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Exelon Generation

Project No.: 713

September 5, 2001

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Subject: Response to NRC Comment Letter Regarding Exelon Generation Company's Proposed Licensing Approach for the Pebble Bed Modular Reactor (PBMR) in the United States

Reference: NRC letter dated August 16, 2001 from Thomas L. King to Kevin F. Borton – Manager Licensing, Exelon Generation Company

Dear Sir/Madam,

Attached is Exelon Generation Company's (Exelon's) response to the referenced NRC comment letter regarding the "Proposed Licensing Approach for the Pebble Bed Modular Reactor in the United States." The attachment restates the NRC's comments contained in the referenced letter and provides an individual Exelon response to each comment. This letter also supports Exelon's current licensing approach document requested by the NRC, and submitted by letter dated August 31, 2001.

If the NRC staff has any questions or requires additional information please do not hesitate to contact me (610-765-5528).

Sincerely,

Kevin F. Borton
Manager, Licensing

Attachment

cc: Thomas King, RES
William Borchardt, Associate Director NRR
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ATTACHMENT

Project Number: 713

Exelon Generation Company

"Response to NRC comment letter dated August 16, 20001,
Regarding Exelon's
Proposed Licensing Approach
For The
Pebble Bed Modular Reactor
In The United States"

12 pages
September 5, 2001

Response to NRC Staff Comments on Proposed Licensing Approach

Response to NRC comments on Licensing Approach:

NRC Comment:

1. Exelon has indicated that the NRC staff's review of the proposed licensing approach should focus on the acceptability of the approach and not the acceptability of the PBMR design. The NRC staff agrees that this should be the focus of its review at this stage of the pre-application process. It would also be the focus of the Commission paper to be issued in November 2001. However, the licensing approach documents reviewed to date include a number of unsubstantiated statements or assumptions about the pebble bed modular reactor (PBMR) design. The staff has requested that a revised licensing approach be submitted to the NRC by August 31, 2001. The staff's review of the licensing approach will not assess the acceptability of statements relative to the design of the PBMR.

Response:

Exelon submitted a letter, dated August 31, 2001, that represents the current proposed licensing approach for the PBMR in the United States. The submittal is with the NRC staff understanding that the staff's review should focus on the acceptability of the approach as a method as opposed to a review of the design.

NRC Comment:

2. Completeness and modeling uncertainty in accident potential and subsequent analysis is generally handled by including defense-in-depth (DID) and safety margins in the plant design and operation. The Exelon documents reviewed suggest that the DID principles in Reg Guide 1.174 will be considered and that the PRA will include an assessment of the contributors to uncertainty resulting in a quantitative assessment of the safety margin. Detailed information on how this will be accomplished will be necessary for the staff to make a final determination of the acceptability of Exelon's licensing approach.

Response:

Exelon's current licensing approach document submitted on August 31, 2001 explicitly addresses DID and PRA uncertainties that contribute to the determination of safety margins.

NRC Comment:

3. Exelon has proposed a licensing approach which identifies Top Level Regulatory Criteria (TLRC) and which are depicted on a diagram of the mean frequency per plant year vs. dose at the exclusion area boundary. This figure shows schematically how Exelon proposes to use risk criteria for the PBMR as a basis to determine anticipated operational occurrences (AOOs), design basis events (DBEs), and emergency planning basis events (EPBEs), which are collectively called Licensing Basis Events

(LBEs). The use of this approach in a supplemental role to deterministic methods and existing risk metrics is encouraged subject to verification of the assumption that the frequency ranges are validated by analysis and testing. This approach could be expanded to worker protection (e.g., 10 CFR Part 20 has occupational dose criteria for normal operation and 10 CFR Part 50, Appendix A, Criterion 19 has a dose criteria for personnel in the control room during DBEs). Risk assessments of DOE non-reactor nuclear facilities have used both public and worker dose criteria as risk criteria.

Response:

Exelon agrees that the use of deterministic methods is an essential element of the licensing approach. Furthermore, the frequency ranges used in the PBMR PRA will recognize uncertainties and be of a high quality consistent with current PRA practices. Also as discussed in previous meetings, existing LWR risk metrics are not applicable to the PBMR. Accordingly, Exelon has proposed an approach to PBMR risk metrics in the August 31, 2001 licensing approach and are summarized in the response to NRC comment number 11 below.

Exelon does not consider that it is necessary or appropriate to establish risk-informed criteria for occupational exposures. Other reactors, both existing and advance designs, have not established such criteria and the state of regulation regarding theses issues are not sufficiently developed.

NRC Comment:

4. With regard to the TLRC criteria themselves, several issues need to be addressed. First, the current regulations include a frequency reference for the definition of AOOs but a similar reference does not exist for DBEs. Exelon's selection of 1E-4/yr as the lower frequency for a DBE is not consistent with (A) current licensing practice; (B) the RIP50 (Risk Informing of 10 CFR Part 50) Option 3 framework guidelines provided in SECY-00-0086; (C) the frequencies of accident that are to be compared to the dose criteria contained in 10 CFR Part 100 and 10 CFR 50.34; and (D) the frequencies used in evaluating other advanced reactors.

Response:

We have not found a suitable definition for the lower frequency of the DBE region, above which the PRA accident families become DBEs for which it must be shown that the safety related equipment is sufficient to mitigate the events. We have selected $1x10^{-4}$ per plant year on the basis that events within the design basis region should not be expected in a plant's lifetime but might occur in the lifetime of a population (several hundred) of nuclear power plants.

The above basis is independent of nuclear power plant type. However, note that specifying the frequency on a per plant basis reflects the probability for all reactors in a plant. Thus, for independent events for one reactor in a 10-reactor PBMR plant, the proposed criterion is $1x10^{-5}$ per reactor year. Furthermore, to conservatively account for uncertainties, the selection of the DBE is with the assessed upper bound of the mean frequency uncertainty. Thus, in a practical

sense, the lower frequency proposed for the DBE region is effectively less than 10^{-4}/plant year.

We would like to work together with the staff to formulate a sound basis for the PBMR that is applicable to existing and advanced reactors. We suggest that a working session be held to exchange information and insights.

(A) **Current licensing practice**

The current licensing practice evaluates DBEs selected deterministically, as it evolved prior to the advent of PRA. Initiating events are evaluated conservatively with assumed failures and with only the safety-related equipment responding. Thus, the sequence frequencies of the LWR DBE could be expected to extend as low as 10^{-6}/reactor year. However, it can not be said that all events above that frequency have been considered or are bounded by those that are considered.

Thus, in order to judge consistency of our proposed lower frequency for the DBE region with current licensing practice, we have had to infer the frequency which is beyond the design basis region. Since LWR core damage accidents with or without a large early release are not considered design basis accidents, we reviewed the results of published PRAs for the core damage frequency from internal events at full power and found that they typically range from $1x10^{-5}$ per reactor year to $1x10^{-4}$ per reactor year with some specific plant PRA results above and below this range. The effect of multiple reactor plants would raise the above numbers. Core damage frequencies for events during shutdown could provide additional insights. Similarly, a review of seismic events at LWR sites reveals that sequence frequencies beyond the design basis are in the same range.

Based on the above cursory review, we consider our proposal to be consistent with current licensing practice.

(B) **RIP50 Option 3 guidelines**

The frequency metrics from the Option 3 framework are applicable to LWR accident types involving core damage and large early releases. No comparable end states exist for PBMRs. Therefore, the quantitative guidelines provided in the Option 3 framework are not applicable as a result, the quantitative thresholds used in the TLRC appear inconsistent. However, what is more important is that the proposed PBMR licensing approach general principles are consistent with the Option 3 framework and Reg. Guide 1.174: consideration of both accident prevention and mitigation, defense-in-depth and safety margins as applied to a set of LBEs that are uniquely appropriate for the PBMR.

(C) **10CFR100/50.34 accident frequencies**

In general, the frequencies of the design basis accidents that are analyzed in a Final Safety Analysis Report (FSAR), Chapter 15, that are compared against the dose criteria in 10 CFR 100 and 10 CFR 50.34, are not assessed. One exception to this is that the frequencies of selected external initiating events may be known from application of Standard Review Plan guidance for establishing the design basis of safety related SSCs. Many of the DBE would be expected to have extremely low frequencies as a result of the specific assumptions made in the DBE analysis. For example, a double-ended guillotine break of the largest pipe would be expected to have a very low frequency, much lower than $1x10^{-4}$/reactor year when considering the frequency of the event and then considering the probability of the limiting single failures assumed as well as the non-functioning of all the non safety-related equipment. However, certain risk-important sequences of smaller pipe breaks having higher frequencies are not included in the FSAR Chapter 15 analyses.

To recap, the 10CFR100/50.34 criteria have been used in the past for deterministically-selected DBEs, some of which can have a very low frequency, but may miss the more likely and higher risk events. PBMR proposes to use these dose criteria, but to select a comprehensive set of events using the PRA within a DBE region that is also achievable by the existing LWR, namely, our proposed 10^{-4}/plant year for the lower boundary.

(D) Frequencies used in evaluating other advanced reactors

We are not aware of a defined frequency range for the DBEs for Advance Reactors. As such, the best guidance for how to treat advanced reactors is in the Advanced Reactor Policy Statement, which expects at least the same level of safety, but with enhanced safety margins. PBMR proposes to show large defendable safety margins in meeting generic TLRC, including a definition of the DBE region applicable to all reactor types.

NRC Comment:

5. 10 CFR Part 100 and 10 CFR 50.34 criteria of 25 rem TEDE assume that the containment is intact, i.e., the dose occurs due to leakage from the containment. Exelon should explain the assumptions being used in the TLRC.

Response:

The licensing approach for the PBMR does not prescribe the accidents to be compared to the TLRC requirements. Only the exposure dose criteria within 10CFR100/50.34 were selected as TLRC. Events to be compared to 10CFR100/50.34 may include any combination of failures, including dependent and common cause failures unconstrained by the single failure criterion, as predicted by the PRA to be within the DBE region. The containment or other retention barrier may or may not successfully perform its safety function, or its

capabilities degraded according to the event sequence, but the dose criteria reflected in the TLRC still has to be met.

A strength of this approach relative to existing LWR licensing practice is that the PBMR containment systems will be designed to support the meeting of 10CFR100/50.34 dose criteria based on a rigorous quantification of source term and source term uncertainties rather than the predefined TID 14844 source term used to establish the design basis leak rate for existing containments. LWR source term was defined to provide a conservative basis for siting the plants and determining the design basis containment leak rates. This is a reflection of the fact that containments were not designed to survive any mechanistic interpretation of a core damage event. By contrast the PBMR containment will be designed with appropriate conservative margins to perform its safety function for all DBEs consistent with the $1x10^{-4}$ per plant year threshold.

NRC Comment:

6. In addition to the TLRC, Exelon should consider the use of deterministic licensing criteria, such as a peak pebble temperature, degraded pebble geometric configurations, or flow bypass caused by unexpected flow channelization for selection of structures, systems, and components (SSCs) to mitigate LBEs.

Response:

Exelon agrees with the comment. The current licensing approach document submitted on August 31, 2001, discusses the approach to determining these SSC criteria. Each DBE is evaluated to show compliance with the dose criteria by deterministically assuming that only the safety-related SSC are available. In this way, deterministic acceptance criteria for the safety-related SSC are developed in terms of temperature, pressures, loads, stresses, etc.

NRC Comment:

7. The Exelon documents reviewed compare the calculated dose from individual DBEs, AOOs, and EPBEs to the TLRC by depicting the calculated doses and the TLRC on a diagram of the mean frequency per plant year vs. dose at the exclusion area boundary. We are unclear on what is actually being compared. It is possible to interpret the AOO and DBE portions as graphical representations of the criteria used in the licensing of existing reactors. Specifically, the listed criteria are essentially the same as those used in current Final Safety Analysis Report Chapter 15 analyses. In this interpretation, the AOO and DBE frequencies used in the comparison to the criteria would be the frequencies for mitigated accidents, since this is what is currently done. In this interpretation, deterministic criteria must also be established for determining the adequacy of the SSCs for mitigating the transients and accidents chosen from the PRA to be LBEs.

Response:

On the PBMR Risk Criteria Chart contained in the August 31, 2001 current licensing approach document, the mean and upper bound consequences of the AOO and DBE are compared to the corresponding TLRC. However, the AOO and DBE include the response in terms of frequency (prevention) and consequences (mitigation) of the entire plant, whether safety-related or not. Then the consequence analyses are repeated with only the safety-related SSC to confirm that they are a sufficient set to meet the criteria on a mean and upper bound (95%tile) basis. This is similar to the Chapter 15 accident analyses in current FSARs. In this way, a sound case is provided that 1) the expected sequence (with the entire plant responding) is acceptable with a known safety margin, and 2) the conservative condition with only the safety-related SSC responding is also acceptable with a known safety margin and specified confidence level in characterizing the consequence uncertainties. Additionally, once the safety-related SSCs are selected, design criteria are deterministically identified for these SSCs to ensure that they can perform their safety function.

NRC Comment:

8. The licensing approach should be used to show that the cumulative risk from all accidents of a particular frequency is less than the value of the TLRC at that particular frequency. In this usage, the y-axis on the TLRC should be the frequency of exceedance of a calculated dose. A hundred accidents each with a low frequency may result in an acceptable dose but when summed, the total frequency for those accidents can lead to unacceptable risk. In addition, the cumulative risk from all accidents should be less than that stated in the NRC Safety Goal Policy Statement.

Response:

Section 2 of the August 31, 2001 current licensing approach document identifies which TLRC are to be evaluated on a per event basis (e.g., DBE against 10CFR100/50.34) and which on a cumulative basis (e.g., the Safety Goals). The PBMR Risk Chart is an illustration that attempts to show as many of the TLRC as possible on one page. The evaluations will be comprehensive and include the other doses to the public. Care will be exercised to assure that the frequencies of events of similar consequence phenomenology are properly summed. Thus, each LBE family will include the frequency contributions of similar events. For example, the frequencies of all slow helium coolant leaks will be summed separately from those of all fast leaks since the release magnitudes and timing differ.

NRC Comment:

9. The NRC Advanced Reactor Policy Statement expects that advanced reactors will provide enhanced safety margins compared to current generation light-water reactors. Exelon should explain how the use of the top level regulatory criteria will achieve enhanced safety margins consistent with the NRC policy statement.

Response:

The Top Level Regulatory Criteria are intended to be sufficient for all reactors. By agreeing on a quantitative set of direct measures of risk to the public, the degree of enhanced safety provided by advanced reactors such as the PBMR will be transparent. In the case of the PBMR, the intent is to meet the Protective Action Guidelines at the site boundary, which will result in safety margins several orders of magnitude within the TLRC. Additional safety margins are introduced by examining both the mean and ranges of the distributions that characterize the uncertainty in both the frequency and consequence estimates. Further margins are introduced in defining specific regulatory design criteria for SSCs that participate in the LBEs.

NRC Comment:

10. Exelon's licensing approach will use risk assessment to identify licensing basis events (LBEs), the safety functions needed to mitigate these events, and the SSCs that need to be given special treatment. Exelon should explain how non-safety SSCs will be treated in the risk assessment.

Response:

All SSC, whether safety-related or not, are treated the same way in the risk assessment, consistent with the standard methodology utilized in all PRA. The event and fault trees for SSC classified as safety-related will reflect their special treatment. Those for non safety-related SSC will reflect the availability, investment protection, and other design requirements of the user.

Currently, it is not expected that there will be a need for special treatment for SSCs solely for the purpose of preventing or mitigating EPBEs. For example, for the Modular High Temperature Gas-cooled Reactor (MHTGR), the design functions that ensured that EPBEs remained within acceptable limits were the same functions that were needed for the DBEs. Since an appropriate level of special treatment is applied to the ensure the reliability and availability of these design functions for purposes of protecting against DBEs, additional treatment is not needed for these functions with respect to EPBEs. A similar result is expected for the PBMR.

Additionally, it is expected that some non-safety-related SSCs will perform a defense-in-depth function or provide safety margin. These SSCs will be evaluated on a case-by-case basis to determine whether enhanced treatment (i.e., treatment in excess of normal industrial practices) is warranted. In some cases such as fire protection systems and radwaste systems, some enhanced treatment may be warranted. For active systems that are normally operating, no additional treatment may be warranted.

NRC Comment:

11. Exelon has indicated that core damage frequency (CDF), large early release frequency (LERF), and containment performance may not be appropriate risk measures for the PBMR due to its inherent and passive safety features. Exelon should address questions such as what alternative metrics are proposed and how important concerns will not be precluded through the third selection criteria for the TLRC, i.e., that the TLRC should be well defined and quantifiable.

Response:

As discussed in Section 4 of the August 31, 2001 current licensing approach document, the alternative metrics for the PBMR are the accident family consequences and frequencies, (e.g., frequency of a slow release of circulating activity; frequency of a delayed release from the initially failed fuel particles; variations of these with or without some degree of core oxidation, etc.). By examining a spectrum of events, there is greater assurance that the TLRC are met and that a sound and comprehensive set of licensing bases are developed. Just as accident families such as core damage events and large early releases evolved through experience in performing LWR PRAs, a somewhat larger set of accident families will emerge through experience in performing PBMR PRAs. The licensing approach document and Exelon presentations to the NRC have identified accident families from the MHTGR PRA that are expected to appear in the PBMR accident families when the first completed PBMR PRAs are available for the staff to review.

The main point is that the NRC should not expect to see PBMR accident families such as "core damage" and "large early release" as these terms are not applicable to the PBMR. We agree that the proposed licensing approach requires risk metrics that are well defined and are quantifiable and these requirements will be met.

<u>Response to NRC Comments on Implementation Issues:</u>

NRC Comment:

1. In order to better plan and budget NRC activities, Exelon should provide a schedule of when the licensing approach will be implemented including milestones such as identification of LBEs, identification of SSCs, etc.

Response:

The process that has been presented to the NRC over the period from May to August 2001 in this pre-application phase is reflected in the August 31, 2001 current licensing approach document. The TLRC and the process for preliminary screening of a set of regulations can be implemented immediately. If the NRC and Exelon reach agreement on the approach, Exelon will develop an implementation program schedule that it will provide to the NRC. That program will outline the major milestones that will support the development and

submittal of our planned Combined Operating License (COL) application in early 2003. Final LBE and SSC identification will be included in the FSAR that accompanies the application.

NRC Comment:

2. Exelon's licensing approach includes a process for screening existing NRC regulations for applicability to the PBMR and acknowledges the possibility that new PBMR-specific requirements and new PBMR-specific guidance could be required. In order to determine the applicability of existing regulations to the PBMR and to determine the need for new requirements or guidance, PBMR design and probabilistic risk assessment (PRA) information is required. In their absence, the applicability evaluations appear to be based on assumption of design characteristics that have not been clearly documented. Therefore, while it is recognized that a final decision by the staff on the need for new requirements and guidance will not be possible until detailed PBMR design and PRA information is available, for pre-licensing reviews articulation and documentation of design assumptions will be required.

Response:

The proposed screening approach for existing regulations is described in the August 31, 2001 current licensing approach document. Exelon considers that an iterative process will have to be employed to reach final agreement on the set of regulatory criteria that shape the content of the application and form the basis for the NRC review of that application. The preliminary conclusions reached on the applicability of the sample of current regulations is to illustrate the process that will have to be employed on the full set of applicable regulatory requirements and guidance existing today.

Exelon agrees that the final determination of applicability will depend on the full design and PRA when they are available. However, based on the material available during the pre-application period there should be sufficient information to extensively exercise the process that is described in current l licensing approach document. The pre-application period interchange of views on these items is important to clarifying how the primarily LWR-based regulatory set will be addressed in Exelon's COL application. Exelon also believes it will be important that the NRC and Exelon use an agreed upon process to the maximum degree possible in order to clearly identify and discuss the assumptions made about the future design in reaching agreement on the applicability of current regulatory guidance. In this way, a high quality application can be submitted.

NRC Comment:

3. The staff and Exelon should have a common understanding of terms to facilitate effective pre-application and licensing reviews. The Exelon documents reviewed use several terms that the staff will need to better understand such as "poor performance of the fuel," "effects of poor performance of the fuel on plant risk," "failure of

significant number of fuel particle coatings" and "accident conditions that can lead to failure of the coatings or fuel particles."

Response:

The current licensing approach document and subsequent technical papers as part of the pre-application phase will provide information that clarifies terms used in the PBMR design.

NRC Comment:

4. The Exelon documents reviewed state that the TLRC should be a necessary and sufficient set of direct statements of acceptable health and safety as measured by the risks of radiological consequences to individuals and the environment. A footnote to this statement states that the term risk as used here implies the definition of a reasonably complete set of event sequences or scenarios, estimates of their frequencies and consequences, and a thorough understanding and quantification of uncertainties in these frequency and consequence estimates. Exelon should define what is meant by a reasonably complete set of event sequences or scenarios, including what criteria would be used to exclude event sequences or scenarios from the PRA, and how the adequacy of the PRA will be assured with the exclusion of these sequences and scenarios.

Response:

The "reasonably complete" language was used in the same context that appears in the High Level Requirements in the ASME PRA standard. This term means that the PRA will strive to achieve completeness within the state of the art of PRA technology and recognizes that 100% completeness is an unattainable goal. So as to not to imply an insufficient or arbitrary level of completeness, we have changed it to "sufficiently complete" for this context. Criteria for screening of events and scenarios will be consistent with accepted practice in PRA technology as reflected in the High Level and Supporting Requirements of the ASME PRA standard.

NRC Comment:

5. The Exelon documents reviewed state that the PRA to be used in the licensing process will meet acceptable standards. A clear explanation is needed as to what this statement means.

Response:

The August 31, 2001 current licensing approach document, section 4, discusses the PRA Standards that can be met. These include the ASME and ANS completed and ongoing PRA standards that the NRC and industry have been involved with (ASME PRA-S-2001, "Standard For Probabilistic Risk Assessment For Nuclear Power Plant Applications," revision May 14, 2001). As described in the response to NRC comment 4, the PRA is envisioned to achieve completeness within the state of the art of PRA technology and recognizes that

applicable supporting requirements of capability category III, as characterized in the ASME PRA Standard, will be met.

NRC Comment:

6. The licensing approach does not address how safeguards and sabotage will be addressed, i.e., will there be a safeguards PRA or will traditional approaches be used.

Response:

Preliminary PBMR information indicates that safeguards and sabotage will be approached in a traditional fashion. Should the use of PRA be considered, Exelon will initiate pre-application discussions to describe the scope and methodology to be employed.