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DRAFT REGULATORY GUIDE

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DRAFT REGULATORY GUIDE DG-1247

(New Regulatory Guide)

DESIGN-BASIS HURRICANE AND HURRICANE MISSILES FOR NUCLEAR POWER PLANTS

A. INTRODUCTION

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable to support reviews of applications that the agency expects to receive for new nuclear reactor construction permits or operating licenses under 10 CFR Part 50; design certifications under 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants" (Ref. 9); and combined licenses under 10 CFR Part 52 that do not reference a standard design. Specifically, this regulatory guide provides new guidance that the NRC staff considers acceptable for use in selecting the design-basis hurricane windspeed and hurricane-generated missiles that a new nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public. This guidance applies to the contiguous United States but does not address the determination of the design-basis hurricane windspeed and hurricane missiles for sites located along the Pacific coast or in Alaska, Hawaii, or Puerto Rico; the NRC will evaluate such determinations on a case-by-case basis. This guide also does not identify the specific structures, systems, and components that should be designed to withstand the effects of the design-basis hurricane or that should be protected from hurricane-generated missiles and remain functional. Nor does this guide address effects resulting from externally generated hazards, such as aviation crashes, nearby accidental explosions resulting in blast overpressure levels and explosion-borne debris and missiles, and turbine missiles.

General Design Criterion (GDC) 2, "Design Bases for Protection against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations*, Part 50 (10 CFR Part 50), "Domestic Licensing of Production and Utilization Facilities" (Ref. 1), requires that structures, systems, and components that are important to safety shall be designed to withstand the effects of natural phenomena, such as hurricanes, without loss of capability to perform their safety functions. GDC 2 also requires that the design bases for these structures, systems, and

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This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received final staff review or approval and does not represent an official NRC final staff position.

Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rulemaking and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; submitted through the NRC's interactive rulemaking Web page at http://www.nrc.gov; or faxed to (301) 492-3446. Copies of comments received may be examined at the NRC's Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by October 21, 2010.

Electronic copies of this draft regulatory guide are available through the NRC's interactive rulemaking Web page (see above); the NRC's public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/; and the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession No. ML100480890. The regulatory analysis may be found in ADAMS under Accession No. ML102310249.

components shall reflect (1) 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, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed.

GDC 4, "Environmental and Dynamic Effects Design Bases," of Appendix A to 10 CFR Part 50 requires, in part, that structures, systems, and components that are important to safety shall be adequately protected against the effects of missiles resulting from events and conditions outside the plant.

For stationary power reactor site applications submitted before January 10, 1997, paragraph 100.10(c)(2) of 10 CFR Part 100, "Reactor Site Criteria" (Ref. 2), states that meteorological conditions at the site and in the surrounding area should be considered in determining the acceptability of a site for a power reactor.

For stationary power reactor site applications submitted on or after January 10, 1997, 10 CFR 100.20(c)(2) requires that meteorological characteristics of the site that are necessary for safety analysis or may have an impact on plant design (such as maximum probable windspeed) must be considered in determining the acceptability of a site for a nuclear power plant. In addition, 10 CFR 100.21(d) requires 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.

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0011, 3150-0151, and 3150-0093, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Determination of Hurricane Windspeeds

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 NRC considered such conditions for tornadoes in Regulatory Guide (RG) 1.76, "Design-Basis Tornado for Nuclear Power Plants," issued April 1974 (Ref. 3). The NRC based the original version of RG 1.76 on WASH-1300 "Technical Basis for Interim Regional Tornado Criteria" (Ref. 4). WASH-1300 chose the design-basis tornado windspeeds so that the probability that a tornado exceeding the design basis would occur was on the order of 10^{-7} per year per nuclear power plant. WASH-1300 used only 2 years (1971 and 1972) of observed tornado intensity data to derive the conditional probability that, if a tornado were to strike a nuclear power plant, the maximum tornado windspeed would exceed a specified value. The probability that the tornado would strike a nuclear power plant (treated as a point) was based on more data. Estimates of tornado intensity were regionalized to three regions of the contiguous United States in the original version of RG 1.76. Each region was assigned an associated set of design basis tornado characteristics, including maximum windspeed.

In March 2007, the NRC issued Revision 1 of RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" (Ref. 5). This revised regulatory guide, which was based on Revision 2 of NUREG/CR-4461, "Tornado Climatology of the Contiguous United States," issued February 2007 (Ref. 6), resulted in the modification of the regionalization presented in the original version of RG 1.76. The tornado database used in Revision 2 of NUREG/CR-4461 included information recorded for more than 46,800 tornado segments occurring from January 1, 1950, through August 31, 2003. More than 39,600 of those segments had sufficient information on their location, intensity, length, and width to be used in the analysis of tornado strike probabilities and maximum windspeeds. The second revision of NUREG/CR-4461 also 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 windspeed. The use of the Enhanced Fujita Scale, in addition to the availability of additional tornado data, supported a decrease in design-basis tornado windspeed criteria presented in Revision 1 of RG 1.76.

Since design-basis tornado windspeeds 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 windspeeds would bound design-basis hurricane windspeeds in all areas of the United States. This prompted an investigation into extreme wind gusts during hurricanes and their relation to design-basis hurricane windspeeds. The NRC commissioned a report (Ref. 7) that considers peak-gust windspeeds and estimates maximum hurricane windspeeds for hurricanes that originate in the Atlantic and make landfall along the Atlantic and Gulf coasts of the contiguous United States. This report does not include locations outside the contiguous 48 states and does not consider hurricanes that originate in the Pacific Ocean.

The NRC staff has determined that the design-basis hurricane windspeeds should correspond to the exceedance frequency of 10^{-7} per year (calculated as a best estimate). This is the same exceedance frequency used to establish the design-basis tornado parameters in Rev. 1 to RG 1.76. This exceedance frequency is also consistent with the Standard Review Plan (NUREG-0800, Ref. 8) Section 2.2.3 (Evaluation of Potential Accidents) criterion for identifying design-basis events involving hazardous materials or activities on site and in the vicinity of a proposed site.

Design-Basis Hurricane Windspeeds

The analysis in Reference 7 is based on the peer-reviewed hurricane simulation model that was used for the development of windspeed maps for Standard ASCE/SEI 7-05 (Ref. 9), "Minimum Design Loads for Buildings and Other Structures," from the American Society of Civil Engineers (ASCE) and the Structural Engineering Institute (SEI). The model generated peak-gust windspeeds at 3,575 grid points along and inland of the Atlantic and Gulf Coasts of the United States. A stratified sampling approach facilitated a simulation with an effective length of 10 million years that computed windspeeds for each model hurricane at each affected grid point. The range of hurricane parameters in the precomputed wind fields in the model was extended to cover the smaller and more intense hurricanes that are occasionally simulated in the 10-million-year event set. In addition to the computation of a deterministic peak-gust windspeed for each model hurricane, the analysis incorporated a wind field modeling error term. The error term includes the inability of the wind model to capture some asymmetries in the underlying model pressure fields, as well as the inability of the model to capture small-scale features such as extreme convective gusts. The inclusion of this error term resulted in an effective maximum peak gust in the range of 1.7 to 1.8 times the mean windspeed.

The resulting windspeeds are nominal 3-second peak-gust values at a height of 10 meters (m) (33 feet (ft)) in flat open terrain, which is consistent with the definition of design windspeeds in the ASCE/SEI design standard. Figures 1 through 3 provide hurricane windspeed contour maps from Reference 7 that correspond to an exceedance frequency of 10^{-7} per year.

Hurricane-Generated Missiles

In accordance with 10 CFR 50.34, "Contents of Applications; Technical Information," GDC 2, and GDC 4, structures, systems, and components that are important to safety must be designed to withstand the effects of natural phenomena without losing the capability to perform their safety function. Hurricane missiles (i.e., objects moving under the action of aerodynamic forces induced by the hurricane wind) are among the most extreme effects of credible natural phenomena that can occur at nuclear power plant sites subject to hurricanes.

To ensure the safety of nuclear power plants in the event of a hurricane strike, NRC regulations require that nuclear power plant designs consider the impact of hurricane-generated missiles, in addition to the direct action of the hurricane wind. Hurricanes are capable of generating missiles from objects lying within the path of the hurricane wind and from the debris of nearby damaged structures. The two basic approaches used to characterize hurricane-generated missiles are (1) a standard spectrum of hurricane missiles, and (2) a site-specific probabilistic assessment of the hurricane hazard. No definitive guidance has been developed for use in characterizing site-dependent hurricane-generated missiles by hazard probability methods. Damage to safety-related structures by hurricane or other wind-generated missiles implies that a sequence of random events has occurred. That event sequence typically includes a wind-based occurrence in the plant vicinity in excess of 34 m/s (75 mph)[1], existence and availability of missiles in the area, injection of missiles into the wind field, suspension and flight of those missiles, impact of the missiles on safety-related structures, and resulting damage to critical equipment. Given defense-in-depth considerations, the uncertainties in these events preclude the use of a probabilistic assessment as the sole basis for assessing how well the plant is protected against hurricane missile damage.

Protection from a spectrum of missiles (ranging from a massive missile that deforms on impact to a rigid penetrating missile) provides assurance that the necessary structures, systems, and components will be available to mitigate the potential effects of a hurricane on plant safety. Given that the design-basis hurricane windspeed has a very low frequency of occurrence, to be credible, the representative missiles must be common items around the plant site and must have a reasonable probability of becoming airborne within the hurricane wind field.

Design-Basis Hurricane Missile Spectrum

To evaluate the resistance of barriers to penetration and gross failure, the hurricane missile velocities must also be defined. In addition to the report on design-basis hurricane windspeeds (Ref. 7), the NRC also commissioned a report on design-basis, hurricane-borne missile velocities (Ref. 10). This report describes the method used to calculate the horizontal and total velocities associated with several types of missiles considered for different hurricane windspeeds. The

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1 The 75 mph wind speed criterion for generating wind-borne missiles is from the March 2007 Revision 1 to RG 1.76 (Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants) (see pg 6). It is not based on the minimum wind speed to designate a hurricane.

selected design-basis hurricane missile spectrum for nuclear power plants is the same as the design-basis tornado missile spectrum presented in RG 1.76. This spectrum includes (see Table 1) (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).

The NRC considers the design-basis hurricane missiles listed in Table 1 to be capable of striking in all directions with the horizontal velocities shown in Table 2 and with a vertical velocity of 26 m/s. The horizontal missile velocities shown in Table 2 were taken from Table 5 of Reference 10 and represent maximum horizontal missile speeds in open terrain. The vertical missile velocity of 26 m/s bounds all the vertical missiles velocities calculated from Table 2 of Reference 10 which shows terminal total missile velocities (over open terrain) and the associated angle of incidence with respect to the ground. RG 1.76 uses two different automobile missiles as a function of tornado region (i.e., a larger and heavier automobile for tornado Regions I and II and a smaller and lighter automobile for tornado Region III) because the lighter automobile was found to have a higher kinetic energy in Region III as compared to the heavier automobile. However, in the case of the hurricane wind field, the heavier automobile was found to have a higher kinetic energy for all wind speeds as compared to the lighter automobile and therefore the design-basis hurricane automobile missile is based only on the heavier design-basis automobile missile presented in RG 1.76.

Barrier design should be evaluated assuming a normal impact to the surface for the automobile and Schedule 40 pipe (6.625 in. diameter) missiles. The automobile missile is considered to impact at all altitudes less than 9.14 m (30 ft) above all grade levels within 0.8 kilometers (0.5 miles) of the plant structures.

The hurricane missile analyses presented in Reference 10 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. In particular, no dependence of missile drag coefficient on missile position or relative missile speed with respect to the windflow was considered. 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 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 windspeeds 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) windspeed.

C. REGULATORY POSITION

The NRC staff has established the following regulatory positions for use in selecting the design-basis hurricane windspeed and hurricane-generated missiles that a new nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public.

1. Design-Basis Hurricane Windspeeds

Windspeeds specified in Figures 1, 2, and 3 for the appropriate regions identified are acceptable to the NRC staff for defining the design-basis hurricane for a new nuclear power plant. If a design-basis hurricane proposed for a given site is characterized by parameter values less conservative than the values presented in Figures 1 through 3, a comprehensive analysis should be provided to justify the selection of the less conservative design-basis hurricane. Linear interpolation for sites located between two wind contour lines is permitted.

2. Design-Basis Hurricane-Generated Missiles

The design-basis hurricane-generated missile spectrum given in Table 1 and the corresponding missile velocities given in Table 2 are acceptable to the staff for the design of new nuclear power plants.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC's plans for using this draft regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

The NRC has issued this draft guide to encourage public participation in its development. The NRC will consider all public comments received in development of the final guidance document. In some cases, applicants may propose an alternative or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications.

Figure 1. Design-Basis Hurricane Windspeeds for the Western Gulf of Mexico U.S. Coastline Representing Exceedance Probabilities of 10^{-7} per Year. Values are nominal 3-second gust windspeeds in miles per hour (meters per second) at 33 feet (10 meters) above ground over open terrain (reproduced from Reference 6).

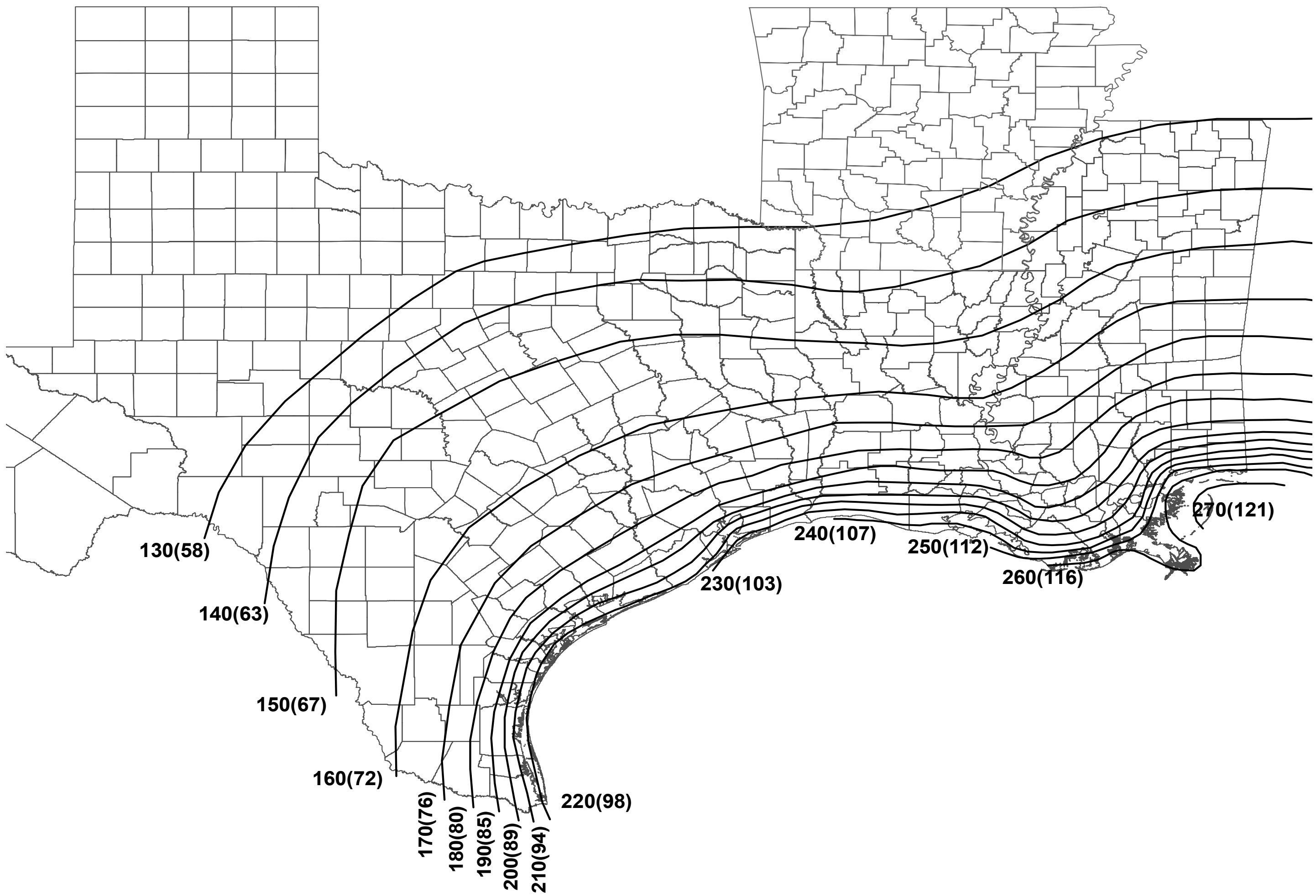

Figure 2. Design-Basis Hurricane Windspeeds for the Eastern Gulf of Mexico and Southeastern Atlantic U.S. Coastline Representing Exceedance Probabilities of 10^{-7} per year. Values are nominal 3-second gust windspeeds in miles per hour (meters per second) at 33 feet (10 meters) above ground over open terrain (reproduced from Reference 6).

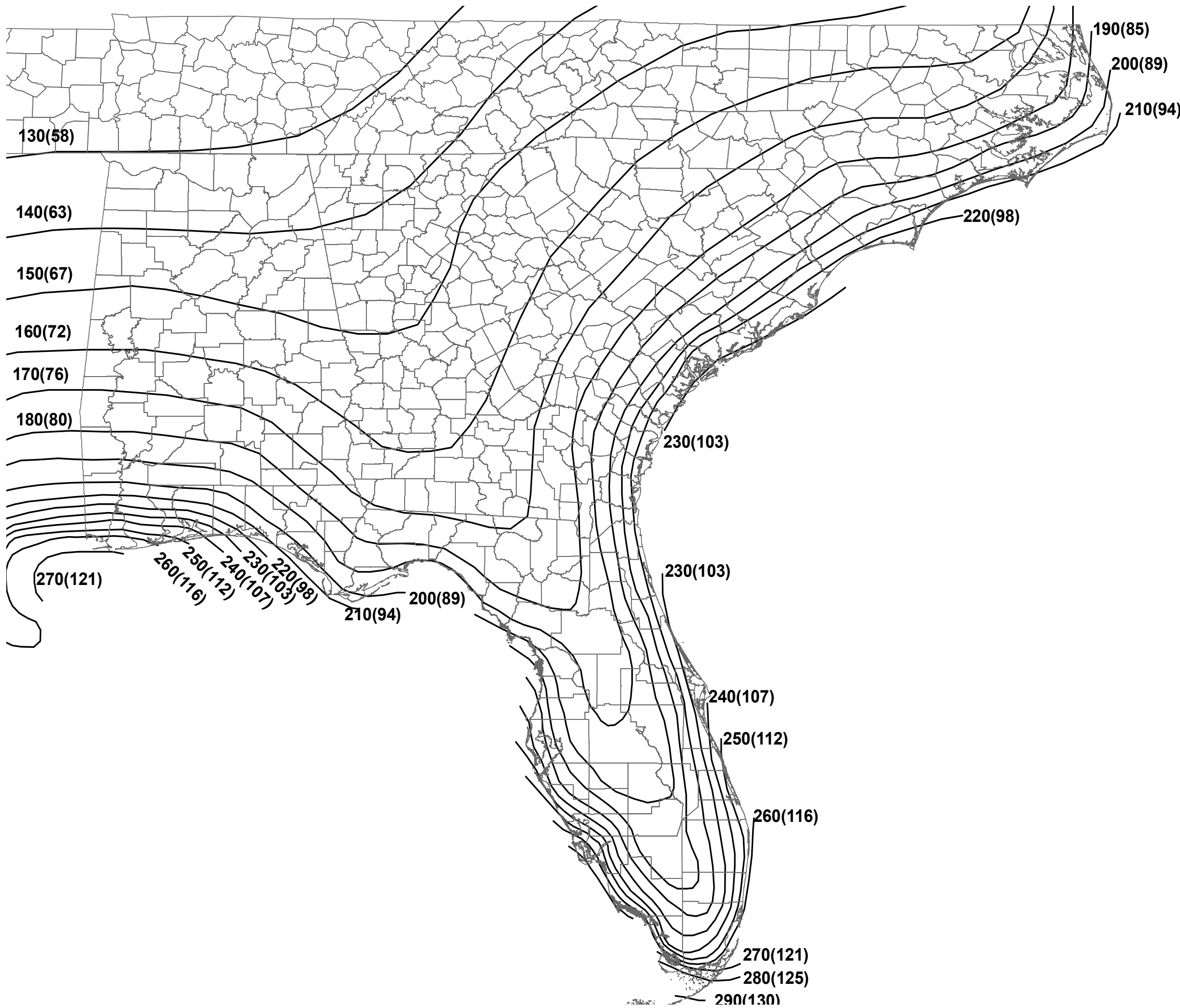

Figure 3. Design-Basis Hurricane Windspeeds for the Mid- and Northern Atlantic U.S. Coastline Representing Exceedance Probabilities of 10^{-7} per year. Values are nominal 3-second gust windspeeds in miles per hour (meters per second) at 33 feet (10 meters) above ground over open terrain (reproduced from Reference 6).

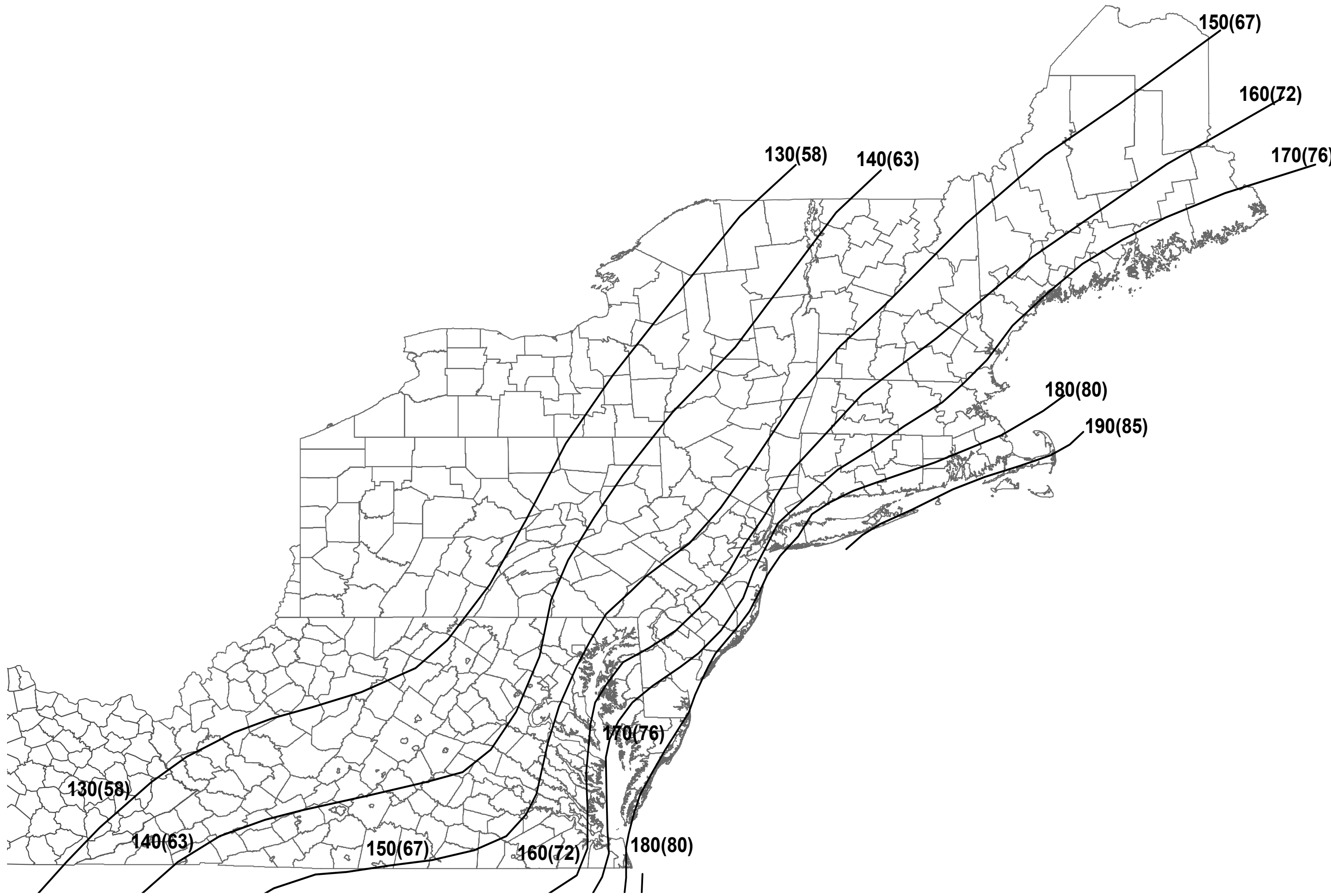

Table 1. Design-Basis Hurricane Missile Spectrum

Missile Type	Dimensions	Mass
Automobile	5 m × 2 m × 1.3 m (16.4 ft x 6.6 ft x 4.3 ft)	1,810 kg (4,000 lb)
Schedule 40 Pipe	0.168 m dia × 4.58 m long (6.625 in. dia × 15 ft long)	130 kg (287 lb)
Solid Steel Sphere	25.4 mm (1 in.) diameter	0.0669 kg (0.147 lb)

Table 2. Design-Basis Missile Velocities as a Function of Hurricane Windspeed

Hurricane Windspeed m/s (mph)	Horizontal Missile Velocity m/s (mph)		
	Auto	**Pipe**	**Sphere**
40 (89)	16.6 (37)	11.7 (26)	9.9 (22)
45 (101)	19.9 (45)	14.2 (32)	12.1 (27)
50 (112)	23.4 (52)	17.0 (38)	14.4 (32)
55 (123)	27.1 (61)	19.8 (44)	17.0 (38)
60 (134)	30.9 (69)	22.9 (51)	19.6 (44)
65 (145)	34.9 (78)	26.0 (58)	22.4 (50)
70 (157)	39.0 (87)	29.3 (66)	25.4 (57)
75 (168)	43.1 (96)	32.8 (73)	28.4 (64)
80 (179)	47.4 (106)	36.3 (81)	31.6 (71)
85 (190)	51.8 (116)	39.9 (89)	34.9 (78)
90 (201)	56.2 (126)	43.7 (98)	38.3 (86)
95 (213)	60.7 (136)	47.5 (106)	41.8 (94)
100 (224)	65.2 (146)	51.4 (115)	45.3 (101)
105 (235)	69.9 (156)	55.4 (124)	49.0 (110)
110 (246)	74.5 (167)	59.4 (133)	52.7 (118)
115 (257)	79.2 (177)	63.6 (142)	56.5 (126)
120 (268)	84.0 (188)	67.7 (151)	60.4 (135)
125 (280)	88.8 (199)	72.0 (161)	64.3 (144)
130 (291)	93.6 (209)	76.3 (171)	68.3 (153)
135 (302)	98.5 (220)	80.6 (180)	72.3 (162)
140 (313)	103.4 (231)	85.0 (190)	76.4 (171)
145 (324)	108.3 (242)	89.5 (200)	80.6 (180)
150 (336)	113.2 (253)	94.0 (210)	84.8 (190)

The hurricane windspeed values are nominal 3-second gust windspeeds at 10 m (33 ft) above ground. The design-basis vertical missile velocity for all missiles is 26 m/s (58 mph).

REFERENCES[2]

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.

2. 10 CFR Part 100, "Reactor Site Criteria," U.S. Nuclear Regulatory Commission, Washington, DC.

3. Regulatory Guide 1.76, Revision 0, "Design-Basis Tornado for Nuclear Power Plants," U.S. Atomic Energy Commission, Washington, DC, April 1974.

4. WASH-1300, "Technical Basis for Interim Regional Tornado Criteria," U.S. Atomic Energy Commission, Washington, DC, May 1974.

5. Regulatory Guide 1.76, Revision 1, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

6. Ramsdell, J.V., Jr., NUREG/CR-4461, Revision 2, "Tornado Climatology of the Contiguous United States," PNNL-15112, U.S. Nuclear Regulatory Commission, Washington, DC, February 2007.

7. NUREG/CR-7005, "Technical Basis for Regulatory Guidance on Design-Basis Hurricane Windspeeds for Nuclear Power Plants," Draft, December 2009.

8. NUREG-0800, Revision 3, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," March 2007.

9. Standard ASCE/SEI 7-05, "Minimum Design Loads for Buildings and Other Structures," from the American Society of Civil Engineers (ASCE) and the Structural Engineering Institute (SEI).[3]

10. NUREG/CR-7004, "Technical Basis for Regulatory Guidance on Design-Basis Hurricane-Borne Missile Speeds for Nuclear Power Plants," Draft, December 2009.

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[2] Publicly available NRC published documents such as Regulations, Regulatory Guides, NUREGs, and Generic Letters listed herein are available electronically through the Electronic Reading room on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR.Resource@nrc.gov.

[3] Copies of the non-NRC documents included in these references may be obtained directly from the publishing organization.