

# Draft for Comment



## U.S. NUCLEAR REGULATORY COMMISSION **DESIGN-SPECIFIC REVIEW STANDARD FOR NuScale SMR DESIGN**

### **3.3.1 SEVERE WIND LOADING**

#### **REVIEW RESPONSIBILITIES**

**Primary -** Organization responsible for structural analysis reviews

**Secondary -** None

#### **I. AREAS OF REVIEW**

The following areas are related to the design of structures that must withstand the effects of the specified design wind speed for the plant. These areas are reviewed to ensure conformance with Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Appendix A, General Design Criterion (GDC) 2.

The specific areas of review are as follows:

1. The design wind speed, its recurrence interval, the speed variation with height, and the applicable gust factors from the standpoint of use in defining the input parameters for the structural design criteria appropriate to account for wind loadings.
2. The procedures that are used to transform the design wind speed into an equivalent pressure applied to structures are reviewed taking into consideration the geometrical configuration and physical characteristics of the structures and the distribution of wind pressure on the structures.
3. Regulatory treatment of non-safety systems (RTNSS) "B" SSCs relied upon for maintaining key safety functions after 72 hours following the onset of postulated accidents should be protected from the effects of severe winds which is addressed in this DSRS Section. Selection of RTNSS "B" SSCs and compliance with other augmented design standards are reviewed in accordance with guidance in SRP Section 19.3 and other applicable DSRS.
4. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this Design Specific Review Standard (DSRS) section in accordance with DSRS Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this DSRS section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with Standard Review Plan (SRP) Section 14.3.

5. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

6. Wind Load Effects for NuScale Applications

The specific areas of review items 1 through 5 discussed above are generally applicable provided that unique NuScale design features and containment configurations as described below are adequately accounted for in the review.

The NuScale light-water small modular reactor (SMR) is a small-size reactor inside a tightly conforming containment in a below-grade water-filled reactor pool in the reactor building with up to 12 total reactor modules. A refueling bay and the spent fuel pool are also part of the reactor building pool within the reactor building structure. The reactor/containment modules are moved to the refueling bay for inspection, refueling and transfer of spent fuel to the spent fuel pool for storage. The reactor building sits above the reactor module pool, the refueling bay, and the spent fuel pool. The pools are below grade. The turbine generator buildings sit above grade on either side of the reactor building. The control room building, with the control room below grade, also sits next to one end of the reactor building. The radwaste building is above grade and sits adjacent to the reactor building at the end opposite from the control room building. This DSRS section determines the design basis severe wind speed loads for all Seismic Category I structures.

### Review Interfaces

Other SRP and DSRS sections interface with this section as follows.

1. The adequacy of the most severe regional and local meteorological data used to specify design wind load parameters for SSCs of the nuclear power plant that may be affected by weather phenomena is reviewed in accordance with SRP Sections 2.3.1 and 2.3.2.
2. Review of the description and results of the probabilistic risk assessment is performed under SRP 19.0, and RTNSS, for passive advanced light water reactors, is reviewed under SRP Section 19.3 and those DSRS sections that address specific non-safety SSCs within the scope of RTNSS.

The specific acceptance criteria and review procedures are contained in the referenced SRP and DSRS Sections.

## I. ACCEPTANCE CRITERIA

### Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR 50, Appendix A, GDC 2 requires that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions as it relates to natural phenomena. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.
2. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission (NRC) regulations.
3. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

### DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. As an alternative, and as described in more detail below, an applicant may identify the differences between a DSRS section and the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and discuss how the proposed alternative provides an acceptable method of complying with the NRC regulations that underlie the DSRS acceptance criteria.

1. The wind speed 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 have been accumulated.
2. The acceptance criteria for the design wind speed, its recurrence interval, the speed variation with height, the applicable gust factors, and the bases for determining these site-related parameters, are stated in SRP Sections 2.3.1 and 2.3.2. The approved values of these parameters should serve as basic input to the review and evaluation of the structural design procedures.
3. The procedures used to transform the wind speed into an equivalent pressure to be applied to structures and parts, or portions of structures, as delineated in American

Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 7-05, "Minimum Design Loads for Buildings and Other Structures," are acceptable. In particular, the procedures used are acceptable if found in accordance with the following:

- A. For a design wind speed,  $V$ , the basic velocity pressure,  $q_z$ , evaluated at height,  $z$ , is given by:

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I \text{ (lb/ft}^2\text{)}$$

Where:

$K_z$  = velocity pressure exposure coefficient evaluated at height,  $z$ , as defined in ASCE/SEI 7-05, Table 6-3, but not less than 0.87

$K_{zt}$  = topographic factor equal to 1.0

$K_d$  = wind directionality factor equal to 1.0

$V$  = design wind speed in miles per hour (mi/h) as stated in SRP Section 2.3.1

$I$  = importance factor equal to 1.15

- B. For each wind direction considered, the upwind exposure category should be based on ground surface roughness that is determined from natural topography, vegetation, and constructed facilities. Surface roughness C is defined as open terrain with scattered obstructions having heights generally less than 30 ft. This category includes flat open country, grasslands, and all water surfaces in hurricane prone regions. Because most nuclear power plants are located in relatively open country,  $K_z$  values in Table 6-3 should be selected from the Exposure C column. The definition of Exposure C is provided in ASCE/SEI 7-05, Section 6.5.6.3.
- C. Design wind loads should be determined in accordance with the following sections in ASCE/SEI 7-05, as applicable.
- i. Section 6.5.12 - Design Wind Loads on Enclosed and Partially Enclosed Buildings
  - ii. Section 6.5.13 - Design Wind Loads on Open Buildings with Monoslope, Pitched, or Troughed Roofs
  - iii. Section 6.5.14 - Design Wind Loads on Solid Freestanding Walls and Signs
  - iv. Section 6.5.15 - Design Wind Loads on Other Structures
4. The staff will evaluate and verify that RTNSS "B" SSCs are protected against or designed to withstand the effects of severe winds including gusts and sustained winds without loss of the capability to perform their intended safety functions.

## Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Compliance with GDC 2 requires that nuclear power plant SSCs important to safety shall 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.
2. The acceptance criteria outlined above include reference to proven industry standards and data for evaluating wind loading on structures. These standards and data have been reviewed by and are acceptable to the staff.
3. Meeting the requirements of GDC 2 provides assurance that SSCs important to safety will withstand the most severe wind loads without loss of capability to perform their intended safety functions.

### III. REVIEW PROCEDURES

The reviewer will select and emphasize material from the procedures described below, as may be appropriate for a particular case.

These review procedures are based on the identified DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

1. Selected Programs and Guidance - In accordance with the guidance in NUREG-0800, "Introduction - Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Integral Pressurized Water Reactor Edition" (NUREG-0800 Intro Part 2) as applied to this DSRS Section, the staff will review the information proposed by the applicant to evaluate whether it meets the acceptance criteria described in Subsection II of this DSRS. As noted in NUREG-0800 Intro Part 2, the NRC requirements that must be met by an SSC do not change under the SMR framework. Using the graded approach described in NUREG-0800 Intro Part 2, the NRC staff may determine that, for certain structures, systems, and components (SSCs), the applicant's basis for compliance with other selected NRC requirements may help demonstrate satisfaction of the applicable acceptance criteria for that SSC in lieu of detailed independent analyses. The design-basis capabilities of specific SSCs would be verified where applicable as part of completion of the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is described in Figure 1 of NUREG-0800, Introduction - Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:
  - 10 CFR Part 50, Appendix A, General Design Criteria (GDC), Overall Requirements, Criteria 1 through 5
  - 10 CFR Part 50, Appendix B, Quality Assurance (QA) Program
  - 10 CFR 50.49, Environmental Qualification of Electrical Equipment (EQ) Program

- 10 CFR 50.55a, Code Design, Inservice Inspection and Inservice Testing (ISI/IST) Programs
- 10 CFR 50.65, Maintenance Rule requirements
- Reliability Assurance Program (RAP)
- 10 CFR 50.36, Technical Specifications
- Availability Controls for SSCs Subject to Regulatory Treatment of Non-Safety Systems (RTNSS)
- Initial Test Program (ITP)
- Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

This list of examples is not intended to be all-inclusive. It is the responsibility of the technical reviewers to determine whether the information in the application, including the degree to which the applicant seeks to rely on such selected programs and guidance, demonstrates that all acceptance criteria have been met to support the safety finding for a particular SSC.

1. In accordance with 10 CFR 52.47(a)(8),(21), and (22), and 10 CFR 52.79(a)(17), (20) and (37) for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues that are identified in the version of NUREG-0933 current on the date up to six months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding safety evaluation report (SER) section.
3. The design wind speed parameters for severe wind loading described in subsection I.1 are reviewed in accordance with SRP Sections 2.3.1 and 2.3.2. The staff examines these parameters to ensure that they are consistent with those contained in SRP Sections 2.3.1 and 2.3.2, as applicable to the specific 10 CFR Part 52 application types.
4. After the acceptability of the design basis wind speed parameters is established, the reviewer proceeds with the evaluation of the structural aspects of wind design. The procedures used by the applicant to transform wind speeds into equivalent pressures are reviewed and compared with those procedures delineated in subsection II of this DSRS.
5. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. The reviewer should also consider the appropriateness of identified COL action items in the design control document. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

#### IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

The applicant has met the requirements of GDC 2 with respect to the capability of the structures to withstand design wind loading so that their design reflects the following:

1. Appropriate consideration for the most severe wind 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 designed the plant structures with sufficient margin to prevent structural damage during the most severe wind loadings that have been determined appropriate for the site so that the requirements in Item 1 listed above are met. The applicant has used methods provided in ASCE/SEI 7-05, which the staff reviewed and found acceptable, to transform the wind speed into an equivalent pressure on structures and to select pressure coefficients corresponding to the structure's geometry and physical configuration.

The procedures used to determine the loadings on structures induced by the design wind speed specified for the plant are acceptable because these procedures have been used in the design of conventional structures and proven to provide an adequate basis which together with other engineering design considerations ensures that the structures will withstand such environmental forces. In addition, the design of seismic Category 1 structures, as required by Item 2 listed above, has included load combinations of the most severe wind load and the loads resulting from normal and accident conditions.

The use of these procedures provides reasonable assurance that in the event of design basis winds, the structural integrity of the plant structures that must be designed to resist the effects of the design wind speed will not be impaired and, in consequence, safety-related systems and components located within these structures are adequately protected and will perform their intended safety functions if needed, thus satisfying the requirement of Item 3 listed above.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

## V. IMPLEMENTATION

The regulations in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), and 10 CFR 52.79(a)(41) establish requirements for applications for ESPs, DCs, and COLs, respectively. These regulations require the application to include an evaluation of the site (ESP), standard plant design (DC), or facility (COL) against the Standard Review Plan (SRP) revision in effect six months before the docket date of the application. While the SRP provides generic guidance, the staff developed the SRP guidance based on the staff's experience in reviewing applications for construction permits and operating licenses for large light-water nuclear power reactors. The proposed small modular reactor (SMR) designs, however, differ significantly from large light-water nuclear reactor power plant designs.

In view of the differences between the designs of SMRs and the designs of large light-water power reactors, the Commission issued SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (ML102510405) (SRM). In the SRM, the Commission directed the staff to develop risk-informed licensing review plans for each of the SMR design reviews, including plans for the associated pre-application activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for the evaluation of a NuScale-specific application submitted pursuant to 10 CFR Part 52, and the staff has determined that each application may address the DSRS in lieu of addressing the SRP, with specified exceptions. These exceptions include particular review areas in which the DSRS directs reviewers to consult the SRP and others in which the SRP is used for the review. If an applicant chooses to address the DSRS, the application should identify and describe all differences between the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and the guidance of the applicable DSRS section (or SRP section as specified in the DSRS), and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria.

The staff has accepted the content of the DSRS as an alternative method for evaluating whether an application complies with NRC regulations for NuScale SMR applications, provided that the application does not deviate significantly from the design and siting assumptions made by the NRC staff while preparing the DSRS. If the design or siting assumptions in a NuScale application deviate significantly from the design and siting assumptions the staff used in preparing the DSRS, the staff will use the more general guidance in the SRP as specified in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), or 10 CFR 52.79(a)(41), depending on the type of application. Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design or siting assumptions.



## VI. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena."
2. American Society of Civil Engineers/Structural Engineering Institute. "Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-05," American Society of Civil Engineers, Reston, Virginia, 2006.