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(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

5.3.3 REACTOR VESSEL INTEGRITY

REVIEW RESPONSIBILITIES

Primary - Materials Engineering Branch (MTEB)

Secondary - None

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 by MTEB for compatibility of design with material properties and fabrication methods and by MTEB 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 by MTEB as described in SRP Section 5.2.3, "Reactor Coolant Pressure Boundary Materials," and in SRP Section 5.3.1, "Reactor Vessel Materials."

3. Fabrication Methods

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

4. Inspection Requirements

The inspection test methods and requirements are reviewed by MTEB 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 by MTEB 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 by MTEB as described in SRP Section 5.3.2, "Pressure-Temperature Limits."

7. Inservice Surveillance

Plans and provisions for inservice surveillance of the reactor vessel are reviewed by MTEB as described in SRP Sections 5.3.1 and 5.2.4.

In addition, the MTEB will coordinate evaluations of other branches that interface with the overall review of the reactor vessel as follows:

The Mechanical Engineering Branch (MEB) reviews the reactor vessel design regarding compliance with §50.55a of 10 CFR Part 50 and regarding applicable Code Cases, as part of its primary review responsibility for SRP Sections 5.2.1.1 and 5.2.1.2.

The review for Quality Assurance is coordinated and performed by the Quality Assurance Branch (QAB) as part of its primary review responsibility for SRP Sections 17.1 and 17.2.

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

II. ACCEPTANCE CRITERIA

The basic acceptance criteria for each review area are covered by other standard review plan 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; Appendices B, G, and H; and §50.55a. Interrelationships among review areas, and criteria for consistency, compatability, and technical coherence among review areas, are emphasized in the following discussion:

1. Design

The quality standards requirements of GDC 1, GDC 30, and §50.55a are met, regarding compatibility of design with material properties and fabrication methods, by compliance with the provisions of the ASME 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, "Reactor Coolant Pressure Boundary Inservice Inspection and Testing." This satisfies the requirements of GDC 32 and §50.55a regarding inservice inspection.

If the neutron radiation exposure of the reactor vessel becomes high enough that the predicted value of the adjusted reference temperature of the material exceeds 200°F, the design must be adequate to permit in-place annealing of the vessel to restore ductility and toughness, in accordance with Appendix G, "Fracture Toughness Requirements," of 10 CFR Part 50. This satisfies the fracture toughness requirement of GDC 31.

2. <u>Materials of Construction</u>

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 Section 5.2.3, "Reactor Coolant Pressure Boundary Materials," and in SRP Section 5.3.1, "Reactor Vessel Materials." 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. 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 Cl 1, SA 508 Cl 2, and SA 508 Cl 3. Acceptability criteria for other grades will have to be developed before they can be used.

The relationships among material compositions, expected neutron fluence, and requirements for the material surveillance program must be compatible. 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 must be at least as conservative as that obtained by use of Regulatory Guide 1.99, "Effects of Residual Elements on Predicted Radiation Damage to Reactor Vessel Materials." 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 must 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 Sections III and 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 must determine that the methods of inspection, the sensitivity levels, and flaw evaluation criteria are compatible with Section XI, and that 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 must determine that these criteria will be adequate, based on current technology.

If the basic criteria are not followed, either intentionally or through error, the reviewer must 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, "Pressure-Temperature Limits." These acceptance criteria are given in Appendix G, "Fracture Toughness Requirements," to 10 CFR Part 50.

The criterion for acceptable behavior is that the vessel must remain 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 Standard Review Plan Section 5.2.4, "Reactor Coolant Pressure Boundary Inservice Inspection and Testing." These criteria are those of Section XI of the Code.

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 he will not normally be responsible for the basic reviews of all of these areas, he will consult with those responsible for basic review of the other areas to determine that all areas are individually acceptable.

He 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 can readily pick out any differences from past practice. He will evaluate these in detail, consulting with other MTEB members as appropriate.

IV. EVALUATION FINDINGS

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

The staff concludes that 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 Appendices B, G, and H of 10 CFR Part 50; and the requirements of Section 50.55a of 10 CFR Part 50. 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, "RCPB Materials."

(2) SRP Section 5.2.4, "RCPB Inservice Inspection and Testing."

(3) SRP Section 5.3.1, "Reactor Vessel Materials."

(4) SRP Section 5.3.2, "Pressure-Temperature Limits."

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 Nonductile Failure," of ASME Code Section III, and Appendix G, 10 CFR Part 50.

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 transients;

(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.

V. IMPLEMENTATION

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

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.

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

VI. REFERENCES

1. Standard Review Plan Section 5.2.3, "RCPB Materials."

2. Standard Review Plan Section 5.2.4, "RCPB Inservice Inspection and Testing."

3. Standard Review Plan Section 5.3.1, "Reactor Vessel Materials."

4. Standard Review Plan Section 5.3.2, "Pressure-Temperature Limits."

5. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants." (Criterion 1, "Quality Standards and Records;" Criterion 4, "Environmental and Missile Design Bases;" Criterion 14, "Reactor Coolant Pressure Boundary;" Criterion 30, "Quality of Reactor Coolant Pressure Boundary;" Criterion 31, "Fracture Prevention of Reactor Coolant Pressure Boundary;" and Criterion 32, "Inspection of Reactor Coolant Pressure Boundary.")

6. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."

7. 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements."

8. 10 CFR Part 50, Appendix H, "Reactor Vessel Material Surveillance Program Requirements."

9. 10 CFR Part 50, Section 50.55a, "Codes and Standards."

10. ASME Boiler and Pressure Vessel Code, Section III, especially Appendix G, "Protection Against Nonductile Failure," American Society of Mechanical Engineers.

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

12. Regulatory Guide 1.99, "Effects of Residual Elements on Predicted Radiation Damage to Reactor Vessel Materials."