UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 13, 2017

MEMORANDUM TO: David A. Wrona, Chief
Plant Licensing Branch III
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

FROM: Greg A. Casto, Chief **/RA/**
Probabilistic Risk Assessment Licensing Branch B
Division of Risk Assessment
Office of Nuclear Reactor Regulation

SUBJECT: SAFETY EVALUATION REGARDING THE PROPOSED LICENSE AMENDMENT TO REVISE THE BYRON LICENSING BASES FOR PROTECTION FROM TORNADO-GENERATED MISSILES (CAC NUMBER MF8446 and 8447)

By letter dated October 7, 2016, as supplemented by letter dated March 20, 2017, Exelon Generating Company (EGC) requested the U.S. Nuclear Regulatory Commission's (NRC) approval of a proposed license amendment request to revise the Byron Station, Units 1 and 2 plant licensing bases for protection from tornado-generated missiles. The proposed license amendment would modify the Byron Station, Units 1 and 2 plant licensing bases by revising the Updated Final Safety Analysis Report (UFSAR) to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs); and to describe the results of the Byron Station site-specific tornado hazard risk analysis.

The Probabilistic Risk Assessment Licensing Branch B (APLB) staff has reviewed the subject request, and concludes that EPRI TORMIS methodology, within the scope of APLB review, is implemented appropriately in accordance with the NRC guidance. Furthermore, the staff concurs that the reported results comply with the NRC guidance and are acceptable. The enclosed safety evaluation completes the APLB staff's efforts for CAC Number MF8446 and 8447.

Docket Nos.: 50-454 and 50-455

Enclosure:
Safety Evaluation

CONTACTS: Z. Gary Wang, NRR/DRA
301-415-1686

SUBJECT: SAFETY EVALUATION REGARDING THE PROPOSED LICENSE AMENDMENT TO REVISE THE BYRON LICENSING BASES FOR PROTECTION FROM TORNADO-GENERATED MISSILES (CAC NUMBER MF8446 and 8447) June 13, 2017

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**SAFETY EVALUATION BY THE PRA LICENSING BRANCH B**

**TORMIS COMPUTER CODE METHODOLOGY**

**EXELON GENERATING COMPANY, LLC**

**BYRON STATION UNITS 1 AND 2**

**DOCKET NUMBERS 50-454 AND 50-455**

**DRAFT**

## 1.0 INTRODUCTION

By letter dated October 7, 2016 (Agencywide Document Access and Management System (ADAMS Accession No. ML16281A174, Reference 1), as supplemented by letter dated March 20, 2017 (ADAMS Accession No. ML17079A130, Reference 2), Exelon Generating Company, LLC (EGC, the licensee), submitted a request to the U.S. Nuclear Regulatory Commission (NRC) to revise licensing bases by revising the Updated Final Safety Analysis Report (UFSAR) for protection from tornado-generated missiles for Byron Station, Unit 1 and Unit 2. The proposed license amendment describes the methodology and result of analysis performed to evaluate the protection of plant's structure, systems and components (SSCs) from tornado-generated missiles. This analysis utilized a Monte Carlo simulation methodology to assess, through the TORMIS methodology, the probability of multiple missile hits causing acceptable damage to unprotected safety-significant SSCs at Byron plant.

The Electric Power Research Institute (EPRI) developed the TORMIS methodology. TORMIS computer code employs Monte Carlo techniques in order to simulate the transport of
tornado-generated missiles and to assess the frequency of missile strikes causing damage to unprotected SSCs. TORMIS estimates the cumulative annual frequency of missiles striking and damaging individual target SSCs and groups of target SSCs.

## 2.0 REGULATORY EVALUATION

The NRC requires that nuclear power plants be designed to withstand the effects of natural phenomena, including tornado and high-wind-generated missiles so as not to adversely impact the health and safety of the public in accordance with the requirements of 10 CFR 50, Appendix A, General Design Criterion (GDC) 2, "Design Bases for Protection against Natural Phenomena," and GDC 4, "Environmental and Dynamic Effects Design Bases." Methods acceptable to the NRC to comply with the aforementioned regulations are described in Regulatory Guides (RG) 1.117, "Tornado Design Classification," Revision 1, April 1978 and NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Section 3.5.1.4, "Missiles Generated by Natural Phenomena," and Section 3.5.2, "Structures, Systems, and Components to be Protected from Externally-Generated Missiles," Revision 2, July 1981.

SRP Sections 3.5.1.4 and 3.5.2, contain the current acceptance criteria governing tornado missile protection. These criteria generally specify that SSCs that are important to safety be provided with sufficient, positive tornado missile protection (i.e., barriers) to withstand the maximum credible tornado threat. The appendix to RG 1.117, lists the types of SSCs that should be protected from design basis tornadoes. However, SRP Section 3.5.1.4 permits relaxation of the above deterministic criteria if it can be demonstrated that the frequency of damage to unprotected essential safety-related features is sufficiently small.

To use this probabilistic criterion, the EPRI developed the tornado missile probabilistic methodology described in two topical reports, EPRI NP-768 and NP-769, "Tornado Missile Risk Analysis and Appendices," issued May 1978, (References 3 and 4) and EPRI NP-2005, "Tornado Missile Risk Evaluation Methodology," Volumes I and II, issued August 1981 (Reference 5). These topical reports document the TORMIS computer code methodology. The EPRI methodology employs Monte Carlo techniques to assess the frequency of tornado missile strikes that will cause unacceptable damage to safety-related plant equipment.

The NRC staff issued a safety evaluation report (SER), dated October 26, 1983 (Reference 6) that the EPRI TORMIS methodology can be used in lieu of the deterministic methodology when assessing the need for positive tornado missile protection for specific safety-related plant features in accordance with the criteria of SRP Section 3.5.1.4. In that SER the staff concluded that the methodology had limitations for its use that licensees must consider five plant-specific points and provide appropriate information regarding its use.

In June 16, 2008, the NRC issued Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," (Reference 7). This RIS addresses: (1) the NRC staff position on the use of the TORMIS computer code for assessing nuclear power plant tornado missile protection, (2) issues identified in previous license amendment requests to use the TORMIS computer code, and (3) information needed in license amendment applications using the TORMIS computer code.

Although the TORMIS methodology utilizes acceptance criteria for the frequency of tornado induced loss of system function, the NRC approval for implementation of TORMIS is not a risk informed approach. As such, approval of TORMIS allows an alternate method for meeting regulatory requirements under very specific circumstances with respect to the evaluation of specific plant features where additional costly tornado missile protective barriers or alternate systems are under consideration. A licensee may submit a license amendment application utilizing a risk-informed change process consistent with the guidelines of Regulatory Guide 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk Informed Decision on Plant-Specific Changes to the Licensing Basis.” If a risk-informed process was proposed, it would have to meet the five key principles of risk informed regulation described in Regulatory Guide 1.174.

## 3.0 TECHNICAL EVALUATION

### 3.1 Background

The current licensing basis for tornado missile protection is presented in Byron UFSAR Sections 3.5.3, "Barrier Design Procedures," and 3.5.4, "Analysis of Missiles Generated by a Tornado." Most safety related systems and components are located inside structures designed to protect them from tornado-generated missiles as discussed in UFSAR Section 3.5.3.

UFSAR Section 3.5.4 describes the licensing basis for safety-related components located outdoors. Section 3.5.4 states the following:

> "Effects of tornado missiles have been assessed for safety-related components located outdoors. These components are the essential service water cooling towers (Byron only), the emergency diesel exhaust stacks, diesel ventilating and combustion air intake, diesel crankcase vents, the fuel handling building door, and the main steam safety and relief valve stacks."

Section 3.5.4 provides a discussion addressing how the existing missile protection (or lack of missile protection) is acceptable. Section 3.5.4.1, "Essential Service Water Cooling Tower (SXCT)," specifically addresses the tornado missile protection for the SXCTs. It is acknowledged that certain portions of the SXCTs are not tornado missile protected. The Byron Ultimate Heat Sink (UHS) is a common system for the two Byron Station units and consist of two mechanical draft cooling towers (i.e., 0A and 0B). Each tower has four cells and each cell has a manually actuated fan (see Attachment 1-2, Figures 1 and 2 of LAR). Two fans in Tower 0A are powered from Unit 1, Division 11, and the other two fans are powered from Unit 2, Division 21. Similarly, two fans in Tower 0B are powered from Unit 1, Division 12; and the other two fans are powered from Unit 2, Division 22. Each cell is served by a riser pipe which delivers the return water to the spray header.

As discussed in LAR Section 3.4.3, "Boolean Logic for the Ultimate Heat Sink," regarding the UHS along with its components, was used to compute boolean combinations of target hit and damage probabilities over multiple targets. The licensee stated that the SXCT fans and cells that survive a tornado strike will be credited for UHS cooling, as opposed to the original licensing basis that assumed all the unprotected SXCT fans are damaged by missiles. There are no technical specifications changes related to this license amendment request.

EGC has decided to pursue NRC approval to employ the TORMIS methodology for assessing tornado-generated missile protection of the Byron Station SSCs. In this amendment request, EGC has identified 153 components that are not protected from tornado-generated missiles. These include safety-significant SSCs associated with the UHS equipment, and components associated with SXCTs, fans, riser pipes, cells, walls and electrical bus, and the steam generator power operated relief valve (PORV) tailpipes, main steam safety valve (MSSV) tailpipes, and the auxiliary feedwater diesel exhaust stacks and

RWST hatches.

## 3.2 Staff Evaluation

This SER evaluates the acceptability of the TORMIS analysis for calculating the appropriate mean strike and damage probabilities and of the TORMIS results against the guidance provided in the SER on EPRI TORMIS methodology and RIS 2008-14. Therefore, this SER evaluates only those parts of the submittal that pertain to the proposed change in UFSAR Sections 3.3-1 through 3.5-49.

Tables 3.4.4-1 and 3.4.4-2 in Section 3.4.4 of the LAR provided the estimated damage frequencies of 9.13E-07 and 8.83E-07 for Unit 1 for one cell and two cells out of service cases, respectively, and estimated damage frequencies of 9.66E-07 and 9.36E-07 for Unit 2 for one cell and two cells out of service cases, respectively. The licensee further stated that each individual unit damage frequency meets the acceptance criteria of 1.0E-06 per year established in SRP Section 2.2.3, "Evaluation of Potential Accidents," and the NRC memorandum from Harold R. Denton to Victor Stello, "Position on Use of Probabilistic Risk Assessment In Tornado Missile Protection Licensing Actions," dated November 7, 1983 (ADAMS Accession No. ML080870287). However, for considering multi-unit site basis, the licensee stated that the estimated composite site damage frequencies are slightly over the acceptance criteria. The estimated composite site damage frequencies are 1.61E-06 per year and 1.58E-06 per year for the "1 Cell out of Service" case and "2 Cells out of Service" case, respectively.

In request for additional information (RAI) 11, the staff requested that the licensee justify how their calculation for a per unit/per year aligns with EPRI NP-2005, and whether this is a deviation from the model methodology. Additionally, staff requested that the licensee provide information for calculation of the composite site damage frequency, whether that aligns with EPRI NP-2005 calculations, and why that result should not be considered for meeting the acceptance criteria of 1.0E-6 per year. Specifically, the staff cited references and calculations that appeared to describe a single, site consideration for event frequency as an overall conclusion, as opposed to a per unit conclusion.

In its response to RAI 11, contained in a letter, "Response to Request for Additional Information (RAI) Regarding the License Amendment Request to Utilize the TORMIS Computer Code Methodology," dated March 20, 2017, the licensee stated that the damage frequency from the TORMIS methodology was used on a per year basis, citing EPRI NP-2005 Volume I, Figure II-4, and equations 34-36. The licensee further stated, in part, the following:

> "… The Byron TORMIS calculation damage frequency uses the damage frequency straight from the TORMIS methodology on a per year basis. NP-2005 Volume I, Figure II-4, "Risk Aggregation for Multiple Time Periods," (found on page II-30) and Equations 34-36 (found on page II-33) address calculating the mean damage

probability for multiple time periods such as different phases of plant construction for a multi-unit site. [ …]

This discussion does not identify acceptance criteria nor does it discuss application of acceptance criteria on either a ***unit-specific or total site basis*** [emphasis added].

The potential outage missile sources are modeled in distinct TORMIS runs representing outage time periods. Three time periods were simulated with TORMIS: (1) Unit 1 in an outage state with Unit 2 operational; (2) Unit 2 in an outage state with Unit 1 operational; and (3) Unit 1 and Unit 2 operational. […] These three time periods were combined to calculate a ***per-unit*** [emphasis added] and composite site damage frequency, consistent with the methodology in NP-2005. Thus, there is no deviation from the TORMIS methodology for computing per year damage frequency for individual units and/or the plant."

The staff reviewed EPRI NP-2005, including multiple references throughout the narrative portion of the document. Specific to reference to Equations 34-36, EPRI NP-2005 Volume 1 provides the following information:

Page II-33, Multiple Time Periods:

"…The analysis of multiple time periods, corresponding to different phases of plant construction, for example, requires independent simulations. Thus, the combination of probabilities for a multi-unit plant might require the simulation of construction and operational phases. The total probability over time T for *y* time periods is determined from (Equation 34), where ($A_1$) denotes the probability over time period Ti. By assuming independence among damage within each time interval, Eq. 34 can be calculated by (Equation 35).

It is noted that, if the units of PT(A) are per reactor rather than per plant, the $PT_1$ (A) should be in the proper units before making the calculation in Eq. 35. With these results, the mean probability per year, P(A), is simply (Equation 36)…"

As shown above, Equation 35 and 36 provide a per reactor option in performing calculations.

The licensee also cited precedent for analysis of a two-unit site calculated per reactor/per year that was described in a letter, from J. F. Stang (NRC) to R. P. Powers (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 1 and 2 - Issuance of Amendments," dated November 17, 2000 (Reference 8). In the staff's safety evaluation of this application, the justification for a per reactor/per year frequency conclusion was approved. Donald C. Cook's license application did not identify that a per reactor/per year frequency calculation was a deviation to TORMIS modeling, and the staff did not discuss this approach as a deviation in the safety evaluation approval of the amendment.

The staff reviewed the treatment of operational phases, as addressed by the licensee in the LAR. The licensee provided information that applied to specific calculations performed for non-outage and outage time periods, and considered the potential increase in missiles that could be expected during outage conditions.

Additionally, the licensee considered common structures, systems, and components shared between the two units, and adjusted per reactor/per year modeling of unit specific SSCs to overlap common SSCs into frequency determinations. Each unit specific calculations also include common SSCs as part of analysis for that unit.

In addition, the NRC memorandum from Harold R. Denton to Victor Stello, "Position on Use of Probabilistic Risk Assessment in Tornado Missile Protection Licensing Actions," dated November 7, 1983 (Reference 9), the NRC staff states that the guidance of SRP Section 2.2.3 is applicable to tornado missiles. This guidance, which the NRC uses in probabilistic evaluation of the protection of SSCs against tornado-generated missiles, states that an expected rate of occurrence of potential exposures in excess of 10 CFR 100 guidelines of approximately 1.0E-6 per year is acceptable if, when combined with reasonable qualitative arguments, the risk can be expected to be lower.

Based on the above information, , the staff determined that the licensee's response to RAI-11 and application of acceptance criteria on a per unit basis are acceptable because the licensee demonstrated that their amendment performed equations 34-36 in accordance with the NRC approved TORMIS modeling in EPRI NP-2005.

In RAI 12, the staff requested that the licensee clarify the meaning of a statement in Section 4.4 that referred to "many additional aspects of the TORMIS modeling and inputs that ensure bounding and conservative results."

In its response to RAI 12, the licensee stated that "the intent of this statement was to generally summarize that various aspects of the modeling and input parameters already mentioned in the LAR ensure bounding and conservative results." The licensee further provided a list of items in the Sections 3.4.1, 3.4.3, and 3.4.6, which were noted in the LAR as conservatisms in the analysis.

In RAI 13, the staff requested that the licensee clarify if the calculation of any mean (cumulative) tornado missile damage frequency uses any intersection (∩) operator that requires damaging multiple targets simultaneously for establishing a damaged state. This RAI requested that the licensee summarize the guidelines used to identify such groups and explain how they are modeled in TORMIS if multiple targets need to be simultaneously struck.

In its response, the licensee stated that the intersection operator, that required damaging multiple targets simultaneously for establishing a damage state, was used to calculate the TORMIS tornado missile damage frequency for the UHS target group.

Thus, multiple targets need to be damaged during the simulated tornado to result in failure of the UHS.

A listing of failure events affecting the survival of the UHS are defined in Attachment 1-1, Table 4 of the LAR. As an example, combination number 10 is Fan H and Fan D damaged by tornado missiles. For the 1 cell out of service case, this results in 1 cell out of service (Cell B is assumed to be randomly out of service for maintenance), 2 cells lost to the single failure (Cells E and F are assumed to be out of service because Electrical Room 132Z experienced random electrical failure), 2 cells lost to tornado missiles (Fan H and Fan D) with 3 cells surviving, which is not considered a failure. An additional UHS target would need to be damaged to result in a UHS target group failure.

The licensee stated that the Boolean Logic was modeled in the analysis with the TORMIS post-processor TORSCR using the Boolean intersection (∩) operator. LAR Section 3.4.2 described that TORSCR is a FORTRAN computer code used to post-process TORMIS output files. Its primary function is to compute Boolean combinations of target hit and damage probabilities over multiple targets. The intersection operator was only used for the UHS in the Byron Station TORMIS analysis.

The Boolean Logic was created for the UHS based on minimum tower requirement as described in LAR Section 3.4.3. The licensee further stated that the use of the Boolean Logic approach was previously approved by the NRC for Limerick Generating Station, "Limerick Generating Station, Analysis of Tornado Missile Effects on Ultimate Heat Sink (SSER Open Issue No 2,) (Reference 10)

In RAI 8 response, the licensee stated that the basis for success of UHS is at least defined as 3 of the remaining 5 cells surviving for the 1 cell out service case; or 2 of 4 remaining cells surviving in the 2 cells out of service case depending on outside air wet bulb temperature and number of operating units. Each case assumes a worst case single failure of an electrical bus that results in the loss of power to a two paired SXCT fans. For more details, refer to the Reference 2.

With that information provided by the licensee, the staff determined that the licensee's response to RAI-13 is acceptable

## 4.0 CONCLUSION

Based on the evaluation, the staff concludes that the EPRI TORMIS methodology, within the scope of this review by APLB, is implemented appropriately in accordance with the guidance provided in the 1983 TORMIS SER and RIS 2008-14. Furthermore, the staff concludes that the reported results comply with the NRC guidance and are acceptable. Therefore, the NRC staff finds that the proposed revisions to the Section 3.3-1 through 3.5-49 of UFSAR appropriately reflect Byron compliance with the NRC guidance and the use of NRC approved methodology for

TORMIS analysis. This SER does not provide conclusions regarding the five specific concerns identified in the SER approving EPRI TORMIS methodology. The review of those concerns, which must be addressed by license amendment applications using TORMIS methodology, is done outside APLB.

5.0 REFERENCE


1. Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. NRC, "License Amendment Request to Utilize the TORMIS Computer Code Methodology," dated October 7, 2016 (ML16281A174)

2. Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. NRC, "Response to request for Additional Information Regarding the License Amendment Request to Utilize the TORMIS Computer Code Methodology," dated March 20, 2017 (ML17079A130)

3. Electric Power Research Institute Report – EPRI NP-768, "Tornado Missile Risk Analysis," May 1978

4. Electric Power Research Institute Report – EPRI NP-769, "Tornado Missile Risk Analysis - Appendices," May 1978

5. Electric Power Research Institute Report – EPRI NP-2005 Volumes, I and 2, "Tornado Missile Risk Evaluation Methodology," August 1981

6. NRC Safety Evaluation Report, "Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology," dated October 26, 1983 (ML080870291)

7. NRC Regulatory Issue Summary RIS 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (ML080230578)

8. NRC Memorandum from Harold R. Denton to Victor Stello, “Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions,” dated November 7, 1983 (ML080870287)

9. Letter from J. F. Stang (NRC) to R. P. Powers (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 1 and 2 – Issuance of Amendments," dated November 17, 2000

10. Letter from J. S. Kemper (Philadelphia Electric Company) to A. S. Schwencer (NRC), "Limerick Generating Station, Analysis of Tornado Missile Effects on Ultimate Heat Sink (SSER Open Issue No 2)," dated March 22, 1984

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