ANS 2005 WINTER MEETING

Nuclear technology—A good story untold

NOT OFTEN IS a standing ovation accorded a speaker at an American Nuclear Society meeting, but that's what happened at the end of environmentalist Patrick Moore's presentation extolling nuclear power. Moore, a cofounder of Greenpeace, broke away from that group and in 1991 started another organization called Greenspirit because, as he explained, he had been against various things for so long that it was time to be in favor of something.

Today that something includes nuclear power. Speaking at the opening plenary session of the 2005 ANS Winter Meeting—held November 13–17 in Washington, D.C., with the theme *Talk About Nuclear Differently: A Good Story Untold*—Moore announced that there are currently two kinds of environmental thinkers: those who believe that fossil fuels and nuclear power can be phased out so that renewables and alternative sources can supply the world's energy needs, and those who are "more sensible environmentalists like myself" who do not believe it is possible to reduce fossil fuel consumption by a considerable amount unless nuclear is part of the equation.


Moore

After describing his early days as an environmentalist in the late 1960s and early 1970s—protecting baby seals from clubbing and protesting nuclear bomb testing—Moore said that he made the transition in the mid-1980s from the politics of confrontation to the politics of consensus, "moving from problems to solutions." He commented that sustainability is the next logical step after environmental activism. "After all," he said, "there is no getting away from the fact that over 6 billion people wake up every morning on this planet with real needs for food, energy, and material. Sustainability is about continuing to provide for those needs."

Moore pointed out that although 14 percent of the world's energy is provided by renewables, most of it is from the burning of wood and other combustibles such as dung and straw, which produce carbon dioxide, for heating and cooking mainly in the tropical developing countries. Hydroelectric is the next biggest provider of renewable power, he said, and all the other renewables combine to offer only about 0.5 percent of the world's energy supply. And so, he questioned, if environmental groups such as Greenpeace and the Sierra Club are against the use of fossil fuels, nuclear energy, big hydro dams, and even the burning of wood to produce power, what is left? There is wind power, of course, but even a noted "green" advocate like Bobby Kennedy, Jr., has announced he is against the wind farm at Cape Cod. To be against all these various sources is unfathomable, said Moore, who added, "What kind of an environmental policy is that, to be against 99.5 percent of all the energy in the world?"

Moore continued by noting that one energy source far overlooked is geothermal, and that "every structure in the world" could be retrofitted to draw heat from the earth. "A geothermal heat pump, through a series of pipes, pulls heat into a house and magnifies it," he said. "There are tens of times more energy underneath the average city lot than is required in a home."

To close the so-called carbon cycle of energy production, Moore said, the world must adopt a three-step program. The first step is to use more renewable energy, the second is to develop an aggressive nuclear power program, and the third is to grow

Major themes of the meeting:

- *Expressing the positive aspects of nuclear energy in a variety of applications*
- *Differing views on proliferation by haves and have-nots*
- *Infrastructure and workforce needs of a reviving nuclear power industry*
- *Global oversight of spent fuel*
- *The uses of information from probabilistic risk assessments*

more trees and use more wood, "the exact opposite of what Greenpeace, the Sierra Club, and the Rainforest Action Network are telling people," he said. Moore explained that countries that use the most wood are also the countries where the forests are stable or growing in size. "When people use wood, people grow trees," he explained. "We have all been duped into thinking that when we use wood, we cause the forest to be lost. But what we're really doing is sending a signal into the market to plant more trees to provide more wood."

Moore also called the nuclear industry's Three Mile Island-2 accident a success story because it proved to the world that radiation could be contained. (Chernobyl, on the other hand, was a disaster, he said, but it was caused by the lack of containment, bad design, and "stupid operating procedure.") Activists in the United States say that nuclear power is unsafe, he noted, even though no one has died as the result of a radiation-related accident in the history of the North American civilian nuclear program. Moore concluded by stating that "40 000 people die in automobile accidents every year, and yet nobody is campaigning to ban the car."

Moore's presentation appeared to hit home, as at its conclusion a healthy share of the audience rose from their seats to applaud him. His message was long overdue in its telling, at least to a pronuclear crowd, that got him a standing ovation.

Sen. Chuck Hagel (R., Neb.) declared that today is an "almost golden time of possibilities," because more good can be done now for humankind than ever before. He cautioned that there are or will be unprecedented challenges—terrorism, pandemic diseases, endemic poverty, cycles of despair, and more than 6 billion people on earth, "over a third under the age of 19 years, and most of them in the troubled regions of the world"—but that a mix of assets could be used to overcome them. These assets consist of technology, leadership, resources, and "industries like [nuclear] that will help find our way through this and build a better world," he said.

Hagel

Hagel, whose home state receives about 30 percent of its electricity from its two nuclear power plants (Cooper and Fort Calhoun), said that nuclear must be "a very significant part" of the nation's energy portfolio. He added that people are starting to see the need for an expanded fleet of commercial power reactors in the United States.

Backing up Hagel's words about the growing acceptance of nuclear was Ann Bisconti, of Bisconti Research, who cited polls showing that 70 percent of Americans now favor the use of nuclear power. This public acceptance is a milestone, representing the highest level reached in more than 20 years. "Perhaps even more important is the fact that strong supporters now outweigh strong opponents by nearly three to one," she said.

Bisconti

Bisconti stated that the reasons for this support are fourfold. First, the nation's nuclear fleet has operated safely for decades, and the public recognizes this. Second, the public is aware that the nation needs nuclear energy because of wake-up calls such as the electricity problems in California and elsewhere in 2001, the major blackout in parts of the United States and Canada in August 2003, soaring gas prices at the pump and for home heating, the impact of hurricanes on the nation's energy supplies, and the continuing conflict in the Middle East. Third, the benefits of nuclear energy are being accepted by the public. Fourth, the industry itself has projected a positive attitude in recent years.

"[T]here is no getting away from the fact that over 6 billion people wake up every morning on this planet with real needs for food, energy, and material."

Bisconti brought forth chuckles from the audience when she showed a slide of *Elle* fashion magazine and explained that its September issue featured a list of "25 cool things for fall." Ranked at number 14 on the list was nuclear power. "It's clear that the news media find the idea of a nuclear renaissance intriguing," she said.

James Asselstine, a managing director for Lehman Brothers, an investment bank, offered his views on how the financial world views nuclear power. In assessing the existing fleet of nuclear plants in the United States, he said, investors realize that nuclear has a number of advantages: low and stable fuel costs, an environmental advantage over fossil fuels because of the zero greenhouse gas emissions factor, and the fact that nuclear plants are large baseload generators that benefit from economies of scale.

Asselstine

There are investor concerns, however, such as the risk of an extended plant shutdown due to operating issues. "Investors and analysts within the industry are all mindful of the Davis-Besse experience in which the unit was down for a couple of years due to the vessel head erosion problem," he said. "They are concerned about the risk of similar events in the future, and they place a high premium on the industry's ability to identify and correct problems of that type before they get to the point where they lead to extended plant shutdown."

Another concern—and one that is related to the first concern—is the material condition of the plants as they age, Asselstine said. Other concerns that he noted are security and terrorism, waste storage, and the potential for regulatory uncertainty.

Asselstine added that he gets questions from investors about investing in new nuclear projects. These queries pertain to the industry's history of a lack of standardization and regulatory issues that in the past added costs and caused delays to the completion of some of the current generation of plants. There also are questions about construction complexity and the high initial capital investment for building a new nuclear plant, as well as concerns about technology risk, the potential for new regulatory requirements, and the potential for licensing and litigation delays.

Asselstine explained that there are three financing models that could be used by utilities as they go forward to build the next-generation plants. The first model is to finance a plant as part of a regulated utility system, which is the way virtually all existing nuclear plants in the United States were financed. The second model is to finance and build a plant as part of an unregulated merchant generation company. In this scenario, investors would look at the size of the company, its assets, and its cash flow to assess how much protection is offered against the incremental risk associated with building a new nuclear plant. The third model involves "non-recourse project finance-style structures," which have been used for some non-nuclear generation in the past. This sort of model is a highly structured transaction that Asselstine called a single-purpose legal entity in which the new power plant is

the only asset of the entity and the only source of revenues to repay the debt financing associated with the project.

Asselstine concluded that it should be feasible to finance the next-generation plants using any of the three financing models, as long as the nuclear-related provisions in the Energy Policy Act of 2005 are implemented and there is a successful validation of the Nuclear Regulatory Commission's new licensing process.

Mike Wallace, president of Constellation Generation Group, agreed that some form of financing for new nuclear plants will be needed in the future. According to some projections, he said, increased electricity demand in the United States will require that 100 new reactors come on line between 2015 and 2025. Wallace and Tom Christopher, president and chief executive officer of Areva, Inc., are cochairs of the new company UniStar Nuclear, and they served as general cochairs for the Winter Meeting.

Wallace talked about a concept brought up during Moore's presentation regarding the environment, energy, and economics and how they are all connected—"E-cubed," he called it, in "engineer speak." He said that never before in his three decades in the energy business have the public, Congress, and the White House been so aligned as they are now in support of the expansion of nuclear power. "The groundwork has been laid over the course of the past 15 or 20 years through the operation of the plants, through a revisiting of the regulatory process, through changes in the regulatory process, and, more recently, through the Energy Policy Act," he said.


Wallace

The pitfall, he cautioned, could be the regulatory process. With a goal of building new plants and in preparing the licensing packages to be reviewed by the NRC, the industry has to be able to provide that agency with "the type of submittals, studies, and analyses that we as talented engineers are fully capable of producing," he said.

The NRC would review those packages, with the industry's expected result of having licenses issued for new plants. Wallace stressed, however, that a challenge in the review process is to capture the public's acceptance that the NRC is "a tough regulating body" made up of talented and expert people. "We need the general public to gain confidence in the next generation of plants by being able to see and follow a very robust regulatory process" as carried out by the NRC, he said.

That task puts the responsibility on everybody in the industry—the licensees, vendors, consultants, and contractors—to make sure that the packages submitted are complete and accurate and that they conform to the regulatory mechanism.

Wallace said that the new process for design certification, early site permits, and combined construction/operating licenses is intended to move risk and uncertainty away from the back end, when the plant is already built, to the front end, before significant financial commitments are made. "It's a shifting of a risk profile," he said, "without compromising in any way the general public's opportunity to fully and completely challenge any aspect of the design, the site, or the plant that's being built."

"We need the general public to gain confidence in the next generation of plants by being able to see and follow a very robust regulatory process."

Wallace closed by talking about the Energy Policy Act of 2005, which includes provisions for nuclear in the form of loan guarantees, standby support, and production tax credits. These provisions amount to "risk insurance" to offset the likely burdens of building the early plants and getting them on line. The bottom line, he said, is that it "is all about the regulatory process."

Emerging nonproliferation issues

The "President's Special Session on Emerging Nonproliferation Issues," hosted by ANS President James Reinsch, provided a reminder to Americans that much of the rest of the world takes a different view of the proliferation of weapons material than the United States does. Long after the end of the Cold War, the United States and other weapon states tend to be more concerned about "horizontal" proliferation—the spread of nuclear weapons capability to nations that did not previously have it. Non-weapon states, on the other hand, see "vertical" proliferation as a greater issue and believe that the weapon states are not taking sufficient steps toward disarmament. This dichotomy was apparent in the presentations by Linton Brooks, director of the U.S. Department of Energy's National Nuclear Security Administration, and Ambassador Sergio Duarte, of the Foreign Ministry of Brazil. The third speaker—Richard J. Stratford, acting assistant secretary in the U.S. State Department's Bureau of Nonproliferation—took a position similar to that of Brooks.

Brooks said that the United States is reducing its weapons arsenal, noting a 200-tonne reduction in fissionable material inventory announced earlier in November. Of this, 160 t will be retained for naval reactor use, 20 t for space missions and high-enriched uranium (HEU) research reactors (all of which will be converted to use low-enriched uranium [LEU] by 2014), and 20 t will be downblended for use in civilian nuclear power. As for the reduction in the former Soviet arsenal, Brooks noted that the Megatons to Megawatts program reached its halfway point in October, and the liability dispute with the Russian Federation concerning whether U.S. officials and contractors working on weapons material conversion in the former Soviet Union could be held liable for mishaps has now been resolved, although he gave no further details.

On emerging issues, Brooks cited the Global Threat Reduction Initiative, through which 105 research reactors outside the United States will be converted from HEU to LEU. Also, Russia has pledged to improve security at nuclear facilities by 2008, and plutonium production reactors at Zeleznigorsk will be closed in 2008 and 2010. Even so, Brooks quoted Energy Secretary Samuel Bodman as having said that the threat of proliferation has never been more grave than it is now. Brooks also restated the long-standing U.S. policy (shared by essentially all of the major nuclear nations) that fuel services (conversion, enrichment, and fabrication) from the countries with an existing fuel infrastructure would always be available to other countries that do not seek to develop such an infrastructure on their own.


Brooks

Duarte's perspective, closer to that of the weapons "have-nots," was made more emphatic by his experience as chair of the Nuclear Nonproliferation Treaty (NPT) review conference held earlier in 2005. Making it clear that his views are his own and not those of the Brazilian government, he called the conference "highly frustrating," saying that it did not go far enough to enlarge the realm of nonproliferation and to achieve disarmament by weapon states. He said that nearly every nation has now signed the NPT, and "only a couple of parties" have not complied fully.

During the review conference in 2000, Duarte said, there was an "unequivocal undertaking" by weapon states to pursue disarmament, but the general feeling at the 2005 conference was that this commitment has eroded, with a belief among nonweapon states that weapon states were trying to restrict access to civilian nuclear technologies. The 2005 conference produced no substantive recommendations, and because of this Duarte declined to issue a summary when the meeting concluded. He asserted that it is vital for all three goals of the NPT to be pursued: Disarm the existing weapon states, prevent the emergence of new weapon states or entities, and promote the peaceful uses of nuclear energy. Duarte said that new dangers, such as the possibility of terrorists' obtaining nuclear weapons, should not be used by the weapon states as an excuse to impede progress toward those goals.


Duarte

While Duarte spoke only for himself, Stratford said that his formal presentation would express the Bush administration's policy but that his answers to questions from the floor would reflect only his own views. Echoing some of what Brooks had said earlier, he also mentioned the willingness to pursue "counter-proliferation" to halt rogue nuclear programs that may be in progress. He cited efforts by several nations to interrupt the spread of enrichment know-how originating with former Urenco employee A. Q. Khan and the use of existing laws "in innovative ways" to interdict such trafficking. Stratford added that the United States is not doing this on its own, thanks to various multilateral efforts. He also noted that the Nuclear Suppliers Group, reassembled in 1991, is a valuable resource for preventing proliferation. Also, countries cooperating in a worldwide effort to stop money laundering (the Egmont Group) have made available the ability to freeze assets believed to be connected with clandestine weapons programs.

Stratford said that the United States wants the International Atomic Energy Agency's "additional protocol" on safeguards to become effectively universal and would like the signing of the protocol to be a precondition for gaining access to any nuclear fuel. He also said that the United States has a different view on the NPT conference than Duarte, with Stratford denying that it was a complete failure. He admitted that there is a disconnect between the views of weapon and nonweapon states, but he asserted that the goals are not incompatible. Still, he made it clear where the administration's priority lies on the importance of horizontal or vertical proliferation: Given noncompliance in Iran and North Korea, "If somebody's going to get nuked, it's going to come from there."

When the session was opened to questions from the floor, Brooks was asked whether the free market could take charge of the take-back of spent fuel. He said that either that or a supplier-driven approach could be acceptable, as long as plutonium is not separated from the fuel. He added that as far as he is aware, the free market has not made a concerted effort to gain the authority to buy spent fuel.

Duarte was then asked what could be done during the next NPT review conference to improve the situation. He replied that while the provisions on horizontal proliferation are clear and precise, the provisions on disarmament are not. He said that weapon states need to be more accountable and show that they are willing to meet their responsibilities.

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Questioned about whether the proposed nuclear rapprochement between the United States and India conflicts with other administration policies, Stratford said that it will be necessary to draft the agreement so that it does not conflict with U.S. law. The pact would have to look like those the United States has with other nations, but exclude acceptance of full-scope safeguards. To satisfy all legal requirements, the United States might seek to recover all nuclear materials that were used in India's Tarapur boiling water reactors (none of which were actually used in the development of India's nuclear weapons program). Also, India might ask for programmatic approval for spent fuel reprocessing, which the United States has given to Euratom and Japan. Stratford noted that if the agreement with India is found not to comply with Section 123 of the Atomic Energy Act, it would have to be approved by both houses of Congress.

Asked whether the United States would be setting a bad example by using commercial power reactors to produce tritium for the weapons program, Brooks answered with a flat no. He said that the plan, in which the Tennessee Valley Authority's Watts Bar-1 would provide enough tritium to avert the construction of a new production reactor within the weapons complex, is a responsible approach, given his view that nuclear weapons are not going to be eradicated any time soon. He then stated his belief that tritium by itself is not a proliferation concern.

At various times during the session, Duarte portrayed the United States as pursuing its own agenda, while Stratford denied that the United States was going it alone, pointing out the country's involvement in a variety of multilateral efforts. Stratford was asked from the floor whether these multilateral efforts were coalitions the United States had assembled in order to pursue its own goals, or whether the United States had joined up with any efforts initiated entirely by other countries. He gave it a great deal of thought, and then stated his belief that the convention whereby a nation must adopt effective controls against the reexport of nuclear material in order to be granted access to nuclear-related supplies and equipment did not originate in the United States.

Good stories to be told

The general chair's special session, titled "Critical Infrastructures: Good Stories Untold," looked at some of the efforts taking place to prepare the industry for a renaissance. Session cochair Michael Wallace, of Constellation Generation Group, said that the session would highlight people, for it is people, he explained, who "have been the key to our success in the past . . . and they will be in the future. They will need to solve the critical infrastructure issues of building new nuclear plants and will provide the leadership for a sustainable future." That future, Wallace said, could include the recycling of spent fuel, a possibility discussed by a speaker from Areva, who not only detailed the case for reprocessing, but put forward a plan to achieve it in the United States.

Maria Korsnick, vice president of the R. E. Ginna plant, described some of the successful measures being used by Constellation to meet the challenge of an aging workforce. "Constellation is seeing 50 percent of our generation workforce eligible for retirement in the next five years," Kors-

nick said. "In our nuclear fleet, 57 percent of our workers are 45 years or older." Many of these, and others like them in the industry, she said, lived through the original licensing of the plants, solved the problems, such as those brought up by the Three Mile Island accident, and are the reason that the nuclear industry has the respect it does today in America.

Korsnick had been in charge of the transition of Ginna from a single-unit plant to a member of the Constellation Energy fleet when it was acquired in June 2004. The challenge, she said, is to take the existing talent and use it in the best possible way, which means working as a team, innovating, and sharing knowledge. Ginna is doing this, she said, as shown in its last outage, which was 30 percent shorter than the previous best as a stand-alone plant. This was achieved as a direct result of sharing fleet resources.

To remain effective as experienced people have left the plant, Ginna undertook a program to gather detailed knowledge of the workforce and plan for the changes that were coming. This included learning when and where retirements will occur to determine from a critical standpoint which talent will need to be replaced first. This has allowed for identification of the areas where there could be problems.

Constellation recently conducted a nuclear staffing study. This allowed it to benchmark exactly what it wanted the nuclear organization to look like and to standardize this within Constellation, Korsnick said. Using the same positions and titles and the same scope of responsibility across the fleet allows sharing resources more quickly. From a succession planning standpoint, particularly considering new people coming into the industry, the company also identified key talent and when they will be ready for leadership positions. This allows development plans to be set for these individuals to ensure their success.

One concern as knowledgeable workers leave is that many things they know have not been documented. This knowledge needed to be captured in the plant procedures and processes. As part of its workforce planning effort, the company identified these people and their expertise through interviews and work is under way to bring their knowledge into the plant and the training program. She said that the workforce is passionate about sharing their knowledge.

Another method of transferring knowledge that Constellation is using is a mentoring process that pairs individuals who may be retiring with some of the newer talent being brought in. "So we have processes in place to ensure that knowledge is being captured," Korsnick said.

In addition, Constellation is rehiring retirees. Unfortunately, she said, there are policies and restrictions in place throughout the industry that discourage this practice, and, she added, this needs to change. These retirees, she noted, are of particular use as part of outages and special projects. For example, at Ginna, a power uprate project—at 17 percent, the most significant power uprate at a pressurized water reactor—is under way. A retired shift manager who was very interested in that project has been brought back, said Korsnick, and is now a key member of that project.

Graduate programs have been reinvigorated in many companies, she said, as well as intern programs. The industry is not only looking for professionals, but also for many welders, electricians, radiological protection and instrumentation and control technicians, etc. In the crafts program at Constellation, Korsnick said, the company is partnering with local colleges and high schools in order to attract talent in those key areas. At Ginna there is now a chapter of the North American Young Generation in Nuclear, which has become a very popular program. Korsnick said that these young professionals recognize that nuclear is a vibrant industry.

Supporting industry's needs

Lee Dodds, head of the nuclear engineering department at the University of Tennessee (UT) and a member of the board of the Nuclear Energy Institute (NEI), described how universities are gearing up to support the growing needs of the industry. "In my opinion, the educational pipeline is working well," he said. There has been a tremendous increase in enrollment, and the number of university programs is growing as well, he said. In the past five years, enrollment has more than doubled in undergraduate nuclear education courses across the country, he noted, and graduate student numbers have increased 15 percent. Also, over the past few years, a number of new nuclear programs have started up or have been revitalized; there are now 31 of them. Universities also conduct nuclear-related R&D projects and provide other services, such as continuing education short courses, distance education programs, teacher workshops, summer activities for high school students, and consulting.

Dodds

This year there are 1800–1900 undergraduate students enrolled in nuclear engineering programs across the country, including health physics, radiological engineering, and medical physics. More than 450 degrees were awarded in 2004.

Besides these numbers, Dodds had a good story to tell about distance education, which he said is ideal for working professionals who want to continue their education but are not near a university. Several universities now offer them, including the University of Tennessee, which offers a master's in nuclear engineering and two graduate certificates, one in nuclear criticality safety and the other in reliability and maintainability (R&M). UT is also planning to offer a master's in R&M, and it offers several short courses, as well.

"What is unique about our program," he said, "is that it is interactive in real time." This means that students, no matter where they are located, can question the professors and receive the answers back in real time, and local students and distance students can be taught simultaneously. "This is a real trick," he said. "So now we have distance students communicating in real time with local students in the classroom. We are excited about this." He said that about 30 percent are distance students, many of whom are working at nuclear facilities.

Dodds then explained what the industry can do to help. First, he said, is to increase collaboration with universities—programs are in jeopardy, he stressed, without industry collaboration. Probably the single best thing is to partner on "real world" R&D projects. Such collaboration, he noted, helps improve quality, foster enthusiasm, and keep industry in touch with academia.

Companies also should increase campus recruiting, he said, even if they are not in a hiring mode. "Just showing up really helps us," Dodds declared. Other ways the industry can help include hiring more summer interns, offering to present seminars and colloquia on campus, serving on nuclear program advisory committees, and inviting nuclear program faculty and students to use plant training facilities.

Dodds noted that 80 percent of UT's graduate students are U.S. citizens, unlike the areas of electrical and computer engineering. At the undergraduate level, he said that nearly 100 percent of students are U.S. citizens.

Critical infrastructure

Tom Houghton, senior project manager for new plant deployment at NEI, began his talk on infrastructure with a slide showing new nuclear plant demand. In the United States, it listed a possible 12 units under construction in 2012, with the first starting in 2010. Outside the United States, the number exceeds 50 units by 2020. "I could not have produced this slide six months ago," he said.

This also means, said Houghton, that infrastructure is becoming urgent, which is why it has been included as an "essential activity" in the NEI 2006 Business Plan. The other essentials are enhancing the regulatory environment, managing used nuclear fuel, advancing a national energy policy, and branding to build public support.

Areva, GE hold job fairs

While it is not yet a certainty that the United States will again begin ordering new power reactors, each week or month seems to bring new signs that a growing number of people in and around the nuclear community believe that such a revival is inevitable. At the ANS Winter Meeting, the most persuasive signs were events staged on Tuesday night by Areva and GE Nuclear Energy (GENE), both of which declared their intent to hire nuclear professionals in large numbers to support engineering efforts on expected new reactor orders.

Areva had clearly planned far in advance for its job fair, which was publicized with placards in the exhibit and registration areas from the very beginning of the meeting. The fair was held in a meeting room, with catered steam-table food. Areva's Bernie Copsey told *NN* that the company is looking to add about 200 new people to work not only on the company's reactor sales effort in the United States (EPR design certification preparations over the next two years, and then the UniStar construction/operating license applications) but also on other existing or potential Areva projects, such as pending reactor sales to China.

A. J. Nosek, a student at the University of Wisconsin, was one of the dozens of interested parties who came to hear what Areva had to say. His own work is in supercritical water reactor design, but he also has experience with the design of fuel particles. He said that the Areva recruiters were especially interested in the latter because of the company's longer-range effort to develop gas-cooled reactors for Generation IV. He said, however, that he is not necessarily poised to jump to the industry and that he might stay in school and pursue a Ph.D.

Copsey said that Areva is not only planning to hire in a wide range of specialties (electrical and mechanical engineering, reactor physics, etc.), but both new and experienced professionals. He noted that many of the students at the fair were aiming to find employment at the end of the current school year, in spring or summer 2006, but he said that if necessary Areva was prepared to hire people that very night.

GENE's gathering was on a smaller scale in virtually every respect: meeting room size, advance publicity (a few posted flyers), number of recruiters, catering (mainly cheese and fruit, no steam tables), and number of opportunities. Still, GENE is looking to hire 50 new people, which would have drawn considerably more attention had Areva not declared a desire to add 200. The company is recruiting primarily for work connected with ESBWR certification and licensing, based mainly at the company's Wilmington, N.C., office. Like Areva, GENE wants professionals, both new and experienced, in all fields.

Deepan Kothari, a student at Washington State University, attended the GENE fair, primarily to gather information. He said that he is not currently looking for a job in industry and is aiming mainly to continue his pursuits in radiochemistry through academia. Still, he was keeping an open mind.

And so it was that on Tuesday night at the 2005 ANS Winter Meeting there was considerable activity that had nothing to do with the meeting's programmed events, occurring simultaneously in three adjacent rooms in the northeast corner of the main floor of the Omni Shoreham Hotel: the Areva job fair, the GE job fair, and a meeting of the Operation and Power Division's Committee on New Construction, devoted to the same situation that had prompted Areva and GENE to step up their recruiting.—*E.M.B.*

Houghton addressed the critical areas of workforce, fuel, physical (manufacturing/supplier) infrastructure, and financial concerns for both current and future plants.

Regarding financial requirements, he said that industry needs investment stimulus, to offset the higher cost of first units and to ensure that they are economically viable, and investment protection, to protect against delays due to factors beyond a utility's control. "Many here remember the period of long delays created by the Three Mile Island accident," he said.

The new Energy Act, Houghton said, provides loan guarantees of up to 80 percent of project costs, which also applies to alternative energy sources. It could mean a $300-million benefit. A production tax credit also puts nuclear on an equal footing with other zero-emission technologies and applies to the first 6000 MW of plants put on line. As for insurance protection, which is needed against Nuclear Regulatory Commission licensing and litigation delays, the coverage is $500 million apiece for the first two plants, and $250 million for the next four plants. The coverage is there for both debt service and purchased power costs.

Concerning the workforce, he warned, if there is a surge in construction, there may be geographical distribution issues—getting workers to the plants. Encouraging people to move to these areas will be a challenge, he said, particularly as there is competition with other industries. For example, Hurricane Katrina will lead to major new liquified natural gas terminal construction. Nuclear requires higher standards regarding training and qualifications, safety knowledge, occupational dose limits, and work time restrictions, he said.

The issue of physical infrastructure—the manufacture and supply of components—has been put into the NEI business plan for the first time, Houghton said. An industry task force was formed with representatives from vendors, architect-engineers, utilities, and technical organizations. The first thing it did was to review existing studies. An infrastructure study is now planned for 2006, to be called the *NEI Study of Potential Gaps in Physical Infrastructure*.

Houghton said that the first thing to be done as part of the study will be to identify several construction scenarios and then determine total demand for key components and commodities (steel, concrete, piping, specialty metals, steam generators, pressure vessels). An assessment of current suppliers against these demand scenarios will follow to identify strengths, weaknesses, and gaps. Global supply and demand and other U.S. infrastructure needs will have to be considered, he noted, including the supply of qualified manufacturers, the availability of NRC inspection at plants and manufacturers, and transportation. From this, an integrated strategy to address physical infrastructure needs will be developed.

Asked about the availability of skilled project management, Houghton said that mentoring from those with such experience will be an important element. Maria Korsnick added that the large projects undertaken in recent years, such as replacing steam generators and reactor vessel heads, have been a "breeding ground" for finding and developing managers for new construction, adding that key project management talent might have to be brought in from outside the industry.

Regarding uranium supplies, Houghton said that there may be a shortage for about 10 years, but that depends on developments in China and India.

In conclusion, Houghton said he expects demand for personnel to eventually create the supply, although there may be short-term problems in some areas. The need now is to focus on those. He considers that this is a real opportunity to rejuvenate the country's heavy manufacturing sector and increase the highly skilled labor pool.

Closing the fuel cycle

The last speaker, Jacques Besnainou, a senior executive vice president with Areva, provided a road map for closing the fuel cycle in the United States. Besnainou started by listing reasons to reverse current U.S. policy. First and foremost is to optimize the

operation of the Yucca Mountain repository in order to postpone the need for an additional site. Currently, Yucca Mountain is limited by law to taking only 63 000 t of material, an amount that will accumulate by 2010. Optimizing repository loading requires reducing volume, and, more important, reducing heat load. This is most effectively done, said Besnainou, by removing the three most important contributors to heat loading: one long-term contributor, americium, and two short-term, cesium (Cs) and strontium (Sr).

Other reasons favoring reversal of U.S. policy, Besnainou noted, include energy security, keeping costs down, and developing a convincing solution to nonproliferation concerns, one that avoids any accumulation of separated plutonium.

Besnainou then set out the following two-phase road map. The first phase is the construction of an evolutionary recycle plant, which includes reprocessing and mixed-oxide (MOX) fuel fabrication, for operation in 2020. This plant would allow:

- "Early" treatment of newly discharged fuel (about three years).
- Treatment of low burnup legacy fuel.
- Vitrification of waste products (which includes Cs and Sr).
- Uranium/plutonium coextraction and recycle (as MOX).
- Reprocessed uranium (REPU) recycling.
- Used-MOX fuel storage for recycle in Generation IV reactors.

Early treatment—that is, removing uranium and plutonium from newly discharged fuel—avoids the buildup of americium, Besnainou said, while the heat generated by the other two main components of the heat load (Cs and Sr) would be locked in the vitrified waste and would decay over 30–50 years. These measures would result in a savings of 75 percent of repository capacity, he observed, and the plant would also treat the old low burnup legacy fuel, which has low americium content. He added that this strategy would also avoid the generation of neptunium, a product of americium, which is the largest contributor to the long-term radiation hazard.

The new plant would use "evolutionary" design technology, based on French experience with the La Hague reprocessing facility and the Melox MOX fuel fabrication plant, which would help keep costs low, and would use a U/Pu coextraction process, so there would be no separated plutonium. Furthermore, he added, integrating reprocessing and recycled fuel fabrication would mean "used fuel in—MOX out." The recycling of plutonium and REPU would provide up to 30 percent uranium savings, and the used MOX fuel would be stored for later treatment and recycle in Generation IV reactors. Advanced safeguards would be employed as they are for the MOX fuel fabrication plant being built at the Savannah River site.

This strategy would have a huge impact on the used fuel inventory in the United States, Besnainou said. The impact on Yucca Mountain loading could be even bigger: If only vitrified HLW were accepted, Yucca Mountain could be operated for the next 400 or 500 years.

While Phase I is evolutionary, the plant could be capable of integrating new development (for example, through modular design). This, Besnainou said, would ensure that improvements could be implemented when required. Phase II, some 20 years later, would involve construction of a new plant geared to Generation IV reactor operation, he said, which would include Gen IV fuel recycling and better actinide management, which would help to further optimize Yucca Mountain.

Finally, Besnainou discussed why it is necessary to decide now to build the first plant for operation by 2020. It would:

1. Stop the accumulation of used fuel in interim storage.
2. Significantly optimize Yucca Mountain loading, which should ease the licensing process. In fact, if only vitrified (glass) logs were placed there, it could become a "clean" facility.
3. Bring a much needed high level of certainty to the used fuel management program, using a technology that exists today.
4. Provide a sustainable foundation for the impending nuclear renaissance, because without recycling, Yucca Mountain will be legally full by 2010, before it opens.

Besnainou made one last point: "I travel the world and see that the nuclear renaissance is happening everywhere. China and India are very strongly committed to this renaissance and to the closed fuel cycle. I am both French and American, and I want my country, the United States, to be the first to build an evolutionary recycling plant."

Workforce challenges

When two units at Ontario Power Generation's Pickering A plant were being refurbished to bring them back into service, staff training couldn't be static because the work scope was always changing. Elizabeth Lopez, acting director for technical programs in training for OPG Nuclear, explained during the session titled "Current Experiences in Meeting Training and Workforce Challenges for New Nuclear Power Plants" that training plans had to be changed and extra training added to keep employees current with their jobs. "It wasn't like people could be trained once and then put on hold until the plant was ready," she said.

Pickering A, which consists of four CANDU reactors, was shut down for repairs in 1997. Unit 1 started its refurbishment project in 2000 and came back into service in 2003. Unit 4 started its project in mid-2004 and came back in 2005. Units 2 and 3 are still closed down.

Although Pickering A is not a new plant (in line with the session's subject matter), the extensive refurbishments made it seem as if it were new, coming back into service after its extended shutdown, according to Lopez.

For the training of control room operators, Pickering A used more than its full-scale simulators. In addition to those full-scale models, the plant provided classroom training that used desktop simulators, where operators viewed mimicked control panels. The desktop simulators were used to walk operators through scenarios to see how they and the systems responded to various situations. The desktop equipment proved to be an invaluable tool, Lopez said, because it "freed up the full-scale simulators that are already used 16 hours a day."

Because Pickering A's units had been off line for so long, many of the employees who were brought back to work had to undergo reentry testing.

Pickering A also conducted on-site training at mock equipment stages. For instance, demonstration models have been set up to show cutaway views of valves and other components, and a mock generator is used to practice synchronizations.

Lopez said that while Pickering A has used a form of distance learning, the site's training computers offer only an information transfer capability, not interactive activities. This means the computers are used by employees to call up required reading assignments. "We actually used [distance learning] quite a bit for the revised training," she said. "After the initial training had occurred, we kept track of changes to the work scope. Then we informed the affected employees of the changes and the required readings. For us, it was a very effective tool, and for the workforce it afforded a huge flexibility."


Lopez

Because Pickering A's units had been off line for so long, many of the employees who

were brought back to work had to undergo reentry testing. "They had to show that they had some baseline knowledge retention of the subject matter before they were put into a retraining program," Lopez said.

Joseph Safieh, of France's Commissariat à l'Energie Atomique, detailed the new European Nuclear Education Network (ENEN), which was formed in September 2003 in part to establish a basis for conserving nuclear knowledge and expertise.

ENEN members represent 35 universities and six research centers in the following countries: Austria, Belgium, the Czech Republic, Finland, France, Germany, Hungary, Greece, Italy, the Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.


Safieh

The goals of ENEN regarding universities, according to Safieh, are to develop a more harmonized approach for education in the nuclear sciences and engineering in Europe, integrate European education and training in nuclear safety and radiation protection, and achieve better cooperation and sharing of resources and capabilities at the national and international levels. A key to achieving these goals, Safieh said, is to assist universities in attracting "young and brilliant students by identifying, developing, and disseminating new and challenging subjects for research and establishing links and cooperation with research centers."

Another key is to "convince universities to recruit new academic members for teaching and research in nuclear disciplines and maintaining expertise in key nuclear areas." This could be accomplished, he continued, by developing, promoting, and supporting ENEN exchange courses in nuclear disciplines, disseminating and supporting the concept of life-long learning in nuclear disciplines, and facilitating and coordinating the participation of universities in European research projects.

ENEN's goals regarding the nuclear industry and regulatory bodies, Safieh added, are to create a secure basis of skills and knowledge of value to the European Union, to maintain an adequate supply of qualified human resources for design, construction, operation, and maintenance of nuclear infrastructures and plants, and to hold on to the necessary competence and expertise for the continued safe use of nuclear energy and applications of radiation in industry and medicine. Safieh said that one action that could help conserve knowledge and improve expertise would be to develop and establish databases, Web sites, and distance-learning tools.

ENEN has five committees that report to its governing board, according to Safieh. The committees are the Teaching and Academic Affairs Committee, responsible for implementing a "road map" that shows how to obtain a European master of science degree in nuclear engineering; the Advanced Courses and Research Committee, which ensures the link between ENEN members and EU research laboratories; the Training and Industrial Projects Committee, responsible for integration of industrial and national projects and the organization of continuous training; the Quality Assurance Committee, which takes care of the quality assurance process to be applied in the operation of education and training by ENEN's members; and the Knowledge Management Committee, which identifies and monitors deficiencies in scientific knowledge relevant to nuclear technology and safety.

Safieh also mentioned that ENEN wants to continue to support and strengthen cooperation with the World Nuclear University and the regional nuclear education networks in Asia, North America, and elsewhere.

At the start of the session, prior to the presentations by Lopez and Safieh, session organizer Pierre Tremblay presented 2005 Training Excellence Awards from the ANS Education and Training Division to Jane LeClair, of Constellation Nuclear's Nine Mile Point nuclear power plant, and Jo-Ann Rolle, of South Carolina State University. Tremblay is the chair of the Education and Training Division.

LeClair and Rolle were honored for, among other things, their contributions to and leadership in nuclear utility training and university education, and for being strong backers of nuclear industry professional development.

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Spent fuel storage

A special panel session titled "International Storage of Spent Fuel—a Status Report" provided an update on the proposal to set up an international spent fuel storage facility in Russia. The chair, Herbert Feinroth, of Gamma Engineering, explained that a session on this topic was first held at the 2002 ANS Annual Meeting in Hollywood, Fla. One year later, in May 2003, a workshop on the possibility of setting up such a facility was organized in Moscow by the U.S. and Russian academies of sciences, and a second one in June 2005 in Vienna. The panelists for this session came from the U.S. and Russian academies and from three countries that may wish to use such a facility—the Czech Republic, Japan, and Taiwan.


Feinroth

At the time of the Hollywood meeting, there was quite a bit of optimism about the possibility of establishing an international storage project, Feinroth said. Russia seemed the ideal candidate for such a project, as it had experience from the Soviet era when fuel supply contracts with countries operating Soviet reactors included the return of the spent fuel, which was stored awaiting eventual reprocessing.

Unfortunately, the reasons that the proposal did not move forward three years ago remain today—any transfer of U.S.-origin fuel to Russia would require a cooperation agreement, and such an accord remains hostage to the countries' disagreement over Iran. Feinroth said that he had recently met with one of the Russian supporters of this idea, Valentin Ivanov, who had spoken in Hollywood about the prospects. Now a deputy member of the Duma, Ivanov believes that this concept—of putting spent fuel into a few places—is one of the most important nonproliferation initiatives that can be taken. Ivanov told Feinroth that he is going to propose that this issue be placed on the agenda for the next G8 summit, which is being hosted by Russia.

The first panelist, Milton Levenson, an ANS past president (1983–1984), cochaired the inter-academy workshops with Nikolai Lavorov, of the Russian Academy of Sciences. Although no project has been initiated, things have evolved, Levenson said, and there remains considerable support for the idea. Russian President Vladimir Putin promised his support after the first workshop, and when International Atomic Energy Agency (IAEA) Director General Mohamed ElBaradei was informed of the second workshop planned for Vienna, he offered the use of agency facilities and translators. ElBaradei himself strongly promotes the regional development of fuel cycle activities such as this one.

Continued

Having only a few regional spent fuel storage facilities, Levenson said, would be more secure than a lot of dispersed sites and would have economic advantages, adding that Russia seemed to be the best place to start. The aim of the first project will be to identify the issues and problems that might arise in a host country, as well as in user countries, and to clarify the best way to proceed.

The workshop in Vienna, Levenson said, covered much more than the technical issues because of the participation of legal and liability experts, politicians, and others. The Russians have already been examining some of the difficulties and ways to resolve them. For example, by not including Russian nuclear material in an international repository, a number of sovereignty issues for them would no longer apply, and the IAEA could set its own safeguards rules.

Levenson also noted that this project will be self-financing, which should be an important advantage, although he doubted that money will be a major problem because of the high cost to countries having to deal with the problem nationally. For example, he said, Italy, having shut down its three operating nuclear plants in the 1980s after a national referendum, has had to spend a lot of money to look after its spent fuel while not earning anything from it.

The second panelist, Leonid Bolshov, is director of the nuclear safety institute of the Russian Academy of Sciences. The desire for further nuclear cooperation in dealing with spent fuel, he noted, is driven by a number of concerns, including the need to strengthen the nonproliferation regime, constraints on fuel markets, and environmental fears. He also stressed the security advantages, pointing out that because of the public's fear of radiation, a terrorist does not need to disperse a lot of material to have a major impact—just enough to make the level of contamination measurable. This, Bolshov said, could "kill the nuclear renaissance."

He noted that many countries are very much interested in international storage. While the scale of nuclear activities differs from country to country, and each has its own policy on waste management, most plan to store their spent fuel until decisions on reprocessing and disposal can be made. Russia's interests, he said, include securing financial resources for dealing with its own nuclear legacy. One major legal issue was resolved when legislation was passed that allows importing spent fuel for interim storage for reprocessing. He noted, however, that interim storage without a contract for reprocessing may be a problem.

The possibility of an international storage project is being widely discussed in Russia by the government, regulators, parliamentarians, and others, said Bolshov, with no unified voice emerging so far. Nevertheless, he said, Russia is moving ahead, in particular by investigating technical, legislative, and other issues. While the idea of having only foreign fuel in an international storage facility has some merit, he said that he thought it would still be better to start with a national facility and then expand the idea internationally.

There are several sites for a possible facility under consideration, including one in the Kola peninsula, near where nuclear submarines are stored, and one in Krasnoyarsk (about 150 km from the Krasnoyarsk reprocessing facility), which has good geology but little infrastructure. In the Transbaikal region of Siberia, a uranium mining complex whose reserves are petering out appears to be a very good candidate. Its tunnels could be used in developing a storage facility, and the area has the infrastructure in place to support development. Also, the local community would like to have it, said Bolshov. Geochemical studies support its use, he said, and the uranium deposit has been shown not to have moved in 1.5 billion years.

Having only a few regional spent fuel storage facilities, Levenson said, would be more secure than a lot of dispersed sites and would have economic advantages, adding that Russia seemed to be the best place to start.

In conclusion, Bolshov said, the implementation of a shared repository needs international agreements, large-scale research and development, the resolution of a number of legal issues, and effective mechanisms to implement a program. Most of the institutional requirements and legislation regarding the import of spent fuel and liability are in place for setting up a project, although there are still issues to resolve. Investigations have begun in various regions.

Potential customers

Frantisek Pazdera, director general of the Rez Nuclear Research Institute, noted that most of Europe (excluding Russia) has very limited reserves of fossil fuels or uranium, at least in comparison with demand. If the development of nuclear power fails and/or fossil fuels (possibly with carbon capture and storage) are not available, he said, countries will have to develop renewables, which will be very expensive.

If the world standard of living approaches that of the EU level, Pazdera said, there will be a tremendous demand for electricity. If the nuclear solution is adopted, with a target of 50 percent of electricity demand, some 4000 GWe of capacity will be needed in 2100. But when a capacity of about 1000 GWe is reached, breeders will be needed to allow further expansion. It also seems clear, he said, that because smaller countries cannot be expected to invest in the whole fuel cycle, regional solutions will be necessary to accommodate them.

At the front end of the fuel cycle, if installed capacity grows quickly, there may be security of supply problems, he said. As for the back end, the question of going to a closed or open fuel cycle must be resolved. Unfortunately, Pazdera warned, today this issue is not being discussed "in a market or in a rational way," but rather along political lines, with proliferation concerns an important element. An open fuel cycle, he said, is rational only if nuclear plays merely a supplementary role in meeting demand and is not the major component. Wide use of nuclear energy will require a closed fuel cycle, Pazdera said, unless substantial new uranium resources become available. Furthermore, delays in closing the fuel cycle will require long-term storage or "retrievable" repositories.

Pazdera also looked closely at various international fuel cycle configurations, from regional storage-only facilities to regional fuel centers that include storage, reprocessing, fuel fabrication, and disposal. He stressed that the criteria for establishing international programs, including financing requirements and access, must be carefully set out. Because there are risks, he also suggests keeping open national alternatives. Another issue that arises with regional spent fuel storage is that the material will eventually have to be returned for disposal.

For back end services, regional approaches can bring many advantages, but they also have risks, Pazdera noted. Referring to the earlier fuel contracts with the Soviet Union in which used fuel was returned, "Our own history shows that premature agreements can make it difficult to preserve market conditions," he warned. No matter what solutions are being considered, he noted, ways to preserve market conditions should be developed.

Continued on page 63

Continued from page 58

Kazuaki Matsui, research director of the Institute of Applied Energy and Japan's representative to the Generation IV International Forum, stressed that his presentation does not reflect his government's view. Japan, Matsui said, is the only non-nuclear weapons state with nearly the full range of fuel cycle activities except for uranium mining and conversion.

Japan has chosen the reprocessing/recycling route with no plan to dispose of spent fuel. Therefore, there must be sufficient spent fuel storage capacity available to support this strategy. Japan's first interim storage facility, which recently got the green light, should start taking material in 2010. Even so, the Russian proposal is of interest, said Matsui. The first commercial reprocessing plant in Rokkasho-mura, which is now being commissioned, will not have enough capacity to reprocess all the spent fuel from the country's nuclear plants, and eventually a second facility will be needed. The second plant should also be able to handle used mixed-oxide fuel. Matsui noted, however, that under the current plan, most of the storage margins will be used. This is not realistic, he said. If full reprocessing operations are not achieved in a timely manner, Japan will need additional spent fuel storage facilities, and this could include sending the fuel to an international facility in Russia.

Under the current plan, Taiwan is to have a new LLW repository in operation by 2013. Site investigations are now under way.

Matsui also explained that he chairs the waste management working group of the Pacific Nuclear Council, which is looking at the possibilities of international cooperation in managing spent fuel and high-level waste. This group has identified many potential advantages of regional storage, which include economy of scale, cost savings, availability of more options, improved security, and enhanced transparency. There are several drawbacks, however, including the need for complex international negotiations, the possible impact on national programs, and increased spent fuel transportation. Policy issues that must be set include what services are to be offered, who takes responsibility, how to select host states, and what international institutional arrangements will need to be made.

The final panelist, Shih-Kuei Chen, is the representative of the Taiwan Atomic Energy Council, the country's nuclear regulator, at the Taipei Economic and Cultural Representative Office in Washington, D.C. He was previously deputy director of the Institute of Nuclear Energy Research in Taiwan. Taiwan Power Company, which is responsible for managing its waste, has had difficulties in developing waste disposal plans. The company was unable to expand its Lan-Yu low-level waste storage site on account of local opposition and had to stop taking waste in 1996. Under the current plan, Taiwan is to have a new LLW repository in operation by 2013. Site investigations are now under way.

Taiwan's spent fuel policy is to develop a repository, Chen said. Investigations have identified host rocks in certain regions of the country that are worthy of further investigation. A preliminary feasibility study will be submitted by the end of 2009. Nevertheless, Taiwan, like Japan, has shown interest in using a regional repository.

Emerging topics in safety

In the session titled "Emerging Topics in Nuclear Installation Safety Technology," Amy Hull, an Argonne National Laboratory materials engineer on temporary assignment to Oak Ridge National Laboratory, reported on lessons learned halfway through the power license renewal and aging management process. She stated that once aging is taken into account, the existing regulations and design bases have been found to be sufficient for the continuation of reactor operation beyond the original 40-year license term. She noted the recent revisions to the relevant guidance documentation, including the Generic Aging Lessons Learned (GALL) report (NUREG-1801), which were carried out to incorporate accumulated operating experience and were intended to make the documents more widely applicable and user-friendly.

The overall lessons learned from the program to date, Hull said, include the needs to improve technical bases for aging management programs and regulations, reduce exceptions to GALL criteria, and make license renewal applications more consistent. Asked whether the process over the years has become more or less stringent, Hull said only that the Advisory Committee on Reactor Safeguards has never found a problem with any renewal request, and that the committee reviews each application very late in the approval process.

The Davis-Besse vessel head erosion, which had started years before it was noticed in 2002, continues to be a reminder for other power reactor staffs as they seek to gain much earlier indications of such component degradation at their own plants. Chris Hovde, head of the Ohio office of Southwest Sciences, reported on the possible use of lasers to detect water vapor leakage from reactor hardware and thus pinpoint locations that might require prompt attention and repair. The system reads reflected light from the laser, which is tuned to the absorption spectrum of water vapor, so while it does not actually indicate the presence of corrosion, it can locate regions where corrosion might eventually take place, as long as the laser can be positioned with an unobstructed line of slight. A questioner noted that water vapor can arise from a variety of sources within a reactor containment and asked whether the system could be tuned to the boron absorption spectra and thus detect possible corrosion more directly. Hovde said that there has been no attempt yet to use the laser to detect boron.

The proposed hydrogen economy might do more than just give power reactors a new mission—that of producing hydrogen for fuel cells. M. J. Driscoll, professor of nuclear engineering at the Massachusetts Institute of Technology, has examined whether fuel cells themselves might become part of the hardware used by power reactors, specifically to replace diesel generators as backup power for the emergency core cooling system of a gas-cooled fast reactor (GCFR). He and his coauthors determined that GCFR shutdown circulators need about 40 kW in each of four 50 percent–capable loops. With fuel cells' ability to reach full power almost immediately, the circulators could be operated by the present-day fuel cells used to power one commuter bus. In contrast, diesels—which must start up gradually, pushing moving parts from stasis into motion and setting priorities on which end-uses can receive power earliest—would need to be capable of 2500 kW in each of the three generators required. Driscoll said that further work would have to focus on common-cause failures that might prevent requisite operations. He noted that 98 percent of the failures in fuel cells to date have taken place not in the cell stack that produces the electricity, but in the support systems that deliver the power where it is needed.

The use of risk information

Rather than looking at how probabilistic risk assessment (PRA) works, the panel session titled "Management Perspectives on the Use of Risk Information in Operational Plant Management" focused on how management uses risk information and on the value of that information to the plant. The session chair, Mark Reinhart, of the Nuclear Regulatory Commission, said that those involved in PRA know how good it is. But, he asked, how well is this communicated to management, and does management use it for making operational decisions, such as

whether to operate, shut down, or do certain maintenance?

Gene Hughes, a director of Etranco, worked on Exelon's risk management program for some years to help bring risk assessment into daily operations at the plant. Hughes ran through some of the risk-engaging activities that plants deal with today, including the maintenance rule and the significance determination process (SDP).

The maintenance rule requires licensees to assess and manage the increase in risk that may result from any proposed maintenance activity. Since the maintenance rule came out, Hughes said, expectations for its effectiveness have been greatly exceeded. Systems for the evaluation of risk that are very sophisticated and that work very well have been put in place—for example, configuration risk management, which is a well-known structured process. The maintenance rule fits nuclear plant culture—of seeking perfection—perfectly, he said. Even the "unintended consequences" that have arisen from its introduction have been positive, Hughes said.

The maintenance rule requires licensees to assess and manage the increase in risk that may result from any proposed maintenance activity.

SDP is a plant indicator devised to provide a way for NRC inspectors to characterize the significance of their findings in a risk-informed, objective, and predictable way. It uses a color scheme in which "no color" means that the findings are "in compliance." The colors—green, white, yellow, and red—indicate a deficiency. Green, the lowest level, means that the licensee's own corrective action program can resolve the problem. The other colors require some level of direct NRC involvement.

Hughes said that he has found that SDP is a less effective procedure in terms of how it is implemented and its impact. SDP was to be "black or white," but it turns out to be very gray, he said. It works, but reluctance on the part of operators to be "non-green"—because of the "perfect" culture that exists at nuclear plants—leads to the green-white's threshold becoming a large issue. As a PRA person, he said, he likes SDP a lot, because it provides something to delve deeply into. He said that as a plant management team member, however, he does not like SDP because it can use a lot of resources.

Hughes also had a message for PRA people about defense-in-depth. PRA, he said, is moving into the mainstream of plant management and operation, and it is challenging many things that are done at plants. Plants were designed with a defense-in-depth approach, which has been very effective, he noted, but costly. Risk information allows measures to be taken to reduce cost while maintaining effectiveness, he observed.

Operation and maintenance people think deterministically, Hughes added, and PRA people must appreciate that when communicating with them. There is a tension here: People with a deterministic background want clear safety margins, but PRA must be realistic. "We really need to understand the deterministic role," he said. The conflict between deterministic margins and PRA realism is something that needs to be bridged. Plants work best, he said, with an underlying deterministic approach overlaid with risk applications. He said he would like to see this approach brought into the culture of a plant. To foster this, he said, he advises his PRA people to take a deterministic person to lunch and ask them why they do what they do. He advises the deterministic people to do the same.

Joe Donahue, vice president for nuclear engineering at Progress Energy, described the company's PRA program and how it uses and builds on PRA. As a fleet of four sites with different types of plants, the PRA group needs four different models, which means they do not get the economies of scale that some companies do.

The PRA group at Progress has recently moved out of the fuel organization and integrated into the central engineering organization. It has both pressurized water reactor and boiling water reactor experts, which, he said, allows a sort of independent evaluation to be made within the group. About half of the staff comes originally from systems engineering and half from operations, he said, a good mix, in his opinion. He noted that risk assessments are used by several groups—for example, engineering uses them to look at plant improvements and operability determinations.

The PRA group looks at any corrective actions that have the potential of being a regulatory problem or of causing significant unreliability. It also provides risk insights that help prioritize safety improvements and other activities proposed for inclusion in the company's business plan. One of the keys, Donahue said, is to have quality plant models. One of the most significant things done this year, he said, was to update the human performance and equipment reliability database used in the model.

PRA, Donahue stated, has improved plant availability and reliability. The important trick, he said, is to achieve the right balance. He said that he thinks it's perfectly all right to have a little more unavailability time—planned unavailability time—to have better reliability. Improved reliability will in turn minimize unplanned unavailability. As a former operator, Donahue said, he prefers that equipment be down longer for maintenance so that it works on demand.

Another key use of PRA is in operational decision-making, Donahue said. When there is a degraded condition, a formal decision-making process on whether to continue to operate takes place that requires PRA, as well as safety and regulatory input. The process brings management together "not to search for the right answer, but to search for the right operational answer," he said, adding that risk is brought to the table in a nonconfrontational way.

The license group uses PRA to obtain extended allowed outage times to do maintenance, as well as extended limiting conditions for operation when it makes sense to reduce the risk profile or to improve reliability.

One reason Donahue moved the PRA group into central engineering, he said, is his focus on equipment reliability. Plant components have been categorized to identify in particular the "critical" and "noncritical-but-important" ones, and the categorization is checked each year. PRA is also used to look at vendor quality, he said, and if a component is critical, there will be more vendor surveillance and checking.

PRA has been rolled into project management and capital allocation, Donahue noted. On the project management side, the level of management involvement in maintenance and modifications will be increased if work is being done on critical components. PRA, he said, plays a role in capital allocation regarding engineering modification projects to make sure that those chosen provide the most improvement in safety and reliability.

The final speaker was Harry Faulhaber, division manager of nuclear engineering with the Omaha Public Power District (OPPD), which owns only one reactor—publicly owned Fort Calhoun. "We have been involved heavily in PRA," Faulhaber said, "because we felt we had to stay in the forefront to operate competitively with such a small organization." One important activity of his four-member PRA group was to incorporate risk information into the company's nuclear asset management program used for project prioritization, long-range planning, and budgeting.

With only one nuclear plant in OPPD's fleet, Faulhaber has to compete at a corporate level with a wide variety of other business units for funding. The utility's corporate model for capital project allocation takes a basic financial perspective that makes the case for nuclear safety improve-

ments a real challenge. The challenge he set was to use risk-informed insights to get capital projects approved at the corporate level. Was it possible, he asked, to translate the benefits of safety into economic terms? In fact, his team came up with a successful approach that made use of SDP.

The initial approach taken was to develop a method that puts an economic value on making improvements to two major safety indicators: core damage frequency (CDF) and large early release frequency. Faulhaber said that an improvement in CDF of a factor of two is worth $100 000, according to industry information. As the soundness of this number was not absolutely clear, however, the group looked for another approach. They then had the idea of using the SDP. A yellow SDP finding, they realized, would result in additional NRC inspections that the company had to pay for, as well as other possible NRC actions.

Faulhaber said that a fairly basic analysis was done of the costs of the inspection hours, as well as the cost of its own staff time, travel expenses, etc. It added up to a $400 000 cost to the organization—which meant something to the accountants. They understood that in the case of a yellow SDP finding, a response was called for, he explained, and this had a real financial impact. In this way, he noted, improvements in safety that would prevent the occurrence of yellow findings could be translated into economic terms. As a result, he said, he has had an easier time getting projects approved.

Risk insights have been integrated into the day-to-day operation of the station, Faulhaber said, including the implementation of a risk color scheme. It is important for people to understand the risk level at the plant, he said. As for training, he said, the risk significance of equipment and tasks, as well as events, is designed into the program. Staff are also taught how risk is incorporated into the site and into their activities.

Faulhaber said he believes that the staff has embraced the risk management concept throughout the station. Management, he said, understands the value of risk information, and it is being applied throughout the organization, improving operational flexibility and business decision-making.

Equipment reliability

Substituting for Walter Justice in the session, "Equipment Reliability: A Driving Force in Nuclear Asset Performance," fellow Tennessee Valley Authority (TVA) engineer Doug Helms reported on a project to reduce trips and forced outages at the utility. Working with Performance Improvement International, TVA set up fault trees to find single-point vulnerabilities in critical components, and then to replace those components that have been notably involved in reactor trips. The effort entailed examination of causes of trips both within TVA and in the industry in general and giving priority attention to components that have caused trouble in both.

Helms said that with the program in place at Sequoyah, trips at that plant are down noticeably since 2003. Asked if there were components that showed a high degree of trip involvement (three or more events) in both TVA and the industry, Helms said that the most vulnerable turned out to be neutron monitoring power sources. He said that he had not expected beforehand that this would be a problem area, but once it came to light, TVA replaced those power sources that had been in service for more than half of the mean failure-rate time.

Steve Swearingen, head of reliability at Omaha Public Power District's Fort Calhoun plant, reported on actions taken at the 478-MWe pressurized water reactor to boost reliability. Fort Calhoun has gone "breaker-to-breaker" (uninterrupted power production) in three of its last five fueling cycles, and Swearingen said that one reason was the plant staff's use of the Nuclear Regulatory Commission's maintenance rule to enhance the plant's availability margin. He noted that reactor coolant pump seals have been a chronic problem area, and so they receive extra attention. A "summer reliability" team was set up to ensure smooth operation through the period of highest power demand in Nebraska, with prospective actions either performed in advance or deferred as needed to get the reactor through the summer. After the reactor's license was renewed, the condenser and moisture separator were replaced. Swearingen said that since the license now extends to 2033, the 2006 refueling outage will be especially busy as it will include replacing the steam generators, vessel head, and low-pressure turbine.

Osamu Maekawa, a technology executive with Toshiba Nuclear Energy Systems, reported on a number of techniques used by Toshiba to increase equipment reliability and availability at Japanese power reactors. He said that laser peening of reactor internals is used to counter residual stress on core shrouds and control rod drive stub tube weldments in boiling water reactors and on bottom-mounted instrumentation in pressurized water reactors. Also, he added, advanced induction heating stress improvement is used on a variety of welds, and an electrical discharge machining technique is used to repair cracks.

University work

Much has been accomplished involving virtual reality (VR) reactor design at the University of Illinois at Urbana-Champaign (UIUC). During the session titled "Impact of Innovations in Nuclear Infrastructure and Education on University Research Reactors–II," UIUC's Rizwan Uddin provided an update on what has happened with the VR work since he first reported on it at the 2004 Winter Meeting (*NN*, Jan. 2005, p. 49.)

In another area of research being conducted at UIUC, the university is developing and testing concepts for new research reactor designs.

Supported by the Department of Energy's Innovations in Nuclear Infrastructure and Education (INIE) program, UIUC is progressing with its development of a VR reactor, control rooms, and components. The UIUC program now has access to three operational VR facilities on campus: a six-walled 3-D environment (called the CUBE), a four-walled CAVE (Cave Automatic Virtual Environment) display, and a single-walled VisBox component (what Uddin called "an immersive 3-D display").

Uddin

Recent focus has been on two fronts, Uddin said. The first is on developing models in standard CAD (computer-aided design) formats and then importing them into a VR environment. "CAD drawings already contain all of the necessary 3-D information, and we did a few conversions," he said. The second front is on enhancing the models by using game engines in order to take advantage of the speed and efficiency of those engines.

Currently being implemented is the ability to interact with the VR environments through the introduction of hands-on aids such as control panels and touch-screen monitors, which will enhance navigation through VR scenarios such as a boiling water reactor simulator.

In another area of research being conducted at UIUC, the university is developing and testing concepts for new research reactor designs. One design under consideration is a variation of the German FRM-II, a 20-MW reactor that uses a high-enriched uranium fuel. UIUC's research team

An image from UIUC's VR control room (Graphic: Halden Reactor Project)

changed the design specs to low-enriched uranium (LEU) fuel and 10 MW of power while keeping the same maximum thermal flux per megawatt (MTF/MW) requirement as in the FRM-II. Uddin said that with an asymmetric design using the LEU fuel, in which half of the annular core is of different thickness than the other half, the same MTF/MW is achieved as in the FRM-II. He added that the design produces a high thermal neutron flux zone (3.9×10^{14} n/cm^2-sec), a moderate thermal neutron flux zone (2.4×10^{14} n/cm^2-sec), and a low thermal neutron flux zone (1.0×10^{14} n/cm^2-sec) in the outer reflector.

Uddin, a nuclear engineering professor, said the design's features make it "an interesting candidate for the next generation of research reactors."

Kaushal K. Mishra, a nuclear engineering graduate student at North Carolina State University (NCSU), described a thermal neutron imaging facility that is in the early stages of operation at the school's PULSTAR reactor. The PULSTAR is an open pool–type 1-MW design with the core placed inside a 15 000-gallon tank of water. Six beam tubes (BT) are positioned in the pool and provide neutrons for experimental purposes.

The new facility is currently equipped to perform conventional radiography and tomography. Initial testing supported by INIE has started using BT no. 5 of the reactor. Mishra said that the thermal neutron flux at the entrance of this BT was measured and found to be about 2.5×10^{12} n/cm^2-sec with a cadmium ratio of about 90.

The facility's design includes four main parts: the collimator, the beam shutter, the shielding, and the sample positioning and detection system. The beam shutter has a rotating drum design, which is opened by an air cylinder, while the closing of the shutter is gravity controlled, which provides passive safety, Mishra said. The shielding of the beam has walls that include a ¼-in.-thick boral plate and 6 in. of lead followed by about 19 in. of RX-277 (a concrete-type material with 1.6 percent boron content).

Mishra

The detection system is based on using various types of imaging approaches, Mishra said. This includes the use of conventional radiography film along with gadolinium-loaded image plates. He added that modern and innovative imaging methods are currently being tested and implemented at the facility.

NCSU is also considering replacing some of the PULSTAR's 4 percent–enriched fuel with 6 percent–enriched fuel. To do so would require a license amendment from the Nuclear Regulatory Commission. Matthew Miller, a nuclear engineering graduate student at the University of Tennessee, worked on determining the power peaking factors for the PULSTAR's replacement fuel.

The core assembly in PULSTAR consists of 25 assemblies in a 5×5 array. Using the MonteBurns computer code and other programs, Miller said that test results showed that 6 percent–enriched fuel can be used to replace some of the 4 percent–enriched fuel without exceeding peak to average power ratios specified by the NRC's safety analysis report for licensing the PULSTAR.

Other presentations during the session included a review of operational benchmarks for a Monte Carlo model of the University of Wisconsin's 1-MW pool-type TRIGA reactor, a review of neutron radi-

ography development at the University of Texas at Austin's TRIGA reactor, and an explanation of the work done by the National Institute of Standards and Technology on the use of internal standardization—known as the k_0 method—in cold neutron prompt gamma-ray activation analysis.

Other sessions

In the session "Emerging Nonproliferation Issues and Compact Reactors," past ANS President Alan Waltar (1994–1995), retired from Pacific Northwest National Laboratory, reported on what is being called the "Atoms for Peace" reactor design. Taking its name from President Dwight Eisenhower's historic 1958 speech, the design would be a 100-MWe boiling light-water reactor with crossflow cooling. The reactor would be delivered sealed, with an installed fuel core intended to last as long as 60 years, and would operate on the Rankine cycle. Conceived as a proliferation-resistant option for third-world electricity infrastructures, the reactor would use spherical fuel elements, and the design could later evolve toward superheat and supercritical cycles. Asked whether a prospective buyer would have to pay up front for the whole 60-year cost of the system, Waltar said that there would have to be a creative approach to financing, perhaps treating the fuel cost as a rental.

At the second session on medical physics research, David W. Nigg, manager of radiation physics at Idaho National Laboratory, reported on the initial performance characteristics of a thermal neutron beam for neutron capture therapy at Washington State University. The school's 1-MWt TRIGA research reactor has an added epithermal neutron beam for large-animal research, and Nigg said that directing the beam through heavy water and a 3.5-foot thickness of borated concrete would produce the desired boron neutron capture therapy reaction (^{10}B[n, a]^{7}Li) and block all other gamma radiation aside from the desired 0.48 MeV emission. Nigg said that future applications could involve liposomal delivery and the administration of diffusive and active agents.

The ["Atoms for Peace"] reactor would be delivered sealed, with an installed fuel core intended to last as long as 60 years.

At the session on advanced nuclear energy systems research and development, Jay F. Kunze, dean of the College of Engineering at Idaho State University, proposed a system whereby nuclear power would not only produce hydrogen but would also have a use for the oxygen generated in the same hydrolysis process. Kunze noted that for combined-cycle coal gasification to be a reasonable option, pure oxygen should be used as an input rather than air. Assuming completely clean combustion and total carbon dioxide sequestration, the hydrogen and oxygen produced by an additional 250 GWe of existing-technology reactors would cover all further power demand and also allow conversion of the entire transportation sector from gasoline to fuel cells. In response to a later question, Kunze said that this should be possible even with the relatively modest hydrolysis that can be achieved with light-water reactors.—*E. Michael Blake, Dick Kovan, and Rick Michal* NN