ANS WINTER MEETING

Nuclear power in the 21st century

There was good news about nuclear power at the ANS Winter Meeting in Long Beach, Calif., as the industry prepared for the turn of the millennium.

NUCLEAR IS STARTING to be seriously discussed at the global warming conferences, said ANS President Andy Kadak at the opening plenary of the ANS Winter Meeting, held November 14–18 in Long Beach, Calif. This may indeed be progress compared with the earlier total lack of recognition of the role of nuclear power in reducing greenhouse gas emissions. A notable lack of mention of nuclear, however, was still evident in the official resolutions that came out of a rather indecisive COP5 meeting in Bonn, Germany, just before the ANS meeting (*NN,* Dec. 1999, pp. 18 and 55). Kadak mentioned other efforts of the industry and the Society to open up communications on nuclear issues such as Yucca Mountain, reconsideration of low-level radiation limits, rethinking of policy on the recycling of used fuel, and development of fourth-generation nuclear plants, which would help to establish the sustainability of the nuclear energy option.

Kadak

Senator Larry Craig (R., Idaho), while acknowledging that nuclear power was the "silent partner in clean air compliance," was also fairly upbeat about the prospects for nuclear power in the new millennium. He certainly considered that news of the demise of the nuclear industry was greatly exaggerated. With more than 100 plants supplying 20 percent of the country's electricity and recognition that most plants can operate for their full 60-year potential, there is still a lot of life left in the nuclear industry, he said. Research funding, however, will be critical to get a new generation of young engineers enthused about the next generation of nuclear power plants, he noted.

Nuclear waste, Craig said, was "only frustrating to those who want to make it so." In comparison with the environmental impact of other sources of energy, nuclear waste is a "tremendous story to tell," he said. But responding to a question about market forces, Craig said that he was extremely cautious about deregulation of the markets because the "marketplace does not have the wisdom of looking over the horizon."

Craig

Nils Diaz, a commissioner on the Nuclear Regulatory Commission, noted that 16 of the 31 states in the United States had already decided to deregulate electricity. Times have certainly changed, he said, and "could go good or could go bad." Citing a Mexican proverb, he said, "When the river is turbulent the fishermen benefit."

The good news from the massive restructuring of the electric utility industry was that stranded costs are now almost nonexistent, and operators of the existing nuclear plants have shown that safety and competitive costs are compatible, Diaz observed. But for the competitiveness of new plants, he said he did not believe that the nuclear industry was going to get a level playing field anytime soon. For the near future, the nuclear industry is going to have to be better than the competition, Diaz declared. From the regulatory point of view, he added, the most important development will be the adoption of risk-informed regulation so that spending can be better focused on real safety issues. He urged utilities to complete the development of functional probabilistic risk assessments and the training of operators to use them. "One avoided shutdown will pay for it," he said.

Diaz

Risk-informed regulation was a topic that recurred at several sessions of the meeting,

where it was seen as a glimmer of hope for a more cost-effective approach to licensing of future nuclear plants. It is one of the projects of the Department of Energy's Nuclear Energy Research Initiative (NERI), which was mentioned by Melanie Kenderdine, of the DOE, as one of the areas where government funding is providing some support for the nuclear industry.


Kenderdine

Apart from NERI, which Kenderdine said had so far received only $5 million of funding, the other main area of DOE energy research and development that seems to be moving ahead is a six-year, $800-million program to support the development of a technology road map for the accelerator transmutation of waste, which is described in more detail later in this report. Kenderdine thought that it could complement the proposals for a geologic waste repository.

In the absence of anything more down to earth in the way of nuclear energy R&D, the plenary session organizer chairman Harold Ray included a final paper to encourage a little futuristic stargazing. Veteran astronaut Franklin Chang-Diaz reported enthusiastically on the progress of the National Aeronautic and Space Administration's development program for ion propulsion systems that could eventually open up the possibility of a manned flight to Mars. For the benefit of his nuclear audience, Chang-Diaz stressed that it would be an absolute necessity to have nuclear reactors to provide the tens of megawatts of power to drive the ion propulsion engines on an eventual manned mission. But for the flight demonstration of a small prototype engine using hydrogen propellant—which he said was now ready to go—the power requirements of 10 to 15 kWe will be provided by two large, 12-meter-long solar panels.


Chang-Diaz

In the colorful visuals of a conceptual manned spacecraft, which were presumably drafted for wider public dissemination, little prominence was given to two small nuclear reactors that would be mounted on long extending arms. Development work on suitable reactors is apparently being carried out at Los Alamos National Laboratory, together with a system of heat pipes, which would deliver power to thermoelectric generators. These generators would power lightweight superconducting magnets for ionization and acceleration of hydrogen propellant.

Fourth-generation reactor?

The ANS President's Special Session on fourth-generation reactors at this year's Winter Meeting was devoted to the ever popular pastime at nuclear conferences of discussing new conceptual designs of reactors—or perhaps old ones revived. The session was tinged with plenty of realism about the need for a next-generation reactor to be truly competitive even on a less-than-level playing field with other sources of energy. But it took retired GE executive Bert Wolfe, speaking from the floor, to remind the meeting that the industry had been here before. Back in 1959, he said, what was then the Atomic Energy Commission produced a list of 11 reactor designs that were thought to have a chance of making it commercially. At the top of the list was the organic-cooled reactor, which, surprisingly, does not seem to have been rediscovered in the latest batch of next-generation reactors. Wolfe urged everyone to think very carefully before abandoning the huge amount of effort and money that has gone into the very successful development of today's light-water reactors.

Bill Magwood, director of the U.S. Department of Energy's Office of Nuclear Energy, Science and Technology, sought to define what was meant by generation-4 reactors. Generation-1 were the reactors of the late 1950s that first demonstrated the possibilities of commercial production of electricity from nuclear power. Generation-2 are the reactors that are now successfully generating electricity around the world. Generation-3 are the new advanced and evolutionary light-water reactors that were designed for the 1990s, but, Magwood said, the target for which they were designed unfortunately has been largely bypassed, at least in the United States. These reactors are still very attractive and expected to do quite well in parts of the world such as Asia, but for the United States, Magwood thought that "something new will have to happen" before there is large-scale reordering of nuclear power plants. That is the motivation behind the present consideration of a new generation-4 reactor, which, he said, would have to address the issues of economics, proliferation, safety and waste.


Magwood

A favorite at recent international conferences has been the South African concept of a modular high-temperature gas-cooled reactor—known as the Pebble Bed Modular Reactor (PBMR). This is certainly nothing new, deriving as it does from the small pebble bed reactor developed and successfully operated for many years in Germany in the 1960s and 1970s.

But a breath of fresh air was provided by David Nicols, from South Africa's Eskom. He was enthusiastic, but still very down to earth, about the prospects for this reactor in the special market situation in South Africa, and considered that if it is successful there, it might have considerable potential in other countries, both developed and developing.

Although he is a former nuclear submariner from the United Kingdom, Nicols maintains that he was rather skeptical about nuclear options when Eskom embarked upon a wide-ranging study of its future generating plant requirements. He explained that the generating cost has to be seen against the 1.3 ¢/kWh that Eskom is presently paying for electricity from a string of 11 standardized 4000-MWe coal-fired plants sitting on top of coal mines around Johannesburg. It was accepted that new generating capacity would cost more, especially when located some 1400 km away on the southern coast, to serve the growing demand around Cape Town, but the target for the studies was still set at a challenging 1.5 ¢/kWh. The conceptual design of the Pebble Bed Modular Reactor (PBMR), which has now been completed, comes in at 1.43 ¢/kWh.

Details of the PBMR have been widely reported in the past year, but highlights from the table of plant parameters for a 114-MWe net module include: a capital cost of about $100 million per module; a 40-year plant lifetime; on-load fuel cycling; general overhauls of 30 days every 72 months; a construction period of 24 months; and an operational staff level of 80 for a 10-module site.


Nicols

Nicols said that the main reason for the low capital cost was the "walk-away" safety features of the reactor design. With conventional light-water reactors, he claimed that about 75 percent of the cost was related to the provision of a safety system. Also, the ability to give an unqualified "no" in answer to the question "Can the nuclear plant have an accident which could affect the public?" gives a major boost to public acceptance.

On the inevitable waste question, the design concept adopts the relatively simple solution of diverting the spherical fuel elements—once they have reached a very high burnup—directly to storage containers in a basement below each module. Sufficient capacity for all the spent fuel from 40 years of operation will be provided, and when the reactor modules are decommissioned, the spent fuel will be left in the storage basements for a further 40-year cooling period, by which time it should be suitable for placing in a final repository.

Nicols outlined the current status of the PBMR project. A submission to the licensing authorities in 1998 and an environmental impact assessment started in 1999 are expected to lead to decisions on the licensability of the plant at a proposed site by March 2000. If favorable, detailed design work could commence in July, followed by a final investment decision from Eskom in October. Construction work could then start in January 2001, leading to a start of non-nuclear hot functional testing in mid-2003, criticality in mid-2004, and power operation by December 2004.

The other speakers indicated that plenty of work is still continuing on other nuclear options for the future. An academic perspective of some of the options was provided by Mujid Kazimi, a professor at the Massachusetts Institute of Technology. He mentioned renewed interest in LWRs with epithermal neutron spectra, allowing the seed-blanket fuel approach to proliferation-resistant burning of plutonium and utilization of the thorium fuel cycle. And he dared to speculate on the reemergence of fast neutron spectra in future reactors.

Reviewing work being carried out under the DOE's Nuclear Energy Research Initiative (NERI), George Davis, of ABB Combustion Engineering, echoed the views of many of those present when he said, "In a deregulated market place, if you are not economic you are dead." He identified reduction of capital costs as the primary objective—saying that there is not much margin for further reduction of fuel and O&M costs below the level of 1 ¢/kWh now being achieved at operating plants. He was looking for a reduction of at least 35 percent in capital costs for new plants, or an overnight capital cost of $1000/kWe, and construction schedules of three years or less. Some ideas of what might help to achieve these reductions included: redefining regulatory and design bases, using a risk-informed approach; introducing advanced, computer-based technologies into plant designs; and utilizing advanced, computer-based technologies in processes for design, fabrication, procurement, and construction.

Davis

Who is going to build a fourth-generation nuclear plant? The electric utility industry, of course, and most likely one of the large nuclear generators that are emerging from recent mergers and acquisitions within the utility industry. The final speaker in the President's Special Session provided a reality test. Ward Sproat, director of strategic programs at PECO Nuclear, titled his paper, "So you want to build a nuke?" with the subtitle, "If it can't make money, forget it!" He went on to outline some of the challenging requirements that will have to be met, including a target generation cost of less than 3 ¢/kWh; licensing certainty with a one-stop process and clear risk-informed regulatory requirements; a capacity factor greater than 85 percent, with 24-month refueling cycles, load following capability, and a 60-year operating life; inherent safety features to tolerate operator errors and equipment failures; high-integrity fuel and a fully developed probabilistic safety assessment that shows significant risk reduction from current-generation nuclear plants.

Sproat also emphasized the importance of maintainability. He said that maintenance requirements should be fully integrated into the design; on-line maintenance should be the norm; manpower for surveillance testing should be minimized; and in-service test requirements should be risk-informed.

The Tokaimura accident

The Technical Program Chair's Special Session about the criticality accident in a uranium conversion plant at Tokaimura, Japan, and the emergency response, provided detailed facutal information on the September 30 incident. The Japanese speakers, two from the Japan Atomic Energy Research Institute (JAERI) and one from the Japan Atomic Industrial Forum (JAIF) were apologetic about the accident, which they said was "inexcusable," "really regrettable," and "shocking to us in Japan."

They gave a full and frank description of the event and its consequences, generally confirming the facts as reported in *Nuclear News* (Nov. 1999, p. 42). Additional information, mainly related to the amount of fission that took place during the criticality, has been reconstructed from samples taken from the vessel in which the event occurred and from measurements of neutron activation of a stainless steel cooler on the outside wall of the plant. Also provided was additional information on the radiation doses received by workers and members of the public, which generally confirms that apart from the three workers who were exposed to very high doses of radiation, others received only low doses which are very unlikely to have any adverse health effects.

And extensive monitoring programs have confirmed that radioactive contamination was very slight and almost entirely confined to the plant.

Kunihisa Soda, Deputy Director of JAERI's Tokai research center, which is 6 km away from the JCO plant, gave some more exact details of the unauthorized procedures of dissolving U_3O_8 powder in nitric acid in a stainless steel bucket before transferring it to the precipitation vessel in which the criticality occurred. He said that on the previous days, September 28 and 29, seven batches containing a total of 9.6 kg of the 18.5 percent enriched uranium had been transferred to the vessel. On September 30, three workers were involved in transferring a final three batches, each containing 2.4 kg of uranium. A beaker was actually being used to transfer the last batch from the bucket to the precipitation vessel, and all but 0.2 kg of the batch had been transferred when the criticality occurred. This means that the total uranium in the vessel would have been around 16.6 kg with an estimated concentration of 370 g(U)/liter.


Soda

Soda showed what he said was the only continuous measurement of neutrons, from the beginning to the end of the event, which had been obtained from two JAERI monitoring posts located 2 km west of the JCO plant. These clearly show an initial peak lasting a few seconds followed by a long, more or less steady reading for the following 19 hours and 40 minutes until the reaction in the vessel was finally stopped by draining water from a surrounding cooling jacket.

From samples removed hastily from the vessel on October 28, two independent teams came up with a figure of 2.5×10^{18} for the total number of fissions that had occurred during the criticality. Subsequent activation analysis of steel in surrounding pipework yielded a figure of 2.4×10^{18}. Soda said that he considered that they had a very reliable figure for the total number of fission neutrons. Reconstructing the time profile of the neutron emissions with the help of associated gamma measurement, it appears that 1.3×10^{18} neutrons were emitted during the plateau period of 19-plus hours, which suggests that 1.2×10^{18} neutrons were emitted in a first power transient of a few seconds.

Shohei Kato, the head of JAERI's radiation risk laboratory, summarized the results from environmental monitoring and dose reconstruction programs. The latest figures for dose reconstruction of the three severely exposed workers are approximately 9000, 5000, and 1000 mGy.

Among some 124 other persons on or near the site, 36 workers had doses detected on personal dosimeters and 22 from film badge measurement. Twenty-one workers engaged in the operation to drain water from the cooling jacket around the precipitation vessel recorded doses in the range 0.05 to 120 mSv, and six more workers involved in feeding boric acid into the vessel recorded 0.03 to 0.61 mSv. Another 56 workers around the site are estimated to have received whole body doses in the range 0.1 to 23 mGy.

Three Tokaimura firemen who came to the site and escorted the three severely injured workers to the hospital underwent whole body monitoring and were estimated to have received doses in the range 0.5 to 4.1 mGy. Seven scaffolding workers on a construction site near the fence closest to the accident were also found, from whole body monitoring, to have received estimated doses between 0.5 and 9.4 mGy.


Kato

Looks like global warming is for real

The year 1998 was the warmest in the past decade; it was the warmest since instrumented records began some 120 years ago; it was almost certainly the warmest year of the last six or seven centuries, and likely the warmest in the last thousand years. And it looks as if 1999 is going to be up there with 1998. "So it seems that there is little doubt that global warming is occurring," concluded Johnathan Overpeck, a leading paleoclimatologist who spoke at the opening session of a Special Symposium on Global Warming that was incorporated into the ANS Winter Meeting.

Although Overpeck and other speakers at the session were presenting a lot of new results from numerous scientific studies and highlighting the unprecedented increase of around 0.7 °C in average global temperatures in the past century and the very dramatic increase of 7 °C in the last 10 years, the most interesting feature of the presentations was the reconstruction of climate conditions over many thousands of years—which is what paleoclimatology is all about. This relies on analyzing tree rings, core samples from the center of ancient corals, the ice layers of glaciers and core samples from the polar ice caps, and other data. It is possible to reconstruct likely temperatures and trace gases in the atmosphere going back many thousands of years. It is also possible to validate the analytical models from the overlap of those data with data recorded by humans over the past century or so.

"The nice thing about this field is that there is a lot of exchange and all the data and different views are available on the Web," Overpeck said, as he presented what seemed to be a very comprehensive picture of global temperature variations. The variability is very apparent, and several dramatic changes in climate can be identified with different forcing factors, such as periods of exceptional volcanic activity. The variations due to small orbital changes of the Earth around the Sun can also be clearly seen and are now very predictable. The correlation of temperature variations with CO_2 and other greenhouse gases also looks to be very convincing. "One message that we can take back," Overpeck said, "is that this century [he was speaking before the end of 1999] and particularly the last couple of decades is almost without doubt the warmest that we have seen for the last several centuries, particularly the last thousand years."

The important question is what portion of the recent temperature increases is due to natural variability, how much might be due to other natural forcing effects, and how much is due to human activities since the start of the industrial revolution. The speakers at the session indicated that they had been prepared to look closely at the various conflicting arguments, but increasingly they supported a consensus view that only 0.2 °C of the 0.6–0.7 °C rise in mean temperature over the past century could be attributable to natural forcing effects. At least two-thirds is believed to be due to the greenhouse effect resulting from man-made emissions.

It would be a concern if there were also some natural variability coming into play, "because it could produce some even nastier surprises," Overpeck said. One of the nasty surprises that attracted some serious discussion was the possibility of melting Arctic ice diluting the salty water at the northern extremity of the Gulf Stream, thereby preventing its sinking to the deep ocean return currents—the so-called conveyor belt. This could halt or reverse the Gulf Stream almost overnight, which would have a devastating effect on the climate of northern Europe.

Environmental costs

A recent study released by an arm of the Department of Energy has forecast that nuclear power will wither as an energy source in the United States within 20 years (*NN,* Dec. 1999, p. 55). The void created by its absence, according to the report, will be largely filled by the increased use of coal and natural gas, with no restrictions on carbon emissions coming from those fossil-burning plants. Not all DOE employees agree with that prediction, termed "antinuclear" by Madeline Feltus, assistant director of the DOE's Office of Nuclear Energy, Science and Technology (NEST). "We have a constant battle with our Energy Information Agency [EIA—the agency that produced the study] within the DOE," said Feltus. "They're the ones we have to set straight."

Feltus, a panelist at the "Accounting for Environmental Costs in the Production of Electrical Energy" session, said that the environmental cost advantages of nuclear were not accounted for in the EIA study. Its problem—and the problem of a similar study produced by five national labs, she added—is that it assumes fossil fuel energy production will increase without any changes in the economic basis. Feltus considers that unrealistic.

To provide a more likely forecast, NEST commissioned two energy studies of its own. The first, produced in 1999 by Oak Ridge National Laboratory, uses capital and operating costs to look to the year 2020 for electricity

generation. Its objective is "to evaluate a few possible scenarios: A change in gas prices, real inflation, and a carbon tax strategy," Feltus said.

Seven scenarios are considered in the Oak Ridge study, including a reference case, a gas-price escalation case, and one for reducing nuclear's capital costs. Each scenario measures the amount of carbon-emission tax that would have to be levied on fossil units in order for nuclear to be economically competitive in the future. In most of the seven scenarios, fossil units would have to be taxed between $50 and $80 per metric ton of carbon emission. However, Feltus said if gas prices increased just slightly over the next 20 years, nuclear would need a tax of only about $8 per metric ton of carbon emissions to compete.


Feltus

The best-case scenario for nuclear, according to Feltus, would be if gas prices increased slightly *and* nuclear plants reduced their capital costs by 10 percent. "Then a carbon tax wouldn't be necessary at all for nuclear to compete," she said.

All seven scenarios in the Oak Ridge study are based on the following configurations: The nuclear plant is an Nth of its kind advanced light-water reactor, at 1300 megawatts, needing no more than six years to build and license. (In explaining the construction period of this new plant, Feltus said, "A new nuclear power plant will not be built in the U.S. *unless* it takes less than six years."); the coal plant has three pressurized fluidized bed combustion units, each at 400 MWe, with a construction time of four years; and the gas plant is a combined cycle turbine, four units, each at 300 MWe, built in 2 ¾ years.

The second NEST study, done by Brookhaven National Laboratory and as yet unpublished as of the date of the session, looks at four scenarios. The first scenario is the EIA base case, or the "antinuclear scenario" as Feltus called it, with no restriction on carbon emissions from fossil plants. It assumes that the existing nuclear power plants in the United States continue to operate without any license renewal and that no plants are built. In this scenario, by 2025, nuclear holds about a five percent share of the nation's electricity generation.

At the other end of the spectrum is the pronuclear scenario, what the study calls the "nuclear option with stabilization" case, in which current nuclear plants are permitted to operate through their current licenses, license renewals are allowed, and new reactors are built if their prices are competitive. In this scenario, CO_2 stabilization is in place, meaning emissions for the United States cannot exceed 1990 levels by the year 2010 and beyond. Here, nuclear holds about a 65 percent share of the nation's electricity generation.

The bottom line of the Brookhaven study, Feltus summarized, is that without new nuclear power plants and license renewal, fossil units will spew about 750 million metric tons of carbon into the atmosphere per year by 2025, as opposed to the roughly 500 million metric tons that are released today. But under the "nuclear option with stabilization" scenario, emissions will be cut to just more than 150 million tons by 2025. "The main thing here," she concluded, "is that if we stabilized our CO_2 emissions with nuclear, we can allow our demand growth to grow by a factor of 1.4 by 2025. And if we stabilize our CO_2 emissions with nuclear, we can still allow coal to play a role in electricity production."

Speaking on coal's role in the coming decades was Nader Mansour, manager of Departmental Regulations for Southern California Edison Company. SCE owns shares in four coal-fired units: Two are located at the southern tip of Nevada, and two are at the northwest corner of New Mexico.


Mansour

Mansour opened his talk by stating what most would consider as obvious: "Coal is going to continue to be a player in the energy mix in the United States." But, he added, even for those in the coal business, the statement is not as obvious

as it seems. According to U.S. Environmental Protection Agency projections, Mansour said, coal generation will rise to about 2 million GWhs by 2005 before starting a slow decline between the 2005 and 2010 period. Because of having to comply with upcoming governmental regulations as early as 2008, he said, environmental costs for coal producers will be expensive. The regulations will deal with controlling NO_x emissions, CO_2 greenhouse gas emissions, Mercury and toxic emissions, thermal discharge in water, and disposal of solid wastes such as fly ash and scrubber waste. Those regulations, when implemented, will be a "nightmare" for most coal producers, he said.

How expensive will new controls be for coal-power producers? "You're looking at scrubbers, for instance, at [a cost of] about $200 per kW," Mansour said. "If you're looking at NO_x control, maybe somewhere in the neighborhood of $40–$100 a kW, depending on what kind of control you use."

For now, what the coal industry is doing is moving from high-sulfur coal to low-sulfur coal, with the sulfur content dropping by about 20 percent. "That seems to be the strategy of choice to meet the sulfur restrictions that the EPA has imposed," Mansour said.

The coal industry has also started investigating carbon sequestration through a reforestation project, through which trees would consume CO_2. "I've seen estimates about what that might cost, ranging from $25 a ton," Mansour said. "The idea would be to purchase a plot of land in a locale that is sufficient to sustain a forest, replant it, and make sure nobody cuts down the trees. You'd have to make sure the wood never burned, never decayed. That's part of the weakness of the strategy."

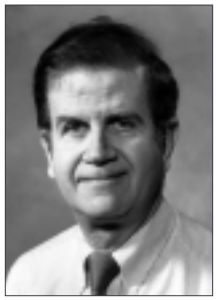
Another weakness of reforestation, according to Mansour, is that he is unsure if it would be sufficient to stabilize CO_2 levels, "let alone achieve the reduced levels sought at Kyoto. So even if it worked as a strategy, you'd still have to figure out something else for the CO_2, if indeed the claims about global warming are valid," he said.

The DOE, added Feltus, is spending "lots of money" on carbon sequestration, "much more than they're putting into nuclear energy." One possible DOE research project involves taking the effluent from coal plants and piping it under the ocean or into salt domes. "You listen to this and ask yourself, 'Where are they going to get the energy to do this?'" she questioned. Feltus said the cost would be $40 million to research it and $200 million to demonstrate it. But the bottom line, she said, was that taking carbon and pumping it underneath the ocean would cause a huge wave in the environmental community. "If you don't think there's going to be a big environmental outcry from that, you're mistaken," she concluded. "I cannot see people in Texas advocating taking carbon and NO_x gas and pumping it several hundred miles underneath the Gulf Sea and expecting it to be environmentally safe."

Moving on to coal's competition from other energy producers, Mansour said he didn't see coal and gas as competing for the same market. "Gas combined cycle is going to continue to peak their market by and large," he said. "They will not ever be able to get into $16 or $12 a megawatt-hour." He added that nuclear would be coal's main competitor because "I don't think [nuclear is] going to be able to compete with the combined cycle. I think at the present price of gas turbines, you can run gas turbines at 80–90 percent and they will beat coal and nuclear right now. So I think in terms of the current price of gas, you'll build gas instead of nuclear or coal."

Most new gas plants, however, are peaking plants, Feltus commented, and those that are baseload units are small because the nation's population centers already have the baseload capacity they need. Feltus added that there are parts of the country where natural gas is not cost-effective because of low population density. "There's no way in South Dakota they're going to have natural gas lines," she said. "I live 40 miles outside of Washington, D.C., and I don't have natural gas. I have to use propane. That boggles my mind."

Herbert Inhaber, president of the consulting firm Risk Concepts and author of the book *Slaying the NIMBY Dragon,* talked about leveling the playing field for all energy producers. Before the oil crisis of 1973, Inhaber said, nuclear had an advantage on the field in terms of being the beneficiary of governmental subsidies and public interest.



Inhaber

Since then, the field has slanted the other way, with nuclear power regarded as not worthy of subsidy, and the public losing interest. As revealed by results of public opinion polls over the years, Inhaber continued, the public's interest has turned "very strongly" toward the development of renewable energies such as wind and solar. "So we clearly have an unlevel playing field, and this is evidenced in the research money given to renewables by the DOE," he said.

Making the field more level—for nuclear "it probably will never be completely level," Inhaber said—will depend on how much positive information about nuclear power is accepted by the public press and into the public mind.

Inhaber stressed the need for a future research project comparing the health and environmental impacts of all forms of energy in a variety of ways. "To my knowledge, nothing comparable to this has been done in the U.S. for many years. There have been studies comparing different forms of energy—health impacts and the like—but nothing comprehensive. So there is a research opportunity here," he said.

He recalled as a model a similar study done in the early 1970s by the Atomic Energy Commission, which specifically laid out the environmental and health risk aspects of nuclear and coal. Another model was a large study done in Europe called "ExternE," which was conducted by 30 research centers starting in 1991. But while heavy on data, no conclusions were drawn in "ExternE," according to Inhaber.

The challenge in trying to compare all forms of energy is to use only the most reasonable assumptions, he said. "In other words, some are very contradictory. Certain people have made the assumption that [another] Chernobyl will happen in a year. So one has to be courageous and throw away the things that are not reasonable. On the other hand, you [also have to] try to keep the amount of [pronuclear] bias down to a minimum," he said.

Equally important, Inhaber said, is that the results of the study, once obtained, have to be presented in a form directed at the general public. For example, data on health, environmental factors, etc., would have to be converted to simple bottom-line monetary figures showing Energy System A as more economically beneficial than Energy System B. "If your results are presented in a form only scientists and engineers can understand, then I think half the battle is lost," he said. "How do you get it in journalists' heads and how do you get your points across that will get published? If it's not published, you've failed."

Ultimately, Inhaber concluded, leveling the playing field will mean shaping public opinion, because without the latter, the former "will never take place."

LNT: A matter of "fraud"?

When an audience member questioned whether support of the linear no-threshold (LNT) hypothesis, also known as LNTH, amounted to nothing more than "scientific fraud," an explosion of agreement came from some panelists at the "Low-Level Radiation Health Effects" session during the ANS Winter Meeting, held November 14–18, 1999, in Long Beach, Calif.

The LNT, the recommendation upon which national and international radiation protection policies are based, holds that any amount of radiation down until zero dose could have a negative effect on living organisms. Detractors of the LNT, including the panelists at the session, counter that studies have shown that certain lower levels of radiation have no detrimental effect and in fact are beneficial. Scientific evidence has proved that the LNT "is not consistent with the biology as we know it," according to Myron Pollycove, M.D., one of the panelists and special assistant to the deputy executive director of operations of the Nuclear Regulatory Commission. There also are charges that data supporting the LNT have, as the panelists claim, been substantially misrepresented, that good data exist that contradict the LNT, that these good data have not been adequately considered in setting public policy,

Pollycove

and that billions of dollars are wasted in the unnecessary cleanup of sites to background levels. All these factors seem to give support to James Muckerheide, session organizer, who said that the effort to retire the LNT "is not something that we feel we are stretching the bounds on."

The challenge in this regard is to keep promoting data that contradict the LNT, the panelists agreed. "There's been a lot of effort to recognize that the LNT is not the right model to use scientifically for what's going on with radiation," said panelist Theodore Rockwell.

Rockwell

Rockwell noted that Sen. Pete Domenici (R., N.M.) pushed for funding for a new low-level radiation research project to be conducted by the Department of Energy (a 10-year DOE study on health risks of low radiation exposures is under way—see *NN,* Oct. 1999, p. 68), and that the American Nuclear Society has recently released a position statement on the health effects of low-level radiation (*NN,* Aug. 1999, p. 108). The ANS position statement declared that there is "insufficient scientific evidence to support the use" of the LNTH.

But the LNT won't go away without a long struggle, admitted Rockwell, a founding director of Radiation, Science & Health, Inc. "If you're talking about the LNT hypothesis, you'll be handed a 300-page report from the NCRP [National Council of Radiation Protection], who defend it, or the BEIR [Biological Effects of Ionizing Radiation committees], who defend it. This report, with equations and figures, is a pretty imposing challenge," he said.

The bottom line, the panelists agreed, is not in determining whether the line in the LNT is indeed linear or exactly at which point a threshold exists, but in doing away with the hypothesis that claims that low levels of radiation are harmful, as its supporters insist. Panelist Al Tschaeche, CEO of Nuclear Standards Unlimited, related a story about his drive up from San Diego where he was slowed by an accident on the freeway: "It occurred to me as I was sitting in the car waiting to go that what I was doing in driving up here was almost infinitely more hazardous than if I were to get a few millirem of radiation."

"From a physician's point of view and a common sense point of view, we don't know of anything biologically that works on a linear basis," said Pollycove. Pollycove has been with the NRC for eight years, after years as head of nuclear medicine and the clinical laboratory at the University of California–San Francisco. He also formerly was head of nuclear medicine at San Francisco General Hospital.

Pollycove, as a medical doctor, admitted that for the ll years he worked in nuclear medicine, he never questioned the LNT and assumed that the people spending their time and money issuing reports on it had a credible scientific basis. "But I was shocked when I had the time to look into it" and realized that there was no proof behind the hypothesis, he said.

Using examples from the world of physiology to support the argument against the LNT, Pollycove recounted that too much physical exercise can wear out the body, while too little can cause it to atrophy. The right amount, however, benefits the body and makes it stronger. Likewise are the effects of mental stress on a human: too much can cause a nervous breakdown, too little can cause the mind to vegetate. In the same category are poisons, he said, from arsenic to strychnine to selenium, which are all toxic if taken in large doses, yet have beneficial uses if taken in very small amounts. "It is odd, then, that somehow radiation should become the sole exception to this rule," he said.

In explaining the logic that contradicts the LNT, Pollycove said the human body endogenously creates 200 million times more "free radicals" (disease-causing mutations) per day than does a normal daily dose of background radiation, which, he said, is one-tenth of a centigray (cGy), or rad. Each day, he explained, 1 billion free radicals are produced in each cell of the human body, but only 1 in 1000 get to the DNA to cause damage to the body. These mutations are the same as free radicals generated by radiation. The free radicals in the DNA are normally removed and damage repaired by the body's immune system, which generates antioxidants that fight the free radicals.

And so, while it is accepted that a healthy human body naturally fights off billions of mutations endogenously created per day (in addition to the daily dose of background radiation) without any deleterious effect, the LNT theorizes that even a fraction of the daily dose of background radiation can be harmful, according to Pollycove. The illogic of this "has all been ignored," he said.

On the contrary, Pollycove said, when background radiation is increased tenfold, to 1 cGy, as was established in UNSCEAR'94 (United Nations Scientific Committee on the Effects of Atomic Radiation), low-dose radiation has proved to stimulate antioxidant production. When antioxidants are increased, he said, "we wind up with fewer mutations per day, which adds up to less aging per day, longer life, fewer degenerative diseases that are associated with these mutations, and less cancer." This process has led in the last three years to the coining of the term "radiation hormesis," according to Pollycove, which means that low-level radiation "stimulates the organism, stimulates antioxidants that prevent damage to DNA, stimulates enzymatics that repair damage, and stimulates the immune system." Although the scientific community has yet to determine the "why" behind beneficial stimulation, Pollycove admitted, what is certain at this time is that "certain genes are turned on by ionizing radiation."

In addition to talking about studies where laboratory mice fought off diseases after receiving low-dose radiation treatments, Pollycove referenced a pair of clinical trials, the first at Harvard University in the 1970s and the second conducted in Japan in the early 1990s, that showed how low levels of radiation stimulated immune systems to fight cancer. In both trials, non-Hodgkins lymphoma patients were treated to low doses of radiation using linear accelerators, in addition to the patients' usual treatment of chemotherapy and local radiation for large tumors. In each case, over a period of five weeks, each patient was given a total dose of 150 cGy. During the treatment, Pollycove said, results showed that the low-dose treatments stimulated the immune systems of the patients and they experienced no symptomatic side effects.

After four years, the results of each trial showed that none of the patients had died; after nine years (results from the Harvard trial only) more than 80 percent of the patients were still surviving, versus the normal 60 percent survival rate for patients who receive only chemotherapy and localized radiation.

Yet, Pollycove wondered, why were these two clinical trials conducted 20 years apart when the results of the Harvard trial in the 1970s showed such a distinct improvement in the patients? "The only explanation I have is that there was money for research from the pharmaceutical companies for chemotherapy, but there wasn't similar funding for radiation," he said.

Rockwell related his take on the LNT: An overwhelming amount of evidence that contradicts it is "not being utilized in the study of public policy," he said. Quoting partially from NCRP 121, which lays out the scientific case for the LNT, Rockwell read: "'Few experimental studies and essentially no human data can be said to prove or even provide direct support for the [LNT].'" Yet, he said, the data that challenge the LNT "are being ignored."

An illustration of how LNT contradiction is being ignored took place in October 1998, when the NCRP SC-16 report that looks at the LNT came out in draft form for public comment, Rockwell said. One of the vehicles for commenting was through an advisory committee set up by the NRC, through which Rockwell and other LNT detractors gave comment. Prior to the draft report's release, the NRC advisory committee formally expressed concern to the NCRP that all comments should be regarded objectively in the report. Yet when the draft report was released, according to Rockwell, none of the LNT detractors' comments had been taken into account. "We tried to approach the NCRP to follow up on that," he said, "but in response the project officer made a short but impassioned speech that it would be improper to tell [NCRP] what to do. Besides, he said that they'd written a wonderful report and everybody thought it was just grand."

But all is far from grand in the debate over the LNT, according to Rockwell. There have been other areas in which scientific data are being suppressed by bodies such as the NCRP, the BEIR committees, and the International Council for Radiation Protection (ICRP), he said. Rockwell declared that all of them have ignored or misinterpreted a high-

dose radiation workers study, a nuclear shipyard workers study, and a series of other studies that have shown that low-level radiation is either harmless or beneficial.

Not only are data being suppressed, but evidence in support of the LNT has been "inappropriately juggled," Rockwell said. As an example, he talked of graphs in support of the hypothesis that show a curve in which data points come down into the beneficial area for certain low doses and then go back up into the harmful area as dose is increased. "What they've done in a couple cases is to take the data—such as the nuclear shipyard workers study, because most of your data are in the low levels—and since they don't like to see the points drop below the line [into the beneficial area], they take all the data from zero to 50 rad [cGy] and call it a single point and squeeze it above the curve [into the harmful area]," he said. Rockwell called this misrepresention of data "not proper, and when it changes the answer from yes to no, it's no longer a trivial matter."

Supporting Rockwell's stance is Senator Domenici, who has expressed belief that data are being improperly examined, according to Rockwell. He said that Domenici has prompted an investigation of the LNT in the form of a 10-year DOE research program. In addition, Domenici requested that the U.S. Government Accounting Office study the LNT and evaluate whether it is the proper application of public policy. The GAO is expected to release its report by June 2000.

Other encouragements, according to Rockwell, include ANS's recent position statement on low-level radiation health effects. Rockwell said that he and others are trying to get this statement amended to include the following "key sentences": 1) "In presentations to the ANS and to policy-making groups, it has been shown that some reports that claim to support the LNT substantially misrepresent the data." 2) "A large body of credible, replicable statistically significant scientific data exists that directly contradicts the LNT." 3) "ICRP, NCRP, and BEIR reports fail to adequately consider this evidence."

The paradigm is the problem, according to Tschaeche. The paradigm in the minds of the public is that radiation, in any amount, equals harm. "The thing that drives the pro-LNT people is fear," he said. "They're afraid that if they go away from this idea that they've had—that a little bit of radiation may be harmful—that someday they'll realize they were wrong from going away from it in the first place."

Before 1968, the United States and the rest of the world worked to the radiation standards that existed at the time, Tschaeche said. "I was at Westinghouse then and we worked to 5 rem per year," he said. "There was no ALARA [as low as reasonably achievable]. ALARA was a concept that health physicists had, but it wasn't a regulatory requirement. And everything was fine."

What happened in 1968, he said, was that an analysis was done that concluded that the effluent levels from one nuclear reactor in the midwestern United States would kill thousands of people if its releases resulted in exposures of 170 millirem per year to the general public. That study, according to Tschaeche, was simply a hypothesis.

But giving support to the hypothesis were the radiation data that existed at the time, which consisted of results from the Japanese atomic bomb [high-dose] studies. "We didn't have any low dose statement," Tschaeche said. "So somebody had to come up with the idea of how to tell what are the effects that low doses would have on people." And so the LNT appeared, he said, although he was unsure of exactly when or how it first arrived, and that perhaps it was just a refinement of earlier radiation-protection statements. The only problem, he said, was that the LNT's only purpose was to be for the setting of radiation protection standards, and not as a representation of reality.

What happened next, according to Tschaeche, was that antinuclear groups latched on to the LNT to help orchestrate their cause through the media. (Tschaeche said he once wrote a letter to *Time* magazine complaining about a reporter's bias in an article. *Time* wrote back, he said, replying that "total objectivity" in their magazine articles was "not only impossible to achieve, but undesirable as well.") That orchestration has helped lead to the current belief that "one proton will kill you. And the public believes it," Tschaeche said. The result, he continued, is a public policy that results in "spending billions to clean up sites down to background."

And so while the NCRP and ICRP make recommendations based on the LNT, it is governmental agencies and organizations like the American National Standards Institute (ANSI), ISO (International Organization for Standardization), and International Atomic Energy Agency that set standards, he said.

The task, then, is doing something about the standards. Tschaeche has started a standards activity in the ISO, and is planning to submit to ANS a standard on permissible radiation levels to be put into the ANSI standards system. "If we had this standard for dose that is reasonable that didn't have the LNT in it, maybe we could get the government to turn its head around and go in the right direction," he said.

More than 100 years ago, since 1896, science was using low levels of radiation to stimulate the immune systems of animals to cure infections, said James Muckerheide, a nuclear engineer with the state of Massachusetts Emergency Management Agency. Yet those scientists had no knowledge of the molecular biology and cellular response effects that exist today. So, with the body of knowledge now in place and the current investigation into the LNT, it is only a matter of time before "science comes around," he said.

Muckerheide has been instrumental in leading the effort to look at LNT feasibility. He first pulled data together in 1993–1994 during an assignment for the governor of Massachusetts. Later in 1994, he initiated the first session at an ANS meeting on the subject.

Muckerheide provided an overview of some of the activities taking place in the investigation of the LNT. In 1997 the Wingspread Conference was held, consisting of about 50 leaders and representatives from many national and international radiation protection institutions, including the ICRP, NCRP, NRC, and U.S. Environmental Protection Agency. The attendees at that meeting, according to Muckerheide, acknowledged that no data exist that support adverse health effects below at least 10 cGy (10 rem) and that hundreds of billions of dollars in environmental cleanup costs were producing no public health benefits. (A follow-up meeting to Wingspread was scheduled for December 1–5, 1999.)

Coming out of the 1997 Wingspread meeting, Muckerheide said, there should have been a new initiative in recognition of the acknowledgement, according to the recommendations of that conference. But that new initiative never occurred, he said, which was part of the reason why Senator Domenici procured funding for DOE research and requested work on the upcoming GAO report.

Another meeting, this one of the International Radiation Protection Association scheduled for May in Hiroshima, Japan, Muckerheide said, will possibly have a paper submitted by Roger Clark, head of the ICRP. According to Muckerheide, Clark will propose that the LNT threshold be lowered from 10 millirem to 3 millirem, which, Muckerheide noted, will still have the effect of saying "that very low levels of radiation can kill you, but at some level we'll just decide that it's not worth chasing anymore."

Besides saving billions of dollars on unnecessary cleanup of sites, retiring the LNT could also result in enhancing the appeal of nuclear energy, Muckerheide said. "At a basic pressurized water reactor plant," he said, "30 percent of the investment in the plant is to generate power and 70 percent is to provide safety. Certainly you'd expect to protect the core as an intrinsic part of safety. But if you use risk-informed decision-making so that you don't try to prevent every radioisotope from leaving containment but stay within reasonable bounds of assured safety, there are many things that can be done to bring nuclear [power] to a more cost-effective level."

Nuclear medicine could also benefit, he said. "The costs in nuclear medicine have been driven largely by the regulatory burdens and problems with producing and handling isotopes and controlling nuclear material," he said. Muckerheide related a story about a visit to a Toronto hospital that had its nuclear medicine department on the 18th floor. Below, on the 6th floor, were giant tanks able to receive waste from patients having iodine-131 treatments. "They had these giant tanks to hold the waste streams for an eight-day half-life of iodine-131 at a cost of many hundreds of thousands of dollars," he said. "At the same time, there were complaints that there was contamination in the waste pipes that came down from the 18th floor to the 6th floor. Now they've got to begin shielding the pipes be-

cause there's residual half-life stuff in them. So there's an aspect of this that we don't always consider in terms of cost."

Muckerheide also wondered whether the nuclear industry was taking the right path when it talks of the protections it has in place for radiation instead of, in many cases, stressing the low risk levels of certain wastes. "We're taking radioactivity that's simply going to decay away and be a small fraction of an environmental concern, and we're treating it as though it needs a [high] level of security," he said. "We don't tell people that radiation at low doses is safe. We tell them it's safe because we've spent millions of dollars assuring it's safe by securing it and when transporting it."

Radiation, Muckerheide concluded, is intrinsically part of our background environment. It is what we grew up in and it is part of our biological process. "So how a small amount of radiation that is well within the natural variations in nature could be intrinsically harmful is really hard to fathom," he said.

Theodore Rockwell worried that the industry will continue being its own worst enemy in trying to explain that not all radiation is harmful. "When we talk about the public's irrational fear of radiation, we create that fear," he said. "Ralph Nader or Jane Fonda didn't invent the China Syndrome or the LNT." He told a story of how the DOE had once issued a press statement, "out of the clear blue sky, for no particular reason," to announce results of a six-year study on what the effects would be of transporting shielded weapons radwaste across the country to Yucca Mountain. "The punchline was that they were going to kill 23 people by irradiation by subjecting millions of people with trivial quantities of radiation," he said. "It's like saying that we know that 100 aspirin will kill you, so if we give each person in the country one aspirin [1/100 of the 100-aspirin dose], we're going to kill 2.5 million people" [1/100 of the 1990 U.S. population of 250 million].

It is that kind of reasoning that ends up being used against all things nuclear, Rockwell continued. "I've been up against antinuclear people who open their statements by saying, 'Using the government's own methods for calculating these things, this will lead to so many cancers,'" he said. A better way of educating people has to be found, he added.

Possibly a better way is by getting the medical community involved in promoting radiation's benefits, a task that won't be easy, Pollycove conceded. Pollycove's comment came after a statement from an audience member who said that he (the audience member) probably received more radiation dose from one angiogram test performed on his heart than he got from his entire career working at a nuclear facility. "There was no indication that I was receiving any radiation whatsoever except that I was aware of it," said the audience member. "So I question if the doctors, in trying to treat their patients, are being too coy and subtle to the point where the public is unaware of the benefits they're getting from the diagnostic treatment of nuclear medicine." Pollycove's comment: "You're right. They run into so much opposition from antinukes and from the occasional patients who are frightened to death [of radiation] that they don't want to even bring up the subject."

Tschaeche added that the reason there is no support from the medical community is that it enjoys what basically is an exemption from radiation protection requirements. "The reason why we don't have data from medical disclosures is because there is no requirement to calculate the dose," he said. "That's one of the reasons why, in the [planned] U.S. ANSI standard, we're going to see if we could put the requirement to have medical exposures included." Pollycove also implied that the NCRP and ICRP were looking the other way in this regard. "They don't want to touch medicine," he said, "because they say at these doses there's so little harm compared to good that they really don't need to be concerned about this."

Muckerheide said that if it weren't for low-level waste, nuclear medicine wouldn't have a common interest with other nuclear industries. "But if you really look at radiation exposure [as performed by radiologists], you have to say that if the LNT were true, radiologists would be killing more people than anybody," he said. "And yet the linkage isn't there."

A final few pieces of support for LNT contradiction are currently in production. The

first is *Radiation Hormesis: The Scientific Foundation,* which will be funded by the NRC and published in year 2000, according to Pollycove. The report will evaluate about 500 papers on the subject of the LNT, about 10 percent of which have been termed "excellent in statistics," he said. In his research, he said, he has not been able to find one statistically significant study that does not demonstrate radiation hormesis in the low-dose range—that is, 120 rad. In fact, he said, "every single one that is statistically significant shows a *clear beneficial effect,* not 'no harm,' but a clear beneficial effect." The *Radiation Hormesis* report will be available on the World Wide Web, he said, which will make it "hard for the kind of chicanery that's been going on" to continue. LNT supporters will have to "face the actual publication," Pollycove said. "That, I think, will be a significant step forward" for the contradiction of the LNT.

Pollycove noted that a second work is being compiled by the International Center for Low Dose Research, which is part of the University of Ottawa, Canada. The center is evaluating radiation papers and fostering current research showing what effects low doses may have, he said.

Pollycove closed the session by mentioning a Canadian fluoroscopy study of 32 000 women in tuberculosis sanitariums that was conducted between 1930 and 1952. By sheer coincidence, he said, each woman received a number of fluoroscopic exams, and each one was 2/10 rad, which is about the average dose in the mammogram given today. Results showed that the women who received 15 rad over two to three years had 34 percent less death from breast cancer than the women who were considered the controls, who received anywhere from 1 to 9 rad. "The 34 percent reduction was more than two standard deviations below the controls," Pollycove said.

The results of the study were published many years later in *The New England Journal of Medicine* and it was peer reviewed by radiation experts. But the authors had published the data in tabular form and never plotted it out, so that their conclusion, according to Pollycove, was that "one rad equaled risk." The authors, Pollycove said, "knew that if they plotted it, anybody could look at it and see [that low doses had beneficial effects]." One of the authors rereleased the paper in 1996, under the pretense of updating it, Pollycove said. In the preamble, according to Pollycove, the author stated that no low-dose data existed, so that it was necessary to use high doses and extrapolate down. What the author did, according to Pollycove, was to eliminate the 10–20, 21–30, and 30–50 rad categories and put them all in one category, 0–50, and then went up from there. The author, Pollycove added, is a member of the BEIR VII committee, and the paper is one that the committee is going to use to examine the LNT. The only way the paper could show linearity, Pollycove concluded, was if some of the data had been "juggled."—*Rick Michal and Simon Rippon*

TOPICAL MEETING

Deregulation overview

The "Executive Overview of Electric Power Deregulation" session (the opening plenary of the ANS Topical Meeting on Electric Power Deregulation: Industry Update) was a follow-up to a first meeting on the subject that was held at the 1995 ANS Winter Meeting in San Francisco, where the state of California was poised to begin restructuring its electric utility industry. Four years later, with California's work of restructuring done, a panel of industry executives offered perspectives on deregulation, comments on lessons learned, and forecasts on what the future may hold.

William Campbell, executive vice president–nuclear for Duke Engineering Services, in talking from the experience of implementing the independent system operator (ISO) concept in California, said that deregulation didn't catch the nuclear industry off guard. "The analogy is that deregulation in the electric utility business is like a surprise attack by the Goodyear blimp: You see it coming a long way off," he said. The nuclear industry was ready for that attack because it had leadership in place 10 years ago that was moving it toward deregulation, he said.

Duke Engineering has been involved in project management and formation of infrastructure for the implementation of the ISO concept in California. While nuclear power has been treated fairly during the transition, Campbell said, there remain some significant issues that affect nuclear plants, especially grid stability and voltage support.

Giving a "bug's eye view of deregulation" as an ISO in California was Dwight Nunn, vice president of engineering for Southern California Edison Company. SCE operates the two-unit San Onofre nuclear power plant, in San Clemente, Calif. In the days before restructuring in California—prior to April 1998, when deregulation started in the state—SCE had forecast what it "thought" the cost of operating and maintaining a nuclear plant would be. But under restructuring, Nunn said, every penny of a plant's costs must be nailed down. So, he said, there will be increased pressure to keep the plant on line.

Nunn

The economics of a plant should never affect its safety, said David Matthews, director of regulatory improvement programs at the Nuclear Regulatory Commission's Office of Nuclear Reactor Regulation. A policy statement from the NRC has identified specific safety concerns about deregulation and restructuring, such as reductions in manpower, training costs, O&M, and capital additions; increased on-line maintenance and fuel burnup; and shorter outages.

Because the impact of budgetary reductions can cut across all plant safety-related programs, Matthews said, other impacts may occur. For example, he said, a merchant plant operator with no assets other than the nuclear plant could be vulnerable to an extended outage if the operator does not have an adequate financial cushion to pay costs incurred during the outage.

Matthews concluded that the effects of deregulation and restructuring on plant operations will be mixed, but that an efficient and economical plant will often be a safe one.

Robert McWhinney, president and chief executive officer of Stone & Webster Management Consultants, looked at power-plant values. In the past two years, he said, various types of power plants have been sold in the United States. The average price of those transactions has been in the range of $350 per kilowatt. In comparison, he said, the cost of building a new combined-cycle plant would be in the range of $600 per kilowatt, while the price on the table for the nuclear plant transactions approved by the NRC (Pilgrim and Three Mile Island-1) is in the range of $50 per kilowatt. The implication is that nuclear plants will continue to operate, even in a deregulated market. "All of these plants are selling into a merchant market, where the buyer only cares about the energy, not the source of energy," McWhinney said.

McWhinney

Roger Fagan, vice president of business development in the Americas for ABB/Com-

bustion Engineering, closed the session by reviewing Europe's deregulated energy market and what the U.S. power industry might learn from it.


Fagan

As in the United States, Fagan said, the degree of implementation of deregulation varied by region in Europe. Much of its power industry is undergoing a transition from state ownership and government control to private ownership and open markets. Yet the changeover has happened more quickly than expected, he said. The reason is the European Union (EU), which is the central driving force behind deregulation, versus the decentralized state-driven implementation occurring in the United States. "The EU sets goals for deregulation that the electricity markets in the member countries are expected to achieve in the next few years," he said.

Each country addresses deregulation in its own way, although France has resisted change, he said. The EU plan is rather modest, according to Fagan. The objective is for 30 percent of each country's market to be opened to competition by 2000, and then 35 percent by 2003. Already the United Kingdom, Sweden, Norway, and Finland have opened 100 percent of their electricity markets to competition, he said. Denmark will be at 100 percent by 2002, while Germany, the Netherlands, and Austria are close behind. By 2003, 80 percent of EU countries will be deregulated, far surpassing the established 35 percent goal. "One thing we can learn from Europe is that once deregulation starts, it will go quickly," he said.

Fagan added that European nuclear power plants are cost-competitive with coal and gas. A large part of cost savings in Europe has come from staff reductions. The full-time equivalent for personnel is 0.35 per megawatt for European nuclear plants, Fagan said, and for U.S. nuclear plants it is 0.64 per megawatt.—*Rick Michal*

TOPICAL MEETING

ATW road map

SOMETHING OF A double take was experienced upon going from the ANS President's Special Session on Fourth Generation Nuclear Reactors to an accelerator transmutation of waste (ATW) session of the Topical Meeting on Nuclear Applications of Accelerator Technology. In both cases, the speakers were discussing the merits of different advanced reactor concepts that look to be strangely familiar. The only difference in the ATW case is the addition of accelerators to drive them with neutrons in a subcritical state so that they can be used to transmute actinide wastes from commercial nuclear power plants.

One impact of this is that in addition to consideration of the different permutations of coolants, neutron spectra, and fuel cycles associated with critical reactors, there are also options for the type of accelerator and the configurations of targets for production of spallation neutrons. And there are also different technology options for the separation of the actinides and maybe other long-lived fission products that are to be transmuted in the ATW systems.

Speakers—including Gregory Van Tuyle and Denis Beller, of Los Alamos National Laboratory, and Dale Lancaster, of TRW Environmental Safety Systems Inc.—were mainly concerned with identifying a reference design from the various options to form the basis of a technology development "road map" for which Congress mandated funds of $4 million in fiscal year 1999. The reference ATW system that is evolving, according to Van Tuyle, will use a linear accelerator (linac) in preference to a cyclotron because of the high proton beam power required. A fast neutron spectrum has been chosen for the subcritical transmuter (reactor) for two reasons: first, nearly all actinides will fission in a fast spectrum, giving maximum flexibility for the blend of fuel; and second, the fast spectrum produces many excess neutrons that can be used to transmute long-lived iodine and technetium isotopes. In order to achieve a fast neutron spectrum, a liquid metal is the preferred coolant. Although there is an extensive international base of experience with sodium coolant, Van Tuyle said that liquid lead-bismuth may offer significant advantages over sodium as both a spallation target and as a coolant. The choice of pyrometallurgical technology for the actinide separation drives the design toward metal fuel.


Van Tuyle

The reference ATW subcritical transmuter has been sized to develop a thermal power of 840 MWth. This is partly because it will make the facility a close look-alike to the advanced liquid-metal cooled reactor concept (known as PRISM), which was the subject of extensive design effort and cost optimization in the past. Some alternative systems mentioned briefly by Lancaster include thermal neutron spectrum converters, which look rather like the molten salt reactor concepts of the past, and a system with coated particle fuel in spherical graphite elements, which looks like the recently revived pebble bed high-temperature gas-cooled reactor concept except for the inclusion of light water or liquid metal as optional coolants.

The ATW "road map" envisages a reference plant consisting of eight of the 840-MWth liquid-metal cooled transmuters driven by two 45-MW accelerators and associated chemical facilities for front end separation of uranium from spent fuel and back end processing of the short-lived transmuted waste. During 60 years of life, this reference ATW plant is intended to process just over 10 000 te of spent fuel. This should be seen against the total current inventory of U.S. spent fuel of around 40 000 te, which is projected to increase to around 86 000 te if all plants run until their licenses expire.

Optimistic nuclear energy scenarios for the 21st century certainly include license renewal to extend the operating life of many of the present LWRs, as well as new advanced reactors offering greatly increased fuel burnup, especially of plutonium. Beller considered some of the system studies that have been carried out to see what ATW systems might be needed to deal with the residual long-lived actinide wastes from some of these long-term nuclear power scenarios.

The interesting figure is the support ratio—the number of new reactors that could be supported by one reference ATW plant. With continued use of the once-through cycle in LWRs, the support ratio is seven reactors per ATW plant; for a denatured thorium-uranium fuel cycle in LWRs, the ratio is 16; with recycle of MOX fuel in LWRs, it would be 12; for liquid metal fast breeder reactors it would be 23, and for the modular high-temperature gas-cooled reactors, one ATW would support 27 blocks of reactors of 1000 MWe capacity.—*Simon Rippon* NN