U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

5.4.12 REACTOR COOLANT SYSTEM HIGH POINT VENTS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of reactor thermal-hydraulic systems in Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs)

Secondary - None

I. AREAS OF REVIEW

All light-water nuclear power reactors are required to contain reactor coolant system (RCS) high-point vents in accordance with 10 CFR 50.46a. With the exception of high points in steam generator tubes, RCS high-point vents must be provided at all RCS locations where accumulation of noncondensible gases could inhibit natural circulation core cooling. The following criteria also apply:

1. The high-point vents must be remotely operated from the control room.

2. Design of the vents and associated controls, instruments, and power sources must conform to Appendices A and B to 10 CFR Part 50 (see SRP Chapter 17 for review guidance).

3. The design must ensure that the vents will perform their safety function.

4. The design must ensure that an inadvertent or irreversible actuation of a vent will not occur.

The specific areas of review are as follows:

1. The location, size, discharge capacity, functions, and discharge area(s) of the vent system.

2. Supporting loss-of-coolant accident (LOCA) analyses for breaks in the vent line to demonstrate compliance with 10 CFR 50.46 unless vent line flow area is restricted to prevent the flow from exceeding the charging capability in the event of a vent line break.

3. For standard design certifications (DCs) and combined licenses (COLs), compliance with the 10 CFR 50.34(f) and 10 CFR 52.79(b) requirement to demonstrate that high-point vents should not lead to an unacceptable increase in the probability of LOCA accidents.

4. Redundancy and failure modes of the valve train.

5. Procedures for using the vent system and the bases for these procedures.

6. Information available to the operator for initiating and terminating vent system operation.

7. System environmental qualification to demonstrate compliance with 10 CFR 50.49.

8. 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 SRP section in accordance with 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 SRP 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 Section 14.3.

9. 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 SRP sections interface with this section as follows:

1. Review of the design analyses, procedures, and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena such as the safe-shutdown earthquake (SSE), is performed under SRP Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5.

2. Verification that the components, piping, and structures are designed in accordance with applicable codes and standards is performed under SRP Sections 3.9.1 through 3.9.3. Review of the seismic and quality group classifications for system components is performed under SRP Sections 3.2.1 and 3.2.2. In addition, the review of the inservice testing program of valves is performed under SRP Section 3.9.6 and the review of seismic and dynamic qualification, including vibration assessment, of mechanical and electrical equipment is performed under SRP Section 3.10.

3. Verification that inservice inspection requirements are met for system components is performed under SRP Section 6.6 and, upon request, the primary reviewer under SRP Section 6.6 verifies the compatibility of the materials of construction with service conditions.

4. Verification that the adequacy of the design, installation, inspection, and testing of all essential instrumentation and control components required for proper operation is performed under SRP Section 7.1.

5. Verification that the adequacy of the design, installation, inspection, and testing of all essential electrical components required for proper operation is performed under SRP Section 8.1.

6. Review of the acceptability of mixing of discharged gases within the containment atmosphere and ensures that containment design limits will not be exceeded by venting during an accident condition is performed under SRP Sections 6.2.1 through 6.2.6.

7. Review of the vent systems initial test program and test procedures is performed under SRP Section 14.2.

8. Review of the acceptability of the environmental qualification of all vent system components is performed under SRP Section 3.11.

9. Review of technical specifications is performed under SRP Section 16.0.

10. Review of the human factors engineering for the control room portion of the vent system to ensure that personnel can operate the system in an error- free manner is performed under SRP Section 18.0.

11. For standard DCs and COLs, the organization responsible for the review of PRA submittals and severe accidents design features reviews the licensee's assessment to ascertain that high-point vents should not lead to an unacceptable increase in the probability of LOCA accidents in SRP Chapter 19.

12. Quality assurance aspects are reviewed using the guidance of SRP Chapter 17.

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

II. ACCEPTANCE CRITERIA

Requirements

The objective of the review is to determine whether the vent system (1) is capable of removing noncondensible gases from the primary coolant system with a minimal probability of inadvertent or spurious actuation and (2) has been acceptably assessed with respect to causing a LOCA.

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

1. 10 CFR 50.46a, as it relates to the provision of, and requirements related to, high-point vents for the RCS, the reactor vessel head, and other systems required to maintain adequate core cooling if the accumulation of noncondensible gases would cause the loss of function of these systems.

2. 10 CFR 50.46(b), as it relates to the long-term cooling of the core following any calculated successful initial operation of the emergency core cooling system (ECCS) to remove decay heat for an extended period of time.

3. 10 CFR 50.49, as it relates to environmental qualification of electrical equipment necessary to operate the reactor coolant vent system.

4. 10 CFR 50.55a and General Design Criteria (GDC) 1 and 30 found in Appendix A to 10 CFR Part 50, as they relate to the vent system components that are part of the reactor coolant pressure boundary (RCPB) being designed, fabricated, erected, and tested and maintained to high quality standards.

5. GDC 14, as it relates to the RCPB being designed, fabricated, erected, and tested to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

6. GDC 17 and 34, as they relate to the provision of normal and emergency power for the vent system components.

7. GDC 19, as it relates to the vent system controls being operable from the control room.

8. GDC 36, as it relates to the vent system being designed to permit periodic inspection.

9. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations;

10. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

Specific criteria necessary to meet the regulations identified above are as follows:

1. The reactor coolant vent design must ensure that use of these vents during and following an accident does not aggravate the challenge to containment or the course of the accident.

2. Vent capability should be provided on high points of the RCS (including the pressurizer on PWRs and the hot legs on Babcock and Wilcox designs) to vent gases which may inhibit core cooling. For reactors with U-tube steam generators, procedures should be developed to remove sufficient gas from the U-tubes to ensure continued core cooling, since it is impractical to individually vent the thousands of U-tubes. In general, vent paths are not required for local high points at locations where gas accumulation would not be expected to jeopardize core cooling such as a reactor coolant pump valve body.

3. A single failure of a vent valve, power supply, or control system should not prevent isolation of the vent path. On boiling water reactors, block valves are not required in lines with safety valves used for venting.

4. The design should incorporate sufficient redundancy to minimize the probability of inadvertent actuation. Other methods to reduce the chances of inadvertent actuation, such as removing power or administrative controls, may be considered.

5. Since the RCS vent will be part of the RCPB, all requirements for the RCPB must be met.

6. The size of the vent should be smaller than the size corresponding to the definition of a LOCA (Appendix A to 10 CFR Part 50, 10 CFR 52.47(a)(1)(ii), and 10 CFR 52.79(b)) to avoid unnecessary challenges to the ECCS, unless the applicant provides justification for a larger size.

7. Vent paths to the containment should discharge into areas that provide good mixing with containment air and are able to withstand steam, water, noncondensibles, and mixtures of the above.

8. The vent system should be operable from the control room and provide positive valve position indication. Power should be supplied from emergency buses.

9. It is important that the control room displays and controls for the RCS vents do not increase the potential for operator error. A human-factor analysis should be performed that considers the following:

   A. The use of this information by an operator during both normal and abnormal plant conditions

   B. Integration into emergency procedures

   C. Integration into operator training

   D. Other alarms during an emergency and need for prioritization of alarms

10. The design should have provisions for testing the operability of the reactor coolant vent system. Testing should be performed in accordance with Subsection IWV of Section XI of the ASME Code for Category B valves.

11. The reactor coolant vent system (i.e., vent valves, block valves, position indication devices, cable terminations, and piping) should be seismically and environmentally qualified in accordance with IEEE 344, as supplemented by Regulatory Guide 1.100 and Regulatory Guide 1.92. Environmental qualifications must be in accordance with 10 CFR 50.49.

12. The reactor coolant vent system should be designed to withstand the dynamic loads that will be encountered during operation from high RCS pressure to the approximate atmospheric pressure at the vent system exhaust.

13. Procedures to effectively operate the vent system must consider when venting is needed and when it is not needed. A variety of initial conditions for which venting may be required should be considered. Operator actions and the necessary instrumentation should be identified.

14. The reactor coolant vent system should meet the quality assurance acceptance criteria provided in SRP Chapter 17.

Technical Rationale

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

1. 10 CFR 50.46a requires that light-water nuclear power reactors be designed with RCS high-point vents to maintain adequate core cooling if the accumulation of noncondensible gases would cause the loss of function of the core cooling systems. During the Three Mile Island Unit 2 accident, a substantial volume of hydrogen was generated in the primary system. To resolve concerns that such a gas volume could interfere with postaccident natural circulation or pump operation, the foregoing regulation was promulgated. This rule establishes specific design requirements that all license applicants must meet. Compliance with 10 CFR 50.46a assures that there is a means to exhaust gases from the RCS that might otherwise inhibit long-term cooling following an accident, thereby ensuring the establishment and maintenance of adequate reactor core cooling.

2. 10 CFR 50.46(b) establishes specific reactor core temperature, cladding oxidation, hydrogen generation, and cooling requirements that are designed to protect the fuel and fuel cladding. The RCS vent system supports long-term core cooling following an accident by exhausting gases from the primary system that could otherwise inhibit natural circulation or pump operation.

3. 10 CFR 50.49 requires environmental qualification of safety-related electrical equipment to ensure that such equipment operates satisfactorily in the most severe environment (i.e., temperature, humidity, radiation, etc.) that it may encounter. Since the RCS vent system contains safety-related electrical equipment that must operate in a post-LOCA containment environment, it must meet the environmental qualification rules. Meeting 10 CFR 50.49 will ensure that under the most severe conditions the vents will function as designed.

4. 10 CFR 50.55a, GDC 1, and GDC 30 require that systems be designed, built, tested, and maintained to the highest appropriate quality standards to assure they will satisfactorily perform their safety functions. The RCS vent system fulfills two vital safety functions in that it exhausts gases from the RCS to ensure the continuance of long-term core cooling and also acts as a part of the RCPB. Compliance with 10 CFR 50.55a, GDC 1, and GDC 30 ensures the application of quality standards in the design, construction, and maintenance of the RCS vent system, thus providing assurance that the system is able to perform its safety functions and that the integrity of the RCPB is maintained.

5. GDC 14 requires that all RCPB components be designed and constructed such that there is an extremely low probability that these components will fail and cause a primary leak or LOCA. The RCS vent system is an integral part of the RCPB which is designed to establish a controlled leakage path to vent gases from the RCS. Appropriate design and construction standards will ensure that in its static condition the RCS vent system will not leak, and in its dynamic condition will operate only when called on to do so. Following GDC 14 will ensure that the integrity of the RCPB is preserved and that adequate core cooling is maintained.

6. GDC 17 requires that onsite and offsite electric power systems be provided for all safety-related structures, systems, and components. The electric power systems must have adequate independence, redundancy, and testability and provide sufficient capacity and capability to assure that fuel and RCPB design limits are not exceeded and

that core cooling and containment integrity are maintained. The RCS vents require electric power to function properly. Meeting the requirements of GDC 17 will ensure that power is maintained to the vent system during accidents. This will enable the vent system to fulfill its safety function of venting gases from the RCS, thereby ensuring that adequate core cooling is established and maintained.

7. GDC 19 requires that the plant design incorporate a control room from which emergency actions can be taken to maintain the plant in a safe condition under accident conditions. The reactor coolant vents are remotely operable from the control room such that the vent system can properly fulfill its safety function of venting primary system gases during an accident. Compliance with GDC 19 will provide assurance that control room operability is preserved such that the RCS vents can be operated during an accident, thereby ensuring that core cooling is maintained.

8. GDC 32 requires components that are part of the RCPB to be designed to permit periodic inspection and testing to assess their structural and leaktight integrity and an appropriate material surveillance program for the reactor pressure vessel. The RCS high-point vents are considered part of the RCPB and should be inspected and tested periodically to ensure that the vents are able to perform their design function.

9. SRP Chapter 17 provides additional guidance and discussion concerning the technical rationale.

III. REVIEW PROCEDURES

The reviewers use the procedures below during the construction permit (CP) review to assure that the design criteria and bases and the preliminary design as set forth in the preliminary safety analysis report meet the acceptance criteria given in Subsection II.

For operating license (OL) reviews, the reviewers use the procedures to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report. The OL review also evaluates the proposed technical specifications to assure that they are adequate in regard to limiting conditions of operation and periodic surveillance testing.

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

These review procedures are based on the identified SRP 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.

For DC and COL applications submitted under Part 52, the level of information reviewed should be consistent with that of a FSAR submitted in an OL application. However, verification that the as-built facility conforms to the approved design is performed through the ITAAC process.

1. The organization responsible for the review of reactor thermal-hydraulic systems reviews the vent system description to determine that the vent paths are capable of venting RCS high points. For areas that may be impractical to vent, such as the U-tubes in steam generators, the reviewer determines that adequate procedures have been developed to assure coolability.

2. At request of the reviewer of reactor thermal-hydraulic systems, the organization responsible for the review of instrumentation and control systems reviews the instrumentation, vent controls, and power source to establish that a single failure will not prevent isolation of the vent system.

3. The reviewer of reactor thermal-hydraulic systems examines valve redundancy and other methods to minimize inadvertent actuation. The review should compare the methods to prevent inadvertent actuation with those of other safety-related systems.

4. The reviewer of reactor integrity issues related to the RCPB evaluates the vent system to determine that all requirements for the RCPB are met.

5. The reviewer of reactor thermal-hydraulic systems examines the size of the vent line and orifices to see if the smallest flow area is smaller than the LOCA definition. If the vent path capacity is of LOCA size, a LOCA analysis should be provided. In a case where the pressurizer power-operated relief valve or its equivalent is used for pressurizer venting, an inadvertent valve opening or failure would initiate a LOCA. However, the path also contains a block valve, and this LOCA should have been addressed as part of the 10 CRF 50.46 assessment. In this case, the reviewer will assess the licensee's treatment of the LOCA and will request that the reviewers of instrumentation and control systems, and human performance assess the capability of closing the block valve under the LOCA conditions.

6. The organization responsible for mechanical engineering determines that the areas of discharge for the vent system are capable of withstanding all substances that may be vented. In addition, the organization responsible for the review of containment integrity examines these areas to verify that adequate mixing with the containment atmosphere is provided.

7. The organization responsible for electrical engineering reviews examines the description and piping and instrumentation diagrams to assure that the vents are operable from the control room and that power is supplied from emergency buses.

8. The organization responsible for the review of human performance determines that the control room displays and controls for the RCS vent system do not increase the potential for operator error.

9. The organization responsible for mechanical engineering reviews examines provisions to test for operability of the reactor coolant vent system. Testing should be performed in accordance with Subsection IWV of Section XI of the ASME Code for Category B valves.

10. The organization responsible for mechanical engineering reviews, examines the reactor coolant vent system (i.e., vent valves, block valves, position indication devices, cable terminations, and piping) to assure that it is seismically qualified in accordance with IEEE 344, as supplemented by Regulatory Guide 1.100, and Regulatory Guide 1.92.

11. The organization responsible for environmental qualification review (i.e., vent valves, block valves, position indication devices, and cable terminations) assures that the reactor coolant vent system is environmentally qualified in accordance with 10 CFR 50.49.

12. The organization responsible for review of reactor thermal-hydraulic systems evaluates the procedures necessary to operate the vent system. The operating procedures should include the following:

    A. When venting is needed and when it is not needed

    B. The method for determining the size of a noncondensible bubble

    C. A variety of initial conditions from which venting may take place

    D. Operator actions and necessary instrumentation

13. The organization responsible for mechanical engineering reviews the reactor coolant vent system to assure it is designed to withstand the dynamic loads associated with operation at RCS pressure with discharge to approximate atmospheric pressure.

14. The reviewer of the reactor coolant vent system determines that the applicable SRP Chapter 17 subjects are acceptably addressed.

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 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, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

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

> The staff concludes that the design of the RCS high-point vents is acceptable and meets the relevant requirements of 10 CFR Part 50, 10 CFR 50.44(c), 10 CFR 50.46, 10 CFR 50.46a, 10 CFR 50.49, and 10 CFR 50.55a, and GDC 1, 14, 17, 19, 30, 34, and 36 and Appendix B to 10 CFR Part 50. This conclusion is based on the following:
>
> The RCS high-point vents include components and piping to remotely relieve noncondensible gases from the primary coolant system and vent the gases to the containment atmosphere or to holdup tanks within containment. [The review has included the applicant's proposed design criteria and design bases, and these meet the requirements for the CP stage.] [The review has included the applicant's analysis of the vent system design with the design criteria and design bases and has included operating procedures for the vents for the OL stage.]
>
> In addition, the basis for acceptance in the staff review is conformance of the applicant's designs, design criteria, and design bases for the RCS vents and supporting systems to applicable regulatory guides, branch technical positions, and industry standards [identify each document and describe how the applicant has implemented each].

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 SRP section.

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

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

The referenced regulations, regulatory guides, and NUREGs contain implementation schedules for conformance to parts of the method discussed in this section.

VI. REFERENCES

1. 10 CFR 50.34, "Contents of Applications; Technical Information."

2. 10 CFR 50.44, "Standards for Combustible Gas Control System in Light-Water-Cooled Power Reactors."

3. 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors."

4. 10 CFR 50.46a, "Acceptance Criteria for Reactor Coolant Venting Systems."

5. 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants."

6. 10 CFR 50.55a, "Codes and Standards."

7. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

8. 10 CFR Part 50, Appendix A, General Design Criterion 14, "Reactor Coolant Pressure Boundary."

9. 10 CFR Part 50, Appendix A, General Design Criterion 17, "Electric Power Systems."

10. 10 CFR Part 50, Appendix A, General Design Criterion 19, "Control Room."

11. 10 CFR Part 50, Appendix A, General Design Criterion 30, "Quality of Reactor Coolant Pressure Boundary."

12. 10 CFR Part 50, Appendix A, General Design Criterion 34, "Residual Heat Removal."

13. 10 CFR Part 50, Appendix A, General Design Criterion 36, "Inspection of Emergency Core Cooling System."

14. 10 CFR Part 50, Appendix A, "Quality Assurance Criteria for Nuclear Plants and Fuel Reprocessing Plants."

15. 10 CFR 52, "Early Site Permits; Standard Design Certification; And Combined Licenses For Nuclear Power Plants."

16. 10 CFR 52.47, "Contents of Applications."

17. NRC Regulatory Guide 1.92, “Combining Modal Responses and Special Components in Seismic Response Analysis.”

18. NRC Regulatory Guide 1.100, “Seismic Qualification of Electric Equipment for Nuclear Power Plants.”

19. NUREG-0718, “Licensing Requirements for Pending Applications for Construction Permits and Manufacturing Licenses.”

20. NUREG-0737, “Clarification of TMI Action Plan Requirements.”

21. ASME Boiler and Pressure Vessel Code, Section XI, Subsection IWV, “Inservice Testing of Valves in Light-Water Reactor Power Plants.”

22. IEEE 344-1987, “Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.”