



U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

3.3.2 TORNADO LOADINGS

REVIEW RESPONSIBILITIES

Primary - ~~Structural Engineering Branch (SEB)~~Civil Engineering and Geosciences Branch (ECGB)¹

Secondary - None

I. AREAS OF REVIEW

The following areas relating to the design of structures that have to withstand the effects of the design basis tornado specified for the plant are reviewed to ~~assure~~ensure² conformance with the requirements of General Design Criterion 2 (GDC 2)³ ~~(Ref. 1)~~.⁴

1. The design parameters applicable to the tornado, including the tornado wind translational and tangential velocities; the tornado-generated pressure differential and its associated time interval; and the spectrum of tornado-generated missiles, including their characteristics, are reviewed from the standpoint of use in defining the input parameters for the structural design criteria appropriate to account for tornado loadings. ~~The bases for the selection and the values of these parameters are within the review responsibility of the Accident Evaluation Branch (AEB) as stated in SRP Sections 2.3.1, 2.3.2, and 3.5.1.4.~~⁵
2. The procedures that are utilized to transform the tornado parameters into effective loads on structures are reviewed, including the following:
 - a. The transformation of the tornado wind into an effective pressure applied to structures, taking into consideration the geometrical configuration and physical

DRAFT Rev. 3 - April 1996

USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

characteristics of the structures and the distribution of wind pressure on the structures.

- ~~b.~~ ~~If venting of a structure is used, the procedures for transforming the tornado-generated differential pressure into an effective reduced pressure are reviewed by the Auxiliary Systems Branch (ASB) upon SEB request.⁶~~
 - ~~eb.~~⁷ The transformation of tornado-generated missile loadings, which are impactive dynamic loads, into effective loads.
 - ~~dc.~~⁸ The combination of the above individual loadings in a manner that will produce the most adverse total tornado effect on structures.
3. The information provided to demonstrate that failure of any structure or component not designed for tornado loads will not affect the capability of other structures or components to perform necessary safety functions.

Review Interfaces

ECGB will coordinate other branch evaluations that interface with the overall review of tornado loadings, as follows:⁹

- A. The bases for selecting and the values of tornado wind translational and tangential velocities, as well as the tornado-generated pressure differential and its associated time interval, are within the review responsibilities of the Emergency Preparedness and Radiation Protection Branch (PERB) as stated in Standard Review Plan (SRP) Sections 2.3.1 and 2.3.2.¹⁰
- B. The spectrum of tornado-generated missiles, including their characteristics, are within the review responsibilities of the Plant Systems Branch (SPLB) as stated in SRP Section 3.5.1.4.¹¹
- C. If venting of a structure is used, the procedures for transforming the tornado-generated differential pressure into an effective reduced pressure are reviewed by SPLB as requested by ECGB.¹²

For those areas of review identified as part of the primary responsibility of other branches, the acceptance criteria and methods of application are contained in the referenced SRP section.¹³

II. ACCEPTANCE CRITERIA

~~SEB~~The ECGB¹⁴ accepts the design of structures that must withstand the effects of the design tornado wind load and the associated missiles if the relevant requirements of General Design Criterion 2 concerning natural phenomena are complied with. The criteria necessary to meet the relevant requirements of GDC 2 are as follows:

1. The tornado wind and associated missiles generated by the tornadic winds used in the design shall be the most severe wind that has been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which historical data has been accumulated.
2. The acceptance criteria for the tornado wind velocity, the differential pressure and its associated time interval, ~~the spectrum of tornado-generated missiles and their characteristics, and the bases for determining these parameters, are established by the Accident Evaluation Branch (AEB) as described in SRP Sections 2.3.1, 2.3.2, and 3.5.1.4.~~ and the bases for determining these parameters are established by PERB as described in SRP Sections 2.3.1 and 2.3.2. The spectrum of tornado-generated missiles and their characteristics, as well as the bases for determining these parameters are established by the SPLB as described in SRP Section 3.5.1.4.¹⁵ The approved values of these parameters should serve as basic input to the review and evaluation of the structural design procedures.
3. The acceptance criteria for the procedures used to transform the tornado parameters into effective loadings on structures are as follows:
 - a. For transforming the tornado wind velocity into an effective pressure applied to structures, the criteria delineated in ~~either~~¹⁶ the American Society of Civil Engineers (ASCE) Paper No. 3269, "Wind Forces on Structures," ~~(Ref. 2),~~¹⁷ or in ANSI A58.1, "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures" (Ref. 3) are, in general, acceptable. In particular, the following shall apply:
 - (i) The maximum velocity pressure, p , should be based upon the maximum tornado velocity, V , using the following formula:

$$p = 4.73 \times 10^{-5} V^2 \text{ kPa, in which } V \text{ is in km/h.}$$

$$(p = 0.00256 V^2 \text{ psf, in which } V \text{ is in mph}).^{18}$$
 - (ii) The velocity pressure should be assumed constant with height.
 - (iii) The maximum velocity pressure, p , applies at the radius of the tornado funnel at which the maximum velocity occurs. The tangential velocity varies with the radial distance from the center of the tornado core. The variation may be considered in accordance with that described in the paper, "Tornado Resistant Design of Nuclear Power Plants," ~~(Ref. 4).~~¹⁹
 - (iv) For calculating velocity pressures on external surfaces of structures, on external portions thereof, and on internal surfaces where there are openings in the structure, appropriate shape coefficients shall be used in accordance with ASCE Paper No. 3269 ~~(Ref. 2).~~²⁰ Gust factors may be taken as unity.

- b. If venting of a structure is adopted as a design measure to permit transforming the tornado-generated differential pressure into an effective reduced pressure, the acceptance criteria are established on a case-by-case basis, upon request, by the ~~Auxiliary Systems Branch (ASB)~~SPLB.²¹
- c. The acceptance criteria for transforming the tornado-generated missile impact into an effective or equivalent static load on structures are delineated in subsection II of SRP Section 3.5.3.
- d. Having established the effective loads for each of the above three individual tornado-generated effects, the combination thereof should then be determined in a conservative manner for each particular structure, as applicable. An acceptable method of combining these effects is as follows:
 - (i) $W_t = W_w$
 - (ii) $W_t = W_p$
 - (iii) $W_t = W_m$
 - (iv) $W_t = W_t + .5 W_p$
 - (v) $W_t = W_t + W_m$
 - (vi) $W_t = W_t + .5 W_p + W_m$

where: W_t total tornado load,
 W_w tornado wind load,
 W_p tornado differential pressure load, and
 W_m tornado missile load.

For each particular structure or portion thereof, the most adverse of the above combinations should be used, as appropriate.

These combined effects constitute the total tornado load which should then be combined with other loads as specified in SRP Sections 3.8.1, 3.8.4, and 3.8.5.

- 4. The information provided to demonstrate that failure of any structure or component not designed for tornado loads will not affect the capability of other structures or components to perform necessary safety functions, is acceptable if found in accordance with either of the following:
 - a. The postulated collapse or structural failure of structures and components not designed for tornado loads, including missiles, can be shown not to result in any structural or other damage to safety-related structures or components.

- b. Safety-related structures are designed to resist the effects of the postulated structural failure, collapse, or generation of missiles from structures and components not designed for tornado loads.

Technical Rationale²²

The technical rationale for application of these acceptance criteria for reviewing compliance with GDC 2 is discussed in the following paragraphs:

Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their intended safety functions.

The acceptance criteria outlined above include references to proven industry standards and data for evaluating tornado loading on structures. These standards and data have been reviewed by the staff and found to be acceptable.

Meeting the requirements of GDC 2 provides assurance that structures, systems, and components important to safety and subject to tornado loading will be designed to withstand the most severe tornado loads likely to occur without loss of capability to perform their intended safety functions.²³

III. REVIEW PROCEDURES

The reviewer selects and emphasizes material from the review procedures described below, as may be appropriate for a particular case.

1. The site-related parameters described in ~~subsection I.1. Review Interfaces,~~ subsection I.A,²⁴ are reviewed by the ~~Accident Evaluation Branch (AEB) PERB~~²⁵ in accordance with SRP Sections ~~2.3.1, 2.3.2, and 3.5.1.4.~~ 2.3.1 and 2.3.2. The spectrum and characteristics of tornado missiles (and venting pressure loads, if applicable), as described in subsections I.B and I.C, are reviewed by SPLB in accordance with SRP Section 3.5.1.4.²⁶ The structural reviewer examines the ~~approved values of forces and loads derived by the applicant from~~²⁷ these parameters to ~~assure~~²⁸ that they are consistent ~~with those contained in the SRP sections stated above.~~²⁹
2. After the acceptability of the site-related parameters is established, the ~~SEBECGB~~³⁰ reviewer proceeds ~~with his~~ to review ~~of~~³¹ the structural aspects of tornado design in the following manner:
 - a. The procedures used by the applicant to transform tornado wind velocities into effective pressures are reviewed and compared with those procedures delineated in either ASCE Paper No. 3269 or in ANSI A58.1, whichever is selected, and, in particular, with the acceptance criteria delineated in subsection II.3.a.
 - b. Where venting is used, procedures for transforming the tornado-generated differential pressure into an effective reduced pressure are reviewed, ~~upon~~

request, by the Auxiliary Systems Branch (ASB) upon SEB request by SPLB as requested by ECGB.³²

- c. The treatment of tornado-generated missiles is covered in SRP Section 3.5.1.4 and the review procedures for design of missile barriers are described in SRP Section 3.5.3.
 - d. After procedures for determining the individual tornado effects are reviewed, the manner in which these effects are then combined to arrive at the most adverse total tornado effect is reviewed and compared with the acceptance criteria delineated in subsection II.3.d. Other proposed methods which may depend upon the geometry and configuration of a particular structure are reviewed on a case-by-case basis.
3. The information provided to demonstrate that failure of any structure or component not designed for tornado loads will not affect the capability of other structures or components to perform necessary safety functions is reviewed to assure³³ that one of the acceptance criteria of subsection II.4 is satisfied.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.³⁴

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided to satisfy the requirements of this SRP section, and concludes that his evaluation is sufficiently complete and adequate to support the following type of statement to be included in the staff's safety evaluation report (SER).³⁵

The staff concludes that the plant design is acceptable and meets the requirements of General Design Criterion 2. This conclusion is based on the following:

³⁶The applicant has met the requirements of GDC 2 with respect to the structure capability to withstand design tornado wind loading and tornado missiles so that their design reflects:

1. Appropriate consideration for the most severe tornado recorded for the site with an appropriate margin;
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 function to be performed.

The applicant has met these requirements by using ANSI A58.1 ~~and/or~~³⁷ ASCE paper No. 3269, which the staff has reviewed and found acceptable, to transform the wind velocity generated by the tornado into an effective pressure on structures and for selecting pressure coefficients corresponding to structures geometry and physical configuration.

The applicant has designed the plant structures with sufficient margin to prevent structural damage during the most severe tornado loadings that have been determined appropriate for the site so that the requirements of Item 1 listed above are met. In addition, the design of seismic Category I structures, as required by Item 2 listed above, has included in an acceptable manner, load combinations which occur as a result of the most severe tornado wind load and the loads resulting from normal and accident conditions.

The procedures utilized to determine the loadings on structures induced by the design basis tornado specified for the plant are acceptable since these procedures have been used in the design of conventional structures and proven to provide a conservative basis which together with other engineering design considerations ~~assures~~³⁸ ~~sensures~~ that the structures ~~can~~³⁹ withstand such environmental forces.

The use of these procedures provides reasonable assurance that in the event of a design basis tornado, the structural integrity of the plant structures that have to be designed for tornadoes will not be impaired and, in consequence, safety-related systems and components located within these structures will be adequately protected and may be expected to perform necessary safety functions as required, thus satisfying the requirement of item 3 listed above.

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.⁴⁰

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.⁴¹ Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.⁴²

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."
2. ASCE Paper No. 3269, "Wind Forces on Structures," Transactions of the American Society of Civil Engineers, Vol. 126, Part II (1961).
3. ANSI A58.1-1972⁴³, "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures," Committee A58.1, American National Standards Institute.⁴⁴
4. J. R. McDonald, K. C. Mehta, and J. E. Minor, "Tornado-Resistant Design of Nuclear Power Plant Structures," Nuclear Safety, Vol. 15, No. 4, July-August 1974.

SRP Draft Section 3.3.2
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current primary review branch designation and abbreviation	Deleted "Structural Engineering Branch (SEB)" and substituted "Civil Engineering and Geosciences Branch (ECGB)."
2.	Editorial	Substituted "ensure" for "assure" to correct grammar.
3.	Editorial	Introduced "GDC 2" as initialism for "General Design Criterion 2."
4.	SRP-UDP format item	Deleted superfluous citation of reference number.
5.	SRP-UDP format item	Deleted sentence referring to review interface branch responsibility. This information is included in the new "Review Interfaces" subsection included in the text that follows.
6.	SRP-UDP format item	Deleted subsection I.2.b, referring to review interface branch responsibility. This information is included in the new "Review Interfaces" subsection included in the text that follows.
7.	Editorial	Changed paragraph designation from I.2.c to I.2.b.
8.	Editorial	Changed paragraph designation from I.2.d to I.2.c.
9.	SRP-UDP format item	Added "Review Interfaces" subsection and lead-in paragraph under REVIEW RESPONSIBILITIES.
10.	SRP-UDP format item	Added subsection I.A under "Review Interfaces," the text of which was adapted from subsection I.1.
11.	SRP-UDP format item	Added subsection I.B under "Review Interfaces," the text of which was adapted from subsection I.1.
12.	SRP-UDP format item	Added subsection I.C, under "Review Interfaces," the text of which was adapted from deleted subsection I.2.b.
13.	SRP-UDP format item	Added paragraph on interrelationship between review branches.
14.	Current primary review branch abbreviation	Replaced "SEB" with "The ECGB."

SRP Draft Section 3.3.2
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
15.	Current review interface branch abbreviations and responsibilities	Deleted the end of the sentence, "the spectrum of tornado-generated missiles and their characteristics, and the bases for determining these parameters, are established by the Accident Evaluation Branch (AEB) as described in SRP Sections 2.3.1, 2.3.2, and 3.5.1.4." Substituted "and the bases for determining these parameters are established by the PERB as described in SRP Section 2.3.1 and 2.3.2. The spectrum of tornado-generated missiles and their characteristics, as well as the bases for determining these parameters are established by the SPLB as described in SRP Section 3.5.1.4." These changes reflect current review interface branch responsibilities and abbreviations.
16.	Editorial	Deleted the word "either" which is misleading in this sentence. ANSI/ASCE 7-88 and ASCE Paper 3269 may both be used and need not be cited as alternatives.
17.	SRP-UDP format item	Deleted superfluous citation of reference number.
18.	SRP-UDP format item	Cited nomenclature and equation for tornado wind velocity pressure in SI units. Formula in English is retained, as an alternative, in parenthesis, in accordance with standard practice.
19.	SRP-UDP format item	Deleted superfluous citation of reference number.
20.	SRP-UDP format item	Deleted superfluous citation of reference number.
21.	Current review interface branch abbreviation	Substituted "SPLB" for "Auxiliary Systems Branch (ASB).
22.	SRP-UDP format item	Added "Technical Rationale" Subsection to ACCEPTANCE CRITERIA.
23.	GDC 2	Added description of the technical rationale for compliance with GDC 2.
24.	Editorial/ SRP-UDP format item	Revised description of information in subsection I to conform to revised text. Deleted "subsection I.1." and substituted "Review Interfaces, subsection I.A."
25.	Current review interface branch abbreviation	Deleted "Accident Evaluation Branch (AEB)" and substituted "PERB."
26.	Editorial/ SRP-UDP format item	Added text to describe current review interface branch responsibilities and relocated text.
27.	Editorial	Deleted "approved values of" and substituted "forces and loads that the applicant derives from" in the sentence to clarify the structural reviewers responsibility.
28.	Editorial	Substituted "ensure" for "assure" to correct grammar.

SRP Draft Section 3.3.2
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
29.	Editorial	Deleted the phrase "with those contained in the SRP sections stated above" at the end of the sentence to clarify the structural reviewers responsibility.
30.	Current primary review branch abbreviation	Deleted "SEB" and substituted "ECGB."
31.	Editorial	Modified to eliminate gender-specific pronoun.
32.	Current review interface branch and primary review branch abbreviations	Deleted citation of ASB and SEB and substituted SPLB and ECGB respectively. Deleted redundant words in existing sentence.
33.	Editorial	Substituted "ensure" for "assure" to correct grammar.
34.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
35.	Editorial	Provided "SER" as initialism for "safety evaluation report."
36.	Editorial	Indented 5 paragraphs of description of staff's bases for concluding that applicant meets GDC, in accordance with format in other SRP sections.
37.	Editorial	Substituted the word "or" for "and" in the sentence to conform the citations in the rest of the SRP section.
38.	Editorial	Substituted "ensures" for "assures" to correct grammar.
39.	Editorial	Added the word "can" in the sentence to improve the grammar.
40.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
41.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
42.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
43.	Integrated Impact 1470	Added the applicable version date to the reference for ANSI A58.1.
44.	Integrated Impact No. 522	This is a placeholder integrated impact. Consideration should be given to updating the citations of ANSI A58.1 to the latest version (ANSI/ASCE 7-88).

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SRP Draft Section 3.3.2
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
522	Update citation of ANSI A58.1 to the current version (ANSI/ASCE 7-88)	This is a placeholder integrated impact and will not be processed further.
523	Add Review Procedures to SRP Section 3.3.2 to identify further acceptable methods for the consideration of tornado loadings, based on NRC approval of applications that reference Bechtel Topical Report BC-TOP-3.	No modifications were made to SRP Section 3.3.2 based on Integrated Impact No. 523. Use of topical reports is an option for applicants but topical reports are not usually cited by the NRC staff in the SRP.
1470	Update the citation of ANSI A58.1 to cite the 1972 version.	REFERENCES
1471	Revise the Review Procedures to address the staff's position regarding maximum tornado wind speeds.	Note: This issue is adequately addressed through the existing interface with SRP Section 2.3.1 and the changes implemented to that section by ROC 226. This ROC will not be processed further.