ANS ANNUAL MEETING

On the 50th anniversary, golden opportunities foreseen

- *Nuclear renaissance possible, if issues are resolved*
- *TMI-2 changed how the industry does business*
- *ANS should lead in presenting demonstrated science*
- *Zero fuel defects should be the industry's goal*
- *Shift is away from prescriptive standards*
- *Nuclear desalination faces several challenges*
- *Not just one solution to sump clogging at PWRs*
- *Improvements suggested to upgrade safety culture*

THE AMERICAN NUCLEAR Society gathered June 13–17 in Pittsburgh, Pa., for its 50th anniversary at a moment when memories of the origins of ANS—the aftermath of President Eisenhower's "Atoms for Peace" initiative, and the numerous possibilities foreseen for bringing nuclear science and technology to applications for the benefit of all humanity—could be accompanied by optimism for the short- and long-term future of the field. The theme of the meeting was *A Golden Anniversary—A Golden Opportunity*, and although during the second half of the Society's existence no power reactor orders have been placed in the United States, the 1073 attendees who gathered in Pittsburgh in mid-June could look to a new reactor order in Finland, a likely order to follow in France, the U.S. nuclear industry consortia preparing to test the new system for licensing, and signs of more favorable public attitudes toward new nuclear plants as indications that a nuclear power renaissance might occur in the United States early in the Society's second half-century.

The memories of the first half-century, and the accomplishments of ANS and the nuclear community, were evoked during the 50th Anniversary Banquet on Sunday night, the first official event of the meeting. Susan Eisenhower, granddaughter of former President Dwight D. Eisenhower and president of the Eisenhower Institute, gave a presentation in which she noted the appropriateness of Pittsburgh—the birthplace of commercial nuclear power generation—as the location of ANS's anniversary meeting, and thanked the Society for helping to transform her grandfather's "Atoms for Peace" vision into reality.

Following her talk, she introduced John Simpson, ANS past President (1973–74) and honorary chair of the meeting, and presented him with an ANS Presidential Citation for his lifetime of achievements. Simpson's talk provided insight into the sense of adventure that existed at the dawn of the nuclear age, and into what it was like to be one of the nuclear pioneers. He related firsthand stories about important figures of the early times, and conveyed the excitement of those who took nuclear through the transition from wartime use to commercial power generation. He was one of 19 ANS past Presidents in attendance at the dinner, where they and the Society's other previous leaders were honored for their contributions.

Seizing opportunities

Speakers at the opening plenary session on Monday morning touched on the meeting's theme, but tempered slightly their assessment of the opportunities for nuclear development in the coming years.

While all agreed that ANS, and nuclear professionals in general, can do much to seize the opportunities and broaden the benefits to the nation and world from nuclear energy, they made it clear that real progress depends also on developments outside the nuclear community, in the political and public arenas. The consensus was that a nuclear renaissance is possible, and may be becoming more likely, but can occur only if issues such as high-level waste disposal

are resolved fully.

The early part of the session focused on ANS matters. Joe Colvin, of the Nuclear Energy Institute, presented the Henry DeWolf Smyth Nuclear Statesman Award—a joint award of ANS and NEI—to former ANS President and Nuclear Regulatory Commission Chairman Joseph P. Hendrie. Stephen R. Tritch, of Westinghouse, a general co-chair of the meeting, read a letter from President George W. Bush congratulating ANS on its 50th anniversary. Then the other meeting co-chair, Gary Leidich, of FirstEnergy Nuclear Operating Company, presented a video that pointed out some of the nuclear community's many roots in the Pittsburgh area: the original power reactor at Shippingport (both as a light-water reactor starting in the 1950s, and as a light-water breeder reactor starting in the 1970s), and the nearby two-unit Beaver Valley plant in operation today.

Leidich

Leidich then presented the plenary speakers. Sen. Larry Craig (R., Ida.) was unable to attend in person, because the various memorial services for the late President Ronald Reagan in Washington, D.C., during the previous week had forced legislative business to be rescheduled; he sent a videotape in which he explained that work on defense high-level waste appropriations forced him to remain in the capital. (Technical glitches in the video, and Craig's largely off-the-cuff remarks, supported the impression that Craig had indeed changed his plans suddenly and made the video only as a last resort.) Craig said that there was still a "slim but outside chance" that comprehensive energy legislation could be passed by Congress before this year's election. He noted the public's reaction to this year's rise in gasoline prices, and said, "This reality check . . . may well jar Congress into action." He added that any serious push by the federal government for new energy sources would include a large nuclear component.

Current NRC Chairman Nils J. Diaz joined in the celebratory mood of the session, praising nuclear pioneers (including past ANS Presidents) for the legacy they have left, including power reactors and other nuclear facilities now in operation. But he said that the technology's safety record "is not to be taken for granted," and the prolonged outage at Davis-Besse (and the discovery there of an eroded cavity in the upper vessel head) should serve as a wake-up call. He noted that the Three Mile Island-2 accident in 1979 forced a realignment of the nuclear industry, and an awareness that a problem at one plant can reflect on all others. Diaz endorsed the prescriptive approach to regulation in use at the time, but said that several hundred reactor-years of additional operating experience, and the development of risk analysis techniques, have made it possible for regulation to become more risk-informed and performance-based. Also, raising an issue that would be revisited by many other speakers at the meeting, Diaz noted that the new generation of professionals entering the nuclear fields is not large enough to replace the retiring pioneers, and said that ANS is "never more needed than today" to assure an abundant supply of qualified personnel.

Diaz

Pittsburgh was also important in the development of the nuclear Navy, through the Bettis Laboratory. Thomas H. Beckett, deputy director of the Naval Reactors Program, summarized the program to date, noting that it has logged more than 130 million miles of submarine travel without a single accident, health impact, or instance of environmental damage. He credited this record to the core values established by the program's founder, Adm. Hyman Rickover: technical excellence and competence, meritocracy, acceptance of complete responsibility, training of and challenge to all personnel, firm authority, and total commitment to honesty, safety, and environmental stewardship. Beckett also noted that unlike in the civilian power sector, naval reactor ordering has not paused, with new orders placed in the 1980s, 1990s, and since 2000. Later this year, he added, the first Virginia-class submarine will be commissioned, with a core intended to last for the whole 33-year life of the craft.

Beckett

Kingsley's seven points

Next to speak was Oliver D. Kingsley, Jr., chief operating officer of Exelon, with remarks that were to be cited and quoted frequently by other speakers for the duration of the meeting. Kingsley recalled that five years earlier he had told a reporter that a nuclear renaissance was approaching, and said he believes that it is now in its early stages—but does not have an assured future. After summarizing the activities to date of the NuStart consortium, of which Exelon is a member, and its plan to apply for site approval and a construction/operating license even though none of the NuStart partners currently intends to order a reactor, he listed seven preconditions that would have to be met before new plants would be built:

Kingsley

[A] nuclear renaissance is possible, and may be becoming more likely, but . . . only if issues such as high-level waste disposal are resolved.

■ The market must create a demand for more power. Kingsley noted that there have been about $50 million in losses from "merchant" plants, built as speculative investments with traditional rate-base inclusion, and this environment won't support nuclear plants. Reserve margins are declining, however, and Kingsley said that with 90 percent of all recent generation additions being gas-fired, there has been an adverse effect on the price of gas in the fuel's traditional markets, like fertilizer and home heating. He said that the price of gas in four major Exelon regions translates to electricity costs in excess of $50/MWh for that fuel.

■ Someone, preferably a utility CEO, must lead the way, perhaps risking the presumed ire of the financial community by showing a clear intent to build a new nuclear plant. Kingsley cited the late William Lee, of Duke Power Company, as an example of the kind of leader who would be needed.

■ There must be new, deliverable technology—not experimental, but already able to provide "operational comfort." The ABWR, for instance, already has operational experience. The certification of the AP1000 and ESBWR may satisfy this condition, from the standpoint of NuStart.

■ There must be regulatory predictability and stability. Kingsley said that he thinks this is in place now as far as reactors are concerned, but said that it would be difficult to announce new orders unless another regulated project—the proposed high-level waste repository at Yucca Mountain, Nev.—is determined to be a licensable site.

Continued

■ Acceptable financial returns must be available. Kingsley said that construction cost is a major concern, and there should be financial incentives for "first movers" who would make their commitments before economy of scale and proven performance could make reactor ordering more attractive. He noted that there is currently 10 times as much federal funding for fossil and renewable energy as there is for nuclear.

■ The infrastructure to design and build power reactors must be reestablished. He recalled attending a World Association of Nuclear Operators meeting in Osaka, Japan, and wondered if there were more nuclear construction capability around Osaka Bay than in all of the United States. He said the issue is not just whether there are enough engineers and university nuclear programs, but whether craft workers, technicians, training programs, and apprenticeships will be in place.

■ There must be public confidence in nuclear power. Kingsley exhorted nuclear professionals to quit apologizing and proclaim the progress of power reactors. Reitation is an important aid to nuclear development, and cited as an example the order for the Olkiluoto-3 reactor in Finland a few months earlier.

There remains, however, great uncertainty on upcoming energy choices in many nations. Echávarri said that countries accustomed to command-and-control decision-making are being forced to learn about the workings of the market. He also mentioned the Generation IV international forum, with 11 countries working on six advanced reactor concepts, as a way for the worldwide nuclear community to help advance the technology to newer systems and a gateway to the hydrogen economy.

Questions for the panel

In the ensuing panel discussion, Leidich asked Kingsley how ANS could help meet the seven preconditions. Kingsley replied that the Society and its members could help uphold nuclear education, stress positives in public debates, and serve as a common ground for the whole nuclear community.

Kingsley's call for a CEO to lead the way in plant ordering prompted a question from the audience by former ANS President Andrew Kadak, who asked Kingsley if he were volunteering. Kingsley (Exelon's COO, not CEO) said only that Exelon is willing to make a substantial investment once other needs are met—especially regarding Yucca Mountain.

In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business.

On the same topic, Kingsley was asked about a recent statement by Dominion Energy CEO Thomas Capps, that the utility consortia have "unrealistic" ambitions (*NN*, July 2004, p. 12), and whether Kingsley saw NuStart evolving eventually into an entity that would order, build, and operate new reactors. On the Capps statement, Kingsley acknowledged the awareness of financial risk that gave rise to it, and said that NuStart is nowhere near the point of considering an order, but added that it would be worthwhile for several utilities to be involved, and share the accompanying risks.

To an extent, the panelists were chided by audience members for limiting their near-future focus. One questioner said that economy of scale argued for resuming construction with more than one reactor; Kingsley said that the first step had to be the establishment of a single reactor project, and that if it went as intended, others would follow. "My heart says eight," he said, "but my head says one."

Another questioner wondered whether the addition of new reactors would put a strain on the uranium supply in the once-through fuel cycle now in place, and whether nuclear could expand without breeder reactors. Tritch responded that the focus should stay on what's needed to resume reactor ordering, and that it would be unwise to push for breeders.

Tritch

turning to the financial state of the electricity industry in general, he noted that since the start of 2002, the Dow-Jones utility index was down 13 percent overall, but the stock prices for nuclear plant owners had risen, and the six utilities that have bought power reactors from other utilities are up 65 percent. He added that the nuclear industry will not be able to tolerate poorly performing reactors anywhere in the country. "If you're not getting better," he concluded, "you're certainly moving backwards."

The final speaker was Luis E. Echávarri, director-general of the Organization for Economic Cooperation and Development's (OECD) Nuclear Energy Agency. He said there are now more than 10 000 reactor-years of experience worldwide, but OECD countries are growing more dependent on energy from unstable regions of the world. He said that the Kyoto treaty on carbon dioxide emission lim-

Echávarri

TMI-2: The lessons learned

It was 25 years ago in March that the commercial nuclear industry learned that it was fallible. In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business, from education and training and plant operations, to regulatory oversight, and brought the phrase "lessons learned" into the nuclear lexicon. The Monday afternoon session at the ANS Annual Meeting, "Twenty-five Years After TMI-2: Lessons We Need to Remember," took a look at some of those changes and asked the question: Are we starting to forget why we made these changes in the first place? The session was organized by Jim Byrne, of FirstEnergy Nuclear Operating Company, sponsored by the ANS Decommissioning, Decontamination and Reutilization Division, and cosponsored by the Education and Training Division and the Operations and Power Division.

Bob Long was a vice president at TMI operator GPU Nuclear when the accident occurred. With the accident now 25 years in the past, he felt compelled to remind the session audience just how devastating the accident had been for the reactor and the company that owned and operated it. As he noted, the reactor core was destroyed, with 70 percent of the fuel damaged and more than 50 percent of it melted; a million gallons of highly contaminated water collected in the reactor and auxiliary building basements; a large volume of krypton gas accumulated in the reactor building; and local residents suffered considerable mental stress and local businesses suffered economic losses. And because of the high levels of radioactivity after the accident, much of the damage would remain unknown for many more years.

Long

The full picture of just how damaged the reactor was began to emerge in 1986, Long said. The first images of the shattered fuel rods, the molten mass at the bottom of the vessel, the melted instrument tubes, remain

"burned into the memory of everyone in the power business," Long commented. In addition, as reported in 1993, accident analysts eventually determined that a square meter section at the bottom of the reactor vessel reached 1100 °C, which is considered white hot. Nonetheless, the vessel did not rupture.

The social consequences of the accident were equally dramatic, Long said. Although there were no deaths or injuries, the plant was ruined, never to operate again; it took a billion dollars to clean up the mess; adjoining TMI-1 was shut down for more than six years; GPU was driven to the edge of bankruptcy (its stock dropped from $18 a share before the accident to just over $3); the public emotion about the accident remained intense, with people still expressing concern about living near TMI; and billions of dollars were spent worldwide to improve plant safety and performance.

Tony Barratta, professor emeritus at Penn State University, discussed the accident's impact on nuclear engineering education. Prior to the accident, nuclear engineering education programs had remained somewhat static, but not long after the accident, enrollments began to increase—driven, Barratta said, by a response to the challenge of making nuclear energy safer, especially among the better students. This increase, however, was short-lived, especially after the 1986 accident at Chernobyl disillusioned students who thought things had changed and as the "cyber revolution" enticed the cutting-edge students away.


Barratta

Today enrollments are again increasing, but the ability for the nation's universities to respond has decreased. Only 27 university reactors remain operational. Today's faculty members often lack a depth of understanding (few have power reactor experience, Barratta said). Many programs have merged into more traditional engineering fields (mechanical, electrical, etc.), which can create problems for nuclear engineering education because the traditional programs often do not provide the emphasis on safety that the specialized programs have. Most important, Barratta concluded, industry support has been lagging, and industry especially does little to support faculty research, an area that universities still find valuable.

Changes in training, operations

TMI also changed the face of nuclear training forever, noted Jane LeClair, from Constellation Energy's Nine Mile Point nuclear station. At TMI, she said, operators were faced with a situation they had never seen before, were working with confusing procedures, lacked a fundamental knowledge of the reactor workings, and had no knowledge of lessons learned from previous operating experiences at other plants. Among nuclear utilities, prior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

After TMI, the industry worked quickly to fill the training void. In May 1982, the Institute of Nuclear Power Operations (INPO) established an accreditation program for the industry, and the industry responded by preparing its training programs for accreditation. The U.S. Nuclear Regulatory Commission endorsed the INPO accreditation program in March 1985, and issued a training rule in April 1993 that recognized industry's training and accreditation efforts. And the American Nuclear Society developed standards for training and qualification of nuclear plant personnel.

[P]rior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

More specifically, she said, the industry systematized its training program; increased eligibility requirements for senior operators and operators; added training in heat transfer, fluid flow, and thermodynamics; increased training emphasis on reactor transients and on mitigating core damage; and toughened NRC licensing examinations. Finally, plant-specific simulator training became the norm for all operator training.

Changes in plant operations were addressed by Pete Sena, operations manager at Beaver Valley. "It's all about people these days," he said, and "managing people is tough."

Sena outlined the way an "effective organization" looks at operations. Among the highlights: an emphasis on people, and "ownership" by employees and unions of the tasks they are assigned to do; an emphasis on constantly improving performance; team benchmarking with other plants; and high expectations. For example, an effective organization looks at a "near miss" as a failure, and constantly reviews minor slips. A less effective organization, on the other hand, might look at a near miss as a success, because, after all, nothing bad happened.

At Beaver Valley, every job is briefed prior to the job and afterwards. Lessons learned are saved and incorporated into future procedures. "Peer checks" provide a second set of eyes for every action. Sena admitted that industry is split pretty much 50/50 on peer checks, but he feels that they serve a valuation function. "If you do it right the first time as a result of a peer check, ultimately your productivity goes up."

A dedication to following procedures is another important aspect of operations at Beaver Valley. "We have procedures for following procedures," Sena laughed. But by emphasizing procedures, he said, "operators stay in 'rule-based land,' and don't go into 'knowledge-based land.'"

Regulations and response

The accident brought a new world view to the NRC, noted David Matthews, director of the agency's Division of Regulatory Improvement Programs. In addition to a raft of new regulations, the accident brought about an increase in opportunities for the public to make their opinions known during the regulatory process. This provided a sea change in the utility world, where the prevailing attitude had been that it's best if no one knows about them. Even today, he said, some utilities still look at the public process as an intrusion, but the NRC is committed to the change.

One problem the NRC still faces is "connecting the dots" from previous experiences, because there are still roadblocks to data sharing. Can we use INPO experience or is it confidential? Some foreign countries may not want to share experience that might reflect badly on them. In many ways, Matthews said, we face the same problems as the many entities of the intelligence community—that is, whose data is it, anyway?

In subsequent discussion, Long mentioned one other area of improvement: emergency response. There was no such thing as an effective emergency response program when TMI happened, he said. In those pre-cell-phone days, there were no telephones for reporters to call in their stories (the only telephone was in the control room, Long commented, and it had been "off the hook" since the accident), no trained briefers, no equipment or supplies for briefers or reporters. "We had a trailer with no furniture, no pencils, no paper, nothing," Long said.

Today, 25 years later, the good performance of today's nuclear plants is testament to the effectiveness of the post-TMI improvements. But "continuous vigilance" is needed, Long cautioned. Indeed, he noted, things are not as good as you would like

them to be, and they are not in an improving trend. For example, significant events increased 40 percent in 2003; forced shutdowns during the first 10 days after a refueling outage have increased; and since 2000, there has been a 27 percent decrease in the number of plants in INPO's "excellent" category. And, Long concluded, the recent issue of the corroded reactor head at Davis-Besse proves that the industry must remain vigilant, and must never forget the lessons learned from this country's worst commercial nuclear accident.

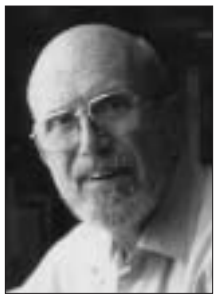
Realism: Set the record straight

In the ANS President's Special Session, *Realism in Evaluating Nuclear Hazards*, outgoing President Larry Foulke said that one of ANS's priorities is to be a source of credible information on science and technology. A critical issue that needs to be put right in this regard, he said, is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts. As members of this Society, Foulke said, "we have a responsibility to correct this."


Foulke

ANS, he added, "should take a leadership position" on this issue, and he added his hope that this session would mark a step along the way. The speakers, said Foulke, would be describing how conservatisms in the models, methods, and input have led to calculations predicting that there would be high levels of cancer fatalities and risk, and would show that these conservatisms and the results of the calculations have no basis in reality. Using conservative values and computer models that actually reflect reality, he noted, the numbers associated with consequences become ever so small.

The session was led by Ted Rockwell, who, at Foulke's request, has been heading up a group preparing a White Paper on this topic. Rockwell is currently vice president and founding officer of Radiation, Science & Health, Inc., an international public interest organization of independent radiation experts committed to bringing radiation policy into line with scientific data and theory.


Rockwell

Nuclear experts' attitude, Rockwell said, is that a major core accident would never be allowed to happen, because that would mean the end of nuclear power. It is something so unimaginable that there is no desire even to want to talk about it. In fact, a lot of work has been done to determine realistic scenarios of the release and dispersion of fission products and how the consequences are limited by the actual physical properties of the materials at hand. There is a good realistic story to tell, he said, based on facts, knowledge, and understanding.

Rockwell explained how this issue has come to a head. About two years ago, Nuclear Regulatory Commission Chairman Nils Diaz began addressing ANS and other organizations, saying that it is necessary to start using realistic figures. We cannot continue using extreme unrealistic assumptions. "Here is the chief watchdog telling us that we do not become safer going to extremes," said Rockwell, who added that Larry Foulke has taken on the challenge and is personally championing this issue.

A critical issue . . . is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts.

Ian Wall, a consultant and the first speaker, was involved in the early work at EPRI on accidents and has contributed to the White Paper. He became involved in risk assessment in 1967 while working at General Electric. Upon joining the NRC in 1974, said Wall, one of his first jobs was to correct a serious error in the consequence model then used. He developed a new code that showed that the consequences were concentrated mainly near the plant, that there would be time to evacuate, and that the risks become very small at distances farther away from the plant. "The point," he said, "is that realistic models changed our perspective about offsite consequences."


Wall

By introducing realism, said Wall, WASH 1400 (known as the Rasmussen Report) also changed the perspective of what was important to reactor safety. Prior to WASH 1400, the consensus of experts was that the probability of core damage was infinitesimally small, while the consequences were very large. WASH 1400, he said, showed that the probability was larger than expected, but the consequences were tiny.

Prior to the accident at Three Mile Island-2, safety experts assumed that the iodine released would be elemental and gaseous and a large fraction would be discharged to the atmosphere. Under this premise, said Wall, the TMI accident sequence should have released millions of curies of iodine-131. It turned out that only a very small amount was released. The subsequent investigations identified mechanisms—such as nuclides being dissolved in water and plating out—that meant most were retained at the plant. This further changed the perspective of the consequences of reactor accidents.

During the 1980s, EPRI undertook work on accidents, which added more realism. Wall's part involved setting out a program of experiments to characterize and measure the retention of radioactive material within fuel, within the reactor system, and within the containment. This resulted in a tenfold reduction in the WASH 1400 source term.

In general, Wall said, a much better job is being done than before. He added that reactor designs should be conservative, but should be supported by probabilistic risk assessments that are as realistic as possible.

Realistic conservatism

Before introducing the next speaker, Rockwell explained another event that is driving this work. Recently, an antinuclear report analyzing a hypothetical fuel pool fire associated with a terrorist attack predicted thousands of radiation-induced deaths hundreds of miles away, and demanded that all such fuel be transferred to dry storage casks. The report was given to Congress, which asked the National Research Council to look into it. The authors said that they did not invent the numbers and the methods used: They were taken directly from reports prepared by Sandia National Laboratories and other nuclear laboratories. In fact, the NRC accepted this point, and to its credit took up the challenge, realizing that there is a wider issue here. In its testimony, the commission underlined that the type of analysis done here—the sort carried out over many years—is not relevant to the real world because the premises are too unrealistic. The NRC explained that the premises may have been right for scoping studies, when they were looking to bound a problem, but they are not right for predicting deaths.

The next speaker was Farouk Eltawila, director of the Division of Systems Analysis and Regulatory Effectiveness in the NRC's Office of Nuclear Regulatory Research. Eltawila began by defining "realistic conservatism," a term coined by NRC Chairman Diaz, who believes that public policy should not be based on the most con-

servative assumptions and extreme scenarios. Conservativism, he said, means employing a defense-in-depth strategy and ensuring there are adequate safety margins. Realism comes from using the best information you have from science, engineering, and operating experience.

Today, the commission has much better knowledge of phenomena such as fracture mechanics and aging, Eltawila explained. This helps reduce uncertainties, improve the quantification of safety margins, and provide a better understanding of the safety issues associated with accidents. This is helping the NRC move away from the use of the traditional deterministic conservative assumptions to calculate consequences, toward what he called "risk-informed realistic conservatism."

Regarding the issue of a spent fuel fire, Eltawila discussed NUREG-1738, a spent fuel pool analysis carried out in 1999–2000 by Sandia and Brookhaven national laboratories. This study was done for a specific purpose and used a great deal of conservatism. In fact, it assumed the worst possible scenario. In this case, he said, the analysis gave a very low risk, which the NRC said was acceptable. There was no reason to go further because the answer already provided the information needed to make a regulatory decision. The NRC understood the conservatism used, he noted, which involved assumptions that were not realistic or appropriate for making a decision regarding a terrorist attack—a situation where realism is needed. Unfortunately, he said, people have tried to extrapolate that type of information from a hypothetical accident to a terrorist attack and have come up with a huge number of cancer fatalities.

The NRC's latest review, said Eltawila, indicates that the pool's structure is very robust and the location of fuel in pools make them highly resistant to terrorist attack. A transient analysis has indicated that fuel is more easily cooled and the decay heat level is much lower than predicted in earlier studies. There are at least 24 hours from the time the pool empties of water and the start of fuel damage and the release of fission products.

Realism comes from using the best information you have from science, engineering, and operating experience.

The review, said Eltawila, shows that the demand for the transfer of spent fuel from the pool to dry casks at the cost of billions of dollars is not justified. He added that the NRC has identified a strategy for loading spent fuel into the pool that can substantially reduce cooling time of freshly discharged fuel, further reducing any consequences from an incident.

Rockwell commented that Eltawila and Diaz are owed a big vote of thanks for tackling this issue, and recognizing that although some try to characterize it differently, no one is trying to reduce safety. "Getting more realistic is not reducing safety, it is getting safer."

Transport realities

Ruth Weiner, senior staff scientist at Sandia National Laboratories and a member of the NRC's Advisory Committee on Nuclear Waste, described the arbitrary premises that produce large overestimates of radiation dose from a postulated radiological incident involving nuclear transport. Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials or ionizing radiation. This is not surprising, she said, given the extreme tests undertaken.

Weiner

Conservatism in transportation is used, she said, at four points: computer models; inputs to the model; interpretation of results; and the notion of the bounding case. This last one, she noted, implies that if we can show that nothing much happens in the worst possible case, then clearly the situation is not bad. These four conservatisms were used in NUREG-0170 (1970), the first environmental impact statement on transportation of radioactive material by air and other means. The NRC and utilities still use it, with advanced computer codes of course.

Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials.

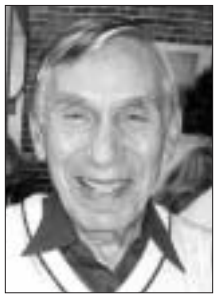
Weiner then described what real measurements do to a conservative model. To show this, she described the calculation of dose from an incident-free transportation operation. In this case, the truck is modeled by a sphere rolling down the road with dose measured at 1 meter from the surface. There are other conditions, such as that the truck stops every 100 miles for an inspection in a crowded urban area, and that no one moves. There was no validation done on this until a few years ago, she said, when a graduate student did some actual measurements at Hanford. It turned out that this model is extremely conservative.

"You give it stupid numbers," she said, "and it gives you stupid numbers back." The model never tells anything that it is not told first, she said, adding that opponents say they use the same models as those used by the experts and get tremendously high doses. The reason, Weiner explained, is that they start with tremendously high numbers.

The modeling of real accident situations is more complex, she said. Her colleagues at Sandia came up with NUREG-6672, which constructs 19 accident scenarios for trucks and 21 for rail. This gives much more realistic levels of doses of release than the previous NUREG, she noted, but is still excessively conservative.

The facts about buried HLW

Bernard Cohen, professor emeritus of Physics and Environmental and Occupational Health at the University of Pittsburgh, focused on the concerns of high-level waste (HLW) buried a half-mile underground. Cohen has authored many papers and several books on assessing nuclear power risks. For the purposes of his talk, he used rock as an analog for HLW—in its own form, encased or converted into glass or into another rock-type matrix known as "Synrock." He queried that if the HLW is buried a half-mile underground, why should this be dissolved out by groundwater any sooner than 2000 feet of rock above it? We understand natural rock, he said, and we ought to use this understanding.



Cohen

An example of not using what we know about rock was a study carried out about 20 years ago by the National Academy of Sciences (NAS) on HLW glass that presented

calculations of releases and health effects. It did not identify anything catastrophic. Going over this work, however, Cohen saw how totally unrealistic it was. Taking the method used by the NAS, the rock 2000 feet deep would dissolve at a rate of about 1 percent per year—so in other words, it would last only about 100 years. But it is well known that rock 2000 feet deep dissolves at a rate of about one ten-millionth of a percent per year and lasts about 1 billion years. In other words, they made an error of a factor of about 10 million. He showed other weaknesses in the NAS approach, and in the end, he observed that this report, hailed by the nuclear industry at the time, made all the mistakes that Ted Rockwell talked about.

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel.

Cohen also discussed the risk of cancer fatalities due to buried HLW generated from 100 nuclear plants, and compared it to the risks from coal-fired plants. The bottom line is that each of the three different types of waste released from coal burning—airborne pollution, chemical carcinogens in coal ash, and radioactive waste in coal (uranium, thorium, and radium, and the subsequent radon emissions)—cause 1000 times more deaths than HLW. Cohen added that the natural radioactivity in the ground above the waste from uranium and thorium provides 100 times more cancer doses than the waste.

Cohen also "unpicked" the picture that the antinuclear groups try to paint. For example, groundwater does not flow like a river; it is more like dampness seeping through the ground. At Yucca Mountain, groundwater moves at about 1 foot per year. He also noted that it would take groundwater at 2000 feet below the surface about 1000 years to get to the surface. Any radioactive material, however, would be held up by a number of processes, and would be expected to take 1000 times longer to get to the surface.

ANS White Paper

Rockwell concluded with some thoughts about the White Paper (ANS member input on the White Paper was being requested as of late June on the ANS Web site). The report, he stressed, is a working document designed to get the message clear as to what the realistic facts are about radiation hazards in the worst case and in the real situations people face.

He particularly wanted to "knock out" two false premises: that a severe accident would be the end of the world and that "one damn ray will kill you." As an example of the problem, he noted that when an incident occurs, such as the Davis-Besse problem, it is usually reported as almost a major accident, as if a small hole in the reactor would lead to thousands of deaths.

As for very low-dose radiation, Rockwell said that there is no real scientific basis for assuming it is harmful. In fact, he observed, there is considerable evidence that some radiation is beneficial. He noted that the goal is not to try to overturn the science on which their recommendations are based, and said that he believes that many of the advisory committees promoting the linear no-threshold concept have been remiss in their not examining, evaluating, and reporting on the massive amount of evidence on the beneficial effects of low-dose radiation.

Rockwell also challenged the idea that it is safer and more beneficial to assume that the world is different than it is. Putting some realism in place of "silly" premises does not represent a decrease in safety, he said. He was not talking about regulators' yielding to pressure from the industry to be less safe. If a most realistic assessment of the situation is made, "with conservative elbow room," then there will have been movement toward "safer, not less safe."

Fuel issues

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel, according to Ivan Maldonado, associate professor of Mechanical, Industrial and Nuclear Engineering at the University of Cincinnati.

The industry is increasing capacity factors and cycle lengths at the same time that power uprates are occurring. By many accounts, these factors "are conspiring to test the bounds of the performance and reliability of nuclear fuel," said Maldonado, organizer of the session on "Current Issues in LWR Nuclear Fuel Performance and Reliability."

Zero fuel defects should be that boundary of performance and reliability, suggested Bill Pierce, site vice president at Beaver Valley nuclear power plant, operated by FirstEnergy Nuclear Operating Company (FENOC). Beaver Valley has two Westinghouse pressurized water reactors. Unit 1 is rated at 821 MWe (net) and Unit 2 at 831 MWe (net). "We need to challenge the fuel vendors to continue robust fuel development," Pierce said. "We need to challenge the core designers to guard fuel margins. We have to challenge fuel handlers to protect fuel during movement. We need to challenge workers to prevent foreign material exclusion [FME]."

Pierce chastised the industry for not having a goal of zero fuel defects, and for its "lack of [having] a cohesive plan to achieve the things we need to achieve regarding fuel performance."

The industry, he continued, should get to a point where a defective fuel pin at a nuclear plant would be something that draws interest. "Today, we look at it as an accepted thing," he said. "If it happens, we feel like we're powerless to deal with it. We've got to get to a point where we see fuel defects as something we're not going to tolerate."

Underlying the zero-defect goal is a nontechnical issue, meaning that it's the general public that demands perfection from the nuclear industry. "I think the public domain that allows us to operate these plants expects us to have zero fuel defects," he said. "I just believe that it's bad business to have fuel leaks [because any minor nuclear blip is perceived by the public as a bad thing] and that [leaks] will be a problem for us as an industry."

The industry itself, of course, will have to foot the bill to support development of zero-defect fuel, he noted, but at the same time it is important to retain the low cost of fuel. "The heart of the electric industry using nuclear power for production is low fuel costs," he said. "Besides that one issue, we would not be competitive with other sources of electricity generation, because our base costs are higher."

FENOC operates three nuclear sites—Beaver Valley, in Shippingport, Pa.; Davis-Besse, an 873-MWe (net) Babcock & Wilcox PWR in Oak Harbor, Ohio; and Perry-1, a 1235-MWe (net) General Electric boiling water reactor in North Perry, Ohio. Combined, 66 percent of the FENOC plant's collective fuel failures have been caused by grid fretting, 28 percent by debris, and 6 percent through fabrication.

Countering Pierce's argument was Paul Edelmann, a fuels engineer for Constellation Energy's two-unit Nine Mile Point nuclear power plant, who noted that he would never expect fuel to be made entirely leak proof. "I don't think that's possible," he said. "I don't know how much more improvement you can design into fuel. But I do know from working at a BWR plant that there is a lot of room for improvement in control of plant


Edelmann

chemistry, and especially in foreign material exclusion."

He recounted a story from last spring, when Nine Mile Point-2, an 1148-MWe (net) General Electric BWR in Scriba, N.Y., was entering a refueling outage. Thirteen hundred workers were brought on site to work the outage. For most, it was their first experience at a nuclear plant. Their inexperience showed, he said, as illustrated by a pile of debris that collected on the refuel floor during the outage. "This became big news" within the plant, he said, because with the industry spending millions on FME programs, "somebody [at Nine Mile Point] was missing something."

Edelmann advised that strict adherence to good FME and chemistry practices, combined with safe rod pattern development and cycle operation, "can and should prevent BWR fuel from undergoing any failures, even with higher power demands and longer cycle duties."

A lesson learned at Nine Mile Point, he said, was that modern fuel designs will perform well when treated with care.

Identifying fuel leaks

Ed Price, a senior engineer for Duke Power, stated that Duke plants have been free of fuel leaks since 2001. Duke operates the two Catawba units, which are 1129-MWe (net) Westinghouse PWRs, in Clover, S.C.; the two McGuire units, which are 1100-MWe (net) Westinghouse PWRs, in Cornelius, N.C.; and the three Oconee units, which are 846-MWe (net) B&W PWRs, in Seneca, S.C.

The Catawba and McGuire plants switched in 2000 to Westinghouse robust fuel assemblies with zirconium cladding from the AREVA/Framatome ANP Mark-BW design, and Oconee switched in 2001 to AREVA/Framatome ANP Mark-B11 fuel with M5 cladding.

Price said that the whole process of identifying leakers, at least recently, has been akin to searching in the dark. "You expect when you have leakers to have iodine activity go up, but we've had many cycles with leakers with very low iodine activity," he said. "We've also had mysterious leaks at plants where we know we had leakers, but little or no spiking during transients."


Price

Once leakers were discovered at Duke plants, he said, there were problems in isolating the failed fuel assemblies. That's because ultrasonic testing (UT) has had "very poor reliability for us the past few years," he said. "Many overcalls, many cores that had leakers in them, did not show up on the UT."

As an example, Price explained a fuel-leak search at Catawba-1 from several years ago. The core showed a substantial increase in xenon-133, and a UT campaign was done that resulted in the identification of four suspect fuel rods. "We pulled the rods, but eddy current testing showed all the rods were sound," he said. "So, we did not find failures in any of these rods."

Price claimed that INPO's Fuel Reliability Indicator (FRI)—defined as the steady-state primary coolant iodine-131 activity (microcuries/gram), corrected for the tramp contribution and power level, and normalized to a common purification rate and average linear heat generation rate—is not a credible measure. A team is being put together, of which Price will be a member, to reevaluate FRI to come up with something "more realistic," he said.

A problem with today's FRI is that a core can have leakers with low iodine activities and low power defects, but still be under the FRI criteria for zero defects, he said.

With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good."

Price wondered what had happened to diagnostics over the past few years. Stretching back a decade or two, UT was considered 85 percent efficient. But over the past five years, "we haven't been able to find anything," he said. "It makes me wonder if now the threshold is so low for leakers that we're looking for things that, in the past [when the threshold was higher], we would see without paying much attention."

From the fuel manufacturers' side, Olga Correal-Price, a principal engineer for Westinghouse Electric Corp., noted that 25 percent of leakers are from unknown causes, and that the percentage is increasing. She stressed that finding the reason for those leakers is "today's challenge."

John Schardt, chief technologist of Global Nuclear Fuel, Ltd./General Electric Nuclear Energy, said that in the old days, thousands of fuel rods used to fail throughout the industry. Today, however, "we're talking about tens." With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good," he said.

Schardt declared that his company and probably every fuel manufacturer in existence has a "zero leak mentality." Every leaker "hurts everyone. It hurts our customers and it hurts the vendor. Each day that there is a leaker, we know about it that day," he said.

Schardt implied that people all the way up the management chain of command "hurt" when they learn about a leaker, because "most of us thought that by now we might have almost licked" the leaker problem. He added, "We don't know of a manufacturing defect that has caused a leaker in 10 years."

Roger Reynolds, director of Fuel Technologies and Reliability for Framatome ANP, Inc., followed up on Schardt's comments by declaring that "'Zero tolerance for failure' is the way we do our work."

Standards: A shift in philosophy

The ANS Standards Board has initiated work to revise many of its standards using risk-informed and performance-based concepts. This session, "A Movement Toward Risk-Informed, Performance-Based Standards: A Shift in Philosophy," explained chair Don Eggett, senior management and manager of business development for Automated Engineering Services Corp., was planned to look at the reasons for moving from conventional prescriptive standards to more performance-based and risk-informed standards, and how this is being implemented in ANS-sponsored standards. The movement to this new approach involves more than a shift in philosophy, he said. It reflects a more general shift in the attitude of industry to use these concepts to evaluate operation.

Standards, Eggett explained, can be performance-based or performance-based risk-informed, depending on what the needs are or what the focus will be. To distinguish these sometimes confusing concepts, the Board generated the following explanations:

On performance-based: Decide what the objective is to be then select a series of tasks, tests, etc., that will get you to the end point. Selection of the tasks is arbitrary based upon the particular situation and plant, and are not deterministic for every plant and situation.

On risk-informed (which can couple with performance-based): For each design basis accident or serious event, determine the risks to the public health and safety that the occurrence of the event will entail and then determine the mitigating events that are necessary to reduce public risk to a predetermined acceptable level.

Don Spellman, of Oak Ridge National Laboratory and chair of the ANS Nuclear

Facilities Standards Committee (one of four standards consensus committees), explained that the go-ahead was just made at the Board's last meeting and that this session is the first presentation of its observations and of some of the work being done. ANS often takes the initiative in this type of effort, Spellman said, where there is something industry needs to address. "And besides," he added, "we like the challenge." The Board will develop a set of criteria that explains how to create or revise a standard or convert it from prescriptive to performance-based.

Jim Mallay, director of regulatory affairs for Framatome ANP and chair of the ANS Standards Board, opened the session with a presentation on the benefits of moving from a prescriptive to a more performance-based standard. Most of the standards developed within ANS, said Mallay, are intended to either complement or positively influence current and planned regulatory expectations. In many cases, he noted, the NRC has asked ANS to develop standards on selected subjects, adding weight to any regulation that is based on those standards because the commission knows that industry has reached consensus that these are appropriate criteria and requirements.


Mallay

A particular feature of the standards groups, said Mallay, is that they provide the only forum for technical information to be exchanged freely among all parties, many of whom are in competition with each other or are regulated by the NRC, which is represented on nearly all of ANS's standards committees. And so, for Mallay, even if a working group is not successful in developing an approved standard, the fact that the people in the group have gotten together and communicated is a major benefit to them individually and to the industry.

Usually only a portion of a standard will be performance-based . . . as there will be many situations where prescriptive criteria are necessary.

Another interesting feature of standards that is rarely used in regulatory guidance documents, is the use of the verb "may," which denotes "permission." "May" allows the use of a technique at the user's discretion. This is an added value of standards, said Mallay, especially for those used to help interpret or complement regulatory documents.

Mallay explained the shift in approach as due in part to the needs of industry. During the last few years, there has been a significant decline in the demand for ANS standards. To some extent, this reflects the maturity of the industry (and the fact that no one is building plants). Nevertheless, the Board also had to consider whether it was really serving the interests of the users. In looking at that, said Mallay, the Board determined that maybe there were too many inefficiencies in the application of standards. Many were probably too prescriptive and inflexible, he noted, and therefore would not be used.

Unlike prescriptive requirements . . . the performance-based approach . . . ensures that the focus is on those things that are more important to safety.

So, the Board turned to techniques being advocated by the Nuclear Energy Institute (NEI) and the NRC—namely a performance-based, risk-informed approach. Mallay defined a performance-based requirement as a required design objective or operational behavior, including those attributes that are necessary to verify that the objective or behavior can be achieved. A performance-based standard, he said, is a standard that contains performance-based requirements together with measures that can be used to assess the degree to which the attributes can be achieved. These measures of success can be qualitative, quantitative, or some combination of the two.

Prescriptive requirements, Mallay added, have no flexibility and tell the user nothing about why the rule was established. Performance-based criteria tell you why—that is, makes the basis for a criterion explicit—and provides flexibility. But this does not work for all requirements. Usually only a portion of a standard will be performance-based, he said, as there will be many situations where prescriptive criteria are necessary. Standards based on performance-based criteria are also expected to have a longer life because the objectives, when stated properly, are not going to change as much as prescriptive requirements might. Furthermore, they allow revisions more readily.

Finally, said Mallay, performance-based requirements force people to work in "success space," not "failure space." One is never looking at a worst case, but at successful performance, where there are more opportunities.

Duke Energy, said Mallay, was recently allowed to establish performance-based criteria for the inspection and surveillance of the new steam generators being put into its Catawba plant. To deal with a number of outstanding safety issues raised by the NRC, the company proposed using a performance-based approach, which the NRC accepted. Mallay said he thinks that this is a milestone in this area.

According to Mallay, the first ANS performance-based standard (on the application of PRA for making risk-informed decisions on external events) came out about a year ago. He also noted that ANS has developed a draft standard for low-power and shutdown operating states, and plans to risk-inform its standards on design criteria for light-water reactors.

NRC pushing performance-based approach

Prasad Kadambi, of the NRC's Office of Nuclear Regulatory Research, has been active in pushing ANS toward performance-based standards. This approach, he said, accepts that nuclear activities are rather complex, with people, systems, and institutions all interacting for a common purpose. In this case, the common purpose is safety.


Kadambi

Regulations, he explained, deal with higher-level, more conceptual requirements, while standards address the lower level, the nuts and bolts of any activity. Traditionally, both have been prescriptive, Kadambi said, with requirements and instruction very specifically laid out. But recently, there has been a recognition of a need for change. In particular, said Kadambi, prescriptive requirements lack flexibility. They also have technological implications in that sometimes conditions are included in regulations that tend to freeze technology, particularly if there is

perception that there is only one way to comply with the regulation. This may inhibit technological creativity.

Things have been changing, he said. In 1993, Congress passed the Government Performance and Results Act. This legislation emphasizes outcomes rather than outputs; it makes agencies think whether they are doing the right kind of work, rather than just focusing on how well they are working. The legislation also requires agencies to develop strategic and performance plans so the public would know what ultimate results they are seeking to bring about. Another piece of legislation (Public Law 104-113) requires government agencies to think about consensus standards in lieu of regulatory requirements.

Kadambi noted that the NRC issued the first strategic plan (2000–2005) in 1999 and the second is now in preparation (2004–2009). It also issued a management directive explaining how staff can participate in standards activities. These direct the staff to consider performance-based approaches as appropriate. In addition, NRC staff issued NUREG-BR-0303, "Guidance for Performance-Based Regulation," in December 2002.

Kadambi asked the question: Why performance-based standards? Basically, he said that he believes that a new approach is needed, particularly if the nuclear industry does experience renewed growth. It is crucial, he declared, for working groups to have the flexibility to consider the best way to develop standards. They can consider using performance-based or prescriptive approaches as appropriate. This, he said, promises a more efficient development of standards once a learning curve is passed: It offers more effective application (particularly for new technology), more economical maintenance, and more equitable sharing of the burdens between standards developers and users. Performance-based standards should also last much longer. He commended ANS for this initiative.

Unlike prescriptive requirements, he added, the performance-based approach also ensures that the focus is on those things that are more important to safety, ensuring that resources are applied where they are most effective.

Over the last six or seven years Neil Brown, of Lawrence Livermore National Laboratory, has been involved at the working group level on a set of standards related to seismic design of nuclear facilities. It was only toward the end of the process, he said, that the performance-based concept was taken on board.

These new standards, not yet completed, will replace an original set developed by the Department of Energy for its nuclear facilities, Brown said. During a revision, the parties involved agreed to convert these to approved national standards. The DOE standards concerned natural phenomena hazards (NPH)—that is, seismic, wind, and floods. They start by categorizing certain structures, systems, and components (SSC), and then develop prescriptive rules about how a design should address these three natural phenomena. The original standards had risk goals set in terms of probabilities of safety consequences, doses, and failures.

The safety community, Brown said, even in the seismic area, is not eager to go to a fully risk-informed standard in the sense that the ability to estimate probabilities of failures of SSC and to relate those to a dose consequence, and so forth, is still limited. The DOE standards are risk-goal based—that is, they have clearly stated risk goals—and the SSC categorization is based on a specific set of risk goals. He said, however, that the participants could not agree on the desired risk goals for the new standard. Brown explained that agreement was eventually reached on using a magnitude of "unmitigated" consequence of a failure as opposed to failure probability to define the categories. And so, the categorization of an SSC was determined by the unmitigated consequence of its failure, not on the basis of risks.

The final presentation was by Paul Fishbeck, professor of Social and Decision Sciences, and Engineering and Public Policy, at Carnegie Mellon University, and director of the university's Center for the Study and Improvement of Regulation. He provided his experience from other fields where risk-informed and performance-related rules and standards are applied. Performance-based standards work well, he said, when you can actually measure performance. For example, consider how much pollution comes out of a smoke stack. In fact, he said, that can be measured, and criteria set. Penalties, such as withholding payments, can be applied if the criteria are not met.

Other areas being discussed, however, involve long-term, rare events, where performance is difficult to measure, Fishbeck said. If you are talking about fire safety, for example, how do you measure that a building is fire safe? What criteria do you use to base the performance of, for example, a sprinkler system? Is it the amount of water coming out in a certain time period?

A prescriptive standard, he noted, says: Use this, put it here, make it this big. These things can be checked very easily, he observed, but performance-based standards are much more complex.

He then raised the question of uncertainty. A prescriptive standard almost ignores uncertainty. Using a performance-based standard is to admit that there is uncertainty out there.

Fishbeck presented some examples to show how complex the area of standards can be. As other speakers had done before him, he recognized that the work leads to useful discussions among all interests and develops a lot of understanding along the way. There are methodologies that allow you to address these concerns, "but [they are] not for free."

Water desalination

Over the next two decades, there will be a 40 percent increase in water use around the world, according to the International Atomic Energy Agency (IAEA), and 33 percent of the world's population—about 2 billion people—will be in absolute water scarcity by the year 2025.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases. The fact is that there isn't enough fresh water on the planet. The session, "The Use of Nuclear Energy for Desalination," explained nuclear's role as an economical power source for methods of water desalination—two of which are distillation and reverse osmosis (RO)—that have high-energy consumption requirements and high hot-water production costs.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases.

The IAEA defines nuclear desalination as the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy for the desalination process. The facility may be used solely for the production of potable water, or dually for the generation of electricity and the production of potable water, in which case only a portion of the reactor's energy output would be used for water production. In either case, a nuclear desalination plant is defined as an integrated facility in which both the reactor and the desalination system are located on a common site and energy is produced on site for use in the desalination system.

Small and medium reactors are important for desalination because the countries most in need of fresh water often have limited industrial infrastructures and electricity grids, explained Akira Omoto, director of the IAEA's Nuclear Power Division. Smaller

reactors, he said, also are "more appropriate for remote areas" unsuitable for connections to the grid.

Omoto noted that nuclear power plants around the world have long been used for water desalination. For example, Kazakhstan's BN-350, a liquid metal–cooled fast-breeder reactor that operated until 1999, was used to produce electricity and heat for desalination (approximately 80 000 m^3 of water per day) for 27 years. And, currently, Pakistan's Kanupp has a small RO facility in operation and is building another desalination demonstration plant on site to be commissioned in 2005. Meanwhile, India's Kalpakkam has an experimental facility in operation and another under commissioning that is expected to process 6300 m^3/day.


Omoto

Expanding nuclear's role in the world's desalination process will include four challenges, he noted. First is economics, of course, where the target for desalinating water is \$0.40 to \$0.60/m^3. Next is public understanding. Then comes the issue of disparity, meaning that nations having water scarcity may not be holders of nuclear technology. Finally, in what is not directly a nuclear issue, infrastructure for distributing desalinated water is necessary.

Roger Humphries, president of Canadian desalinating company Candesal, said that a message not heard enough is that water shortages are quite often localized. In Indonesia, for example, rain falls almost every day during the rainy season. "But the issue is a point of mal-distribution," he said. "The water is not where the people are. It's not accessible because it cannot be collected and captured." He added that Indonesia's city of Jakarta and its surrounding rain forests have some of the lowest availabilities of safe, fresh water per person of any place in the world.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing. "As we draw fresh water out of sources that are nonrenewable, they get replaced by salt water," he said. "So, we're finding what used to be fresh water [in] a lot of aquifers [now has] a salinity level reaching 1000, 2000, 2300 ppm, basically making it unsafe to drink."

Desalination solves problems in that, politically, it keeps nations from "stealing" water from one another, and, environmentally, because it's a "friendly" way for creating new sources of potable water, as no fossil fuels are burned in the process, Humphries said.

Si-Hwan Kim, director of the SMART R&D Center of the Korea Atomic Energy Research Institute, explained South Korea's plan for a SMART desalination plant. SMART stands for System-integrated Modular Advanced ReacTor. The plant, which is under construction and is expected to be in operation in 2008, will produce both electricity (90 MWe) and potable water (40 000 tons/day).

Ron Faibish, project manager for nuclear desalination at Argonne National Laboratory, said that potable water issues exist here at home in the United States. "Drought conditions now in the Southwest have increased dramatically," he said. News reports have claimed that the drought in the West is the worst in 400 years. "We have big challenges in the U.S.," he added, "and they're not just focused in the West. We have issues in the East as well, and on the Texas coast."

Population growth along coastal Southern California, Texas, and Florida has been on the order of 20 percent in the past decade, and for the country as a whole, 60.6 billion additional m^3 of potable water per year will be needed by 2020 for municipal and light industrial uses.

The U.S. Bureau of Reclamation, together with Sandia National Laboratories, has developed a roadmap for desalination in the United States, he said. Published in 2003, the roadmap declares that by 2020, desalination and water purification technologies will contribute to ensuring a "safe, sustainable, affordable and adequate" water supply to the United States. "These words are important," he said. "The terms affordable and adequate—those are the ones I think have to be first in term of securing the future of the technology."

The roadmap's 2008 objective, he said, is for desalination technologies to realize a 20 percent improvement in capital costs, operating costs, and energy efficiency. By 2020, improvement in those areas needs to reach 80 percent.

Those goals are ambitious because today the cost of treating water in the United States using a conventional (chemical) treatment is about \$0.10/m^3. In Southern California, reclaimed water from industry costs about \$0.60/m^3. Brackish water desalination is between \$0.26 and \$0.79/m^3. For seawater desalination (the biggest operation, in Tampa Bay, Fla., currently is suffering problems, Faibish said), the forecast is \$0.55 cents/m^3.

Sump clogging is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors.

An "interesting factoid," he said, is that desalination in the United States could cost \$0.79/m^3 (\$3 per thousand gallons). "That seems expensive, but the U.S. consumer is paying an average of \$2099 per cubic meter for bottled water. When you put this into perspective, [desalination] seems rather cheap," he said.

The latest on sump clogging

At the panel session "Hot topics and emergent issues: Containment sump clogging," session chair and organizer Steve Stamm, of The Shaw Group, opened with an explanation of why sump clogging was billed as a "hot topic." Sump clogging, he said, is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors. This session, he said, would cover the problem's background, describe the methodology that is being used to resolve it, and present some of the plant activities and potential modifications being introduced.

Mike Marshall, lead project manager on the issue at the Nuclear Regulatory Commission, began with an overview of the topic and the status of work on PWR sump performance. According to Marshall, the NRC's primary concern is that the sump screen is doing its job too well. The purpose of the screen is to keep debris from damaging pumps or blocking spray nozzles and other components downstream. Retaining debris smaller than the system is designed to, he explained, results in excessive head

loss that can affect operation of the pumps. This is the same concern that the NRC had with boiling water reactors.

There are also some secondary concerns, such as the downstream effects of debris getting past the screen, that might have an impact on pump operations or accumulate enough to affect cooling of fuel. These are not the primary concerns, but the NRC wants them taken into account when solutions are considered or when evaluating the adequacy of existing designs. But most of the effort has been focused on head loss at the screen and whether it affects operations.

Because of the variation in the materials at individual plants, as well as the differences in the containment and layout of screens, the NRC agrees with industry that this is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action. One thing that is becoming clear is that the existing license base for a number of plants is probably insufficient and will need changing.

Marshall explained that unlike BWRs, it appears unlikely that every PWR is going to have to implement a fix. But each operator will have to evaluate the situation and decide if there is a problem that needs resolving, either procedurally or by a hardware modification or some other means. The evaluations will include: identifying the different debris sources, particularly those that would likely cause some clogging; estimating the amount of debris generated; estimating the amount of debris transported to the sump screen; and estimating what the head loss impact would be.

This issue first came up in the early 1980s, when the Advisory Committee on Reactor Safeguards became interested to see if air injection would have an impact on the operation of the emergency core cooling system (ECCS) pumps. The question of debris came up later. Research undertaken between 1980 and 1985 did not identify a particular problem. While the NRC could see some benefits in preventing entrainment, they were insufficient for action to be taken. In 1985, however, it recommended that new plants and plants undergoing material changes—such as of insulation—consider the issue and provided some regulatory guidance.

In 1992, an event occurred at the Barsebäck BWR in Sweden, where the NRC's 1985 guidance had been adopted. Based on this, the plant had assumed that the ECCS system would operate for a day or two before the strainers (screens) became clogged. The incident occurred when water was released into the drywell, taking a lot of insulation with it. The clogging occurred not within a day, but within an hour or two of the activation of the emergency systems. This was communicated to other regulators, and investigations ensued that identified weaknesses with the guidance and the underpinning research. This started a new run of research around the world on sump issues.

The focus at first was on BWRs because there were three similar events in U.S. plants, although not on the scale of Barsebäck. It eventually became clear that although clogging would occur sooner in BWRs than in PWRs, the weaknesses were common to both reactor types. New work undertaken identified weaknesses in the previous correlations. In particular, the fiberglass insulation debris was more like "cotton candy" shreds than the "slices of cake" that were used in the old research. The shreds produce much greater head loss. Furthermore, the fiberglass acted as a filter, capturing small items that had been expected to pass through the screen, adding to the head loss.

All the BWR stations introduced a combination of fixes. These included minimizing debris sources, cleaning the suppression pools, and increasing the surface area of the sump strainers.

Soon after completing the work on the BWRs, work on the PWRs started. From a parametric study, the NRC staff concluded that there was enough of a concern to warrant individual plant evaluations. NRC has been working with the Nuclear Energy Institute (NEI) since about 2000 on developing a suitable methodology.

[T]his is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action.

The next speaker was John Butler, senior project manager at NEI, which has completed guidance for carrying out a sump performance evaluation that is now being reviewed by the NRC. The guidance will help operators evaluate the situation at their plants regarding debris generation, transport, and accumulation on the screens and whether there is adequate net positive suction head (NPSH) margin available for ECCS recirculation. This effort, said Butler, is primarily funded by the Westinghouse Owners Group and coordinated by the NEI PWR Sump Performance Task Force.

A draft sump performance evaluation guidance document was given to NRC staff in October 2003, and the final version was submitted on May 28, just a couple of weeks before the ANS Annual Meeting. The review process should be completed by this fall, with final approval expected in October.

The end result of the evaluation guidance is to determine the adequacy of the NPSH margin, Butler said. The calculation is complicated by the large number of phenomena and uncertainties that need to be addressed. These include:

- Size and location of a postulated break. Location is probably more important than size regarding the potential debris generated.
- Debris generation (quantity, types, size, distribution). The orientation of the break affects what debris is going to be generated. Besides calculating the amount, it is necessary to determine the size distribution of the debris, which affects its transportability.
- Debris transport and holdup. The "transport media" is a combination of debris, the containment spray, and washdown, all of which determine the amount that collects at the sump.
- Debris deposition on screen and resulting head loss. The resulting head loss is highly dependent on the types of debris deposited.

The guidance addresses the uncertainties and complexities in a traditional conservative fashion. "It is a balancing act," Butler said. "I think I can say we have a conservative methodology that is not *too* conservative."

He then described the basic evaluation methodology, which starts with a baseline analysis, a conservative first step in the evaluation. Some plants can go through the baseline and find that they have adequate NPSH margin and can stop at that point. A number of others will find that they do not have adequate NPSH margin, and will have to continue the evaluation process by refining the analysis in one or two ways: refine their analytical methods to take out some of the conservatism, or modify their design, which may involve removing potential debris sources, changeout of insulation (which contributes most debris), or modifying their screen design. The process continues until an adequate NPSH is achieved.

NEI is now working with the NRC to try to introduce a risk-informed option in the methodology, acknowledging that the large double-ended break, which would generate the most debris, sump blockage, and head loss, is a very low-frequency event. A risk-informed option would allow more meaningful breaks and conditions to be applied to assess sump performance. The details of such an option are now being discussed with NRC staff.

Continued

Sump performance evaluation methodology

More details on using the evaluation methodology were given by Tim Andreychek, of Westinghouse Electric Company. Andreycheck has been working on the issue for the last seven years, and is the lead author of the NEI PWR post-accident sump performance document. The purpose of the methodology, he explained, is to provide a consistent approach for utilities to perform a conservative evaluation of their containment sump performance post-accident. Analytical refinements are also identified to provide options for removing some of the conservatisms.

The "baseline," said Andreychek, starts with plant specific information—basically a scoping study or a first shot to see if there is something to worry about. If the results are acceptable, the issue can be closed out. If not, the methodology provides a guide as to how to proceed. This involves further analysis and reanalysis, with possible design modifications. The process continues until NPSH requirements are satisfied.

Andreychek provided an example of a "baseline analysis" that took a very conservative line. Regarding break size, the baseline assumes a double-ended guillotine break. For the break location, he determined the maximum debris generation and the worst combination of debris to create the biggest head loss. To determine debris generation, a zone of influence (ZOI)—a region around the break where the destruction of insulation and other materials occurs—was defined. His baseline calculation assumed an unrestrained jet stream from the break, which destroys the insulation, forming debris.

[S]ome plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

Latent or resident debris (the dust and dirt that collects) is not considered a major contributor, Andreychek said, but has to be accounted for. The baseline methodology provides an easy-to-use estimate of the contribution. He mentioned, however, that some plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

The head loss correlation being used, based on a NUREG document, is a semi-empirical correlation and provides for a conservative pressure-drop calculation. The effects of debris composition and material properties are accounted for in the calculation. Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it. This, he noted, was a particularly bad situation for BWRs, causing big pressure drops.

Andreychek also went into various analytical refinements to the baseline evaluation. By replacing the conservatism with more realistic conditions, the amount of debris generated can be reduced, its transportability lessened, and the accumulation and blockage of the sump screens can be decreased, leading to a better NPSH margin.

Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it.

Kenneth Ainger, licensing manager at Exelon Nuclear, is responsible for licensing activities at the Byron, Braidwood, and Three Mile Island-1 nuclear stations. He provided an operator's perspective on this issue, describing the evaluations that he will be performing, some interim measures, and potential enhancements being considered to fully resolve the issue, if necessary.

Ainger's description of the different sump/screen configurations at three plants provided insight into the real problems that operators have with this issue. For example, both Byron and Braidwood have two sumps that are enveloped by an outer screen. Overall, there are three screens that protect the suction lines to the ECCS and containment spray system. The outer screen encloses the middle and inner screens for both sumps. The outer screen extends about 4 feet above the floor of the containment, and the inner screen is installed below the containment floor inside each sump.

As for potential debris sources, the main containment insulation at Byron and Braidwood is reflective metal insulation. When the steam generators at Byron-1 and Braidwood-1 were replaced, their insulation and that of the associated piping were replaced with fiberglass blankets, covered with stainless steel sheathing. The TMI-1 containment has about 600 ft^3 of fibrous insulation. Ainger also pointed out the problem of unqualified equipment coatings—for example, the coatings on valve handles and reactor coolant pump housings—as possible debris. The baseline evaluations will look at the reflective metal insulation, fibrous insulation, coatings, tags, labels, and foreign material. All of these potential debris sources will be examined in light of the four transport mechanisms: blowdown transport; washdown transport; pool fill transport; and recirculation transport.

For the sump screens, the initial evaluation for Byron and Braidwood indicates no concerns regarding structural integrity or excessive blockage. Byron-1 and Braidwood-1, however, may not pass the evaluation in light of the fiberglass insulation used on the replacement steam generators. This might require an additional engineering analysis. With the performance of ZOI evaluations at the plants, Ainger noted, a risk-informed approach would probably provide benefits if it is used to assess the consequences of the occurrence of a break at the steam generator nozzles of the two reactors described above.

For TMI-1, the adequacy of the sump design may not pass the new evaluation, and so some design change to the sump or to the areas along the path to the sump may have to be considered. Enhancements could include modifications to the floor to help direct debris or prevent some pooling of water. These have not yet been scoped, but could be significant.

Ainger said that several interim measures have been implemented to ensure the working of the ECCS while pursuing the long-term resolution of the issue. The loss of recirculation capability has been addressed at Byron and Braidwood in the emergency procedures. Additional training for operators has been provided, including simulator training. The company has strengthened the foreign material exclusion and walkdown procedures for the containment, and has enhanced the refueling outage surveillance procedure for visual examination of the sump screens. For TMI-1, the B&W Owners Group guidelines for sump blockage were implemented and training in ECCS pump throttling criteria was provided to avoid damage in the early stages of potential sump blockage. New procedures for cleaning and inspecting drains inside the containment have been implemented. The existing refueling outage inspection procedures for the sump screen were determined to be adequate.

Ainger said that they are also looking at removing the fibrous insulation associated with the replacement steam generators.

Regarding costs, Ainger estimated that at Byron and Braidwood, Exelon will spend about $3 million over four years to pay for all the evaluations, including additional engineering analyses, licensing submittals and responses to the NRC Generic Letter (*NN*, May 2004, p. 15), and some insulation modifications. For TMI-1, the estimate is high, at about $4.5 million over four years, as some extensive modifications inside the containment seem likely.

Safety culture

During the Tuesday afternoon "Safety Culture" session, Joe Carson, a licensed professional engineer and a nuclear safety engineer for the Department of Energy, observed that ANS's bylaws, which he said have remained constant since the beginning of the Society 50 years ago, should be revised. The bylaws, he noted, "[don't] reflect that ANS holds a public trust when developing standards of care for its members."


Carson

Carson, a former member of the ANS Special Committee on Ethics, stressed that he wanted to see ANS as "an organization that is flexible, responsive to members, and capable of dealing with change."

Change is necessary, he said, because ANS has evolved since its creation a half-century ago. "Fifty years ago," he said, "I don't think ANS held a public trust, but I think it does now today."

Examples of that public trust include ANS's role in accrediting engineering schools for nuclear engineering, and its work in developing codes and standards that are adopted internationally. ANS, then, has "an important role with nuclear science and technology in public policy," he said.

Carson, who described himself as an "eight-time prevailing" DOE whistleblower (as detailed on his Web site, <www.carsonversusdoe.com>), noted that the words "ethics" and "peaceful" and the phrase "promote the professional interests of its members" are absent from ANS's bylaws. And although the word "safety" is included in ANS's goals, the bylaws do not include "any form of the word 'safe,'" he said.

Carson suggested that ANS modify its bylaws, mission statement, and goals to more clearly capture its identity as a professional society. He also called for all nuclear engineers to be licensed by states, something that is a "distinguishing characteristic" of members of such professions as medicine, accounting, and architecture. "Engineers, by and large, are not licensed," he said. "Well, why not?"

ANS's new code

Vic Uotinen, chairman of the ANS Special Committee on Ethics for 2003–2004, remarked that ANS does have a new Code of Ethics, replacing an earlier code dating back to 1973, which was altered somewhat in 1984. The new code, which was adopted by the ANS Board of Directors in 2003, is more specific and comprehensive than the earlier version, and it "reflects the expectation of a more conscious commitment to professional ethics by ANS members," he said.

The new code [of ethics] . . . "reflects the expectation of a more conscious commitment to professional ethics by ANS members."

The new code also is at the same level as the ethics codes of several other engineering societies, such as the American Society of Mechanical Engineers, American Institute of Chemical Engineers, Society of Civil Engineers, and IEEE. "I think it's important for us to realize that all of these engineering societies, by upgrading their codes of ethics, were in essence sending a signal to their constituencies that we, as professional societies, consider professional ethics to be important, and that we consider upholding this higher code of ethics, this higher standard, to be a true mark of professionalism," he said.


Uotinen

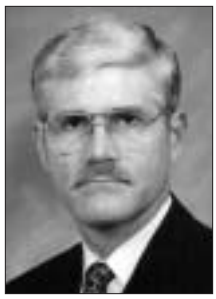
Uotinen gave examples of how the new code is an upgrade over the older version. The old code, for instance, said, "An ANS member shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties," while the new code says much more: "We hold paramount the safety, health, and welfare of the public and fellow workers to protect the environment and to strive to comply with the principles of sustainable development in the performance of our professional duties." It also adds a new paragraph: "We will formally advise our employers, clients, or any appropriate authority and, if warranted, consider further disclosure, if and when we perceive that pursuit of our professional duties might have adverse consequences for the present or future public and fellow worker health and safety or his environment."

Another example is in the area of acting in accordance with applicable laws and practices. Whereas the old code didn't mention this area at all, the new code says, "We act in accordance with all applicable laws and these practices, lend support to others who strive to do likewise, and report violations to appropriate authorities."

Ethics and competency

Ethics and competency are interrelated, remarked Dwight Baker, who was making a presentation for the absent William Corcoran, of Nuclear Safety Review Concepts. Baker said that if anybody at Davis-Besse had operated according to the ANS Code of Ethics, the vessel head degradation could have been prevented from becoming so severe. "You can certainly say that if you saw [the signs of degradation, such as piles of rust that collected on a flange] and ignored it, if you were the manager who would have signed off saying 'We don't need to work on that,' if you were the outage manager who shut down [a vessel head cleanup job prior to the degradation's discovery], maybe then there should be an ethics complaint filed," said Baker, of Cumberland Consulting. "But I'd put a dollar to a donut that those people are not ANS members."

Baker said that in many cases where workers "behave badly at the technical level, those technical people are neither professional engineers nor ANS members, with no requirement that they be." Further, he said, in "about 99 percent" of the cases where a nuclear professional should be punished for ethical misbehavior, the management personnel who would make those decisions are not ANS members.


Baker

As long as there is no requirement that an engineer be licensed, society will think "we're just computer programmers, and we really don't affect their health and safety," he said. Without that public pressure, there will be no incentive for companies to hire licensed engineers, or have existing staff attain licensing. Without licensing, there will be no living up to a code of ethics. "It's really a public education job, to impose a licensure requirement just like for doctors and lawyers," he said.

Continued

Baker said short of requiring licensing, which is "really a big piece of work, and I don't know if it's doable," one way that a plant can attain higher overall quality is to provide long-term financial incentives to company executives. "Think about it," he said. "Having the plant run well in the long term is in the stockholders' interest. So, there may actually be a strategy that is doable, from the business organization side of it."

A case in point is that some ANS members are utility executives with access to compensation committees. These executives, he said, may "have some good ideas on how to structure stock options that are only exercisable seven years from now." *—E. Michael Blake, Dick Kovan, Rick Michal, and Nancy Zacha*

TOPICAL MEETING

Advances in Nuclear Power Plants (ICAPP 2004)

- *South Korea aims for large H output by 2020*
- *European utilities judge next-stage reactors*
- *MIT study on nuclear role in carbon-constrained world*

As the world's nuclear energy nations have come into greater agreement on nuclear power's medium- to long-term future—the development of "Generation IV" reactor designs, the coupling of these designs to hydrogen production, and the opportunity for actinide burning to extend fuel resources, deter proliferation, and reduce radwaste generation—many of the speakers at the 2004 International Congress on Advances in Nuclear Power Plants (ICAPP 2004) agreed in their presentations to such an extent that some of them apologized for repeating what others had already said. ICAPP 2004—which this year was embedded as a topical meeting in the ANS Annual Meeting in Pittsburgh (June 13–17)—included five plenary sessions, and despite the organizers' attempt to give each session its own unique theme, some overlap was unavoidable.

Whether there will be enough trained professionals in place if there is a sudden demand for new nuclear power was much on the minds of several speakers. Andy White, of General Electric Nuclear Energy, told a plenary session audience that 40 percent of GE's employees in nuclear fields are within five years of retirement age. He called for an industry-wide focus on development of a larger talent pool of nuclear expertise. The next speaker, Russ Bell of the Nuclear Energy Institute, also included the aging nuclear workforce as one of the main challenges facing the industry now (and not just in the future). The other challenges, in Bell's view: keeping fuel economical and reliably supplied; managing materials at aging facilities; securing nuclear facilities (Bell said they were safe before 9/11, and are safer now, but this is a very high-profile public issue); and providing spent fuel disposal. Bell acknowledged the problem that had arisen with high-level waste funding, in which the Bush administration had expected to use money from the Nuclear Waste Fund but Congress had not authorized it (see page 113, this issue), but said that the Department of Energy, "with industry support, is pursuing legislation" to assure adequate funding for the proposed high-level waste repository at Yucca Mountain, Nev., in the FY 2005 federal budget.

Later in that session, Peter Lyons, of the Senate Committee for Energy and Natural Resources staff, spoke more pointedly about the Yucca Mountain funding situation. He said that the way the administration presented the bill, with only $131 million to be appropriated in the FY 2005 budget and $749 million presumed to be available from the Nuclear Waste Fund, created "an immense problem," and led to only the $131 million being approved for Yucca Mountain, nowhere near enough for the DOE to remain on schedule to open the repository in 2010. Lyons also said that the entire FY 2005 budget request was "an immense surprise" to the committee, leading to concern that nuclear research and development could be undermined, and that the reformulation of the Idaho National Laboratory might not be given a "focus for success."

At the second plenary, Steve Melancon, of Entergy Corporation, echoed the concern about Yucca Mountain, and the extent to which the future of new power reactors in the United States depends on resolution of the high-level waste issue. "Yucca Mountain needs to become a reality," he said, "or I don't think any new nuclear plants will be built." Also during his address, Melancon recounted the formation of NuStart Corporation (an industry consortium seeking Department of Energy matching funds to apply for site approval, design certification, and licensing of new power reactors), but departed somewhat in his personal views from the procedure announced thus far for NuStart, in which approval would be sought from the Nuclear Regulatory Commission for two sites, as well as certification for two reactor designs, but ultimately the construction/operating license (COL) would be sought for a single reactor design at one site. Melancon said NuStart should choose *at least* one plant for the COL; he would like to see enough money made available to pursue both designs, and both sites.

With the meeting taking place in the United States, and with so many recent developments in the U.S. nuclear realm, the above topics and more like them drew a great deal of attention during the meeting, but ICAPP is indeed an international event, and speakers from most of the world's large nuclear power programs reported on numerous technical and programmatic developments. Their reports, like those from the U.S., ranged from improvements on existing reactors to the many first steps being taken toward the goal of Generation IV.

South Korea's vision

Next year's ICAPP will be held in Seoul, South Korea, and there was a substantial Korean presence at this ICAPP, both to pre-

sent papers and to promote the event in 2005. A table outside the topical's largest meeting room was stacked with brochures on travel to Korea. The viewgraphs of three of the five Korean speakers at the plenary sessions had bands at the bottom reading: "See you in 2005, ICAPP Seoul!"

During the first plenary, Joong-Jae Lee, of Korea Hydro and Nuclear Power, traced the development of nuclear power in South Korea, which is now sixth in the world in both installed nuclear capacity and annual nuclear power generation. He said that in some countries where nuclear power has been accepted for some time, "challenges and new issues are growing" (which could describe the emergence of public opposition to nuclear in both South Korea and Taiwan), and there is a need for breakthroughs in technology and cooperation within the nuclear community. With 14 of South Korea's 18 power reactors achieving 2003 capacity factors above 90 percent, and the other four over 80 percent, Lee asserted that outstanding performance is the best way to respond to nuclear controversy. As for technology breakthroughs, Lee described the APR 1400 pressurized water reactor being developed in Korea to supplement and eventually replace the current generation of reactors; work has begun on the first APR 1400, Shin-Kori-3, scheduled to begin operation in 2011.

South Korea . . . has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances.

At the second plenary, Dong-Su Kim, of Korea Power Engineering Company, described the evolution of the APR 1400, the latest step in the development of the nuclear industry in South Korea—which has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances. He said that the current social environment (alluded to by Lee) "requires unlimited safety" and "faultless and eventless operations." He added that in South Korea, as in the United States, there is concern about the future supply of trained personnel, as students are tending not to pursue engineering. The belief that public acceptance can exist only with perfect operation drew a comment from the audience by Ted Rockwell, former technical director of the U.S. Naval Reactors Program. He said that one cannot convince the public that there will never be an accident, because one cannot reasonably make such a claim. He advised that one should take the position that the effects of any accident would be mitigated, and rebut the argument that exposure to any amount of radiation is dangerous.

Chung-Won Cho, of South Korea's Ministry of Science and Technology, extended his country's nuclear program into the future during the third plenary, citing its proposal for the System-integrated Modular Advanced Reactor (SMART), for both electricity production and seawater desalination, and participation thus far in Generation IV projects. SMART is intended as a PWR with the steam generator included in the reactor vessel, offering enhanced safety, economics, and environmental advantages. For Generation IV and beyond, Cho's projections were extremely ambitious, anticipating a "waste-free and pollution-free" nuclear fuel cycle with consumption of all actinides, and a timetable whereby South Korea would switch from fossil fuel to hydrogen so quickly that nuclear energy would produce 20 percent of the needed hydrogen by 2020. Questioned about this goal by an audience member, Cho said that a 16-year program is now starting, aiming at development of small-scale modular gas-cooled reactors, but that wider application was still under discussion, and the 20 percent goal should not be taken as a firm commitment.

Jong-Hwa Chang, of the Korea Atomic Energy Research Institute (KAERI), elaborated further on the 20 percent hydrogen goal in his address at the fifth plenary. One-fifth of the expected vehicle fuel demand in South Korea in 2020 would require 8.5 billion barrels of oil per year, which could be replaced by 3.3 million tons of hydrogen. KAERI's anticipated demo nuclear plant (a very high temperature gas-cooled reactor, or VHTR) would produce about 30 000 tons of hydrogen per year, so at least 100 plants of this capability would be needed to meet the hydrogen goal. At the same time, Chang said that security concerns in South Korea—which still has a hostile neighbor to the north—argue against distributed nuclear-hydrogen facilities, because of the potential for sabotage. Therefore, the reactors—more than 100—would be concentrated at a small number of sites that could be guarded well.

New scheme in Europe

The lull in power reactor ordering in Europe has not been as long as that in the United States, and with a new order placed in Finland and another on the way in France, it can be said that the lull is in fact over. Still, plenty has changed in the decade or so that elapsed, with moves toward the opening of electricity markets and attempts to normalize regulation. The old paradigm of a state-owned electric utility ordering the only design available from a state-owned manufacturer is eroding, and one indication of this is the development of European Utility Requirements (EUR) documents, which essentially tell manufacturers what the utilities want, need, and expect from power plant hardware and services.

Gianfranco Saiu, of the Italian firm Ansaldo, described the EUR process while presenting a technical paper on the EUR assessment of the Westinghouse AP1000 reactor design. The EUR effort began in 1991, with five utilities; six others joined later. Along with expressing what the utilities wanted, the documents provide bases for harmonization of safety approaches and targets, design standardization and objectives, equipment specifications and standards, and information for safety, reliability, and cost assessment. In 1997, the effort enlarged so that each document included a Volume 3, which compared a specific reactor design against the requirements. (Volume 1 includes nuclear island requirements, and Volume 2 covers balance-of-plant.)

Development of a Volume 3 for the AP1000 was based on previous work on advanced Westinghouse designs. Saui noted, however, that while the utilities' team was at work on this volume (the process can take years), Westinghouse moved on from the design. Saiu said that although the AP1000 was driven by U.S. market considerations, it had incorporated lessons from EUR work on earlier designs, including a low-boron core. As things stand now, the AP1000 is slightly out of compliance with EUR, both in technical areas (the cooldown time is longer than what the EUR prefers) and in semantics (whether it is preferable to state that radiation exposures *shall be* as low as reasonably achievable, or *are* as low as reasonably achievable). There will be more meetings intended to resolve the differences.

Pierre Berbey, of Electricité de France, spoke at greater length on the EUR's place in the evolving power generation environment in Europe. Even with efforts like EUR intended to normalize agreement on basic principles of safety and operation, the differing regulatory schemes of individual countries can work against standardization and increase costs. Berbey said that there should be common "rules of the game." He noted that the Western European Nuclear Regulator's Association is working to define reference safety approaches that could become common to all nuclear power nations in Europe. Berbey also noted a number of non-nuclear challenges now faced by electricity organizations in Europe, such as the synchroniza-

tion of the western European transmission grid with bordering nations like Poland and Romania. In the end, Berbey said that the EUR effort will try to deliver documents supporting four to six standard reactor designs; along with AP1000, EUR is also doing Volume 3 work on the AES92, an advanced version of the Russian VVER water-cooled reactor.

A carbon-constrained world?

During the fifth and final plenary, Ernest Moniz, of Massachusetts Institute of Technology (MIT)—who described himself as neither pro- nor anti-nuclear—presented results from a 2003 MIT study on what might happen if there is a significant worldwide adoption of new nuclear power. (The study, headed by Moniz and John Deutch, is posted online at <web.mit.edu/nuclearpower/>.) The study looked at the presence of a terawatt of nuclear capacity in place by 2050 (for comparison, the current worldwide nuclear capacity is less than half a terawatt). Moniz said this does not seem possible without the emergence of a "game changer" that would make nuclear the preferred choice for decision makers and the public. He said that global warming appears to be the strongest candidate to be the game changer. He said that if the only way to prevent a self-reinforcing rise in the greenhouse effect is to make this a "carbon-constrained world" by reducing carbon dioxide emissions, nuclear power and all other nonemissive options would be needed, and may not be enough.


Moniz

Moniz said that a new, nonamortized nuclear plant with no federally backed financing cannot currently compete with coal- and gas-fired generation (with CO_2 not taken into account). Not only must plant capital cost be reduced, but a series of plants would have to be built on budget and schedule to show that financial risk is not excessive. The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

If the world is carbon-constrained, Moniz said, the obligation to reduce emissions would fall hard on the power industry. Manufacturers that emit CO_2 can be moved offshore—in an observation specific to Pittsburgh, he noted that Alcoa is moving all aluminum production to Trinidad—but power plants must remain connected to the home nation's grid. Moniz added later that there will likely emerge a formal "cap-and-trade" system of incentives for carbon emission, started by the power industry in return for a rational, stable system of federal oversight.

Moniz said that even if the openly established "fuel cycle states" have 80 percent of the expected nuclear generating capacity, that would leave 200 gigawatts in other nations, raising nonproliferation concerns. Incentives to prevent rogue states from developing independent nuclear capability would have to include not only assured fuel supplies, but also spent fuel removal, which means resolution of high-level waste problems worldwide. Moniz said that it would be necessary for spent fuel to be stored for 50 to 75 years, despite what he termed the industry's "religion" of fuel cycle closure. He noted that the expected carbon emission mitigation cost for fossil generation would be at least $50 per ton of carbon, or $8 per megawatt-hour, which is far more than all expected fuel and waste costs for nuclear—so carbon constraint can become an incentive for nuclear, in full compliance with the Non-Proliferation Treaty.

Although the MIT study looked at a large addition of nuclear power extending to mid-century, Moniz was dubious of a major prospect used recently to argue in favor of advanced nuclear power: hydrogen production. He said that significant use of hydrogen as a fossil-fuel substitute "may be decades away at a minimum . . . we're all getting carried away" on hydrogen's likelihood of displacing oil use. He advised the audience not to lose sight of the scale of what would have to be done (as had been shown in the Korean presentations reported above). He called hydrogen "intrinsically inferior" to petroleum, and said that nuclear power should continue to be presented as an electricity option, with no attempt to oversell hydrogen.

The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

Other presentations

There were occasional moments at ICAPP 2004 when it seemed that two U.S. reactor designs—Westinghouse's AP1000, and General Electric's ESBWR—were being compared to one another. These are the designs chosen by NuStart for certification, and (despite Steve Melancon's position) apparent competition. Thus, fairly or otherwise, the designs are now seen as linked, and in a race that would end with one being the preferred choice and the other at least having to wait. Atam Rao, of GE, in his presentation to the second plenary on ESBWR, described this reactor as having a capability of 1550 MWe (the AP1000 is currently rated at 1117 MWe), and said that it will use components similar to those already being made for the ABWRs coming into service. He admitted, however, that the ESBWR is not as far along as the AP1000, which he said is "two years ahead of us" in the design completion and NRC certification processes.


Rao

In a session on the Very High Temperature Reactor (VHTR), which is the principal Generation IV design being pursued in the United States, Phil McDonald, of the Idaho National Engineering and Environment Laboratory, reported on a point design study that compared pebble bed core design to the "block" design, with fuel and moderator in parallel vertical blocks. He said that he would not choose one over the other, but concluded that fuel cycle costs would appear to be lower for pebble bed than for blocks. In the next paper, Yasushi Muto, of Tokyo Institute of Technology—working from different design assumptions—found that a cooling system that allowed for horizontal as well as vertical flow could help reduce some of the drawbacks associated with pebble bed cores. This flow pattern offers a 2 percent improvement in thermal efficiency and 5 percent less core pressure drop, allowing the maximum fuel temperature to be as low as 1110 °C.

Perhaps the most inopportune turn of phrase at the meeting came from Norbert Frischauf, of the European Space Agency's (ESA) European Space Technology Center, who chaired the session on nuclear power and propulsion systems, and opened it with remarks on European perspectives on the topic. After concluding that Europe should work on materials and other support issues, and decide later whether ESA should enter reactor development, he said that it was necessary to "go back to the classroom" to educate the public on nuclear materials used in spacecraft—to actively provide information, "and not let it fall down from the sky." Whether a nuclear spacecraft would fall down from the sky is, of course, exactly what the public would worry about.—*E. Michael Blake* NN

ANS ANNUAL MEETING

On the 50th anniversary, golden opportunities foreseen

- *Nuclear renaissance possible, if issues are resolved*
- *TMI-2 changed how the industry does business*
- *ANS should lead in presenting demonstrated science*
- *Zero fuel defects should be the industry's goal*
- *Shift is away from prescriptive standards*
- *Nuclear desalination faces several challenges*
- *Not just one solution to sump clogging at PWRs*
- *Improvements suggested to upgrade safety culture*

THE AMERICAN NUCLEAR Society gathered June 13–17 in Pittsburgh, Pa., for its 50th anniversary at a moment when memories of the origins of ANS—the aftermath of President Eisenhower's "Atoms for Peace" initiative, and the numerous possibilities foreseen for bringing nuclear science and technology to applications for the benefit of all humanity—could be accompanied by optimism for the short- and long-term future of the field. The theme of the meeting was *A Golden Anniversary—A Golden Opportunity*, and although during the second half of the Society's existence no power reactor orders have been placed in the United States, the 1073 attendees who gathered in Pittsburgh in mid-June could look to a new reactor order in Finland, a likely order to follow in France, the U.S. nuclear industry consortia preparing to test the new system for licensing, and signs of more favorable public attitudes toward new nuclear plants as indications that a nuclear power renaissance might occur in the United States early in the Society's second half-century.

The memories of the first half-century, and the accomplishments of ANS and the nuclear community, were evoked during the 50th Anniversary Banquet on Sunday night, the first official event of the meeting. Susan Eisenhower, granddaughter of former President Dwight D. Eisenhower and president of the Eisenhower Institute, gave a presentation in which she noted the appropriateness of Pittsburgh—the birthplace of commercial nuclear power generation—as the location of ANS's anniversary meeting, and thanked the Society for helping to transform her grandfather's "Atoms for Peace" vision into reality.

Following her talk, she introduced John Simpson, ANS past President (1973–74) and honorary chair of the meeting, and presented him with an ANS Presidential Citation for his lifetime of achievements. Simpson's talk provided insight into the sense of adventure that existed at the dawn of the nuclear age, and into what it was like to be one of the nuclear pioneers. He related firsthand stories about important figures of the early times, and conveyed the excitement of those who took nuclear through the transition from wartime use to commercial power generation. He was one of 19 ANS past Presidents in attendance at the dinner, where they and the Society's other previous leaders were honored for their contributions.

Seizing opportunities

Speakers at the opening plenary session on Monday morning touched on the meeting's theme, but tempered slightly their assessment of the opportunities for nuclear development in the coming years.

While all agreed that ANS, and nuclear professionals in general, can do much to seize the opportunities and broaden the benefits to the nation and world from nuclear energy, they made it clear that real progress depends also on developments outside the nuclear community, in the political and public arenas. The consensus was that a nuclear renaissance is possible, and may be becoming more likely, but can occur only if issues such as high-level waste disposal

are resolved fully.

The early part of the session focused on ANS matters. Joe Colvin, of the Nuclear Energy Institute, presented the Henry DeWolf Smyth Nuclear Statesman Award—a joint award of ANS and NEI—to former ANS President and Nuclear Regulatory Commission Chairman Joseph P. Hendrie. Stephen R. Tritch, of Westinghouse, a general co-chair of the meeting, read a letter from President George W. Bush congratulating ANS on its 50th anniversary. Then the other meeting co-chair, Gary Leidich, of FirstEnergy Nuclear Operating Company, presented a video that pointed out some of the nuclear community's many roots in the Pittsburgh area: the original power reactor at Shippingport (both as a light-water reactor starting in the 1950s, and as a light-water breeder reactor starting in the 1970s), and the nearby two-unit Beaver Valley plant in operation today.

Leidich

Leidich then presented the plenary speakers. Sen. Larry Craig (R., Ida.) was unable to attend in person, because the various memorial services for the late President Ronald Reagan in Washington, D.C., during the previous week had forced legislative business to be rescheduled; he sent a videotape in which he explained that work on defense high-level waste appropriations forced him to remain in the capital. (Technical glitches in the video, and Craig's largely off-the-cuff remarks, supported the impression that Craig had indeed changed his plans suddenly and made the video only as a last resort.) Craig said that there was still a "slim but outside chance" that comprehensive energy legislation could be passed by Congress before this year's election. He noted the public's reaction to this year's rise in gasoline prices, and said, "This reality check . . . may well jar Congress into action." He added that any serious push by the federal government for new energy sources would include a large nuclear component.

Current NRC Chairman Nils J. Diaz joined in the celebratory mood of the session, praising nuclear pioneers (including past ANS Presidents) for the legacy they have left, including power reactors and other nuclear facilities now in operation. But he said that the technology's safety record "is not to be taken for granted," and the prolonged outage at Davis-Besse (and the discovery there of an eroded cavity in the upper vessel head) should serve as a wake-up call. He noted that the Three Mile Island-2 accident in 1979 forced a realignment of the nuclear industry, and an awareness that a problem at one plant can reflect on all others. Diaz endorsed the prescriptive approach to regulation in use at the time, but said that several hundred reactor-years of additional operating experience, and the development of risk analysis techniques, have made it possible for regulation to become more risk-informed and performance-based. Also, raising an issue that would be revisited by many other speakers at the meeting, Diaz noted that the new generation of professionals entering the nuclear fields is not large enough to replace the retiring pioneers, and said that ANS is "never more needed than today" to assure an abundant supply of qualified personnel.

Diaz

Pittsburgh was also important in the development of the nuclear Navy, through the Bettis Laboratory. Thomas H. Beckett, deputy director of the Naval Reactors Program, summarized the program to date, noting that it has logged more than 130 million miles of submarine travel without a single accident, health impact, or instance of environmental damage. He credited this record to the core values established by the program's founder, Adm. Hyman Rickover: technical excellence and competence, meritocracy, acceptance of complete responsibility, training of and challenge to all personnel, firm authority, and total commitment to honesty, safety, and environmental stewardship. Beckett also noted that unlike in the civilian power sector, naval reactor ordering has not paused, with new orders placed in the 1980s, 1990s, and since 2000. Later this year, he added, the first Virginia-class submarine will be commissioned, with a core intended to last for the whole 33-year life of the craft.

Beckett

Kingsley's seven points

Next to speak was Oliver D. Kingsley, Jr., chief operating officer of Exelon, with remarks that were to be cited and quoted frequently by other speakers for the duration of the meeting. Kingsley recalled that five years earlier he had told a reporter that a nuclear renaissance was approaching, and said he believes that it is now in its early stages—but does not have an assured future. After summarizing the activities to date of the NuStart consortium, of which Exelon is a member, and its plan to apply for site approval and a construction/operating license even though none of the NuStart partners currently intends to order a reactor, he listed seven preconditions that would have to be met before new plants would be built:

Kingsley

[A] nuclear renaissance is possible, and may be becoming more likely, but . . . only if issues such as high-level waste disposal are resolved.

■ The market must create a demand for more power. Kingsley noted that there have been about $50 million in losses from "merchant" plants, built as speculative investments with traditional rate-base inclusion, and this environment won't support nuclear plants. Reserve margins are declining, however, and Kingsley said that with 90 percent of all recent generation additions being gas-fired, there has been an adverse effect on the price of gas in the fuel's traditional markets, like fertilizer and home heating. He said that the price of gas in four major Exelon regions translates to electricity costs in excess of $50/MWh for that fuel.

■ Someone, preferably a utility CEO, must lead the way, perhaps risking the presumed ire of the financial community by showing a clear intent to build a new nuclear plant. Kingsley cited the late William Lee, of Duke Power Company, as an example of the kind of leader who would be needed.

■ There must be new, deliverable technology—not experimental, but already able to provide "operational comfort." The ABWR, for instance, already has operational experience. The certification of the AP1000 and ESBWR may satisfy this condition, from the standpoint of NuStart.

■ There must be regulatory predictability and stability. Kingsley said that he thinks this is in place now as far as reactors are concerned, but said that it would be difficult to announce new orders unless another regulated project—the proposed high-level waste repository at Yucca Mountain, Nev.—is determined to be a licensable site.

Continued

■ Acceptable financial returns must be available. Kingsley said that construction cost is a major concern, and there should be financial incentives for "first movers" who would make their commitments before economy of scale and proven performance could make reactor ordering more attractive. He noted that there is currently 10 times as much federal funding for fossil and renewable energy as there is for nuclear.

■ The infrastructure to design and build power reactors must be reestablished. He recalled attending a World Association of Nuclear Operators meeting in Osaka, Japan, and wondered if there were more nuclear construction capability around Osaka Bay than in all of the United States. He said the issue is not just whether there are enough engineers and university nuclear programs, but whether craft workers, technicians, training programs, and apprenticeships will be in place.

■ There must be public confidence in nuclear power. Kingsley exhorted nuclear professionals to quit apologizing and proclaim the progress of power reactors. Reitation is an important aid to nuclear development, and cited as an example the order for the Olkiluoto-3 reactor in Finland a few months earlier.

There remains, however, great uncertainty on upcoming energy choices in many nations. Echávarri said that countries accustomed to command-and-control decision-making are being forced to learn about the workings of the market. He also mentioned the Generation IV international forum, with 11 countries working on six advanced reactor concepts, as a way for the worldwide nuclear community to help advance the technology to newer systems and a gateway to the hydrogen economy.

Questions for the panel

In the ensuing panel discussion, Leidich asked Kingsley how ANS could help meet the seven preconditions. Kingsley replied that the Society and its members could help uphold nuclear education, stress positives in public debates, and serve as a common ground for the whole nuclear community.

Kingsley's call for a CEO to lead the way in plant ordering prompted a question from the audience by former ANS President Andrew Kadak, who asked Kingsley if he were volunteering. Kingsley (Exelon's COO, not CEO) said only that Exelon is willing to make a substantial investment once other needs are met—especially regarding Yucca Mountain.

In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business.

On the same topic, Kingsley was asked about a recent statement by Dominion Energy CEO Thomas Capps, that the utility consortia have "unrealistic" ambitions (*NN*, July 2004, p. 12), and whether Kingsley saw NuStart evolving eventually into an entity that would order, build, and operate new reactors. On the Capps statement, Kingsley acknowledged the awareness of financial risk that gave rise to it, and said that NuStart is nowhere near the point of considering an order, but added that it would be worthwhile for several utilities to be involved, and share the accompanying risks.

To an extent, the panelists were chided by audience members for limiting their near-future focus. One questioner said that economy of scale argued for resuming construction with more than one reactor; Kingsley said that the first step had to be the establishment of a single reactor project, and that if it went as intended, others would follow. "My heart says eight," he said, "but my head says one."

Another questioner wondered whether the addition of new reactors would put a strain on the uranium supply in the once-through fuel cycle now in place, and whether nuclear could expand without breeder reactors. Tritch responded that the focus should stay on what's needed to resume reactor ordering, and that it would be unwise to push for breeders.

Tritch

turning to the financial state of the electricity industry in general, he noted that since the start of 2002, the Dow-Jones utility index was down 13 percent overall, but the stock prices for nuclear plant owners had risen, and the six utilities that have bought power reactors from other utilities are up 65 percent. He added that the nuclear industry will not be able to tolerate poorly performing reactors anywhere in the country. "If you're not getting better," he concluded, "you're certainly moving backwards."

The final speaker was Luis E. Echávarri, director-general of the Organization for Economic Cooperation and Development's (OECD) Nuclear Energy Agency. He said there are now more than 10 000 reactor-years of experience worldwide, but OECD countries are growing more dependent on energy from unstable regions of the world. He said that the Kyoto treaty on carbon dioxide emission lim-

Echávarri

TMI-2: The lessons learned

It was 25 years ago in March that the commercial nuclear industry learned that it was fallible. In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business, from education and training and plant operations, to regulatory oversight, and brought the phrase "lessons learned" into the nuclear lexicon. The Monday afternoon session at the ANS Annual Meeting, "Twenty-five Years After TMI-2: Lessons We Need to Remember," took a look at some of those changes and asked the question: Are we starting to forget why we made these changes in the first place? The session was organized by Jim Byrne, of FirstEnergy Nuclear Operating Company, sponsored by the ANS Decommissioning, Decontamination and Reutilization Division, and cosponsored by the Education and Training Division and the Operations and Power Division.

Bob Long was a vice president at TMI operator GPU Nuclear when the accident occurred. With the accident now 25 years in the past, he felt compelled to remind the session audience just how devastating the accident had been for the reactor and the company that owned and operated it. As he noted, the reactor core was destroyed, with 70 percent of the fuel damaged and more than 50 percent of it melted; a million gallons of highly contaminated water collected in the reactor and auxiliary building basements; a large volume of krypton gas accumulated in the reactor building; and local residents suffered considerable mental stress and local businesses suffered economic losses. And because of the high levels of radioactivity after the accident, much of the damage would remain unknown for many more years.

Long

The full picture of just how damaged the reactor was began to emerge in 1986, Long said. The first images of the shattered fuel rods, the molten mass at the bottom of the vessel, the melted instrument tubes, remain

"burned into the memory of everyone in the power business," Long commented. In addition, as reported in 1993, accident analysts eventually determined that a square meter section at the bottom of the reactor vessel reached 1100 °C, which is considered white hot. Nonetheless, the vessel did not rupture.

The social consequences of the accident were equally dramatic, Long said. Although there were no deaths or injuries, the plant was ruined, never to operate again; it took a billion dollars to clean up the mess; adjoining TMI-1 was shut down for more than six years; GPU was driven to the edge of bankruptcy (its stock dropped from $18 a share before the accident to just over $3); the public emotion about the accident remained intense, with people still expressing concern about living near TMI; and billions of dollars were spent worldwide to improve plant safety and performance.

Tony Barratta, professor emeritus at Penn State University, discussed the accident's impact on nuclear engineering education. Prior to the accident, nuclear engineering education programs had remained somewhat static, but not long after the accident, enrollments began to increase—driven, Barratta said, by a response to the challenge of making nuclear energy safer, especially among the better students. This increase, however, was short-lived, especially after the 1986 accident at Chernobyl disillusioned students who thought things had changed and as the "cyber revolution" enticed the cutting-edge students away.


Barratta

Today enrollments are again increasing, but the ability for the nation's universities to respond has decreased. Only 27 university reactors remain operational. Today's faculty members often lack a depth of understanding (few have power reactor experience, Barratta said). Many programs have merged into more traditional engineering fields (mechanical, electrical, etc.), which can create problems for nuclear engineering education because the traditional programs often do not provide the emphasis on safety that the specialized programs have. Most important, Barratta concluded, industry support has been lagging, and industry especially does little to support faculty research, an area that universities still find valuable.

Changes in training, operations

TMI also changed the face of nuclear training forever, noted Jane LeClair, from Constellation Energy's Nine Mile Point nuclear station. At TMI, she said, operators were faced with a situation they had never seen before, were working with confusing procedures, lacked a fundamental knowledge of the reactor workings, and had no knowledge of lessons learned from previous operating experiences at other plants. Among nuclear utilities, prior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

After TMI, the industry worked quickly to fill the training void. In May 1982, the Institute of Nuclear Power Operations (INPO) established an accreditation program for the industry, and the industry responded by preparing its training programs for accreditation. The U.S. Nuclear Regulatory Commission endorsed the INPO accreditation program in March 1985, and issued a training rule in April 1993 that recognized industry's training and accreditation efforts. And the American Nuclear Society developed standards for training and qualification of nuclear plant personnel.

[P]rior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

More specifically, she said, the industry systematized its training program; increased eligibility requirements for senior operators and operators; added training in heat transfer, fluid flow, and thermodynamics; increased training emphasis on reactor transients and on mitigating core damage; and toughened NRC licensing examinations. Finally, plant-specific simulator training became the norm for all operator training.

Changes in plant operations were addressed by Pete Sena, operations manager at Beaver Valley. "It's all about people these days," he said, and "managing people is tough."

Sena outlined the way an "effective organization" looks at operations. Among the highlights: an emphasis on people, and "ownership" by employees and unions of the tasks they are assigned to do; an emphasis on constantly improving performance; team benchmarking with other plants; and high expectations. For example, an effective organization looks at a "near miss" as a failure, and constantly reviews minor slips. A less effective organization, on the other hand, might look at a near miss as a success, because, after all, nothing bad happened.

At Beaver Valley, every job is briefed prior to the job and afterwards. Lessons learned are saved and incorporated into future procedures. "Peer checks" provide a second set of eyes for every action. Sena admitted that industry is split pretty much 50/50 on peer checks, but he feels that they serve a valuation function. "If you do it right the first time as a result of a peer check, ultimately your productivity goes up."

A dedication to following procedures is another important aspect of operations at Beaver Valley. "We have procedures for following procedures," Sena laughed. But by emphasizing procedures, he said, "operators stay in 'rule-based land,' and don't go into 'knowledge-based land.'"

Regulations and response

The accident brought a new world view to the NRC, noted David Matthews, director of the agency's Division of Regulatory Improvement Programs. In addition to a raft of new regulations, the accident brought about an increase in opportunities for the public to make their opinions known during the regulatory process. This provided a sea change in the utility world, where the prevailing attitude had been that it's best if no one knows about them. Even today, he said, some utilities still look at the public process as an intrusion, but the NRC is committed to the change.

One problem the NRC still faces is "connecting the dots" from previous experiences, because there are still roadblocks to data sharing. Can we use INPO experience or is it confidential? Some foreign countries may not want to share experience that might reflect badly on them. In many ways, Matthews said, we face the same problems as the many entities of the intelligence community—that is, whose data is it, anyway?

In subsequent discussion, Long mentioned one other area of improvement: emergency response. There was no such thing as an effective emergency response program when TMI happened, he said. In those pre-cell-phone days, there were no telephones for reporters to call in their stories (the only telephone was in the control room, Long commented, and it had been "off the hook" since the accident), no trained briefers, no equipment or supplies for briefers or reporters. "We had a trailer with no furniture, no pencils, no paper, nothing," Long said.

Today, 25 years later, the good performance of today's nuclear plants is testament to the effectiveness of the post-TMI improvements. But "continuous vigilance" is needed, Long cautioned. Indeed, he noted, things are not as good as you would like

them to be, and they are not in an improving trend. For example, significant events increased 40 percent in 2003; forced shutdowns during the first 10 days after a refueling outage have increased; and since 2000, there has been a 27 percent decrease in the number of plants in INPO's "excellent" category. And, Long concluded, the recent issue of the corroded reactor head at Davis-Besse proves that the industry must remain vigilant, and must never forget the lessons learned from this country's worst commercial nuclear accident.

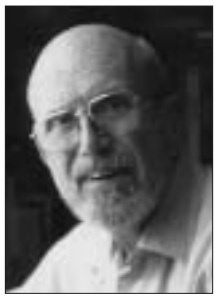
Realism: Set the record straight

In the ANS President's Special Session, *Realism in Evaluating Nuclear Hazards*, outgoing President Larry Foulke said that one of ANS's priorities is to be a source of credible information on science and technology. A critical issue that needs to be put right in this regard, he said, is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts. As members of this Society, Foulke said, "we have a responsibility to correct this."


Foulke

ANS, he added, "should take a leadership position" on this issue, and he added his hope that this session would mark a step along the way. The speakers, said Foulke, would be describing how conservatisms in the models, methods, and input have led to calculations predicting that there would be high levels of cancer fatalities and risk, and would show that these conservatisms and the results of the calculations have no basis in reality. Using conservative values and computer models that actually reflect reality, he noted, the numbers associated with consequences become ever so small.

The session was led by Ted Rockwell, who, at Foulke's request, has been heading up a group preparing a White Paper on this topic. Rockwell is currently vice president and founding officer of Radiation, Science & Health, Inc., an international public interest organization of independent radiation experts committed to bringing radiation policy into line with scientific data and theory.


Rockwell

Nuclear experts' attitude, Rockwell said, is that a major core accident would never be allowed to happen, because that would mean the end of nuclear power. It is something so unimaginable that there is no desire even to want to talk about it. In fact, a lot of work has been done to determine realistic scenarios of the release and dispersion of fission products and how the consequences are limited by the actual physical properties of the materials at hand. There is a good realistic story to tell, he said, based on facts, knowledge, and understanding.

Rockwell explained how this issue has come to a head. About two years ago, Nuclear Regulatory Commission Chairman Nils Diaz began addressing ANS and other organizations, saying that it is necessary to start using realistic figures. We cannot continue using extreme unrealistic assumptions. "Here is the chief watchdog telling us that we do not become safer going to extremes," said Rockwell, who added that Larry Foulke has taken on the challenge and is personally championing this issue.

A critical issue . . . is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts.

Ian Wall, a consultant and the first speaker, was involved in the early work at EPRI on accidents and has contributed to the White Paper. He became involved in risk assessment in 1967 while working at General Electric. Upon joining the NRC in 1974, said Wall, one of his first jobs was to correct a serious error in the consequence model then used. He developed a new code that showed that the consequences were concentrated mainly near the plant, that there would be time to evacuate, and that the risks become very small at distances farther away from the plant. "The point," he said, "is that realistic models changed our perspective about offsite consequences."


Wall

By introducing realism, said Wall, WASH 1400 (known as the Rasmussen Report) also changed the perspective of what was important to reactor safety. Prior to WASH 1400, the consensus of experts was that the probability of core damage was infinitesimally small, while the consequences were very large. WASH 1400, he said, showed that the probability was larger than expected, but the consequences were tiny.

Prior to the accident at Three Mile Island-2, safety experts assumed that the iodine released would be elemental and gaseous and a large fraction would be discharged to the atmosphere. Under this premise, said Wall, the TMI accident sequence should have released millions of curies of iodine-131. It turned out that only a very small amount was released. The subsequent investigations identified mechanisms—such as nuclides being dissolved in water and plating out—that meant most were retained at the plant. This further changed the perspective of the consequences of reactor accidents.

During the 1980s, EPRI undertook work on accidents, which added more realism. Wall's part involved setting out a program of experiments to characterize and measure the retention of radioactive material within fuel, within the reactor system, and within the containment. This resulted in a tenfold reduction in the WASH 1400 source term.

In general, Wall said, a much better job is being done than before. He added that reactor designs should be conservative, but should be supported by probabilistic risk assessments that are as realistic as possible.

Realistic conservatism

Before introducing the next speaker, Rockwell explained another event that is driving this work. Recently, an antinuclear report analyzing a hypothetical fuel pool fire associated with a terrorist attack predicted thousands of radiation-induced deaths hundreds of miles away, and demanded that all such fuel be transferred to dry storage casks. The report was given to Congress, which asked the National Research Council to look into it. The authors said that they did not invent the numbers and the methods used: They were taken directly from reports prepared by Sandia National Laboratories and other nuclear laboratories. In fact, the NRC accepted this point, and to its credit took up the challenge, realizing that there is a wider issue here. In its testimony, the commission underlined that the type of analysis done here—the sort carried out over many years—is not relevant to the real world because the premises are too unrealistic. The NRC explained that the premises may have been right for scoping studies, when they were looking to bound a problem, but they are not right for predicting deaths.

The next speaker was Farouk Eltawila, director of the Division of Systems Analysis and Regulatory Effectiveness in the NRC's Office of Nuclear Regulatory Research. Eltawila began by defining "realistic conservatism," a term coined by NRC Chairman Diaz, who believes that public policy should not be based on the most con-

servative assumptions and extreme scenarios. Conservativism, he said, means employing a defense-in-depth strategy and ensuring there are adequate safety margins. Realism comes from using the best information you have from science, engineering, and operating experience.

Today, the commission has much better knowledge of phenomena such as fracture mechanics and aging, Eltawila explained. This helps reduce uncertainties, improve the quantification of safety margins, and provide a better understanding of the safety issues associated with accidents. This is helping the NRC move away from the use of the traditional deterministic conservative assumptions to calculate consequences, toward what he called "risk-informed realistic conservatism."

Regarding the issue of a spent fuel fire, Eltawila discussed NUREG-1738, a spent fuel pool analysis carried out in 1999–2000 by Sandia and Brookhaven national laboratories. This study was done for a specific purpose and used a great deal of conservatism. In fact, it assumed the worst possible scenario. In this case, he said, the analysis gave a very low risk, which the NRC said was acceptable. There was no reason to go further because the answer already provided the information needed to make a regulatory decision. The NRC understood the conservatism used, he noted, which involved assumptions that were not realistic or appropriate for making a decision regarding a terrorist attack—a situation where realism is needed. Unfortunately, he said, people have tried to extrapolate that type of information from a hypothetical accident to a terrorist attack and have come up with a huge number of cancer fatalities.

The NRC's latest review, said Eltawila, indicates that the pool's structure is very robust and the location of fuel in pools make them highly resistant to terrorist attack. A transient analysis has indicated that fuel is more easily cooled and the decay heat level is much lower than predicted in earlier studies. There are at least 24 hours from the time the pool empties of water and the start of fuel damage and the release of fission products.

Realism comes from using the best information you have from science, engineering, and operating experience.

The review, said Eltawila, shows that the demand for the transfer of spent fuel from the pool to dry casks at the cost of billions of dollars is not justified. He added that the NRC has identified a strategy for loading spent fuel into the pool that can substantially reduce cooling time of freshly discharged fuel, further reducing any consequences from an incident.

Rockwell commented that Eltawila and Diaz are owed a big vote of thanks for tackling this issue, and recognizing that although some try to characterize it differently, no one is trying to reduce safety. "Getting more realistic is not reducing safety, it is getting safer."

Transport realities

Ruth Weiner, senior staff scientist at Sandia National Laboratories and a member of the NRC's Advisory Committee on Nuclear Waste, described the arbitrary premises that produce large overestimates of radiation dose from a postulated radiological incident involving nuclear transport. Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials or ionizing radiation. This is not surprising, she said, given the extreme tests undertaken.

Weiner

Conservatism in transportation is used, she said, at four points: computer models; inputs to the model; interpretation of results; and the notion of the bounding case. This last one, she noted, implies that if we can show that nothing much happens in the worst possible case, then clearly the situation is not bad. These four conservatisms were used in NUREG-0170 (1970), the first environmental impact statement on transportation of radioactive material by air and other means. The NRC and utilities still use it, with advanced computer codes of course.

Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials.

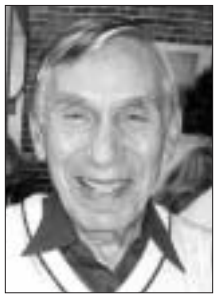
Weiner then described what real measurements do to a conservative model. To show this, she described the calculation of dose from an incident-free transportation operation. In this case, the truck is modeled by a sphere rolling down the road with dose measured at 1 meter from the surface. There are other conditions, such as that the truck stops every 100 miles for an inspection in a crowded urban area, and that no one moves. There was no validation done on this until a few years ago, she said, when a graduate student did some actual measurements at Hanford. It turned out that this model is extremely conservative.

"You give it stupid numbers," she said, "and it gives you stupid numbers back." The model never tells anything that it is not told first, she said, adding that opponents say they use the same models as those used by the experts and get tremendously high doses. The reason, Weiner explained, is that they start with tremendously high numbers.

The modeling of real accident situations is more complex, she said. Her colleagues at Sandia came up with NUREG-6672, which constructs 19 accident scenarios for trucks and 21 for rail. This gives much more realistic levels of doses of release than the previous NUREG, she noted, but is still excessively conservative.

The facts about buried HLW

Bernard Cohen, professor emeritus of Physics and Environmental and Occupational Health at the University of Pittsburgh, focused on the concerns of high-level waste (HLW) buried a half-mile underground. Cohen has authored many papers and several books on assessing nuclear power risks. For the purposes of his talk, he used rock as an analog for HLW—in its own form, encased or converted into glass or into another rock-type matrix known as "Synrock." He queried that if the HLW is buried a half-mile underground, why should this be dissolved out by groundwater any sooner than 2000 feet of rock above it? We understand natural rock, he said, and we ought to use this understanding.



Cohen

An example of not using what we know about rock was a study carried out about 20 years ago by the National Academy of Sciences (NAS) on HLW glass that presented

calculations of releases and health effects. It did not identify anything catastrophic. Going over this work, however, Cohen saw how totally unrealistic it was. Taking the method used by the NAS, the rock 2000 feet deep would dissolve at a rate of about 1 percent per year—so in other words, it would last only about 100 years. But it is well known that rock 2000 feet deep dissolves at a rate of about one ten-millionth of a percent per year and lasts about 1 billion years. In other words, they made an error of a factor of about 10 million. He showed other weaknesses in the NAS approach, and in the end, he observed that this report, hailed by the nuclear industry at the time, made all the mistakes that Ted Rockwell talked about.

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel.

Cohen also discussed the risk of cancer fatalities due to buried HLW generated from 100 nuclear plants, and compared it to the risks from coal-fired plants. The bottom line is that each of the three different types of waste released from coal burning—airborne pollution, chemical carcinogens in coal ash, and radioactive waste in coal (uranium, thorium, and radium, and the subsequent radon emissions)—cause 1000 times more deaths than HLW. Cohen added that the natural radioactivity in the ground above the waste from uranium and thorium provides 100 times more cancer doses than the waste.

Cohen also "unpicked" the picture that the antinuclear groups try to paint. For example, groundwater does not flow like a river; it is more like dampness seeping through the ground. At Yucca Mountain, groundwater moves at about 1 foot per year. He also noted that it would take groundwater at 2000 feet below the surface about 1000 years to get to the surface. Any radioactive material, however, would be held up by a number of processes, and would be expected to take 1000 times longer to get to the surface.

ANS White Paper

Rockwell concluded with some thoughts about the White Paper (ANS member input on the White Paper was being requested as of late June on the ANS Web site). The report, he stressed, is a working document designed to get the message clear as to what the realistic facts are about radiation hazards in the worst case and in the real situations people face.

He particularly wanted to "knock out" two false premises: that a severe accident would be the end of the world and that "one damn ray will kill you." As an example of the problem, he noted that when an incident occurs, such as the Davis-Besse problem, it is usually reported as almost a major accident, as if a small hole in the reactor would lead to thousands of deaths.

As for very low-dose radiation, Rockwell said that there is no real scientific basis for assuming it is harmful. In fact, he observed, there is considerable evidence that some radiation is beneficial. He noted that the goal is not to try to overturn the science on which their recommendations are based, and said that he believes that many of the advisory committees promoting the linear no-threshold concept have been remiss in their not examining, evaluating, and reporting on the massive amount of evidence on the beneficial effects of low-dose radiation.

Rockwell also challenged the idea that it is safer and more beneficial to assume that the world is different than it is. Putting some realism in place of "silly" premises does not represent a decrease in safety, he said. He was not talking about regulators' yielding to pressure from the industry to be less safe. If a most realistic assessment of the situation is made, "with conservative elbow room," then there will have been movement toward "safer, not less safe."

Fuel issues

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel, according to Ivan Maldonado, associate professor of Mechanical, Industrial and Nuclear Engineering at the University of Cincinnati.

The industry is increasing capacity factors and cycle lengths at the same time that power uprates are occurring. By many accounts, these factors "are conspiring to test the bounds of the performance and reliability of nuclear fuel," said Maldonado, organizer of the session on "Current Issues in LWR Nuclear Fuel Performance and Reliability."

Zero fuel defects should be that boundary of performance and reliability, suggested Bill Pierce, site vice president at Beaver Valley nuclear power plant, operated by FirstEnergy Nuclear Operating Company (FENOC). Beaver Valley has two Westinghouse pressurized water reactors. Unit 1 is rated at 821 MWe (net) and Unit 2 at 831 MWe (net). "We need to challenge the fuel vendors to continue robust fuel development," Pierce said. "We need to challenge the core designers to guard fuel margins. We have to challenge fuel handlers to protect fuel during movement. We need to challenge workers to prevent foreign material exclusion [FME]."

Pierce chastised the industry for not having a goal of zero fuel defects, and for its "lack of [having] a cohesive plan to achieve the things we need to achieve regarding fuel performance."

The industry, he continued, should get to a point where a defective fuel pin at a nuclear plant would be something that draws interest. "Today, we look at it as an accepted thing," he said. "If it happens, we feel like we're powerless to deal with it. We've got to get to a point where we see fuel defects as something we're not going to tolerate."

Underlying the zero-defect goal is a nontechnical issue, meaning that it's the general public that demands perfection from the nuclear industry. "I think the public domain that allows us to operate these plants expects us to have zero fuel defects," he said. "I just believe that it's bad business to have fuel leaks [because any minor nuclear blip is perceived by the public as a bad thing] and that [leaks] will be a problem for us as an industry."

The industry itself, of course, will have to foot the bill to support development of zero-defect fuel, he noted, but at the same time it is important to retain the low cost of fuel. "The heart of the electric industry using nuclear power for production is low fuel costs," he said. "Besides that one issue, we would not be competitive with other sources of electricity generation, because our base costs are higher."

FENOC operates three nuclear sites—Beaver Valley, in Shippingport, Pa.; Davis-Besse, an 873-MWe (net) Babcock & Wilcox PWR in Oak Harbor, Ohio; and Perry-1, a 1235-MWe (net) General Electric boiling water reactor in North Perry, Ohio. Combined, 66 percent of the FENOC plant's collective fuel failures have been caused by grid fretting, 28 percent by debris, and 6 percent through fabrication.

Countering Pierce's argument was Paul Edelmann, a fuels engineer for Constellation Energy's two-unit Nine Mile Point nuclear power plant, who noted that he would never expect fuel to be made entirely leak proof. "I don't think that's possible," he said. "I don't know how much more improvement you can design into fuel. But I do know from working at a BWR plant that there is a lot of room for improvement in control of plant


Edelmann

chemistry, and especially in foreign material exclusion."

He recounted a story from last spring, when Nine Mile Point-2, an 1148-MWe (net) General Electric BWR in Scriba, N.Y., was entering a refueling outage. Thirteen hundred workers were brought on site to work the outage. For most, it was their first experience at a nuclear plant. Their inexperience showed, he said, as illustrated by a pile of debris that collected on the refuel floor during the outage. "This became big news" within the plant, he said, because with the industry spending millions on FME programs, "somebody [at Nine Mile Point] was missing something."

Edelmann advised that strict adherence to good FME and chemistry practices, combined with safe rod pattern development and cycle operation, "can and should prevent BWR fuel from undergoing any failures, even with higher power demands and longer cycle duties."

A lesson learned at Nine Mile Point, he said, was that modern fuel designs will perform well when treated with care.

Identifying fuel leaks

Ed Price, a senior engineer for Duke Power, stated that Duke plants have been free of fuel leaks since 2001. Duke operates the two Catawba units, which are 1129-MWe (net) Westinghouse PWRs, in Clover, S.C.; the two McGuire units, which are 1100-MWe (net) Westinghouse PWRs, in Cornelius, N.C.; and the three Oconee units, which are 846-MWe (net) B&W PWRs, in Seneca, S.C.

The Catawba and McGuire plants switched in 2000 to Westinghouse robust fuel assemblies with zirconium cladding from the AREVA/Framatome ANP Mark-BW design, and Oconee switched in 2001 to AREVA/Framatome ANP Mark-B11 fuel with M5 cladding.

Price said that the whole process of identifying leakers, at least recently, has been akin to searching in the dark. "You expect when you have leakers to have iodine activity go up, but we've had many cycles with leakers with very low iodine activity," he said. "We've also had mysterious leaks at plants where we know we had leakers, but little or no spiking during transients."


Price

Once leakers were discovered at Duke plants, he said, there were problems in isolating the failed fuel assemblies. That's because ultrasonic testing (UT) has had "very poor reliability for us the past few years," he said. "Many overcalls, many cores that had leakers in them, did not show up on the UT."

As an example, Price explained a fuel-leak search at Catawba-1 from several years ago. The core showed a substantial increase in xenon-133, and a UT campaign was done that resulted in the identification of four suspect fuel rods. "We pulled the rods, but eddy current testing showed all the rods were sound," he said. "So, we did not find failures in any of these rods."

Price claimed that INPO's Fuel Reliability Indicator (FRI)—defined as the steady-state primary coolant iodine-131 activity (microcuries/gram), corrected for the tramp contribution and power level, and normalized to a common purification rate and average linear heat generation rate—is not a credible measure. A team is being put together, of which Price will be a member, to reevaluate FRI to come up with something "more realistic," he said.

A problem with today's FRI is that a core can have leakers with low iodine activities and low power defects, but still be under the FRI criteria for zero defects, he said.

With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good."

Price wondered what had happened to diagnostics over the past few years. Stretching back a decade or two, UT was considered 85 percent efficient. But over the past five years, "we haven't been able to find anything," he said. "It makes me wonder if now the threshold is so low for leakers that we're looking for things that, in the past [when the threshold was higher], we would see without paying much attention."

From the fuel manufacturers' side, Olga Correal-Price, a principal engineer for Westinghouse Electric Corp., noted that 25 percent of leakers are from unknown causes, and that the percentage is increasing. She stressed that finding the reason for those leakers is "today's challenge."

John Schardt, chief technologist of Global Nuclear Fuel, Ltd./General Electric Nuclear Energy, said that in the old days, thousands of fuel rods used to fail throughout the industry. Today, however, "we're talking about tens." With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good," he said.

Schardt declared that his company and probably every fuel manufacturer in existence has a "zero leak mentality." Every leaker "hurts everyone. It hurts our customers and it hurts the vendor. Each day that there is a leaker, we know about it that day," he said.

Schardt implied that people all the way up the management chain of command "hurt" when they learn about a leaker, because "most of us thought that by now we might have almost licked" the leaker problem. He added, "We don't know of a manufacturing defect that has caused a leaker in 10 years."

Roger Reynolds, director of Fuel Technologies and Reliability for Framatome ANP, Inc., followed up on Schardt's comments by declaring that "'Zero tolerance for failure' is the way we do our work."

Standards: A shift in philosophy

The ANS Standards Board has initiated work to revise many of its standards using risk-informed and performance-based concepts. This session, "A Movement Toward Risk-Informed, Performance-Based Standards: A Shift in Philosophy," explained chair Don Eggett, senior management and manager of business development for Automated Engineering Services Corp., was planned to look at the reasons for moving from conventional prescriptive standards to more performance-based and risk-informed standards, and how this is being implemented in ANS-sponsored standards. The movement to this new approach involves more than a shift in philosophy, he said. It reflects a more general shift in the attitude of industry to use these concepts to evaluate operation.

Standards, Eggett explained, can be performance-based or performance-based risk-informed, depending on what the needs are or what the focus will be. To distinguish these sometimes confusing concepts, the Board generated the following explanations:

On performance-based: Decide what the objective is to be then select a series of tasks, tests, etc., that will get you to the end point. Selection of the tasks is arbitrary based upon the particular situation and plant, and are not deterministic for every plant and situation.

On risk-informed (which can couple with performance-based): For each design basis accident or serious event, determine the risks to the public health and safety that the occurrence of the event will entail and then determine the mitigating events that are necessary to reduce public risk to a predetermined acceptable level.

Don Spellman, of Oak Ridge National Laboratory and chair of the ANS Nuclear

Facilities Standards Committee (one of four standards consensus committees), explained that the go-ahead was just made at the Board's last meeting and that this session is the first presentation of its observations and of some of the work being done. ANS often takes the initiative in this type of effort, Spellman said, where there is something industry needs to address. "And besides," he added, "we like the challenge." The Board will develop a set of criteria that explains how to create or revise a standard or convert it from prescriptive to performance-based.

Jim Mallay, director of regulatory affairs for Framatome ANP and chair of the ANS Standards Board, opened the session with a presentation on the benefits of moving from a prescriptive to a more performance-based standard. Most of the standards developed within ANS, said Mallay, are intended to either complement or positively influence current and planned regulatory expectations. In many cases, he noted, the NRC has asked ANS to develop standards on selected subjects, adding weight to any regulation that is based on those standards because the commission knows that industry has reached consensus that these are appropriate criteria and requirements.


Mallay

A particular feature of the standards groups, said Mallay, is that they provide the only forum for technical information to be exchanged freely among all parties, many of whom are in competition with each other or are regulated by the NRC, which is represented on nearly all of ANS's standards committees. And so, for Mallay, even if a working group is not successful in developing an approved standard, the fact that the people in the group have gotten together and communicated is a major benefit to them individually and to the industry.

Usually only a portion of a standard will be performance-based . . . as there will be many situations where prescriptive criteria are necessary.

Another interesting feature of standards that is rarely used in regulatory guidance documents, is the use of the verb "may," which denotes "permission." "May" allows the use of a technique at the user's discretion. This is an added value of standards, said Mallay, especially for those used to help interpret or complement regulatory documents.

Mallay explained the shift in approach as due in part to the needs of industry. During the last few years, there has been a significant decline in the demand for ANS standards. To some extent, this reflects the maturity of the industry (and the fact that no one is building plants). Nevertheless, the Board also had to consider whether it was really serving the interests of the users. In looking at that, said Mallay, the Board determined that maybe there were too many inefficiencies in the application of standards. Many were probably too prescriptive and inflexible, he noted, and therefore would not be used.

Unlike prescriptive requirements . . . the performance-based approach . . . ensures that the focus is on those things that are more important to safety.

So, the Board turned to techniques being advocated by the Nuclear Energy Institute (NEI) and the NRC—namely a performance-based, risk-informed approach. Mallay defined a performance-based requirement as a required design objective or operational behavior, including those attributes that are necessary to verify that the objective or behavior can be achieved. A performance-based standard, he said, is a standard that contains performance-based requirements together with measures that can be used to assess the degree to which the attributes can be achieved. These measures of success can be qualitative, quantitative, or some combination of the two.

Prescriptive requirements, Mallay added, have no flexibility and tell the user nothing about why the rule was established. Performance-based criteria tell you why—that is, makes the basis for a criterion explicit—and provides flexibility. But this does not work for all requirements. Usually only a portion of a standard will be performance-based, he said, as there will be many situations where prescriptive criteria are necessary. Standards based on performance-based criteria are also expected to have a longer life because the objectives, when stated properly, are not going to change as much as prescriptive requirements might. Furthermore, they allow revisions more readily.

Finally, said Mallay, performance-based requirements force people to work in "success space," not "failure space." One is never looking at a worst case, but at successful performance, where there are more opportunities.

Duke Energy, said Mallay, was recently allowed to establish performance-based criteria for the inspection and surveillance of the new steam generators being put into its Catawba plant. To deal with a number of outstanding safety issues raised by the NRC, the company proposed using a performance-based approach, which the NRC accepted. Mallay said he thinks that this is a milestone in this area.

According to Mallay, the first ANS performance-based standard (on the application of PRA for making risk-informed decisions on external events) came out about a year ago. He also noted that ANS has developed a draft standard for low-power and shutdown operating states, and plans to risk-inform its standards on design criteria for light-water reactors.

NRC pushing performance-based approach

Prasad Kadambi, of the NRC's Office of Nuclear Regulatory Research, has been active in pushing ANS toward performance-based standards. This approach, he said, accepts that nuclear activities are rather complex, with people, systems, and institutions all interacting for a common purpose. In this case, the common purpose is safety.


Kadambi

Regulations, he explained, deal with higher-level, more conceptual requirements, while standards address the lower level, the nuts and bolts of any activity. Traditionally, both have been prescriptive, Kadambi said, with requirements and instruction very specifically laid out. But recently, there has been a recognition of a need for change. In particular, said Kadambi, prescriptive requirements lack flexibility. They also have technological implications in that sometimes conditions are included in regulations that tend to freeze technology, particularly if there is

perception that there is only one way to comply with the regulation. This may inhibit technological creativity.

Things have been changing, he said. In 1993, Congress passed the Government Performance and Results Act. This legislation emphasizes outcomes rather than outputs; it makes agencies think whether they are doing the right kind of work, rather than just focusing on how well they are working. The legislation also requires agencies to develop strategic and performance plans so the public would know what ultimate results they are seeking to bring about. Another piece of legislation (Public Law 104-113) requires government agencies to think about consensus standards in lieu of regulatory requirements.

Kadambi noted that the NRC issued the first strategic plan (2000–2005) in 1999 and the second is now in preparation (2004–2009). It also issued a management directive explaining how staff can participate in standards activities. These direct the staff to consider performance-based approaches as appropriate. In addition, NRC staff issued NUREG-BR-0303, "Guidance for Performance-Based Regulation," in December 2002.

Kadambi asked the question: Why performance-based standards? Basically, he said that he believes that a new approach is needed, particularly if the nuclear industry does experience renewed growth. It is crucial, he declared, for working groups to have the flexibility to consider the best way to develop standards. They can consider using performance-based or prescriptive approaches as appropriate. This, he said, promises a more efficient development of standards once a learning curve is passed: It offers more effective application (particularly for new technology), more economical maintenance, and more equitable sharing of the burdens between standards developers and users. Performance-based standards should also last much longer. He commended ANS for this initiative.

Unlike prescriptive requirements, he added, the performance-based approach also ensures that the focus is on those things that are more important to safety, ensuring that resources are applied where they are most effective.

Over the last six or seven years Neil Brown, of Lawrence Livermore National Laboratory, has been involved at the working group level on a set of standards related to seismic design of nuclear facilities. It was only toward the end of the process, he said, that the performance-based concept was taken on board.

These new standards, not yet completed, will replace an original set developed by the Department of Energy for its nuclear facilities, Brown said. During a revision, the parties involved agreed to convert these to approved national standards. The DOE standards concerned natural phenomena hazards (NPH)—that is, seismic, wind, and floods. They start by categorizing certain structures, systems, and components (SSC), and then develop prescriptive rules about how a design should address these three natural phenomena. The original standards had risk goals set in terms of probabilities of safety consequences, doses, and failures.

The safety community, Brown said, even in the seismic area, is not eager to go to a fully risk-informed standard in the sense that the ability to estimate probabilities of failures of SSC and to relate those to a dose consequence, and so forth, is still limited. The DOE standards are risk-goal based—that is, they have clearly stated risk goals—and the SSC categorization is based on a specific set of risk goals. He said, however, that the participants could not agree on the desired risk goals for the new standard. Brown explained that agreement was eventually reached on using a magnitude of "unmitigated" consequence of a failure as opposed to failure probability to define the categories. And so, the categorization of an SSC was determined by the unmitigated consequence of its failure, not on the basis of risks.

The final presentation was by Paul Fishbeck, professor of Social and Decision Sciences, and Engineering and Public Policy, at Carnegie Mellon University, and director of the university's Center for the Study and Improvement of Regulation. He provided his experience from other fields where risk-informed and performance-related rules and standards are applied. Performance-based standards work well, he said, when you can actually measure performance. For example, consider how much pollution comes out of a smoke stack. In fact, he said, that can be measured, and criteria set. Penalties, such as withholding payments, can be applied if the criteria are not met.

Other areas being discussed, however, involve long-term, rare events, where performance is difficult to measure, Fishbeck said. If you are talking about fire safety, for example, how do you measure that a building is fire safe? What criteria do you use to base the performance of, for example, a sprinkler system? Is it the amount of water coming out in a certain time period?

A prescriptive standard, he noted, says: Use this, put it here, make it this big. These things can be checked very easily, he observed, but performance-based standards are much more complex.

He then raised the question of uncertainty. A prescriptive standard almost ignores uncertainty. Using a performance-based standard is to admit that there is uncertainty out there.

Fishbeck presented some examples to show how complex the area of standards can be. As other speakers had done before him, he recognized that the work leads to useful discussions among all interests and develops a lot of understanding along the way. There are methodologies that allow you to address these concerns, "but [they are] not for free."

Water desalination

Over the next two decades, there will be a 40 percent increase in water use around the world, according to the International Atomic Energy Agency (IAEA), and 33 percent of the world's population—about 2 billion people—will be in absolute water scarcity by the year 2025.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases. The fact is that there isn't enough fresh water on the planet. The session, "The Use of Nuclear Energy for Desalination," explained nuclear's role as an economical power source for methods of water desalination—two of which are distillation and reverse osmosis (RO)—that have high-energy consumption requirements and high hot-water production costs.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases.

The IAEA defines nuclear desalination as the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy for the desalination process. The facility may be used solely for the production of potable water, or dually for the generation of electricity and the production of potable water, in which case only a portion of the reactor's energy output would be used for water production. In either case, a nuclear desalination plant is defined as an integrated facility in which both the reactor and the desalination system are located on a common site and energy is produced on site for use in the desalination system.

Small and medium reactors are important for desalination because the countries most in need of fresh water often have limited industrial infrastructures and electricity grids, explained Akira Omoto, director of the IAEA's Nuclear Power Division. Smaller

reactors, he said, also are "more appropriate for remote areas" unsuitable for connections to the grid.

Omoto noted that nuclear power plants around the world have long been used for water desalination. For example, Kazakhstan's BN-350, a liquid metal–cooled fast-breeder reactor that operated until 1999, was used to produce electricity and heat for desalination (approximately 80 000 m^3 of water per day) for 27 years. And, currently, Pakistan's Kanupp has a small RO facility in operation and is building another desalination demonstration plant on site to be commissioned in 2005. Meanwhile, India's Kalpakkam has an experimental facility in operation and another under commissioning that is expected to process 6300 m^3/day.


Omoto

Expanding nuclear's role in the world's desalination process will include four challenges, he noted. First is economics, of course, where the target for desalinating water is \$0.40 to \$0.60/m^3. Next is public understanding. Then comes the issue of disparity, meaning that nations having water scarcity may not be holders of nuclear technology. Finally, in what is not directly a nuclear issue, infrastructure for distributing desalinated water is necessary.

Roger Humphries, president of Canadian desalinating company Candesal, said that a message not heard enough is that water shortages are quite often localized. In Indonesia, for example, rain falls almost every day during the rainy season. "But the issue is a point of mal-distribution," he said. "The water is not where the people are. It's not accessible because it cannot be collected and captured." He added that Indonesia's city of Jakarta and its surrounding rain forests have some of the lowest availabilities of safe, fresh water per person of any place in the world.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing. "As we draw fresh water out of sources that are nonrenewable, they get replaced by salt water," he said. "So, we're finding what used to be fresh water [in] a lot of aquifers [now has] a salinity level reaching 1000, 2000, 2300 ppm, basically making it unsafe to drink."

Desalination solves problems in that, politically, it keeps nations from "stealing" water from one another, and, environmentally, because it's a "friendly" way for creating new sources of potable water, as no fossil fuels are burned in the process, Humphries said.

Si-Hwan Kim, director of the SMART R&D Center of the Korea Atomic Energy Research Institute, explained South Korea's plan for a SMART desalination plant. SMART stands for System-integrated Modular Advanced ReacTor. The plant, which is under construction and is expected to be in operation in 2008, will produce both electricity (90 MWe) and potable water (40 000 tons/day).

Ron Faibish, project manager for nuclear desalination at Argonne National Laboratory, said that potable water issues exist here at home in the United States. "Drought conditions now in the Southwest have increased dramatically," he said. News reports have claimed that the drought in the West is the worst in 400 years. "We have big challenges in the U.S.," he added, "and they're not just focused in the West. We have issues in the East as well, and on the Texas coast."

Population growth along coastal Southern California, Texas, and Florida has been on the order of 20 percent in the past decade, and for the country as a whole, 60.6 billion additional m^3 of potable water per year will be needed by 2020 for municipal and light industrial uses.

The U.S. Bureau of Reclamation, together with Sandia National Laboratories, has developed a roadmap for desalination in the United States, he said. Published in 2003, the roadmap declares that by 2020, desalination and water purification technologies will contribute to ensuring a "safe, sustainable, affordable and adequate" water supply to the United States. "These words are important," he said. "The terms affordable and adequate—those are the ones I think have to be first in term of securing the future of the technology."

The roadmap's 2008 objective, he said, is for desalination technologies to realize a 20 percent improvement in capital costs, operating costs, and energy efficiency. By 2020, improvement in those areas needs to reach 80 percent.

Those goals are ambitious because today the cost of treating water in the United States using a conventional (chemical) treatment is about \$0.10/m^3. In Southern California, reclaimed water from industry costs about \$0.60/m^3. Brackish water desalination is between \$0.26 and \$0.79/m^3. For seawater desalination (the biggest operation, in Tampa Bay, Fla., currently is suffering problems, Faibish said), the forecast is \$0.55 cents/m^3.

Sump clogging is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors.

An "interesting factoid," he said, is that desalination in the United States could cost \$0.79/m^3 (\$3 per thousand gallons). "That seems expensive, but the U.S. consumer is paying an average of \$2099 per cubic meter for bottled water. When you put this into perspective, [desalination] seems rather cheap," he said.

The latest on sump clogging

At the panel session "Hot topics and emergent issues: Containment sump clogging," session chair and organizer Steve Stamm, of The Shaw Group, opened with an explanation of why sump clogging was billed as a "hot topic." Sump clogging, he said, is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors. This session, he said, would cover the problem's background, describe the methodology that is being used to resolve it, and present some of the plant activities and potential modifications being introduced.

Mike Marshall, lead project manager on the issue at the Nuclear Regulatory Commission, began with an overview of the topic and the status of work on PWR sump performance. According to Marshall, the NRC's primary concern is that the sump screen is doing its job too well. The purpose of the screen is to keep debris from damaging pumps or blocking spray nozzles and other components downstream. Retaining debris smaller than the system is designed to, he explained, results in excessive head

loss that can affect operation of the pumps. This is the same concern that the NRC had with boiling water reactors.

There are also some secondary concerns, such as the downstream effects of debris getting past the screen, that might have an impact on pump operations or accumulate enough to affect cooling of fuel. These are not the primary concerns, but the NRC wants them taken into account when solutions are considered or when evaluating the adequacy of existing designs. But most of the effort has been focused on head loss at the screen and whether it affects operations.

Because of the variation in the materials at individual plants, as well as the differences in the containment and layout of screens, the NRC agrees with industry that this is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action. One thing that is becoming clear is that the existing license base for a number of plants is probably insufficient and will need changing.

Marshall explained that unlike BWRs, it appears unlikely that every PWR is going to have to implement a fix. But each operator will have to evaluate the situation and decide if there is a problem that needs resolving, either procedurally or by a hardware modification or some other means. The evaluations will include: identifying the different debris sources, particularly those that would likely cause some clogging; estimating the amount of debris generated; estimating the amount of debris transported to the sump screen; and estimating what the head loss impact would be.

This issue first came up in the early 1980s, when the Advisory Committee on Reactor Safeguards became interested to see if air injection would have an impact on the operation of the emergency core cooling system (ECCS) pumps. The question of debris came up later. Research undertaken between 1980 and 1985 did not identify a particular problem. While the NRC could see some benefits in preventing entrainment, they were insufficient for action to be taken. In 1985, however, it recommended that new plants and plants undergoing material changes—such as of insulation—consider the issue and provided some regulatory guidance.

In 1992, an event occurred at the Barsebäck BWR in Sweden, where the NRC's 1985 guidance had been adopted. Based on this, the plant had assumed that the ECCS system would operate for a day or two before the strainers (screens) became clogged. The incident occurred when water was released into the drywell, taking a lot of insulation with it. The clogging occurred not within a day, but within an hour or two of the activation of the emergency systems. This was communicated to other regulators, and investigations ensued that identified weaknesses with the guidance and the underpinning research. This started a new run of research around the world on sump issues.

The focus at first was on BWRs because there were three similar events in U.S. plants, although not on the scale of Barsebäck. It eventually became clear that although clogging would occur sooner in BWRs than in PWRs, the weaknesses were common to both reactor types. New work undertaken identified weaknesses in the previous correlations. In particular, the fiberglass insulation debris was more like "cotton candy" shreds than the "slices of cake" that were used in the old research. The shreds produce much greater head loss. Furthermore, the fiberglass acted as a filter, capturing small items that had been expected to pass through the screen, adding to the head loss.

All the BWR stations introduced a combination of fixes. These included minimizing debris sources, cleaning the suppression pools, and increasing the surface area of the sump strainers.

Soon after completing the work on the BWRs, work on the PWRs started. From a parametric study, the NRC staff concluded that there was enough of a concern to warrant individual plant evaluations. NRC has been working with the Nuclear Energy Institute (NEI) since about 2000 on developing a suitable methodology.

[T]his is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action.

The next speaker was John Butler, senior project manager at NEI, which has completed guidance for carrying out a sump performance evaluation that is now being reviewed by the NRC. The guidance will help operators evaluate the situation at their plants regarding debris generation, transport, and accumulation on the screens and whether there is adequate net positive suction head (NPSH) margin available for ECCS recirculation. This effort, said Butler, is primarily funded by the Westinghouse Owners Group and coordinated by the NEI PWR Sump Performance Task Force.

A draft sump performance evaluation guidance document was given to NRC staff in October 2003, and the final version was submitted on May 28, just a couple of weeks before the ANS Annual Meeting. The review process should be completed by this fall, with final approval expected in October.

The end result of the evaluation guidance is to determine the adequacy of the NPSH margin, Butler said. The calculation is complicated by the large number of phenomena and uncertainties that need to be addressed. These include:

- Size and location of a postulated break. Location is probably more important than size regarding the potential debris generated.
- Debris generation (quantity, types, size, distribution). The orientation of the break affects what debris is going to be generated. Besides calculating the amount, it is necessary to determine the size distribution of the debris, which affects its transportability.
- Debris transport and holdup. The "transport media" is a combination of debris, the containment spray, and washdown, all of which determine the amount that collects at the sump.
- Debris deposition on screen and resulting head loss. The resulting head loss is highly dependent on the types of debris deposited.

The guidance addresses the uncertainties and complexities in a traditional conservative fashion. "It is a balancing act," Butler said. "I think I can say we have a conservative methodology that is not *too* conservative."

He then described the basic evaluation methodology, which starts with a baseline analysis, a conservative first step in the evaluation. Some plants can go through the baseline and find that they have adequate NPSH margin and can stop at that point. A number of others will find that they do not have adequate NPSH margin, and will have to continue the evaluation process by refining the analysis in one or two ways: refine their analytical methods to take out some of the conservatism, or modify their design, which may involve removing potential debris sources, changeout of insulation (which contributes most debris), or modifying their screen design. The process continues until an adequate NPSH is achieved.

NEI is now working with the NRC to try to introduce a risk-informed option in the methodology, acknowledging that the large double-ended break, which would generate the most debris, sump blockage, and head loss, is a very low-frequency event. A risk-informed option would allow more meaningful breaks and conditions to be applied to assess sump performance. The details of such an option are now being discussed with NRC staff.

Continued

Sump performance evaluation methodology

More details on using the evaluation methodology were given by Tim Andreychek, of Westinghouse Electric Company. Andreycheck has been working on the issue for the last seven years, and is the lead author of the NEI PWR post-accident sump performance document. The purpose of the methodology, he explained, is to provide a consistent approach for utilities to perform a conservative evaluation of their containment sump performance post-accident. Analytical refinements are also identified to provide options for removing some of the conservatisms.

The "baseline," said Andreychek, starts with plant specific information—basically a scoping study or a first shot to see if there is something to worry about. If the results are acceptable, the issue can be closed out. If not, the methodology provides a guide as to how to proceed. This involves further analysis and reanalysis, with possible design modifications. The process continues until NPSH requirements are satisfied.

Andreychek provided an example of a "baseline analysis" that took a very conservative line. Regarding break size, the baseline assumes a double-ended guillotine break. For the break location, he determined the maximum debris generation and the worst combination of debris to create the biggest head loss. To determine debris generation, a zone of influence (ZOI)—a region around the break where the destruction of insulation and other materials occurs—was defined. His baseline calculation assumed an unrestrained jet stream from the break, which destroys the insulation, forming debris.

[S]ome plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

Latent or resident debris (the dust and dirt that collects) is not considered a major contributor, Andreychek said, but has to be accounted for. The baseline methodology provides an easy-to-use estimate of the contribution. He mentioned, however, that some plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

The head loss correlation being used, based on a NUREG document, is a semi-empirical correlation and provides for a conservative pressure-drop calculation. The effects of debris composition and material properties are accounted for in the calculation. Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it. This, he noted, was a particularly bad situation for BWRs, causing big pressure drops.

Andreychek also went into various analytical refinements to the baseline evaluation. By replacing the conservatism with more realistic conditions, the amount of debris generated can be reduced, its transportability lessened, and the accumulation and blockage of the sump screens can be decreased, leading to a better NPSH margin.

Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it.

Kenneth Ainger, licensing manager at Exelon Nuclear, is responsible for licensing activities at the Byron, Braidwood, and Three Mile Island-1 nuclear stations. He provided an operator's perspective on this issue, describing the evaluations that he will be performing, some interim measures, and potential enhancements being considered to fully resolve the issue, if necessary.

Ainger's description of the different sump/screen configurations at three plants provided insight into the real problems that operators have with this issue. For example, both Byron and Braidwood have two sumps that are enveloped by an outer screen. Overall, there are three screens that protect the suction lines to the ECCS and containment spray system. The outer screen encloses the middle and inner screens for both sumps. The outer screen extends about 4 feet above the floor of the containment, and the inner screen is installed below the containment floor inside each sump.

As for potential debris sources, the main containment insulation at Byron and Braidwood is reflective metal insulation. When the steam generators at Byron-1 and Braidwood-1 were replaced, their insulation and that of the associated piping were replaced with fiberglass blankets, covered with stainless steel sheathing. The TMI-1 containment has about 600 ft^3 of fibrous insulation. Ainger also pointed out the problem of unqualified equipment coatings—for example, the coatings on valve handles and reactor coolant pump housings—as possible debris. The baseline evaluations will look at the reflective metal insulation, fibrous insulation, coatings, tags, labels, and foreign material. All of these potential debris sources will be examined in light of the four transport mechanisms: blowdown transport; washdown transport; pool fill transport; and recirculation transport.

For the sump screens, the initial evaluation for Byron and Braidwood indicates no concerns regarding structural integrity or excessive blockage. Byron-1 and Braidwood-1, however, may not pass the evaluation in light of the fiberglass insulation used on the replacement steam generators. This might require an additional engineering analysis. With the performance of ZOI evaluations at the plants, Ainger noted, a risk-informed approach would probably provide benefits if it is used to assess the consequences of the occurrence of a break at the steam generator nozzles of the two reactors described above.

For TMI-1, the adequacy of the sump design may not pass the new evaluation, and so some design change to the sump or to the areas along the path to the sump may have to be considered. Enhancements could include modifications to the floor to help direct debris or prevent some pooling of water. These have not yet been scoped, but could be significant.

Ainger said that several interim measures have been implemented to ensure the working of the ECCS while pursuing the long-term resolution of the issue. The loss of recirculation capability has been addressed at Byron and Braidwood in the emergency procedures. Additional training for operators has been provided, including simulator training. The company has strengthened the foreign material exclusion and walkdown procedures for the containment, and has enhanced the refueling outage surveillance procedure for visual examination of the sump screens. For TMI-1, the B&W Owners Group guidelines for sump blockage were implemented and training in ECCS pump throttling criteria was provided to avoid damage in the early stages of potential sump blockage. New procedures for cleaning and inspecting drains inside the containment have been implemented. The existing refueling outage inspection procedures for the sump screen were determined to be adequate.

Ainger said that they are also looking at removing the fibrous insulation associated with the replacement steam generators.

Regarding costs, Ainger estimated that at Byron and Braidwood, Exelon will spend about $3 million over four years to pay for all the evaluations, including additional engineering analyses, licensing submittals and responses to the NRC Generic Letter (*NN*, May 2004, p. 15), and some insulation modifications. For TMI-1, the estimate is high, at about $4.5 million over four years, as some extensive modifications inside the containment seem likely.

Safety culture

During the Tuesday afternoon "Safety Culture" session, Joe Carson, a licensed professional engineer and a nuclear safety engineer for the Department of Energy, observed that ANS's bylaws, which he said have remained constant since the beginning of the Society 50 years ago, should be revised. The bylaws, he noted, "[don't] reflect that ANS holds a public trust when developing standards of care for its members."


Carson

Carson, a former member of the ANS Special Committee on Ethics, stressed that he wanted to see ANS as "an organization that is flexible, responsive to members, and capable of dealing with change."

Change is necessary, he said, because ANS has evolved since its creation a half-century ago. "Fifty years ago," he said, "I don't think ANS held a public trust, but I think it does now today."

Examples of that public trust include ANS's role in accrediting engineering schools for nuclear engineering, and its work in developing codes and standards that are adopted internationally. ANS, then, has "an important role with nuclear science and technology in public policy," he said.

Carson, who described himself as an "eight-time prevailing" DOE whistleblower (as detailed on his Web site, <www.carsonversusdoe.com>), noted that the words "ethics" and "peaceful" and the phrase "promote the professional interests of its members" are absent from ANS's bylaws. And although the word "safety" is included in ANS's goals, the bylaws do not include "any form of the word 'safe,'" he said.

Carson suggested that ANS modify its bylaws, mission statement, and goals to more clearly capture its identity as a professional society. He also called for all nuclear engineers to be licensed by states, something that is a "distinguishing characteristic" of members of such professions as medicine, accounting, and architecture. "Engineers, by and large, are not licensed," he said. "Well, why not?"

ANS's new code

Vic Uotinen, chairman of the ANS Special Committee on Ethics for 2003–2004, remarked that ANS does have a new Code of Ethics, replacing an earlier code dating back to 1973, which was altered somewhat in 1984. The new code, which was adopted by the ANS Board of Directors in 2003, is more specific and comprehensive than the earlier version, and it "reflects the expectation of a more conscious commitment to professional ethics by ANS members," he said.

The new code [of ethics] . . . "reflects the expectation of a more conscious commitment to professional ethics by ANS members."

The new code also is at the same level as the ethics codes of several other engineering societies, such as the American Society of Mechanical Engineers, American Institute of Chemical Engineers, Society of Civil Engineers, and IEEE. "I think it's important for us to realize that all of these engineering societies, by upgrading their codes of ethics, were in essence sending a signal to their constituencies that we, as professional societies, consider professional ethics to be important, and that we consider upholding this higher code of ethics, this higher standard, to be a true mark of professionalism," he said.


Uotinen

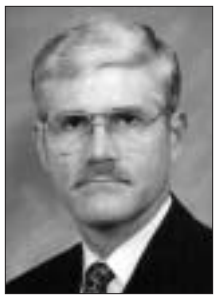
Uotinen gave examples of how the new code is an upgrade over the older version. The old code, for instance, said, "An ANS member shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties," while the new code says much more: "We hold paramount the safety, health, and welfare of the public and fellow workers to protect the environment and to strive to comply with the principles of sustainable development in the performance of our professional duties." It also adds a new paragraph: "We will formally advise our employers, clients, or any appropriate authority and, if warranted, consider further disclosure, if and when we perceive that pursuit of our professional duties might have adverse consequences for the present or future public and fellow worker health and safety or his environment."

Another example is in the area of acting in accordance with applicable laws and practices. Whereas the old code didn't mention this area at all, the new code says, "We act in accordance with all applicable laws and these practices, lend support to others who strive to do likewise, and report violations to appropriate authorities."

Ethics and competency

Ethics and competency are interrelated, remarked Dwight Baker, who was making a presentation for the absent William Corcoran, of Nuclear Safety Review Concepts. Baker said that if anybody at Davis-Besse had operated according to the ANS Code of Ethics, the vessel head degradation could have been prevented from becoming so severe. "You can certainly say that if you saw [the signs of degradation, such as piles of rust that collected on a flange] and ignored it, if you were the manager who would have signed off saying 'We don't need to work on that,' if you were the outage manager who shut down [a vessel head cleanup job prior to the degradation's discovery], maybe then there should be an ethics complaint filed," said Baker, of Cumberland Consulting. "But I'd put a dollar to a donut that those people are not ANS members."

Baker said that in many cases where workers "behave badly at the technical level, those technical people are neither professional engineers nor ANS members, with no requirement that they be." Further, he said, in "about 99 percent" of the cases where a nuclear professional should be punished for ethical misbehavior, the management personnel who would make those decisions are not ANS members.


Baker

As long as there is no requirement that an engineer be licensed, society will think "we're just computer programmers, and we really don't affect their health and safety," he said. Without that public pressure, there will be no incentive for companies to hire licensed engineers, or have existing staff attain licensing. Without licensing, there will be no living up to a code of ethics. "It's really a public education job, to impose a licensure requirement just like for doctors and lawyers," he said.

Continued

Baker said short of requiring licensing, which is "really a big piece of work, and I don't know if it's doable," one way that a plant can attain higher overall quality is to provide long-term financial incentives to company executives. "Think about it," he said. "Having the plant run well in the long term is in the stockholders' interest. So, there may actually be a strategy that is doable, from the business organization side of it."

A case in point is that some ANS members are utility executives with access to compensation committees. These executives, he said, may "have some good ideas on how to structure stock options that are only exercisable seven years from now." *—E. Michael Blake, Dick Kovan, Rick Michal, and Nancy Zacha*

TOPICAL MEETING

Advances in Nuclear Power Plants (ICAPP 2004)

- *South Korea aims for large H output by 2020*
- *European utilities judge next-stage reactors*
- *MIT study on nuclear role in carbon-constrained world*

As the world's nuclear energy nations have come into greater agreement on nuclear power's medium- to long-term future—the development of "Generation IV" reactor designs, the coupling of these designs to hydrogen production, and the opportunity for actinide burning to extend fuel resources, deter proliferation, and reduce radwaste generation—many of the speakers at the 2004 International Congress on Advances in Nuclear Power Plants (ICAPP 2004) agreed in their presentations to such an extent that some of them apologized for repeating what others had already said. ICAPP 2004—which this year was embedded as a topical meeting in the ANS Annual Meeting in Pittsburgh (June 13–17)—included five plenary sessions, and despite the organizers' attempt to give each session its own unique theme, some overlap was unavoidable.

Whether there will be enough trained professionals in place if there is a sudden demand for new nuclear power was much on the minds of several speakers. Andy White, of General Electric Nuclear Energy, told a plenary session audience that 40 percent of GE's employees in nuclear fields are within five years of retirement age. He called for an industry-wide focus on development of a larger talent pool of nuclear expertise. The next speaker, Russ Bell of the Nuclear Energy Institute, also included the aging nuclear workforce as one of the main challenges facing the industry now (and not just in the future). The other challenges, in Bell's view: keeping fuel economical and reliably supplied; managing materials at aging facilities; securing nuclear facilities (Bell said they were safe before 9/11, and are safer now, but this is a very high-profile public issue); and providing spent fuel disposal. Bell acknowledged the problem that had arisen with high-level waste funding, in which the Bush administration had expected to use money from the Nuclear Waste Fund but Congress had not authorized it (see page 113, this issue), but said that the Department of Energy, "with industry support, is pursuing legislation" to assure adequate funding for the proposed high-level waste repository at Yucca Mountain, Nev., in the FY 2005 federal budget.

Later in that session, Peter Lyons, of the Senate Committee for Energy and Natural Resources staff, spoke more pointedly about the Yucca Mountain funding situation. He said that the way the administration presented the bill, with only $131 million to be appropriated in the FY 2005 budget and $749 million presumed to be available from the Nuclear Waste Fund, created "an immense problem," and led to only the $131 million being approved for Yucca Mountain, nowhere near enough for the DOE to remain on schedule to open the repository in 2010. Lyons also said that the entire FY 2005 budget request was "an immense surprise" to the committee, leading to concern that nuclear research and development could be undermined, and that the reformulation of the Idaho National Laboratory might not be given a "focus for success."

At the second plenary, Steve Melancon, of Entergy Corporation, echoed the concern about Yucca Mountain, and the extent to which the future of new power reactors in the United States depends on resolution of the high-level waste issue. "Yucca Mountain needs to become a reality," he said, "or I don't think any new nuclear plants will be built." Also during his address, Melancon recounted the formation of NuStart Corporation (an industry consortium seeking Department of Energy matching funds to apply for site approval, design certification, and licensing of new power reactors), but departed somewhat in his personal views from the procedure announced thus far for NuStart, in which approval would be sought from the Nuclear Regulatory Commission for two sites, as well as certification for two reactor designs, but ultimately the construction/operating license (COL) would be sought for a single reactor design at one site. Melancon said NuStart should choose *at least* one plant for the COL; he would like to see enough money made available to pursue both designs, and both sites.

With the meeting taking place in the United States, and with so many recent developments in the U.S. nuclear realm, the above topics and more like them drew a great deal of attention during the meeting, but ICAPP is indeed an international event, and speakers from most of the world's large nuclear power programs reported on numerous technical and programmatic developments. Their reports, like those from the U.S., ranged from improvements on existing reactors to the many first steps being taken toward the goal of Generation IV.

South Korea's vision

Next year's ICAPP will be held in Seoul, South Korea, and there was a substantial Korean presence at this ICAPP, both to pre-

sent papers and to promote the event in 2005. A table outside the topical's largest meeting room was stacked with brochures on travel to Korea. The viewgraphs of three of the five Korean speakers at the plenary sessions had bands at the bottom reading: "See you in 2005, ICAPP Seoul!"

During the first plenary, Joong-Jae Lee, of Korea Hydro and Nuclear Power, traced the development of nuclear power in South Korea, which is now sixth in the world in both installed nuclear capacity and annual nuclear power generation. He said that in some countries where nuclear power has been accepted for some time, "challenges and new issues are growing" (which could describe the emergence of public opposition to nuclear in both South Korea and Taiwan), and there is a need for breakthroughs in technology and cooperation within the nuclear community. With 14 of South Korea's 18 power reactors achieving 2003 capacity factors above 90 percent, and the other four over 80 percent, Lee asserted that outstanding performance is the best way to respond to nuclear controversy. As for technology breakthroughs, Lee described the APR 1400 pressurized water reactor being developed in Korea to supplement and eventually replace the current generation of reactors; work has begun on the first APR 1400, Shin-Kori-3, scheduled to begin operation in 2011.

South Korea . . . has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances.

At the second plenary, Dong-Su Kim, of Korea Power Engineering Company, described the evolution of the APR 1400, the latest step in the development of the nuclear industry in South Korea—which has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances. He said that the current social environment (alluded to by Lee) "requires unlimited safety" and "faultless and eventless operations." He added that in South Korea, as in the United States, there is concern about the future supply of trained personnel, as students are tending not to pursue engineering. The belief that public acceptance can exist only with perfect operation drew a comment from the audience by Ted Rockwell, former technical director of the U.S. Naval Reactors Program. He said that one cannot convince the public that there will never be an accident, because one cannot reasonably make such a claim. He advised that one should take the position that the effects of any accident would be mitigated, and rebut the argument that exposure to any amount of radiation is dangerous.

Chung-Won Cho, of South Korea's Ministry of Science and Technology, extended his country's nuclear program into the future during the third plenary, citing its proposal for the System-integrated Modular Advanced Reactor (SMART), for both electricity production and seawater desalination, and participation thus far in Generation IV projects. SMART is intended as a PWR with the steam generator included in the reactor vessel, offering enhanced safety, economics, and environmental advantages. For Generation IV and beyond, Cho's projections were extremely ambitious, anticipating a "waste-free and pollution-free" nuclear fuel cycle with consumption of all actinides, and a timetable whereby South Korea would switch from fossil fuel to hydrogen so quickly that nuclear energy would produce 20 percent of the needed hydrogen by 2020. Questioned about this goal by an audience member, Cho said that a 16-year program is now starting, aiming at development of small-scale modular gas-cooled reactors, but that wider application was still under discussion, and the 20 percent goal should not be taken as a firm commitment.

Jong-Hwa Chang, of the Korea Atomic Energy Research Institute (KAERI), elaborated further on the 20 percent hydrogen goal in his address at the fifth plenary. One-fifth of the expected vehicle fuel demand in South Korea in 2020 would require 8.5 billion barrels of oil per year, which could be replaced by 3.3 million tons of hydrogen. KAERI's anticipated demo nuclear plant (a very high temperature gas-cooled reactor, or VHTR) would produce about 30 000 tons of hydrogen per year, so at least 100 plants of this capability would be needed to meet the hydrogen goal. At the same time, Chang said that security concerns in South Korea—which still has a hostile neighbor to the north—argue against distributed nuclear-hydrogen facilities, because of the potential for sabotage. Therefore, the reactors—more than 100—would be concentrated at a small number of sites that could be guarded well.

New scheme in Europe

The lull in power reactor ordering in Europe has not been as long as that in the United States, and with a new order placed in Finland and another on the way in France, it can be said that the lull is in fact over. Still, plenty has changed in the decade or so that elapsed, with moves toward the opening of electricity markets and attempts to normalize regulation. The old paradigm of a state-owned electric utility ordering the only design available from a state-owned manufacturer is eroding, and one indication of this is the development of European Utility Requirements (EUR) documents, which essentially tell manufacturers what the utilities want, need, and expect from power plant hardware and services.

Gianfranco Saiu, of the Italian firm Ansaldo, described the EUR process while presenting a technical paper on the EUR assessment of the Westinghouse AP1000 reactor design. The EUR effort began in 1991, with five utilities; six others joined later. Along with expressing what the utilities wanted, the documents provide bases for harmonization of safety approaches and targets, design standardization and objectives, equipment specifications and standards, and information for safety, reliability, and cost assessment. In 1997, the effort enlarged so that each document included a Volume 3, which compared a specific reactor design against the requirements. (Volume 1 includes nuclear island requirements, and Volume 2 covers balance-of-plant.)

Development of a Volume 3 for the AP1000 was based on previous work on advanced Westinghouse designs. Saui noted, however, that while the utilities' team was at work on this volume (the process can take years), Westinghouse moved on from the design. Saiu said that although the AP1000 was driven by U.S. market considerations, it had incorporated lessons from EUR work on earlier designs, including a low-boron core. As things stand now, the AP1000 is slightly out of compliance with EUR, both in technical areas (the cooldown time is longer than what the EUR prefers) and in semantics (whether it is preferable to state that radiation exposures *shall be* as low as reasonably achievable, or *are* as low as reasonably achievable). There will be more meetings intended to resolve the differences.

Pierre Berbey, of Electricité de France, spoke at greater length on the EUR's place in the evolving power generation environment in Europe. Even with efforts like EUR intended to normalize agreement on basic principles of safety and operation, the differing regulatory schemes of individual countries can work against standardization and increase costs. Berbey said that there should be common "rules of the game." He noted that the Western European Nuclear Regulator's Association is working to define reference safety approaches that could become common to all nuclear power nations in Europe. Berbey also noted a number of non-nuclear challenges now faced by electricity organizations in Europe, such as the synchroniza-

tion of the western European transmission grid with bordering nations like Poland and Romania. In the end, Berbey said that the EUR effort will try to deliver documents supporting four to six standard reactor designs; along with AP1000, EUR is also doing Volume 3 work on the AES92, an advanced version of the Russian VVER water-cooled reactor.

A carbon-constrained world?

During the fifth and final plenary, Ernest Moniz, of Massachusetts Institute of Technology (MIT)—who described himself as neither pro- nor anti-nuclear—presented results from a 2003 MIT study on what might happen if there is a significant worldwide adoption of new nuclear power. (The study, headed by Moniz and John Deutch, is posted online at <web.mit.edu/nuclearpower/>.) The study looked at the presence of a terawatt of nuclear capacity in place by 2050 (for comparison, the current worldwide nuclear capacity is less than half a terawatt). Moniz said this does not seem possible without the emergence of a "game changer" that would make nuclear the preferred choice for decision makers and the public. He said that global warming appears to be the strongest candidate to be the game changer. He said that if the only way to prevent a self-reinforcing rise in the greenhouse effect is to make this a "carbon-constrained world" by reducing carbon dioxide emissions, nuclear power and all other nonemissive options would be needed, and may not be enough.


Moniz

Moniz said that a new, nonamortized nuclear plant with no federally backed financing cannot currently compete with coal- and gas-fired generation (with CO_2 not taken into account). Not only must plant capital cost be reduced, but a series of plants would have to be built on budget and schedule to show that financial risk is not excessive. The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

If the world is carbon-constrained, Moniz said, the obligation to reduce emissions would fall hard on the power industry. Manufacturers that emit CO_2 can be moved offshore—in an observation specific to Pittsburgh, he noted that Alcoa is moving all aluminum production to Trinidad—but power plants must remain connected to the home nation's grid. Moniz added later that there will likely emerge a formal "cap-and-trade" system of incentives for carbon emission, started by the power industry in return for a rational, stable system of federal oversight.

Moniz said that even if the openly established "fuel cycle states" have 80 percent of the expected nuclear generating capacity, that would leave 200 gigawatts in other nations, raising nonproliferation concerns. Incentives to prevent rogue states from developing independent nuclear capability would have to include not only assured fuel supplies, but also spent fuel removal, which means resolution of high-level waste problems worldwide. Moniz said that it would be necessary for spent fuel to be stored for 50 to 75 years, despite what he termed the industry's "religion" of fuel cycle closure. He noted that the expected carbon emission mitigation cost for fossil generation would be at least $50 per ton of carbon, or $8 per megawatt-hour, which is far more than all expected fuel and waste costs for nuclear—so carbon constraint can become an incentive for nuclear, in full compliance with the Non-Proliferation Treaty.

Although the MIT study looked at a large addition of nuclear power extending to mid-century, Moniz was dubious of a major prospect used recently to argue in favor of advanced nuclear power: hydrogen production. He said that significant use of hydrogen as a fossil-fuel substitute "may be decades away at a minimum . . . we're all getting carried away" on hydrogen's likelihood of displacing oil use. He advised the audience not to lose sight of the scale of what would have to be done (as had been shown in the Korean presentations reported above). He called hydrogen "intrinsically inferior" to petroleum, and said that nuclear power should continue to be presented as an electricity option, with no attempt to oversell hydrogen.

The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

Other presentations

There were occasional moments at ICAPP 2004 when it seemed that two U.S. reactor designs—Westinghouse's AP1000, and General Electric's ESBWR—were being compared to one another. These are the designs chosen by NuStart for certification, and (despite Steve Melancon's position) apparent competition. Thus, fairly or otherwise, the designs are now seen as linked, and in a race that would end with one being the preferred choice and the other at least having to wait. Atam Rao, of GE, in his presentation to the second plenary on ESBWR, described this reactor as having a capability of 1550 MWe (the AP1000 is currently rated at 1117 MWe), and said that it will use components similar to those already being made for the ABWRs coming into service. He admitted, however, that the ESBWR is not as far along as the AP1000, which he said is "two years ahead of us" in the design completion and NRC certification processes.


Rao

In a session on the Very High Temperature Reactor (VHTR), which is the principal Generation IV design being pursued in the United States, Phil McDonald, of the Idaho National Engineering and Environment Laboratory, reported on a point design study that compared pebble bed core design to the "block" design, with fuel and moderator in parallel vertical blocks. He said that he would not choose one over the other, but concluded that fuel cycle costs would appear to be lower for pebble bed than for blocks. In the next paper, Yasushi Muto, of Tokyo Institute of Technology—working from different design assumptions—found that a cooling system that allowed for horizontal as well as vertical flow could help reduce some of the drawbacks associated with pebble bed cores. This flow pattern offers a 2 percent improvement in thermal efficiency and 5 percent less core pressure drop, allowing the maximum fuel temperature to be as low as 1110 °C.

Perhaps the most inopportune turn of phrase at the meeting came from Norbert Frischauf, of the European Space Agency's (ESA) European Space Technology Center, who chaired the session on nuclear power and propulsion systems, and opened it with remarks on European perspectives on the topic. After concluding that Europe should work on materials and other support issues, and decide later whether ESA should enter reactor development, he said that it was necessary to "go back to the classroom" to educate the public on nuclear materials used in spacecraft—to actively provide information, "and not let it fall down from the sky." Whether a nuclear spacecraft would fall down from the sky is, of course, exactly what the public would worry about.—*E. Michael Blake* NN

ANS ANNUAL MEETING

On the 50th anniversary, golden opportunities foreseen

- *Nuclear renaissance possible, if issues are resolved*
- *TMI-2 changed how the industry does business*
- *ANS should lead in presenting demonstrated science*
- *Zero fuel defects should be the industry's goal*
- *Shift is away from prescriptive standards*
- *Nuclear desalination faces several challenges*
- *Not just one solution to sump clogging at PWRs*
- *Improvements suggested to upgrade safety culture*

THE AMERICAN NUCLEAR Society gathered June 13–17 in Pittsburgh, Pa., for its 50th anniversary at a moment when memories of the origins of ANS—the aftermath of President Eisenhower's "Atoms for Peace" initiative, and the numerous possibilities foreseen for bringing nuclear science and technology to applications for the benefit of all humanity—could be accompanied by optimism for the short- and long-term future of the field. The theme of the meeting was *A Golden Anniversary—A Golden Opportunity*, and although during the second half of the Society's existence no power reactor orders have been placed in the United States, the 1073 attendees who gathered in Pittsburgh in mid-June could look to a new reactor order in Finland, a likely order to follow in France, the U.S. nuclear industry consortia preparing to test the new system for licensing, and signs of more favorable public attitudes toward new nuclear plants as indications that a nuclear power renaissance might occur in the United States early in the Society's second half-century.

The memories of the first half-century, and the accomplishments of ANS and the nuclear community, were evoked during the 50th Anniversary Banquet on Sunday night, the first official event of the meeting. Susan Eisenhower, granddaughter of former President Dwight D. Eisenhower and president of the Eisenhower Institute, gave a presentation in which she noted the appropriateness of Pittsburgh—the birthplace of commercial nuclear power generation—as the location of ANS's anniversary meeting, and thanked the Society for helping to transform her grandfather's "Atoms for Peace" vision into reality.

Following her talk, she introduced John Simpson, ANS past President (1973–74) and honorary chair of the meeting, and presented him with an ANS Presidential Citation for his lifetime of achievements. Simpson's talk provided insight into the sense of adventure that existed at the dawn of the nuclear age, and into what it was like to be one of the nuclear pioneers. He related firsthand stories about important figures of the early times, and conveyed the excitement of those who took nuclear through the transition from wartime use to commercial power generation. He was one of 19 ANS past Presidents in attendance at the dinner, where they and the Society's other previous leaders were honored for their contributions.

Seizing opportunities

Speakers at the opening plenary session on Monday morning touched on the meeting's theme, but tempered slightly their assessment of the opportunities for nuclear development in the coming years.

While all agreed that ANS, and nuclear professionals in general, can do much to seize the opportunities and broaden the benefits to the nation and world from nuclear energy, they made it clear that real progress depends also on developments outside the nuclear community, in the political and public arenas. The consensus was that a nuclear renaissance is possible, and may be becoming more likely, but can occur only if issues such as high-level waste disposal

are resolved fully.

The early part of the session focused on ANS matters. Joe Colvin, of the Nuclear Energy Institute, presented the Henry DeWolf Smyth Nuclear Statesman Award—a joint award of ANS and NEI—to former ANS President and Nuclear Regulatory Commission Chairman Joseph P. Hendrie. Stephen R. Tritch, of Westinghouse, a general co-chair of the meeting, read a letter from President George W. Bush congratulating ANS on its 50th anniversary. Then the other meeting co-chair, Gary Leidich, of FirstEnergy Nuclear Operating Company, presented a video that pointed out some of the nuclear community's many roots in the Pittsburgh area: the original power reactor at Shippingport (both as a light-water reactor starting in the 1950s, and as a light-water breeder reactor starting in the 1970s), and the nearby two-unit Beaver Valley plant in operation today.

Leidich

Leidich then presented the plenary speakers. Sen. Larry Craig (R., Ida.) was unable to attend in person, because the various memorial services for the late President Ronald Reagan in Washington, D.C., during the previous week had forced legislative business to be rescheduled; he sent a videotape in which he explained that work on defense high-level waste appropriations forced him to remain in the capital. (Technical glitches in the video, and Craig's largely off-the-cuff remarks, supported the impression that Craig had indeed changed his plans suddenly and made the video only as a last resort.) Craig said that there was still a "slim but outside chance" that comprehensive energy legislation could be passed by Congress before this year's election. He noted the public's reaction to this year's rise in gasoline prices, and said, "This reality check . . . may well jar Congress into action." He added that any serious push by the federal government for new energy sources would include a large nuclear component.

Current NRC Chairman Nils J. Diaz joined in the celebratory mood of the session, praising nuclear pioneers (including past ANS Presidents) for the legacy they have left, including power reactors and other nuclear facilities now in operation. But he said that the technology's safety record "is not to be taken for granted," and the prolonged outage at Davis-Besse (and the discovery there of an eroded cavity in the upper vessel head) should serve as a wake-up call. He noted that the Three Mile Island-2 accident in 1979 forced a realignment of the nuclear industry, and an awareness that a problem at one plant can reflect on all others. Diaz endorsed the prescriptive approach to regulation in use at the time, but said that several hundred reactor-years of additional operating experience, and the development of risk analysis techniques, have made it possible for regulation to become more risk-informed and performance-based. Also, raising an issue that would be revisited by many other speakers at the meeting, Diaz noted that the new generation of professionals entering the nuclear fields is not large enough to replace the retiring pioneers, and said that ANS is "never more needed than today" to assure an abundant supply of qualified personnel.

Diaz

Pittsburgh was also important in the development of the nuclear Navy, through the Bettis Laboratory. Thomas H. Beckett, deputy director of the Naval Reactors Program, summarized the program to date, noting that it has logged more than 130 million miles of submarine travel without a single accident, health impact, or instance of environmental damage. He credited this record to the core values established by the program's founder, Adm. Hyman Rickover: technical excellence and competence, meritocracy, acceptance of complete responsibility, training of and challenge to all personnel, firm authority, and total commitment to honesty, safety, and environmental stewardship. Beckett also noted that unlike in the civilian power sector, naval reactor ordering has not paused, with new orders placed in the 1980s, 1990s, and since 2000. Later this year, he added, the first Virginia-class submarine will be commissioned, with a core intended to last for the whole 33-year life of the craft.

Beckett

Kingsley's seven points

Next to speak was Oliver D. Kingsley, Jr., chief operating officer of Exelon, with remarks that were to be cited and quoted frequently by other speakers for the duration of the meeting. Kingsley recalled that five years earlier he had told a reporter that a nuclear renaissance was approaching, and said he believes that it is now in its early stages—but does not have an assured future. After summarizing the activities to date of the NuStart consortium, of which Exelon is a member, and its plan to apply for site approval and a construction/operating license even though none of the NuStart partners currently intends to order a reactor, he listed seven preconditions that would have to be met before new plants would be built:

Kingsley

[A] nuclear renaissance is possible, and may be becoming more likely, but . . . only if issues such as high-level waste disposal are resolved.

■ The market must create a demand for more power. Kingsley noted that there have been about $50 million in losses from "merchant" plants, built as speculative investments with traditional rate-base inclusion, and this environment won't support nuclear plants. Reserve margins are declining, however, and Kingsley said that with 90 percent of all recent generation additions being gas-fired, there has been an adverse effect on the price of gas in the fuel's traditional markets, like fertilizer and home heating. He said that the price of gas in four major Exelon regions translates to electricity costs in excess of $50/MWh for that fuel.

■ Someone, preferably a utility CEO, must lead the way, perhaps risking the presumed ire of the financial community by showing a clear intent to build a new nuclear plant. Kingsley cited the late William Lee, of Duke Power Company, as an example of the kind of leader who would be needed.

■ There must be new, deliverable technology—not experimental, but already able to provide "operational comfort." The ABWR, for instance, already has operational experience. The certification of the AP1000 and ESBWR may satisfy this condition, from the standpoint of NuStart.

■ There must be regulatory predictability and stability. Kingsley said that he thinks this is in place now as far as reactors are concerned, but said that it would be difficult to announce new orders unless another regulated project—the proposed high-level waste repository at Yucca Mountain, Nev.—is determined to be a licensable site.

Continued

■ Acceptable financial returns must be available. Kingsley said that construction cost is a major concern, and there should be financial incentives for "first movers" who would make their commitments before economy of scale and proven performance could make reactor ordering more attractive. He noted that there is currently 10 times as much federal funding for fossil and renewable energy as there is for nuclear.

■ The infrastructure to design and build power reactors must be reestablished. He recalled attending a World Association of Nuclear Operators meeting in Osaka, Japan, and wondered if there were more nuclear construction capability around Osaka Bay than in all of the United States. He said the issue is not just whether there are enough engineers and university nuclear programs, but whether craft workers, technicians, training programs, and apprenticeships will be in place.

■ There must be public confidence in nuclear power. Kingsley exhorted nuclear professionals to quit apologizing and proclaim the progress of power reactors. Reitation is an important aid to nuclear development, and cited as an example the order for the Olkiluoto-3 reactor in Finland a few months earlier.

There remains, however, great uncertainty on upcoming energy choices in many nations. Echávarri said that countries accustomed to command-and-control decision-making are being forced to learn about the workings of the market. He also mentioned the Generation IV international forum, with 11 countries working on six advanced reactor concepts, as a way for the worldwide nuclear community to help advance the technology to newer systems and a gateway to the hydrogen economy.

Questions for the panel

In the ensuing panel discussion, Leidich asked Kingsley how ANS could help meet the seven preconditions. Kingsley replied that the Society and its members could help uphold nuclear education, stress positives in public debates, and serve as a common ground for the whole nuclear community.

Kingsley's call for a CEO to lead the way in plant ordering prompted a question from the audience by former ANS President Andrew Kadak, who asked Kingsley if he were volunteering. Kingsley (Exelon's COO, not CEO) said only that Exelon is willing to make a substantial investment once other needs are met—especially regarding Yucca Mountain.

In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business.

On the same topic, Kingsley was asked about a recent statement by Dominion Energy CEO Thomas Capps, that the utility consortia have "unrealistic" ambitions (*NN*, July 2004, p. 12), and whether Kingsley saw NuStart evolving eventually into an entity that would order, build, and operate new reactors. On the Capps statement, Kingsley acknowledged the awareness of financial risk that gave rise to it, and said that NuStart is nowhere near the point of considering an order, but added that it would be worthwhile for several utilities to be involved, and share the accompanying risks.

To an extent, the panelists were chided by audience members for limiting their near-future focus. One questioner said that economy of scale argued for resuming construction with more than one reactor; Kingsley said that the first step had to be the establishment of a single reactor project, and that if it went as intended, others would follow. "My heart says eight," he said, "but my head says one."

Another questioner wondered whether the addition of new reactors would put a strain on the uranium supply in the once-through fuel cycle now in place, and whether nuclear could expand without breeder reactors. Tritch responded that the focus should stay on what's needed to resume reactor ordering, and that it would be unwise to push for breeders.

Tritch

turning to the financial state of the electricity industry in general, he noted that since the start of 2002, the Dow-Jones utility index was down 13 percent overall, but the stock prices for nuclear plant owners had risen, and the six utilities that have bought power reactors from other utilities are up 65 percent. He added that the nuclear industry will not be able to tolerate poorly performing reactors anywhere in the country. "If you're not getting better," he concluded, "you're certainly moving backwards."

The final speaker was Luis E. Echávarri, director-general of the Organization for Economic Cooperation and Development's (OECD) Nuclear Energy Agency. He said there are now more than 10 000 reactor-years of experience worldwide, but OECD countries are growing more dependent on energy from unstable regions of the world. He said that the Kyoto treaty on carbon dioxide emission lim-

Echávarri

TMI-2: The lessons learned

It was 25 years ago in March that the commercial nuclear industry learned that it was fallible. In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business, from education and training and plant operations, to regulatory oversight, and brought the phrase "lessons learned" into the nuclear lexicon. The Monday afternoon session at the ANS Annual Meeting, "Twenty-five Years After TMI-2: Lessons We Need to Remember," took a look at some of those changes and asked the question: Are we starting to forget why we made these changes in the first place? The session was organized by Jim Byrne, of FirstEnergy Nuclear Operating Company, sponsored by the ANS Decommissioning, Decontamination and Reutilization Division, and cosponsored by the Education and Training Division and the Operations and Power Division.

Bob Long was a vice president at TMI operator GPU Nuclear when the accident occurred. With the accident now 25 years in the past, he felt compelled to remind the session audience just how devastating the accident had been for the reactor and the company that owned and operated it. As he noted, the reactor core was destroyed, with 70 percent of the fuel damaged and more than 50 percent of it melted; a million gallons of highly contaminated water collected in the reactor and auxiliary building basements; a large volume of krypton gas accumulated in the reactor building; and local residents suffered considerable mental stress and local businesses suffered economic losses. And because of the high levels of radioactivity after the accident, much of the damage would remain unknown for many more years.

Long

The full picture of just how damaged the reactor was began to emerge in 1986, Long said. The first images of the shattered fuel rods, the molten mass at the bottom of the vessel, the melted instrument tubes, remain

"burned into the memory of everyone in the power business," Long commented. In addition, as reported in 1993, accident analysts eventually determined that a square meter section at the bottom of the reactor vessel reached 1100 °C, which is considered white hot. Nonetheless, the vessel did not rupture.

The social consequences of the accident were equally dramatic, Long said. Although there were no deaths or injuries, the plant was ruined, never to operate again; it took a billion dollars to clean up the mess; adjoining TMI-1 was shut down for more than six years; GPU was driven to the edge of bankruptcy (its stock dropped from $18 a share before the accident to just over $3); the public emotion about the accident remained intense, with people still expressing concern about living near TMI; and billions of dollars were spent worldwide to improve plant safety and performance.

Tony Barratta, professor emeritus at Penn State University, discussed the accident's impact on nuclear engineering education. Prior to the accident, nuclear engineering education programs had remained somewhat static, but not long after the accident, enrollments began to increase—driven, Barratta said, by a response to the challenge of making nuclear energy safer, especially among the better students. This increase, however, was short-lived, especially after the 1986 accident at Chernobyl disillusioned students who thought things had changed and as the "cyber revolution" enticed the cutting-edge students away.


Barratta

Today enrollments are again increasing, but the ability for the nation's universities to respond has decreased. Only 27 university reactors remain operational. Today's faculty members often lack a depth of understanding (few have power reactor experience, Barratta said). Many programs have merged into more traditional engineering fields (mechanical, electrical, etc.), which can create problems for nuclear engineering education because the traditional programs often do not provide the emphasis on safety that the specialized programs have. Most important, Barratta concluded, industry support has been lagging, and industry especially does little to support faculty research, an area that universities still find valuable.

Changes in training, operations

TMI also changed the face of nuclear training forever, noted Jane LeClair, from Constellation Energy's Nine Mile Point nuclear station. At TMI, she said, operators were faced with a situation they had never seen before, were working with confusing procedures, lacked a fundamental knowledge of the reactor workings, and had no knowledge of lessons learned from previous operating experiences at other plants. Among nuclear utilities, prior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

After TMI, the industry worked quickly to fill the training void. In May 1982, the Institute of Nuclear Power Operations (INPO) established an accreditation program for the industry, and the industry responded by preparing its training programs for accreditation. The U.S. Nuclear Regulatory Commission endorsed the INPO accreditation program in March 1985, and issued a training rule in April 1993 that recognized industry's training and accreditation efforts. And the American Nuclear Society developed standards for training and qualification of nuclear plant personnel.

[P]rior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

More specifically, she said, the industry systematized its training program; increased eligibility requirements for senior operators and operators; added training in heat transfer, fluid flow, and thermodynamics; increased training emphasis on reactor transients and on mitigating core damage; and toughened NRC licensing examinations. Finally, plant-specific simulator training became the norm for all operator training.

Changes in plant operations were addressed by Pete Sena, operations manager at Beaver Valley. "It's all about people these days," he said, and "managing people is tough."

Sena outlined the way an "effective organization" looks at operations. Among the highlights: an emphasis on people, and "ownership" by employees and unions of the tasks they are assigned to do; an emphasis on constantly improving performance; team benchmarking with other plants; and high expectations. For example, an effective organization looks at a "near miss" as a failure, and constantly reviews minor slips. A less effective organization, on the other hand, might look at a near miss as a success, because, after all, nothing bad happened.

At Beaver Valley, every job is briefed prior to the job and afterwards. Lessons learned are saved and incorporated into future procedures. "Peer checks" provide a second set of eyes for every action. Sena admitted that industry is split pretty much 50/50 on peer checks, but he feels that they serve a valuation function. "If you do it right the first time as a result of a peer check, ultimately your productivity goes up."

A dedication to following procedures is another important aspect of operations at Beaver Valley. "We have procedures for following procedures," Sena laughed. But by emphasizing procedures, he said, "operators stay in 'rule-based land,' and don't go into 'knowledge-based land.'"

Regulations and response

The accident brought a new world view to the NRC, noted David Matthews, director of the agency's Division of Regulatory Improvement Programs. In addition to a raft of new regulations, the accident brought about an increase in opportunities for the public to make their opinions known during the regulatory process. This provided a sea change in the utility world, where the prevailing attitude had been that it's best if no one knows about them. Even today, he said, some utilities still look at the public process as an intrusion, but the NRC is committed to the change.

One problem the NRC still faces is "connecting the dots" from previous experiences, because there are still roadblocks to data sharing. Can we use INPO experience or is it confidential? Some foreign countries may not want to share experience that might reflect badly on them. In many ways, Matthews said, we face the same problems as the many entities of the intelligence community—that is, whose data is it, anyway?

In subsequent discussion, Long mentioned one other area of improvement: emergency response. There was no such thing as an effective emergency response program when TMI happened, he said. In those pre-cell-phone days, there were no telephones for reporters to call in their stories (the only telephone was in the control room, Long commented, and it had been "off the hook" since the accident), no trained briefers, no equipment or supplies for briefers or reporters. "We had a trailer with no furniture, no pencils, no paper, nothing," Long said.

Today, 25 years later, the good performance of today's nuclear plants is testament to the effectiveness of the post-TMI improvements. But "continuous vigilance" is needed, Long cautioned. Indeed, he noted, things are not as good as you would like

them to be, and they are not in an improving trend. For example, significant events increased 40 percent in 2003; forced shutdowns during the first 10 days after a refueling outage have increased; and since 2000, there has been a 27 percent decrease in the number of plants in INPO's "excellent" category. And, Long concluded, the recent issue of the corroded reactor head at Davis-Besse proves that the industry must remain vigilant, and must never forget the lessons learned from this country's worst commercial nuclear accident.

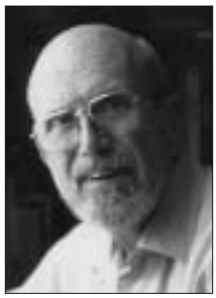
Realism: Set the record straight

In the ANS President's Special Session, *Realism in Evaluating Nuclear Hazards*, outgoing President Larry Foulke said that one of ANS's priorities is to be a source of credible information on science and technology. A critical issue that needs to be put right in this regard, he said, is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts. As members of this Society, Foulke said, "we have a responsibility to correct this."


Foulke

ANS, he added, "should take a leadership position" on this issue, and he added his hope that this session would mark a step along the way. The speakers, said Foulke, would be describing how conservatisms in the models, methods, and input have led to calculations predicting that there would be high levels of cancer fatalities and risk, and would show that these conservatisms and the results of the calculations have no basis in reality. Using conservative values and computer models that actually reflect reality, he noted, the numbers associated with consequences become ever so small.

The session was led by Ted Rockwell, who, at Foulke's request, has been heading up a group preparing a White Paper on this topic. Rockwell is currently vice president and founding officer of Radiation, Science & Health, Inc., an international public interest organization of independent radiation experts committed to bringing radiation policy into line with scientific data and theory.


Rockwell

Nuclear experts' attitude, Rockwell said, is that a major core accident would never be allowed to happen, because that would mean the end of nuclear power. It is something so unimaginable that there is no desire even to want to talk about it. In fact, a lot of work has been done to determine realistic scenarios of the release and dispersion of fission products and how the consequences are limited by the actual physical properties of the materials at hand. There is a good realistic story to tell, he said, based on facts, knowledge, and understanding.

Rockwell explained how this issue has come to a head. About two years ago, Nuclear Regulatory Commission Chairman Nils Diaz began addressing ANS and other organizations, saying that it is necessary to start using realistic figures. We cannot continue using extreme unrealistic assumptions. "Here is the chief watchdog telling us that we do not become safer going to extremes," said Rockwell, who added that Larry Foulke has taken on the challenge and is personally championing this issue.

A critical issue . . . is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts.

Ian Wall, a consultant and the first speaker, was involved in the early work at EPRI on accidents and has contributed to the White Paper. He became involved in risk assessment in 1967 while working at General Electric. Upon joining the NRC in 1974, said Wall, one of his first jobs was to correct a serious error in the consequence model then used. He developed a new code that showed that the consequences were concentrated mainly near the plant, that there would be time to evacuate, and that the risks become very small at distances farther away from the plant. "The point," he said, "is that realistic models changed our perspective about offsite consequences."


Wall

By introducing realism, said Wall, WASH 1400 (known as the Rasmussen Report) also changed the perspective of what was important to reactor safety. Prior to WASH 1400, the consensus of experts was that the probability of core damage was infinitesimally small, while the consequences were very large. WASH 1400, he said, showed that the probability was larger than expected, but the consequences were tiny.

Prior to the accident at Three Mile Island-2, safety experts assumed that the iodine released would be elemental and gaseous and a large fraction would be discharged to the atmosphere. Under this premise, said Wall, the TMI accident sequence should have released millions of curies of iodine-131. It turned out that only a very small amount was released. The subsequent investigations identified mechanisms—such as nuclides being dissolved in water and plating out—that meant most were retained at the plant. This further changed the perspective of the consequences of reactor accidents.

During the 1980s, EPRI undertook work on accidents, which added more realism. Wall's part involved setting out a program of experiments to characterize and measure the retention of radioactive material within fuel, within the reactor system, and within the containment. This resulted in a tenfold reduction in the WASH 1400 source term.

In general, Wall said, a much better job is being done than before. He added that reactor designs should be conservative, but should be supported by probabilistic risk assessments that are as realistic as possible.

Realistic conservatism

Before introducing the next speaker, Rockwell explained another event that is driving this work. Recently, an antinuclear report analyzing a hypothetical fuel pool fire associated with a terrorist attack predicted thousands of radiation-induced deaths hundreds of miles away, and demanded that all such fuel be transferred to dry storage casks. The report was given to Congress, which asked the National Research Council to look into it. The authors said that they did not invent the numbers and the methods used: They were taken directly from reports prepared by Sandia National Laboratories and other nuclear laboratories. In fact, the NRC accepted this point, and to its credit took up the challenge, realizing that there is a wider issue here. In its testimony, the commission underlined that the type of analysis done here—the sort carried out over many years—is not relevant to the real world because the premises are too unrealistic. The NRC explained that the premises may have been right for scoping studies, when they were looking to bound a problem, but they are not right for predicting deaths.

The next speaker was Farouk Eltawila, director of the Division of Systems Analysis and Regulatory Effectiveness in the NRC's Office of Nuclear Regulatory Research. Eltawila began by defining "realistic conservatism," a term coined by NRC Chairman Diaz, who believes that public policy should not be based on the most con-

servative assumptions and extreme scenarios. Conservativism, he said, means employing a defense-in-depth strategy and ensuring there are adequate safety margins. Realism comes from using the best information you have from science, engineering, and operating experience.

Today, the commission has much better knowledge of phenomena such as fracture mechanics and aging, Eltawila explained. This helps reduce uncertainties, improve the quantification of safety margins, and provide a better understanding of the safety issues associated with accidents. This is helping the NRC move away from the use of the traditional deterministic conservative assumptions to calculate consequences, toward what he called "risk-informed realistic conservatism."

Regarding the issue of a spent fuel fire, Eltawila discussed NUREG-1738, a spent fuel pool analysis carried out in 1999–2000 by Sandia and Brookhaven national laboratories. This study was done for a specific purpose and used a great deal of conservatism. In fact, it assumed the worst possible scenario. In this case, he said, the analysis gave a very low risk, which the NRC said was acceptable. There was no reason to go further because the answer already provided the information needed to make a regulatory decision. The NRC understood the conservatism used, he noted, which involved assumptions that were not realistic or appropriate for making a decision regarding a terrorist attack—a situation where realism is needed. Unfortunately, he said, people have tried to extrapolate that type of information from a hypothetical accident to a terrorist attack and have come up with a huge number of cancer fatalities.

The NRC's latest review, said Eltawila, indicates that the pool's structure is very robust and the location of fuel in pools make them highly resistant to terrorist attack. A transient analysis has indicated that fuel is more easily cooled and the decay heat level is much lower than predicted in earlier studies. There are at least 24 hours from the time the pool empties of water and the start of fuel damage and the release of fission products.

Realism comes from using the best information you have from science, engineering, and operating experience.

The review, said Eltawila, shows that the demand for the transfer of spent fuel from the pool to dry casks at the cost of billions of dollars is not justified. He added that the NRC has identified a strategy for loading spent fuel into the pool that can substantially reduce cooling time of freshly discharged fuel, further reducing any consequences from an incident.

Rockwell commented that Eltawila and Diaz are owed a big vote of thanks for tackling this issue, and recognizing that although some try to characterize it differently, no one is trying to reduce safety. "Getting more realistic is not reducing safety, it is getting safer."

Transport realities

Ruth Weiner, senior staff scientist at Sandia National Laboratories and a member of the NRC's Advisory Committee on Nuclear Waste, described the arbitrary premises that produce large overestimates of radiation dose from a postulated radiological incident involving nuclear transport. Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials or ionizing radiation. This is not surprising, she said, given the extreme tests undertaken.

Weiner

Conservatism in transportation is used, she said, at four points: computer models; inputs to the model; interpretation of results; and the notion of the bounding case. This last one, she noted, implies that if we can show that nothing much happens in the worst possible case, then clearly the situation is not bad. These four conservatisms were used in NUREG-0170 (1970), the first environmental impact statement on transportation of radioactive material by air and other means. The NRC and utilities still use it, with advanced computer codes of course.

Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials.

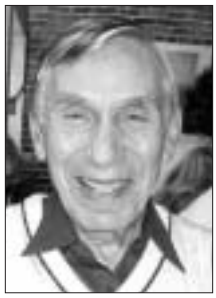
Weiner then described what real measurements do to a conservative model. To show this, she described the calculation of dose from an incident-free transportation operation. In this case, the truck is modeled by a sphere rolling down the road with dose measured at 1 meter from the surface. There are other conditions, such as that the truck stops every 100 miles for an inspection in a crowded urban area, and that no one moves. There was no validation done on this until a few years ago, she said, when a graduate student did some actual measurements at Hanford. It turned out that this model is extremely conservative.

"You give it stupid numbers," she said, "and it gives you stupid numbers back." The model never tells anything that it is not told first, she said, adding that opponents say they use the same models as those used by the experts and get tremendously high doses. The reason, Weiner explained, is that they start with tremendously high numbers.

The modeling of real accident situations is more complex, she said. Her colleagues at Sandia came up with NUREG-6672, which constructs 19 accident scenarios for trucks and 21 for rail. This gives much more realistic levels of doses of release than the previous NUREG, she noted, but is still excessively conservative.

The facts about buried HLW

Bernard Cohen, professor emeritus of Physics and Environmental and Occupational Health at the University of Pittsburgh, focused on the concerns of high-level waste (HLW) buried a half-mile underground. Cohen has authored many papers and several books on assessing nuclear power risks. For the purposes of his talk, he used rock as an analog for HLW—in its own form, encased or converted into glass or into another rock-type matrix known as "Synrock." He queried that if the HLW is buried a half-mile underground, why should this be dissolved out by groundwater any sooner than 2000 feet of rock above it? We understand natural rock, he said, and we ought to use this understanding.



Cohen

An example of not using what we know about rock was a study carried out about 20 years ago by the National Academy of Sciences (NAS) on HLW glass that presented

calculations of releases and health effects. It did not identify anything catastrophic. Going over this work, however, Cohen saw how totally unrealistic it was. Taking the method used by the NAS, the rock 2000 feet deep would dissolve at a rate of about 1 percent per year—so in other words, it would last only about 100 years. But it is well known that rock 2000 feet deep dissolves at a rate of about one ten-millionth of a percent per year and lasts about 1 billion years. In other words, they made an error of a factor of about 10 million. He showed other weaknesses in the NAS approach, and in the end, he observed that this report, hailed by the nuclear industry at the time, made all the mistakes that Ted Rockwell talked about.

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel.

Cohen also discussed the risk of cancer fatalities due to buried HLW generated from 100 nuclear plants, and compared it to the risks from coal-fired plants. The bottom line is that each of the three different types of waste released from coal burning—airborne pollution, chemical carcinogens in coal ash, and radioactive waste in coal (uranium, thorium, and radium, and the subsequent radon emissions)—cause 1000 times more deaths than HLW. Cohen added that the natural radioactivity in the ground above the waste from uranium and thorium provides 100 times more cancer doses than the waste.

Cohen also "unpicked" the picture that the antinuclear groups try to paint. For example, groundwater does not flow like a river; it is more like dampness seeping through the ground. At Yucca Mountain, groundwater moves at about 1 foot per year. He also noted that it would take groundwater at 2000 feet below the surface about 1000 years to get to the surface. Any radioactive material, however, would be held up by a number of processes, and would be expected to take 1000 times longer to get to the surface.

ANS White Paper

Rockwell concluded with some thoughts about the White Paper (ANS member input on the White Paper was being requested as of late June on the ANS Web site). The report, he stressed, is a working document designed to get the message clear as to what the realistic facts are about radiation hazards in the worst case and in the real situations people face.

He particularly wanted to "knock out" two false premises: that a severe accident would be the end of the world and that "one damn ray will kill you." As an example of the problem, he noted that when an incident occurs, such as the Davis-Besse problem, it is usually reported as almost a major accident, as if a small hole in the reactor would lead to thousands of deaths.

As for very low-dose radiation, Rockwell said that there is no real scientific basis for assuming it is harmful. In fact, he observed, there is considerable evidence that some radiation is beneficial. He noted that the goal is not to try to overturn the science on which their recommendations are based, and said that he believes that many of the advisory committees promoting the linear no-threshold concept have been remiss in their not examining, evaluating, and reporting on the massive amount of evidence on the beneficial effects of low-dose radiation.

Rockwell also challenged the idea that it is safer and more beneficial to assume that the world is different than it is. Putting some realism in place of "silly" premises does not represent a decrease in safety, he said. He was not talking about regulators' yielding to pressure from the industry to be less safe. If a most realistic assessment of the situation is made, "with conservative elbow room," then there will have been movement toward "safer, not less safe."

Fuel issues

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel, according to Ivan Maldonado, associate professor of Mechanical, Industrial and Nuclear Engineering at the University of Cincinnati.

The industry is increasing capacity factors and cycle lengths at the same time that power uprates are occurring. By many accounts, these factors "are conspiring to test the bounds of the performance and reliability of nuclear fuel," said Maldonado, organizer of the session on "Current Issues in LWR Nuclear Fuel Performance and Reliability."

Zero fuel defects should be that boundary of performance and reliability, suggested Bill Pierce, site vice president at Beaver Valley nuclear power plant, operated by FirstEnergy Nuclear Operating Company (FENOC). Beaver Valley has two Westinghouse pressurized water reactors. Unit 1 is rated at 821 MWe (net) and Unit 2 at 831 MWe (net). "We need to challenge the fuel vendors to continue robust fuel development," Pierce said. "We need to challenge the core designers to guard fuel margins. We have to challenge fuel handlers to protect fuel during movement. We need to challenge workers to prevent foreign material exclusion [FME]."

Pierce chastised the industry for not having a goal of zero fuel defects, and for its "lack of [having] a cohesive plan to achieve the things we need to achieve regarding fuel performance."

The industry, he continued, should get to a point where a defective fuel pin at a nuclear plant would be something that draws interest. "Today, we look at it as an accepted thing," he said. "If it happens, we feel like we're powerless to deal with it. We've got to get to a point where we see fuel defects as something we're not going to tolerate."

Underlying the zero-defect goal is a nontechnical issue, meaning that it's the general public that demands perfection from the nuclear industry. "I think the public domain that allows us to operate these plants expects us to have zero fuel defects," he said. "I just believe that it's bad business to have fuel leaks [because any minor nuclear blip is perceived by the public as a bad thing] and that [leaks] will be a problem for us as an industry."

The industry itself, of course, will have to foot the bill to support development of zero-defect fuel, he noted, but at the same time it is important to retain the low cost of fuel. "The heart of the electric industry using nuclear power for production is low fuel costs," he said. "Besides that one issue, we would not be competitive with other sources of electricity generation, because our base costs are higher."

FENOC operates three nuclear sites—Beaver Valley, in Shippingport, Pa.; Davis-Besse, an 873-MWe (net) Babcock & Wilcox PWR in Oak Harbor, Ohio; and Perry-1, a 1235-MWe (net) General Electric boiling water reactor in North Perry, Ohio. Combined, 66 percent of the FENOC plant's collective fuel failures have been caused by grid fretting, 28 percent by debris, and 6 percent through fabrication.

Countering Pierce's argument was Paul Edelmann, a fuels engineer for Constellation Energy's two-unit Nine Mile Point nuclear power plant, who noted that he would never expect fuel to be made entirely leak proof. "I don't think that's possible," he said. "I don't know how much more improvement you can design into fuel. But I do know from working at a BWR plant that there is a lot of room for improvement in control of plant


Edelmann

chemistry, and especially in foreign material exclusion."

He recounted a story from last spring, when Nine Mile Point-2, an 1148-MWe (net) General Electric BWR in Scriba, N.Y., was entering a refueling outage. Thirteen hundred workers were brought on site to work the outage. For most, it was their first experience at a nuclear plant. Their inexperience showed, he said, as illustrated by a pile of debris that collected on the refuel floor during the outage. "This became big news" within the plant, he said, because with the industry spending millions on FME programs, "somebody [at Nine Mile Point] was missing something."

Edelmann advised that strict adherence to good FME and chemistry practices, combined with safe rod pattern development and cycle operation, "can and should prevent BWR fuel from undergoing any failures, even with higher power demands and longer cycle duties."

A lesson learned at Nine Mile Point, he said, was that modern fuel designs will perform well when treated with care.

Identifying fuel leaks

Ed Price, a senior engineer for Duke Power, stated that Duke plants have been free of fuel leaks since 2001. Duke operates the two Catawba units, which are 1129-MWe (net) Westinghouse PWRs, in Clover, S.C.; the two McGuire units, which are 1100-MWe (net) Westinghouse PWRs, in Cornelius, N.C.; and the three Oconee units, which are 846-MWe (net) B&W PWRs, in Seneca, S.C.

The Catawba and McGuire plants switched in 2000 to Westinghouse robust fuel assemblies with zirconium cladding from the AREVA/Framatome ANP Mark-BW design, and Oconee switched in 2001 to AREVA/Framatome ANP Mark-B11 fuel with M5 cladding.

Price said that the whole process of identifying leakers, at least recently, has been akin to searching in the dark. "You expect when you have leakers to have iodine activity go up, but we've had many cycles with leakers with very low iodine activity," he said. "We've also had mysterious leaks at plants where we know we had leakers, but little or no spiking during transients."


Price

Once leakers were discovered at Duke plants, he said, there were problems in isolating the failed fuel assemblies. That's because ultrasonic testing (UT) has had "very poor reliability for us the past few years," he said. "Many overcalls, many cores that had leakers in them, did not show up on the UT."

As an example, Price explained a fuel-leak search at Catawba-1 from several years ago. The core showed a substantial increase in xenon-133, and a UT campaign was done that resulted in the identification of four suspect fuel rods. "We pulled the rods, but eddy current testing showed all the rods were sound," he said. "So, we did not find failures in any of these rods."

Price claimed that INPO's Fuel Reliability Indicator (FRI)—defined as the steady-state primary coolant iodine-131 activity (microcuries/gram), corrected for the tramp contribution and power level, and normalized to a common purification rate and average linear heat generation rate—is not a credible measure. A team is being put together, of which Price will be a member, to reevaluate FRI to come up with something "more realistic," he said.

A problem with today's FRI is that a core can have leakers with low iodine activities and low power defects, but still be under the FRI criteria for zero defects, he said.

With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good."

Price wondered what had happened to diagnostics over the past few years. Stretching back a decade or two, UT was considered 85 percent efficient. But over the past five years, "we haven't been able to find anything," he said. "It makes me wonder if now the threshold is so low for leakers that we're looking for things that, in the past [when the threshold was higher], we would see without paying much attention."

From the fuel manufacturers' side, Olga Correal-Price, a principal engineer for Westinghouse Electric Corp., noted that 25 percent of leakers are from unknown causes, and that the percentage is increasing. She stressed that finding the reason for those leakers is "today's challenge."

John Schardt, chief technologist of Global Nuclear Fuel, Ltd./General Electric Nuclear Energy, said that in the old days, thousands of fuel rods used to fail throughout the industry. Today, however, "we're talking about tens." With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good," he said.

Schardt declared that his company and probably every fuel manufacturer in existence has a "zero leak mentality." Every leaker "hurts everyone. It hurts our customers and it hurts the vendor. Each day that there is a leaker, we know about it that day," he said.

Schardt implied that people all the way up the management chain of command "hurt" when they learn about a leaker, because "most of us thought that by now we might have almost licked" the leaker problem. He added, "We don't know of a manufacturing defect that has caused a leaker in 10 years."

Roger Reynolds, director of Fuel Technologies and Reliability for Framatome ANP, Inc., followed up on Schardt's comments by declaring that "'Zero tolerance for failure' is the way we do our work."

Standards: A shift in philosophy

The ANS Standards Board has initiated work to revise many of its standards using risk-informed and performance-based concepts. This session, "A Movement Toward Risk-Informed, Performance-Based Standards: A Shift in Philosophy," explained chair Don Eggett, senior management and manager of business development for Automated Engineering Services Corp., was planned to look at the reasons for moving from conventional prescriptive standards to more performance-based and risk-informed standards, and how this is being implemented in ANS-sponsored standards. The movement to this new approach involves more than a shift in philosophy, he said. It reflects a more general shift in the attitude of industry to use these concepts to evaluate operation.

Standards, Eggett explained, can be performance-based or performance-based risk-informed, depending on what the needs are or what the focus will be. To distinguish these sometimes confusing concepts, the Board generated the following explanations:

On performance-based: Decide what the objective is to be then select a series of tasks, tests, etc., that will get you to the end point. Selection of the tasks is arbitrary based upon the particular situation and plant, and are not deterministic for every plant and situation.

On risk-informed (which can couple with performance-based): For each design basis accident or serious event, determine the risks to the public health and safety that the occurrence of the event will entail and then determine the mitigating events that are necessary to reduce public risk to a predetermined acceptable level.

Don Spellman, of Oak Ridge National Laboratory and chair of the ANS Nuclear

Facilities Standards Committee (one of four standards consensus committees), explained that the go-ahead was just made at the Board's last meeting and that this session is the first presentation of its observations and of some of the work being done. ANS often takes the initiative in this type of effort, Spellman said, where there is something industry needs to address. "And besides," he added, "we like the challenge." The Board will develop a set of criteria that explains how to create or revise a standard or convert it from prescriptive to performance-based.

Jim Mallay, director of regulatory affairs for Framatome ANP and chair of the ANS Standards Board, opened the session with a presentation on the benefits of moving from a prescriptive to a more performance-based standard. Most of the standards developed within ANS, said Mallay, are intended to either complement or positively influence current and planned regulatory expectations. In many cases, he noted, the NRC has asked ANS to develop standards on selected subjects, adding weight to any regulation that is based on those standards because the commission knows that industry has reached consensus that these are appropriate criteria and requirements.


Mallay

A particular feature of the standards groups, said Mallay, is that they provide the only forum for technical information to be exchanged freely among all parties, many of whom are in competition with each other or are regulated by the NRC, which is represented on nearly all of ANS's standards committees. And so, for Mallay, even if a working group is not successful in developing an approved standard, the fact that the people in the group have gotten together and communicated is a major benefit to them individually and to the industry.

Usually only a portion of a standard will be performance-based . . . as there will be many situations where prescriptive criteria are necessary.

Another interesting feature of standards that is rarely used in regulatory guidance documents, is the use of the verb "may," which denotes "permission." "May" allows the use of a technique at the user's discretion. This is an added value of standards, said Mallay, especially for those used to help interpret or complement regulatory documents.

Mallay explained the shift in approach as due in part to the needs of industry. During the last few years, there has been a significant decline in the demand for ANS standards. To some extent, this reflects the maturity of the industry (and the fact that no one is building plants). Nevertheless, the Board also had to consider whether it was really serving the interests of the users. In looking at that, said Mallay, the Board determined that maybe there were too many inefficiencies in the application of standards. Many were probably too prescriptive and inflexible, he noted, and therefore would not be used.

Unlike prescriptive requirements . . . the performance-based approach . . . ensures that the focus is on those things that are more important to safety.

So, the Board turned to techniques being advocated by the Nuclear Energy Institute (NEI) and the NRC—namely a performance-based, risk-informed approach. Mallay defined a performance-based requirement as a required design objective or operational behavior, including those attributes that are necessary to verify that the objective or behavior can be achieved. A performance-based standard, he said, is a standard that contains performance-based requirements together with measures that can be used to assess the degree to which the attributes can be achieved. These measures of success can be qualitative, quantitative, or some combination of the two.

Prescriptive requirements, Mallay added, have no flexibility and tell the user nothing about why the rule was established. Performance-based criteria tell you why—that is, makes the basis for a criterion explicit—and provides flexibility. But this does not work for all requirements. Usually only a portion of a standard will be performance-based, he said, as there will be many situations where prescriptive criteria are necessary. Standards based on performance-based criteria are also expected to have a longer life because the objectives, when stated properly, are not going to change as much as prescriptive requirements might. Furthermore, they allow revisions more readily.

Finally, said Mallay, performance-based requirements force people to work in "success space," not "failure space." One is never looking at a worst case, but at successful performance, where there are more opportunities.

Duke Energy, said Mallay, was recently allowed to establish performance-based criteria for the inspection and surveillance of the new steam generators being put into its Catawba plant. To deal with a number of outstanding safety issues raised by the NRC, the company proposed using a performance-based approach, which the NRC accepted. Mallay said he thinks that this is a milestone in this area.

According to Mallay, the first ANS performance-based standard (on the application of PRA for making risk-informed decisions on external events) came out about a year ago. He also noted that ANS has developed a draft standard for low-power and shutdown operating states, and plans to risk-inform its standards on design criteria for light-water reactors.

NRC pushing performance-based approach

Prasad Kadambi, of the NRC's Office of Nuclear Regulatory Research, has been active in pushing ANS toward performance-based standards. This approach, he said, accepts that nuclear activities are rather complex, with people, systems, and institutions all interacting for a common purpose. In this case, the common purpose is safety.


Kadambi

Regulations, he explained, deal with higher-level, more conceptual requirements, while standards address the lower level, the nuts and bolts of any activity. Traditionally, both have been prescriptive, Kadambi said, with requirements and instruction very specifically laid out. But recently, there has been a recognition of a need for change. In particular, said Kadambi, prescriptive requirements lack flexibility. They also have technological implications in that sometimes conditions are included in regulations that tend to freeze technology, particularly if there is

perception that there is only one way to comply with the regulation. This may inhibit technological creativity.

Things have been changing, he said. In 1993, Congress passed the Government Performance and Results Act. This legislation emphasizes outcomes rather than outputs; it makes agencies think whether they are doing the right kind of work, rather than just focusing on how well they are working. The legislation also requires agencies to develop strategic and performance plans so the public would know what ultimate results they are seeking to bring about. Another piece of legislation (Public Law 104-113) requires government agencies to think about consensus standards in lieu of regulatory requirements.

Kadambi noted that the NRC issued the first strategic plan (2000–2005) in 1999 and the second is now in preparation (2004–2009). It also issued a management directive explaining how staff can participate in standards activities. These direct the staff to consider performance-based approaches as appropriate. In addition, NRC staff issued NUREG-BR-0303, "Guidance for Performance-Based Regulation," in December 2002.

Kadambi asked the question: Why performance-based standards? Basically, he said that he believes that a new approach is needed, particularly if the nuclear industry does experience renewed growth. It is crucial, he declared, for working groups to have the flexibility to consider the best way to develop standards. They can consider using performance-based or prescriptive approaches as appropriate. This, he said, promises a more efficient development of standards once a learning curve is passed: It offers more effective application (particularly for new technology), more economical maintenance, and more equitable sharing of the burdens between standards developers and users. Performance-based standards should also last much longer. He commended ANS for this initiative.

Unlike prescriptive requirements, he added, the performance-based approach also ensures that the focus is on those things that are more important to safety, ensuring that resources are applied where they are most effective.

Over the last six or seven years Neil Brown, of Lawrence Livermore National Laboratory, has been involved at the working group level on a set of standards related to seismic design of nuclear facilities. It was only toward the end of the process, he said, that the performance-based concept was taken on board.

These new standards, not yet completed, will replace an original set developed by the Department of Energy for its nuclear facilities, Brown said. During a revision, the parties involved agreed to convert these to approved national standards. The DOE standards concerned natural phenomena hazards (NPH)—that is, seismic, wind, and floods. They start by categorizing certain structures, systems, and components (SSC), and then develop prescriptive rules about how a design should address these three natural phenomena. The original standards had risk goals set in terms of probabilities of safety consequences, doses, and failures.

The safety community, Brown said, even in the seismic area, is not eager to go to a fully risk-informed standard in the sense that the ability to estimate probabilities of failures of SSC and to relate those to a dose consequence, and so forth, is still limited. The DOE standards are risk-goal based—that is, they have clearly stated risk goals—and the SSC categorization is based on a specific set of risk goals. He said, however, that the participants could not agree on the desired risk goals for the new standard. Brown explained that agreement was eventually reached on using a magnitude of "unmitigated" consequence of a failure as opposed to failure probability to define the categories. And so, the categorization of an SSC was determined by the unmitigated consequence of its failure, not on the basis of risks.

The final presentation was by Paul Fishbeck, professor of Social and Decision Sciences, and Engineering and Public Policy, at Carnegie Mellon University, and director of the university's Center for the Study and Improvement of Regulation. He provided his experience from other fields where risk-informed and performance-related rules and standards are applied. Performance-based standards work well, he said, when you can actually measure performance. For example, consider how much pollution comes out of a smoke stack. In fact, he said, that can be measured, and criteria set. Penalties, such as withholding payments, can be applied if the criteria are not met.

Other areas being discussed, however, involve long-term, rare events, where performance is difficult to measure, Fishbeck said. If you are talking about fire safety, for example, how do you measure that a building is fire safe? What criteria do you use to base the performance of, for example, a sprinkler system? Is it the amount of water coming out in a certain time period?

A prescriptive standard, he noted, says: Use this, put it here, make it this big. These things can be checked very easily, he observed, but performance-based standards are much more complex.

He then raised the question of uncertainty. A prescriptive standard almost ignores uncertainty. Using a performance-based standard is to admit that there is uncertainty out there.

Fishbeck presented some examples to show how complex the area of standards can be. As other speakers had done before him, he recognized that the work leads to useful discussions among all interests and develops a lot of understanding along the way. There are methodologies that allow you to address these concerns, "but [they are] not for free."

Water desalination

Over the next two decades, there will be a 40 percent increase in water use around the world, according to the International Atomic Energy Agency (IAEA), and 33 percent of the world's population—about 2 billion people—will be in absolute water scarcity by the year 2025.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases. The fact is that there isn't enough fresh water on the planet. The session, "The Use of Nuclear Energy for Desalination," explained nuclear's role as an economical power source for methods of water desalination—two of which are distillation and reverse osmosis (RO)—that have high-energy consumption requirements and high hot-water production costs.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases.

The IAEA defines nuclear desalination as the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy for the desalination process. The facility may be used solely for the production of potable water, or dually for the generation of electricity and the production of potable water, in which case only a portion of the reactor's energy output would be used for water production. In either case, a nuclear desalination plant is defined as an integrated facility in which both the reactor and the desalination system are located on a common site and energy is produced on site for use in the desalination system.

Small and medium reactors are important for desalination because the countries most in need of fresh water often have limited industrial infrastructures and electricity grids, explained Akira Omoto, director of the IAEA's Nuclear Power Division. Smaller

reactors, he said, also are "more appropriate for remote areas" unsuitable for connections to the grid.

Omoto noted that nuclear power plants around the world have long been used for water desalination. For example, Kazakhstan's BN-350, a liquid metal–cooled fast-breeder reactor that operated until 1999, was used to produce electricity and heat for desalination (approximately 80 000 m^3 of water per day) for 27 years. And, currently, Pakistan's Kanupp has a small RO facility in operation and is building another desalination demonstration plant on site to be commissioned in 2005. Meanwhile, India's Kalpakkam has an experimental facility in operation and another under commissioning that is expected to process 6300 m^3/day.


Omoto

Expanding nuclear's role in the world's desalination process will include four challenges, he noted. First is economics, of course, where the target for desalinating water is \$0.40 to \$0.60/m^3. Next is public understanding. Then comes the issue of disparity, meaning that nations having water scarcity may not be holders of nuclear technology. Finally, in what is not directly a nuclear issue, infrastructure for distributing desalinated water is necessary.

Roger Humphries, president of Canadian desalinating company Candesal, said that a message not heard enough is that water shortages are quite often localized. In Indonesia, for example, rain falls almost every day during the rainy season. "But the issue is a point of mal-distribution," he said. "The water is not where the people are. It's not accessible because it cannot be collected and captured." He added that Indonesia's city of Jakarta and its surrounding rain forests have some of the lowest availabilities of safe, fresh water per person of any place in the world.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing. "As we draw fresh water out of sources that are nonrenewable, they get replaced by salt water," he said. "So, we're finding what used to be fresh water [in] a lot of aquifers [now has] a salinity level reaching 1000, 2000, 2300 ppm, basically making it unsafe to drink."

Desalination solves problems in that, politically, it keeps nations from "stealing" water from one another, and, environmentally, because it's a "friendly" way for creating new sources of potable water, as no fossil fuels are burned in the process, Humphries said.

Si-Hwan Kim, director of the SMART R&D Center of the Korea Atomic Energy Research Institute, explained South Korea's plan for a SMART desalination plant. SMART stands for System-integrated Modular Advanced ReacTor. The plant, which is under construction and is expected to be in operation in 2008, will produce both electricity (90 MWe) and potable water (40 000 tons/day).

Ron Faibish, project manager for nuclear desalination at Argonne National Laboratory, said that potable water issues exist here at home in the United States. "Drought conditions now in the Southwest have increased dramatically," he said. News reports have claimed that the drought in the West is the worst in 400 years. "We have big challenges in the U.S.," he added, "and they're not just focused in the West. We have issues in the East as well, and on the Texas coast."

Population growth along coastal Southern California, Texas, and Florida has been on the order of 20 percent in the past decade, and for the country as a whole, 60.6 billion additional m^3 of potable water per year will be needed by 2020 for municipal and light industrial uses.

The U.S. Bureau of Reclamation, together with Sandia National Laboratories, has developed a roadmap for desalination in the United States, he said. Published in 2003, the roadmap declares that by 2020, desalination and water purification technologies will contribute to ensuring a "safe, sustainable, affordable and adequate" water supply to the United States. "These words are important," he said. "The terms affordable and adequate—those are the ones I think have to be first in term of securing the future of the technology."

The roadmap's 2008 objective, he said, is for desalination technologies to realize a 20 percent improvement in capital costs, operating costs, and energy efficiency. By 2020, improvement in those areas needs to reach 80 percent.

Those goals are ambitious because today the cost of treating water in the United States using a conventional (chemical) treatment is about \$0.10/m^3. In Southern California, reclaimed water from industry costs about \$0.60/m^3. Brackish water desalination is between \$0.26 and \$0.79/m^3. For seawater desalination (the biggest operation, in Tampa Bay, Fla., currently is suffering problems, Faibish said), the forecast is \$0.55 cents/m^3.

Sump clogging is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors.

An "interesting factoid," he said, is that desalination in the United States could cost \$0.79/m^3 (\$3 per thousand gallons). "That seems expensive, but the U.S. consumer is paying an average of \$2099 per cubic meter for bottled water. When you put this into perspective, [desalination] seems rather cheap," he said.

The latest on sump clogging

At the panel session "Hot topics and emergent issues: Containment sump clogging," session chair and organizer Steve Stamm, of The Shaw Group, opened with an explanation of why sump clogging was billed as a "hot topic." Sump clogging, he said, is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors. This session, he said, would cover the problem's background, describe the methodology that is being used to resolve it, and present some of the plant activities and potential modifications being introduced.

Mike Marshall, lead project manager on the issue at the Nuclear Regulatory Commission, began with an overview of the topic and the status of work on PWR sump performance. According to Marshall, the NRC's primary concern is that the sump screen is doing its job too well. The purpose of the screen is to keep debris from damaging pumps or blocking spray nozzles and other components downstream. Retaining debris smaller than the system is designed to, he explained, results in excessive head

loss that can affect operation of the pumps. This is the same concern that the NRC had with boiling water reactors.

There are also some secondary concerns, such as the downstream effects of debris getting past the screen, that might have an impact on pump operations or accumulate enough to affect cooling of fuel. These are not the primary concerns, but the NRC wants them taken into account when solutions are considered or when evaluating the adequacy of existing designs. But most of the effort has been focused on head loss at the screen and whether it affects operations.

Because of the variation in the materials at individual plants, as well as the differences in the containment and layout of screens, the NRC agrees with industry that this is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action. One thing that is becoming clear is that the existing license base for a number of plants is probably insufficient and will need changing.

Marshall explained that unlike BWRs, it appears unlikely that every PWR is going to have to implement a fix. But each operator will have to evaluate the situation and decide if there is a problem that needs resolving, either procedurally or by a hardware modification or some other means. The evaluations will include: identifying the different debris sources, particularly those that would likely cause some clogging; estimating the amount of debris generated; estimating the amount of debris transported to the sump screen; and estimating what the head loss impact would be.

This issue first came up in the early 1980s, when the Advisory Committee on Reactor Safeguards became interested to see if air injection would have an impact on the operation of the emergency core cooling system (ECCS) pumps. The question of debris came up later. Research undertaken between 1980 and 1985 did not identify a particular problem. While the NRC could see some benefits in preventing entrainment, they were insufficient for action to be taken. In 1985, however, it recommended that new plants and plants undergoing material changes—such as of insulation—consider the issue and provided some regulatory guidance.

In 1992, an event occurred at the Barsebäck BWR in Sweden, where the NRC's 1985 guidance had been adopted. Based on this, the plant had assumed that the ECCS system would operate for a day or two before the strainers (screens) became clogged. The incident occurred when water was released into the drywell, taking a lot of insulation with it. The clogging occurred not within a day, but within an hour or two of the activation of the emergency systems. This was communicated to other regulators, and investigations ensued that identified weaknesses with the guidance and the underpinning research. This started a new run of research around the world on sump issues.

The focus at first was on BWRs because there were three similar events in U.S. plants, although not on the scale of Barsebäck. It eventually became clear that although clogging would occur sooner in BWRs than in PWRs, the weaknesses were common to both reactor types. New work undertaken identified weaknesses in the previous correlations. In particular, the fiberglass insulation debris was more like "cotton candy" shreds than the "slices of cake" that were used in the old research. The shreds produce much greater head loss. Furthermore, the fiberglass acted as a filter, capturing small items that had been expected to pass through the screen, adding to the head loss.

All the BWR stations introduced a combination of fixes. These included minimizing debris sources, cleaning the suppression pools, and increasing the surface area of the sump strainers.

Soon after completing the work on the BWRs, work on the PWRs started. From a parametric study, the NRC staff concluded that there was enough of a concern to warrant individual plant evaluations. NRC has been working with the Nuclear Energy Institute (NEI) since about 2000 on developing a suitable methodology.

[T]his is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action.

The next speaker was John Butler, senior project manager at NEI, which has completed guidance for carrying out a sump performance evaluation that is now being reviewed by the NRC. The guidance will help operators evaluate the situation at their plants regarding debris generation, transport, and accumulation on the screens and whether there is adequate net positive suction head (NPSH) margin available for ECCS recirculation. This effort, said Butler, is primarily funded by the Westinghouse Owners Group and coordinated by the NEI PWR Sump Performance Task Force.

A draft sump performance evaluation guidance document was given to NRC staff in October 2003, and the final version was submitted on May 28, just a couple of weeks before the ANS Annual Meeting. The review process should be completed by this fall, with final approval expected in October.

The end result of the evaluation guidance is to determine the adequacy of the NPSH margin, Butler said. The calculation is complicated by the large number of phenomena and uncertainties that need to be addressed. These include:

- Size and location of a postulated break. Location is probably more important than size regarding the potential debris generated.
- Debris generation (quantity, types, size, distribution). The orientation of the break affects what debris is going to be generated. Besides calculating the amount, it is necessary to determine the size distribution of the debris, which affects its transportability.
- Debris transport and holdup. The "transport media" is a combination of debris, the containment spray, and washdown, all of which determine the amount that collects at the sump.
- Debris deposition on screen and resulting head loss. The resulting head loss is highly dependent on the types of debris deposited.

The guidance addresses the uncertainties and complexities in a traditional conservative fashion. "It is a balancing act," Butler said. "I think I can say we have a conservative methodology that is not *too* conservative."

He then described the basic evaluation methodology, which starts with a baseline analysis, a conservative first step in the evaluation. Some plants can go through the baseline and find that they have adequate NPSH margin and can stop at that point. A number of others will find that they do not have adequate NPSH margin, and will have to continue the evaluation process by refining the analysis in one or two ways: refine their analytical methods to take out some of the conservatism, or modify their design, which may involve removing potential debris sources, changeout of insulation (which contributes most debris), or modifying their screen design. The process continues until an adequate NPSH is achieved.

NEI is now working with the NRC to try to introduce a risk-informed option in the methodology, acknowledging that the large double-ended break, which would generate the most debris, sump blockage, and head loss, is a very low-frequency event. A risk-informed option would allow more meaningful breaks and conditions to be applied to assess sump performance. The details of such an option are now being discussed with NRC staff.

Continued

Sump performance evaluation methodology

More details on using the evaluation methodology were given by Tim Andreychek, of Westinghouse Electric Company. Andreycheck has been working on the issue for the last seven years, and is the lead author of the NEI PWR post-accident sump performance document. The purpose of the methodology, he explained, is to provide a consistent approach for utilities to perform a conservative evaluation of their containment sump performance post-accident. Analytical refinements are also identified to provide options for removing some of the conservatisms.

The "baseline," said Andreychek, starts with plant specific information—basically a scoping study or a first shot to see if there is something to worry about. If the results are acceptable, the issue can be closed out. If not, the methodology provides a guide as to how to proceed. This involves further analysis and reanalysis, with possible design modifications. The process continues until NPSH requirements are satisfied.

Andreychek provided an example of a "baseline analysis" that took a very conservative line. Regarding break size, the baseline assumes a double-ended guillotine break. For the break location, he determined the maximum debris generation and the worst combination of debris to create the biggest head loss. To determine debris generation, a zone of influence (ZOI)—a region around the break where the destruction of insulation and other materials occurs—was defined. His baseline calculation assumed an unrestrained jet stream from the break, which destroys the insulation, forming debris.

[S]ome plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

Latent or resident debris (the dust and dirt that collects) is not considered a major contributor, Andreychek said, but has to be accounted for. The baseline methodology provides an easy-to-use estimate of the contribution. He mentioned, however, that some plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

The head loss correlation being used, based on a NUREG document, is a semi-empirical correlation and provides for a conservative pressure-drop calculation. The effects of debris composition and material properties are accounted for in the calculation. Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it. This, he noted, was a particularly bad situation for BWRs, causing big pressure drops.

Andreychek also went into various analytical refinements to the baseline evaluation. By replacing the conservatism with more realistic conditions, the amount of debris generated can be reduced, its transportability lessened, and the accumulation and blockage of the sump screens can be decreased, leading to a better NPSH margin.

Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it.

Kenneth Ainger, licensing manager at Exelon Nuclear, is responsible for licensing activities at the Byron, Braidwood, and Three Mile Island-1 nuclear stations. He provided an operator's perspective on this issue, describing the evaluations that he will be performing, some interim measures, and potential enhancements being considered to fully resolve the issue, if necessary.

Ainger's description of the different sump/screen configurations at three plants provided insight into the real problems that operators have with this issue. For example, both Byron and Braidwood have two sumps that are enveloped by an outer screen. Overall, there are three screens that protect the suction lines to the ECCS and containment spray system. The outer screen encloses the middle and inner screens for both sumps. The outer screen extends about 4 feet above the floor of the containment, and the inner screen is installed below the containment floor inside each sump.

As for potential debris sources, the main containment insulation at Byron and Braidwood is reflective metal insulation. When the steam generators at Byron-1 and Braidwood-1 were replaced, their insulation and that of the associated piping were replaced with fiberglass blankets, covered with stainless steel sheathing. The TMI-1 containment has about 600 ft^3 of fibrous insulation. Ainger also pointed out the problem of unqualified equipment coatings—for example, the coatings on valve handles and reactor coolant pump housings—as possible debris. The baseline evaluations will look at the reflective metal insulation, fibrous insulation, coatings, tags, labels, and foreign material. All of these potential debris sources will be examined in light of the four transport mechanisms: blowdown transport; washdown transport; pool fill transport; and recirculation transport.

For the sump screens, the initial evaluation for Byron and Braidwood indicates no concerns regarding structural integrity or excessive blockage. Byron-1 and Braidwood-1, however, may not pass the evaluation in light of the fiberglass insulation used on the replacement steam generators. This might require an additional engineering analysis. With the performance of ZOI evaluations at the plants, Ainger noted, a risk-informed approach would probably provide benefits if it is used to assess the consequences of the occurrence of a break at the steam generator nozzles of the two reactors described above.

For TMI-1, the adequacy of the sump design may not pass the new evaluation, and so some design change to the sump or to the areas along the path to the sump may have to be considered. Enhancements could include modifications to the floor to help direct debris or prevent some pooling of water. These have not yet been scoped, but could be significant.

Ainger said that several interim measures have been implemented to ensure the working of the ECCS while pursuing the long-term resolution of the issue. The loss of recirculation capability has been addressed at Byron and Braidwood in the emergency procedures. Additional training for operators has been provided, including simulator training. The company has strengthened the foreign material exclusion and walkdown procedures for the containment, and has enhanced the refueling outage surveillance procedure for visual examination of the sump screens. For TMI-1, the B&W Owners Group guidelines for sump blockage were implemented and training in ECCS pump throttling criteria was provided to avoid damage in the early stages of potential sump blockage. New procedures for cleaning and inspecting drains inside the containment have been implemented. The existing refueling outage inspection procedures for the sump screen were determined to be adequate.

Ainger said that they are also looking at removing the fibrous insulation associated with the replacement steam generators.

Regarding costs, Ainger estimated that at Byron and Braidwood, Exelon will spend about $3 million over four years to pay for all the evaluations, including additional engineering analyses, licensing submittals and responses to the NRC Generic Letter (*NN*, May 2004, p. 15), and some insulation modifications. For TMI-1, the estimate is high, at about $4.5 million over four years, as some extensive modifications inside the containment seem likely.

Safety culture

During the Tuesday afternoon "Safety Culture" session, Joe Carson, a licensed professional engineer and a nuclear safety engineer for the Department of Energy, observed that ANS's bylaws, which he said have remained constant since the beginning of the Society 50 years ago, should be revised. The bylaws, he noted, "[don't] reflect that ANS holds a public trust when developing standards of care for its members."


Carson

Carson, a former member of the ANS Special Committee on Ethics, stressed that he wanted to see ANS as "an organization that is flexible, responsive to members, and capable of dealing with change."

Change is necessary, he said, because ANS has evolved since its creation a half-century ago. "Fifty years ago," he said, "I don't think ANS held a public trust, but I think it does now today."

Examples of that public trust include ANS's role in accrediting engineering schools for nuclear engineering, and its work in developing codes and standards that are adopted internationally. ANS, then, has "an important role with nuclear science and technology in public policy," he said.

Carson, who described himself as an "eight-time prevailing" DOE whistleblower (as detailed on his Web site, <www.carsonversusdoe.com>), noted that the words "ethics" and "peaceful" and the phrase "promote the professional interests of its members" are absent from ANS's bylaws. And although the word "safety" is included in ANS's goals, the bylaws do not include "any form of the word 'safe,'" he said.

Carson suggested that ANS modify its bylaws, mission statement, and goals to more clearly capture its identity as a professional society. He also called for all nuclear engineers to be licensed by states, something that is a "distinguishing characteristic" of members of such professions as medicine, accounting, and architecture. "Engineers, by and large, are not licensed," he said. "Well, why not?"

ANS's new code

Vic Uotinen, chairman of the ANS Special Committee on Ethics for 2003–2004, remarked that ANS does have a new Code of Ethics, replacing an earlier code dating back to 1973, which was altered somewhat in 1984. The new code, which was adopted by the ANS Board of Directors in 2003, is more specific and comprehensive than the earlier version, and it "reflects the expectation of a more conscious commitment to professional ethics by ANS members," he said.

The new code [of ethics] . . . "reflects the expectation of a more conscious commitment to professional ethics by ANS members."

The new code also is at the same level as the ethics codes of several other engineering societies, such as the American Society of Mechanical Engineers, American Institute of Chemical Engineers, Society of Civil Engineers, and IEEE. "I think it's important for us to realize that all of these engineering societies, by upgrading their codes of ethics, were in essence sending a signal to their constituencies that we, as professional societies, consider professional ethics to be important, and that we consider upholding this higher code of ethics, this higher standard, to be a true mark of professionalism," he said.


Uotinen

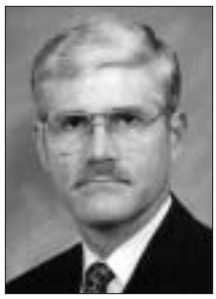
Uotinen gave examples of how the new code is an upgrade over the older version. The old code, for instance, said, "An ANS member shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties," while the new code says much more: "We hold paramount the safety, health, and welfare of the public and fellow workers to protect the environment and to strive to comply with the principles of sustainable development in the performance of our professional duties." It also adds a new paragraph: "We will formally advise our employers, clients, or any appropriate authority and, if warranted, consider further disclosure, if and when we perceive that pursuit of our professional duties might have adverse consequences for the present or future public and fellow worker health and safety or his environment."

Another example is in the area of acting in accordance with applicable laws and practices. Whereas the old code didn't mention this area at all, the new code says, "We act in accordance with all applicable laws and these practices, lend support to others who strive to do likewise, and report violations to appropriate authorities."

Ethics and competency

Ethics and competency are interrelated, remarked Dwight Baker, who was making a presentation for the absent William Corcoran, of Nuclear Safety Review Concepts. Baker said that if anybody at Davis-Besse had operated according to the ANS Code of Ethics, the vessel head degradation could have been prevented from becoming so severe. "You can certainly say that if you saw [the signs of degradation, such as piles of rust that collected on a flange] and ignored it, if you were the manager who would have signed off saying 'We don't need to work on that,' if you were the outage manager who shut down [a vessel head cleanup job prior to the degradation's discovery], maybe then there should be an ethics complaint filed," said Baker, of Cumberland Consulting. "But I'd put a dollar to a donut that those people are not ANS members."

Baker said that in many cases where workers "behave badly at the technical level, those technical people are neither professional engineers nor ANS members, with no requirement that they be." Further, he said, in "about 99 percent" of the cases where a nuclear professional should be punished for ethical misbehavior, the management personnel who would make those decisions are not ANS members.


Baker

As long as there is no requirement that an engineer be licensed, society will think "we're just computer programmers, and we really don't affect their health and safety," he said. Without that public pressure, there will be no incentive for companies to hire licensed engineers, or have existing staff attain licensing. Without licensing, there will be no living up to a code of ethics. "It's really a public education job, to impose a licensure requirement just like for doctors and lawyers," he said.

Continued

Baker said short of requiring licensing, which is "really a big piece of work, and I don't know if it's doable," one way that a plant can attain higher overall quality is to provide long-term financial incentives to company executives. "Think about it," he said. "Having the plant run well in the long term is in the stockholders' interest. So, there may actually be a strategy that is doable, from the business organization side of it."

A case in point is that some ANS members are utility executives with access to compensation committees. These executives, he said, may "have some good ideas on how to structure stock options that are only exercisable seven years from now." *—E. Michael Blake, Dick Kovan, Rick Michal, and Nancy Zacha*

TOPICAL MEETING

Advances in Nuclear Power Plants (ICAPP 2004)

- *South Korea aims for large H output by 2020*
- *European utilities judge next-stage reactors*
- *MIT study on nuclear role in carbon-constrained world*

As the world's nuclear energy nations have come into greater agreement on nuclear power's medium- to long-term future—the development of "Generation IV" reactor designs, the coupling of these designs to hydrogen production, and the opportunity for actinide burning to extend fuel resources, deter proliferation, and reduce radwaste generation—many of the speakers at the 2004 International Congress on Advances in Nuclear Power Plants (ICAPP 2004) agreed in their presentations to such an extent that some of them apologized for repeating what others had already said. ICAPP 2004—which this year was embedded as a topical meeting in the ANS Annual Meeting in Pittsburgh (June 13–17)—included five plenary sessions, and despite the organizers' attempt to give each session its own unique theme, some overlap was unavoidable.

Whether there will be enough trained professionals in place if there is a sudden demand for new nuclear power was much on the minds of several speakers. Andy White, of General Electric Nuclear Energy, told a plenary session audience that 40 percent of GE's employees in nuclear fields are within five years of retirement age. He called for an industry-wide focus on development of a larger talent pool of nuclear expertise. The next speaker, Russ Bell of the Nuclear Energy Institute, also included the aging nuclear workforce as one of the main challenges facing the industry now (and not just in the future). The other challenges, in Bell's view: keeping fuel economical and reliably supplied; managing materials at aging facilities; securing nuclear facilities (Bell said they were safe before 9/11, and are safer now, but this is a very high-profile public issue); and providing spent fuel disposal. Bell acknowledged the problem that had arisen with high-level waste funding, in which the Bush administration had expected to use money from the Nuclear Waste Fund but Congress had not authorized it (see page 113, this issue), but said that the Department of Energy, "with industry support, is pursuing legislation" to assure adequate funding for the proposed high-level waste repository at Yucca Mountain, Nev., in the FY 2005 federal budget.

Later in that session, Peter Lyons, of the Senate Committee for Energy and Natural Resources staff, spoke more pointedly about the Yucca Mountain funding situation. He said that the way the administration presented the bill, with only $131 million to be appropriated in the FY 2005 budget and $749 million presumed to be available from the Nuclear Waste Fund, created "an immense problem," and led to only the $131 million being approved for Yucca Mountain, nowhere near enough for the DOE to remain on schedule to open the repository in 2010. Lyons also said that the entire FY 2005 budget request was "an immense surprise" to the committee, leading to concern that nuclear research and development could be undermined, and that the reformulation of the Idaho National Laboratory might not be given a "focus for success."

At the second plenary, Steve Melancon, of Entergy Corporation, echoed the concern about Yucca Mountain, and the extent to which the future of new power reactors in the United States depends on resolution of the high-level waste issue. "Yucca Mountain needs to become a reality," he said, "or I don't think any new nuclear plants will be built." Also during his address, Melancon recounted the formation of NuStart Corporation (an industry consortium seeking Department of Energy matching funds to apply for site approval, design certification, and licensing of new power reactors), but departed somewhat in his personal views from the procedure announced thus far for NuStart, in which approval would be sought from the Nuclear Regulatory Commission for two sites, as well as certification for two reactor designs, but ultimately the construction/operating license (COL) would be sought for a single reactor design at one site. Melancon said NuStart should choose *at least* one plant for the COL; he would like to see enough money made available to pursue both designs, and both sites.

With the meeting taking place in the United States, and with so many recent developments in the U.S. nuclear realm, the above topics and more like them drew a great deal of attention during the meeting, but ICAPP is indeed an international event, and speakers from most of the world's large nuclear power programs reported on numerous technical and programmatic developments. Their reports, like those from the U.S., ranged from improvements on existing reactors to the many first steps being taken toward the goal of Generation IV.

South Korea's vision

Next year's ICAPP will be held in Seoul, South Korea, and there was a substantial Korean presence at this ICAPP, both to pre-

sent papers and to promote the event in 2005. A table outside the topical's largest meeting room was stacked with brochures on travel to Korea. The viewgraphs of three of the five Korean speakers at the plenary sessions had bands at the bottom reading: "See you in 2005, ICAPP Seoul!"

During the first plenary, Joong-Jae Lee, of Korea Hydro and Nuclear Power, traced the development of nuclear power in South Korea, which is now sixth in the world in both installed nuclear capacity and annual nuclear power generation. He said that in some countries where nuclear power has been accepted for some time, "challenges and new issues are growing" (which could describe the emergence of public opposition to nuclear in both South Korea and Taiwan), and there is a need for breakthroughs in technology and cooperation within the nuclear community. With 14 of South Korea's 18 power reactors achieving 2003 capacity factors above 90 percent, and the other four over 80 percent, Lee asserted that outstanding performance is the best way to respond to nuclear controversy. As for technology breakthroughs, Lee described the APR 1400 pressurized water reactor being developed in Korea to supplement and eventually replace the current generation of reactors; work has begun on the first APR 1400, Shin-Kori-3, scheduled to begin operation in 2011.

South Korea . . . has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances.

At the second plenary, Dong-Su Kim, of Korea Power Engineering Company, described the evolution of the APR 1400, the latest step in the development of the nuclear industry in South Korea—which has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances. He said that the current social environment (alluded to by Lee) "requires unlimited safety" and "faultless and eventless operations." He added that in South Korea, as in the United States, there is concern about the future supply of trained personnel, as students are tending not to pursue engineering. The belief that public acceptance can exist only with perfect operation drew a comment from the audience by Ted Rockwell, former technical director of the U.S. Naval Reactors Program. He said that one cannot convince the public that there will never be an accident, because one cannot reasonably make such a claim. He advised that one should take the position that the effects of any accident would be mitigated, and rebut the argument that exposure to any amount of radiation is dangerous.

Chung-Won Cho, of South Korea's Ministry of Science and Technology, extended his country's nuclear program into the future during the third plenary, citing its proposal for the System-integrated Modular Advanced Reactor (SMART), for both electricity production and seawater desalination, and participation thus far in Generation IV projects. SMART is intended as a PWR with the steam generator included in the reactor vessel, offering enhanced safety, economics, and environmental advantages. For Generation IV and beyond, Cho's projections were extremely ambitious, anticipating a "waste-free and pollution-free" nuclear fuel cycle with consumption of all actinides, and a timetable whereby South Korea would switch from fossil fuel to hydrogen so quickly that nuclear energy would produce 20 percent of the needed hydrogen by 2020. Questioned about this goal by an audience member, Cho said that a 16-year program is now starting, aiming at development of small-scale modular gas-cooled reactors, but that wider application was still under discussion, and the 20 percent goal should not be taken as a firm commitment.

Jong-Hwa Chang, of the Korea Atomic Energy Research Institute (KAERI), elaborated further on the 20 percent hydrogen goal in his address at the fifth plenary. One-fifth of the expected vehicle fuel demand in South Korea in 2020 would require 8.5 billion barrels of oil per year, which could be replaced by 3.3 million tons of hydrogen. KAERI's anticipated demo nuclear plant (a very high temperature gas-cooled reactor, or VHTR) would produce about 30 000 tons of hydrogen per year, so at least 100 plants of this capability would be needed to meet the hydrogen goal. At the same time, Chang said that security concerns in South Korea—which still has a hostile neighbor to the north—argue against distributed nuclear-hydrogen facilities, because of the potential for sabotage. Therefore, the reactors—more than 100—would be concentrated at a small number of sites that could be guarded well.

New scheme in Europe

The lull in power reactor ordering in Europe has not been as long as that in the United States, and with a new order placed in Finland and another on the way in France, it can be said that the lull is in fact over. Still, plenty has changed in the decade or so that elapsed, with moves toward the opening of electricity markets and attempts to normalize regulation. The old paradigm of a state-owned electric utility ordering the only design available from a state-owned manufacturer is eroding, and one indication of this is the development of European Utility Requirements (EUR) documents, which essentially tell manufacturers what the utilities want, need, and expect from power plant hardware and services.

Gianfranco Saiu, of the Italian firm Ansaldo, described the EUR process while presenting a technical paper on the EUR assessment of the Westinghouse AP1000 reactor design. The EUR effort began in 1991, with five utilities; six others joined later. Along with expressing what the utilities wanted, the documents provide bases for harmonization of safety approaches and targets, design standardization and objectives, equipment specifications and standards, and information for safety, reliability, and cost assessment. In 1997, the effort enlarged so that each document included a Volume 3, which compared a specific reactor design against the requirements. (Volume 1 includes nuclear island requirements, and Volume 2 covers balance-of-plant.)

Development of a Volume 3 for the AP1000 was based on previous work on advanced Westinghouse designs. Saui noted, however, that while the utilities' team was at work on this volume (the process can take years), Westinghouse moved on from the design. Saiu said that although the AP1000 was driven by U.S. market considerations, it had incorporated lessons from EUR work on earlier designs, including a low-boron core. As things stand now, the AP1000 is slightly out of compliance with EUR, both in technical areas (the cooldown time is longer than what the EUR prefers) and in semantics (whether it is preferable to state that radiation exposures *shall be* as low as reasonably achievable, or *are* as low as reasonably achievable). There will be more meetings intended to resolve the differences.

Pierre Berbey, of Electricité de France, spoke at greater length on the EUR's place in the evolving power generation environment in Europe. Even with efforts like EUR intended to normalize agreement on basic principles of safety and operation, the differing regulatory schemes of individual countries can work against standardization and increase costs. Berbey said that there should be common "rules of the game." He noted that the Western European Nuclear Regulator's Association is working to define reference safety approaches that could become common to all nuclear power nations in Europe. Berbey also noted a number of non-nuclear challenges now faced by electricity organizations in Europe, such as the synchroniza-

tion of the western European transmission grid with bordering nations like Poland and Romania. In the end, Berbey said that the EUR effort will try to deliver documents supporting four to six standard reactor designs; along with AP1000, EUR is also doing Volume 3 work on the AES92, an advanced version of the Russian VVER water-cooled reactor.

A carbon-constrained world?

During the fifth and final plenary, Ernest Moniz, of Massachusetts Institute of Technology (MIT)—who described himself as neither pro- nor anti-nuclear—presented results from a 2003 MIT study on what might happen if there is a significant worldwide adoption of new nuclear power. (The study, headed by Moniz and John Deutch, is posted online at <web.mit.edu/nuclearpower/>.) The study looked at the presence of a terawatt of nuclear capacity in place by 2050 (for comparison, the current worldwide nuclear capacity is less than half a terawatt). Moniz said this does not seem possible without the emergence of a "game changer" that would make nuclear the preferred choice for decision makers and the public. He said that global warming appears to be the strongest candidate to be the game changer. He said that if the only way to prevent a self-reinforcing rise in the greenhouse effect is to make this a "carbon-constrained world" by reducing carbon dioxide emissions, nuclear power and all other nonemissive options would be needed, and may not be enough.


Moniz

Moniz said that a new, nonamortized nuclear plant with no federally backed financing cannot currently compete with coal- and gas-fired generation (with CO_2 not taken into account). Not only must plant capital cost be reduced, but a series of plants would have to be built on budget and schedule to show that financial risk is not excessive. The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

If the world is carbon-constrained, Moniz said, the obligation to reduce emissions would fall hard on the power industry. Manufacturers that emit CO_2 can be moved offshore—in an observation specific to Pittsburgh, he noted that Alcoa is moving all aluminum production to Trinidad—but power plants must remain connected to the home nation's grid. Moniz added later that there will likely emerge a formal "cap-and-trade" system of incentives for carbon emission, started by the power industry in return for a rational, stable system of federal oversight.

Moniz said that even if the openly established "fuel cycle states" have 80 percent of the expected nuclear generating capacity, that would leave 200 gigawatts in other nations, raising nonproliferation concerns. Incentives to prevent rogue states from developing independent nuclear capability would have to include not only assured fuel supplies, but also spent fuel removal, which means resolution of high-level waste problems worldwide. Moniz said that it would be necessary for spent fuel to be stored for 50 to 75 years, despite what he termed the industry's "religion" of fuel cycle closure. He noted that the expected carbon emission mitigation cost for fossil generation would be at least $50 per ton of carbon, or $8 per megawatt-hour, which is far more than all expected fuel and waste costs for nuclear—so carbon constraint can become an incentive for nuclear, in full compliance with the Non-Proliferation Treaty.

Although the MIT study looked at a large addition of nuclear power extending to mid-century, Moniz was dubious of a major prospect used recently to argue in favor of advanced nuclear power: hydrogen production. He said that significant use of hydrogen as a fossil-fuel substitute "may be decades away at a minimum . . . we're all getting carried away" on hydrogen's likelihood of displacing oil use. He advised the audience not to lose sight of the scale of what would have to be done (as had been shown in the Korean presentations reported above). He called hydrogen "intrinsically inferior" to petroleum, and said that nuclear power should continue to be presented as an electricity option, with no attempt to oversell hydrogen.

The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

Other presentations

There were occasional moments at ICAPP 2004 when it seemed that two U.S. reactor designs—Westinghouse's AP1000, and General Electric's ESBWR—were being compared to one another. These are the designs chosen by NuStart for certification, and (despite Steve Melancon's position) apparent competition. Thus, fairly or otherwise, the designs are now seen as linked, and in a race that would end with one being the preferred choice and the other at least having to wait. Atam Rao, of GE, in his presentation to the second plenary on ESBWR, described this reactor as having a capability of 1550 MWe (the AP1000 is currently rated at 1117 MWe), and said that it will use components similar to those already being made for the ABWRs coming into service. He admitted, however, that the ESBWR is not as far along as the AP1000, which he said is "two years ahead of us" in the design completion and NRC certification processes.


Rao

In a session on the Very High Temperature Reactor (VHTR), which is the principal Generation IV design being pursued in the United States, Phil McDonald, of the Idaho National Engineering and Environment Laboratory, reported on a point design study that compared pebble bed core design to the "block" design, with fuel and moderator in parallel vertical blocks. He said that he would not choose one over the other, but concluded that fuel cycle costs would appear to be lower for pebble bed than for blocks. In the next paper, Yasushi Muto, of Tokyo Institute of Technology—working from different design assumptions—found that a cooling system that allowed for horizontal as well as vertical flow could help reduce some of the drawbacks associated with pebble bed cores. This flow pattern offers a 2 percent improvement in thermal efficiency and 5 percent less core pressure drop, allowing the maximum fuel temperature to be as low as 1110 °C.

Perhaps the most inopportune turn of phrase at the meeting came from Norbert Frischauf, of the European Space Agency's (ESA) European Space Technology Center, who chaired the session on nuclear power and propulsion systems, and opened it with remarks on European perspectives on the topic. After concluding that Europe should work on materials and other support issues, and decide later whether ESA should enter reactor development, he said that it was necessary to "go back to the classroom" to educate the public on nuclear materials used in spacecraft—to actively provide information, "and not let it fall down from the sky." Whether a nuclear spacecraft would fall down from the sky is, of course, exactly what the public would worry about.—*E. Michael Blake* NN

ANS ANNUAL MEETING

On the 50th anniversary, golden opportunities foreseen

- *Nuclear renaissance possible, if issues are resolved*
- *TMI-2 changed how the industry does business*
- *ANS should lead in presenting demonstrated science*
- *Zero fuel defects should be the industry's goal*
- *Shift is away from prescriptive standards*
- *Nuclear desalination faces several challenges*
- *Not just one solution to sump clogging at PWRs*
- *Improvements suggested to upgrade safety culture*

THE AMERICAN NUCLEAR Society gathered June 13–17 in Pittsburgh, Pa., for its 50th anniversary at a moment when memories of the origins of ANS—the aftermath of President Eisenhower's "Atoms for Peace" initiative, and the numerous possibilities foreseen for bringing nuclear science and technology to applications for the benefit of all humanity—could be accompanied by optimism for the short- and long-term future of the field. The theme of the meeting was *A Golden Anniversary—A Golden Opportunity*, and although during the second half of the Society's existence no power reactor orders have been placed in the United States, the 1073 attendees who gathered in Pittsburgh in mid-June could look to a new reactor order in Finland, a likely order to follow in France, the U.S. nuclear industry consortia preparing to test the new system for licensing, and signs of more favorable public attitudes toward new nuclear plants as indications that a nuclear power renaissance might occur in the United States early in the Society's second half-century.

The memories of the first half-century, and the accomplishments of ANS and the nuclear community, were evoked during the 50th Anniversary Banquet on Sunday night, the first official event of the meeting. Susan Eisenhower, granddaughter of former President Dwight D. Eisenhower and president of the Eisenhower Institute, gave a presentation in which she noted the appropriateness of Pittsburgh—the birthplace of commercial nuclear power generation—as the location of ANS's anniversary meeting, and thanked the Society for helping to transform her grandfather's "Atoms for Peace" vision into reality.

Following her talk, she introduced John Simpson, ANS past President (1973–74) and honorary chair of the meeting, and presented him with an ANS Presidential Citation for his lifetime of achievements. Simpson's talk provided insight into the sense of adventure that existed at the dawn of the nuclear age, and into what it was like to be one of the nuclear pioneers. He related firsthand stories about important figures of the early times, and conveyed the excitement of those who took nuclear through the transition from wartime use to commercial power generation. He was one of 19 ANS past Presidents in attendance at the dinner, where they and the Society's other previous leaders were honored for their contributions.

Seizing opportunities

Speakers at the opening plenary session on Monday morning touched on the meeting's theme, but tempered slightly their assessment of the opportunities for nuclear development in the coming years.

While all agreed that ANS, and nuclear professionals in general, can do much to seize the opportunities and broaden the benefits to the nation and world from nuclear energy, they made it clear that real progress depends also on developments outside the nuclear community, in the political and public arenas. The consensus was that a nuclear renaissance is possible, and may be becoming more likely, but can occur only if issues such as high-level waste disposal

are resolved fully.

The early part of the session focused on ANS matters. Joe Colvin, of the Nuclear Energy Institute, presented the Henry DeWolf Smyth Nuclear Statesman Award—a joint award of ANS and NEI—to former ANS President and Nuclear Regulatory Commission Chairman Joseph P. Hendrie. Stephen R. Tritch, of Westinghouse, a general co-chair of the meeting, read a letter from President George W. Bush congratulating ANS on its 50th anniversary. Then the other meeting co-chair, Gary Leidich, of FirstEnergy Nuclear Operating Company, presented a video that pointed out some of the nuclear community's many roots in the Pittsburgh area: the original power reactor at Shippingport (both as a light-water reactor starting in the 1950s, and as a light-water breeder reactor starting in the 1970s), and the nearby two-unit Beaver Valley plant in operation today.

Leidich

Leidich then presented the plenary speakers. Sen. Larry Craig (R., Ida.) was unable to attend in person, because the various memorial services for the late President Ronald Reagan in Washington, D.C., during the previous week had forced legislative business to be rescheduled; he sent a videotape in which he explained that work on defense high-level waste appropriations forced him to remain in the capital. (Technical glitches in the video, and Craig's largely off-the-cuff remarks, supported the impression that Craig had indeed changed his plans suddenly and made the video only as a last resort.) Craig said that there was still a "slim but outside chance" that comprehensive energy legislation could be passed by Congress before this year's election. He noted the public's reaction to this year's rise in gasoline prices, and said, "This reality check . . . may well jar Congress into action." He added that any serious push by the federal government for new energy sources would include a large nuclear component.

Current NRC Chairman Nils J. Diaz joined in the celebratory mood of the session, praising nuclear pioneers (including past ANS Presidents) for the legacy they have left, including power reactors and other nuclear facilities now in operation. But he said that the technology's safety record "is not to be taken for granted," and the prolonged outage at Davis-Besse (and the discovery there of an eroded cavity in the upper vessel head) should serve as a wake-up call. He noted that the Three Mile Island-2 accident in 1979 forced a realignment of the nuclear industry, and an awareness that a problem at one plant can reflect on all others. Diaz endorsed the prescriptive approach to regulation in use at the time, but said that several hundred reactor-years of additional operating experience, and the development of risk analysis techniques, have made it possible for regulation to become more risk-informed and performance-based. Also, raising an issue that would be revisited by many other speakers at the meeting, Diaz noted that the new generation of professionals entering the nuclear fields is not large enough to replace the retiring pioneers, and said that ANS is "never more needed than today" to assure an abundant supply of qualified personnel.

Diaz

Pittsburgh was also important in the development of the nuclear Navy, through the Bettis Laboratory. Thomas H. Beckett, deputy director of the Naval Reactors Program, summarized the program to date, noting that it has logged more than 130 million miles of submarine travel without a single accident, health impact, or instance of environmental damage. He credited this record to the core values established by the program's founder, Adm. Hyman Rickover: technical excellence and competence, meritocracy, acceptance of complete responsibility, training of and challenge to all personnel, firm authority, and total commitment to honesty, safety, and environmental stewardship. Beckett also noted that unlike in the civilian power sector, naval reactor ordering has not paused, with new orders placed in the 1980s, 1990s, and since 2000. Later this year, he added, the first Virginia-class submarine will be commissioned, with a core intended to last for the whole 33-year life of the craft.

Beckett

Kingsley's seven points

Next to speak was Oliver D. Kingsley, Jr., chief operating officer of Exelon, with remarks that were to be cited and quoted frequently by other speakers for the duration of the meeting. Kingsley recalled that five years earlier he had told a reporter that a nuclear renaissance was approaching, and said he believes that it is now in its early stages—but does not have an assured future. After summarizing the activities to date of the NuStart consortium, of which Exelon is a member, and its plan to apply for site approval and a construction/operating license even though none of the NuStart partners currently intends to order a reactor, he listed seven preconditions that would have to be met before new plants would be built:

Kingsley

[A] nuclear renaissance is possible, and may be becoming more likely, but . . . only if issues such as high-level waste disposal are resolved.

■ The market must create a demand for more power. Kingsley noted that there have been about $50 million in losses from "merchant" plants, built as speculative investments with traditional rate-base inclusion, and this environment won't support nuclear plants. Reserve margins are declining, however, and Kingsley said that with 90 percent of all recent generation additions being gas-fired, there has been an adverse effect on the price of gas in the fuel's traditional markets, like fertilizer and home heating. He said that the price of gas in four major Exelon regions translates to electricity costs in excess of $50/MWh for that fuel.

■ Someone, preferably a utility CEO, must lead the way, perhaps risking the presumed ire of the financial community by showing a clear intent to build a new nuclear plant. Kingsley cited the late William Lee, of Duke Power Company, as an example of the kind of leader who would be needed.

■ There must be new, deliverable technology—not experimental, but already able to provide "operational comfort." The ABWR, for instance, already has operational experience. The certification of the AP1000 and ESBWR may satisfy this condition, from the standpoint of NuStart.

■ There must be regulatory predictability and stability. Kingsley said that he thinks this is in place now as far as reactors are concerned, but said that it would be difficult to announce new orders unless another regulated project—the proposed high-level waste repository at Yucca Mountain, Nev.—is determined to be a licensable site.

Continued

■ Acceptable financial returns must be available. Kingsley said that construction cost is a major concern, and there should be financial incentives for "first movers" who would make their commitments before economy of scale and proven performance could make reactor ordering more attractive. He noted that there is currently 10 times as much federal funding for fossil and renewable energy as there is for nuclear.

■ The infrastructure to design and build power reactors must be reestablished. He recalled attending a World Association of Nuclear Operators meeting in Osaka, Japan, and wondered if there were more nuclear construction capability around Osaka Bay than in all of the United States. He said the issue is not just whether there are enough engineers and university nuclear programs, but whether craft workers, technicians, training programs, and apprenticeships will be in place.

■ There must be public confidence in nuclear power. Kingsley exhorted nuclear professionals to quit apologizing and proclaim the progress of power reactors. Reitation is an important aid to nuclear development, and cited as an example the order for the Olkiluoto-3 reactor in Finland a few months earlier.

There remains, however, great uncertainty on upcoming energy choices in many nations. Echávarri said that countries accustomed to command-and-control decision-making are being forced to learn about the workings of the market. He also mentioned the Generation IV international forum, with 11 countries working on six advanced reactor concepts, as a way for the worldwide nuclear community to help advance the technology to newer systems and a gateway to the hydrogen economy.

Questions for the panel

In the ensuing panel discussion, Leidich asked Kingsley how ANS could help meet the seven preconditions. Kingsley replied that the Society and its members could help uphold nuclear education, stress positives in public debates, and serve as a common ground for the whole nuclear community.

Kingsley's call for a CEO to lead the way in plant ordering prompted a question from the audience by former ANS President Andrew Kadak, who asked Kingsley if he were volunteering. Kingsley (Exelon's COO, not CEO) said only that Exelon is willing to make a substantial investment once other needs are met—especially regarding Yucca Mountain.

In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business.

On the same topic, Kingsley was asked about a recent statement by Dominion Energy CEO Thomas Capps, that the utility consortia have "unrealistic" ambitions (*NN*, July 2004, p. 12), and whether Kingsley saw NuStart evolving eventually into an entity that would order, build, and operate new reactors. On the Capps statement, Kingsley acknowledged the awareness of financial risk that gave rise to it, and said that NuStart is nowhere near the point of considering an order, but added that it would be worthwhile for several utilities to be involved, and share the accompanying risks.

To an extent, the panelists were chided by audience members for limiting their near-future focus. One questioner said that economy of scale argued for resuming construction with more than one reactor; Kingsley said that the first step had to be the establishment of a single reactor project, and that if it went as intended, others would follow. "My heart says eight," he said, "but my head says one."

Another questioner wondered whether the addition of new reactors would put a strain on the uranium supply in the once-through fuel cycle now in place, and whether nuclear could expand without breeder reactors. Tritch responded that the focus should stay on what's needed to resume reactor ordering, and that it would be unwise to push for breeders.

Tritch

turning to the financial state of the electricity industry in general, he noted that since the start of 2002, the Dow-Jones utility index was down 13 percent overall, but the stock prices for nuclear plant owners had risen, and the six utilities that have bought power reactors from other utilities are up 65 percent. He added that the nuclear industry will not be able to tolerate poorly performing reactors anywhere in the country. "If you're not getting better," he concluded, "you're certainly moving backwards."

The final speaker was Luis E. Echávarri, director-general of the Organization for Economic Cooperation and Development's (OECD) Nuclear Energy Agency. He said there are now more than 10 000 reactor-years of experience worldwide, but OECD countries are growing more dependent on energy from unstable regions of the world. He said that the Kyoto treaty on carbon dioxide emission lim-

Echávarri

TMI-2: The lessons learned

It was 25 years ago in March that the commercial nuclear industry learned that it was fallible. In the aftermath of the accident at Three Mile Island-2, the industry made changes in almost all aspects of how it did business, from education and training and plant operations, to regulatory oversight, and brought the phrase "lessons learned" into the nuclear lexicon. The Monday afternoon session at the ANS Annual Meeting, "Twenty-five Years After TMI-2: Lessons We Need to Remember," took a look at some of those changes and asked the question: Are we starting to forget why we made these changes in the first place? The session was organized by Jim Byrne, of FirstEnergy Nuclear Operating Company, sponsored by the ANS Decommissioning, Decontamination and Reutilization Division, and cosponsored by the Education and Training Division and the Operations and Power Division.

Bob Long was a vice president at TMI operator GPU Nuclear when the accident occurred. With the accident now 25 years in the past, he felt compelled to remind the session audience just how devastating the accident had been for the reactor and the company that owned and operated it. As he noted, the reactor core was destroyed, with 70 percent of the fuel damaged and more than 50 percent of it melted; a million gallons of highly contaminated water collected in the reactor and auxiliary building basements; a large volume of krypton gas accumulated in the reactor building; and local residents suffered considerable mental stress and local businesses suffered economic losses. And because of the high levels of radioactivity after the accident, much of the damage would remain unknown for many more years.

Long

The full picture of just how damaged the reactor was began to emerge in 1986, Long said. The first images of the shattered fuel rods, the molten mass at the bottom of the vessel, the melted instrument tubes, remain

"burned into the memory of everyone in the power business," Long commented. In addition, as reported in 1993, accident analysts eventually determined that a square meter section at the bottom of the reactor vessel reached 1100 °C, which is considered white hot. Nonetheless, the vessel did not rupture.

The social consequences of the accident were equally dramatic, Long said. Although there were no deaths or injuries, the plant was ruined, never to operate again; it took a billion dollars to clean up the mess; adjoining TMI-1 was shut down for more than six years; GPU was driven to the edge of bankruptcy (its stock dropped from $18 a share before the accident to just over $3); the public emotion about the accident remained intense, with people still expressing concern about living near TMI; and billions of dollars were spent worldwide to improve plant safety and performance.

Tony Barratta, professor emeritus at Penn State University, discussed the accident's impact on nuclear engineering education. Prior to the accident, nuclear engineering education programs had remained somewhat static, but not long after the accident, enrollments began to increase—driven, Barratta said, by a response to the challenge of making nuclear energy safer, especially among the better students. This increase, however, was short-lived, especially after the 1986 accident at Chernobyl disillusioned students who thought things had changed and as the "cyber revolution" enticed the cutting-edge students away.


Barratta

Today enrollments are again increasing, but the ability for the nation's universities to respond has decreased. Only 27 university reactors remain operational. Today's faculty members often lack a depth of understanding (few have power reactor experience, Barratta said). Many programs have merged into more traditional engineering fields (mechanical, electrical, etc.), which can create problems for nuclear engineering education because the traditional programs often do not provide the emphasis on safety that the specialized programs have. Most important, Barratta concluded, industry support has been lagging, and industry especially does little to support faculty research, an area that universities still find valuable.

Changes in training, operations

TMI also changed the face of nuclear training forever, noted Jane LeClair, from Constellation Energy's Nine Mile Point nuclear station. At TMI, she said, operators were faced with a situation they had never seen before, were working with confusing procedures, lacked a fundamental knowledge of the reactor workings, and had no knowledge of lessons learned from previous operating experiences at other plants. Among nuclear utilities, prior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

After TMI, the industry worked quickly to fill the training void. In May 1982, the Institute of Nuclear Power Operations (INPO) established an accreditation program for the industry, and the industry responded by preparing its training programs for accreditation. The U.S. Nuclear Regulatory Commission endorsed the INPO accreditation program in March 1985, and issued a training rule in April 1993 that recognized industry's training and accreditation efforts. And the American Nuclear Society developed standards for training and qualification of nuclear plant personnel.

[P]rior to 1980, operator training was considered a minor function, and training staffs were poorly funded and inadequately staffed.

More specifically, she said, the industry systematized its training program; increased eligibility requirements for senior operators and operators; added training in heat transfer, fluid flow, and thermodynamics; increased training emphasis on reactor transients and on mitigating core damage; and toughened NRC licensing examinations. Finally, plant-specific simulator training became the norm for all operator training.

Changes in plant operations were addressed by Pete Sena, operations manager at Beaver Valley. "It's all about people these days," he said, and "managing people is tough."

Sena outlined the way an "effective organization" looks at operations. Among the highlights: an emphasis on people, and "ownership" by employees and unions of the tasks they are assigned to do; an emphasis on constantly improving performance; team benchmarking with other plants; and high expectations. For example, an effective organization looks at a "near miss" as a failure, and constantly reviews minor slips. A less effective organization, on the other hand, might look at a near miss as a success, because, after all, nothing bad happened.

At Beaver Valley, every job is briefed prior to the job and afterwards. Lessons learned are saved and incorporated into future procedures. "Peer checks" provide a second set of eyes for every action. Sena admitted that industry is split pretty much 50/50 on peer checks, but he feels that they serve a valuation function. "If you do it right the first time as a result of a peer check, ultimately your productivity goes up."

A dedication to following procedures is another important aspect of operations at Beaver Valley. "We have procedures for following procedures," Sena laughed. But by emphasizing procedures, he said, "operators stay in 'rule-based land,' and don't go into 'knowledge-based land.'"

Regulations and response

The accident brought a new world view to the NRC, noted David Matthews, director of the agency's Division of Regulatory Improvement Programs. In addition to a raft of new regulations, the accident brought about an increase in opportunities for the public to make their opinions known during the regulatory process. This provided a sea change in the utility world, where the prevailing attitude had been that it's best if no one knows about them. Even today, he said, some utilities still look at the public process as an intrusion, but the NRC is committed to the change.

One problem the NRC still faces is "connecting the dots" from previous experiences, because there are still roadblocks to data sharing. Can we use INPO experience or is it confidential? Some foreign countries may not want to share experience that might reflect badly on them. In many ways, Matthews said, we face the same problems as the many entities of the intelligence community—that is, whose data is it, anyway?

In subsequent discussion, Long mentioned one other area of improvement: emergency response. There was no such thing as an effective emergency response program when TMI happened, he said. In those pre-cell-phone days, there were no telephones for reporters to call in their stories (the only telephone was in the control room, Long commented, and it had been "off the hook" since the accident), no trained briefers, no equipment or supplies for briefers or reporters. "We had a trailer with no furniture, no pencils, no paper, nothing," Long said.

Today, 25 years later, the good performance of today's nuclear plants is testament to the effectiveness of the post-TMI improvements. But "continuous vigilance" is needed, Long cautioned. Indeed, he noted, things are not as good as you would like

them to be, and they are not in an improving trend. For example, significant events increased 40 percent in 2003; forced shutdowns during the first 10 days after a refueling outage have increased; and since 2000, there has been a 27 percent decrease in the number of plants in INPO's "excellent" category. And, Long concluded, the recent issue of the corroded reactor head at Davis-Besse proves that the industry must remain vigilant, and must never forget the lessons learned from this country's worst commercial nuclear accident.

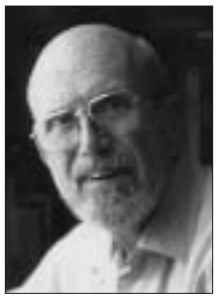
Realism: Set the record straight

In the ANS President's Special Session, *Realism in Evaluating Nuclear Hazards*, outgoing President Larry Foulke said that one of ANS's priorities is to be a source of credible information on science and technology. A critical issue that needs to be put right in this regard, he said, is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts. As members of this Society, Foulke said, "we have a responsibility to correct this."


Foulke

ANS, he added, "should take a leadership position" on this issue, and he added his hope that this session would mark a step along the way. The speakers, said Foulke, would be describing how conservatisms in the models, methods, and input have led to calculations predicting that there would be high levels of cancer fatalities and risk, and would show that these conservatisms and the results of the calculations have no basis in reality. Using conservative values and computer models that actually reflect reality, he noted, the numbers associated with consequences become ever so small.

The session was led by Ted Rockwell, who, at Foulke's request, has been heading up a group preparing a White Paper on this topic. Rockwell is currently vice president and founding officer of Radiation, Science & Health, Inc., an international public interest organization of independent radiation experts committed to bringing radiation policy into line with scientific data and theory.


Rockwell

Nuclear experts' attitude, Rockwell said, is that a major core accident would never be allowed to happen, because that would mean the end of nuclear power. It is something so unimaginable that there is no desire even to want to talk about it. In fact, a lot of work has been done to determine realistic scenarios of the release and dispersion of fission products and how the consequences are limited by the actual physical properties of the materials at hand. There is a good realistic story to tell, he said, based on facts, knowledge, and understanding.

Rockwell explained how this issue has come to a head. About two years ago, Nuclear Regulatory Commission Chairman Nils Diaz began addressing ANS and other organizations, saying that it is necessary to start using realistic figures. We cannot continue using extreme unrealistic assumptions. "Here is the chief watchdog telling us that we do not become safer going to extremes," said Rockwell, who added that Larry Foulke has taken on the challenge and is personally championing this issue.

A critical issue . . . is the discrepancy between the apocalyptic depiction of a nuclear accident and the demonstrated scientific facts.

Ian Wall, a consultant and the first speaker, was involved in the early work at EPRI on accidents and has contributed to the White Paper. He became involved in risk assessment in 1967 while working at General Electric. Upon joining the NRC in 1974, said Wall, one of his first jobs was to correct a serious error in the consequence model then used. He developed a new code that showed that the consequences were concentrated mainly near the plant, that there would be time to evacuate, and that the risks become very small at distances farther away from the plant. "The point," he said, "is that realistic models changed our perspective about offsite consequences."


Wall

By introducing realism, said Wall, WASH 1400 (known as the Rasmussen Report) also changed the perspective of what was important to reactor safety. Prior to WASH 1400, the consensus of experts was that the probability of core damage was infinitesimally small, while the consequences were very large. WASH 1400, he said, showed that the probability was larger than expected, but the consequences were tiny.

Prior to the accident at Three Mile Island-2, safety experts assumed that the iodine released would be elemental and gaseous and a large fraction would be discharged to the atmosphere. Under this premise, said Wall, the TMI accident sequence should have released millions of curies of iodine-131. It turned out that only a very small amount was released. The subsequent investigations identified mechanisms—such as nuclides being dissolved in water and plating out—that meant most were retained at the plant. This further changed the perspective of the consequences of reactor accidents.

During the 1980s, EPRI undertook work on accidents, which added more realism. Wall's part involved setting out a program of experiments to characterize and measure the retention of radioactive material within fuel, within the reactor system, and within the containment. This resulted in a tenfold reduction in the WASH 1400 source term.

In general, Wall said, a much better job is being done than before. He added that reactor designs should be conservative, but should be supported by probabilistic risk assessments that are as realistic as possible.

Realistic conservatism

Before introducing the next speaker, Rockwell explained another event that is driving this work. Recently, an antinuclear report analyzing a hypothetical fuel pool fire associated with a terrorist attack predicted thousands of radiation-induced deaths hundreds of miles away, and demanded that all such fuel be transferred to dry storage casks. The report was given to Congress, which asked the National Research Council to look into it. The authors said that they did not invent the numbers and the methods used: They were taken directly from reports prepared by Sandia National Laboratories and other nuclear laboratories. In fact, the NRC accepted this point, and to its credit took up the challenge, realizing that there is a wider issue here. In its testimony, the commission underlined that the type of analysis done here—the sort carried out over many years—is not relevant to the real world because the premises are too unrealistic. The NRC explained that the premises may have been right for scoping studies, when they were looking to bound a problem, but they are not right for predicting deaths.

The next speaker was Farouk Eltawila, director of the Division of Systems Analysis and Regulatory Effectiveness in the NRC's Office of Nuclear Regulatory Research. Eltawila began by defining "realistic conservatism," a term coined by NRC Chairman Diaz, who believes that public policy should not be based on the most con-

servative assumptions and extreme scenarios. Conservativism, he said, means employing a defense-in-depth strategy and ensuring there are adequate safety margins. Realism comes from using the best information you have from science, engineering, and operating experience.

Today, the commission has much better knowledge of phenomena such as fracture mechanics and aging, Eltawila explained. This helps reduce uncertainties, improve the quantification of safety margins, and provide a better understanding of the safety issues associated with accidents. This is helping the NRC move away from the use of the traditional deterministic conservative assumptions to calculate consequences, toward what he called "risk-informed realistic conservatism."

Regarding the issue of a spent fuel fire, Eltawila discussed NUREG-1738, a spent fuel pool analysis carried out in 1999–2000 by Sandia and Brookhaven national laboratories. This study was done for a specific purpose and used a great deal of conservatism. In fact, it assumed the worst possible scenario. In this case, he said, the analysis gave a very low risk, which the NRC said was acceptable. There was no reason to go further because the answer already provided the information needed to make a regulatory decision. The NRC understood the conservatism used, he noted, which involved assumptions that were not realistic or appropriate for making a decision regarding a terrorist attack—a situation where realism is needed. Unfortunately, he said, people have tried to extrapolate that type of information from a hypothetical accident to a terrorist attack and have come up with a huge number of cancer fatalities.

The NRC's latest review, said Eltawila, indicates that the pool's structure is very robust and the location of fuel in pools make them highly resistant to terrorist attack. A transient analysis has indicated that fuel is more easily cooled and the decay heat level is much lower than predicted in earlier studies. There are at least 24 hours from the time the pool empties of water and the start of fuel damage and the release of fission products.

Realism comes from using the best information you have from science, engineering, and operating experience.

The review, said Eltawila, shows that the demand for the transfer of spent fuel from the pool to dry casks at the cost of billions of dollars is not justified. He added that the NRC has identified a strategy for loading spent fuel into the pool that can substantially reduce cooling time of freshly discharged fuel, further reducing any consequences from an incident.

Rockwell commented that Eltawila and Diaz are owed a big vote of thanks for tackling this issue, and recognizing that although some try to characterize it differently, no one is trying to reduce safety. "Getting more realistic is not reducing safety, it is getting safer."

Transport realities

Ruth Weiner, senior staff scientist at Sandia National Laboratories and a member of the NRC's Advisory Committee on Nuclear Waste, described the arbitrary premises that produce large overestimates of radiation dose from a postulated radiological incident involving nuclear transport. Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials or ionizing radiation. This is not surprising, she said, given the extreme tests undertaken.

Weiner

Conservatism in transportation is used, she said, at four points: computer models; inputs to the model; interpretation of results; and the notion of the bounding case. This last one, she noted, implies that if we can show that nothing much happens in the worst possible case, then clearly the situation is not bad. These four conservatisms were used in NUREG-0170 (1970), the first environmental impact statement on transportation of radioactive material by air and other means. The NRC and utilities still use it, with advanced computer codes of course.

Since records on transportation incidents began, there have been only 90 cask accidents, none of which released radioactive materials.

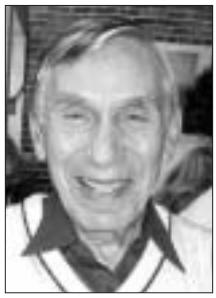
Weiner then described what real measurements do to a conservative model. To show this, she described the calculation of dose from an incident-free transportation operation. In this case, the truck is modeled by a sphere rolling down the road with dose measured at 1 meter from the surface. There are other conditions, such as that the truck stops every 100 miles for an inspection in a crowded urban area, and that no one moves. There was no validation done on this until a few years ago, she said, when a graduate student did some actual measurements at Hanford. It turned out that this model is extremely conservative.

"You give it stupid numbers," she said, "and it gives you stupid numbers back." The model never tells anything that it is not told first, she said, adding that opponents say they use the same models as those used by the experts and get tremendously high doses. The reason, Weiner explained, is that they start with tremendously high numbers.

The modeling of real accident situations is more complex, she said. Her colleagues at Sandia came up with NUREG-6672, which constructs 19 accident scenarios for trucks and 21 for rail. This gives much more realistic levels of doses of release than the previous NUREG, she noted, but is still excessively conservative.

The facts about buried HLW

Bernard Cohen, professor emeritus of Physics and Environmental and Occupational Health at the University of Pittsburgh, focused on the concerns of high-level waste (HLW) buried a half-mile underground. Cohen has authored many papers and several books on assessing nuclear power risks. For the purposes of his talk, he used rock as an analog for HLW—in its own form, encased or converted into glass or into another rock-type matrix known as "Synrock." He queried that if the HLW is buried a half-mile underground, why should this be dissolved out by groundwater any sooner than 2000 feet of rock above it? We understand natural rock, he said, and we ought to use this understanding.



Cohen

An example of not using what we know about rock was a study carried out about 20 years ago by the National Academy of Sciences (NAS) on HLW glass that presented

calculations of releases and health effects. It did not identify anything catastrophic. Going over this work, however, Cohen saw how totally unrealistic it was. Taking the method used by the NAS, the rock 2000 feet deep would dissolve at a rate of about 1 percent per year—so in other words, it would last only about 100 years. But it is well known that rock 2000 feet deep dissolves at a rate of about one ten-millionth of a percent per year and lasts about 1 billion years. In other words, they made an error of a factor of about 10 million. He showed other weaknesses in the NAS approach, and in the end, he observed that this report, hailed by the nuclear industry at the time, made all the mistakes that Ted Rockwell talked about.

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel.

Cohen also discussed the risk of cancer fatalities due to buried HLW generated from 100 nuclear plants, and compared it to the risks from coal-fired plants. The bottom line is that each of the three different types of waste released from coal burning—airborne pollution, chemical carcinogens in coal ash, and radioactive waste in coal (uranium, thorium, and radium, and the subsequent radon emissions)—cause 1000 times more deaths than HLW. Cohen added that the natural radioactivity in the ground above the waste from uranium and thorium provides 100 times more cancer doses than the waste.

Cohen also "unpicked" the picture that the antinuclear groups try to paint. For example, groundwater does not flow like a river; it is more like dampness seeping through the ground. At Yucca Mountain, groundwater moves at about 1 foot per year. He also noted that it would take groundwater at 2000 feet below the surface about 1000 years to get to the surface. Any radioactive material, however, would be held up by a number of processes, and would be expected to take 1000 times longer to get to the surface.

ANS White Paper

Rockwell concluded with some thoughts about the White Paper (ANS member input on the White Paper was being requested as of late June on the ANS Web site). The report, he stressed, is a working document designed to get the message clear as to what the realistic facts are about radiation hazards in the worst case and in the real situations people face.

He particularly wanted to "knock out" two false premises: that a severe accident would be the end of the world and that "one damn ray will kill you." As an example of the problem, he noted that when an incident occurs, such as the Davis-Besse problem, it is usually reported as almost a major accident, as if a small hole in the reactor would lead to thousands of deaths.

As for very low-dose radiation, Rockwell said that there is no real scientific basis for assuming it is harmful. In fact, he observed, there is considerable evidence that some radiation is beneficial. He noted that the goal is not to try to overturn the science on which their recommendations are based, and said that he believes that many of the advisory committees promoting the linear no-threshold concept have been remiss in their not examining, evaluating, and reporting on the massive amount of evidence on the beneficial effects of low-dose radiation.

Rockwell also challenged the idea that it is safer and more beneficial to assume that the world is different than it is. Putting some realism in place of "silly" premises does not represent a decrease in safety, he said. He was not talking about regulators' yielding to pressure from the industry to be less safe. If a most realistic assessment of the situation is made, "with conservative elbow room," then there will have been movement toward "safer, not less safe."

Fuel issues

The long-term success of the nuclear power industry and light-water reactors in particular is tied to the reliability of nuclear fuel, according to Ivan Maldonado, associate professor of Mechanical, Industrial and Nuclear Engineering at the University of Cincinnati.

The industry is increasing capacity factors and cycle lengths at the same time that power uprates are occurring. By many accounts, these factors "are conspiring to test the bounds of the performance and reliability of nuclear fuel," said Maldonado, organizer of the session on "Current Issues in LWR Nuclear Fuel Performance and Reliability."

Zero fuel defects should be that boundary of performance and reliability, suggested Bill Pierce, site vice president at Beaver Valley nuclear power plant, operated by FirstEnergy Nuclear Operating Company (FENOC). Beaver Valley has two Westinghouse pressurized water reactors. Unit 1 is rated at 821 MWe (net) and Unit 2 at 831 MWe (net). "We need to challenge the fuel vendors to continue robust fuel development," Pierce said. "We need to challenge the core designers to guard fuel margins. We have to challenge fuel handlers to protect fuel during movement. We need to challenge workers to prevent foreign material exclusion [FME]."

Pierce chastised the industry for not having a goal of zero fuel defects, and for its "lack of [having] a cohesive plan to achieve the things we need to achieve regarding fuel performance."

The industry, he continued, should get to a point where a defective fuel pin at a nuclear plant would be something that draws interest. "Today, we look at it as an accepted thing," he said. "If it happens, we feel like we're powerless to deal with it. We've got to get to a point where we see fuel defects as something we're not going to tolerate."

Underlying the zero-defect goal is a nontechnical issue, meaning that it's the general public that demands perfection from the nuclear industry. "I think the public domain that allows us to operate these plants expects us to have zero fuel defects," he said. "I just believe that it's bad business to have fuel leaks [because any minor nuclear blip is perceived by the public as a bad thing] and that [leaks] will be a problem for us as an industry."

The industry itself, of course, will have to foot the bill to support development of zero-defect fuel, he noted, but at the same time it is important to retain the low cost of fuel. "The heart of the electric industry using nuclear power for production is low fuel costs," he said. "Besides that one issue, we would not be competitive with other sources of electricity generation, because our base costs are higher."

FENOC operates three nuclear sites—Beaver Valley, in Shippingport, Pa.; Davis-Besse, an 873-MWe (net) Babcock & Wilcox PWR in Oak Harbor, Ohio; and Perry-1, a 1235-MWe (net) General Electric boiling water reactor in North Perry, Ohio. Combined, 66 percent of the FENOC plant's collective fuel failures have been caused by grid fretting, 28 percent by debris, and 6 percent through fabrication.

Countering Pierce's argument was Paul Edelmann, a fuels engineer for Constellation Energy's two-unit Nine Mile Point nuclear power plant, who noted that he would never expect fuel to be made entirely leak proof. "I don't think that's possible," he said. "I don't know how much more improvement you can design into fuel. But I do know from working at a BWR plant that there is a lot of room for improvement in control of plant


Edelmann

chemistry, and especially in foreign material exclusion."

He recounted a story from last spring, when Nine Mile Point-2, an 1148-MWe (net) General Electric BWR in Scriba, N.Y., was entering a refueling outage. Thirteen hundred workers were brought on site to work the outage. For most, it was their first experience at a nuclear plant. Their inexperience showed, he said, as illustrated by a pile of debris that collected on the refuel floor during the outage. "This became big news" within the plant, he said, because with the industry spending millions on FME programs, "somebody [at Nine Mile Point] was missing something."

Edelmann advised that strict adherence to good FME and chemistry practices, combined with safe rod pattern development and cycle operation, "can and should prevent BWR fuel from undergoing any failures, even with higher power demands and longer cycle duties."

A lesson learned at Nine Mile Point, he said, was that modern fuel designs will perform well when treated with care.

Identifying fuel leaks

Ed Price, a senior engineer for Duke Power, stated that Duke plants have been free of fuel leaks since 2001. Duke operates the two Catawba units, which are 1129-MWe (net) Westinghouse PWRs, in Clover, S.C.; the two McGuire units, which are 1100-MWe (net) Westinghouse PWRs, in Cornelius, N.C.; and the three Oconee units, which are 846-MWe (net) B&W PWRs, in Seneca, S.C.

The Catawba and McGuire plants switched in 2000 to Westinghouse robust fuel assemblies with zirconium cladding from the AREVA/Framatome ANP Mark-BW design, and Oconee switched in 2001 to AREVA/Framatome ANP Mark-B11 fuel with M5 cladding.

Price said that the whole process of identifying leakers, at least recently, has been akin to searching in the dark. "You expect when you have leakers to have iodine activity go up, but we've had many cycles with leakers with very low iodine activity," he said. "We've also had mysterious leaks at plants where we know we had leakers, but little or no spiking during transients."


Price

Once leakers were discovered at Duke plants, he said, there were problems in isolating the failed fuel assemblies. That's because ultrasonic testing (UT) has had "very poor reliability for us the past few years," he said. "Many overcalls, many cores that had leakers in them, did not show up on the UT."

As an example, Price explained a fuel-leak search at Catawba-1 from several years ago. The core showed a substantial increase in xenon-133, and a UT campaign was done that resulted in the identification of four suspect fuel rods. "We pulled the rods, but eddy current testing showed all the rods were sound," he said. "So, we did not find failures in any of these rods."

Price claimed that INPO's Fuel Reliability Indicator (FRI)—defined as the steady-state primary coolant iodine-131 activity (microcuries/gram), corrected for the tramp contribution and power level, and normalized to a common purification rate and average linear heat generation rate—is not a credible measure. A team is being put together, of which Price will be a member, to reevaluate FRI to come up with something "more realistic," he said.

A problem with today's FRI is that a core can have leakers with low iodine activities and low power defects, but still be under the FRI criteria for zero defects, he said.

With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good."

Price wondered what had happened to diagnostics over the past few years. Stretching back a decade or two, UT was considered 85 percent efficient. But over the past five years, "we haven't been able to find anything," he said. "It makes me wonder if now the threshold is so low for leakers that we're looking for things that, in the past [when the threshold was higher], we would see without paying much attention."

From the fuel manufacturers' side, Olga Correal-Price, a principal engineer for Westinghouse Electric Corp., noted that 25 percent of leakers are from unknown causes, and that the percentage is increasing. She stressed that finding the reason for those leakers is "today's challenge."

John Schardt, chief technologist of Global Nuclear Fuel, Ltd./General Electric Nuclear Energy, said that in the old days, thousands of fuel rods used to fail throughout the industry. Today, however, "we're talking about tens." With about 2 million fuel rods in place in operating reactors in the United States and only handfuls failing, "the reliability has been very, very good," he said.

Schardt declared that his company and probably every fuel manufacturer in existence has a "zero leak mentality." Every leaker "hurts everyone. It hurts our customers and it hurts the vendor. Each day that there is a leaker, we know about it that day," he said.

Schardt implied that people all the way up the management chain of command "hurt" when they learn about a leaker, because "most of us thought that by now we might have almost licked" the leaker problem. He added, "We don't know of a manufacturing defect that has caused a leaker in 10 years."

Roger Reynolds, director of Fuel Technologies and Reliability for Framatome ANP, Inc., followed up on Schardt's comments by declaring that "'Zero tolerance for failure' is the way we do our work."

Standards: A shift in philosophy

The ANS Standards Board has initiated work to revise many of its standards using risk-informed and performance-based concepts. This session, "A Movement Toward Risk-Informed, Performance-Based Standards: A Shift in Philosophy," explained chair Don Eggett, senior management and manager of business development for Automated Engineering Services Corp., was planned to look at the reasons for moving from conventional prescriptive standards to more performance-based and risk-informed standards, and how this is being implemented in ANS-sponsored standards. The movement to this new approach involves more than a shift in philosophy, he said. It reflects a more general shift in the attitude of industry to use these concepts to evaluate operation.

Standards, Eggett explained, can be performance-based or performance-based risk-informed, depending on what the needs are or what the focus will be. To distinguish these sometimes confusing concepts, the Board generated the following explanations:

On performance-based: Decide what the objective is to be then select a series of tasks, tests, etc., that will get you to the end point. Selection of the tasks is arbitrary based upon the particular situation and plant, and are not deterministic for every plant and situation.

On risk-informed (which can couple with performance-based): For each design basis accident or serious event, determine the risks to the public health and safety that the occurrence of the event will entail and then determine the mitigating events that are necessary to reduce public risk to a predetermined acceptable level.

Don Spellman, of Oak Ridge National Laboratory and chair of the ANS Nuclear

Facilities Standards Committee (one of four standards consensus committees), explained that the go-ahead was just made at the Board's last meeting and that this session is the first presentation of its observations and of some of the work being done. ANS often takes the initiative in this type of effort, Spellman said, where there is something industry needs to address. "And besides," he added, "we like the challenge." The Board will develop a set of criteria that explains how to create or revise a standard or convert it from prescriptive to performance-based.

Jim Mallay, director of regulatory affairs for Framatome ANP and chair of the ANS Standards Board, opened the session with a presentation on the benefits of moving from a prescriptive to a more performance-based standard. Most of the standards developed within ANS, said Mallay, are intended to either complement or positively influence current and planned regulatory expectations. In many cases, he noted, the NRC has asked ANS to develop standards on selected subjects, adding weight to any regulation that is based on those standards because the commission knows that industry has reached consensus that these are appropriate criteria and requirements.


Mallay

A particular feature of the standards groups, said Mallay, is that they provide the only forum for technical information to be exchanged freely among all parties, many of whom are in competition with each other or are regulated by the NRC, which is represented on nearly all of ANS's standards committees. And so, for Mallay, even if a working group is not successful in developing an approved standard, the fact that the people in the group have gotten together and communicated is a major benefit to them individually and to the industry.

Usually only a portion of a standard will be performance-based . . . as there will be many situations where prescriptive criteria are necessary.

Another interesting feature of standards that is rarely used in regulatory guidance documents, is the use of the verb "may," which denotes "permission." "May" allows the use of a technique at the user's discretion. This is an added value of standards, said Mallay, especially for those used to help interpret or complement regulatory documents.

Mallay explained the shift in approach as due in part to the needs of industry. During the last few years, there has been a significant decline in the demand for ANS standards. To some extent, this reflects the maturity of the industry (and the fact that no one is building plants). Nevertheless, the Board also had to consider whether it was really serving the interests of the users. In looking at that, said Mallay, the Board determined that maybe there were too many inefficiencies in the application of standards. Many were probably too prescriptive and inflexible, he noted, and therefore would not be used.

Unlike prescriptive requirements . . . the performance-based approach . . . ensures that the focus is on those things that are more important to safety.

So, the Board turned to techniques being advocated by the Nuclear Energy Institute (NEI) and the NRC—namely a performance-based, risk-informed approach. Mallay defined a performance-based requirement as a required design objective or operational behavior, including those attributes that are necessary to verify that the objective or behavior can be achieved. A performance-based standard, he said, is a standard that contains performance-based requirements together with measures that can be used to assess the degree to which the attributes can be achieved. These measures of success can be qualitative, quantitative, or some combination of the two.

Prescriptive requirements, Mallay added, have no flexibility and tell the user nothing about why the rule was established. Performance-based criteria tell you why—that is, makes the basis for a criterion explicit—and provides flexibility. But this does not work for all requirements. Usually only a portion of a standard will be performance-based, he said, as there will be many situations where prescriptive criteria are necessary. Standards based on performance-based criteria are also expected to have a longer life because the objectives, when stated properly, are not going to change as much as prescriptive requirements might. Furthermore, they allow revisions more readily.

Finally, said Mallay, performance-based requirements force people to work in "success space," not "failure space." One is never looking at a worst case, but at successful performance, where there are more opportunities.

Duke Energy, said Mallay, was recently allowed to establish performance-based criteria for the inspection and surveillance of the new steam generators being put into its Catawba plant. To deal with a number of outstanding safety issues raised by the NRC, the company proposed using a performance-based approach, which the NRC accepted. Mallay said he thinks that this is a milestone in this area.

According to Mallay, the first ANS performance-based standard (on the application of PRA for making risk-informed decisions on external events) came out about a year ago. He also noted that ANS has developed a draft standard for low-power and shutdown operating states, and plans to risk-inform its standards on design criteria for light-water reactors.

NRC pushing performance-based approach

Prasad Kadambi, of the NRC's Office of Nuclear Regulatory Research, has been active in pushing ANS toward performance-based standards. This approach, he said, accepts that nuclear activities are rather complex, with people, systems, and institutions all interacting for a common purpose. In this case, the common purpose is safety.


Kadambi

Regulations, he explained, deal with higher-level, more conceptual requirements, while standards address the lower level, the nuts and bolts of any activity. Traditionally, both have been prescriptive, Kadambi said, with requirements and instruction very specifically laid out. But recently, there has been a recognition of a need for change. In particular, said Kadambi, prescriptive requirements lack flexibility. They also have technological implications in that sometimes conditions are included in regulations that tend to freeze technology, particularly if there is

perception that there is only one way to comply with the regulation. This may inhibit technological creativity.

Things have been changing, he said. In 1993, Congress passed the Government Performance and Results Act. This legislation emphasizes outcomes rather than outputs; it makes agencies think whether they are doing the right kind of work, rather than just focusing on how well they are working. The legislation also requires agencies to develop strategic and performance plans so the public would know what ultimate results they are seeking to bring about. Another piece of legislation (Public Law 104-113) requires government agencies to think about consensus standards in lieu of regulatory requirements.

Kadambi noted that the NRC issued the first strategic plan (2000–2005) in 1999 and the second is now in preparation (2004–2009). It also issued a management directive explaining how staff can participate in standards activities. These direct the staff to consider performance-based approaches as appropriate. In addition, NRC staff issued NUREG-BR-0303, "Guidance for Performance-Based Regulation," in December 2002.

Kadambi asked the question: Why performance-based standards? Basically, he said that he believes that a new approach is needed, particularly if the nuclear industry does experience renewed growth. It is crucial, he declared, for working groups to have the flexibility to consider the best way to develop standards. They can consider using performance-based or prescriptive approaches as appropriate. This, he said, promises a more efficient development of standards once a learning curve is passed: It offers more effective application (particularly for new technology), more economical maintenance, and more equitable sharing of the burdens between standards developers and users. Performance-based standards should also last much longer. He commended ANS for this initiative.

Unlike prescriptive requirements, he added, the performance-based approach also ensures that the focus is on those things that are more important to safety, ensuring that resources are applied where they are most effective.

Over the last six or seven years Neil Brown, of Lawrence Livermore National Laboratory, has been involved at the working group level on a set of standards related to seismic design of nuclear facilities. It was only toward the end of the process, he said, that the performance-based concept was taken on board.

These new standards, not yet completed, will replace an original set developed by the Department of Energy for its nuclear facilities, Brown said. During a revision, the parties involved agreed to convert these to approved national standards. The DOE standards concerned natural phenomena hazards (NPH)—that is, seismic, wind, and floods. They start by categorizing certain structures, systems, and components (SSC), and then develop prescriptive rules about how a design should address these three natural phenomena. The original standards had risk goals set in terms of probabilities of safety consequences, doses, and failures.

The safety community, Brown said, even in the seismic area, is not eager to go to a fully risk-informed standard in the sense that the ability to estimate probabilities of failures of SSC and to relate those to a dose consequence, and so forth, is still limited. The DOE standards are risk-goal based—that is, they have clearly stated risk goals—and the SSC categorization is based on a specific set of risk goals. He said, however, that the participants could not agree on the desired risk goals for the new standard. Brown explained that agreement was eventually reached on using a magnitude of "unmitigated" consequence of a failure as opposed to failure probability to define the categories. And so, the categorization of an SSC was determined by the unmitigated consequence of its failure, not on the basis of risks.

The final presentation was by Paul Fishbeck, professor of Social and Decision Sciences, and Engineering and Public Policy, at Carnegie Mellon University, and director of the university's Center for the Study and Improvement of Regulation. He provided his experience from other fields where risk-informed and performance-related rules and standards are applied. Performance-based standards work well, he said, when you can actually measure performance. For example, consider how much pollution comes out of a smoke stack. In fact, he said, that can be measured, and criteria set. Penalties, such as withholding payments, can be applied if the criteria are not met.

Other areas being discussed, however, involve long-term, rare events, where performance is difficult to measure, Fishbeck said. If you are talking about fire safety, for example, how do you measure that a building is fire safe? What criteria do you use to base the performance of, for example, a sprinkler system? Is it the amount of water coming out in a certain time period?

A prescriptive standard, he noted, says: Use this, put it here, make it this big. These things can be checked very easily, he observed, but performance-based standards are much more complex.

He then raised the question of uncertainty. A prescriptive standard almost ignores uncertainty. Using a performance-based standard is to admit that there is uncertainty out there.

Fishbeck presented some examples to show how complex the area of standards can be. As other speakers had done before him, he recognized that the work leads to useful discussions among all interests and develops a lot of understanding along the way. There are methodologies that allow you to address these concerns, "but [they are] not for free."

Water desalination

Over the next two decades, there will be a 40 percent increase in water use around the world, according to the International Atomic Energy Agency (IAEA), and 33 percent of the world's population—about 2 billion people—will be in absolute water scarcity by the year 2025.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases. The fact is that there isn't enough fresh water on the planet. The session, "The Use of Nuclear Energy for Desalination," explained nuclear's role as an economical power source for methods of water desalination—two of which are distillation and reverse osmosis (RO)—that have high-energy consumption requirements and high hot-water production costs.

Currently, 1.2 billion people lack access to potable water, and 2 million per year will die due to water-related diseases.

The IAEA defines nuclear desalination as the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy for the desalination process. The facility may be used solely for the production of potable water, or dually for the generation of electricity and the production of potable water, in which case only a portion of the reactor's energy output would be used for water production. In either case, a nuclear desalination plant is defined as an integrated facility in which both the reactor and the desalination system are located on a common site and energy is produced on site for use in the desalination system.

Small and medium reactors are important for desalination because the countries most in need of fresh water often have limited industrial infrastructures and electricity grids, explained Akira Omoto, director of the IAEA's Nuclear Power Division. Smaller

reactors, he said, also are "more appropriate for remote areas" unsuitable for connections to the grid.

Omoto noted that nuclear power plants around the world have long been used for water desalination. For example, Kazakhstan's BN-350, a liquid metal–cooled fast-breeder reactor that operated until 1999, was used to produce electricity and heat for desalination (approximately 80 000 m^3 of water per day) for 27 years. And, currently, Pakistan's Kanupp has a small RO facility in operation and is building another desalination demonstration plant on site to be commissioned in 2005. Meanwhile, India's Kalpakkam has an experimental facility in operation and another under commissioning that is expected to process 6300 m^3/day.


Omoto

Expanding nuclear's role in the world's desalination process will include four challenges, he noted. First is economics, of course, where the target for desalinating water is \$0.40 to \$0.60/m^3. Next is public understanding. Then comes the issue of disparity, meaning that nations having water scarcity may not be holders of nuclear technology. Finally, in what is not directly a nuclear issue, infrastructure for distributing desalinated water is necessary.

Roger Humphries, president of Canadian desalinating company Candesal, said that a message not heard enough is that water shortages are quite often localized. In Indonesia, for example, rain falls almost every day during the rainy season. "But the issue is a point of mal-distribution," he said. "The water is not where the people are. It's not accessible because it cannot be collected and captured." He added that Indonesia's city of Jakarta and its surrounding rain forests have some of the lowest availabilities of safe, fresh water per person of any place in the world.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing.

As the world has a shortage of fresh water, a growing problem is that salinity levels of fresh-water aquifers are increasing. "As we draw fresh water out of sources that are nonrenewable, they get replaced by salt water," he said. "So, we're finding what used to be fresh water [in] a lot of aquifers [now has] a salinity level reaching 1000, 2000, 2300 ppm, basically making it unsafe to drink."

Desalination solves problems in that, politically, it keeps nations from "stealing" water from one another, and, environmentally, because it's a "friendly" way for creating new sources of potable water, as no fossil fuels are burned in the process, Humphries said.

Si-Hwan Kim, director of the SMART R&D Center of the Korea Atomic Energy Research Institute, explained South Korea's plan for a SMART desalination plant. SMART stands for System-integrated Modular Advanced ReacTor. The plant, which is under construction and is expected to be in operation in 2008, will produce both electricity (90 MWe) and potable water (40 000 tons/day).

Ron Faibish, project manager for nuclear desalination at Argonne National Laboratory, said that potable water issues exist here at home in the United States. "Drought conditions now in the Southwest have increased dramatically," he said. News reports have claimed that the drought in the West is the worst in 400 years. "We have big challenges in the U.S.," he added, "and they're not just focused in the West. We have issues in the East as well, and on the Texas coast."

Population growth along coastal Southern California, Texas, and Florida has been on the order of 20 percent in the past decade, and for the country as a whole, 60.6 billion additional m^3 of potable water per year will be needed by 2020 for municipal and light industrial uses.

The U.S. Bureau of Reclamation, together with Sandia National Laboratories, has developed a roadmap for desalination in the United States, he said. Published in 2003, the roadmap declares that by 2020, desalination and water purification technologies will contribute to ensuring a "safe, sustainable, affordable and adequate" water supply to the United States. "These words are important," he said. "The terms affordable and adequate—those are the ones I think have to be first in term of securing the future of the technology."

The roadmap's 2008 objective, he said, is for desalination technologies to realize a 20 percent improvement in capital costs, operating costs, and energy efficiency. By 2020, improvement in those areas needs to reach 80 percent.

Those goals are ambitious because today the cost of treating water in the United States using a conventional (chemical) treatment is about \$0.10/m^3. In Southern California, reclaimed water from industry costs about \$0.60/m^3. Brackish water desalination is between \$0.26 and \$0.79/m^3. For seawater desalination (the biggest operation, in Tampa Bay, Fla., currently is suffering problems, Faibish said), the forecast is \$0.55 cents/m^3.

Sump clogging is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors.

An "interesting factoid," he said, is that desalination in the United States could cost \$0.79/m^3 (\$3 per thousand gallons). "That seems expensive, but the U.S. consumer is paying an average of \$2099 per cubic meter for bottled water. When you put this into perspective, [desalination] seems rather cheap," he said.

The latest on sump clogging

At the panel session "Hot topics and emergent issues: Containment sump clogging," session chair and organizer Steve Stamm, of The Shaw Group, opened with an explanation of why sump clogging was billed as a "hot topic." Sump clogging, he said, is something that boiling water reactors had experienced that has now become an important issue for pressurized water reactors. This session, he said, would cover the problem's background, describe the methodology that is being used to resolve it, and present some of the plant activities and potential modifications being introduced.

Mike Marshall, lead project manager on the issue at the Nuclear Regulatory Commission, began with an overview of the topic and the status of work on PWR sump performance. According to Marshall, the NRC's primary concern is that the sump screen is doing its job too well. The purpose of the screen is to keep debris from damaging pumps or blocking spray nozzles and other components downstream. Retaining debris smaller than the system is designed to, he explained, results in excessive head

loss that can affect operation of the pumps. This is the same concern that the NRC had with boiling water reactors.

There are also some secondary concerns, such as the downstream effects of debris getting past the screen, that might have an impact on pump operations or accumulate enough to affect cooling of fuel. These are not the primary concerns, but the NRC wants them taken into account when solutions are considered or when evaluating the adequacy of existing designs. But most of the effort has been focused on head loss at the screen and whether it affects operations.

Because of the variation in the materials at individual plants, as well as the differences in the containment and layout of screens, the NRC agrees with industry that this is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action. One thing that is becoming clear is that the existing license base for a number of plants is probably insufficient and will need changing.

Marshall explained that unlike BWRs, it appears unlikely that every PWR is going to have to implement a fix. But each operator will have to evaluate the situation and decide if there is a problem that needs resolving, either procedurally or by a hardware modification or some other means. The evaluations will include: identifying the different debris sources, particularly those that would likely cause some clogging; estimating the amount of debris generated; estimating the amount of debris transported to the sump screen; and estimating what the head loss impact would be.

This issue first came up in the early 1980s, when the Advisory Committee on Reactor Safeguards became interested to see if air injection would have an impact on the operation of the emergency core cooling system (ECCS) pumps. The question of debris came up later. Research undertaken between 1980 and 1985 did not identify a particular problem. While the NRC could see some benefits in preventing entrainment, they were insufficient for action to be taken. In 1985, however, it recommended that new plants and plants undergoing material changes—such as of insulation—consider the issue and provided some regulatory guidance.

In 1992, an event occurred at the Barsebäck BWR in Sweden, where the NRC's 1985 guidance had been adopted. Based on this, the plant had assumed that the ECCS system would operate for a day or two before the strainers (screens) became clogged. The incident occurred when water was released into the drywell, taking a lot of insulation with it. The clogging occurred not within a day, but within an hour or two of the activation of the emergency systems. This was communicated to other regulators, and investigations ensued that identified weaknesses with the guidance and the underpinning research. This started a new run of research around the world on sump issues.

The focus at first was on BWRs because there were three similar events in U.S. plants, although not on the scale of Barsebäck. It eventually became clear that although clogging would occur sooner in BWRs than in PWRs, the weaknesses were common to both reactor types. New work undertaken identified weaknesses in the previous correlations. In particular, the fiberglass insulation debris was more like "cotton candy" shreds than the "slices of cake" that were used in the old research. The shreds produce much greater head loss. Furthermore, the fiberglass acted as a filter, capturing small items that had been expected to pass through the screen, adding to the head loss.

All the BWR stations introduced a combination of fixes. These included minimizing debris sources, cleaning the suppression pools, and increasing the surface area of the sump strainers.

Soon after completing the work on the BWRs, work on the PWRs started. From a parametric study, the NRC staff concluded that there was enough of a concern to warrant individual plant evaluations. NRC has been working with the Nuclear Energy Institute (NEI) since about 2000 on developing a suitable methodology.

[T]his is not a problem where one solution fits all. Each plant will have to assess the situation and decide on appropriate action.

The next speaker was John Butler, senior project manager at NEI, which has completed guidance for carrying out a sump performance evaluation that is now being reviewed by the NRC. The guidance will help operators evaluate the situation at their plants regarding debris generation, transport, and accumulation on the screens and whether there is adequate net positive suction head (NPSH) margin available for ECCS recirculation. This effort, said Butler, is primarily funded by the Westinghouse Owners Group and coordinated by the NEI PWR Sump Performance Task Force.

A draft sump performance evaluation guidance document was given to NRC staff in October 2003, and the final version was submitted on May 28, just a couple of weeks before the ANS Annual Meeting. The review process should be completed by this fall, with final approval expected in October.

The end result of the evaluation guidance is to determine the adequacy of the NPSH margin, Butler said. The calculation is complicated by the large number of phenomena and uncertainties that need to be addressed. These include:

- Size and location of a postulated break. Location is probably more important than size regarding the potential debris generated.
- Debris generation (quantity, types, size, distribution). The orientation of the break affects what debris is going to be generated. Besides calculating the amount, it is necessary to determine the size distribution of the debris, which affects its transportability.
- Debris transport and holdup. The "transport media" is a combination of debris, the containment spray, and washdown, all of which determine the amount that collects at the sump.
- Debris deposition on screen and resulting head loss. The resulting head loss is highly dependent on the types of debris deposited.

The guidance addresses the uncertainties and complexities in a traditional conservative fashion. "It is a balancing act," Butler said. "I think I can say we have a conservative methodology that is not *too* conservative."

He then described the basic evaluation methodology, which starts with a baseline analysis, a conservative first step in the evaluation. Some plants can go through the baseline and find that they have adequate NPSH margin and can stop at that point. A number of others will find that they do not have adequate NPSH margin, and will have to continue the evaluation process by refining the analysis in one or two ways: refine their analytical methods to take out some of the conservatism, or modify their design, which may involve removing potential debris sources, changeout of insulation (which contributes most debris), or modifying their screen design. The process continues until an adequate NPSH is achieved.

NEI is now working with the NRC to try to introduce a risk-informed option in the methodology, acknowledging that the large double-ended break, which would generate the most debris, sump blockage, and head loss, is a very low-frequency event. A risk-informed option would allow more meaningful breaks and conditions to be applied to assess sump performance. The details of such an option are now being discussed with NRC staff.

Continued

Sump performance evaluation methodology

More details on using the evaluation methodology were given by Tim Andreychek, of Westinghouse Electric Company. Andreycheck has been working on the issue for the last seven years, and is the lead author of the NEI PWR post-accident sump performance document. The purpose of the methodology, he explained, is to provide a consistent approach for utilities to perform a conservative evaluation of their containment sump performance post-accident. Analytical refinements are also identified to provide options for removing some of the conservatisms.

The "baseline," said Andreychek, starts with plant specific information—basically a scoping study or a first shot to see if there is something to worry about. If the results are acceptable, the issue can be closed out. If not, the methodology provides a guide as to how to proceed. This involves further analysis and reanalysis, with possible design modifications. The process continues until NPSH requirements are satisfied.

Andreychek provided an example of a "baseline analysis" that took a very conservative line. Regarding break size, the baseline assumes a double-ended guillotine break. For the break location, he determined the maximum debris generation and the worst combination of debris to create the biggest head loss. To determine debris generation, a zone of influence (ZOI)—a region around the break where the destruction of insulation and other materials occurs—was defined. His baseline calculation assumed an unrestrained jet stream from the break, which destroys the insulation, forming debris.

[S]ome plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

Latent or resident debris (the dust and dirt that collects) is not considered a major contributor, Andreychek said, but has to be accounted for. The baseline methodology provides an easy-to-use estimate of the contribution. He mentioned, however, that some plants power wash parts of their containment, which, although done primarily for radiological purposes, also reduces the amount of latent debris.

The head loss correlation being used, based on a NUREG document, is a semi-empirical correlation and provides for a conservative pressure-drop calculation. The effects of debris composition and material properties are accounted for in the calculation. Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it. This, he noted, was a particularly bad situation for BWRs, causing big pressure drops.

Andreychek also went into various analytical refinements to the baseline evaluation. By replacing the conservatism with more realistic conditions, the amount of debris generated can be reduced, its transportability lessened, and the accumulation and blockage of the sump screens can be decreased, leading to a better NPSH margin.

Andreychek described the "thin bed" effect, in which a fibrous debris covers the screens and captures particulates behind it.

Kenneth Ainger, licensing manager at Exelon Nuclear, is responsible for licensing activities at the Byron, Braidwood, and Three Mile Island-1 nuclear stations. He provided an operator's perspective on this issue, describing the evaluations that he will be performing, some interim measures, and potential enhancements being considered to fully resolve the issue, if necessary.

Ainger's description of the different sump/screen configurations at three plants provided insight into the real problems that operators have with this issue. For example, both Byron and Braidwood have two sumps that are enveloped by an outer screen. Overall, there are three screens that protect the suction lines to the ECCS and containment spray system. The outer screen encloses the middle and inner screens for both sumps. The outer screen extends about 4 feet above the floor of the containment, and the inner screen is installed below the containment floor inside each sump.

As for potential debris sources, the main containment insulation at Byron and Braidwood is reflective metal insulation. When the steam generators at Byron-1 and Braidwood-1 were replaced, their insulation and that of the associated piping were replaced with fiberglass blankets, covered with stainless steel sheathing. The TMI-1 containment has about 600 ft^3 of fibrous insulation. Ainger also pointed out the problem of unqualified equipment coatings—for example, the coatings on valve handles and reactor coolant pump housings—as possible debris. The baseline evaluations will look at the reflective metal insulation, fibrous insulation, coatings, tags, labels, and foreign material. All of these potential debris sources will be examined in light of the four transport mechanisms: blowdown transport; washdown transport; pool fill transport; and recirculation transport.

For the sump screens, the initial evaluation for Byron and Braidwood indicates no concerns regarding structural integrity or excessive blockage. Byron-1 and Braidwood-1, however, may not pass the evaluation in light of the fiberglass insulation used on the replacement steam generators. This might require an additional engineering analysis. With the performance of ZOI evaluations at the plants, Ainger noted, a risk-informed approach would probably provide benefits if it is used to assess the consequences of the occurrence of a break at the steam generator nozzles of the two reactors described above.

For TMI-1, the adequacy of the sump design may not pass the new evaluation, and so some design change to the sump or to the areas along the path to the sump may have to be considered. Enhancements could include modifications to the floor to help direct debris or prevent some pooling of water. These have not yet been scoped, but could be significant.

Ainger said that several interim measures have been implemented to ensure the working of the ECCS while pursuing the long-term resolution of the issue. The loss of recirculation capability has been addressed at Byron and Braidwood in the emergency procedures. Additional training for operators has been provided, including simulator training. The company has strengthened the foreign material exclusion and walkdown procedures for the containment, and has enhanced the refueling outage surveillance procedure for visual examination of the sump screens. For TMI-1, the B&W Owners Group guidelines for sump blockage were implemented and training in ECCS pump throttling criteria was provided to avoid damage in the early stages of potential sump blockage. New procedures for cleaning and inspecting drains inside the containment have been implemented. The existing refueling outage inspection procedures for the sump screen were determined to be adequate.

Ainger said that they are also looking at removing the fibrous insulation associated with the replacement steam generators.

Regarding costs, Ainger estimated that at Byron and Braidwood, Exelon will spend about $3 million over four years to pay for all the evaluations, including additional engineering analyses, licensing submittals and responses to the NRC Generic Letter (*NN*, May 2004, p. 15), and some insulation modifications. For TMI-1, the estimate is high, at about $4.5 million over four years, as some extensive modifications inside the containment seem likely.

Safety culture

During the Tuesday afternoon "Safety Culture" session, Joe Carson, a licensed professional engineer and a nuclear safety engineer for the Department of Energy, observed that ANS's bylaws, which he said have remained constant since the beginning of the Society 50 years ago, should be revised. The bylaws, he noted, "[don't] reflect that ANS holds a public trust when developing standards of care for its members."


Carson

Carson, a former member of the ANS Special Committee on Ethics, stressed that he wanted to see ANS as "an organization that is flexible, responsive to members, and capable of dealing with change."

Change is necessary, he said, because ANS has evolved since its creation a half-century ago. "Fifty years ago," he said, "I don't think ANS held a public trust, but I think it does now today."

Examples of that public trust include ANS's role in accrediting engineering schools for nuclear engineering, and its work in developing codes and standards that are adopted internationally. ANS, then, has "an important role with nuclear science and technology in public policy," he said.

Carson, who described himself as an "eight-time prevailing" DOE whistleblower (as detailed on his Web site, <www.carsonversusdoe.com>), noted that the words "ethics" and "peaceful" and the phrase "promote the professional interests of its members" are absent from ANS's bylaws. And although the word "safety" is included in ANS's goals, the bylaws do not include "any form of the word 'safe,'" he said.

Carson suggested that ANS modify its bylaws, mission statement, and goals to more clearly capture its identity as a professional society. He also called for all nuclear engineers to be licensed by states, something that is a "distinguishing characteristic" of members of such professions as medicine, accounting, and architecture. "Engineers, by and large, are not licensed," he said. "Well, why not?"

ANS's new code

Vic Uotinen, chairman of the ANS Special Committee on Ethics for 2003–2004, remarked that ANS does have a new Code of Ethics, replacing an earlier code dating back to 1973, which was altered somewhat in 1984. The new code, which was adopted by the ANS Board of Directors in 2003, is more specific and comprehensive than the earlier version, and it "reflects the expectation of a more conscious commitment to professional ethics by ANS members," he said.

The new code [of ethics] . . . "reflects the expectation of a more conscious commitment to professional ethics by ANS members."

The new code also is at the same level as the ethics codes of several other engineering societies, such as the American Society of Mechanical Engineers, American Institute of Chemical Engineers, Society of Civil Engineers, and IEEE. "I think it's important for us to realize that all of these engineering societies, by upgrading their codes of ethics, were in essence sending a signal to their constituencies that we, as professional societies, consider professional ethics to be important, and that we consider upholding this higher code of ethics, this higher standard, to be a true mark of professionalism," he said.


Uotinen

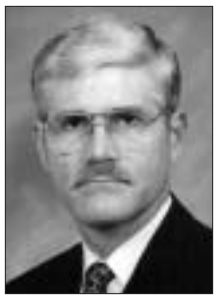
Uotinen gave examples of how the new code is an upgrade over the older version. The old code, for instance, said, "An ANS member shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties," while the new code says much more: "We hold paramount the safety, health, and welfare of the public and fellow workers to protect the environment and to strive to comply with the principles of sustainable development in the performance of our professional duties." It also adds a new paragraph: "We will formally advise our employers, clients, or any appropriate authority and, if warranted, consider further disclosure, if and when we perceive that pursuit of our professional duties might have adverse consequences for the present or future public and fellow worker health and safety or his environment."

Another example is in the area of acting in accordance with applicable laws and practices. Whereas the old code didn't mention this area at all, the new code says, "We act in accordance with all applicable laws and these practices, lend support to others who strive to do likewise, and report violations to appropriate authorities."

Ethics and competency

Ethics and competency are interrelated, remarked Dwight Baker, who was making a presentation for the absent William Corcoran, of Nuclear Safety Review Concepts. Baker said that if anybody at Davis-Besse had operated according to the ANS Code of Ethics, the vessel head degradation could have been prevented from becoming so severe. "You can certainly say that if you saw [the signs of degradation, such as piles of rust that collected on a flange] and ignored it, if you were the manager who would have signed off saying 'We don't need to work on that,' if you were the outage manager who shut down [a vessel head cleanup job prior to the degradation's discovery], maybe then there should be an ethics complaint filed," said Baker, of Cumberland Consulting. "But I'd put a dollar to a donut that those people are not ANS members."

Baker said that in many cases where workers "behave badly at the technical level, those technical people are neither professional engineers nor ANS members, with no requirement that they be." Further, he said, in "about 99 percent" of the cases where a nuclear professional should be punished for ethical misbehavior, the management personnel who would make those decisions are not ANS members.


Baker

As long as there is no requirement that an engineer be licensed, society will think "we're just computer programmers, and we really don't affect their health and safety," he said. Without that public pressure, there will be no incentive for companies to hire licensed engineers, or have existing staff attain licensing. Without licensing, there will be no living up to a code of ethics. "It's really a public education job, to impose a licensure requirement just like for doctors and lawyers," he said.

Continued

Baker said short of requiring licensing, which is "really a big piece of work, and I don't know if it's doable," one way that a plant can attain higher overall quality is to provide long-term financial incentives to company executives. "Think about it," he said. "Having the plant run well in the long term is in the stockholders' interest. So, there may actually be a strategy that is doable, from the business organization side of it."

A case in point is that some ANS members are utility executives with access to compensation committees. These executives, he said, may "have some good ideas on how to structure stock options that are only exercisable seven years from now." *—E. Michael Blake, Dick Kovan, Rick Michal, and Nancy Zacha*

TOPICAL MEETING

Advances in Nuclear Power Plants (ICAPP 2004)

- *South Korea aims for large H output by 2020*
- *European utilities judge next-stage reactors*
- *MIT study on nuclear role in carbon-constrained world*

As the world's nuclear energy nations have come into greater agreement on nuclear power's medium- to long-term future—the development of "Generation IV" reactor designs, the coupling of these designs to hydrogen production, and the opportunity for actinide burning to extend fuel resources, deter proliferation, and reduce radwaste generation—many of the speakers at the 2004 International Congress on Advances in Nuclear Power Plants (ICAPP 2004) agreed in their presentations to such an extent that some of them apologized for repeating what others had already said. ICAPP 2004—which this year was embedded as a topical meeting in the ANS Annual Meeting in Pittsburgh (June 13–17)—included five plenary sessions, and despite the organizers' attempt to give each session its own unique theme, some overlap was unavoidable.

Whether there will be enough trained professionals in place if there is a sudden demand for new nuclear power was much on the minds of several speakers. Andy White, of General Electric Nuclear Energy, told a plenary session audience that 40 percent of GE's employees in nuclear fields are within five years of retirement age. He called for an industry-wide focus on development of a larger talent pool of nuclear expertise. The next speaker, Russ Bell of the Nuclear Energy Institute, also included the aging nuclear workforce as one of the main challenges facing the industry now (and not just in the future). The other challenges, in Bell's view: keeping fuel economical and reliably supplied; managing materials at aging facilities; securing nuclear facilities (Bell said they were safe before 9/11, and are safer now, but this is a very high-profile public issue); and providing spent fuel disposal. Bell acknowledged the problem that had arisen with high-level waste funding, in which the Bush administration had expected to use money from the Nuclear Waste Fund but Congress had not authorized it (see page 113, this issue), but said that the Department of Energy, "with industry support, is pursuing legislation" to assure adequate funding for the proposed high-level waste repository at Yucca Mountain, Nev., in the FY 2005 federal budget.

Later in that session, Peter Lyons, of the Senate Committee for Energy and Natural Resources staff, spoke more pointedly about the Yucca Mountain funding situation. He said that the way the administration presented the bill, with only $131 million to be appropriated in the FY 2005 budget and $749 million presumed to be available from the Nuclear Waste Fund, created "an immense problem," and led to only the $131 million being approved for Yucca Mountain, nowhere near enough for the DOE to remain on schedule to open the repository in 2010. Lyons also said that the entire FY 2005 budget request was "an immense surprise" to the committee, leading to concern that nuclear research and development could be undermined, and that the reformulation of the Idaho National Laboratory might not be given a "focus for success."

At the second plenary, Steve Melancon, of Entergy Corporation, echoed the concern about Yucca Mountain, and the extent to which the future of new power reactors in the United States depends on resolution of the high-level waste issue. "Yucca Mountain needs to become a reality," he said, "or I don't think any new nuclear plants will be built." Also during his address, Melancon recounted the formation of NuStart Corporation (an industry consortium seeking Department of Energy matching funds to apply for site approval, design certification, and licensing of new power reactors), but departed somewhat in his personal views from the procedure announced thus far for NuStart, in which approval would be sought from the Nuclear Regulatory Commission for two sites, as well as certification for two reactor designs, but ultimately the construction/operating license (COL) would be sought for a single reactor design at one site. Melancon said NuStart should choose *at least* one plant for the COL; he would like to see enough money made available to pursue both designs, and both sites.

With the meeting taking place in the United States, and with so many recent developments in the U.S. nuclear realm, the above topics and more like them drew a great deal of attention during the meeting, but ICAPP is indeed an international event, and speakers from most of the world's large nuclear power programs reported on numerous technical and programmatic developments. Their reports, like those from the U.S., ranged from improvements on existing reactors to the many first steps being taken toward the goal of Generation IV.

South Korea's vision

Next year's ICAPP will be held in Seoul, South Korea, and there was a substantial Korean presence at this ICAPP, both to pre-

sent papers and to promote the event in 2005. A table outside the topical's largest meeting room was stacked with brochures on travel to Korea. The viewgraphs of three of the five Korean speakers at the plenary sessions had bands at the bottom reading: "See you in 2005, ICAPP Seoul!"

During the first plenary, Joong-Jae Lee, of Korea Hydro and Nuclear Power, traced the development of nuclear power in South Korea, which is now sixth in the world in both installed nuclear capacity and annual nuclear power generation. He said that in some countries where nuclear power has been accepted for some time, "challenges and new issues are growing" (which could describe the emergence of public opposition to nuclear in both South Korea and Taiwan), and there is a need for breakthroughs in technology and cooperation within the nuclear community. With 14 of South Korea's 18 power reactors achieving 2003 capacity factors above 90 percent, and the other four over 80 percent, Lee asserted that outstanding performance is the best way to respond to nuclear controversy. As for technology breakthroughs, Lee described the APR 1400 pressurized water reactor being developed in Korea to supplement and eventually replace the current generation of reactors; work has begun on the first APR 1400, Shin-Kori-3, scheduled to begin operation in 2011.

South Korea . . . has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances.

At the second plenary, Dong-Su Kim, of Korea Power Engineering Company, described the evolution of the APR 1400, the latest step in the development of the nuclear industry in South Korea—which has progressed over the past three decades from turnkey projects through technology transfer to indigenous advances. He said that the current social environment (alluded to by Lee) "requires unlimited safety" and "faultless and eventless operations." He added that in South Korea, as in the United States, there is concern about the future supply of trained personnel, as students are tending not to pursue engineering. The belief that public acceptance can exist only with perfect operation drew a comment from the audience by Ted Rockwell, former technical director of the U.S. Naval Reactors Program. He said that one cannot convince the public that there will never be an accident, because one cannot reasonably make such a claim. He advised that one should take the position that the effects of any accident would be mitigated, and rebut the argument that exposure to any amount of radiation is dangerous.

Chung-Won Cho, of South Korea's Ministry of Science and Technology, extended his country's nuclear program into the future during the third plenary, citing its proposal for the System-integrated Modular Advanced Reactor (SMART), for both electricity production and seawater desalination, and participation thus far in Generation IV projects. SMART is intended as a PWR with the steam generator included in the reactor vessel, offering enhanced safety, economics, and environmental advantages. For Generation IV and beyond, Cho's projections were extremely ambitious, anticipating a "waste-free and pollution-free" nuclear fuel cycle with consumption of all actinides, and a timetable whereby South Korea would switch from fossil fuel to hydrogen so quickly that nuclear energy would produce 20 percent of the needed hydrogen by 2020. Questioned about this goal by an audience member, Cho said that a 16-year program is now starting, aiming at development of small-scale modular gas-cooled reactors, but that wider application was still under discussion, and the 20 percent goal should not be taken as a firm commitment.

Jong-Hwa Chang, of the Korea Atomic Energy Research Institute (KAERI), elaborated further on the 20 percent hydrogen goal in his address at the fifth plenary. One-fifth of the expected vehicle fuel demand in South Korea in 2020 would require 8.5 billion barrels of oil per year, which could be replaced by 3.3 million tons of hydrogen. KAERI's anticipated demo nuclear plant (a very high temperature gas-cooled reactor, or VHTR) would produce about 30 000 tons of hydrogen per year, so at least 100 plants of this capability would be needed to meet the hydrogen goal. At the same time, Chang said that security concerns in South Korea—which still has a hostile neighbor to the north—argue against distributed nuclear-hydrogen facilities, because of the potential for sabotage. Therefore, the reactors—more than 100—would be concentrated at a small number of sites that could be guarded well.

New scheme in Europe

The lull in power reactor ordering in Europe has not been as long as that in the United States, and with a new order placed in Finland and another on the way in France, it can be said that the lull is in fact over. Still, plenty has changed in the decade or so that elapsed, with moves toward the opening of electricity markets and attempts to normalize regulation. The old paradigm of a state-owned electric utility ordering the only design available from a state-owned manufacturer is eroding, and one indication of this is the development of European Utility Requirements (EUR) documents, which essentially tell manufacturers what the utilities want, need, and expect from power plant hardware and services.

Gianfranco Saiu, of the Italian firm Ansaldo, described the EUR process while presenting a technical paper on the EUR assessment of the Westinghouse AP1000 reactor design. The EUR effort began in 1991, with five utilities; six others joined later. Along with expressing what the utilities wanted, the documents provide bases for harmonization of safety approaches and targets, design standardization and objectives, equipment specifications and standards, and information for safety, reliability, and cost assessment. In 1997, the effort enlarged so that each document included a Volume 3, which compared a specific reactor design against the requirements. (Volume 1 includes nuclear island requirements, and Volume 2 covers balance-of-plant.)

Development of a Volume 3 for the AP1000 was based on previous work on advanced Westinghouse designs. Saui noted, however, that while the utilities' team was at work on this volume (the process can take years), Westinghouse moved on from the design. Saiu said that although the AP1000 was driven by U.S. market considerations, it had incorporated lessons from EUR work on earlier designs, including a low-boron core. As things stand now, the AP1000 is slightly out of compliance with EUR, both in technical areas (the cooldown time is longer than what the EUR prefers) and in semantics (whether it is preferable to state that radiation exposures *shall be* as low as reasonably achievable, or *are* as low as reasonably achievable). There will be more meetings intended to resolve the differences.

Pierre Berbey, of Electricité de France, spoke at greater length on the EUR's place in the evolving power generation environment in Europe. Even with efforts like EUR intended to normalize agreement on basic principles of safety and operation, the differing regulatory schemes of individual countries can work against standardization and increase costs. Berbey said that there should be common "rules of the game." He noted that the Western European Nuclear Regulator's Association is working to define reference safety approaches that could become common to all nuclear power nations in Europe. Berbey also noted a number of non-nuclear challenges now faced by electricity organizations in Europe, such as the synchroniza-

tion of the western European transmission grid with bordering nations like Poland and Romania. In the end, Berbey said that the EUR effort will try to deliver documents supporting four to six standard reactor designs; along with AP1000, EUR is also doing Volume 3 work on the AES92, an advanced version of the Russian VVER water-cooled reactor.

A carbon-constrained world?

During the fifth and final plenary, Ernest Moniz, of Massachusetts Institute of Technology (MIT)—who described himself as neither pro- nor anti-nuclear—presented results from a 2003 MIT study on what might happen if there is a significant worldwide adoption of new nuclear power. (The study, headed by Moniz and John Deutch, is posted online at <web.mit.edu/nuclearpower/>.) The study looked at the presence of a terawatt of nuclear capacity in place by 2050 (for comparison, the current worldwide nuclear capacity is less than half a terawatt). Moniz said this does not seem possible without the emergence of a "game changer" that would make nuclear the preferred choice for decision makers and the public. He said that global warming appears to be the strongest candidate to be the game changer. He said that if the only way to prevent a self-reinforcing rise in the greenhouse effect is to make this a "carbon-constrained world" by reducing carbon dioxide emissions, nuclear power and all other nonemissive options would be needed, and may not be enough.


Moniz

Moniz said that a new, nonamortized nuclear plant with no federally backed financing cannot currently compete with coal- and gas-fired generation (with CO_2 not taken into account). Not only must plant capital cost be reduced, but a series of plants would have to be built on budget and schedule to show that financial risk is not excessive. The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

If the world is carbon-constrained, Moniz said, the obligation to reduce emissions would fall hard on the power industry. Manufacturers that emit CO_2 can be moved offshore—in an observation specific to Pittsburgh, he noted that Alcoa is moving all aluminum production to Trinidad—but power plants must remain connected to the home nation's grid. Moniz added later that there will likely emerge a formal "cap-and-trade" system of incentives for carbon emission, started by the power industry in return for a rational, stable system of federal oversight.

Moniz said that even if the openly established "fuel cycle states" have 80 percent of the expected nuclear generating capacity, that would leave 200 gigawatts in other nations, raising nonproliferation concerns. Incentives to prevent rogue states from developing independent nuclear capability would have to include not only assured fuel supplies, but also spent fuel removal, which means resolution of high-level waste problems worldwide. Moniz said that it would be necessary for spent fuel to be stored for 50 to 75 years, despite what he termed the industry's "religion" of fuel cycle closure. He noted that the expected carbon emission mitigation cost for fossil generation would be at least $50 per ton of carbon, or $8 per megawatt-hour, which is far more than all expected fuel and waste costs for nuclear—so carbon constraint can become an incentive for nuclear, in full compliance with the Non-Proliferation Treaty.

Although the MIT study looked at a large addition of nuclear power extending to mid-century, Moniz was dubious of a major prospect used recently to argue in favor of advanced nuclear power: hydrogen production. He said that significant use of hydrogen as a fossil-fuel substitute "may be decades away at a minimum . . . we're all getting carried away" on hydrogen's likelihood of displacing oil use. He advised the audience not to lose sight of the scale of what would have to be done (as had been shown in the Korean presentations reported above). He called hydrogen "intrinsically inferior" to petroleum, and said that nuclear power should continue to be presented as an electricity option, with no attempt to oversell hydrogen.

The MIT study concluded that there would have to be tax incentives for the "first movers," who ordered roughly the first 10 reactors.

Other presentations

There were occasional moments at ICAPP 2004 when it seemed that two U.S. reactor designs—Westinghouse's AP1000, and General Electric's ESBWR—were being compared to one another. These are the designs chosen by NuStart for certification, and (despite Steve Melancon's position) apparent competition. Thus, fairly or otherwise, the designs are now seen as linked, and in a race that would end with one being the preferred choice and the other at least having to wait. Atam Rao, of GE, in his presentation to the second plenary on ESBWR, described this reactor as having a capability of 1550 MWe (the AP1000 is currently rated at 1117 MWe), and said that it will use components similar to those already being made for the ABWRs coming into service. He admitted, however, that the ESBWR is not as far along as the AP1000, which he said is "two years ahead of us" in the design completion and NRC certification processes.


Rao

In a session on the Very High Temperature Reactor (VHTR), which is the principal Generation IV design being pursued in the United States, Phil McDonald, of the Idaho National Engineering and Environment Laboratory, reported on a point design study that compared pebble bed core design to the "block" design, with fuel and moderator in parallel vertical blocks. He said that he would not choose one over the other, but concluded that fuel cycle costs would appear to be lower for pebble bed than for blocks. In the next paper, Yasushi Muto, of Tokyo Institute of Technology—working from different design assumptions—found that a cooling system that allowed for horizontal as well as vertical flow could help reduce some of the drawbacks associated with pebble bed cores. This flow pattern offers a 2 percent improvement in thermal efficiency and 5 percent less core pressure drop, allowing the maximum fuel temperature to be as low as 1110 °C.

Perhaps the most inopportune turn of phrase at the meeting came from Norbert Frischauf, of the European Space Agency's (ESA) European Space Technology Center, who chaired the session on nuclear power and propulsion systems, and opened it with remarks on European perspectives on the topic. After concluding that Europe should work on materials and other support issues, and decide later whether ESA should enter reactor development, he said that it was necessary to "go back to the classroom" to educate the public on nuclear materials used in spacecraft—to actively provide information, "and not let it fall down from the sky." Whether a nuclear spacecraft would fall down from the sky is, of course, exactly what the public would worry about.—*E. Michael Blake* NN