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Proposed EMCB RAI for Pre-Licensing Review of PBMR Design

(W. H. Koo)

(1) Exelon plans to use ASME Code Cases N-499 and N-201 for the design of reactor pressure vessel (RPV) and the core support component of the core barrel, respectively for limited service at elevated temperature. NRC has not endorsed the use of these two code cases for any design applications. For NRC to perform a proper review of these two Code cases for design applications in the PBMR, Exelon should provide the basis and justification to demonstrate that it is conservative to design and fabricate the referenced components based on the requirements provided in the subject code cases. In particular, Excelon should address the effects of the bounding environment condition, including irradiation, in addition to the effects of temperature and time on the mechanical and physical property values of the materials that are provided in the subject code cases. Test data should also be provided to support the discussion and conclusion. If relevant test data are not available, Exelon may propose a test program to verify or validate the assumed property values that are used for component design.

(2) In a letter dated October 23, 2001, Exelon stated that the top reflector is suspended from the core barrel top plate by means of carbon-carbon composite tie rods. Exelon should provide detailed information regarding the mechanical and physical properties of the carbon-carbon composite materials, method of fabrication and installation, and the geometry of mechanical joints that connects the graphite top reflector to the core barrel top plate. The details of design criteria including materials property requirements and

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nondestructive evaluation procedures should be identified and discussed. If a threaded configuration is designed for the mechanical joint, other details such a lubricants or surface treatments and preload provisions should be provided. Exelon should also discuss the bases for selecting this material for tie rods and provide the service experience of the carbon-carbon composite in an environment similar to PBMR.

(3) Exelon should briefly discuss the extent to which the design criteria of the plant structures, systems, and components important to safety meet the NRC "General Design Criteria for Nuclear Power Plants specified in Appendix A to 10 CFR Part 50 for LWRs. For each criterion, a summary should be provided to show how the principal design features meet the criterion. Any exceptions to criteria should be identified and the justification for each exception should be discussed. (From Regulatory Guide 1.70, Revision 3, section 3.1, Conformance with NRC General Design Criteria) It is expected that some criteria unique to water cooled nuclear power plants may not be directly applicable to gas cooled nuclear power plants, such as the PBMR.

(4) List all materials used for the reactor pressure vessel and its appurtenances, core support structures, primary pressure boundary, connecting piping, and other components important to safety and provide the applicable material specifications, design time at temperature and other environmental conditions. Identify the grade or type and condition of the materials to be placed in service. If the code approved material specifications for the intended applications are not available, relevant material specifications should be developed following the format of American Society for Testing

and Materials (ASTM) specifications. The subject specifications should be supported by the data and information as identified in ASME Code, Section III, Appendix IV for approval of the new materials. Additional information unique to the application in the PBMR environment and condition should also be provided.

(5) Exelon should establish a quality assurance program for design, procurement, construction and operation of the proposed nuclear power plant that are consistent with the design bases specified in the license application. The program must meet the requirements of Appendix B to 10 CFR Part 50. The program will have to meet the applicable requirements, based on Appendix B to Part 50, determined for the regulatory frame work applied to the PBMR.

(6) Describe in detail the leak detection systems and/or monitoring program to identify leakage from the primary pressure boundary and the internal leakage from the sleeves of the hot piping and from the water/gas interface of the secondary water cooling systems. To ensure early detection of leakage, the sensitivity, response time, and monitoring frequency of the designed leakage detection systems/monitoring program should also be discussed. If you plan to apply leak before break (LBB) in the design, discuss how its leak detection requirements are met. If leak detection system is not planned in the plant design, provide justification why it is not needed, and also discuss how the design philosophy of defense in depth is met to ensure safe plant cperation.

(7) In a supporting document provided in a letter dated October 23, 2001, a table presenting the data of temperature and fluence level at various locations inside the PBMR reactor is provided. Please provide details regarding how these data are derived. If these data are analytically calculated, please identify the procedures, assumptions and models/computer codes that are used for the calculations. If you plan to use those data for design of PBMR reactor components, provide the following information (i) the scatter bands and/or uncertainties that are associated with the calculated results, (ii) your plan to verify/validate the calculated results by testing in PBMR configuration and operating conditions.

(8) Exelon plans to use ASME Code Case N-499-1 for the design of reactor pressure vessel so that the selected vessel material will be allowed to operate for a limited period at elevated temperature. The Code Case N-499-1 allows the selected vessel material to operate for limited periods in the temperature range of 371°C to 538°C. Exelon also identified that during the off-normal operating condition, the temperature of the reactor pressure vessel could be as high as 476°C. Since this temperature is only about 11% below the maximum temperature allowed by Code Case N-499, Exelon should provide detailed discussion regarding how the maximum temperature during off normal operating condition was calculated and the magnitude of uncertainties associated with the calculated results. Also discuss the results of sensitivity studies, if performed. The staff understands that the reported maximum temperatures are based on the thermo-hydraulic simulations of a "Reactor C" configuration and the PBMR design is still under

development. Is there a plan to verify or validate the calculated results through experiments or demonstration plants when the design is finalized.

(9) Provide the basis and justification regarding designing the connecting piping as pressure vessels and not as pipes. Compare the differences in requirements pertaining to design criteria, welding, fabrication, installation, pre-service inspection, in-service inspections and any others.

(10) In the white paper provided in the December 17, 2001 letter, Exelon stated that the impurities in the helium gas could lead to either carburization or internal oxidation of the materials, which in turn would affect the creep and fatigue properties of the materials. Exelon also concluded that based on the test results that the helium impurities effects are only appreciable at high temperatures(> 550° C) and, therefore, Exelon expects no significant effects on the reactor pressure vessel and pressure boundary piping. However, the staff notes that the design of the hot pipes utilizes an internal sleeve, made of Incoloy 800H. The internal sleeve is exposed to a maximum temperature of 900°C during normal operating condition. Excelon should provide detailed discussion regarding the effects of helium impurities on the creep and fatigue properties of the internal sleeve, and identify any design measures and/or monitoring/inspection programs that will be implemented to mitigate the potential degradation of material properties. The hot piping at the core inlet is exposed to a maximum temperature of 600°C during off-normal operating condition for 100,000 hours (30% of life); the effects of helium impurities to the material properties should also be discussed.

(11) The graphite spheres and fuel spheres are continuously moving through the core cavity and the transfer channels. The repeated motion of the spheres under load could cause material loss at the surface of the spheres and the supporting graphite components. Therefore, the staff recommends that the wear/abrasion property of the graphite materials used for manufacturing components of reflectors, graphite spheres and fuel spheres be evaluated and specified in the materials or components specifications to ensure structural integrity of the components as well as to minimize the graphite dust in the reactor environment. If Exelon believes that this is not necessary, provide your basis and justification including supporting test data.

(12) The staff understands that the irradiation database for the graphite materials is very limited and will not cover the irradiation requirements of the PBMR for a design plant life of 35 fpy. Furthermore, most of the test data are derived from graphite materials exposed to conditions of relatively low fluence and temperature. Exelon indicated that several semi-empirical relationships are developed based on such data. Exelon plans to use those empirical relationships to assess the graphite performance at PBMR conditions. The staff has concern regarding the use of these semi-empirical relationship to extrapolate the material properties for conditions of high fluence and temperature, because the extrapolated material properties may not be conservative when the relationships are based only on the low fluence/low temperature test data. To ensure there is adequate safety margin in component designs, the graphite material properties used in design need to be verified or validated by testing of the specific graphite materials selected for manufacturing the reactor components.

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