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April 5, 2002

SUBJECT: Notes on MEETING WITH EXELON GENERATION COMPANY, DEPARTMENT OF ENERGY, AND OTHER INTERESTED STAKEHOLDERS REGARDING THE PEBBLE BED MODULAR REACTOR (PROJECT 713) EARLY SITE PERMIT PROCESS AND FUEL QUALIFICATION TEST PROGRAM

On March 28, 2002, the Nuclear Regulatory Commission (NRC) staff met with representatives of the Exelon Generation Company (Exelon), the Department of Energy (DOE), and other interested stakeholders to discuss the pebble bed modular reactor (PBMR) preapplication review initiatives. This was the 10th meeting held to discuss preapplication activities related to the PBMR. Attachment 1 is a list of the attendees. Attachment 2 is a copy of NRR presentation slides concerning "Early Site Permit Activities". Attachment 3 is a copy of slides used by Exelon for the "Pebble Bed Modular Reactor Fuel Qualification Test Program" presentation. Attachment 4 is the March 18, 2002, Working Draft paper on the "Pebble Bed Modular Reactor - PBMR - Fuel Qualification Test Program," that was available to attendees.

Stuart Rubin (NRC) opened the meeting by stating the purpose was to discuss preapplication activities of the PBMR, including Early Site Permit (ESP) activities and the fuel qualification test program being developed. He stated that important licensing issues include licensing basis events, fuel fabrication and qualification, and the containment functional design, and that the NRC staff output will be significant safety issues, Commission policy issues, and guidance to Exelon on resolving these issues. In his opening remarks, Kevin Borton of Exelon noted that representatives from Exelon and PBMR would be taking part in the Exelon presentation.

The following summarizes the subsequent presentations:

Early Site Permit Activities

Jack Cushing (NRC) made a presentation of early site permit activities, as outlined in attachment 2. Edwin Fox noted that a memorandum of understanding (MOU) between NRC and the Federal Emergency Management Agency (FEMA) had been noticed in FRN 47996, and he distributed copies of NUREG-0654, Rev. 1, Supp. 2, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, Criteria for Emergency Planning in an Early Site Permit Application, Draft Report for Comment," April 1996. Jack Cushing noted that NRC would follow NUREG-1555 in developing an environmental impact statement (EIS), and would obtain assistance from the National Labs.

Any draft EIS will be published for comment to the Public, Industry, Government Agencies, and other interested stakeholders. All parties will be required to provide comments concurrently during the comment period.

PBMR Fuel Qualification Test Program

Exelon presenters used Attachment 3 as a framework for their presentation concerning the PBMR fuel qualification test program. The presentation was made with periodic breaks for questions from the audience.

Fuel Testing and Licensing

Peter Pagano (Exelon) began the presentation and continued to the point represented by page 6 of Attachment 3, where he asked for questions. Points made during this initial portion of the presentation were that Exelon believes that (1) there is a large body of data available on fuel that has essentially the same design as that proposed for use in the PBMR, (2) the PBMR test program will be confirmatory in nature with test results used to show production fuel complies with "PBMR Licensing Basis Performance Requirements," (3) test results are not required for approval of a COL (combined construction and provisional operating license), although "some early results may be relevant," and (4) manufacture of the initial core load could be completed prior to completion of the test program.

Jerry Wilson (NRC) stated testing necessary to qualify the proposed PBMR design would be needed before a license could be issued. R. Krich (Exelon) said there will be some test results. Stuart Rubin (NRC) said that AVR (former German HTGR) fuel would not be considered the same as the fuel proposed for the PBMR. P. Pagano (Exelon) said that data would be available on production fuel irradiated in Russia, South Africa, and China. Ralph Caruso (NRC) stated that the proposed PBMR conditions, such as enrichment, fuel loading, operating conditions, will be different and Exelon needs to show how this other data is relevant.

S. Rubin (NRC) stated that we need to know the licensing basis events and that the Advanced Reactor Policy Statement requires NRC address fuel performance in severe accidents. R. Krich (Exelon) said the PRA (probabilistic risk assessment) is being developed and that the PRA and peer review would address emergency planning basis events, that is, beyond design basis events. S. Rubin stated that that the most limiting accidents postulated for this design are different for Asia (China and Japan) and Europe (Germany) and this needs to be considered. Yuri Orechwa (NRC) stated that with continuous movement of fuel, there is a need to define the initial core and the initial period of operation.

R. Tripathi (NRC) stated that consequence analyses depend on the containment. R. Krich (Exelon) stated that the proposed PBMR will have a containment, but the containment leakage characteristics will be different from that of LWR (light water reactor) containments. John Flack (NRC) noted that there is a future meeting planned for containments/confinements.

Production of PBMR Fuel

Peter Pagano (Exelon) continued the presentation through about page 9 of Attachment 3. The main point was that the TRISO fuel proposed for the PBMR was essentially the same as the German AVR 21-2 fuel, on which data was available.

Steve Arndt (NRC) asked whether parameters will be monitored and fed back into the fuel fabrication process. S. Rubin (NRC) asked for the basis for selecting pebbles for testing considering the possible variability of batches. Johan Venter (PBMR [Pty] Ltd) said the pebbles will be picked at random after production has reached equilibrium. J. Flack stated there is a need to define when equilibrium has been reached.

Y. Orechwa (NRC) said there are lots of types of German fuel and there is a need to define what is being tested and confirmed. R. Kirch (Exelon) said that AVR 21-2 is the reference fuel that they are planning to produce. Y. Orechwa (NRC) said that if AVR 21-2 is the reference fuel, then other data on other fuels is irrelevant, because different fuels have different distributions of parameters and properties. J. Venter (PBMR) said that coated particle design does not change, although enrichment and other things might. Y. Orechwa (NRC) questioned whether this is really confirmatory testing. R. Kirsh (Exelon) said they want to test to confirm that the proposed fuel behaves the same as all previous fuel. S. Rubin (NRC) asked if tests were performed on a defect rate, would the results be the same under normal operating and accident conditions.

S. Rubin (NRC) asked when the NRC will get to consider the characteristics of the final fuel design, which is now proprietary. R. Kirsh (Exelon) said it will be some time later this year. S. Rubin said NRC needs to know the key process variables, and J. Venter (PBMR) replied that it is at the basic design development stage. S. Rubin said the test fuel will reflect the final fuel specifications.

Supporting International Data

P. Pagano (Exelon) continued the presentation through page 18 of Attachment 3. The main point was that much data is available on UO_2 TRISO fuel similar to that proposed for the PBMR, much of which is documented in IAEA-TECDOC-978, "Fuel Performance and Fission Product Behavior in Gas-Cooled Reactors". PBMR expects the proposed fuel will perform as well or better than the German fuel.

R. Caruso (NRC) noted that the data was for fuels with different coating thicknesses, enrichments, and so on. J. Venter (PBMR) said that you are really testing the coated design, and that all TRISO family fuel is similar in that they use the German fuel design. When asked by Caruso whether problems were experienced for the 81-88 TRISO fuel, Venter replied that no problems were experienced for this group of fuel, called "low enriched TRISO" with 8-16% enrichment. Caruso asked whether they had tested pebbles with the same proposed number of coated particles, and how the key parameters varied with changes in conditions.

Don Carlson (NRC) said there was only discussion of results from fuel from Japan, China, and Russia, but no mention of the US experience. J. Venter (PBMR) said that the US fuel was not the same and produced bad results. Carlson said the US data would be useful because it shows possible fuel behavior. John Flack (NRC) pointed to the "German Results" figure (page 17 of Attachment 3) and questioned that with all the parameters that can change, how do you know how fuel will perform.

Undine Shoop (NRC) asked whether data was available for operation under conditions similar to load following [mode of plant operation in which power is cyclically increased and decreased to satisfy changing load conditions in a pattern that might be repeated, e.g., on a daily basis]. R.

Kirsh (Exelon) stated there is no plan to have load following in the licensing basis. S. Rubin (NRC) stated this will simplify the licensing basis. J. Venter (PBMR) noted that load can followed simply by changing the helium mass flow.

S. Rubin (NRC) stated that most of the data was from test reactors and questioned whether it was representative, as the IAEA report showed higher particle failures that did not seem to show up in the test reactor results. J. Venter (PBMR) said you can cycle in a test reactor by changing temperature, but that it was difficult to change temperature smoothly. In 45 hours, you could cause a change similar to that for an accident, but if you want to test, you should test realistically. S. Rubin (NRC) said you will actually test in temperature transients similar to that for accident conditions for the PBMR. J. Venter said they will do some of that testing. R. Caruso (NRC) questioned whether external point loads would be applied during testing, and Venter replied that they would not. Caruso then asked whether finite element analysis will be done of mechanical loads on the fuel elements, and whether NRC will get to see the results., and Venter replied yes.

D. Carlson (NRC) asked what the maximum temperatures will be in the PBMR and how do we know they will be as expected? J. Venter (PBMR) replied that no one knows what the highest temperature will be, and there is still discussion in Germany about this. Carlson asked for the technical basis for the maximum operating temperature and said he could not see any. Venter replied that the release-to-birth ratio has been the same for different design fuels. Carlson stated that most testing has been out-of-pile heatup testing and questioned how you would show in-pile heatup would be the same in an accident?

R. Caruso (NRC) asked whether at some point in the test program there was a plan to submit computer codes for the proposed design, in order to get approval for the test program. R. Kirch (Exelon) said they have to decide what will be done, as they want NRC feedback. Caruso then said that licensees explain the reasons for the specifications for fuel, and whether and when NRC will receive these. R. Kirch said they are using German codes, mainly. S. Rubin (NRC) then asked what codes the NRC will be receiving. J. Flack (NRC) noted that questions about the codes can be included in an RAI (request for additional information). Caruso noted NRC needs to be told what the models are. J. Flack questioned what the NRC will see for source terms, for the spectrum from normal to accident conditions, and for conditions like air ingress. R. Kirch said they do not expect significant air or moisture ingress, and J. Flack emphasized that the NRC needs to know about air and moisture ingress.

[Lunch break 12:00 - 12:45]

<u>Fuel Qualification Testing, Overview, Fuel Failure Mechanisms, Key Parameters, Testing Considerations, and Statistical Considerations</u>

P. Pagano (Exelon) continued the presentation from page 19 through page 29 of Attachment 3, at which point there was a break for questions. In the Overview section, P. Pagano noted that "safety (heatup) testing" would be performed at 1600° C. (degrees centigrade), and limited testing above this.

S. Rubin (NRC) asked how data from this testing will compare with model validation data for the source term. J. Venter (PBMR) replied that they are in the process of verifying and validating

codes and that calculations of stresses in silicon carbide will be done using codes developed from the THTR. For example, Rubin noted that the graphite matrix material can cause an order of magnitude difference in the diffusion coefficient in the material, and he asked how they plan to model diffusion coefficients in graphite. R. Caruso (NRC) said they should consider draft Regulatory Guide 10.96, Methods to Quantify Uncertainty, when developing experiments. Y. Orechwa (NRC) added this should be done both for normal operations and transients.

S. Rubin (NRC) asked whether operating data can be related to fuel performance, or whether fuel failures will be latent, that is, failure prone fuel will not exhibit failures until accidents, and he asked what test data PBMR will be using to indicate weakened fuel. J. Venter (PBMR) said there is no way to predict that a particle is ready or starting to fail. S. Rubin said he was not asking whether they could predict failure. R. Caruso (NRC) asked whether they knew why a particular batch of fuel exhibited a higher failure rate than expected. S. Rubin said the concern is identifying latent defects, that is, failures that do not show until an accident occurs, and it was not clear how this would or could be done.

When P. Pagano stated that "large air or water ingress and large reactivity insertion events are low probability events," J. Flack asked for a definition of "large," and Pagano replied that large was something that would significantly damage the fuel. Pagano added that Exelon feels these are not licensing basis events and therefore does not plan to do testing for this.

R. Caruso (NRC) asked what is the design basis distribution for burnup. He added that NRC normally licenses for a certain level of burnup.

Fuel Irradiation and Fuel Safety Testing, Post Irradiation Exams, and Review of Objectives

P. Pagano (Exelon) continued the presentation from page 30 through the "Review of Objectives" on page 39 of Attachment 3. At that point there was a break for questions.

J. Flack (NRC) said there was a need to understand where fuel begins to fail and how much margin there is before failure. R. Kirch (Exelon) said that the behavior of the fuel is well known and there is no need to take the fuel to the failure point, because they already know they will not get to that point during operation.

S. Rubin (NRC) said that testing at 1600° C. + 100° C., say "hot plus 100 degrees," was something, but what if you start with a larger "hot"? Rubin also asked about the ALARA issue, that is, what will be the expected doses to workers.

Meeting Concluded

Edwin Lyman (Nuclear Control Institute) stated it was a mistake to think the proposed project (1) did not need a containment [with design similar to that required for existing light water reactors], and (2) did not need full testing to prove the fuel would perform as predicted. Another comment made was that HTGR particles with identical manufacturing backgrounds performed differently.

S. Rubin (NRC) noted that there was a future meeting planned specifically for containment/confinement issues. S. Rubin thanked the meeting participants and attendees. He noted that the RAIs are due in early May. He also noted that while this was not an application

stage, the white papers should be revised and supplemented to resolve the things that came up at this meeting.

Attachments: As stated