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From: Makuteswara Srinivasan
To: AdvReactor
Date: Tue, Aug 6, 2002 11 11 AM
Subject: On Exelon RAIs

QUESTIONS REMAIN ON PBMR FUEL, NRC RESEARCH LOOKS AT HTGRs

From "Nuclear Fuel" - August 5, 2002

Since Exelon Generation has withdrawn from the pebble bed modular reactor (PBMR) project in South Africa, the NRC staff has scaled back, but not eliminated, plans for research on issues related to licensing high-temperature gas reactors (HTGRs)

A letter sent last month to Exelon contained pages of questions on PBMR fuel, fuel fabrication quality control measures, performance monitoring, and fuel qualification testing While the staff does not expect answers to most of its questions, it is going through the motions of formally documenting its review, should the design concept be revived at a later date

Also, the NRC Office of Nuclear Regulatory Research's (RES) draft advanced reactor research plan, released last month, included plans for fuel performance testing and fuel qualification, and work on source term. While RES has retained PBMR-related research within the scope of its work plan for future licensing of advanced reactors, it has had to consider accommodating other designs that might come under pre-certification review, including two advanced BWR designs - General Electric's ESBWR and Framatome's SWR- 1000—and Atomic Energy of Canada Ltd 's heavy-water design, the ACR-700.

Still, the staff says the "existing research and regulatory infrastructure primarily supports licensing of the current generation of LWRs" and that there are "gaps" for HTGRs. Massachusetts Institute of Technology (MIT) professor Andrew Kadak says the university is still developing a 110- MW PBMR design concept, and General Atomics is pursuing pre-certification of its gas turbine-modular helium reactor (GT-MHR) Wherever possible, the staff is trying to partner with, or piggyback off of, international researchers or work planned by the U.S government or universities The European Commission (EC) is sponsoring a $16-million, four-year research program on HTGRs, which includes work on fuel.

MIT also is conducting work on HTGRs. MIT's Kadak asked NRC Chairman Richard Meserve and Energy Secretary Spencer Abraham not to shut the door on research. Kadak has submitted proposals to DOE's Nuclear Energy Research Initiative. He says he hopes a consortium of universities, national labs, and industry interests will work to build a PBMR demonstration plant at a DOE national laboratory site in the U S He noted work MIT is doing with the Germans and labs. Some projects include developing "a new state-of-the-art performance model with irradiation testing of new fuels," research on advanced fuel coatings, and a study on the spent fuel waste.

A June 28 letter from RES Director Ashok Thadani to Kadak indicated NRC was interested in participating in some of the research activities. "As you know," Thadani wrote, "we are continuing to explore the possibility of a cooperative agreement with MIT." If the agency is able to reach an agreement, Thadani said he would then be able to discuss the proposals Possible joint research includes sharing of pebble bed reactor physics codes and models, according to NRC's research paper.

RAIs On Fuel Issues

Exelon filed a series of white papers with the NRC between October 2001 and March 2002, including three on fuel-related topics: "PBMR Nuclear Fuel" (White Paper Number 8), "Fuel Fabrication Quality Control Measures and Performance Monitoring Plans for PBMR Fuel" (White Paper No. 9), and "Pebble Bed Modular Reactor Fuel Qualification Test Program" (White Paper No. 10). The NRC staff last month sent requests for additional information (RAIs) on those topics, covering a range of technical, safety, and policy issues

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On the fuel, the staff had questions on the properties of the coated particle fuel, such as how the material, physical, and chemical characteristics compared to the German reference fuel particles, or the so-called Triso coated particle fuel This fuel process starts with a grain-sized uranium oxide kernel that is protected by four layers, or coatings, built up to create a billiard ball-sized fuel pebble. Exelon had wanted to rely on data from the Germans, where pebble bed fuel was irradiated for more than two decades in the AVR reactor, and use that as the basis for its fuel qualification strategy Exelon said it would use the same manufacturing and inspection processes NRC, in its draft research plan, said the integrity of the fuel was key because it would act as a primary fission product barrier during normal operation and under accident conditions.

"These fuel temperatures are predicted by reactor system calculations using a combination of codes and models for core neutronics, decay heat power, and system thermal hydraulics," the report said. But experiments in German's AVR reactor "showed the unexpected presence of in-core hot spots," and the staff was concerned about the ability to predict maximum fuel temperatures for the PBMR and other HTGRs NRC is planning on obtaining German AVR "archive" fuel to conduct irradiation tests simulating PBMR operating and postulated accident conditions These tests are expected to provide a fuel performance benchmark for PBMR fuel manufactured at a later date for the demonstration plant in South Africa, and potentially for use at future commercial PBMR reactors The new fuel, however, is not expected to be produced and available for testing until after 2005, NRC said

In the staff's RAIs, it asked for the material, physical, chemical, and microstructural characteristics that Exelon would use to determine if the PBMR fuel met German specifications. The staff had questions on quality assurance procedures related to the accuracy of temperature measurements, fast fluence calculations, and burn-up calculations. It wanted information on fuel particle behavior under certain accident scenarios, such as a severe oxidation event in which air got through to the core as a result of a large break loss-of-coolant accident
There were questions on the acceptance and rejection criteria for a batch of fuel and what a sample size would look like. The staff asked for the expected maximum burnup of the fuel on its last pass through the core and the "effects of the worst case fuel pebble burnup measurement inaccuracy."

The RES research paper noted there are several factors that affect fuel performance, including the operating temperatures, fuel burnup, and particle fast fluence, among others. During an accident, the primary concern is the peak particle temperature, although another issue is the effect of chemical attack on the fuel element and/or coated fuel, caused, for example, by
oxidation.

"The fuel safety margin is on top of the fuel design margin," the RES staff said in its paper.

While the applicant would have to demonstrate design and safety margins, NRC anticipates research is needed to confirm these assessments "since HTGR designers and applicants generally oppose testing fuel to conditions that go substantially beyond the licensing basis," the report said. Nonetheless, the report says applicants or vendors would be responsible for undertaking research on "a range of significant fuel design, fuel manufacture, fuel quality, and fuel performance issues "

Fuel Fabrication

The NRC staff involved in Exelon's pre-application review had more than three pages of questions on the fuel fabrication quality control measures. "Studies have shown that the fuel fabrication process specifications for HTGR fuel are as important or even more important than the design or product specifications for the fuel," the staff said in an RAI on Exelon's White Paper No 9. It asked how the Germans' precise process would be emulated and how the PBMR process would differ. The staff wanted to know the "key" fuel fabrication processes, including temperature, flow rate, pressure, and coating rate It had questions about the type of equipment that would be used, whether there were any plans for monitoring fission product releases, and how much variation was expected in the number of particles per fuel sphere. There would be about 15,000 coated particles per fuel element

Fuel Qualification Testing

The bulk of the staff's RAIs were in the category of fuel qualification testing, on Exelon's White Paper No 10. It sent Exelon seven and a half pages of questions, asking about everything from the licensing basis events considered in establishing fuel performance requirements, to fuel accident testing, to planned manufacturing specifications on the fabrication process to ensure consistent quality over the life of the plant.

"Provide an assessment of the applicability of out-of reactor, post-irradiation heatup tests and power transient tests for demonstrating Triso fuel performance in reactor accidents," the staff asked in one request. Another RAI requested the analytical codes and materials property data basis for determining BMR fuel oxidation rates, particle failures, and product releases for postulated accidents caused by air ingress The NRC staff said the EC plans to "re-establish knowhow" on the coated particle fuel fabrication process and that it plans to enter into a cooperative agreement with the project. It also wants to exchange information with China and Japan to get more information for establishing expertise in the fabrication process. - Jenny Weil, Washington