U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.2.7 FRACTURE PREVENTION OF CONTAINMENT PRESSURE BOUNDARY

REVIEW RESPONSIBILITIES

Primary - Materials and Chemical Engineering Branch (EMCB)~~(MTEB)~~[1]

Secondary - None

I. AREAS OF REVIEW

The reactor containment pressure boundary relates to the reactor containment system. The reactor containment system design must include the functional capability of enclosing the reactor system and of providing a final barrier against the release of radioactive fission products attendant to[2] postulated accidents. This SRP section reviews fracture prevention of the reactor containment pressure boundary materials.

The review of the reactor containment system is addressed further[3] within the context of General Design Criterion (GDC) 51 of Appendix A of 10 CFR Part 50 and Section III, Division 1,[4] Subsection NE of the ASME Boiler and Pressure Vessel Code (Reference 8)[5], as~~ endorsed by 10 CFR Part 50, and~~[6] ~~stated by~~reflected in[7] Standard Review Plan (SRP) Section 3.8.1, "Concrete Containment" and SRP Section 3.8.2, "Steel Containment." The reactor containment system, as addressed in the NRC licensing review process, includes (a) the containment vessel, and[8] (b) all penetration assemblies or appurtenances attached to the containment vessel, all piping, pumps and valves attached to the containment vessel, or to penetration assemblies out to and including the pressure boundary materials of any valves required to isolate the system and provide a pressure boundary for the containment function.[1]

The reactor containment pressure boundary, as addressed in the NRC licensing review process, consists of those ferritic steel parts of the reactor containment system which sustain loading and

provide a pressure boundary in the performance of the containment function under the operating, maintenance, testing and postulated accident conditions cited by GDC 51. Within this context, typically reviewed are the ferritic materials of components such as freestanding containment vessels, equipment hatches, personnel airlocks, heads of primary containment drywells, tori, containment penetration sleeves, process pipes, end closure caps and flued heads,[9] and penetrating-piping systems connecting to penetration process pipes and extending to and including the system isolation valves.

Review Interfaces:[10]

The EMCB also also performs the following reviews under the SRP sections indicated: Reviews the adequacy of programs for assuring the integrity of bolting and threaded fasteners as part of its primary review responsibility for SRP Section 3.13 (proposed).[11]

The ~~Materials Engineering Branch~~EMCB[12] will coordinate other branches' evaluations that interface with the overall review of this area as follows:~~its licensing review with interfacing licensing reviews by the Structural~~[13] The Civil Engineering and Geosciences Branch (ECGB)~~(SEB)~~[14] reviews the design of concrete containments as part of its primary review responsibility for~~as addressed by~~ SRP Section 3.8.1, ~~which addresses concrete containments~~ and the design of steel containments as part of its primary review responsibility for SRP Section 3.8.2.~~, which addresses steel containments.~~[15]

For the areas of review identified above as part of the review under other SRP sections, the acceptance criteria and their methods of application are contained in the referenced SRP sections.[16]

II. ACCEPTANCE CRITERIA

The EMCB~~MTEB~~[17] review applies acceptance criteria based on meeting the relevant requirements of the following Commission regulations:

1. General Design Criterion 1, as it relates to the quality standards for design and fabrication.[18]

2. General Design Criterion 16, as it relates to the prevention of the release of radioactivity to the environment.[19]

3. General Design Criterion 51, as it relates to the reactor containment pressure boundary being designed with sufficient margin to assure that under operating, maintenance, testing, and postulated accident conditions (1) its ferritic materials behave in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized.

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[1]For components which also ~~may be~~perform other pressure-retaining functions important to safety in addition to comprising a part of the containment pressure boundary (e.g., part of the reactor coolant pressure boundary), the provisions of 10 CFR Part 50, §50.55a are also applicable. These aspects are considered in other SRP s~~S~~ections such as 5.2.3.[20]

To meet the requirements of GDC 1, 16 and 51, ferritic containment pressure boundary materials should meet the fracture toughness criteria and requirements for testing~~for Class 2 components~~ identified in Article NE-2300 of Section III, Division 1 of the ASME Code or, for materials that were not fracture toughness tested as discussed below, the fracture toughness criteria for Class 2 components identified in the Summer 1977 Addenda to~~the Summer 1977 Addenda of~~[21] Section III, Division 1, Subsection NC (Reference 7)[22] of the ASME Code.~~ These criteria were selected to provide for a uniform review, consistent with the safety function of the containment pressure boundary within the context of Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants." The consistency is developed in that the containment system is addressed in the licensing review process as an engineered safety feature, as is, for example, the emergency core cooling system. Regulatory Guide 1.26 is silent with respect to the containment pressure boundary, but does assign Group B Quality Standard to the emergency core cooling system. Regulatory Guide 1.26 assigns correspondence of Group B Quality Standard to ASME Code Section III Class 2.~~[23]

Mandatory fracture toughness testing of ASME Code Section III Class 2 materials was first identified in the Summer 1977 Addenda Code Class 2 rules. As a result, cases exist where Class 2 ferritic materials of the reactor containment pressure boundary were not fracture toughness tested, because the ASME Code Edition and Addenda in effect at the time the components were ordered, did not require that they be tested. The staff's assessment of the fracture toughness of materials that were not fracture toughness tested is based on the metallurgical characterization of these materials and fracture toughness data presented in NUREG-0577, "Potential for Low Fracture Toughness and Lamellar Tearing on PWR Steam Generator and Reactor Coolant Pump Supports," ~~USNRC, October 1979 (Draft)~~(Reference 6)[24] and ASME Code Section III, Summer 1977 Addenda, Subsection NC. The metallurgical characterization of these materials, with respect to their fracture toughness, is developed from a review of how these materials were fabricated and what thermal history they experienced during fabrication. The metallurgical characterization of these materials, when correlated with the data presented in NUREG-0577 and the Summer 1977 Addenda of the ASME Code Section III, provides the technical basis for the staff's evaluation of the compliance with Code Class 2 requirements of the materials which were not fracture toughness tested.

Technical Rationale:[25]

The technical rationale for application of the above acceptance criteria to fracture prevention of containments is discussed in the following paragraphs:

1. GDC 1 requires that systems be designed, built, tested and maintained to appropriate quality standards to assure they will satisfactorily perform their safety functions. This SRP section evaluates the fracture toughness of the containment pressure boundary ferritic materials to ensure they are not subject to brittle fracture. ASME Code Section III, Division 1, Class MC (Metal Containment) or Class 2 component criteria are used in the performance of this fracture toughness evaluation. The application of Code Class MC component criteria for the evaluation metal containment components and the specific application of Subsection NE-2000 for evaluation of steel containment materials are established staff practices reflecting that Code Class MC requirements for materials,

design, fabrication, and testing are commensurate with the safety function of containment (see SRP Sections 3.2.2 and 3.8.2). The application of Code Class 2 criteria for materials that were not fracture toughness tested is consistent with the methodology for application of quality standards to pressure-retaining components commensurate with the importance of their safety functions as described in Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants." The consistency is developed in that the containment system is addressed in the licensing review process as an engineered safety feature, as is, for example, the emergency core cooling system. Regulatory Guide 1.26 does not explicitly discuss or classify the containment pressure boundary, but does assign a Quality Group B classification to the emergency core cooling system. Regulatory Guide 1.26 assigns correspondence between Quality Group B components and ASME Code Section III, Division 1 requirements for Class 2 components.[26] The containment pressure boundary is one of the barriers that prevent the release of radioactivity to the environment in the event of an accident, and therefore fulfills a vital safety-related role. Use of appropriate design and fabrication standards in conjunction with Article NE-2300 fracture toughness testing or evaluation of ferritic containment pressure boundary materials with respect to ASME Code Class 2 fracture toughness requirements provides assurance that containment will not fail due to brittle behavior and will thus be capable of preventing the release of radioactivity to the environment.

2. GDC 16 requires containment to be designed as a leak tight barrier that will withstand the most extreme accident conditions for the duration of any postulated accident. Containment must be leak tight and withstand accidents because it is the final barrier against the release of radioactivity to the environment in the event of a LOCA. To ensure leak tightness, containment must not be subject to brittle fracture even under the most severe postulated conditions. Meeting GDC 16 provides assurance that containment will satisfactorily fulfill its safety role and that significant radioactivity will not be released to the environment.

3. GDC 51 provides the baseline requirement that the reactor containment design precludes brittle behavior of ferritic materials and minimizes the probability of rapidly propagating fracture during postulated operation, testing, maintenance, and accident conditions. As the final barrier against the release of radioactivity to the environment, containment must not be subject to brittle failure or rapidly propagating fracture, either of which could cause a breach of containment integrity. Meeting GDC 51 will ensure that the containment pressure boundary remains intact during the harshest expected conditions thereby precluding the release of radioactivity to the environment.

III. REVIEW PROCEDURES

The licensing review process assesses the fracture toughness of the materials of the components of the reactor containment pressure boundary identified in Section I, within the context of compliance with the criteria of Article NE-2300 ~~for Class 2 components identified in the Summer 1977 Addenda~~ of Section III, Division 1[27] of the ASME Code.[28]

The reviewer addresses the information provided by the applicant for the materials of the components of interest. Such information should consist of construction drawings, piping system diagrams and related supplemental information, ASME Code Data Reports and certified material test reports.

For those ferritic materials for which fracture toughness data are unavailable, or are inappropriate, the reviewer addresses the applicant's assessment of their fracture toughness based on a metallurgical characterization developed from a review of how these materials were fabricated and what thermal history they experienced during fabrication. The reviewer addresses the applicant's correlation of this information with the fracture toughness data presented in NUREG-0577 and ASME Section III, Summer 1977 Addenda, Subsection NC. The reviewer addresses the applicant's justification of the acceptability of these materials within the context of the criteria for Class 2 materials as stated in the Summer 1977 Addenda, ASME Code Section III. The reviewer verifies that the Class 2 requirements of the Summer 1977 Addenda of ASME Section III code have been met by the applicant.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[29]

IV. EVALUATION ~~OF~~ FINDINGS[30]

The reviewer verifies that information provided by the applicant through construction drawings, piping system diagrams and related supplemental information, ASME Code Data Reports and certified material test reports, is sufficient to support ~~the~~ statements and conclusions of the following type in the staff's safety evaluation report:[31]

> The staff concludes that reasonable assurance has been provided that the materials of the reactor containment pressure boundary, under operating, maintenance, testing and postulated accident conditions, will not undergo brittle fracture, and that the probability of rapidly propagating fracture will be minimized, so that the requirements of General Design Criteria 1, 16, and 51 will be met. This conclusion is based on the following (provide the finding that applies):[32]
>
> > Based on its review, the staff finds that the ferritic materials of the reactor containment pressure boundary were (or will be where appropriate) acceptably tested and demonstrated to meet the fracture toughness requirements for Class MC components as specified in Article NE-2300 of ASME Code Section III, Division 1.
>
> OR[33]

For ferritic reactor containment pressure boundary materials that were not fracture toughness tested, ~~B~~based[34] on the licensing process review of the applicant's available fracture toughness data, metallurgical characterizations of the materials of interest developed from their fabrication and thermal histories,[35] and correlations of metallurgical histories with fracture toughness data presented in NUREG-0577 and ASME Code Section III, ~~SUMMER~~Summer[36] 1977 Addenda, Subsection NC, the conclusion is made that the fracture toughness of the materials of the reactor containment pressure boundary meet the fracture toughness requirements invoked for ASME Code Section III Class 2 materials effective with the Summer 1977 Addenda."[37]

~~The staff concludes that reasonable assurance has been provided that the materials of the reactor containment pressure boundary, under operating, maintenance, testing and postulated accident conditions, will not undergo brittle fracture, that the probability of rapidly propagating fracture will be minimized, so that the requirements of General Design Criteria 1, 16, and 51 will be met.~~[38]

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[39]

V. IMPLEMENTATION

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

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[40] Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[41]

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced ~~regulatory guides and NUREGs~~regulations.[42]

VI. REFERENCES[43]

1. 10 CFR Part 50, §50.55a, Codes and Standards.[44]

~~1~~2. 10 CFR Part 50,[45] Appendix A, General Design Criterion 1, "Quality Standards and Records."

~~2~~3. 10 CFR Part 50, Appendix A, General Design Criterion 16, "Containment Design."

~~3~~4. 10 CFR Part 50, Appendix A, General Design Criterion 51, "Fracture Prevention of Containment Pressure Boundary."

~~6~~5. Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants."

~~5~~6. NUREG-0577 Revision 1, "Potential for Low Fracture Toughness and Lamellar Tearing on PWR Steam Generator and Reactor Coolant Pump Supports," USNRC, October 1983~~1979 (Draft)~~.[46]

~~4~~7. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Summer 1977 Addenda, Subsection NC, "Class 2 Components", American Society of Mechanical Engineers.[47]

8. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NE, "Class MC Components," American Society of Mechanical Engineers.[48]

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SRP Draft Section 6.2.7
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
2.	Editorial	Added the word "to" to clarify the sentence.
3.	Editorial	Revised to reflect wording as an area of review. Also, since SRP Section 6.2.7 cites relevant requirements of GDC 51 and Subsection NE of Section III of the ASME Code, added "further" to reflect that some aspects of the review for compliance with GDC 51 and Subsection NE are obviously within the Areas of Review of SRP Section 6.2.7.
4.	Reference verification	Revised to reflect that Subsection NE is within Section III, Division 1 of the Code.
5.	SRP-UDP format item, reference citations	Format change to make the citation of references consistent with the SRP-UDP required format.
6.	Reference verification	Based upon review of current 10 CFR Part 50 requirements, no evidence could be found that Subsection NE of Section III of the ASME Code is "endorsed by 10 CFR Part 50," (although 10 CFR Part 50 references portions of Subsection NE, e.g., subsubarticle NE-3220) thus allusion to such endorsement was deleted.
7.	Editorial	This information is not explicitly stated in SRP Section 3.8.1 or 3.8.2, therefore revised to indicate that the approach described is reflected in these SRP sections.
8.	Editorial	Added the word "and" to clarify the sentence.
9.	Editorial	Added a comma to clarify the sentence.
10.	SRP-UDP format item, Reformat Areas of Review	Added "Review Interfaces" heading to Areas of Review. Reformatted existing description of one review interface to describe how ECGB reviews aspects of the containment design under other SRP sections and how another branch supports the review.
11.	SRP-UDP Integration of Bolting Issues, Potential Impact 25750	Added a review interface reflecting reviews of bolting and threaded fastener programs under new SRP Section 3.13.
12.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section. Used PRB abbreviation rather than name for consistency with other sections.

Item	Source	Description
13.	SRP-UDP format item, Reformat Areas of Review	Modified Review Interfaces lead in sentence for consistency with other sections and recommended SRP-UDP format.
14.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for SRP Sections 3.8.1 and 3.8.2.
15.	SRP-UDP format item, Reformat Areas of Review	Modified Review Interfaces wording for consistency with other sections and recommended SRP-UDP format.
16.	SRP-UDP format item, Reformat Areas of Review	Added a Review Interfaces closure sentence for consistency with other sections and recommended SRP-UDP format.
17.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
18.	Editorial	A period was added to the first two general Acceptance Criteria for clarity and consistency with other sections.
19.	Editorial	A period was added to the first two general Acceptance Criteria for clarity and consistency with other sections.
20.	Reference verification	Revised the note to reflect the current scope of 10 CFR 50.55a requirements which address the application of ASME Code Class 1-3 requirements to Quality Groups A-C pressure-retaining components.
21.	**Integrated Impact 283**, Incorporation of PRB Comment on earlier draft	The specific criterion was modified to refer to ASME Code Section III, Subsection NE-2000, (Article NE-2300 as the specific location of fracture toughness criteria) and to restore Class 2 component criteria for materials which were not fracture toughness tested.
22.	SRP-UDP format item, Reference verification	Revised to reflect that the relevant Addenda modifies Subsection NC within Section III, Division 1 of the Code and to identify the Addenda by reference number at the point of its first citation, consistent with SRP-UDP format.
23.	Editorial	Discussion regarding Regulatory Guide 1.26 was moved to subsection II, Acceptance Criteria, Technical Rationale 1. This discussion is not an acceptance criteria, but rather an explanation of why certain acceptance criteria exist. The discussion is more appropriate in the new Technical Rationale subsection. The text of the discussion was updated to reflect terminology used in the current revision of Regulatory Guide 1.26.

Item	Source	Description
24.	SRP-UDP format item, reference verification/citation	Revised citation for NUREG-0577 October 1979 (Draft) to cite NUREG-0577. Applicable version of this standard is specified in the References subsection. Also added parenthetical citation for this reference per SRP-UDP guidance.
25.	SRP-UDP format item, Develop Technical Rationale	Added Technical Rationale for GDC's 1, 16, and 51. Technical Rationale is a new SRP-UDP format item.
26.	Editorial	Discussion regarding Regulatory Guide 1.26 was moved from Subsection II, Acceptance Criteria.. This discussion is not an acceptance criteria, but rather an explanation of why certain acceptance criteria exist. The discussion is more appropriate in the new Technical Rationale subsection. The text of this discussion was updated to reflect terminology used in the current revision of Regulatory Guide 1.26.
27.	Reference verification	Revised to reflect that Subsection NE is within Section III, Division 1 of the Code.
28.	**Integrated Impact 283**	The first paragraph of Review Procedures was modified to refer to ASME Code Section III, Article NE-2300 consistent with previously added specific criteria.
29.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
30.	Editorial	Deleted "OF" from the subsection title for consistency with other SRP Sections.
31.	Editorial	For clarity and consistency with other sections, modified the lead in sentence for the Evaluation Findings subsection to read in part "sufficient to support statements and conclusions of the following type."
32.	Editorial	Moved the conclusion paragraph up and added "This conclusion is based on the following:" to facilitate adding subsequent revisions to the Evaluation Findings subsection. Also numbered the Evaluation Findings items for clarity and consistency with other sections.
33.	**Integrated Impact 283**	Added a new item to the Evaluation Findings subsection to discuss findings pertinent to ASME Code Section III, Article NE-2300 and provided for a contingent finding based on whether materials were fracture toughness tested.
34.	Editorial	Added a lead in phrase for the second evaluation finding. This clarifies the item and facilitates adding a new evaluation finding item 1.
35.	Editorial	Added a comma to the sentence to provide clarity.

Item	Source	Description
36.	Editorial	Revised "SUMMER" to " Summer" to correct the ASME Code title.
37.	Editorial	Deleted stray quotation mark.
38.	Editorial	Moved the conclusion paragraph up to facilitate revising the Evaluation Findings subsection.
39.	10 CFR 52 applicability related change	Discussion of findings for design certification reviews was added to the Evaluation Findings subsection as required by the SRP-UDP Program.
40.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
41.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
42.	Editorial	Replaced "regulatory guides and NUREGs" with "regulations" to provide a more generic categorization of the implementing documents.
43.	SRP-UDP format item, Editorial	References have been reordered per SRP-UDP guidance and due to the addition of a new reference 1. New references are interspersed with old ones, and items have been renumbered accordingly.
44.	SRP-UDP format item, reference verification	Added to CFR 50.55a to reference list consistent with the SRP-UDP guidance. This reference is cited in footnote 1 (Areas of Review).
45.	Editorial	A comma was added after "10 CFR 50" in references 2, 3, and 4 for clarity and consistency with other sections.
46.	SRP-UDP format item, reference verification.	Updated NUREG-0577 reference to revision 1 which is the version currently approved by the NRC.
47.	Editorial	Modified the title of this ASME Code section for completeness and consistency with other ASME Code citations.
48.	**Integrated Impact 283**, SRP-UDP format item, reference verification.	Added ASME Code Section III, Division 1, Subsection NE to the list of references consistent with the SRP-UDP guidance.

Integrated Impact No.	Issue	SRP Subsections Affected
283	Consider modifying this section such that ASME Code references are not specific to a particular version and year.	Subsection II, Acceptance Criteria, specific criteria paragraph. Subsection III, Review Procedures, first paragraph. Subsection IV, Evaluation Findings.
969	This Integrated Impact identifies a future work issue to add a new section to Regulatory Guide 1.70 covering fracture prevention of containment pressure boundary.	None