ANS ANNUAL MEETING

Nuclear's bright future

Meeting session coverage:

- *Lessons learned from Fukushima Daiichi*
- *The ongoing process of using 10CFR52*
- *Plans for long-term HLW storage*
- *LWR sustainability becomes more specific*

In the wake of the accident at Japan's Fukushima Daiichi nuclear power plant and the resulting political decisions that have affected nuclear programs in a number of countries, the theme of the American Nuclear Society's Annual Meeting, "Seizing the Opportunity: Nuclear's Bright Future," might have seemed an unfortunate choice.

But it worked.

It worked because of the enthusiasm and the positive vibes of the 950 people who attended the meeting. It worked because everyone seemed willing to tackle the Fukushima issue and recognize that steps might need to be taken to avoid similar consequences elsewhere. It worked because nuclear energy is a necessity in today's world.

After welcoming the attendees to the opening plenary session of the Annual Meeting, held June 26–30 in Hollywood, Fla., ANS President Joe Colvin immediately turned to the topic of Japan's east coast, which was struck on March 11 by a magnitude 9 earthquake and a tremendous tsunami that devastated the area.

"From our perspective, the key feature of this event has been the impact on the Japanese nuclear program and all the nuclear programs the world over," he said. "We all want to express our profound sorrow for the suffering of the Japanese people and to convey our deepest gratitude to the Japanese plant workers who worked tirelessly in unbelievable conditions and at great personal risk to gain control of the situation at the plant."

Colvin

Colvin noted that ANS had been very proactive in dealing with the great number of inquiries it received from the media and the public after the Japan event. For example, ANS members participated in more than 250 media events in the first three weeks following March 11, reaching more than 81 million Americans with factual and credible information on the event and its impacts. Another example is the support of the Japan Relief Fund, established by ANS and the Nuclear Energy Institute, which by the end of June had raised over $175 000 to help the workers at the plant and their families.

Colvin said that there have been many lessons learned from the Fukushima accident and that it would take time to collect all the data and draw accurate conclusions to be used to improve the safety of reactors around the world. In this regard, he said, ANS has established a special committee to review Fukushima's lessons learned from a scientific, technical, and policy perspective. Former Nuclear Regulatory Commission chairman Dale Klein and Michael Corradini, ANS's current vice president/president-elect, are cochairs of the special committee. Colvin also highlighted the meeting's two special sessions dealing with Fukushima (see coverage elsewhere in this section).

Jim Ferland, president of Westinghouse Electric Company's Americas Region, picked up where Colvin left off regarding Fukushima. "One of the hallmarks of our industry is our ability to incorporate lessons learned in all that we do and constantly raise the bar on our own performance," he said.

Ferland

Ferland remarked that he has had many discussions with people wanting to know what impact Fukushima will have on the industry and on new nuclear construction in the United States. He said that he answers these questions by saying, in part, that nuclear power, both before and after the Fukushima event, has been a clean technology and a reliable source of baseload power. The industry manages 100 percent of its waste stream, he said, and has the existing infrastructure to meet the rising demand for electricity. "Those fundamental facts remain in place today, just as they did six months ago," he said. "We need to incorporate the lessons learned from Fukushima, but the fundamental strength of the nuclear proposition in electricity generation is still here."

Two drivers that will push the United States toward new nuclear plants are the unpredictable price of natural gas and the slow growth of the economy, he said. The construction of new nuclear plants in the United States will have to be done well, he added. "That means high quality. It means safely. It also means on schedule and on budget."

Ferland noted that in addition to site work being done for four Westinghouse AP1000 reactors in the United States (two at Southern Nuclear Operating Company's Vogtle site, in Waynesboro, Ga., and two at South Carolina Electric & Gas Company's Summer site, in Parr, S.C.), four AP1000s are currently under construction in China.

During a recent visit to China, Ferland toured one of the sites where a new plant is under construction. "The level of energy on that site was incredible," he said. "Just the feeling you get from being around new nuclear construction that is real and is coming

up out of the ground is fantastic. You watch 4000 workers on that site actively building the facility. You walk into the building next door and see 100 engineers working through the day-to-day issues. It kind of brought home that this new technology is real and there's a ton of energy behind it."

Pete Lyons, assistant secretary for nuclear energy at the Department of Energy, commented that he felt "very pleased and proud" regarding the United States' response to Japan's March events. He noted that President Obama had spoken early and carefully about the Fukushima accident and had asked the NRC to do a careful review of safety and to explore whether there were lessons to be learned. "He did not order the shutdown of any plants," Lyons said. "In contrast to some other countries, I think we should be very proud of the actions taken by our president in response to the tragedy in Japan."


Lyons

Lyons cautioned that the U.S. nuclear industry needs to be careful not to move too quickly to draw comprehensive explanations or understandings from Fukushima. "I think there are still many unanswered questions on precisely what happened, some of the details of the accident and progression, some of the timing of the different steps," he said. "All of those need to be carefully understood as we move forward."

The DOE, he said, reacted immediately to the event. Within an hour after the earthquake hit, DOE personnel began to realize the magnitude of the issues in Japan, and the DOE's Operation Center was activated. DOE teams of about 40 people each were sent almost immediately to Japan, and tons of equipment were shipped within the first few days. "We've been very active from the standpoint of analysis, trying to look at a number of 'what if' questions and providing suggestions to our Japanese colleagues," he said.

The DOE, through its National Nuclear Security Administration, set up an aerial system that flew countless missions in Japan to monitor ground deposition. Many mobile ground-based monitoring systems were also set up to help map the details of the contamination and to better understand the challenges.

Lyons noted that ANS also played a substantial role. "Their Web site [<www.ans.org> and <www.ansnuclearcafe.org>] was certainly one of the very useful ones in trying to better understand the accident progression and the issues within Japan," he said. In addition, a number of international meetings have been held and are proposed for different aspects of the responses to Fukushima. "I think it's very important for the international community, and especially for the International Atomic Energy Agency, to begin to organize their thinking, their responses, and their action plans for looking into the future," he said.

Turning to other matters, Lyons said that he is "extremely enthusiastic" about the future for small modular reactors (SMR), which have a number of features that lead to potential safety enhancements, including below-grade construction, integral construction, and extremely robust accident responses. He said that he is pleased that the Obama administration has supported a five-year program, starting with $67 million in fiscal year 2012, to competitively select two light-water SMR designs and move them through design certification.

Lyons closed by quoting from President Obama's 2011 State of the Union Address: "By 2045, 80 percent of America's electricity will come from clean energy sources. Some folks want wind and solar. Others want nuclear, clean coal, and natural gas. To meet this goal, we will need all of them." Obama has stated that his support for nuclear is strong, Lyons said, and that nuclear power, post-Fukushima, remains a key part of the nation's clean energy portfolio moving into the future.

Continued

Bill McCollum, chief operating officer at the Tennessee Valley Authority, explained that TVA is a corporation owned by the federal government but fully funded by the sales of electricity to its customers. "We receive no federal appropriations, no tax dollars," he said.


McCollum

The company operates five nuclear units in Alabama and Tennessee, and expects to bring the Watts Bar-2 plant on line in 2013 (see article on page 23).

McCollum said that TVA is taking a disciplined approach to project development and execution for new reactors that the company may pursue. "We'll do our projects in three phases: study our options, making sure that they're really solid options for TVA; do the engineering to make sure we know the scope of the project and how we're going to execute the project; and then the actual construction phase," he said, adding that there will be no more than one nuclear project in each of the phases at any one time.

TVA's uncompleted Bellefonte-1 plant, in Alabama, may one day be completed and brought on line. Bellefonte-1 is an 1180-MWe unit that has been idle for more than 20 years and is about 55 percent complete. McCollum said that the unit's design was well ahead of its time, incorporating features that some of the newer designs today have, such as a dual containment. "We're in the engineering phase at Bellefonte and are looking at it as a very real option in the 2018 to 2020 time frame," he said, adding that the company is also studying SMRs to see if they could fit into TVA's portfolio.

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McCollum was followed by another utility executive, Jim Miller, president and chief executive officer of Southern Nuclear Operating Company, who stated during the meeting that he would soon retire.

Miller said that he has been asked why Southern is going forward with plans to build Vogtle-3 and -4, even after the accident at Fukushima. His response, he said, is that there are three reasons: a continued need for clean electricity; strong support for new nuclear plants in the South; and the attractiveness of the new advanced reactor design, the Westinghouse AP1000.


Miller

Miller noted that in 25 years, the nation's electricity demand will increase by more than 30 percent, and 40 percent of the population will live in the South. He said that Georgia Power, which is a partner in Vogtle-3 and -4, in the past five years has added 15 000 to 20 000 new customers. "There are families behind each one of those," he said. "They want electricity. Baseload generation is growing. So one of the reasons that we stayed with Vogtle-3 and -4 is because there is a need."

NRC Commissioner Bill Magwood remarked that building a nuclear power plant is a long, complex, expensive, and difficult process. "It's not something for the squeamish," he said. "Add to that a global financial crisis and a prolonged economic recession, and then you see stories about the fizzling nuclear renaissance. And then, Fukushima."


Magwood

Magwood said that like many other organizations, the NRC was able to help in Japan. "Many on the NRC staff immediately became volunteers as soon as we heard about Fukushima," he said, adding that within hours of learning the plant was in trouble, three NRC experts were on a plane to Japan. "When they got there, they had no idea what they were going to do, who they were going to talk to, or what function they would play. But they wanted to be there to offer their help."

Some NRC experts remained in Japan for months. "They are among the most committed and passionate public service individuals I've ever encountered, and it's a pleasure serving with them," he said.

Magwood wondered, however, what long-term effect an accident like the one at Fukushima would have on the public. "Do you believe the public anxiety over radiation or waste will be less 50 years from this debate?" he asked. It might be higher, he said, which is why effective regulation must continue to improve safety.

Recent technology improvements will provide the higher levels of standards that the public is likely to demand, he said, and he cited the Blue Ribbon Commission's recommendations, SMRs, and passive safety designs, among others things, as stepping stones to even more advanced technologies. "The subject of discussion is nuclear's bright future," he said. "It's important to remember that having a bright future must also have a bright vision behind it."

Fukushima lessons (part one)

The ANS Annual Meeting took place less than four months after the Fukushima Daiichi accident in Japan, and at the time of the meeting, Tokyo Electric Power Company personnel were still working to stabilize the damaged reactors and ensure that radioactive material would be contained. The accident was not only a major event in the history of nuclear energy, but one that was (and is) still ongoing. It was no surprise then that two sessions—the ANS President's Special Session on Monday and another Special Session on Tuesday—were devoted to the accident. Both were held after the technical sessions had ended for the day so that everyone who wanted to attend could do so.

A vast amount of detailed coverage, in this publication and elsewhere, has been given the Fukushima Daiichi accident. Both sessions at the Annual Meeting included information on what was then the current status of the reactors and the recovery effort. As more than two months have passed since those sessions were held and our coverage has continued, the reports of the sessions will not repeat what has been covered in our news reportage in the July, August, and September issues of *Nuclear News*.

Because it is generally believed that there is much more to be learned as work continues at Fukushima Daiichi, many observers are waiting to decide on the lessons to be learned from the accident. Nonetheless, at the first session on the accident, Akira Omoto, a member of the Japan Atomic Energy Commission and a professor at the University of Tokyo, presented the following list of key lessons that he said should be learned:


Omoto

- Reactors should be designed so as not to be vulnerable to common-cause failures from natural or human-caused hazards.
- There should be design considerations to cope with the total loss of on-site and off-site power and isolation from ultimate heat sink. These would entail diversified supplies of power (such as air-cooled diesel generators) and water (such as from a dammed reservoir) and the diversification of the heat sink through residual heat re-

moval and emergency equipment cooling systems.

■ Multiunit plants should be studied for hazards that differ in degree or kind from those at single-unit plants.

■ Passive safety features should be employed. As examples, Omoto cited heat removal from the reactor core, containment, and spent fuel pool through an isolation condenser, passive containment cooling, external containment vessel cooling, and wall cooling, and he called for preparations in case on-site recovery actions are disabled.

■ Extra attention should be paid to the location of a plant's spent fuel storage and to whether spent fuel should be transferred elsewhere (such as to dry storage) sooner than originally planned.

■ Under accident management, reviews and drills should be conducted for the use of all available resources. Omoto cited the example of the Apollo 13 lunar mission, in which the astronauts returned safely to Earth through makeshift life-support enhancements cobbled together from materials on the spacecraft. He advised the on-site storage of fire engines, water pumps, batteries, remote sensing devices and spray systems, and robotic devices, along with the training of personnel in their use, as well as agreements with national or regional nuclear crisis centers or the World Association of Nuclear Operators for outside assistance.

Omoto also said that there should be advance planning for recovery actions in a harsh radiation environment, awareness of the potential for the detonation of leaked hydrogen outside of a BWR Mark I containment vessel, and detailed study of the structure of the emergency management organization.

■ As a severe accident management operational aid, Omoto advised the real-time simulation of plant behavior to support decision-making and allow for an assessment of risk potentials, backed by a precise accident data tracking system that would record every plant behavior and remedial action.

■ Sufficiently dependable instrumentation should be in place to provide a clear understanding of the accident.

■ Exactly who is in charge during an accident should be clearly defined.

■ The role and authority of regulatory agencies should be clearly defined.

■ International peer reviews of reactor designs and severe accident management plans should be conducted.

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The next speaker was Michael Weber, the NRC's deputy executive director for operations for materials, waste, research, state, tribal, and compliance programs. He had anticipated, correctly, that he would have to defend the NRC's decision shortly after the accident to advise the evacuation of Americans within a 50-mile radius of Fukushima Daiichi. He said that the NRC saw the need for a "protracted response," because the release of radioactive material would take place over long periods, rather than as the immediate releases addressed in most studies of accident scenarios. Weber also described the agency's near- and long-term task forces on how Fukushima Daiichi might affect U.S. reactors and their regulation by the NRC. (An article on the Near-Term Task Force's report appears on page 27 of this issue.)

Weber

The next speaker, former NRC chairman Dale Klein, said that Fukushima Daiichi may be a case of "too much data and not enough information." Bringing about a clear understanding of the accident by the general public will be a major challenge, he said, although, he added, "we're going to learn a lot more about nuclear reactors from the events at Fukushima than we ever did from Three Mile Island and Chernobyl." Klein mentioned that he is cochairing, with incoming ANS Vice President/President-Elect Michael Corradini, ANS's Special Committee on the Japanese Fukushima Accident to examine the technical aspects of the event to help produce the sought-after public understanding of the accident's consequences and the lessons for the nuclear community in the United States.

Klein

Asked whether the accident will change the way the United States responds to future accidents, Klein said that he considered an expanded role for the IAEA to be unlikely. If nothing else, the United States would not agree to delegating any authority away from the NRC. Regarding one of the potential changes to U.S. plant operations—the provision of longer-lasting battery power in the event of the loss of off-site and external on-site power sources—Klein said that the industry is "looking at battery life" from the standpoint of shifting the energy consumption by the equipment connected to the battery to maximize duration and safety-related equipment coverage.

The floor was then opened to questions. On whether there should now be an insistence on passive safety features, Klein replied that while several new designs employ them, zero risk is not reasonable. "If you make things perfectly safe," he said, "we can't afford it."

On whether Japan could perform first-of-a-kind work, such as reprocessing the damaged fuel, Omoto said that some thought is being given to that, but first, the fuel in the spent fuel pools must be addressed, and then the fuel in the core, with the need to relocate all of it.

Asked how the Japanese people responded to the U.S. NRC's calling for a 50-mile evacuation zone (which exceeded the 19-mile evacuation zone set by the Japanese government), Omoto said that they were "embarrassed." Weber, noting that the NRC's recommendation was conveyed through the U.S. embassy as an advisory for U.S. nationals within that zone, said that other nations had told their citizens to leave Japan altogether. There followed several challenges to Weber on the NRC's announcement, including ANS past president William Burchill's statement that an input to the NRC's decision was a belief that the Unit 4 spent fuel pool had gone dry, which he said put the agency in an "untenable position of credibility." Weber said that the decision inputs included the prospect of multiple core releases of radioactive material, as well as releases from the spent fuel pools.

Burchill

Fukushima lessons (part two)

The second session on Fukushima Daiichi began with another report from Japan, this time by Hisashi Ninokata, of the Tokyo Institute of Technology. His presentation included a photograph of the tsunami moving inland to the populated area near the plant, showing not only what the plant site had to deal with, but also the difficulty of getting

immediate, large-scale assistance from elsewhere.

In his recounting of the events of the accident, Ninokata noted that both trains of Unit 1's isolation condenser were turned off after the earthquake triggered the shutdown of the reactors. This was in keeping with established operating procedures, and plant personnel believed that one operating train would be sufficient to depressurize and cool the core and pressure vessel. This was about 30 minutes before the tsunami reached the plant site. After the tsunami hit, DC power was unable to operate both trains. In the many recovery efforts over the next two hours, extra power sources could not be attached to Unit 1 because the reactor's power panels were soaked with tsunami water, so there was no chance for the batteries to be recharged.

Ninokata noted that there might have been damage to some equipment and facilities at the plant caused by the quake itself, rather than the tsunami, that perhaps was not apparent at the time.

At 6:18 p.m., almost three hours after the tsunami, it was discovered that the isolation condenser's indicator lamp was lit. At this point, DC power was again available for the isolation condenser. The motor-operated valve was opened, and seven minutes later it was closed—"for some reason," as Ninokata put it—and it remained closed for the next three hours. After the valve was reopened, steam was seen rising from the reactor building. Ninokata said that there is speculation that the isolation condenser was working until about midnight, and that a key task of the follow-up investigation should be to determine more precisely when it stopped working in order to pinpoint when core degradation began. Ninokata stated that the loss of the isolation condenser "was the cause of the meltdown. That was clear."

Although all three of the reactors that were operating at the time of the earthquake shut down automatically because of the quake, Ninokata noted that there might have been damage to some equipment and facilities at the plant caused by the quake itself, rather than the tsunami, that perhaps was not apparent at the time. He added, however, that any such damage to concrete and piping systems specifically caused by the quake may never be known because of the later damage from the tsunami and the hydrogen explosions.

Michael Weber, of the NRC, also spoke at this session, as he had at the previous one on Fukushima. This time he addressed spent fuel management in the United States, stating that the NRC's assessment of several earlier studies and more recent tests have led the agency to conclude that no spent fuel storage safety concerns arise from the Fukushima Daiichi accident. During the later question-and-answer period, however, he was again put in the position of having to justify or defend the NRC's recommending a 50-mile evacuation of the plant vicinity.

Robert Budnitz, who works in the Earth Sciences Division at Lawrence Berkeley National Laboratory, explained how a design basis is established. Committees are set up to determine the appropriate codes and safety principles for the construction of all facilities, he said, and the designers then follow the rules related to the codes. Budnitz said, however, that it is not possible to design for the largest possible earthquake, because there is no way of knowing what that is.

Steven Root, manager of special projects at Southern California Edison Company's San Onofre plant, addressed management during events that go beyond a plant's design basis. He said that "with some upgrades," reactors now operating in the United States could reduce the consequences of an event such as the one at Fukushima Daiichi. A plant's alternative AC power source and switchgear must be protected from that kind of initiating event. Within the industry, he said, consideration is being given to storing emergency equipment in seismically secure buildings.

Peter Caracappa, a professor at Rensselaer Polytechnic Institute, spoke on the release of radioactive material from Fukushima Daiichi and dose consequences. He said that the releases of cesium-137 and iodine-131 were less than 10 percent of what was released during the Chernobyl-4 accident in the Soviet Union in 1986. There have been no deaths caused by direct radiation exposure from the Fukushima accident, and Caracappa projected that cancer deaths from accumulated radiation exposure within the life spans of the affected population could be in excess of 100, out of an expected total of roughly 10 million cancer deaths from all causes. During the question-and-answer period he was challenged on this conclusion, to the extent that the mortality is inferred from collective dose. Caracappa said he was limiting his conclusion to highly exposed populations.

Long-term waste storage

The very long-term dry storage of used fuel has become a real possibility now that the Yucca Mountain repository program appears to be dead. The NRC, the DOE, the Electric Power Research Institute, the U.S. Nuclear Waste Technology Review Board (NWTRB), U.S. utilities and cask vendors, and some international participants are taking actions to prepare for the potential eventuality of very long-term storage. Updates on some of the steps that have been taken were discussed during a session on the topic.

Robert Einziger, senior materials scientist in the NRC's Division of Spent Fuel Storage and Transportation and chair of the session, explained that the NRC has started looking at used fuel storage for periods ranging from 120 years up to 300 years.

Einziger

Currently, the NRC licenses dry storage facilities for up to an initial period of 40 years, with the potential for a 20-year extension through an adequate aging-management plan.

There is no intention for the NRC to recommend that licenses be granted for 300 years, Einziger said, but the storage systems should be designed to last that long. "There is not a technical basis for the 300 years," he said. "It may be, in the course of the analysis, that there is some natural breakpoint where there is something happening [such as degradation mechanisms affecting the fuel cladding or storage cask] that dictates either a period of time when an action needs to be taken or that dry storage is no longer viable. That has not been decided yet."

Andy Kadak, an ANS past president (1999–2000), speaking on behalf of the NWTRB, noted that a study was conducted by the NWTRB about two years ago on the technical basis of extended dry storage and transportation. The study, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel,* was published in December 2010 and is available from the Web site at <www.nwtrb.gov/reports/eds-final.pdf>.

Kadak said that the study was done because there had been no detailed analytical modeling of dry storage for extended periods. The NWTRB started out reviewing whatever literature was available on the subject, hoping to identify the technical knowledge gaps that would help lead to a basis for determining whether or not waste could be stored for up to 120 years.

Among the findings in the final report are that little information is available on the behavior of high-burnup fuel during dry storage or on its behavior during subsequent handling and transportation, and no infor-

mation is available on the behavior during dry storage of the more advanced materials now being used for fuel cladding and for the fabrication of fuel assembly structural components.

Kadak said that the report recommended that a number of research and development programs be implemented to demonstrate that used fuel can be stored safely in dry storage facilities for extended periods. He added that research alone will not be sufficient, however, because in-service inspection and maintenance programs appear to be necessary as part of a used fuel management program that includes long-term dry storage.


Kadak

Brady Hanson, of the DOE's Pacific Northwest National Laboratory (PNNL), explained that no one had planned on used fuel being kept in dry storage for more than two decades at the most. "Then it was supposed to go to a repository," he said.

PNNL's research into very long-term storage revealed that fuel cladding topped the list of degradation effects in used fuel storage. Hanson said that cladding was considered as potentially more important to safety than other components, such as the cask, canister, or storage pad.

Also ranking high on the list was the used fuel canister, because it provides the used fuel system's major confinement barrier. "Maintaining its integrity—especially the welds, bolts, and seals—is of extremely high importance," he said.


Hanson

Other issues of research that have rated high on PNNL's list are temperature profiles within the entire storage system; water drainage from canisters; maintaining subcriticality; and cask monitoring.

John Kessler, the project manager of EPRI's Extended Storage Collaboration Program, provided an overview of the components of a dry cask storage system, including the various sealing components and the reinforced concrete pad upon which the dry cask storage system is placed. The EPRI program, which includes membership from the DOE, the NRC, the NWTRB, U.S. utilities and cask vendors, and international organizations, is reviewing the current technical bases for storage licenses and conducting a gap analysis. A second phase of the program includes field studies, experiments, and additional analyses to address the gaps. A third phase plans on a high burnup spent-fuel dry storage demonstration.


Kessler

Kessler commented, "Utilities are loading into canisters spent fuel that is too hot right now for transportation," but in context, he explained, some of the loaded spent fuel has burnups that are not yet licensed for transportation.

The NRC is concerned about high-burnup spent fuel properties being different from low-burnup fuel properties, but EPRI research over the past 10 years has evaluated this issue, and the conclusion is that there is no technical problem with the transportation of high-burnup spent fuel. "EPRI believes that there's enough defense-in-depth to transport high-burnup fuel," Kessler said.

Robert Sindelar, senior advisory engineer in the Materials Science and Technology Directorate at the Savannah River National Laboratory, discussed various materials aging reviews of storage system components. "The approach to look at the specific materials and specific service environments in

evaluation of component performance is important," he said. "You do have to do somewhat of a breakdown. You can't just lump everything together. A bolt is not a bolt, a gasket is not a gasket. It's very type-specific."

Sindelar added that accurate constitutive relationships for changes in a material's condition over time in service are essential for predicting component performance for long-term storage. In response to a question posed by Einzinger on the consideration of most concern regarding materials degradation in extended storage, Sindelar noted that the potential impact on required safety functions (per 10CFR72) drives the importance of materials degradation.

Sindelar

There are four components of a dry cask storage system that have long-term aging issues: the stainless steel canister, the reinforced concrete, metal gaskets that lose sealing force over time, and the behavior of used fuel in storage. "The Zircaloy cladding of the fuel will become brittle as it gets cold," Sindelar said. "This will reduce the fuel's flaw tolerance and therefore the ability to retrieve it from the system after centuries of storage and then to transport it in casks. Cracking and spallation is a potential degradation mode of the reinforced concrete used in the construction of the pad for casks, and that would impose challenges to retrieval of fuel canisters."

Sindelar also expressed his opinion that fuel retrievability should be the target for aging management throughout the storage period. "Given that the stainless steel fuel storage canister that is a confinement barrier may be susceptible to the development of flaws in extended storage, it is desirable to have the fuel in a condition that would enable ready repacking, as needed," he said.

New reactor lessons

The licensing process for new reactors under 10 CFR Part 52 has been in use for nearly eight years, if one counts the demonstration-scale applications for early site permits that were submitted in 2003. After all this time, not one new-reactor project has advanced to the stage of safety-related construction, let alone electricity production, but progress continues to be made, however slowly and with whatever uncertainty has been added by the Fukushima Daiichi accident. The meeting session on lessons learned from the use of 10 CFR Part 52 was not the first of its kind and will probably not be the last, because each time a project advances, a new trail is blazed farther into previously uncharted territory.

David Matthews, director of the Division of New Reactor Licensing in the NRC's Office of New Reactors, looked back on the applications for combined construction and operating licenses (COL) that the NRC has been reviewing for about three years. He noted that many of the proceedings have had common threads, which he chose to refer to as "characteristic" rather than "generic." He said that despite the existence of design-centered working groups in which COL applicants planning to use a certain reactor design work together, they have sometimes waited too long to engage with the vendor applying for the certification of that reactor design. He also said that COL applicants have tended to underestimate the supporting information that the NRC needed from them. As an example, he cited the use of lumped mass instead of finite element analysis, which represents the choice of a method that is too simple to satisfy the rigor needed by the NRC for its technical reviews.

Matthews

There are already challenges in construction, even though no COLs have yet been issued. Matthews said that in the past year he has seen problems with the post-COL change process and the decision to set a "freeze point" on a project's design. There can be conflicts between safety margins and construction schedule demands, he said, and hundreds of requests for COL amendments could be made as a new reactor is being built.

Plenty of issues are also still arising during COL application reviews. Matthews said that earlier involvement between applicants and the NRC would have helped in at least two areas: digital instrumentation and controls (regarding the potential for common-cause failure and assurance of independence, diversity, and defense-in-depth) and sump strainer performance (regarding the development of testing requirements). Whether it will be possible to apply these lessons to later applications is not clear, although some projects have been delayed to the point that if an item is eventually resolved in a reference COL (R-COL), a subsequent COL (S-COL) that has not yet addressed that issue could benefit from the experience with the R-COL.

Matthews also mentioned as issues still affecting COL reviews the addition of aircraft impact assessment since July 2009, balance-of-plant details (because a lack of them in design certification means an abundance of them in COLs), seismic and hydrological aspects of plant structures and system interaction, and coordination among the NRC, the U.S. Army Corps of Engineers (USACE), and other federal and state agencies involved in the approval process.

Keith Paulson, senior technical manager for Mitsubishi Nuclear Energy Systems (MNES), has a different set of lessons learned from his perspective in the effort to certify the design of the US-APWR pressurized water reactor. He described 10 CFR Part 52 as being in a "constant state of flux" because of the lack of resolution of issues such as aircraft impact and sump strainers. Matthews had said that applicants underestimate the detail required by the NRC; Paulson countered that applicants must account for "NRC biases concerning methodology preferences" and that for the NRC, "sophistication usually wins over practicality." He acknowledged that computation capability now makes it easier for applicants to meet NRC expectations, and although this took some of the sting out of his statement, it was clear that his position differed from Matthews's in several respects.

Matthews said that in the past year he has seen problems with the post-COL change process and the decision to set a "freeze point" on a project's design.

Paulson

The US-APWR's certification reviews, like those for Areva's U.S. EPR, have been slowed by the need to satisfy the NRC's requests for additional information (RAI) on digital I&C and other design parameters. The design has not yet completed the second of the six phases of the technical reviews—the safety evaluation report with open items, which is currently scheduled for completion in January—with the final phase to be completed in May 2013 and the final certification rule to be published in October 2013. The design is being used in the COL applications for Luminant's Comanche Peak-3 and -4 and Dominion Generation's North Anna-3. The COLs can be issued only after the design issues have been resolved. Currently,

NRC decisions on the issuance of COLs for both projects are scheduled for November 2013.

Paulson said that Phase 2 is the difficult one. After that point, the open items are seen by the NRC to have closure paths. He said that MNES has made significant design changes, not cosmetic ones, and that he accepts that they were necessary—although it was apparent that he hasn't enjoyed the experience of resolving the sump strainer issue. Regarding other lessons, he agreed with Matthews on the need to communicate early and often. An applicant should report changes to the design control document immediately, he said.

Paulson added that an applicant should try to understand the NRC's resource limits and how the agency sets priorities in favor of applicants who are making progress. If a project bogs down, he said, the NRC may devote less effort to advancing it. He advised paying attention to different levels of commitments by the applicant in response to NRC RAIs. Also, he said, "Observe the [Advisory Committee on Reactor Safeguards] in action. The members often pose very sophisticated questions independent of and in addition to the NRC technical staff."

Next to speak was Amy Monroe, of SCANA, the managing partner of Summer -2 and -3. This is the first S-COL among the projects using Westinghouse's AP1000 PWR, and it is almost at an even pace with the R-COL, Southern Nuclear Operating Company's Vogtle-3 and -4. Monroe noted that the COL revision for Vogtle that incorporates the latest design changes in the AP1000 was submitted to the NRC on June 24, and that Summer's comparable revision would be submitted on June 28. She had relatively little to say on lessons to be learned, other than to note that an unfinished design certification is a "challenge" and that open communication is helpful. Overall, she said, Summer has been about the smoothest COL application, with Vogtle taking the lead on the translation of issues from design certification to plant licensing, and Summer then submitting what are known in the industry as "me too" letters agreeing with what was decided on Vogtle.

Monroe

Monroe said that she expected Summer's final safety evaluation report (FSER) to be issued at some point during the summer. It had been scheduled for June, but as with Vogtle, Summer's FSER has to wait until the issuance of the FSER for the AP1000, which was still awaiting the resolution of confirmatory items. She added that the mandatory hearing for Summer-2 and -3 was expected to begin in "late summer." COL issuance could occur late this year or early next year, and startups are still planned in 2016 and 2019. Monroe said that excavation for the nuclear islands had begun and that NRC inspections were under way. She noted that work had also begun on circulating water piping away from the excavation, concrete batch plants, modular assembly buildings, crane assembly, and cooling tower foundations. Summer does not have a limited work authorization (as Vogtle does), but the excavation work is permitted, and evaluations can be done to support the other work.

For Calvert Cliffs-3, Gibson said that he expects about $25 million to be spent over the next two years on construction inspection, including the support of five resident inspectors.

Gregory Gibson, senior vice president of UniStar Nuclear Energy, picked up on a point that Matthews had made earlier: that while the NRC is the lead agency in power reactor licensing, there are other participants in the process that must also be satisfied. He cited the USACE, which for its part of the environmental review required information beyond what UniStar had provided to the NRC on the Calvert Cliffs-3 COL project. This additional work delayed the issuance of the final environmental impact statement by about three months. Gibson also raised the question of whether a schedule change is really a delay, because in the original schedule, the amount of time that it will take to fulfill an RAI can only be estimated.

Gibson

Looking ahead, Gibson said that the task forces established and the joint efforts already undertaken to establish the construction reactor oversight process and construction inspection program have been "invaluable." For Calvert Cliffs-3, he said that he expects about $25 million to be spent over the next two years on construction inspection, including the support of five resident inspectors, which he called "prudent." Gibson said that he expects the project's inspections, tests, analyses, and acceptance criteria (ITAAC) to total 1724 different items.

During the question-and-answer period, Gibson was asked about the status of the Calvert Cliffs-3 licensing in light of UniStar's foreign ownership by Electricité de France. He said that EDF is actively seeking a U.S.-based partner to meet the regulatory requirement for majority ownership of U.S. power reactors by U.S. organizations. (At this writing, the Atomic Safety and Licensing Board in this case was considering UniStar's request that an intervenor contention on foreign ownership be held in abeyance, as the ownership issue doesn't need to be enforced until the point of COL issuance, which in the case of Calvert Cliffs-3 will not take place until 2013 at the earliest.)

A session attendee argued that the NRC's ideal—that a license applicant would refer to a reactor design that is already certified—is unlikely, because the NRC is reluctant to work on a design that does not have interest from customers, while customers are unwilling to wait through an entire certification process before applying for licenses. Matthews agreed that this has been the reality because of NRC budget issues. After the current wave of design certifications and COLs is over, he said, priorities might be assigned based on a certification applicant's business case.

Another attendee commented that the designers of SMRs and their potential customers will be in the same situation as that of large light-water reactors, with certification and licensing being pursued in parallel. Matthews said he thinks that the large LWR situation will stabilize in a few years, but he agreed that SMRs may indeed repeat the experience that large LWRs are going through now. Asked about the Tennessee Valley Authority's approach to SMRs, with the two-stage 10 CFR Part 50 licensing process to be used while the Babcock & Wilcox mPower design goes through the certification process, Matthews said that so far, the NRC finds the TVA plan acceptable.

LWR sustainability

Personnel from the DOE's Light Water Reactor Sustainability Program have made presentations at previous ANS meetings, but this time there was a difference. The earlier talks were fairly general, dealing mainly with goals and issues for the program's mission of keeping the existing U.S. fleet of LWRs safe and operable through license renewal and potentially into a second

20-year renewal period. At the June 2011 meeting, it was clear that work has progressed to the point that these matters can be addressed in much more detail.

Richard Reister, the program's manager, summarized research and development that is now under way and identified issues that could affect long-term operation (up to 80 years from startup, with a second license renewal). Among other things, the DOE is working with the NRC to expand the scope of the proactive materials degradation assessment to broader systems and longer lifetimes for core internals, primary piping, pressure vessels, concrete, and cabling.

Studies of silicon carbide (SiC) ceramic matrix composite as a possible fuel cladding material could have applications for reactors in general, and not just for long-term sustainability. Reister noted that SiC is stable at high temperatures, has low chemical reactivity and neutron absorption, and does not generate hydrogen from contact with steam at high temperatures. But it is brittle and difficult to manufacture, and its interaction with fuel in various scenarios and failure modes is not fully understood. So far, the sustainability program has backed work in triplex SiC development, exposure and quench tests, and corrosion tests (short term in an autoclave, long term in a research reactor).


Reister

The program is also involved with pilot projects at two of the oldest power reactors in the United States, Constellation Energy's Ginna and Nine Mile Point-1, where containment concrete and reactor metals are being studied. (Constellation has stated that it will decide in the next eight years or so whether to apply for second renewals; both reactors are now operating in their first renewal periods.) At Ginna, the work includes tendon monitoring and baffle bolt examination; at Nine Mile Point-1, the tops of guide tubes are being checked for cracks.

Reister added that the decontamination and decommissioning of the two Zion reactors in Illinois have made available to the program specimens of concrete and reactor vessels for study.

Bruce Hallbert, of Idaho National Laboratory (INL), discussed advanced instrumentation, information, and control systems technologies (effectively expanding the common abbreviation I&C to II&C). More than half of the U.S. power reactor fleet has been approved for license renewal, but few reactor owners have embarked on a substantial conversion of their existing analog systems to digital upgrades. Hallbert's work has touched on both the development of digital systems and on studies of how analog systems hold up over the passage of decades.

The DOE is working with EPRI to explore ways to add or upgrade cooling capability at power reactors in order to deal with excessive heat in the water and to minimize evaporation.

Hongbin Zhang, also of INL, delivered two presentations, one on efficiency improvements, the other on fuel development. Much of the first was devoted to coolant issues. The DOE is working with EPRI to explore ways to add or upgrade cooling capability at power reactors in order to deal with excessive heat in the water (both inflow and outflow) and to minimize evaporation. Eight collaborative projects have been proposed, and EPRI has issued requests for proposals for two of them: strategies from outside the industry to address water consumption, and a peer-reviewed paper on cooling concepts for power reactors. On the subject of fuel development, Zhang presented more detail on the ongoing SiC irradiation.

During the question-and-answer period, an attendee asked whether the siting of new reactors with operating reactors would create a new version of the analog/digital conflict, with both in use at the same site. Hallbert said that analog systems can continue to be maintained for a while, but that eventually they will have to be replaced. He added that he had looked into whether the digital I&C for Westinghouse's AP1000 reactor could be ported to existing reactors and had found that it would not be an easy thing to do.

Waste forms and storage

The 20-year license renewal for the independent spent fuel storage installation (ISFSI) at the site of the decommissioned Fort St. Vrain nuclear power plant in Platteville, Colo., was the subject of a presentation during the session titled "Used Fuel Component Recycle Advanced Waste Forms and Storage." The license renewal for the ISFSI was issued by the NRC in late July, just weeks after the session was held, and the DOE, which holds the license, is now allowed to possess and store spent fuel and associated radioactive wastes at the site until November 30, 2031.

Gregory Hall, a consulting engineer with CH2M-WG Idaho LLC, which manages the ISFSI for the DOE, described the development of the ISFSI's license renewal application.

The Fort St. Vrain nuclear plant was built and operated during the 1970s and 1980s. It was permanently shut down in 1989, and decommissioning was completed by 1992. The ISFSI was designed to hold 1482 fuel elements (approximately 15 metric tons heavy metal [tHM]), but actually stores 1458 fuel elements. Another 7 to 8 tHM is in dry storage at the DOE's INL. Hall said that the ISFSI's initial 20-year license was transferred in June 1999 from Public Service Company of Colorado to the DOE, and the application for license renewal was submitted to the NRC in November 2009.

The ISFSI uses a modular vault dry storage system designed to hold the spent fuel from the Fort St. Vrain high-temperature gas-cooled reactor for 40 years. It is the only ISFSI of its design in the United States, Hall said, and the only other similar facility is at the Paks nuclear power plant in Hungary, which is home to four currently operating pressurized water reactors.


Hall

Hall explained that during an evaluation for preparing the license application, seven of the ISFSI's systems, structures, and components (SSC) were identified as important to safety: fuel storage containers (FSC), FSC support stools, standby storage wells (SSW), the container handling machine (CHM) raise/lower mechanism, the CHM FSC grapple, the charge face structure structural steel, and the cask load/unload port. Two other SSCs were classified as not important to safety, but their failures could prevent functions that are important to safety from being fulfilled.

Hall said that of the nine SSC reviews performed, "eight indicated aging effects requiring management above and beyond routine inspections. One SSC review indicated the need for an aging concrete surface monitoring program."

During the reviews, he said, moisture condensation was found on the inside walls and pooled in the bottom of the SSWs. The internal surfaces of the SSWs were dried and cleaned and later passed inspection. The SSWs were sealed to prevent further moisture intrusion, and the routine inspec-

The Fort St. Vrain ISFSI (Photo: DOE)

tion frequency was increased. Subsequent aging-management activities include routine inspections at five-year intervals and inspections following off-normal (tornado or seismic) events.

Hall said that the NRC had submitted 28 RAIs to the DOE to complete the technical review of the application and the environmental assessment of the proposed license renewal. The RAIs included requests for additional documentation, design information, clarifications, aging management, 10CFR72.48 evaluated changes, effluent monitoring, license termination, monitoring and surveillance, and impact on critical habitat.

In a letter dated July 18, 2011, the NRC informed the DOE of the renewed license, which "constitutes authorization for a 20-year extension to possess, store, and transfer spent fuel" at Fort St. Vrain's ISFSI.

Mary Lou Dunzik-Gougar, an assistant professor of nuclear engineering at Idaho State University, tackled the issue of vitrifying integral fast reactor (IFR) electrorefiner salt wastes. She said that research into the issue was done by Darryl Siemer, a retired chemist from INL, who performed the work in his own laboratory.

Dunzik-Gougar

A presumed weakness of the IFR concept, she noted, is that the alkali chloride salt–based radioactive waste generated by the electrorefiner can't be efficiently vitrified because of the assumption that the waste form must immobilize chloride. Chloride immobilization is unnecessary, however, because it is neither toxic nor radioactive, she said. Further, the task, if carried out, should be simple, first to separate the chloride and then to convert the remaining primarily alkali metals and fission products to a durable iron phosphate–type glass.

Experiments were conducted to show that the separation/conversion alternative would work. Dunzik-Gougar explained that the production of a glass waste form material from the electrorefiner waste salt surrogate entailed two steps: First, volatilizing the bulk of the chloride through the reaction of a mixture of powdered salt with ferric oxide and hot phosphoric acid, and second, vitrifying the mixture at about 1050 °C.

Dunzik-Gougar said that more than 20 Fe-P glass specimens were batch-melted in crucibles from mixtures of potassium, lithium, and sodium chloride salts representing electrorefiner salt waste streams. Tests have demonstrated that glass formulations featuring a molar ratio of iron to phosphorus of about 0.8 and a molar ratio of total alkali to phosphorous of less than 1.5 are much more durable than the DOE's high-level waste benchmark, known as "environmental assessment" glass. In fact, she said, the test results have shown that the glass formulations also surpass the tougher standard that the DOE's proposed low-level waste glasses are supposed to meet. The formulations contain very little leachable chloride because almost all of it boils off before the glass actually forms.

During the tests, the time required to produce a good quality glass from raw salt mixtures was about 45 minutes, about half of which was spent doing a preliminary boil-down with a resistance heating coil, Dunzik-Gougar said.

Because the Fe-P glasses can accommodate up to 7.5 millimolar per gram total alkalis, and 100 percent of them originate from the waste itself, Dunzik-Gougar said, under this scenario, the product's effective waste loading is more than five times greater than that of glasses or glass ceramics.—*E. Michael Blake and Rick Michal* NN