THE *NUCLEAR NEWS* INTERVIEW

Corbin McNeill: A PBMR in Exelon's future?

Corbin McNeill, chairman and co-chief executive officer of Exelon Corporation, is guardedly optimistic about the involvement of the Pebble Bed Modular Reactor (PBMR) in the future of nuclear power in the United States.

The PBMR, a new design being pursued by Exelon in association with South Africa's state-owned utility Eskom, is claimed to be safer, cheaper, and faster to build than other reactor technologies. As such, Exelon is watching carefully its design development, which may lead to a decision to go forward with a PBMR demonstration project to be started later this year in South Africa, according to McNeill.

The PBMR is a high-temperature, helium-cooled reactor using a direct-cycle gas turbine. It is designed in 110-MWe modules for relatively quick operation in an electricity environment where 1000-MWe units may be too big and costly to compete in a deregulated market. According to information made available by Eskom, it is inherently safe in operation, and much of it can be "factory built" before assembly at a site.

The PBMR works by using nuclear fuel contained in balls—pebbles—with a 60-mm diameter. About 400 000 of these fuel balls lie within a graphite-lined vessel that will be 20 m high and 6 m in diameter.

Helium at a temperature of about 500 °C is introduced into the top of the reactor. After the gas passes between the fuel balls, it leaves at the bottom at a temperature of about 900 °C. This gas passes through three turbines. The first two turbines drive compressors, and the third drives the generator, from where the power emerges.

At that stage, the gas is about 530 °C, and it then goes into a recuperator, where it loses excess energy and leaves at about 140 °C. A water-cooled cooler takes it down further to about 30 °C. The gas is then repressurized in a turbo-compressor before moving back to the regenerator heat-exchanger, where it picks up the residual energy and goes back into the reactor.

Spent fuel balls are passed pneumatically to large storage tanks at the base of the plant, where there is enough storage capacity to hold all spent fuel through the life of the plant. The tanks are also designed to hold the spent fuel for 40 to 50 years after shutdown. About 2.5 million fuel balls will be required for the 40-year life of a 100-MWe reactor.

McNeill: "[PBMRs] could dramatically boost the prospect of nuclear energy on a global scale."

With its interest in the PBMR, Exelon Corp. last year contacted the Nuclear Regulatory Commission to set up discussions about the licensing of the PBMR in the United States. These discussions are still ongoing.

McNeill, who also is president of Exelon Generation, talked at length about Exelon's involvement in the development of the PBMR. This interview was conducted by Rick Michal, *NN* senior associate editor, *You have gone on record as predicting that new nuclear power plants will be built in the United States. When will they start being built, and will they be exclusively of PBMR technology?*

I don't control all of that decision making, of course. The demand for electricity is continuing to increase as we move more toward an information technology age. We're seeing in Chicago, for instance, load growth rising at about 4–4 ½ percent per year. That's substantially above what we've seen earlier. The demands on the generating community with that kind of electricity growth continue to be challenging. I believe that nuclear can be one of the answers to the needs of the country, and at the same time be one that is environmentally friendly.

Having said that, I don't know of anybody who has plans to build a new nuclear plant in the next several years. Our interest at Exelon is in a new technology—the PBMR [Pebble Bed Modular Reactor]—which could produce a new plant maybe in five years in this country. But that will depend on the completion of our design feasibility study from which we will be able to predict what the costs will be and whether a plant of that nature would be competitive in the kind of deregulated environment that we see today.

What are the technical and economic advantages of the PBMR?

I think there are a number of those. The PBMR is smaller and has a modular design that affords a degree of flexibility. In terms of construction, a utility would be making what might be a $120-million investment decision instead of a $2-billion–$3-billion investment decision. PBMRs are faster to construct. We think that they can be built in the neighborhood of 18–36 months as opposed to perhaps 5-plus years for a larger plant. The PBMR will have the thermal efficiency of about 40–42 percent, versus a 28–30 percent efficiency for today's light-water reactors [LWRs]. There is a significantly higher degree of safety of the PBMR in that during the worst predicted accident, the temperature that would be achieved in the reactor would be well below fuel damage temperatures, so no meltdown could occur like in an LWR. The operating costs of a PBMR are substantially less because of the staffing characteristics and the lower fuel costs. There is lower low-level waste production in a PBMR as opposed to an LWR. And, finally, PBMRs maintain the traditional characteristics of nuclear plants in that there won't be any atmospheric emissions associated with them.

At the ANS/ENS International Meeting last November in Washington, D.C., you said that another LWR would never again be built in the U.S. Why?

I want to make sure that everyone who reads this understands that this is my own personal opinion. The current LWR designs require extensive safety systems to assure public safety, including large containments. That structure of large containments that contain the energy associated with the steam release of a hypothetical LWR accident, plus holding all the radioactive products that might come out of that, produces a relatively high initial construction cost and long construction period. Much of that construction is done on site, as opposed to in a factory, which we would do with a PBMR. The investment risk in today's environment and the large size net generation output that is necessary to even make the costs competitive can tend to disrupt the electricity markets and depress prices. I think it's very unlikely that any major investor would decide to build an LWR.

The PBMR will have the thermal efficiency of about 40–42 percent, versus a 28–30 percent efficiency for today's light-water reactors.

Exelon has invested $7.5 million in a PBMR project being developed by Eskom, in South Africa. What is Exelon's financial position on this investment—i.e., is it equity in the project?

It is an equity position in the intellectual property development of the PBMR. For the $7.5 million, we've got about a 12 ½ percent share. If the design feasibility study is favorable, it also would allow us to participate in the construction of the first plant. We have certain contractual rights to build these and market them in various parts of the world.

Is Exelon also participating in the Eskom design effort for the PBMR?

We have somewhere between six and 10 people who spend anywhere from a small amount of time to perhaps 60 percent of their time in South Africa today, not necessarily doing direct engineering, but reviewing engineering, helping to review cost-prediction methodologies, trying to develop the best probabalistic risk assessment tools for the design, and things of that nature. We're providing what I would call a contribution to the design effort, but we are not the designers.

How dedicated is Exelon to PBMR technology? Would the company be willing to invest more into the South African project?

It's too early to tell. Our current investment commitment is designed to take us through the completion of the design feasibility study. At that point, we should have a good estimate of what the construction costs and the feasibility of the operation of the design will be. We would then make a separate decision as to whether to continue to participate in the project or not.

When is the PBMR's feasibility study expected to be completed?

The path that we are pursuing in the current development is to conclude the design feasibility study sometime early in the third quarter of 2001. If that proves that there is economic and technical feasibility for the PBMR design, then we would request approval from the South African government to construct a single demonstration plant of 110-MWe design in South Africa, which would take roughly 36 months to construct and about a year's worth of testing after that. If, at some point in time, we were confident about the design, we might then begin to pursue licensing in the United States. We probably would not have a plant completed in this country for five or more years on the current schedule.

How closely do you think other U.S. nuclear utilities are watching what Exelon is doing with its involvement in the PBMR?

I think they're aware of what we're doing. I don't know of any specific effort to do much beyond that. I know that the Nuclear Energy Institute is promoting a broad, general effort to try and promote new nuclear construction in the country, and this is one possible part of that. But I don't know specifically what anybody's doing one way or the other in that regard.

Does the PBMR have a containment?

This design does provide a containment, but there needs to be an understanding of the rationale behind it. In an LWR, under accident conditions where the safety system has failed, fuel damage can occur very quickly. Therefore, there needs to be in place a containment mechanism to make sure that it doesn't escape during those potential early minutes of an accident situation.

In a PBMR, however, the time frames for developing those accident conditions is hours and even up to days. The temperature rise in a PBMR that undergoes a loss-of-coolant accident is very slow, as opposed to minutes in an LWR. What a PBMR design does is allow for the release of the helium coolant in a loss-

PBMR information on line

Eskom, the South African utility that is leading the effort to develop the Pebble Bed Modular Reactor, has a Web site that contains information on various aspects of the design. An overview of the PBMR is included, along with information about its operational requirements, safety principles, main power system, operating principles, fuel, construction, and maintenance. The Web site is at <www.pbmr.co.za>.

of-coolant accident. It also establishes a containment to make sure that if fission products are released within the following several days, they are contained within the containment structure of the PBMR design.

The kind of containment that would be required for licensing a PBMR in the United States is not yet clear. However, there is an NRC policy statement, SECY 93-092, which has looked at the need for conventional containment for advanced reactors like the PBMR. It provides some guidance on containment design and concludes that conventional containment is not mandated for a high-temperature gas reactor.

Also, I think some of the PBMR's civil structure itself ends up providing containment.

In terms of time limits, is there a window of opportunity for PBMR technology to be introduced to the U.S.?

That's one of the issues that we are trying to resolve in the design feasibility study. Here is the issue. The PBMR advantages that we discussed earlier have a bottom line that says that this reactor has to be economically feasible. We will make a comparison with other forms of generation and the costs of those generations that are available in general. We believe that the PBMR will be a very competitive design. Therefore, for the foreseeable future, we should be able to build it if it meets the economic criteria that we are looking for from the design feasibility study. The window of opportunity is really the technology that is being developed, but we have to be confident about the technical and economic parameters of the design.

Could you talk about the long-term storage of the PBMR's spent fuel pebbles?

They are much easier to store than our current fuel rods, for a couple of reasons. First, the silicon-carbide coating on the fuel particles will, in fact, isolate the decayed products for hypothetically a million years. And sec-

PBMR licensing in the United States

Before a Pebble Bed Modular Reactor (PBMR) could be built in the United States, design certification would first have to be granted by the Nuclear Regulatory Commission. Tom King, director of the NRC's Division of Risk Analysis and Applications within the Office of Nuclear Regulatory Research, is leading the agency's effort to set up a review process in the event a PBMR licensing application comes in.

Exelon Corporation, which is currently involved in the PBMR development effort of Eskom in South Africa, first approached the NRC in November to discuss the design's possible licensing in the U.S. A face-to-face meeting was held, followed by a letter from Exelon to the NRC in December, putting in writing the fact that the utility is involved in the PBMR project and requesting interaction with the agency early on. According to King, Exelon hopes that by meeting with the NRC before an application is filed, the utility will get a sense of what requirements lie ahead. That knowledge will help Exelon make a decision on whether a licensing request should proceed.

King said preliminary talks have revealed that Exelon is interested in receiving licensing within two to three years following submittal of an application. "At this point, I can't say whether [Exelon's expectations are] reasonable or not, until we know more about the design and their approach for licensing it," King told *Nuclear News.*

What King can say is that the licensing process would parallel the path taken by three other newer generation designs that have received NRC approval—the Westinghouse AP600, the General Electric Advanced Boiling Water Reactor, and the ABB Combustion Engineering System 80. "The process would be the same," he said. "It's defined in 10 CFR Part 52."

The process would include an application for design certification, a review by NRC staff and a separate review by the NRC's Advisory Committee on Reactor Safeguards, and the opportunity for public hearings.

While the review process would be the same, the time element would be expected to be shortened, NRC spokesperson Victor Dricks added. The NRC took eight to 10 years to certify the three newer generation reactor designs, but, Dricks stressed, that is because of three reasons: NRC budget resources available at the time, project priority, and demonstration of safety features.

Dricks said the review history of those other certifications should not be tied to what should be expected for the PBMR, and that a two- to three-year approval process could be realistic. "Our expectation is that we'll be able to accommodate a request for a design certification in two to three years by what we call a pre-application review," he said. "That means that we'll have had discussion with the licensee on various design and engineering features of what they're going to bring to us, so that we'll be familiar with the technology and we'll have done some advance planning before an application actually comes in."

The NRC, Dricks continued, has made an attempt to familiarize itself with the PBMR review process by offering regulatory assistance to the South African government for its licensing of the Eskom project. So far, though, that government has not responded.

As the NRC waits for a possible PBMR application, King has studied the technoloond, the carbide ball has characteristics around it that allow it to be directly stored for not only the life of the plant, but for the permanent storage. We think this is easier to store than the current rods, but we still need a location. That's why any nuclear plant is dependent upon the Department of Energy coming up with some solution to the long-term storage problem. Hopefully, the decision on Yucca Mountain, with an affirmative suitability determination, will be made this coming year.

We believe that the PBMR will be a very competitive design.

A member of the NRC's Advisory Committee on Reactor Safeguards, in a memorandum last June, concluded that if cost and safety goals are met, "we can expect to see literally hundreds of PBMR modules being built around the world in the next decade or two." Do you have any comments on this statement?

I'm not going to project any number for PBMRs. I do think that if the promise of the design pans out, it could dramatically boost the prospect of nuclear energy on a global scale as a non-polluting power source. That could bridge us to a hydrogen economy over the next century—I don't know exactly when. As the world economy expands and Third World countries develop, the demand for electricity is going to increase. I'm seeing and hearing that international demand is almost going to double by 2020. That clearly presents an opportunity for a nonpolluting, safe source of electricity. NN

gy. Because of the design's inherent safety characteristics, he said, it requires a smaller emergency planning zone (EPZ) of two miles, compared with the limit for current light-water reactors of 10 miles. However, King added, "What our position would be in [approving an EPZ], it's certainly one of the major issues we'd have to look at."

King talked about the make-up of the fuel for the PBMR. "The basic element of the fuel is about the size of a poppy seed," he said. That "poppy seed" is a unit of enriched uranium dioxide that has three coatings covering it. The first is a carbon coating to absorb fission products, the second is a silicon carbide coating that is the pressure-retaining boundary, and the third is another outer coating of carbide to prevent abrasion and rubbing against other particles. About 15 000 of these poppy seeds form one fuel pebble, about the size of a tennis ball. The pebbles fit in the reactor inside "something like graphite blocks" that are up against the steel vessel wall, he added.

Once loaded into the reactor, the pebbles are cycled out of the bottom in an on-line refueling scheme. "There is no refueling outage," King said. "This is on-line refueling. This process is continuing as the reactor operates. [Plant workers] are constantly taking pebbles out the bottom, checking the burnup, checking for leakers, and then putting them back in the top or discarding them and putting fresh ones in the top."

The PBMR, then, would shut down only once every several years for maintenance of other mechanical parts of the plant, King said.

He said the PBMR has "control rods to compensate for initial heat-up" and "for achieving full cold shutdown." For normal operational control while the plant is producing power, according to King, the temperature of the core is moderated by raising or lowering helium pressure. With more helium in the vessel, the pressure goes up and the heat transfer gets better, which cools the core. "Cooling the core increases the power level," King explained. "And, vice versa, if they take helium out and lower the pressure, that reduces the heat transfer, the core heats up, and the power starts to shut down."

It is helium that drives the turbine, and as such, no steam generator exists for a PBMR plant. Cool helium is put into the reactor vessel where the nuclear chain reaction heats it up. The hot helium under pressure goes to the turbine, driving its blades. During this process, the helium's pressure and temperature are reduced. It is then funneled to a compressor, where pressure is increased, and it is put back in the reactor to be heated up again. "It's pretty straightforward in terms of a simple heat-transfer cycle," King said. "It's strictly a closed helium loop with a turbine in-line in the primary coolant piping."

Because there is no steam generator, the volume of water that is going through a PBMR system is a fraction of what is needed for an LWR. In fact, King commented, it is important to keep water out of the primary system because it reacts with hot graphite and degrades the integrity of the fuel particles, as well as produces hydrogen, carbon monoxide, and carbon dioxide. Water is used only for cooling some of the components that are in the primary cooling system, such as circulators.

For now, King is doing preparatory work to better understand the PBMR design, looking at experiences that other countries have had with high-temperature gas reactors (HTGRs), particularly pebble beds. Germany operated two HTGRs, according to King, but both were shut down.

Key issues of the PBMR design, such as containment, will likely involve policy judgment by the NRC commissioners, King concluded. "The sooner we can get [key issues] settled, the better off the staff will be in terms of being prepared to review [the PBMR]," he said, "and the better off Exelon will be in terms of knowing what's coming down the road that they will have to deal with." NN