Evaluation of Natural Hazards other than Seismic and Flooding

Contents

1.0. Summary

As described in SECY-15-0137, "Proposed Plans for Resolving Open Fukushima Tier 2 and 3 Recommendations," dated October 29, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15254A008), and SECY-16-0074, "Assessment of Fukushima Tier 2 Recommendation Related to Evaluation of Natural Hazards other than Seismic and Flooding" (ADAMS Accession No. ML16102A297), the staff undertook a series of screening-type evaluations to determine if there is a need to take additional regulatory action to address external hazards other than seismic and flooding warranted. The screening-type evaluations for external hazards other than seismic and flooding cover a variety of potential natural events that were either: (1) not addressed within existing licensing basis documents (e.g., final safety analysis reports), or (2) calculated to be more severe than described in licensing basis documents when reevaluated using present day information and methodologies.

In assessing whether additional regulatory action is warranted, the staff took a holistic approach considering the likelihood of the event, the assumed severity of the event, and the plant's ability to respond to the event. When evaluating the plant's ability to respond, the staff considered both the protection provided by structures, systems and components (SSCs) in pre-Fukushima configurations and capabilities that have been added as part of post-Fukushima upgrades. The primary post-Fukushima upgrade relevant to this analysis is the additional capabilities required by Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," dated March 12, 2012 (ADAMS Accession No. ML12054A735). The staff's evaluations were performed using guidance such as Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection," to determine if additional regulatory actions were justified.

The NRC divided the review process into the following four tasks:

1. Define natural hazards other than seismic and flooding to determine those hazards that could potentially pose a threat to nuclear power plants and perform a screening to determine which of those should be reviewed generically. As part of this task, the staff also screened hazards for additional reviews if new information or guidance was issued since the plant received its operating license.

2. Determine and apply screening criteria to remaining hazards from Task 1 and appropriately exclude certain natural hazards from further generic evaluations, or exclude some plants from considering certain hazards. Examples of screening criteria include conservatism in design, low frequency of occurrence of a given hazard, and available warning time.

3. Perform a technical evaluation to assess the need for additional actions if the hazard or plant was not screened out generically in Task 2.

4. As discussed in SECY-15-0137, the last task in the process would be for the staff to determine if additional actions, such as a plant-specific backfit, are needed.

The Commission approved the resolution plan for this issue in the staff requirements memorandum (SRM) to SECY-15-0137, dated February 8, 2016 (ADAMS Accession No. ML16039A175), and directed the staff to provide the Commission the results of Task 2 by the end of May 2016.

As directed by the Commission in SRM to SECY-15-0137, in SECY-16-0074 the staff provided the Commission with the results of Task 2 of its evaluation. As discussed in SECY-16-0074, the staff's assessment performed in accordance with Task 1 screened out all natural hazards (other than seismic and flooding, which are being addressed separately as part of an ongoing activity) with the exception of high winds, extreme ambient temperatures, drought and other low-water conditions, and winter precipitation that results in snow and ice loading on structures. As documented in SECY-16-0074, based on its assessment in accordance with Task 2 of the process, the NRC staff determined that additional regulatory actions are not warranted for extreme ambient temperatures and drought and other low-water conditions. The hazards proceeding to the third task in the screening process include high winds and snow and ice loads. As such, Task 1 and Task 2 activities are complete, as documented in SECY-16-0074.

This paper provides the staff's preliminary assessment for high winds and snow loads, in accordance with Task 3 of the process outlined in SECY-15-0137, and SECY-16-0074. Based on the assessment that follows, the staff's preliminary conclusion is that additional regulatory actions for high winds and snow loads are not warranted.

2.0. Discussion

As discussed in SECY-16-0074, the staff identified high winds and snow loads for evaluation in accordance with Task 3 of the process described above because new regulatory guidance was developed for these hazards since the majority of the currently operating reactors received their operating licenses. The purpose of the Task 3 evaluation is to determine if application of the new guidance to currently operating plants would result in identification of the need for additional regulatory action for these plants, such as a plant-specific backfit.

Tornado and Hurricane Missile Loads

Many of the currently operating plants were licensed before the 1975 version of the, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NUREG-0800, formerly issued as NUREG/75-087)."[1] As such, the staff determined that it would be appropriate to review the design-basis tornado missile protection for these older plants against the current standard review plan and Regulatory Guide (RG) 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, dated March 2007 (ADAMS Accession No. ML100541776). The NRC staff also reviewed current operating plants that were licensed against the 1975 version of the Standard Review Plan (SRP) using the current version of the SRP and RG 1.76, Revision 1.

[1] Both current and previous versions of the SRP are publicly available in ADAMS and can be accessed at the following web address: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/

The staff determined that additional review of hurricane-driven missiles was warranted because of recently issued guidance in this area. In October 2011 the staff issued RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants" (ADAMS Accession No. ML110940300). RG 1.221 notes that, because the potential size of a hurricane, hurricane-driven missiles can be subjected to high winds throughout their trajectory, resulting in higher missile speeds. In contrast, for a tornado, the wind field is smaller, so tornado-driven missiles are subjected to the strongest winds only at the beginning of their 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 wind speed.

The staff's evaluation of high wind hazards is provided in Section 2.1.

Snow and Ice Loads

On June 23, 2009, the staff issued interim staff guidance (ISG) DC/COL-ISG-007, "Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures" (ADAMS Accession No. ML091490556). This guidance was issued for new reactor reviews since the existing guidance in NUREG-0800 did not provide specific approaches to consider snow loads at ground and roof levels due to normal and extreme winter precipitation events for the design of seismic Category I structures. The staff determined it was appropriate to advance this external natural event through the screening process because the recent updated guidance provides approaches for considering snow loads that were not used when some of the operating plants were initially licensed.

The staff's evaluation of snow and ice loads is provided in Section 2.2.

2.1. Evaluation of High Winds

The staff's evaluation of high wind hazards is broken into five parts:

1. comparison of current tornado and hurricane guidance to previous guidance used to license the currently operating reactor fleet,

2. a discussion of the licensing basis for the currently operating reactor fleet,

3. insights from recent inspection findings related to tornadoes that led to the generation of a generic communication,

4. an evaluation comparing results from analyses completed by the staff using current guidance against the licensing basis of operating reactors, and

5. the NRC staff's preliminary conclusion for its evaluation of tornado and hurricane winds.

2.1.1. Comparison of Current Guidance to Previous Guidance for Tornado and Hurricane Missile Protection

To characterize the change in missile protection requirements for nuclear power plants, the NRC staff compared the current guidance to the guidance in place during the licensing of operating plants. The existing regulatory guidance documents that the staff used are:

- Tornado Missiles
  - RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, March 2007 (ADAMS Accession No. ML070360253)
  - RG 1.76, Revision 1, is based on tornado hazard curves provided in NUREG/CR-4461, "Tornado Climatology of the Contiguous United States" (ADAMS Accession No. ML070810400)
- Hurricane Missiles
  - RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plant," October 2011 (ADAMS Accession No. ML110940300)
  - RG 1.221 is based on data provided in NUREG/CR 7005, "Technical Basis for Regulatory Guidance on Design Basis Hurricane Wind Speeds for Nuclear Power Plants," December 2009 (ADAMS Accession No. ML11335A031) and NUREG/CR 7004, "Technical Basis for Regulatory Guidance on Design-Basis Hurricane-Borne Missile Speeds for Nuclear Power Plants," February 2011 (ADAMS Accession No. ML11341A102)

The NRC staff reviewed both RG 1.76, Revision 1, and RG 1.221, because improved understanding and enhanced models have indicated that for some sites, hurricane winds, which often have lower speeds than design basis tornado winds, may produce more intense missiles than tornado winds. RG 1.221 notes that 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 wind speed. Thus, even though the maximum wind speed in a hurricane may be bound by the maximum tornado wind speed, the missile generated from a hurricane may reach a higher maximum speed than the tornado missile.

The following example illustrates the changes in the missile spectrum characteristics over time:

- Based on Standard Review Plan Section 3.5.1.4, "Missiles Generated by Natural Phenomena," Revision 2, dated July 1981, one of two missile spectrums could be used by licensees. SRP Section 3.5.1.4 previously provided the missile spectrum and velocities to be considered in a plant's design. The missile spectrum and velocity profiles were moved to RG 1.76, Revision 1, during an update to SRP 3.5.1.4. Regardless, many of the currently operating plants were designed to the earlier version of the SRP that assumed either Spectrum I or Spectrum II missiles. Both spectrum include consideration of automobile missiles:

- o Spectrum I missiles – a 1800 kilograms (3970 pound) automobile in the region of the United States susceptible to tornadoes that are capable of generating the highest wind speed would have a velocity of 56 meters per second (126 miles per hour).

- o Spectrum II missiles – a 1810 kilogram (3990 pound) automobile would have a velocity of 59 meters per second (132 miles per hour).

- o This regulatory guide contained additional guidance that allowed applicants who were required to design to the 1975 version of the SRP at the construction permit stage to have the option at the operating licensing stage of showing conformance with their original commitment. The 1975 version of the SRP included an automobile of 4000 pounds having a velocity of 100 feet per second (68 miles per hour).

- Based on RG 1.76, Revision 1, a 4000 pound automobile in the region of the United States susceptible to tornadoes that are capable of generating a maximum wind speed of 230 miles per hour would have a characteristic velocity of 135 feet per second (93 miles per hour).

- Based on RG 1.221, a 4000 pound automobile in a 235 mile per hour hurricane would have a characteristic velocity of 156 miles per hour.

Based on the example above, the staff notes that depending on the time a plant was licensed, it could have a range of assumed automobile-type missile speeds, including:

- In some cases the automobile missile speeds went down from 126 miles per hour to 93 miles per hour based on comparing the 1981 SRP Spectrum I missile characteristic to the current RG 1.76, Revision 1, characteristics for tornadoes.

- Also, the automobile-type missile speed went down from 132 miles per hour to 93 miles per hour based on comparing 1981 SRP Spectrum II missile characteristics to current RG 1.76, Revision 1, guidance.

- Based on the options provided in the 1981 version of the SRP, if plants used the option of demonstrating compliance with commitments made at the construction permit stage, an automobile missile velocity could increase from 68 miles per hour to 93 miles per hour based on comparing this option to the guidance in RG 1.76, Revision 1.

- However, the automobile speed increased from 126 miles (Spectrum I missile characteristics) or 132 miles per hour (Spectrum II missile characteristics) to 156 miles per hour based on comparing the 1981 SRP characteristics to the current RG 1.221 characteristics for hurricanes.

Because of the various options provided above and noting that some plants were licensed before the 1975 version of the SRP existed, the staff performed a review of the licensing basis for the current operating fleet and compared the licensing basis automobile missile speed (if applicable) to that found in RG 1.76, Revision 1. Based on this review, the staff found that approximately two thirds of plants have automobile missile speeds lower than that found in the latest regulatory guidance (i.e., Revision 1 to RG 1.76 or RG 1.221).

In addition to the automobile missile described above, other missiles were identified in RG 1.76 and RG 1.221. RG 1.76, Revision 0, and the 1975 version of SRP 3.5.1.4 had six different missile characteristics, while the RG 1.76, Revision 1, and RG 1.221 have three. Regardless of the version of the regulatory guidance, the missile characteristics that were chosen included at least one of the following: (1) a massive high-kinetic-energy missile that deforms on impact (i.e., an automobile), and (2) a rigid missile that tests penetration resistance. Later guidance provided a small rigid missile of a size sufficient to pass through openings in protective barriers. Below is a comparison of the missile characteristics of the various versions of the regulatory guidance. Note that different speeds were assumed for each type of missile, based on the corresponding tornado or hurricane wind speed characteristics.

Missile Type	Tornadoes		Hurricanes
	RG 1.76, Revision 0, and SRP 3.5.1.4 1975 Version	RG 1.76, Revision 1	RG 1.221
Massive high-kinetic energy missile that deforms on impact	Automobile	Automobile	Automobile
A rigid missile that tests penetration resistance	• Wood plank, 4 inches x 12 inches x 12 feet long weighing 200 lbs • Steel pipe, 3 in diameter, 10 feet long weighing 78 lbs • Steel pipe, 6 inches in diameter 15 feet long weighing 285 lbs • Steel pipe, 12 inches diameter, 15 feet long, weighing 743 lbs • Utility pole, 13.5 inches diameter, 35 feet long, weighing 1490 lbs	Schedule 40 pipe 6.625 inches in diameter x 15 ft long weighing 287 lbs	Schedule 40 pipe, 6.625 inches in diameter x 15 ft long, weighing 287 lbs
A small rigid missile of a size sufficient to pass through openings and protective barriers	Not applicable	Solid steel sphere 1 inch in diameter weighing 0.147 lbs	Solid steel sphere 1 inch in diameter weighing 0.147 lbs

Conclusion

For some plants, although the speed of the tornado may have decreased based on a comparison of the licensing basis to current guidance found in RG 1.76, Revision 1, the speed of the automobile missile may have increased. In addition, for some coastal sites, hurricane-driven automobile missile speeds increased from that found in the current licensing basis to that found in RG 1.221.

2.1.2. Licensing Basis for Currently Operating Reactors

Currently operating power plants have been analyzed against tornado missiles. The extent of the evaluation conducted for tornado missiles varies and is based on when the plant was originally licensed. However, as described above, hurricane-generated missiles were not specifically modeled as they were previously considered to be bounded by tornado events.

In 1977, the NRC initiated the Systematic Evaluation Program (SEP) to review the designs of 51 older, operating nuclear power plants. The SEP was divided into two phases. In Phase I, the staff defined 137 issues for which regulatory requirements had changed enough over time to warrant an evaluation of those plants licensed before the issuance of the 1975 version of SRP. In Phase II, the staff compared the designs of 10 of the 51 older plants to the SRP issued in 1975. Based on these reviews, the staff identified 27 of the original 137 issues that required some corrective action at one or more of the 10 plants that were reviewed. The staff referred to this smaller list as the SEP lessons-learned issues and concluded that they would generally apply to operating plants that received operating licenses before the SRP was issued in 1975. The staff used NUREG-1742, "Perspectives Gained from the Individual Plant Examination of External Events (IPEEE)," available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1742 as an aid in identifying the current fleet of operating units that were evaluated under the SEP. NUREG- 1742, Table 5.6, "GSI 156, Systematic Evaluation Program," provides a listing of plants that were evaluated under the SEP.

Plants Included in the Systematic Evaluation Program

The staff used its generic safety program to track the resolution of the SEP issues. As documented in NUREG-0933, "Resolution of Generic Safety Issues" (available at: http://nureg.nrc.gov/sr0933)," the staff identified the resolution of this issue as Generic Safety Issue (GSI) 156: "Systematic Evaluation Program." GSI 156 was comprised of various issues identified under the SEP program, including Issue 156.1.5 related to protection against tornadoes. The objective of GSI 156.1.5: "Tornado Missiles," was to ensure that safety-related SSCs can withstand the impact of an appropriate postulated spectrum of tornado-generated missiles. At the time, the NRC's focus was on evaluating plants that received operating licenses before 1976 to ensure they were adequately protected against tornado-generated missiles; in particular, those reviewed before 1968 when criteria on tornado protection were first developed.

As a result of the SEP review, all current operating plants have been analyzed for tornado-generated missiles to some degree as reflected in the current version of the plant's Updated Final Safety Analysis Report (UFSAR) or in the IPEEE evaluation. The criteria used to evaluate these plants vary greatly and in some cases consist of two missiles (e.g., a rigid steel pipe and a telephone pole) and in other cases rely on probabilistic risk assessments (PRA) methodologies.

In some cases plants were backfit to provide additional tornado missile protection or took steps as a result of insights gained from their IPEEEs to provide more robust protection from tornado missiles.

Later Generation Plants

The staff reviewed the tornado-missile spectrum and velocities assumed for plants that were licensed in accordance with the 1975 version of the SRP and, in general, found the following:

- For rigid missiles that test penetration resistance, these plants have robust tornado missile protection design basis requirements for their safety-related SSCs when compared to the newer criteria found in RG 1.76, Revision 1, and RG 1.221.

- However, speeds for tornado-generated automobile-type missiles increased by around 50 percent for many sites based on RG 1.76, Revision 1, as compared to the 1975 version of the SRP, and based on RG 1.221 criteria for hurricanes, automobile missile speeds for coastal sites are generally not bounded by the tornado-generated automobile missile speeds found in the 1975 version of the SRP.

The staff notes that some of the plants performed a PRA of tornadoes,[2] which indicated that based on conformance with the 1975 version of the SRP or completion of a PRA, these plants were adequately protected against the effects of tornadoes. The NRC staff considered IPEEE insights when evaluating this issue for later generation plants.

Conclusion

Tornado missile protection for operating power plants has been reviewed under previous NRC initiatives to determine the appropriate design basis for the plant:

- Plants licensed before the 1975 version of the SRP was available were evaluated in accordance with the SEP process.

- Tornado missile protection for later generation plants was reviewed in accordance with the guidance found in the 1975 version of the SRP.

- During the IPEEE process, licensees evaluated high winds, including tornado missile protection, and verified through reviews and walkdowns that their plant met the guidance found in the 1975 version of the SRP or alternatively performed a probabilistic risk assessment.

As a result of these regulatory programs, licensees took actions to upgrade tornado missile protection, as appropriate.

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[2] The majority of plants that were reviewed against the 1975 version of the SRP did not perform a high-winds PRA. The IPEEE process allowed licensees to forgo a high-winds PRA if the plant was reviewed against this version of the SRP and plant walkdowns confirmed the licensing basis assumptions associated with this regulatory guidance.

2.1.3. Insights from Regulatory Issue Summary 2015-06, "Tornado Missile Protection"

To further assess the risk posed by tornadoes, the NRC staff considered insights from the agency's recent assessments and enforcement discretion related to tornado missile protection. The background and the risk insights related to this issue are summarized below.

The SSCs of nuclear power plants are designed to withstand natural phenomena, such as earthquakes, tornadoes, hurricanes, and floods, without the loss of capability to safely maintain the plant. In general, the design bases for these SSCs 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.

In designing SSCs for the consequences of design-basis tornadoes, tornado-generated missiles must be considered. The specific tornado missile protection criteria for each nuclear power plant are contained in the individual plant's licensing basis. There are several design methods typically used for protecting SSCs from tornado-generated missiles. These include placing the SSC within a structure designed to withstand tornado missiles, designing the SSC to withstand the tornado missile, or installing a barrier designed to withstand tornado missiles around the SSC. In addition to physical design methods, the NRC allows the use of probability analysis to demonstrate that the probability of a tornado-generated missile striking a component required to safely maintain the plant is sufficiently low that no additional measures are required.

Most facilities use deterministic methods when evaluating protection from tornado-generated missiles and as a basis for complying with these regulations. However, NUREG-0800, Section 3.5.1.4, Revision 0, includes acceptance criteria that permit the use of an alternative approach if it can be demonstrated that the probability of strike to unprotected essential safety-related features is sufficiently small. Some licensees used this alternative approach by incorporating the NRC-approved, EPRI-developed TORMIS methodology, or another NRC-approved probabilistic risk assessment methodology via the license amendment process. Over the past several years, licensees and the NRC have identified facilities that have not conformed to their licensing basis for tornado-generated missile protection and are therefore not in compliance with applicable regulations. These noncompliances have been documented in NRC inspection reports and in some cases, have resulted in license amendment requests. Some of the nonconforming SSCs included TS-required equipment (e.g., emergency diesel generator exhaust header/ductwork, pipe risers, fan motors, etc.), which required an operability determination. In cases where the licensee concluded that the TS-required SSC was inoperable, the licensee was required to complete any actions specified by the TS.

As a result of non-conformances, the NRC issued Regulatory Issue Summary (RIS) 2015-06, "Tornado Missile Protection" (ADAMS Accession No. ML15020A419). The intent of the RIS was to reinforce the need to conform to a plant's current, site-specific licensing basis for tornado-generated missile protection, and provide examples of recently-identified failure to conform to a plant's tornado-generated missile licensing basis.

The RIS 2015-06 notes that the NRC may grant enforcement discretion in accordance with Enforcement Guidance Memorandum (EGM) 15-002, "Enforcement Discretion for Tornado Missile Protection Noncompliance" (ADAMS Accession No. ML15111A269), to licensees who are in non-compliance with their plant-specific licensing bases for issues related to tornado missile protection. EGM 15-002 provides a basis for granting enforcement discretion, including that tornado missile scenarios that may lead to core damage are generally low probability events. For a tornado-missile-induced scenario to occur, a tornado would have to hit the site and result in the generation of missiles that would hit and fail vulnerable, unprotected safety-related equipment and/or unprotected safety-related subcomponents in a manner that is nonrepairable and nonrecoverable. In addition, because plants are designed with redundancy and diversity, other trains may be available to achieve safe shutdown if a tornado missile were to impact a single train of a safety system.

The EGM 15-002 included a generic risk analysis of potential tornado missile protection noncompliances to examine the risk significance of these scenarios. This assessment (ADAMS Accession No. ML14114A556) uses tornado hazard curves to provide a bounding estimate of the initiating event frequency of a damaging tornado missile and then it uses PRA tools to analyze the failure of SSCs that have typically been found to not meet the licensing basis for tornado missile protection for selected plant facilities. This analysis used tornado hazard curves provided in NUREG/CR-4461, "Tornado Climatology of the Contiguous United States," Revision 2 (ADAMS Accession No. ML070810400), and Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missile for Nuclear Power Plants," Revision 1 (ADAMS Accession No. ML070360253).

The generic risk analysis performed by the Office of Nuclear Reactor Regulation (NRR), Division of Risk Assessment, concluded that the non-conformance with tornado missile protection requirements does not rise to the level of an adequate protection concern or require immediate plant shutdown because the risk is bounded by the initiating event frequency of 4E-4 per year even in the most severe tornado region, which is well below the 1E-3 per year threshold provided in NRR Office Instruction LIC-504, "Integrated Risk-Informed Decision-Making Process for Emergent Issues." Therefore, the EGM concluded that enforcement discretion of up to 5 years, accounting for differences in initiating event frequency based on the geographical location of the plants, will not impose significant additional risk to public health and safety. The EGM notes that the enforcement discretion will expire 3 years after the issuance date of RIS 2015-06 for plants of a higher tornado missile risk (Group A plants) and 5 years after RIS issuance for plants of a lower tornado missile risk (Group B plants).

Therefore, regarding the tornado licensing basis for operating plants:

- The staff notes that the tornado missile protection design basis requirements are generally conservative.

- The staff has taken advantage of current licensing processes to ensure that licensees continue to meet their tornado missile protection design basis by alerting licensees to issues the NRC has identified in various inspections as documented in RIS 2015-06.

- EGM 15-002 provides a basis for granting enforcement discretion that notes in general tornado missile scenarios that may lead to core damage are low probability events, because safety-related SSCs are typically designed to withstand the effects of tornadoes.

2.1.4 Evaluation of Current Operating Plants' Tornado Wind Protection Against Current Guidance

The risk study discussed above indicates that the risk from tornadoes is low. Nevertheless, the NRC staff performed a deterministic evaluation to identify insights based on its review of current tornado and hurricane guidance against the licensing basis for current operating plants. The staff's deterministic review process had three parts:

- assessment of wind loads based on wind speeds from current guidance in RG 1.76, Revision 1, and RG 1.221, as compared to the current licensing basis wind speed loads for operating plants;
- assessment of the ability of tornado or hurricane missiles to damage structures protecting safety-related SSCs based on current guidance in RG 1.76, Revision 1, and RG 1.221, as compared to the current licensing basis missile design spectrum for operating plants; and
- assessment of structural loads from a large missile (i.e., automobile) based on current guidance in RG 1.76, Revision 1, and RG 1.221, as compared to the margin provided in current licensing basis structural design-basis.
    - For this assessment the NRC staff reviewed the automobile missile structural loads from current guidance as compared to those used to establish the current licensing basis for the plant. In cases where the use of current-day guidance resulted in a potentially more damaging missile than addressed in a plant's licensing basis, the staff then assessed the new information against the structural margin in the operating power plant. The NRC staff believes a margin assessment of structural loads from an automobile missile impact is a logical first step in determining if additional regulatory action might be warranted to request additional information or require licensees for current operating plants to perform analyses using RG 1.76, Revision 1, and RG 1.221 guidance.

2.1.4.1. High Wind Velocity Pressure Loads

To assess wind velocity pressure loads, the staff relied on licensees' UFSARs and on licensees' integrated plans provided in response to the mitigating strategies Order EA-12-049. Licensees' UFSARs typically provide a discussion of the design-basis tornado wind speed loads assumed in the structural analysis. The licensee's integrated plan response to Order EA-12-049 included a discussion of whether the plant met the criteria for a high wind evaluation.

Figure 2.1.4-1, "Comparison of Current Design Basis Tornado Wind Speeds vs Updated Tornado and Hurricane Wind Speed," plots the data that the NRC staff collected. As noted with the blue shade plot in Figure 2.1.4-1, the majority of nuclear power plants were designed for a tornado wind speed of 360 miles per hour. Figure 2.1.4-1 shows that for the majority of the sites, the RG 1.76, Revision 1, tornado wind speeds (shown as the purple line in the plot) are less than those assumed in the design of the plant. Regarding hurricanes, Figure 2.1.4-1 shows that not every plant has an associated hurricane wind speed (shown by the red bars in the plot). This is consistent with the guidance found in RG 1.221 that does not provide hurricane wind speeds for plants that are far inland because of the assumption that the tornado wind speed will bound a hurricane wind speed for these sites. Regardless, Figure 2.1.4-1 shows that for the majority of sites, the hurricane wind speed is bounded by the design-basis tornado wind speed provided in the UFSAR.

The staff notes that for one site (Ginna), on the far right of the horizontal axis in Figure 2.1.4.1-1, the design-basis tornado wind speed is less than that found in RG 1.76, Revision 1 (for tornados), or RG 1.221 (for hurricanes). One of the sites design basis tornado wind speed is not the same for all safety-related SSCs (Oyster Creek). In addition, not every site was licensed with a design-basis tornado wind speed (Nine Mile Point 1 and Indian Point 2).

The staff reviewed the IPEEEs for the four sites whose tornado design-basis wind speed does not exist or whose tornado design-basis wind speed is lower than the RG 1.76, Revision 1, tornado wind speed or the RG 1.221 hurricane wind speed. The safety evaluations associated with the IPEEEs noted core damage frequencies (CDFs) due to high winds for two of the sites to be less than 5E-6 per year for high winds (Oyster Creek and Nine Mile Point 1). One of the sites had a CDF due to high winds of 3E-5 per year with the dominate contributor being a loss of all alternating current (AC) power resulting in loss of reactor coolant pump (RCP) seal cooling (Indian Point 2). For this site, the staff notes the low CDF contribution and also notes that loss of AC power resulting in loss of RCP seal cooling is a scenario that is addressed as part of the mitigating strategies order. The last site (Ginna) did not calculate a CDF, instead noting that as part of the SEP review it made several modifications to the plant to increase the protection from high winds. Based on walkdowns, coupled with a review of the SEP results, the licensee for Ginna concluded that the CDF was less than 1E-6 in accordance with Section 5.2.4, "Determine if the Hazard Frequency is Acceptably Low," of NUREG 1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities" (ADAMS Accession No. ML063550238).

The staff concludes that for the majority of sites the design basis tornado wind speed bounds updated wind speed guidance provided in RG 1.76, Revision 1, and RG 1.221. Therefore, for these sites the staff has determined that additional regulatory action is not warranted in this area. For the four sites whose design basis tornado wind speed does not bound wind speed guidance provided in RG 1.76, Revision 1, and RG 1.221, the staff performed a review of the IPEEEs to determine if additional regulatory action is needed. Based on the insights from the IPEEEs and the additional capability provided in response to the mitigation strategies order, the staff has determined that additional regulatory actions are not warranted.

2.1.4.2. Tornado and Hurricane Missile's Ability To Penetrate Structures

In evaluating missile hazards, the staff compared tornado- or hurricane-borne missiles believed to be able to penetrate concrete walls in place to protect safety-related SSCs. The staff used these calculations to determine the minimum concrete thickness needed to prevent perforation of the structure by the bounding tornado missile in the current licensing basis for operating plants, as described in the UFSAR, against the bounding missile's minimum concrete thickness to prevent perforation for either tornadoes or hurricanes based on RG 1.76, Revision 1, or RG 1.221. The staff used this method of comparison because the tornado missiles described in the operating plant UFSARs differ from the missiles described in RG 1.76, Revision 1, and RG 1.221. Converting a missile's energy and contact area to a concrete penetration depth allows for comparison of the existing missile protection requirements for operating plants against current-day regulatory guidance.

The staff used a formula to convert a missile's mass, velocity, and contact area into a concrete penetration depth based on guidance found in SRP Section 3.5.3, "Barrier Design Procedures," March 2007 (ADAMS Accession No. ML070570004). SRP 3.5.3 notes that several empirical equations, such as the modified National Defense Research Council equation, proposed in "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects," by R.P. Kennedy, Nuclear Engineering and Design (the Kennedy paper), are available to estimate missile penetration into concrete.

Figure 2.1.4-2 is an NRC staff-developed plot using the Kennedy paper formula to develop minimum concrete thickness to prevent perforation based on design-basis tornado missile characteristics found in a plant's UFSAR as compared to the minimum concrete thickness to prevent perforation when struck by a schedule 40 pipe based on guidance in Revision 1 to RG 1.76 or RG 1.221 guidance (whichever results in the higher velocity missile). Figure 2.1.4-2 presents concrete thicknesses that are calculated values at various sites based on tornado missile characteristics found in the UFSAR and does not represent actual value of concrete thickness of safety-related structures at a given site. The staff performed this calculation to use as one of the screening tools to aid it in determining whether additional regulatory action is warranted related to tornado and hurricane missile protection.

Based on this assessment, the staff found that the majority of the current operating plants have design-basis missile characteristics that bound the missile characteristic of the rigid pipe found in RG 1.76, Revision 1, or RG 1.221. There are six sites (Brunswick, D.C. Cook, Saint Lucie, Robinson, Turkey Point, and Ginna) for which this is not the case. Four of these six sites have a ratio of the calculated penetration depth for the RG 1.76, Revision 1, or RG 1.221 missile characteristic that is within a factor of 1.5 or less of the UFSAR design basis value. Based on structural margins associated with safety-related structures, the staff believes it is unlikely that safety-related SSCs will fail at the higher velocities assumed for the schedule 40 pipe in RG 1.76, Revision 1, or RG 1.221. Two of the 6 sites have a ratio that is higher than 1.5. (Turkey Point and Ginna). The staff reviewed the IPEEEs for these two sites. For one of the sites (Turkey Point), the CDF was calculated to be less than 1E-6 from tornadoes. Tornado-induced failure of the condensate storage tanks and the failure of a fossil-fired smoke stack falling on one of the units' emergency diesel generators were found to dominate all other tornado hazards. The staff notes that the risk is small. In addition, although the contributor of tornado-induced failure of the condensate storage tank remains, the failure of the fossil-fired smoke stack falling is no longer germane because the smoke stack is no longer needed and is being removed from the site. The other site (Ginna) is discussed above. The licensee for Ginna did not calculate a CDF, instead noting that as part of the SEP review, it made several modifications to the plant to increase the protection from high winds. Based on walkdowns coupled with a review of the SEP results the licensee concluded that the CDF was less than 1E-6 in accordance with Section 5.2.4 of NUREG 1407.

In addition to the six sites whose missile penetration capability is not bounded by the FSAR design basis value, two sites do not have a tornado design basis tornado and associated missile spectrum (Indian Point 2 and Nine Mile Point 1). The results of the staff's review of the IPEEE for these two sites are discussed in the previous section.

In summary, the staff reviewed the IPEEEs for the eight combined sites whose calculated missile penetration capability is not bounded by the value calculated by the staff using the UFSAR tornado missile characteristics to determine if a basis for additional regulatory action to address missile penetration protection exists. Highlights from the staff's review of the IPEEEs include:

- Five of the eight sites had a calculated CDF due to high winds of less than 3E-5 per year.
- Three of the eight site performed a bounding CDF analysis based on compliance with the 1975 version of the SRP and concluded that their CDFs due to high winds was less than 1E-6 per year.

The staff compared the CDF values to those found in NUREG/BR-0058, Revision 4, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission" (available at: http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0058/br0058r4.pdf). NUREG/BR-0058, Section 3.3.1 provides a process for evaluating whether a proposed regulatory action to prevent or reduce the likelihood of sequences that can lead to core damage should be pursued. If a calculated change in CDF is less than 1E-5, then it is recommended that no action be pursued. The staff notes that the eight sites who calculated a tornado-induced CDF fall in this range. The staff also notes that the IPEEE analysis, which were performed in the 1990s, does not credit mitigating strategies equipment or equipment required to comply with loss of large areas of the plant due to fire or explosion in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 50.54(hh)(2) since these requirements were imposed after the IPEEE were performed. The staff believes that if this equipment is credited, the IPEEE calculated values would be even lower.

Therefore, the staff concludes that, for the majority of sites, the design-basis tornado missile characteristic associated with missile penetration depth bounds the missile characteristic for a schedule 40 pipe provided in Revision 1 to RG 1.76 and RG 1.221. For these sites the staff has determined that additional regulatory action is not warranted in this area. For the eight sites whose tornado or hurricane-born rigid missile design basis speed does not bound rigid missile speed guidance provided in Revision 1 to RG 1.76 and RG 1.221, the staff performed a review of the IPEEEs to determine if additional regulatory action is needed. Based on the insights from the IPEEEs and the additional capability provided in response to the mitigation strategies order, the staff has determined that additional regulatory actions are not warranted.

2.1.4.3. Tornado and Hurricane Automobile Missile Evaluation

The staff assessed the automobile missile loads from a tornado or a hurricane. As indicated above, both tornadoes and hurricanes have the potential to produce more intense automobile missiles than that assumed in previous guidance. The staff notes that the automobile missile can be considered a surrogate for a spectrum of missiles that can be found at a site, including objects like heating, ventilation, and air conditioning units on roof tops.

Figure 2.1.4-3 provides a plot of the 1E-7 tornado and hurricane missile speeds based on RG 1.76, Revision 1, and RG 1.221 guidance, respectively. Figure 2.1.4-3 also provides a plot of 5.9E-4 hurricane-driven automobile missile speeds based on wind speed data from American

Society of Civil Engineers (ASCE) 7, “Minimum Design Loads for Buildings and Other Structures,” and the corresponding automobile missile speed for the given hurricane wind speed from RG 1.221. The staff chose the 5.9E-4 automobile missile speed data because this information was available and it is at the frequency that provides useful insights to the staff’s consideration of whether additional regulatory actions are warranted based on guidance provided in NUREG/BR-0058 (i.e., while wind speeds from less frequent events may result in higher missile speeds, they would be less likely to result in the need for a plant-specific backfit based solely on event frequency). For many sites RG 1.76, Revision 1, automobile missile speeds for a 1E-7 event are in the 90 miles per hour range and for some coastal sites, the RG 1.221 automobile missile speeds for a 1E-7 event are above 120 miles per hour.

The staff used a conservative approach to assess the impact of the increased automobile missile speed as compared to the current plant’s missile protection requirements. The staff used a systematic screening method to assess the potential impact that the updated automobile missile speeds could have on the operating fleet. Current guidance uses the automobile as the most limiting missile for a high-wind scenario. However, some plants were licensed using relatively lower velocities for their automobile missiles (as low as 33 miles per hour). At some sites the utility pole missile was considered the most limiting impact load in the current licensing basis due to its relatively high weight, large diameter, and high speed. Thus, the automobile missile was not always the most limiting case in the staff’s re-analysis.

The first step in the staff’s screening evaluation was to compare the peak force calculated using a plant’s UFSAR missile data to the calculated peak force from missiles using current guidance. The staff determined the highest-impact load for each site based on the licensing basis (e.g., tornado-driven automobile or tornado-driven telephone pole). This load was then compared to the load calculated using automobile characteristics from RG 1.76 traveling at either NUREG-4461 tornado missile speeds or NUREG-7005 hurricane missile speeds, whichever was greater.

The initial insights from the comparison indicated that the automobile missile speeds estimated using present-day guidance are higher than similar missiles within the licensing basis for many plants. The difference in estimated missile speeds is mainly driven by the fact that for 1E-7 tornado and hurricane events, the velocity of the automobile was increased by a median factor of two from automobile speeds found in the current operating plants’ licensing bases. Thus, the kinetic energy of the automobile was increased by a median factor of four based on the kinetic energy of an object being equivalent to half the mass of an object times the velocity squared. Some UFSARs described automobile-type missiles with higher velocities, but many UFSARs discussed estimated speeds between 50 and 75 miles per hour.

To provide additional context to the missile-resistance capacity of reinforced concrete walls, the staff performed a calculation of representative concrete walls of varying thicknesses to determine the speed at which automobile missile impact loads could be expected to exceed structural capacity. The staff chose representative reinforced concrete walls that are 12 inches, 18 inches and 24 inches thick. The staff chose this range of thicknesses because safety related structures have a range of concrete thicknesses. For example, service water intake structures and auxiliary building typically have concrete thicknesses in the 12 to 18 inch range, while containments typically have greater than 24 inch thick concrete protecting systems and components.

The staff performed these calculations using a targeted ductility factors of 10 and 30. Ductility is a measure of the ability of structures/structural elements to deform prior to ultimate failure, once the structure has surpassed its yield strength (i.e., in the inelastic range). The staff calculated a ratio comparing the deformation caused by the impact loading and the representative walls' ultimate deformation, and compared it against the targeted ductility factors. Once the deformation ratio exceeded the targeted ductility factor (10 or 30), the staff assumed the wall had failed. A flexural ductility factor of 10 was chosen because code design requirements for impactive and impulsive loads from the American Concrete Institute limits the allowable ductility to 10. However, topical report BC-TOP-9A, "Design of Structures for Missile Impact," suggest that a higher maximum ductility ratios in flexure of up to 30 may be justified; so the staff used that value as a sensitivity case to provide further context to the magnitude of missile speeds expected to be required to cause a structural failure of a reinforced concrete wall. The results of this calculation are shown in the following table.

Thickness of Representative Concrete Wall	Automobile Impact Speed to Exceed Ductility of 10 in miles per hour	Automobile Impact Speed to Exceed Ductility of 30
12 inches	110 mph	200 mph
18 inches	180 mph	275 mph
24 inches	240 mph	360 mph

The staff notes that based on the above simplified calculation and assuming a ductility of 10, a 12-inch representative concrete wall would have sufficient structural capacity to withstand:

- all of the 1E-7 tornado automobile missile speeds associated with RG 1.76, Revision 1.

- the majority of the 1E-7 automobile missile speeds associated with RG 1.221, noting that the 18 inch wall would have capacity to withstand all 1E-7 hurricane automobile missile speeds.

- all of the 5.9E-4 automobile missile speeds.

Assuming a ductility factor of 30 for the conservative 12-inch wall would bound all 1E-7 tornado and hurricane automobile missile speeds from RG 1.76, Revision 1, and RG 1.221.

Based on the results of the deterministic screening approach, and recognizing that plant's licensing basis are unique, the staff also considered insights from high wind risk studies.

2.1.4.4. Additional Safety Insights

The NRC staff notes that early insights from recent PRAs do not identify extreme tornadoes and hurricanes as dominant risk contributors to a plant's CDF. Rather, the more common tornado and hurricanes that fail offsite power and damage important non-safety related equipment have been identified as needing further study. This was described in a meeting summary dated

May 28, 2015, which discusses technical aspects of high wind probabilistic risk methodologies (ADAMS Accession No. ML15187A266). The summary includes the following insights:

- Challenges exist in the characterization of a hazard curve with respect to straight winds, hurricanes, and tornadoes. Peak wind gusts between 115 and 150 miles per hour would typically represent the range where potential damage to buildings due to debris and structural impacts could be observed. There is a need for stochastic modeling in hazard characterization, given the potentially large uncertainties involved. Two important aspects not typically considered were: (1) consideration of directional wind analysis for vulnerable structures to reduce the level of conservatism in straight winds analysis, and (2) assessment of the impact of rain on plant equipment, as this phenomenon often accompanies high wind events.

- The National Institute of Standards and Technology plans to update current guidance on tornado wind risk, aimed at leveraging new data that became available over the past decade to derive tornado risk maps for the United States. As part of this work, factors affecting hazard modeling, such as the inconsistent reporting of tornadoes across different time periods, path area uncertainties, and the wind speed relationship across commonly used scales (e.g., Fujita and Enhanced Fujita Scale) will be taken into account to better reflect the extremely large epistemic uncertainties associated with tornado hazard modeling.

Based on the early insights from ongoing high wind PRAs and insights gained from the IPEEEs, the NRC staff believes that long-term activities are better focused on updating its PRA tools for high wind events. Examples of this work include the following:

- The NRC identified issues in an August 10, 2015, letter, “User Need Request for Support in the Development and Enhancement of NRC Risk Analysis Tools” (ADAMS Accession No. ML15110A210, non-public). The letter requests that the NRC’s Office of Nuclear Regulatory Research enhance existing tools to make external event analysis more risk informed.

- A September 21, 2011, SRM (ADAMS Accession No. ML112640419) directed the staff to conduct a full-scope comprehensive site Level 3 PRA, as described in SECY-11-0089, “Options for Proceeding with the Future Level 3 Probabilistic Risk Assessment Activities” (ADAMS Accession No. ML11090A041). Southern Nuclear Company volunteered to cooperate with the staff and offered Vogtle Units 1 and 2 to be the subject of this study. This work includes assessments of external hazards and involves the development of high wind PRA.

While the NRC staff believes this work can improve the understanding of the risk profiles for plants and provide insights for future licensing and oversight decisions, it does not believe these activities need to be completed to support the Task 3 assessment for tornadoes and hurricanes. The consideration of deterministic and risk-informed approaches within the Task 3 assessment is sufficient to determine if NRC-imposed actions on licensees might be warranted.

As discussed above, the following factors were considered by the staff in its assessment of the need for additional regulatory actions for high winds:

- While a tornado and tornado-generated missiles impacting a nuclear power plant are low frequency events, hurricane force winds impacting a nuclear power plants are not low frequency events for nuclear power plants along the Atlantic Coast and the Gulf of Mexico Coast. The staff notes that based on preliminary recent PRA insights and past IPEEE insights, CDF for high winds from hurricanes is typically driven by wind-induced failure of offsite power and wind-induced damage to important non-safety related equipment. For example, for one site, the IPEEE risk insights notes that the dominant high wind core damage sequences are station blackout sequences, responsible for 87% of the high wind CDF. Due to the resulting station blackout, RCP seal cooling is lost, resulting in loss of coolant accident through the RCP seals with no RCS make up capability.

- Based on hurricane weather forecasts and the warning time associated with these forecasts, licensees take preplanned actions to prepare for the onset of high winds on the site, including shutting down the plant if winds greater than a certain speed are expected on the site. Based on these insights, the staff reviewed the severe weather procedures for four coastal plants related to hurricanes (i.e., Saint Lucie, Turkey Point, Brunswick, and Waterford). In all cases the severe weather procedures direct the operators to shutdown the plant prior to hurricane force winds arriving onsite. In addition, procedures direct staff personnel to perform walkdowns to look for and address potential hurricane induced missiles and to ensure emergency diesel generators have adequate fuel supplies and have been recently tested to ensure high reliability if a loss of offsite power should occur. Licensee actions, based on warning time, prior to a hurricane impacting a site reduce the risk of core damage from these events.

- NRC-endorsed guidance document NEI 12-06 Revision 2, “Diverse and Flexible Coping Strategies (FLEX) Implementation Guidance,” (ADAMS Accession No. ML16005A625) provides implementation guidance for the mitigation strategies Order EA-12-049 that includes additional capabilities beyond the protection of safety-related equipment for plants dealing with the possible effects of hurricanes and tornadoes. Step 2C, “Assess Impact of Severe Storms with High Winds,” in NEI 12-06 notes that severe storms with high winds can create a significant challenge to plant safety, simultaneous extended loss of ac power and loss of the ultimate heat sink. NEI 12-06 Section 7.3 includes provisions for the protection and deployment of FLEX equipment that include guidance for the configuration of the storage of this equipment and deployment of the equipment. Therefore, the staff believes that implementation of FLEX strategies reduces risk from high wind events leading to loss of core or spent fuel pool cooling.

- The NRC staff has continually assessed regulatory requirements related to tornadoes and hurricanes as part of the operating experience lessons learned process. As an example, GI-178, “Effect of Hurricane Andrew on Turkey Point,” documents the steps the NRC took to compile lessons that might benefit other nuclear facilities. These efforts are summarized in NUREG-1474, “Effect of Hurricane Andrew on the Turkey Point Nuclear Generating Station from August 20 through 30, 1992,” which was distributed to all power reactor licensees. In addition, similar lessons learned activities were associated with the effects of Hurricane Katrina and Hurricane Sandy.

2.1.5. Conclusion of Evaluation of Tornado and Hurricane Missile Protection

The NRC staff's preliminary conclusion is that additional regulatory actions are not warranted to address beyond-design-basis tornadoes and hurricanes based on: low risk; conservatism in design; additional capabilities to address these events based on compliance with the mitigation strategies Order EA-12-049; lessons learned from past events being incorporated into licensees' and NRC actions; and for hurricanes, the additional warning time associated with these events.

2.2. Evaluation of Snow Loads

The evaluation of snow and ice loads is focused on the potential challenge to seismic Category I structures at a nuclear power plant, such that additional regulatory action (beyond what the NRC currently requires) is warranted to address the hazard. The staff performed the evaluation to assess the differences in snow load estimates using assumptions described in present-day guidance and methods as compared to operating plants' licensing bases information. The staff applied the following three criteria as part of its evaluation:

1. conservatism of design safety margins;

2. low frequency of occurrence/low risk; and

3. warning time available to allow measures to be taken to prevent an accident from occurring.

On June 23, 2009, the staff issued interim staff guidance (ISG) DC/COL-ISG-007, "Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures" (ADAMS Accession No. ML091490556). This guidance was issued for new reactor reviews because at the time of the issuance of the ISG, the SRP did not provide specific approaches for considering snow loads at ground level due to normal and extreme winter precipitation events for the design of seismic Category I structures. The currently operating reactor fleet was designed to guidance that predates DC/COL-ISG-007. Given the recently updated guidance for snow loads, the staff determined that it was appropriate to further assess this external natural event as part of Task 3 in the staff's evaluation process.

DC/COL-ISG-007 guidance notes the following:

> Seismic Category I structures are required to be designed to withstand the effects of natural phenomena to meet the requirements of GDC [General Design Criterion] 2 in Appendix A to 10 CFR Part 50. Therefore, Seismic Category I structures must be designed to withstand the effects of winter precipitation events.
>
> Roofs of Seismic Category I structures not protected by a shield building will be subject to loading due to accumulation of winter precipitation. In SRP Section 2.3.1 identifies winter precipitation event site characteristics/site parameters at ground level. Therefore, these site characteristics/site parameters must be converted to corresponding roof loads.

> Currently, no guidance is included in any of the SRP sections regarding how snow loads at ground level should be converted to snow loads on the roofs of Seismic Category I structures. Further, SRP sections pertaining to design of Seismic Category I structures do not provide any guidance as to how roof loads due to normal and extreme winter precipitation events should be included in loading combinations for design of Seismic Category I structures. This ISG includes guidance for NRC staff members for acceptable methods for (a) converting winter precipitation site characteristics/site parameters (as ground snow loads) to roof loads, and (b) including roof loads due to normal and extreme winter precipitation events into loading combinations for the design of Seismic Category I structures.

The DC/COL ISG-007 is consistent with the guidance for the plants that were reviewed against the 1975 version of the SRP. In accordance with the 1975 version of the SRP, roofs were designed and evaluated for snow, and negative pressure due to tornado suction, and were checked for the effects of probable maximum precipitation. Live loads were considered in combination with other loads (e.g., dead loads, like those from the weight of structures and equipment, and accident loads like those associated with earthquakes) and were evaluated using guidance found in SRP Sections 3.8.1, "Concrete Containments," and 3.8.4, "Other Seismic Category I Structures." In addition, as discussed in a March 24, 1975, branch technical position, "Site Analysis Branch Position – Winter Precipitation Loads" (ADAMS Accession No. ML050630277), a 48-hour probable maximum precipitation (PMP) were to be considered in addition to the 100-year snow load event.

The winter precipitation events to be included in the combination of extreme winter precipitation roof loads are based on the weight of the antecedent snowpack resulting from the normal winter precipitation event plus the larger resultant weight from either (1) the extreme frozen winter precipitation event or (2) the extreme liquid winter precipitation event. The NRC staff recognizes that an ice storm can lead to loss of offsite power. However, because the additional weight of the ice is evaluated as part of the 48-hour PMP, the staff considers its evaluation of the 48-hour PMP under "extreme snow loads" to bound ice storm structural loads.

Plants licensed before the 1975 version of the SRP did not consider the additional weight of the 48-hour probable maximum winter precipitation at ground level for the month corresponding to the selected snowpack. The purpose of the staff's assessment of this issue is to determine if the treatment of snow loads in accordance with DC/COL ISG-007 leads to a determination that additional regulatory action is needed. As discussed above the staff identified several screening criteria in evaluating a hazard, including comparing new hazard information against the safety structural margins inherent in the design of nuclear power plants.

In assessing the conservatism of design safety margins relative to snow loads, the staff evaluation has two parts: plants that were licensed before the 1975 version of the SRP and plants reviewed against the 1975 version of the SRP. The staff's evaluation is divided into these two parts because, based on the application of review guidance at the time, plants that were licensed against the 1975 version of the standard review plan, in general, are expected to have additional design safety margins associated with load combinations compared to plants licensed before the 1975 version of the standard review plan existed.

Plants Included in the Systematic Evaluation Program

As was discussed under the tornado evaluation, the staff used its generic safety program to track the resolution of the SEP issues. As documented in NUREG-0933, "Resolution of Generic Safety Issues" (available at: http://nureg.nrc.gov/sr0933), the staff identified the resolution of this issue as Generic Safety Issue (GSI) 156, "Systematic Evaluation Program." The objective of GSI 156.2.1, "Severe Weather Effects on Structures," was to identify those meteorological conditions that should be considered in structural reviews to determine the ability of structures to withstand these conditions. The staff's resolution of this issue noted that snow and ice loads, when accompanied by strong winds, caused several complete and partial losses of offsite power and the potential of causing severe accidents and would be evaluated under the Individual Plant Evaluation program. The staff's evaluation at that time also stated that snow and ice loads alone are judged, based on limited PRA experience, to be unlikely to cause significant structural failure that might lead to severe accidents at nuclear power plants.

NUREG-1742, "Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program," Section 4.1.3.2, "Guidance for Conduction IPEEE HFO [High Winds, Floods, and Other External Events] Analyses," provides a screening approach that includes a determination of whether the plant conforms to the guidance in the 1975 standard review plan, and performance of a plant walkdown. The majority of the plants licensed before the 1975 SRP was available used this method for dispositioning snow loads, as documented in NUREG-1742, Table 4.1, "Methodologies and results for the HFO [High Winds Floods and Other External Events] external events." Only the Haddam Neck nuclear plant (which ceased operations in 1996) performed a snow and ice PRA and reported a CDF contribution of 7E-6 from snow and ice. It is not clear whether or not the assessment of these plants against the 1975 version of the SRP also considered the March 24, 1975, branch technical position. Regardless, snow loads were considered as part of the IPEEEs that were performed for plants included in the SEP and it was determined that additional regulatory action was not needed to address snow loads.

Plants Evaluated Using the 1975 Version of the Standard Review Plan

Plants that were evaluated using the 1975 version of the SRP include snow loading (if applicable) as part of the load combinations for structural analysis associated with Category I structures. The NRC staff reviewed the IPEEEs for these plants, and notes that these licensees did not identify snow-load related vulnerabilities for safety-related structures for plants in this category.

2.2.1. Snow Load Deterministic Evaluation

The NRC staff calculated the 100-year snow load and extreme snow load for the current operating fleet based on guidance provided in DC/COL-ISG-7. Figure 2.2-1 provides a plot of the staff-calculated 100-year snow load and extreme snow loads for current operating nuclear power plants (ten sites whose 100-year snow load is zero based on ASCE-7 information are not plotted on this figure). The staff performed additional structural assessments for these sites by developing equivalent roof loading for a representative reinforced concrete roof. The staff's evaluation included developing the dead load for this representative roof. Figure 2.2-1 plots double the dead load of a representative concrete roof that equates to a 225 pounds per square foot roof loading. Doubling the representative roof dead load is within the structural design margin of the representative roof.

The extreme roof snow loads are within the structural margins for a representative concrete roof slab, providing confidence that such roofs will not fail due to extreme roof snow load conditions. This is based, in part, on the margin inherent in the design due to the use of linear analysis approaches, lower-bound material properties, and conservative estimates of structural capacities. Other considerations include roof load path redundancy, such that the loads are distributed from structural members approaching its design capacity to other parts with available design margin.

The staff recognizes that roof structures that protect safety-related equipment vary across the operating fleet. For example, pressurized water reactor (PWR) concrete containment domes are sloped in such a manner that they prevent accumulation of snow and are typically very thick. PWR auxiliary building roofs and roofs protecting safety-related PWR and boiling water reactor (BWR) intake structures are typically flat reinforced concrete structures. BWR Mark I and II reactor building roofs are not typically reinforced concrete structures. Instead, for the purposes of missile protection, such BWR designs typically rely on safety-related equipment being protected against vertical missiles by concrete floor slabs, with missile shields protecting the containment. To protect the spent fuel pool, many BWR Mark I and Mark II containments rely on 24 feet or more of water above the top of the spent fuel, preventing gross structural damage to the spent fuel and the spent fuel pool from a vertical missile. The spent fuel pools are typically constructed of thick concrete walls, which provides protection against missiles in the horizontal direction. For Mark I and Mark II containments and other structures that may not have reinforced concrete roofs (e.g., some intake structures have a similar design for missile protection as that found in Mark I and Mark II containments), the staff notes that such structures would typically exhibit roof deformations in the event that snow loads significantly exceed the design margin, which would alert operators to take appropriate actions.

In addition to the structural assessment discussed above, the staff reviewed the UFSARs for the operating fleet to determine if the design-basis roof loading for a power plant may warrant additional regulatory actions when compared to an extreme roof snow loading calculated in accordance with DC/COL-ISG-7. Based on the UFSAR review and insights from the structural assessments, the staff identified five northern sites for additional assessment (Point Beach, Prairie Island, Nine Mile Point 1, Fitzpatrick, and Susquehanna).

For these five sites, the staff applied the screening criteria of warning time associated with extreme snow events. In addition to the warning time provided by the weather forecasting, the roof loading associated with an anticipated extreme snow event would take days to develop. The staff reviewed the severe weather procedures for these five sites and confirmed that these procedures direct licensees to take precautionary actions prior to winter events and to monitor potential adverse effects at these sites.

2.2.2. Qualitative Considerations

The NRC's post-Fukushima mitigating strategies order, EA-12-049, also serves to provide additional protection again extreme snow and ice. Step 2D, "Assess Impact of Snow, Ice and Extreme Cold," of NEI 12-06, the NRC-endorsed guidance document for compliance with

EA-12-049, notes that snow, ice storms, and extreme cold can be contributors to simultaneous extended loss of AC power and loss of normal access to the ultimate heat sink. NEI 12-06, Section 8.3, includes provisions for protection and deployment of FLEX equipment and notes that for sites subject to significant snowfall and ice storms, portable FLEX equipment should be stored in one of two configurations:

a. in a structure that meets the plant's design basis for the snow, ice, and cold conditions; or

b. in a structure designed to or evaluated equivalent to ASCE 7-10, "Minimum Design Load for Buildings and Other Structures," for snow, ice, and cold conditions from the site's design basis

Accordingly, mitigating strategies developed by licensees in response to Order EA-12-049 provide defense in depth should a site be adversely affected by snow and ice.

The staff also notes that:

- a structural failure of a roof due to extreme snow loads does not necessarily lead to loss of spent fuel pool or core cooling.

- it is unlikely that a roof collapse would disable multiple trains (at different physical locations) of safety-related systems.

- The extreme snow load calculation in present-day regulatory guidance is based on water being retained by a snow pack. The staff notes that in response to Generic Letter 89-22, "Potential for Increased Roof Loads and Plant Area Flood Runoff Depth at Licensed Nuclear Power Plants Due to Recent Change in Probable Maximum Precipitation Criteria Developed by the National Weather Service," some licensees made changes to their roof drain designs to provide additional paths to prevent roof ponding.

  In the staff guidance for performing IPEEEs (NUREG-1407), the staff stated:

  > "for existing plants, the NRC recommended that licensees review the information contained in Generic Letter 89-22 and determine if they need to take additional action. For the IPEEE, the severe accident risk from PMP should be assessed. The licensees should assess the effects of applying this new PMP criterion to their plants in terms of onsite flooding and roof ponding to determine whether that would lead to severe accidents."

  Roof drains were also within the scope of the flooding walkdowns performed in accordance with NTTF Recommendation 2.3 of the NRC's March 12, 2012, request for information issued pursuant to 10 CFR 50.54(f). Actions taken as a result of Generic Letter 89-22 and in response to the March 12, 2012, request for information should reduce the likelihood of gross amounts of water being trapped on roofs that are assumed under extreme snow load conditions.

2.2.3. Snow Load Conclusion

The NRC staff's preliminary conclusion is that additional regulatory actions are not warranted to address beyond-design-basis snow loads. This conclusion is based on conservatism in design, warning time associated with the event, additional capabilities to address these events based on compliance with the Order EA-12-049, and the fact that roof failures from such an events would not necessarily leading to loss of spent fuel pool or core cooling.

3.0. Stakeholder Interactions

As documented in SECY-15-0137, the staff supported several public meetings during the development of the processes described in this paper. This included a meeting held on October 6, 2015, in which the NRC staff provided the Advisory Committee on Reactor Safeguards (ACRS) Fukushima Subcommittee an overview of the staff's plans to resolve the open Tier 2 and 3 recommendations. A similar meeting occurred with the ACRS Full Committee on November 5, 2015. In addition, the staff provided an overview of its proposed resolution plans for all the open Tier 2 and 3 recommendations during a Category 2 public meeting held on October 20, 2015. The staff also briefed the Commission on status of Tier 2 and 3 activities in public meetings held on November 17, 2015, and May 17, 2016.

In addition to the meetings to support SECY-15-0137, the staff held a number of public meetings to solicit input on its evaluation of natural hazards other than seismic and flooding. The NRC staff provided a draft white paper to stakeholders for their review and comment prior to the public meetings (ADAMS Accession No. ML16039A054), which contained much of the staff's assessment found in this document. The staff held a Category 3 public meeting on April 5, 2016. In addition, the NRC staff provided an email address and accepted comments on the draft white paper through April 12, 2016. A summary of the April 5, 2016, public meeting is available in ADAMS at Accession No. ML16106A234.

The NRC staff also briefed the ACRS Fukushima Subcommittee on April 21, 2016, and ACRS Full Committee on May 5, 2016, on the staff's assessment of natural hazards other than seismic and flooding. The ACRS issued a letter on May 17, 2016 (ADAMS Accession No. ML16130A254), providing its conclusions and recommendations associated with the staff's assessment. The NRC staff intends to engage the ACRS again as it completes its assessment for high winds and snow loads and during these interactions will brief the ACRS on changes that were made to the assessment based on the ACRS's May 17, 2016.

More recently the staff held a public meeting on July 21, 2016, to solicit stakeholder comments on its approach to addressing high winds and snow loads. The summary of the meeting can be found in ADAMS at Accession No. ML16207A436.

4.0. Conclusion

Based on its assessment provided above, the staff's preliminary conclusion from the Task 3 process described in SECY-16-0074 is that high winds and snow loads do not warrant additional regulatory action.

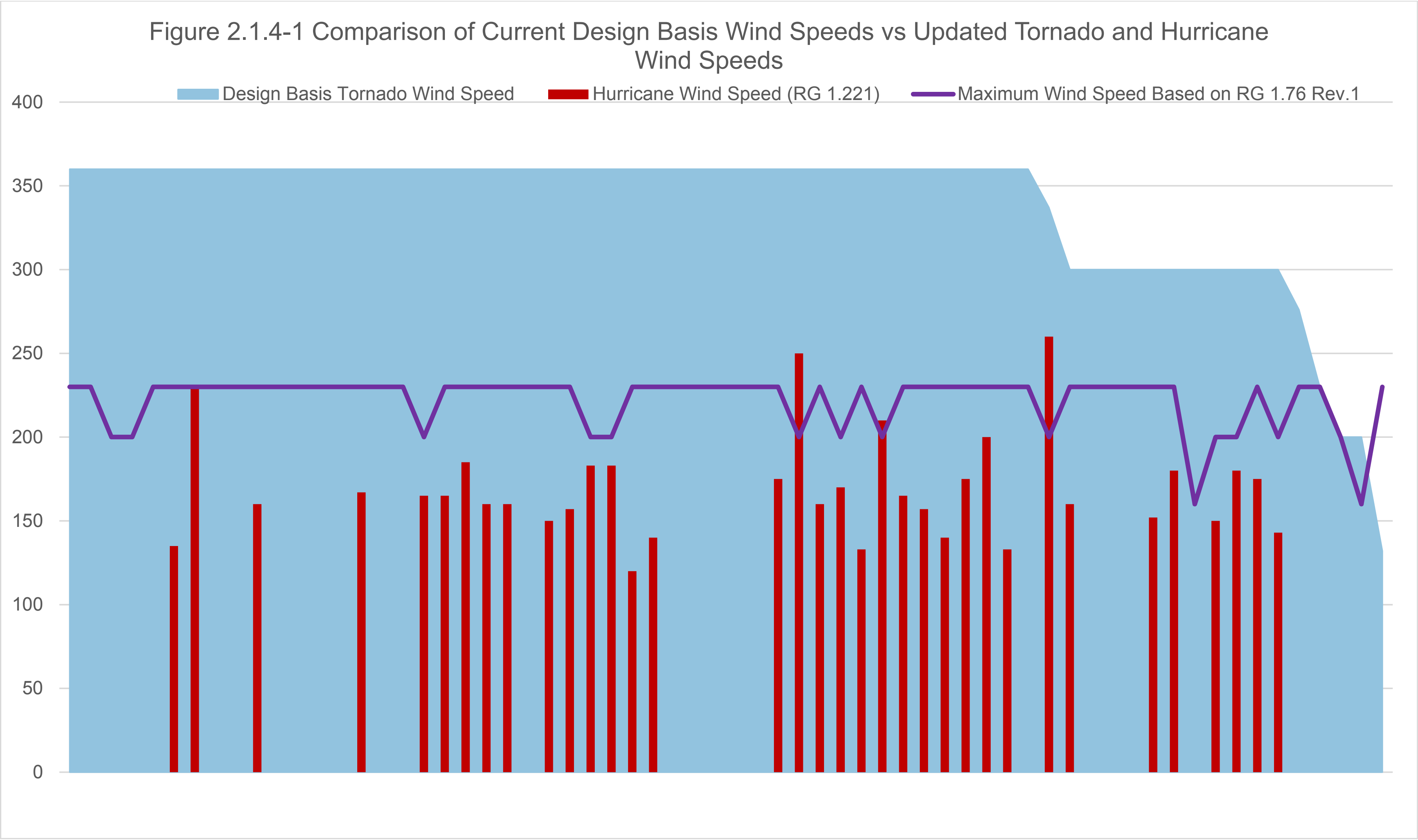
Figure 2.1.4-1 Comparison of Current Design Basis Wind Speeds vs Updated Tornado and Hurricane Wind Speeds
Design Basis Tornado Wind Speed
Hurricane Wind Speed (RG 1.221)
Maximum Wind Speed Based on RG 1.76 Rev.1
400
350
300
250
200
150
100
50
0

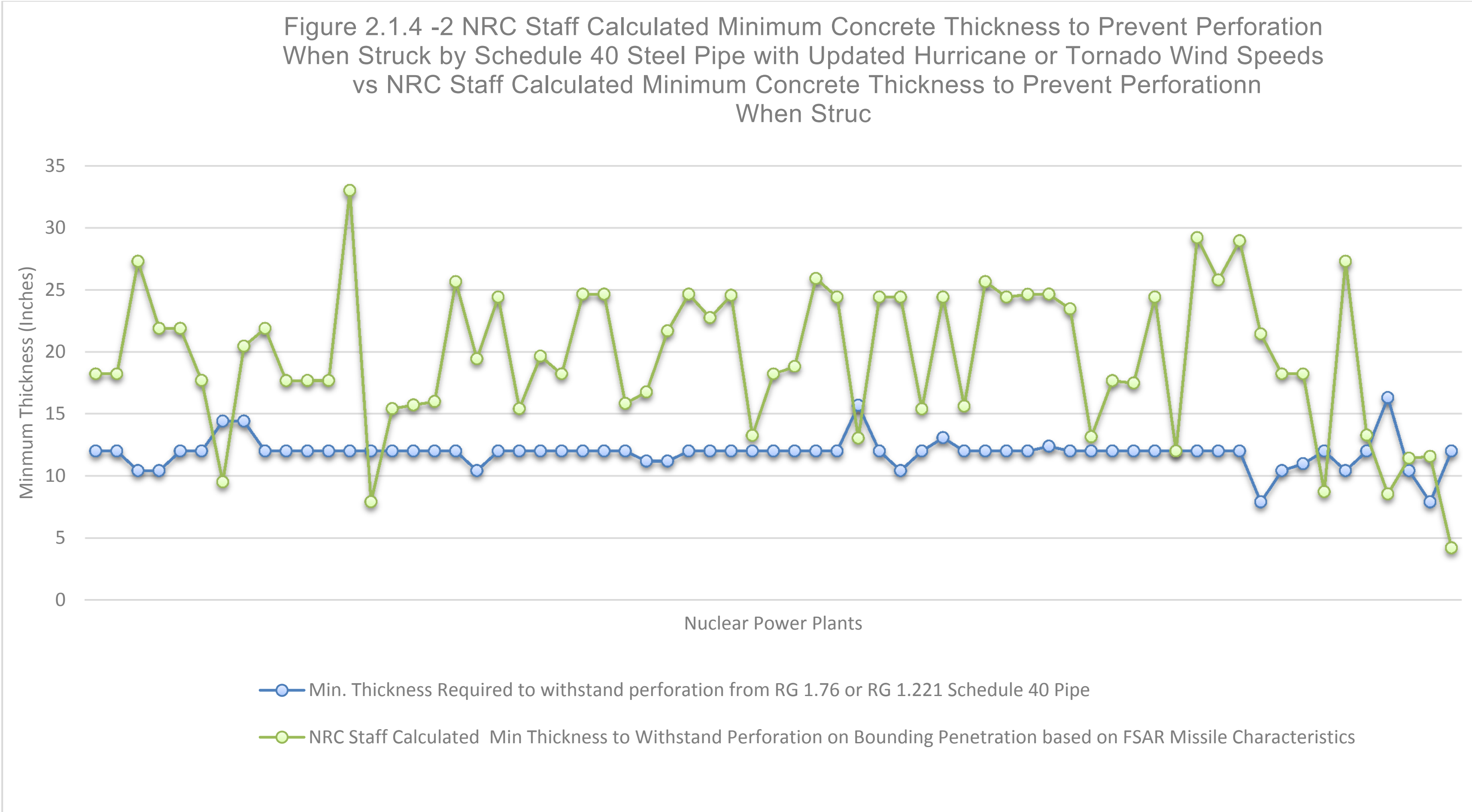
Figure 2.1.4 -2 NRC Staff Calculated Minimum Concrete Thickness to Prevent Perforation When Struck by Schedule 40 Steel Pipe with Updated Hurricane or Tornado Wind Speeds vs NRC Staff Calculated Minimum Concrete Thickness to Prevent Perforationn When Struc
35
30
25
20
15
10
5
0
Minmum Thickness (Inches)
Nuclear Power Plants
Min. Thickness Required to withstand perforation from RG 1.76 or RG 1.221 Schedule 40 Pipe
NRC Staff Calculated Min Thickness to Withstand Perforation on Bounding Penetration based on FSAR Missile Characteristics

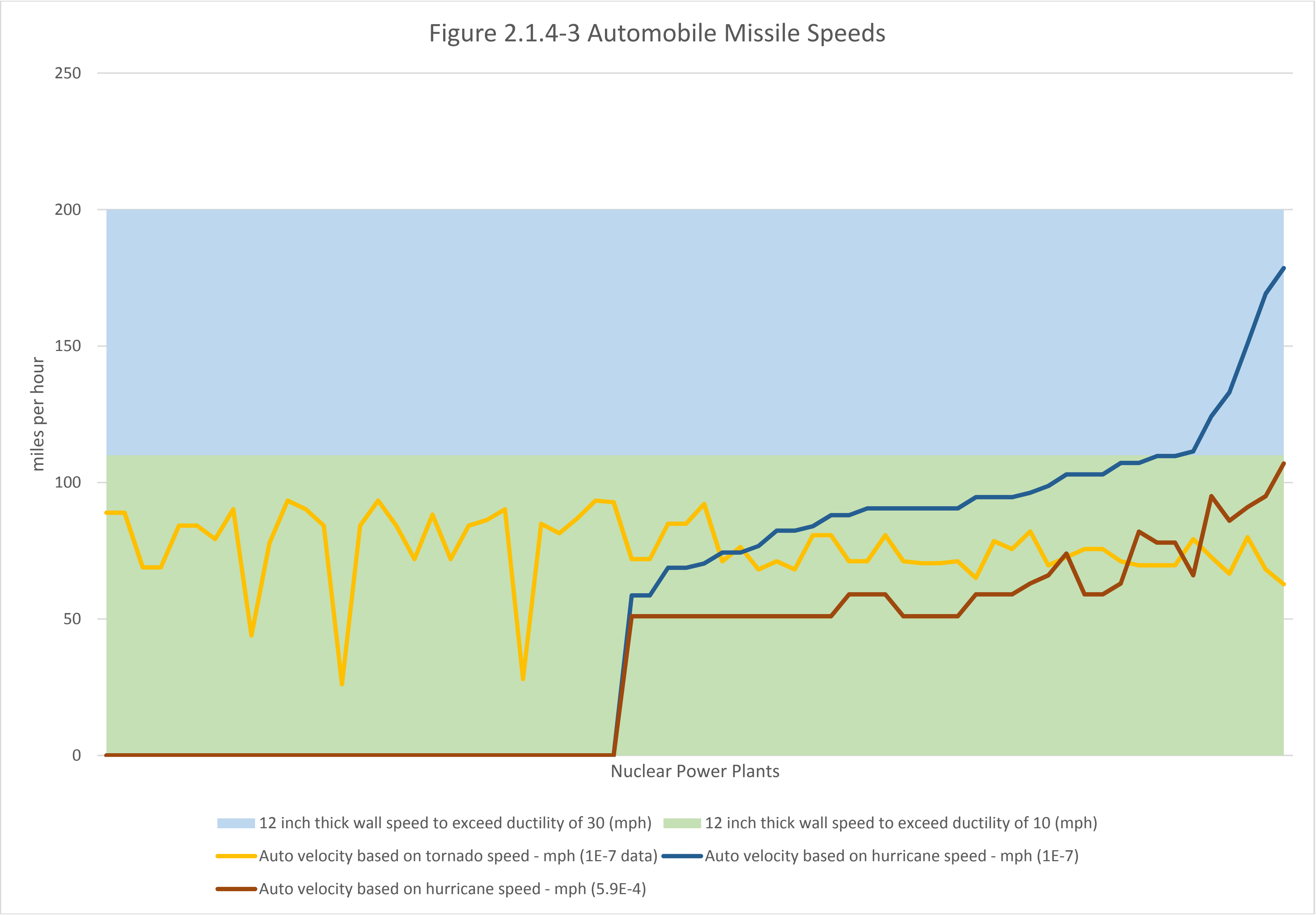
Figure 2.1.4-3 Automobile Missile Speeds
250
200
150
100
50
0
miles per hour
Nuclear Power Plants
12 inch thick wall speed to exceed ductility of 30 (mph)
12 inch thick wall speed to exceed ductility of 10 (mph)
Auto velocity based on tornado speed - mph (1E-7 data)
Auto velocity based on hurricane speed - mph (1E-7)
Auto velocity based on hurricane speed - mph (5.9E-4)

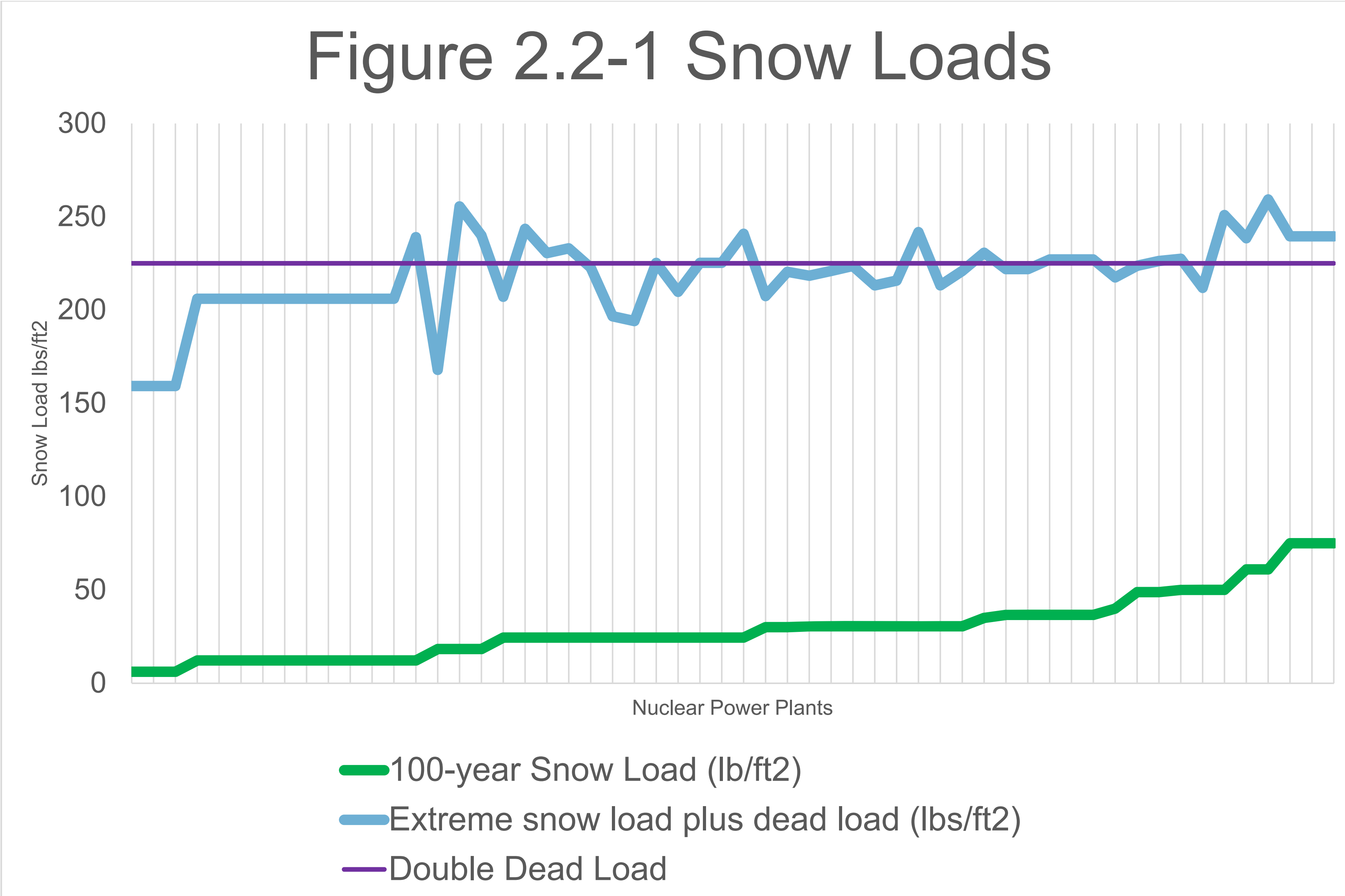

Figure 2.2-1 Snow Loads
300
250
200
150
100
50
0
Snow Load lbs/ft2
Nuclear Power Plants
100-year Snow Load (lb/ft2)
Extreme snow load plus dead load (lbs/ft2)
Double Dead Load