Response to

Request for Additional Information No. 126 (944), Revision 0

10/31/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.03.02 - Tornado Loads
Application Section: EPR FSAR Section 3.3.2

QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)

Question 03.03.02-1:

1. In Section 3.3.2.2 (Determination of Tornado Forces on Structures) of the FSAR, the equation for wind pressure velocity uses a value of K_z and a value of I both equal to 1.0, while in the SRP the value of Kz is equal to .87 and the value of I is equal to 1.15. This results in a pressure load that is slightly lower than that provided in the SRP. Provide the basis for using different factors from those of the SRP and discuss their impact on the design of Seismic Category I structures.

2. Non safety-related structures must not adversely affect the ability of safety-related structures to perform their intended safety-related functions. In Section 3.3.2.3 (Effect of Failure of Structures or Components not Designed for Tornado Loads) of the FSAR, it states that the methodology of ASCE 58 is used to show that the NAB will not collapse under tornado loads. To review the basis for concluding that the NAB will not collapse, provide the methodology from ASCE 58 that was used for the NAB structural analysis.

3. In FSAR Section 3.3.2.3 (Effect of Failure of Structures or Components not Designed for Tornado Loads), it states that for the ACB and the TB 'one of the above methods' will be utilized to ensure that the adjacent Nuclear Island Basemat Structure is protected from the failure of the ACB or TB due to tornado loading. It is not clear what methods are being referenced and how they will be used to ensure that adjacent Nuclear Island Basemat Structures are protected from failure of the ACB or TB due to tornado loading. Specify and provide the method or methods that will be used and how they will be implemented to assure protection of Seismic Category I structures from ACB or TB failure.

4. Editorial comment-the acronyms for structures in Figure 3B-1 do not agree with the acronyms used in the text.

5. Acceptance Criteria 3 of SRP 3.8.3 endorsed that all loads combinations are to be in accordance with ACI 349. The reduction to 25% live load with tornado load as stated in FSAR Sections 3.3.2 (Tornado Loading) and 3.8.4.3.2 (Loading Combinations) contradict with ACI 349 and RG 1.143 Table 3 which use full live load instead of the 25% live load noted above. Provide the bases of this live load reduction in combination with tornado load and justify this deviation from pertinent provisions of the SRP 3.8.3.

6. Referring to previous Item 3 above, discuss the effects of vortex shedding on the vent stack structural integrity with respect to tornado load.

Response to Question 03.03.02-1:

1. U.S. EPR FSAR Tier 2, Section 3.3.2.2.1, "Notes on Values Used", is intended to reconcile the differences between the FSAR specified values of velocity pressure exposure coefficient (K_z) and the importance factor (I) and those in the SRP. As stated in U.S. EPR FSAR Tier 2, Section 3.3.2.2.1, using the values of the factors K_z and I from U.S. EPR FSAR Tier 2, Section 3.3.2.2, the procedure results in a conversion of tornado wind speed into an equivalent tornado wind pressure with no significant differences from the results generated using the factors as given in the SRP.

2. The U.S. EPR FSAR Tier 2, Section 3.3.2.3, will be updated to state:

"The NAB is a reinforced concrete structure. The methodology of ASCE 43 (Limit State A) is utilized to ensure that the NAB will not collapse under tornado loads and affect Seismic Category I Nuclear Island Common Basemat structures. Additionally, the NAB is evaluated for tornado loadings per RG 1.143 due to its classification as RW-IIa per RG 1.143."

3. The methods referred to are the three bulleted items in U.S. EPR FSAR Tier 2, Section 3.3.2.3. Specifically, the three methods referred to are:

   - The adjacent non-Seismic Category I structure is designed to resist applicable tornado loadings.

   - The integrity of a Seismic Category I structure is evaluated for failure of an adjacent non-Seismic Category I structure during a design basis tornado to verify the functionality and continued operation of the Seismic Category I structure during and after the tornado.

   - A structural barrier(s) is provided to protect the Seismic Category I structure from failure of the adjacent non-Seismic Category I as a result of a tornado.

U.S. EPR FSAR Tier 2, Section 3.3.2.3, will be updated to state:

"The ACB is a reinforced concrete or steel frame building. One of the methodologies identified in the preceding three bullets will be utilized to provide reasonable assurance that the ACB will not collapse under tornado loads and affect Seismic Category I Nuclear Island Common Basemat structures."

U.S. EPR FSAR Tier 2, Section 3.3.2.3, will be updated to state:

"The TB is a steel frame building. One of the methodologies identified in the preceding three bullets will be utilized to provide reasonable assurance that the TB will not collapse under tornado loads and affect Seismic Category I Nuclear Island Common Basemat structures."

U.S. EPR FSAR Tier 2, Section 3.3.2.3, 3rd bullet will be updated to state:

"A structural barrier(s) is provided to protect the Seismic Category I structure from failure of the adjacent non-Seismic Category I structure as a result of a tornado."

4. All systems, structures, and components are coded using the Kraftwerk Kennzeichen System (KKS) coding system. The three letter abbreviations shown throughout the U.S. EPR FSAR Tier 2, Section 3B figures are the KKS codes for the structures, not acronyms. For clarity, abbreviations utilized throughout the FSAR text are typically selected as a generic acronym (i.e., Reactor Building = RB, Fuel Building = FB) rather than the KKS code (i.e., Reactor Building = UJA, Fuel Building = UFA).

5. One hundred percent of the live load is used for structural design activities.

U.S. EPR FSAR Tier 2, Section 3.3.2, will be updated to state:

> "One hundred percent of the design live load is considered with tornado load combinations."

Contrary to the question, there is currently no mention of the use of twenty-five percent of the live load in U.S. EPR FSAR Tier 2, Section 3.8.4.3.2. However, the reference to use twenty-five percent of the live load in U.S. EPR FSAR Tier 2, Section 3.8.1.3.2, 2nd bullet will be updated to state:

> "Twenty-five percent of the design live load is considered during static analysis with seismic load combinations. The full potential live load is used for local analysis of structural members."

Similarly, the reference to use twenty-five percent of the live load in U.S. EPR FSAR Tier 2, Section 3.8.4.4.1, 9th bullet will be updated to state:

> "Twenty-five percent of the design live load is considered during static analysis with seismic load combinations. The full potential live load is used for local analysis of structural members."

Similarly, the reference to use twenty-five percent of the live load in U.S. EPR FSAR Tier 2, Section 3.8.5.4.1, 4th bullet will be updated to state:

> "Twenty-five percent of the design live load is considered during static analysis with seismic load combinations. The full potential live load is used for local analysis of structural members."

6. The effects of vortex shedding with respect to tornado wind parameters defined in U.S. EPR FSAR Tier 2, Section 3.3.2.1 have been investigated. It was determined that a tuned mass damper will be utilized to minimize the effects of vortex shedding induced loads. With a tuned mass damper in place, vortex shedding is not the controlling load case for design; safe shutdown earthquake load cases control the design of the vent stack.

FSAR Impact:

U.S. EPR FSAR Tier 2, Sections 3.3.2, 3.3.2.3, 3.8.1.3.2, 3.8.4.4.1 and 3.8.5.4.1 will be revised as described in the response and indicated on the enclosed markup.

Question 03.03.02-2:

(1) In FSAR Section 3.3.2.2 it states that the exterior walls and roofs of Seismic Category I structures are designed for the maximum differential pressure of 1.2 psi and that when the pressure boundary is not established by exterior walls or roofs, the differential pressure is taken as zero. If there are any structures which are partially enclosed (vented) for which the pressure drop was assumed to be less than the full differential pressure drop, then according to SRP 3.3.2 the assumed pressure drop for these structures must be reviewed on a case-by-case basis. If there are such that fall into this category, provide the structure(s) and the basis for the assumed pressure drop.

(2) In FSAR Section 3.3.2.3 it states that acceptance criteria for the vent stack include ASCE 43 (Limit State A) for overall stability and ACI 349 (Appendix B) for the anchorage of the vent stack to the stair tower roof slab. It is not clear from this description what loads are being applied to the vent stack including the basis for the tornado load. The applicant should provide the factors used for developing the tornado load, the basis for the loads used to design the anchorages and the margin of safety for the vent stack against its collapse on adjacent Seismic Category I structures.

Response to Question 03.03.02-2:

1. No Seismic Category I structures have been identified to fall into partially enclosed category.

2. Although the vent stack is classified as a Seismic Category II structure, it is globally designed to the same requirements as a Seismic Category I structure due to its proximity to other Seismic Category I structures as stated in U.S. EPR FSAR Tier 2, Section 3.7.2.8. Accordingly, the factors used for development of tornado wind loads on the vent stack are as specified in U.S. EPR FSAR Tier 2, Section 3.3.2.2. These loadings are used for the design of the vent stack structure, as well as the anchorage of the vent stack structure to the stair tower roof slab. Therefore, since the vent stack is globally designed as a Seismic Category I structure, an interaction analysis is not required. To clarify, U.S. EPR FSAR Tier 2, Section 3.3.2.3, will be updated to read:

   > “The Vent Stack is a steel structure which is categorized as a Seismic Category II structure. It is supported on the roof slab of the Seismic Category I stair tower located between the Seismic Category I Fuel Building and the Seismic Category I Safeguard Building 4. Due to the proximity of the vent stack to other Seismic Category I structures, it is conservatively treated as a Seismic Category I structure for the purposes of global design.”

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.3.2.3 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

A COL applicant that references the U.S. EPR design certification will demonstrate that failure of site-specific structures or components not included in the U.S. EPR standard plant design, and not designed for tornado loads, will not affect the ability of other structures to perform their intended safety functions.

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Tornado loads include loads caused by the tornado wind pressure (W_w), tornado atmospheric pressure change effect (W_p), and tornado-generated missile impact (W_m). ~~Twenty five (25)~~ One hundred percent of the design live load is considered with tornado load combinations. Refer to Section 3.8 for loading combinations and acceptance criteria for tornado loads considered in combination with other loads. Refer to Section 3.5 for a description of tornado wind-generated missile loads and design criteria.

Local damage, such as cracking and spalling of concrete and permanent deformation of structural members and elements, is permissible when structures are designed for tornado missile impact loads, provided that Seismic Category I structures remain functional during and subsequent to the missile strike. Structural integrity is demonstrated for all Seismic Category I structures as a result of a tornado wind-generated missile impact analysis, see Section 3.5.1.4. No adverse effects, such as concrete spalling and cracking, occur as a result of secondary missiles.

3.3.2.1 Applicable Tornado Design Parameters

The following parameters, determined in conformance with RG 1.76, are used for the design basis tornado:

- Radius of maximum rotational speed = 150 ft.
- Maximum wind speed = 230 mph.
- Maximum rotational speed = 184 mph.
- Maximum translational speed = 46 mph.
- Maximum pressure drop = 1.2 psi.
- Rate of pressure drop = 0.5 psi/s.

The design basis tornado for the U.S. EPR standard plant design is selected for a worst-case site in the contiguous United States, and represents a probability of exceedance of 1×10^{-7} per year.

3.3.2.2 Determination of Tornado Forces on Structures

Tornado wind velocity is converted into effective pressure loads in accordance with Reference 1 and with guidance provided in NUREG 0800 SRP Section 3.3.2.

$$Wt = Ww + 0.5Wp + Wm$$

Exterior walls and roofs of Seismic Category I structures are designed for the maximum differential pressure of 1.2 psi. When the tornado pressure boundary is not established by exterior walls or roofs, the differential pressure is taken as zero.

3.3.2.2.1 Note on Values Used

The use of the values stated previously for K_z = 1.0 and I = 1.0 provides essentially identical results as those recommended in NUREG 0800, SRP Section 3.3.2, for K_z = 0.87 and I = 1.15. That is, the product of the U.S. EPR values is 1.0 x 1.0 = 1.0, whereas the product of SRP 3.3.2 values is 0.87 x 1.15 = 1.0005.

3.3.2.3 Effect of Failure of Structures or Components not Designed for Tornado Loads

Non- Seismic Category I structures are not designed for tornado loads unless their failure during a tornado could adversely affect nearby Seismic Category I ~~SSCs~~SSC. Seismic Category I structures are protected from failure of adjacent non- Seismic Category I structures during a tornado by one of the following methods:

- The adjacent non- Seismic Category I structure is designed to resist applicable tornado loadings.
- The integrity of a Seismic Category I structure is evaluated for failure of an adjacent non- Seismic Category I structure during a design basis tornado to verify the functionality and continued operation of the Seismic Category I structure during and after the tornado.
- A structural barrier(s) is provided to protect the Seismic Category I structure from failure of the adjacent non- Seismic Category I structure as a result of a tornado.

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The non- Seismic Category I structures that are adjacent to the Seismic Category I Nuclear Island Common Basemat Structure, Emergency Power Generation Buildings (EPGB), and Essential Service Water Buildings (ESWB) include the Vent Stack (VSTK), Nuclear Auxiliary Building (NAB), Radioactive Waste Processing Building (RWB), Access Building (ACB), and Turbine Building (TB). Figure 3B-1 provides a site plan of the U.S. EPR standard plant showing the plant layout.

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The Vent Stack is a steel structure which is categorized as a Seismic Category II structure. It~~The steel structure of the vent stack~~ is supported on the roof slab of the Seismic Category I stair tower located between the Seismic Category I Fuel Building and the Seismic Category I Safeguard Building 4. Due to the proximity of the vent stack to other Seismic Category I structures, it is conservatively treated as a Seismic Category I structure for the purposes of global design.~~Tornado differential pressure does not result in overall loading of the vent stack since it is a vented structure.~~

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~~Acceptance criteria for the design of the vent stack include ASCE 43 (Limit State A) for the overall stability of the vent stack, and ACI 349 (Appendix B) for the anchorage of the vent stack to the stair tower roof slab.~~

The NAB is a reinforced concrete structure.~~, which is evaluated for tornado loadings per RG 1.76 to demonstrate that it will not collapse and affect adjacent Seismic Category I Nuclear Island Common Basemat structures.~~ The methodology of ASCE ~~58~~43 (Limit State A) is utilized to ensure~~show~~ that the NAB will not collapse under tornado loads and affect Seismic Category I Nuclear Island Common Basemat structures. Additionally, the NAB is evaluated for ~~the~~ tornado loadings per RG 1.143 due to its classification as RW-IIa per RG 1.143.

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The RWB is a reinforced concrete structure which is required to be designed for tornado loading per RG 1.143 due its classification as RW-IIa per RG 1.143. RWB has no potential to interact with either the NI Common Basemat Structures or the other nearby Seismic Category I Structure, the EPGB. The NAB is located between the RWB and the NI Common Basemat Structure and shields it from potential interaction. Potential interaction between the RWB and the EPGB is precluded by separation and design. The RWB is embedded over 31.5 ft below grade and has a clear height above grade of 52.5 ft; whereas, the clearance between the two structures is 52.06 ft. Furthermore the failure of the RWB in such a manner as to adversely impact the functionality and continued operation of the EPGB is not considered credible because of the design of the RWB for ½ SSE.

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The ACB is a reinforced concrete or steel frame building. One of the methodologies identified in the preceding three bullets ~~above methods~~ will be utilized to provide reasonable assurance~~ensure~~ that the ACB will not collapse under tornado loads and affect Seismic Category I~~adjacent~~ Nuclear Island Common Basemat structures~~structure is protected from failure of the ACB due to tornado loadings~~.

The TB is a steel frame building. One of the methodologies identified in the preceding three bullets ~~above methods~~ will be utilized to ~~ensure~~provide reasonable assurance that the TB will not collapse under tornado loads and affect~~adjacent~~ Seismic Category I Nuclear Island Common Basemat structures~~ is protected from failure of the TB due to tornado loadings~~.

3.3.3 References

1. ASCE/SEI Standard 7-05, “Minimum Design Loads for Buildings and Other Structures,” American Society of Civil Engineers/Structural Engineering Institute, 2005.

2. ASCE paper No. 3269, “Wind Forces on Structures,” Transactions of the American Society of Civil Engineers, Vol. 126, Part II, 1961.

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- The live load (L) is applicable after construction of containment. Construction loadings, temporary or otherwise, may also be considered as live loads and included within appropriate loading combinations.

- Twenty-~~-~~five percent of the design live load is considered during static analysis with seismic load combinations~~with tornado load combinations~~. The full potential live load is used for local analysis of structural members.

- Unless a time-history analysis is performed to justify otherwise, the maximum values of load combinations including the loads P_a, T_a, R_a, R_{rr}, R_{rj}, R_{rm}, or G are used, including an appropriate dynamic load factor.

- For concrete members, U_S is defined as the required section strength for service loads based on the allowable stresses defined in Subarticle CC-3430 of the ASME BPV Code, Section III, Division 2, with additional guidance provided by NUREG-0800.

- For concrete members, U_F is defined as the required section strength for factored loads based on the allowable stresses defined in Subarticle CC-3420 of the ASME BPV Code, Section III, Division 2, with additional guidance provided by NUREG-0800.

- The following requirements are met for the design of concrete components for factored load conditions:

  – Primary forces must not bring the local section to a general yield state with respect to any component of section membrane strain or section flexural curvature. General yield state is the point beyond which additional section deformation occurs without an increase in section forces.

  – Under combined primary and secondary forces on a section, the development of a general yield state with respect to those membrane strains or flexural curvatures that correspond to secondary stress components is acceptable, and is subject to rebar strain limits specified in Subarticle CC 3420 of the ASME BPV Code, Section III, Division 2. The concept of a general yield state is not applicable to strains associated with radial shear stress.

- Primary and secondary forces are as defined in Subarticle CC-3130 of the ASME BPV Code, Section III, Division 2.

- Limitations on maximum concrete temperatures as defined in Subarticle CC-3440 of the ASME BPV Code, Section III, Division 2 are observed.

- Loads and loading combinations encompass the soil cases described in Section 3.7.1, using the design criteria described in Section 3.7.1 and Section 3.7.2.

The following load combinations define the design limits for the Seismic Category I concrete RCB. These load combinations define the design limits for the Seismic Category I steel liner plate for the RCB, except that load factors are considered to be 1.0.

The design of bolted connections in combination with welded connections is in accordance with Section Q.15.10 of ANSI/AISC N690.

Loads and load combinations defined in Section 3.8.4.3 are used to determine strength requirements of members and elements of other Seismic Category I structures. Abnormal pipe break accident loads only apply to limited areas of structures located on the NI Common Basemat Structure. The following criteria apply for load combinations for concrete and steel other Seismic Category I structures:

- The one-third increase in allowable stresses for concrete and steel members due to seismic (E') or wind (W and Wt) loadings is not permitted.
- Where any load reduces the effects of other loads, the corresponding coefficient for that load is 0.9 if it can be demonstrated that the load occurs simultaneously with other loads.
- Where the structural effects of differential settlement, creep, or shrinkage may be significant, they are included with the dead load (D) as applicable.
- For load combinations in which a reduction of the maximum design live load (L) has the potential to produce higher member loads and stresses, multiple cases are considered where the live load (L) is varied between its maximum design value and zero.
- Roofs with a slope of less than 0.25 inches per foot are analyzed for adequate stiffness to preclude progressive deflection as water ponding is created from the snow load or from rainfall on the surface. The analysis considers the potential blockage of the primary drainage system of the area that is subject to ponding loads. The analysis uses the larger of the snowmelt depth or rain load.
- For steel members, thermal loads may be neglected when it can be shown that they are secondary and self limiting in nature.
- For load combinations including the loads P_a, T_a, R_a, R_{rr}, R_{rj}, or R_{rm}, the maximum values of these loads, including a dynamic load factor, are used unless a time-history analysis is performed to justify otherwise.
- For load combinations including loads R_{rr}, R_{rj}, R_{rm}, or W_m, these load combinations are first satisfied with these loads set to zero. However, when considering these concentrated loads, local section strength capacities may be exceeded under the effect of these concentrated loads, provided there is not a loss of function of any safety-related SSC.
- Twenty~~-~~-five percent of the design live load is considered during static analysis with ~~tornado~~seismic load combinations. The full potential live load is used for the local analysis of structural members.

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The design of concrete foundations for Seismic Category I structures is performed using the strength-design methods described in ACI 349-01, with the exception that a shear reduction factor of 0.85 is used as allowed in ACI 349-06 (Reference 39). The ductility provisions of ACI 349-01 are satisfied to provide a steel reinforcing failure mode and to prevent concrete failure for design basis loadings.

Design of steel structures used for Seismic Category I foundations is performed in accordance with ANSI/AISC N690-1994 (R2004), including Supplement 2 (GDC 1). Steel member design uses the allowable stress design methods of ANSI/AISC N690.

Foundation design is performed for the spectrum of soil cases described in Section 3.7.1. Section 2.5 and Section 3.7 describe seismic parameters and design methods used for analyzing and designing Seismic Category I structures.

Soil-structure interaction and structure-soil-structure interaction effects are considered in the seismic analyses of Seismic Category I structures as described in Section 3.7.2. Figure 3B-1 illustrates separation distances between Seismic Category I structures upon which these interaction evaluations are based.

The NI Common Basemat Structure is designed for an average static soil bearing pressure of 14,500 pounds per square foot and a maximum static bearing pressure of 22,000 pounds per square foot. Accordingly, Seismic Category I foundations are sized and reinforced to accommodate these bearing pressure values.

The following criteria apply for load combinations for concrete and steel Seismic Category I foundations:

- The one-third increase in allowable stresses for concrete and steel members due to seismic (E') or wind (W and W_t) loadings is not permitted.
- Where any load reduces the effects of other loads, the corresponding coefficient for that load is 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with other loads.
- For load combinations in which a reduction of the maximum design live load (L) has the potential to produce higher member loads and stresses, multiple cases are considered where the live load (L) is varied between its maximum design value and zero.
- Twenty~~-~~-five percent of the design live load is considered during static analysis with ~~tornado~~seismic load combinations. The full potential live load is used for the local analysis of structural members.

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- For load combinations that include a tornado load (W_t), the tornado load parameter combinations described in Section 3.3 are used.