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Probabilistic Exclusion Methodology to Evaluate Tornado Missile Protection

October 27, 2015

Division of Safety Systems and Division of Risk Assessment
Office of Nuclear Reactor Regulation

Public Meeting Purpose

- Category 2 Public Meeting
- Discuss risk-informed approach
  - RG 1.174 and ASME/ANS PRA Standard
  - Peer review Regulatory Guide 1.200
- Discuss probabilistic methods of analysis using deterministic license amendments

Tornado Missile Protection History

- Late 1970s/Early 1980s - Licensees and NRC identified non-conformances with tornado missile protection licensing bases.
- 1983 - NRC approved TORMIS in a safety evaluation report (SER), dated October 26, 1983 (ML080870291) and staff position (ML080870287) for use "in lieu of the deterministic methodology when assessing the need for positive tornado missile protection for specific safety-related plant features …"
- 1983 - Current - Plants evaluated non-protected SSCs using TORMIS and other probabilistic methodology, with approval of license amendments and changes to licensing bases

Previous Generic Communications

- **Information Notice (IN) 96-06** (ML031060290) - Design and Testing Deficiencies of Tornado Dampers at Nuclear Power Plants
- **Regulatory Issue Summary (RIS) 2006-23** (ML061720371) - Post-tornado Operability of Ventilating and Air-conditioning Systems Housed in Emergency Diesel Generator Rooms
- **RIS 2008-14** (ML080230578) - Use of TORMIS Computer Code for Assessment of Tornado Missile Protection
- **RIS 2013-05** (ML13056A077) - NRC Position on the Relationship between General Design Criteria and Technical Specification Operability
- **RIS 2015-06** (ML15020A419) - Tornado Missile Protection
- **Enforcement Guidance Memorandum (EGM) 15-002** (ML15111A269) – Enforcement Discretion for Tornado-generated Missile Protection Noncompliance

Recent Communications

- Public meeting, September 10, 2015 “ENFORCEMENT DISCRETION FOR TORNADO GENERATED MISSILE PROTECTION”
- DRAFT Interim Staff Guidance (ISG) - Clarification of Licensee Actions in Receipt of Enforcement Discretion per Enforcement Guidance Memorandum EGM 15-002, “Enforcement Discretion for Tornado-generated Missile Protection Noncompliance”
  - Federal Register Notice - **NRC-2015-0231** (pending)
  - ADAMS Accession No.: ML15259A029
  - What compensatory actions would be acceptable for initial compensatory measures and comprehensive compensatory measures?
  - How should noncompliant equipment be considered in regard to operability status per TS once EGM referenced initial compensatory measures were implemented?

Two Options for Accepting Unprotected SSCs

- Use of Frequency of damage to "important to safety" SSCs (discussed later)
  - Identification of SSCs credited to mitigate tornados (important to safety SSCs)
  - Identification of unprotected important to safety SSCs
  - Determination of frequency of damage to identified SSCs (TORMIS/probabilistic analysis)
  - Frequency of damage to unprotected SSCs less than 1E-6 need not be included in design basis
- Use of RG 1.174 risk-informed process
  - Development of Tornado PRA per the ASME/ANS PRA Standard
    - Identification of all unprotected SSCs in the internal events PRA
    - Determination of initiating event frequency and SSC failure probabilities
    - Calculation of tornado missile CDF and LERF
    - RG 1.174 process more work but can credit all plant equipment

Risk analysis per RG 1.200

- NRR/DRA division director discussed topic at the Amelia UWC for work being done on high wind analysis

- If a licensee decides it wants a risk-informed exemption from GDC 2 (for example), RG 1.200 calls for a PRA for any hazards "important to the decision."

- For tornado missile protection exemptions, a high winds (i.e., Tornado) PRA would normally be needed that had been peer reviewed to the endorsed ASME/ANS PRA Standard. NRC review would likely be lengthy for this first-of-a-kind application.

Stakeholder Discussion

- Discussion of risk informed process
- Potential license amendment elements

Probabilistic Analysis Component Overview

- Deterministic technical evaluation using probabilistic exclusion methods (from 1983 Safety Evaluation)
  - Frequency of damage to “important to safety” structures, systems, and components (SSCs)
  - Frequency of damage to unprotected important to safety SSCs less than 1E-6 does not need to be physically protected
- Only acceptable for existing non-protected SSCs, not acceptable for removing protection for existing protected SSCs
- Fermi TORMIS safety evaluation latest approved
  - License Amendment – ADAMS Accession No. ML 13273A467 and ML14016A487
  - Safety Evaluation – ADAMS Accession No. ML 13011A377

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Probabilistic Analysis Component Overview

Tornado Modeling

- Wind field model
- Tornado strike analysis (frequency and probability)

Tornado Missile Impact Analysis

- Plant component modeling
- Component failure modeling

Tornado Missile Spectrum

- Missile Characterization
- Missile Density

Tornado Missile Transport

- Injection and trajectory analysis
- Vertical and horizontal Missile Constraints

Resultant Probabilistic Risk Assessment

- Site-wide cumulative probability from all unprotected important to safety SSCs
- Expected rate of occurrence less than 10-6 per year for Part 100 applicable SSCs is acceptable

Probabilistic Analysis Component Overview (cont)

Tornado Modeling

- Wind field model
- Tornado strike analysis
- Example: The EPRI study proposes a modified tornado classification, F'-scale, for which the velocity ranges are lower by as much as 25 percent than the velocity ranges originally proposed in the Fujita, F-scale. Insufficient documentation was provided in the studies in support of the reduced F'-scale. The F-scale tornado classification should therefore be used in order to obtain conservative results.

  The licensee stated that the original Enhanced Fujita scale wind speeds were utilized in the analysis. The NRC adopted the EF scale in the positions of Regulatory Guide 1.76, Revision 1, that are based on NUREG/CR-4461, Revision 2.

- Example: Data on tornado characteristics should be employed for both broad regions and small areas around the site. The most conservative values should be used in the risk analysis or justification provided for those values selected.

  UFSAR Section 2.3.1.3.2 estimates the probability of a tornado strike to be 4.075 x 10-5 per year. The licensee performed a site-specific analysis to generate a tornado hazard curve data set for the TORMIS analysis. The analysis used data from the National Climatic Center Storm Events Data Base (NGOC 2006) for the years 1950 - 2006 to analyze broad and small regions around the site to identify a suitable sub-region for the site. Statistical tests were performed to identify suitably homogeneous sub-regions. Historical records of tornado occurrences within the sub-region were used to establish the tornado occurrence rate.

Probabilistic Analysis Component Overview (cont)

Tornado Missile Spectrum

- Missile characterization
- Missile density
- Example: Models should calculate the effect of assuming velocity profiles with ratios Vo (speed at ground level) / V33 (speed at 33 feet elevation) higher than that in the EPRI study. Discussion of sensitivity of the results to changes in the modeling of the tornado wind speed profile near the ground should be provided.

  To address the reductions in tornado missile speed near the ground due to surface friction effects that are not sufficiently documented in the EPRI study. the licensee stated that the TORMIS rotational velocity Profile 3 was used. This profile has increased wind speeds over the TORMIS Profile 5 values used in the 1981 EPRI TORMIS reports. A sensitivity study was conducted by running the original EPRI profiles and comparing the results. The Profile 3 study (enhanced near-ground wind speeds below 33 feet) resulted in damage probabilities that were greater than the Profile 5 results. The use of Profile 3 with higher near-ground wind speeds is conservative..

- Example: Models should provide sufficient information to justify the assumed missile density based on site specific missiles sources and dominant tornado paths of travel.

  The licensee performed walkdowns of the site prior to refueling outages to characterize missile sources and plant configuration. Missile sources were catalogued and modeled to a distance of approximately 2,500 feet. Performing the site surveys prior to refueling outages maximized the estimated potential missile sources. More than 75,000 missiles were postulated. This is a reasonable missile density in comparison to some other plants that use 25,000 to 74,000.

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Probabilistic Analysis Component Overview (cont)

- **Tornado Missile Transport**
  - Missile behavior during transport
  - Tornado forces and gravity forces
  - Example: Methodology includes aerodynamics, trajectory, and injection models. Could simplify if direct relationship established between number of missiles in target area and resultant damage (if struck, then damaged)

    Conservative assumption made in this analysis is that if a missile strikes any part of component, it is assumed to fail. More likely, failure probability is less than 10%. With respect to wind speeds (and resulting missile velocity), no tornados greater than F-3 intensity (206 mph) are expected to be experienced, and damage to fail component must crush pipe significantly to restrict flow (>50% restriction). In consideration for other engineering judgement already incorporated, a 1.0 value is used. (if struck, then fails).

Probabilistic Analysis Component Overview (cont)

- **Tornado Missile Impact analysis**
  - Plant component modeling
  - Component failure modeling
  - Example: Methodology used in the submittal for calculating the mean aggregate tornado missile damage probability should not use logic (e.g., "AND" gates) that requires damaging multiple targets simultaneously for establishing a damaged state.

A licensee stated that no "AND" Boolean operations, which require damage to multiple targets in the same tornado event, were used for the TORMIS analysis of the targets that were included in the analysis.

Probabilistic Analysis Component Overview (cont)

- **Resultant Probabilistic Risk Assessment**
  - Site-wide cumulative probability from all exposed SSCs
  - Expected rate of occurrence less than 10-6 per year for Part 100 applicable SSCs is acceptable
  - Example: Once the methodology has been chosen, justification should be provided for any deviations from the calculational approach.

The licensee stated that the TORMIS code, a legacy FORTRAN computer code, has been updated to modem computers. The updates and enhancements include: porting the legacy . code from the mainframe to minicomputer to PC computers; post processing data routines; updating the random number generation; updating the aerodynamic tip loss function, and addressing compiler differences and numerical round-off issues in various functions from the legacy code. Code changes have been checked and verified through comparisons to the preceding versions. An enhanced method was used for evaluating missiles passing through openings such as pipe penetrations in concrete walls, in addition to the standard TORMIS hit probability for such targets. This provides supplemental outputs intended to cover special cases of missiles going through wall openings.

Use of Alternate Probabilistic Methodology

- Methodology used by some plants to justify non-protection
- Calvert Cliffs approach as alternative model (Alt model) to TORMIS
- Specific conditions for use of Alt model in following examples:
  - Elements discussed prior included or bounded by justified conservatism
  - Alt model was robust and documented
  - All known non-protected SSCs included in Alt model
  - Missile spectrum includes analysis considers all directions
  - Site-wide probability < 1 X 10-6 for structures, systems and components required to prevent a release of radioactivity in excess of 10 CFR Part 100

Stakeholder Discussion

- Discussion of deterministic approach
- Discussion of methodology elements

- Additional questions and comments