Interim Staff Guidance
Implementation of Regulatory Guide 1.221 on
Design-Basis Hurricane and Hurricane Missiles
DC/COL-ISG-024

Issue Status

Proposed

Purpose

The purpose of this interim staff guidance (ISG) is to provide the U.S. Nuclear Regulatory Commission (NRC) staff guidance regarding the application of Regulatory Guide (RG) 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," in support of NRC reviews of early site permit (ESP), standard design certification (DC), and combined license (COL) applications being performed under the March 2007 version of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

Background

a. Regulatory Requirements

General Design Criterion (GDC) 2 in Appendix A to Title 10 of the *Code of Federal Regulations,* (10 CFR) Part 50 states, in part, that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as tornadoes and hurricanes without loss of capability to perform their safety functions. The design bases for these SSCs shall reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Analogous to GDC 2, the regulations concerning the content of ESP and COL applications (Subparts A and C to 10 CFR Part 52, respectively) state that ESP and COL applications must identify the meteorological characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated (10 CFR 52.17(a)(1)(vi) and 10 CFR 52.79(a)(1)(iii), respectively).

The regulations concerning the content of a DC application (Subpart B to 10 CFR Part 52) state that DC applications must include the site parameters postulated for the design and an analysis and evaluation of the design in terms of those site parameters (10 CFR 52.47(a)(1)). For those COL applicants who reference a DC, 10 CFR 52.79(d)(1) states that the COL application must

contain information sufficient to demonstrate that the site characteristics fall within the site parameters specified in the DC.

GDC 4 of Appendix A to 10 CFR Part 50 requires, in part, that SSCs that are important to safety be adequately protected against the effects of missiles resulting from events and conditions outside the nuclear power unit.

The regulations concerning reactor site criteria for stationary power reactor site applications filed on or after January 10, 1997 (Subpart B to 10 CFR Part 100) state, in part, that meteorological characteristics of the site that are necessary for safety analysis or that may have an impact upon plant design (such as maximum probable wind speed) must be identified and characterized (10 CFR 100.20(c)(2)). The regulations further state, in part, that the physical characteristics of the site, including meteorology, must be evaluated and site parameters established such that potential threats from such physical characteristics will pose no undue risk to the type of facility proposed to be located at the site (10 CFR 100.21(d)).

b. Regulatory Guidance

Nuclear power plants must be designed so that they remain in a safe condition under extreme meteorological events, including those that could result in the most extreme wind events (tornadoes and hurricanes) that could reasonably be predicted to occur at the site. Initially, the U.S. Atomic Energy Commission (predecessor to the NRC) considered tornadoes to be the bounding extreme wind events and issued RG 1.76, ‘‘Design-Basis Tornado for Nuclear Power Plants,’’ in April 1974. The design-basis tornado wind speeds were chosen so that the probability that a tornado exceeding the design basis would occur at the plant was on the order of 10^{-7} per year per nuclear power plant.

In March 2007, the NRC issued Revision 1 of RG 1.76, ‘‘Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants.’’ Revision 1 of RG 1.76 relied on the Enhanced Fujita Scale which was implemented by the National Weather Service in February 2007. The Enhanced Fujita Scale is a revised assessment relating tornado damage to wind speed which resulted in a decrease in design-basis tornado wind speed criteria in Revision 1 of RG 1.76.

Since design-basis tornado wind speeds were decreased as a result of the analysis performed to update RG 1.76, it was no longer clear that the revised tornado design-basis wind speeds would bound design-basis hurricane wind speeds in all areas of the United States. This prompted an investigation into extreme wind gusts during hurricanes and their relation to design-basis hurricane wind speeds, which resulted in issuing RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants,” in October 2011.

The NRC staff has determined that the design-basis hurricane wind speeds should correspond to the exceedance frequency of 10^{-7} per year per nuclear power plant, calculated as a best estimate. This is the same exceedance frequency used to establish the design-basis tornado parameters in Revision 1 of RG 1.76 and is consistent with the direction provided to the NRC staff by the Commission in defining the design-basis tornado in the Staff Requirements

Memorandum related to Commission Paper SECY-04-0200, “A Risk-Informed Approach to Defining the Design Basis Tornado for New Reactor Licensing.”

To ensure the safety of new nuclear power plants in the event of a hurricane strike, NRC regulations require that a nuclear power plant design consider the impact of hurricane-generated missiles in addition to the direct action of the hurricane wind. RG 1.221 presents a design-basis hurricane missile spectrum for nuclear power plants which is the same as the design-basis tornado missile spectrum presented in Revision 1 of RG 1.76. This spectrum includes (1) a massive high kinetic-energy missile that deforms on impact (an automobile), (2) a rigid missile that tests penetration resistance (a pipe), and (3) a small rigid missile of a size sufficient to pass through any opening in protective barriers (a solid steel sphere).

To evaluate the resistance of barriers to penetration and gross failure, RG 1.221 assigns missile velocities as a function of hurricane wind speed. The hurricane missile velocities presented in RG 1.221 are based on missile aerodynamic and initial condition assumptions that are similar to those used for the analyses of tornado-borne missile velocities adopted for Revision 1 of RG 1.76. However, the assumed hurricane wind field differs from the assumed tornado wind field in that the hurricane wind field does not change spatially during the missile’s flight time but does vary with height above the ground. Because the size of the hurricane zone with the highest winds is large relative to the size of the missile trajectory, the hurricane missile is subjected to the highest wind speeds throughout its trajectory. In contrast, the tornado wind field is smaller, so the tornado missile is subject to the strongest winds only at the beginning of its flight. This results in the same missile having a higher maximum velocity in a hurricane wind field than in a tornado wind field with the same maximum (3-second gust) wind speed. For example, the massive high-kinetic-energy tornado missile (a 1810 kg (4000 lb) automobile) in Revision 1 of RG 1.76 is assigned a velocity of 41 m/s (92 mi/h) in tornado intensity Region I, which has a design-basis tornado wind speed of 103 m/s (230 mi/h). The same missile is assigned a velocity of 68 m/s (152 mi/h) in a hurricane wind field with the same design-basis wind speed of 103 m/s (230 mi/h).

Issue Discussion

NRC regulatory guidance suggests two “design points” for wind loads as shown in Table 1. Revision 2 of RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (other than Reactor Vessels and Containments),” states that the procedures and requirements described in American Concrete Institute (ACI) Standard 349-97, “Code Requirements for Nuclear Safety Related Concrete Structures,” are generally acceptable to the staff. As a result, the guidance in ACI 349-97 (and its successor, ACI 349-06), as well as the guidance presented in several Standard Review Plan (SRP) sections (such as SRP 2.3.1, “Regional Climatology,” and SRP 3.8.4, “Other Seismic Category I Structures”), form the basis for Table 1.

Table 1. Design Basis Wind Load Criteria

Site Parameter/ Characteristic	Definition	Exceedance Frequency
Operating Basis Wind	A severe environmental load that could infrequently be encountered during the plant life	10^{-2} per year
Design Basis Tornado	An extreme environmental load that is credible but highly improbable	10^{-7} per year

The first design point is commonly called an "operating basis wind" load, which represents a severe environmental load that could infrequently be encountered during the life of the plant. ACI 349-97 and SRP 2.3.1 define the operating basis wind as wind velocities and forces associated with a 100-year recurrence interval, which is an exceedance frequency of 10^{-2} per year. SRP 3.3.1, "Wind Loadings," describes the procedures that should be used to transform the operating basis wind load into an equivalent pressure.

The second design point is commonly called the "design basis tornado," which represents an extreme environmental load that is credible but highly improbable. Revision 1 of RG 1.76 defines the design basis tornado as corresponding to an exceedance frequency of 10^{-7} per year per nuclear power plant calculated as a best estimate. SRP 3.3.2, "Tornado Loadings," describes the procedures that should be used to transform the design basis tornado parameters into equivalent loads.

The operating basis wind load and the design basis tornado load are used with different load factors and load combinations in ACI 349-97 to evaluate the capacity of concrete structures to withstand wind pressures. RG 1.221 is intended to present hurricane loads that represent an extreme environmental load that is credible but highly improbable, similar to that of a design basis tornado which has an exceedance frequency of 10^{-7} per year per nuclear power plant.

The GDC 2 criterion that the design criteria for SSCs important to safety reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated is satisfied through a combination of SRP 3.3.1 and 3.3.2. SRP 3.3.1 defines a wind load based on the operating basis wind, which is defined in ACI 349-97 as having an exceedance frequency of 10^{-2} per year. The operating basis wind load is a severe environmental load that could infrequently be encountered during the life of the plant. ACI 349-97 utilizes a 1.7 load factor for the operating basis wind load to reflect the consideration that the operating basis wind may not be the highest wind recorded for the site and that it is possible that the operating basis wind may be exceeded during the life of the plant. SRP 3.3.2 addresses the GDC 2 requirement that SSCs important to safety be designed to withstand the effects of the most severe of the natural phenomena that

have been historically reported for the site and surrounding area by considering the extreme environmental loads associated with the 10^{-7} per year design-basis tornadoes and hurricanes specified in RG 1.76 and RG 1.221, respectively. NRC design principles generally do not address initiating events that have an exceedance frequency of less than 10^{-7} per year.

SRP 3.3.2 is concerned with the design of structures that must withstand the effects of the extreme environmental loads associated with the design basis tornado. Revision 3 of SRP 3.3.2 states that tornado effects can be divided into three groups:

1. Tornado effects caused by the direct action of air flow on structures, W_w

2. Atmospheric pressure change effects caused by the differential pressure between the interior and exterior of a structure during the passage of a tornado, W_p

3. Tornado-generated missile impacts, W_m

Tornado effects considered in the design include combinations of tornado wind effects, atmospheric pressure change effects, and tornado-generated missile impact effects as follows:

$$W_t = W_p \quad (1)$$

$$W_t = W_w + 0.5W_p + W_m \quad (2)$$

where W_t is the total tornado load.

It is appropriate to use the same approach to combine the effects of hurricane winds and missiles, with the exception that the load from the hurricane atmospheric pressure change can be considered to be negligible.[1] Therefore,

$$W_h = W_w + W_m \quad (3)$$

where W_h is the total hurricane load, W_w is now the load from the hurricane wind and W_m is now the load from the hurricane missile impact.

Staff Guidance

For those sites along the Gulf and Atlantic coasts where the design-basis tornado may not bound the design-basis hurricane, applicants for new power plants are expected to show that their applicable structures can withstand, independently, the total design-basis tornado load and the total design-basis hurricane load as extreme environmental conditions.

[1] The rate of pressure change at a specific location from the passage of a hurricane will be much slower as compared to the passage of a tornado because a hurricane produces a large pressure drop over a distance of tens of miles whereas a tornado produces a similar, or possibly larger, pressure drop over only a few hundred feet.

a. Early Site Permit Applications

An ESP applicant should use RG 1.221 to determine a site-specific design basis hurricane wind speed for its site. If the site-specific design basis hurricane wind speed equals or exceeds 140 mi/h (63 m/s), the ESP applicant should add a site characteristic value called "Design Basis Hurricane Wind Speed" to its lists of site characteristics in its site safety analysis report (SSAR).[2]

b. Standard Design Certification Applications

A DC applicant should add the following two site parameters to its list of site parameter values in Tier 1 and Tier 2 of the design control document (DCD):

- Design Basis Hurricane Wind Speed (3-second gust)
- Design Basis Hurricane Missile Spectra (including missile mass and velocity)

The DC applicant should also describe in Chapter 3 of Tier 2 of the DCD how SSCs important to safety are protected from the combined effects of the design basis hurricane winds and missiles.

c. Combined License Applications

A COL applicant should use RG 1.221 to determine a site-specific design basis hurricane wind speed and hurricane missile spectra (including missile mass and velocity) for its site. If the site-specific design basis hurricane wind speed equals or exceeds 140 mi/h (63 m/s), the COL applicant should add these values to its lists of site characteristics in its COL Final Safety Analysis Report (FSAR).

For a COL applicant referencing a DC (or DC application) that contains design basis hurricane site parameter values, the COL FSAR should demonstrate that the design basis hurricane characteristics of the site fall within the design basis hurricane site parameters specified in the DCD.

For a COL applicant referencing the Advanced Boiling Water Reactor (ABWR), Section 3.5.4.2 of the DCD states, in part, that the COL applicant shall identify missiles generated by other site-specific natural phenomena that may be more limiting than the tornado-generated missiles considered in the ABWR design and shall provide protection for SSCs against such missiles. Therefore, COL applicants referencing the ABWR should consider hurricane-generated

[2] 140 mi/h (63 m/s) is the threshold value for reporting a design basis hurricane wind speed as a site characteristic value in ESP and COL applications. Figure 1 of RG 1.76 shows that all Gulf and Atlantic coast locations that are subjected to hurricanes are either in Tornado Intensity Region I or II. Sites with design basis hurricane wind speeds exceeding approximately 140 mi/h (63 m/s) are predicted to have automobile missiles that can exceed the design basis tornado missile speed in Region II. This means that sites with design basis hurricane wind speeds greater than 140 mi/h (63 m/s) could have loads associated with the design basis hurricane that exceed the loads associated with the design basis tornado.

missiles. In protecting against such missiles, concurrent loads, including loads from hurricane wind speeds, should also be considered.

For a COL applicant referencing the AP1000, Section 3.5.4 of the DCD states that if the energy of missiles from external events other than tornadoes is greater than the tornado missile spectrum energy evaluated in the DCD, the COL applicant must evaluate and show that it will not compromise the safety of AP1000 safety-related structures and components. Therefore, COL applicants referencing the AP1000 should consider hurricane-generated missiles. In protecting against such missiles, concurrent loads, including loads from hurricane wind speeds, should also be considered

For a COL applicant referencing a DC (or DC application) other than those described above, the COL applicant should comply with the appropriate COL action items in the DCD and any exclusions that may be included in the final rule certification.

For a COL applicant that has SSCs important to safety that are outside the scope of a referenced DC (or a COL applicant that does not reference a DC), the COL applicant should ensure that these site-specific SSCs are designed to protect against the combined effects of hurricane winds and missiles.

Final Resolution Method

The NRC staff will subsequently incorporate the contents of this ISG into appropriate sections of RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," and the next revisions to the SRP sections listed below:

a. SRP 2.0, Site Characteristics and Site Parameters

- Hurricane wind speed and hurricane-generated missile spectra should be added to Table 1 of Appendix A of this SRP section as example site characteristics and site parameters.

b. SRP 2.3.1, Regional Climatology

- This SRP section should be expanded to state that design basis hurricane parameters should be identified based on RG 1.221.

c. SRP 3.3.1, Wind Loading

- The title of this SRP section should be changed from "Wind Loading" to "Severe Wind Loads."

d. SRP 3.3.2, Tornado Loads

- The title of this section should be changed from "Tornado Loads" to "Extreme Wind Loads (Hurricanes and Tornadoes)."

- This SRP section should be expanded to include (i) evaluating the design-basis hurricane effects discussed in RG 1.221, including the combination of hurricane wind effects and hurricane-generated missile impact effects and (ii) recommendations for evaluating the load from the hurricane and tornado generated missile impacts (W_m).

e. SRP 3.5.1.4, Missiles Generated by Tornadoes and Extreme Winds

- The title of this SRP section should be changed from "Missiles Generated by Tornado and Extreme Winds" to "Missiles Generated by Extreme Winds."

- This SRP section should be revised to identify RG 1.221 as describing an acceptable design-basis hurricane-generated missile spectrum for the design of nuclear power plants.

f. SRP 3.5.2, Structures, Systems, and Components to be Protected from Externally-Generated Missiles

- This SRP section should be revised to state that the review of SSCs to be protected from externally-generated missiles should include protection from external missiles generated by hurricanes.

g. SRP 3.5.3, Barrier Design Procedures

- This SRP section should be revised to provide criteria for protection against the hurricane-generated missile spectrum specified in RG 1.221.

h. SRP 3.8.1, Concrete Containment, SRP 3.8.2, Steel Containment, and SRP 3.8.4, Other Seismic Category I Structures

- These SRP sections should be expanded to identify the design-basis hurricane defined in RG 1.221 as a design load for Seismic Category I structures that should be sustained during extreme environmental conditions.

Applicability

This ISG is applicable to ongoing and future reviews of DC, COL and ESP applications being performed under the March 2007 version of NUREG-0800.

This ISG shall remain in effect until it has been superseded, withdrawn, or incorporated into revisions of the applicable SRP sections and RG 1.206.

Backfit Determination

This ISG is not considered backfitting as defined in 10 CFR 50.109(a)(1), nor is it in conflict with any of the issue finality provisions in 10 CFR Part 52, because the ISG applies to DC, COL, and ESP applications currently under review.