January 30, 2002

APPLICANT: Exelon Generation Company, LLC (Exelon)

FACILITIES: Peach Bottom Atomic Power Station, Units 2 and 3

SUBJECT: TELECOMMUNICATION WITH EXELON GENERATING COMPANY TO DISCUSS INFORMATION IN THEIR LICENSE RENEWAL APPLICATION ON SECTION 4.3, METAL FATIGUE

On January 3, 2002, after the NRC staff reviewed information provided in Section 4.3 of the license renewal application (LRA), a conference call was conducted between the staff and representatives of Exelon Generating Company to clarify information presented in the application pertaining to metal fatigue. The information discussed, the applicant's revised response, and the follow-up actions are in Attachment 1. Applicant's earlier response and the follow-up actions are also attached in Attachment 2. A list of participants is included in Attachment 3.

A draft of this telephone conversation summary was provided to the applicant to allow them the opportunity to comment on the contents of its input prior to the summary being issued.

/***RA***/

Raj K. Anand, Project Manager
License Renewal and Environmental Impacts Program
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Docket Nos. 50-277 and 50-278

Attachments: As stated

cc w/attachments: See next page

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SUMMARY OF TELECOMMUNICATION WITH
EXELON GENERATING COMPANY
PEACH BOTTOM UNITS 2 AND 3

SECTION 4.3 - METAL FATIGUE

4.3-1

Section 4.3.1 of the LRA indicates that the reactor vessel closure studs are projected to have a CUF>1.0 during the current period of operation. The LRA further indicates that the studs are included in the fatigue management program (FMP). Provide the reason the projected CUF for the closure studs is expected to exceed 1.0 during the current operating period. Discuss the potential corrective actions that will be implemented prior to the period of extended operation.

Response to 4.3-1:

The applicant stated that fatigue evaluation for the reactor vessel closure studs is based on very conservative analysis techniques that, in turn, lead to a somewhat artificially inflated CUF. In addition, various scaling factor approaches have been applied over time to conservatively incorporate effects of modified plant operations (i.e., power uprate), and increased cycle counts have been incorporated into the evaluation to account for actual event accumulation. Despite these conservatisms present in the CUF estimate for the studs, and in view of the fact that the studs are replaceable components, Exelon has chosen to continue using the existing evaluation for the immediate future, while commensurately considering corrective actions consistent with ASME Code, Section XI, Nonmandatory Appendix L. However, Exelon recognizes that to-date, the NRC has not endorsed the currently existing Appendix L approach. The primary NRC concerns with Appendix L include crack aspect ratio and acceptable fatigue crack growth rates (including environmental effects).

The approach to be used for the fatigue management program will include one or more of the following options:

1. Refinement of the fatigue analysis to lower the CUF to below 1.0, or
2. Repair/replacement of the studs, or
3. Manage the effects of fatigue by an inspection program (e.g., periodic non-destructive examination of the studs at certain inspection intervals).

The reactor vessel closure studs are monitored in the improved fatigue-monitoring program. As soon as the CUF value approaches 1.0, the above corrective action will be triggered.

Should Exelon select Option 3 (i.e., inspection) to manage fatigue, inspection details such as scope, qualification, method, and frequency will be provided to the NRC for review and approval prior to implementation.

Discussion: Applicant's revised response is acceptable to the staff. However, the staff will issue the RAI to obtain the response on the docket.

4.3-2

Section 4.3.1 of the LRA indicates that an improved program is being developed which will use temperature, pressure, and flow data to calculate and record accumulated usage factors for critical RPV locations and subcomponents. Describe how the monitored data will be used to calculate the usage factors for the monitored components. Indicate how the fatigue usage of the monitored components is estimated for the time prior to implementation of the improved program.

Response to 4.3-2:

As discussed in Section 4.3.1 of the PBAPS LRA, Exelon is implementing the “Fatigue Pro” fatigue monitoring system for tracking cycles and CUF in critical plant component locations. FatiguePro monitors CUF for the selected locations in one of two ways:

1. *Stress-Based Fatigue Monitoring*: Stress-based fatigue (SBF) monitoring consists of computing a “real time” stress history for a given component from actual temperature, pressure, and flow histories via a finite element based Green's Function approach. CUF is then computed from the computed stress history using appropriate cycle counting techniques, and appropriate ASME Code, Section III fatigue analysis methodology. SBF monitoring is intended to duplicate the methodology used in the governing ASME Code, Section III stress report for the component in question, but uses actual transient severity in place of design basis transient severity.

2. *Cycle-Based Fatigue Monitoring*: Cycle-based fatigue (CBF) monitoring consists of a two-step process: (a) automated cycle counting, and (b) CUF computation based on the counted cycles:
(a) Automated Cycle Counting: Categorization and counting of plant transients is accomplished by the FatiguePro automated cycle counting (ACC) module. The ACC module counts each transient that is defined in the plant licensing basis based on the mechanistic process or sequence of events experienced by the plant (as determined from monitored plant instruments). This approach is conservative because it assumes each actual transient has a severity equal to that assumed in the design basis. The unique severity of any transient identified by FatiguePro is captured for each monitored component, for ready comparison to design basis transient severity. Transients defined in the PBAPS Updated Final Safety Analysis Report are identified and implemented in the ACC module. Any additional system-specific transients that are experienced by the Group I piping systems, which contribute significantly to the calculated CUF, are also monitored.
(b) CUF Computation: CUF computation calculates fatigue directly from counted transients and parameters, as determined by the ACC module, for the monitored components. CUF is computed via a design-basis fatigue calculation where the fatigue table from the governing stress report is used as a basis, but actual numbers of cycles are substituted for assumed design basis numbers of cycles. The CUF calculations are conservative in that design basis transient severity is assumed.

Limiting components throughout the Group I pressure boundary were selected for monitoring that bound or represent all other components. The components identified in NUREG/CR-6260 for the older vintage BWR plant are also encompassed by the locations selected for monitoring. Inclusion of Group I piping systems into the fatigue management program provides a complete

structural assessment of the Group I pressure boundary. The monitored locations and the fatigue computation method employed are summarized in
Table 1.

The applicant stated that for the time period prior to Fatigue Pro implementation, fatigue usage was estimated in one of two ways. For the SBF components, the initial CUF was determined based on a linear projection of the design basis CUF, including the increased cycle counts resulting from tracking actual plant operation. For example, if the design 40-year CUF for an SBF component is 0.70, and the improved program was implemented after 20 years of plant operation, the initial CUF was estimated to be (20/40) * 0.70 = 0.35. Continued CUF monitoring into the future will be used to demonstrate the conservatism of this estimate (i.e., show that the rate of actual CUF accumulation is less than the rate of design basis fatigue accumulation). For the CBF components, the initial CUF estimate was determined based on the cycle counts to-date since initial plant startup, and the design basis fatigue calculation methodology described above. These initial CUF estimates therefore considered all cycles experienced by PBAPS to-date, and assumed design basis severity for each event.

Table 1
Monitored Components and Method of CUF Calculation

Location	Fatigue Estimation Basis
RPV feedwater nozzles (Loops A and B)	SBF
RPV support skirt	SBF
RPV closure studs	CBF
RPV shroud support	CBF
RPV core spray nozzle safe end	CBF
RPV recirculation inlet nozzle	CBF
RPV recirculation outlet nozzle	CBF
RPV refueling containment skirt	CBF
RPV jet pump shroud support	CBF
Residual heat removal (RHR) 24" return line (Loop A)	CBF
RHR 20" supply line (Loops A and B)	CBF
Recirc. whip restraints (Unit 2 Loop A)-not included in LRA Table	CBF
Core spray piping – not included in LRA Table	CBF
(Reviewed, bounded by RPV Core Spray nozzle, not monitored)	
Feedwater piping	CBF
Main steam piping	CBF
RHR Tee (Loop A)	CBF
RHR Tee (Loop B)	CBF
Feedwater piping (Node 754)	CBF
Main steam piping (Node 606)	CBF
Torus penetrations Unit 2	CBF
Torus penetrations Unit 3	CBF
Torus shell	**CBF**

Discussion: Applicant's revised response is acceptable to the staff. However, the staff will issue the RAI to obtain the response on the docket.

4.3-3

Section 4.3.2.1 of the LRA indicates that fatigue analyses of the core shroud supports were reevaluated for effects of increased recirculation pump starts with the loop outside thermal limits. Describe the reevaluations that were performed considering an increase in recirculation pump starts. Indicate the reason that the reevaluations were necessary.

Response to 4.3-3:

The applicant stated that issue is thermal events associated with the PBAPS Technical Specification requirement that limits the temperature difference (@T) between an idle recirculation loop and the vessel coolant to be within 50°F of each other prior to pump start. Specifically of concern is the @T following initiation of the first of two idle recirculation pumps. Since PBAPS has experienced events of this type in the past, the plant Technical Specification requirements triggered the evaluations in question.

The design basis Sudden Start event provides conservative and convenient criteria for accounting for the actual events experienced at the PBAPS units. This design basis event is much more severe than the events actually experienced at PBAPS, as the actual @Ts were significantly lower than the @T evaluated for the design event. Since the design basis event consists of a very conservative step change in temperature, the fatigue contribution for this event is driven almost exclusively by the @T during the event. Therefore, the @T of the actual events were compared to the @T of the design basis events to establish partial cycle counts for these events. *This method leads to revised CUF estimates that are linear with respect to @T, which is conservative compared to more traditional CUF estimates where stress is linearly related to @T. The conservatism of this method is demonstrated in Figure 1.* Since the Sudden Start event is a primary contributor to the shroud support CUF value, this component was selected for evaluation of these events. Other affected RPV and piping locations were also evaluated, but were less limiting than the shroud support from a CUF perspective. Note that although the shroud support is not an ASME Code pressure boundary component, it was considered in this evaluation since it was included as a part of the original ASME Code, Section III design basis evaluation for the reactor pressure vessel.

The fatigue analyses that were performed for the core shroud support essentially consisted of a cycle counting evaluation, using partial cycles, to ascertain the acceptability of the events experienced at PBAPS. The design basis Sudden Start event has an analyzed limit of 40 cycles, and the past accumulation of events was determined to be 7.8 events for the limiting PBAPS unit, which is acceptable.

The event in question, the shroud support location, and all past occurrences are all included as a part of Exelon's improved fatigue monitoring program implemented at PBAPS, so this issue will continue to be monitored throughout the period of extended operation.

Discussion: Applicant's revised response is acceptable to the staff. However, the staff will issue the RAI to obtain the response on the docket.

4.3-4

Section 4.3.2.1 of the LRA indicates that the limiting fatigue usage for the core shroud and jet pump assembly is based on the evaluation of a plant with a configuration similar to PBAPS. As discussed in RAI 4.3-3, the PBAPS core shroud supports were reevaluated for the effects of increased recirculation pump starts with the loop outside thermal limits. Indicate whether the increase in recirculation pumps starts has any impact on the fatigue usage of the core shroud and jet pump assembly.

Response to 4.3-4:

The applicant stated that as indicated in the response to 4.3-3 above, the shroud support is not an ASME Code pressure boundary component, but it was considered in the evaluation of recirculation pump start events because it was included as a part of the original ASME Code, Section III design basis evaluation for the reactor pressure vessel. The core shroud and jet pumps are not ASME Code pressure boundary components, and therefore, do not have design basis fatigue evaluations. Aging management of both of these components, which address

both IGSCC and fatigue concerns, is addressed by the Reactor Pressure Vessel and Internals ISI Program as discussed in Appendix B.2.7 of the PBAPS LRA.

The information included in Section 4.3.2.1 of the PBAPS LRA associated with the core shroud and jet pump assembly refers to a location documented in the PBAPS UFSAR that is identified as the "Jet Pump Shroud Support." This identification refers to a location on the shroud support structure where the jet pump adapter is attached. The CUF value for this location is based on generic BWR evaluation performed by General Electric associated with jet pump design, and the associated impact on the shroud support structure. That analysis was included as a part of the evaluation described in the response to RAI 4.3-3 above, and the location is included in Exelon's improved fatigue monitoring program implemented at PBAPS. Therefore, this issue will continue to be monitored throughout the period of extended operation.

Discussion: Applicant’s revised response is acceptable to the staff. However, the staff will issue RAI to obtain the response on the docket.

4.3-5

Section 4.3.3.3 of the LRA indicates that the NSSS vendor specified the RHR system for a finite number of cycles for each of its elevated-temperature operating modes. The LRA also indicates that no description of these design operating cycles was found in the BPAPS licensing basis documents. According to the LRA, Group 1 RHR piping inside the drywell was analyzed to the ASME Section III Class 1 rules. The LRA further indicates that an evaluation of the remaining Group I and Group II piping projected that the number of thermal cycles would be substantially less the 7,000 cycle limit contained in USAS B31.1. Provide further clarification regarding the details of the NSSS vendor specification. Describe the basis for assuming the 7,000 cycle limit contained in USAS B31.1 satisfies the vendor specification.

Response to 4.3-5:

Clarification of the NSSS Vendor Specification

Piping of the entire RHR system (including some valves) was originally designed to USAS B31.1 rules. However, Group 1 RHR Shutdown Cooling portions of the system, inside containment, were replaced with the Recirculation piping to mitigate IGSCC concerns. This replacement piping was analyzed under ASME III Class 1 rules, and the original B31.1 design no longer applies. LRA Section 4.3.3.1 addresses the RHR piping with a class I analysis.

For piping designed to USAS B31.1, the Code assumes no more than 7,000 equivalent full-range thermal cycles as the limit beyond which a stress range reduction factor must be applied.

The statement that “No description of these [original vendor] design operating cycles was found in the PBAPS licensing basis documents” means that although there is a *vendor specification* description of certain thermal cycles for the original system design, there is no *licensing basis* which requires any thermal cycle design analysis, other than (1) the B31.1 thermal cycle limit, or (2) those thermal cycle considerations which might be required by codes and standards for components, and invoked by reference to those codes and standards. Design to the vendor-

specified cycles is therefore not a TLAA, except as it may be included within code design requirements.

The specifications and design codes for components (pumps, heat exchangers, any valve standards other than B31.1) were examined to determine if any code basis might have existed which would have incorporated a thermal cycle design analysis or assumption into the licensing basis. The result of that investigation was negative. All RHR components, other than B31.1 piping and valves, were specified either for temperature ranges which did not require thermal cycle analysis or assumptions, or to codes whose date or addendum did not provide for thermal cycle analysis or assumptions.

Exelon therefore concluded that no design analysis for thermal cycles had been applied to any of the non-Class 1-analysis portions of the RHR system, other than the stress range reduction factor required under USAS B31.1 rules for piping.

<u>Basis for assuming the 7,000 cycle limit contained in USAS B31.1 satisfies the vendor specification</u>:

The NSSS vendor's original specification included 30 cycles of normal operating suppression pool cooling, and one cycle of end-of-life, post-accident suppression pool cooling with containment spray operation. In addition, normal operating shutdown cooling (which, from a separate source, would be 120 cycles) was also considered. The severity of these specified RHR cycles is no worse than the maximum-range thermal cycle. This specification therefore amounted to no more than 151 equivalent full-range thermal cycles under USAS B31.1 rules. As stated above, (1) there is no licensing basis for analysis of the vendor-specified cycles beyond the code rules, and therefore any such analysis is not a TLAA, and (2) a review of specific equipment specifications and codes discovered no such design, nor any to other cyclic design bases, other than USAS B31.1. The disposition of this TLAA therefore did not specifically address the cycles specified by the NSSS vendor.

However, the disposition did address the B31.1 system design, and even if design to the vendor-specified cycles were a TLAA, 151 cycles is a small fraction of the number of cycles for which the system was designed under B31.1 rules.

The evaluation of USAS B31.1 piping systems found that 700 equivalent full-range thermal cycles would be expected in a 40-year lifetime based on the expected Recirculation System cycles, certainly no more than 1000 (neglecting feedwater transients, which do not affect RHR - see LRA Section 4.3.3.2). This is the basis for the following statement in the LRA validation:

"The total number of cycles assumed for the original 40-year plant life is, conservatively, less than 1,000. For the period of extended operation, the number of thermal cycles for piping analyses would be proportionately increased to 1,500, which is still significantly less than the 7,000 cycle threshold. The code stress range reduction factor therefore remains at 1.0 and is not affected by extending the operating period to 60 years."

Discussion: Applicant's revised response is acceptable to the staff. However, the staff will issue RAI to obtain the response on the docket.

4.3-6

Section 4.3.4 of the LRA contains a discussion of Generic Safety Issue (GSI) 190, "Fatigue Evaluation of Metal Components For 60-year Plant Life." GSI-190 addresses the effect of the reactor water environment on the fatigue life of metal components. The discussion in Section 4.3.4 indicates that EPRI license renewal fatigue studies have demonstrated that sufficient conservatism exists in the design transient definitions to compensate for potential reactor water environmental effects. The staff does not agree with the contention that the EPRI fatigue studies have demonstrated that sufficient conservatism exists in the design transient definitions to compensate for potential reactor water environmental effects. The staff identified several technical concerns regarding the EPRI studies. The staff technical concerns are contained in an August 6, 1999, letter to NEI. Although these concerns involved the EPRI procedure and its application to PWRs, the technical concerns regarding the application of the Argonne National Laboratory (ANL) statistical correlations and strain threshold values are also relevant to BWRs. In addition to the concerns referenced above, the staff has additional concerns regarding the applicability of the EPRI BWR studies to PBAPS. EPRI Report TR-107943, "Environmental Fatigue Evaluations of Representative BWR Components," addressed a BWR-6 plant and EPRI Report TR-110356, "Evaluation of Environmental Thermal Fatigue Effects on Selected Components in a Boiling Water Reactor Plant," used plant transient data from a newer vintage BWR-4 plant. The applicability of the EPRI fatigue studies to PBAPS has not been demonstrated. Provide the following additional information regarding resolution of the environmental fatigue issue:

a. Indicate whether the staff comments provided in the staff 's August 6, 1999, letter to NEI, which are applicable to PBAPS, have been considered in the assessment of the environmental fatigue issue at PBAPS. Discuss how the applicable staff comments were considered in the evaluation of environmental fatigue.

b. Discuss the applicability of the component fatigue assessments in the EPRI Reports TR-107943 and TR-110356 to components in PBAPS. The discussion should include a comparison of design transients, operating cycles and fabrication details for each component. In addressing fabrication details, compare pipe diameters and thicknesses at PBAPS with the components evaluated in the EPRI reports. This comparison should also include a comparison of the fabrication details at the tee connections. Also include a comparison of the hydrogen water chemistry used at PBAPS with the hydrogen water chemistry considered in the EPRI reports.

c. The staff assessed the impact of reactor water environment on fatigue life at high fatigue usage locations and presented the results in NUREG/CR-6260, "Application of NUREG/CR-5999, ‘Interim Fatigue Curves to Selected Nuclear Power Plant Components’," March 1995. Formulas currently acceptable to the staff for calculating the environmental correction factors for carbon and low-alloy steels are contained in NUREG/CR-6583, "Effects of LWR Coolant Environments on Fatigue Design Curves of Carbon and Low-Alloy Steels," and those for austenitic stainless steels are contained in NUREG/CR-5704, "Effects of LWR Coolant Environments on Fatigue Design of Austenitic Stainless Steels." Provide an assessment of the six locations identified in NUREG/CR-6260 for an older vintage BWR-4 considering the applicable environmental fatigue correlations provided in NUREG/CR-6583 and NUREG/CR-5704 reports for PBAPS.

Response to 4.3-6:

The applicant stated that Section 4.3.4 of the LRA describes Exelon's evaluation of the impact of the reactor water environment on the fatigue life of the components identified in NUREG/CR-6260. In particular, that evaluation relied on several industry background studies that have been performed by EPRI and NEI to address EAF effects in reactor coolant system components. In particular, one study for a newer vintage BWR-4 plant was used to provide an assessment of environmental effects for PBAPS on the locations identified in NUREG/CR-6260 for the older vintage BWR plant using a design basis transient severity approach.

Because of the more recent issues raised by the NRC staff relative to the use of the EPRI/GE F_{en} methodology (Reference EPRI Report No. TR-105759) in various industry applications (as highlighted in the NRC staff 's August 6, 1999 letter to NEI), as well as additional laboratory fatigue data in simulated LWR environments that have been generated by Argonne National Laboratory (ANL) for carbon, low-alloy, and stainless steels (as published in NUREG/CR-6583 and NUREG/CR-5704), Exelon has decided to perform plant-specific calculations for PBAPS for the locations identified in NUREG/CR-6260 for the older vintage BWR plant. For each of these locations, detailed environmental fatigue calculations will be performed using the appropriate F_{en} relationships from NUREG/CR-6583 (for carbon/low alloy steels) and NUREG/CR-6704 (for stainless steels), as appropriate for the material for each location. The detailed calculations will include calculation of an appropriate F_{en} factor for each individual load pair in the governing fatigue calculation so that an overall multiplier on CUF for environmental effects can be determined for each location. These calculations will be performed prior to entry into the period of extended operation, and appropriate corrective action will be taken if the resulting CUF values exceed 1.0.

When completed, the plant-specific calculations for PBAPS are expected to validate the conclusions identified with respect to the EAF effects documented in the LRA. This modified approach is expected to adequately address the concerns identified in Items (a), (b), and (c) of this RAI.

Exelon reserves the right to modify this position in the future based on the results of industry activities currently underway, as well as based on the results of any other methodology improvements that may be made associated with environmental fatigue. It is understood that any such modifications will be subject to NRC approval prior to implementation at PBAPS.

Per the NRC/Exelon telecon discussion on January 3, 2002 the following additional clarification is provided. The first sentence on page 4-26 of the LRA section 4.3.4 is revised to state: “For relatively high temperature (>200°C), low dissolved oxygen, and a low (bounding) strain rate, the environmental shift correction factor may be as high as 15.35.” The last part of this sentence is deleted.

Discussion: Applicant’s revised response is acceptable to the staff. However, the staff will issue the RAI to obtain the response on the docket.

4.3-7

Table 4.3.4-3 of the LRA provides projected 60-year fatigue usage factors for selected PBAPS components. Confirm that the usage factors reported for the feedwater line (RCIC Tee) are correct.

Response to 4.3-7:

The applicant stated that Table 4.3.4-3 of the PBAPS LRA documents a projected CUF of 0.049 for the RCIC tee for the limiting PBAPS unit. This value is correct, based on cycles experienced to-date. The value was determined as discussed below.

The governing design basis for the PBAPS Class 1 piping is ANSI B31.1. As a result, design basis CUF calculations do not exist for most of the Class 1 piping. (Note that some piping, like the recirculation piping and portions of the reactor water cleanup and residual heat removal piping, have been replaced at PBAPS and have a governing Class 1 fatigue analysis.) However, as a part of implementation of the improved fatigue monitoring program at PBAPS, CUF evaluation was performed for the limiting locations of the major Class 1 piping systems. This was done in order to establish a CUF basis for the Class 1 piping to include in the improved fatigue monitoring program. The feedwater piping was one of the major systems included in this evaluation.

The limiting 40-year CUF value for the feedwater piping was determined to be 0.069 at the weld between a 12" 90° short radius elbow and a 24"x24"x12" tee. This location bounded all other locations in the feedwater line, including the RCIC tee. As a result, it was considered to also represent the RCIC tee location identified in NUREG-6260. As discussed in the response to RAI 4.3-2 above, this location is included in the improved fatigue monitoring program as a CBF component (i.e., "Feedwater Piping" location shown in Table 1). Therefore, if PBAPS experiences all events assumed in the design basis in the same quantities assumed in the design basis, the fatigue monitoring program will reproduce the "design" CUF value of 0.069 for this location.

As discussed in the response to RAI 4.3-2 above for the CBF components, the initial CUF estimate at the time the fatigue monitoring program was implemented, was determined based on the cycle counts to-date since initial plant startup, and the design basis fatigue calculation methodology. This initial CUF estimate (covering approximately 27 years of plant operation for the limiting PBAPS unit) was determined to be 0.022 based on all cycles experienced to-date, and assuming design basis severity for each event. The linearly extrapolated CUF value for 60 years is therefore 0.022 (60/27) = 0.049.

Since this location is included in Exelon's improved fatigue monitoring program implemented at PBAPS, this issue will continue to be monitored throughout the period of extended operation. This monitoring will include revised CUF projections as events are experienced.

Discussion: Applicant's response is acceptable to the staff. However, the staff will issue theRAI to obtain the response on the docket.

Telephone Conference Summary

Exelon Generating Company, LLC and NRC Staff

Draft Responses to Staff's Requests for Additional Information

On January 3, 2002, representatives from the Exelon Generating Company (Exelon) and the staff participated in a telephone conference (telecon) regarding Exelon's draft responses to the staff's requests for additional information (RAIs) 4.3-1, 4.3-2, 4.3-3, 4.3-5, and 4.3-6. The telecon participants are listed in Attachment A.

4.3-1

Section 4.3.1 of the LRA indicates that the reactor vessel closure studs are projected to have a CUF>1.0 during the current period of operation. The LRA further indicates that the studs are included in the fatigue management program (FMP). Provide the reason the projected CUF for the closure studs is expected to exceed 1.0 during the current operating period. Discuss the potential corrective actions that will be implemented prior to the period of extended operation.

Response to 4.3-1

The fatigue evaluation for the reactor vessel closure studs is based on very conservative analysis techniques that, in turn, lead to a somewhat artificially inflated CUF. In addition, various scaling factor approaches have been applied over time to conservatively incorporate effects of modified plant operations (i.e., power uprate). Despite the conservatism present in the CUF estimate for the studs, and in view of the fact that the studs are replaceable components, Exelon has chosen to continue using the existing evaluation for the immediate future, while commensurately considering corrective actions consistent with ASME Code, Section XI, Nonmandatory Appendix L. However, Exelon recognizes that to-date, the NRC has not endorsed the currently existing Appendix L approach. The primary NRC concerns with Appendix L include crack aspect ratio and acceptable fatigue crack growth rates (including environmental effects).

The approach to be used for the fatigue management program will include one or more of the following options:

1. Refinement of the fatigue analysis to lower the CUF to below 1.0, or
2. Repair/replacement of the studs, or
3. Manage the effects of fatigue by an inspection program (e.g., periodic non-destructive examination of the studs at certain inspection intervals).

The reactor vessel closure studs are monitored in the improved fatigue-monitoring program. As soon as the CUF value approaches 1.0, the above corrective action will be triggered.

Should Exelon select Option 3 (i.e., inspection) to manage fatigue, inspection details such as scope, qualification, method, and frequency will be provided to the NRC for review and approval prior to implementation.

Discussion of Response to 4.3-1

The staff felt that the draft RAI response did not clarify that, for those components whose CUF exceeded 1, that the cause was not only due to modified plant operations (i.e., power uprate), but also due to certain transients, as identified in license renewal application Table 4.3.4-1. The staff suggested, and the applicant agreed, that the RAI response should be revised to clarify the basis for exceeding a CUF of 1.

4.3-2

Section 4.3.1 of the LRA indicates that an improved program is being developed which will use temperature, pressure, and flow data to calculate and record accumulated usage factors for critical RPV locations and subcomponents. Describe how the monitored data will be used to calculate the usage factors for the monitored components. Indicate how the fatigue usage of the monitored components is estimated for the time prior to implementation of the improved program.

Response to 4.3-2

As discussed in Section *4.3.1* of the PBAPS LRA, Exelon is implementing the FatiguePro fatigue monitoring system for tracking cycles and CUF in critical plant component locations. FatiguePro monitors CUF for the selected locations in one of two ways:

1. *Stress-Based Fatigue Monitoring*: Stress-based fatigue (SBF) monitoring consists of computing a "real time" stress history for a given component from actual temperature, pressure, and flow histories via a finite element based Green's Function approach. CUF is then computed from the computed stress history using appropriate cycle counting techniques, and appropriate ASME Code, Section III fatigue analysis methodology. SBF monitoring is intended to duplicate the methodology used in the governing ASME Code, Section III stress report for the component in question, but uses actual transient severity in place of design basis transient severity.

2. *Cycle-Based Fatigue Monitoring*: Cycle-based fatigue (CBF) monitoring consists of a two-step process: (a) automated cycle counting, and (b) CUF computation based on the counted cycles:

   (a) Automated Cycle Counting: Categorization and counting of plant transients is accomplished by the FatiguePro automated cycle counting (ACC) module. The ACC module counts each transient that is defined in the plant licensing basis based on the mechanistic process or sequence of events experienced by the plant (as determined from monitored plant instruments). This approach is conservative because it assumes each actual transient has a severity equal to that assumed in the design basis. The unique severity of any transient identified by Fatigue Pro is captured for each monitored

component, for ready comparison to design basis transient severity. Transients defined in the PBAPS Updated Final Safety Analysis Report are identified and implemented in the ACC module. Any additional system-specific transients that are experienced by the Group I piping systems, which contribute significantly to the calculated CUF, are also monitored.

(b) CUF Computation: CUF computation calculates fatigue directly from counted transients and parameters, as determined by the ACC module, for the monitored components. CUF is computed via a design-basis fatigue calculation where the fatigue table from the governing stress report is used as a basis, but actual numbers of cycles are substituted for assumed design basis numbers of cycles. The CUF calculations are conservative in that design basis transient severity is assumed.

Limiting components throughout the Group I pressure boundary were selected for monitoring that bound or represent all other components. -The components identified in NUREG/CR-6260 for the older vintage BWR plant are also encompassed by the locations selected for monitoring. Inclusion of Group I piping systems into the fatigue management program provides a complete structural assessment of the Group I pressure boundary. The monitored locations and the fatigue computation method employed are summarized in Table 1.

For the time period prior to FatiguePro implementation, fatigue usage was estimated in one of two ways. For the SBF components, the initial CUF was determined based on a linear projection of the design basis CUF. For example, if the design CUF for an SBF component is 0.70, and the improved program was implemented after 20 years of plant operation, the initial CUF was estimated to be (20/40) * 0.70 = 0.35. Continued CUF monitoring into the future will be used to demonstrate the conservatism of this estimate (i.e., show that the rate of actual CUF accumulation is less than the rate of design basis fatigue accumulation). For the CBF components, the initial CUF estimate was determined based on the cycle counts to-date since initial plant startup, and the design basis fatigue calculation methodology described above. These initial CUF estimates therefore considered all cycles experienced by PBAPS to-date, and assumed design basis severity for each event.

Table 1
Monitored Components and Method of CUF Calculation

Location	Fatigue Estimation Basis	
	RPV feedwater nozzles (Loops A and B)	SBF
	RPV support skirt	SBF
	RPV closure studs	CBF
	RPV shroud support	CBF
	RPV core spray nozzle safe end	CBF
	RPV recirculation inlet nozzle	CBF
	RPV recirculation outlet nozzle	CBF
	RPV refueling containment skirt	CBF
	RPV jet pump shroud support	CBF

Residual heat removal (RHR) 24" return line (Loop A)	CBF
RHR 20" supply line (Loops A and B)	CBF
Recirc. whip restraints (Unit 2 Loop A)-not included in LRA Table	CBF
Core spray piping – not included in LRA Table (Reviewed, bounded by RPV Core Spray nozzle, not monitored)	CBF
Feedwater piping	CBF
Main steam piping	CBF
RHR Tee (Loop A)	CBF
RHR Tee (Loop B)	CBF
Feedwater piping (Node 754)	CBF
Main steam piping (Node 606)	CBF
Torus penetrations Unit 2	CBF
Torus penetrations Unit 3	CBF
Torus shell	CBF

Discussion of Response to 4.3-2

The staff felt that the applicant's response should be revised to clarify that, for the RPV feedwater nozzles (Loops A and B) and for the RPV support skirt, the initial fatigue estimate should consider the number of actual transients occur prior to FatiguePro implementation. The applicant agreed to revise the response.

4.3-3

Section 4.3.2.1 of the LRA indicates that fatigue analyses of the core shroud supports were reevaluated for effects of increased recirculation pump starts with the loop outside thermal limits. Describe the reevaluations that were performed considering an increase in recirculation pump starts. Indicate the reason that the reevaluations were necessary.

Response to 4.3-3

At issue are thermal events associated with the PBAPS Technical Specification requirement that limits the temperature difference (@T) between an idle recirculation loop and the vessel coolant to be within 50@F of each other prior to pump start. Specifically of concern is the @T following initiation of the first of two idle recirculation pumps. Since PBAPS has experienced events of this type in the past, the plant Technical Specification requirements triggered the evaluations in question.

The design basis Sudden Start event provides conservative and convenient criteria for accounting for the actual events experienced at the PBAPS units. This design basis event is much more severe than the events actually experienced at PBAPS, as the actual @Ts were significantly lower than the @T evaluated for the design event. Since the design basis event consists of a very conservative step change in temperature, the fatigue contribution for this event is driven almost exclusively by the @T during the event. Therefore, the @T of the actual events were compared to the @T of the design basis events to establish partial cycle counts for these events. Since the Sudden Start event is a primary contributor to the shroud support CUF

value, this component was selected for evaluation of these events. Other affected RPV and piping locations were also evaluated, but were less limiting than the shroud support from a CUF perspective. Note that although the shroud support is not an ASME Code pressure boundary component, it was considered in this evaluation since it was included as a part of the original ASME Code, Section III design basis evaluation for the reactor pressure vessel.

The fatigue analyses that were performed for the core shroud support essentially consisted of a cycle counting evaluation, using partial cycles, to ascertain the acceptability of the events experienced at PBAPS. The design basis Sudden Start event has an analyzed limit of 40 cycles, and the past accumulation of events was determined to be 7.8 events for the limiting PBAPS unit, which is acceptable.

The event in question, the shroud support location, and all past occurrences are all included as a part of Exelon's improved fatigue monitoring program implemented at PBAPS, so this issue will continue to be monitored throughout the period of extended operation.

Discussion of Response to 4.3-3

The staff felt that the response should more clearly discuss how the credit that is taken for partial cycles based on reduced @T are applied in CUF calculations. The applicant agreed to clarify how this credit is applied in the CUF calculation.

4.3-5

Section 4.3.3.3 of the LRA indicates that the NSSS vendor specified the RHR system for a finite number of cycles for each of its elevated-temperature operating modes. The LRA also indicates that no description of these design operating cycles was found in the BPAPS licensing basis documents. According to the LRA, Group 1 RHR piping inside the drywell was analyzed to the ASME Section III Class 1 rules. The LRA further indicates that an evaluation of the remaining Group I and Group II piping projected that the number of thermal cycles would be substantially less the 7,000 cycle limit contained in USAS B31.1. Provide further clarification regarding the details of the NSSS vendor specification. Describe the basis for assuming the 7,000 cycle limit contained in USAS B31.1 satisfies the vendor specification.

Response to 4.3-5

Clarification of the NSSS Vendor Specification

Piping of the entire RHR system (including some valves) was originally designed to USAS B31.1 rules. However, Group 1 RHR Shutdown Cooling portions of the system, inside containment, were replaced with the Recirculation piping to mitigate IGSCC concerns. This replacement piping was analyzed under ASME III Class 1 rules, and the original B31.1 design no longer applies. LRA Section 4.3.3.1 addresses the RHR piping with a class I analysis.

For piping designed to USAS B31.1, the Code assumes no more than 7,000 equivalent full-range thermal cycles as the limit beyond which a stress range reduction factor must be applied.

The statement that "No description of these [original vendor] design operating cycles was found in the PBAPS licensing basis documents" means that although there is a *vendor specification* description of certain thermal cycles for the original system design, there is no *licensing basis* which requires any thermal cycle design analysis, other than (1) the B31.1 thermal cycle limit, or (2) those thermal cycle considerations which might be required by codes and standards for components, and invoked by reference to those codes and standards. Design to the vendor-specified cycles is therefore not a TLAA, except as it may be included within code design requirements.

The specifications and design codes for components (pumps, heat exchangers, any valve standards other than B31.1) were examined to determine if any code basis might have existed which would have incorporated a thermal cycle design analysis or assumption into the licensing basis. The result of that investigation was negative. All RHR components, other than B31.1 piping and valves, were specified either for temperature ranges which did not require thermal cycle analysis or assumptions, or to codes whose date or addendum did not provide for thermal cycle analysis or assumptions.

Exelon therefore concluded that no design analysis for thermal cycles had been applied to any of the non-Class 1-analysis portions of the RHR system, other than the stress range reduction factor required under USAS B31.1 rules for piping.

<u>Basis for assuming the 7,000 cycle limit contained in USAS B31.1 satisfies the vendor specification</u>:

The NSSS vendor's original specification included 30 cycles of normal operating suppression pool cooling, and one cycle of end-of-life, post-accident suppression pool cooling with containment spray operation. In addition, normal operating shutdown cooling (which, from a separate source, would be 120 cycles) was also considered. The severity of these specified RHR cycles is no worse than the maximum-range thermal cycle. This specification therefore amounted to no more than 151 equivalent full-range thermal cycles under USAS B31.1 rules. As stated above, (1) there is no licensing basis for analysis of the vendor-specified cycles beyond the code rules, and therefore any such analysis is not a TLAA, and (2) a review of specific equipment specifications and codes discovered no such design, nor any to other cyclic design bases, other than USAS B31.1. The disposition of this TLAA therefore did not specifically address the cycles specified by the NSSS vendor.

However, the disposition did address the B31.1 system design, and even if design to the vendor-specified cycles were a TLAA, 151 cycles is a small fraction of the number of cycles for which the system was designed under B31.1 rules.

The evaluation of USAS B31.1 piping systems found that 700 equivalent full-range thermal cycles would be expected in a 40-year lifetime based on the expected Recirculation System cycles, certainly no more than 1000 (neglecting feedwater transients, which do not affect RHR - see LRA Section 4.3.3.2). This is the basis for the following statement in the LRA validation:

"The total number of cycles assumed for the original 40-year plant life is, conservatively, less than 1,000. For the period of extended operation, the number of thermal cycles for piping analyses would be proportionately increased to 1,500, which is still significantly less than the 7,000 cycle threshold. The code stress range reduction factor therefore remains at 1.0 and is not affected by extending the operating period to 60 years."

Discussion of Response to RAI 4.3-5

The staff wanted verification that there were no calculations that used vendor specifications. The applicant confirmed that this was the case.

RAI 4.3-6

Section 4.3.4 of the LRA contains a discussion of Generic Safety Issue (GSI) 190, "Fatigue Evaluation of Metal Components For 60-year Plant Life." GSI-190 addresses the effect of the reactor water environment on the fatigue life of metal components. The discussion in Section 4.3.4 indicates that EPRI license renewal fatigue studies have demonstrated that sufficient conservatism exists in the design transient definitions to compensate for potential reactor water environmental effects. The staff does not agree with the contention that the EPRI fatigue studies have demonstrated that sufficient conservatism exists in the design transient definitions to compensate for potential reactor water environmental effects. The staff identified several technical concerns regarding the EPRI studies. The staff technical concerns are contained in an August 6, 1999, letter to NEI. Although these concerns involved the EPRI procedure and its application to PWRs, the technical concerns regarding the application of the Argonne National Laboratory (ANL) statistical correlations and strain threshold values are also relevant to BWRs. In addition to the concerns referenced above, the staff has additional concerns regarding the applicability of the EPRI BWR studies to PBAPS. EPRI Report TR-107943, "Environmental Fatigue Evaluations of Representative BWR Components," addressed a BWR-6 plant and EPRI Report TR-110356, "Evaluation of Environmental Thermal Fatigue Effects on Selected Components in a Boiling Water Reactor Plant," used plant transient data from a newer vintage BWR-4 plant. The applicability of the EPRI fatigue studies to PBAPS has not been demonstrated. Provide the following additional information regarding resolution of the environmental fatigue issue:

a. Indicate whether the staff comments provided in the staff 's August 6, 1999, letter to NEI, which are applicable to PBAPS, have been considered in the assessment of the environmental fatigue issue at PBAPS. Discuss how the applicable staff comments were considered in the evaluation of environmental fatigue.

b. Discuss the applicability of the component fatigue assessments in the EPRI Reports TR-107943 and TR-110356 to components in PBAPS. The discussion should include a comparison of design transients, operating cycles and fabrication details for each component. In addressing fabrication details, compare pipe diameters and thicknesses at PBAPS with the components evaluated in the EPRI reports. This comparison should also include a comparison of the fabrication details at the tee connections. Also include a comparison of the hydrogen water chemistry used at PBAPS with the hydrogen water chemistry considered in the EPRI reports.

c. The staff assessed the impact of reactor water environment on fatigue life at high fatigue usage locations and presented the results in NUREG/CR-6260, "Application of

NUREG/CR-5999, ‘Interim Fatigue Curves to Selected Nuclear Power Plant Components’," March 1995. Formulas currently acceptable to the staff for calculating the environmental correction factors for carbon and low-alloy steels are contained in NUREG/CR-6583, "Effects of LWR Coolant Environments on Fatigue Design Curves of Carbon and Low-Alloy Steels," and those for austenitic stainless steels are contained in NUREG/CR-5704, "Effects of LWR Coolant Environments on Fatigue Design of Austenitic Stainless Steels." Provide an assessment of the 6 locations identified in NUREG/CR-6260 for an older vintage BWR-4 considering the applicable environmental fatigue correlations provided in NUREG/CR-6583 and NUREG/CR-5704 reports for PBAPS.

Response to 4.3-6

Section 4.3.4 of the LRA describes Exelon's evaluation of the impact of the reactor water environment on the fatigue life of the components identified in NUREG/CR-6260. In particular, that evaluation relied on several industry background studies that have been performed by EPRI and NEI to address EAF effects in reactor coolant system components. In particular, one study for a newer vintage BWR-4 plant was used to provide an assessment of environmental effects for PBAPS on the locations identified in NUREG/CR-6260 for the older vintage BWR plant using a design basis transient severity approach.

Because of the more recent issues raised by the NRC staff relative to the use of the EPRI/GE Fen methodology (Reference EPRI Report No. TR-105759) in various industry applications (as highlighted in the NRC staff ’s August 6, 1999 letter to NEI), as well as additional laboratory fatigue data in simulated LWR environments that have been generated by Argonne National Laboratory (ANL) for carbon, low-alloy, and stainless steels (as published in NUREG/CR-6583 and NUREG/CR-5704), Exelon has decided to perform plant-specific calculations for PBAPS for the locations identified in NUREG/CR-6260 for the older vintage BWR plant. For each of these locations, detailed environmental fatigue calculations will be performed using the appropriate Fen relationships from NUREG/CR-6583 (for carbon/low alloy steels) and NUREG/CR-6704 (for stainless steels), as appropriate for the material for each location. The detailed calculations will include calculation of an appropriate Fen factor for each individual load pair in the governing fatigue calculation so that an overall multiplier on CUF for environmental effects can be determined for each location. These calculations will be submitted to the NRC for approval prior to entry into the period of extended operation.

When completed, the plant-specific calculations for PBAPS are expected to validate the conclusions identified with respect to the EAF effects documented in the LRA. This modified approach is expected to adequately address the concerns identified in Items (a), (b), and (c) of this RAI.

Exelon reserves the right to modify this position in the future based on the results of industry activities currently underway, as well as based on the results of any other methodology improvements that may be made associated with environmental fatigue. It is understood that any such modifications will be subject to NRC approval prior to implementation at PBAPS.

Discussion of Response to 4.3-6

The staff noted that the commitment to submit the environmental calculations to the staff for approval went beyond the commitment provided by previous applicants. Other applicants

committed to using the environmental fatigue factors in determining the CUF. Should the calculated CUF exceed 1, previous applicants committed to implementing appropriate corrective actions (i.e., refine the calculations in an attempt to demonstrate the CUF<1.0, repair or replace the affected locations). The use of alternative aging management programs or alternative methods to account for environmental effects will require prior staff review and approval. The applicant agreed to reconsider their initial commitment.

As part of the response to RAI 4.3-6, the applicant also agreed to revise page 4-26 of the LRA to revise the first full sentence to state, "For relatively high temperature (>200 °C), low dissolved oxygen, and a low (bounding) strain rate, the environmental correction factor may be as high as 15.35."

Telecon Participants

Exelon	NRC
Jerry Phillabaum	John Fair
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Attachment 3