U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

3.9.1 SPECIAL TOPICS FOR MECHANICAL COMPONENTS

REVIEW RESPONSIBILITIES

Primary - Mechanical Engineering Branch ~~(MEB)~~(EMEB)[1]

Secondary - None

I. AREAS OF REVIEW

The ~~(MEB)~~(EMEB)[2] reviews information in the safety analysis report (SAR),[3] concerning methods of analysis for seismic Category I components and supports, including both those designated as Code[*] Class 1, 2, 3, or CS and those not covered by the Code. Certain aspects of dynamic system analysis methods are discussed in Standard Review Plan (SRP)[4] Section 3.9.2 as well as this SRP section. Information is also reviewed concerning design transients for Code Class 1 and CS components and supports. The following specific subjects are reviewed under this SRP section:

1. Transients which are used in the design and fatigue analyses of all Code Class 1 and CS components, and supports and reactor internals.

2. Description and verification of all computer programs which will be used in analyses of seismic Category I Code and non-Code items listed in this SRP section.

3. Description of any experimental stress analysis programs which will be used in lieu of theoretical stress analyses.

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[*]American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III (hereafter "the Code").

4. Description of the analysis methods which will be used if the applicant elects to use elastic-plastic stress analysis methods in the design of any of the above-noted components.

5. The environmental conditions to which all safety-related components will be exposed over the life of the plant.[5]

Review Interfaces[6]

1. The Reactor Systems Branch (SRXB)[7] confirms on request the acceptability of the listed transients and the number of cycles and events expected over the service lifetime of the plant.

2. The ~~Structural Engineering Branch~~Civil Engineering and Geosciences Branch (ECGB)[8] confirms the seismic cyclic ground input loading as described in SRP Section 3.7.3. The method used to determine the seismic cyclic loading used for fatigue analysis of appropriate components and supports will be reviewed.

3. The Materials and Chemical Engineering Branch (EMCB) reviews programs for ensuring bolting and threaded fastener adequacy and integrity, as part of its primary review responsibility for SRP Section 3.13 (proposed).[9] In addition, the EMCB reviews the consideration given to minimize the degradation of materials due to corrosion based upon the environmental conditions to which equipment will be exposed as described in SRP Section 6.1.1.[10]

For those areas of review identified above as part of the review under other SRP sections, the acceptance criteria and methods of application are contained in the referenced SRP sections.[11]

II. ACCEPTANCE CRITERIA

~~MEB~~EMEB[12] acceptance criteria is based on meeting the relevant requirements of the following regulations:

~~1~~A.[13] General Design Criterion 1 (GDC 1)[14] as it relates to components important to safety being designed, fabricated, erected, constructed, tested and inspected in accordance with the requirements of applicable codes and standards commensurate with the importance of the safety-function to be performed.

~~2~~B. General Design Criterion 2 (GDC 2)[15] as it relates to safety-related mechanical components of systems being designed to withstand seismic events without loss of capability to perform their safety function.

~~3~~C. General Design Criterion 14 (GDC 14)[16] as it relates to the reactor coolant pressure boundary being designed so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

~~4~~D. General Design Criterion 15 (GDC 15)[17] as it relates to the mechanical components of the reactor coolant system being designed with sufficient margin to ~~assure~~ ensure[18] that the design conditions of the reactor coolant pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences.

~~5~~E. 10 CFR Part 50, Appendix B, as it relates to design quality control.

~~6~~F. 10 CFR Part 100, Appendix A, as it relates to the suitability of the plant design bases for mechanical components established in consideration of site seismic characteristics.

Specific criteria necessary to meet the relevant requirements of the regulations listed above are as follows:

1. To meet the requirements of ~~GDC~~ General Design Criteria[19] 1, 2, 14, 15, and 10 CFR Part 100, Appendix A, the applicant shall provide a complete list of transients to be used in the design and fatigue analysis of all Code Class 1 and CS components, supports and reactor internals within the reactor coolant pressure boundary. The number of events for each transient and the number of load and stress cycles per event and for events in combination shall be included. All transients such as startup and shutdown operations, power level changes, emergency and recovery conditions (including, for new applications, natural convection cooldown)[20], switching operations (i.e., startup or shutdown of one or more coolant loops), control system or other system malfunctions, component malfunctions, transients resulting from single operator errors, inservice hydrostatic tests, seismic events as determined from the criteria specified in Appendix A to 10 CFR Part 100, and design basis events, that are contained in the Code-required "Design Specifications" for the components of the reactor coolant pressure boundary shall be specified, including reactor internals and core support structures.

   The section of the applicant's SAR which pertains to transients will be acceptable if the transient conditions selected for equipment fatigue evaluation are based upon a conservative estimate of the magnitude and frequency of the temperature and pressure conditions resulting from those transients. To a large extent the selection of these specific transient conditions is based upon engineering judgment and experience. Some guidance on the selection of these transients and combinations can be found in References 8 and 9. Transients and resulting loads and load combinations with appropriate specified design and service limits must provide a complete basis for design of the reactor coolant pressure boundary for all conditions and events expected over the service lifetime of the plant.

   Consideration should be given to the number of transients appropriate for the design life of the plant. Also, environmental conditions to which equipment important to safety will be exposed (e.g., chemistry of the coolant water) should be considered to minimize the degradation of materials due to corrosion.[21]

2. To meet the requirements of 10 CFR Part 50, Appendix B, and GDC 1, a list of computer programs that will be used (preferably programs which are recognized and widely known) in dynamic and static analyses to determine the structural and functional integrity

of seismic Category I Code and non-Code items, and the analyses to determine stresses shall be provided. For each program the following information shall be provided to demonstrate its applicability and validity:

a. The author, source, dated version and facility.

b. A description, and the extent and limitation of its application.

c. The computer program solutions to a series of test problems which shall be demonstrated to be substantially similar to solutions obtained from any one of sources 1 through 4, and source 5:

(1) hand calculations[22]

(2) analytical results published in the literature

(3) acceptable experimental tests

(4) by an MEB acceptable similar program

(5) the benchmark problems prescribed in Reference 10.

A summary comparison of the solution obtained by using sources 1 through 4 shall be provided, in either graphical or numerical form. For source 5, the complete computer printout of the input and the solution shall be submitted for every benchmark problem. These solutions may be referenced, and need not be resubmitted, in subsequent license application provided the information submitted under a. and b. remains unchanged.

3. To meet the requirements of ~~GDC~~ General Design Criteria 1, 14, and 15, if experimental stress analysis methods are used in lieu of analytical methods, for any seismic Category I Code or non-Code items, the section of the SAR discussing the experimental stress analysis methods will be acceptable if the information provided meets the provisions of Appendix II to Reference 7, and as in the case of analytical methods, if the information provided is sufficiently detailed to show the validity of the design to meet the provisions of the Code-required "Design Specifications."

4. To meet the requirements of ~~GDC~~ General Design Criteria 1, 14, and 15 when Service Level D limits are specified by the applicant for Code Class 1 and CS components, and for supports, reactor internals, and other non-Code items, the methods of analysis used to calculate the stresses and deformations shall conform to the methods outlined in Appendix F to Reference 7, subject to the conditions discussed in subsection III.4 below.

Technical Rationale[23]

The technical rationale for application of these acceptance criteria to reviewing special topics for mechanical components is discussed in the following paragraphs:[24]

1. Compliance with GDC 1 requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. Related compliance with Appendix B to 10 CFR Part 50 requires that the applicant provide information that demonstrates the applicability and validity of the design methods and computer programs used for the design and analysis of seismic Category I Code Class 1, 2, 3, CS structures, and non-Code structures within current state-of-the-art limits. Further, the applicant should have design control measures that are acceptable to staff for ensuring the quality of computer programs.

   Special topics for mechanical components encompass items related to design transients such as component supports, core supports, and reactor internals designated as Class 1, 2, and 3 under ASME Code, Section III, and those not covered by the Code. The applicability and validity of these criteria are demonstrated by establishing requirements that the design methods and computer programs used in design and analysis are within current state-of-the-art limits and having design control measures acceptable to the staff.

   Meeting the requirements of GDC 1 provides added assurance that the regulatory requirements related to design methodology and quality assurance are satisfied so that structures, systems, and components important to safety are capable of performing their intended functions.[25]

2. Compliance with GDC 2 requires that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The related requirements in Appendix A to 10 CFR Part 100 specify that applicants include seismic events in the design basis and include seismic events in their postulated design transients.

   GDC 2 applies to this SRP section because the reviewer evaluates whether mechanical components are designed to withstand the loads generated by natural phenomena. The reviewer also verifies that the applicant has provided a list of postulated design transients that includes consideration of seismic events.

   Meeting the requirements of GDC 2 provides added assurance that structures, systems, and components important to safety will have the capability to withstand the effects of natural phenomena and thereby perform their intended functions.[26]

3. Compliance with GDC 14 requires that the reactor coolant pressure boundary be designed, fabricated, erected, and tested to demonstrate an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture.

Compliance with GDC 15 requires that the reactor coolant system and associated auxiliary, control, and protection systems be designed with sufficient margin to ensure that the design conditions of the reactor coolant pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences.

GDC 14 and GDC 15 apply to this SRP section because structures, systems, and components important to safety are exposed to postulated transients anticipated during the design life of the plant. If structures, systems, and components are to perform their design functions, adequate assurance must be provided that mechanical components will remain functional under all postulated combinations of normal operating conditions, anticipated operational occurrences, postulated pipe breaks, and seismic events.

Meeting the requirements of GDC 14 and GDC 15 provides added assurance that the design transients and resulting loads and load combinations (with the appropriate specific design and service limits for ASME Code, Class 1, and CS components and supports and reactor internals) form a complete basis for the design of the reactor coolant pressure boundary for all anticipated conditions and extremely low-probability events expected during the service life of the plant.[27]

III. REVIEW PROCEDURES

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

1. The list of transients, the number of events estimated for each transient presented in the applicant's SAR, and the method used to determine this number are compared ~~to~~ with[28] the same information on similar and previously licensed applications and to the acceptance criteria outlined in subsection II above. Any deviations from previous accepted practice are noted and the applicant is required to justify these deviations. For Code Class 1 and CS components and supports the ~~MEB~~EMEB[29] verifies that for each transient loading condition or combination an acceptable Code service limit has been specified, i.e., Design, Level A, Level B, Level C, or Level D as specified in Reference 7.

   Any deviations that have not been justified to the satisfaction of the staff are identified and the finding is transmitted to the applicant with a request that, unless conformance with the MEB acceptance criteria is agreed upon, additional technical justification be submitted.

2. The information pertaining to computer programs which is presented in the applicant's SAR is reviewed as follows:

   a. The list of programs is evaluated to determine that the applicant has adequately described each program with respect to the type of analysis that is performed and the specific components to which the program is applied.

b. The submitted computer solutions to the test problems required in subsection II.2 of this SRP section are reviewed and compared ~~to~~ with the test solutions. Satisfactory agreement of computer and test solutions, usually within a ±5% error band, provides verification of the quality and adequacy of the computer programs to perform the functions for which they were designed.

Any deviations that have not been justified to the satisfaction of the staff are identified and the finding is transmitted to the applicant with a request that, unless conformance with the ~~MEB~~EMEB[30] acceptance criteria is agreed upon, additional technical justification be submitted.

3. If the applicant elects to use experimental stress analysis techniques in lieu of theoretical stress analyses, sufficient information must be presented in the SAR to demonstrate that the requirements of Appendix II to Reference 7 as they apply to the conditions set forth in the "Design Specifications" have been met.

4. If the applicant employs an elastic or an elastic-plastic method of analysis to evaluate the design of safety-related Code or non-Code items for which Service Level D limits have been specified (NB-3225 and Appendix F to Reference 7), the review covers the following points:

   a. The applicant must demonstrate that the stress-strain relationship for component materials that will be used in the analysis is valid. The ultimate strength values at service temperature must be justified.

   b. The analytical procedures to be used in the analysis are reviewed to determine the validity of the analysis. If a computer program is used, the applicable requirements of subsection II.2 above shall be met.

   c. If elastic system analysis is used, its application may require detailed review and justification if applied to the analysis of systems which contain active components with close tolerances, or systems in which the sequence of load application could significantly affect the actual stress distribution.

   d. If elastic, elastic-plastic or limit analysis methods are used for components in conjunction with elastic or elastic-plastic system analyses, the basis upon which these procedures are used are reviewed. The applicant shall provide assurance that the calculated item or item support deformations and displacements do not violate the corresponding limits and assumptions on which the methods used for the system analysis are based.

Any deviations that have not been justified to the satisfaction of the staff are identified and the finding is transmitted to the applicant with a request that, unless conformance with the ~~MEB~~EMEB[31] acceptance criteria is agreed upon, additional technical justification be submitted.

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.[32]

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided in accordance with this SRP section~~,~~ and that ~~his~~ the[33] evaluation supports conclusions of the following type, to be included in the staff's safety evaluation report (SER):[34]

> The staff concludes that the design transients and resulting loads and load combinations with appropriate specified design and service limits for mechanical components is acceptable and meets the relevant requirements of General Design Criteria 1, 2, 14, 15; 10 CFR Part 50, Appendix B; and 10 CFR Part 100, Appendix A. This conclusion is based on the following:
>
> 1. The applicant has met the relevant requirements of General Design Criteria 14 and 15 by demonstrating that the design transients and resulting loads and load combinations with appropriate specified design and service limits which the applicant has used for designing Code Class 1 and CS components and supports, and reactor internals provide a complete basis for design of the reactor coolant pressure boundary for all conditions and events expected over the service lifetime of the plant.
>
> 2. The applicant has met the relevant requirements of General Design Criteria 2 and 10 CFR Part 100, Appendix A, by including seismic events in design transients which serve as design basis to withstand the effects of natural phenomena.
>
> 3. The applicant has met the relevant requirements of 10 CFR Part 50, Appendix B, and General Design Criteria 1 by having submitted information that demonstrates the applicability and validity of the design methods and computer programs used for the design and analysis of seismic Category I Code Class 1, 2, 3, and CS structures, and non-Code structures within the present state-of-the-art limits and by having design control measures which are acceptable to ~~assure~~ ensure the quality of the computer programs.

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.[35]

V. IMPLEMENTATION

The following is intended to provide guidance to applicants regarding the NRC staff's plan 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.[36] Except in those cases in which the applicant proposes acceptable alternative methods for complying with specified portions of the Commission's regulations, the methods described here 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.[37]

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guide.[38]

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design[39] Criterion 1, "Quality Standards and Reports."

2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against National Phenomena."

3. 10 CFR Part 50, Appendix A, General Design Criterion 14, "Reactor Coolant Pressure Boundary."

4. 10 CFR Part 50, Appendix A, General Design Criterion 15, "Reactor Coolant System Design."

5. 10 CFR Part 50, Appendix B, "Quality Assurance Requirements for Nuclear Power Plants and Fuel Reprocessing Plants."

6. 10 CFR Part 100, Appendix A, "~~Reactor Site Criterion~~Seismic and Geologic Siting Criteria for Nuclear Power Plants[40]."

7. ASME Boiler and Pressure Vessel Code, Section III, Division I, "Nuclear Power Plant Components," American Society of Mechanical Engineers."

8. Regulatory Guide 1.68, "Initial Test Programs for Water-Cooled Reactor Power Plants."

9. Standard Review Plan Section 3.9.3, "ASME Code Class 1, 2, 3 Components,Component Supports, and Core Support Structures."

10. Report NUREG/CR-1677, "Piping Benchmark Problems."

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SRP Draft Section 3.9.1
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 name and abbreviation	Changed PRB to EMEB.
2.	Current PRB abbreviation	Changed PRB to EMEB.
3.	Editorial	Defined "SAR" as "safety analysis report."
4.	Editorial	Provided "SRP" as initialism for "Standard Review Plan."
5.	Integrated Impact No. 315	Added extended design life review responsibility.
6.	SRP-UDP format item	Added "Review Interfaces" to AREAS OF REVIEW and organized in numbered paragraph form to describe how other branches support review of SRP Section 9.3.1.
7.	Current SRB abbreviation	Identified SRB as SRXB.
8.	Current SRB name and abbreviation	Changed SRB to Civil Engineering and Geosciences Branch (ECGB).
9.	Potential Impact 995	Added a review interface reflecting a special topic of review that is relevant to SSC mechanical design adequacy.
10.	PRB Comment	Added Review Interface discussion to incorporate EMEB comment in NRC Memo, Wessman to Borchardt, dated March 4, 1996.
11.	SRP-UDP format item	Added standard paragraph on protocol for review interface branches.
12.	Current PRB name and abbreviation	Changed PRB to EMEB.
13.	Editorial	Changed paragraph numbers to letters to provide an unambiguous designation in subsection II.
14.	Editorial	Introduced "GDC 1" as initialism for "General Design Criterion 1."
15.	Editorial	Introduced "GDC 2" as initialism for "General Design Criterion 2."
16.	Editorial	Introduced "GDC 14" as initialism for "General Design Criterion 14."
17.	Editorial	Introduced "GDC 15" as initialism for "General Design Criterion 15."
18.	Editorial	Changed "assure" to "ensure" (global change for this section).

Item	Source	Description
19.	Editorial	Replaced "GDC" with "General Design Criteria" to accommodate plural usage (global change for this section).
20.	Integrated Impact 843.	Specific criteria, paragraph II.1, provides examples of transients that should be considered in the design and fatigue analysis of Code Class 1 and CS components. This general list of transients is revised to include "natural convection cooldown" in parentheses as an example of emergency and recovery conditions that should be considered.
21.	Integrated Impact No. 315	Added extended design life review responsibility.
22.	Editorial	Added blank lines between the subsections that follow.
23.	SRP-UDP format item	Added "Technical Rationale" to ACCEPTANCE CRITERIA and organized in numbered paragraph form to describe the bases for referencing the General Design Criteria.
24.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."
25.	SRP-UDP format item	Added technical rationale for GDC 1.
26.	SRP-UDP format item	Added technical rationale for GDC 2.
27.	SRP-UDP format item	Added technical rationale for GDC 14 and GDC 15.
28.	Editorial	Changed "compared to" to "compared with" to accommodate scientific usage (global change for this section).
29.	Current PRB name and abbreviation	Changed PRB to EMEB.
30.	Current PRB name and abbreviation	Changed PRB to EMEB.
31.	Current PRB name and abbreviation	Changed PRB to EMEB.
32.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
33.	Editorial	Modified to eliminate use of gender-specific pronoun.
34.	Editorial	Provided "SER" as "safety evaluation report."
35.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items relevant to the SRP section.
36.	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.

Item	Source	Description
37.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
38.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
39.	Editorial	Added "General Design" to "Criterion" for each of the General Design Criteria listed in REFERENCES.
40.	Reference Verification	Revised to reflect current title.

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SRP Draft Section 3.9.1
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
315	Develop the 60-Year Design Life Review subsection of SRP Section 3.9.1. Consideration should be given to the number of transients and degradation of ASME Code Class 1, 2, 3, and CS components and supports and those not covered by the Code was given.	AREAS OF REVIEW, Item 5 ACCEPTANCE CRITERIA, end of Item 1
843	Modify Review Procedures to assure that the appropriate number of natural convection cooldown events are included in the transients used in the design and fatigue analysis of Code Class 1 and CS components.	ACCEPTANCE CRITERIA, specific criteria II.1
1224	Revise the SRP to incorporate the new and revised requirements from proposed rulemaking 59 FR 52255 amending 10 CFR 50 and 10 CFR 100 with regard to source term and dose considerations, and seismic and earthquake considerations related to reactor siting.	None.