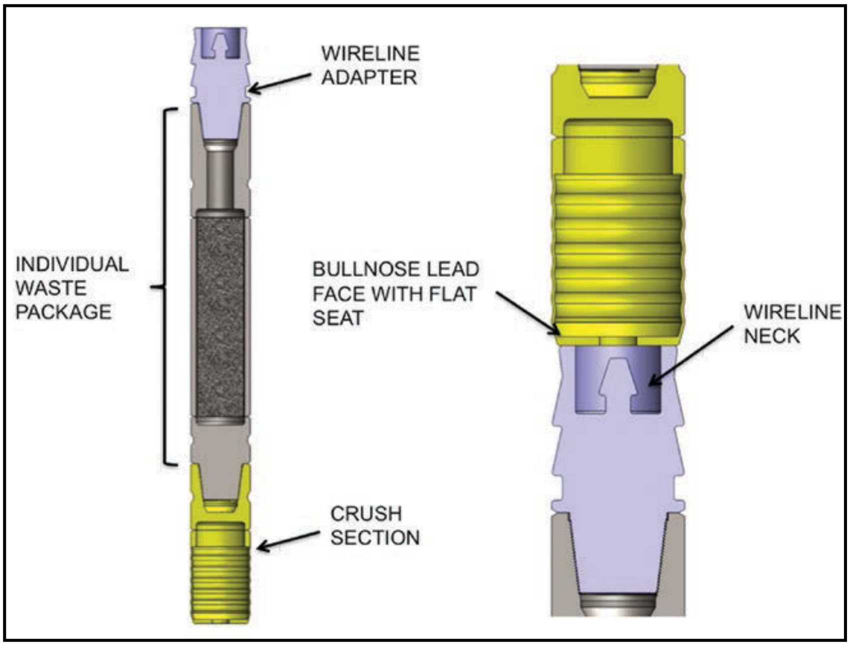

Fig. 4. Conceptual design for waste packaging with threaded ends for connecting packages in strings or for attachment of adapters and impact limiters to single packages (package length not to scale).

Engineering Demonstration

In addition to large-diameter deep drilling, demonstration activities will include the design and fabrication of test packages, then emplacement and retrieval of a small number of packages in the field test borehole [14]. The packages will be thick-walled, welded vessels capable of resisting the down-hole pressure (9,650 pounds per square inch, bounded by a fluid column with 1.3× the density of pure water), with an appropriate factor of safety. Packages will have threaded and/or tapered plugs with welded seals and will be unshielded in order to maximize the volume available for waste (in a disposal application). They will have connections on the ends, so they can be joined in strings if desired. The connectors can also be used to attach impact limiters below and latches for grappling from above (Fig. 4).

Handling of waste packages at a future disposal site will require a shielded cask that can be upended and set onto a receiving flange at the borehole collar (Fig. 5). The cask must have doors at both ends so that the waste package can be lowered into the borehole. Such a cask may be designed only for package transfers to the borehole from transportation casks of existing designs.

Two basic options are available for emplacing waste packages in the borehole: 1) lowering single packages on a modern electric wireline of the type used offshore and in deviated wells (Fig. 4 or Fig. 2) or lowering strings of packages that are threaded together, using threaded sections of drill pipe handled with a workover rig (Fig. 6). The wireline method is conceptually simpler, whereas the drill-string method would require installation of more extensive equipment under the rig ("basement") to contain the equipment for threading packages together, in addition

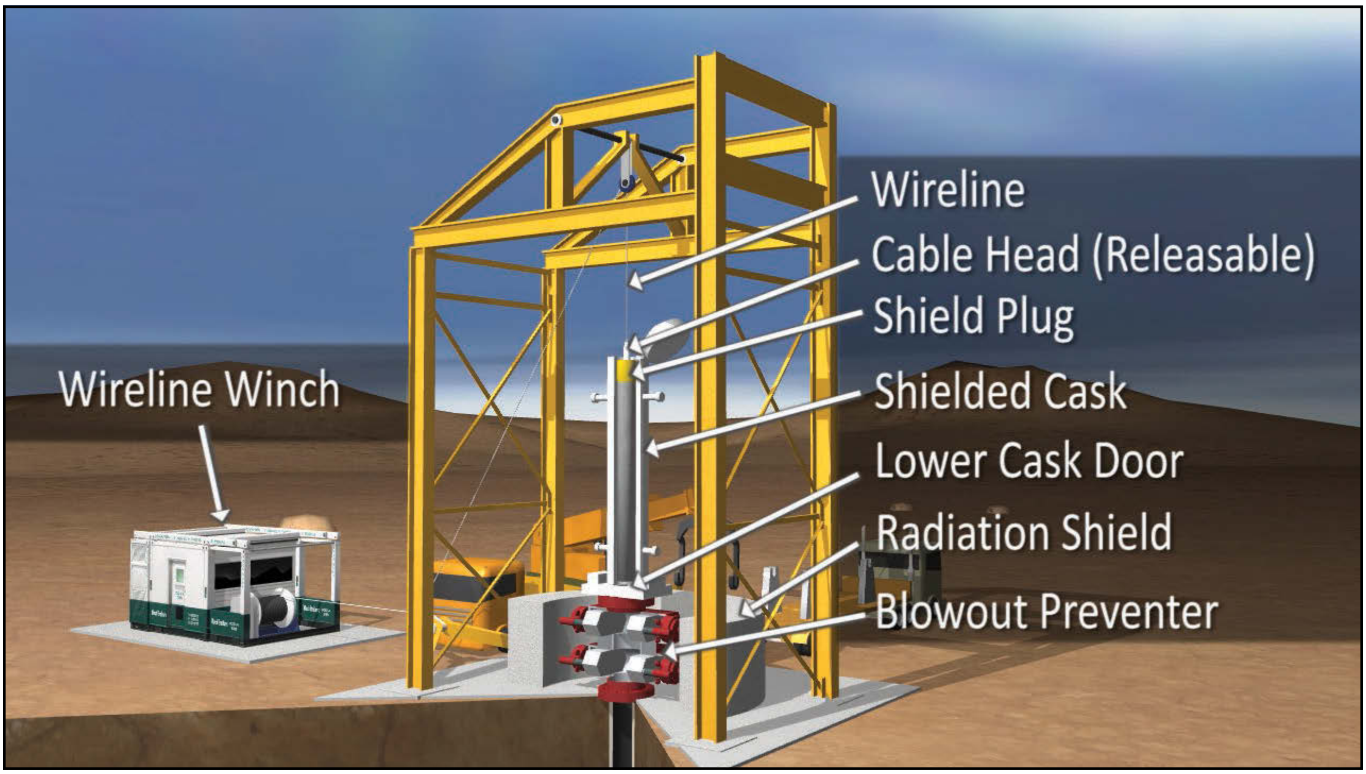

Fig. 5. Visualization of wireline method for waste package emplacement.

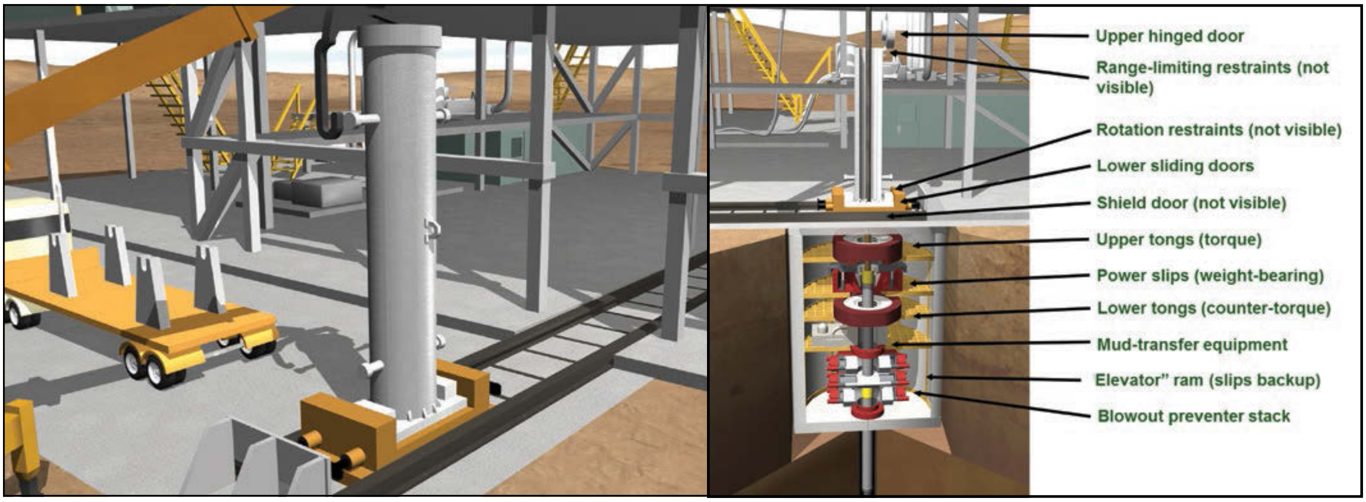

Fig. 6. Visualization of drill-string method for waste package emplacement: (left) waste package in shielded transfer cask, installed on carrier car to be translated under the drill rig; and (right) rig basement showing specialized equipment for assembling strings of waste packages, threaded together, for lowering in the borehole on drill pipe.

to blowout preventers and mud handling.

A multiattribute utility study was performed to compare the risks and costs associated with the two emplacement options identified for disposal of 400 waste packages in a single, prototypical borehole. For each option, an event tree was constructed to represent possible outcomes, including waste package drops, drill-string drops, and packages becoming stuck above or within the designated disposal zone (Fig. 7). A hazard analysis identified four types of initiating events involving package or drill-string drops and getting packages stuck. These top-level initiating events were decomposed and probabilities developed using fault trees. A panel of subject-matter experts developed the probability estimates needed for fault-tree calculations, as well as estimates of the probability of breaching one or more waste

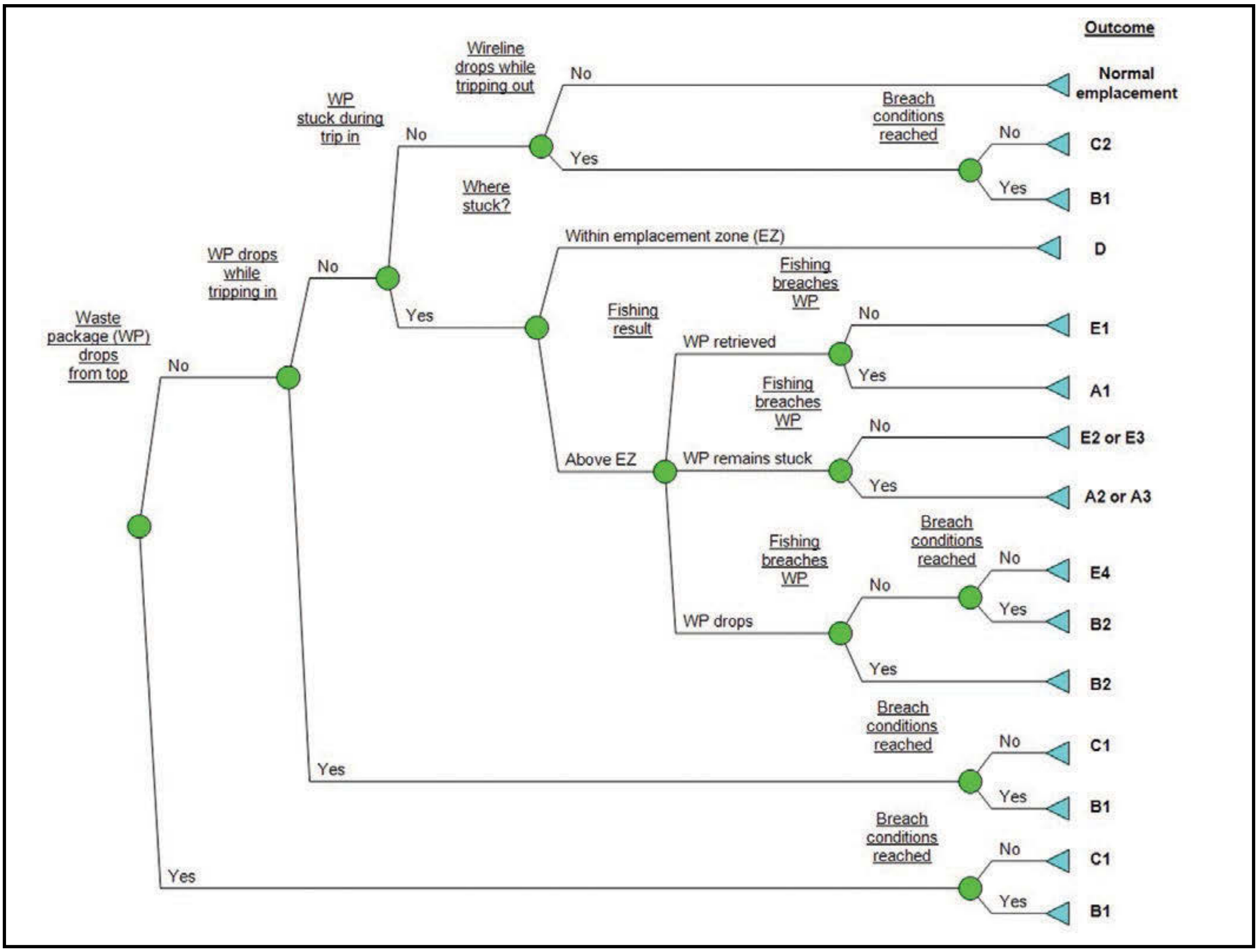

Fig. 7. Event tree for preclosure operations, wireline emplacement.

packages during drops or fishing operations. Costs were estimated for the normal and off-normal outcomes, including costs for fishing stuck packages, remediating contamination, and opportunity costs from termination of disposal operations.

The multiattribute study produced a recommendation to use the wireline emplacement method, because the total probability of a breached package is estimated to be lower by a factor of about 55 for wireline emplacement versus drill-string emplacement, and the cost of wireline emplacement is estimated to be substantially less. The lower probability of a waste package breach with wireline emplacement results because lowering single packages involves much less weight and facilitates the use of impact limiters on every package. The formidable weight of a package string or a drill string is likely to breach waste packages in the event of an accidental drop. Costs for off-normal event recovery are dominated by delay and decontamination that would ensue from breaching a package. Although more trips are needed in and out with the wireline method, increasing the risk of becoming stuck, the trips are faster, and the resulting minimal risk of breaching a package by an accidental drop leads to the preference for wireline over drill-string emplacement.

Planning for the engineering demonstration is proceeding, with engineering contractors performing design studies, fabricating test packages, and developing a prototype handling/emplacement system. The objective is to demonstrate the entire process, including test packages, handling and transfers, and emplacement/retrieval in the field test borehole. The demonstration will emphasize developmental aspects unique to potential future waste disposal in deep boreholes. Package instrumentation will be used for monitoring of down-hole conditions such as package temperature and acceleration. The demonstration will also focus on the working interface between nuclear materials handling specialists and borehole contractors (e.g., drilling, wireline logging) that would be required for future disposal operations.

Sealing Technology R&D

As discussed above, there is thought to be a need for borehole seals during the thermal period. Many sealing materials are available, and R&D is under way to understand the evolution of representative materials over hundreds to thousands of years. The current approach is to investigate the properties and stability of cementitious and clay-based materials (e.g., bentonite), starting with cements that are used in oil and gas wells because they are used successfully in deep boreholes. Properties and longevity can be effectively studied in the laboratory without the expense of *in situ* testing. Tests of emplacement methods could be implemented in shallower test wells. Eventually, a field test of seal emplacement could be performed at full depth of up to 10,000 ft (3 km).

Technology Challenges for the DBFT

An expert panel recently indicated that the field test borehole is technically feasible, but field experience is limited [15]. The field test borehole will advance international experience with drilling of large-diameter, deep boreholes in crystalline rock. Another challenge is sampling of deep-formation water (free water and pore water) in sufficient quantities and with sufficient preservation of ambient quality for a range of chemical and isotopic analyses. This will be accomplished using an integrated approach that combines available borehole methods with the use of tracers in all fluids introduced to the characterization borehole.

Test packages will have a function that is unique to geologic disposal applications: containment with external pressure and corrosion at down-hole conditions (pressure, temperature, salinity). Staging of shielded casks over a borehole is a new requirement, especially if heavy shielding is used. Lowering of waste packages presents challenges in controlling pressure surge in the borehole and in predicting package behavior in the event of a drop.

Postclosure Performance of DBD

The basis for waste isolation performance in deep boreholes was summarized by Brady et al. [12]: "...physical transport of radionuclides away from HLW and SNF at multi-kilometer depths would be limited by: low water content, low porosity and low permeability of crystalline basement rock, high overburden pressures that contribute to the sealing of transport pathways; and the presence of convectively stable saline fluids." Crystalline rock has low intact porosity and low matrix permeability, because previous metamorphic or igneous processes have determined the rock fabric. Hydraulic permeability is dominated by fractures that form due to injection or tectonics, but which are at least partially closed by *in situ* stresses acting at depth. The presence of ancient saline groundwater is evidence for static hydrology over geologic time, and it resists convective circulation that might be caused by changes in the hydraulic head gradient (vertical or lateral), surface loading, or localized heating. Such stable conditions have been represented in idealized, generic (non-site-specific) projections of waste isolation performance [16, 17]. More advanced mechanistic studies of potential perturbations are under way, supported by systematic development and screening of features, events, and processes (FEPs) specific to borehole disposal [12]. Some of these processes are discussed further below.

Thermally driven convective circulation is included in thermal-hydrology simulations [18], which show that the magnitude and duration are likely to be insignificant. Thermal convection is sensitive to changes in permeability, but only if assigned much greater values of permeability than are expected to be present along potential transport pathways. Permeability is an important parameter to be investigated by the DBFT characterization borehole.

Corrosion of metals, cement, and other engineered materials is potentially significant during disposal operations (e.g., the first few years) when it is important that packages provide containment and that disposal zone geometry is preserved. However, after permanent closure (i.e., after sealing and plugging of a disposal borehole) such containment may not be as important, and it is not included in current predictive models of waste isolation performance. The disposal zone will eventually be filled with corrosion products (e.g., magnetite) and residues from degradation of cements and waste forms. Consolidation of this mixture may occur to the extent that any significant voids remain. Long-term degradation behavior of engineered materials in the disposal zone, and other sealing and plugging materials, is being addressed by laboratory studies associated with the DBFT.

Corrosion of metals in water at reducing conditions in the disposal zone will produce hydrogen [3]. Some H_2 will dissolve in water at *in situ* pressure, but mass balance arguments show that the total H_2 production will exceed solubility in the borehole, and that the rate of production might exceed the rate that H_2 can diffuse away from the borehole (see [19]). Expulsion of contaminated fluid into the overburden has been proposed as the endpoint for an H_2-generation scenario [3]. However, this may essentially be a material selection problem, and there are slowly corroding materials available (e.g., stainless steel casing). Also, experience with oil and

gas wells suggests that well-cemented casing corrodes slowly even in aggressive chemical environments (with appropriate choice of cement). In addition, buildup of H_2 pressure will eventually dissipate and H_2 gas generation would likely never lead to unworkable requirements on disposal zone completion. This issue will be examined further during the course of the DBFT.

support a feasibility evaluation for future DBD projects.

At the conclusion of drilling, construction, down-hole testing, and field demonstration activities, the DBFT boreholes and field site will be available for additional R&D. This might include transfer of ownership to an entity such as an institute or university, to be used for down-hole testing or as an observatory.

Closing Discussion

Technical criteria for selection of the DBFT location include attributes such as maximum depth of 2 km to the top of the crystalline basement and evidence for ancient groundwater at depth [13]. The DBFT characterization borehole and associated scientific investigations are planned to determine whether these technical attributes exist and to demonstrate the use of state-of-the-art methods for obtaining supporting measurements and samples. These activities are scheduled to get under way in early 2016, with borehole completion by mid-2017 and down-hole scientific testing in the following months. A program of sampling and testing activities has been prepared for planning purposes [6], but will be reviewed in 2016 with site management and the drilling contractor support team.

Planning for engineering demonstration activities is under way, and conceptual design will be completed in mid-2016. Final design activities will follow, then prototype fabrication and testing, system integration testing, and finally field demonstration in 2018 or 2019. The demonstration will evaluate prototype test package performance and evaluate the selected system for package handling, transfer, emplacement, and retrieval. The demonstration will generate new information on technical performance, operational efficiency and safety, and cost that will

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Seismic Anchorage of Dry Storage Casks

By Joel E. Parks, Chris P. Pantelides, Luis Ibarra, and David Sanders

Dry storage casks (DSCs) store spent nuclear fuel (SNF) rods from nuclear power plants and are placed on sites adjacent to the plant. These sites are known as independent spent fuel storage installations, and regulations ensure adequate passive heat removal and radiation shielding during normal operations, off-normal events, and accident scenarios [1]. DSCs are a temporary storage solution licensed for 20 years, although they may be relicensed for operational periods up to 60 years. DSCs are being re-evaluated as a potential midterm storage solution, where operating periods may be extended to 300 years. With DSCs storing SNF for hundreds of years the seismic hazard analysis results in very large horizontal accelerations and destabilizing effects from vertical accelerations.

DSCs are typically freestanding structures that rest on a reinforced concrete pad. During a large seismic event a freestanding DSC may tip over or experience excessive sliding, which can lead to a collision with another cask or other structural component and cause damage to the contents of the casks. This research focuses on the benefits of seismic anchorage for DSCs to reduce damage to the cask and its contents during a large seismic event. Two types of anchorage are investigated: (a) conventional bolt details with steel chairs, and (b) stretch-length bolt details with steel chairs. Both anchorage methods are depicted in Fig. 1. A stretch-length bolt is an anchor bolt that has a length extending beyond the concrete in which it is anchored.

Vertical containment structures that do not have significant ductility, such as DSCs, could benefit from plastic yielding of the anchor bolts used to connect the structure to its foundation [2]. The stretch length increases the lateral displacement capacity of the system, and can be designed to meet the displacement criteria of the structure. The stretch length in this research is equivalent to 8 bar diameters (8D). To provide additional displacement ductility to the system, a steel chair designed to yield is investigated and compared to a steel chair that is designed to remain elastic.

To evaluate the effectiveness of providing a stretch length equivalent to 8D and/or a steel chair designed to yield, single-anchor tests were performed by loading the anchor bolt and steel chair assembly in monotonic or cyclic shear. After evaluation of the single-anchor tests, a group of anchors was tested on a 1:2.5-scale DSC under a quasistatic horizontal cyclic load applied at the centroidal height. A steel ring designed to clamp the cask was used as part of the anchoring system. The experimental results are presented and compared for conventional and stretch-length bolts, yielding and elastic chair

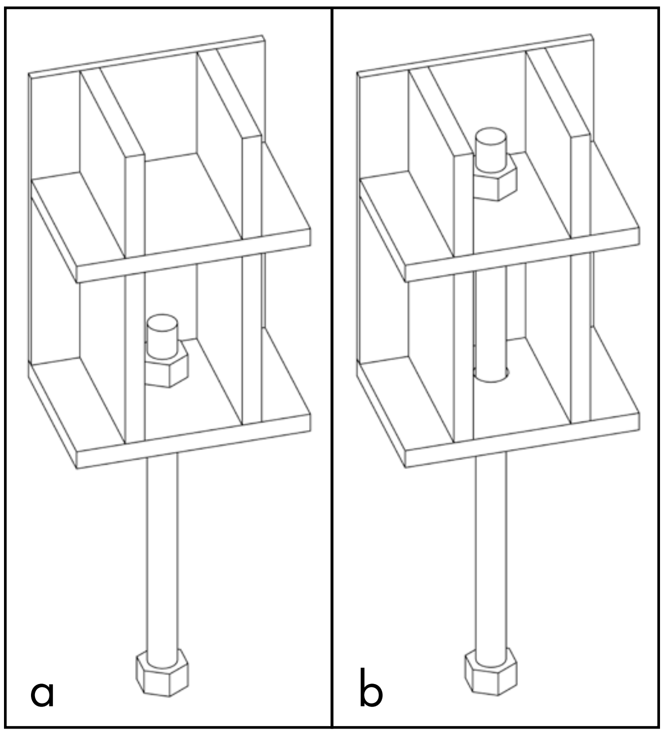

Fig. 1. Anchor bolt chairs: (a) conventional anchor bolt; (b) anchor bolt with stretch length.

Fig. 2. Single-anchor test setup.

details, as well as the scaled DSC in terms of load and displacement capacity.

Single-anchor tests

For this research, 19-millimeter-diameter ASTM F1554 Gr. 36 hex-headed anchor bolts were used. The 19-mm-diameter anchor bolts conform to both ACI 318-14 and ACI 349-13 standards [3, 4] and were chosen to provide an appropriately scaled anchor for the 1:2.5-scaled DSC. For an anchor bolt diameter of 19 mm, the 8D stretch length is 152 mm.

The design of the steel chair was performed according to the American Petroleum Institute standard 650 [5]. This is an allowable stress design, which produced a steel chair that remains elastic at full tensile strength of the anchor bolt. The design procedure resulted in a steel chair with 12.7-mm steel, except for the plate that is in contact with the DSC, which is 6.4 mm thick. A steel chair that yields before the full tensile strength of the anchor is reached was also built with 6.4-mm steel plates.

Twelve single-anchor tests were performed to evaluate four parameters: conventional and stretch-length bolts, and 6.4-mm and 12.7-mm chairs. Eight of these specimens were tested in monotonic shear, and the remaining four specimens were tested in cyclic shear. All tests were performed using a single hydraulic actuator that applied a horizontal load to the top 127 mm of the chair to simulate rotation under an overturning moment. Fig. 2 shows the test setup used for the single-anchor tests.

Single-anchor test results

Monotonic shear

The results for single-anchor monotonic shear tests are presented in Fig. 3. For clarity, only a single experiment per steel chair and anchor combination was chosen, as the results were consistent and repeatable. The specimen identification nomenclature in Fig. 3 is as follows: the first letter represents the anchor type tested (stretch-length anchor = S; conventional anchor = C); the second letter represents the loading type (monotonic = M; cyclic = C); and the number represents the plate thickness used for the steel chair in millimeters. Also, experiments that used 6.4-mm chairs have a solid line type, while experiments that used 12.7-mm chairs have a dashed line type.

As observed, stretch-length anchors and steel chairs intended to yield affect both lateral load and displacement capacity. By providing a stretch-length bolt, a yielding steel chair, or both, the load was reduced when compared to C-M-12.7, but the displacement capacity was increased. For the conventional anchor cases where failure is not obvious, system failure was taken at the point at which a 20 percent drop in lateral load had occurred. Using a conventional anchor and providing a steel chair that is

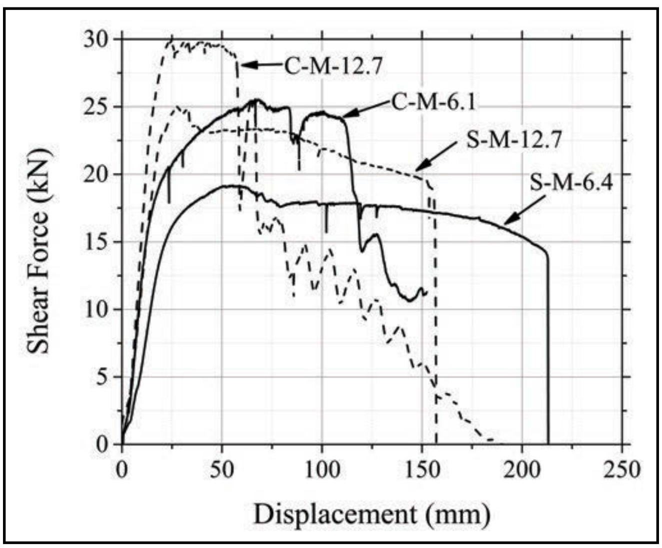

Fig. 3. Monotonic single-anchor test results.

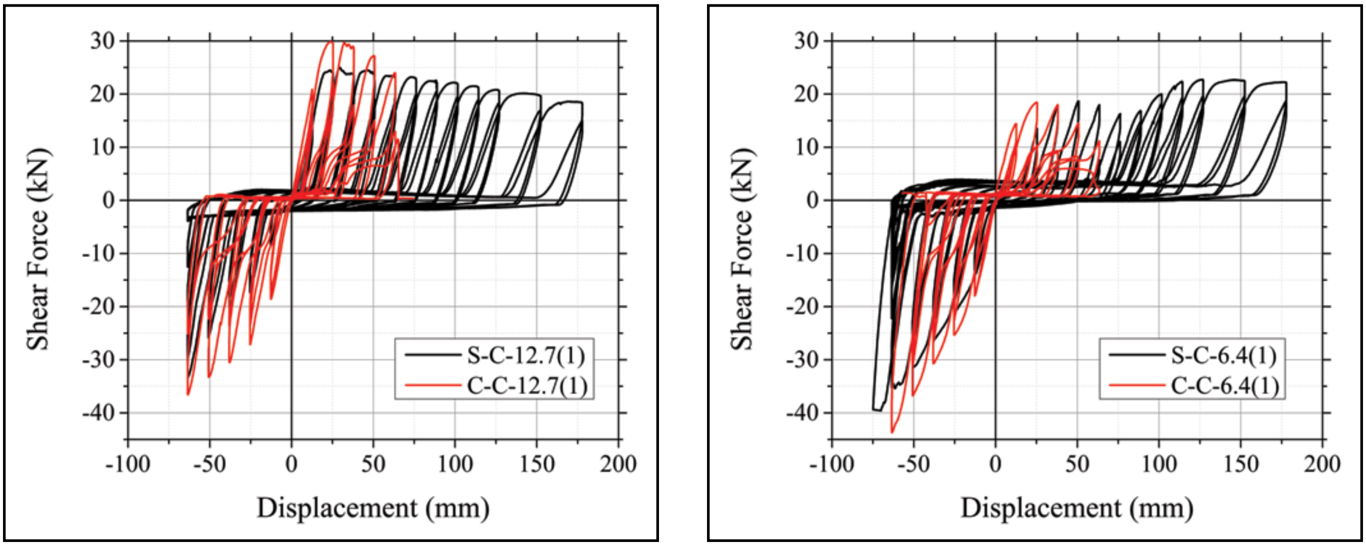

Fig. 4. Cyclic single-anchor test results: (left) 12.7-mm chair; (right) 6.4-mm chair.

allowed to yield (C-M-6.4), the load was reduced by 15 percent and the ultimate displacement was increased by 1.95 times that of C-M-12.7.

In contrast, when a stretch-length anchor is used along with a steel chair that remains elastic (S-M-12.7), the load is reduced by 15 percent, and the lateral displacement capacity is increased by 2.68 times that of C-M-12.7. This indicates that providing a bolt with a stretch length equivalent to 8D is more effective at increasing the component ductility than providing a steel chair that is anticipated to yield. When a stretch-length anchor is combined with the steel chair intended to yield (S-M-6.4), the load is reduced by 37 percent, and the greatest increase in lateral displacement capacity is achieved with an increase of 3.72 times that of C-M-12.7.

Cyclic shear

Results for single-anchor cyclic shear tests are presented in Fig. 4. Similar to the monotonic shear tests, it is clear that providing a stretch length substantially increases the assembly ductility; both stretch-length specimens reached a displacement of 178 mm without failure. Unlike the monotonic shear tests,

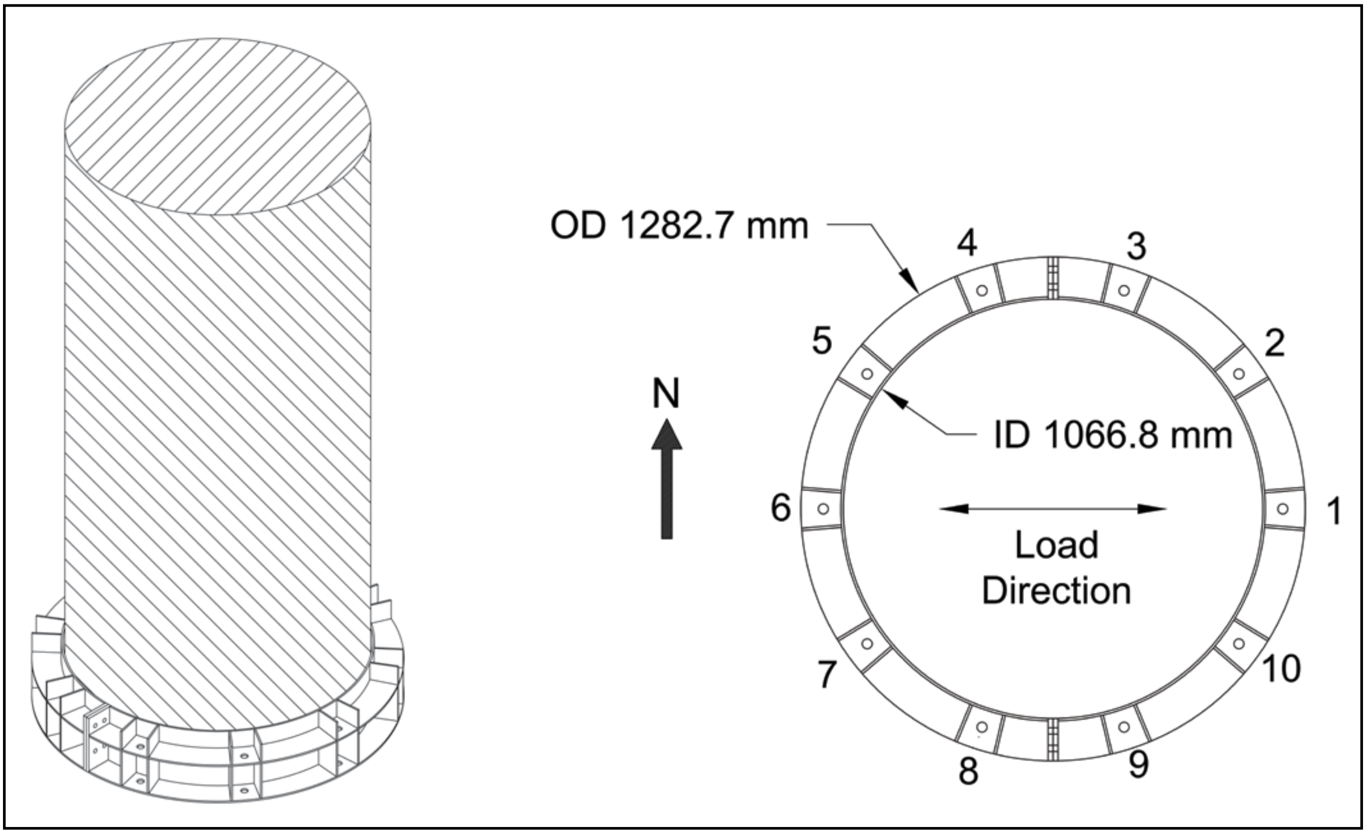

Fig. 5. Anchored cask: (left) clamp assembly with cask; (right) clamp assembly plan view.

providing a steel chair that yields did not produce a more ductile system for the conventional anchor case; failure of the anchor bolt occurred during the 64-mm displacement step for the 6.4-mm steel chair and the 76-mm displacement step for the 12.7-mm chair.

Anchored dry storage cask test

The single-anchor tests showed that combining stretch-length anchors with a steel chair intended to yield produces the most ductile anchorage system. For the 1:2.5-scale DSC, an anchorage system was developed that consisted of a steel clamp ring made up of 6.4-mm steel plates and bolts with a 152-mm stretch length.

To test the effectiveness of the ductile anchorage system, an anchored 1:2.5-scale DSC was tested under quasistatic displacements. The horizontal lateral load was applied at the mass centroidal height of the scaled DSC to represent the overturning moment from a seismic event. The scale DSC had a height of 240 centimeters and a diameter of 105.4 cm; the center of gravity of the DSC is 120 cm above the ground. The number of bolts was determined following anchorage requirements from both ACI 318-14 and ACI 349-13 and ensuring that the strength was governed by a ductile steel element, the anchor bolt. The design indicated that 10 anchor bolts could withstand the computed equivalent lateral load from a severe seismic event of 271 kilonewtons, based on the expected spectral accelerations of the DSC.

The final anchorage design is shown in Fig. 5, with the bolt numbering sequence and direction of loading. The inner diameter of the clamp ring was made slightly larger than the diameter of the DSC to allow easier installation; the inner diameter of the clamp ring was 106.7 cm, leaving a gap of 6.4 mm between the clamp ring and the DSC. This 6.4-mm gap was filled with a high-flow grout of a compressive strength equal to 87 megapascal on the day of the test.

The hysteretic response of the anchored DSC is shown in Fig. 6. Essentially, two different experiments were performed: (i) when grout was present in the gap between the clamp ring and cask, and (ii) when there was no grout in the gap. After the 63.5-mm displacement step, the grout in the gap between the DSC and the clamp ring began to pulverize, leaving a void where the grout once was. As the grout began to crush, a drop in lateral load was observed until the grout was pulverized, leaving a 6.4-mm gap between the clamp ring and the DSC. Once the grout was pulverized, a large lateral displacement was needed to wedge the DSC in the steel clamp ring. This occurred at a displacement of 114 mm as the load began to increase once more.

This response was unexpected, because instead of the DSC

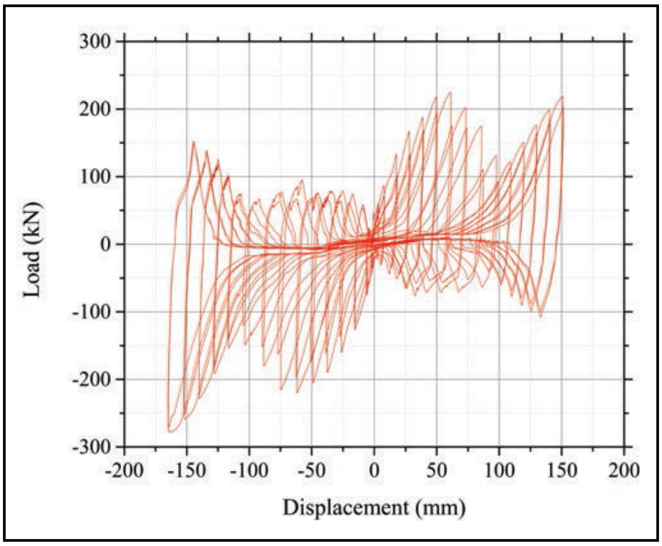

Fig. 6. Anchored DSC hysteretic response.

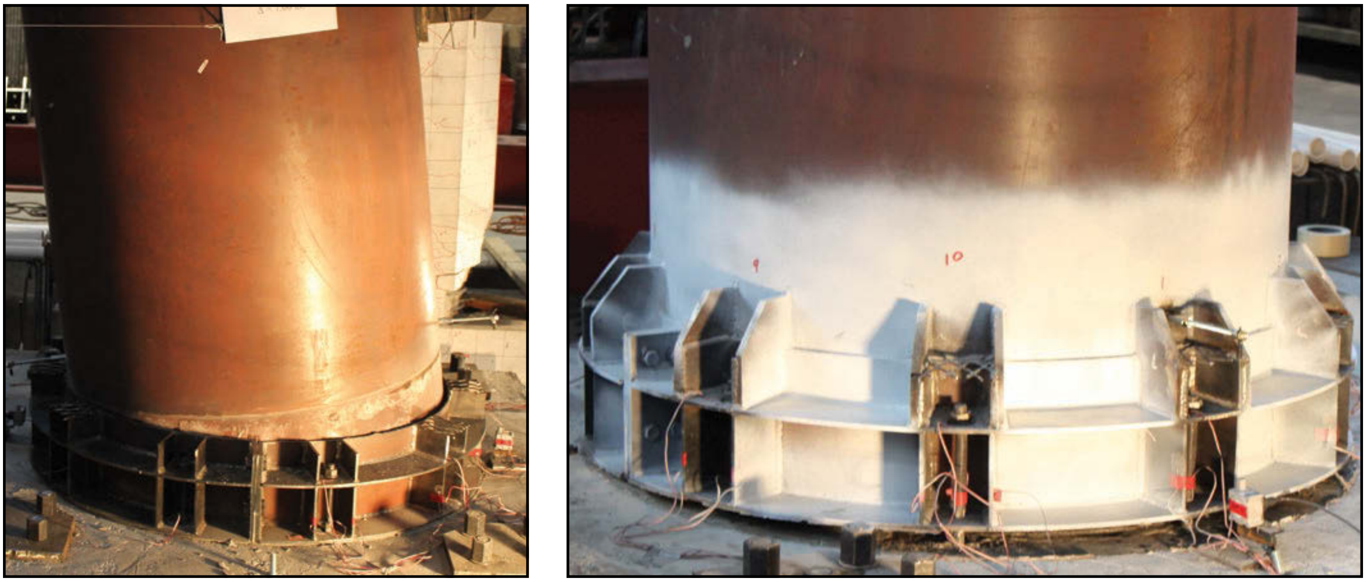

Fig. 7. Anchored DSC: (left) noncomposite action; (right) composite action.

and clamp ring showing composite action, the two components behaved independently as shown in Fig. 7; the cask was displaced 178 mm while the clamp ring remained stationary. Thus, the steel clamp ring successfully restrained the DSC from moving horizontally, but provided very little vertical restraint; the latter was due to friction between the DSC and the ring. After the 178-mm displacement step, the test was terminated. Due to the noncomposite performance of the system, it was determined that a retrofit of the ring design was needed to develop composite action.

Retrofitted dry storage cask anchorage

To ensure that the DSC and the clamp ring acted compositely, steel stiffeners were welded to the cask and all vertical top plates of the ring. This method is more representative of a newly constructed DSC, because existing casks cannot be welded. The retrofitted cask was retested quasistatically in the same manner as the original.

Testing showed that composite action between the DSC and ring was achieved. Fig. 8 shows the hysteretic response of the retrofitted anchored DSC, which is different from the previous experiment due to the composite action between the DSC and clamp ring. This is evident by the increased lateral load of 476 kN and the flag-shaped hysteretic response in Fig. 8. Composite action between the DSC and ring is also evident in Fig. 7, as no relative movement between the cask and the clamp ring was observed. The flag-shaped response is created due to the fact that the anchor bolts do not go into compression. As the rotation of the cask increases due to the overturning moment, the bolts begin to elongate in tension. Thus, once the maximum displacement is reached and the cask begins to move in the opposite direction, there is no resistance until the rotation of the cask is large enough to engage the nut of the bolts.

During the first cycle of the 63.5-mm displacement step, failure of the extreme east anchor bolt, bolt No. 1, occurred, as denoted by a green square in Fig. 8. In the second cycle of the 63.5-mm displacement step, bolts No. 2 and No. 10 failed almost simultaneously. This event is denoted by a green circle in Fig. 8. Failure of these bolts resulted in a lateral load capacity drop greater than 20 percent. Inspection of the DSC after testing

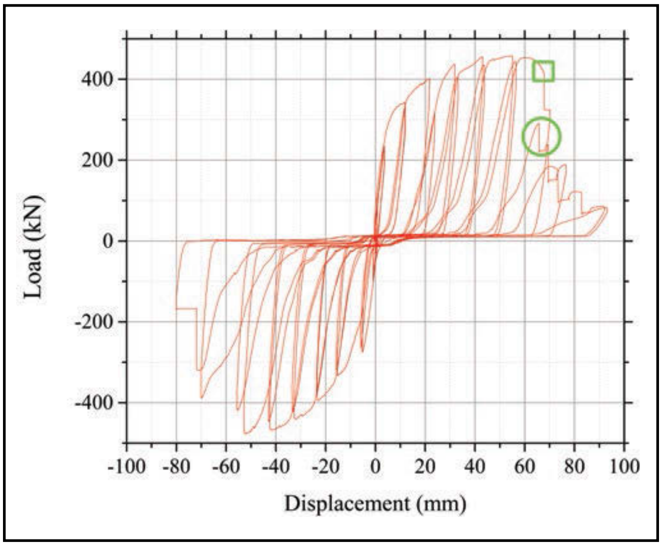

Fig. 8. Anchored DSC retrofit hysteretic response.

showed no damage, while the clamp ring showed severe structural damage. Damage to the clamp ring included buckling of the vertical side plates at bolts No. 1 and No. 6, along with top-plate yielding at all bolt locations.

The hysteretic response and the test observations show that providing anchors with a stretch length of 8D along with steel chairs intended to yield produces a ductile performance while retaining the cask in both the horizontal and vertical directions.

Conclusions

Twelve single-anchor tests were performed with eight specimens undergoing monotonic shear and four specimens undergoing cyclic shear. From the single-anchor shear tests it was found that by providing a stretch-length anchor and/or a steel chair that is allowed to yield, an increase in the displacement capacity can be achieved. When compared with a typical anchorage system, C-M-12.7, the displacement capacity can be increased by 1.95 times when the steel chair is designed to yield; by 2.68 times when a stretch length of 8D is used with a steel chair that remains elastic; and by 3.72 times when a stretch-length anchor is combined with steel chair designed to yield.

The DSC was anchored with bolts having a stretch length of 8D and a steel clamp ring allowed to yield. The results of the DSC test showed that the anchorage system worked well at restraining the cask in the horizontal direction. However, it provided very little resistance in the vertical direction due to lack of composite action between the DSC and steel clamp ring. A retrofit of the steel ring was carried out to ensure composite action, and the anchorage system was re-tested. The results of the retrofitted anchored cask showed good composite action between the steel ring and the DSC, which produced an anchorage system that exhibited a ductile performance while restraining the cask in both the horizontal and vertical directions.

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Nuclear fuel cycles in the U.K.

Moving from a closed to open fuel cycle within the United Kingdom while keeping future fuel cycle options open.

By Fiona Rayment

Nuclear energy is a mature, reliable, low-carbon technology with a secure and abundant fuel source and is an essential contributor to the energy mix. In the early years of nuclear energy development, up to the 1980s, a fully closed fuel cycle in which uranium and plutonium were separated from used nuclear fuel for recycling as new fuel into fast reactors was pursued internationally as the optimum solution.

The decrease in the growth of nuclear energy, however, coupled with the availability of cheap gas and the slower-than-expected development of commercial-scale fast reactors led to widespread doubts about the benefits of closing the fuel cycle. By the 2000s, the only countries with commercial-scale reprocessing plants treating used fuel were the United Kingdom, Russia, and France (with Japan at that time undergoing commissioning of a reprocessing facility). Without fast reactors, separated plutonium is either being recycled as (U,Pu) mixed oxide (MOX) fuel in thermal reactors (most successfully in France) or stored pending decisions regarding future disposition.

Within the U.K., nuclear power has provided around 20 percent of the energy mix for decades through, initially, a Magnox and, latterly, an advanced gas-cooled reactor (AGR) fleet of nuclear power plants. Throughout this period from the 1960s to present day, a partially closed fuel cycle had been operated where the used fuel from the Magnox and AGR reactors was reprocessed at facilities at the Sellafield nuclear site to recover valuable uranium and plutonium fuel. Although the U.K. also has one operating pressurized water reactor plant, with much of the existing fleet coming off line in the next decade or so, a decision has been made to retain a significant component of nuclear energy within the generating mix through (at least)

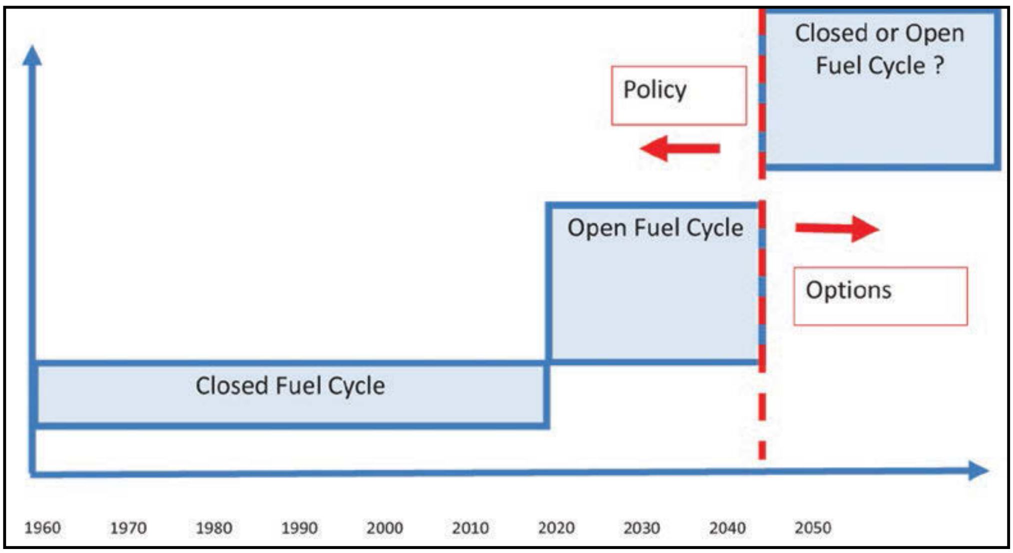

Fig. 1. U.K.: past, present, and future.

Right: A National Nuclear Laboratory technologist works in the Plutonium and Minor Actinides (PuMA) lab at NNL's Central Laboratory at Sellafield. The PuMA facility is used for actinide science and separations research and development.

replacement of the existing nuclear fleet. This will mean the building of new nuclear power plants to ensure energy production of an additional 16 GWe by the end of the next decade.

This new fleet, consisting of EPR (European Pressurized Reactor), ABWR (advanced boiling water reactor), and AP1000 reactors will not follow the closed fuel cycle of the past, and instead will follow an open cycle where used fuel will be stored for a period of time once out of the reactor followed by final disposal in a geological disposal facility (GDF).

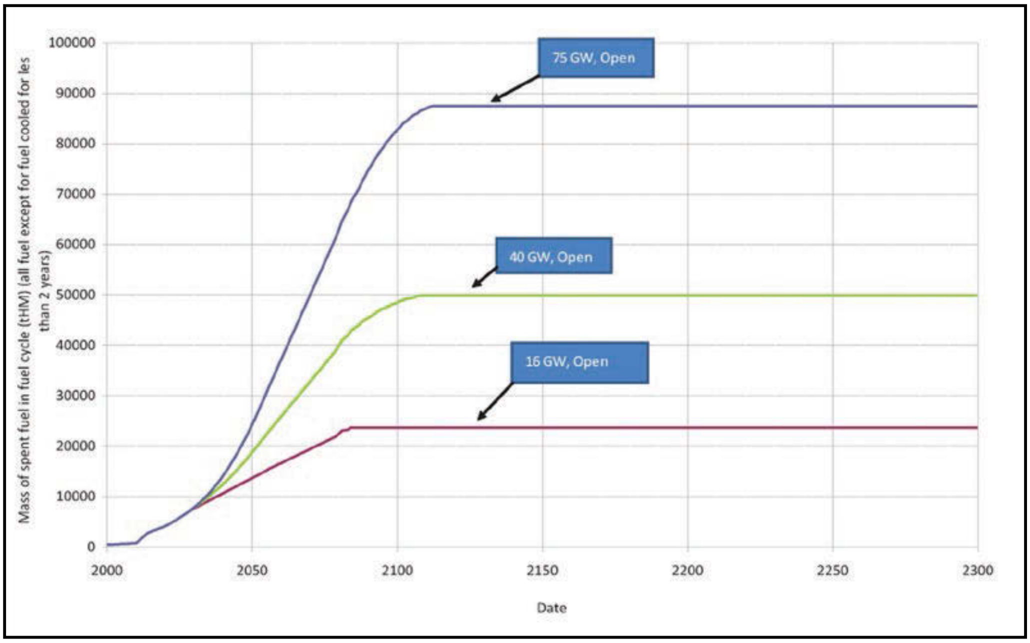

Fig. 2. Predictions of total U.K. spent nuclear fuel inventory at 16, 40, and 75 GWe open cycle using ORION.

Following closure of the THORP (Thermal Oxide Reprocessing Plant) and Magnox reprocessing plants in 2020, approximately 7,700 metric tons (t) of used fuel are planned for disposal in a GDF. A further 23,500 t of fuel will be generated through the planned new build program in the U.K.

In addition to this, consideration is also being given to the most effective method for disposition of the current U.K. plutonium stockpile. This has been generated through decades of reprocessing operations with a prior intent for use in a future fast-reactor program. Options being considered are reuse as MOX in light water reactors (reference case), reuse as MOX in Candu-6 technology, reuse within PRISM technology, or immobilization.

It is also recognized that providing 16 GWe of capacity through a new build program may not be enough for the U.K., and as such expansion scenarios ranging from 16 GWe to 75 GWe nuclear energy production are being considered through the development of a U.K. roadmap. This roadmap will explore a variety of energy scenarios and options, but it should be noted that the deciding factor on the type and mix of any energy program will not be made on technology choice alone. Instead, the rate and direction of growth of any future energy program will depend on a complex mix of U.K. government policy, relative economics of nuclear power and other technologies, market decisions, public opinion, and of course, technology choice.

The U.K. pathway to an advanced, closed fuel cycle would necessarily include and begin with the current plans for 16 GWe of new nuclear build capacity on an open fuel cycle basis by the end of the next decade. Through these expansion studies, a number of power-generation and associated fuel-cycle options will be considered. This includes open and closed (partial and fully) fuel cycles and a variety of reactor technologies, including expansion of existing light water reactor capability, introduction of fast reactors, and the use of smaller modular reactor technology in combination with larger power plants. The bounding case for this pathway involves the construction of a series of fast reactor units with a combined installed capacity of up to 75 GWe by the middle of the 21st century, operating a closed fuel cycle involving the reprocessing of fast-reactor used fuels and multiple recycling of plutonium.

For open cycles, the key benefits can be summarized in terms of enhanced economics of the system, especially over shorter timeframes (60 years), and enhanced proliferation resistance, although this is subject to much debate at an international level. Within the U.K., however, the associated management of the used fuel inventory in an open cycle becomes more challenging with the higher energy scenarios (50,000 t and 100,000 t).

As such, closed nuclear fuel cycles could offer a potential solution to deal with large volumes of used fuel together with optimizing the sustainability of nuclear energy for decades to come. To achieve this, however, further advances will be required in reprocessing technologies that are more economical, generate less wastes, and offer greater proliferation resistance than traditional PUREX reprocessing technology.

This is also the case globally, where the renewed interest in nuclear energy as a safe, secure, low-carbon energy source has led to further research into optimizing the whole fuel cycle. For instance, the Generation IV Forum objectives include enhanced safety and sustainability of nuclear electricity generation. Furthermore, it should be noted that although the current global preference is for an open cycle, with continued reprocessing in France plus the growth in nuclear energy in Russia, China, and India, by 2050 advanced closed cycles may become the preferred choice for several nations once more.

For the U.K.'s future energy choices, the topic of an open versus a closed fuel cycle is one for continued debate but will depend on the energy required to be generated from nuclear, GDF availability, the reactor technologies of choice, and the economics of the system chosen. Whatever option or options might be chosen, however, further research will be required to understand the perceived benefits of open and closed (fully and partially) cycles. ■

Fiona Rayment is the director for fuel cycle solutions within the United Kingdom's National Nuclear Laboratory, covering technology developments in advanced fuels, spent fuel management, asset care, safety, security, and safeguards.

This article is based on a paper presented at the 2015 American Nuclear Society Winter Meeting and Expo, held Nov. 8-12 in Washington, D.C.

R&D Progress on Recovery/Recycle of Zirconium from Used Fuel Cladding[1]

By Emory D. Collins, Guillermo Daniel DelCul, Barry B. Spencer, Jared A. Johnson, Ronald R. Brunson, and Rodney D. Hunt

A dry chlorination process for the recovery and purification of zirconium from UNF cladding is being developed at ORNL.

After uranium, the second largest mass contained in most used nuclear fuel (UNF) is the zirconium in the fuel cladding, commonly accounting for about 25 percent of the mass. In current practice, the cladding requires disposal in a geologic repository. Process development studies are being conducted to recover, decontaminate, and possibly recycle the valuable hafnium-free zirconium while keeping costs of the recovery process below those for current compaction treatment and disposal. The recovered product must contain lowered impurity concentrations that would allow disposal as low-level radioactive waste or would be inconsequential to use in future nuclear applications, recognizing that the recovered zirconium will inherently contain Zr-93 (half-life = 1.5 million years and a weak beta radiation emitter). Radioactive impurities include uranium, transuranium elements, fission products, and activation products other than Zr-93. Chemical impurities include tin, niobium, iron, nickel, chromium, nitrogen, oxygen, and carbon.

Significant progress has been accomplished at Oak Ridge National Laboratory (ORNL) on the development of a dry chlorination process for recovery and purification of zirconium from UNF cladding by conversion to zirconium tetrachloride, which sublimes to a vapor and is then condensed as a dry salt product, essentially free of fuel and alloy components (impurities). The current laboratory testing design is shown in Fig. 1.

Development and testing

Both nonradioactive process development tests and radioactive feasibility tests with actual UNF cladding hulls or fuel rods have been made to determine optimum processing conditions, equipment design, and configuration of the batch chlorination reactor and condenser (gas up flow, down flow, and horizontal flow). Radioactive and nonradioactive impurities that are present in the zirconium tetrachloride salt product have also been determined.

Heating is initially required to raise the cladding temperature to the chlorination reaction temperature of 350–400 °C. The reaction is highly exothermic, so once the reaction is initiated, cooling is required to remove the heat of reaction. The operating procedure has been to first heat the cladding hulls or fuel rods to operating temperature under a stream of argon gas to dry the system, and then to introduce the chlorine gas at a controlled flow rate as necessary to limit the reaction rate and exothermic heat evolution to effectively control the reaction temperature at the desired level.

Feasibility tests with actual UNF have demonstrated that impurities can be removed from UNF cladding in a process that produces recovered zirconium that can be handled without shielding or significant dose [1, 2]. However, the feasibility tests with actual UNF cladding also showed that the presence of an apparent oxide layer on the cladding surface can cause an initial incubation period in the reaction of chlorine with the zirconium. A series of nonradioactive tests were made to determine, quantitatively, the reduction of chlorination rate due to the thickness of an anhydrous layer of zirconium oxide, which had been applied as a result of prior oxidation in air at 600 °C for varying lengths of time. Various treatments of the oxidized cladding to mitigate the reduced chlorination reaction rate were tested and included various pre-washings with acidic or alkaline liquids or by dry treatment at elevated temperatures with argon gas saturated with carbon tetrachloride.

Further studies of the chlorination were performed to determine the effects of reactor temperature and chlorine concentration on the reaction rate. Finally, a series of tests were completed to determine the effects of increasing the amount of cladding from 15 to 500 grams per batch and to determine the heat removal requirements due to the exothermic heat of reaction in order to maintain the reactor temperature in the range of 350-400 °C. In addition, product purification needs were assessed to determine experimental and analytical needs for future process development. For these studies, the glassware configuration included a horizontal reactor and a vertical condenser (Fig. 1). The glass reactor was designed and built to fit a horizontal clamshell furnace, thus enabling visual observation of zirconium alloy cladding tubes during chlorination. The vertical condenser was modified to include rotating blades to prevent the condensed $ZrCl_4$ salt powder from collecting on the walls of the condenser and to promote movement into the collection bottle.

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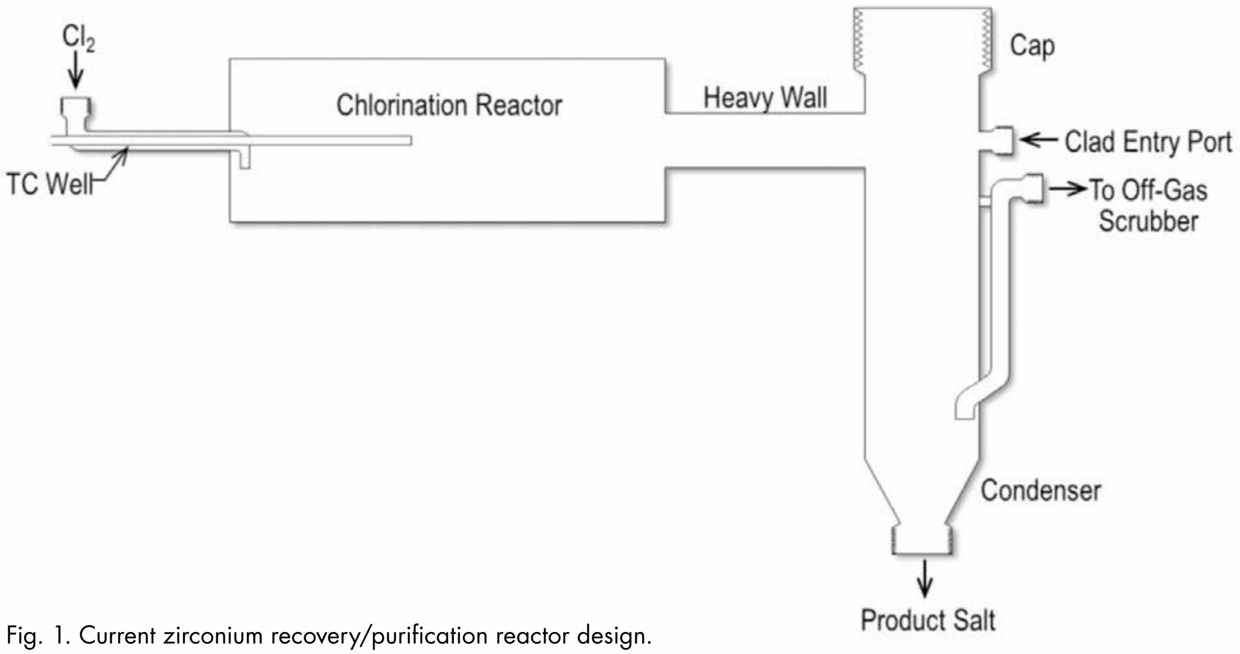

Fig. 1. Current zirconium recovery/purification reactor design.

Glassware equipment was used for all preliminary tests of the process, including those made to scale up the process from approximately 15 g/batch to 500 g/batch, the latter producing more than 1 kilogram of zirconium salt per batch. Metal equipment, primarily nickel-plated or high-nickel-content stainless steel, was built for radioactive tests with actual UNF at 100–500 g of cladding per test. The metal equipment has undergone initial testing with unirradiated Zircaloy cladding in preparation for the larger-scale demonstration of the process in a hot cell environment. Fig. 2 illustrates a potential flow sheet for hot-cell application in which the condenser, trapping system, and off-gas handling are outside of the shielded area with only the reaction vessel requiring shielding.

Results

The feasibility tests with actual UNF cladding showed that a $ZrCl_4$ product salt can be obtained with very little radioactive impurities and without the need for shielding to handle the product. Product analyses have indicated that 10 CFR 61.55 limits for low-level radioactive waste can be met, thus making disposal of the product salt as low-level waste acceptable should that option prove the most cost effective. However, the feasibility tests were made with UNF that had a relatively low burnup and a long cooling period. Future tests with higher-burnup UNF and shorter cooling periods are planned.

The major radioactive material in UNF cladding is cesium-137.

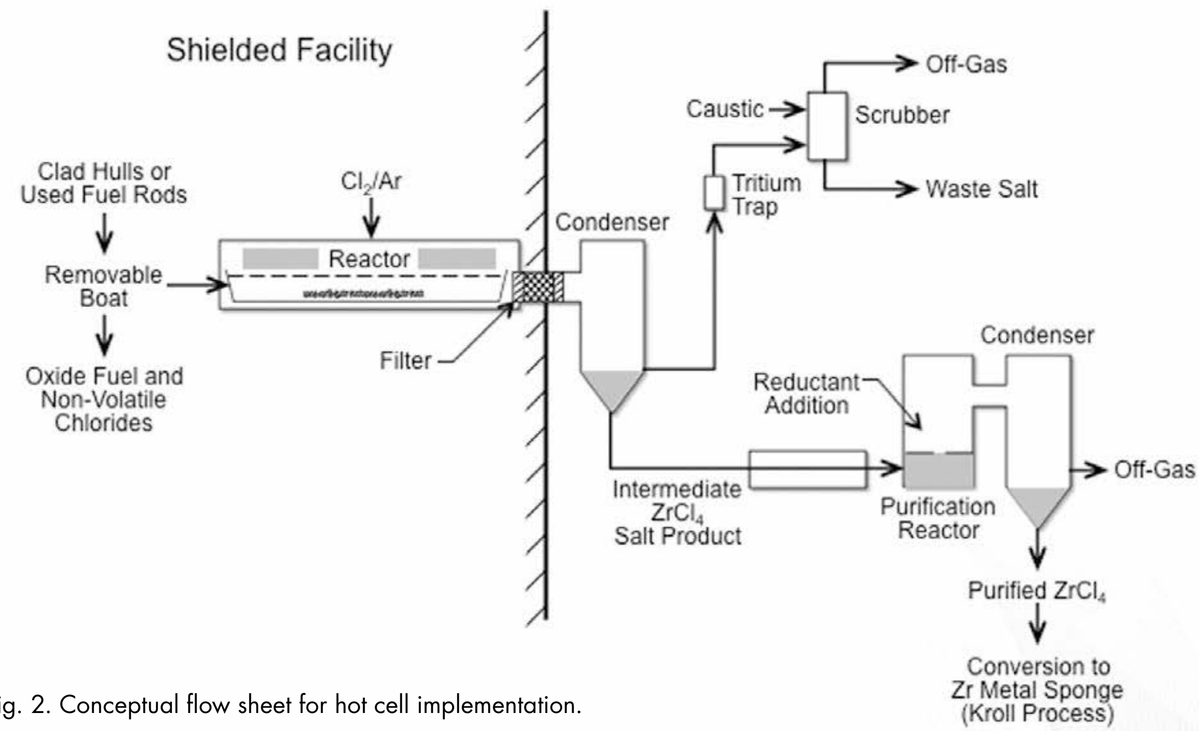

Fig. 2. Conceptual flow sheet for hot cell implementation.

All indications of test results have been that cesium is not volatized during the chlorination of zirconium and volatilization of $ZrCl_4$. The degree of decontamination of the product salt appears to depend on effective filtration of the gaseous $ZrCl_4$ to capture entrained particulates contaminated with nuclides, such as Cs-137.

Process development tests have shown that average chlorination reaction rates of about 30 percent per hour, based on the initial reactor clad loading, can be achieved if adequate cooling capacity can be designed into the chlorination reactor and if the zirconium oxide layer is effectively removed. Tests performed with glassware and 500 g of cladding per batch did not have adequate cooling; however, average reaction rates were still acceptable (about 10 percent per hour).

Tests with nonradioactive Zircaloy have indicated that the tin, iron, and niobium alloying components found in fuel cladding can form volatile species that accompany the $ZrCl_4$ product. The radioactive Nb-94 activation product in UNF cladding may be a concern in higher-burnup UNF cladding; also antimony-125 in shorter-cooled UNF cladding may be a concern. Therefore, the current flow sheet (Fig. 2) indicates the need for a purification step for the product $ZrCl_4$ salt, and process development tests have begun to determine effective means for purification. Two university teams have been funded by the U.S. Department of Energy's Nuclear Energy University Program to study alternative methods of $ZrCl_4$ salt purification in collaboration with the current lead effort at ORNL.

Conclusions

Significant progress has been accomplished on developing a chlorination process for removing the zirconium in UNF cladding and purifying the product salt for reuse, possibly in the manufacture of new cladding, or at a minimum to meet specifications for disposal as low-level radioactive waste. Either end point will allow a significant economic advantage, since costly disposal by means of emplacement in a geologic repository will not be required. Currently, the UNF cladding from industrial-scale reprocessing of UNF represents essentially the same volume of waste requiring geologic emplacement as that from the high-level radioactive waste fission products, so a volume reduction of 50 percent is possible.

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Borehole disposal of LLW

In Zagreb, Croatia, IAEA nuclear engineers have been testing a method of disposing of low-level radioactive sealed sources in boreholes.

Using nonradioactive materials, the International Atomic Energy Agency late last year tested the proof of concept for what it calls a promising technology for moving and storing low-level radioactive sealed sources. The testing was conducted in Croatia and may pave the way for dealing with small volumes of radioactive waste around the world by disposing of sealed radioactive sources in narrow boreholes a few hundred meters deep.

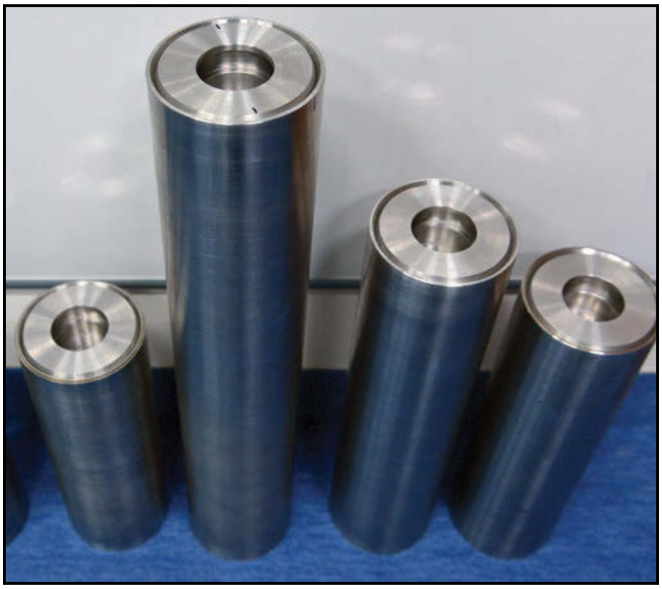
Above: A group of IAEA nuclear engineers test a transfer cask designed for borehole disposal in Zagreb, Croatia, in November 2015. The IAEA is developing a new method for the disposal of low-level radioactive waste as a safe, practical, and secure solution to the disposal of radioactive sources, a problem many countries face. (Photos courtesy of Laura Gil Martinez and Dean Calma/IAEA)

While the use of radioactive sources in health care, industry, and other sectors is common worldwide, many countries do not have the equipment or staff needed to deal with the sources once they are no longer usable. Under typical circumstances, a developing country using sealed radioactive sources may generate hundreds of disused sources with low levels of radioactivity over several years, according to IAEA estimates.

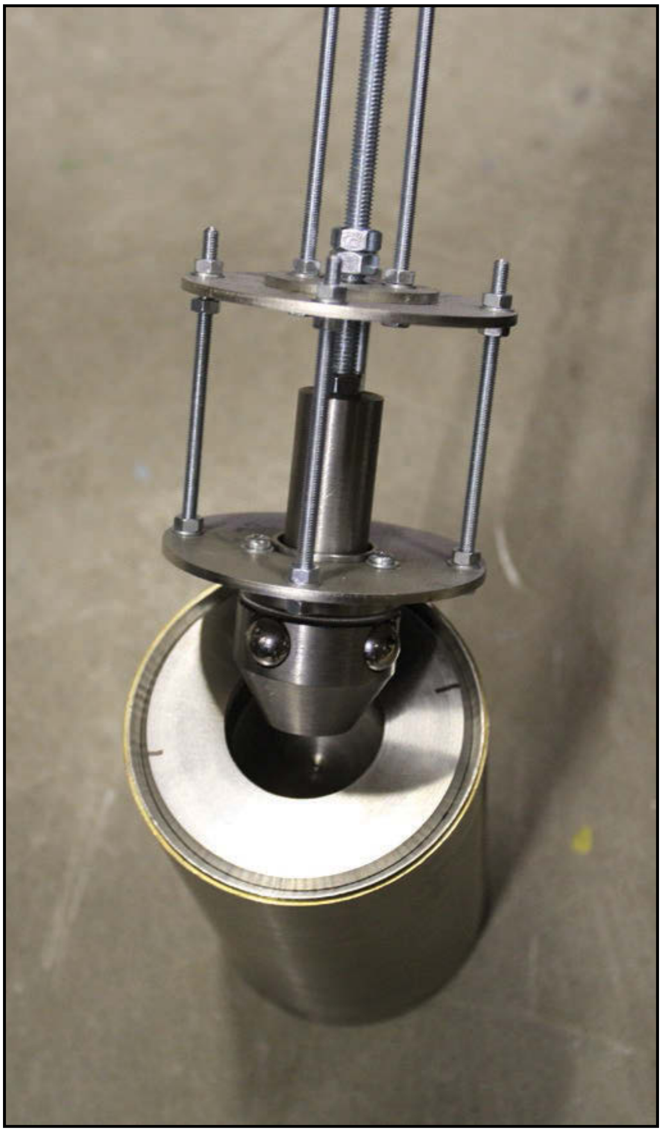
In most developing countries, sealed radioactive sources are stored temporarily. Some developed countries have disposal facilities close to the surface. Both of these options pose a security risk if the sources are not sufficiently protected. According to the IAEA, the new disposal method represents a long-term solution to this problem that will ultimately help protect people and the environment.

The IAEA has said that equipment tests conducted by its

Before disposal, all sources are treated and repackaged through a process called conditioning. Once the borehole is in place, the conditioned sources will be loaded into a specially designed canister, or disposal package, which is then sealed.



The sealed canisters that will be planted in the borehole have different sizes, depending on the dimensions of the sources they will contain.



A simplified dummy grabber was designed and produced for the test. This is a temporary tool that will be further developed.

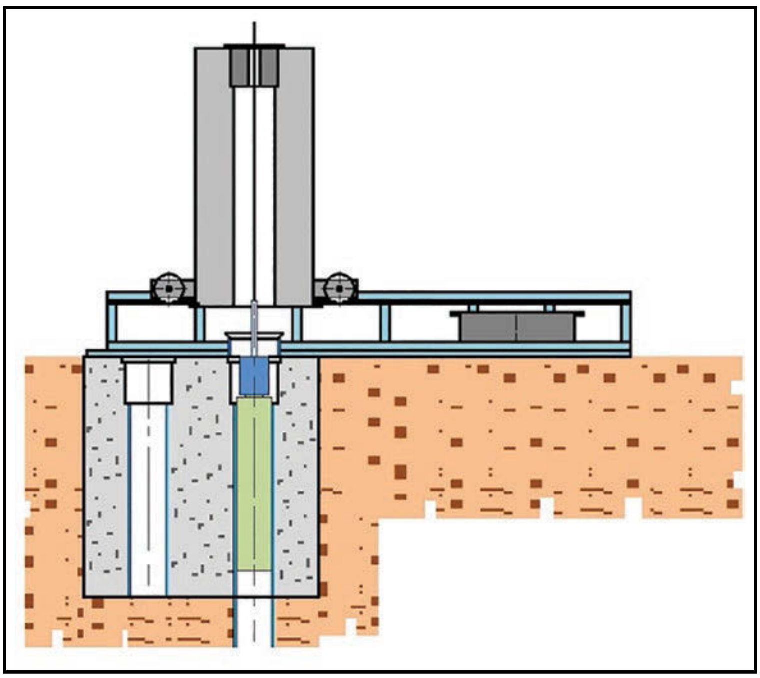
The dummy tool was used to grab the canister, which in real operation would be loaded with low-activity sources. The tool is used to lift and insert the canister into the top of the transfer cask.

Engineers remove the bottom shield of the transfer cask during the test, so that they could place it over the borehole.

After moving the transfer cask over the mock borehole, the disposal canister is lowered down into the transfer cask with a cable.

The borehole itself is a narrow hole drilled directly from the surface. The technology to drill it is similar to that used to extract water and is widely available in most countries.

engineers and a Croatian radiation protection company have confirmed the feasibility of the borehole disposal system. The tested technology, developed for disused sources with low levels of radioactivity, relies on a robust metal platform and a mobile transfer cask, which is used to move the sources into the borehole safely.



A robust metal platform is required to lower low-activity sources into the borehole.

"It's simple, affordable, and can be deployed worldwide," said Janos Balla, a waste technology engineer at the IAEA.

Before disposal, all sources are treated and repackaged through a conditioning process, which is designed to slow the release of radionuclides from the disposed waste package into the environment. When prepared according to this method for disposal, hundreds of sources—the typical amount generated by a developing country each year—take up less than a cubic meter, the size of a small wardrobe.

Once the borehole is in place, the conditioned sources will be loaded into a specially designed canister, or disposal package, which is then sealed. The sealed canister will then be placed inside the transfer cask and moved over, and eventually into, the borehole.

According to the IAEA, increasing nuclear security is an important driver behind the development of the new method.

"Given that disused sources remain radioactive, we want to limit the probability of these being reached and used for terrorist activities," said Gert Liebenberg, a nuclear security officer at the IAEA. "Once in the borehole, they are no longer easily accessible to anyone."

The original borehole idea was developed by the South African Nuclear Energy Corporation, and subsequently adapted by the IAEA to incorporate the disposal of sources with higher levels of radioactivity. The IAEA said it is ready to train experts in countries interested in using the borehole disposal method and provide them with the necessary assistance, either equipment or technical specifications, to build their own transfer cask. The technology to drill the hole is similar to that used to extract water and is widely available in most countries, including less developed ones. ■

Removing Hanford's Environmental Contaminants

A worker drains a pipe that contains liquid chromium that was added to cooling water used in Hanford reactors to prevent corrosion. DOE contractor WCH completed cleanup of chromium contamination at the Hanford Site in 2015. (Photos courtesy of the DOE.)

Remediation work at Hanford progressed in 2015, with contractors removing 2 million tons of chromium-contaminated soil and treating 2.4 billion gallons of groundwater.

WCH workers excavate soil contaminated with chromium down to 85 feet below the surface near Hanford's D and DR Reactors.

As environmental remediation work continues at the Hanford Site near Richland, Wash., the Department of Energy announced in November 2015 that it has completed chromium cleanup along the Columbia River, which runs through the nuclear reservation.

According to the DOE, more than 2 million tons of chromium-contaminated soil has been moved away from several areas near the Columbia River. Under the direction of the DOE's Richland Operations Office, contractor Washington Closure Hanford (WCH) excavated chromium-contaminated soil from a set of waste sites, disposed of the contaminated soil, and backfilled the waste sites with clean soil. Work is now ongoing to restore the sites with native vegetation.

The work is part of the DOE's $2.9 billion River Corridor Closure Project. The 220-square-mile River Corridor was home to Hanford's plutonium production reactors and fuel development facilities, along with hundreds of support structures that operated during the Manhattan Project and Cold War eras.

The contaminated soil contained an estimated total of 129 tons of concentrated chromium chemical from the B, C, D, F, and H Reactor areas. The chromium-contaminated soil was transported, treated when necessary to meet disposal facility requirements, and disposed at the Environmental Restoration Disposal Facility, Hanford's onsite, regulated disposal facility for low-level radioactive, hazardous, and mixed wastes.

"Removing the source of contamination is a critical step in protecting groundwater, and removing chromium while it is in the soil will significantly reduce the amount of time that our groundwater pump-and-treat facilities are operated," said Mark French, the DOE's federal project director for the River Corridor.

Recently, workers near Hanford's D and DR Reactor areas completed remediation of the largest source of chromium

Soil contaminated with concentrated chromium is treated before disposal in a regulated disposal facility on the Hanford Site.

After backfilling the chromium sites near Hanford's B and C Reactors, WCH workers contoured and revegetated the area with native grasses and plants.

The 200 West Pump and Treat System is one of six pump-and-treat systems at the Hanford Site. Last year, DOE contractors treated 2.4 billion gallons of groundwater.

The 200 West Pump and Treat System treats eight contaminants of concern.

contamination near the Columbia River. The work involved digging down 85 feet to groundwater at three waste sites: D-100, D-30, and D-104. The dig sites, because of their size, were engineered like open pit mines. The D-100 site covered the area of more than seven-and-a-half football fields at ground surface and about one football field at the bottom.

"Removing the chromium contamination keeps it from being driven into the groundwater by rain and snow and is a major success for protecting the river and groundwater from future contamination," said Rob Cantwell, WCH director of closure operations. "We take a lot of pride in knowing we are protecting the environment and the contamination is no longer a threat to the Columbia River."

Groundwater treatment

The DOE also announced in late 2015 that it has treated a record amount of groundwater to remove contamination in the last year. For the 2015 fiscal year, which began in October 2014 and runs through September 2015, Hanford workers processed 2.4 billion gallons of groundwater through the site's groundwater treatment facilities.

Six pump-and-treat systems treat groundwater at Hanford by pumping groundwater up through wells and treating it to remove contaminants, before the water is reinjected into the ground. The groundwater contamination resulted from operations to produce plutonium from the 1940s through the end of the 1980s.

According to the DOE, the department set a goal for contractor CH2M Hill Plateau Remediation Company (CH2M) to treat 2.1 billion gal by the end of FY 2015. CH2M met this key performance goal more than a month ahead of schedule in mid-August and removed more than 75 t of contaminants from groundwater during the year.

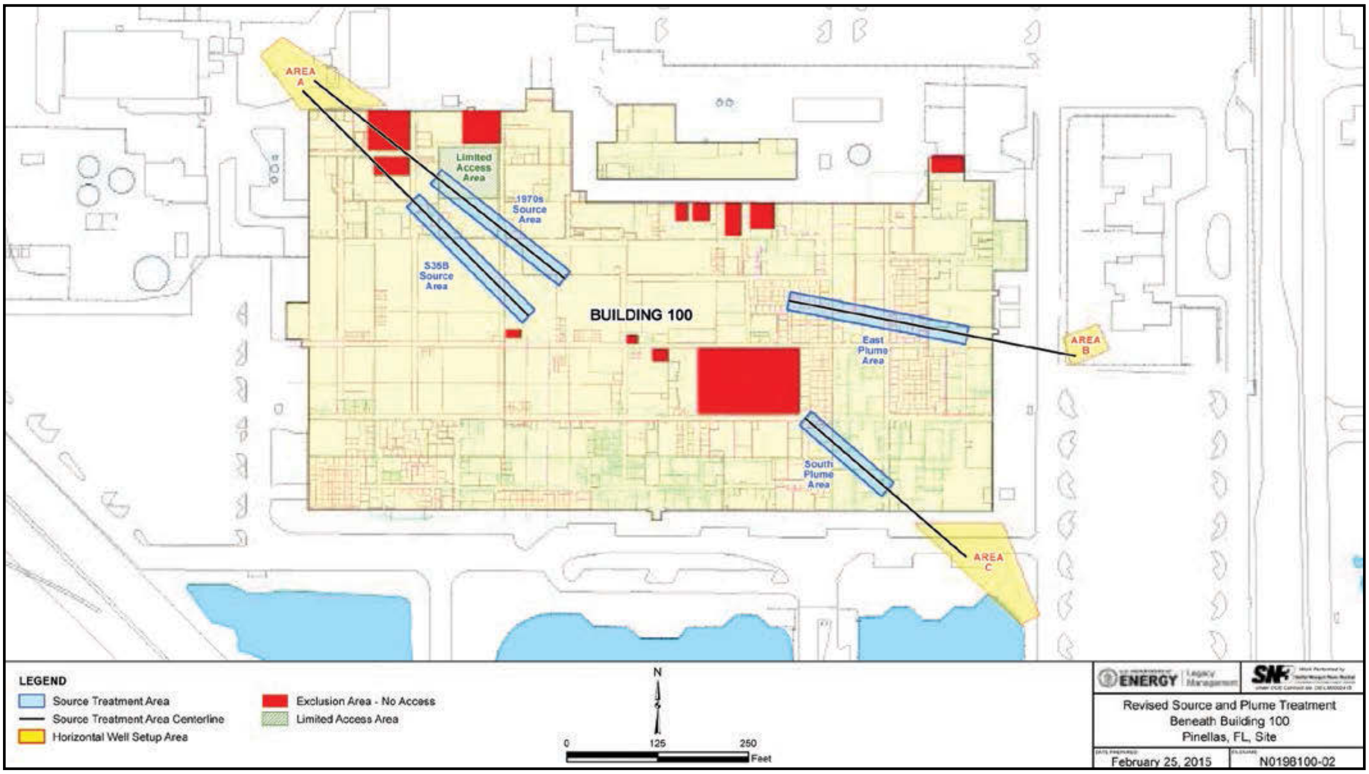
"We're treating more groundwater and removing more contamination than any year in the past two decades of cleanup," said Michael Cline, director of the soil and groundwater division with the DOE Richland Operations Office. "Not only are we treating more groundwater each year, we're also removing more contamination and expanding the area we're pumping from to remove contamination."

"Our groundwater treatment programs are designed to protect the river, by slowing the spread of contamination near the river and preventing contamination in the center of the Hanford Site from making its way to the river," said Karen Wiemelt, vice president of soil and groundwater remediation for CH2M.

CH2M also exceeded last year's treatment record of 1.9 billion gal. To date, Hanford contractors have treated more than 13 billion gal of groundwater and removed more than 200 t of contaminants, including nitrate, carbon tetrachloride, hexavalent chromium, uranium, and technetium-99.

"We continue to find innovative ways to increase treatment capacity," said Wiemelt. "As a whole, our systems are operating at about 113 percent of their designed capacity, and with several upgrades we'll finish this year, that number will be even higher."

Since 2009, CH2M has more than quadrupled the groundwater treatment capacity at the Hanford Site, from 500 million gal a year to 2.1 billion gal a year, according to the DOE. ■



Treatment area locations beneath Building 100.

Bioremediation at Pinellas

In an effort to clean up plumes of contaminated groundwater, horizontal wells have been employed at the Pinellas Site in Florida.

Operations to develop and manufacture components at the former Pinellas Plant in Florida during the nation's Cold War–era nuclear weapons program released solvents to subsurface soils beneath the plant's 11-acre Building 100. Release areas became sources of dissolved contamination, creating groundwater plumes that extended south and east from the source areas beneath Building 100 and onto private property.

After the Cold War ended, the plant was closed and the site was redeveloped for economic use. However, the contaminated groundwater plumes remained. Today, the U.S. Department of Energy Office of Legacy Management (LM) continues environmental restoration at the site, which is now known as the Young-Rainey Science, Technology, and Research (STAR) Center.

Bioremediation proved to be a successful approach to cleaning up two other STAR Center areas in the past, and so enhanced bioremediation was chosen to treat the chlorinated-solvent source areas and groundwater plumes beneath Building 100. The remediation method used a concentrated solution of emulsified vegetable oil (EVO) and bacteria (*Dehalococcoides mccartyi,* or DHM), diluted with water prior to injection to maximize its subsurface distribution. Once introduced into the subsurface, the bioremediation mixture fermented and produced dissolved hydrogen, which the DHM used to break the bonds on contaminant molecules, resulting in nontoxic end products.

Building 100 is owned by Pinellas County and fully occupied by tenants, so remedial action could not be conducted from inside the building. The best option for implementing enhanced bioremediation beneath the building was to install injection wells via directional drilling, in a horizontal configuration. Also, remediation work was performed during the building's second shift time frame to minimize disruptions to tenant activities.

In July, August, and September 2015, eight horizontal wells were installed (as deep and shallow pairs) to target the deep and shallow aquifer portions beneath Building 100 (see site map, above). Installation depths ranged from 13 to 32 feet below the surface. Horizontal well lengths ranged from 350 to 470 ft, and the slotted sections of each well ranged from 150 to 250 ft. The slot size and spacing (0.013 inch wide and 1.5 in. long, with one slot per 2-ft well section) were specifically designed for injecting EVO and DHM. The 3-in.-diameter wells were constructed of fiberglass-reinforced epoxy, a high-strength material that was chosen to limit the potential for well failure during installation.

The property landlord and tenants were kept informed during all field activity phases to address any concerns or questions. Locating subsurface utilities prior to drilling was critical to the project's success, due to the shallow drilling angle (15 degrees below horizontal). Using a supplemental drilling navigation system (the short steering tool) was also critical, because radio interference inside the building, combined with no- or limited-access areas, precluded sole use of the typical surface navigation system (see site map).

The horizontal wells were used to inject EVO and DHM in November 2015. Diluted EVO and DHM volumes ranged from 4,500 to 7,500 gallons, depending on slotted well length. These volumes included approximately three well casing volumes of clean water, injected to flush the EVO and DHM from the well. Monitoring wells placed inside and outside Building 100 will be used to monitor project performance. ■

Courtesy of the Department of Energy, Office of Legacy Management.

Budgets and schedules

Federal funding, or lack thereof, was a subject of the 2015 RadWaste Summit, held near Las Vegas, along with updates on possible timelines for Yucca Mountain, consolidated interim storage, and the reopening of WIPP.

Despite what at the time appeared to be another dismal budget process for fiscal year 2016, cleanup of the nation's legacy sites continues to be a top priority for the U.S. Congress with a considerable amount of bipartisan support. That was the message of Rep. Chuck Fleischmann (R., Tenn.) at ninth annual RadWaste Summit, held September 8-11 in Summerlin, Nev., and sponsored by Exchange Monitor Publications and Forums. This year's summit was the first under the direction of Exchange Monitor's new owner, Access Intelligence, which bought the publication company last year.

Fleischmann, who delivered the keynote address via a live video link, noted that, as a country, we have not been as careful as we should have been in the past managing waste from nuclear defense-related work and that this has resulted in contaminated legacy sites. "It is our duty to work to clean up these sites," he said. "These communities deserve it." While recognizing the contentious political environment in Washington D.C., Fleischmann said there is tremendous support among Democrats and Republicans in both the House of Representatives and the Senate for cleaning up the nation's legacy sites.

Along with Rep. Ben Ray Luján (D., N.M.), Fleischmann is co-chair of the House Nuclear Cleanup Caucus, which raises awareness of environmental cleanup of the country's legacy sites and advocates for resources to carry out remediation work. Fleischmann represents the city of Oak Ridge, Tenn., and Luján's district includes the Los Alamos National Laboratory. Fleischmann, who is also co-chair of the House Science and National Labs Caucus, said he is proud of the work the Nuclear Cleanup Caucus has done and noted that attendance at caucus meetings is up.


Fleischmann

Speaking less than a month before the start of the new fiscal year, Fleischmann was not optimistic that Congress would pass a 2016 omnibus bill. "Clearly the House and the Senate are somewhat at odds with the budget process, along with the administration," he said. While Fleischmann said he would prefer to see a budget pass that addresses the current needs of the cleanup sites, including the increased funding needed to recover the Waste Isolation Pilot Plant in New Mexico, he admitted that the "easiest and safest bet is probably a continuing resolution."

In response to a question concerning the National Nuclear Security Administration's Uranium Processing Facility (UPF) project at Oak Ridge, Fleischmann said that despite the budget uncertainties there is funding available to complete the construction of the new state-of-the-art facility by 2025. Fleischmann said the UPF is critical to replacing the aging facilities at the Y-12 National Security Complex and that the contractor, Consolidated Nuclear Security, has been diligently working on a redesign of the UPF.

Highlighting another bright spot for waste management, Fleischmann noted that currently there is a favorable climate on Capitol Hill for moving forward on the Yucca Mountain project. The recent court order to the Nuclear Regulatory Commission to resume the review of the Department of Energy's license application for the Nevada repository, along with vocal support in the House from Rep. John Shimkus (R., Ill.), bode well for the project's future, he said. While the House has shown it is willing to provide more Yucca Mountain funding, however, Fleischmann conceded that the Senate has not been so inclined to do so.

Used fuel management

While Fleischmann appeared optimistic that Yucca Mountain remains very much alive, the Department of Energy is continuing to work to move beyond the project by establishing a new adaptive, consent-based path to nuclear waste disposal. As part of its new strategy, the DOE announced in March 2015 its plan to develop separate repositories for civilian and defense-generated used nuclear fuel and high-level radioactive waste. William Boyle, director of used fuel disposition research and development with the DOE's Office of Nuclear Energy, discussed that plan during the RadWaste Summit keynote session, "Management of Used Fuel and High-Level Radioactive Waste in the United States."

As Boyle noted, the DOE has decided to develop a separate but parallel path for defense and civilian waste from energy production, where previously it was intended that all used fuel and HLW, from both civilian and defense sites, would be comingled at Yucca Mountain. The reason the DOE decided to change strategies, Boyle said, is because a number of circumstances have changed since the original plan was developed. Namely, the DOE now maintains that the heterogeneous nature of defense waste, the cessation of defense activities resulting in waste production, and the impasse associated with citing a repository make the new strategy more attractive. Citing Energy Secretary Ernest Moniz, Boyle said that creating a separate pathway for defense waste will offer the country greater "flexibility and optionality" to dealing with its inventory of radioactive waste.

Boyle said that the Obama administration requested $108 million for FY 2016 to fund research and development of the dual-path plan to disposing of civilian and defense waste. The Office of Nuclear Energy currently is conducting R&D on the long-term storage, siting, and transportation issues surrounding nuclear waste, Boyle said.

Regardless of the end path for waste disposal, Boyle said the nation needs a comprehensive, workable solution, and that a one-size-fits-all approach is not necessarily the best method. For example, Boyle noted that the DOE is looking into using deep boreholes to dispose of some of the DOE's inventory of smaller waste, including cesium capsules currently stored at the Hanford Site in Washington State. Used nuclear fuel casks, however, are physically too large to be placed in boreholes to the necessary depths, he said. The DOE may consider separate disposal options based on the physical size and shape of the waste container.

Consent-based siting

Following the recommendations of President Obama's Blue Ribbon Commission on America's Nuclear Future, the Department of Energy intends to take a consent-based approach to siting a repository for its inventory of defense-related waste. The consent-based approach also will be used for siting an interim storage facility for commercial used nuclear fuel and high-level waste. While some communities have indicated their willingness to host such a site, including those in West Texas and New Mexico, it remains unclear what exactly a consent-based process will look like in the U.S.

Noting that it may be easier to define what consent-based is by what it is not, Baltzer said that it is not just a matter of money to local communities.

Timothy Frazier, a senior advisor for

the Bipartisan Policy Center, served as a designated federal officer for the Blue Ribbon Commission, which provided a very general definition of consent-based siting. Frazier, who moderated the panel discussion, “Consent-Based Siting for Interim Storage,” said the commission was purposely vague on what consent would entail. “One of the reasons we were so vague in regard to consent-based siting is because I had 15 different people with 15 different views on what it looks like,” he said. In introducing the panel members, Frazier said he hoped their discussion would help flesh out what a possible consent-based process would consist of.

Rod Baltzer, president of Waste Control Specialists (WCS), said consent-based siting is difficult to define. “It is one of those things where I know it when I see it,” he said. In February, WCS announced that it intends to submit an application with the Nuclear Regulatory Commission to build an interim storage site at its facility in Andrews County, Texas.

Noting that it may be easier to define what consent-based is by what it is not, Baltzer said that it is not just a matter of money to local communities. That is, no amount of economic incentives will suffice if a community is not willing to host an interim storage site. Baltzer said WCS is lucky in that many West Texas residents work in the oil and gas industry and are knowledgeable of energy production and the risks involved. They understand that managing radioactive waste is in many ways safer than oil and gas drilling while still enhancing the area’s economic diversity (a portion of WCS fees go to Andrews County and the state), he said.

Baltzer also said that gaining consent, both locally and at the state level, cannot be rushed. “It is not done in a hurry,” he said, pointing out that WCS first began the process of constructing its facility for low-level radioactive waste in 1995.

While the West Texas residents near the WCS facilities may understand what is involved in hosting an interim storage site, Monty Humble, co-owner of AFCI Texas, said that every community is different and has its own culture. In order to gain consent, the local community must be engaged, he said, adding that there is no common method for gaining community consent. AFCI Texas has expressed interest in siting a HLW facility in Loving County, Texas.

Humble said he’s confident Texas eventually will host an interim storage site, whether it be in Loving County or at WCS’s site, if Congress and the DOE will approve it. “Texas is ready to go,” he said. It is not clear, however, that there is a willingness on the national level to move forward on interim storage, he added. Along with finding a national consensus on storing used fuel and HLW, Humble said the two greatest threats to consolidated interim storage are federal funding and the issue of linkage, where the construction of an interim storage site is linked to the building of a permanent geologic repository.

John Heaton, chairman of the Eddy-Lea Energy Alliance, which is working with Holtec International on a proposed interim storage site just across the border from WCS in New Mexico, did not express much optimism that much could get done at the national level. “The politics are so contentious in Washington D.C. that it is hard to believe anything will get done,” he said.

While Heaton stressed the importance of having state support for an interim storage site, he said that every state has its own idea of what a consent-based process involves. Heaton said the process must begin with a willing community or region, and that it must first be known whether the region is geologically suitable to host such a site. States also must tentatively agree to host the site before money is spent on site characterization, he said.

As a cautionary tale on what can go wrong in a consent-based siting process, Eric Knox of AECOM pointed to Private Fuel Storage’s (PFS) consolidated interim storage site in Utah. That site was developed to the point where it received a license from the Nuclear Regulatory Commission. Yet the project was cancelled in 2012 when PFS was unable to secure the necessary rights to transport used fuel to the site. Knox noted that it was not the DOE, the NRC, nor the Environmental Protection Agency that killed the project, but the Department of Interior. “You can have a willing host community, you can follow a long, arduous process, and you can do your due diligence, but politics in the U.S. make things very difficult,” he said.

The lesson of PFS, Knox said, is the need to learn from the mistakes of the past, as well as to anticipate potential obstacles and understand how to overcome them. Knox pointed to Canada’s adaptive, phased-management approach to siting a geologic repository as an example of how other countries are using a consent-based siting process.

WIPP

During the keynote session “WIPP Restart and Long-Term Outlook,” Ryan Flynn, cabinet secretary of the New Mexico Environment Department, said that his state is committed to reopening the Waste Isolation Pilot Plant. Located near Carlsbad, N.M., the repository for defense-related transuranic waste has been closed since February 2014 due to an underground truck fire and subsequent but unrelated radiological release from a breached waste drum. Flynn said that while both accidents were preventable, WIPP performed well in minimizing the impacts of the incidents. “This facility works and works really well,” he said.

Referencing a recent settlement between the state of New Mexico and the Department of Energy, Flynn stressed that his department is focused on implementing corrective actions rather than on punishing the DOE. According to Flynn, those corrective actions include triennial reviews of the facility, enhanced training for workers in the nonradiological areas of the mine, and changes to the DOE’s waste characterization programs.

Also noting the DOE’s recent announcement that the department will be unable to meet its initial goal of resuming partial operations at WIPP by early 2016, Flynn said that it is more important to get the recovery work done right than opening “on time.” The schedule for resuming WIPP operations largely depends on the DOE and Congress, he said, adding that DOE’s ability to manage its contractors in implementing changes also will influence the recovery schedule.


Flynn


Marcinowski

Flynn indicated that WIPP may be able to temporarily store waste above ground while recovery work proceeds. Frank Marcinowski, deputy assistant secretary of waste management with the DOE’s Office of Environmental Management, confirmed that the DOE is looking at the option of surface storage at WIPP for transuranic waste containers. Surface storage at WIPP will allow the DOE to move forward with removing waste from cleanup sites and will demonstrate to site states that the DOE is working to meet its cleanup commitments, Marcinowski said.

When the DOE could resume shipments of waste to WIPP, however, remains uncertain, Marcinowski said. Factors that need to be considered before shipments can begin include the capability of WIPP to store waste and the regulatory compliance of waste-generating sites, he said. ■

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Moving Up

People in the news

Kurion Inc. has appointed **Jonathan Foster** as chief financial officer and **David Carlson** as senior vice president of tritium removal operations. Foster has served as CFO for a number of venture capital–backed companies and has worked for both private and publicly traded organizations. Carlson was most recently chief operating officer and chief nuclear officer at Gen4 Energy.


Foster

The International Atomic Energy Agency's board of governors has elected by acclamation **Laércio Antonio Vinhas,** of Brazil, chairman of the board for 2015–2016. He replaces **Marta Ziaková** of Slovakia. Vinhas took up his post as resident representative of Brazil to the IAEA and to the Comprehensive Nuclear Test Ban Treaty Organization in January 2012. From 1965 to 2011, he served at the Brazilian National Nuclear Energy Commission in various capacities, including as director of the Institute of Radiation Protection and Dosimetry, head of the Safeguards Department, and director of nuclear safety, security, and safeguards. He has been a member of the Brazilian delegation to the IAEA General Conference and to the board of governors since 1990.

The Electric Power Research Institute has announced the appointments of **Doug Esamann**, an executive vice president of Duke Energy and president of the company's Midwest and Florida regions, and **Jeff Lyash**, president and chief executive officer of Ontario Power Generation, as interim members of its board of directors. Esamann will serve until April 2017, and Lyash until April 2016. Both will then be eligible for election to full four-year terms. Before assuming his current position with Duke in June of last year, Esamann served as president of the utility's Indiana operations. Lyash was formerly the president of CB&I Power, a provider of engineering, procurement, and construction services for utilities in the United States and abroad.

Manuel Lachaux has been appointed vice president of financial communications and investor relations at Areva. Lachaux joined Areva's financial communications department in 2007 as investor relations manager. Since 2009, he has held several positions as a financial controller for the company's front-end activities, including Areva's fuel business.

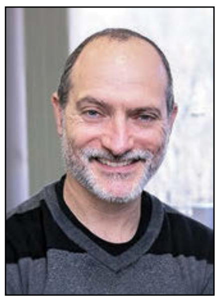
Rex D. Geveden has been named chief operating officer of BWX Technologies. Geveden most recently was executive vice president at Teledyne Technologies, where he led two of Teledyne's four operating segments. He also spent 17 years at the National Aeronautics and Space Administration, where he served as the agency's associate administrator.


Geveden

Peter Montague has been appointed closure director of Magnox Limited's Sizewell A site in Suffolk, England, succeeding **Tim Watkins**, who stepped down in November. Montague, who has spent most of his career in radiological protection and safety roles, most recently led the delivery of decommissioning programs at the company's Hinkley Point A site in Somerset

Government

Adam Cohen, deputy director of operations at the Princeton Plasma Physics Lab oratory since 2009, has been named deputy undersecretary for science and energy at the Department of Energy, succeeding **Michael Knotek**, who retired on September 30. Cohen will assist the undersecretary for science and energy, **Franklin "Lynn" Orr Jr.,** in overseeing the DOE's Office of Science and several other DOE program offices, including the Office of Nuclear Energy. Cohen served as deputy associate director for energy sciences and engineering at Argonne National Laboratory from 2006 to 2009.


Cohen

Sandia National Laboratories has appointed **James M. Chavez** vice president of its Energy, Nonproliferation, and High Consequence Security Division and its

International, Homeland, and Nuclear Security Program Management Unit. He replaces **Jill Hruby**, who became Sandia president and labs director in July. Chavez, who joined Sandia in 1981 as a researcher in Intrusion Detection Systems, was most recently the director of the Monitoring Systems and Technology Center and the Remote Monitoring and Verification Program.

Susan Pepper has been named chair of the Nonproliferation and National Security Department (NNS) at Brookhaven National Laboratory. A lab employee since 1985, Pepper worked in the Department of Nuclear Energy's Structural Analysis Division for eight years before joining NNS, where she served as liaison officer for the U.S. Mission to U.N. System Organizations in Vienna. After four years there, she returned to Brookhaven to head the International Safeguards Project Office. She was named deputy department chair of NNS in September 2010 and interim chair in January 2015.


Pepper

Glenn Tracy has moved from his position as director of the Nuclear Regulatory Commission's Office of New Reactors to that of deputy executive director for materials, waste, research, state, tribal, compliance, administration, and human capital. Since joining the agency in 1989 as a reactor engineer, Tracy has held a number of leadership positions at the NRC, including director of the Division of Nuclear Security in the Office of Nuclear Security and Incident Response, director of the Division of Construction Inspection and Operational Programs, and deputy chief of human capital.


Tracy

Utilities

Duke Energy's board of directors has unanimously elected company president, chief executive officer, and vice chairman **Lynn Good** as its new chairman. Good succeeds **Ann Maynard Gray**, who remains on the board as a director. The board also unanimously elected **Michael Browning**, chairman of Browning Consolidated LLC of Indianapolis, Ind., as its independent lead director.

Paul Hinnenkamp has been named senior vice president and chief operating officer for Entergy Corporation, succeeding **Mark Savoff**, who is retiring. Hinnenkamp, who most recently served as Entergy's senior vice president for capital project management and technology, joined the company in February 2001 as vice president of operations support for its southern nuclear fleet and has since served in various capacities. **Tim Mitchell** has been named Entergy's acting chief nuclear officer, filling in for **Jeff Forbes,** who also is retiring. Mitchell, who was previously senior vice president for nuclear operations, joined Entergy in 1989 as a plant engineer at Arkansas Nuclear One and has since held a number of managerial and leadership positions.


Hinnenkamp

Accolades

Gregg Lumetta, a chemist at the Pacific Northwest National Laboratory, has received the Glenn T. Seaborg Actinide Separations Award in recognition of his contributions to the field of actinide separation, including methods used to treat high-level radioactive waste at the Hanford Site and the design and application of new ligands (molecules that bond to metal ions) to bind specific elements for waste cleanup applications. Lumetta leads PNNL's Actinide Science Team and serves as the principal investigator for a Department of Energy project seeking to develop new methods for separating actinides from irradiated nuclear fuel.

Kris Singh, Holtec International's president and chief executive officer and the inventor of Holtec's HI-STORM UMAX, was recognized at the 36th Edison Patent Awards Ceremony and Reception, held on November 12, 2015. The Research and Development Council of New Jersey established the Edison Patent Award to recognize and honor New Jersey's scientists and inventors. The HI-STORM UMAX patent was selected in the Public Health and Safety category. ■


Singh

It's Business

Contracts, business news, etc.

Business developments

In a deal announced on October 27, 2015, **Westinghouse Electric Company** agreed to acquire all of the equity interests of **CB&I Stone and Webster**, the nuclear construction business of CB&I, Westinghouse's consortium partner in the construction of AP1000 reactors in the United States and China. As an offshoot of the acquisition, Westinghouse is engaging **Fluor Corporation** as a subcontractor for the four AP1000 reactors currently being built in the United States. The U.S. government approved the acquisition on December 31.

CB&I said that it expected to receive cash payments from Westinghouse of $229 million, of which $161 million is to be received upon the substantial completion of the consortium's nuclear projects, and the remaining $68 million upon the attainment of certain milestones related to CB&I's continued supply of discrete scopes of modules, fabricated pipe, and specialty services to Westinghouse on a subcontract basis for the nuclear projects. CB&I, however, said that it anticipated incurring a noncash after-tax charge of approximately $1 billion to $1.2 billion related to a "loss on the transaction and the impairment of goodwill and intangible assets."

As a result of the acquisition, Westinghouse now owns the business of engineering, construction, procurement, management, design, installation, startup, and testing of nuclear-fueled facilities, including the Summer project in South Carolina, the Vogtle project in Georgia, and the AP1000 projects in China.

According to Westinghouse, beyond the focus of current new-build nuclear projects, the agreement supports the company's growth in decontamination, decommissioning, and remediation services; enhances its major nuclear project management and environmental services offerings; and adds to its extensive innovation-driven engineering expertise.

Consistent with Westinghouse's strategy to grow its decommissioning business, the company announced on November 2, 2015, that it has signed a contract with **Barsebäck Kraft AB** for the segmentation of reactor pressure vessel internals at the dual-unit Barsebäck nuclear power plant in the south of Sweden. Barsebäck-1 was shut down in 1999, and Barsebäck-2 in 2005. Westinghouse said that the project will begin immediately and is expected to take about four years to complete. Mechanical segmentation will begin in 2016.

GE announced the completion of its acquisition of **Alstom** on November 2, 2015. **GE Power & Water** and **Alstom Power** now have combined to form **GE Power**. Employing more than 65,000 people in more than 150 countries and with an estimated revenue of $30 billion, the newly formed company will be headquartered in Schenectady, N.Y. Steve Bolze will serve as president and chief executive officer of GE Power, which combines the attributes of GE's power generation technologies, services, and expertise with Alstom Power's technology and geography. GE Power will serve the global utility sector as a supplier of total power plant and life-cycle solutions that can support equipment from multiple suppliers.

Irvine, Calif.–based **Kurion Inc.** announced on December 8, 2015, that it has acquired **Oxford Technologies Ltd.**, a robotic and remote handling systems company located in the United Kingdom. According to Kurion, the acquisition expands the company's existing Robotic Systems and Services team, which has delivered and designed more than 180 systems for projects around the world, including the technology used to investigate a damaged reactor at Fukushima Daiichi in Japan. Oxford Technologies specializes in full life-cycle remote handling systems, complex plant assembly, and radiation-hardened systems. Its remote systems have been employed at decommissioning sites worldwide, including Sellafield and Dounreay in the U.K. Oxford Technologies' suite of technologies, client base, and team of more than 60 skilled engineers and project managers will augment the Kurion team and provide an established base of operations for the company's continued expansion in Europe, Kurion said. Terms of the acquisition were not disclosed.

Kurion also announced on December 9, 2015, that it has renewed licensing agreements for its GeoMelt vitrification technology with **ISV Japan** and **Daiei Kankyo**. According to Kurion, the agreements build on a 20-year history of licensing the technology to ISV Japan with a goal of collaborating more closely on the treatment of nuclear waste in Japan. Daiei Kankyo, ISV Japan's parent company, operates a GeoMelt Hazardous Waste Treatment Plant in Iga City, Japan, for the treatment of asbestos, PCBs, dioxins, and other persistent organic pollutants. Fumio Kaneko, chief executive officer of Daiei Kankyo, said that the company renewed its licensing agreement to work more closely with Kurion, strengthening its position to enter the nuclear waste management market in Japan.

Used nuclear fuel

Westinghouse Electric Company and **Holtec International** jointly announced on September 16, 2015, that they have signed a 10-year teaming agreement to provide pool-to-pad services to U.S. nuclear power sites using Holtec's dry cask spent fuel storage technology. According to the companies, U.S. customers will benefit from the combination of Westinghouse's experience as a leader in dry storage canister welding and Holtec as the original equipment manufacturer service provider, offering cross-qualified, experienced crew members to meet the growing demand for dry storage resources.

Areva announced on October 5, 2015, that its **Areva TN** division signed a contract with **Xcel Energy** to provide dry fuel storage management services to the company's Prairie Island and Monticello nuclear power plants in Red Wing and Monticello, Minn., respectively. Under the multiyear contract, Areva will oversee and perform the removal of nuclear fuel from the Prairie Island reactor's spent fuel storage pool, its placement in dry storage casks, and its secure storage on the site's existing interim storage pad. At Monticello, the company will deliver and install 10 NUHOMS 61BTH dry fuel storage systems in 2017, and will manage and perform the pool-to-pad process to place the used fuel in the shielded storage modules in 2018. The value of the contract was not disclosed.

Areva also announced on December 22, 2015, that Areva TN signed an agreement at the end of November 2015 for a strategic partnership with the Chinese company **Shangai Apollo Machinery Company,** a qualified Chinese supplier for the nuclear industry. Areva said that it will work closely with Apollo to develop used nuclear fuel storage casks meeting high levels of quality and safety. The agreement, signed in the presence of local authorities and utilities during an official ceremony in Shanghai, is a milestone in Areva TN's localization strategy for China and is strongly supported by Shanghai Nuclear Power Office because it represents an important step for the development of the nuclear fuel cycle industry in the country, according to Areva.

Ukrainian manufacturer **Turboatom** will manufacture spent nuclear fuel dry storage casks engineered by **Holtec International** under a memorandum of understanding (MOU) signed on October 28, 2015, in Brussels, Belgium, between the two companies and **Energoatom**, Ukraine's national nuclear energy generating company. According to Holtec, the initial focus of the cooperative agreement will be on Turboatom's manufacturing and supplying HI-STORM 190 vertical ventilated casks for Ukraine's central spent fuel storage facility (CSFSF), with an initial order of 94 casks. According to Energoatom, the estimated cost of Turboatom's services to Holtec may reach \$200 million for the next 10 years, including approximately \$60 million for CSFSF equipment. The CSFSF is being built to store spent VVER fuel from Ukaine's nine reactors and is expected to be commissioned in 2018. According to Holtec, the MOU is a milestone in the company's quest to localize manufacturing in Ukraine and develop a manufacturing ally in eastern Europe to serve its growing business activities in the region.

Low-level waste

Amec Foster Wheeler announced on September 17, 2015, that it has been awarded a series of contracts from **CERN**, the European Organization for Nuclear Research, to carry out radiochemical testing. According to the company, the work, which began earlier in 2015 and is ongoing, involves the characterization of waste components taken from high-energy accelerators, including the world's largest particle accelerator, the Large Hadron Collider, located beneath the France-Switzerland border. Samples are sent from CERN's headquarters near Geneva, Switzerland, for analysis at Amec

Foster Wheeler's laboratories in the United Kingdom. The values of the contracts were not disclosed.

On November 24, 2015, Amec Foster Wheeler announced that it will use radiation survey equipment to support the cleanup of approximately 1.2 million cubic meters of historic low-level radioactive waste from various sites in Southern Ontario, Canada, under a Can$1.57-million (about $1.14-million) contract awarded by **Canadian Nuclear Laboratories**. The company said that it is deploying its advanced ORION ScanPlot overland radiation survey system to collect radiological data at the sites. As part of the Port Hope Area Initiative, Amec Foster Wheeler personnel are surveying approximately 175 roads and other public rights of way.

D&D

Areva announced on September 30, 2015, that its **Dismantling and Services** business signed a five-year contract valued at several million euros with France's **Commissariat à l'Énergie Atomique et aux Énergie Alternatives** (CEA) for the cleanup of the Atelier de Décontamination, d'Expertise et de Conditionnement (ADEC) facility. Located at the Saclay site in France's Ile-de-France region, ADEC is a decontamination, appraisal, and packaging facility that was originally commissioned in 1962 and was shut down in 2011. Under the contract, Areva will restore the ADEC facility to radiologically clean conditions. Areva Dismantling and Services will be in charge of the cleanup of a 2,250-m^2 area containing radioactive wastes stored in both solid and liquid forms.

Areva also signed a series of agreements worth approximately €370 million (about $392 million) with CEA for the management of nuclear facilities being dismantled at Marcoule and for assistance with on-site work covering the period 2016–2020, it was announced on December 17, 2015. The contracts renew Areva's cooperation with CEA as the former nuclear operator at the Marcoule site and CEA's leading partner for dismantling services. According to Areva, the contracts concern primarily industrial operator services on behalf of the CEA, treatment of site effluents, recovery and reconditioning of legacy waste, and support for CEA's suppliers at facilities undergoing dismantling.

Areva announced on November 5, 2015, that it has signed a contract with **Électricité de France** (EDF) to carry out preventive chemical cleaning services of the steam generators at the Cattenom-2 nuclear power plant, a 91-MWe pressurized water reactor in Moselle, France. The contract also includes the treatment of associated effluents. According to the company, the cleaning technology eliminates micro-deposits of iron and copper that may be present in the upper part of the steam generators, preventing clogging and improving the overall performance of the equipment. The value of the contract was not disclosed.

Areva also signed a contract with EDF for the dismantling of the vessel internals of the Superphénix reactor in Creys-Malville, France, it was announced on December 1, 2015. According to Areva, the contract is worth "several tens of millions of euros." The contract scope, which will be performed by Areva's Dismantling and Services business, includes preliminary design, process qualification, manufacturing of tools, and equipment dismantling. It also includes the packaging of highly radioactive waste. The project is expected to run until 2024 and will mobilize more than 50 people during the peak period of work, Areva said.

On December 21, 2015, Areva announced that it has been awarded a contract by the utility **Vattenfall Europe Nuclear Energy** to decontaminate the primary loop of the Krümmel nuclear power plant, located in Geesthacht near Hamburg, Germany. Areva said that it will use its proprietary decontamination techniques, CORD UV and AMDA, to reduce the radiation level in the reactor pressure vessel, auxiliary systems, and piping. The project was to begin by the end of December 2015 and the decontamination be completed during the first half of 2016, according to the company. The value of the contract was not disclosed.

Hitachi-GE Nuclear Energy, in Tokyo, Japan, announced on November 11, 2015, that it has concluded cooperative agreements with both **Cavendish Nuclear Limited** in the United Kingdom and **Areva NC S.A.** in France with respect to boiling water reactor decommissioning in Japan. According to Hitachi-GE, the collaboration with Cavendish and Areva will further the company's goals of using its technology, experience, and know-how to propose and support the decommissioning plans of Japan's utilities. Hitachi-GE said that it will take preparatory steps toward the decommissioning of Japan's BWRs, fully backed by the companies' international experience.

Environmental management

Enercon Services announced on October 20, 2015, that it has acquired **Terra Environmental Services,** of Tampa, Fla., whose offerings will complement Enercon's existing remediation and environmental services. Terra specializes in remediation support, including responsible party determination, remedial investigation, and remedial design. Valued at $300 million, Enercon is a diversified energy consulting company offering engineering, environmental, and management services. The terms of the acquisition were not disclosed.

CH2M announced on December 15, 2015, that it has been awarded the 2016 Gold Medal Award for International Corporate Achievement in Sustainable Development by the World Environment Center (WEC). The award is to be presented to CH2M chairman and chief executive officer Jacqueline Hinman on May 19, 2016, at the 32nd Annual WEC Gold Medal Gala in Washington, D.C. CH2M, an environmental and engineering services firm, is being recognized for its commitment to sustainability and social responsibility throughout the company, including valuing ecosystems services, partnering with leading environmental nonprofits, and acting as a global leader in international water initiatives. WEC is a global nonprofit, nonadvocacy organization that advances sustainable development through the business practices of member companies and in partnership with governments and other organizations.

DOE

The Department of Energy's Office of Environmental Management (EM) announced on September 23, 2015, that it has awarded a cost-plus-award fee contract worth up to $310 million to Los Alamos National Laboratory (LANL) contractor **Los Alamos National Security** (LANS). The bridge contract is for legacy cleanup activities at LANL and is being issued as part of the efforts to transition EM-funded legacy cleanup activities at the site, which was previously managed by the National Nuclear Security Administration. LANS is formed by the University of California, Bechtel, BWXT Technical Services Group, and URS Energy and Construction (AECOM). LANS will continue to provide solid waste stabilization and disposition, soil and water remediation, and deactivation and decommissioning of defense nuclear facilities at LANL. The contract will have a one-year base period with two six-month option periods.

The Department of Energy announced on September 29, 2015, that it is extending its contract with **Idaho Treatment Group** (ITG) for the Advanced Mixed Waste Treatment Project at the Idaho Site for a period of six months. ITG's contract was to expire on September 30. The contract extension is valued at $65 million and, according to the DOE, is intended to accommodate the department's competitive procurement process for the new Idaho Cleanup Project Core contract. Under the contract extension, ITG will continue to characterize, certify, package, and store transuranic waste for off site disposal; dispose of mixed low-level waste at an appropriate treatment or disposal facility; and retrieve stored waste from the site's Transuranic Storage Area-Retrieval Enclosure. ITG consists of BWXT Technical Services Group, URS Energy and Construction (AECOM), and Energy Solutions Federal Services.

The Department of Energy announced on October 21, 2015, that it has awarded a four-year contract with an approximate value of $31.6 million to **Spectra Tech,** of Oak Ridge, Tenn., for managing spent nuclear fuel storage facilities and licenses under Nuclear Regulatory Commission regulations. According to the DOE, the scope of the facilities procurement contract includes the management and operation of the Fort St. Vrain independent spent fuel storage installation (ISFSI) in Colorado (including security); the management, operation, and oversight of the Three Mile Island-2 ISFSI at the Idaho Nuclear Technology and Engineering Center in Idaho; and management of the Idaho Spent Fuel Facility license. The hybrid-type contract has a firm-fixed-price, indefinite delivery/indefinite quantity, and cost-reimbursable contract line item numbers.

On December 9, 2015, **Areva** announced that its subsidiary **Areva Federal Services** has been awarded a contract worth $8.6 million by the Department of Energy for the design and fabrication of prototype railcars for nuclear material transportation. The railcars will be used for the large-scale transport of used nuclear fuel and other high-level radioactive waste to interim and eventual permanent storage facilities. According to the company, the contract includes the conceptual design and dynamic modeling of HLW transport cask cars, as well as buffer cars, which provide spacing between the cask railcars and the locomotive. Areva will begin the fabrication of the prototype cask and buffer railcars once the Association of American Railroads certifies the concepts for HLW transport. A team led by Areva Federal Services will include **KASGRO Rail,** the fabricator of the only cask car currently certified for HLW transport, and **Transportation Technology Center,** a railcar dynamic modeling and testing facility. **Stoller Newport News Nuclear** and **MHF Logistics** will support conceptual design reviews. ■

ANS D&RS 2016 - Decommissioning and Remote Systems

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Conference Purpose

In 2016, the DES and RRS divisions will host a Decommissioning and Remote Systems (D&RS) Joint Topical Meeting. The D&RS 2016 topical meeting is anticipated to draw over 300 professionals from the decommissioning, environmental, and remote systems industries. The ANS D&RS Topical Meeting is a forum for the discussion of the social, regulatory, scientific, and technical aspects of decontamination, decommissioning, and reutilization, and waste management.

Program

The 2016 program will include commercial, government, and international project updates and discussion of technology developments in the areas of decommissioning, waste management, site closure, and legacy management. The meeting will also feature professional development programs including EPA Radiation Risk Assessment Training, a workshop on the Robot Operating System (ROS), and an exciting technical tours program.

Business Opportunities

The broad spectrum of companies and government organizations participating in the D&RS topical meeting makes it an excellent setting to conduct business and teaming discussions.

Technology Expo

A technical exhibit will be held in conjunction with the meeting, bringing together exhibitors from a wide range of companies in the Decommissioning and Robotics industries. These exhibits will allow meeting participants to learn about cutting-edge products and technologies that are directly applicable to their current projects.

Technology Transfer

Knowledge of experience gained in other countries on similar decommissioning projects is conveyed during sessions on topics such as waste management, stewardship, and decommissioning.

Social Events

Meet up with your colleagues at the Sunday welcome reception, Monday's Gateway Clipper Dinner Cruise, a Pittsburgh brewpub, or the many other networking activities planned for you!

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Mark Marano
President, Americas, Westinghouse Electric Company

Technical Program Coordinator
James Byrne
Principal, Byrne & Assoc., LLC

DES Technical Program Chair
Sue Aggarwal
President, New Millennium Nuclear Technologies Int.

RRS Technical Program Chair
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Remediating the Past and Preparing for the Future at Sandia National Laboratories. By Thomas L. Sanders. Jan. 1996: 32-41.

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Accelerating SRS Tank Closure with Help from Partners, Technology. By Rick Kelley. Sept./Oct. 2009: 25-30.

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Decommissioning at Savannah River—With a Focus on F Canyon Deactivation. By Nancy J. Zacha. Mar./Apr. 2005: 62-63.

Developing a Gamma Spectroscopy System at the Savannah River Site. By David A. Filler and Brian S. Crandall. Nov. 1996: 49-52.

Digging in the Canyons: Simplifying Waste Removal from Chemical Separations Operations at the Savannah River Site. By Eric V. Szendrei. Jan./Feb. 2002: 33-36.

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Further Development of Modified Monosodium Titanate, an Improved Sorbent for Pretreatment of High-Level Nuclear Waste at the Savannah River Site. By Kathryn M. L. Taylor-Pashow, Fernando F. Fondeur, Samuel D. Fink, and David T. Hobbs. Jan.-Apr. 2012: 64-81.

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The Good, the Bad, and the Money; Or, What's Right and Wrong with Privatization. By Nancy J. Zacha. Jan./Feb. 1999: 38-40.

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Let's Model It: Using Computer Simulation to Improve Waste Processing Safety. By Jerry Fireman. Nov./Dec. 2000: 31-33.

The Little Facility That Could: SRS's Effluent Treatment Project Celebrates 20 Years of Successful Operation. Jan./Feb. 2009: 30-31.

The Lowdown on L-Lake: A GIS Evaluation of Proposed Savannah River Site L-Lake Drawdown. By James S. Bollinger and David L. Dunn. Mar./Apr. 1999: 53-57.

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New Era of Salt Waste Processing Begins at SRS. By Dale Townsend. July/August 2008: 28-31.

A New Era of Waste Vitrification at SRS. By Dean Campbell. July/Aug. 2005: 30-34.

New Technologies in the SRS "Toolbox." By David Yannitell. July/Aug. 2000: 28-34.

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West Valley Demonstration Project

WIPP

Yucca Mountain

Utilities

Vitrification

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Calendar

Meetings of Interest

March

Mar. 6-10 **Waste Management Conference (WM2016)**, Phoenix, Ariz. Sponsored by WM Symposia. Contact: Melanie Ravalin, WM Symposia, phone 480/557-0263; fax 520/829-3550; e-mail melanie@wmarizona.org; web www.wmsym.org.

Mar. 31-Apr. 3 **2016 ANS Student Conference**, Madison, Wis. Sponsored by ANS and hosted by the University of Wisconsin-Madison. Contact: Matthew Jasica, Kalin Kiesling, or A.J. Gross, phone 608/572-7267; e-mail ansstudentconference2016@gmail.com; web www.ansstudentconference2016.com.

April

Apr. 4-6 **World Nuclear Fuel Cycle**, Abu Dhabi, United Arab Emirates. Organized by the Nuclear Energy Institute and the World Nuclear Association. Contact: Michael Jordan, NEI, phone 202/739-8000; e-mail mjj@nei.org; web www.wnfc.info.

May

May 3-5 **Used Fuel Management Conference**, Orlando, Fla. Sponsored by the Nuclear Energy Institute. Contact: Denise Bell, NEI, phone 202/739-8039; e-mail registrar@nei.org; web www.nei.org.

May 23-26 **63rd Annual Industry Conference and Supplier Expo: Nuclear Energy Assembly**, Miami, Fla. Sponsored by the Nuclear Energy Institute. Contact: NEI, phone 202/739-8000; e-mail conferences@nei.org; web www.nei.org.

May 23-27 **International Conference on Advancing the Global Implementation of Decommissioning and Environ-**

mental Remediation Programmes, Madrid, Spain. Organized by the International Atomic Energy Agency. Contact: Karen Morrison, IAEA, phone +43 1 2600 21317; e-mail k.morrison@iaea.org; web http://www-pub.iaea.org/iaeameetings/2016.

June

June 5-10 **5th International Atalante Conference on Nuclear Chemistry for Sustainable Fuel Cycles (Atalante 2016)**, Montpellier, France. Organized by LGI Consulting. Contact: LGI Consulting, phone +33 1 84 16 30 73; e-mail contact@lgi-consulting.com; web www.atalante2016.org.

June 12-16 **2016 ANS Annual Meeting**, New Orleans, La. Sponsored by the American Nuclear Society. Contact: Donna Jacobs, Entergy Corporation, phone 601/368-5517; e-mail djacob2@entergy.com; web www.ans.org/meetings/m_146.

June 20-23 **EPRI International Low-Level Waste Conference and Decommissioning Workshop, with the ASME/EPRI Radwaste Workshop 2016**, Orlando, Fla. Sponsored by the Electric Power Research Institute and the American Society of Mechanical Engineers. Contact: Linda Nelson, To Plan Ahead, phone 828/318-8428; e-mail lnelson@toplanahead.com; web www.epri.org.

June 27-30 **Radiological Effluents and Environmental Workshop**, Newport, R.I. Sponsored by the Nuclear Energy Institute. Contact: NEI, phone 202/739-8000; e-mail conferences@nei.org; web www.nei.org.

July

July 17-21 **HPS 61st Annual Meeting**, Spokane, Wash. Sponsored by the Health Physics Society. Contact: HPS, phone 703/790-1745; fax 703/790-2672; e-mail hps@burkinc.com; web http://hps.org/meetings/meeting39.html.

July 24-28 **INMM 57th Annual Meeting**, Atlanta, Ga. Sponsored by the Institute of Nuclear Materials Management. Contact: Christopher Viglione, INMM, phone 847/686-2365; e-mail inmm@inmm.org; web www.inmm.org.

July 31-Aug. 4 **Decommissioning and Remote Systems (D&RS 2016)**, Pittsburgh, Pa. Sponsored by the ANS Decommissioning & Environmental Sciences and Robotics & Remote Systems Divisions. Contact: D&RS 2016, e-mail ansdrs2016@gmail.com; web http://drs.ans.org.

And coming up (ANS meetings) . . .

2016 ANS Winter Meeting and Nuclear Technology Expo, Nov. 6-10, Las Vegas, Nev.

2017 ANS Annual Meeting, June 11-15, 2017, San Francisco, Calif.

2017 ANS Winter Meeting and Nuclear Technology Expo, Oct. 29-Nov. 2, 2017, Washington, D.C. ■