U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

6.2.5 COMBUSTIBLE GAS CONTROL IN CONTAINMENT

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of containment integrity

Secondary - None

I. AREAS OF REVIEW

NuScale is an integrated 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.

This section covers the information presented in the applicant's submittal concerning the control of combustible gases in the containment to ensure conformance with the requirements of General Design Criteria (GDC) 5, "Sharing of Structures, Systems, and Components," 41, "Containment Atmosphere Cleanup," 42, "Inspection of Containment Atmosphere Cleanup Systems," and 43, "Testing of Containment Atmosphere Cleanup Systems"; and Title 10 of the *Code of Federal Regulations* (CFR) 50.44, "Combustible Gas Control for Nuclear Power Reactors."

The following NuScale SMR design features are credited with controlling combustible gases and maintaining containment integrity:

1. The containment vessel is maintained at vacuum pressures under normal operating conditions and is submerged in the reactor pool, which provides a passive heat sink for the containment heat removal under loss-of-coolant accident (LOCA) conditions. The containment vessel is designed to withstand the environment of the reactor pool as well as the high pressure and temperature of any design basis accident.

2. The containment vessel evacuation system is designed to establish the vacuum conditions in the containment vessel for normal operations. This system also transfers removed gases directly to the gaseous waste management system and liquids either to the liquid waste management system or to the reactor pool.

3. Unlike large light water reactor designs, the NuScale containment vessel does not have subcompartments. This feature of the design supports the capability to ensure there is a mixed atmosphere in containment, as required by 10 CFR 50.44(c)(1).

The design does not rely on active systems or components (e.g., fans, fan coolers, or containment spray) to promote a mixed atmosphere in containment. After an accident,

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hydrogen and oxygen may accumulate inside the containment. After an accident, combustible gas is predominantly generated within the containment because of the reaction between the fuel cladding and the reactor coolant. Hydrogen and oxygen are also generated because of radiolytic decomposition of the post-accident emergency coolant.

If a sufficient amount of combustible gas is generated, it may react with any oxygen present in the containment at a rate rapid enough to breach the containment or cause a leakage rate in excess of technical specification limits. Additionally, the associated pressure and temperature increase could damage systems and components essential to continued control of the post-accident conditions. This review includes the following general areas:

1. the production and accumulation of combustible gases within the containment following a beyond-design-basis accident

2. the capability to mix the combustible gases within the containment and prevent high concentrations of combustible gases in local areas

3. the capability to monitor combustible gas concentrations within containment

4. the capability to reduce combustible gas concentrations within containment by suitable means, as required

The following are the specific areas of review:

1. analysis of combustible gas (e.g., hydrogen) production and accumulation within the containment after a beyond-design-basis accident

2. analysis of the functional capability of the systems or passive design features to mix the combustible gas within the containment

3. analysis of the functional capability of the systems to reduce combustible gas concentrations within the containment

4. analyses of the capability of systems or system components to withstand dynamic effects, such as transient differential pressures that would occur early in the blowdown phase of an accident

5. analyses of the consequences of single active component malfunctions, in case there are any, to meet GDC 41

6. the quality classification of each system

7. the seismic design classification of each system

8. the results of qualification tests performed on system components to demonstrate functional capability

9. the design provisions and proposed program, including technical specifications, for periodic inservice inspection, operability testing, and leakage rate testing of each system or component

10. The functional aspects of instrumentation to monitor system or system component performance

    A. The staff reviews the final designs of these systems to verify they meet the acceptance criteria detailed in subsection II of this Design-Specific Review Standard (DSRS) section.

11. Inspections, tests, analyses, and acceptance criteria (ITAAC)

    A. 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 DSRS section in accordance with Standard Review Plan (SRP Sections 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria" and 14.3.11, "Containment Systems-Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes 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 14.3.11.

12. COL action items and certification requirements and restrictions

    A. 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 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.

<u>Review Interfaces</u>

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

1. The review of seismic design and quality group classifications is performed under SRP Section 3.2.1 and SRP Section 3.2.2, respectively.

2. The actuation and control features of active components are reviewed under DSRS Section 7.2.

3. The qualification test program for electrical valve operators, sensing, and actuation instrumentation of the plant protection system, and the hydrogen sampling or analyzing equipment, located both inside and outside the reactor containment, is reviewed by the organization responsible for instrumentation and control (DSRS 3.11).

4. Proposed technical specifications pertaining to the operability and leakage rate testing of systems and components is reviewed under DSRS Section 16.0.

5. Accessibility of combustible gas control systems equipment under postulated accident conditions is reviewed under DSRS Section 12.3-12.4.

6. Probabilistic risk assessment and severe accident evaluation for NuScale for integral pressurized-water (iPWR) design and LOCA analysis scenarios are discussed in SRP Section 19.

II. ACCEPTANCE CRITERIA

Requirements

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

1. Regulations in 10 CFR 50.44 state:

   A. *Mixed atmosphere:* Containments must have a capability for ensuring a mixed atmosphere during design-basis and significant beyond design-basis accidents.

   B. *Combustible gas control:* Containments must limit hydrogen concentrations in containment during and following an accident that releases an equivalent amount of hydrogen as would be generated from a 100 percent fuel clad-coolant reaction, uniformly distributed, to less than 10 percent (by volume).

   C. *Equipment Survivability.* Containments must be able to establish and maintain safe shutdown and containment structural integrity with systems and components capable of performing their functions during and after exposure to the environmental conditions created by the burning of hydrogen. Environmental conditions caused by local detonations of hydrogen must also be included, unless such detonations can be shown unlikely to occur. The amount of hydrogen to be considered must be equivalent to that generated from a fuel clad-coolant reaction involving 100 percent of the fuel cladding surrounding the active fuel region.

   D. *Monitoring.* Equipment provided for monitoring hydrogen in the containment must be functional, reliable, and capable of continuously measuring the concentration of hydrogen in the containment atmosphere following a significant beyond design-basis accident for accident management, including emergency planning.

   E. *Structural analysis.* An applicant must perform an analysis that demonstrates containment structural integrity. The analysis must address an accident that releases hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by the hydrogen burning. Systems necessary to ensure containment integrity must also be demonstrated to perform their unction under these conditions.

2. GDC 5 as it relates to providing assurance that the sharing of SSCs important to safety among nuclear power units will not significantly impair their ability to perform their safety functions.

3. GDC 41 as it relates to systems being provided to control the concentration of hydrogen or oxygen that may be released into the reactor containment following postulated accidents to ensure that containment integrity is maintained; systems being designed to

suitable requirements, i.e., that there be suitable redundancy in components and features, and suitable interconnections to ensure that for either a loss of onsite or a loss of offsite power the system safety function can be accomplished, assuming a single failure; and systems being provided with suitable leak detection, isolation, and containment capability to ensure that system safety function can be accomplished.

4. GDC 42 as it relates to the design of the systems to permit appropriate periodic inspection of components to ensure the integrity and capability of the systems.

5. GDC 43 as it relates to the systems being designed to permit periodic testing to ensure system integrity, and the operability of the systems and active components.

6. Regulations in 10 CFR 52.47(b)(1), which require a DC application to 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) regulations.

7. Regulations in 10 CFR 52.80(a), which require a COL application to 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 AEA, 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 listed 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 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 NRC regulations that underlie the DSRS acceptance criteria.

1. In meeting the requirements of 10 CFR 50.44, and GDC 41 to provide systems that control the concentration of hydrogen or oxygen in the containment atmosphere, the applicant should demonstrate by analysis the design can safely accommodate hydrogen generated by an equivalent of a 100 percent fuel clad-coolant reaction, while limiting containment hydrogen concentration, with the hydrogen uniformly distributed, to less than 10 percent (by volume), and while maintaining containment structural integrity.

2. In meeting the requirements of 10 CFR 50.44(c)(3), regarding equipment survivability, equipment necessary for achieving and maintaining safe shutdown of the plant and maintaining containment structural integrity should perform its safety function during and after being exposed to the environmental conditions that come with the release of hydrogen generated by the equivalent of a 100 percent fuel clad-coolant reaction, including the environmental conditions created by the burning of hydrogen.

3. To meet the requirements of 10 CFR 50.44 (to provide the capability for ensuring a mixed atmosphere in the containment during design-bases and significant beyond-design-bases accidents) and of GDC 41 (to provide systems necessary to maintain containment integrity), the NuScale SMR design uses a passive system. For passive systems that use convection to mix the combustible gases, the containment internal structures should be designed to promote the free circulation of the atmosphere. An analysis of the effectiveness of the method used for mixing the atmosphere should be provided. This analysis is acceptable if it shows combustible gases will not accumulate within a compartment or cubicle to form a combustible or detonable mixture that could cause loss of containment integrity.

4. To satisfy the design requirements of GDC 41:

   A. Performance tests should be performed on system components, such as combustible gas monitors. The tests should support the analyses of the functional capability of the equipment.

   B. Combustible gas control system designs should include instrumentation needed to monitor system or component performance under normal and accident conditions. The instrumentation should be capable of determining that a system is performing its intended function or that a system train or component is malfunctioning and should be isolated. The instrumentation should have readout and alarm capability in the control room. The containment hydrogen and oxygen monitors should meet the provisions of Regulatory Guide (RG) 1.7, "Control of Combustible Gas Concentrations in Containment," Revision 3, Section C.2.

5. To satisfy the inspection and test requirements of GDC 41, 42, and 43, combustible gas control and monitoring systems should be designed for periodic inservice inspection, operability testing, and leak rate testing of the systems or components.

6. In meeting the requirements of 10 CFR 50.44(c)(5) regarding containment structural integrity, an analysis must demonstrate containment structural integrity, using an analytical technique that is accepted by NRC staff and including sufficient supporting justification to show that the technique describes the containment response to the structural loads involved. The analysis must address an accident that releases hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning. Systems necessary to ensure containment integrity must also demonstrate the capability to perform their functions under these conditions. One acceptable analytical technique is a demonstration that specific criteria of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code are met, as described in RG 1.7, Revision 3, Section C.5.

III. REVIEW PROCEDURES

The procedures described below offer guidance for the detailed review of the combustible gas control systems.

Upon request from the primary review organization, the organizations with interface responsibilities will supply input, as stated in Subsection I of this DSRS section. The input will ensure that the review is complete. 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. The system description and schematic drawings presented in the safety analysis report (SAR) should be sufficiently detailed to permit judgments to be made regarding system acceptability.

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: Light-Water Small Modular 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 small modular reactor (SMR) framework. Using the graded approach described in NUREG-0800, Intro Part 2, the NRC staff may determine that, for certain 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 completing the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is shown in Figure 1 of NUREG-0800, Intro Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

    - 10 CFR Part 50, Appendix A, GDC, Overall Requirements, Criteria 1–5
    - 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 Nonsafety 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 DC or COL applications submitted under 10 CFR 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, "Resolution of Generic Safety Issues," 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 reviewer determines that all potential, active mechanical failures and passive electrical failures have been identified and that no single failure would incapacitate an entire system.

4. The reviewer compares the quality standards applied to the systems to the provisions of RG 1.7, Revision 3.

5. The reviewer compares the seismic design classifications of the systems to the provisions of RG 1.7, Revision 3.

6. The reviewer examines the qualification testing of systems and components to establish the functional capability of the equipment.

7. The reviewer scrutinizes the provisions made in the design of the systems and the program for periodic inservice inspection and operability testing of the systems or components. The inspections are reviewed with regard to the purpose of each inspection. The operability tests that will be conducted are reviewed with regard to what each test is intended to accomplish. Judgment and experience from previous reviews are used to determine the acceptability of the inspection and test program.

8. The reviewer evaluates the proposed technical specifications for the systems used to control combustible gas and oxygen concentrations in the containment to ensure that the requirements of 10 CFR 50.44 and GDC 5, 41, 42, and 43 are met.

9. The reviewer inspects the capability to monitor system performance to be sure control can be exercised over a system and a malfunctioning system train or component can be isolated. The instrumentation provided for this purpose should be redundant and should enable the operator to identify the malfunctioning system train or component.

10. The reviewer examines analyses of the functional capability of the systems or passive design features provided to mix combustible gases within the containment. The reviewer surveys the supporting information in the safety analysis report, which should include elevation drawings of the containment vessel showing the routing of piping and the circulation patterns caused by thermal convection. Special attention is paid to any interior compartments or areas to ensure that combustible gases cannot collect in them without mixing with the bulk containment atmosphere. The reviewer ensures that any

such compartments are identified in the SAR and the provisions made to ensure circulation within them are discussed. The reviewer determines if these provisions are sufficient to ensure that the concentration of hydrogen in any part of containment is below a level that could lead to combustion or detonation and cause a loss of containment integrity.

11. The reviewer examines the analysis of containment structural integrity. The reviewer evaluates the methods used by the applicant for (1) predicting the internal pressure capacity for containment structures above the design-basis accident pressure, and, (2) demonstrating containment structural integrity related to combustible gas control. Specifically, the reviewer confirms the analysis addresses an accident that releases hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning. The guidance for this analysis is found in RG 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings above Design Basis Pressure."

12. The reviewer scrutinizes equipment survivability provisions for severe accidents that include the combustion of hydrogen. The reviewer evaluates equipment design data, testing data or test descriptions, or ITAAC that support a determination systems necessary to ensure containment integrity are demonstrated to perform their functions under the conditions associated with the burning of hydrogen.

13. For review of a DC application, the reviewer should follow the above procedures to verify 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 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 (ESP), or other NRC approvals (e.g., manufacturing license, site suitability report, or topical report).

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

IV. EVALUATION FINDINGS

The reviewer verifies the applicant has provided sufficient information and 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 type of conclusions in the staff's SER. The reviewer also states the bases for those conclusions.

The staff concludes the design and expected performance of the combustible gas control systems are acceptable and meet the requirements of 10 CFR Part 50.44, and GDC 5, 41, 42, and 43. This conclusion is based on the following:

1. 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 acceptable with respect to the regulation being discussed)

   A. meeting the regulatory positions in RG (s) ________;

   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 Branch Technical Position (BTP) ___;

   D. using calculation methods for (state what was evaluated) that have been previously 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; and/or

   E. meeting the provisions of (industry standard, number and title) that have been reviewed by the staff and determined to be appropriate for this application.

2. Repeat discussion for each regulation cited 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 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 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, "Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010. 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. Nuclear Regulatory Commission "Control of Combustible Gas Concentrations in Containment," Regulatory Guide (RG) 1.7, Revision 3, March 2007, Agencywide Document Access and Management System (ADAMS) Accession No. ML070290080.

2. U.S. Nuclear Regulatory Commission, "Final Rulemaking—Risk-Informed 10 CFR 50.44, "Combustible Gas Control in Containment," SECY-03-0127, July 24, 2003, ADAMS Accession No. ML031640408.

3. U.S. Nuclear Regulatory Commission, "Status Report on Study of Risk-informed Changes to The Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control)," SECY-00-0198, September 14, 2000, ADAMS Accession No. ML003747699.

4. U.S. Nuclear Regulatory Commission, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," SECY-93-087, April 2, 1993, ADAMS Accession No. ML003708021.

5. U.S. Nuclear Regulatory Commission "Station Blackout," RG 1.155, August 1988, ADAMS Accession No. ML003740034.

6. U.S. Nuclear Regulatory Commission, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design (Docket No. 52-002)," NUREG-1462, August 1994.

7. U.S. Nuclear Regulatory Commission, "Final Safety Evaluation Report Related to the Certification of the Advance Boiling Water Reactor Design," NUREG-1503, July 1994, ADAMS Accession No. ML080670560.

8. U.S. Nuclear Regulatory Commission, "Final Safety Evaluation Report Related to the Certification of the AP600 Standard Design, Supplement 1, Docket No. 52-003," September 1998, NUREG-1512, ADAMS Accession No. ML993550127.

9. U.S. Nuclear Regulatory Commission, “Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, Docket No. 52-006,” NUREG-1793, September 2004, ADAMS Accession No. ML043450288.

10. U.S. Nuclear Regulatory Commission, “Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident,” Regulatory Guide (RG) 1.97, Revision 3, May 1983, ADAMS Accession No. ML003740282.

11. U.S. Nuclear Regulatory Commission, “Initial Test Programs for Water-Cooled Nuclear Power Plants,” RG 1.68, June 2013, ADAMS Accession No. ML13051A027.

12. U.S. Nuclear Regulatory Commission, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants” RG 1.160, May 2012, ADAMS Accession No. ML113610098.

13. U.S. Nuclear Regulatory Commission, Combined License Applications for Nuclear Power Plants (LWR Edition), RG 1.206.

14. U.S. Nuclear Regulatory Commission, “Guidance for ITAAC Closure under 10 CFR Part 52,” RG 1.215, ADAMS Accession No. ML091480076.

15. *U.S. Code of Federal Regulations*, “Combustible Gas Control for Nuclear Power Reactors,” Part 50, Section 44, Title 10, “Energy.”

16. *U.S. Code of Federal Regulations,* “Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Cooled Reactors,” Part 50, Section 46, Title 10, “Energy,”

17. *U.S. Code of Federal Regulations,* “Acceptance Criteria for Reactor Coolant System Venting Systems,” Part 50, Section 46a, Title 10, “Energy.”

18. *U.S. Code of Federal Regulations,* “General Design Criteria for Nuclear Power Plants,” Part 50, Appendix A, Title 10, “Energy”

19. 10 CFR Part 50, Appendix A, General Design Criterion 41, “Containment Atmosphere Cleanup.”

20. 10 CFR Part 50, Appendix A, General Design Criterion 42, “Inspection of Containment Atmosphere Cleanup System.”

21. 10 CFR Part 50, Appendix A, General Design Criterion 43, “Testing of Containment Atmosphere Cleanup System.”

22. U.S. Nuclear Regulatory Commission, “Detonability of H-Air-Diluent Mixtures,” Sandia National Laboratory, June 1987, NUREG/CR-4905, ADAMS Accession No. ML071650381.

23. U.S. Nuclear Regulatory Commission, “A Summary of Hydrogen-Air Detonation Experiments,” Sandia National Laboratory, June 1987, NUREG/CR-4961.

24. U.S. Nuclear Regulatory Commission “Flame Facility, The Effect of Obstacles and Transverse Venting on Flame Acceleration and Transition to Detonation of Hydrogen-Air Mixtures at Large Scale,” Sandia National Laboratory, April 1989, NUREG/CR-5275, ADAMS Accession No. ML071700076.

25. U.S. Nuclear Regulatory Commission “Hydrogen-Air-Diluent ,” Sandia National Laboratory, December 1990, NUREG/CR-5525, ADAMS Accession No. ML071700388.

26. U.S. Nuclear Regulatory Commission, “Containment Structural Integrity Evaluation for Internal Pressure Loadings above Design Basis Pressure”, RG 1.216, August 2010, ADAMS Accession No. ML093200703.

27. Staff Requirements Memorandum (SRM)-COMGBJ-10-0004/COMGEA-10-0001, “Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews,” dated August 31, 2010

28. 10 CFR Part 50, Appendix A, General Design Criterion 5, “Sharing of Structures, Systems, and Components.”