

U.S. NUCLEAR REGULATORY COMMISSION



# DESIGN-SPECIFIC REVIEW STANDARD FOR NuSCALE SMR DESIGN

## 10.4.4 TURBINE BYPASS SYSTEM

### REVIEW RESPONSIBILITIES

**Primary -** Organization responsible for the review of power conversion systems.

**Secondary -** None

#### I. AREAS OF REVIEW

The turbine bypass system (TB) is designed to discharge a stated percentage of rated main steam flow directly to the main condensers, bypassing the turbine. This steam bypass enables the plant to take step load reductions up to the TB capacity without the reactor or turbine tripping. The system is also used during startup and shutdown to control steam generator pressure. The TB is not required for safe shutdown, as the relief and safety valves are operated under emergency conditions. The system is not required to function as a heat sink for the prevention or mitigation of postulated accidents. Failure of the TB during a load reduction or turbine trip would result in the actuation of the relief valves and possibly the safety valves.

The specific areas of review are as follows:

1. Review of the system from the branch connection at the main steam system to the main condensers.
2. Review of the TB to determine that a failure of the system or system components will not have an adverse effect on essential equipment.
3. Review of the TB functional requirements for both normal and abnormal operating conditions, and with respect to the following: (1) capability to isolate those portions of the system that could leak or malfunction; (2) capability to perform adequate operational testing and inservice inspection; (3) to ensure there are no adverse effects of postulated system piping failures on safety-related or Regulatory Treatment of Nonsafety Systems (RTNSS) Category B equipment; and (4) to reduce the possibility of reactor transients due to inadvertent operation of the TB from faults in the TB instrumentation and control.
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 Standard Review Plan (SRP) 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 SRP-Sections 14.3 and DSRS Section 14.3.7.

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.

### Review Interfaces

Other DSRS/SRP sections interface with this section as follows:

1. Review to ensure conformance to Branch Technical Position (BTP) 3-3, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," concerning cracks and breaks in high- and moderate-energy piping outside containment is performed under SRP Section 3.6.1.
2. Review of the fire protection program is performed under SRP Section 9.5.1.1.
3. Review of the seismic and quality group classifications is performed under SRP Sections 3.2.1 and 3.2.2.
4. Review to ensure conformance to BTP 3-4, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment," concerning cracks and breaks in high- and moderate-energy piping outside containment.
5. Review to ensure the steam bypass capacity is consistent with reactor transient analysis is performed under DSRS Section 4.4.
6. Acceptability of the preoperational and startup tests is performed under DSRS Section 14.2.
7. Review of technical specifications is performed under DSRS Section 16.0.
8. Review of quality assurance programs is performed under SRP Chapter 17.
9. Review of the probabilistic risk assessment performed under SRP Chapter 19.0 for potential risk significance of TB elements.

For those areas of review identified above as part of the primary review responsibility of other staff, the acceptance criteria necessary for the review and their methods of application are contained in the referenced DSRS/SRP sections of the corresponding primary reviewers.

## II. ACCEPTANCE CRITERIA

### Requirements

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

1. General Design Criterion (GDC) 4, Environmental and Dynamic Effects Design Bases.

2. GDC 34, Residual Heat Removal.
3. 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 facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) rules and regulations.
4. 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 COL, the provisions of the AEA, and the NRC's rules and regulations.

#### DSRS Acceptance Criteria

1. 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.
2. Piping Failures. The requirements of GDC 4 related to the ability SSCs important to safety to meet environmental conditions associated with normal operation, maintenance, testing, and postulated accident conditions is met by demonstrating that failure of the TB due to a pipe break or malfunction of the TB will not adversely affect essential systems or components (i.e., those necessary for safe shutdown or accident prevention or mitigation).
3. Residual Heat Removal. The requirements of GDC 34 related to providing a reliable system that removes residual heat during normal plant shutdown is met by demonstrating the ability to use the turbine bypass system for shutting down the plant during normal operations. The operation of the TB eliminates the need to rely solely on safety systems, which are required to meet the redundancy and power source requirements of this criterion.

#### 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. GDC 4 requires that SSCs important to safety be designed to meet environmental conditions associated with normal operation, maintenance, testing, and postulated accident. However, dynamic effects associated with postulated pipe ruptures in nuclear power plants may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of a rupture in the

fluid system piping is extremely low under conditions consistent with the design basis for the piping.

Although the turbine bypass system is not classified as a system important to safety, GDC 4 applies to this DSRS section because a failure of the TB or one of its components could have an adverse impact on a safety-related or risk-significant structure, system, or component.

Meeting the requirements of this criterion provides a level of assurance that SSCs will not be adversely affected by a failure of the turbine bypass system.

2. GDC 34 requires that the applicant provide a system to remove residual heat, and it establishes specific requirements related to performance, redundancy, and reliability.

Although the TB is not the residual heat removal system specified in GDC 34, it can perform that function. GDC 34 applies to this SRP section because using the TB during normal plant shutdown reduces demands on systems important to safety.

Meeting the requirements of this criterion provides a level of assurance that the residual heat removal system will remain operable and that safety systems will have the capability to transfer residual heat from the reactor core at a rate that does not exceed specified fuel design limits or the design conditions of the reactor pressure boundary.

### III. REVIEW PROCEDURES

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.

2. In accordance with 10 CFR 52.47(a)(8),(21), and (22), and 10 CFR 52.79(a)(17), (20) and (37), for design certification or combined 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 which are identified in the version of NUREG-0933 current on the date up to 6 months before the docket date of the application and which 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) for a DC application, and except paragraphs (f)(1)(xii), (f)(2)(ix), (f)(2)(xxv), and (f)(3)(v) for a COL application. 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 application is reviewed to determine that the system description and schematics and piping and instrumentation diagrams (P&IDs) delineate the system and components.
4. The safety analysis report (SAR) is reviewed to verify that the system design bases and an evaluation of the system capacity are provided, including valve capacity in terms of percentage of rated main steam flow, the maximum reactor power step change the system is designed to accommodate without a reactor or turbine trip, and the maximum electric load step change the reactor is designed to accommodate without reactor control rod motion or steam bypassing.
5. The reviewer uses engineering judgment and the results of failure modes and effects analyses to determine that:
  - A. Failure of the TB to operate will not preclude operation of any essential systems. Statements in the SAR that confirm the above are acceptable.
  - B. Failure of the TB high energy piping will not have adverse effects on any safety-related or RTNSS B systems or components that may be located close to the system.

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. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. 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 DCD.

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 (ESP) 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 technical review and analysis 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 TB includes all components and piping from the branch connection at the main steam system to the main condensers. The scope of review of the turbine bypass system included layout drawings, P&IDs, and descriptive information for the TB and auxiliary supporting systems that are essential to its operation.

The basis for acceptance of the TB in the staff's review was conformance of the designs, design criteria, and design bases to the Commission's regulations as set forth in GDC 4 and GDC 34 of Appendix A to 10 CFR Part 50.

1. The applicant has met the requirements of GDC 4, "Environmental and Dynamic Effects Design Bases," with respect to the system being designed such that a safe shutdown will not be precluded as a result of the TB failure and the programmatic requirements will provide assurance that the TB will be designed, installed, and tested as described in the DCD or the FSAR.
2. The applicant has met the requirements of GDC 34, "Residual Heat Removal," with respect to the ability to use the turbine bypass system for shutting down the plant during normal operations. The turbine bypass system is designed such that sufficient steam can be bypassed to the main condenser so that the plant can be shutdown during normal operations without using the turbine generator.

The staff concludes that the design of the turbine bypass system conforms to all applicable GDCs, staff positions and industry standards and is therefore acceptable.

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 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 4, "Environmental and Dynamic Effects Design Bases."
2. 10 CFR Part 50, Appendix A, GDC 34, "Residual Heat Removal."
3. 10 CFR 52.47, "Contents of applications; technical information."
4. 10 CFR 52.80(A), "Contents of applications; additional technical information."

5. Regulatory Guide 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.”
6. Regulatory Guide 1.68, “Initial Test Programs for Water-Cooled Nuclear Power Plants,”