U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

5.3.3 REACTOR VESSEL INTEGRITY

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of component integrity issues related to reactor vessels

Secondary - Organization responsible for component integrity issues related to reactor coolant pressure boundary

I. AREAS OF REVIEW

The portions of the applicant's safety analysis report (SAR) listed below are reviewed. These portions are all related to the integrity of the reactor vessel. Although most of these areas are reviewed separately in accordance with other standard review plan (SRP) sections, the integrity of the reactor vessel is of such importance that a special summary review of all factors relating to the integrity of the reactor vessel is warranted. The information in each area is reviewed to ensure that the information is complete, and that no inconsistencies in information or requirements exist that would reduce the certainty of vessel integrity.

The specific areas of review are as follows:

1. Design. The basic design of the reactor vessel is reviewed for compatibility of design with established quality standards for material properties and fabrication methods as described in SRP Section 5.3.1, "Reactor Vessel Materials," and for compatibility with required inspections as described in SRP Section 5.2.4, "Reactor Coolant Pressure Boundary Inservice Inspection and Testing."
2. Materials of Construction. The materials of construction are each taken into consideration as described in SRP Section 5.2.3, "Reactor Coolant Pressure Boundary Materials," and in SRP Section 5.3.1.

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3. Fabrication Methods. The processes used to fabricate the reactor vessel, including forming, welding, cladding, and machining, are reviewed as described in SRP Section 5.3.1.

4. Inspection Requirements. The inspection test methods and requirements are reviewed as described in SRP Section 5.3.1.

5. Shipment and Installation. Protective measures taken during shipment of the reactor vessel and its installation at the site are reviewed to verify that the as-built characteristics of the reactor vessel are not degraded by improper handling.

6. Operating Conditions. All the operating conditions as they relate to the integrity of the reactor vessel are reviewed as described in SRP Section 5.3.2, “Pressure-Temperature Limits and Pressurized Thermal Shock.”

7. Inservice Surveillance. Plans and provisions for inservice surveillance of the reactor vessel are reviewed as described in SRP Section 5.3.1 and in SRP Section 5.2.4.

8. Operational Program Description and Implementation. For a COL application, the staff reviews the Inservice Inspection and Reactor Vessel Material Surveillance Programs description and the proposed implementation milestones. The staff also reviews final safety analysis report (FSAR) Table 13.x to ensure that the Inservice Inspection and Reactor Vessel Material Surveillance Programs and associated milestones are included.

9. Threaded Fasteners. The adequacy of programs for assuring the integrity of bolting and threaded fasteners is reviewed as described in SRP Section 3.13, “Threaded Fasteners - ASME Code Class 1, 2, and 3.”

10. 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.

11. 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:

This SRP section involves the integrated review of SRP Sections 5.2.3, 5.2.4, 5.3.1, and 5.3.2 as they relate to reactor vessel integrity.

Other SRP sections interface with this section as follows:

1. Review of the reactor vessel design regarding compliance with § 50.55a of 10 CFR Part 50 and regarding applicable Code Cases, as part of is performed under SRP Sections 5.2.1.1 and 5.2.1.2.

2. The review of the quality assurance program is performed under SRP Chapter 17.

3. For COL reviews of operational programs, the review of the applicant's implementation plan is performed under SRP Section 13.4, "Operational Programs."

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

II. ACCEPTANCE CRITERIA

Requirements

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

The basic acceptance criteria for each review area are covered by other SRP sections, so they will be discussed here only in general terms. References are made to the SRP sections that include detailed criteria. The acceptance criteria in these SRP sections describe methods to meet the requirements of the following Commission regulations in 10 CFR Part 50: General Design Criteria 1, 4, 14, 30, 31, and 32 of Appendix A; Appendix B; § 50.60 and associated Appendices G and H; § 50.55a; and § 50.61 (for PWRs).

1. 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;

2. 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.

1. Design. With regard to compatibility of design with material properties and fabrication methods, the quality standards requirements of GDC 1, GDC 30, and § 50.55a are met by compliance with the provisions of the ASME boiler and pressure vessel code. The basic acceptance criteria for the design of the vessel are the requirements of Section III of the ASME Boiler and Pressure Vessel Code (hereafter "the Code"). The design of the reactor vessel must be compatible with the properties of the materials used, and must permit construction by the use of standard and well proven fabrication methods. The design details should not include new or novel concepts unless they are substantiated by a comprehensive justification showing that no aspects of the design will compromise the overall integrity of the vessel in any manner.

   The design details must be adequate to permit all required inspections and to provide required access to all areas requiring inservice inspection in conformance with Section XI of the Code, as detailed in SRP Section 5.2.4. This satisfies the requirements of GDC 32 and § 50.55a regarding inservice inspection.

   If the procedures of Section IV.A of Appendix G, "Fracture Toughness Requirements," to 10 CFR Part 50 do not indicate the existence of an equivalent safety margin, then Section IV.B allows the reactor vessel beltline to be given a thermal annealing treatment to recover the fracture toughness of the material, subject to the requirements of 10 CFR 50.66, "Requirements for thermal annealing of the reactor pressure vessel." Annealing of the reactor vessel provides assurance that fracture toughness properties can be restored to satisfy the fracture toughness requirements of GDC 31.

2. Materials of Construction. The basic acceptance criteria for the materials used in the construction of the reactor vessel, and the regulations that they satisfy, are detailed in SRP Sections 5.2.3 and 5.3.1. These criteria are the requirements of Appendix G, 10 CFR Part 50, as augmented by Sections III and IX of the Code.

   The materials must be compatible with the design requirements in the GDC. Acceptability is based on standard practice and engineering judgement, with consideration being given to such factors as material form, size-related variations in properties, and nonisotropic characteristics.

   Although many materials are acceptable for reactor vessels according to Section III of the Code, the special considerations relating to fracture toughness and radiation effects effectively limit the basic materials that are currently acceptable for most parts of reactor vessels to SA 533 Gr B C1 1, SA 508 C1 2, and SA 508 C1 3. Acceptability criteria for other grades will have to be developed before they can be used.

Material compositions and expected neutron fluence must be compatible with the requirements for the material surveillance program. The reviewer uses published data to ensure that the predicted shift in toughness properties (RT_{NDT} and upper shelf energy) is conservative, based on actual material composition and predicted fluence. The predicted shift in toughness properties should be at least as conservative as that obtained by use of the most recent revision of Regulatory Guide (RG) 1.99. Acceptability of the material surveillance program, as specified in Appendix H, “Reactor Vessel Material Surveillance Program Requirements,” of 10 CFR Part 50, depends on these relationships.

3. Fabrication Methods. Acceptance criteria for the basic fabrication processes and their qualification and control requirements, and the regulations satisfied by these criteria, are detailed in SRP Section 5.3.1. These criteria are given in Sections III and IX of the Code.

   Although a particular fabrication process (such as multiple wire-high heat input welding) may be generally acceptable, it may not be suitable for reactor vessel fabrication for some materials without further justification or qualification. The reviewer uses “state-of-the-art” criteria and past practice to evaluate the acceptability of materials process combinations.

   Because fabrication methods, materials, and the effectiveness of nondestructive evaluation methods are interrelated, the reviewer should rely on state-of-the-art knowledge and past practice to determine whether the proposed combinations are compatible and acceptable.

4. Inspection Requirements. The basic requirements for performing nondestructive inspections, the quality assurance criteria for the reactor vessel, and the regulations that all of these criteria satisfy, are detailed in SRP Section 5.3.1. These requirements and criteria are contained in Section III of the Code. Additional criteria are contained in Section V of the Code.

   Acceptance criteria for compatibility with materials and fabrication areas are discussed in previous sections.

   Very important relationships are those among in-process and final shop inspections, and the inservice inspection requirements of Section XI of the Code. The reviewer should determine whether the methods of inspection, the sensitivity levels, and flaw evaluation criteria are compatible with Section XI, and whether the results of the preservice baseline inspection can be correlated with the results of later inservice inspections.

5. Shipment and Installation. The basic acceptance criteria for procedures and care to maintain proper cleanliness and freedom from contamination during all stages of shipping, storage, and installation of the reactor vessel, and the regulations that these criteria satisfy, are given in SRP Section 5.2.3.

   The purpose of this area of review is to verify that the as-built characteristics of the reactor vessel are not degraded by improper handling. Acceptability in these areas is assured for current designs and materials by compliance with the basic acceptance criteria. If nonstandard materials or designs are used, the reviewer should determine whether criteria will be adequate, based on current technology.

If the basic criteria are not followed, either intentionally or through error, the reviewer should evaluate, on a case basis, whether the integrity of the reactor vessel is compromised, using current technology, past practice, and experience as applicable.

6. Operating Conditions. Acceptance criteria for operating limits for the reactor vessel, and the regulations that they satisfy, are detailed in SRP Section 5.3.2. These acceptance criteria are given in Appendix G, “Fracture Toughness Requirements,” to 10 CFR Part 50 and for PWRs, 10 CFR 50.61, “Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events.”

   The criterion for acceptable behavior is that the vessel remains leaktight enough to support adequate core cooling. The generally accepted principles and procedures of linear elastic fracture mechanics provide the basis for acceptance of analyses that support conformance with this criterion.

7. Inservice Surveillance. The acceptance criteria for adequacy of the reactor vessel materials surveillance program, and the regulations satisfied by the criteria, are detailed in SRP Section 5.3.1. The criteria are based on the requirements of Appendix H, “Reactor Vessel Material Surveillance Program Requirements,” to 10 CFR Part 50.

   The SAR also provides information regarding the inservice inspections to be performed on the reactor vessel. The acceptance criteria for accessibility and inspection plan details, and the regulations that they satisfy, are detailed in SRP Section 5.2.4. These criteria are those of Section XI of the Code.

8. Operational Programs. For COL reviews, the description of the operational program and proposed implementation milestone(s) for the Inservice Inspection and Reactor Vessel Material Surveillance Programs are reviewed under SRP Section 5.2.4 and 5.3.1 respectfully, in accordance with 10 CFR 50.55a(g), 10 CFR 50.60 and 10 CFR 50, Appendix H. The Reactor Vessel Material Surveillance Program and associated implementation milestone(s) are included within the license condition on operational program implementation.

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:

This SRP section involves the integrated review of reactor vessel integrity based on individual reviews performed for other SRP sections and does not introduce any new or additional criteria. Technical rationale for the acceptance criteria described above are provided in SRP Sections 5.2.3, 5.2.4, 5.3.1, and 5.3.2.

III. REVIEW PROCEDURES

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.

Because the reviewer is familiar with the specific procedures used by the reactor vendor, he or she can readily pick out any differences from past practice. The reviewer will evaluate these in detail, consulting with other staff as appropriate.

Operational Programs. The reviewer verifies that the Inservice Inspection and Reactor Vessel Material Surveillance Programs are fully described and that implementation milestones have been identified. The reviewer verifies that the program and implementation milestones are included in FSAR Table 13.x.

Implementation of this program will be inspected in accordance with NRC Inspection Manual Chapter IMC-2504, "Construction Inspection Program - Non-ITAAC Inspections."

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.

> For the reasons set forth above, the staff concludes that the structural integrity of the reactor vessel is acceptable and meets the requirements of General Design Criteria 1, 4, 14, 30, 31, and 32 of Appendix A of 10 CFR Part 50; the requirements of 10 CFR Part 50, Appendix B; the requirements of 10 CFR 50.60 and associated Appendices G, and H; the requirements of 10 CFR 50.55a; and for PWRs, the requirements of 10 CFR

50.61. This conclusion is based on the staff's review of the safety analysis report (SAR), conducted in accordance with the following standard review plan sections, and supplemented by the acceptance criteria of SRP Section 5.3.3:

(1) SRP Section 5.2.3, “Reactor Coolant Pressure Boundary Materials.”

(2) SRP Section 5.2.4, “Reactor Coolant Pressure Boundary Inservice Inspection and Testing.”

(3) SRP Section 5.3.1, “Reactor Vessel Materials.”

(4) SRP Section 5.3.2, “Pressure-Temperature Limits and Pressurized Thermal Shock.”

(5) SRP Section 3.13, “Threaded Fasteners - ASME Code Class 1, 2, and 3.”

We have reviewed all factors contributing to the structural integrity of the reactor vessel and conclude there are no special considerations that make it necessary to consider potential reactor vessel failure for this plant. The bases for our conclusion are that the design, materials, fabrication, inspection, and quality assurance requirements for the plant will conform to applicable NRC regulations and regulatory guides, and to the rules of the ASME Boiler and Pressure Vessel Code, Section III. The stringent fracture toughness requirements of the regulations and ASME Code Section III will be met, including requirements for surveillance of vessel material properties throughout service life, in accordance with Appendix H of 10 CFR Part 50. Also, operating limitations on temperature and pressure will be established for this plant in accordance with Appendix G, “Protection Against Non-ductile Failure,” of ASME Code Section III, Appendix G to 10 CFR Part 50, and 10 CFR 50.61 (for PWRs).

The integrity of the reactor vessel is assured because the vessel

(1) will be designed and fabricated to the high standards of quality required by the ASME Boiler and Pressure Vessel Code and any pertinent Code Cases;

(2) will be made from materials of controlled and demonstrated high quality;

(3) will be subjected to extensive preservice inspection and testing to provide assurance that the vessel will not fail because of material or fabrication deficiencies;

(4) will be operated under conditions and procedures and with protective devices that provide assurance that the reactor vessel design conditions will not be exceeded during normal reactor operation, maintenance, testing, and anticipated operational occurrences;

(5) will be subjected to periodic inspection to demonstrate that the high initial quality of the reactor vessel has not deteriorated significantly under service conditions;

(6) may be annealed to restore the material toughness properties if this becomes necessary; and

(7) will be subjected to surveillance to account for neutron irradiation damage so that the operating limitations may be adjusted.

The applicant described the Inservice Inspection Program and its implementation in SRP Section 5.2.4 in conformance with 10 CFR 50.55a(g). In addition, the applicant described the Reactor Vessel Material Surveillance program and its implementation in SRP Section 5.3.1 in conformance with 10 CFR 50.60 and 10 CFR 50, Appendix H.

The reviewer ensures the Inservice Inspection and Reactor Vessel Material Surveillance Programs and their associated implementation milestones in SRP Section 5.2.4 and SRP Section 5.3.1 are included within the license condition on operational program implementation. 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 following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

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.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulations and regulatory guide.

VI. REFERENCES

1. 10 CFR 50.55a, "Codes and Standards."

2. 10 CFR 50.60, "Acceptance Criteria for Fracture Prevention Measures for Light-water Nuclear Power Reactors for Normal Operation."

3. 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events."

4. 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1, “Quality Standards and Records.”

5. 10 CFR Part 50, Appendix A, GDC 4, “Environmental and Dynamic Effects Design Bases.”

6. 10 CFR Part 50, Appendix A, GDC 14, “Reactor Coolant Pressure Boundary.”

7. 10 CFR Part 50, Appendix A, GDC 30, “Quality of Reactor Coolant Pressure Boundary.”

8. 10 CFR Part 50, Appendix A, GDC 31, “Fracture Prevention of Reactor Coolant Pressure Boundary.”

9. 10 CFR Part 50, Appendix A, GDC 32, “Inspection of Reactor Coolant Pressure Boundary.”

10. 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.”

11. 10 CFR Part 50, Appendix G, “Fracture Toughness Requirements.”

12. 10 CFR Part 50, Appendix H, “Reactor Vessel Material Surveillance Program Requirements.”

13. Regulatory Guide 1.99, Revision 2, “Radiation Embrittlement of Reactor Vessel Materials.”

14. ASME Boiler and Pressure Vessel Code, Sections II, III, V, IX, and XI, American Society of Mechanical Engineers.

15. ASME Boiler and Pressure Vessel Code, Section III, Appendix G, “Protection Against Nonductile Failure,” American Society of Mechanical Engineers.

16. 10 CFR 50.66, “Requirements for thermal annealing of the reactor pressure vessel.”

17. NRC Inspection Manual Chapter IMC-2504, “Construction Inspection Program - Non-ITAAC Inspections,” issued April 25, 2006.