From: Yuri Orechwa > NRR
To: Amy Cubbage
Date: Fri, Jan 25, 2002 1:34 PM
Subject: RAIs - Hight-Temperature Materials Graphite

Amy,

Attached are some comments and RAIs with regard to the Excelon White Paper "High-Temperature Materials Graphite".

Yuri

CC: Frank Akstulewicz; Ralph Caruso; Undine Shoop

Cd46

Comments and RAIs on the PBMR White Paper - High-Temperature Materials Graphite

The subject White Paper consists mainly of sections and figures copied from the short summary report "Graphite for High-Temperature Reactors", EPRI, August 2001, prepared B. Marsden of AEA Technology in England. These sections are annotated with comments as to the relevance of the material to PBMR conditions. This material together with the handout "Pebble Bed Modular Reactor High Temperature Materials Graphite" by Mark A Davies, October 2001 will be the context of what follows. In general, the data exhibited and the statements made in the above do not indicate whether they apply to a He atmosphere or some other atmosphere such as CO_2 in the case of British data. It is well known that the type of atmosphere affects the behavior of graphite at high temperatures and irradiation. In general, for all data presented for review it should be indicated what the atmosphere was under which the data were collected, ora justification given why data collected in another atmosphere is applicable.

Nuclear Graphite Manufacture:

a) On page 37 of the handout the statement is made "Suitable Nuclear Grade Graphites can be determined by appropriate choice of manufacturing process parameters". How can you be sure that you can make such a determination, what appears to be a priori, in light of the fact that there is no data beyond "turnaround" for PBMR conditions?

b) PBMR has chosen Sigri Great Lakes as the preferred supplier for the graphite reflector. A table is show of some of physical properties of the unirradiated graphites. Does data exist for these products for irradiated conditions? In particular, if these data exist, what is their relation to the conditions of interest in PBMR?

The Damage Process:

a) It is not clear what measure of fast neutron dose is to be used in the analysis and prediction of graphite behavior at high temperatures in PBMR. If the integrated flux above 0.18 Mev is used, what is the basis for this choice? If EDND is used, what is the evidence that the Thompson-Wright damage function and the standard nickel flux in DIDO are appropriate for PBMR conditions?

b) It is stated that "It is assumed that for the type of graphite to be used in PBMR, in the temperature and fluence range of interest, the graphite behavior is consistent, i.e. the material properties, when irradiated in a similar flux, may be described by mathematical equations, which are functions of irradiation temperature and dose."

i) Do you mean that the mathematical equations for all graphites of interest to PBMR and the graphites used in existing and past reactors have the same analytic form with regard to temperature and fluence? The figure on page 19 of the handout implies that there is significant material to material variability with regard to turnaround and the fluence level at the material exhaustion limit. What are the mathematical expressions used to characterize the material behavior of the relevant graphites; and how do you plan to estimate the coefficients which distinguish the behaviors between particular graphites?

ii) In computing the predicted state at end of service life based on the mathematical models, the fluence is a monotonic function of time while the temperature is not. How will the temperature be quantified so as to represent the correct damage contribution? How will the uncertainty in the prediction be computed? How will the distinction between fixed and random effects be made?

iii) Do you account for cyclic fatigue, such as due to thermal striping in the plenums?

c) Is the expression on page 18 of the White Paper for creep or the creep rate?

i) The expression includes primary and secondary creep terms. Is there a tertiary creep term in the case of PBMR conditions?

ii) What is the limiting creep level (irradiation and thermal) for the PMBR design? Does it vary with temperature and fluence?

iii) Under what conditions, if any, does material exhaustion supersede the creep limit?

Component Performance Assessment:

a) Since fast neutron irradiation rapidly increases the strength of graphite due to pinning of the dislocations in the basal planes for PBMR conditions which is a more limiting failure criterion, one based on unirradiated graphite properties with the standard safety factors, or one derived using the UK proposed Griffith failure criterion and taking into account irradiated graphite properties. In particular, when considered for a fixed level of confidence and in the context of a modified Weibull distribution and a probability of crack initiation of 10^{-4} as proposed in the ASME code?

b) The recommended failure criteria for PBMR graphite components give on page 22 of the White Paper is consistent with how many effective full power years of PBMR operation? Are these criteria affected by the reported premature cracking in AGRs (Nucleonics Week, January 24, 2002)?

c) If the option of replacement of the inner reflectors is pursued, are there scenarios in which a reflector brick can be dropped? If yes, what damage if any can result and how will the graphite brick be retrieved?