DRAFT REVISION TO
STANDARD REVIEW PLAN - NUREG-0800
IN CONJUNCTION WITH RISK-INFORMED REVISION TO 50.44

SECTION 6.2.5 COMBUSTIBLE GAS CONTROL IN CONTAINMENT

REVIEW RESPONSIBILITIES

Primary - Plant Systems Branch (SPLB)

Secondary - None

I. AREAS OF REVIEW

10 CFR 50.44, "Combustible Gas in Containment," is applicable to each boiling or pressurized water nuclear power reactor with an operating license on [EFFECTIVE DATE] and all construction permits or operating licenses under this part, and to all design approvals, design certifications, combined licenses or manufacturing licenses under part 52 of this chapter, any of which are issued after [EFFECTIVE DATE]. Draft Regulatory Guide DG-1117, "Control of Combustible Gas Concentrations in Containment" (Ref. 1), describes methods that are acceptable to the NRC staff for implementing 10 CFR 50.44.

Note: This SRP is primarily intended to cover new plant applications. Guidance for a plant which had already received its operating license as of [EFFECTIVE DATE] may be found in Draft Regulatory Guide DG-1117.

SPLB reviews the information presented in the applicant's safety analysis report (SAR) or design control document (DCD) concerning the control of combustible gases in the containment following a beyond-design-basis accident involving 100% fuel clad-coolant reaction or postulated accident to ensure conformance with the requirements of General Design Criteria 5, 41, 42, and 43, and 10 CFR 50.44. Following an accident, hydrogen and oxygen may accumulate inside the containment.

After an accident, combustible gas is predominantly generated within the containment as a result of:

a. Fuel clad-coolant reaction between the fuel cladding and the reactor coolant.

b. Molten core-concrete interaction in a severe core melt sequence with a failed reactor vessel.

If a sufficient amount of combustible gas is generated, it may react with the 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.

The SPLB 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 with the containment atmosphere and prevent high concentrations of combustible gases in local areas.

3. The capability to monitor combustible gas concentrations within containment, and, for inerted containments, oxygen concentrations within containment.

4. The capability to reduce combustible gas concentrations within containment by suitable means, such as igniters.

The SPLB review specifically covers the following analyses and aspects of combustible gas control system designs:

1. Analysis of combustible gas (e.g., hydrogen, carbon monoxide, oxygen) production and accumulation within the containment following a beyond-design-basis accident.

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

3. Analysis of the functional capability of the systems provided 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, 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 at the operating license (OL) or combined license (COL) stage of review) for periodic inservice inspection, operability testing, and leakage rate testing of each system or component.

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

At the construction permit (CP) or early site permit stage of review, the design of the systems provided for monitoring and controlling combustible gases within the containment may not be completely determined. In such cases, SPLB reviews the applicant's preliminary designs and statements of intent to comply with the acceptance criteria for such systems. At the OL or COL stage, SPLB reviews the final designs of these systems to verify that they meet the acceptance criteria detailed in subsection II of this SRP section. For design approvals and certifications, SPLB reviews the applicant's preliminary designs and statements of intent to comply with the acceptance criteria for such systems.

Review Interfaces

SPLB will coordinate other branch evaluations that interface with the overall review of combustible gas control as follows:

1. The Mechanical and Civil Engineering Branch (EMEB) will review seismic design and quality group classifications as part of its primary review responsibility for SRP Section 3.2.1 and SRP Section 3.2.2, respectively.

2. The Electrical and Instrumentation and Controls Branch (EEIB), as part of its primary review responsibility for SRP Section 7.5, will evaluate the actuation and control features of active components, including the hydrogen and oxygen monitors.

3. The EEIB, as part of its primary review responsibility for SRP Section 3.11, will evaluate the qualification test program for electric valve operators, fans, hydrogen/oxygen sampling or analyzing equipment, igniters, and sensing and actuation instrumentation of the plant protection system, located both inside and outside the reactor containment.

4. The Probabilistic Safety Assessment Branch (SPSB), as part of its primary review responsibility for SRP Section 12.3, will evaluate the accessibility of combustible gas control systems equipment under postulated accident conditions.

5. The Operating Reactor Improvements Program (RORP), as part of its primary review responsibility for SRP Section 16.0, will review, at the OL or COL stage of review, proposed Technical Specifications pertaining to the operability and leakage rate testing of systems and components.

For those areas of review identified above that are being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

SPLB acceptance criteria for the design of the systems provided for combustible gas control are the relevant requirements of 10 CFR Part 50, § 50.44, and General Design Criteria 5, 41, 42, and 43. The requirements are as follows:

1. 10 CFR Part 50, § 50.44, as it relates to BWR and PWR plants being designed to:

   a. accommodate hydrogen generation equivalent to a 100% fuel clad-coolant reaction,

   b. limit containment hydrogen concentration to no greater than 10%,

   c. have a capability for ensuring a mixed atmosphere,

   d. provide containment-wide hydrogen control (such as igniters or inerting) for severe accidents. Post-accident conditions should be such that an uncontrolled hydrogen/oxygen recombination would not take place in the containment, or the plant should withstand the consequences of uncontrolled hydrogen/oxygen recombination without loss of safety function or containment structural integrity.

2. General Design Criterion 5 as it relates to providing assurance that sharing of structures, systems and components important to safety among nuclear power units will not significantly impair their ability to perform their safety functions.

3. General Design Criterion 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. General Design Criterion 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. General Design Criterion 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.

Specific criteria necessary to meet the requirements of 10 CFR Part 50, § 50.44, and GDC 5, 41, 42 and 43, are as follows:

1. In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 to provide systems to control the concentration of hydrogen in the containment atmosphere, materials within the containment that would yield hydrogen gas due to corrosion from the emergency cooling or containment spray solutions should be identified, and their use should be limited as much as practicable.

2. In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 to provide systems to control the concentration of hydrogen or oxygen in the containment atmosphere, the applicant should demonstrate by analysis, for non-inerted containments, that the design can safely accommodate hydrogen generated by an equivalent of a 100% fuel clad-coolant reaction, while limiting containment hydrogen concentration, with the hydrogen uniformly distributed, to less than 10%, and while maintaining containment structural integrity.

3. In meeting the requirements of 10 CFR Part 50, § 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 attendant with the release of hydrogen generated by the equivalent of a 100 percent fuel clad-coolant reaction including the environmental conditions created by activation of the combustible gas control system.

4. In meeting the requirements of 10 CFR Part 50, § 50.44, to provide the capability for ensuring a mixed atmosphere in the containment, and of GDC 41 to provide systems as necessary to ensure that containment integrity is maintained, this capability may be provided by an active, passive, or combination system. Active systems may consist of a fan, a fan cooler, or containment spray. For passive or combination systems that use convective mixing to mix the combustible gases, the containment internal structures should have design features which promote the free circulation of the atmosphere. For all containment types, an analysis of the effectiveness of the method used for providing a mixed atmosphere should be provided. This analysis is acceptable if it shows that combustible gases will not accumulate within a compartment or cubicle to form a combustible or detonable mixture that could cause loss of containment integrity.

   Atmosphere mixing systems prevent local accumulation of combustible or detonable gases which could threaten containment integrity or equipment operating in a local compartment. Active systems installed to mitigate this threat should be reliable, redundant, single failure proof, able to be tested and inspected, and remain operable with a loss of onsite or offsite power.

5. In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the design should meet the provisions of Draft Regulatory Guide DG-1117, section C.1.

6. To satisfy the design requirements of GDC 41:

   a. Performance tests should be performed on system components, such as hydrogen igniters and 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 Draft Regulatory Guide DG-1117, section C.2.

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

8. In meeting the requirements of 10 CFR Part 50, § 50.44(c)(5), regarding containment structural integrity, an analysis must demonstrate containment structural integrity, using an analytical technique that is accepted by the 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% fuel clad-coolant reaction accompanied by combustible gas 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 the following specific criteria of the ASME Boiler and Pressure Vessel Code as described in Draft Regulatory Guide DG-1117, section C.5.

   As a minimum, the specific code requirements set forth for each type of containment will be met for a combination of dead load and an internal pressure of 45 psig. Modest deviations from these criteria will be considered by the staff, if good cause is shown by an applicant.

9. In meeting the requirements of 10 CFR Part 50, § 50.44(c), and GDC 41 for the design and functional capability of the combustible gas control systems, preliminary system designs and statements of intent in the SAR are acceptable at the CP or early site

permit stage of review if the guidelines of Draft Regulatory Guide DG-1117 are endorsed.

III. REVIEW PROCEDURES

The procedures described below provide guidance for the detailed review of the combustible gas control systems. The reviewer selects and emphasizes material from this SRP section, as may be appropriate for a particular case. Portions of the review may be done on a generic basis for aspects of combustible gas control systems design common to a class of plants or by adopting the results of previous reviews of similar plants.

Upon request from the primary reviewer, other review branches will provide input for the areas of review stated in subsection I, above. The primary reviewer obtains and uses such input as required to ensure that this review procedure is complete.

The combustible gas control systems include systems for mixing the combustible gases, monitoring combustible gas concentrations, and reducing the combustible gas concentrations. In general, all of the combustible gas control systems should meet the design requirements outlined in subsection II. The system description and schematic drawings presented in the safety analysis report should be sufficiently detailed to permit judgments to be made regarding system acceptability.

1. SPLB determines that all potential, active mechanical failures and passive electrical failures have been identified and that no single failure would incapacitate an entire system.

2. SPLB compares the quality standards applied to the systems to the provisions of draft Regulatory Guide DG-1117.

3. SPLB compares the seismic design classifications of the systems to the provisions of draft Regulatory Guide DG-1117.

4. SPLB reviews the qualification testing of systems and components, to establish the functional capability of the equipment.

5. SPLB reviews 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.

6. SPLB reviews the proposed technical specifications, for plants at the OL or COL stage of review, for the systems used to control and monitor combustible gas and oxygen concentrations in the containment to ensure that the requirements of 10 CFR 50.44 and General Design Criteria 5, 41, 42, and 43 are met.

7. SPLB reviews the capability to monitor system performance and control active components to be sure that control can be exercised over a system and that 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.

8. SPLB reviews analyses of the functional capability of the systems, or passive design features provided to mix combustible gases within the containment. SPLB reviews the supporting information in the safety analysis report which should include elevation drawings of the containment showing the routing of ductwork and the circulation patterns caused by fans, sprays, or thermal convection. Special attention is paid to interior compartments to ensure that combustible gases cannot collect in them without mixing with the bulk containment atmosphere. SPLB ensures that interior compartments are identified in the safety analysis report and the provisions made to ensure circulation within them are discussed.

   Systems provided to mix the combustible gases within the containment may also be used for containment heat removal, e.g., the fan cooler and spray systems. The acceptability of the design of these systems is considered in the review of the containment heat removal systems in SRP Section 6.2.2.

9. SPLB reviews the manner in which the systems provided to reduce combustible gas concentrations will be operated. The point at which the system is actuated (the control point) will be determined from the safety analysis report. For deliberate ignition systems, the control point is typically core exit temperature exceeding 1200 degrees Fahrenheit.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and that his evaluation supports conclusions of the following type, to be included in the staff's safety evaluation report:

The staff concludes that the design and expected performance of the combustible gas control systems are acceptable and meet the requirements of 10 CFR Part 50, § 50.44, and Criteria 5, 41, 42, and 43. This conclusion is based on the following: [The reviewer should discuss each item of the regulations or related set of regulations as indicated.]

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 Regulatory Guide(s) ________;

b. providing and meeting an alternative method to regulatory positions in Regulatory Guide _____, that the staff has reviewed and found to be acceptable;

c. meeting the regulatory position in BTP ___;

d. using calculational 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 design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including site interface requirements and combined license action items that are relevant to this SRP section.

V. IMPLEMENTATION

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

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52. Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.

VI. REFERENCES

1. Draft Regulatory Guide DG-1117, “Control of Combustible Gas Concentrations in Containment,” dated [DATE OF RULE?].

2. SECY-00-0198, “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),” dated September 14, 2000.

3. SECY-93-087, “Policy, Technical, And Licensing Issues Pertaining to Evolutionary And Advanced Light-water Reactor (ALWR) Designs,” dated April 2, 1993.

4. USNRC, “Station Blackout,” Regulatory Guide 1.155, Revision 0, August 1988.

5. USNRC, “Final Safety Evaluation Report Related to the Certification of the System 80+ Design, Docket No. 52-002,” NUREG-1503, July 1994.

6. USNRC, “Final Safety Evaluation Report Related to the Certification of the Advance Boiling Reactor Design,” NUREG-1462, August 1994.

7. USNRC, “Final Safety Evaluation Report Related to the Certification of the AP600 Standard Design, Docket No. 52-003,” NUREG-1512, September 1998.

8. USNRC, “Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident,” Regulatory Guide 1.97, Revision 3, May 1983.

9. 10 CFR Part 50, § 50.44, "Combustible Gas Control in Containment."

10. 10 CFR Part 50, § 50.46, “Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Reactors."

11. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems and Components."

12. 10 CFR Part 50, Appendix A, General Design Criterion 41, "Containment Atmosphere Cleanup."

13. 10 CFR Part 50, Appendix A, General Design Criterion 42, "Inspection of Containment Cleanup System."

14. 10 CFR Part 50, Appendix A, General Design Criterion 43, "Testing of Containment Atmosphere Cleanup System."

15. Branch Technical Position ASB 9-2, "Residual Decay Energy for Light Water Reactors for Long-Term Cooling," attached to SRP Section 9.2.5.

16. NUREG/CR-4905, "Detonability of H -Air-Diluent Mixtures," Sandia National Laboratory, June 1987.

17. NUREG/CR-4961, "A Summary of Hydrogen-Air Detonation Experiments," Sandia National Laboratory, June 1987.

18. NUREG/CR-5275, "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.

19. NUREG/CR-5525, "Hydrogen-Air-Diluent Detonation Study of Nuclear Reactor Safety Analyses," Sandia National Laboratory, December 1990.