# REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**APR1400 Design Certification**

**Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD**

**Docket No. 52-046**

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| **RAI No.:** | **270-7894** |
| **SRP Section:** | **SRP 19** |
| **Application Section:** | **19.1.** |
| **Date of RAI Issue:** | **10/22/2015** |

## Question No. 19-14

10 CFR 52.47(a)(27) states that a DC application must contain an FSAR that includes a description of the design-specific PRA and its results. In addition, SRP Chapter 19, Revision 3 (Draft), Section III. "REVIEW PROCEDURES," Item 1A under Subsection "Design-Specific PRA" states that "The applicant's analyses should be comprehensive in scope and address all applicable internal and external events and all plant operating modes." Therefore, in order for the staff to reach a reasonable finding that the scope, level of detail, and technical adequacy of the design-specific PRA are appropriate, please describe the quantitative or qualitative, as applicable, risk assessment associated with the applicable external hazards (e.g., high winds, tornados, external flooding), provide the results of the probabilistic evaluation of these hazards, and include the discussions in the DCD.

## Response – (Rev. 1)

The results of Other External Events Risk Evaluation are summarized in the DCD Section 19.1.5.4, which is replaced in its entirety to this response as shown in the Attachment 1.

The DCD markups associated with Issue #'s PRA-19 (AI 19-019), PRA-119 (AI 19-126), and Issue # PRA-156 (AI 19-163) will be incorporated in the DCD Rev. 1 'as-is.'

The DCD mark ups associated with Issue #'s PRA-118 (AI 19-125) and PRA-151 (AI 19-158) are incorporated in Attachment 1 of this RAI response.

The DCD mark ups associated with Issue # PRA-130 (AI 19-137) are incorporated in Attachment 2 of this RAI response.

The DCD markups associated with Issue # PRA-98 (AI 19-098) is no longer applicable, since the associated texts were removed from the DCD.

Issue # SA-4 (AI 19-117) was addressed in the response to Issue # PRA-156 (AI 19-163) above.

**Impact on DCD**

DCD will be revised as discussed above.

**Impact on PRA**

There is no impact on the PRA.

**Impact on Technical Specifications**

There is no impact on the Technical Specifications.

**Impact on Technical/Topical/Environmental Reports**

There is no impact on any Technical, Topical, or Environmental Report.

potential for accumulation and propagation to impact equipment in the auxiliary building.

f. The lowest flood areas in each quadrant of the auxiliary building are designed to contain over 2,271 $m^3$ (600,000 gal) of water without impacting equipment in adjoining quadrants. Watertight barriers, designed to withstand at least 9 ft of accumulation, are provided between quadrants on the lowest elevation of the auxiliary building.

19.1.5.4 Other External Events Risk Evaluation

replace with "A"

~~External events considered are those whose cause is external to all systems associated with normal and emergency operations situations, with the exception of internal fires and floods. Some external events may not pose a significant threat of a severe accident. Some external events are considered at the design stage and have a sufficiently low contribution to plant risk.~~

~~The set of external events was taken from the ASME/ANS PRA Standard and represents a consensus listing of external events for nuclear power plant. Table 19.1-80 presents the screening analysis of these external events (based upon recommendations in the ASME/ANS PRA Standard). Those events that are not screened or subsumed within other hazard categories need to be addressed in a site-specific PRA.~~

~~Chapter 2 contains site-specific parameters for the following attributes.~~

~~a. Nearby industrial, transportation, and military facilities~~

~~b. Meteorology~~

~~c. Hydrologic engineering~~

~~d. Geology, seismology, and geotechnical engineering~~

~~Evaluation of potential accidents for the nearby industrial, transportation, and military facilities in Chapter 2 is a probabilistic and predictive approach that is to be followed and documented in the COLA to verify that a $1\times10^{-7}$/year occurrence rate has been demonstrated. For low probability events, where data may not be available, a $1\times10^{-6}$/year~~

replace with "A"

~~occurrence rate can be utilized when combined with reasonable qualitative arguments. Otherwise, a PRA may need to be performed to comply with the guidance of the ASME/ANS PRA Standard. The screening criteria for other external events need to be determined at the COL phase, with confirmation that the screening criteria are below the plant-specific risk target.~~

19.1.6 Safety Insights from the PRA for Other Modes of Operation

This section summarizes Level 1 and 2 internal events, internal flooding, and internal fire PRAs for the low power and shutdown (LPSD) operations, including results and risk insights.

19.1.6.1 Level 1 Internal Events PRA for Low Power and Shutdown Operations

A description of the Level 1 internal events PRA for LPSD operations, including the results from the PRA, is provided in the following subsections.

19.1.6.1.1 Description of Level 1 Internal Events PRA for Low Power and Shutdown Operations

19.1.6.1.1.1 Methodology

The scope of this analysis included quantitative evaluation of internal events for the LPSD operations. The development of the LPSD PRA includes the following nine major technical tasks.

a. Plant Operating State Development

b. Initiating Events Analysis

c. Accident Sequence Analysis

d. Success Criteria Analysis

e. Systems Analysis

f. Data Analysis

"A"

RAI 270-7894 - Question 19-14

This section summarizes the analysis of hazards to the APR1400 design from external events other than plant fires and seismic events. The sections that follow detail the evaluation of external hazards.

19.1.5.4.1 Assumptions

The following assumptions were used to develop the APR1400 Other External Events analysis:

1. All SSCs that are modeled in the PRA are designed to withstand the design-basis tornado (DBT) and design-basis hurricane (DBH) including all effects, i.e., pressure loading, pressure drop and missile impacts.
2. The non-safety related systems, structures, and components (SSCs) are designed such that they will not collapse on or impact the seismic Category I structures containing SSCs (item 1 above) and will not generate missiles more damaging than the DBT and DBH missiles.

19.1.5.4.2 Analysis

The external hazard probabilistic risk assessment (PRA) methodology for currently-operating plants is described in a number of references. Examples include References 2, 4, and 40. The major elements of an external hazard PRA are:

- Initial screening of external hazards based on a set of qualitative criteria,
- Bounding analysis for the screened-in external hazards,
- Detailed PRA for the remaining external hazards.

The initial screening of external hazards is done by first enumerating all potential external hazards that may impact the plant and screen them out using a set of criteria based on magnitude, distance, frequency and severity of the hazard. For an existing plant, these hazards will have been studied during the site selection and plant design. For example, the following USNRC regulatory guides and standard review plan sections provide acceptable criteria for excluding certain external hazards from the design basis of the plant:

- RG 1.78, “Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release” (Reference 55)
- RG 1.91, “Evaluations of Explosions Postulated To Occur on Transportation Routes Near Nuclear Power Plants” (Reference 56)
- RG 1.115, “Protection Against Low-Trajectory Turbine Missiles” (Reference 57)

- SRP Section 3.5.1.6, "Aircraft Hazards" (Reference 58)

For the screened-in external hazards, a bounding or demonstrably conservative analysis is done to show either 1) the mean value of the frequency of the design-basis hazard used in the plant design is less than $10^{-5}$yr and the conditional core damage probability is less than $10^{-1}$, given the occurrence of the design-basis hazard event or 2) the core damage frequency (CDF) from the external hazard is less than $10^{-6}$/yr.

For the remaining external hazard, a detailed PRA is performed; the major elements of such a PRA are:

- Probabilistic external hazard analysis to develop a hazard curve depicting the annual frequency of exceeding different hazard intensities; the uncertainties in the data and model are propagated through the hazard analysis to derive a family of hazard curves with associated weights (or subjective probabilities)
- Fragility analysis to identify the SSCs that are susceptible to the effects of the external hazard and to determine the plant-specific failure probabilities as a function of the intensity of the hazard.
- External hazard plant response model to (a) develop a plant response model by modifying the internal events at-power PRA model to include the effects of the external hazard in terms of initiating events and failures caused; (b) quantify this model to provide the conditional core damage probability (CCDP) and conditional large release probability (CLRP) for each defined external hazard plant damage state and (c) evaluate the unconditional CDF and LRF by integrating the CCDP/CLRP with the frequencies of the plant damage states obtained by combining the results of hazard analysis and fragility analysis.

While this methodology is equally applicable to new reactors under design certification, some key differences do exist.

- Most of the external hazards are location specific. Since the plant site is not known, initial screening of the external hazards cannot be performed. However, the combined operating license (COL) applicant is expected to select the site that meets the enveloping site parameters (DCD Table 2.0-1) and conforms to the NRC regulatory guides and SRP. This practice will provide the basis for screening of many external hazards.
- The plant design will not have progressed to the extent that plant-specific fragilities of SSCs could be evaluated. Therefore bounding or demonstrably conservative analysis of many screened-in external hazards cannot be meaningfully done.

19.1.5.4.3 Initial Screening of External Hazards

For a selected site, the COL applicant will perform the initial screening of hazards complying with ASME/ANS PRA Standard Part 6 Addendum B and NRC RG 1.200 Revision 2.

External hazards screened out during the design stage are:

- Transportation accidents: DCD Section 2.2.3 requires the COL applicant to identify and evaluate potential accidents arising from nearby industrial, transportation (aircraft routes, highways, railways, navigable waters and pipelines), and military facilities. The COL applicant will select the design basis event following the standard review plan (SRP) Section 2.2.3 acceptance criteria. The following principal types of hazards will be considered.

  - Toxic vapors or gases and their potential for incapacitating nuclear plant control room operators
  - Overpressure resulting from explosions or detonations involving materials such as munitions, industrial explosives, or explosive vapor clouds resulting from the atmospheric release of gases (such as propane and natural gas or any other gas) with a potential for ignition and explosion
  - Missile effect attributable to mechanical impacts, such as aircraft impacts, explosion debris, and impacts from waterborne items such as barges
  - Thermal effects attributable to fires

  The identification of design-basis events resulting from the presence of hazardous materials or activities in the vicinity of the plant is acceptable if all postulated types of accidents are included for which the expected rate of occurrence of potential exposures resulting in radiological dose in excess of the 10 CFR Part 100 limits is estimated to exceed the NRC staff objective of an order of magnitude of $10^{-7}$ per year. If data are not available to make an accurate estimate, this event probability could be of the order of magnitude of $10^{-6}$ per year if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower.

  The specific guidance in RG 1.76, RG 1.91 and SRP Section 3.5.1.6 are followed in this evaluation.

  After an APR1400 unit is built at a site, the COL holder should complete the external hazard PRA conforming to RG 1.206; the screening of external hazards such as transportation accidents should be documented.

- Turbine Missile: The turbine generator layout for the APR1400 is considered to be a favorable orientation and excludes SSCs from low-trajectory turbine missile strikes. This conforms to RG 1.115. DCD Section 3.5.1.3 states that the probability of unacceptable damage resulting from turbine failure is less than $1x10^{-7}$ per year. Therefore, turbine missile is not considered as a design-basis event. The turbine missile hazard is also screened out in the PRA because of the low probability.

19.1.5.4.4 Bounding Analysis for Screened in External Hazards

Based on previous external hazard PRAs, the following hazards may not be screened using initial screening:

- Extreme Winds and Tornadoes
- External Flooding

19.1.5.4.4.1 Extreme Winds and Tornadoes

This group of external hazards includes tornadoes, hurricanes and thunderstorms. All potential sites for APR1400 are exposed to tornadoes and thunderstorms; coastal sites are in addition exposed to hurricanes.

DCD Section 3.3 describes the design basis for tornadoes and hurricanes. The design basis tornado (DBT) is selected as corresponding to Region I of RG 1.76. The maximum windspeed of the DBT is 230 mph and corresponds to a probability of exceedance of $10^{-7}$ per year. The design basis hurricane (DBH) is selected as having a maximum windspeed of 260 mph and corresponds to a probability of exceedance of $10^{-7}$ per year at most US coastal sites (except Southern Florida) as specified in RG 1.221. The standard plant structures (i.e., containment building, containment building internal structures, auxiliary building and emergency generator building and diesel oil fuel tank) will be designed to the maximum of the load effects from the DBT and DBH with additional conservatisms in the structural acceptance criteria. The design against DBT also includes the effect of pressure drop as the tornado moves over the building.

DCD Section 3.5 describes how the APR1400 structures will be designed against the design basis missile spectrum for the DBT and DBH as specified in RG 1.76 and RG 1.221. The exterior walls and roof slabs of seismic Category I structures will be designed to withstand the local and global effects of these missiles.

The non-safety-related SSCs (e.g., Turbine Generator Building) adjacent to seismic Category I structures are designed such that they will not collapse on or impact seismic Category I structures. The COL applicant will provide reasonable assurance that site-specific structures and components not designed for extreme wind loads will not affect the ability of seismic Category I structures to perform their intended safety function and will not generate missiles with more severe effects than the missiles from the DBT and DBH.

The bounding analysis for extreme winds and tornadoes is based on the following assumptions:

1. All SSCs that are modeled in the PRA are designed to withstand the DBT and DBH including all effects (i.e., pressure loading, pressure drop and missile impacts).
2. The non-safety related SSCs are designed such that they will not collapse on or impact the seismic Category I structures containing SSCs (item 1 above) and will not generate missiles more damaging than the DBT and DBH missiles.

With these assumptions, the contribution to CDF and LERF from extreme winds is judged to be less than $10^{-7}$ per year and could be screened out from detailed PRA.

After an APR1400 unit is built at a site, the COL holder should confirm that the above assumptions are met and complete the external hazard PRA conforming to RG 1.206 and ASME/ANS PRA Standard Part 6 and 7 requirements.

19.1.5.4.4.2 External Flooding

There are several types of external flooding phenomena that need to be considered, depending on the site where the APR1400 is located. These include both natural phenomena (high river or lake water, ocean flooding such as from high tides or wind driven storm surges, extreme precipitation, tsunamis, seiches, flooding from landslides, etc.), and man-made events (principally failures of dams, levees, and dikes). It is also important to consider rational probabilistic combinations of the above phenomena. The consequences of heavy rain and other flooding, such as water collected on rooftops and in low-lying plant area are also within the scope of external flooding PRA.

river flooding,

The maximum flood elevation is specified in DCD Table 2.0-1 as 1-foot below the plant grade in the vicinity of the SSCs important to safety. DCD Section 2.4 describes the flood analysis for different sources that the COL applicant has to perform in the site selection and design of the plant. It is expected that the COL applicant will make use of the on-going studies for

reevaluation of external floods at current nuclear power plant sites in response to Fukushima NTTF Recommendation 2.1.

It is concluded that the external flooding will not be a significant contributor to CDF and LERF based on the site selection and design features implemented by the COL applicant.

After an APR1400 unit is built at a site, the COL holder should confirm that the above assumptions are met and complete the external hazard PRA conforming to RG 1.206 and ASME/ANS PRA Standard Part 6 and 8 requirements.

, see COL 19.1(8)

Issue # PRA-130 (AI 19-137)

**APR1400 DCD TIER 2**

RAI 270-7894 - Question 19-14_Rev. 1

## Attachment 1 – Section 19.1.9 DCD Markup for Question PRA-130

[Section 19.1.9, Pages 19.1-234 and 19.1-235]

COL 19.1(8) The COL applicant is to address the following issues with a site-specific risk assessment, as applicable:

- ~~Dam failure~~
- Aircraft crash event
- External flooding
- Extreme winds and tornadoes
- Industrial or military facility
- Lightning
- Pipeline accident
- Release of chemicals from onsite storage
- River diversion /River flooding
- ~~Sandstorm~~
- Storm surge
- Toxic gas
- Transportation accidents
- ~~Aircraft crash event~~

In addition, the COL applicant is to ensure the site specific susceptibility is not an outlier for the following issues, as applicable:

- Avalanche
- Biological events
- Coastal erosion
- Dam failure
- Drought
- Forest fire

Issue # PRA-130 (AI 19-137)

RAI 270-7894 - Question 19-14_Rev. 1

**APR1400 DCD TIER 2**

- High summer temperature
- Hurricane
- Landslide
- Low lake/river water level
- Low winter temperature
- Sandstorm
- Tsunami
- Volcanic activity

See Subsection 19.1.5.4.

COL 19.1(9) The COL applicant is to describe the uses of PRA in support of licensee programs such as Maintenance Rule implementation during the operational phase. See Subsection 19.1.7.2.

42. NUREG-1921, "EPRI/NRC-RES Fire Human Reliability Analysis Guidelines," U.S. Nuclear Regulatory Commission, November 2009.

43. EPRI 1016735, "Fire PRA Methods Enhancements: Additions, Clarifications, and Refinements to EPRI 1019189," Electric Power Research Institute, December 2008.

44. NUREG/CR-4527, "An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Control Cabinets, Part II: Room Effects Tests," U.S. Nuclear Regulatory Commission, April 1987.

45. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, September 1976.

46. EPRI 1021086, "Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments (PRAs)," Electric Power Research Institute, October 2010.

47. NUREG/CR-6144 (BNL-NUREG-52399), "Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Surry, Unit 1," U.S. Nuclear Regulatory Commission, June 1994.

48. Inspection Manual Chapter 0609, Appendix G, "Shutdown Operations Significance Determination Process," U.S. Nuclear Regulatory Commission, February 2005.

49. NUMARC 93-01, "Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Nuclear Energy Institute, July 2000.

50. NEI 00-04, "10 CFR 50.69 SSC Categorization Guideline," Rev. 0, Nuclear Energy Institute, July 2005.

51. CAFTA 6.0b, Software Manual, EPRI, Palo Alto, CA, 2014.

52. NUREG/CR-7114, "A Framework for Low Power/Shutdown Fire PRA," U.S. Nuclear Regulatory Commission, September 2013.

53. NUREG/CR-7150, "Joint Assessment of Cable Damage and Quantification of Effects from Fire (JACQUE-FIRE)," May 2014.

54. [Already used]

55. RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," USNRC, Rev. 1, December 2001.

56. RG 1.91, "Evaluations of Explosions Postulated To Occur on Transportation Routes Near Nuclear Power Plants," USNRC, Rev. 2, April 2013.

57. RG 1.115, "Protection Against Low-Trajectory Turbine Missiles," USNRC, Rev. 2, January 2012.

58. NUREG-0800, SRP Section 3.5.1.6, "Aircraft Hazards," USNRC, Rev. 4, March 2010.