2006 HIGH-LEVEL WASTE CONFERENCE

Safe disposal on a global basis

AFTER A THREE-YEAR hiatus, the International High-Level Radioactive Waste Conference returned, this time to the city of Las Vegas, where it was first held 15 years ago. This year's version—the 11th such conference—centered on the theme *Global Progress Toward Safe Disposal*.

The general chair of the conference, Dan Bullen, a managing engineer with the consulting firm Exponent, Inc., remarked during the opening plenary session that this year's meeting was much like the inaugural conference. That first meeting, in 1991, he said, had 217 papers or panel presentations that focused largely on the proposed repository at Yucca Mountain and covered such areas as engineering systems, natural systems, transportation of spent fuel, regulations, and performance assessment. Only about 15 percent of the papers/presentations were non-U.S. focused.


Bullen

This year's conference, held April 30–May 4, attracted 210 papers or panel presentations, with most again dealing in some way with the Yucca Mountain repository program. The difference was that about 40 percent of this year's presentations were non-U.S. based, with participation coming from 23 countries, making for "much more of an international conference," Bullen said.

The conference also featured a day-long tour to the proposed repository at Yucca Mountain. The tour, with a maximum capacity of 130, filled up quickly and was heavily attended by non-U.S. meeting participants.

Before turning the plenary over to the scheduled speakers, Bullen noted that the next International High-Level Radioactive Waste Conference was being targeted for two years from now, with a hoped-for return to Las Vegas. He then announced that the plenary's speakers would represent "the spectrum of the U.S. repository program"—the Nuclear Regulatory Commission, the Environmental Protection Agency (EPA), and the Department of Energy—with closing remarks supplied by the president-elect of the American Nuclear Society.

Major themes of the plenary:

- *Securing spent nuclear fuel requires a permanent disposal solution.*
- *The EPA's revised standards for Yucca Mountain are due by the end of the year.*
- *The repository system at Yucca Mountain will be "safer, simpler, and more reliable. . . ."*
- *Going forward with nuclear expansion will require safe operation of facilities.*

Following Bullen, Jack Strosnider, director of the NRC's Office of Nuclear Material Safety and Safeguards, remarked that the agency believes that securing spent fuel and other high-level radioactive waste "requires a permanent disposal solution" and that a deep geological repository "can provide the means to secure these wastes in a safe manner." Until a permanent disposal solution is available, however, the NRC considers available technologies for wet and dry storage of spent fuel at reactor sites to be "safe and secure," Strosnider said, adding that interim technologies would continue to adequately protect public health and safety and the environment. The NRC also considers the current regulatory system to be capable of providing reasonable assurance that spent-fuel shipping campaigns "can be safely and securely conducted with low risk to the public and the environment," he said.


Strosnider

Strosnider made it a point to emphasize that the NRC "has taken no position at this time on whether construction of a repository at Yucca Mountain should be authorized." He said that the NRC would not reach a decision to allow operation of the repository "until after an exhaustive, independent technical safety review of the DOE's license application and a formal public hearing based on objective evaluation" of the project is held.

To a question on whether or not the NRC has taken a position on the construction of a second repository that would be located nearer than Yucca Mountain to seaports or to where most of the spent fuel is generated, Strosnider replied, "The simple answer is, no, we have not taken a position on that." He added that the idea of a second repository would be more an issue of national policy, to be decided by Congress and then the DOE.

Elizabeth Cotsworth, director of the EPA's Office of Radiation and Indoor Air,

Cotsworth

announced that final radiation-protection standards for Yucca Mountain should be issued by the end of the year. Cotsworth detailed the challenge made by parties to a court case in 2004 that resulted in the vacating of the EPA's 2001 standards by the U.S. District Court, which determined that a 10 000-year compliance period was not based on, nor was it consistent with recommendations from the National Academy of Sciences (NAS). The court upheld the standards on all counts except for the 10 000-year period. All other challenges, such as to the EPA's groundwater standard, were dismissed.

In its 1995 report, "Technical Bases for Yucca Mountain Standards," the NAS recommended that compliance with the standards be measured at the time of peak radiation risk, "within the limits imposed by the long-term stability of the geologic environment, which is on the order of 1 million years." Calculations for Yucca Mountain show that "peak risks might occur tens- to hundreds-of-thousands of years or even farther into the future," the NAS report noted.

The EPA's 2001 standards set an overall dose limit of 15 millirem (mrem) per year for people living in the vicinity of Yucca Mountain during and up to 10 000 years after the repository closes. The overall annual dose limit takes into account exposure through all pathways: air, groundwater, and soil.

EPA amendments to the 2001 standards added a limit of 350 mrem (3.5 millisieverts) per year from 10 000 years up to 1 million years. During this time period, the standards limit the maximum radiation from the facility so that people living close to Yucca Mountain for a lifetime during the 1 million-year time frame would receive a total dose no higher than that received by people living elsewhere in the United States. "We have to remember in terms of context that 1 million years covers 25 000 generations," Cotsworth said. "One million years is about 990 000 years beyond the earliest civilization at the time when man first roamed the earth. For a very long time period, such as up to the 1 million years, the total radiation exposure [from the Yucca Mountain repository] would be no higher than that which people experience and live with routinely from natural levels."

As soon as the EPA's new standards are issued, the DOE will move closer to finalizing a license application for the repository, according to Eric Knox, associate director for Systems Operation and External Relations for the DOE's Office of Civilian Radioactive Waste Management. "We have to know what standard we're going to meet," he said. "That guides and dictates our design specifications."

Knox noted that when Samuel Bodman became energy secretary last year, he made it clear that he wanted the DOE to develop a license application and repository system that was "safer, simpler, and more reliable than anything we've done in the past." Bodman's message resulted in the development of the Transportation, Aging, and Disposal (TAD) canister system, which the DOE is now working on incorporating into Yucca Mountain's final design. The TAD system will allow disposition-ready waste packages to be delivered to Yucca Mountain. "We believe it makes a lot more sense to allow the people who have the most experience handling the fuel—and that's the generators of the waste—to handle the packaged fuel," he said.

Knox also said that the DOE should have a schedule by this summer for submitting a license application to the NRC. The new schedule is also to include a timetable for when Yucca Mountain would be able to start accepting waste packages.

Allowing the Yucca Mountain repository to operate would be a boon to the nuclear industry, which is already involved in a renaissance. Harold McFarlane, deputy associate director for nuclear programs at the Idaho National Laboratory (INL) and then-president-elect of ANS, said that things are now on the upswing for nuclear. "It's actually gotten to be kind of cool in conversations," he noted. "It's gotten some very strong environmental endorsements over the last several years. And, economically, it's extremely good right now."

McFarlane

The renaissance is apparent in other countries, too, he added, such as China, India, and South Korea, where expanding populations have moved those countries to embark on nuclear building programs. "Quite often we hear, at least in this country, that the nuclear renaissance is coming. I'll say that it's actually gone along—it's simply a matter [of whether] the United States will join in [on the construction]," he said.

McFarlane concluded that one criterion for going forward with nuclear expansion is the continued safe operation of facilities. "This applies not just to nuclear power plants," he said, "but also to other types of nuclear operations, including the operation of [waste] repositories."

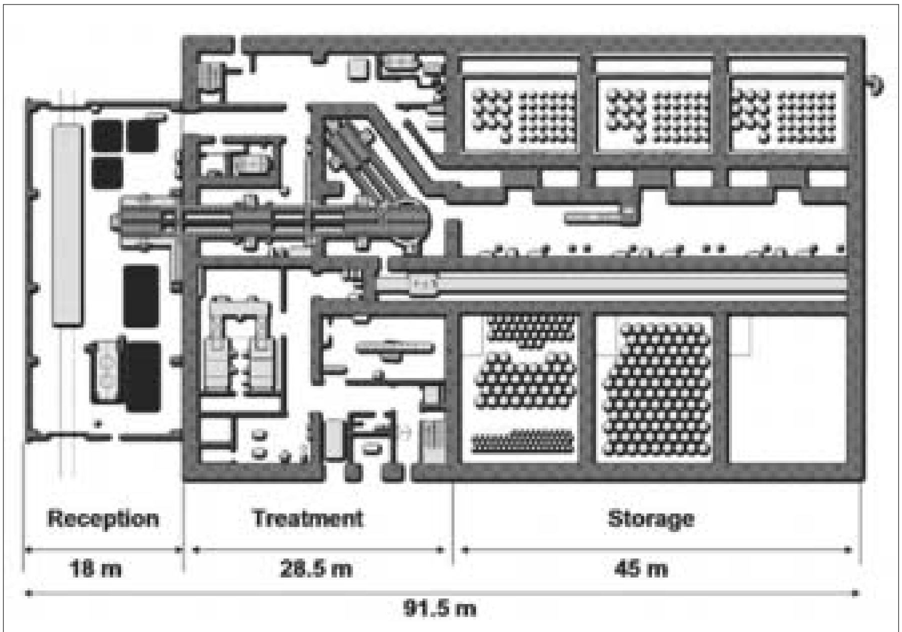
Handling and storage

The Netherlands stores all of its radioactive waste in aboveground facilities because it is "a very wet country" and "shallow land burial is not possible," according to Hans Codée, executive director of the Central Organization for Radioactive Waste (COVRA N.V.), which manages all radioactive waste in the Netherlands. The plan is to keep the waste in aboveground storage for at least 100 years, until a deep geologic repository may become available.

Codée

For the storage of high-level waste, the Netherlands opened the HABOG (High Active Treatment and Storage Facility) in 2003, at a cost of $140 million to build and operate. Since then, as Codée explained during the session titled "Waste Handling, Storage, and Emplacement," some spent

The exterior of the Netherlands' HABOG high-level waste storage building. (Photo: COVRA N.V.)



Ground floor of the HABOG (Drawings: COVRA N.V.)

fuel from research reactors and vitrified waste from reprocessing has been treated and stored at the HABOG.

The 100-year waste-storage period is divided into two parts, the first part consisting of 15 years of active operation of the HABOG, and the second and much longer part calling for the passive operation of the facility. Following the passive period, Codée said, it will be decided "whether to store the waste in a final repository, or use new techniques to process and store the waste."

The HABOG can store a range of high-level radioactive waste, Codée said. This includes waste from the reprocessing of spent fuel elements from power reactors, such as vitrified residues, compacted hulls and ends, and cemented or bituminized waste; spent fuel elements, including both high- and low-enriched uranium fuel from research reactors; and various high-level wastes from research activities.

In the design of the HABOG, a distinction was made between heat-generating and nonheat-generating waste. The former requires cooling for the spent fuel elements and vitrified reprocessing waste, while the latter needs only a well-shielded storage area. The canisters with heat-generating waste are stored in vertical storage wells, which are cooled by natural (passive) ventilation.

The HABOG was designed to protect its contents from earthquake, flooding, aircraft crashes, and other external hazards. The design also took into account any "internal influences," according to Codée, such as high radiation levels and heat production.

The outside dimensions of the HABOG facility are 91.5 × 46 × 40 meters (l × w × h); the reception area is 35 × 18 × 18.6 m; the treatment area is 46 × 28.5 × 18.6 m (half of the treatment area houses the auxiliary building, with ventilation systems, power supply, etc.); and the storage area is 45 × 46 × 18.6 m.

The HABOG is a modular building, meaning it can be extended if necessary. The outside of the building is painted orange to reflect a high level of radiation inside, and the formulas of Einstein and Planck are painted in green, representing the process taking place within. Every time the building needs repainting, it will be done in a slightly lighter shade, until after about 100 years the color will be almost white, the fading color representing the decay of the heat production of the hottest waste inside.

The HABOG has three vaults for storing heat-generating waste and three bunkers for storing nonheat-generating waste. The facility's license, however, permits a full load of only two of the three vaults or bunkers. The capacity of each vault is 135 canisters of vitrified waste and 35 canisters of spent fuel. The capacity of two bunkers is approximately 600 drums, containing various types of conditioned waste. The total volume of all the waste will be 750 m^3.

Codée said that the design of the HABOG would allow it to receive a heat load of 190 kW in one vault during the first six years of operation and an additional 228 kW for the second vault during the next six years of operation. "This means a maximum heat load of 394 kW after 12 years, taking into account the decay of the waste," he said. He added that inside and outside the building, except at the air inlet at the electrostatic filters, the radiation levels do not exceed the background level.

Since the start of the HABOG's operations in November 2003, only minor problems have occurred, such as some small flaws in the software of the control system, which have been fixed. Besides these minor problems, "the facility operates very well," said Codée.

Finland's investigation into horizontal disposal of spent fuel was the subject of Erik Thurner's talk. Thurner, of the Swedish Nuclear Fuel and Waste Management Company (SKB), explained that an SKB project was begun in 2003 on the horizontal deposition (KBS-3H) concept as an alternative disposal method to vertical deposition (KBS-3V). The goal of the project, according to Thurner, is to prove that 3H is a viable alternative to 3V by 2008, when SKB intends to submit an application to Finnish authorities for approval of an underground repository at the Olkiluoto nuclear power plant site.

Both storage-orientation methods are based on the KBS-3 concept, which in-

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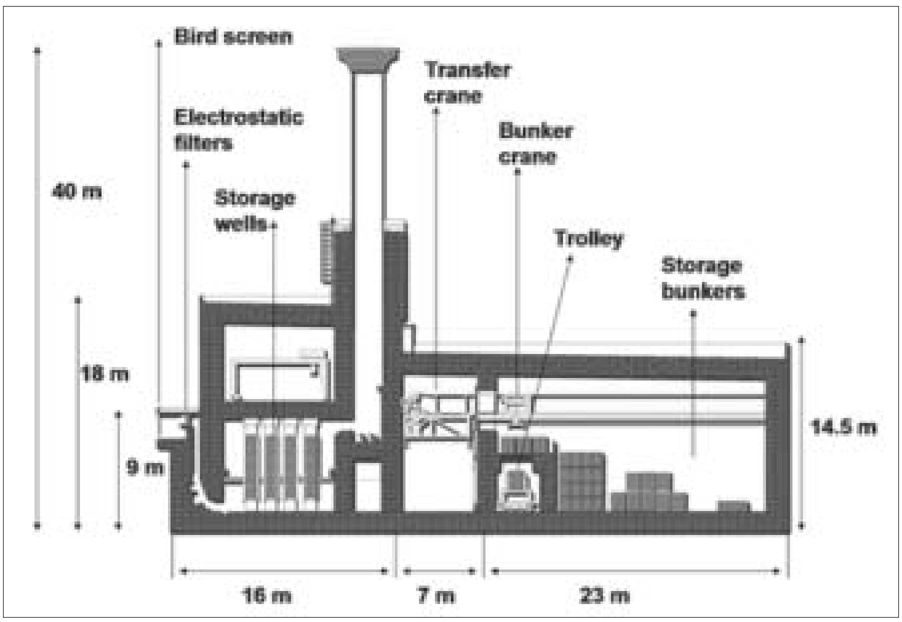


Cross-section of the HABOG

Continued from page 54

Thurner

cludes multiple barrier systems. Thurner said that the canisters in the 3V and 3H concepts are identical, but that the canisters would have different orientations. In the 3V concept, for example, the canister and a component called a buffer are installed top to bottom in sequence in deposition holes drilled in the floor of the deposition tunnel. In the case of the 3H, however, the canister and buffer are placed sideways in a perforated steel container, called the super container, and placed in a long horizontal drift.

Currently, the 3H project is in its demonstration phase, which started in 2004. The demonstration will last until 2007, after which an evaluation of the project will begin. The demonstration is taking place at the Äspö Hard Rock Laboratory in Sweden, where two horizontal drifts have been excavated in a niche specially prepared at a level 220 meters below ground.

For its KBS-3 underground repository program, Sweden's SKB is researching the best method for positioning spent-fuel canisters—vertically or horizontally.

Two designs are being considered for the 3H project canisters: the Basic Design, and the DAWE (Drainage, Artificial Watering, and air Evacuation) design. Thurner said that each design is being developed to a "proper level of details" based on bedrock data from Olkiluoto in order to evaluate the feasibility of the 3H concept in 2007.

In response to a question about why horizontal emplacement would be better than vertical, Thurner said it was because of "environmental reasons" and that laying the spent-fuel canisters sideways seemed a better method for storage because of the limited dimensions of the bedrock material at Olkiluoto.

Hideki Kawamura, of Japan's Obayashi Corporation, explained that Japan has given itself 20 years to locate a site to host an underground high-level waste (HLW) repository. As the search continues, the development of engineered barrier system technology is under way, with an end goal of allowing HLW to be transported and emplaced in the repository without direct human intervention. Kawamura said that this would be done through the use of tele-handling or robotic technology.

In the past few years, he said, options for Japan's emplacement process have been examined, with a focus on those that are "practical [and] safe, and can be carried out with assured quality using tele-handled processes."

Kawamura

Factors that need to be considered include the difficult operating conditions experienced in an underground repository because of high humidity, dust, temperature, and the restricted clearance for maneuvering; the large size and weight of and the heat output and radiation from the waste packages; the need for a high reliability of the emplacement processes—from preparing the waste packages to putting them in their final resting place—because, as one reference case stated, 40 000 waste packages would need to be emplaced at a rate of five per day; the need for a fail-safe strategy in case human intervention is needed because of operational problems; and the requirement that the quality of a remotely monitored emplaced system is ensured.

To date, work has focused on developing individual tele-handling technologies and expanding on the design options so that they can be compared and ranked by analysis. The next main step, Kawamura said, will involve more rigorous testing of designs in an underground test facility. "Such testing will not only serve as proof of concept," he said, "but will examine the robustness of the system to a range of different perturbations in order for improvements to be incorporated before second-generation tests at potential repository sites in Japan."

Waste packages

For its KBS-3 underground repository program, Sweden's SKB is researching the best method for positioning spent-fuel canisters—vertically or horizontally. At the same time, SKB has looked into techniques for sealing the canisters after they have been loaded with spent fuel.

During the session "Waste Package Fabrication," SKB's Hakan Ryden explained

Ryden

that after several years of research into sealing techniques, two final candidates remained: electron beam welding and friction stir welding (FSW). The former is a fusion method, and the latter is a thermomechanical solid-state process. After deliberation, SKB decided last year on the FSW technique.

At SKB's "canister laboratory," encapsulation techniques are built to full scale and are then demonstrated. "The critical part of the encapsulation of spent fuel is the sealing of the canister, which is done by welding the copper lid to the cylindrical

A shot of friction stir welding of a spent-fuel canister's copper lid, during testing at SKB's canister laboratory in Sweden. (Photo: SKB) part of the canister," Ryden said.

For the FSW sealing, SKB built a tool that consists of two parts: a tapered probe and a shoulder. The function of the tool is to heat up the sealing material by means of friction. Because of the tool's engineering, the material is forced to flow around the probe, thus creating a sealing joint. The advantages of the FSW tool, according to Ryden, are its "reliability, robustness, testability, and functionality."

The concept of the KBS-3 repository program is based on multiple barriers, where the canister and bentonite—an absorbent aluminum silicate clay formed from volcanic ash—are the primary blockades in the repository. The plan is to encapsulate the canisters, which have an outer 30–50 mm-thick shield of copper, into crystalline rock embedded in bentonite at a depth of about 500 m.

Ryden said that milestones in SKB's program include, as SKB's Thurner noted in the "Waste Handling, Storage, and Emplacement" session, the submission of a repository application in 2008 to Finnish authorities and start of operations at the repository in 2017.

Eddy-current testing (ET) of canister closure welds was described by Dennis Kunerth, of the Idaho National Laboratory (INL). Under the Department of Energy's Spent Nuclear Fuel (SNF) program, standardized canisters have been developed for the handling and interim storage of spent fuel at various DOE sites. These canisters are capable of transporting waste and being buried at an underground repository.

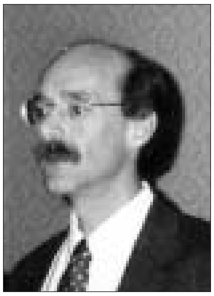
Under INL's Waste Package Closure System (WPCS) initiative, which operates as part of the SNF program, the canisters are loaded and final closure welds are done remotely in a hot cell. Kunerth explained that these welds must meet the American Society of Mechanical Engineers (ASME) Section III, Division 3 code requirements, which include volumetric and surface nondestructive evaluation to verify integrity.

Kunerth

According to Kunerth, ET has not been widely used in the SNF program for canister weld inspection because of its inability to perform volumetric inspection of ferromagnetic materials and because of difficulties associated with weld crown geometries. He added, however, that ET is well suited for surface or near-surface inspections, and, in many cases, ET can "detect surface-breaking defects or characterize weld uniformity in thin sections" of a canister.

Kunerth concluded that ET is capable of being remotely operated in a hot cell, which results in the elimination of waste streams that would be produced by penetrant testing of canisters.

Additional welding inspection techniques were detailed by INL's Kevin Skinner. The WPCS's design for sealing canisters calls for welding three lids and the purge port cap. This is followed by nondestructive examination using a combination of four methods of testing. All of these jobs are performed remotely (i.e., by robots).



Skinner

Skinner explained that the four nondestructive methods used for inspecting the integrity of the closure welds are leak detection, visual inspection, and ultrasonic testing, in addition to ET. Most closure welds are inspected using at least two of these techniques. The canister's outer lid, however, is inspected by three methods: ET, visual, and ultrasonic.

Development work on a full-scale weld-closure system was explained by Herschel Smartt, of INL. During the design phase at INL, five different potential equipment configurations were considered: a simple six-axis (a three-axis rotational device mounted to a three-axis translation device) robot; two cell-mounted robotic arms; two coordinate gantry machine-mounted robotic arms; a center pivot machine mounted on top of the waste package; and a circular track machine.

INL selected a circular track machine, incorporating a large-diameter ball bearing slewing ring, two articulated-arm robots mounted to the ring, a set of five end-effectors for each robot for welding, inspection, and weld dressing, removable tool trays, and associated means of cable management.

Smartt said that the system's circular track will be mounted to the operating floor of the hot cell and that the top of the waste package will be placed about 8 to 12 in. below that floor level. A hole in the floor will allow the waste package to be placed in position for welding and inspection, and the circular track will be mounted on the floor, concentric with the hole.

Smartt

"Two robotic arms will be mounted on the circular track to move equipment around the waste package during welding and inspection," he said. Control, data, power, and other cables and hoses will run from the control area to the robot mounts, which will be capable of motions in excess of 180 degrees around the waste package. "This will allow for overlap of both welding and inspection lengths," he said.

Smartt added that the robotic arms will have sufficient range of motion to allow them to move themselves and any attached end-effectors to a position that will allow lids to be placed on the canisters without removing the robots from the circular track.

A set of five end-effectors for each robot will be used for welding, inspection, and repair of the canisters. The end-effectors will

A drawing of a welding and inspection system under review by INL. In this drawing, a robot arm is shown mounted to a circular track, with a tool tray mounted to the robot mount. The robot is welding a joint on top of a spent-fuel canister. (Drawing: INL) connect to the robotic arms by means of quick-release tool-change connectors, and they will be stored in a tool tray on the robot mount when not in use. The tool tray will connect to the robot mount by means of a quick-disconnect tool plate and will incorporate a second quick disconnect on top to allow the coordinate gantry machine to easily move it to a glovebox or maintenance area.

Moving on to discuss another subject—Hanford's high-level waste canisters—was Chris Musick, of Bechtel National, Inc. Musick said that Bechtel has been contracted by the DOE to design, construct, and commission the world's largest radioactive waste immobilization plant, at the Hanford Site, near Richland, Wash. High-level tank waste will be delivered to the Hanford facility, where it will be separated into low-level waste and HLW.

Bechtel has been contracted by the DOE to design, construct, and commission the world's largest radioactive waste immobilization plant.

Musick noted that an HLW waste package must be designed and tested to ensure compliance with the DOE's requirements for acceptance for disposal at a federal repository.

Bechtel developed two HLW canister designs—the baseline and the alternate. Each one is 4.5 m long, with an outside diameter of 0.61 m, and weighs more than 3200 kg. The baseline canister design has a 0.95-cm (0.375-in.) sidewall. The alternate canister design has identical top and bottom head design as the baseline canister, but the sidewall thickness is reduced to 0.34 cm (0.1345 in.). The alternate canister was designed to increase its total volume by 4 percent. "Though this increase is small, it would reduce the total number of canisters produced over the life of the Hanford waste treatment mission by an estimated 480 canisters," Musick said.

Musick

Both canisters, according to Musick, have participated in significant engineering analysis and testing to satisfy Hanford's design requirements, interim storage requirements, U.S. Department of Transportation requirements, and federal repository requirements.

Physical testing of the canisters consisted of dropping and welding them. They were also filled with 1150 °C nonradioactive molten borosilicate glass and then cooled. Once the canisters reached ambient temperature, the canister geometry was measured and documented to ensure that they met the straightness and bulge requirements and retained their cylinder shape, as defined by the DOE.

The results of these tests proved a successful qualification of the HLW canisters, Musick said.

Other sessions

During the panel session titled "Communicating in a Political Environment," the DOE's Allen Benson commented that what bothers him most is inaccurate reporting about the Yucca Mountain program. Benson, communications manager for the DOE's Office of Repository Development, recounted how one Nevada newspaper—which he did not name—never fails to run a blaring headline about Yucca Mountain, followed by a story filled with half truths. "I don't mind talking to a reporter," Benson said, "but what I do mind is that the story that comes out of it is accurate."

Benson said that in his job, it quickly becomes evident when a reporter has an agenda. Panelist Elaine Hiruo, a writer for Platts, the energy division of the McGraw-Hill Companies, agreed with Benson, saying that a journalist should instead strive to present a balanced story that tells both sides of an issue. She said that she had been a reporter with no specific knowledge of nuclear issues when she first came to work for Platts, and that she learned about the industry by talking extensively to people involved in it, on both the "pro" and "anti" sides. She noted that people involved in nuclear are eager to talk about the technology and that she has never been turned away while trying to seek knowledge. Hiruo's knowledge-gathering has served her well, it seems, as Benson commended her for her fair reporting on the Yucca Mountain project.

During that same session, panelist Irene Navis, of the Clark County Department of Comprehensive Planning, said that although she is neutral on the idea of a repository at Yucca Mountain, the people for whom she works—the county commissioners—are against the project. Clark County, home to Las Vegas, is a neighbor to Nye County, where Yucca Mountain is located.

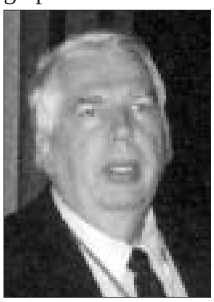
Navis also said that a recent survey of Clark County residents found that two-thirds of them feel that a repository at Yucca Mountain would have a negative impact on their quality of life.

Can canister containment be maintained after accidental drop events? This was a question posed by Dana Morton during a "Near-Field Processes" session. Morton, of INL, explained that the DOE performed a number of structural tests intended to provide data that can be used to substantiate the position that the DOE's spent fuel canisters, in fact, can maintain containment after accidental drops. The canisters, which are disposable and can be placed directly into a repository waste package, are made from austenitic stainless steels.

Morton

Morton said that drop tests have demonstrated that two standardized DOE canisters (one of 18-in. diameter and a second of 24-in. diameter) and another modified canister can survive a 30-ft drop with impact velocities of 44 ft/sec onto a flat, essentially unyielding surface, or a 40-in. drop onto a 6-in.-diameter puncture bar.

During that same session, Charles Forsberg, of Oak Ridge National Laboratory, spoke about the impacts on a repository of spent fuel from an Advanced High-Temperature Reactor (AHTR). The AHTR is a large (>2400-MWt) liquid salt–cooled high-temperature reactor that uses a graphite-matrix coated-particle fuel similar to that used in modular high-temperature gas-cooled reactors.



Forsberg

Forsberg said that when compared with spent fuel from a pressurized water reactor, AHTR spent fuel will require less repository area per unit of electricity produced because of the higher efficiency in converting heat to electricity. In addition, the AHTR would require fewer uranium resources and generate less depleted uranium than a PWR per unit of electricity produced.

Based on limited data, Forsberg noted, the potential performance of AHTR spent fuel in a repository is several orders of magnitude better than that of PWR spent fuel.

Additional information

For more reports from the 2006 International High-Level Radioactive Waste Management Conference, see the July/August 2006 issue of *Radwaste Solutions* magazine, a sister publication of *Nuclear News*, available from the American Nuclear Society.—*Rick Michal* NN