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MFN 08-199, Supplement 2

Docket No. 52-010

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U.S. Nuclear Regulatory Commission
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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 246 Related to ESBWR Design Certification Application - RAI Numbers 19.1-167 S01 and 19.1-169 S02**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by NRC letter 246 dated August 21, 2008 (Reference 1). Previous RAIs and responses are in References 2 through 5.

The GEH response to RAI Numbers 19.1-167 S01 and 19.1-169 S02 are in Enclosure 1.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

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References:

1. MFN 08-657, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request For Additional Information Letter No. 246 Related To ESBWR Design Certification Application.* August 21, 2008.

2. MFN-08-040, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request For Additional Information Letter No. 132 Related To ESBWR Design Certification Application.* January 15, 2008.

3. MFN 08-199, Response to Portion of NRC Request for Additional Information Letter No. 132 Related to ESBWR Design Certification Application, ESBWR Probabilistic Risk Assessment, RAI Numbers 19.1-156 through 19.1-159, 19.1-165 through 19.1-170 and 22.5-20, dated March 8, 2008.

4. MFN 08-552, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 214 Related To ESBWR Design Certification Application,* dated June 25, 2008.

5. MFN 08-199, Supplement 1, *Response to Portion of NRC Request for Additional Information Letter No. 214 Related to ESBWR Design Certification Application ESBWR RAI Number 19.1-169 S01,* dated August 1, 2008.

Enclosure

1. Response to Portion of NRC Request for Additional Information Letter No. 246 Related to ESBWR Design Certification Application ESBWR Probabilistic Risk Assessment RAI Numbers 19.1-167 S01 and 19.1-169 S02

cc: AE Cubbage USNRC (with enclosure)
RE Brown GEH/Wilmington (with enclosure)
eDRF Sections 0000-0093-6871
0000-0093-2749

Enclosure 1

MFN 08-199, Supplement 2

Response to Portion of NRC Request for

Additional Information Letter No. 246

Related to ESBWR Design Certification Application

ESBWR probabilistic Risk Assessment

RAI Numbers 19.1-167 S01 and 19.1-169 S02

RAI Response 19.1-167 (original)

Please describe specifically how the effects of tornado missiles on Seismic Category II and RTNSS structures were accounted for in the ESBWR high winds PRA. If such effects were not modeled, explain the reason(s)/justification for not performing the evaluation.

GEH Response (original)

Section 14.9 reference 14.9-2 provides the following bases for the calculation of the high winds risk assessment:

- "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)."
- Wind speed design parameters for RTNSS "...hurricane wind speed (3-second gust) shall be taken as 87.2 m/sec (195 mph)..."
- In addition, standard missile impact for RTNSS is designed for "hurricane wind speed (87.2 m/sec (195 mph) 3-second gust)..."

In conducting the ESBWR high winds risk analysis, the seismic design criteria and location of system components is identified. Components designed for Seismic Category I or located with buildings that are designed as Seismic Category I structures are assumed to perform their function during all high wind scenarios, including tornado missiles. Components designed as Seismic Category II or RTNSS structures that are not housed in Seismic Category I buildings are considered to be susceptible to tornado missiles and no credit is taken for the function of these components during the F4/5 tornado high wind analysis.

High Wind Risk Analysis	Hurricane Category	Wind Speed[1] (mph)		ESBWR Plant Structures[4]			
				SC-I	SC-II	RTNSS	NS
Hurricane	Cat. 3/4/5	> 155		✔	✔	✔	x
High Wind Risk Analysis	Tornado Category	Wind Speed 3-sec gust (mph)		ESBWR Plant Structures			
		Fujita[2]	EF Scale[3]	SC-I	SC-II	RTNSS	NS
F2/3	F2/EF2/F3/EF3	118 - 161	110 - 137	✔	✔	✔	x
F4/5	F4/EF4/F5/EF5	262 - 317	200 - 234	✔	x	x	x

Notes:

1 Based on Saffir-Simpson Hurricane Scale
2 Based on Fujita Scale
3 Based on Enhanced Fujita Scale
4 "✔" indicate no damage to structure sustained; "x" indicate structure will sustain damage.

DCD/NEDO-33201 Impact (original)

No DCD change will be made in response to this RAI.

No change to the NEDO-33201, Rev. 3 will be made in response to this RAI.

RAI 19.1-167 S01

Question Summary: Clarify how the effects of tornado missiles on ESBWR structures, systems, and components were used in the estimation of core damage frequency.

Full Text:

RAI 19.1-167 addressed the staff's concerns about apparent contradictions between NEDO-33201 and ESBWR DCD Revision 5. GEH responded to this concern in a letter dated March 8, 2008, which clarified how GEH performed its high winds risk assessment for ESBWR. During a teleconference between the staff and GEH regarding GEH's RAI response, GEH indicated it would augment its high winds risk assessment write up to clarify how the effects of tornado missiles on ESBWR tructures, systems, and components (SSCs) were assessed in the calculations. However, modifications made by GEH in NEDO-33201, Revision 3,which were suppose to clarify how tornado missiles are considered in the risk assessment, continue to appear to contradict ESBWR DCD Revision 5,Section 3.3 and GEH's RAI response to 19.1-167, dated March 8, 2008.

It is the staff's understanding that Seismic Category II buildings could be damaged by EF4 or EF5 tornado missiles, and they should not be credited in the high winds tornado risk assessment. In fact, GEH's response to RAI 19.1-167, dated March 8,2008, states that "(c)omponents designed as Seismic Category II or RTNSS structures that are not housed in Seismic Category I buildings are considered to be susceptible to tornado missiles and no credit is taken for the function of these components during the F4/5 tornado high winds analysis." In addition, ESBWR DCD Revision 5, Section 3.3 states that "Seismic Category II structures are designed for extreme and tornado wind[s] (excluding tornado missiles)."

However as augmented, Section 14.5.1 of NEDO-33201, Revision 3, where core damage frequency (CDF) due to the impact of high winds on ESBWR SSCs is estimated, states that the CDF was evaluated based on the input from Tables 14.3-1 and 14.3-2. Table 14.3-2, "ESBWR Tornado Wind - PRA Predicted Structure Damage", implies that Seismic Category II structures will suffer no significant damage from EF 4 tornados. In fact, no direct mention of tornado missiles and their effect on SSCs is given in the table or surrounding text. Similarly, through lack of any direct mention of tornado missile damage, the table appears to assert that no damage would be suffered by Category II structures from EF 5 tornados and their missiles. In addition, Section 14.4.1, Tornado Strike Frequency, in discussing the strike frequency assumed in the risk assessment for EF4/EF5 tornados when the reactor is at power, states that "EF4/EF5 tornado wind speeds would exceed the design of RTNSS and NS structures, but not SCI or SC II structures. Therefore, for EF4 and EF5 tornados, the equipment located in RTNSS structures and the yard will be assumed to fail." There is no mention of the effect tornado missiles would have on Seismic Category II structures.

The staff finds that statements on the effect that tornado missiles have on CDF calculations are contradictory in ESBWR DCD Revision 5, in the RAI response of March

8, 2008, on tornado missiles, and in NEDO-33201, Revision 3. Clarification is required. It is not clear from NEDO-33201, Revision 3 whether the high winds risk assessment properly considers tornado missiles when estimating core damage frequency. How tornado missiles affect core damage frequency calculations needs to be explicitly discussed and the apparent contradictions need to be removed. This continues to be an Open Item.

It appears that the note on the effect of hurricane missiles on Category II structures made in Table 14.3-2 for EF 5 tornados belongs in Table 14.3-1, ESBWR Hurricane Wind - PRA Predicted Structure Damage, not in Table 14.3-2. This should be corrected.

GEH Response

Statements contained in the NEDO-33201 Rev. 3, ESBWR DCD Rev. 5 and GEH's response to RAI 19.1-167 regarding the analysis of tornado missiles for high wind risk analysis are accurate and correct.

Key assumptions related to tornado missiles and the ESBWR high wind risk analysis include the following:

- Only components located at or above grade are considered to be vulnerable to tornado missile damage.
- Components classified as seismic category I (SC I) or located within a structure designated as SC I are NOT susceptible to damage from tornado missiles.
- Components not classified as SC I or not located within a structure designated as SC I are susceptible to damage from tornado missiles.

Results for the high winds risk analysis presented in NEDO-33201, Section 14, Rev. 3 do account for potential tornado missile impacts. While the seismic category II (SC II) components are designed to withstand the extreme wind associated with F5 tornados, they are not designed to withstand F5 tornado missiles. As stated in ESBWR DCD Rev. 5, site buildings and components classified as SC II include the Service Building (SB) and some components of the fire protection system such as the secondary motor-driven fire pump and makeup water tank. It should be noted for the high wind risk analysis, no components credited in the PRA are located in the SB. (The Turbine Building (TB) is currently being revised from non-seismic to a SC II structure and will be addressed as so in the NEDO-33201 Rev. 4.)

For the purpose of the ESBWR NEDO-33201, Rev. 3 high wind risk analysis, component failures associated with extreme winds and missiles for F4 and F5 tornados were treated similarly. This assumption was made to reduce the complexity of the analysis and also because only a small number of SC II components were credited. The data provided in NEDO-33201 Rev. 3 high winds risk analysis represents the failure of all SC II components under both F4 and F5 tornado extreme wind and missile events. This assumption adds conservatism to the ESBWR tornado risk analysis. A summary of failures assumed in conducting the high wind risk analysis are shown below.

ESBWR Structures		ESBWR Design Basis		PRA High Wind Analysis Tornado F4/5	
Name	ID	Seismic Category	Max. Tornado Wind Speed (mph)	Extreme Winds	Missiles
Reactor Building	RB	I	330	No failures	No failures
Control Building	CB	I	330	No failures	No failures
Fuel Building	FB	I	330	No failures	No failures
Fire Water Service Complex	FWSC	I	330	No failures	No failures
Turbine Building	TB	NS	330	No failures	Grade and above failures
Service Building	SB	II	330	No failures	Grade and above failures
Radwaste Building	RW	NS	330	No failures	Grade and above failures
Circulating Water Pump House	CP	NS	---	Failures	Failures
Service Water Building	SF	NS	---	Failures	Failures
Electrical Building	EB	NS	---	Failures	Failures

NEDO-33201, Table 14.3-2 was reworded to provide additional clarifications for the predicted ESBWR tornado damage.

DCD/NEDO-33201 Impact

No DCD change will be made in response to this RAI.

No change to the NEDO-33201, Section 14, Rev. 3 will be made in response to this RAI. Changes to Table 14.3-2, as shown below, and updated high wind risk analyses will be provided in NEDO-33201, Section 14, Rev. 4.

RAI Response 19.1-169 (original)

Please explain the basis for assuming in the high winds risk assessment that no hurricane or tornado will significantly damage any ESBWR Seismic Category 1 and 2 structure.

GEH Response (original response)

Please refer to GEH response to RAI 19.1-167 for a discussion and table providing information on wind speeds and impact to ESBWR structures.

DCD/NEDO-33201 Impact (original)

No DCD change will be made in response to this RAI.

No change to the NEDO-33201, Rev. 3 will be made in response to this RAI.

RAI Response 19.1-169 S01 *Revised*

(Note: This RAI supercedes RAI 19.1-169 S01 issued in RAI Letter 186)

GEH's response to RAI 19.1-169 indicated that the buildings were built to withstand seismic criteria and are assumed to be able to withstand high winds. It did not provide a technical basis for why hurricane or tornados cannot at any probability damage seismic Category I or II structures. Their argument is a deterministic, not a probabilistic one.

Explain the basis for assuming in the high winds risk assessment that no hurricane or tornado will significantly damage any ESBWR Seismic Category 1 and 2 structure.

[In addition, please provide the engineering basis for the estimated probability of failure of a Seismic Category I structures when subjected to a Category 4 or 5 hurricane.

In general, please justify why the conditional probability of a Seismic Category I structure suffering significant damage from a Category 4 or 5 hurricane (considering that Category 5 winds may exceed those assumed in the ESBWR FSAR) is smaller that 10^{-7}.

One acceptable approach is to compare the design loads generated by a hurricane load combination to the actual controlling design or failure loads of the structure. Based on the controlling design load or the actual estimated failure load of the structure, estimate an equivalent failure hurricane wind speed and its associated annual exceedance probability. Calculate the structural failure probability associated with the equivalent failure hurricane wind. Discuss the calculations and major assumptions made.]

GEH Response

The information used in the PRA high winds risk analysis is based on the ESBWR bounding site characteristics for extreme wind and tornados. The site characteristics defining wind events are specified based on the seismic classification of ESBWR structures and are used to determine wind loadings for hurricanes and tornados. A summary of this information is provided in the DCD, Rev. 5, Table 2.0-1. By applying the wind loadings associated with each of the wind events, an assessment of potential damage is predicted for site structures based on the seismic classification of the structures. A summary of the potential site damage for specific wind events is contained in NEDO-33201, Rev. 3 Table 14.3-1 for hurricane winds and Table 14.3-2 for tornado winds.

For hurricane wind loads, the loading is based on the basic wind speed and is applied to the roof slabs and external, above grade walls of the structures. Similarly, the tornado wind loading is based on the maximum tornado wind speed and is applied to the roof slabs and external, above grade walls of the structures. In addition to the wind velocity component of the tornado wind load, differential pressure loads and missile loads are included in the overall tornado wind load and applied to the structures (see example below). For the site characteristics and design basis data shown in the table below, wind

load values for seismic category I structures ranged from 7 to 9 kN/m^2 for hurricane events and from 9 to 13 kN/m^2 for tornados (equal to maximum force of about 22 MN). This comparison of the hurricane and tornado wind loads shows the tornado wind loadings to be equivalent to or greater than the hurricane wind loads. For the ESBWR, tornados represent the dominant force in generating potential high wind damage to site structures.

Wind Loads for Tornado, W_t

$$W_t = W_w + 0.5\ W_p + W_m$$

where W_w = total wind load
W_p = total differential pressure load
W_m = total missile load

In order to assess potential damage to ESBWR structures predicted from wind events, the seismic classification of the structures was used. Design basis seismic forces applied to the ESBWR seismic category I structures ranged from about 45 to 840 MN. The forces associated with the design basis seismic events represent forces that are two to almost 40 times greater than the forces associated with the high wind events. Thus, the high wind forces are bounded by the seismic forces with considerable margin. Because the ESBWR seismic category I structures are designed to withstand these seismic forces, it is reasonable to assume that high wind events do not result in forces that would adversely impact the seismic fragility of the ESBWR structures. The margin established by the seismic design basis of the ESBWR supports the structural damage predictions used in the PRA high wind analysis.

ESBWR Buildings		ESBWR Design Basis		
Name	ID	Seismic Category[1]	Hurricane	Tornado[2]
			Basic Wind Speed (mph)	Maximum Tornado Wind Speed (mph)
Reactor Building	RB	I	150[3]	330
Control Building	CB	I	150[3]	330
Fuel Building	FB	I	150[3]	330
Fire Water Service Building	FWSB	I	150[3]	330
Turbine Building	TB	NS[6]	195[7]	330
Service Building	SB	II	150[3]	330
Radwaste Building	RW	NS[4]	130[5]	330
Circulating Water Pump House	CP	NS	130[5]	---
Service Water Building	SF	NS[6]	195[7]	---
Electrical Building	EB	NS[6]	195[7]	---

Notes: [1] Building classification based on Table 3.2-1, Rev. 5 of DCD
[2] Wind event speeds based on Table 2.0-1, Rev. 5 of DCD

[3] 100-year wind speed based on 3-sec gust
[4] Requirements based on RG 1.143 for Safety Class RW-IIa, some exceptions – see Note 1: Table 2.0-1
[5] 50-year wind speed based on 3-sec gust
[6] Building classification based on Section 3.2-1, Rev. 5 of DCD (last paragraph)
[7] Category 5 Hurricane, 3-sec gust wind speed over water

The bounding site characteristics and design basis data form the basis for the PRA high wind risk analysis. In conducting the high wind risk analysis, some wind events have the potential to exceed bounding site characteristics for high wind events. For example, hurricane wind speeds associated with a Category 5 wind event may exceed the ESBWR site characteristics. However, as demonstrated by the analysis of wind loads to seismic category I structures, these wind events are bounded by the site characteristic tornado winds, and for PRA purposes, no damage is assumed. In conjunction with the design basis for site structures, all ESBWR structures are assumed to be constructed and maintained to survive the design basis wind events.

Recognizing that some damage to these structures may occur at some point during certain high wind events, a sensitivity was conducted to evaluated the impact to CDF for a postulated wind damage scenario beyond site characteristics and design basis. Wind damage to seismic category I and II structures would be localized and not considered significant. A sensitivity was performed on select components of the seismic category II portion of the fire protection system (FPS). Insights on possible localized damage scenarios and the results are included in NEDO-33201, Rev. 3 Section 22.14.4.

DCD/NEDO-33201 Impact

No DCD change was required in response to this RAI.

NEDO-33201, Rev. 3 was updated to provide the additional predicted wind damage tables and the high wind sensitivities as clarification in support of this RAI.

RAI Response 19.1-169 S02

In 19.1-169 SO1, the staff asked GEH to provide the engineering basis for the estimated conditional failure probability of a Seismic Category 1 structure subjected to a Category 4 or 5 hurricane. In particular, GEH was to justify the conditional probability of no significant damage to Seismic Category 1 structures from such winds. GEH provided a response in August 1, 2008, that was deterministic and not probabilistic in nature. It discussed that Seismic Category 1 structures are to be built to meet seismic design loads that considerably exceed the loads associated with high wind events. It did not provide a numerical or engineering basis for the seven orders of magnitude reduction in risk assigned by GEH to the robustness of the Seismic Category 1 structures compared to high winds events, nor did it discuss uncertainties or the effects of design or construction errors. The staff finds this response unacceptable.

The staff would find is acceptable for GEH either to (1) provide a probabilistic defense for its use of seven orders of magnitude reduction in risk that provides an engineering basis for the reduction that links the strengths of the design to specific numerical analyses (e.g. fragility curves) that address conditional probabilities of failure, or (2) provide qualitative arguments as to why high winds do not constitute outliers in risk, qualitative arguments why high winds do not challenge the Safety Goals, a discussion of why the risk from high winds events is lower than for operating plant designs, and a list of safety insights that are important for the as-built, as-operated plant to follow to assure that the assumptions in the high winds risk analysis are valid and remain valid during the lifetime of the plant. Use of Option 2 could satisfy the requirements of 10 CFR 52 that an applicant address Safety Goals, risk outliers, and reduction in expected risk compared to existing plant designs. However, a qualitative analysis does not constitute a probabilistic risk assessment.

GEH Response

Assumptions used in conducting the ESBWR high wind risk analysis state that no significant damage of the seismic category I (SC I) structures will occur from hurricane Category 4 or 5 winds. This assumption is supported in part by the design basis of SC I ESBWR structures. In addition, fragility curves (provided below) were developed for one- and three-story concrete buildings based on gust wind speeds over the range of hurricane wind speeds of 75 to 300 miles per hour (mph). The one-story fragility curve is characteristic of the ESBWR control building (CB), fuel building (FB) and fire service water complex (FWSC); the three-story fragility curve is characteristic of the ESBWR reactor building (RB). The probability of extensive or complete damage to a one-story concrete building is essentially zero over the range of hurricane wind speeds. Similarly, a probability of extensive or complete damage to three-story concrete buildings is essentially zero up to a hurricane gust speed of about 225 mph. This further supports the ESBWR high wind risk analysis assumption that no significant damage of the SC I structures will occur from hurricane Category 4 or 5 winds.

Hurricane Fragility Curve Parameters[1]

Building Type	# of Stories	Gust Wind Speed (mph)							
		Slight Damage[2]		Moderate Damage[3]		Extensive Damage[4]		Complete Damage[5]	
		μ^{in}	σ^{in}	μ^{in}	σ^{in}	μ^{in}	σ^{in}	μ^{in}	σ^{in}
Concrete	1	4.920	0.150	5.110	0.190	7.000	0.100	7.000	0.100
	2	4.920	0.140	5.200	0.220	7.000	0.100	7.000	0.100
	3	4.900	0.130	5.180	0.220	5.640	0.080	5.740	0.100

[1] "Projecting Catastrophic Losses in a Multi-Hazard Environment", Gerbaudo and Saffar, Mecanica Computacional, Vol XXVI, October 2007.

[2] Diagonal hairline cracks on most concrete shear wall surfaces; minor concrete spalling at few locations

[3] Most shear wall surfaces exhibit diagonal cracks; some shear walls have exceeded yield capacity indicated by larger diagonal cracks and minor concrete spalling at wall ends

[4] Most concrete shear walls have exceeded their yield capacities; some walls have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks, extensive spalling around the cracks and visible buckled wall reinforcement or rotation

[5] Structure has collapsed or is in imminent danger of collapse due to failure of most of the shear walls and failure of some critical beams or columns.

Figure 1 - Fragility Curve for 1-Story Concrete Building

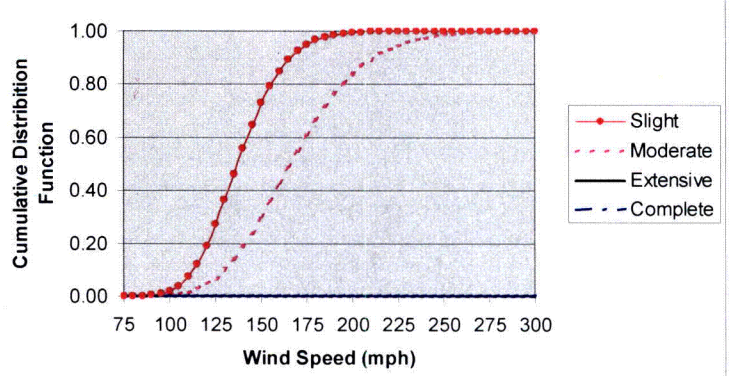
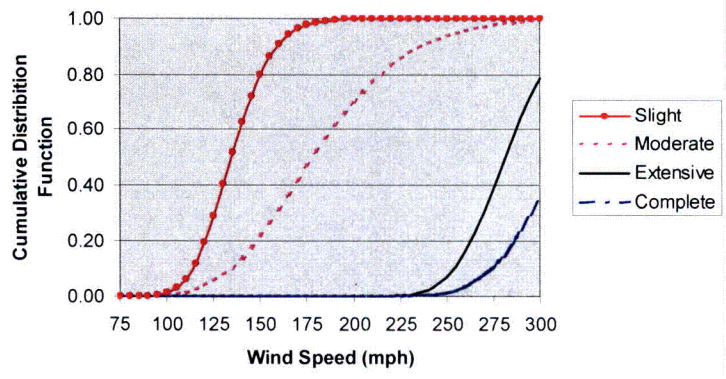


Figure 2 - Fragility Curve for 3-Story Concrete Building



Furthermore, the frequency of complete failure of the RB and the frequency of occurrence of a major hurricane (Category 3, 4 or 5) combined to result in an overall failure rate of less than 1E-12 per year of the ESBWR RB and is considered to be statistically insignificant.

DCD/NEDO-33201 Impact

No DCD change was required in response to this RAI.

No change to the NEDO-33201, Rev. 4 will be made in response to this RAI.

ATTACHMENT 1

NEDO-33201 Markup

Table 14.3-2

ESBWR Tornado Wind – PRA Predicted Structure Damage

Tornado Category	Classification of ESBWR Seismic Category[1]			
	SC I	SC II	RTNSS	NS
EF 0	No damage	No damage	No damage	No damage
EF 1	No damage	No damage	No damage	No damage
EF 2	No damage	No damage	No damage	Failure
EF 3	No damage	No damage	No damage	Failure
EF 4	No damage	No damage	Failure	Failure
EF 5	No damage	~~No~~ Possible ~~damage~~ failures associated with ~~from hurricane~~ tornado missiles	Failure	Failure

Notes: [1] The ESBWR seismic categories are identified as seismic category I (SC I), seismic category II (SC II), regulatory treatment of non-safety systems (RTNSS), and non seismic (NS).