



U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

6.2.1 CONTAINMENT FUNCTIONAL DESIGN

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of Containment Integrity

Secondary - None

I. AREAS OF REVIEW

NuScale is an integral pressurized-water, small modular reactor (SMR) with the reactor, steam generator, pressurizer, and control rod drives all in a single pressure vessel. The NuScale reactor containment is an evacuated, low-alloy steel vessel surrounding the smaller reactor vessel and immersed in a large, borated reactor building pool that serves as the passive ultimate heat sink for containment heat removal.

The responsible staff reviews information regarding the functional capability of the reactor containment presented in Section 6.2.1 of the application. The containment encloses the reactor system and is the final barrier against the release of significant amounts of radioactive fission products in the event of an accident. The containment structure must be capable of withstanding, without loss of function, the pressure and temperature conditions resulting from postulated loss-of-coolant accident (LOCA), steam line, or feedwater line break accidents. The containment structure must also maintain long-term functional integrity after a postulated accident (i.e., it must remain a low leakage barrier against the release of fission products for as long as postulated accident conditions require). The containment structure must be able to withstand postulated hydraulic forces caused by being immersed in the reactor building pool, flooding, and tsunami hazards.

The design and sizing of containment systems are largely based on the pressure and temperature conditions that result from release of the reactor coolant during a LOCA. The containment design basis includes the effects of stored energy in the reactor coolant system, decay energy, and energy from other sources, such as the secondary system and metal-water reactions, including the recombination of hydrogen and oxygen. The containment system is not required to be a complete and independent safeguard against a LOCA by itself, but it functions to contain any fission products released while the emergency core cooling system (ECCS) cools the reactor core.

The evaluation of a containment functional design includes calculation of the various effects associated with the postulated rupture in the primary or secondary coolant system piping. The subsequent thermodynamic effects in the containment resulting from the release of the coolant mass and energy are determined from a solution of the incremental space and time-dependent energy, mass, and momentum conservation equations. The basic functional design requirements for containment are given in General Design Criteria (GDC) 4, 16, and 50 in Appendix A to Title 10 of *Code of Federal Regulations* (10 CFR) Part 50, and in 10 CFR Part 50, Appendix K. GDC 4 provides the basic environmental and dynamic effects design requirements for all structures, systems, and components (SSCs) important to safety, including

leak-before-break. GDC 16 establishes the fundamental requirement to design a containment that is essentially a leak-tight barrier against the uncontrolled release of radioactivity to the environment. GDC 50, among other things, requires that consideration be given to the potential consequences of degraded engineered safety features, such as the containment heat removal system and the ECCS, the limitations in defining accident phenomena, and the conservatism of calculation models and input parameters in assessing containment design margins. And 10 CFR Part 50 Appendix K.I.D.2 requires that the containment pressure used for evaluating cooling effectiveness during reflood and spray cooling shall not exceed a pressure calculated conservatively for this purpose. The regulation in 10 CFR 50 Appendix K.I.A provides the sources of energy that are required and acceptable to be included in determining the mass and energy release from loss-of-coolant accidents and secondary systems pipe ruptures.

The various aspects to be reviewed under this Design-Specific Review Standard (DSRS) section have been separated and assigned to a set of other Standard Review Plan (SRP) and DSRS sections as follows:

1. NuScale SMR evacuated containment, DSRS Section 6.2.1.1.A.
2. "Subcompartment Analysis," SRP Section 6.2.1.2.
3. "Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents," DSRS Section 6.2.1.3.
4. "Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures," DSRS Section 6.2.1.4.

Areas related to the evaluation of the containment functional capability are treated in other DSRS sections (e.g., "Containment Heat Removal" (DSRS Section 6.2.2), "Containment Isolation System" (DSRS Section 6.2.4), "Combustible Gas Control in Containment" (DSRS Section 6.2.5), and "Containment Leakage Testing" (DSRS Section 6.2.6)). In addition, the evaluation of the secondary containment functional design capability is reviewed in SRP Section 6.2.3, even though the NuScale SMR design does not credit secondary containment functions.

The specific areas of review are described in the Areas of Review subsections of the five SRP and DSRS sections listed above.

Review Interfaces:

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

1. the review of effects of static and dynamic hydraulic forces on containment caused by tsunami hazards under SRP Section 2.4.6.
2. the review of flooding protection measures under SRP Section 2.4.10.
3. the review of effects of groundwater on the underground containment structure, including effects of groundwater levels, piezometric/hydraulic heads, and other hydrodynamic effects of groundwater on the design bases of subsurface safety-related SSCs under SRP Section 2.4.12.
4. the design adequacy of mechanical components and their supports under SRP Section 3.9.3.

5. the review of areas relating to steel containments or to other Class MC steel portions of steel/concrete containments under DSRS Section 3.8.2.
6. determination of SSC risk significance under SRP Section 19.0.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are given in the Acceptance Criteria subsections of the SRP and DSRS sections listed above.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the U.S. Nuclear Regulatory Commission's (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 (for design certification (DC) and combined operating license (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.

III. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the staff's technical review and analysis, as augmented by the application of programmatic requirements in accordance with the staff's technical review approach in the DSRS Introduction, support including the following conclusions in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. Containment Functional Design

The scope of review of the functional design of the containment for the NuScale nuclear power plant design has included a review of plant arrangement drawings, system drawings, and descriptive information for the containment building, subcompartments, and associated SSCs that are essential to the functional capability and integrity of the containment. The review has included the applicant's proposed design bases for the containment building and internal structures, and associated SSCs upon which the containment function depends, and the applicant's analysis of postulated accidents and operational occurrences that support the adequacy of the design bases.

The basis for the staff's acceptance has been conformance of designs and design bases for the containment building, internal structures, and associated SSCs to the Commission's regulations, as set forth in GDCs, and applicable regulatory guides, branch technical positions, and industry codes and standards. (Special problems or exceptions that the staff takes to the design or functional capability of containment SSCs should be discussed.)

To support the basis for the staff's acceptance of the containment system, the reviewer of the containment system should include in the staff's safety evaluation report, as necessary, the results of the reviews for the five Areas of Review SRP and DSRS sections above. The SER writeup should demonstrate conformance with the Commission's

regulations in the manner indicated. The staff concludes that the containment functional design is acceptable and meets the requirements of GDC 4, 16, and 50 and 10 CFR Part 50 Appendix K. The conclusion is based on the following: (The reviewer should discuss each item of the regulations or related set of regulations as indicated.)

2. The applicant has met the requirements of (cite regulation) with respect to (state limits of review in relation to regulation) by (for each item that is applicable to the review, state how it was met and why it is acceptable with respect to regulation being discussed):
 - A. meeting the regulatory positions in Regulatory Guide (RG)_____ or guides
 - B. providing and meeting an alternative method to regulatory positions in RG _____, that the staff has reviewed and found to be acceptable because _____
 - C. meeting the regulatory position in the branch technical position (BTP)
 - D. using calculation methods for (state what was evaluated) that have previously been reviewed by the staff and found acceptable; the staff has reviewed the impact parameters in this case and found them to be suitably conservative or performed independent calculations to verify acceptability of their analysis
 - E. meeting the provisions of (industry standard, number and title) that has been reviewed by the staff and determined to be appropriate for this application
3. Repeat discussion for each regulation cited above.
4. The temperature and pressure profiles provided in the applicant's technical submittal for the spectrum of LOCA and main steam line break accidents are acceptable for use in equipment qualification (i.e., there is reasonable assurance that the actual temperatures and pressures for the postulated accidents will not exceed these profiles anywhere within the specified environmental zones, except in the break zone).

IV. 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 SRP revision in effect 6 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 SMR designs, however, differ significantly from large light-water nuclear 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 Staff Requirements Memorandum (SRM)-COMGBJ-10-0004/COMGEA-10-0001. 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 preapplication activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for evaluating 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 to address new design or siting assumptions.

VI. REFERENCES

1. *U.S. Code of Federal Regulations*, “Standards for Protection against Radiation.” Part 20, Title 10, “Energy.”
2. *U.S. Code of Federal Regulations*, “Domestic Licensing of Production and Utilization Facilities,” Part 50, Title 10, “Energy.”
3. *U.S. Code of Federal Regulations*, “Early Site Permits; Standard Design Certifications; and Combined Licenses,” Part 52, Subparts A, B, and C, Title 10, “Energy.”
4. GDC 61, “Fuel Storage and Handling and Radioactivity Control.”
5. GDC 19, “Control Room.”
6. GDC 4, “Environmental and Dynamic Effects Design Bases.”
7. U.S. Nuclear Regulatory Commission, “Control of Combustible Gas Concentrations in Containment,” Regulatory Guide (RG) 1.7, Agencywide Documents Access and Management System (ADAMS) Accession No. ML070290080.
8. U.S. Nuclear Regulatory Commission, “Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors,” RG 1.112, ADAMS Accession No. ML003740361.
9. U.S. Nuclear Regulatory Commission, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” RG 1.183, ADAMS Accession No. ML003716792.
10. American National Standards Institute/American Nuclear Society (ANSI/ANS) 18.1-1999, “Source Term Specification.”
11. U.S. Nuclear Regulatory Commission, “Clarification of TMI Action Plan Requirements.”

- NUREG-0737, November 1980, ADAMS Accession No. ML051400209.
12. *U.S. Code of Federal Regulations*, “Environmental Radiation Protection Standards for Nuclear Power Operations,” Part 190, Title 40, “Protection of Environment.”
 13. U.S. Nuclear Regulatory Commission, “Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants,” RG 1.89, Revision 1, June 1984, ADAMS Accession No. ML003740271.
 14. U.S. Nuclear Regulatory Commission, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants,” RG 1.143, Revision 2, November 2001, ADAMS Accession No. ML013100305.
 15. U.S. Nuclear Regulatory Commission, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” RG 1.26, Revision 4, March 2007, ADAMS Accession No. ML070290283.
 16. U.S. Nuclear Regulatory Commission, “Seismic Design Classification,” RG 1.29, Revision 4, March 2007, ADAMS Accession No. ML070310052.
 17. U.S. Nuclear Regulatory Commission, “Tornado Design Classification,” RG 1.117, Revision 1, April 1978, ADAMS Accession No. ML003739346.
 18. U.S. Nuclear Regulatory Commission, “Combined License Applications for Nuclear Power Plants (LWR Edition),” RG 1.206, June 2007, ADAMS Accession No. ML07020184.
 19. Electric Power Research Institute (EPRI), “Pressurized Water Reactor Primary Water Chemistry Guidelines.”
 20. EPRI, “Pressurized Water Reactor Primary Water Zinc Application Guidelines.”
 21. EPRI, “Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant.”
 22. U.S. Nuclear Regulatory Commission, “NRC Review of Electric Power Research Institute’s Advanced Light Water Reactor Utility Requirements Document, Passive Plant Designs” Volume 3, Part 1 and Volume 3, Part 2, NUREG 1242, ADAMS Accession Nos. ML070600372 and ML070600373.
 23. EPRI, “Cobalt Reduction Guidelines.”
 24. U.S. Nuclear Regulatory Commission, “Information Relevant to Assuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as is Reasonably Achievable,” RG 8.8, Revision 3, June 1978, ADAMS Accession No. ML003739549.
 25. U.S. Nuclear Regulatory Commission, Staff Requirements Memorandum (SRM)-COMGBJ-10-0004/COMGEA-10-0001, “Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews,” August 2010, ADAMS Accession No. ML102510405.