3.3 Wind and Tornado Loadings

Seismic Category I structures are designed to withstand the effects of wind and tornado loadings. A combined license (COL) applicant that references the U.S. EPR design certification will determine site-specific wind and tornado design parameters and compare these to the standard plant criteria. If the site-specific wind and tornado parameters are not bounded, then the COL applicant will evaluate the design for site-specific wind and tornado events and demonstrate that these loadings will not adversely affect the ability of safety-related structures to perform their safety functions during or after such events.

3.3.1 Wind Loadings

The U.S. EPR wind pressure loads are determined in conformance with ASCE/SEI Standard 7-05, "Minimum Design Loads for Buildings and Other Structures" (Reference 1). 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 wind loads, will not affect the ability of other structures to perform their intended safety functions.

3.3.1.1 Design Wind Velocity

The design basic wind speed is a 3-second gust speed at 33 feet above ground. The basic wind speed (V) is 145 mph in open terrain, exposure category C associated with a 50-year mean recurrence interval. The basic wind speed is increased by an importance factor of 1.15 to obtain a 100-year mean recurrence interval for the design of safety-related and quality-related structures.

3.3.1.2 Determination of Applied Wind Forces

Wind velocity is converted into an effective pressure to be applied to surfaces of structures in conformance with Reference 1.

Effective wind design velocity pressure (q_z) on structural elements is calculated in conformance with Reference 1, Equation 6-15, as follows:

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I\ (\text{lb/ft}^2),$$

Where:

q_z = velocity pressure in pounds per square foot at height "z".

K_z = velocity pressure exposure coefficient at height "z" for Exposure Category C, which is determined in conformance with Reference 1, Table 6-3.

(SRP Section 3.3.1 sets a lower limit of 0.87 for K_z, whereas this value could be as low as 0.85 per Reference 1, Table 6-3 for Exposure C.)

K_{zt} = topographic factor = 1.2 for U.S. EPR standard plant design.

(This is more conservative than the value of K_{dt} = 1.0 recommended in SRP Section 3.3.1.)

K_d = wind directionality factor, which is determined in conformance with Reference 1, Table 6-4.

(SRP Section 3.3.1 sets K_d = 1.0, whereas this value could be as low as 0.85 per Reference 1, Table 6-4.)

V = basic wind speed in miles per hour = 145 mph.

I = importance factor = 1.15 for safety-related and quality-related structures, systems and components (SSC). The importance factor is used to adjust the velocity pressure, q_z, to the appropriate 100-year mean recurrence interval for design of safety-related and quality-related SSCs.

Effective pressure loads on structural elements and members are determined in conformance with the applicable requirements of Reference 1, Sections 6.5.12 and 6.5.13. Gust factors are applied in accordance with requirements of this standard.

ASCE paper No. 3269, "Wind Forces on Structures" (Reference 2) is used to determine the shape coefficients for distribution of wind pressures around the circumferences of the Reactor Shield Building and the vent stack.

3.3.1.2.1 Note on Values Used

The use of the values stated previously for K_z = 0.85 or greater, K_{zt} = 1.2, and K_d = 0.85 or greater provides essentially identical results as those recommended in NUREG 0800, SRP, Section 3.3.1 for K_z = 0.87, K_{dt} = 1.0, and K_d = 1.0. That is, the product of the U.S. EPR values is 0.85 x 1.2 x 0.85 = 0.867, whereas the product of SRP, 3.3.1, values is 0.87 x 1.0 x 1.0 = 0.87.

3.3.2 Tornado Loadings

Seismic Category I structures are designed to resist tornado loadings and remain functional during and following a tornado event. In addition, Non-Seismic Category I structures, that have the potential to interact with Seismic Category I structures are evaluated to demonstrate they do not affect Seismic Category I structures under tornado load conditions. Tornado loads are applied to the roofs and exterior walls of such structures. For Radwaste Seismic Structures, classified as RW-IIa per RG 1.143, additional tornado loadings also apply, as specified in RG 1.143.

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.

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) 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.

Effective tornado wind velocity pressure, q_z, is calculated as follows:

$$q_z = 0.00256\ K_z\ K_{zt}\ K_d\ V^2\ I\ (lb/ft^2),$$

Where:

q_z = velocity pressure in pounds per square foot at height "z."

K_z = 1.0, tornado wind velocity pressure is considered constant with height.

(This is an exception to NUREG 0800 SRP Section 3.3.2, which recommends $K_z = 0.87$).

K_{zt} = 1.0, a topographic factor of unity is used because tornado maximum wind speed is not determined based on site topography.

K_d = 1.0, a wind directionality factor of unity is used.

V = 230 mph, tornado maximum wind speed in miles per hour.

I = 1.0, the importance factor is taken as unity.

(This is an exception to NUREG 0800 SRP Section 3.3.2, which recommends I = 1.15).

Based on the stated definitions, the expression for effective tornado wind velocity pressure reduces to the following:

$$q_z = 0.00256\ V^2$$

Effective tornado wind pressure loads (W_w) on exterior surfaces of structural elements and members are determined in conformance with the applicable requirements of Reference 1, Sections 6.5.12 and 6.5.13. Gust factors are taken as unity for tornado wind.

Tornado atmospheric pressure change effect parameters (W_p) and tornado-generated missile impact parameters (W_m) are in conformance with RG 1.76.

The following combinations of the parameters of the total tornado load (W_t) are evaluated in the design of Seismic Category I structures and structures that have the potential to interact with Seismic Category I structures under tornado load conditions, where W_w is the load from tornado wind effect, W_p is the load from tornado atmospheric pressure change effect, and W_m is the load from tornado missile impact effect:

Wt = Wp

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

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. 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 as a result of a tornado.

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.

The Vent Stack structure is a Seismic Category II structure. The steel structure of the vent stack is supported on the roof of the Seismic Category I stair tower located between the Fuel Building and Safeguard Building 4. Tornado differential pressure does not result in overall loading of the vent stack since it is a vented structure. 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 is utilized to show that the NAB will not collapse under tornado loads. Additionally, the NAB is evaluated for the tornado loadings per RG 1.143 due to classification as RW-IIa per RG 1.143.

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.

The ACB is a reinforced concrete or steel frame building. One of the above methods will be utilized to ensure that the adjacent Nuclear Island Common Basemat structure is protected from failure of the ACB due to tornado loadings.

The TB is a steel frame building. One of the above methods will be utilized to ensure that the adjacent Nuclear Island Common Basemat structure 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.

3. ANSI/AISC-N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," with Supplement 2, American Institute of Steel Construction, October 2004.

4. ASCE 43-05, "Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities," American Society of Civil Engineers, January 2005.

5. ACI 349-01/349R-01, "Code Requirements for Nuclear Safety Related Structures and Commentary," American Concrete Institute, January 2001.