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MFN 06-170 Docket No. 52-010

June 16, 2006

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to NRC Request for Additional Information Letter No. 27 Related to ESBWR Design Certification Application – Wind and Tornado Loadings – RAI Numbers 3.3-1 through 3.3-3 and 3.5-16**

Enclosure 1 contains GE's response to the subject NRC RAIs transmitted via the Reference 1 letter. This completes GE's response to RAI Letter No. 27.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Reference:

1. MFN 06-143, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 27 Related to ESBWR Design Certification Application,* May 9, 2006

Enclosure:

1. MFN 06-170 – Response to NRC Request for Additional Information Letter No. 27 Related to ESBWR Design Certification Application – Wind and Tornado Loadings – RAI Numbers 3.3-1 through 3.3-3 and 3.5-16

cc:	WD Beckner	USNRC (w/o enclosures)
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	GB Stramback	GE/San Jose (with enclosures)
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ENCLOSURE 1

MFN 06-170

Response to RAI letter No. 27 Related to ESBWR Design Certification Application

Wind and Tornado Loadings

RAI Numbers 3.3-1 through 3.3-3 and 3.5-16

NRC RAI 3.3-1

DCD Tier 2, Section 3.3.1, states that the procedures utilized to transform the wind velocity into an effective pressure applied to structures and parts, and portions of structures, are as delineated in Reference 3.3-1. Reference 3.3-1 lists ASCE Standard 7-2002, "Minimum Design Loads for Buildings and Other Structures," Committee A.58.1, American National Standards Institute. Since the above referenced standard is still under staff review, confirm that the procedures utilized to transform the wind velocity into an effective pressure applied to structures provided in the reference is consistent with those stipulated in Reference 2 of SRP Section 3.3.1 (Rev. 2, 1981), otherwise, identify and justify deviations from the SRP section.

GE Response

ANSI A58.1 has been superseded by ASCE Standards. Further, 3-sec gust speed has become the basis for wind design codes since 1995. For the ESBWR standard plant a basic wind speed of 140 mph (3-sec gust) at a height of 33 feet and Exposure C category was chosen based on Figure 6-1 of ASCE 7-2002 as it bounded nearly all the US. The corresponding basic wind speed per ANSI A58.1 (Table 1) is 110 mph (fastest mile wind). The velocity pressure for 140 mph (3-sec gust) bounds the velocity pressure for 110 mph (fastest mile wind) for the same height and exposure category C. For category I buildings, an additional margin is provided by choosing a more severe Exposure Category D versus Exposure Category C specified in SRP 3.3.1.II.3. Therefore, the DCD requirements exceed the SRP requirements. Table 2.0-1 and Section 3.3.1.2 will be clarified in the next update as noted in the attached markups.

NRC RAI 3.3-2

DCD Tier 2, Section 3.3.2.1 states that the design basis tornado and applicable missiles are described in Subsections 2.3.1 and 2.3.2, and Table 2.0-1. Subsection 2.3.1 of Table 2.0-1 provides parameters defining a design basis tornado for the ESBWR excluding the maximum rotational speed of the same. This is not consistent with Table I of Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," which lists rotational speed as one of the parameters defining a design basis tornado. Explicitly provide rotational wind speed information in DCD Tier 2, Table 2.0-1, or discuss GE's basis for omitting the parameter in the Table.

GE Response

Agreed. The rotational wind speed is 116.2 m/s (260 mph). DCD Table 2.0-1 will be revised in the next update as noted in the attached markup.

NRC RAI 3.3-3

DCD Tier 2, Section 3.3.3.2 states that the COL applicant shall ensure that the remainder of plant structures, systems, and components (SSC's) not designed for tornado loads are analyzed for the site-specific loadings to ensure that their modes of failure do not affect the ability of the Seismic Category I ESBWR Standard Plant SSC's to perform their intended functions. Since the site-specific loadings cited above exclude tornado loads, confirm that these SSC's were all assumed to fail under the tornado loadings, and appropriate tornado-related II/I interaction analyses were performed for the SSC's to ensure that their modes of failure do not affect the ability of the Seismic Category I ESBWR Standard Plant SSC's to perform their intended functions.

GE Response

The DCD will be revised to show that C-II structures are designed for tornado loads (wind force only and no missiles) to preclude adverse II/I interactions. Non-safety related, Non-seismic (NS) SSCs are postulated to fail under tornado loadings. The DCD will be clarified to require that these NS structures will be located at least one story height-above-grade from C-I or C-II structures.

DCD Sections 3.3 and 3.3.2.3 will be revised and DCD Section 3.3.3.2 will be deleted in the next update as noted in the attached markups.

<u>NRC RAI 3.5-16</u>

DCD Tier 2, Subsection 3.5.1.4 states that "an evaluation of nonsafety-related structures, systems, and components (not housed in a tornado structure) whose failure due to a design basis tornado missile could adversely impact the safety function of safety-related systems and components," shall be provided to the NRC by the applicant referencing the ESBWR design. It is not clear to the staff what "tornado structure" means. The applicant is asked to provide the definition of "tornado structure."

<u>GE Response</u>

The reference to "tornado structure" was intended to be a reference to "tornado-resistant structure".

In addition to clarifying DCD Section 3.5.1.4 to address the above RAI, other clarifications and minor editorial changes/deletions to DCD Sections 3.5.1.1.1.2, 3.5.1.4, 3.5.1.5, 3.5.4.1, 3.5.4.2, 3.5.4.3, 3.5.4.4, and 3.5.4.5 will be made and Section 3.5.3.3 will be added in the next update as noted in the attached markups.

Table 2.0-1

Envelope of ESBWR Reference Plant Site Design Parameters, Considerations and/or Limits

Subsection	Subject	Parameters/Considerations/Limits
2.3.1	Regional Climatology	ESBWR DCD: The basic speed (3-sec gust) of extreme winds used for design of seismic C-I or C-II structures is 62.6 m/sec (140 mph). The basic speed of extreme wind for nonsafety-related, non-seismic (NS) structures is determined by the COL applicant. The following importance factors and exposure categories are used for scaling wind forces for types of structures: Type / Importance Factor / Exposure Category C-I or C-II / 1.15 / D Nonsafety-Related, NS Structures / Determined by the COL applicant / Determined by the COL applicant The maximum design ambient temperature corresponding to a one percent exceedance value is 37.8°C (100°F) dry bulb with a coincident wet bulb temperature of 26.1°C (79°F) and 27.8°C (82°F) for non-coincident wet bulb. The minimum design temperature corresponding to a one percent exceedance value is -23.3°C (-10°F). The zero percent exceedance dry bulb temperature is 46.1°C (115°F) with a coincident wet bulb temperature of 26.7°C (80°F) and 29.4°C (85 °F) for non-coincident wet bulb. The minimum temperature for this exceedance value is -40°C (-40°F). The maximum rainfall rate for roof design is 49.3cm/h (19.4 in./h), which is based on the probable maximum precipitation (PMP) for one hour over one square mile with a ratio of 5 minutes to one hour PMP of 0.32, as found in National Weather Service Publication HMR No. 52. The maximum short-term rainfall rate is 15.7cm (6.2 in.). The maximum snow load for roof design is 2394 Pa (50 lbf/ sq ft). The maximum tornado wind speed is 147.5m/s (330 mph), with a rotational velocity of 116.2 m/s (260 mph), a translational velocity of 31.3m/s (70 mph), and a radius of 45.7m (150 ft). The maximum atmospheric pressure differential is 16.6 kPa (2.4 psi) and the rate of pressure change is 11.7 kPa/s (1.7 psi/s). The missile spectra is per Spectra I of Standard Review Plan 3.5.1.4. COL applicant to confirm or reanalyze in accordance with SRP 2.3.1.

3.3 WIND AND TORNADO LOADINGS

ESBWR Standard Plant structures, which are Seismic Category I, are designed for tornado and extreme wind phenomena. Seismic Category II structures are designed for extreme and tornado wind (excluding tornado missiles).

3.3.1 Wind Loadings

As discussed in SRP 3.3.1, the design wind velocity and its recurrence interval, the velocity variation with height, and the applicable gust factors are used in defining the input parameters for the structural design criteria appropriate to account for wind loadings. The procedures that are utilized to transform the design wind velocity into an effective pressure applied to structures takes into consideration the geometrical configuration and physical characteristics of the structures and the distribution of wind pressure on the structures.

The design of structures that must withstand the effects of the design wind load consider the relevant requirements of General Design Criterion 2 concerning natural phenomena. The wind used in the design includes the most severe wind that has been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which historical data has been accumulated. Appropriate consideration has been given for the design wind velocity and its recurrence interval, the velocity variation with height, the applicable gust factors, and the bases for determining these site-related parameters. The procedures utilized to transform the wind velocity into an effective pressure applied to structures and parts and portions of structures, are as delineated in Reference 3.3-1.

3.3.1.1 Design Wind Velocity and Recurrence Interval

Seismic Category I and II structures are designed to withstand a design wind velocity and recurrence interval as described in DCD Tier 2 Subsection 2.3.1 and 2.3.2 and listed in Table 2.0-1. Refer to Subsection 3.3.3.2 for interface requirements for non-tornado designed SSC's.

3.3.1.2 Determination of Applied Forces

The design wind velocity is converted to velocity pressure in accordance with Reference 3.3-1. The importance factor, which depends on the type of exposure is 1.15 based on Category IV building and Exposure D.

The design velocity for use in the ESBWR is established in Sections 2.3.1 and 2.3.2. Reference 3.3-2 is used to obtain the effective wind pressures for geometric and physical cases that Reference 3.3-1 does not cover.

3.3.2 Tornado Loadings

As discussed in SRP 3.3.2, the design of structures that have to withstand the effects of the design basis tornado are in conformance with the requirements of General Design Criterion 2.

3.3.2.1 Applicable Design Parameters

The design basis tornado and applicable missiles are described in Subsections 2.3.1 and 2.3.2 and Table 2.0-1.

Refer to Subsection 3.3.3 for COL information.

3.3.2.2 Determination of Forces on Structures

The procedures of transforming the tornado loading into effective loads and the distribution across the structures are in accordance with Reference 3.3-3. The velocity pressure used meets the SRP 3.3.2 discussion. The procedure for transforming the tornado-generated missile impact into an effective or equivalent static load on structures is given in Subsection 3.5.3. The loading combinations of the individual tornado loading components and the load factors are in accordance with SRP 3.3.2.

Loading combinations and load factors used are as follows:

$W_t = W_w$

$W_t = W_p$

$W_t = W_m$

$W_t = W_w + 0.5\ W_p$

$W_t = W_w + W_m$

$W_t = W_w + 0.5\ W_p + W_m$

Where:

W_t = total tornado load

W_w = total wind load

W_p = total differential pressure load

W_m = total missile load

The reactor building is not a vented (enclosed) structure. The exposed exterior roofs and walls of this structure are designed for the full pressure drop. Tornado dampers are provided on all air intake and exhaust openings. These dampers are designed to withstand the full negative pressure drop.

3.3.2.3 Effect of Failures of Structures or Components Not Designed for Tornado Loads

Safety-related systems and components are protected within tornado-resistant structures. The remainder of plant systems and components not designed for tornado load are arranged or designed such that their failures do not adversely affect the ability of any Seismic Category I ESBWR Standard Plant structures, systems and components to perform its safety-related function(s). The non-safety related, non-seismic (NS) structures postulated to fail under tornado loading are located at least one story height-above-grade from C-I or C-II structures.

3.3.3 COL Information

3.3.3.1 Site-Specific Design Basis Wind and Tornado

The COL applicant shall confirm that the site-specific design basis wind and tornado and recurrence interval are bounded by the criteria given in Subsection 2.3.1, 2.3.2 and Table 2.0-1.

3.3.4 References

3.3-1 American Society of Civil Engineers, "Minimum Design Loads for Buildings and Other Structures," ASCE Standard 7-2002, Committee A. 58.1, American National Standards Institute.

3.3-2 American Society of Civil Engineers, "Wind Forces on Structures," ASCE Paper No. 3269, Transactions of the American Society of Civil Engineers," Vol. 126, Part II.

3.3-3 Bechtel Topical Report BC-TOP-3-A, Revision 3, "Tornado and Extreme Wind Design Criteria for Nuclear Power Plants."

(7) Electrical and control systems and wiring required for operation of items (1) through (6); and

(8) Remote shutdown panel.

The following general criteria are used in the design, manufacture, and inspection of equipment:

- All pressurized equipment and sections of piping that may periodically become isolated under pressure are provided with pressure-relief valves acceptable under ASME Code Section III. The valves ensure that no pressure buildup in equipment or piping sections exceeds the design limits of the materials involved.
- Components and equipment of the various systems are designed and built to the standards established by the ASME Code or other equivalent industrial standard. A stringent quality control program is also enforced during manufacture, testing, and installation.
- Volumetric and ultrasonic testing where required by code, coupled with periodic in-service inspections of materials used in components and equipment, add further assurance that any material flaws that could permit the generation of missiles are detected.

3.5.1.1 Internally Generated Missiles (Outside Containment)

This subsection addresses structures, systems and components (SSC) provided to support the reactor facility, and that require protection from internally generated missiles (outside containment) to ensure conformance with the requirements of General Design Criterion 4. The design addresses concerns for missiles that could result from in-plant component overspeed failures and high-pressure system ruptures as discussed in SRP 3.5.1.1, when applicable.

3.5.1.1.1 Rotating Equipment

3.5.1.1.1.1 Missile Characterization

Equipment within the general categories of pumps, fans, blowers, diesel generators, compressors, and turbines and, in particular, components in systems normally functioning during power reactor operation have been examined for any possible source of credible and significant missiles.

3.5.1.1.1.2 Main Steam Turbine

Acceptance criterion 1 of SRP Section Turbine Missiles considers a plant with a favorable turbine generator placement and orientation, and adhering to the guidelines of Regulatory Guide 1.115, as adequately protected against turbine missile hazards. Further, this criterion specifies that exclusion of safety-related structures, systems or components from low trajectory turbine missile strike zones constitutes adequate protection against low trajectory turbine missiles. The turbine generator placement and orientation of the ESBWR as shown in Figure 3.5-2 meets the guidelines of Regulatory Guide 1.115. Refer to Subsection 3.5.4.1 and 3.5.4.2 for COL licensing information.

At COL the applicant shall meet the minimum requirements for the probability of turbine missile generation given in Table 3.5-1.

3.5.1.2.4 Evaluation of Potential Gravitational Missiles Inside Containment

Gravitational missiles inside the containment have been considered as follows:

Seismic Category I systems, components, and structures are not potential gravitational missile sources.

Non-Seismic Category I items and systems inside containment are considered as follows:

- Cable Trays - All cable trays for both Class 1E and non-Class 1E circuits are seismically supported whether or not a hazard potential is evident.
- Conduit and Nonsafety-related Pipe - Non-Class 1E conduit is seismically supported if it is identified as a potential hazard to safety-related equipment. All nonsafety-related piping that is identified as a potential hazard is seismically analyzed per Subsection 3.7.3.8.
- Equipment for Maintenance - All other equipment, such as a hoist, that is required during maintenance is either removed during operation, moved to a location where it is not a potential hazard to safety-related equipment, or seismically restrained to prevent it from becoming a missile.

3.5.1.3 Turbine Missiles

See Subsection 3.5.1.1.1.2.

3.5.1.4 Missiles Generated by Natural Phenomena

In accordance with SRP 3.5.1.4, this subsection considers possible hazards due to missiles generated by the design basis tornado, flood, and any other natural phenomena identified in DCD Section 3.5.

Tornado generated missiles have been determined to be the limiting natural phenomena hazard in the design of all structures required for safe shutdown of the nuclear power plant. Because tornado missiles are used in the design basis, they envelope less intense phenomena such as extreme winds. See Reference 3.5-8.

The design basis tornado and missile spectrum as defined in DCD Subsection 2.3.1, 2.3.2 and Table 2.0-1, is included in the design of Seismic Category I buildings, and is in compliance with the positions C1 and C2 of Regulatory Guides 1.76, "Design Basis Tornado," and positions C1 and C2 of Regulatory Guide 1.117, "Tornado Design Classification."

Non-tornado resistant building superstructures are constructed from materials such as reinforced concrete block, and/or structural steel with metal siding and roof deck. Potential missiles or debris from these materials, resulting from failure of superstructure or from items blown off, when subjected to winds of tornado intensity, are not considered to generate missiles more severe than the Spectrum I missiles of SRP 3.5.1.4 in accordance with Reference 3.5-8.

3.5.1.5 Site Proximity Missiles (Except Aircraft)

The site is selected such that the probability of occurrence of the Site Proximity Missile (except aircraft) is less than 10^{-7} occurrences per year. The Site Proximity Missile has been dismissed from further consideration because at that likelihood it is considered not to be a statistically significant risk.

3.5.1.6 Aircraft Hazards

The probability of aircraft hazards impacting the ESBWR Standard Plant and causing consequences greater than 10 CFR 100 (and 10 CFR 50.34(a)) exposure guidelines is $\leq 10^{-7}$ per year.

3.5.2 Structures, Systems, and Components to be Protected from Externally Generated Missiles

In accordance with SRP 3.5.2, this subsection discusses the SSC to be protected from externally generated missiles and includes all safety-related SSC on the plant site that have been provided to support the reactor facility.

The sources of external missiles, which could affect the safety of the plant, are identified in Subsection 3.5.1. Certain items in the plant are required to safely shut down the reactor and maintain it in a safe condition assuming an additional single failure. These items, whether they are structures, systems or components, must all be protected from externally generated missiles.

These items are the safety-related items listed in Table 3.2-1; appropriate safety classes and equipment locations are given in this table. All of the safety-related systems listed are located in buildings that are designed as tornado resistant. Because the tornado missiles are the design basis missiles, the systems, structures, and components listed are adequately protected. Provisions are made to protect the charcoal delay tanks against tornado missiles.

3.5.3 Barrier Design Procedures

The procedures by which structures and barriers are designed to resist the missiles described in Subsection 3.5.1 are presented in this section. The following procedures are in accordance with Section 3.5.3 of NUREG-0800 (Standard Review Plan) and ensure that the design of structures, shields, and barriers that must withstand the effects of environmental and natural phenomena meet the relevant requirements of GDC 2 and GDC 4.

3.5.3.1 Local Damage Prediction

The prediction of local damage in the impact area depends on the basic material of construction of the structure or barrier (i.e., concrete or steel). The corresponding procedures are presented separately.

3.5.3.1.1 Concrete Structures and Barriers

Sufficient thickness of concrete is provided to prevent perforation, spalling or scabbing of the barriers in the event of missile impact. The (modified) National Defense Research Committee (NDRC) formula (Reference 3.5-5) is applied analytically for missile penetration in concrete. To prevent perforation, the ACI-349 Appendix C Section C.7 is used. The resulting thickness of concrete required to prevent perforation, spalling or scabbing should in no case be less than those for Region II listed in Table 1 of SRP 3.5.3.

3.5.3.1.2 Steel Structures and Barriers

The Stanford equation (Reference 3.5-6) is applied for steel structures and barriers. Composite barriers are not utilized in ESBWR Standard Plant for missile protection.

3.5.3.2 Overall Damage Prediction

The overall response of a structure or barrier to missile impact depends largely upon the location of impact (e.g., near mid-span or near a support), dynamic properties of the structure/barrier and missile, and on the kinetic energy of the missile. In general, it has been assumed that the momentum of the missile is transferred to the structure or barrier and only a portion of the kinetic energy is absorbed as strain energy within the structure or barrier.

After demonstrating that the missile does not perforate the structure or barrier, an equivalent static load concentrated at the impact area is determined. The structural response to this load, in conjunction with other appropriate design loads, is evaluated using an analysis procedure similar to that in Reference 3.5-7.

3.5.3.3 Impact of Failure of Nonsafety-Related Structures, Systems and Components

Non-safety related structures could be either Seismic Category II (C-II) or NS. C-II structures are designed not to collapse under tornado wind loads. NS structures are located at least one story height-above-grade from C-I or C-II structures. Per Section 3.5.2, Offgas Charcoal Bed Adsorbers are provided with missile protection.

3.5.4 COL Unit Specific Information

3.5.4.1 Turbine System Maintenance Program

The COL applicant shall provide a Turbine System Maintenance Program. (See Subsection 3.5.1.1.)

3.5.4.2 Probability of Turbine Missile Generation

The COL applicant shall provide a calculation of the probability of turbine missile generation using the criteria used for the probability calculation in accordance with the NRC requirements such as in Reference 3.5-1 and NUREG 0933 item A37. (See Subsection 3.5.1.1.1.2.)

3.5.5 References

3.5-1 USNRC, "Safety Evaluation Report Relating to the Operation of Hope Creek Generating Station," NUREG-1048, Supplement No. 6, July 1986.

3.5-2 C. V. Moore, "The Design of Barricades for Hazardous Pressure Systems," Nuclear Engineering and Design, Vol. 5, 1967.

3.5-3 "River Bend Station Updated Safety Analysis Report," Docket No. 50-458, Volume 6, Pages 3.5-4 and 3.5-5, August 1987.

3.5-4 F. J. Moody, "Prediction of Blowdown Thrust and Jet Forces," ASME Publication 69-HT-31, August 1969.

3.5-5 R. P. Kennedy, "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects," Holmes and Narver, Inc., September 1975.

3.5-6 Oak Ridge National Laboratory, W. B. Cottrell and A. W. Savolainen, "U. S. Reactor Containment Technology," ORNL-NSIC-5, Vol. 1, Chapter 6.

3.5-7 R. A. Williamson and R. R. Alvy, "Impact Effect of Fragments Striking Structural Elements," Holmes and Narver, Inc., Revised November 1973.

3.5-8 J. R. McDonald, "Rationale for Wind-borne Missile Criteria for DOE facilities", Sept. 1999 (UCRL-CR-135687 S/C B505188).