U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

3.3.2 TORNADO LOADINGS

REVIEW RESPONSIBILTIES

Primary - Structural Engineering Branch (SEB)

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 conformance with the requirements of General Design Criterion 2 (Ref. 1).

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.

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 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.

c. The transformation of tornado-generated missile loadings, which are impactive dynamic loads, into effective loads.

d. 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.

II. ACCEPTANCE CRITERIA

SEB 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. The approved values of these paramenters 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 the American Society of Civil Engineers (ASCE) Paper No. 3269, "Wind Forces on Structures" (Ref. 2), 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:

$$p = 0.00256\ V^2 \text{ psf, in which V is in mph.}$$

      (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).

(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). 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).

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) $W_t = W_w + .5\ W_p$
(v) $W_t = W_w + W_m$
(vi) $W_t = W_w + .5\ W_p + W_m$

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.

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. are reviewed by the Accident Evaluation Branch (AEB) in accordance with SRP Sections 2.3.1, 2.3.2, and 3.5.1.4. The structural reviewer examines the approved values of these parameters to assure that they are consistent with those contained in the SRP sections stated above.

2. After the acceptability of the site-related parameters is established, the SEB reviewer proceeds with his review of 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.

   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 assure that one of the acceptance criteria of subsection II.4 is satisfied.

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.

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:

The 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 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 that the structures 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.

V. IMPLEMENTATION

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

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.

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, "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures," Committee A58.1, American National Standards Institute.

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.