U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

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 review of 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.

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.

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. 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.”

9. Inspection, Test, Analysis, and Acceptance Criteria (ITAAC)

For design certification and combined license (COL) reviews, the applicant’s proposed information on the ITAAC associated with the systems, structures, and components (SSCs) related to this SRP section is reviewed in accordance with SRP Section 14.3. It is recognized that the review of ITAAC is performed after review of the rest of this portion of the application against acceptance criteria contained in this SRP section.

Furthermore, the ITAAC are reviewed to assure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

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.

In addition, the listed 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.

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

II. ACCEPTANCE CRITERIA

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[1] 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). In addition, the acceptance criteria describe methods to meet the requirements of 10 CFR Part 52 including:

A. 10 CFR 52.47(a)(1)(vi), as it relates to ITAAC (for design certification) sufficient to assure that SSCs will operate in accordance with the certification.

B. 10 CFR 52.97(b)(1), as it relates to ITAAC (for combined licenses) sufficient to assure that SSCs have been constructed and will be operated in conformity with the license and the Commission's regulations.

Interrelationships among review areas, and criteria for consistency, compatibility, and technical coherence among review areas, are emphasized in the following discussion:

[1]Note: 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 an acceptable method of complying 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 Code (References 14 and 15). 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.

Technical Rationale:

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 and emphasize material from the procedures described below, as may be appropriate for a particular case. The reviewer initially determines that the basic criteria are met in each review area covered by this SRP section. Although not normally responsible for the basic reviews of all of these areas, the reviewer will consult with those responsible for basic review of these areas to determine that all areas are individually acceptable. These review procedures are based on the identified SRP acceptance criteria. For deviations from these specific acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives to the SRP criteria provide an acceptable method of complying with the relevant NRC requirements identified in specific review areas.

The reviewer then reviews each area again, considering the information presented in other areas that interrelate with it, as discussed in Subsection II above.

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 branch members as appropriate.

For reviews of COL applications under 10 CFR Part 52, the reviewer should follow the above procedures to verify that the design set forth in the SAR, and if applicable, site interface requirements meets the acceptance criteria. For design certification applications, the reviewer should identify necessary combined license action items. Following this review, SRP Section 14.3 should be followed for the review of Tier I information for the design, including the postulated site parameters, interface criteria, and ITAAC. With respect to COL applications, the scope of the review is dependent on whether the COL applicant references a design certification, an ESP or other NRC-approved material.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information is provided to satisfy the guidance of this SRP section, and that the completeness and technical adequacy of the evaluation will support conclusions of the following type, to be included in the staff's safety evaluation report:

> 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."

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.

For design certification and combined license 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 the ITAAC, including design acceptance criteria (DAC), as applicable, and interface requirements and combined license action items relevant to this SRP section.

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 design certifications and license applications submitted by applicants pursuant to 10 CFR Parts 50 or 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 6 months or more after the date of issuance of this SRP section, unless superceded 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 Lightwater 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.”

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the draft Standard Review Plan are covered by the requirements of 10 CFR 50.54, which were approved by the Office of Management and Budget, approval number 3150 - 0011.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

SRP Section 5.3.3
Description of Changes

The following summarizes the changes in Revision 2, dated xxxxxx 2006.

16. General changes included editorial and formatting changes. Note: minor editorial and formatting changes are not identified by side bars.

17. Standard language was added throughout the SRP section to extend the applicability to licensing and design certification reviews submitted under 10 CFR Part 52, including the applicability of the Combined License Applications for Nuclear Power Plants (LWR Edition) - Regulatory Guide DG-1145 as superceded by the final guide expected December 2006.

18. Language was added to the boilerplate on the front page, acceptance criteria and review procedures to clarify that the SRP represents an acceptable approach for meeting the Commission's regulations and that applicants are required to identify deviations from this criteria and evaluate how the alternative approaches meet the Commission's regulations.

19. Specific changes identified by section of the SRP:

REVIEW RESPONSIBILITIES - Editorial revision to reflect change in primary review branch resulting from office reorganization – identified by function. This change is reflected throughout the SRP section. Added secondary review function as a result of reorganization.

I. AREAS OF REVIEW

1. Design: Editorial change to clarify scope of review and provide reference to the applicable SRP sections.

8. Threaded Fasteners: This item was added to provide a reference to a new SRP section on threaded fasteners, which addresses the resolution of Generic Safety Issue (GSI) 29 as described in Generic Letter 91-17 and NUREG-1339.

9. Inspection, Test, Analysis, and Acceptance Criteria (ITAAC)

   This subsection was added for the purpose of addressing design certification and combined license reviews performed pursuant to 10 CFR Part 52.

Review Interfaces (This heading added as part of SRP updated format):

- Editorial change to capture SRP sections identified in areas of review.
- Reformatted to list interfaces with other SRP sections.

II. ACCEPTANCE CRITERIA

Updated the general discussion of acceptance criteria (first paragraph) to reflect changes and additions to the applicable regulations of 10 CFR Part 50 related to reactor vessel integrity. A citation to 10 CFR Part 52 was added in reference to ITAAC requirements for design certification and combined license reviews.

1. Design: Paragraph on fracture toughness (3rd paragraph under "Design") was revised to identify requirements contained in § 50.66, as they relate to satisfying General Design Criteria (GDC) 31.

2. Materials of Construction: Fourth paragraph provides reference to the latest revision of Regulatory Guide (RG) 1.99 (Rev. 2).

6. Operating Conditions: First paragraph adds a reference to the requirements contained in § 50.61 concerning the protection against pressurized thermal shock (PTS) events at PWRs.

Technical Rationale: Section added as part of the SRP updated format, references the applicable SRP sections for specific technical rationale.

III. REVIEW PROCEDURES

End of Subsection III: Paragraph introduced based on its applicability to standard design certification reviews and combined license reviews under 10 CFR Part 52.

IV. EVALUATION FINDINGS

Most changes are editorial in nature capturing previously described changes, as applicable to this SRP section.

Item (4), (under reactor vessel integrity assurance criteria): Changed "anticipated transients" to "anticipated operational occurrences" in accordance with the resolution of Generic Safety Issue B-3, and consistent with language in Appendix G to Part 50.

Final paragraph of evaluation findings subsection was introduced based on its applicability to standard design certification reviews and combined license reviews under 10 CFR Part 52.

V. IMPLEMENTATION

Editorial changes capturing applicability to Part 52 and time frame in which SRP update goes into effect.

VI. REFERENCES:

Updated to reflect applicable regulations and renumbered per updated SRP format.

II. ACCEPTANCE CRITERIA

Updated the general discussion of acceptance criteria (first paragraph) to reflect changes and additions to the applicable regulations of 10 CFR Part 50 related to reactor vessel integrity. A citation to 10 CFR Part 52 was added in reference to ITAAC requirements for design certification and combined license reviews.

1. Design: Paragraph on fracture toughness (3rd paragraph under "Design") was revised to identify requirements contained in § 50.66, as they relate to satisfying General Design Criteria (GDC) 31.

2. Materials of Construction: Fourth paragraph provides reference to the latest revision of Regulatory Guide (RG) 1.99 (Rev. 2).

6. Operating Conditions: First paragraph adds a reference to the requirements contained in § 50.61 concerning the protection against pressurized thermal shock (PTS) events at PWRs.

Technical Rationale: Section added as part of the SRP updated format, references the applicable SRP sections for specific technical rationale.

III. REVIEW PROCEDURES

End of Subsection III: Paragraph introduced based on its applicability to standard design certification reviews and combined license reviews under 10 CFR Part 52.

IV. EVALUATION FINDINGS

Most changes are editorial in nature capturing previously described changes, as applicable to this SRP section.

Item (4), (under reactor vessel integrity assurance criteria): Changed "anticipated transients" to "anticipated operational occurrences" in accordance with the resolution of Generic Safety Issue B-3, and consistent with language in Appendix G to Part 50.

Final paragraph of evaluation findings subsection was introduced based on its applicability to standard design certification reviews and combined license reviews under 10 CFR Part 52.

V. IMPLEMENTATION

Editorial changes capturing applicability to Part 52 and time frame in which SRP update goes into effect.

VI. REFERENCES:

Updated to reflect applicable regulations and renumbered per updated SRP format.

OFFICE	EMCB:DE	NRPB	DCI/CPNB	DCI/CVIB	OGC (NLO w/comment)	DCI
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