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From: Stuart Rubin RES
To: Undine Shoop NRR
Date: Fri, Aug 17, 2001 11:56 AM
Subject: Questions on PBMR Fuel Irradiation Program

Attached is a still evolving draft on the PBMR Fuel irradaition program. It is based on the first two presentations from Exelon on the Pebble fuel topics. I am organizing the questions so that they track the July meeting prorietry handout on the irradiation program. However I am only less than half way thru that organizing effort. Additional questions are in my head but not yet on the attached. I have recieved input from Tom King, and Steve Arndt. I am still azwaiting input from Ralph Meyer.

I am sending it to you now because you have asked too look at it. Therefore, please provide any substantive additional questions you think should be asked. I am not looking for "word-smithing."

Thanks.

Stu

CC: Amy Cubbage; Diane Jackson

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PBMR Fuel Irradiation ProgramQustions

Slide 3:Purpose of PBMR Fuel Program

Discuss what the irradiation testing program is intended to confirm and qualify: (1) PBMR fuel design specifications; (2) Pelindaba fuel manufacturing plant fuel fabrication equipment and processes; (3) Pelindaba production fuel elements produced for the South African PBMR demonstration plant; (4) production fuel elements that could be produced for PBMRs that might be constructed and licensed to operate in the US. All of these aspects? Explain?

Describe what is specifically meant by "the envelop of German measured irradiation data." Provide or cite the references for the specific German measured irradiation data to which the PBMR fuel irradiation program tests (including accident simulations tests) are to be compared.

The German fuel irradiation testing experience on the reference fuel elements utilizing UO_2 TRISO particle fuel with low enriched uranium (LEU) showed essentially no fuel particle failures over the design burn-up spectrum as well as for post-irradiation accident simulation heat-up tests up to 1600^0 C. What are the success criteria and test objective for the PBMR fuel irradiation program tests including the post-irradiation heat-up tests? Discuss the quantitative statistical measure(s) that was used to determine the performance of the irradiated German fuel and will be similarly used to determine the performance of the irradiated PBMR fuel.

With respect to the fuel irradiation program environment, discuss the important steady-state, slow transient (e.g., fuel element flow through the core) and potential fast transient (e.g., load follow) that define the PBMR plant design operating conditions. Compare these PBMR design operating conditions to the simulated operating conditions in the irradiation tests. Include in the discussions operating conditions such as fuel element surface temperature and interior temperatures, total burnup (i.e., FIMA), burnup vs fast fluence, magnitude and number of power/temperature transient cycles due to fuel element movement down through the core, total irradiation test time. Discuss any potential normal operating conditions of the PBMR that the irradiation test program will not specifically closely simulate (e.g., load follow, length of irradiation period) or will not closely match the actual PBMR operating environment (e.g., burnup vs fast fluence). For any significant differences, explain the basis for the acceptability of the irradiation test program conditions.

Also with respect to the irradiation environment, fuel elements immediately next to or "imbedded" in the central reflector graphite elements could have significantly higher moderation than fuel elements distant from the central and peripheral core reflectors. This may cause the local pebble power and possibly pebble fuel temperatures to be significantly higher than the fuel in the interior of the annular fueled region. AVR fuel pebble melt wire experiments showed significantly higher pebble surface temperatures than predicted. In particular it has been suggested that this was due to the melt wire pebbles being near the protruding graphite control rod noses which resulted in more local moderation and higher pebble power in the nearby fueled pebbles. Discuss this potential local power peaking effect in terms of the acceptability of the planned irradiation test temperatures.

Describe/discuss the spectrum of PBMR postulated events (e.g., normal operation, anticipated transients, design basis accidents and emergency planning basis events) that the irradiation testing program is intended to simulate (e.g., reactivity insertions, loss of flow, loss of coolant,

uncontrolled cool down, water ingress, air ingress).

Slide 4: PBMR Irradiation Program

Provide a general description and discussion of the purpose of the test program in the RSA SAFARI Reactor. Provide a general description and discussion of the purpose of the test program in the Russian IWV-2M Reactor.

For the RSA SAFARI reactor irradiation tests, clearly describe the purpose of each irradiation test (e.g. particle tests: particle performance, fission product transport in intact particles, fission product release from broken particles; fuel element tests: fuel element performance, fission product transport in fuel elements, proof tests) and the number of fuel elements and/or coated particles that will be involved in each kind of test. Similarly describe the purpose of the of the Russian IVV-2M reactor irradiation test program.

Slide 5: Fuel Baseline Program Flow Diagram

Discuss the relation and purpose of the "Fuel Test at SAFARI" to the significant boxes that feed into it (i.e., "Laboratory Pre-Production Process Development," "Fuel Plant Manufacturing Test Program").

With respect to the "Fuel Test at SAFARI" discuss the output and what it is to be used for in relation to the "Fuel Plant Manufacturing Test Program." Following the fuel irradiation test program at SAFARI is it intended that all manufacturing process variables will be fixed or is it expected that process variables could still be revised and refined after the SAFARI test. If they could still be revised and refined, will any of these SAFARI test results be included in the fuel proof test program database. Explain.

For each of the graphite materials and resin used as feed for the manufacture of the fuel elements, discuss the source of the materials that will be used for the manufacture of the fuel particles and fuel elements that will be used for the SAFARI and Russian test reactor irradiation tests. Will each of these sources be the same as those that will be used for manufacturing the production fuel elements for the PBMR demonstration plant? If not explain. Will these sources be the same as those used for manufacturing production fuel for the PBMR plants that may be built in the US? If not explain.

Discuss what is meant by the "Line Qualification Proof Batch." Discuss the specific outputs of this box in relation to the proof batch qualification and "Fuel Test in Russia" box. Specifically, for the completed Pelindaba plant how many TRISO fuel particle production lines (e.g, fluidised bed reactor lines) and fuel element manufacturing lines (e.g., element molding production lines) will be built? Of these, how many of the production lines will participate in making the "proof batch" for the fuel to be used in the irradiation tests in Russia. If only a subset of the total planned number of production lines are to be used to make the "proof batch" of fuel elements for the fuel irradiation program, discuss how the other Pelindaba production lines (and fuel elements they will produce) will be qualified for the manufacture of fuel for the PBMR demonstration reactor in South Africa and PBMRs that may be built and licensed to operated in the US. Discuss the batch size and the number of batches (i.e. lots) of TRISO particle fuel that will be fabricated and characterized (for each of the production lines used to make the "proof batch" for manufacture of the fuel elements that will be used in the fuel irradiation test in Russia. Discuss the production line and batch split sample scheme that will be used to arrive at

a statistically representative sample of TRISO particles that will be used to fabricate the fuel elements used for the fuel irradiation test in Russia. Compare the split sampling scheme use for the irradiation test with the slit sampling scheme that will be used to fabricate production fuel elements at the Pelindaba plant.

There are several statistical sampling methods that are in use today. Provide information on what standards will be used for the sampling of fuel particles for the fuel irradiation program (e.g., ANSI/ASQ Z1.4, MIL-STD-105E, etc.).

How will multiple particle failures during the irradiation or post-irradiation heat-up test from the split samples be handed in the analysis?

Discuss what is meant by the "Quality Achieved?" output diamond from the "Fuel Test in Russia" box. Explain the success criteria ("Yes") qualitatively and, to the extent possible, quantitatively. Explain the failure criteria ("No") qualitatively and, to the extent possible, quantitatively. What are the plans for fuel qualification if the outcome of the Fuel Test in Russia does not meet the success criteria for "Quality Achieved?" Specifically explain the implication of the arrow which goes from the "Quality Achieved" diamond to the box labeled "Fuel Production for Initial Core" if the quality success criteria is not met. Explain the purpose of the Fuel Test in Russia (15 mos) relative to the fuel qualification program proof batch and/or the qualification of the fuel fabrication facility. Explain the purpose of the "Continue" Fuel Test in Russia (2 years) relative to the fuel qualification program proof batch and/or the qualification of the fuel fabrication facility. Explain why is there no "Quality Achieved?" diamond after the "Continue" Fuel Test in Russia (2 years)." What are the irradiation measurements and/or post irradiation examinations and tests that will be performed at the end of the 2 additional years of testing. Explain how this continued testing relate to the box "Fuel Production for Initial Core." What are the plans, if any, for the fuel qualification program if the outcome of the Continued Fuel Test in Russia does not meet the success criteria for "Quality Achieved?"

Explain the purpose, if any, of the SAFARI pre-production fuel test program results relative to the data base to be developed and used for the production fuel proof test (i.e., fuel qualification) program.

With regard to the fuel element production schedule, approximately when is it expected that the "Line Qualification Proof Batch" fuel will be manufactured and ready for the fuel test in Russia. When will the test be completed and approximately when will the test results be analyzed and submitted for staff review. Is it expected that the results will be analyzed and submitted at the time of application for a combined operating license in 2003 or by the time the staff's COL is completed. If neither, when is it expected that the test results would be completed and how would the results be utilized in connection with issuance of approval for PBMR initial fuel loading or operating license?

Explain the purposes of the graphite tests that will be conducted at the Russian IVV-2M reactor. How will these tests be conducted and how do they relate to fuel irradiation tests?

<u>SAFARI Reactor Phase I (Page 7)</u>

What is the basis for selecting 1200°C as the irradiation temperature? What was the basis for selecting 9% FIMA. What is the corresponding fast fluence
What is the purpose of the continuous fission gas release? What fission gases will be

measured?

Discuss the physical characteristics that will be measured before and after irradiation.

What is the nature and purpose of the PIE that will be performed on one fuel element.

If it turns out that there are no initially defective fuel particles from manufacture, no fuel failures during irradiation and no fuel failures during post-irradiation heat up testing how will fission product release data for defective or failed coated particles be obtained for use in model verification for the safety analysis (e.g., source term) for PBMR fuel.

Explain why the post-irradiation fuel element heating test is only to 1600°C whereas the German fuel was also typically tested at 1700°C and 1800°C. Discuss how it is proposed to establish margins to fuel particle failure (and margins to increased fission product release) that would be expected to occur at higher temperatures for the Pelindaba production fuel. What is the post-irradiation fuel heat up ramp rate and its basis.

SAFARI Reactor Phase II (Page 8)

What was the basis for selecting 4.4% FIMA.and 6.4% FIMA? What are the corresponding fast fluences.

Specifically how does (and what aspects of) the irradiation program support the development of development and qualification of the source term model required for licensing basis analyses.

If possible fill in the following table Test vs Test Goal Matrix Table :

	Test						
	Safari		Russian IVV-M2				
Test Goal	Phase I	Phase II	Coated Particles	Pre-Irrad Character	Post-Irrad Character	Destruct Tests	Heating Tests
Particle Performance							
Fission Product Transport in intact Particles							
Release from Broken Particles							
Particle failure model development/validation							
Chemical Effects							
Fuel Element Performance							
Proof Tests							
Source term Model Development							
Other							

What is the purpose of the proposed international irradiation program. What is the purpose of the program relative to the qualification of production fuel to be produced at the Pelindaba plant?