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SECTION XI

Rules for Inservice Inspection of Nuclear Reactor Facility Components

2025 ASME Boiler and Pressure Vessel Code

An International Code

Division 2

Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Reactor Facilities

ASME

SETTING THE STANDARD

AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition July 1, 2025

XI

RULES FOR INSERVICE INSPECTION OF NUCLEAR REACTOR FACILITY COMPONENTS

Division 2

Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Reactor Facilities

ASME Boiler and Pressure Vessel Committee
on Nuclear Inservice Inspection

The American Society of Mechanical Engineers
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FOREWORD*

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating to pressure integrity. The rules govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. For nuclear items other than pressure-retaining components, the Committee also establishes rules of safety related to structural integrity. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. The Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity and, for nuclear items other than pressure-retaining components, structural integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of components addressed by the Code. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

The Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are

* The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

** *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of the Code. Requests for revisions, new rules, Code cases, or interpretations shall be addressed to the staff secretary in writing and shall give full particulars in order to receive consideration and action (see the Correspondence With the Committee page). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in the Code, the singular shall be interpreted as the plural, and vice versa.

The words "shall," "should," and "may" are used in the Code as follows:

– *Shall* is used to denote a requirement.
– *Should* is used to denote a recommendation.
– *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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January 1, 2025

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General

ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number to which the proposed case applies

(4) the editions of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition

of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Inquiry Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

(25)

PREFACE TO SECTION XI

INTRODUCTION

Section XI, Division 1, Rules for Inservice Inspection of Nuclear Power Plant Components, of the ASME Boiler and Pressure Vessel Code provides requirements for examination, testing, and inspection of components and systems, and repair/replacement activities in a nuclear power plant. Application of Division 1 begins when the requirements of the Construction Code have been satisfied.

Section XI, Division 2, Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Reactor Facilities, is a technology-neutral standard of the ASME Boiler and Pressure Vessel Code. It provides requirements for protecting pressure or structural integrity of structures, systems, and components (SSCs) that affect reliability. Application of Division 2 begins when the requirements of the Construction Code have been satisfied. It is applicable regardless of the Construction Code classification used for an SSC if the SSC is designated as important to the safety and reliability of an operating facility. Division 2 is also intended to be used during the design phase of a nuclear facility structure, system, or component and enhance coordination between the design organization and the RIM Program developers. These provisions are intended to ensure access to the applicable SSCs and to ensure the existence of the proper conditions to conduct monitoring and nondestructive examination (MANDE) to support achieving SSC Reliability Targets.

GENERAL

The rules of this Section constitute requirements to maintain the nuclear reactor facility and to return the facility to service, following facility outages, in a safe and expeditious manner.

Division 1 rules require a mandatory program of examinations, testing, and inspections to evidence adequate safety and to manage deterioration and aging effects. The rules also stipulate duties of the Authorized Nuclear Inservice Inspector to verify that the mandatory program has been completed, permitting the plant to return to service in an expeditious manner.

Division 2 rules require the development of a Reliability and Integrity Management (RIM) Program that considers the combination of design, fabrication, degradation mechanisms, inspection, examination, monitoring, operation, and maintenance of SSCs to ensure they will meet their required Reliability Targets. The rules also stipulate duties of the Authorized Nuclear Inservice Inspector to verify that the program has been completed, implemented, and updated in accordance with the requirements of Division 2.

ORGANIZATION OF SECTION XI

(25)

1 DIVISIONS

Section XI consists of two Divisions, as follows:

Division 1 = Inservice Inspection of Nuclear Power Plant Components
Division 2 = Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Reactor Facilities

2 ORGANIZATION OF DIVISION 1

2.1 SUBSECTIONS

Division 1 is broken down into Subsections that are designated by capital letters, preceded by the letters IW. Division 1 consists of Subsections covering the following aspects of the rules:

Subsection	Title
IWA	General Requirements
IWB	Class 1 Components
IWC	Class 2 Components
IWD	Class 3 Components
IWE	Class MC and CC Components
IWF	Class 1, 2, 3, and MC Component Supports
IWG	Core Internal Structures (In course of preparation)
IWL	Class CC Concrete Components

Subsections are divided into Articles, subarticles, paragraphs, and, where necessary, into subparagraphs.

2.2 ARTICLES

Articles are designated by the applicable letters indicated above for the Subsections, followed by Arabic numbers, such as IWA-1000 or IWB-2000. Where possible, Articles dealing with the same general topics are given the same number in each Subsection, in accordance with the following scheme:

Article Number	Title
1000	Scope and Responsibility
2000	Examination and Inspection
3000	Acceptance Standards
4000	Repair/Replacement Activities
5000	System Pressure Tests
6000	Records and Reports

The numbering of Articles and material contained in the Articles may not, however, be consecutive. Due to the fact that the complete outline may cover phases not applicable to a particular Subsection or Article, the requirements have been prepared with some gaps in the numbering.

2.3 SUBARTICLES

Subarticles are numbered in units of 100, such as IWA-1100 or IWA-1200.

2.4 SUBSUBARTICLES

Subsubarticles are numbered in units of 10, such as IWA-2130, and may have no text. When a number such as IWA-1110 is followed by text, it is considered a paragraph.

2.5 PARAGRAPHS

Paragraphs are numbered in units of 1, such as IWA-2131 or IWA-2132.

2.6 SUBPARAGRAPHS

Subparagraphs, when they are *major* subdivisions of a paragraph, are designated by adding a decimal followed by one or more digits to the paragraph number, such as IWA-1111.1 or IWA-1111.2. When they are *minor* subdivisions of a paragraph, subparagraphs may be designated by lowercase letters in parentheses, such as IWA-1111(a) or IWA-1111(b).

3 ORGANIZATION OF DIVISION 2

Division 2 is broken down into Articles that are designated by the capital letters RIM, followed by the Article number. Division 2 Articles consist of the following:

Article	Title
RIM-1	Scope and Responsibility
RIM-2	Reliability and Integrity Management (RIM) Program
RIM-3	Acceptance Standards
RIM-4	Repair/Replacement Activities
RIM-5	System Leak Monitoring and Periodic Tests
RIM-6	Records and Reports
RIM-7	Glossary

Division 2 also maintains Mandatory Appendices that are required for the development and implementation of the RIM Program. Mandatory Appendices consist of the following:

Appendix	Title
I	RIM Decision Flowcharts for Use With the RIM Program
II	Derivation of Component Reliability Targets From Facility Safety Requirements
III	Owner's Record and Report for RIM Program Activities
IV	Monitoring and NDE Qualification
V	Catalog of MANDE Requirements and Areas of Interest
VI	Reliability and Integrity Management Expert Panel (RIMEP)
VII	Provisions Specific to Types of Nuclear Reactor Facilities

Articles are divided into paragraphs and subparagraphs. Appendices are divided into Articles, paragraphs, and subparagraphs.

4 REFERENCES

References used within this Section generally fall into one of six categories, as explained below.

(a) References to Other Portions of This Section. When a reference is made to another Article, subarticle, or paragraph number, all numbers subsidiary to that reference shall be included. For example, reference to IWA-2000 includes all materials in Article IWA-2000; reference to IWA-2200 includes all material in subarticle IWA-2200; reference to IWA-2220 includes all paragraphs in IWA-2220, IWA-2221, and IWA-2222.

(b) References to Other Sections. Other Sections referred to in Section XI are as follows:

(1) Section II, Material Specifications. When a requirement for a material or for the examination or testing of a material is to be in accordance with a specification such as SA-105, SA-370, or SB-160, the reference is to material specifications in Section II. These references begin with the letter "S." Materials conforming to ASTM specifications may be used in accordance with the provisions of the last paragraph of the Foreword to the Boiler Code.

(2) Section III, Nuclear Power Plant Components. Section III references begin with the letter "N" and relate to nuclear power plant design or construction requirements.

(3) Section V, Nondestructive Examination. Section V references begin with the letter "T" and relate to the nondestructive examination of material or welds.

(4) Section IX, Welding and Brazing Qualifications. Section IX references begin with the letter "Q" and relate to welding and brazing requirements.

(c) References to Specifications and Standards Other Than Published in Code Sections

(1) Specifications for examination methods and acceptance standards to be used in connection with them are published by ASTM International.

(2) Recommended practices for qualifying and certifying nondestructive examination personnel are published by the American Society for Nondestructive Testing (ASNT). These documents are designated SNT-TC-1A and CP-189. A reference to SNT-TC-1A or CP-189 shall be understood to mean the practice and its supplements.

(3) Specifications and standards for materials, processes, examination and test procedures, qualifications of personnel, and other requirements of the Code approved by the American National Standards Institute are designated by the letters ANSI followed by the serialization for the particular specification or standard. Standards published by ASME are available from ASME (https://www.asme.org/).

(4) Specifications and standards for materials, processes, examination and test procedures, and other requirements of the Code relating to concrete are listed in Table IWA-1600-1, designated by the letters ACI, and are approved and published by the American Concrete Institute.

(5) Specifications and standards for determining water chemistry as identified in Table IWA-1600-1 by the letter designation APHA are approved and published by the American Public Health Association.

(6) Specifications and standards for welding are listed in Table IWA-1600-1 and are approved and published by the American Welding Society.

(d) References to Government Regulations. U.S. Federal regulations issued by executive departments and agencies, as published in the Federal Register, are codified in the Code of Federal Regulations. The Code of Federal Regulations is published by the Office of the Federal Register, National Archives and Records Service, General Service Administration.

(e) References to Appendices. Two types of Appendices are used in Section XI and are designated Mandatory and Nonmandatory.

(1) Mandatory Appendices contain requirements which must be followed in Section XI activities; such references are designated by a Roman numeral followed by Arabic numerals. A reference to III-1100, for example, refers to a Mandatory Appendix.

(2) Nonmandatory Appendices provide information or guidance for the use of Section XI; such references are designated by a capital letter followed by Arabic numerals. A reference to A-3300, for example, refers to a Nonmandatory Appendix.

(f) References to Technical Reports. The following reports prepared at the request of the American Society of Mechanical Engineers and published by Electric Power Research Institute are relevant to Code-related articles of Section XI.

(1) NP-1406-SR — Nondestructive Examination Acceptance Standards Technical Basis and Development for Boiler and Pressure Vessel Code, ASME Section XI, Division 1, Special Report, May 1980.

(2) NP-719-SR — Flaw Evaluation Procedures — Background and Application of ASME Section XI Appendix A — Special Report, August 1978.

SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(25)**, placed next to the affected area.

Page	*Location*	*Change*
ix	List of Sections	Title of Section XI, Division 1 revised
x	Foreword	Third, fourth, seventh, tenth, and eleventh paragraphs editorially revised
xiii	Personnel	Updated
xxxviii	Preface to Section XI	(1) Introduction and last paragraph of General section revised
		(2) Second and last paragraphs of General section corrected by errata
xxxix	Organization of Section XI	Paragraphs 1, 3, and 4 revised
1	RIM-1.1	Subparagraph (d) added
1	RIM-1.2	Revised in its entirety
1	RIM-1.3	Second sentence of subpara. (b) deleted
1	RIM-1.4	Subparagraph (q) revised
2	RIM-1.6.1	Revised in its entirety
3	Table RIM-1.9-1	Last row added
4	RIM-2.3	Subparagraph (a)(3) revised
5	RIM-2.4.3	Note revised
7	RIM-2.7.6.1	Subparagraph (b)(2) revised in its entirety
11	RIM-2.9.4	First sentence revised
15	RIM-4.2.5	Last sentence revised
15	RIM-4.4	Subparagraph (a)(2) revised
16	RIM-5.1	Revised
16	RIM-5.3	Subparagraph (a)(2) revised
19	RIM-7.1	(1) Definition of alternate requirements revised
		(2) Definitions of coolant boundary and maximum acceptable leakage (MAL) added
29	II-1.3	Step 6 revised
40	Mandatory Appendix V	Title revised
40	Article V-1	Title revised
49	Article V-2	Added
52	Mandatory Appendix VII	Title revised
52	Article VII-1	Title revised
52	VII-1.2	Title revised
53	Table VII-1.2-1	Degradation Mechanism Subtype TT added
13	RIM-3	Revised
60	VII-1.3.2	Subparagraph (b) revised
67	VII-1.5	Subparagraph (a) revised by errata
71	Article VII-2	Added
93	Article VII-3	Title revised
93	VII-3.2	Title revised
100	VII-3.3.2	Subparagraph (b) revised
111	Article VII-4	Title revised
112	Article VII-5	Title revised
113	Article VII-6	Title revised
114	A-1.1	First sentence revised
116	A-2.4	Second sentence revised
117	A-3.1	Revised

Page	Location	Change
117	A-3.2	Title and subpara. (c) revised
117	A-3.3	Fourth sentence revised

CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) *Hierarchy of Subparagraph Breakdowns*

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) *Cross-References to Subparagraph Breakdowns.* Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

ARTICLE RIM-1
SCOPE AND RESPONSIBILITY

(25) RIM-1.1 SCOPE

(a) This Division provides the requirements for establishing Reliability and Integrity Management (RIM) Programs for any type of nuclear reactor facility.

(b) The program shall include the following elements:

(1) Owner's responsibility

(2) areas subject to inspection or monitoring or both

(3) provisions for accessibility and inspection

(4) examination methods and procedures

(5) personnel qualifications

(6) frequency of inspection

(7) record keeping and report requirements

(8) procedures for evaluation of inspection and monitoring results and subsequent disposition of results of evaluations

(9) repair and replacement activity requirements, including procurement, design, welding, brazing, defect removal, fabrication, installation, examination, and leakage testing

(c) The RIM Program addresses a facility's entire life cycle. It is applicable over the entire life of the facility and includes each passive structure, system, or component (SSC) that is in its scope. It specifies a combination of monitoring, examination, tests, operation, and maintenance requirements that ensure SSCs meet the facility risk and reliability goals (i.e., Reliability Targets) that are selected for the RIM Program. The RIM process is described in RIM-2.1.1(d) and is illustrated in Mandatory Appendix I.

(d) When areas within this Division are in the course of preparation, an Owner may develop these areas and submit the information for review and approval to the regulatory authority having jurisdiction over the facility, if required by the regulatory authority. The Owner is encouraged to work with the appropriate ASME Code Committee to develop this information so that it may be incorporated into the ASME BPVC in future editions.

(25) RIM-1.2 JURISDICTION

(a) The RIM Program, as described in RIM-2.1.1(d), consists of the following two phases:

(1) the program development phase

(2) the implementation, performance monitoring, and update phase

(b) If redesign is necessary or recommended under the RIM Program, any redesign shall comply with the Construction Code.

(c) RIM Program implementation begins when all the requirements of the Construction Code or an alternative approved by the regulatory authority have been met, regardless of the physical location. When portions of systems or facilities are completed at different times, the jurisdiction of this Division shall apply to only those portions for which all Construction Code requirements have been met.

(d) Prior to installation, an item that has met all the requirements of the Construction Code may be corrected using the rules of either the Construction Code or this Division, as determined by the Owner.

(e) When Section XI, Division 2 refers to Section XI, Division 1, the reference is to the corresponding Edition of Division 1. In addition, the Owner is responsible for establishing and meeting the Reliability Targets for all SSCs within the scope of this Division.

RIM-1.3 COMPONENTS SUBJECT TO THE REQUIREMENTS OF THIS DIVISION (25)

(a) The RIM Program requirements of this Division shall apply to all SSCs included in the RIM Program scope definition.

(b) SSCs identified in this Division for inspection and monitoring shall be included in the inservice inspection plan.

RIM-1.4 OWNER'S RESPONSIBILITY (25)

The Owner is responsible for meeting the requirements of Section XI, Division I, IWA-1200. In addition, the Owner is responsible for establishing and meeting the Reliability Targets for all SCCs within the scope of this Division. The Owner's responsibilities also include the following:

(a) establishing the Code Editions, Addenda, and Code Cases to be used in Design Specifications and determining that they are acceptable to the regulatory and enforcement authorities having jurisdiction at the nuclear reactor facility site.

(b) preparing preservice and inservice inspection plans, schedules, and RIM Program summary reports.

(c) preparing written examination instructions and procedures, including diagrams or system drawings identifying the extent of areas of components subject to examination.

(d) having an arrangement with an Authorized Inspection Agency, recognized by the ASME or national regulatory authorities used to provide inspection services.

(e) establishing a monitoring and nondestructive examination (MANDE) qualification program in accordance with Mandatory Appendix IV.

(f) establishing a RIM Expert Panel (RIMEP) in accordance with Mandatory Appendix VI responsible for overseeing the RIM Program development and implementation in accordance with Article RIM-2, and for performing the evaluations for alternative requirements in accordance with Nonmandatory Appendix A, if applicable.

(g) establishing a MANDE Expert Panel (MANDEEP) responsible for overseeing the qualification of MANDE methods and techniques in accordance with Mandatory Appendix IV, under the RIM Program.

(h) performing required MANDE and tests.

(i) recording MANDE and test results to provide a basis for evaluation and to facilitate comparison with the results of subsequent MANDE and test activities.

(j) evaluating MANDE and test results.

(k) performing repair/replacement activities in accordance with written programs and plans.

(l) retaining MANDE, test, flaw evaluation, and repair/replacement activity records, such as radiographs, diagrams, drawings, calculations, MANDE and test data, description of procedures used, and evidence of personnel qualifications for the service lifetime of the SSCs.

(m) retaining and maintaining basic calibration blocks and standards used for MANDE and tests of SSCs.

(n) documenting a Quality Assurance Program in accordance with ASME NQA-1. Methods other than written signature may be used for indicating certification, authorization, and approval of records; controls and safeguards shall be provided and described in the Quality Assurance Program to ensure the integrity of the certification, authorization, and approval.

(o) recording of regions in components where flaws or relevant conditions exceeding the acceptance standards have been evaluated by analysis to allow continued operation. Any continued operation time or cycle limits inherent in the analysis shall also be recorded.

(p) recording of regions in ferritic steel components where acceptance standards have been modified by the applicable article of Mandatory Appendix VII.

(q) establishing Reliability Targets for SSCs within the scope of this Division.

(r) developing of analytical evaluation procedures.

RIM-1.5 STANDARD UNITS

The requirements of Section XI, Division 1, IWA-1700 shall apply.

RIM-1.6 INSPECTION

RIM-1.6.1 Duties of the Inspector and Authorized Nuclear Inservice Inspector Supervisor (25)

(a) The duties of the Authorized Nuclear Inservice Inspector Supervisor shall be conducted in accordance with the requirements of ASME QAI-1.

(b) The duties of the Inspector shall be conducted in accordance with ASME QAI-1 and shall include but not be limited to the following:

(1) The Inspector shall review the inspection plan and the implementation schedule prior to the start of preservice inspection and prior to each inspection interval and as necessary as a result of any revisions. The review shall cover any features that are affected by the requirements of this Division, as applicable, and shall include the following:

(-a) examination categories and items
(-b) MANDE requirements
(-c) MANDE methods
(-d) SSCs selected for MANDE and tests
(-e) disposition of MANDE and test results
(-f) test frequency
(-g) system leakage tests
(-h) sequence of successive MANDE

Shop preservice examinations [see RIM-2.7.3(c)] are exempt from prior review by the Inspector.

(2) The Inspector shall review any revisions to the inspection plan and, as necessary, the implementation schedule during the preservice inspection or during the inservice inspection interval.

(3) The Inspector shall submit a report to the Owner documenting review of the items identified in (1) and (2).

(4) The Inspector shall verify that the RIM Program examinations and leak tests have been performed and the results recorded.

(5) The Inspector shall perform any additional investigations necessary to verify that the applicable requirements of RIM-1.6.1 have been met.

(6) The Inspector shall verify that the nondestructive examination (NDE) methods used follow the techniques specified in this Division and that MANDE activities and tests are performed in accordance with written qualified procedures and by personnel employed by the Owner or the Owner's agent and qualified in accordance with Mandatory Appendix IV.

(7) The Inspector may require at any time requalification of any procedure or operator if the Inspector has reason to believe that the requirements of this Division are not being met.

(8) The Inspector shall certify the MANDE and test records after verifying that the requirements of this Division have been met and that the records are correct.

(9) The Inspector shall verify that repair/replacement activities are performed in accordance with the requirements of the Owner's Repair/Replacement Program.

(10) The Inspector shall review the Repair/Replacement Program and its implementation.

RIM-1.6.2 Qualification of Authorized Inspection Agencies, Inspectors, and Supervisors

The requirements of Section XI, Division 1, IWA-2120 shall apply.

RIM-1.6.3 Access for Inspector

The requirements of Section XI, Division 1, IWA-2130 shall apply.

RIM-1.7 REGULATORY REVIEW

Regulatory bodies may adopt the provisions of Nonmandatory Appendix B for reporting requirements established by this Division.

RIM-1.8 TOLERANCES

The requirements of Section XI, Division 1, IWA-1800 shall apply.

RIM-1.9 REFERENCED STANDARDS AND SPECIFICATIONS

When standards and specifications are referenced in this Division, the editions or revisions shown in Table RIM-1.9-1 shall apply.

Table RIM-1.9-1
Referenced Standards and Specifications (25)

Standard, Method, or Specification	Edition or Revision Date
ASME ANDE-1	Latest edition
ASME NQA-1	1994, 2008 through 2015
ASME QAI-1	Latest edition
ASME/ANS RA-S-1.4	Latest edition
ASME/ANS RA-S-1.5	Latest edition

ARTICLE RIM-2
RELIABILITY AND INTEGRITY MANAGEMENT (RIM) PROGRAM

RIM-2.1 RIM PROGRAM OVERVIEW

RIM-2.1.1 Basis, Objective, and Process

(a) The reliability of a nuclear reactor facility and its SSCs is determined by the design, fabrication, inspection, monitoring, operation, and maintenance procedures used to build and operate the facility and its SSCs. Each of these aspects contributes in varying degrees to the reliability of the facility's SSCs. In order for a nuclear reactor facility to have a level of reliability that will satisfy safety goals, an appropriate combination of these contributors to reliability should be identified and implemented. The objectives of the RIM Program are to define, evaluate, and implement strategies to ensure that Reliability Targets for SSCs are defined, achieved, and maintained throughout the facility lifetime.

(b) This Division defines the required elements of the RIM Program for all types of nuclear reactor facilities and provides requirements for RIM Program implementation.

(c) The RIM Program shall specify the combination of inspection, monitoring, operation, examinations, tests, and maintenance requirements that will enable the SSCs to meet their Reliability Targets in an efficient and cost effective manner.

(d) The process of implementing a RIM Program is illustrated in Mandatory Appendix I, Figures I-1.1-1 through I-1.1-6 and shall include the following elements:

(1) RIM Program scope definition

(2) degradation mechanism assessment (DMA)

(3) facility and SSC Reliability Target allocation originating from the probabilistic risk assessment (PRA)

(4) identification and evaluation of RIM strategies

(5) evaluation of uncertainties

(6) RIM Program implementation

(7) performance monitoring and RIM Program updates

RIM-2.1.2 Responsibilities

RIM-2.1.2.1 Owner's RIM Expert Panel (RIMEP). The RIMEP is responsible for the technical oversight and direction of the risk-informed aspects of RIM Program development and implementation.

RIM-2.1.2.2 RIMEP Qualifications. The qualification requirements for the RIMEP are provided in Mandatory Appendix VI.

RIM-2.2 RIM PROGRAM SCOPE AND DEFINITION

The Owner shall document the specific list of SSCs to be evaluated for inclusion within the scope of the RIM Program. The scope shall include SSCs whose failure could adversely affect facility safety and reliability. The Owner shall also document the basis for the exclusion of any SSC considered to be outside the scope of the RIM Program.

RIM-2.3 DEGRADATION MECHANISM ASSESSMENT (DMA) (25)

The potential active degradation mechanisms for the SSCs within the RIM Program scope shall be identified and evaluated.

(a) The following conditions shall be considered in the DMA:

(1) design characteristics, including material, pipe size and schedule, component type (e.g., standard fittings, elbows, flanges), and other attributes related to the system configuration

(2) fabrication practices, including welding and heat treatment

(3) operating and transient conditions, including temperatures, pressures, characteristics of primary and secondary fluid, and service environment (e.g., humidity, radiation)

(4) facility-specific, industry-wide service experience and research experience

(5) results of preservice, inservice, and augmented examinations and the presence and impact of prior repairs in the system

(6) applicable degradation mechanisms, including those identified in Mandatory Appendix VII for the applicable facility type

(7) recommendations by SSC vendors for examination, maintenance, repair, and replacement

(b) The criteria used to identify and evaluate the susceptibility of each SSC to degradation mechanisms shall be specified in the RIM Program documentation. The screening criteria found in Mandatory Appendix VII are minimum requirements to be considered but may be augmented by the RIMEP.

RIM-2.4 FACILITY AND SSC RELIABILITY TARGET ALLOCATION

RIM-2.4.1 Facility-Level Risk and Reliability Targets

(a) The RIMEP shall identify facility-level risk and Reliability Targets for RIM. Facility-level reliability shall be derived from regulatory limits on the risks, frequencies, and radiological consequences of licensing basis events that are defined in the PRA.

The RIM Program may be developed for facilities with a single reactor module or with two or more reactor modules. Event sequence frequencies shall be expressed in terms of events per facility year where the facility may include a single reactor or multiple reactor modules. The event sequence consequences may involve source terms from single or multiple reactor modules, or source terms from non-core-related radionuclide sources and associated off-site radiological consequences.

(b) Facility level RIM goals may include additional goals to meet facility availability.

RIM-2.4.2 SSC-Level Reliability Targets

(a) The RIMEP shall use information provided by the facility-specific PRA to identify SSC-level Reliability Targets for SSCs relied upon to prevent and mitigate the consequences of accident scenarios that is consistent with the facility-level reliability goals. The RIMEP may also identify SCC-level Reliability Targets for overall facility availability considerations (e.g., power production or asset protection).

(b) In deriving SSC Reliability Targets from and consistent with the facility-level reliability goals, the RIMEP shall consider the uncertainties inherent in the prediction of SCC reliability.

(c) The methodology for deriving Reliability Targets is provided in Mandatory Appendix II.

(25) RIM-2.4.3 Scope, Level of Detail, and Technical Adequacy of the PRA

(a) The scope of the PRA used to allocate SSC Reliability Targets shall address the following:

(1) the facility operating states relevant to the facility-level risk and reliability goals and SSC-level Reliability Targets

(2) a full set of initiating events including internal events and events associated with external facility hazards

(3) event-sequence development that is sufficient to support the quantification of mechanistic source terms and off-site radiological consequences consistent with applicable regulatory limits on the frequencies and consequences of accident scenarios

(b) Although all facility operating modes and hazard groups shall be addressed, it is not always necessary to have a full-scope PRA as outlined in (a)(1) through (a)(3) above. Qualitative treatment or other risk information related to missing modes and hazard groups may be sufficient if it can be demonstrated that those risk contributions would not affect the Reliability Targets or other aspects of the RIM Program.

(c) The level of detail required of the PRA is that which is sufficient to establish Reliability Targets for the SSCs to be included in the RIM Program. If the SSCs of interest cannot be associated with elements of the PRA, the PRA should be modified accordingly.

(d) PRA models for current light water reactor (LWR) type plants frequently exclude passive components (e.g., piping) because they have a much lower probability of failure than active components. For implementation of RIM and the allocation of Reliability Targets, such components would need to be included in the PRA if they are included within the scope of the RIM Program.

(e) Technical adequacy refers to the suitability of the PRA modeling and the reasonableness of the underlying assumptions and approximations. The PRA shall meet the requirements of ASME/ANS RA-S-1.4 to the extent necessary to support RIM program development. ASME/ANS RA-S-1.4 provides technical supporting requirements in terms of Capability Categories. The delineation of Capability Categories is such that the PRA scope, level of detail, facility specificity and realism increase from Capability Category I to Capability Category II. Current good practice (Capability Category II) is generally expected to be necessary to support RIM, although Capability Category I may be sufficient for some requirements. All significant PRA peer review findings shall be reviewed and dispositioned by incorporating changes into the PRA model, performing sensitivity studies to evaluate the identified issue, or providing justification for the original PRA model. The results of the PRA peer review and the review of other risk information used in the RIM Program development shall be documented in a characterization of the adequacy of the PRA.

NOTE: ASME/ANS RA-S-1.4 shall be used for advanced non-LWR technology, and ASME/ANS RA-S-1.5 (currently in development) shall be used for advanced LWR Designs.

RIM-2.5 IDENTIFICATION AND EVALUATION OF RIM STRATEGIES

The RIMEP shall identify the RIM strategies that are available to meet the Reliability Targets and shall evaluate and select combinations of strategies that will meet and maintain the Reliability Targets.

RIM-2.5.1 Identification of RIM Strategies

(a) The RIM strategies shall account for all factors that contribute to reliability. These factors shall include but not necessarily be limited to the following:

(1) design strategies, including material selection

(2) fabrication procedures

(3) operating practices
(4) preservice and inservice examinations
(5) testing
(6) MANDE
(7) maintenance, repair, and replacement practices

(b) The evaluated RIM strategies shall account for the potential for specific degradation mechanisms applicable to each SSC in the scope of the RIM Program. See Mandatory Appendix VII for a listing of degradation mechanisms and their attributes.

(c) The RIMEP shall select the RIM strategies or combinations of strategies that are necessary and sufficient to achieve and maintain SSC reliability consistent with SSC Reliability Targets established in RIM-2.4.2.

(d) In addition to probabilistic methods that are permitted by this Division for establishing MANDE criteria, deterministic methodology for examinations and acceptance criteria, as outlined in Nonmandatory Appendix A, A-3.5 may be used.

RIM-2.5.2 Evaluation of RIM Strategy Impacts on SSC Reliability

The RIMEP shall assess how each potential RIM strategy would affect the reliability of each SSC within the scope of the RIM Program. These effects shall be compared to the SSC-level Reliability Targets. This assessment shall include the following:

(a) application of acceptable SSC reliability assessment methods, such as statistical analysis of failure data, probabilistic fracture mechanics, Markov modeling, expert elicitation, or appropriate combinations of these methods.

(b) assessment of SSC facility-specific failure rates that correspond to the frequencies of initiating events and PRA and SSC failure probabilities for mitigating events in the PRA model. This formulation shall be consistent with the reliability metrics selected for the SSC Reliability Target allocation in accordance with RIM-2.4.2.

(c) evaluation of the effectiveness of the RIM strategy that accounts for the quantity and applicability of applied failure data, uncertainty in the estimates of component exposure populations, materials, variability of operating conditions, and variability of expert opinion.

(d) identification and evaluation of the effectiveness and extent of the RIM strategy or combination of strategies including the percentage of the SSCs to which the strategy is applied, probability of detection, inspection frequency, flaw-sizing accuracy, time to detect, accessibility, and other factors of the RIM Program that influence the SSC reliability.

RIM-2.6 EVALUATION OF UNCERTAINTIES

The RIMEP shall identify RIM strategies to specifically address the uncertainties of predicting SSC reliability performance. These strategies shall be in addition to those determined in accordance with RIM-2.5 and shall provide needed assurance that the Reliability Targets will be achieved and maintained during the SSC service lifetime. RIM strategies included in the RIM Program to address these uncertainties shall be documented in accordance with RIM-2.7.1.

RIM-2.7 RIM PROGRAM IMPLEMENTATION

RIM-2.7.1 RIM Program Documentation

(a) The Owner shall document the RIM strategies that are selected for inclusion in the RIM Program. This RIM Program documentation shall include the following:

(1) the scope of SSCs selected for inclusion in the RIM Program
(2) the results of the DMA evaluation for the SSCs in the RIM Program
(3) the facility-level risk and reliability goals
(4) the SCC Reliability Targets derived from the facility-level risk and reliability goals
(5) technical adequacy of the PRA and risk information used to derive the SSC Reliability Target
(6) the specific RIM strategies selected for the RIM Program for each SSC including associated performance parameters (e.g., probability of detection, inspection intervals) that are required to achieve Reliability Targets
(7) evaluation of the impact of RIM strategies and combination of RIM strategies on the SSC reliability performance
(8) quantification of uncertainties and evaluation of additional RIM strategies selected to address uncertainties

(b) The RIM Program documentation shall be updated periodically to evaluate changes to any of the technical inputs as described in RIM-2.8, but no later than the end of each established inspection interval (see RIM-2.7.2).

RIM-2.7.2 Inservice Inspection Interval

(a) Inservice inspections selected for inclusion in the RIM Program for specific SSCs shall be completed during each inspection interval for the service lifetime of the facility. The inspections shall be performed in accordance with the schedule for implementing the RIM Program.

(b) The inspection interval shall be determined by the RIMEP and shall not exceed 12 yr.

(c) The interval shall be divided into two or more approximately equal inspection periods. The examinations required for each interval shall be approximately equally distributed over the inspection periods.

(d) Each inspection interval may be reduced or extended by as much as 1 yr. Adjustments shall not cause successive intervals to be altered by more than 1 yr from the original pattern of intervals. If an inspection interval is extended, neither the start and end dates nor

the RIM Program for the successive interval need be revised.

(e) Examinations may be performed to satisfy the requirements of the extended interval in conjunction with examinations performed to satisfy the requirements of the successive interval. However, an examination performed to satisfy requirements of either the extended interval or the successive interval shall not be credited to both intervals.

(f) That portion of an inspection interval described as an inspection period may be reduced or extended by as much as 1 yr to enable an inspection to coincide with a facility outage. This adjustment shall not alter the requirements for scheduling inspection intervals.

(g) The inspection interval for which an examination was performed shall be identified on examination records.

(h) In addition to (d), for facilities that are out of service continuously for 6 months or more, the inspection interval during which the outage occurred may be extended for an inspection period equivalent to the outage and the original pattern of intervals extended accordingly for successive intervals.

(i) The inspection intervals for items installed by repair/replacement activities shall coincide with remaining intervals, as determined by the calendar years of facility service at the time of the repair/replacement activities.

RIM-2.7.3 Preservice Inspection

(a) For those categories of SSCs for which examinations have been selected as a RIM strategy for inclusion in the RIM Program, a preservice examination shall be performed. If any percentage of the SSC category has been selected for inservice examination, 100% of the SSCs shall be subjected to a preservice examination using the same examination method to be used for inservice examination. The purpose of these preservice examinations is to establish a baseline in case an inservice examination is required at each location. These preservice baseline examinations shall be performed using personnel, equipment, and procedures that have been qualified and demonstrated to be relevant to the applicable Reliability Targets for SSCs. All examination procedures shall define the methodology and criteria for discrimination of indications (e.g., material conditions vs. geometrical conditions vs. flaws) and shall define requirements for documentation of examination results to include, at a minimum, size and location of indications (e.g., location, length, depth, remaining ligament) and basis for disposition, as appropriate for each MANDE method applied. UT examinations shall use encoded equipment and scanners to provide a permanent archival record of the indications. Documentation of non-UT examination shall be as described in the qualified procedure and shall be used to create a permanent record of the indications, as well as the identified material and geometrical conditions. The examination records and results shall be reviewed by the Inspector to ensure that potential flaws are assessed and completeness of records is established. Flaws identified in these examinations shall be evaluated for service in accordance with the flaw acceptance criteria in Article RIM-3. Selection of the analytical evaluation method is the responsibility of the MANDEEP.

(b) The examinations required by this Article for those components initially selected for examination in accordance with the RIM Program shall be completed prior to initial facility startup.

(c) Shop and field examinations may serve in lieu of the on-site preservice examinations, provided all of the following conditions are met:

(1) In the case of vessels only, the hydrostatic test required by the Construction Code has been completed.

(2) Such examinations are conducted and meet the requirements under (a).

(3) The shop and field examination records are, or can be, documented and identified in a form consistent with those required in Article RIM-6.

RIM-2.7.4 Design Requirements for RIM

(a) The RIM Program shall consider the design requirements of SSCs, including the following:

(1) those that are identified as part of the RIM strategies established in RIM-2.5

(2) those that might be required to prevent or reduce susceptibility to degradation mechanisms determined in RIM-2.3

(3) those that might otherwise be needed to support a selected RIM strategy (e.g., provision for an online leak detection system)

(b) The design requirements for SSCs within the scope of the RIM Program shall include considerations for adequate access. This includes adequate access requirements for facility modifications.

RIM-2.7.6 MANDE Requirements for RIM

RIM-2.7.6.1 General Monitoring and Examination Requirements (25)

(a) MANDE shall be performed to demonstrate that the SCCs included in the RIM Program continue to meet the Reliability Targets established in accordance with RIM-2.4.2. MANDE criteria, including scope, method, detection reliability, frequency, and performance demonstration, shall be clearly defined to ensure the MANDE yields the required information.

(b) MANDE performed to provide and maintain SSC Reliability Targets shall meet, where applicable, the following requirements:

(1) The functional or structural reliability of a system or system components shall be monitored using a program that satisfies the following criteria:

(-a) The program shall include consideration of the following factors:

(-1) potential for active degradation mechanisms

(-2) radiological consequences of SSC failure

(-3) personnel radiation exposure

(-4) insights from facility and industry service or research experience

(-b) The program may include one or more of the following activities, which may be performed either periodically or continuously:

(-1) operating fluid leakage detection and monitoring

(-2) monitoring of the amount of make-up fluid

(-3) walkdowns to monitor the operating fluid level in storage tanks

(-4) monitoring of fluid level or flow in drains

(-5) monitoring of humidity levels

(-6) monitoring of radiation levels

(-7) auxiliary operator facility walk-through

(2) MANDE activities shall be conducted on any SSC within the RIM Program scope. These activities may include continuous leakage monitoring or periodic leakage testing as required to support the allocated SSC Reliability Targets. The leak-detection capabilities of monitoring systems employed as a selected RIM strategy shall be qualified by performance demonstrations to show capabilities to detect indication of degradation (ID). The performance characteristics of capabilities to detect ID include probability of detection, time to detect, minimum detectable leak rate, and system reliability. Capabilities to detect ID and availability characteristics of those monitoring systems shall be sufficient to support the SSC RIM Reliability Targets established in accordance with RIM-2.4.2. The operation and effectiveness of online leak-detection systems shall be verified in accordance with RIM-5.2.

(c) For the SSCs within the scope of the RIM Program for which specific requirements have not been specified by the RIMEP and MANDEEP shall define the requirements, which shall be documented with a technical basis.

(d) The MANDE methods and procedures shall account for the potential degradation mechanisms identified in Mandatory Appendix VII.

(e) Examination volumes, methods, and frequencies appropriate for each degradation mechanism are provided in RIM-2.7.7 and Mandatory Appendix V and augmented for specific reactor designs as outlined in the relevant reactor design Article in Mandatory Appendix VII.

RIM-2.7.6.2 Examination Locations. The number and locations of examinations in each inspection interval shall be defined in accordance with the following requirements:

(a) The minimum number of locations shall be selected to meet the SSC Reliability Target.

(b) Examination locations shall be selected in accordance with the following criteria:

(1) locations where a component-level requirement is exceeded

(2) selected to exclude areas with high irradiation levels to maintain personnel exposure within acceptable limits, if possible

(3) locations that permit examination of 100% of the areas of concern

(4) locations where degradation is most likely to occur

(5) a sampling of MANDE out-of-scope SSCs, and other SSCs within the program scope, that do not have examinations specified, to address unexpected degradations, with input from the MANDEEP as noted in Mandatory Appendix I, Figure I-1.1-3

RIM-2.7.6.3 Successive Examinations

(a) If an SSC is accepted for continued service in accordance with Article RIM-3, the areas containing flaws or relevant conditions shall be reexamined based on the MANDE and periodicity criteria established by the flaw evaluation results.

(b) If the reexaminations required by (a) reveal that the flaw or relevant condition remain essentially unchanged, the SSC MANDE schedule may revert to the original schedule of successive inspections.

RIM-2.7.6.4 Additional Examinations

(a) If examinations performed in accordance with Mandatory Appendix V and the applicable Article of Mandatory Appendix VII reveal a flaw or a relevant condition exceeding the acceptance standards of Mandatory Appendix VII, Table VII-1.3.3-1 or Table VII-3.3.3-1, additional examinations shall be performed during the current outage. The additional examinations shall include an additional number of welds, areas of interest, or parts and shall be determined by and the basis shall be documented by MANDEEP. The welds, areas of interest, or parts selected for the additional examinations shall be of material and service similar to that of the originally examined items. This additional selection might require inclusion of SSCs other than the one containing the flaws or relevant conditions.

(b) If the additional examinations required by (a) reveal a flaw or a relevant condition exceeding the acceptance standards of Mandatory Appendix VII, Table VII-1.3.3-1 or Table VII-3.3.3-1, the examinations shall be further extended to include additional examinations during the current outage. These additional examinations shall include the remaining welds, areas of interest, or parts of similar material and service subject to the same type of flaws or relevant conditions.

(c) For the inspection period following the period in which the examinations of (a) or (b) were completed, the examinations shall be performed as originally scheduled.

(d) No additional examinations are required if either of the following applies:

(1) There are no other SSC subject to the same apparent or root cause conditions.

(2) The degradation mechanism no longer exists.

RIM-2.7.7 Examination Methods and Volumes

(a) Examination programs developed in accordance with Article RIM-2 shall use examination techniques suitable for specific degradation mechanisms and examination locations. The examination volumes and methods that shall be considered by MANDEEP in establishing MANDE criteria, and that are applicable to each degradation mechanism, are provided in Mandatory Appendix V and the applicable Article of Mandatory Appendix VII.

(b) The personnel, equipment, and procedures used for the examinations shall be qualified in accordance with Mandatory Appendix IV, to reliably detect and size the relevant degradation identified for each SSC. Examinations shall be conducted and documented in accordance with RIM-2.8.

RIM-2.8 PERFORMANCE MONITORING AND RIM PROGRAM UPDATES

(a) The RIM Program shall be reevaluated as new information affecting the RIM Program's implementation becomes available. New information might include the following:

(1) changes to facility design, which may introduce (or remove) SSCs within the scope of the RIM Program, as well as changes in materials, configurations, stresses, etc. Changes to facility design may also result in significant changes to facility risk, as determined by PRA update, which may require update of the Reliability Target allocations.

(2) changes to facility procedures, such as operating parameters, system lineups, equipment, and operating modes, may result in different degradation mechanisms or MANDE capability. Changes to facility procedures might also result in changes to facility risk, as determined by PRA update.

(3) changes in SSC performance, indicating a potential change in reliability.

(4) MANDE results that indicate service-related degradation.

(5) industry or research experience, including SSC failure or reliability data or degradation mechanisms.

(b) RIM Program updates may include adjustment of SSC Reliability Targets based on new information described in (a) or PRA updates.

(1) Reliability Targets shall not be decreased to correspond with changes in SSC performance or service-related degradation unless the following are considered:

(-a) the risk impact

(-b) the effect on other Reliability Target allocations based on the derivation methodology in Mandatory Appendix II

(-c) additional considerations in RIM-2.10

(2) The minimum frequency of RIM Program updates shall be before each inspection interval as specified in RIM-2.7.2(b). RIM Program updates should be more frequent if dictated by PRA updates or if new degradation mechanisms are identified.

RIM-2.9 EXAMINATION METHODS

RIM-2.9.1 Visual Examinations

Visual examinations shall be conducted in accordance with Section V, Article 9; Section XI, Division 1, Table IWA-2211-1; and the following requirements:

(a) A written procedure and a report of examination results are required.

(b) For procedure demonstration, a test chart containing text with some lowercase characters without an ascender or descender (e.g., a, c, e, o) meeting the requirements of Section XI, Division 1, Table IWA-2211-1 is required. Before initial use of the test chart, an optical comparator (l0X or greater) or other suitable instrument shall be used to measure the height of a representative lower case character without an ascender or descender, for the selected type size, to verify that it meets the requirements of Section XI, Division 1, Table IWA-2211-1.

(c) Remote examination may be substituted for direct examination. The remote examination procedure shall be demonstrated to resolve the selected test chart characters.

(d) Alternatives to the direct visual examination distance requirements of Section V may be used as specified in Section XI, Division 1, Table IWA-2211-1.

(e) It is not necessary to measure illumination levels on each examination surface when the same portable light source or similar installed lighting equipment is demonstrated to provide the illumination specified in Section XI, Division 1, Table IWA-2211-1 at the maximum examination distance.

(f) The adequacy of the illumination levels from battery powered portable lights shall be checked before and after each examination or series of examinations, not to exceed 4 hr between checks. In lieu of using a light meter, these checks may be made by verifying that the illumination is adequate (i.e., no discernable degradation in the visual examination resolution of the procedure demonstration test chart characters).

RIM-2.9.1.1 VT-1 Examination. VT-1 examination is conducted to detect discontinuities and imperfections on the surface of components, including such conditions as cracks, wear, corrosion, or erosion.

RIM-2.9.1.2 VT-2 Examination. VT-2 examination is conducted to detect evidence of leakage from a pressure-retaining component after a repair/replacement activity. The examination shall be conducted in accordance with Article RIM-5.

RIM-2.9.1.3 VT-3 Examination. VT-3 examination is conducted to determine the general mechanical and structural condition of components and their supports by verifying parameters such as clearances, settings, and physical displacements; to detect discontinuities and imperfections, such as loss of integrity at bolted or welded connections, loose or missing parts, debris, corrosion, wear, or erosion; and to detect conditions that could affect operability or functional adequacy of constant load and spring-type supports.

RIM-2.9.1.4 Surface Replication. Surface replication methods may be used for VT-1 and VT-3 examinations when the surface resolution is at least equivalent to that of direct visual observation. The personnel who evaluate the surface replication shall be qualified in accordance with Mandatory Appendix IV.

RIM-2.9.1.5 Remote Visual Examination. When remote visual examination is substituted for direct visual examination, the remote visual requirements of Section V, Article 9 shall be met. In addition, the remote visual examination system shall have the capability of distinguishing and differentiating between the colors applicable to the requirements of VT-1 and VT-3 for the component examinations being conducted.

RIM-2.9.2 Surface Examination

(a) A surface examination may be conducted using a magnetic particle, liquid penetrant, eddy current, or ultrasonic method.

(b) Any linear indication detected by magnetic particle, liquid penetrant, or eddy current examination that exceeds the allowable linear surface flaw standards shall be recorded.

(c) Any flaw recorded by ultrasonic examination shall be compared to the volumetric examination acceptance standards of Mandatory Appendix VII, VII-1.4.3 or VII-3.4.3 for allowable planar or linear flaws.

RIM-2.9.2.1 Magnetic Particle Examination Magnetic particle examination of coated and uncoated materials shall be conducted in accordance with Section V, Article 7.

RIM-2.9.2.2 Liquid Penetrant Examination. Liquid penetrant examination shall be conducted in accordance with Section V, Article 6.

RIM-2.9.2.3 Eddy Current Examination. Eddy current examination for detection of surface flaws shall be conducted in accordance with Section XI, Division 1, Mandatory Appendix IV.

RIM-2.9.2.4 Ultrasonic Examination. An ultrasonic examination performed from the inside surface of piping may be used as a surface examination method for piping welds NPS 4 (DN 100) and larger. The ultrasonic examination technique shall be demonstrated capable of detecting an acceptable flaw having the greatest a/t ratio or a 0.50 aspect ratio at the surface being examined.

RIM-2.9.3 Volumetric Examination

A volumetric examination may be conducted from either the inside or outside surface of a component.

RIM-2.9.3.1 Radiographic Examination. Radiographic examinations employing either X-ray equipment or radioactive isotopes shall be conducted in accordance with Section V, Article 2.

RIM-2.9.3.2 Ultrasonic Examination. Ultrasonic examination shall be conducted in accordance with Section XI, Division 1, Mandatory Appendix I.

RIM-2.9.3.3 Eddy Current Examination. Eddy current examination shall be conducted in accordance with Section V, Article 8.

RIM-2.9.3.4 Acoustic Emission Monitoring and Examination. Acoustic emission monitoring may be used in lieu of the successive inspections of RIM-2.7.6.3 to monitor growth of flaws detected by other NDE methods. The flaws shall be sized by ultrasonic examination in accordance with Section XI, Division 1, Mandatory Appendix I, prior to initiating use of acoustic emission monitoring. Acoustic emission monitoring shall be initiated before the system is put back into operation. Acoustic emission monitoring shall be conducted in accordance with Section V, Article 13.

The following flaw growth calculation and acceptance criteria shall be used:

(a) *Flaw Growth Calculation.* Every 2 months during the current inspection period, calculate the flaw growth in accordance with Section V, Article 13. Using this growth rate, predict the flaw size at the end of the current inspection period.

(b) Acceptance Criteria

(1) If the flaw size calculated in accordance with (a) meets the acceptance criteria of Mandatory Appendix VII, VII-1.5 or VII-3.5, as applicable, continue the 2-month monitoring process described in (a).

(2) If the flaw size calculated in accordance with (a) does not meet the acceptance criteria of Mandatory Appendix VII, VII-1.5 or VII-3.5, as applicable, calculate the size the flaw will be at the end of the next 2-month interval.

(-a) If the flaw size calculated in accordance with (2) meets the acceptance criteria of Mandatory Appendix VII, VII-1.5 or VII-3.5, as applicable, continue the 2-month monitoring process described in (a).

(-b) If the flaw size calculated in accordance with (2) does not meet the acceptance criteria of Mandatory Appendix VII, VII-1.5 or VII-3.5, as applicable, the component shall be corrected by repair/replacement activity in accordance with Mandatory Appendix VII, VII-1.3.1.3 or VII-3.3.1.3, as applicable.

(25) RIM-2.9.4 Alternative Examinations

Alternative examination methods, a combination of methods, or newly developed techniques may be substituted for the methods specified in this Division, provided the following conditions are met:

(a) Any alternative criteria are approved by MANDEEP in accordance with Mandatory Appendix IV.

(b) The Inspector is satisfied that the results are demonstrated to be equivalent or superior to those of the specified method and the basis for this improvement has been fully documented.

(c) The methodology for determining alternative examinations may be determined using the criteria in Nonmandatory Appendix A.

RIM-2.10 ADDITIONAL CONSIDERATIONS FOR RIM PROGRAM IMPLEMENTATION

RIM-2.10.1 Consequence, External Event, and Shutdown Considerations

(a) Allocation of Reliability Targets based on the derivation methodology presented in Mandatory Appendix II should be performed with a PRA model that includes evaluation of consequences (such as release frequency or dose), as well as contribution from external hazards (flood, fire, seismic, high wind, etc.) and low power and shutdown (LPSD) modes of operation.

(b) If the PRA model does not integrate consequences and risk, the RIMEP shall consider whether the SSCs included in the RIM Program are involved in the mitigation of consequences and whether the associated Reliability Targets should be adjusted accordingly.

(c) If the PRA model does not include the analysis of certain external hazards, the RIMEP shall consider whether the SSCs included in the RIM Program are involved in the protection against those external hazards and whether the associated Reliability Targets should be adjusted accordingly. This consideration may be based on qualitative information such as an external hazards screening analysis.

(d) If the PRA model does not include the analysis of LPSD modes, the RIMEP shall consider whether the SSCs included in the RIM Program are important to LPSD safety and whether the associated Reliability Targets should be adjusted accordingly. This consideration may be based on qualitative information such as a shutdown safety plan.

RIM-2.10.2 Principles of Risk-Informed Decision Making

The RIMEP should ensure the principles of risk-informed decision-making are met when implementing the RIM Program.

(a) The RIM Program shall meet current regulations.

(b) The RIM Program shall be consistent with the philosophy of defense-in-depth. The impact of the RIM Program on the functional capability, reliability, and availability should be assessed for the included SSCs that provide layers of defense to ensure that the following criteria are met:

(1) a reasonable balance among the layers of defense is preserved

(2) adequate capability of design features is preserved without overreliance on programmatic activities

(3) system redundancy, independence, and diversity are preserved

(4) adequate defense against potential common-cause failures is preserved

(5) multiple fission product barriers are maintained

(6) sufficient defense against human errors is maintained

(7) the intent of the facility's design criteria continues to be met

(c) The RIM Program shall maintain sufficient safety margins such that the following criteria are met:

(1) the codes and standards approved for use continue to be met

(2) safety analysis acceptance criteria in the licensing basis continue to be met

(d) Risk, including any changes in risk gained from operating experience of an SSC and the impact of uncertainty, should be small and consistent with regulatory requirements.

(1) Evaluation of risk impact might entail the use of quantitative PRA results or bounding risk calculations, or a qualitative assessment may be sufficient depending on the significance of the impact.

(2) The impact of uncertainties, and associated assumptions and approximation, on the risk results should be identified and understood.

(e) The RIM Program shall be monitored using performance measurement strategies (as described in RIM-2.8), such that the following criteria are met:

(1) SSC performance monitoring shall be used to demonstrate the performance is consistent with the assumptions in the RIM Program

(2) The rigor of the SSC performance monitoring shall be commensurate with the safety importance of the SSC

(3) Degradation in the SSC shall be detected and corrected before facility safety is compromised

ARTICLE RIM-3
ACCEPTANCE STANDARDS

(25)

RIM-3.1 EVALUATION OF EXAMINATION RESULTS AND ACCEPTANCE STANDARDS

Flaw acceptance standards for reactor components subjected to various operating environments and constructed to various construction codes may be found in Mandatory Appendix VII.

(a) For components in light water reactor–type facilities, flaw acceptance standards shall be obtained from Article VII-1.

(b) For components in sodium-cooled fast-reactor-type facilities, flaw acceptance standards shall be obtained from Article VII-2.

(c) For components in high-temperature gas-reactor–type facilities, flaw acceptance standards shall be obtained from Article VII-3.

(d) Flaw acceptance standards for the following facility types are in the course of preparation:

(1) molten salt reactor–type facilities (Article VII-4)

(2) generation 2 LWR–type facilities (Article VII-5)

(3) fusion machine–type facilities (Article VII-6)

ARTICLE RIM-4 REPAIR/REPLACEMENT ACTIVITIES

RIM-4.1 SCOPE

If an SSC falls within the scope of the RIM Program, repair/replacement activities shall be performed in accordance with Section XI, Division 1, IWA-4000, except for the following:

(a) In lieu of the preservice inspection requirements of Section XI, Division 1, IWA-4530, the preservice examination requirements of RIM-2.7.3 shall apply.

(b) In lieu of the pressure testing requirements of Section XI, Division 1, IWA-4540(c), the system leakage requirements of RIM-4.2 shall apply.

(c) For applicable paragraphs that identify more than one Code Class, the activity shall be performed to Class 1 requirements, unless otherwise specified in the RIM Program.

RIM-4.2 LEAKAGE TEST REQUIREMENTS AFTER A REPAIR/REPLACEMENT ACTIVITY

Leakage testing shall be performed following repair/replacement activities in accordance with the requirements of RIM-4.2.2 or RIM-4.2.3, regardless of the fluid normally contained in the system during operation.

RIM-4.2.1 Test Boundaries

(a) The pressure boundary affected by the repair/replacement activity shall be tested. Areas of components not affected by the repair/replacement activity need not be tested.

(b) Open-ended portions of a non-closed system extending to the first shutoff valve may be exempted from the test requirements.

RIM-4.2.2 Gas Leakage Test

(a) Test Description. The gas leakage test shall be performed in accordance with Section V, Article 10, Mandatory Appendix IV.

(b) Test Medium. A nonflammable gas shall be used as the test medium.

(c) Pressure and Temperature

(1) Leakage tests shall be conducted at normal operating system pressure.

(2) The test pressure shall be verified by normal system instrumentation (e.g., control room instruments) or test instrumentation.

(3) The test conditions shall be maintained essentially constant for the duration of the test.

(4) The test pressure and temperature may be obtained by using a means that complies with the facility Technical Specifications.

(d) Test Condition Holding Time. A 10-min holding time is required after test pressure is attained.

(e) Visual Examination. The VT-2 visual examination shall be conducted by examining the accessible external exposed surfaces of pressure-retaining components for evidence of leakage.

RIM-4.2.3 Liquid Leakage Test

(a) Test Description. The liquid leakage test shall be performed in accordance with Section V, Article 10, Mandatory Appendix VI.

(b) Test Medium. The contained fluid in the system shall serve as the pressurizing medium.

(c) Pressure and Temperature

(1) Leakage tests shall be conducted at normal operating system pressure.

(2) The test pressure shall be verified by normal system instrumentation (e.g., control room instruments) or test instrumentation.

(3) The test conditions shall be maintained essentially constant for the duration of the test.

(4) When portions of a system are subject to system leakage tests associated with two different system functions, the visual examination need only be performed during the test conducted at the higher of the test pressures of the respective system function.

(5) The test pressure and temperature may be obtained by using a means that complies with the facility Technical Specifications.

(d) Test Condition Holding Time. After the test pressure is attained, it shall be maintained for the time specified below.

(1) 10 min for noninsulated components required to operate during normal facility operation

(2) 4 hr for insulated components required to operate during normal facility operation

(3) 10 min for components not required to operate during normal facility operation

(e) Visual Examination. The VT-2 visual examination shall consist of examining the accessible external exposed surfaces of pressure-retaining components for evidence of leakage.

RIM-4.2.4 NDE in Lieu of Leakage Testing

If the Owner determines that the area affected by the repair/replacement activity cannot be leakage tested, methods of NDE approved by MANDEEP may be performed in lieu of the leakage testing requirements of RIM-4.2.2 or RIM-4.2.3 and flaw acceptance standards shall be as specified in Article RIM-3. If the area affected by the repair/replacement activity is subjected to continuous leakage monitoring in accordance with RIM-5.2, leakage monitoring or the prescribed periodic leakage test shall be conducted when the area is returned to service and shall continue as required by the RIM Program.

(25) RIM-4.2.5 Exemptions From Leakage Tests

(a) No pressure testing is required for the following repair/replacement activities or associated items:

(1) bolts, studs, nuts, and washers

(2) threaded or bolted connections

(3) non-pressure-retaining items, such as supports, mechanical attachments, pump shafts, or valve stem seals

(4) valve discs or seats

(5) heat exchanger tube plugging and sleeving

(b) Replacement components and appurtenances shall be pressure tested in accordance with the Construction Code selected for use in accordance with Section XI, Division 1, IWA-4221 (see RIM-4.1).

(c) The following repair/replacement activities performed by welding or brazing on a pressure-retaining item are exempt from any leak test:

(1) cladding

(2) welding or brazing that does not penetrate through the full thickness of the pressure-retaining material

(3) flange seating surface when less than half the flange axial thickness is removed and replaced

(4) tube-to-tubesheet welding when such welds are made on the cladding

(5) seal welding

(6) welding or brazing joints between non-pressure-retaining items and the pressure-retaining portion of the components

(d) Brazed joints and welds in pressure-retaining replacement parts and piping subassemblies fabricated by the Repair/Replacement Organization or fabricated in accordance with the Construction Code without a hydrostatic or pneumatic pressure test shall be pressure tested as required by (b).

For additional exemptions, refer to the applicable reactor–type provisions in Mandatory Appendix VII.

RIM-4.3 RESPONSIBILITIES

Upon completion of all required activities associated with the Repair/Replacement Plan necessary to return an item to service, the Owner shall prepare the Owner's Repair/Replacement Certification Record, Form NIS-2, in accordance with Mandatory Appendix III.

RIM-4.4 CORRECTIVE ACTION (25)

(a) The sources of leakage detected by a leakage test shall be located and evaluated by the Owner for corrective action as follows:

(1) Leaks such as from seals, seats, and gasket joints in components may be permitted when specifically allowed by the Owner's Design Specification.

(2) An evaluation of the effect of any degraded area upon the structural integrity of the coolant boundary shall be performed in accordance with the provisions of Article RIM-3.

(b) Components requiring corrective action shall have repair/replacement activities performed in accordance with this Article, or corrective measures performed where the relevant condition can be corrected without a repair/replacement activity. All pressure testing required by repair replacement activities shall be completed before an SCC is returned to service.

RIM-4.5 RECORDS

The results of the leakage tests performed to complete a repair/replacement activity shall be documented.

ARTICLE RIM-5
SYSTEM LEAKAGE MONITORING AND PERIODIC TESTS

(25) RIM-5.1 SCOPE

This Article provides requirements for leakage monitoring and periodic leak testing of a coolant boundary.

RIM-5.2 LEAKAGE MONITORING

RIM-5.2.1 General

Systems provided for continuous online leakage monitoring as an element of the RIM Program shall be subjected to the reliability performance requirements of RIM-2.7.6.1(b)(2). During facility operation the leakage detection systems shall be in operation. Proper operation and effectiveness of the leakage detection system shall be verified daily. Verification shall include some or all of the following:

(a) system calibration records
(b) system printouts
(c) system monitoring
(d) system maintenance history
(e) records of performance demonstration tests

RIM-5.2.2 Periodic Leakage Test

Periodic leakage tests shall be conducted in accordance with RIM-4.2.2 or RIM-4.2.3, as applicable.

RIM-5.3 CORRECTIVE ACTION (25)

(a) The sources of leakage detected by leakage monitoring or leakage test shall be located by the Owner and evaluated for corrective action as follows:

(1) Leakages such as from seals, seats, and gasket joints in components may be permitted when specifically allowed by the Owner's Design Specification.

(2) An evaluation of the effect of any degraded area upon the structural integrity of the coolant boundary shall be performed in accordance with the provisions of Article RIM-3.

(b) Components requiring corrective action shall have repair/replacement activities performed in accordance with Article RIM-4 or corrective measures performed where the relevant condition can be corrected without a repair/replacement activity.

RIM-5.4 RECORDS

(a) Verification of satisfactory performance of the leakage monitoring system shall be documented. Any source of leakage or evidence of structural distress shall be itemized, and the location and corrective action documented.

(b) The results of periodic leakage tests shall be documented as required by RIM-6.3.4.

ARTICLE RIM-6
RECORDS AND REPORTS

RIM-6.1 SCOPE

This Article provides the requirements for the preparation, submittal, and retention of records and reports.

RIM-6.2 DOCUMENTATION REQUIREMENTS

RIM-6.2.1 Owner's Responsibilities

The Owner shall prepare the following:

(a) plans and schedules for the RIM Program to meet the requirements of this Division.

(b) records of MANDE results, tests, and repair/replacement activities.

(c) the Owner's Activity Report, Form OAR-1, in accordance with Mandatory Appendix III.

(d) the Owner's Repair/Replacement Certification Record, Form NIS-2, in accordance with Mandatory Appendix III upon completion of the required activities associated with the repair/replacement plan.

RIM-6.2.2 Owner's Activity Report, Form OAR-1

An Owner's Activity Report, Form OAR-1 (see Mandatory Appendix III), shall be processed as specified below following the completion of each scheduled outage for each reactor in a facility.

(a) The items with flaws or relevant conditions that exceeded the acceptance criteria of this Division and that required evaluation to determine acceptability for continued service shall be documented as indicated in Form OAR-1, Table 1. This information is required regardless of whether the flaw or relevant condition was discovered during a scheduled examination, test, or MANDE activity.

(b) An abstract of the repair/replacement activities that were required due to an item containing a flaw or relevant condition that exceeded the acceptance criteria of this Division shall be provided as indicated in Form OAR-1, Table 2. The information is required even if the discovery of the flaw or relevant condition that necessitated the repair/replacement activity did not result from any examination, test or MANDE required by this Division. If the acceptance criterion for a particular item is not specified in this Division, the provisions of Section XI, Division 1, IWA-3100(b) shall be employed for evaluation to determine the disposition.

(c) If no items meet the criteria of (a) and (b), the term "None" should be recorded in the applicable table.

(d) If there are multiple reactors at a facility and inspection plans with different intervals, inspection periods, Editions, or Addenda, each reactor shall be identified on a separate Form OAR-1.

(e) The respective Owner's Form OAR-1 shall be certified by the Owner and presented to the Inspector for the required signature.

RIM-6.2.3 Contracted Repair/Replacement Organization Responsibilities

Refer to Section XI, Division 1, IWA-6212.

RIM-6.2.4 Owners' Repair/Replacement Certification Record NIS-2 Responsibilities

Refer to Section XI, Division 1, IWA-6220.

RIM-6.3 RECORD RETENTION

RIM-6.3.1 Maintenance of Records

In addition to complying with the provisions of Section XI, Division 1, IWA-6310, the Owner shall retain records and reports identified in RIM-6.3.3, RIM-6.3.4, and RIM-6.3.5.

RIM-6.3.2 Reproduction, Digitization, and Microfilming

Refer to Section XI, Division 1, IWA-6320.

RIM-6.3.3 Construction Records

Refer to Section XI, Division 1, IWA-6330.

RIM-6.3.4 RIM Program Records

The Owner shall designate the records to be maintained. Such records shall include the following, as applicable:

(a) record index

(b) the original RIM Program basis documents used for RIM-1.1(b)

(c) RIM inspection plans, schedules and reports

(d) records of flaw acceptance by analytical evaluation

(e) records of regions in ferritic components with modified flaw acceptance standards

(f) nondestructive examination procedures and records

(g) MANDE personnel qualifications

(h) leakage test procedures and records

(i) monitoring procedures and records

(j) records required by Mandatory Appendix IV, Article IV-5

RIM-6.3.5 Repair/Replacement Activity Records

The following records prepared in performance of a repair/replacement activity shall be retained:

(a) evaluations required by Section XI, Division 1, IWA-4160(a), IWA-4160(b), and IWA-4311

(b) repair/replacement program and plans

(c) records and reports of repair/replacement activities

(d) reconciliation documentation

(e) NIS-2 Forms

(f) OAR-1 Forms

(g) documents certifying repair/replacement activities by contracted Repair/Replacement Organizations

ARTICLE RIM-7 GLOSSARY

(25) RIM-7.1 TERMS AND DEFINITIONS

Terms used in this Division are defined in this Article and in Section XI, Division 1, IWA-9000.

accident sequence: a representation in terms of an initiating event followed by a sequence of failures or successes of events (i.e., system, function, or operator performance) that can lead to undesired consequences, with a specified end state.

alternate requirements: monitoring or augmented nondestructive examination (NDE) methodologies used to assess and evaluate component degradation other than the prescribed NDE methods contained in Mandatory Appendix V and the applicable provisions of Mandatory Appendix VII.

availability: the probability that a system or component is capable of supporting its function.

Candidate Reliability Targets: tentative Reliability Targets shown to be sufficient to achieve facility-level safety requirements. A suitable combination of reliability targets is chosen from the Candidate Reliability Targets, as required by Mandatory Appendix II-2.6.

capability category: a measure of the ability of a probabilistic risk assessment (PRA) to support risk-informed applications based on conformance to requirements established for PRA scope, level of detail, facility-specificity, and realism. Two levels are defined in the ASME/ANS PRA Standards (see RIM-1.9), Capability Categories I and II.

component exposure population: the set of equipment included in the scope of the Reliability and Integrity Management (RIM) Program for which a particular RIM strategy is applied to influence reliability.

component-level requirement (CLR): an allowable degradation limit of an individual component from a safety point of view. CLRs are described in accordance with the facility safety evaluation, using quantities such as the break size postulated in an accident scenario. Exceeding a CLR could lead to an increase in the core damage frequency (CDF) or containment failure frequency (CFF) or large early release frequency (LERF) that has been calculated in the safety evaluation of the facility.

compressor: a mechanically driven device that increases the pressure and reduces the volume of a gas.

condition monitoring: the process of systematic data collection and evaluation to identify and quantify usage factors or changes in performance or condition of a structure, system, or component (SCC), such that remedial action may be planned to maintain SSC Reliability Targets.

containment failure frequency (CFF): CFF is the sum of frequencies of various containment failure modes ranging from small leaks to a large and early break of the containment.

coolant boundary: a boundary of any coolant-retaining structure, system, or component of a nuclear reactor facility within the scope of this Division.

core damage frequency (CDF): the expected number of core damage events per unit of time that involve the uncovering and heatup of the reactor core to the point at which prolonged oxidation and severe fuel damage are anticipated and that involve enough of the core to cause a significant release.

degradation mechanism: a phenomenon or process that attacks (e.g., wears, erodes, corrodes, cracks) the material under consideration.

event tree: a logic diagram that begins with an initiating event or condition and progresses through a series of branches that represent expected system or operator performance that either succeeds or fails and arrives at either a successful or failed end state.

event tree top event: the conditions (i.e., system behavior or operability, human actions, or phenomenological events) that are considered at each branch point in an event tree.

failure: events involving conditions that would disable a component's ability to perform its intended safety function.

failure mechanism: any of the processes that result in failure modes, including chemical, electrical, mechanical, physical, thermal, and human error.

false call probability (FCP): the percentage resulting from dividing the number of false calls by the number of unflawed specimens or unflawed grading units examined.

human error (HE): any human action that exceeds some limit of acceptability, including inaction when action is required, but excluding malevolent behavior.

indication of degradation (ID): a signal or response that degradation exists that could lead to the exceedance of a component-level requirement (CLR).

initiating event: any event that perturbs the steady state operation of the facility, if operating, or the steady state operation of the decay heat removal systems during shutdown operations such that a transient is initiated in the facility that leads to the need for reactor subcriticality and decay heat removal.

large early release frequency (LERF): the expected number of large early releases per unit of time involving the rapid, unmitigated release of airborn fission products from the containment to the environment occurring before the effective implementation of off-site emergency response and protective actions such that there is a potential for early health effects.

level of rigor: the level of confidence to which a given examination system should be demonstrated, based upon factors such as user needs, degradation mechanisms, and required Reliability Targets.

MANDE Program: a strategy and process of using Monitoring and NDE (MANDE) to meet SSC Reliability Targets. The MANDE Program is a subset of the RIM Program.

maximum acceptable leakage (MAL): the extent of leakage of coolant above which a leak would lead to an increase in risk indices, such as core damage frequency and containment failure frequency or large early release frequency, that has been calculated in the safety evaluation of the facility.

may: word used to denote an action that is permitted but not required.

monitoring: the systematic process of observing, tracking, and recording activities or data for the purpose of evaluating facility SSC conditions.

monitoring and nondestructive examination (MANDE): a term used in this Division to refer to the activities of monitoring, nondestructive examination (NDE), and use of surveillance specimens, as established by the Monitoring and NDE Expert Panel (MANDEEP).

nuclear reactor facility: a type of nuclear facility wherein interconnected SSCs are assembled for nuclear reactor operation and are distinguishable from colocated or proximate nonreactor nuclear facilities. This is a comprehensive term for a wide range of reactor applications, such as nuclear power plants (including microreactors), isotope production reactors, mobile microreactors, propulsive microreactors, research and test reactors, and fusion reactor facilities.

piping system: an assembly of piping segments, piping supports, and other components with a defined function.

probabilistic risk assessment (PRA): a quantitative assessment of the event sequences involving the release of radioactive material; it includes an estimate of accident frequencies, consequences and uncertainties.

probability of detection (POD): the percentage resulting from dividing the number of detections by the number of flawed specimens or flawed grading units examined. POD indicates the probability that an examination system will detect a given flaw.

reliability: the probability that a system or component will perform its specified function under given conditions upon demand and for a prescribed mission time.

reliability and integrity management (RIM): those aspects of the facility design process that are applied to provide an appropriate level of reliability of structures, systems, and components (SSCs) and a continuing assurance over the life of the facility that such reliability is maintained. These include design features important to reliability performance such as design margins, selection of materials, testing and monitoring, provisions for maintenance, repair and replacement, leakage testing, and nondestructive examinations (NDEs).

Reliability Target: a performance goal established as a means of assessing the probability that an SSC will complete its specified function and thereby achieve facility-level risk and reliability goals.

RIM Program: a comprehensive program to define, evaluate, and implement strategies to ensure that Reliability Targets for SSCs are defined, achieved, and maintained throughout the facility lifetime as administered under RIM-2.

screening: a process that eliminates items from further consideration based on their negligible contribution to the probability of an accident or its consequences.

screening criteria: the values and conditions used to determine whether an item is a negligible contributor to the probability of an accident sequence or its consequences.

shall: word used to denote an action that is mandatory (i.e., the user is obliged to satisfy the provision in order to comply with the standard).

should: word used to denote an action that is not mandatory.

sizing accuracy: the difference between the actual length, depth, flaw separation, and remaining ligaments and the values measured using a nondestructive sizing technique as determined during the performance demonstration process.

SSC: a structure, system, or, component.

surveillance samples: specimens of SSC representative materials used for monitoring the material performance, relevant to meeting the RIM target reliabilities, of inservice SSCs subjected to environmental stressors.

Surveillance samples are located in the same or higher levels of environmental stressors as the inservice SSCs. They are unique for each reactor design, SSC design, and degradation mechanisms of concern.

Trial Reliability Targets: tentative Reliability Targets assigned in trial to evaluate if they are sufficient to achieve facility-level safety requirements, as required by Mandatory Appendix II, II-2.4.

uncertainty:

(a) as used in probabilistic risk assessment (PRA): a representation of the confidence in the state of knowledge about the parameter values and models used in constructing the PRA.

(b) as used in monitoring and nondestructive examination (MANDE): a quantification representing the variability associated with MANDE data and includes many technique- and application-specific parameters such as the minimum detection capability, sizing accuracy, resolution tolerance, repeatability, and consistency.

RIM-7.2 ACRONYMS

CDF = core damage frequency
CFF = containment failure frequency
DMA = degradation mechanism assessment
LERF = large early release frequency
LWR = light water reactor
MANDE = monitoring and nondestructive examination
NDE = nondestructive examination
POD = probability of detection
PRA = probabilistic risk assessment
RIM = reliability and integrity management
SSC = structure, system, or component

MANDATORY APPENDIX I
RIM DECISION FLOWCHARTS FOR USE WITH THE RIM PROGRAM

ARTICLE I-1
FLOWCHARTS

I-1.1 GENERAL

Figures I-1.1-1 through I-1.1-6 begin on the following page. Throughout the figures, the following symbols are used:

(a) Unshaded circles denote inputs to the RIM Program.

(b) Shaded circles and ovals denote inputs to the MANDE Program.

(c) Unshaded octagons denote outputs for redesign.

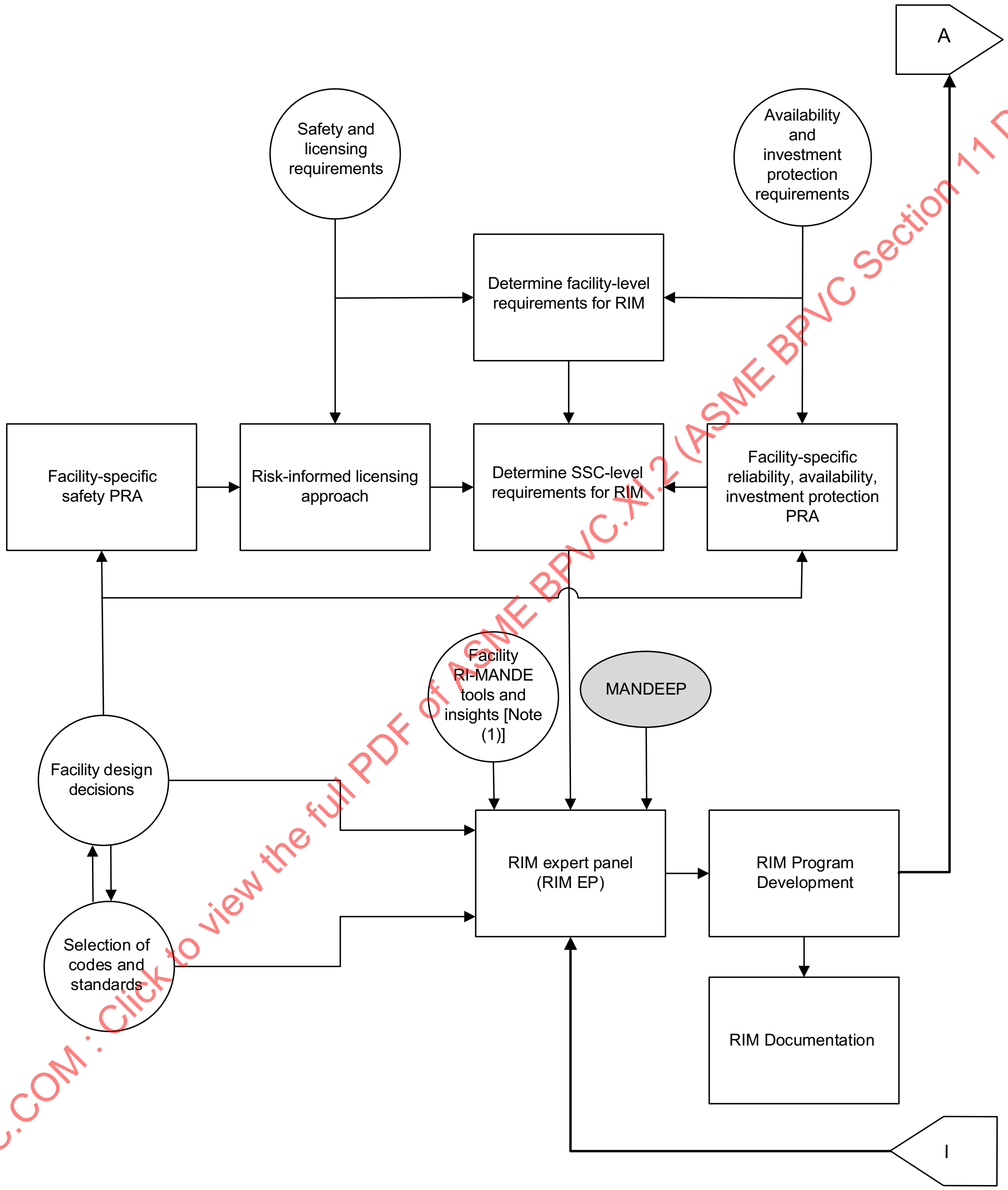
(d) Unshaded rectangles denote process elements.

(e) Shaded rectangles denote MANDE process elements.

(f) Diamonds denote decision points.

Thus, all symbols in the flow charts constitute the RIM Program and all shaded symbols in the flow charts constitute the MANDE Program.

Figure I-1.1-1
Inputs to the RIMEP for NPP Owner's RIM Program Development



NOTE: (1) The term "Facility RI-MANDE tools and insight" refers to the experience gained in deploying risk-informed (RI) ISI methodologies to the Section XI, Division 1 LWR fleet of reactors. This experience will grow as new reactor designs gain operating experience.

Figure I-1.1-2
RIM Program Development and Integration

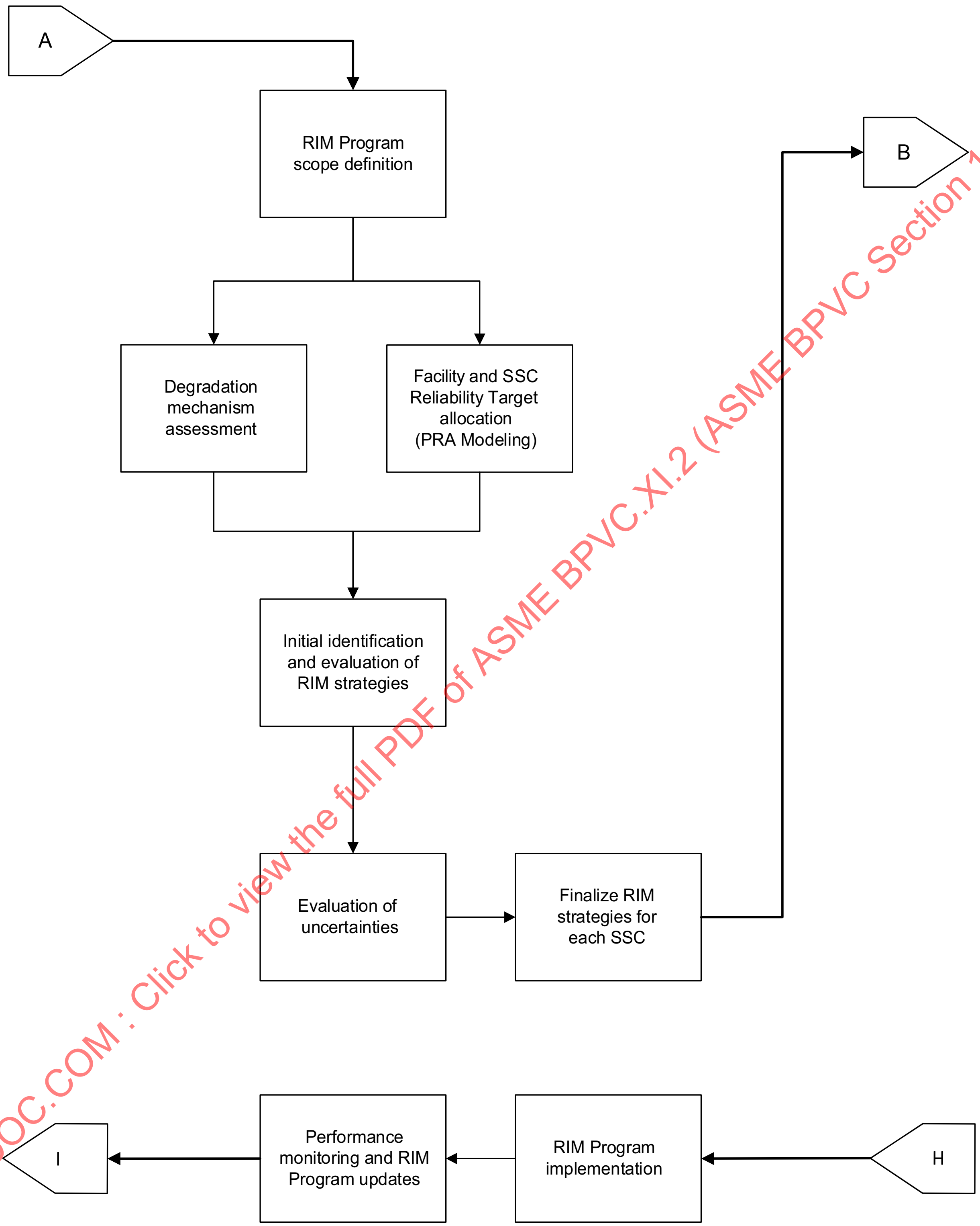


Figure I-1.1-3
Process for Identifying the SSCs to Be in MANDE Program

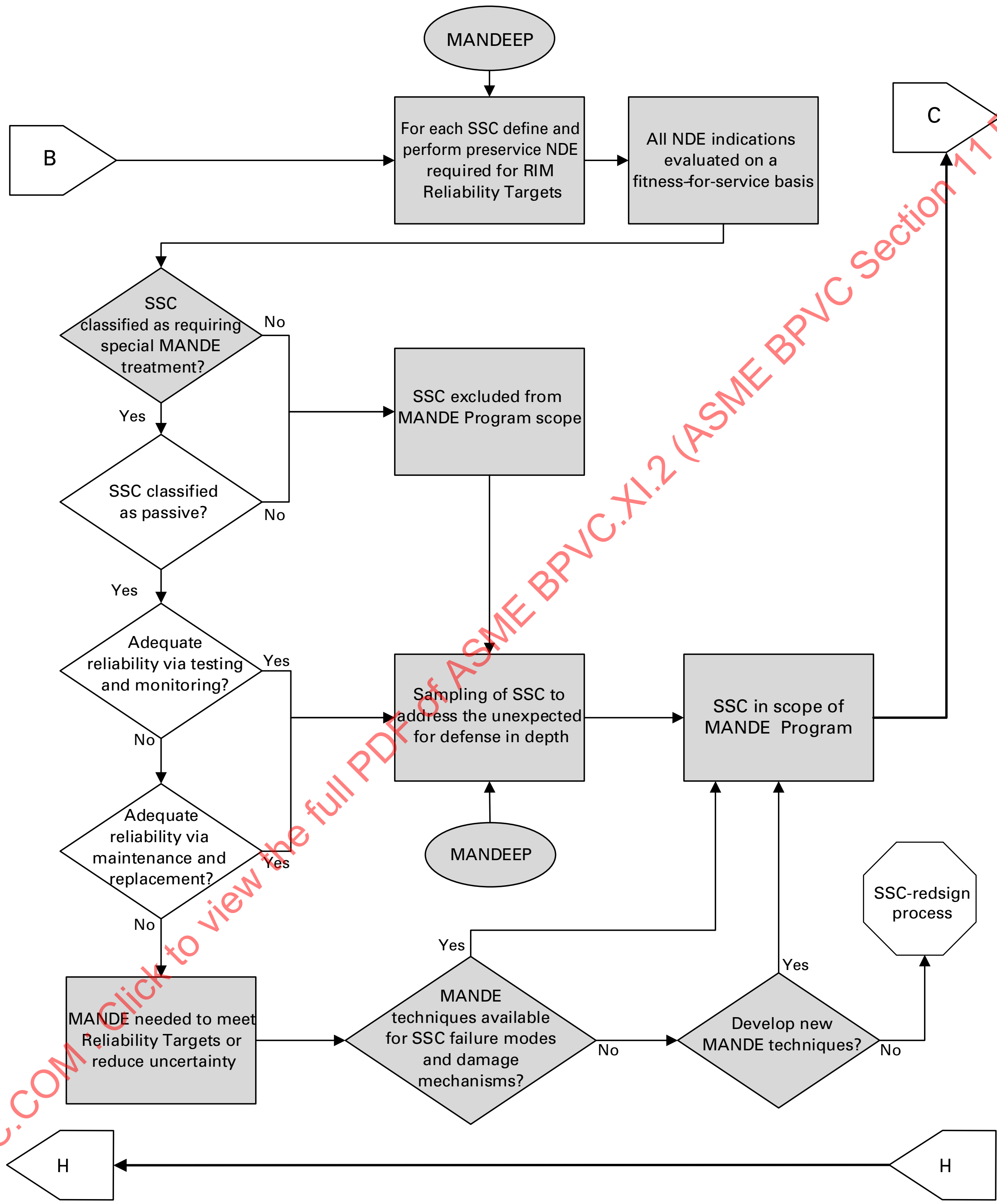


Figure I-1.1-4
Selection of Strategies for SSCs to Meet Reliability Targets

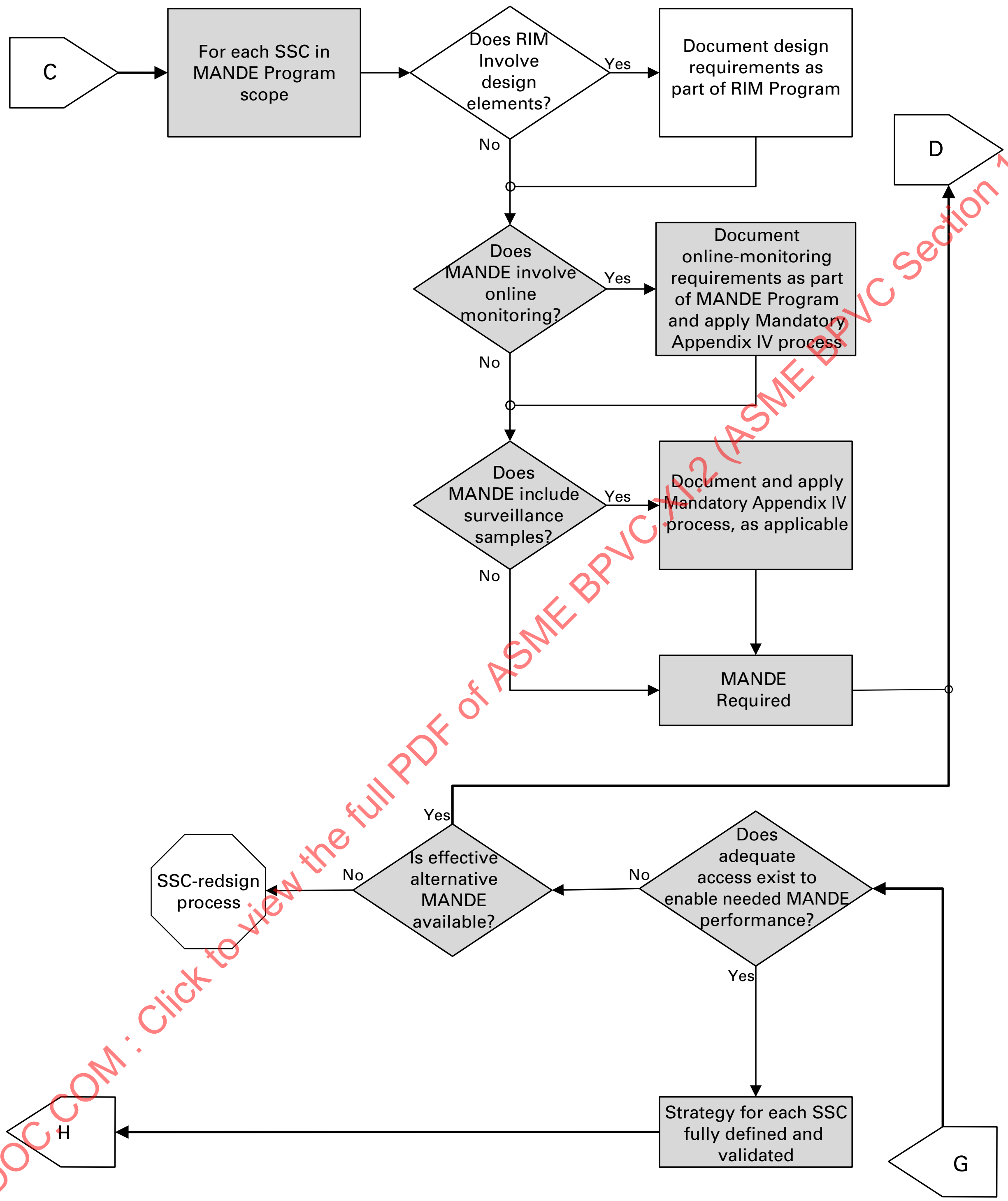


Figure I-1.1-5
Upper Half Shows Input to MANDEEP for Developing MANDE Specification and Lower Half Shows Process for Evaluating if Section XI, Division 1 Requirements Meet MANDE Specifications

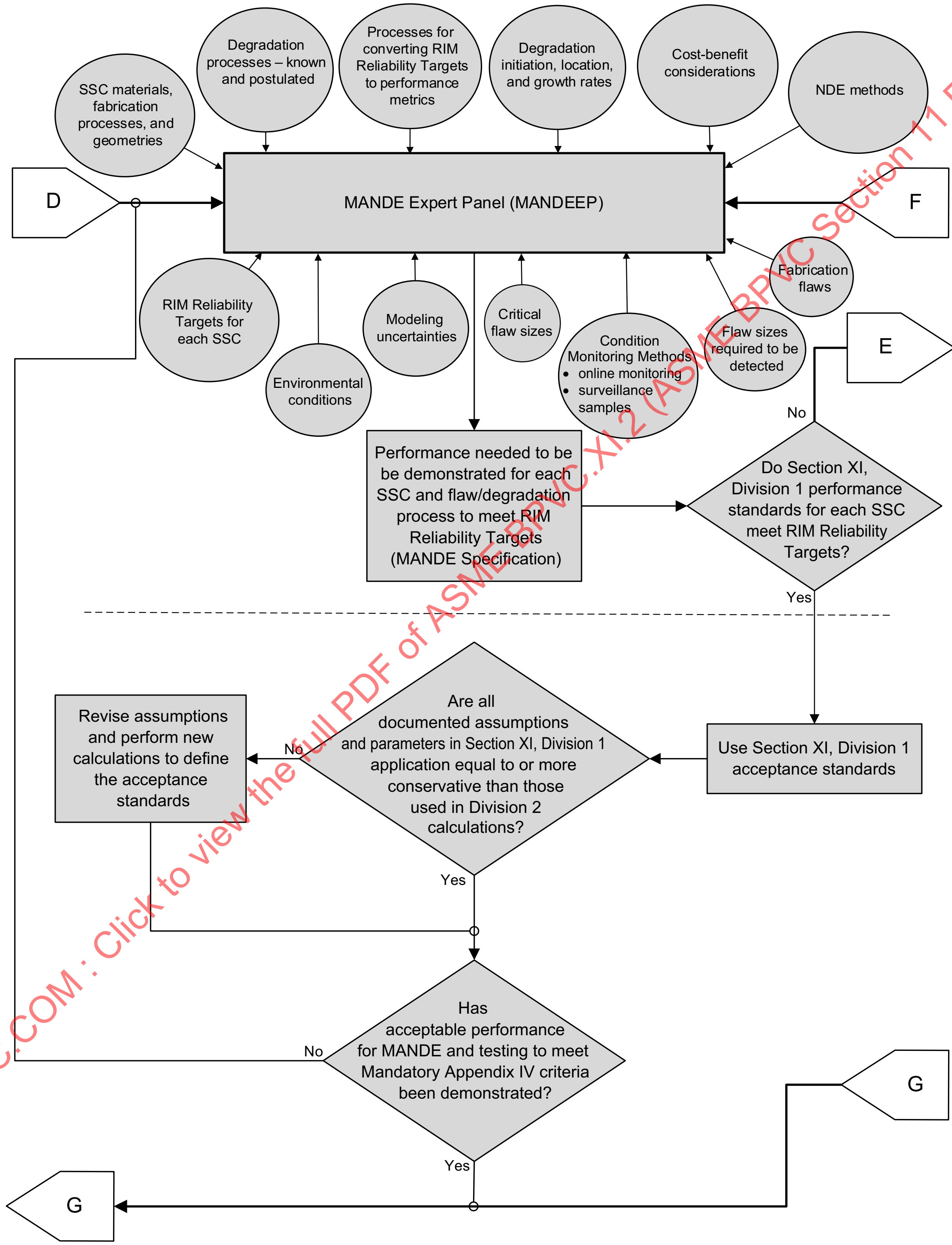
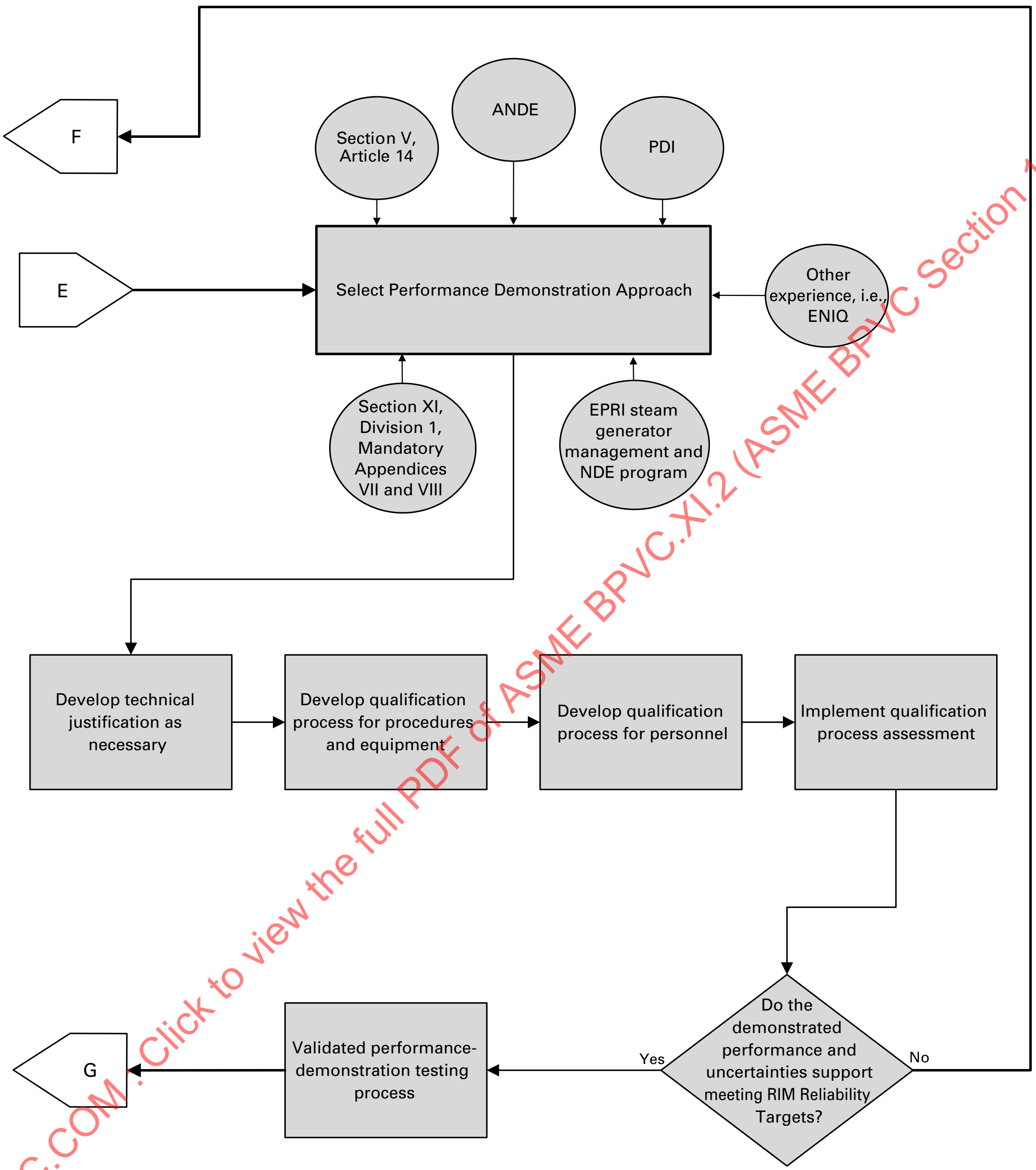


Figure I-1.1-6
Select, Develop, and Validate Performance Demonstration Approach to Meet SSC Reliability Target



Legend:
ANDE = ASME nondestructive examination
ENIQ = European Network for Inspection and Qualification
EPRI = Electric Power Research Institute
PDI = Performance Demonstration Initiative

MANDATORY APPENDIX II
DERIVATION OF COMPONENT RELIABILITY TARGETS FROM FACILITY SAFETY REQUIREMENTS

ARTICLE II-1
GENERAL REQUIREMENTS

II-1.1 SCOPE

This Appendix shall be used for deriving component-level requirements (CLRs) from facility-level safety requirements using probabilistic risk assessment (PRA). This Appendix provides a method for deriving CLRs in the form of SSC Reliability Targets.

II-1.2 ADEQUACY OF THE PRA

The PRA model as required by RIM-2.4.3, shall be constructed so that it is applicable to derivation of component Reliability Targets from facility-level safety requirements.

II-1.3 PROCEDURE OVERVIEW (25)

The derivation procedure includes the following steps:

Step 1: Determine facility-level safety requirements in accordance with II-2.1.

Step 2: Allocate Reliability Targets in accordance with II-2.2.

Step 3: Identify groups of components in accordance with II-2.3.

Step 4: Assign Trial Reliability Targets to the groups in accordance with II-2.4.

Step 5: Evaluate impacts of the Trial Reliability Targets on facility-level risks in accordance with II-2.5.

Step 6: Determine the combination of Reliability Targets for the components in accordance with II-2.6.

ARTICLE II-2
DERIVATION OF RELIABILITY TARGETS

II-2.1 FACILITY-LEVEL SAFETY REQUIREMENTS

(a) For light water reactor (LWR) type facilities, use the facility-level safely goals that are established in terms of core damage frequency (CDF) and large early release frequency (LERF).

(b) For advanced non-LWR type facilities, such as the high-temperature gas reactor (HTGR) types, use appropriate facility-level safety goals, based on metrics such as regulatory limits on the risks, frequencies, and radiological consequences of licensing basis events.

(c) If quantitative facility-level safety requirements are available, based on metrics such as CDF, containment failure frequency (CFF), or LERF, SSC Reliability Targets as obtained herein may be used as component-level reliabilities (CLRs).

II-2.2 ALLOCATION OF RELIABILITY TARGETS

(a) The objective of setting Reliability Targets for SSCs in the scope of the RIM Program is to establish a reference point against which to judge system performance to meet the facility-level safety requirements. The Reliability Targets that the Owner assigns to SSCs should be consistent with the facility-level safety goals. The Owner should consider industry-wide operating experience if practicable.

(b) Reliability Targets may be developed during the initial phase of the RIM Program. These targets are intended to be compared with actual facility performance so that deviations from expected performance may be identified.

(c) The Reliability Target allocation includes the following considerations:

(1) For each PRA scope identified, quantitative facility-level requirements may be divided and distributed by the type of initiating events, initial facility operating states, and accident sequences.

(2) Accident categories shall be identified for each PRA scope based on the PRA model, and a Reliability Targets. The Reliability Target allocated for the PRA scopes shall be divided and distributed for each accident category.

(3) The event trees relevant to passive component failures shall be identified for the accident category. The event tree top events (e.g., see ASME/ANS RA-S-1.4) related to dynamic component failures and human errors may be removed by assuming that their probability is 1. The sequences depending only on dynamic functions shall be excluded from the event trees. Reliability Targets allocated for the accident category shall be divided and distributed for the accident category due to passive component failures and other contributors.

(4) Design and operation information, and past PRA studies shall be used for allocation of Reliability Targets.

II-2.3 IDENTIFICATION OF COMPONENT GROUPS

Groups of components for which loss of function would have the same effect on the PRA model as identified in II-2.2(c)(3) shall be identified.

II-2.4 TRIAL ASSIGNMENT OF RELIABILITY TARGETS

(a) Trial Reliability Targets for the frequency or probability of structural integrity loss shall be assigned to the groups identified in II-2.3.

(b) Design and operation information and past PRA studies shall be used for identification of Trial Reliability Targets.

II-2.5 EVALUATION OF IMPACTS OF RELIABILITY TARGETS ON FACILITY-LEVEL RISK

(a) Risk indices given as quantitative facility-level requirements (e.g., CDF) shall be evaluated using the PRA model identified in II-2.2(c)(3) and using the Trial Reliability Target of the groups identified in II-2.3.

(b) The combinations of Candidate Reliability Targets necessary and sufficient to achieve the allocated Reliability Target for the accident categories due to passive component failures in II-2.2(c)(3) shall be selected.

II-2.6 DETERMINATION OF RELIABILITY TARGETS

A suitable combination of Reliability Targets shall be chosen from the Candidate Reliability Targets selected in II-2.5 by considering the balance of the Reliability Targets among the groups identified in II-2.3.

MANDATORY APPENDIX III OWNER'S RECORD AND REPORT FOR RIM PROGRAM ACTIVITIES

ARTICLE III-1 GUIDES TO COMPLETING FORMS

III-1.1 FORM OAR-1

See Section XI, Division 1, Mandatory Appendix II for Form OAR-1. See Table III-1.1-1 for instructions on completing Form OAR-1.

III-1.2 FORM NIS-2

See Section XI, Division 1, Mandatory Appendix II for Form NIS-2 and the instructions for completing it.

Table III-1.1-1
Guide for Completing Form OAR-1

Reference to Circled Numbers in Form OAR-1	Description
1	A unique number to identify the report.
2	The name and address of the nuclear facility where the inservice examinations, MANDE, and tests were performed. If multiple reactors are located at a single facility, each reactor shall be uniquely identified.
3	The Owner's designated unit identification number.
4	The date determined by the Owner that the unit originally became available for regular production of electricity or process heat.
5	The unique number assigned to the refueling/maintenance outage.
6	Successive RIM interval and duration of the RIM interval.
7	Inspection period within the RIM interval (first, second, or third).
8	The Edition of Section XI applicable to the MANDE and tests represented by the Form.
9	The date and revision level of the inspection plan followed during the MANDE and tests represented by this Form.
10	The Edition of Section XI applicable to the MANDE and tests represented if different from that in number 8 above.
11	Applicable Construction Code or Section XI Code Cases associated with the repair/replacement activity.
12	Same number as in number 5 above.
13	Signature and title of the Owner's Designee who certifies the accuracy of the report.
14	The date this Form was prepared.
15	The name of the Inspector's employer, the Authorized Inspection Agency.
16	The address of the Authorized Inspection Agency (city/town and state or province).
17	Authorized Nuclear Inservice Inspector's signature.
18	Authorized Nuclear Inservice Inspector's National Board Commission Number, including endorsements and, if applicable, justification name and Certificate of the competency number held in the state or province where inspections represented by this Form OAR-1 were performed.
19	The date (month, day, year) the Authorized Nuclear Inservice Inspector signed the Form.
20	Examination category from Mandatory Appendix V, or MANDE alternatives established by Nonmandatory Appendix A.
21	Brief description of indication or "None."
22	Resolution of indication.
23	Construction Code safety classification used for construction.
24	Item description.
25	Indicate "Repair" or "Replacement."
26	Date repair/replacement plan completed.
27	Unique repair/replacement plan number.
28	Describe any additional information not otherwise covered in Owner's Activity Report.

MANDATORY APPENDIX IV
MONITORING AND NDE QUALIFICATION

ARTICLE IV-1
INTRODUCTION

IV-1.1 SCOPE

This Appendix provides requirements for performance-based qualification of monitoring and nondestructive examination (MANDE) methods and techniques, an element of the Owner's RIM Program. It addresses qualification of personnel, procedures, and equipment. The qualification requirements described herein support the strategies required for the applicable structure, system, or component (SSC) Reliability Targets as required by RIM-2.7.6. The MANDE qualification process is illustrated in Mandatory Appendix I, Figures I-1.1-1 through I-1.1-6.

IV-1.2 METHODS

The following MANDE methods are addressed in this Appendix:

(a) acoustic emission (AE)

(1) leakage detection

(2) defect, degradation, and damage detection

(b) eddy current (ET)

(c) leakage testing (LT)

(1) helium mass spectrometer testing

(2) halogen diode leakage testing

(3) ultrasonic leakage detection

(4) pressure change testing

(5) bubble testing

(d) liquid penetrant (PT)

(e) magnetic particle (MT)

(f) online monitoring (e.g., leakage detection, vibration analysis, thermal sensors) and additional monitoring methods as determined by the Monitoring and NDE Expert Panel (MANDEEP) (see IV-1.3)

(g) radiographic examination (RT)

(h) ultrasonic examination (UT)

(i) visual examination (VT) (VT-1, VT-2, or VT-3)

(j) surveillance samples

IV-1.3 OWNER'S MONITORING AND NDE EXPERT PANEL (MANDEEP)

IV-1.3.1 General Responsibilities

The MANDE expert panel (MANDEEP) is responsible for the following, consistent with the Reliability Targets established by the RIM Expert Panel (RIMEP):

(a) fulfilling the requirements of IV-1.3.2 and IV-1.3.3

(b) planning examinations

(c) maintaining calibration standards

(d) preparing and retaining records

IV-1.3.2 MANDEEP-Specific Responsibilities

(a) The MANDEEP shall be responsible for establishing and documenting the following:.

(1) the MANDE specification (Figure I-1.1-5).

(2) the level of rigor required for MANDE qualification. For NDE, reference requirements are as defined for Section V, Article 14.

(3) specific examination requirements, including coverage, frequency, location, and volume.

(4) minimum criteria of MANDE for all SSCs. These criteria shall be based on the following:

(-a) the Reliability Target established for individual SSCs

(-b) degradation mechanisms and stressors assigned to the SSC

(-c) the detection capability and associated uncertainty of the MANDE methods proposed for each application

(-d) relevant design and operating factors specific to a given reactor type

(5) acceptance criteria for evaluation of the identified monitoring or NDE indications.

(b) The MANDEEP shall identify and oversee development of MANDE methods for examinations of SSCs within the scope of the RIM program. The MANDE methods shall be determined by specifying a validation strategy and process designed to achieve the required performance used to support the RIM Program.

(c) The MANDEEP shall specify criteria for qualification of methods, techniques, and procedures. The MANDEEP shall also specify criteria for qualification and certification of examination personnel.

(d) The MANDEEP's work shall be independent from production and operational concerns.

(e) The MANDEEP shall be given full access to necessary data and shall additionally be adequately resourced to complete its work.

(f) MANDEEP members may be part of the Owner's organization or may be independently contracted.

IV-1.3.3 MANDEEP Qualifications

The following requirements shall apply to the MANDEEP:

(a) The MANDEEP shall be formed by, and shall be responsible to, the MANDEEP Chair. The Chair shall have a broad-based knowledge of NDE, engineering mechanics, materials, welding and joining, statistics, and radiation safety in order to select expert panel members. The Chair shall hold a 4-yr technical degree from an accredited college or university. In addition, the Chair shall have 15 yr of related experience in NDE (e.g., examination, research, teaching), including 10 yr of experience in the application of MANDE at nuclear reactor facilities. The Chair shall have functional independence within the facility Owner's organization, similar to the independence afforded to those performing quality assurance functions. The Chair shall be a member of the RIMEP.

(b) The MANDEEP's initial makeup shall be determined by MANDEEP Chair and shall include members with in-depth knowledge of surface and volumetric NDE methods and techniques and the following:

(1) failure modes both known and postulated

(2) engineering mechanics, materials, and fabrication processes

(3) degradation initiation, location, and growth rates

(4) critical flaw sizes and flaw sizes required to be detected during performance demonstration

(5) fabrication flaws requiring detection and accurate characterization

(6) condition monitoring methods including online techniques

(7) cost-benefit considerations

(8) converting RIM Reliability Targets into MANDE performance metrics

(9) testing methodology for performance demonstrations and

(10) operational knowledge of specific nuclear reactor facility design

(c) MANDEEP members shall be selected based on their expertise in a given subject or discipline that contributes to the assigned effort. MANDEEP membership is not based on a detailed education or experience criteria. It shall be based on the individual's expertise in the subject matter and this expertise shall be documented to justify selection of the individual. Only one certified NDE Level III is required for the MANDEEP. If NDE methods or techniques for flaw detection, sizing, or monitoring are detailed in a Code or standard, and a recognized certification is applicable, at least one MANDEEP member shall be certified equivalent to NDE Level III in one or more of these methods. NDE Level III certification in various techniques of a given method is not required. When an NDE Level III is not certified in all methods and applicable techniques required to support achieving the Reliability Targets, the NDE Level III, in coordination with the Panel Chair, shall identify candidates, review their qualifications, and select a subject matter expert (SME) with the applicable expertise to augment the MANDEEP membership. For methods or techniques, that are not standardized or in development, at least one MANDEEP member shall be a senior representative of the developing organization.

(d) The MANDEEP Chair shall establish the MANDEEP with membership initially based on informed assumptions as to the technologies and confidence necessary to achieve the RIM Reliability Targets for each SSC within the RIM Program. The Chair shall prepare a document addressing the basis for panel formation. The basis document shall outline potential MANDE methods or techniques and prioritize their potential to meet examination objectives. This basis document shall be reviewed and validated or modified as determined by the panel formed. The basis document shall describe staffing of the MANDEEP, the work schedule, and the funding necessary to conduct the activities defined in this basis document.

ARTICLE IV-2 PERSONNEL QUALIFICATION

IV-2.1 BASIC PERSONNEL QUALIFICATION

The MANDEEP shall establish programmatic procedures (see Mandatory Appendix I, Figures I-1.1-1 through I-1.1-6) to control personnel qualification in accordance with the following:

(a) One of the following qualification and certification requirements shall be applied:

(1) ASME ANDE-1

(2) the national or international central certification program required by the regulatory and enforcement authorities having jurisdiction at the facility site

(b) For methods or techniques not addressed by (a)(1) or (a)(2), as an alternative to (a), the Owner's program for NDE personnel qualification and certification shall apply.

(c) If personnel qualification programs for MANDE methods exist, the MANDEEP shall review them for acceptance. If qualification programs do not exist or are not acceptable, the MANDEEP shall specify qualification requirements. These qualification requirements shall be based on performance-based qualification principles similar to those included in ASME ANDE-1.

IV-2.2 METHOD-SPECIFIC OR TECHNIQUE-SPECIFIC PERSONNEL QUALIFICATIONS

IV-2.2.1 Data Acquisition Personnel

Personnel performing only data acquisition shall have received specific training and shall be qualified in accordance with the Owner's procedures for the applicable equipment operation and data recording tasks. These qualification requirements shall be based on performance-based qualification principles similar to those included in ASME ANDE-1.

IV-2.2.2 Data Evaluation Personnel

Personnel performing evaluation of examination data shall have received specific training in the data evaluation techniques used in performance demonstration and shall successfully complete the performance demonstration required in Article IV-4.

ARTICLE IV-3
MANDE METHODS AND TECHNIQUES RELIABILITY-BASED QUALIFICATION

IV-3.1 GENERAL

The MANDEEP shall be responsible for determining the performance demonstration requirements for each SSC to reach the Reliability Target based on applicable flaw damage mechanisms, degradation processes, and frequency of examination.

IV-3.2 DETERMINATION OF THE QUALIFICATION REQUIREMENTS

To establish the requirements for qualification of a MANDE specification (method and technique) for an SSC, the MANDEEP shall consider factors relevant to maintaining the Reliability Target including the following:

(a) materials and fabrication processes

(b) part geometry

(c) stress analysis, including the effect of known or postulated fabrication flaws

(d) known and postulated degradation mechanisms

(e) flaw/condition initiation and growth rates

(f) critical flaw size or condition extent (e.g., material loss)

(g) minimum flaw size or condition extent required for detection

(h) sizing accuracy (i.e., length, depth, flaw separation, remaining ligament, etc.)

(i) flaw location and coverage of examination

(j) sample size and distribution

(k) frequency of examination

(l) probability of detection and false calls

(m) accuracy of the MANDE technique

IV-3.3 QUALIFICATION PROCESS

IV-3.3.1 General

The qualification of a MANDE specification supports the Reliability Target for the SSC determined as a result of consideration of the factors listed in IV-3.2. The reliability of the MANDE specification shall be then considered by the MANDEEP in determining any additional controls needed to achieve the necessary Reliability Target of the SSC.

IV-3.3.2 SSC MANDE Specifications (Mandatory Appendix I, Figure I-1.1-5)

A MANDE specification is required for the qualification of monitoring and NDE for each SSC. The MANDE specification is a document describing the MANDE methods and techniques to be used and their required performance. It shall include a reference to the supporting technical justification (see IV-3.3.3), which shall include the principles of the technique as applied to the SSC, an explanation of the procedure, including the equipment to be used, and any relevant laboratory and field experience.

IV-3.3.3 MANDE Technical Justification (Mandatory Appendix I, Figure I-1.1-6)

For each method and technique identified in the MANDE specification, a technical justification shall be prepared. For NDE, reference requirements are as defined for Section V, Article 14. In addition, the technical justifications shall specifically address the application of the method and technique to each SSC for which it is identified in the MANDE specification.

IV-3.3.4 Levels of Rigor (Mandatory Appendix I, Figure I-1.1-6)

(a) The MANDEEP is responsible for establishing the levels of rigor required for qualification for each SSC based on the Reliability Target required. For NDE, reference requirements are as defined for Section V, Article 14.

(b) A high level of rigor is generally required to support a probabilistic risk assessment (PRA) and includes a sufficient number of test specimens to effectively quantify uncertainties, estimate sizing error distributions, and determine a probability of detection (POD) for specific degradation mechanisms or flaw types, locations, and sizes.

IV-3.3.5 Qualification of NDE Methods and Techniques (Mandatory Appendix I, Figure I-1.1-6)

The qualification process for each NDE method and technique shall be defined in a written procedure approved by the MANDEEP. The written procedure shall include the test specimen requirements and essential variable ranges bounding the qualification. Essential variables shall include but are not limited to hardware, equipment settings, operational input values, and software revisions that directly affect the calibration, data acquisition, and analysis parameters. Changes in essential variables of a demonstrated procedure shall not be allowed without requalification of the procedure.

IV-3.3.6 Monitoring Methods and Techniques (Mandatory Appendix I, Figure I-1.1-6)

Special requirements for qualification of monitoring methods and techniques shall be established and defined in a written procedure approved by the MANDEEP. The written procedure shall address the requirements and essential variable ranges bounding the qualification demonstration. Changes in essential variables of a demonstrated procedure shall not be allowed without requalification of the procedure.

IV-3.3.7 Qualification Alternatives

Alternative qualifications for MANDE methods and techniques that have been previously established by existing industry programs accepted by the regulatory and enforcement authorities having jurisdiction at the facility site may be used for methods and techniques to the extent that the MANDEEP determines that they are sufficient to support Reliability Target requirements for the applicable SSCs.

ARTICLE IV-4
MANDE PERFORMANCE DEMONSTRATIONS
(MANDATORY APPENDIX I, FIGURE I-1.1-6)

IV-4.1 GENERAL

Qualification of personnel shall be performed as a blind test where the candidate has no knowledge of the contents of the specimen test set. The specimen test set may include flaws used for the method and technique procedure qualification (see Article IV-3) or other specimens fabricated specifically for the personnel qualification as determined by the MANDEEP.

IV-4.2 PERSONNEL PERFORMANCE DEMONSTRATION FOR MONITORING METHODS

Personnel seeking qualification in monitoring activities shall demonstrate the ability to perform the required monitoring methods and techniques. The performance demonstration requirements shall be commensurate with the site-specific monitoring roles and responsibilities and shall be defined in a written procedure approved by the MANDEEP.

IV-4.3 NDE PERSONNEL PERFORMANCE DEMONSTRATION

NDE personnel performance demonstrations shall be conducted in accordance with a written procedure approved by the MANDEEP. The written procedure shall include the number of test specimens; the number, location, and size or extent of flaws or degradation mechanisms; and the pass/fail criteria established as necessary to support the qualification for the applicable NDE method and technique.

IV-4.4 PROCEDURE AND EQUIPMENT PERFORMANCE DEMONSTRATION

In course of preparation.

ARTICLE IV-5 RECORDS

IV-5.1 GENERAL

Records shall be prepared and maintained as required in Article RIM-6. Additionally, records shall be maintained in support of the qualification program and shall include the MANDE specifications, technical justifications, and written procedures. Records shall also be maintained for performance demonstrations of each MANDE specification (method and technique) and for personnel performance demonstrations. Record retention requirements shall be established by the MANDEEP.

IV-5.2 RECORDS FOR METHODS AND TECHNIQUE QUALIFICATION

The following documents related to method and technique qualifications shall be prepared, reviewed, and maintained:

(a) the SSC MANDE specifications (see IV-3.3.2)
(b) the technical justification (see IV-3.3.3)
(c) the written procedures for qualification process for each method and technique (see IV-3.3.5 and IV-3.3.6)

IV-5.3 RECORDS FOR PERSONNEL PERFORMANCE DEMONSTRATIONS

The written personnel performance demonstration procedures specified in IV-4.2 and IV-4.3 shall be maintained.

MANDATORY APPENDIX V
(25) CATALOG OF MANDE REQUIREMENTS AND AREAS OF INTEREST

ARTICLE V-1
(25) EXAMINATION CATEGORIES FOR LIGHT-WATER-REACTOR-TYPE AND HIGH-TEMPERATURE GAS-REACTOR-TYPE FACILITIES

V-1.1 INITIAL CONSIDERATION

Tables V-1.1-1 through V-1.1-13 show examination categories. The following considerations apply throughout this Article:

(a) If multiple SSCs of similar configuration (e.g., steam generators, attachments to SSCs) exist at a single facility, the MANDEEP shall determine the extent of MANDE that shall be applied to each individual SSC or attachment in consideration of the applicable degradation mechanisms that apply and the required Reliability Target that the SSC must satisfy.

(b) The tables in this Appendix reference Section XI, Division 1 examination categories and examination volumes. These references are not intended to imply that either Class 1 or Class 2 requirements of Section XI, Division 1 are to be used for a particular RIM SSC. Once an SSC is selected for incorporation into the RIM Program, it no longer carries any class designation that might have been used for construction of the SSC. The Section XI, Division 1 figures are referenced in this Appendix solely to denote typical geometries for various SSCs containing welds and related examination volumes that should be considered by the MANDEEP, provided that

Table V-1.1-1
Examination Category A, Pressure-Retaining Welds in Reactor Vessels

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
1.10	Shell welds			
1.11	Circumferential	IWB-2500-1	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.12	Longitudinal (all welds)	IWB-2500-2	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.20	Head welds			
1.21	Circumferential	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.22	Meridional (all welds)	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.30	Shell-to-flange	IWB-2500-4	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.40	Head-to-flange	IWB-2500-5	Volumetric and surface [Note (1)]	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.50	Repair areas [Note (2)]	IWB-2500-1 and IWB-2500-2	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
1.51	Beltline region	IWB-2500-1 and IWB-2500-2	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)

NOTES:
(1) If a preservice or inservice ultrasonic examination has been performed and no flaw exceeding the acceptance criteria of Mandatory Appendix VII, VII-1.4.1 or Mandatory Appendix VII, VII-3.4.1 was detected, only the surface examination requirements of 1.40 need to be met.
(2) Material (base material) weld repairs where repair depth exceeds 10% nominal of the vessel wall. If the location of the repair is not positively and accurately known, then the individual shell plate, forging, or shell course containing the repair shall be included.

Table V-1.1-2
Examination Category B, Pressure-Retaining Welds in Vessels Other Than Reactor Vessels

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
		Pressurizer		
2.10	Shell-to-head			
2.11	Circumferential	IWB-2500-1	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.12	Longitudinal	IWB-2500-2	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.20	Head welds			
2.21	Circumferential	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.22	Meridional	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
		Steam Generators (Primary Side)		
2.30	Head welds			
2.31	Circumferential	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.32	Meridional	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.40	Tubesheet-to-head welds	IWB-2500-6	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
		Heat Exchangers (Primary Side) — Head		
2.50	Head welds			
2.51	Circumferential	IWB-2500-1, IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.52	Meridional	IWB-2500-3	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
		Heat Exchangers (Primary Side) — Shell		
2.60	Tubesheet-to-head welds	IWB-2500-6	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.70	Longitudinal welds (all welds)	IWB-2500-2	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.80	Tubesheet-to-shell welds	IWB-2500-6	Volumetric	Article RIM-3 (VII-1.4.1, VII-3.4.1)
2.90	Tubes to tubesheet	TBD	Volumetric	TBD
2.100	Tubes	TBD	Volumetric	TBD

a weld is specifically included in RIM SSC MANDE population. RIM MANDE is not limited to weld centric examination requirements. Base material MANDE may be more useful for maintaining the Reliability Target of an SSC, based on assigned degradation mechanisms, than merely weld volume examinations (e.g., creep).

Table V-1.1-3
Examination Category D, Full-Penetration Welded Nozzles in Vessels

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
		Reactor Vessel		
3.90	Nozzle-to-vessel welds	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)
3.100	Nozzle inside radius section	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)
		Pressurizer		
3.110	Nozzle-to-vessel welds	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)
		Steam Generators (Primary Side)		
3.130	Nozzle-to-vessel welds	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)
		Heat Exchanger		
3.150	Nozzle-to-vessel welds	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)
3.160	Nozzle inside radius section	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)
3.170	Nozzle-to-nozzle welds	IWB-2500-7 [Note (1)]	Volumetric	Article RIM-3 (VII-1.4.2, VII-3.4.2)

NOTE: (1) The examination volumes shall apply to the applicable figure shown in Section XI, Division 1, Figures IWB-2500-7(a) through IWB-2500-7(d).

Table V-1.1-4
Examination Category F, Pressure-Retaining Dissimilar Welds in Vessel Nozzles

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
		Reactor Vessel		
5.10	NPS 4 (DN 100) or larger nozzle to safe end butt welds	IWB-2500-8	Volumetric and surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.11	NPS 4 (DN 100) or larger nozzle to component butt welds	IWB-2500-8	Volumetric and surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.20	Less than NPS 4 (DN 100) nozzle to safe end butt welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.30	Nozzle to safe end socket welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
		Pressurizer		
5.40	NPS 4 (DN 100) or larger nozzle to safe end butt welds	IWB-2500-8	Volumetric and surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.50	Less than NPS 4 (DN 100) nozzle to safe end butt welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.60	Nozzle to safe end socket welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
		Steam Generator		
5.70	NPS 4 (DN 100) or larger nozzle to safe end butt welds	IWB-2500-8	Volumetric and surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.71	NPS 4 (DN 100) or larger nozzle to component butt welds	IWB-2500-8	Volumetric and surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.80	Less than NPS 4 (DN 100) nozzle to safe end butt welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.90	Nozzle to safe end socket welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
		Heat Exchanger		
5.100	NPS 4 (DN 100) or larger nozzle to safe end butt welds	IWB-2500-8	Volumetric and surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.110	Less than NPS 4 (DN 100) nozzle to safe end butt welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)
5.120	Nozzle to safe end socket welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)

Table V-1.1-5
Examination Category G-1, Pressure-Retaining Bolting Greater Than 2 in. (50 mm) in Diameter

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
Reactor Vessel				
6.10	Closure head nut	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.20	Closure studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.40	Threads in flange	IWB-2500-12(a)	Volumetric	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.50	Closure washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Pressurizer				
6.60	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.70	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.80	Nuts, bushings, and washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Steam Generators				
6.90	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.100	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.110	Nuts, bushings, and washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Heat Exchangers				
6.120	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.130	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.140	Nuts, bushings, and Washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Piping				
6.150	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.160	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.170	Nuts, bushings, and washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Pumps				
6.180	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.190	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.200	Nuts, bushings, and washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Valves				
6.210	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.220	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.230	Nuts, bushings, and washers	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Turbine				
6.240	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.250	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.260	Nuts, bushings, and washers	Surfaces	Visual, VT-2	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Compressor				
6.270	Bolts and studs [Note (1)]	IWB-2500-12(a)	Volumetric [Note (2)]	Article RIM-3 (VII-1.4.4, VII-3.4.4)
6.280	Flange surfaces [Note (3)], when connection disassembled	Surfaces	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
6.290	Nuts, bushings, and washers	Surfaces	Visual, VT-2	Article RIM-3 (VII-1.4.6, VII-3.4.6)

Table V-1.1-5
Examination Category G-1, Pressure-Retaining Bolting Greater Than 2 in. (50 mm) in Diameter (Cont'd)

NOTES:
(1) Bolting may be examined
  (a) in place under tension
  (b) when the connection is disassembled
  (c) when bolting is removed
(2) When bolts or studs are removed for examination, surface examination meeting the acceptance standards of Mandatory Appendix VII, VII-1.4.1 or VII-3.4.4 may be substituted for volumetric examination.
(3) Examination includes 1 in. (25 mm) annular surface of flange surrounding each stud.

Table V-1.1-6
Examination Category G-2, Pressure-Retaining Bolting 2 in. (50 mm) or Less in Diameter

Item No.	Parts Examined [Note (1)]	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
Reactor Vessel				
7.10	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Pressurizer				
7.20	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Steam Generators				
7.30	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Heat Exchangers				
7.40	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Piping				
7.50	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Pumps				
7.60	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Valves				
7.70	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Turbine				
7.80	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)
Compressor				
7.90	Bolts, studs, and nuts	Surface	Visual, VT-1	Article RIM-3 (VII-1.4.6, VII-3.4.6)

NOTE: (1) Examination of bolting is required only when a connection is disassembled or bolting is removed.

Table V-1.1-7
Examination Category J, Pressure-Retaining Welds in Piping

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
9.10	NPS 4 or larger (DN 100)			
9.11	Circumferential welds	IWB-2500-8	Surface and volumetric [Notes (1)–(3)]	Article RIM-3 (VII-1.4.3, VII-3.4.3)
9.20	Less than NPS 4 (DN 100)			
9.21	Circumferential welds other than PWR high-pressure safety-injection system	IWB-2500-8	Volumetric or surface [Note (1)]	Article RIM-3 (VII-1.4.3, VII-3.4.3)
9.22	Circumferential welds of PWR high-pressure safety-injection system	IWB-2500-8	Volumetric [Notes (2) and (3)]	Article RIM-3 (VII-1.4.3, VII-3.4.3)
9.30	Branch pipe connection welds			
9.31	NPS 4 or larger (DN 100)	IWB-2500-9, IWB-2500-10, and IWB-2500-11	Surface and volumetric [Notes (1)-(3)]	Article RIM-3 (VII-1.4.3, VII-3.4.3)
9.32	Less than NPS 4 (DN 100)	IWB-2500-9, IWB-2500-10, and IWB-2500-11	Volumetric or surface [Note (1)]	Article RIM-3 (VII-1.4.3, VII-3.4.3)
9.40	Socket welds	IWB-2500-8	Volumetric or surface	Article RIM-3 (VII-1.4.3, VII-3.4.3)

NOTES:
(1) For circumferential welds with intersecting longitudinal welds, surface examination of the longitudinal piping welds is required for those portions of the welds within the examination boundaries of intersecting Examination Category F and J circumferential welds.
(2) For circumferential welds with intersecting longitudinal welds, volumetric examination of the longitudinal piping welds is required for those portions of the welds within the examination boundaries of intersecting Examination Category F and J circumferential welds. The following requirements shall also be met:
(a) When longitudinal welds are specified and locations are known, examination requirements shall be met for both transverse and parallel flaws at the intersection of the welds and for that length of longitudinal weld within the circumferential weld examination volume.
(b) When longitudinal welds are specified but locations are unknown, or the existence of longitudinal welds is uncertain, the examination requirements shall be met for both transverse and parallel flaws within the entire examination volume of intersecting circumferential welds.
(3) For welds in carbon or low alloy steels, only those welds showing reportable preservice transverse indications need to be examined by the ultrasonic method for reflectors transverse to the weld length direction except that circumferential welds with intersecting longitudinal welds shall meet the requirements of Note (2).

Table V-1.1-8
Examination Category K, Welded Attachments for Vessels, Piping, Rotating Equipment, and Valves

Item No.	Parts Examined [Note (1)]	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
Pressure Vessels				
10.10	Welded attachments	IWB-2500-13, IWB-2500-14, and IWB-2500-15	Surface [Note (2)]	Article RIM-3 (VII-1.4.5, VII-3.4.5)
Piping				
10.20	Welded attachments	IWB-2500-13, IWB-2500-14, and IWB-2500-15	Surface	Article RIM-3 (VII-1.4.5, VII-3.4.5)
Pumps				
10.30	Welded attachments	IWB-2500-13, IWB-2500-14, and IWB-2500-15	Surface	Article RIM-3 (VII-1.4.5, VII-3.4.5)
Valves				
10.40	Welded attachments	IWB-2500-13, IWB-2500-14, and IWB-2500-15	Surface	Article RIM-3 (VII-1.4.5, VII-3.4.5)
Rotating Equipment (Turbines and Compressors)				
10.50	Welded attachments	IWB-2500-13, IWB-2500-14, and IWB-2500-15	Surface	Article RIM-3 (VII-1.4.5, VII-3.4.5)

NOTES:
(1) Weld buildup on nozzles that is in compression under normal conditions and provides only component support is excluded from examination. Examination is limited to those welded attachments that meet the following conditions:
(a) The attachment is on the outside surface of the pressure-retaining component.
(b) The attachment provides component support as defined in Section III, Division 1, Subsection NF, NF-1110.
(c) The attachment weld joins the attachment either directly to the surface of the component or to an integrally cast or forged attachment to the component.
(d) The attachment weld is full penetration, fillet, or partial penetration, either continuous or intermittent.
(2) For the configurations shown in Section XI, Division 1, Figures IWB-2500-13 and IWB-2500-14, a surface examination from an accessible side of the attachment weld shall be performed. Alternatively, for the configuration shown in Figure IWB-2500-14, a volumetric examination of volume A-B-C-D from an accessible side of the attachment weld may be performed in lieu of the examination of surfaces A-B or C-D.

Table V-1.1-9
Examination Category L-2, Pump Casings; Examination Category M-2, Valve Bodies

Item No.	Parts Examined [Note (1)]	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
		Pumps		
12.20	Pump casing (L-2)	Internal surfaces [Notes (1), (2)]	Visual VT-3	Article RIM-3 (VII-1.4.7, VII-3.4.7)
		Valves		
12.50	Valve body exceeding NPS 4 (DN 100) (M-2)	Internal surfaces [Notes (1), (2)]	Visual VT-3	Article RIM-3 (VII-1.4.7, VII-3.4.7)

NOTES:
(1) Examinations are limited to at least one pump in each group of pumps performing similar functions in the system (e.g., recirculating coolant pumps).
(2) Examination is required only when a pump or valve is disassembled for maintenance, or repair. Examination of the internal pressure boundary shall include the internal pressure-retaining surfaces made accessible for examination by disassembly. If a partial examination is performed and a subsequent disassembly of that pump or valve allows a more extensive examination, an examination shall be performed during the subsequent disassembly. A complete examination is required only once during the interval.
(3) Examinations are limited to at least one valve within each group of valves that are of the same size, constructural design (such as globe, gate, or check valves), and manufacturing method, and that perform similar functions in the system (such as containment isolation and system overpressure protection).

Table V-1.1-10
Examination Category N-1, Interior of Reactor Vessels; Examination Category N-2, Welded Core Support Structures and Interior Attachments to Reactor Vessels; Examination Category N-3, Removable Core Support Structures

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
		Reactor Vessel (BWR)		
13.20	Interior attachments within beltline region (N-2)	Accessible welds	Visual, VT-1	Article RIM-3 (VII-1.4.7, VII-3.4.7)
13.30	Interior attachments beyond beltline region (N-2)	Accessible welds	Visual, VT-3	Article RIM-3 (VII-1.4.7, VII-3.4.7)
13.40	Core support structure (N-2)	Accessible surfaces	Visual, VT-3	Article RIM-3 (VII-1.4.7, VII-3.4.7)
		Reactor Vessel (PWR)		
13.50	Interior attachments within beltline region (N-2)	Accessible welds	Visual, VT-1	Article RIM-3 (VII-1.4.7, VII-3.4.7)
13.60	Interior attachments beyond beltline region (N-2)	Accessible welds	Visual, VT-3	Article RIM-3 (VII-1.4.7, VII-3.4.7)
13.70	Core support structure (N-3) [Note (1)]	Accessible surfaces	Visual, VT-3	Article RIM-3 (VII-1.4.7, VII-3.4.7)

NOTE: (1) The structure shall be removed from the reactor vessel for examination.

Table V-1.1-11
Examination Category O, Pressure-Retaining Welds in Control Rod Drive and Instrument Nozzle Housings

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	AcceptanceStandard
		Reactor Vessel (BWR)		
14.10	Welds in control rod drive (CRD) housings	IWB-2500-18	Volumetric or surface	Article RIM-3 (VII-1.4.10, VII-3.4.10)
		Reactor Vessel (PWR)		
14.20	Welds in control rod drive (CRD) housings	IWB-2500-18	Volumetric or surface [Note (1)]	Article RIM-3 (VII-1.4.10, VII-3.4.10)
14.21	Welds in in-core instrumentation nozzle (ICI) housings > NPS 2 (DN 50)	IWB-2500-18	Volumetric or surface [Note (1)]	Article RIM-3 (VII-1.4.10, VII-3.4.10)

NOTE: (1) The surface examination method shall be performed on the inside diameter of the penetration nozzle housing welds as shown in Section XI, Division 1, Figure IWB-2500-18 for examination surface area C-D.

Table V-1.1-12
Examination Category P, All Pressure-Retaining Components

Item No.	Parts Examined	Examination Requirements/ Figure No.	Examination Method	Acceptance Standard
15.10	Pressure-retaining components	System leakage test	Visual, VT-2	Article RIM-3 (VII-1.4.9, VII-3.4.9)
15.20	Pressure-retaining components	System leakage test	Visual, VT-2	Article RIM-3 (VII-1.4.9, VII-3.4.9)

NOTE: (1) VT-2 visual examination of Section XI, Division 1, IWA-5240.

Table V-1.1-13
Examination Category F-A, Supports

Item No.	Parts Examined	Examination Requirements [Notes (1), (2)]/ Figure No.	Examination Method	Acceptance Standard
F1.10 [Note (3)]	Piping supports	IWF-1300-1	Visual, VT-3	Article RIM-3 (VII-1.4.11, VII-3.4.11)
F1.40	Supports other than piping supports	IWF-1300-1	Visual, VT-3	Article RIM-3 (VII-1.4.11, VII-3.4.11)

NOTES:
(1) Examination may be limited to portions of supports that are accessible for examination without disassembly or removal of support members.
(2) To the extent practicable, the same supports selected for examination during the first inspection interval shall be examined during each successive inspection interval.
(3) Item numbers shall be categorized to identify support types by component support function (e.g., A = supports such as one-dimensional rod hangers; B = supports such as multidirectional restraints; and C = supports that allow thermal movement, such as springs).

ARTICLE V-2 EXAMINATION CATEGORIES FOR SODIUM-COOLED FAST REACTOR-TYPE FACILITIES

(25)

V-2.1 INITIAL CONSIDERATION

Tables V-2.1-1 through V-2.1-3 show examination categories. The following considerations apply throughout this Article.

Not all SSCs may be addressed by the listed categories. Including categories not listed, it is the responsibility of the MANDEEP to determine the parts to be examined, the examination method, and the acceptance standards for SSCs in the RIM Program, as required in Mandatory Appendix IV, IV-1.3.2. If multiple SSCs of similar configurations (e.g., steam generators, attachments to SSCs) exist at a single facility, the MANDEEP shall determine the extent of MANDE that shall be applied to each individual SSC or attachment, in consideration of the applicable degradation mechanisms that apply and the required Reliability Target that the SSC must satisfy. RIM MANDE is not limited to weld-centric examination requirements. Base-material MANDE might be more useful for maintaining the Reliability Target of an SSC, based on assigned degradation mechanisms, than MANDE of only the weld volume.

Table V-2.1-1
Examination Category F-A, Liquid-Sodium-Retaining Components

Item No.	Parts Examined	Examination Method [Note (1)]	Acceptance Standard
F1.10	Vessels	Continuous leakage monitoring	Article RIM-3 (VII-2.5.1)
	All liquid-sodium-retaining welds		
	Parts with the smallest reliability margin [Note (2)]		
F1.20	Piping	Continuous leakage monitoring	Article RIM-3 (VII-2.5.1)
	All liquid-sodium-retaining welds		
	Parts with the smallest reliability margin [Note (2)]		
F1.30	Valves	Continuous leakage monitoring	Article RIM-3 (VII-2.5.1)
	Valve body		

NOTES:
(1) The requirements of Mandatory Appendix VII, VII-2.3.1 shall be met.
(2) Exact parts shall be determined based on SSC Reliability Targets and the results of DMA required by RIM-2.3.

Table V-2.1-2
Examination Category F-B, Cover-Gas-Retaining Components

Item No.	Parts Examined	Examination Method [Note (1)]	Acceptance Standard
F2.10	Vessels All cover-gas-retaining welds Nonwelded gas seals Parts with the smallest reliability margin [Note (2)]	Continuous leakage monitoring	Article RIM-3 (VII-2.5.2)
F2.20	Piping All cover-gas-retaining welds Nonwelded gas seals Parts with the smallest reliability margin [Note (2)]	Continuous leakage monitoring	Article RIM-3 (VII-2.5.2)
F2.30	Valves Valve body Nonwelded gas seals	Continuous leakage monitoring	Article RIM-3 (VII-2.5.2)
F2.40	Bolting Bolting	Continuous leakage monitoring	Article RIM-3 (VII-2.5.2)

NOTES:
(1) The requirements of Mandatory Appendix VII, VII-2.3.1 shall be met.
(2) Exact parts shall be determined based on SSC Reliability Targets and the results of DMA required by RIM-2.3.

Table V-2.1-3
Examination Category F-F-A, Supports

Item No.	Parts Examined	Examination Method	Acceptance Standard
F-F1.10	Piping supports [Notes (1)–(3)]	Visual, VT-3	Article RIM-3 (VII-2.5.3)
F-F1.40	Supports other than piping supports [Notes (1) and (2)]	Visual, VT-3	Article RIM-3 (VII, VII-2.5.3)

NOTES:
(1) Examination may be limited to portions of supports that are accessible for examination without disassembly or removal of support members.
(2) To the extent practicable, the same supports selected for examination during the first inspection interval shall be examined during each successive inspection interval.
(3) Item numbers shall be categorized to identify support types by component support function (e.g., A = supports such as one-directional rod hangers; B = supports such as multidirectional restraints; and C = supports that allow thermal movement, such as springs).

MANDATORY APPENDIX VI
RELIABILITY AND INTEGRITY MANAGEMENT EXPERT PANEL (RIMEP)

ARTICLE VI-1
OVERVIEW

VI-1.1 RESPONSIBILITIES AND QUALIFICATIONS OF RIMEP

(a) The RIMEP shall oversee the following:

(1) development, documentation, and implementation of a RIM Program, designed to achieve Reliability Targets, in accordance with Article RIM-2

(2) performance of the evaluations for alternative requirements in accordance with Nonmandatory Appendix A

(3) formation of the MANDEEP, in accordance with Mandatory Appendix IV, IV-1.3.2

(b) The RIMEP shall identify the RIM Program scope, the associated facility and SSC Reliability Targets, and candidate RIM strategies, accounting for uncertainty in predicting SSC reliability performance.

(c) The RIMEP shall document and implement the RIM strategies, MANDE methods specified by the MANDEEP program performance monitoring, and appropriate updates to the RIM Program.

(d) The work of the RIMEP shall be independent from production and operational concerns. The RIMEP shall be given full access to necessary data and shall be adequately funded and provided with reasonable time to complete its work.

(e) The RIMEP shall be formed by and be responsible to the RIMEP Chair. The Chair will have a broad-based knowledge of nuclear facility, system, and component reliability, as well as facility PRA methods and insights, together with a working knowledge of inspection, monitoring, operation, examination, test, and maintenance activities affecting SSC reliability. The Chair shall have at least a 4-yr technical degree from an accredited college or university. In addition, the Chair shall have a minimum of 15 yr of experience in systems risk and reliability. It is recommended that at least 5 yr of this experience was obtained in a nuclear facility operating or nuclear design environment. The Chair shall be organizationally independent within the facility Owner's organization. The Chair and RIMEP members may be employed by the Owner but shall have functional independence, similar to the independence afforded to those performing quality assurance functions.

(f) The initial composition of the RIMEP shall be determined by the Chair and include members with in-depth knowledge of all the relevant technical areas related to RIM for a specific nuclear reactor facility design including the following:

(1) PRA

(2) development of RIM Reliability Targets

(3) application of the RIM process

(4) inservice inspection and NDE

(5) SSC performance

(g) RIMEP members shall be selected based on their expertise in a given subject or discipline that contributes to the assigned effort. The MANDEEP Chair selected in accordance with Mandatory Appendix IV, IV-1.3.3(a) shall be a member of the RIMEP. RIMEP membership shall be based on the individual's expertise in the subject matter and this expertise shall be documented to justify the selection of the individual.

(h) The RIMEP Chair shall establish the RIMEP with membership initially based on informed assumptions as to the scope and technologies necessary to implement the RIM Program. The Chair shall prepare a document addressing the basis for RIMEP formation. The basis document shall describe staffing of the RIMEP and the work schedule, and the funding necessary to conduct the activities defined in the RIMEP basis document. The RIMEP basis document shall be reviewed and validated, or modified as determined by the panel formed.

MANDATORY APPENDIX VII
(25) # PROVISIONS SPECIFIC TO TYPES OF NUCLEAR REACTOR FACILITIES

ARTICLE VII-1
(25) ## LIGHT-WATER-REACTOR–TYPE FACILITIES

VII-1.1 SCOPE

This Article provides requirements for identifying and evaluating potentially active degradation mechanisms to light-water-reactor–type facilities. These and other unique requirements herein shall be used to supplement the RIM Program for light-water-reactor-type facilities.

(a) This Article shall be used only for Generation 3 or above light water reactors (LWRs).

(b) Section XI, Division 1, Article IWA-3000 shall be used as reference information to support this Article and is referenced by this Article.

(c) This Article shall be used only when ferritic components are limited to a maximum Design Temperature of 700°F (370°C) and austenitic components are limited to a maximum Design Temperature of 800°F (426°C).

(25) ### VII-1.2 RIM PROGRAM — DEGRADATION MECHANISM ASSESSMENT

See Table VII-1.2-1.

VII-1.3 ACCEPTANCE STANDARDS

VII-1.3.1 Evaluation of Examination Results

VII-1.3.1.1 Preservice Volumetric and Surface Examinations

(a) General

(1) The preservice volumetric and surface examinations required by RIM-2.7.3 and performed in accordance with RIM-2.9 shall receive an NDE evaluation by comparing the examination results with the acceptance standards specified in (b).

(2) Acceptance of components for service shall be in accordance with (b) and (c).

(b) Acceptance

(1) A component whose volumetric or surface examination in accordance with RIM-2.7.3 meets the criteria of (-a), (-b), or (-c) shall be acceptable for service, provided the verified flaws are recorded in accordance with the requirements of RIM-1.4(i) and RIM-2.9.2(b) in terms of location, size, shape, orientation, and distribution within the component.

(-a) The volumetric or surface examination (see RIM-2.7.3) confirms the absence of flaws or identifies only flaws that have already been shown to meet the NDE acceptance standards of the Construction Code and Owner's Requirements for materials or welds as applicable, documented in quality assurance records.

(-b) Volumetric examination detects flaws that are confirmed by surface or volumetric examination to be non-surface-connected and that do not exceed the acceptance standards of Table VII-1.3.3-1.

(-c) Volumetric examination detects flaws that are confirmed by surface or volumetric examination to be non-surface-connected and that are accepted by analytical evaluation in accordance with the provisions of VII-1.3.1.3(b)(4) to the end of the service lifetime of the component and reexamined in accordance with the requirements of RIM-2.7.6.3(a) and RIM-2.7.6.3(b).

(2) A component whose volumetric or surface examination (see RIM-2.7.3) detects flaws that do not meet the criteria established in (1) shall be unacceptable for service, unless the component is corrected by a repair/replacement activity in accordance with (c) to the extent necessary to meet the provisions of (1) prior to placement of the component in service.

(3) A component whose volumetric or surface examination (RIM-2.7.3) detects flaws, other than those described in (2) that exceed the acceptance standards of Table VII-1.3.3-1 shall be unacceptable for service, unless the component is corrected by a repair/replacement activity to the extent necessary to meet the acceptance standards prior to placement of the component in service.

(c) Repair/Replacement Activity and Preservice Examination. The repair/replacement activity and preservice examination shall comply with the requirements of Article RIM-4. Preservice examination shall be conducted

Table VII-1.2-1 Degradation Mechanism Attributes and Attribute Criteria (LWR)

(25)

Degradation Mechanism Type	Degradation Mechanism Subtype	Attribute Criteria	Degradation Features and Susceptible Regions	Table VII-1.3.3-1 Examination Category (as appropriate)
TF	TASCS	– Single pipe and operating temperature >220°F (104°C) and – Piping >25.4 mm (1 in.) NPS, and – Pipe segment has a slope <45 deg from horizontal (includes elbow or tee into a vertical pipe), and – Potential exists for low flow in a pipe section connected to a component allowing mixing of hot and cold fluids or – Potential exists for leakage flow past a valve (i.e.,in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids or – Potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or – Potential exists for two phase (steam/water) flow, or – Potential exists for turbulent penetration in branch pipe connected to header piping containing hot fluid with high turbulent flow, and – Calculated or measured ΔT > 50°F (28°C), and – Richardson Number >4.0	Cracks can initiate in welds, heat affected zones (HAZ), and base metal at the pipe inner surface Affected locations can include nozzles, branch pipe connections, safe ends, and regions of stress concentration TASCS can occur over extensive portions of the pipe inner surface Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	J, K
	TT	– Operating temperature >270°F (132°C) for stainless steel or – Operating temperature >220°F (104°C) for carbon steel *AND* – Potential for relatively rapid temperature changes including Cold fluid injection into hot pipe segment or Hot fluid injection into cold pipe segment *AND* – $\lvert\Delta T\rvert$ > 200°F (111°C) for stainless steel, or – $\lvert\Delta T\rvert$ > 150°F (83°C) for carbon steel, or – $\lvert\Delta T\rvert$ > ΔT allowable or – Allowable cycles <10^6		J, K
VF	FIV	– Presence of attachments in a high velocity flow field, including Welded attachments, or Attachments with small radii at the attachment junction *OR* – High velocity cross flow over S/G or H/X tube bundles, and – Absence of vibration damping tube supports	Cracks can initiate in welds, HAZ, and base metal at the component inner or outer surface Affected locations can include welded attachments and regions of stress concentration Crack growth can be relatively fast, and through-wall cracks can occur within an inspection period	A, B, D, F, J, K, O
	MF	– Cyclic applied loads, and – Presence of partial penetration welds, or – Presence of small radii at the attachment junction *OR* – Presence of attached vibration sources (e.g., pumps, compressors) and – No preoperational vibration testing or monitoring, or – No vibratory monitoring of vibration sources during operation		B, D, F, J, K, O

Table VII-1.2-1
Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

Degradation Mechanism Type	Degradation Mechanism Subtype	Attribute Criteria	Degradation Features and Susceptible Regions	Table VII-1.3.3-1 Examination Category (as appropriate)
VF (cont'd)	SF	– Relative sliding motion between two contacting surfaces, and – Absence of a solid lubricating system at the contacting surfaces	Cracking, pitting, spalling wear, or seizing can occur at the contact surfaces Cracking is expected to be localized and not grow through-wall	G-1, G-2, K
SCC	IGSCC	– Material is austenitic stainless steel weld or HAZ and – Operating temperature ≥200°F (93°C), and – Susceptible material (carbon content ≥0.035%), and – Oxygen or oxidizing species are present *OR* – Material is Alloy 82 or 182, and – Operating temperature ≥200°F (93°C), and – Oxygen or oxidizing species are present *OR* – Material is austenitic stainless steel weld or HAZ, and – Operating temperature <200°F (93°C), and – Susceptible material (carbon content ≥0.035%), and – Oxygen or oxidizing species are present, and – Initiating contaminants (e.g., thiosulfate, fluoride, chloride) are present *OR* – Material is in an aqueous environment, and – Oxygen or oxidizing species are present, and – Mechanically induced high residual stresses are present	Cracks can initiate in welds and HAZ at the pipe inner surface Affected locations can include pipe welds, branch pipe connections, and safe end attachment welds. Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	A, B, D, F, G-1, G-2, J, K, O
	TGSCC	– Material is austenitic stainless steel, and – Operating temperature >150°F (65°C), and – Halides (e.g., fluoride, chloride) are present, or – Caustic (NaOH) is present, and – Oxygen or oxidizing species are present (only required to be present in conjunction w/halides; not required w/caustic), or – components in stagnant RCS locations such as pressurizer heater bundles	Cracks can initiate in welds, HAZ, and base metal at the pipe inner surface Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	A, B, D, F, G-1, G-2, J, K, O
	ECSCC	– Material is austenitic stainless steel, and – Operating temperature >68°F (20°C), and – An outside piping surface is within five diameters of a probable leak path (e.g., valve stems) and is covered with nonmetallic insulation that is not in compliance with USNRC Reg. Guide 1.36, or – Piping surface is exposed to wetting from chloride bearing environments (e.g., seawater, sea spray, brackish water, brine) during fabrication, storage or operation	Cracks can initiate in welds, HAZ, and base metal at the pipe outer surface ECSCC can occur over extensive portions of the pipe inner or outer surface when exposed to wetting from chloride bearing environments during fabrication, storage or operation Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	J, K

Table VII-1.2-1
Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

Degradation Mechanism		Attribute Criteria	Degradation Features and Susceptible Regions	Table VII-1.3.3-1 Examination Category (as appropriate)
Type	**Subtype**			
SCC (cont'd)	PWSCC	– Piping material is nickel-based alloy (e.g., Alloy 690), and – Exposed to primary water at T > 525°F (274°C), and – The material is mill-annealed and cold worked, or cold worked and welded without stress relief	Cracks can initiate in welds, HAZ, and base metal at the pipe inner surface Affected locations can include welds and HAZ without stress relief, the inside surface of nozzles, and areas of stress concentration Crack growth can be relatively fast, and through-wall cracks can occur within an inspection period	F, J, K
LC	MIC	– Operating temperature <150°F (66°C), and – Low or intermittent flow <8 ft/sec (2.4 m/s), and – pH <10, and – presence/intrusion of organic material (e.g., raw water systems), or – water source is not treated with biocides	Fittings, welds, HAZ's, base metal, dissimilar metal joints (e.g., welds and flanges), and regions containing crevices Diesel fuel MIC can occur at diesel fuel/water interface tanks. The bacteria living in the water use fuel as food. On welded stainless steel, MIC can cause welds to "sugar." The metal crystal structure changes and resembles sugar crystals. Welding tends to segregate metals in the alloy. Metals such as iron and cobalt are more susceptible to MIC than other metals. Iron and sulfur bacteria can lead to corrosion of the interior and exterior surfaces of buried water pipes. Cooling water systems (e.g., cooling tower and circulating water system)	B, D, J, K
	PIT	– Potential exists for low fluid flow, and – oxygen or oxidizing species are present, and – initiating contaminants (e.g., fluoride or chloride) are present	Pitting can initiate in welds, HAZ, base metal at the component inner surface. Forging material used in nozzles is typically SA-508, Class 2 (UNS K12766). These materials are usually clad with austenitic stainless steel weld metal, Type 308 stainless steel, to provide improved pitting resistance during low temperature shutdown. Pitting susceptibility increases for clean surfaces (no passive layer) of Alloy 600 tubing and is a function of copper chloride concentration and temperature.	B, D, F, J, K

Table VII-1.2-1
Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

Degradation Mechanism				
Type	**Subtype**	**Attribute Criteria**	**Degradation Features and Susceptible Regions**	**Table VII-1.3.3-1 Examination Category (as appropriate)**
LC (cont'd)	CC	– crevice condition exists (that is, thermal sleeves), and – operating temperature >150°F (66°C), and – oxygen or oxidizing species are present	Since PWRs that operate in accordance with the EPRI water chemistry guidelines have deaerated environments in both the primary and secondary systems, electrochemical crevice corrosion is not usually a concern. However, it should be noted that off-chemistry oxidizing conditions could occur on the secondary side through the introduction of air-saturated makeup water or through high copper levels that could establish electrochemical crevices. Elevated impurity concentrations and potential gradients in a crevice can initiate stress corrosion cracking in otherwise resistant material, such as non-sensitized Type 316 stainless steel or low carbon grades Type 304L and 316L stainless steel. Surface cold work can lead to initiation and propagation of stress corrosion cracking. Annealed Types 304, 304L, and 316L stainless steel, nickel-based alloys (e.g., Inconel) as well as Alloy 600 are susceptible. During fabrication and installation of components, activities such as grinding, machining, bending, etc., can produce a thin layer of cold-worked metal surface, creating the same susceptibility to initiation as intentionally cold-worked material. Once the crack extends across the cold-work layer, the resulting crevice can provide the electrochemical driving force for continued crack propagation. Susceptible regions include CRD hydraulic return nozzle thermal sleeve (if applicable), spray nozzle thermal sleeve, and feedwater thermal sleeve.	A, B, D, F, J, K, O

Table VII-1.2-1
Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

Degradation Mechanism Type	Degradation Mechanism Subtype	Attribute Criteria	Degradation Features and Susceptible Regions	Table VII-1.3.3-1 Examination Category (as appropriate)
LC (cont'd)	CC (cont'd)		Crevice corrosion can also initiate in welds and HAZ at the component inner surface. Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period.	
FS	E–C	– Existence of cavitation sources (i.e., throttling or pressure-reducing valves or orifices), and – Helium environment, and – No monitoring or control of impurities in the helium flow stream *OR* – Existence of cavitation sources (i.e., throttling or pressure-reducing valves or orifices), and stream environment, and – Operating temperature <250°F (120°C), and – Flow present >100 hr/yr and – Flow velocity >30 ft/sec (9.1 m/s)	Wall thinning can initiate in welds, HAZ, and base metal at the component inner surface Affected locations can include regions up to one or two pipe diameters downstream of the cavitation source Degradation growth is relatively slow, and through-wall degradation is not expected within an inspection period	B, J
	FAC	– Carbon or low alloy steel piping with Cr <0.5% (some literature indicates 0.1%) and – Wet steam environment (i.e., two-phase flow) or – Any high-purity water environment coupled with – Low levels of dissolved oxygen – And flow (there is no known practical threshold velocity below which FAC will not occur) [reference: T. M. Laronge, M. A. Ward, "The Basics and Not so Basics of Water Corrosion Processes Altered by Flow Changes," CORROSION/99, paper 99345, NACE International, Houston, TX (1999)] – Accelerated further by turns in the flow path and – Low or very high pH – Fluid flow present >100 hr/yr	Wall thinning can initiate in welds, HAZ, and base metal at the component inner surface Aaffected locations can include regions where the potential for FAC degradation has been identified FAC can occur over extensive portions of the component inner surface Degradation growth is relatively slow, and through-wall degradation is not expected within an inspection period	A, B, D, F, J, O
	PE	– Solid Particle Erosion (SPE) is damage caused by particles transported by the fluid stream rather than by liquid water or collapsing bubbles. In contrast to liquid impingement erosion, the necessary velocities for SPE are low, approximately 3 ft/sec. SPE also requires the presence of particles of sufficient size, typically >0.004 in. (100 microns). – Erosion rate decreases in ductile materials rapidly with decreasing particle size below 0.004 in. (100 microns).	Wall thinning can initiate in welds, HAZ, and base metal at the component inner surface. "Hard materials" (e.g., Stellite) offered only modest improvement over carbon steel. The Inconel alloys offered only a very modest improvement over carbon steel. Unless exotic materials are used (i.e., ceramics), there is no material solution to SPE. Susceptible regions include valve internals, nozzles, and the steam turbine. Degradation growth is relatively slow, and through-wall degradation is not expected within an inspection period.	B, D, F, J

Table VII-1.2-1
Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

Degradation Mechanism				Table VII-1.3.3-1 Examination Category
Type	Subtype	Attribute Criteria	Degradation Features and Susceptible Regions	(as appropriate)
DEP	WH	– Facility-/plant-specific history of water hammer, in piping containing water/steam, and – No corrective measures have been implemented	Increased potential pipe rupture and extension of existing flaws Affected locations include turns in the pipe run Pipe rupture or extension of existing cracks can occur instantaneously	B, J, K
	RE	– Ferritic steels with high energy (>1 MeV) neutron fluence $>10^{17}$ n/cm^2 *OR* – Austenitic stainless steels with high energy (>1 MeV) neutron fluence $>3 \times 10^{23}$ n/cm^2	Reduced fracture toughness of welds, HAZ, and base metal exposed to high levels of neutron fluence	A, B, D, F, J, O
	LE	– Potential for degradation (deposition/scale formation, fouling, erosion) of heat transfer surface	Reduced emissivity and heat transfer with potential for inadequate cooling	B
SP [Note (1)]	LP	– Potential for debris from failed components/ materials to migrate into the high energy primary coolant flow stream	Susceptible areas include core cooling channels	A, B, J, O
	RIA [Note (1)]	– Component is inaccessible for conventional volumetric or visual inspection	Applicable areas include: Regions with little or no physical access, Environments hazardous to personnel, Cost/benefit of inservice inspection is prohibitive to relative to facility reliability goals	A, B, D, F, G-1, G-2, J, K, O

Legend:
CC = crevice corrosion
CRD = control rod drive
DEP = degradation enhancement phenomena
E–C = erosion–cavitation
ECSCC = external chloride stress corrosion cracking
FAC = flow-accelerated corrosion
FIV = flow-induced vibration
FS = flow sensitive
HAZ = heat-affected zone
HX = heat exchanger
IGSCC = intergranular stress corrosion cracking
LC = localized corrosion
LE = lowered emissivity
LP = loose parts
MF = mechanical fatigue
MIC = microbiologically induced corrosion
PC = pitting corrosion
PE = particle erosion–corrosion
PIT = pitting corrosion
PWSCC = primary water stress corrosion cracking
RCS = reactor coolant system
RE = radiation embrittlement
RIA = restricted inspection access [Note (1)]
SCC = stress corrosion cracking
SF = self-welding and fretting fatigue
SG = steam generator
SP = spatial phenomena [Note (1)]
TA = thermal aging
TASCS = thermal stratification cycling and striping
TF = thermal fatigue

Table VII-1.2-1
Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

(Cont'd)
TGSCC = transgranular stress corrosion cracking
TT = thermal transients
VF = vibration fatigue
WH = water hammer

NOTE: (1) RIA and SP are not degradation mechanisms but should be considered in the development or application of MANDE criteria established by MANDEEP.

in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-1.3.3-1.

VII-1.3.1.2 Preservice Visual Examinations

(a) General

(1) The preservice visual examinations required by RIM-2.7.3 and performed in accordance with RIM-2.9 shall receive an NDE evaluation by comparing the examination results with the acceptance standards specified in Table VII-1.3.3-1.

(2) Acceptance of components for service shall be in accordance with (b) and (c).

(b) Acceptance

(1) Acceptance by Visual Examination

(-a) A component whose visual examination confirms the absence of the relevant conditions described in the acceptance standards of Table VII-1.3.3-1 shall be acceptable for service.

(-b) A component whose visual examination detects the relevant conditions described in the acceptance standards of Table VII-1.3.3-1 shall be unacceptable for service, unless such components meet the requirements of (2) or (3) prior to placement of the component in service.

(2) Acceptance by Supplemental Examination. A component containing relevant conditions shall be acceptable for service if the results of supplemental examinations (see VII-1.3.2) meet the requirements of VII-1.3.1.1.

(3) Acceptance by Corrective Measures or Repair/Replacement Activity. A component containing relevant conditions is acceptable for service if the relevant conditions are corrected by a repair/replacement activity or by corrective measures to the extent necessary to meet the acceptance standards of Table VII-1.3.3-1.

(c) Repair/Replacement Activity and Preservice Examination. The repair/replacement activity and preservice examination shall comply with the requirements of Article RIM-4. Preservice examination shall be conducted in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-1.3.3-1.

VII-1.3.1.3 Inservice Volumetric and Surface Examinations

(a) General

(1) The volumetric and surface examinations required by RIM-2.7.7 and performed in accordance with RIM-2.9 shall receive an NDE evaluation by comparing the examination results with the acceptance standards specified in Table VII-1.3.3-1, except where (2) is applicable.

(2) When flaws are detected by a required volumetric or surface examination, the component is acceptable for continued service provided the requirements of VII-1.3.1.1(b)(1) or the acceptance standards of Table VII-1.3.3-1 are met.

(3) Volumetric and surface examination results shall be compared with recorded results of the preservice examination and prior inservice examinations. Acceptance of the components for continued service shall be in accordance with (b) and (c).

(b) Acceptance

(1) Acceptance by Volumetric or Surface Examination. A component whose volumetric or surface examination either reconfirms the absence of flaws or detects flaws that are acceptable under the provisions of (a)(2) is acceptable for continued service. Confirmed changes in flaws from prior examinations shall be recorded in accordance with RIM-1.4(h) and RIM-2.9.2(b). A component that does not meet the acceptance standards of Table VII-1.3.3-1 shall be corrected in accordance with the provisions of (2), (3), or (4).

(2) Acceptance by Supplemental Examination. A component containing flaws shall be acceptable for service if the results of supplemental examinations (see VII-1.3.2) meet the requirements of VII-1.3.1.1.

(3) Acceptance by Repair/Replacement Activity. A component whose volumetric or surface examination detects flaws that exceed the acceptance standards of Table VII-1.3.3-1 is unacceptable for continued service until the component is corrected by a repair/replacement activity to the extent necessary to meet the acceptance standards of VII-1.3.

(4) Acceptance by Analytical Evaluation. A component whose volumetric or surface examination detects flaws that exceed the acceptance standards of Table VII-1.3.3-1, or for which the acceptance standards

are not applicable, is acceptable for continued service without a repair/replacement activity if an analytical evaluation, as described in VII-1.5, meets the acceptance criteria of VII-1.5. The area containing the flaw shall be subsequently reexamined in accordance with RIM-2.7.6.3(a) and RIM-2.7.6.3(b). If the subsequent RIM-2.7.6.3(a) and RIM-2.7.6.3(b) examinations reveal that the flaws remain essentially unchanged, or the flaw growth is within the growth predicted by the analytical evaluation, and the design inputs for the analytical evaluation have not been affected by activities such as power uprates, the existing analytical evaluation may continue to be used, provided it covers the time period until the next examination.

(c) Repair/Replacement Activity and Reexamination. The repair/replacement activity and reexamination shall comply with the requirements of Article RIM-4. Reexamination shall be conducted in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-1.3.3-1.

VII-1.3.1.4 Inservice Visual Examinations

(a) General

(1) The results of the visual examinations required by RIM-2.7.7 and performed in accordance with RIM-2.9.1 shall be compared to the acceptance standards specified in Table VII-1.3.3-1.

(2) Acceptance of components for continued service shall be in accordance with (b).

(b) Acceptance

(1) Acceptance by Visual Examination

(-a) A component whose visual examination confirms the absence of the relevant conditions described in the standards of Table VII-1.3.3-1 shall be acceptable for continued service.

(-b) A component whose visual examination detects the relevant conditions described in the standards of Table VII-1.3.3-1 shall be unacceptable for continued service, unless such components meet the requirements of (2), (3), or (4).

(2) Acceptance by Supplemental Examination. A component containing relevant conditions shall be acceptable for continued service if the results of supplemental examinations (see VII-1.3.2) meet the requirements of VII-1.3.1.3.

(3) Acceptance by Corrective Measures or Repair/Replacement Activity. A component containing relevant conditions is acceptable for continued service if the relevant conditions are corrected by a repair/replacement activity or by corrective measures to the extent necessary to meet the acceptance standards of Table VII-1.3.3-1.

(4) Acceptance by Evaluation. A component containing relevant conditions is acceptable for continued service if an evaluation demonstrates the component's acceptability. The evaluation and acceptance criteria shall be specified by the Owner. A component accepted for continued service based on evaluation shall be subsequently examined in accordance with RIM-2.7.6.3(a) and RIM-2.7.6.3(b). If the subsequent RIM-2.7.6.3(a) and RIM-2.7.6.3(b) examinations reveal that the relevant conditions remain essentially unchanged, or the changes in the relevant conditions are within the limits predicted by the evaluation, and the design inputs for the evaluation have not been affected by activities such as power uprates, the existing evaluation may continue to be used, provided it covers the time period until the next examination.

(c) Repair/Replacement Activity and Reexamination. The repair/replacement activity and reexamination shall comply with the requirements of Article RIM-4. Reexamination shall be conducted in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-1.3.3-1.

VII-1.3.2 Supplemental Examinations (25)

(a) Volumetric or surface examinations that detect flaws that require NDE evaluation in accordance with the requirements of VII-1.3.1 may be supplemented by other examination methods and techniques (RIM-2.9.4) to determine the character of the flaw (i.e., size, shape, and orientation).

(b) Visual examinations that detect relevant conditions described in the acceptance standards of this Article may be supplemented by surface or volumetric examinations as established by the MANDEEP and documented in the MANDE Specification to determine the extent of the unacceptable conditions and the need for corrective measures, evaluation or repair/replacement activities.

(c) Supplemental examinations shall meet the requirements of RIM-2.9.4 and Mandatory Appendix IV.

VII-1.3.3 Acceptance Standards

The acceptance standards referenced in Table VII-1.3.3-1 shall be applied to determine acceptability for service. The conditions described in VII-1.3.3.1 and VII-1.3.3.2 shall apply.

VII-1.3.3.1 Application of Acceptance Standards

(a) The acceptance standards for ferritic steel components shall be applicable only to those components whose material properties are in accordance with those stated in Table VII-1.3.3-1.

(b) The acceptance standards for ferritic steel components shall be applicable where the maximum postulated defect that determines the limiting operating conditions conforms to the recommendations stated in Section III, Division l, Appendices.

Table VII-1.3.3-1
Acceptance Standards

Examination Category	Component and Part Examined	Acceptance Standard
A, B	Vessel welds	VII-1.4.1
D	Full penetration welded nozzles in vessels	VII-1.4.2
F, J	Dissimilar and similar metal welds in piping and vessel nozzles	VII-1.4.3
G-1	Bolting greater than 2 in. (50 mm) in diameter	VII-1.4.4 and VII-1.4.6
G-2	Bolting 2 in. (50 mm) in diameter and less	VII-1.4.6
K	Welded attachments for vessels, piping, pumps, and valves	VII-1.4.5
L-2, M-2	Pump casings and valve bodies	VII-1.4.7
N-1, N-2, N-3	Interior surfaces and internal components of reactor vessels	VII-1.4.8
O	Control rod drive and instrument nozzle housing welds	VII-1.4.10
P	Pressure-retaining boundary	VII-1.4.9
F-A	Piping and other supports	VII-1.4.11

VII-1.3.3.2 Modification of Acceptance Standards

(a) Where less than the maximum postulated defect is used, as permitted by Section XI, Division 1, Nonmandatory Appendix G, or operating conditions are modified from those originally assumed, the acceptance standards of this Article shall be modified.

(b) The Owner shall be responsible for modification of acceptance standards as necessary to maintain the equivalent structural factors[1] of the acceptance standards of this Article.

(c) Modified acceptance standards shall not allow greater flaw sizes than those specified in this Article for the applicable examination category.

VII-1.3.4 Characterization

Each detected flaw or group of flaws shall be characterized by the requirements of Section XI, Division 1, IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of VII-1.4.

VII-1.3.5 Acceptability

(a) Flaws are acceptable if they do not exceed the dimensions of allowable flaws of VII-1.4 for the respective examination category. However, such flaws are unacceptable in UNS N06600, UNS N06082, or UNS W86182 or in austenitic stainless steels and associated welds that are subject to stress corrosion cracking.

(b) For acceptance by analytical evaluation, planar surface flaws in the materials specified in (a) shall meet the provisions of VII-1.5.

VII-1.4 ACCEPTANCE STANDARDS FOR SPECIFIC EXAMINATION CATEGORIES

VII-1.4.1 Acceptance Standards for Examination Categories A and B, Pressure-Retaining Welds in Reactor Vessel and Other Vessels

VII-1.4.1.1 Planar Flaw Acceptance Standards

(a) The size of allowable planar flaws within the boundary of the examination volumes specified in Section XI, Division 1, Figures IWB-2500-1 through IWB-2500-6 shall not exceed the limits specified in Section XI, Division 1, Table IWB-3510-1 or Table IWC-3510-1 (based on thickness) for ferritic steels or Table IWB-3514-1 for austenitic steels.

(b) Where a flaw extends or lies beyond the examination volumes as detected by the procedures used to examine the specified volumes, the overall size of the flaw shall be compared with the acceptance standards specified in Section XI, Division 1, Table IWB-3510-1 or Table IWC-3510-1 (based on thickness) for ferritic steels or Table IWB-3514-1 for austenitic steels.

(c) Any two or more coplanar aligned flaws characterized as separate flaws by Section XI, Division 1, IWA-3330 are allowable, provided the requirements of IWA-3390 are met.

(d) Surface flaws within cladding are acceptable.

VII-1.4.1.2 Laminar Flaw Acceptance Standards

(a) The areas of allowable laminar flaws as defined by Section XI, Division 1, IWA-3360 within the boundary of the examination zones delineated in the applicable figures specified in VII-1.4.1.1(a) shall not exceed the limits specified in Section XI, Division 1, Table IWB-3510-2.

(b) Laminar flaws that join with a planar flaw shall be governed by the acceptance standards of Section XI, Division 1, Table IWB-3510-1 or Table IWC-3510-1 (based on thickness).

VII-1.4.1.3 Linear Flaw Acceptance Standards

(a) The size of allowable linear flaws as detected by a surface examination [magnetic particle (MT) or liquid penetrant (PT)] or volumetric examination [radiographic (RT)] within the examination boundaries shown in Section IX, Division 1, Figures IWB-2500-1 through IWB-2500-6 shall not exceed the limits specified in Section XI, Division 1, Table IWB-3510-3 for ferritic steels or Table IWB-3514-2 for austenitic steels.

(b) Where a flaw extends beyond the examination boundaries, or separate linear flaws lie both within and beyond the boundaries but are characterized as a single flaw by Section XI, Division 1, IWA-3400, the overall flaw size shall be compared with the acceptance standards of Section XI, Division 1, Table IWB-3510-3 for ferritic steels or Table IWB-3514-2 for austenitic steels.

VII-1.4.1.4 Material Requirements for Application of Acceptance Standards. The acceptance standards in Section XI, Division 1, Tables IWB-3510-1, IWB-3510-3, IWB-3512-1, IWB-3514-1, IWB-3514-4, IWB-3519.2-1, IWC-3510-1, IWC-3511-1, and IWC-3511-2 apply to ferritic steels that satisfy one of the following requirements:

(a) Ferritic steels having specified minimum yield strength of 50 ksi (350 MPa) or less at room temperature shall meet the requirements of Section III, Division 1, Subsection NB, NB-2300 or Subsection NC or Subsection NCD, NC-2300 or NCD-2300.

(b) The material shall meet one of the following:

(1) SA-508 Grade 2 Class 2 (former designation: SA-508 Class 2a) (UNS K12766 1)

(2) SA-508 Grade 3 Class 2 (former designation: SA-508 Class 3a) (UNS K12042 1)

(3) SA-533 Type A Class 2 (former designation: SA-533 Grade A Class 2) (UNS K12521)

(4) SA-533 Type B Class 2 (former designation: SA-533 Grade B Class 2) (UNS K12539 2)

(5) SA-508 Class 1 (UNS K13502)

(c) Ferritic steels having specified minimum yield strength greater than 50 ksi (350 MPa) but not exceeding 90 ksi (620 MPa) at room temperature shall meet the requirements of Section III, Subsection NB, NB-2300, or Subsection NC or Subsection NCD, NC-2300 or NCD-2300, Section III Appendices, Nonmandatory Appendix G, G-2110(b). The acceptance standards may also be applied to materials with dynamic fracture toughness data K_{Id} that exceed the values of K_{Ia} in Section III Appendices, Nonmandatory Appendix G prior to the 1999 Addenda, or K_{IR} in Section III Appendices, Nonmandatory Appendix G prior to the 2007 Edition.

VII-1.4.2 Acceptance Standards for Examination Category D, Full-Penetration Welds of Nozzles in Vessels

VII-1.4.2.1 Planar Flaws Acceptance Standards

(a) The size of allowable planar flaws detected in the nozzle and weld areas within the boundary of the examination volume specified in Section XI, Division 1, Figures IWB-2500-7(a) through IWB-2500-7(d) shall not exceed the limits specified in Section XI, Division 1, Table IWB-3512-1 or Table IWC-3511-1 (based on thickness) for ferritic steels or Table IWB-3514-1 for austenitic steels.

(b) The size of allowable planar flaws detected in the vessel shell (or head) material adjoining the nozzle and weld areas and within the boundary of the examination volumes specified in Section XI, Division 1, Figures IWB-2500-7(a) through IWB-2500-7(d) shall not exceed the limits specified in Section XI, Division 1, Table IWB-3510-1 or Table IWC-3510-1 (based on thickness) for ferritic steels or Table IWB-3514-1 for austenitic steels.

(c) The component thickness t to be applied in calculating the flaw a/t ratio for comparison with the acceptance standards in Section XI, Division 1, Table IWB-3510-1, IWB-3512-1, Table IWC-3510-1, or Table IWC-3511-1, as applicable, shall be selected as specified in Section XI, Division 1, Table IWB-3512-2. This table lists the component thicknesses as a function of flaw location for each type nozzle configuration as shown in Section XI, Division 1, Figures IWB-2500-7(a) through IWB-2500-7(d).

(d) Any two or more coplanar aligned flaws characterized as separate flaws by Section XI, Division 1, IWA-3300 are allowable, provided the requirements of IWA-3390 are met.

VII-1.4.2.2 Laminar Flaw Acceptance Standards

(a) Laminar flaws in vessel shell or head material within the boundary of the examination volumes specified in Section XI, Division 1. Figures IWB-2500-7(a) through IWB-2500-7(d) shall be governed by the acceptance standards of VII-1.4.1.2.

(b) Laminar flaws in the nozzle wall shall be considered as planar flaws and the acceptance standards of VII-1.4.2.1 shall apply.

VII-1.4.2.3 Linear Flaw Acceptance Standards

(a) The size of allowable linear flaws as detected by a surface examination [magnetic particle (MT) or liquid penetrant (PT)] or volumetric examination [radiographic (RT)] within the examination boundaries shown in Section XI, Division 1, Figures IWC-2500-3 and IWC-2500-4 shall not exceed the limits specified in Section XI, Division 1, Table IWC-3511-2 for ferritic steels or Table IWB-3514-2 for austenitic steels.

(b) Where a flaw extends beyond the examination boundaries, or separate linear flaws lie both within and beyond the boundaries but are characterized as a single flaw by Section XI, Division 1, IWA-3400, the overall flaw size shall be compared with the acceptance standards of Section XI, Division 1, Table IWC-3511-2 for ferritic steels or Table IWB-3514-2 for austenitic steels.

VII-1.4.3 Acceptance Standards for Examination Category F, Pressure-Retaining Dissimilar Metal Welds in Vessel Nozzles and Category J, Pressure-Retaining Welds in Piping

(a) The acceptance standards of VII-1.4.3 do not apply to planar surface-connected flaws that are in contact with the reactor coolant environment during normal operation and are detected by inservice examination in the following materials:

(1) for PWRs, UNS N06600, UNS N06082, or UNS W86182 surfaces with a normal operating temperature greater than or equal to 525°F (275°C) and in contact with the reactor coolant environment

(2) for BWRs, UNS N06600, UNS W86182, or austenitic stainless steel and associated weld surfaces in contact with the reactor coolant environment that are susceptible to stress corrosion cracking and not mitigated

(b) If the acceptance standards are not met or are not applicable, for acceptance by analytical evaluation, the planar surface-connected flaws in (a) shall meet the provisions of VII-1.5.

(c) Susceptible materials and mitigation criteria for BWRs are specified in NUREG 0313 Revision 2, Sections 2.1 and 2.2.

(d) Susceptible materials and mitigation criteria for butt welds in PWRs are specified in NUREG/CR 7187, Sections 1 and 2.3.

VII-1.4.3.1 Planar Flaw Acceptance Standards

(a) The size of allowable planar flaws within the boundary of the examination surfaces and volumes delineated in Section XI, Division 1, Figures IWB-2500-8 through IWB-2500-11 shall be in accordance with the acceptance standards of VII-1.4.3.2, VII-1.4.3.3, and VII-1.4.3.4, as applicable. In addition, the requirements of Section XI, Division 1, IWB-3514.8 shall be satisfied for planar surface-connected flaws that are in contact with the reactor coolant environment during normal operation and are detected by preservice examination in materials that are susceptible to stress corrosion cracking, as defined in VII-1.4.3(a)(1) for PWRs and in VII-1.4.3(a)(2) and VII-1.4.3(c) for BWRs.

(b) Where flaws extend beyond the boundaries of the examination surfaces and volumes, or separate flaws are detected that lie both within and beyond the boundaries but are characterized as a single flaw by the requirements of Section XI, Division 1, IWA-3300, the overall flaw size shall be compared with the acceptance standards of (a).

(c) Any two or more coplanar aligned flaws that are characterized as separate flaws by Section XI, Division 1, IWA-3300 are allowable, provided the requirements of IWA-3390 are met.

(d) Inner surface flaws detected by volumetric examination of piping components with austenitic cladding on the inner surface shall be governed by the following acceptance standards:

(1) Surface flaws that do not penetrate through the nominal clad thickness into base metal need not be compared with the acceptance standards of (a).

(2) The size of allowable surface flaws that penetrate through the cladding into base metal shall not exceed the acceptance standards of (a), except that the depth of the flaw shall be the total depth minus the nominal clad thickness.

VII-1.4.3.2 Acceptance Standards for Ferritic Piping

(a) The size of allowable flaws shall not exceed the limits specified in Section XI, Division 1, Table IWB-3514-1.

(b) Where flaws on the outer surface of piping as detected by the surface examination method during an inservice examination exceed the acceptance standards of VII-1.4.3.6, the flaws may be examined by the volumetric method. The acceptance of these flaws shall be governed by the acceptance flaw standards for the volumetric examination method in Section XI, Division 1, Table IWB-3514-1.

VII-1.4.3.3 Acceptance Standards for Austenitic Piping

(a) The size of allowable flaws shall not exceed the limits specified in Section XI, Division 1, Table IWB-3514-1.

(b) Where flaws on the outer surface of piping as detected by the surface examination method during an inservice examination exceed the acceptance standards of VII-1.4.3.6, the flaws may be examined by the volumetric method. The acceptance of these flaws shall be governed by the acceptance flaw standards for the volumetric examination method in Section XI, Division 1, Table IWB-3514-1.

VII-1.4.3.4 Acceptance Standards for Dissimilar Metal Welds

(a) The size of allowable flaws in the carbon or low-alloy-steel end of a dissimilar metal weld joint shall be governed by the standards of VII-1.4.3.2.

(b) The size of allowable flaws in the high-alloy-steel or high-nickel-alloy end and the weld metal of a dissimilar-metal weld joint shall be governed by the standards of VII-1.4.3.3.

VII-1.4.3.5 Laminar Flaw Acceptance Standards. The area of allowable laminar flaws, as defined by Section XI, Division 1, IWA-3360, within the boundary of the examination zones shown in Section XI, Division 1, Figures IWB-2500-8 through IWB-2500-11, shall not exceed the limits specified in Section XI, Division 1, Table IWB-3514-3.

VII-1.4.3.6 Linear Flaw Acceptance Standards for Ferritic Piping and Austenitic Piping

(a) The size of an allowable linear flaw within the boundaries of the examination surfaces in Section XI, Division 1, Figures IWB-2500-8 through IWB-2500-11 shall not exceed the limits specified for ferritic piping in Section XI, Division 1, Table IWB-3514-4 and for austenitic piping in Table IWB-3514-2.

(b) Where a flaw extends beyond the boundaries of the examination surfaces in Section XI, Division 1, Figures IWB-2500-8 through IWB-2500-11, or where discontinuous linear flaws lie both within and beyond the boundaries and are characterized as a single flaw by the requirements in Section XI, Division 1, IWA-3400, the size of allowable linear flaws shall not exceed the limits specified for ferritic piping in Section XI, Division 1, Table IWB-3514-4 and for austenitic piping in Table IWB-3514-2.

VII-1.4.4 Acceptance Standards for Examination Category G-1, Pressure-Retaining Bolting Greater Than 2 in. (50 mm) in Diameter

VII-1.4.4.1 Acceptance Standards for Surface Examinations of Studs and Bolts. Allowable surface flaws in vessel closure studs and pressure-retaining bolting shall not exceed the following limits:

(a) non-axial flaws, $\frac{1}{4}$ in, (6 mm) in length

(b) axial flaws, 1 in. (25 mm) in length

VII-1.4.4.2 Acceptance Standards for Volumetric Examinations of Studs and Bolts

(a) The size of allowable non-axial flaws in vessel closure studs and pressure-retaining bolting within the boundary of the examination volume shown in Section XI, Division 1, Figure IWB-2500-12(a) shall not exceed the limits specified in Table IWB-3515-1.

(b) Any two or more subsurface flaws at any diameter of the stud that combine to reduce the net diameter are acceptable, provided the combined flaw depths do not exceed the sum of the allowable limits specified in Section XI, Division 1, Table IWB-3515-1 for the corresponding flaw aspect ratios, divided by the number of flaws.

(c) Any flaw detected by the volumetric examination shall be investigated by a surface examination. If the flaw is confirmed to be a surface flaw, the acceptance standards of VII-1.4.4.1 shall apply. If the flaw is not a surface flaw, the acceptance standards of (a) and (b) shall apply.

VII-1.4.4.3 Acceptance Standards for Volumetric Examinations of Threads in Stud Holes. The size of allowable flaws within the boundary of the examination volume in Section XI, Division 1, Figure IWB-2500-12(a) and oriented on a plane normal to the axis of the stud shall not exceed 0.2 in. (5 mm) as measured radially from the root of the thread.

VII-1.4.5 Acceptance Standards for Examination Category K, Welded Attachments for Vessels, Piping, Pumps, and Valves

VII-1.4.5.1 Planar Flaw Acceptance Standards

(a) The size of an allowable flaw within the boundary of the examination surfaces and volumes in Section XI, Division 1, Figures IWB-2500-13, IWB-2500-14, and IWB-2500-15 shall not exceed the acceptance standards of this Article for the applicable supported pressure-retaining component to which the attachment is welded. For indications located wholly on the attachment side of the line A-D in Figures IWB-2500-13, IWB-2500-14, and IWB-2500-15, the thickness and the surface of the attachment shall be considered the thickness and surface of the component for purposes of flaw characterization (see Section XI, Division 1, IWA-3300) and for comparison with the acceptance standards. For flaws located in the examination volume A-B-C-D, the flaw shall be characterized considering both the surface of the attachment and the surface of the pressure boundary as the surface of the component for comparison of the flaw size with acceptance standards.

(b) Where a flaw extends beyond the boundaries of the examination surfaces and volumes, or separate flaws are detected that lie both within and beyond the boundaries but are characterized as single flaws by the requirements of Section XI, Division 1, Article IWA-3000, the overall flaw size shall be compared with the acceptance standards of (a).

(c) Where a flaw detected by a surface examination method exceeds the acceptance standards of (a), an optional encoded volumetric examination may be conducted, in which case the acceptance standards for the volumetric examination method shall apply.

VII-1.4.5.2 Laminar Flaw Acceptance Standards

(a) The allowable area of a laminar flaw within the boundary of the examination volume of the attachment or the pressure-retaining membrane to which the support is attached shall be governed by VII-1.4.1 or VII-1.4.3, as applicable.

(b) Where laminar flaws are detected in an attachment that does not transmit tensile load in the through-thickness direction, the laminar flaw acceptance standards need not apply.

VII-1.4.5.3 Linear Flaw Acceptance Standards

(a) The size of an allowable flaw within the boundary of the examination surfaces in Section XI, Division 1, Figure IWC-2500-5 shall not exceed the acceptance standards of this Article for the applicable supported pressure-retaining component to which the attachment is welded.

(b) Where a flaw extends beyond the boundaries of the examination surfaces, or separate flaws are detected that lie both within and beyond the boundaries but are characterized as a single flaw by the requirements of Section XI, Division 1, Article IWA-3000, the overall flaw size shall be compared with the acceptance standards of (a).

(c) Where a flaw detected by a surface examination method exceeds the acceptance standards of (a), an optional volumetric examination may be conducted, in which case the acceptance standards for the volumetric examination method for the applicable supported pressure-retaining component to which the attachment is welded shall apply.

VII-1.4.6 Standards for Examination Category G-1, Pressure-Retaining Bolting Greater Than 2 in. (50 mm) in Diameter, and Examination Category G-2, Pressure-Retaining Bolting 2 in. (50 mm) and Less in Diameter

VII-1.4.6.1 Visual Examination, VT-1. This requirement applies to accessible surfaces of bolting when bolting is examined in place and to all surfaces when bolting is removed for examination. The following relevant conditions[2] shall require corrective action so that the bolting meets the requirements of VII-1.3.1.2(b) prior to service or VII-1.3.1.4(b) prior to continued service:

(a) crack-like flaws that exceed the linear flaw acceptance standards of VII-1.4.4

(b) more than one deformed or sheared thread in the zone of thread engagement of bolts, studs, or nuts

(c) localized general corrosion that reduces the bolt or stud cross-sectional area by more than 5%

(d) bending, twisting, or deformation of bolts or studs to the extent that assembly or disassembly is impaired

(e) missing or loose bolts, studs, nuts, or washers

(f) fractured bolts, studs, or nuts

(g) degradation of protective coatings on bolting surfaces

(h) evidence of coolant leakage near bolting

VII-1.4.7 Acceptance Standards for Examination Categories L-2 and M-2, Equipment Casings and Valve Bodies

VII-1.4.7.1 Visual Examination, VT-3. The following relevant conditions shall require corrective action to meet the requirements of VII-1.3.1.2(b) prior to service or VII-1.3.1.4(b) prior to continued service:

(a) corrosion or erosion that reduces the pressure-retaining wall thickness,[3] determined either from design information, construction drawings, or by measurement on the component, by more than 10%

(b) wear of mating surfaces that may lead to loss of function or leakage, or

(c) crack-like surface flaws developed in service or grown in size beyond that recorded during preservice visual examination

VII-1.4.7.2 Planar Flaw Acceptance Standards. If a supplemental examination is performed that can characterize the flaw size and shape, the following planar flaw acceptance standards shall be applied:

(a) The size of an allowable planar flaw shall not exceed the limits specified in Section XI, Division 1, Table IWB-3519.2-1 or Table IWB-3519.2-2, as applicable. Base metal flaws in castings that are permitted by the governing material specifications meeting the requirements of the Construction Code are acceptable.

(b) If separate flaws are detected and are characterized as a single flaw in accordance with Section XI, Division 1, IWA-3300, the flaw shall meet the requirements of (a).

(c) Any two or more coplanar aligned flaws characterized as separate flaws in accordance with Section XI, Division 1, IWA-3300 are acceptable, provided the requirements of IWA-3390 are met.

(d) If a flaw is detected by radiographic examination and exceeds the surface flaw acceptance standards of Section XI, Division 1, Table IWB-3519.2-1 or Table IWB-3519.2-2, as applicable, surface examination may be performed, with acceptance in accordance with Table IWB-3519.2-1 or Table IWB-3519.2-2. If acceptable by surface examination, the flaw shall meet subsurface flaw acceptance standards of Table IWB-3519.2-1 or Table IWB-3519.2-2.

(e) A surface flaw in the cladding detected by volumetric examination of austenitic clad ferritic base material shall meet the following requirements:

(1) Surface flaws that do not extend to the base material are acceptable.

(2) A surface flaw that extends into the base material shall meet the requirements of (a), considering dimension a, to be the portion of the flaw depth in the base material.

VII-1.4.8 Acceptance Standards for Examination Category N-1, Interior of Reactor Vessel; Examination Category N-2, Welded Core Support Structures and Interior Attachments to Reactor Vessels; and Examination Category N-3, Removable Core Support Structures

VII-1.4.8.1 Visual Examination, VT-1. The following relevant conditions[2] shall require corrective action so that the item meets the requirements of VII-1.3.1.2(b) prior to service or VII-1.3.1.4(b) prior to continued service:

(a) crack-like surface flaws on the welds joining the attachment to the vessel wall that exceed the linear flaw acceptance standards of VII-1.4.1

(b) structural degradation of attachment welds such that the original cross-sectional area[4] is reduced by more than 10%

VII-1.4.8.2 Visual Examination, VT-3. The following relevant conditions[2] shall require corrective action so that the item meets the requirements of VII-1.3.1.2(b) prior to service or VII-1.3.1.4(b) prior to continued service:

(a) structural distortion or displacement of parts to the extent that component function may be impaired

(b) loose, missing, cracked, or fractured parts, bolting, or fasteners

(c) foreign materials or accumulation of corrosion products that could interfere with control rod motion or could result in blockage of coolant flow through fuel

(d) corrosion or erosion that reduces the nominal section thickness by more than 5%

(e) wear of mating surfaces that may lead to loss of function

(f) structural degradation of interior attachments such that the original cross-sectional area is reduced more than 5%

VII-1.4.9 Acceptance Standards for Examination Category P, All Pressure-Retaining Components

VII-1.4.9.1 Visual Examination, VT-2. Relevant conditions do not include conditions that result in condensation on components, normal collection of fluid in sumps, and drips from open drains. A component whose visual examination (see Section XI, Division 1, IWA-5240) detects any of the following relevant conditions shall meet VII-1.3.1.4(b) and Section XI, Division 1, IWA-5250:

(a) any through-wall or through-weld, pressure-retaining material leakage from insulated and noninsulated components

(b) nonborated water leakage in excess of limits established by the Owner from mechanical connections (such as pipe caps, bolted connections, or compression fittings)

(c) areas of general corrosion of a component resulting from leakage

(d) leakage in excess of limits established by the Owner from components provided with leakage limiting devices (such as valve packing glands or pump seals)

(e) borated water leakage or evidence of borated water leakage (discoloration or accumulated residues on surfaces of components, insulation, or floor areas) not addressed in (a) or (d)

(f) leakage or flow test results from buried components in excess of limits established by the Owner

VII-1.4.10 Acceptable Standards for Examination Category O, Pressure-Retaining Welds in Control Rod Drive and Instrument Nozzle Housings

VII-1.4.10.1 Planar Flaw Acceptance Standards

(a) The size of an allowable planar flaw within the boundary of the examination surfaces and volumes delineated in Section XI, Division 1, Figure IWB-2500-18 shall not exceed the limits specified in VII-1.4.10.2 and VII-1.4.10.3, as applicable.

(b) Where a flaw extends beyond the boundaries of the examination surfaces and volumes, or separate flaws are detected that lie both within and beyond the boundaries but are characterized as a single flaw by the requirements of Section XI, Division 1, IWA-3300, the overall flaw size shall be compared with the acceptance standards of (a).

(c) Any two or more coplanar aligned flaws characterized as separate flaws by Section XI, Division 1, IWA-3300 are allowable, provided the requirements of IWA-3390 are met.

VII-1.4.10.2 Acceptance Standards for Surface Examination

(a) The length of allowable flaws shall not exceed $^{3}/_{16}$ in. (5 mm) for the preservice examination and $^{1}/_{4}$ in. (6 mm) for the inservice examination.

(b) Where a flaw on the outer surface of the housing exceeds the allowable standards, the housing may be examined using the volumetric method, and the acceptance standards of VII-1.4.10.3 shall apply.

VII-1.4.10.3 Acceptance Standards for Volumetric Examination

(a) The depth of an allowable preservice flaw shall not exceed 10% of weld thickness; the length shall not exceed 60% of weld thickness.

(b) The depth of an allowable inservice flaw shall not exceed 12.5% of weld thickness; the length shall not exceed 75% of weld thickness.

VII-1.4.11 Acceptance Standards for Examination Category F-A, Component Supports

VII-1.4.11.1 Acceptance by Examination. Component supports whose examinations do not reveal conditions described in VII-1.4.11.4(a) shall be acceptable for continued service. Confirmed changes in conditions from prior examinations shall be recorded in accordance with RIM-1.4(h).

VII-1.4.11.2 Acceptance by Corrective Measures or Repair/Replacement Activity. A component support whose examination detects conditions described in VII-1.4.11.4(a) is unacceptable for continued service until such conditions are corrected by one or more of the following:

(a) adjustment and reexamination for conditions such as the following

(1) detached or loosened mechanical connections

(2) improper hot or cold settings of spring supports and constant load supports

(3) misalignment of supports

(4) improper displacement settings of guides and stops

(b) repair/replacement activities in accordance with Section XI, Division 1, Article IWA-4000 and reexamination

VII-1.4.11.3 Acceptance by Evaluation or Test

(a) As an alternative to the requirements of VII-1.4.11.2, a component support or a portion of a component support containing relevant conditions that do not meet the acceptance standards of VII-1.4.11.4 shall be acceptable for service without corrective actions if an evaluation or test demonstrates that the component support is acceptable for service.

(b) If a component support or a portion of a component support has been evaluated or tested and determined to be acceptable for service in accordance with (a), the Owner may perform corrective measures to restore the component support to its original design condition.

VII-1.4.11.4 Acceptance Standards — Component Support Structural Integrity

(a) Component support conditions that are unacceptable for continued service shall include the following:

(1) deformations or structural degradations of fasteners, springs, clamps, or other support items

(2) missing, detached, or loosened support items

(3) arc strikes, weld spatter, paint, scoring, roughness, or general corrosion on close tolerance machined or sliding surfaces

(4) improper hot or cold settings of spring supports and constant load supports

(5) misalignment of supports

(6) improper clearances of guides and stops

(7) evidence of fluid leakage from viscoelastic dampers

(b) The following are examples of nonrelevant conditions:

(1) fabrication marks (e.g., from punching, layout, bending, rolling, and machining)

(2) chipped or discolored paint

(3) weld spatter on other than close tolerance machined or sliding surfaces

(4) scratches and surface abrasion marks

(5) roughness or general corrosion that does not reduce the load bearing capacity of the support

(6) general conditions acceptable by the material, Design, and/or Construction Specifications

VII-1.5 ANALYTICAL EVALUATION OF PLANAR FLAWS (25)

(a) A flaw that exceeds the size of allowable flaws defined in VII-1.4 may be analytically evaluated using procedures described in this subarticle to calculate flaw growth until the next inspection or the end of the service lifetime of the component.

(b) For purposes of analytical evaluation, the depth of flaws in clad components shall be defined in accordance with Section XI, Division 1, Figure IWB-3600-1 as follows:

(1) Category 1 — A flaw that lies entirely in the cladding, as shown in Figure IWB-3600-1, need not be analytically evaluated.

(2) Category 2 — A surface flaw that penetrates the cladding and extends into the ferritic steel shall be analytically evaluated on the basis of the total flaw depth in both the ferritic steel and the cladding as shown in Figure IWB-3600-1.

(3) Category 3 — A subsurface flaw that lies in both the ferritic steel and the cladding shall be treated as either a surface or a subsurface flaw depending on the relationship between *S* and *d* as shown in Figure IWB-3600-1.

(4) Category 4 — A subsurface flaw that lies entirely in the ferritic steel and terminates at the weld metal interface shall be treated as either a surface or subsurface flaw depending on the relationship between *S* and *d* as shown in Figure IWB-3600-1.

(5) Category 5 — A subsurface flaw contained entirely in the ferritic steel shall be treated as either a surface or a subsurface flaw depending on the relationship between *S* and *d* as shown in Figure IWB-3600-1.

(c) The flaw characterization rules of Section XI, Division 1, IWA-3300 shall be used for transformation of a subsurface flaw to a surface flaw using dimensions *S* and *d* illustrated in Figure IWB-3600-1.

(d) When examination results do not permit accurate determination of the flaw category, a more conservative category shall be selected.

VII-1.5.1 Acceptance Criteria for Ferritic Steel Components 4 in. (100 mm) and Greater in Thickness

(a) A flaw that exceeds the size of allowable flaws defined in VII-1.4.1 and VII-1.4.2 may be analytically evaluated using procedures such as those described in Section XI, Division 1, Nonmandatory Appendix A to calculate its growth until the next inspection or the end of service lifetime of the component.

(b) The component containing the flaw is acceptable for continued service during the evaluated time period if the following are satisfied:

(1) the criteria of VII-1.5.1.1 or VII-1.5.1.2

(2) the primary stress limits of the Construction Code, assuming local area reduction of the pressure-retaining membrane that is equal to the area of the detected flaws as determined by the flaw characterization requirements of Section XI, Division 1, Article, IWA-3000

(c) The analytical evaluation procedures shall be the responsibility of the Owner.

VII-1.5.1.1 Acceptance Criteria Based on Flaw Size. A flaw exceeding the limits of VII-1.4 is acceptable if the critical flaw parameters satisfy the following criteria:

$$a_f < 0.1a_c$$
$$a_f < 0.5a_i$$

where

a_c = minimum critical size of the flaw under normal operating conditions

a_f = maximum size to which the detected flaw is calculated to grow in a specified time period, which can be the next scheduled inspection of the component, or until the end of vessel design lifetime

a_i = minimum critical size of the flaw for initiation of non-arresting growth under postulated emergency and faulted conditions

VII-1.5.1.2 Acceptance Criteria Based on Applied Stress Intensity Factor. A flaw exceeding the limits of VII-1.4 is acceptable if the applied stress intensity factor, K_I, for the flaw dimensions a_f and l_f satisfies the following criteria:

(a) For normal conditions

$$K_I < K_{Ic}/\sqrt{10}$$

where

K_I = applied stress intensity factor for normal conditions, including upset and test conditions for the flaw dimensions a_f and l_f

a_f = end-of-evaluation-period flaw depth defined in VII-1.5.1.1

l_f = end-of-evaluation-period flaw length

K_{Ic} = fracture toughness based on crack initiation for the corresponding crack-tip temperature

(b) For emergency and faulted conditions

$$K_I < K_{Ic}/\sqrt{2}$$

where

K_I = applied stress intensity factor under emergency and faulted conditions for flaw dimensions a_f and l_f

VII-1.5.1.3 Acceptance Criteria for Flanges and Shell Regions Near Structural Discontinuities. The following criteria shall be used for the analytical evaluation of flaws in areas of structural discontinuity, such as vessel flange and nozzle-to-shell regions. A flaw exceeding the limits of VII-1.4 is acceptable if the applied stress intensity factor, K_I, for the dimensions a_f and l_f satisfies the following limits:

(a) For conditions where pressurization does not exceed 20% of the Design Pressure, during which the minimum temperature is not less than RT_{NDT}

$$K_I < K_{Ic}/\sqrt{2}$$

where

K_I = applied stress intensity factor for flaw dimensions a_f and l_f

a_f = end-of-evaluation-period flaw depth defined in VII-1.5.1.1

l_f = end-of-evaluation-period flaw length

K_{Ic} = fracture toughness based on crack initiation for the corresponding crack-tip temperature

(b) For normal conditions (including upset and test conditions), but excluding conditions described in (a), the criteria of VII-1.5.1.1 or VII-1.5.1.2(a) shall be satisfied.

(c) For emergency and faulted conditions, the criteria of VII-1.5.1.1 or VII-1.5.1.2(b) shall be satisfied.

VII-1.5.2 Acceptance Criteria for Ferritic Components Less Than 4 in. (100 mm) in Thickness

The acceptance criteria for ferritic components less than 4 in. (100 mm) in thickness are in the course of preparation. In the interim, the criteria of VII-1.5.1 may be applied.

VII-1.5.3 Analytical Evaluation Procedures and Acceptance Criteria for Flaws in Austenitic and Ferritic Piping

Piping containing flaws exceeding the acceptance standards of VII-1.4.3 may be analytically evaluated to determine acceptability for continued service to the next inspection or to the end of the evaluation period. For purposes of analytical evaluation, the depth of flaws in clad piping items shall be defined in accordance with Section XI, Division 1, Figure IWB-3600-1. The flaw characterization rules of Section XI, Division 1, IWA-3300 shall be used for the transformation of a subsurface flaw to a surface flaw using dimensions *S* and *d*. A pipe containing flaws is acceptable for continued service for a specified evaluation time period if the criteria of VII-1.5.3.2, VII-1.5.3.3, or VII-1.5.3.4 are satisfied. The procedures shall be the responsibility of the Owner.

VII-1.5.3.1 Analytical Evaluation Procedures. Analytical evaluation procedures based on flaw size or applied stress, such as those described in Section XI, Division 1, Nonmandatory Appendix C or Nonmandatory Appendix H, may be used, subject to the following:

(a) The analytical evaluation procedures and acceptance criteria in Section XI, Division 1, Nonmandatory Appendix C are applicable to piping NPS 1 (DN25) and greater. The procedures and criteria in Section XI, Division 1, Nonmandatory Appendix H are applicable to piping NPS 4 (DN 100) and greater. Section XI, Nonmandatory Appendices C and H are applicable to portions of adjoining pipe fittings within a distance of $(R_2t)^{1/2}$ from the weld centerline, where R_2 is the outside radius and t is the nominal thickness of the pipe. The weld geometry and weld-base metal interface are defined in Section XI, Division 1, Nonmandatory Appendix C.

(b) The analytical evaluation procedures and acceptance criteria are applicable to seamless or welded wrought carbon steel pipe and pipe fittings, and associated weld materials that have a specified minimum yield strength not greater than 40 ksi (280 MPa).

(c) The analytical evaluation procedures and acceptance criteria are applicable to seamless or welded wrought or cast austenitic pipe and pipe fittings and associated weld materials that are made of wrought stainless steel, Ni-Cr-Fe alloy, or cast stainless steel, and have a specified minimum yield strength not greater than 45 ksi (310 MPa).

(d) A flaw growth analysis shall be performed on the detected flaw to predict its growth due to fatigue or stress corrosion cracking mechanisms, or both, when applicable, during a specified evaluation time period. The time interval selected for flaw growth analysis (i.e., the evaluation period) shall be until the next inspection or until the end of the evaluation period for the item.

(e) The calculated maximum flaw dimensions at the end of the evaluation period shall be compared to the acceptance criteria for Service Levels A, B, C, and D loadings to determine the acceptability of the item for continued service.

VII-1.5.3.2 Analytical Evaluation Procedures and Acceptance Criteria Based on Failure Mode Determination. Piping containing flaws exceeding the acceptance standards of VII-1.4.3.1 may be analytically evaluated using analytical procedures described in Section XI, Division 1, Nonmandatory Appendix C and is acceptable for continued service during the evaluated time period when the critical flaw parameters satisfy the criteria in Nonmandatory Appendix C. Flaw acceptance criteria are based on allowable flaw size or allowable stress. Flaws with depths greater than 75% of the wall thickness are unacceptable.

VII-1.5.3.3 Analytical Evaluation Procedures and Acceptance Criteria Based on Use of a Failure Assessment Diagram. Piping containing flaws exceeding the acceptance standards of VII-1.4.3.1 may be analytically evaluated using procedures based on use of a failure assessment diagram, such as described in Section XI, Division 1, Nonmandatory Appendix H. Such analytical evaluation procedures may be invoked in accordance with the conditions of VII-1.5.3.1. Flaws with depths greater than 75% of the wall thickness are unacceptable.

VII-1.5.3.4 Alternative Analytical Evaluation Procedure and Acceptance Criteria Based on Applied Stress. Piping containing flaws exceeding the allowable flaw standards of VII-1.4.3.1 is acceptable for continued service until the end of the evaluation period if the alternative analytical evaluation procedure demonstrates, at the end-of-evaluation period, structural factors, based on load, equivalent to the following:

Service Level	Structural Factor
A	2.7
B	2.4
C	1.8
D	1.4

Flaws with depths greater than 75% of the wall thickness are unacceptable.

VII-1.5.4 Evaluation Procedure and Acceptance Criteria for Head Penetration Nozzles of PWR Reactor Vessels

Flaws in the upper and lower head penetration nozzles of PWR reactor vessels may be evaluated in accordance with VII-1.5.4.1 and VII-1.5.4.2 to determine acceptability of the nozzles for continued service. The evaluation procedures and acceptance criteria shall be the responsibility of the Owner.

Note that the acceptance standards of VII-1.4 shall not be used to accept indications in this region.

VII-1.5.4.1 Evaluation Procedure.

(a) Applicability. This evaluation procedure is applicable to head penetration nozzles with nominal outside diameter of 8 in. (200 mm) or less. This procedure shall not be used for partial-penetration nozzle-to-vessel (J-groove) welds.

(b) Procedure

(1) A flaw growth analysis shall be performed on each detected flaw to determine its maximum growth due to fatigue, stress corrosion cracking or both mechanisms, when applicable, during a specified evaluation

period. The minimum time interval for the flaw growth evaluation shall be until the next inspection.

(2) All applicable loadings, including weld residual stress, shall be considered in the calculation of the crack growth.

(3) The flaw shall be characterized in accordance with the requirements of Section XI, Division 1, IWA-3400, including the proximity requirements of Figure IWA-3400-1 for surface flaws.

(4) The flaw shall be projected into both axial and circumferential orientations, and each orientation shall be evaluated. The axial orientation is the same for each nozzle, but the circumferential orientation will vary depending on the angle of intersection of the penetration nozzle with the head. The circumferential orientation is defined in Section XI, Division 1, Figure IWB-3662-1.

(5) The location of the flaw, relative to the J-groove attachment weld, shall be determined.

(6) The flaw shall be evaluated and the following critical flaw parameters shall be calculated using procedures such as those described in Section XI, Division 1, Nonmandatory Appendix O:

a_f = the maximum depth to which the detected flaw is calculated to grow by the end of the evaluation period

l_f = the maximum length to which the detected flaw is calculated to grow by the end of the evaluation period

VII-1.5.4.2 Acceptance Criteria. The maximum flaw dimensions calculated for the end of the evaluation period [see VII-1.5.4.1(b)(6)] shall be compared with the maximum allowable flaw dimensions in Section XI, Division 1, Table IWB-3663-1.

VII-1.6 ANALYTICAL EVALUATION OF FACILITY OPERATING EVENTS

VII-1.6.1 Scope

This subarticle provides requirements for analytical evaluation of events and conditions for pressure boundary components and associated structures in operating facilities.

VII-1.6.2 Unanticipated Operating Events

(a) When an operating event causes an excursion outside the normal operating pressure and temperature limits defined in the facility Technical Specifications, an analytical evaluation shall be performed to determine the effects of the out-of-limit condition on the structural integrity of the pressure boundary.

(b) The analytical evaluation procedures shall be the responsibility of the Owner.

VII-1.6.3 Fracture Toughness Criteria for Protection Against Failure

(a) During reactor operation, load and temperature conditions shall be maintained to provide protection against failure due to the presence of postulated flaws in the ferritic portions of the reactor coolant pressure boundary. Section XI, Division 1, Nonmandatory Appendix G provides analytical evaluation procedures that may be used to define these load and temperature conditions.

(b) For reactor vessels with material upper shelf Charpy impact energy levels less than 50 ft-lb (68 J), service and test conditions may be analytically evaluated, using current-geometry and material properties, to provide protection against ductile failure. Section XI, Division 1, Nonmandatory Appendix K contains analytical evaluation procedures that may be used to demonstrate protection against ductile failure.

(c) The analytical evaluation procedures described in (a) and (b) shall be the responsibility of the Owner.

VII-1.6.4 Operating Facility Fatigue Assessments

(a) Section XI, Division 1, Nonmandatory Appendix L provides analytical evaluation procedures that may be used to assess the effects of thermal and mechanical fatigue concerns on component acceptability for continued service.

(b) Section XI, Division 1, Nonmandatory Appendix L provides analytical evaluation procedures that may also be used when the calculated fatigue usage exceeds the fatigue usage limit defined in the original Construction Code.

ARTICLE VII-2 SODIUM-COOLED FAST-REACTOR-TYPE FACILITIES

(25)

VII-2.1 SCOPE

This Article provides requirements for identifying and evaluating potentially active degradation mechanisms in sodium-cooled fast-reactor-type facilities. These and other unique requirements herein shall be used to supplement the RIM Program for sodium-cooled fast-reactor-type facilities.

VII-2.2 RIM PROGRAM — DEGRADATION MECHANISM ASSESSMENT

See Table VII-2.2-1.

VII-2.3 REACTOR-SPECIFIC EXAMINATION METHODS

VII-2.3.1 Continuous Leakage Monitoring

VII-2.3.1.1 General

(a) Continuous leakage monitoring of the region exterior to components or systems containing liquid sodium or cover gas is used to detect leakage of liquid sodium or cover gas. Calibration of sodium-to-gas leak detectors shall be performed as specified in the Technical Specifications.

(b) It is not intended for all leak detectors to operate 100% of the time. The maximum percentage of leak detectors that may be out of operation at any one time shall be as specified in the Technical Specifications.

(c) Continuous leakage monitoring specified in VII-2.3.1 is intended to address uncertainty, as described in RIM-2.6 and RIM-2.7.1(a)(8), provided the components are shown to meet the Reliability Targets, without crediting the use of MANDE methods. If continuous leakage monitoring is used to ensure that Reliability Targets are met, additional requirements to those in VII-2.3.1 shall be confirmed and documented by the MANDEEP.

VII-2.3.1.2 Liquid Sodium Leakage

(a) Continuous leakage monitoring of liquid sodium, included in Mandatory Appendix V, Article V-2, shall be provided by installed leak detection systems capable of monitoring the exterior of a liquid-sodium-containing system and providing visual and audible alarms when leakage of liquid sodium occurs.

(b) It shall be shown, in accordance with VII-2.6, that the SSC reliability equals or exceeds the Reliability Target to prevent failure without taking account of the contribution of MANDE. The concept of defense-in-depth requires continuous leakage monitoring of liquid sodium, even though the SSC reliability already meets the Reliability Target without any MANDE.

(c) The leakage detectors shall have the ability to detect the maximum acceptable leakage (MAL). In addition, if the extent of leakage estimated by postulating a double-ended break of the SSC is larger than MAL, the detector shall also have its sensitivity set high enough to demonstrate leak before break (LBB) in accordance with VII-2.7.

VII-2.3.1.3 Cover Gas Leakage Continuous leakage monitoring of cover gas, included in Mandatory Appendix V, Article V-2, shall be provided by installed systems such as radiation monitors arranged to detect gas leakage from primary liquid sodium cover gas space. Such systems need not be dedicated to leak detection and might serve additional functions.

VII-2.4 ACCEPTANCE STANDARDS

VII-2.4.1 Evaluation of Monitoring or Examination Results

VII-2.4.1.1 Continuous Leakage Monitoring of Liquid Sodium

(a) General

(1) The continuous leakage monitoring of liquid sodium required by the RIM Program and performed to meet the requirements of VII-2.3.1.2 shall be evaluated by comparing the monitoring results with the acceptance standards specified in Table VII-2.4.3-1.

(2) Acceptance of components for continued service shall be in accordance with (b).

(b) Acceptance. A component with continuous leakage monitoring that demonstrates the absence of the confirmed leakages described in the standards of Table VII-2.4.3-1 is acceptable for continued service.

(c) Repair/Replacement Activity and Reexamination. The repair/replacement activity and reexamination shall comply with the requirements of Article RIM-4. In lieu of the system leakage test required by RIM-4.2, continuous leakage monitoring may be conducted to meet the requirements of VII-2.3.1.2 prior to return to

Table VII-2.2-1 Degradation Mechanism Attributes and Attribute Criteria (SFR)

Degradation Mechanism Type	Degradation Mechanism Subtype	Attribute Criteria	Degradation Features and Susceptible Regions
TF	TASCS	– potential for mixing of hot and cold fluids at core outlet, or – potential for liquid level turbulence, or – potential for inflow of cold fluid to hot outlet plenum during a scram transient	Cracks can initiate in base metal, heat affected zone (HAZ), and welds.
	TT	– potential for relatively rapid temperature change	Cracks can initiate in base metal, HAZ, and welds.
VF	FIV	– high velocity flow, and – absence of vibration damping structures, and – structural natural frequencies in resonance range of flow-induced-vibration frequencies	Cracks can initiate in base metal, HAZ, and welds.
	MF	– presence of attached vibration sources (e.g., pumps, compressors), and – structural natural frequencies in resonance range of mechanical-vibration frequencies	Cracks can initiate in base metal, HAZ, and welds.
	FW	– relative sliding motion between two contacting surfaces, and – absence of a relevant surface treatment	Wall thinning can initiate at the contacting surfaces. Heat exchanger tubes, or other relatively thin component boundaries are particularly susceptible to leaks due to fretting wear.
CR	CV	– high flow velocity, and – absence of a relevant surface treatment	Wall thinning can initiate at the surface in contact with liquid sodium.
	MT	– in contact with liquid metal, and – operating temperature > 400°C (752°F), and – insufficient purity control of sodium, especially in terms of dissolved oxygen	Dissolution of alloy elements can initiate at the surface in contact with liquid sodium.
HTD	CP	– operating temperature >375°C (707°F) (ferritic materials), 425°C (797°F) (austenitic stainless steels), and – stress is present	Cracks can initiate in base metal, HAZ, and welds.
	CFI	– operating temperature >375°C (707°F) (ferritic materials), 425°C (797°F) (austenitic stainless steels), and – cyclic stress is present	Cracks can initiate in base metal, HAZ, and welds.
	CE	– operating temperature >375°C (707°F) (ferritic materials), 425°C (797°F) (austenitic stainless steels), and – stress is present	Ductility reduction of base metal, HAZ, and welds can occur.
	TA	– operating temperature >375°C (707°F) (ferritic materials), 425°C (797°F) (austenitic stainless steels)	Ductility reduction of base metal, HAZ, and welds can occur.
	SRC	– austenitic alloys with large grain size, especially precipitation-hardened alloys, and – high residual stresses from fabrication such as cold-working and welding, and – thick sections at welds, or presence of notches and stress concentrators	Cracks can initiate in HAZ.

Table VII-2.2-1
Degradation Mechanism Attributes and Attribute Criteria (SFR) (Cont'd)

Degradation Mechanism		Attribute Criteria	Degradation Features and Susceptible Regions
Type	Subtype		
DEP	NIE	– neutron irradiation environment	Reduction in ductility and creep strength of base metal and welds can occur.
	LME	– ferritic steels, especially those without appropriate SR treatment or PWHT, and – in contact with liquid sodium, especially liquid sodium with high dissolved oxygen, and – presence of notches and stress concentrators, and – plastic deformation by slow-strain-rate loading below 500℃	Ductility reduction of base metal can occur.
	DCA	– ferritic steel with low Cr content in bimetallic sodium loops consisting of ferritic steel and austenitic stainless steel, or – high temperature section of ferritic steel with low Cr content in monometallic sodium loops with temperature gradient	Reduction in creep strength of base metal and welds can occur.
	CSCC	– austenitic stainless steels or low alloy steels, and – presence of tensile stress, and – adherence of sodium-water reaction products, and – operation in gas space	Cracks can initiate in base metal, HAZ, and welds.
DF	SR	– operating temperature >375°C (707°F) (ferritic materials), 425°C (797°F) (austenitic stainless steels), and – secondary stress is present	Deformation of base metal, HAZ, and welds can progress.
	RD	– constant static stress is present, and – cyclic stress reaching the plastic range is present	Deformation of base metal, HAZ, and welds can accumulate.
LS	...	– stress is present, and – absence of a rotation lock	Reduction in bolt tension can occur.
SP [Note (1)]	LP	– potential for debris from failed components or materials to migrate into the coolant flow stream	Localized damage by abrasion or repeated impact due to flow perturbance or flow blockage can occur. Susceptible areas include core cooling channels or heat exchanger inlets and locations with limited clearances that require relative movement for component function.
	RIA [Note (1)]	– components that are inaccessible for conventional volumetric or visual inspection	Applicable areas include regions with little or no physical access, environments hazardous to personnel, environments for which equipment for MANDE cannot be used, and cost/benefit of inservice inspection is prohibitive relative to facility reliability goals.

Legend:
CE = creep embrittlement
CFI = creep fatigue interaction
CP = creep
CR = corrosion
CSCC = caustic stress corrosion cracking
CV = cavitation
DCA = decarburization
DEP = degradation enhancement phenomena
DF = deformation
FIV = flow-induced vibration
FW = fretting wear
HTD = high-temperature degradation
LME = liquid metal embrittlement
LP = loose parts
LS = looseness

Table VII-2.2-1
Degradation Mechanism Attributes and Attribute Criteria (SFR) (Cont'd)

(Cont'd)

MF = mechanical fatigue
MT = mass transfer
NIE = neutron irradiation effect
RD = ratcheting deformation
RIA = restricted inspection access [Note (1)]
SP = spatial phenomena [Note (1)]
SR = stress relief
SRC = stress relaxation cracking
TA = thermal aging
TASCS = thermal stratification cycling and striping
TF = thermal fatigue
TT = thermal transients
VF = vibration fatigue

NOTE: (1) RIA and SP are not degradation mechanisms but should be considered in the development or application of MANDE criteria established by the MANDEEP.

service, which also serves as reexamination. The pressure of the system shall be raised such that the pressure in all points of the system is not less than the pressure at full-power operation. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-2.4.3-1.

VII-2.4.1.2 Continuous Leakage Monitoring of Cover Gas

(a) General

(1) The continuous leakage monitoring of cover gas required by the RIM Program and performed to meet the requirements of VII-2.3.1.3 shall be evaluated by comparing the monitoring results with the acceptance standards specified in Table VII-2.4.3-1.

(2) Acceptance of components for continued service shall be in accordance with (b).

(b) Acceptance. A component with continuous leakage monitoring that demonstrates the absence of the confirmed leakages described in the standards of Table VII-2.4.3-1 is acceptable for continued service.

(c) Repair/Replacement Activity and Reexamination. The repair/replacement activity and reexamination shall comply with the requirements of Article RIM-4, except for RIM-4.2. In lieu of the system leakage test required by RIM-4.2, continuous leakage monitoring may be conducted to meet the requirements of VII-2.3.1.3 prior to return to service, which also serves as reexamination. The pressure of the system shall be raised such that the pressure in all points of the system is not less than the pressure at full-power operation. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-2.4.3-1.

VII-2.4.1.3 Preservice Visual Examinations

(a) General

(1) The preservice visual examinations required by RIM-2.7.3 and performed in accordance with RIM-2.9 shall receive an NDE evaluation by comparing the examination results with the acceptance standards specified in Table VII-2.4.3-1.

(2) Acceptance of components for service shall be in accordance with (b).

(b) Acceptance

(1) Acceptance by Visual Examination

(-a) A component whose visual examination confirms the absence of the relevant conditions described in the standards of Table VII-2.4.3-1 is acceptable for service.

(-b) A component whose visual examination detects the relevant conditions described in the standards of Table VII-2.4.3-1 is unacceptable for service, unless such components meet the requirements of (2) or (3) prior to placement of the component in service.

(2) Acceptance by Supplemental Examination. A component containing relevant conditions is acceptable for service if the results of supplemental examinations (see VII-2.4.2) meet the requirements of VII-2.4.1.1.

(3) Acceptance by Corrective Measures or Repair/Replacement Activity. A component containing relevant conditions is acceptable for service if the relevant conditions are corrected by a repair/replacement activity or by corrective measures to the extent necessary to meet the acceptance standards of Table VII-2.4.3-1.

(c) Repair/Replacement Activity and Preservice Examination. The repair/replacement activity and preservice examination shall comply with the requirements of Article RIM-4. Preservice examination shall be conducted in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected

to the repair/replacement activity meets the acceptance standards of Table VII-2.4.3-1.

VII-2.4.1.4 Inservice Visual Examinations

(a) General

(1) The visual examinations required by RIM-2.7.7 and performed in accordance with RIM-2.9.1 shall be evaluated by comparing the examination results with the acceptance standards specified in Table VII-2.4.3-1.

(2) Acceptance of components for continued service shall be in accordance with (b).

(b) Acceptance

(1) Acceptance by Visual Examination

(-a) A component whose visual examination confirms the absence of the relevant conditions described in the standards of Table VII-2.4.3-1 is acceptable for continued service.

(-b) A component whose visual examination detects the relevant conditions described in the standards of Table VII-2.4.3-1 is unacceptable for continued service, unless such components meet the requirements of (2), (3), or (4).

(2) Acceptance by Supplemental Examination. A component containing relevant conditions is acceptable for continued service if the results of supplemental examinations (see VII-2.4.2) meet the requirements of VII-2.4.1.3.

(3) Acceptance by Corrective Measures or Repair/Replacement Activity. A component containing relevant conditions is acceptable for continued service if the relevant conditions are corrected by a repair/replacement activity or by corrective measures to the extent necessary to meet the acceptance standards of Table VII-2.4.3-1.

(4) Acceptance by Evaluation. A component containing relevant conditions is acceptable for continued service if an evaluation demonstrates the component's acceptability. The evaluation and acceptance criteria shall be specified by the Owner. A component accepted for continued service based on evaluation shall be subsequently examined in accordance with RIM-2.7.6.3(a) and RIM-2.7.6.3(b). If the subsequent RIM-2.7.6.3(a) and RIM-2.7.6.3(b) examinations reveal that the relevant conditions remain essentially unchanged, or the changes in the relevant conditions are within the limits predicted by the evaluation, and the design inputs for the evaluation have not been affected by activities such as power uprates, the existing evaluation may continue to be used, provided it covers the time period until the next examination.

(c) Repair/Replacement Activity and Reexamination. The repair/replacement activity and reexamination shall comply with the requirements of Article RIM-4. Reexamination shall be conducted in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected to the repair/replacement activity meets the acceptance standards of Table VII-2.4.3-1.

VII-2.4.2 Supplemental Examinations

(a) Visual examinations that detect relevant conditions described in the standards of this Article may be supplemented by surface or volumetric examinations as established by the MANDEEP and documented in the MANDE Specification to determine the extent of the unacceptable conditions and the need for corrective measures, evaluation, or repair/replacement activities.

(b) Supplemental examinations shall meet the requirements of RIM-2.9.4 and Mandatory Appendix IV.

VII-2.4.3 Acceptance Standards

The acceptance standards referenced in Table VII-2.4.3-1 shall be applied to determine acceptability for service.

VII-2.5 ACCEPTANCE STANDARDS FOR SPECIFIC EXAMINATION CATEGORIES

VII-2.5.1 Standards for Examination Categories F-A for Liquid-Sodium-Retaining Components

VII-2.5.1.1 Continuous Leakage Monitoring of Liquid Sodium. Leakage indications shall be evaluated as confirmed or unconfirmed in accordance with the procedure determined by the Owner in advance, including the time for confirmation of leakage. Leakage indications shall be evaluated as confirmed if confirmation takes longer than the determined time. Confirmed liquid sodium leakage shall be cause for immediate shutdown of the system. The system is unacceptable for service until the source of the indicated leakage has been identified and isolated or repaired; the component containing the indicated leakage is unacceptable for service until the leak has been repaired. Unconfirmed indications shall be considered faults of the monitoring system, and the leak detectors shall be repaired to meet the minimum

Table VII-2.4.3-1
Acceptance Standards

Examination Category	Component and Part Examined	Acceptance Standard
F-A	Liquid-sodium-retaining welds in vessels and piping, and liquid-sodium-retaining valves	VII-2.5.1
F-B	Cover-gas-retaining welds and nonwelded gas seals in vessels and piping, and cover gas-retaining valves and bolting	VII-2.5.2
F-F-A	Supports	VII-2.5.3

percentage of working leak detectors required in VII-2.3.1.1(b).

VII-2.5.2 Standards for Examination Category F-B for Cover-Gas-Retaining Components

VII-2.5.2.1 Continuous Leakage Monitoring of Cover Gas. Leakage indications shall be evaluated as confirmed or unconfirmed in accordance with the procedure determined by the Owner in advance. Confirmed leaks of cover gas shall be cause for immediate shutdown of the system, to the extent necessary to establish the requirements for corrective action. Unconfirmed indications shall be considered faults of the monitoring system, and the leak detectors shall be repaired to meet the minimum percentage of working leak detectors required in VII-2.3.1.1(b).

VII-2.5.3 Standards for Examination Category F-F-A for Supports

VII-2.5.3.1 Acceptance by Examination. Component supports whose examinations do not reveal conditions described in VII-2.5.3.4(a) are acceptable for continued service. Confirmed changes in conditions from prior examinations shall be recorded in accordance with RIM-1.4(h).

VII-2.5.3.2 Acceptance by Corrective Measures or Repair/Replacement Activity. A support whose examination detects conditions described in VII-2.5.3.4(a) is unacceptable for continued service until such conditions are corrected by one or more of the following:

(a) adjustment and reexamination for conditions such as

(1) detached or loosened mechanical connections

(2) improper hot or cold settings of spring supports and constant load supports

(3) misalignment of supports

(4) improper displacement settings of guides and stops

(b) repair/replacement activities in accordance with Division 1, Article IWA-4000 and reexamination

VII-2.5.3.3 Acceptance by Evaluation or Test

(a) As an alternative to the requirements of VII-2.5.3.2, a component support or a portion of a component support containing relevant conditions that do not meet the acceptance standards of VII-2.5.3.4 is acceptable for service without corrective actions if an evaluation or test demonstrates that the component support is acceptable for service.

(b) If a component support or a portion of a component support has been evaluated or tested and determined to be acceptable for service in accordance with (a), the Owner may perform corrective measures to restore the component support to its original design condition.

VII-2.5.3.4 Acceptance Standards — Component Support Structural Integrity

(a) Component support conditions that are unacceptable for continued service shall include the following:

(1) deformations or structural degradations of fasteners, springs, clamps, or other support items

(2) missing, detached, or loosened support items

(3) arc strikes, weld spatter, paint, scoring, roughness, or general corrosion on close tolerance machined or sliding surfaces

(4) improper hot or cold settings of spring supports and constant load supports

(5) misalignment of supports

(6) improper clearances of guides and stops

(7) evidence of fluid leakage from viscoelastic dampers

(b) Except as defined in (a), the following are examples of nonrelevant conditions:

(1) fabrication marks (e.g., from punching, layout, bending, rolling, and machining)

(2) chipped or discolored paint

(3) weld spatter on other than close tolerance machined or sliding surfaces

(4) scratches and surface abrasion marks

(5) roughness or general corrosion that does not reduce the load bearing capacity of the support

(6) general conditions acceptable by the material, Design, and/or Construction Specifications

VII-2.6 SUPPLEMENT I: STRUCTURAL RELIABILITY EVALUATION

VII-2.6.1 General

A structural reliability evaluation that considers the SSC-level structural integrity and the probability of failure of the SSC without MANDE under design-basis conditions shall be performed. Applicable failure modes shall be identified based on the degradation mechanisms associated with each SSC. The probability of failure shall be calculated for each of the failure modes. Effects of decreasing the probability of failure by MANDE shall not be considered. The calculated probability of failure shall be compared with the SSC Reliability Target.

VII-2.6.2 Approaches — Probabilistic and Deterministic

This procedure evaluates the reliability of SSCs while considering uncertainties associated with various parameters, such as load, resistance, environment, configuration, initial flaws, and reliability of instrumentation. Therefore, the procedure presumes the use of probabilistic approaches. However, there are cases in which available statistical information is insufficient to permit use of such an approach. For that reason, deterministic approaches are also allowed. Deterministic approaches may be used as a simplified method, regardless of the availability of statistical information.

VII-2.6.3 Input

VII-2.6.3.1 Input Based on Safety Evaluation

(a) Inputs based on the safety evaluation performed before the construction of the facility shall be described either probabilistically or deterministically.

(b) The safety evaluation of a facility usually involves operating and accident scenarios in which the component-level requirements (CLRs) are defined. In the derivation of each CLR, the characteristics of the facility, including the function and configuration of system design, are taken into account.

(c) Deterministically established CLRs shall be described, in accordance with the facility safety evaluation, using applicable conditions postulated in an accident scenario. Such CLRs shall define the allowable limits from a safety perspective. Failure shall be defined based on the CLR. Failure modes associated with each scenario shall also be identified.

VII-2.6.3.2 Input Related to Structural Evaluation. Structure-related input consists of information on those parameters that could potentially affect the integrity of an SSC. These include, but are not limited to, load, resistance, environment, configuration, and initial flaws. They may be used as initial CLRs. Statistical information of parameters, such as a postulated probability distribution, shall be compiled. If statistical information is not available, the Owner shall establish requirements for MANDE sufficient to ensure achievement of the specified Reliability Targets. The basis for these requirements shall be documented in accordance with Article RIM-6.

VII-2.6.4 Probabilistic Approach — Reliability Evaluation

VII-2.6.4.1 Evaluation Procedure. Procedures used for the reliability evaluation shall be capable of assessing applicable failure modes. Reliability evaluations shall be performed based on the Construction Code, in a way that provides statistical information without changing the assumptions in the Construction Code for the SSC. Additional procedures shall be provided to account for failure modes [e.g., stress relaxation cracking (SRC), neutron irradiation effect (NIE)] that are not addressed in the Construction Code. Evaluations not specified in the Construction Code shall be provided in the procedure. Nonmandatory Appendix A, Article A-5 may be used for the evaluation.

VII-2.6.4.2 Criteria. The evaluated reliability shall equal or exceed the SSC Reliability Target.

VII-2.6.5 Deterministic Approach — Margin Assessment

VII-2.6.5.1 Evaluation Procedure. Procedures used for the deterministic evaluation shall be capable of assessing all applicable failure modes. Procedures shall follow the provisions of the Construction Code of the SSC. Evaluations not specified in the Construction Code shall be provided in the procedure. Additional procedures shall be provided to account for failure modes that are not addressed in the Construction Code.

VII-2.6.5.2 Criteria. The evaluated reliability shall equal or exceed the CLRs.

VII-2.7 SUPPLEMENT II: LBB ASSESSMENT PROCEDURES

VII-2.7.1 General

This supplement describes an assessment procedure of leak before break (LBB) for components containing sodium coolant in SFRs. The LBB concept proposes that even if an initial crack exists or is postulated to exist in a component containing fluid, and even if the crack grows and then penetrates the structure, catastrophic failure can be avoided through leak detection and appropriate counter measures.

Concerns about material property changes caused by environmental effects shall be included in the assessment.

VII-2.7.2 Applicability

The LBB assessment is applicable when both of the following conditions apply:

(a) The component to be assessed shall be designed and constructed in accordance with the Construction Code.

(b) Leakage of sodium shall be detected before the leakage has a significant effect on the fracture evaluation.

VII-2.7.3 Assessment Procedure

The LBB assessment shall be performed assuming a through-wall crack in an evaluation target component. The LBB assessment flowchart is shown in Figure VII-2.7.3-1.

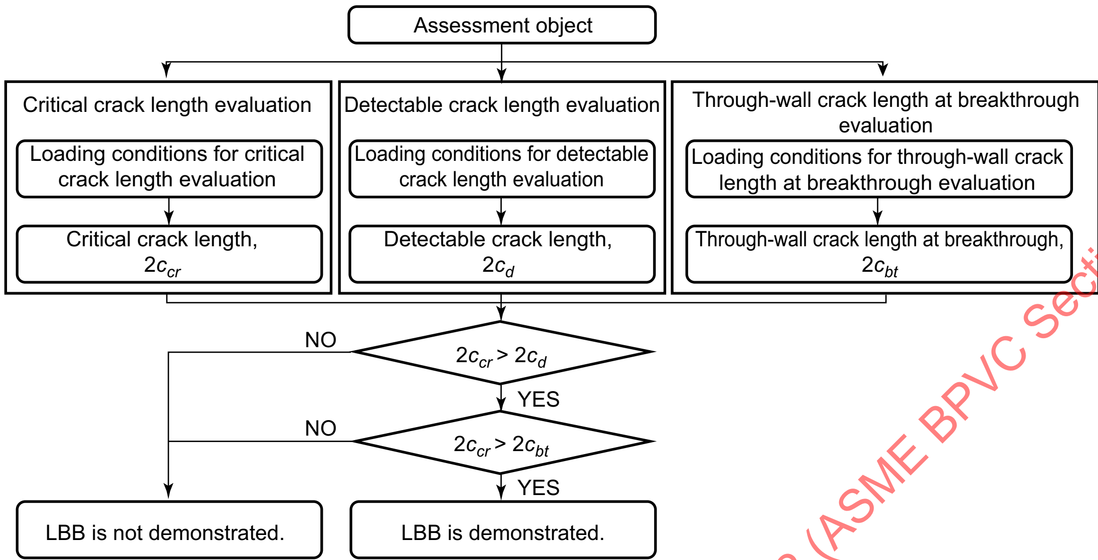
VII-2.7.3.1 Determination of Applied Load (Stress)

(a) Applied Load (Stress) for the Critical-Crack-Length Evaluation

(1) For an axial crack, only the circumferential stress due to internal pressure shall be included to evaluate an axial critical crack length.

(2) For a circumferential crack, only the primary stress perpendicular to the crack surface needs to be included. If the thermal expansion stress is classified as a secondary stress through an elastic follow-up evaluation, it may be neglected.

Figure VII-2.7.3-1
LBB Assessment Flow



(b) Applied Load (Stress) for Detectable-Crack-Length Evaluation. The stress perpendicular to the crack surface shall be included in the detectable-crack-length evaluation.

(c) Applied Load (Stress) for Through-Wall Crack Length at Breakthrough Evaluation. The variable stress due to plant operation that is perpendicular to the crack surface shall be used.

VII-2.7.3.2 Crack-Length Evaluation

(a) Critical-Crack-Length Evaluation. Critical crack length, C_{cr}, shall be evaluated using VII-2.7.4 or finite element analysis (FEA). A structural factor shall be applied to the load (stress), so that the critical crack length is conservative. A structural factor of 1.6 shall be applied for circumferential through-wall cracks, and a factor of 1.8 shall be applied for axial through-wall cracks.

(b) Detectable-Crack-Length Evaluation. The shape of the through-wall crack shall be replaced by a rectangle. Detectable crack length, C_d, shall be evaluated by a crack-opening displacement and leak-rate evaluation using VII-2.7.5.

(c) Through-Wall Crack Length at Breakthrough Evaluation. Through-wall crack length at breakthrough, C_{bt}, shall be evaluated using VII-2.7.6 or FEA.

VII-2.7.3.3 Criteria. C_{cr} shall be longer than both C_d and C_{bt}.

VII-2.7.4 Critical-Crack-Length Evaluation

VII-2.7.4.1 Scope This subparagraph delineates the evaluation method for the calculation of the critical length of axial and circumferential through-wall cracks in a vessel or pipe.

VII-2.7.4.2 Nomenclature

c = crack half-length, in. (mm)
c_{cr} = critical crack half-length on inner side, in. (mm)
D = outer diameter of the cylindrical shape, in. (mm)
E = Young's modulus, ksi (MPa)
J = J-integral, in.-lb/in.^{2} (kJ/m^2)
J_R = J-integral resistance to ductile tearing at prescribed Δc value obtained from accepted test procedures, in.-lb/in.^{2} (kJ/m^2)
J_e = linear elastic J-integral, in.-lb/in.^{2} (kJ/m^2)
K = stress intensity factor, ksi $\sqrt{\text{in.}}$ (MPa $\sqrt{\text{mm}}$)
K_r = ordinate of failure assessment diagram curve
K_r' = value of ordinate of the evaluation point on failure assessment diagram curve
M_2 = bulging factor
P_{bg} = global bending stress, ksi (MPa)
P_m = membrane stress, ksi (MPa)
p = inner pressure, ksi (MPa)
R = mean radius, in. (mm)
R_i = inside radius, in. (mm)
SF = structural factor
S_r = abscissa of failure assessment diagram
S_r' = value of abscissa of the evaluation point on failure assessment diagram curve

$S_{r\text{-max}}$ = maximum value of S_r at vertical (limit load) boundary of failure assessment diagram
t = thickness, in. (mm)
β = angle to neutral axis, radians
ε_{ref} = reference strain
θ = crack half angle, radians
θ_{cr} = critical crack half-angle ($\theta_{cr} \le \pi/2$), radians
σ_f = flow stress, defined by $(\sigma_y + \sigma_u)/2$, ksi (MPa)
σ_{ref} = reference stress, ksi (MPa)
σ_u = ultimate tensile strength, ksi (MPa)
σ_y = yield tensile strength, ksi (MPa)

VII-2.7.4.3 Determination of Analysis Method

(a) For wrought base metal or non-flux welds of austenitic stainless steels, limit load method is applied.

(b) For other materials, a failure assessment diagram (FAD) method is applied.

VII-2.7.4.4 Limit Load Method. A critical crack half-length, c_{cr}, is calculated using the following equations:

(a) For circumferential through-wall cracks

$$c_{cr} = R_i\theta_{cr} \tag{VII-2-1}$$

The critical crack half-angle, θ_{cr}, can be obtained for membrane stress, P_m, and global bending stess, P_{bg}, by satisfying eqs. (VII-2-2) and (VII-2-3).

$$P_{bg} = \frac{2\sigma_f}{\text{SF}\pi}(2\sin\beta - \sin\theta_{cr}) \tag{VII-2-2}$$

$$\beta = \frac{1}{2}\left(\pi - \theta_{cr} - \pi\frac{P_m}{\sigma_f}\right) \tag{VII-2-3}$$

where a structural factor, SF, equals 1.6.

(b) For axial through-wall cracks

$$c_{cr} = \sqrt{\left[\left(\frac{\sigma_f}{\text{SF}}\frac{2t}{pD}\right)^2 - 1\right]\frac{Rt}{1.61}} \tag{VII-2-4}$$

where a structural factor, SF, equals 1.8.

VII-2.7.4.5 Failure Assessment Diagram Method. Figure VII-2.7.4.5-1 shows an image of FAD. Evaluation procedures are as follows:

Step 1. Set the material properties, i.e., modulus of elasticity, yield strength, tensile strength, stress-strain relation, J-R curve.

Step 2. Calculate the $S_{r\text{-max}}$.

$$S_{r\text{-max}} = \frac{\sigma_f}{\sigma_y} \tag{VII-2-5}$$

Step 3. Plot the coordinates (S_r, K_r) as failure assessment curve (FAC) on FAD.

$$K_r(S_r) = \sqrt{\frac{J_e}{J}} \tag{VII-2-6}$$

$$S_r = \frac{\sigma_{\text{ref}}}{\sigma_y} \tag{VII-2-7}$$

$$J = \frac{E\varepsilon_{\text{ref}}}{\sigma_{\text{ref}}}J_e \tag{VII-2-8}$$

$$J_e = \frac{K^2}{E} \tag{VII-2-9}$$

Here, σ_{ref} for circumferential cracks is given by

$$\sigma_{\text{ref}} = \frac{\pi}{2(2\sin\beta - \sin\theta)}P_{bg} \tag{VII-2-10}$$

$$\beta = \frac{1}{2}\left(\pi - \theta - \pi\frac{P_m}{\sigma_y}\right) \tag{VII-2-11}$$

σ_{ref} for axial cracks is given by

$$\sigma_{\text{ref}} = \frac{pDM_2}{2t} \tag{VII-2-12}$$

$$M_2 = \sqrt{1 + 1.61\frac{c^2}{Rt}} \tag{VII-2-13}$$

Step 4. The coordinates of evaluation points (S_r', K_r') are calculated by considering a specified amount of ductile flaw extension, $\Delta\theta$ or Δc.

S_r' is defined by the following equations:

$$S_r' = \text{SF}\frac{\sigma_{\text{ref}}}{\sigma_y} \tag{VII-2-14}$$

where SF is the same value as in the limit load method and σ_{ref} is calculated the same as in Step 3.

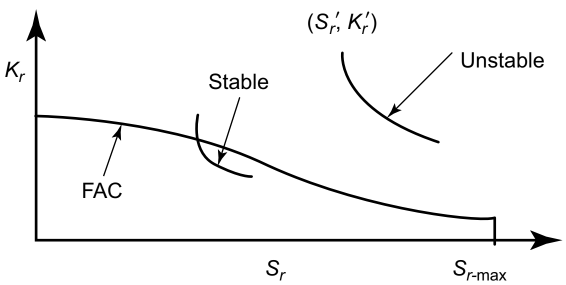
K_r' is defined by the following equation:

$$K_r' = \sqrt{\frac{J_e}{J_R}} \tag{VII-2-15}$$

where J_R and J_e are also calculated for each value of crack length.

The linear elastic J-integral is calculated the same as in Step 3. When J_e is calculated, structural factors of 1.8 for applied primary membrane stress and 1.6 for applied primary bending stress shall be applied in the K calculation.

Figure VII-2.7.4.5-1
Schematic Image of Unstable Fracture Assessment by FAD Method



Step 5. Plot the coordinates (S_r', K_r') as evaluation curve on FAD.

Step 6. If any evaluation point is located under the FAC and lower than $S_{r\text{-max}}$, the crack is stable.

Step 7. When the evaluation curve is in contact with the FAC, the crack size, c, is determined as c_{cr}.

VII-2.7.5 Detectable-Crack-Length Evaluation

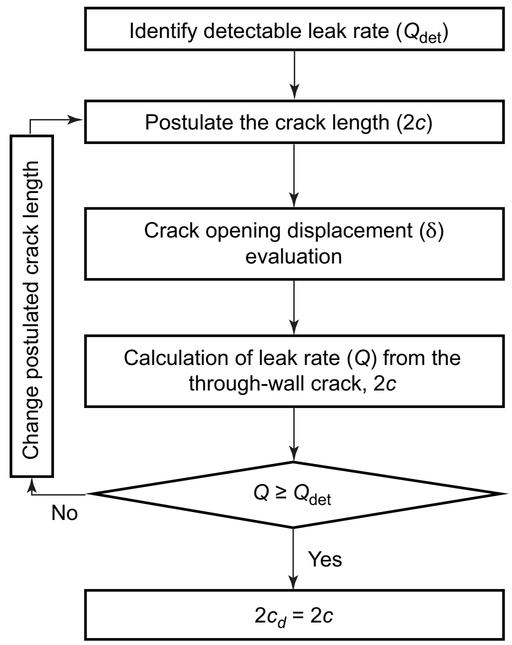
VII-2.7.5.1 Scope This subparagraph delineates the evaluation method for calculation of crack opening displacement (COD) of axial and circumferential through-wall cracks in a vessel or pipe and leakage rate of sodium from a through-wall crack.

VII-2.7.5.2 Nomenclature

A = crack opening area, in.^{2} (mm^2)
A^B = shape correction coefficient to calculate COD for bending stress
A^T = shape correction coefficient to calculate COD for membrane stress
c = crack half-length on inner side, in. (mm)
c_d = detectable crack half-length on inner side, in. (mm)
D_h = hydraulic diameter, in. (mm)
E = Young's modulus, ksi (MPa)
f_F = friction factor
k_B = correction factor due to flow pass configuration.
k_C = correction factor due to surface roughness
L = length of the flow path (equal to the plate thickness), in. (mm)
M = bending moment, in.-kip (N-mm)
$m_1 \sim m_4$ = coefficients used to calculate local plastic COD for circumferential cracks
M_0 = plastic collapse bending moment, in.-kip (N-mm)
M_d = margin of error for detectable leak rate
n = exponent of Ramberg-Osgood stress-strain relation $\left[\frac{\varepsilon}{\varepsilon_0} = \frac{\sigma}{\sigma_0} + \alpha\cdot\left(\frac{\sigma}{\sigma_0}\right)^n\right]$
P = tensile load, kips (N)
P_0 = plastic collapse tensile load, kips (N)
P_0' = plastic collapse load for tension and bending
Δp = difference in pressure inside and outside, ksi (MPa)
Q = leak rate, lb/s (kg/s)
Q_{det} = detectable leak rate using installed leak detector, lb/s (kg/s)
R = mean radius, in. (mm)
Re = Reynolds number
t = thickness, in. (mm)
V = average velocity of the leak flow through the flow path, in./s (mm/s)
V_1^B = coefficient to calculate elastic crack opening displacement for circumferential cracks due to bending stress
V_1^T = coefficient to calculate elastic crack opening displacement for circumferential cracks due to tensile stress
V_2 = coefficient to calculate elastic crack opening displacement for axial cracks
W = equal to half of axial length of cylindrical shape for axial cracks
X = ratio of applied load to the collapse load
α = coefficient of Ramberg-Osgood stress-strain relation $\left[\frac{\varepsilon}{\varepsilon_0} = \frac{\sigma}{\sigma_0} + \alpha\cdot\left(\frac{\sigma}{\sigma_0}\right)^n\right]$
δ = COD, in. (mm)
δ_E = elastic COD, in. (mm)
δ_E^B = elastic COD due to bending stress, in. (mm)
δ_E^T = elastic COD due to tensile stress, in. (mm)
δ_{PL} = fully plastic COD, in. (mm)
δ_{PS} = local plastic COD, in. (mm)
$\Delta\sigma_b$ = bending stress range, ksi (MPa)
$\Delta\sigma_m$ = membrane stress range, ksi (MPa)
ε_0 = reference strain (proportional strain)
ζ = membrane and bending stress ratio
η_1 = coefficients used to calculate fully plastic COD for circumferential cracks
λ = ratio of bending moment to the tensile load
θ = crack half angle, radians
ν = kinematic viscosity of sodium, in.^{2}/s (mm^2/s)
ρ = density of sodium, lb/in.^{3} (kg/mm^3)
σ_0 = reference stress (proportional stress), ksi (MPa)
σ_{bg} = global bending stress, ksi (MPa)
σ_t = membrane stress, ksi (MPa)

VII-2.7.5.3 Evaluation Procedure. The leak rate assessment procedure is shown in Figure VII-2.7.5.3-1. The detectable crack length, c_d, is obtained from the crack opening displacement assessment and the detectable hydraulic diameter assessment. The detectable leak rate, Q_{det}, shall be determined by considering

Figure VII-2.7.5.3-1
Detectable Crack Length Evaluation Procedure



uncertainty of leakage detection capability of the detectors adequately.

VII-2.7.5.4 Crack Opening Displacement Evaluation. Figures VII-2.7.5.4-1 and VII-2.7.5.4-2 show images of circumferential and axial crack geometries. Crack opening displacement, d, is calculated using the following equations or FEA:

(a) For Circumferential Cracks

The total elasto-plastic COD is given by the summation of elastic, locally plastic, and fully plastic components, as follows:

$$\delta = \delta_E + \delta_{PS} + \delta_{PL} \tag{VII-2-16}$$

Elastic component, δ_E , in eq. (VII-2-16) is given by the following equations:

$$\delta_E = \delta_E^T + \delta_E^B \tag{VII-2-17}$$

The COD by elastic membrane stress is given by

$$\delta_E^T = \frac{4\sigma_t R\theta V_1^T}{E} \tag{VII-2-18}$$

$$V_1^T = 1 + A^T\left[4.55\left(\frac{\theta}{\pi}\right)^{1.5} + 47.0\left(\frac{\theta}{\pi}\right)^3\right] \tag{VII-2-19}$$

$$A^T = 0.33\left(\frac{R}{t}\right)^{0.46} \tag{VII-2-20}$$

The COD by elastic bending stress is given by

$$\delta_E^B = \frac{4\sigma_{bg} R\theta V_1^B}{E} \tag{VII-2-21}$$

$$V_1^B = 1 + A^B\left[6.071\left(\frac{\theta}{\pi}\right)^{1.5} + 24.15\left(\frac{\theta}{\pi}\right)^{2.94}\right] \tag{VII-2-22}$$

$$A^B = 0.33\left(\frac{R}{t}\right)^{0.48} \tag{VII-2-23}$$

The locally plastic component, δ_{PS}, is given by the following equations:

$$\delta_{PS} = \left(m_1 X + m_2 X^2 + m_3 X^3 + m_4 X^4\right) R\varepsilon_0 \tag{VII-2-24}$$

where m_1 through m_4 are provided in Tables VII-2.7.5.4-1 through VII-2.7.5.4-12.

Here, for pure membrane stress conditions

$$X = \frac{P}{P_0} \tag{VII-2-25}$$

$$P = 2\pi Rt\sigma_t \tag{VII-2-26}$$

$$P_0 = 2\sigma_0 Rt\left[\pi - \theta - 2\sin^{-1}(0.5\sin\theta)\right] \tag{VII-2-27}$$

For pure bending conditions

$$X = \frac{M}{M_0} \tag{VII-2-28}$$

$$M = \pi R^2 t\sigma_{bg} \tag{VII-2-29}$$

$$M_0 = 4\sigma_0 R^2 t\left[\cos\left(\frac{\theta}{2}\right) - 0.5\sin\theta\right] \tag{VII-2-30}$$

For combination of membrane and bending stress conditions

$$X = \frac{P}{P_0{}'} \tag{VII-2-31}$$

$$P_0{}' = 0.5\left[-\frac{\lambda R P_0^2}{M_0} + \left\{\left(\frac{\lambda R P_0^2}{M_0}\right)^2 + 4P_0^2\right\}^{0.5}\right] \tag{VII-2-32}$$

$$\lambda = \frac{M}{PR} \tag{VII-2-33}$$

The large-scale yielding component, δ_{PL}, is given by the following equation:

$$\delta_{PL} = \alpha \varepsilon_0 R \theta \eta_1 X^n \tag{VII-2-34}$$

where η_1 is provided in Table VII-2.7.5.4-13.

(b) For Axial Cracks

The COD on axial through-wall crack is calculated using following equations:

$$\delta = \delta_E \tag{VII-2-35}$$

$$\delta_E = \frac{4c\sigma_t}{E}V_2 \tag{VII-2-36}$$

$$V_2 = 1 + 0.065\frac{c}{W} - 0.241\left(\frac{c}{W}\right)^2 + 3.76\left(\frac{c}{W}\right)^3 - 6.63\left(\frac{c}{W}\right)^4 + 4.93\left(\frac{c}{W}\right)^5 \tag{VII-2-37}$$

where the value of V_2 can be applied as 1, if W cannot be defined.

VII-2.7.5.5 Leak Rate Evaluation. The leak rate, Q, from the postulated crack, $2c$, is given by the following equations:

$$Q = \frac{\rho V A}{M_d} \tag{VII-2-38}$$

$$A = \pi\frac{\delta}{2}c \tag{VII-2-39}$$

Flow velocity, V, is given by the following equations:

$$V = \sqrt{\frac{2\Delta p}{\rho\left[1.5 + \frac{f_F\{1 + \zeta k_C + (1-\zeta)k_B\}L}{D_h}\right]}\cdot 1000} \tag{VII-2-40}$$

$$\zeta = \frac{\Delta\sigma_m}{\Delta\sigma_m + \Delta\sigma_b} \tag{VII-2-41}$$

$$f_F = \begin{cases} \dfrac{96}{R_e} & (R_e \le 2000) \\ 0.508R_e^{-0.3} & (R_e > 2000) \end{cases} \tag{VII-2-42}$$

$$R_e = \frac{D_h V}{\nu} \tag{VII-2-43}$$

$$D_h = \frac{\pi}{2\sqrt{1 + 1.464\left(\dfrac{\delta}{2c}\right)^{1.65}}}\delta \tag{VII-2-44}$$

$$k_C = \begin{cases} 9 & (\delta < 0.0142) \\ 0.0111\delta^{-1.60} - 1 & (0.0142 \le \delta < 0.0600) \\ 0 & (0.0600 \le \delta) \end{cases} \tag{VII-2-45}$$

$$k_B = \begin{cases} 19 & (\delta < 0.0534) \\ 0.184\delta^{-1.60} - 1 & (0.0534 \le \delta < 0.347) \\ 0 & (0.347 \le \delta) \end{cases} \tag{VII-2-46}$$

where M_d is a margin of error of 3.0 for detectable leak rate to account for the variation in experimental results.

VII-2.7.6 Through-Wall Crack Length at Breakthrough Evaluation

VII-2.7.6.1 Scope. This subparagraph delineates the evaluation method for calculation of through-wall crack length at breakthrough for circumferential and axial semicircular cracks on the inner surface of a vessel or pipe.

VII-2.7.6.2 Nomenclature

A_i = coefficients of through-wall crack length at breakthrough

B_{ji} = coefficients of through-wall crack length at breakthrough

c_{bt} = through-wall crack half-length at breakthrough on inner side, in. (mm)

C_{0ji}, C_{1ji}, C_{2ji}, C_{3ji}, C_{4ji} = coefficients of through-wall crack length at breakthrough

m = the slope of the log (da/dN) versus log (ΔJ)

R = mean radius, in. (mm)

t = thickness, in. (mm)

$\Delta\sigma_b$ = bending stress range, ksi (MPa)

$\Delta\sigma_m$ = membrane stress range, ksi (MPa)

ζ = membrane and bending stress ratio

VII-2.7.6.3 Through-Wall Crack Half-Length at Breakthrough Evaluation

(a) The circumferential through-wall crack half-length at breakthrough is given by

$$\frac{c_{bt}}{t} = \frac{A_1 \zeta}{A_2 + \zeta} + A_3 \qquad \text{(VII-2-47)}$$

where

$$A_i = B_{0i} + B_{1i} m + B_{2i} m^2 \qquad \text{(VII-2-48)}$$

$$B_{ji} = C_{0ji} + C_{1ji}\frac{R}{t} + C_{2ji}\left(\frac{R}{t}\right)^2 + C_{3ji}\left(\frac{R}{t}\right)^3 + C_{4ji}\left(\frac{R}{t}\right)^4 \qquad \text{(VII-2-49)}$$

C_{0ji} through C_{4ji} are provided in Table VII-2.7.6.3-1.

(b) The axial through-wall crack half-length at breakthrough is given by

$$\frac{c_{bt}}{t} = A_0 + A_1\zeta + A_2\zeta^2 + A_3\zeta^3 + A_4\zeta^4 + A_5\zeta^5 + A_6\zeta^6 \qquad \text{(VII-2-50)}$$

where

$$A_i = B_{0i} + B_{1i} m + B_{2i} m^2 + B_{3i} m^3 + B_{4i} m^4 \qquad \text{(VII-2-51)}$$

B_{0i} through B_{4i} are provided in Table VII-2.7.6.3-2.

$$\zeta = \frac{\Delta\sigma_m}{\Delta\sigma_m + \Delta\sigma_b} \qquad \text{(VII-2-52)}$$

Figure VII-2.7.5.4-1
Circumferential Crack Geometry

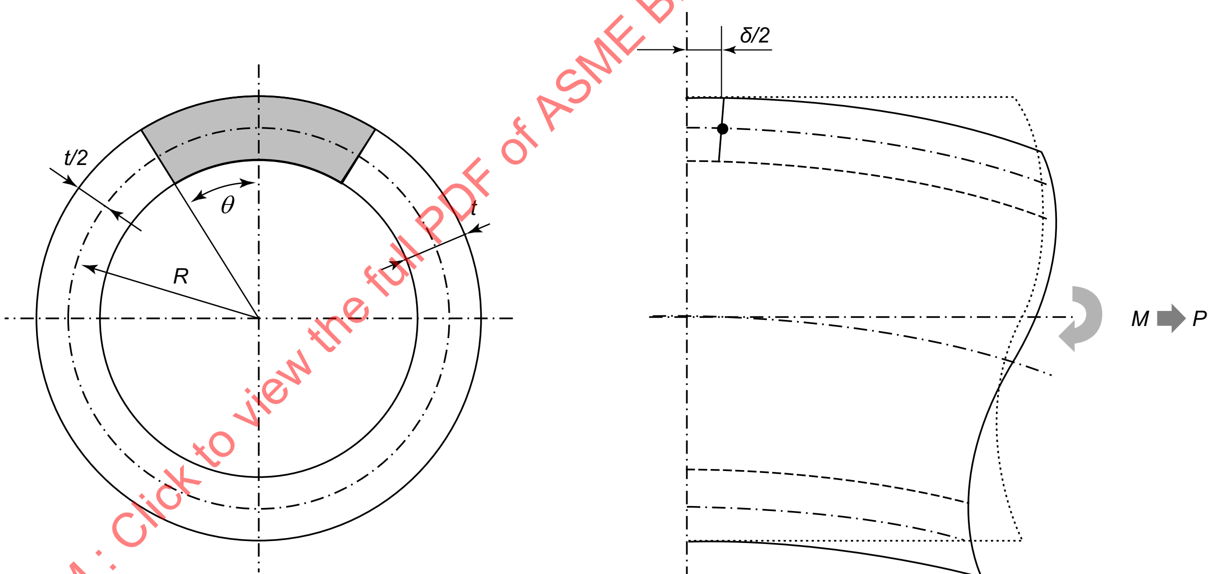


Figure VII-2.7.5.4-2
Axial Crack Geometry

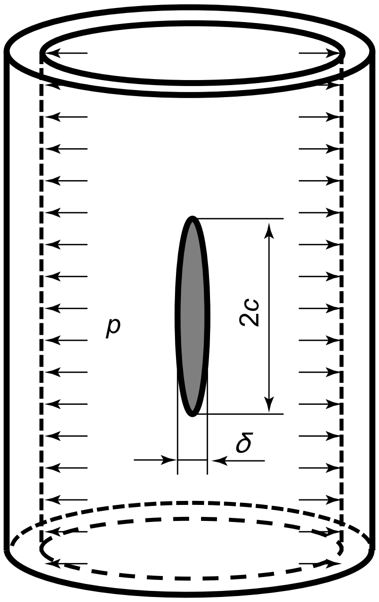


Table VII-2.7.5.4-1
Coefficients m_1, m_2, m_3, and m_4 (R/t = 5, n = 5)

		$\lambda/(1+\lambda)$				
θ/π	Coefficient	0.0	0.2	0.5	0.8	1.0
0.0625	m_1	9.13×10^{-3}	9.26×10^{-3}	5.81×10^{-2}	4.34×10^{-2}	3.64×10^{-2}
	m_2	-1.02×10^{-1}	-1.43×10^{-1}	-3.87×10^{-1}	-3.04×10^{-1}	-2.40×10^{-1}
	m_3	1.61×10^{-1}	2.50×10^{-1}	5.83×10^{-1}	4.62×10^{-1}	3.44×10^{-1}
	m_4	-4.12×10^{-2}	-4.87×10^{-2}	-1.29×10^{-1}	-1.05×10^{-1}	-7.70×10^{-2}
0.125	m_1	1.95×10^{-2}	4.38×10^{-2}	1.23×10^{-1}	8.41×10^{-2}	8.00×10^{-2}
	m_2	-2.18×10^{-1}	-3.53×10^{-1}	-7.48×10^{-1}	-5.69×10^{-1}	-4.80×10^{-1}
	m_3	3.37×10^{-1}	5.32×10^{-1}	1.08	8.50×10^{-1}	6.57×10^{-1}
	m_4	-8.16×10^{-2}	-9.63×10^{-2}	-2.32×10^{-1}	-1.88×10^{-1}	-1.44×10^{-1}
0.25	m_1	1.53×10^{-1}	1.87×10^{-1}	2.24×10^{-1}	1.67×10^{-1}	1.98×10^{-1}
	m_2	-7.35×10^{-1}	-9.96×10^{-1}	−1.35	−1.04	-9.81×10^{-1}
	m_3	8.60×10^{-1}	1.30	1.97	1.52	1.22
	m_4	-1.54×10^{-1}	-2.37×10^{-1}	-4.29×10^{-1}	-3.31×10^{-1}	-2.58×10^{-1}
0.375	m_1	1.96×10^{-1}	2.42×10^{-1}	1.48×10^{-1}	1.36×10^{-1}	1.91×10^{-1}
	m_2	−1.00	−1.37	−1.29	−1.07	−1.02
	m_3	1.23	1.88	2.21	1.71	1.32
	m_4	-2.02×10^{-1}	-3.60×10^{-1}	-4.78×10^{-1}	-3.58×10^{-1}	-2.58×10^{-1}
0.5	m_1	2.41×10^{-1}	1.76×10^{-1}	6.40×10^{-2}	1.31×10^{-1}	2.13×10^{-1}
	m_2	−1.27	−1.27	−1.10	−1.12	−1.12
	m_3	1.61	1.94	2.14	1.80	1.40
	m_4	-2.93×10^{-1}	-3.83×10^{-1}	-4.49×10^{-1}	-3.65×10^{-1}	-2.65×10^{-1}

Table VII-2.7.5.4-2
Coefficients m_1, m_2, m_3, and m_4 (R/t = 5, n = 15)

		$\lambda/(1+\lambda)$				
θ/π	Coefficient	0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-4.32×10^{-2}	-4.53×10^{-1}	-2.64×10^{-1}	-6.26×10^{-2}	-1.18×10^{-1}
	m_2	3.76×10^{-1}	2.99	2.03	5.62×10^{-1}	8.50×10^{-1}
	m_3	-9.84×10^{-1}	−5.97	−4.91	−1.72	−1.98
	m_4	8.23×10^{-1}	3.94	4.16	1.88	1.63
0.125	m_1	-2.45×10^{-1}	-7.51×10^{-1}	-5.19×10^{-1}	-1.38×10^{-1}	-1.98×10^{-1}
	m_2	1.58	4.79	3.61	9.71×10^{-1}	1.23
	m_3	−3.20	−9.30	−7.99	−2.53	−2.58
	m_4	2.21	6.15	6.54	2.78	2.17
0.25	m_1	-4.48×10^{-1}	-8.00×10^{-1}	-1.49×10^{-1}	-3.71×10^{-2}	-2.04×10^{-2}
	m_2	2.78	4.93	1.12	3.41×10^{-3}	-8.62×10^{-2}
	m_3	−5.58	−9.69	−3.44	-4.18×10^{-1}	-7.90×10^{-2}
	m_4	4.20	7.40	5.36	2.36	1.30
0.375	m_1	-4.08×10^{-1}	-5.13×10^{-1}	6.71×10^{-2}	-1.83×10^{-2}	9.23×10^{-2}
	m_2	2.34	2.89	-7.45×10^{-1}	-5.24×10^{-1}	-9.85×10^{-1}
	m_3	−4.77	−5.83	7.51×10^{-1}	1.13	1.71
	m_4	4.50	6.21	3.81	1.98	6.49×10^{-1}
0.5	m_1	-1.13×10^{-1}	-1.75×10^{-1}	-2.95×10^{-1}	-1.53×10^{-1}	1.74×10^{-1}
	m_2	3.46×10^{-1}	4.78×10^{-1}	8.79×10^{-1}	2.26×10^{-2}	−1.52
	m_3	−1.06	−1.04	−1.09	5.17×10^{-1}	2.56
	m_4	2.85	3.80	4.65	2.40	3.09×10^{-1}

Table VII-2.7.5.4-3
Coefficients m_1, m_2, m_3, and m_4 (R/t = 5, n = 25)

		$\lambda/(1+\lambda)$				
θ/π	Coefficient	0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-5.69×10^{-2}	-4.44×10^{-1}	-5.66×10^{-1}	-2.02×10^{-1}	-1.19×10^{-1}
	m_2	4.85×10^{-1}	3.43	4.63	1.72	9.80×10^{-1}
	m_3	−1.28	−7.88	-1.14×10	−4.56	−2.55
	m_4	1.11	5.83	9.23	4.15	2.28
0.125	m_1	-1.08×10^{-1}	-4.98×10^{-1}	-7.05×10^{-1}	-1.96×10^{-1}	-4.56×10^{-2}
	m_2	9.02×10^{-1}	3.89	5.61	1.61	4.09×10^{-1}
	m_3	−2.40	−9.26	-1.37×10	−4.46	−1.49
	m_4	2.17	7.43	1.17×10	4.77	2.06
0.25	m_1	-1.93×10^{-1}	-5.25×10^{-1}	-6.07×10^{-1}	-5.05×10^{-2}	9.88×10^{-2}
	m_2	1.59	4.07	4.57	2.44×10^{-1}	-8.03×10^{-1}
	m_3	−4.45	-1.03×10	-1.15×10	−1.45	9.81×10^{-1}
	m_4	4.61	9.86	1.24×10	4.18	1.37
0.375	m_1	-1.24×10^{-1}	-3.79×10^{-1}	-4.39×10^{-1}	8.03×10^{-2}	2.28×10^{-1}
	m_2	9.62×10^{-1}	2.70	2.83	−1.09	−1.92
	m_3	−3.43	−7.26	−7.12	1.82	3.37
	m_4	5.24	9.42	1.09×10	3.03	4.57×10^{-1}
0.5	m_1	8.40×10^{-2}	-5.33×10^{-2}	-1.93×10^{-1}	2.19×10^{-1}	3.22×10^{-1}
	m_2	-7.16×10^{-1}	3.09×10^{-2}	6.26×10^{-1}	−2.24	−2.55
	m_3	1.38×10^{-1}	−1.27	−1.87	4.27	4.42
	m_4	3.60	6.05	7.88	1.87	2.26×10^{-2}

Table VII-2.7.5.4-4
Coefficients m_1, m_2, m_3, and m_4 (R/t = 10, n = 5)

		$\lambda/(1 + \lambda)$				
θ/π	Coefficient	0.0	0.2	0.5	0.8	1.0
0.0625	m_1	2.28×10^{-3}	1.05×10^{-3}	5.98×10^{-2}	3.41×10^{-2}	3.46×10^{-2}
	m_2	-8.99×10^{-2}	-1.36×10^{-1}	-4.30×10^{-1}	-3.12×10^{-1}	-2.64×10^{-1}
	m_3	1.65×10^{-1}	2.77×10^{-1}	6.95×10^{-1}	5.38×10^{-1}	4.16×10^{-1}
	m_4	-4.26×10^{-2}	-5.44×10^{-2}	-1.56×10^{-1}	-1.24×10^{-1}	-9.52×10^{-2}
0.125	m_1	-4.47×10^{-3}	9.93×10^{-3}	1.32×10^{-1}	7.38×10^{-2}	3.78×10^{-2}
	m_2	-1.89×10^{-1}	-3.16×10^{-1}	-8.86×10^{-1}	-6.38×10^{-1}	-4.44×10^{-1}
	m_3	3.83×10^{-1}	6.21×10^{-1}	1.44	1.12	7.90×10^{-1}
	m_4	-9.46×10^{-2}	-1.10×10^{-1}	-3.13×10^{-1}	-2.56×10^{-1}	-1.77×10^{-1}
0.25	m_1	1.31×10^{-1}	1.61×10^{-1}	1.52×10^{-1}	1.05×10^{-1}	1.47×10^{-1}
	m_2	-8.27×10^{-1}	−1.10	−1.39	−1.09	−1.07
	m_3	1.19	1.81	2.74	2.20	1.77
	m_4	-2.20×10^{-1}	-3.38×10^{-1}	-6.21×10^{-1}	-5.05×10^{-1}	-3.96×10^{-1}
0.375	m_1	1.33×10^{-1}	1.98×10^{-1}	-5.36×10^{-2}	-1.16×10^{-2}	6.51×10^{-2}
	m_2	−1.03	−1.49	-9.77×10^{-1}	-9.01×10^{-1}	-9.27×10^{-1}
	m_3	1.68	2.67	2.99	2.45	1.88
	m_4	-2.82×10^{-1}	-5.36×10^{-1}	-6.81×10^{-1}	-5.46×10^{-1}	-3.90×10^{-1}
0.5	m_1	1.70×10^{-1}	7.51×10^{-2}	-1.67×10^{-1}	-6.62×10^{-2}	2.33×10^{-2}
	m_2	−1.33	−1.28	-6.85×10^{-1}	-8.28×10^{-1}	-8.94×10^{-1}
	m_3	2.19	2.73	2.87	2.47	1.85
	m_4	-4.07×10^{-1}	-5.60×10^{-1}	-6.24×10^{-1}	-5.20×10^{-1}	-3.59×10^{-1}

Table VII-2.7.5.4-5
Coefficients m_1, m_2, m_3, and m_4 (R/t = 10, n = 15)

		$\lambda/(1 + \lambda)$				
θ/π	Coefficient	0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-2.10×10^{-2}	-6.32×10^{-1}	-2.41×10^{-1}	-2.17×10^{-2}	-1.43×10^{-1}
	m_2	2.65×10^{-1}	4.17	2.24	4.74×10^{-1}	1.12
	m_3	-8.60×10^{-1}	−8.29	−6.13	−2.03	−2.76
	m_4	8.41×10^{-1}	5.46	5.67	2.60	2.40
0.125	m_1	-3.04×10^{-1}	−1.19	-4.05×10^{-1}	-5.01×10^{-2}	-2.81×10^{-1}
	m_2	1.96	7.57	3.46	6.11×10^{-1}	1.79
	m_3	−3.99	-1.45×10	−9.04	−2.42	−3.78
	m_4	2.92	9.63	8.91	3.86	3.48
0.25	m_1	-7.08×10^{-1}	−1.26	2.36×10^{-1}	-1.99×10^{-2}	-2.21×10^{-1}
	m_2	4.17	7.57	−1.13	-4.66×10^{-1}	6.48×10^{-1}
	m_3	−7.78	-1.40×10	7.80×10^{-1}	1.55	-2.64×10^{-1}
	m_4	6.18	1.12×10	5.75	2.90	2.30
0.375	m_1	-7.49×10^{-1}	-7.46×10^{-1}	1.44×10^{-1}	-3.05×10^{-1}	-1.66×10^{-1}
	m_2	4.01	4.01	−1.65	5.05×10^{-1}	-1.82×10^{-1}
	m_3	−6.81	−6.61	4.57	1.91	2.34
	m_4	6.72	8.60	4.42	3.19	1.28
0.5	m_1	-4.90×10^{-1}	-4.67×10^{-1}	−1.06	-7.71×10^{-1}	-1.74×10^{-1}
	m_2	2.07	1.75	4.75	2.86	-3.31×10^{-1}
	m_3	−2.74	−1.53	−4.74	−1.48	2.70
	m_4	4.96	6.02	9.04	5.10	1.18

Table VII-2.7.5.4-6
Coefficients m_1, m_2, m_3, and m_4 (R/t = 10, n = 25)

θ/π	Coefficient	$\lambda/(1+\lambda)$				
		0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-9.35×10^{-2}	-7.39×10^{-1}	-1.05	-4.00×10^{-1}	-2.96×10^{-1}
	m_2	7.48×10^{-1}	5.68	8.51	3.36	2.33
	m_3	-1.86	-1.29×10	-2.06×10	-8.63	-5.60
	m_4	1.55	9.36	1.63×10	7.53	4.61
0.125	m_1	-2.32×10^{-1}	-9.31×10^{-1}	-1.39	-4.32×10^{-1}	-1.79×10^{-1}
	m_2	1.79	7.20	1.10×10	3.47	1.37
	m_3	-4.37	-1.68×10	-2.65×10	-8.98	-3.71
	m_4	3.77	1.33×10	2.22×10	9.25	4.37
0.25	m_1	-4.28×10^{-1}	-1.08	-1.37	-3.15×10^{-1}	-1.18×10^{-2}
	m_2	3.10	8.00	1.00×10	1.67	-5.18×10^{-1}
	m_3	-7.48	-1.83×10	-2.24×10	-3.07	1.58
	m_4	7.83	1.75×10	2.32×10	7.79	2.56
0.375	m_1	-4.67×10^{-1}	-1.02	-1.25	-3.50×10^{-1}	8.26×10^{-3}
	m_2	2.99	6.93	8.26	1.14	-1.24
	m_3	-6.71	-1.46×10	-1.60×10	2.62×10^{-1}	4.44
	m_4	9.21	1.73×10	2.11×10	6.84	1.44
0.5	m_1	-2.95×10^{-1}	-7.21×10^{-1}	-1.31	-4.22×10^{-1}	7.72×10^{-2}
	m_2	1.28	4.12	7.95	1.24	-1.99
	m_3	-2.34	-7.48	-1.38×10	7.50×10^{-1}	6.09
	m_4	7.16	1.31×10	1.99×10	6.92	6.06×10^{-1}

Table VII-2.7.5.4-7
Coefficients m_1, m_2, m_3, and m_4 (R/t = 20, n = 5)

θ/π	Coefficient	$\lambda/(1+\lambda)$				
		0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-8.23×10^{-3}	-3.32×10^{-3}	6.97×10^{-2}	3.40×10^{-2}	2.67×10^{-2}
	m_2	-7.06×10^{-2}	-1.49×10^{-1}	-5.13×10^{-1}	-3.56×10^{-1}	-2.69×10^{-1}
	m_3	1.74×10^{-1}	3.39×10^{-1}	8.70×10^{-1}	6.73×10^{-1}	4.84×10^{-1}
	m_4	-4.56×10^{-2}	-6.78×10^{-2}	-1.98×10^{-1}	-1.59×10^{-1}	-1.11×10^{-1}
0.125	m_1	-5.71×10^{-2}	-3.76×10^{-2}	1.08×10^{-1}	1.36×10^{-2}	-1.22×10^{-2}
	m_2	-1.13×10^{-1}	-2.48×10^{-1}	-9.64×10^{-1}	-5.86×10^{-1}	-4.01×10^{-1}
	m_3	4.63×10^{-1}	7.79×10^{-1}	1.91	1.45	1.04
	m_4	-1.19×10^{-1}	-1.36×10^{-1}	-4.23×10^{-1}	-3.37×10^{-1}	-2.40×10^{-1}
0.25	m_1	8.02×10^{-2}	6.20×10^{-2}	-5.02×10^{-2}	-8.43×10^{-2}	1.85×10^{-2}
	m_2	-8.05×10^{-1}	-9.47×10^{-1}	-9.35×10^{-1}	-6.72×10^{-1}	-8.42×10^{-1}
	m_3	1.58	2.33	3.41	2.78	2.32
	m_4	-3.00×10^{-1}	-4.46×10^{-1}	-7.97×10^{-1}	-6.70×10^{-1}	-5.43×10^{-1}
0.375	m_1	3.21×10^{-2}	4.38×10^{-2}	-3.39×10^{-1}	-2.86×10^{-1}	-1.23×10^{-1}
	m_2	-8.60×10^{-1}	-1.20	-2.05×10^{-1}	-1.91×10^{-1}	-5.14×10^{-1}
	m_3	2.11	3.35	3.66	3.01	2.40
	m_4	-3.56×10^{-1}	-6.85×10^{-1}	-8.60×10^{-1}	-7.00×10^{-1}	-5.21×10^{-1}
0.5	m_1	3.74×10^{-2}	-1.81×10^{-1}	-5.82×10^{-1}	-4.25×10^{-1}	-2.06×10^{-1}
	m_2	-1.14	-7.39×10^{-1}	3.97×10^{-1}	7.98×10^{-2}	-3.93×10^{-1}
	m_3	2.78	3.39	3.47	2.99	2.34
	m_4	-5.27×10^{-1}	-7.08×10^{-1}	-7.75×10^{-1}	-6.42×10^{-1}	-4.63×10^{-1}

Table VII-2.7.5.4-8
Coefficients m_1, m_2, m_3, and m_4 (R/t = 20, n = 15)

θ/π	Coefficient	$\lambda/(1+\lambda)$ 0.0	0.2	0.5	0.8	1.0
0.0625	m_1	2.20×10^{-2}	-9.51×10^{-1}	-1.73×10^{-1}	1.09×10^{-1}	-8.35×10^{-2}
	m_2	5.26×10^{-2}	6.25	2.37	-4.09×10^{-2}	9.62×10^{-1}
	m_3	-6.13×10^{-1}	-1.23×10	−7.70	−1.86	−2.99
	m_4	8.66×10^{-1}	8.05	7.86	3.41	3.11
0.125	m_1	-4.72×10^{-1}	−1.91	-2.84×10^{-1}	8.43×10^{-2}	-3.65×10^{-1}
	m_2	2.94	1.19×10	3.31	-8.79×10^{-2}	2.31
	m_3	−5.73	-2.23×10	−9.96	−1.41	−4.70
	m_4	4.29	1.49×10	1.20×10	4.99	5.01
0.25	m_1	−1.23	−2.38	2.51×10^{-1}	-5.96×10^{-1}	-7.45×10^{-1}
	m_2	6.99	1.41×10	-8.90×10^{-1}	2.62	3.30
	m_3	-1.15×10	-2.36×10	2.15	-8.38×10^{-1}	−2.36
	m_4	8.97	1.79×10	7.88	5.67	4.30
0.375	m_1	−1.31	−1.37	−1.44	−1.48	-7.93×10^{-1}
	m_2	6.96	7.53	7.42	6.92	2.93
	m_3	-1.01×10	-1.02×10	−6.57	−4.69	3.95×10^{-1}
	m_4	9.63	1.25×10	1.27×10	8.16	3.22
0.5	m_1	-8.17×10^{-1}	-9.53×10^{-1}	−4.85	−2.48	-6.98×10^{-1}
	m_2	3.54	4.18	2.60×10	1.22×10	2.03
	m_3	−3.03	−2.37	-3.47×10	-1.24×10	2.13
	m_4	6.70	8.79	2.68×10	1.26×10	2.69

Table VII-2.7.5.4-9
Coefficients m_1, m_2, m_3, and m_4 (R/t = 20, n = 25)

θ/π	Coefficient	$\lambda/(1+\lambda)$ 0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-1.75×10^{-1}	−1.19	−1.81	-6.89×10^{-1}	-5.60×10^{-1}
	m_2	1.34	9.12	1.47×10	5.82	4.39
	m_3	−3.14	-2.06×10	-3.54×10	-1.48×10	-1.04×10
	m_4	2.50	1.49×10	2.77×10	1.28×10	8.31
0.125	m_1	-3.81×10^{-1}	−1.48	−2.36	-6.80×10^{-1}	-3.32×10^{-1}
	m_2	2.87	1.14×10	1.85×10	5.36	2.44
	m_3	−6.76	-2.61×10	-4.33×10	-1.33×10	−5.95
	m_4	6.00	2.10×10	3.66×10	1.46×10	7.36
0.25	m_1	-7.15×10^{-1}	−1.91	−2.74	-8.40×10^{-1}	-2.28×10^{-1}
	m_2	4.86	1.38×10	1.99×10	5.00	4.72×10^{-1}
	m_3	-1.00×10	-2.86×10	-4.02×10	−6.44	2.50
	m_4	1.10×10	2.68×10	3.89×10	1.27×10	3.72
0.375	m_1	-8.60×10^{-1}	−1.87	−2.72	−1.05	-2.56×10^{-1}
	m_2	5.43	1.28×10	1.87×10	5.62	-4.26×10^{-2}
	m_3	−9.82	-2.39×10	-3.32×10	−3.89	6.02
	m_4	1.34×10	2.68×10	3.72×10	1.27×10	2.38
0.5	m_1	-6.93×10^{-1}	−1.34	−2.88	−1.24	-2.40×10^{-1}
	m_2	3.61	8.16	1.90×10	6.50	-5.83×10^{-1}
	m_3	−4.58	-1.22×10	-3.15×10	−4.58	7.45
	m_4	1.14×10	2.05×10	3.71×10	1.42×10	2.03

Table VII-2.7.5.4-10
Coefficients m_1, m_2, m_3, and m_4 (R/t = 50, n = 5)

θ/π	Coefficient	$\lambda/(1+\lambda)$				
		0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-3.76×10^{-2}	-2.13×10^{-2}	1.11×10^{-1}	2.99×10^{-2}	5.16×10^{-3}
	m_2	-1.84×10^{-2}	-1.25×10^{-1}	-7.22×10^{-1}	-4.31×10^{-1}	-2.64×10^{-1}
	m_3	2.03×10^{-1}	4.27×10^{-1}	1.27	9.57×10^{-1}	6.42×10^{-1}
	m_4	-5.51×10^{-2}	-7.85×10^{-2}	-2.82×10^{-1}	-2.28×10^{-1}	-1.49×10^{-1}
0.125	m_1	-1.51×10^{-1}	-1.69×10^{-1}	6.25×10^{-2}	-1.13×10^{-1}	-1.40×10^{-1}
	m_2	5.04×10^{-2}	6.59×10^{-2}	-9.19×10^{-1}	-3.27×10^{-1}	-1.70×10^{-1}
	m_3	6.73×10^{-1}	1.02	2.73	2.06	1.52
	m_4	-1.76×10^{-1}	-1.62×10^{-1}	-5.99×10^{-1}	-4.92×10^{-1}	-3.69×10^{-1}
0.25	m_1	8.83×10^{-3}	-5.92×10^{-2}	-3.06×10^{-1}	-3.18×10^{-1}	-1.88×10^{-1}
	m_2	-7.00×10^{-1}	-5.36×10^{-1}	5.43×10^{-2}	2.11×10^{-1}	-1.92×10^{-1}
	m_3	2.18	3.02	4.15	3.50	2.94
	m_4	-4.23×10^{-1}	-5.76×10^{-1}	-9.92×10^{-1}	-8.75×10^{-1}	-7.17×10^{-1}
0.375	m_1	-2.13×10^{-1}	-2.33×10^{-1}	-9.21×10^{-1}	-7.71×10^{-1}	-5.05×10^{-1}
	m_2	-1.75×10^{-1}	-2.77×10^{-1}	2.02	1.62	6.73×10^{-1}
	m_3	2.45	3.96	3.64	3.16	2.78
	m_4	-3.99×10^{-1}	-8.18×10^{-1}	-8.76×10^{-1}	-7.65×10^{-1}	-6.43×10^{-1}
0.5	m_1	-3.71×10^{-1}	-7.92×10^{-1}	−1.49	−1.17	-7.96×10^{-1}
	m_2	-1.08×10^{-1}	1.06	3.59	2.52	1.29
	m_3	3.31	3.78	3.13	3.03	2.52
	m_4	-6.58×10^{-1}	-8.43×10^{-1}	-7.47×10^{-1}	-7.04×10^{-1}	-5.36×10^{-1}

Table VII-2.7.5.4-11
Coefficients m_1, m_2, m_3, and m_4 (R/t = 50, n = 15)

θ/π	Coefficient	$\lambda/(1+\lambda)$				
		0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-3.44×10^{-2}	−2.24	-3.42×10^{-1}	3.71×10^{-1}	-5.10×10^{-2}
	m_2	4.72×10^{-1}	1.41 × 10	4.45	−1.02	1.15
	m_3	−1.55	−2.65 × 10	−1.38 × 10	−1.64	−4.24
	m_4	1.73	1.65 × 10	1.41 × 10	5.38	5.08
0.125	m_1	−1.06	−3.90	-3.75×10^{-2}	2.06×10^{-2}	-8.25×10^{-1}
	m_2	6.29	2.38 × 10	3.01	6.14×10^{-1}	5.07
	m_3	−1.08 × 10	−4.18 × 10	−1.01 × 10	−1.60	−8.32
	m_4	7.69	2.67 × 10	1.63 × 10	7.78	8.58
0.25	m_1	−2.76	−4.29	-8.17×10^{-1}	−2.05	−1.95
	m_2	1.57 × 10	2.61 × 10	6.50	1.18 × 10	1.06 × 10
	m_3	−2.37 × 10	−4.15 × 10	−5.99	−1.12 × 10	−1.05 × 10
	m_4	1.62 × 10	2.94 × 10	1.56 × 10	1.30 × 10	9.63
0.375	m_1	−2.64	−2.67	−7.02	−4.68	−2.13
	m_2	1.46 × 10	1.60 × 10	4.02 × 10	2.58 × 10	1.05 × 10
	m_3	−1.91 × 10	−2.00 × 10	−5.30 × 10	−2.84 × 10	−6.22
	m_4	1.57 × 10	2.04 × 10	3.90 × 10	2.18 × 10	7.53
0.5	m_1	−1.92	−2.45	−1.54 × 10	−6.58	−2.04
	m_2	9.41	1.29 × 10	8.65 × 10	3.58 × 10	8.97
	m_3	−7.42	−9.88	-1.24×10^{2}	−4.21 × 10	−1.84
	m_4	1.09 × 10	1.56 × 10	7.45 × 10	2.97 × 10	5.82

Table VII-2.7.5.4-12
Coefficients m_1, m_2, m_3, and m_4 (R/t = 50, n = 25)

		$\lambda/(1+\lambda)$				
θ/π	Coefficient	0.0	0.2	0.5	0.8	1.0
0.0625	m_1	-3.23×10^{-1}	−2.07	−3.35	−1.32	−1.06
	m_2	2.46	1.59 × 10	2.71 × 10	1.11 × 10	8.34
	m_3	−5.67	−3.60 × 10	−6.47 × 10	−2.78 × 10	−1.96 × 10
	m_4	4.57	2.63 × 10	5.08 × 10	2.41 × 10	1.59 × 10
0.125	m_1	-5.94×10^{-1}	−2.57	−4.13	−1.41	-8.76×10^{-1}
	m_2	4.22	1.93 × 10	3.19 × 10	1.05 × 10	6.01
	m_3	−8.89	−4.19 × 10	−7.06 × 10	−2.21 × 10	−1.13 × 10
	m_4	8.66	3.39 × 10	5.96 × 10	2.40 × 10	1.31 × 10
0.25	m_1	−1.41	−3.77	−4.93	−2.03	-9.68×10^{-1}
	m_2	9.47	2.74 × 10	3.71 × 10	1.39 × 10	5.46
	m_3	−1.62 × 10	−5.25 × 10	−7.03 × 10	−1.76 × 10	−1.26
	m_4	1.66 × 10	4.55 × 10	6.41 × 10	2.33 × 10	7.94
0.375	m_1	−1.87	−3.88	−4.88	−2.39	−1.07
	m_2	1.21 × 10	2.75 × 10	3.58 × 10	1.55 × 10	5.20
	m_3	−1.84 × 10	−4.77 × 10	−6.00 × 10	−1.43 × 10	3.92
	m_4	2.15 × 10	4.66 × 10	6.15 × 10	2.32 × 10	5.68
0.5	m_1	−1.60	−3.17	−6.31	−3.00	−1.06
	m_2	9.20	2.09 × 10	4.42 × 10	1.85 × 10	3.93
	m_3	−8.97	−2.88 × 10	−7.11 × 10	−1.67 × 10	8.31
	m_4	1.80 × 10	3.68 × 10	7.02 × 10	2.68 × 10	4.13

Table VII-2.7.5.4-13
Coefficient η_1

n	R/t	θ/π	$\lambda/(1+\lambda)$ 0.0	0.2	0.5	0.8	1.0
5	5	0.0625	5.16	7.18	6.94	5.37	4.37
		0.125	4.13	5.16	5.30	4.12	3.24
		0.25	2.49	3.09	3.70	2.82	1.97
		0.375	1.48	2.10	2.83	2.10	1.29
		0.5	1.00	1.52	2.24	1.66	8.98×10^{-1}
	10	0.0625	5.85	8.59	8.87	7.32	6.07
		0.125	5.26	6.91	7.63	6.31	5.06
		0.25	3.50	4.54	5.78	4.68	3.36
		0.375	2.09	3.07	4.21	3.39	2.20
		0.5	1.39	2.13	3.16	2.59	1.52
	20	0.0625	6.97	1.05×10^{1}	1.13×10^{1}	9.67	8.14
		0.125	7.14	9.61	1.10×10^{1}	9.44	7.69
		0.25	4.87	6.52	8.59	7.08	5.25
		0.375	2.88	4.29	5.71	4.95	3.37
		0.5	1.85	2.86	4.30	3.66	2.29
	50	0.0625	9.79	1.51×10^{1}	1.62×10^{1}	1.46×10^{1}	1.24×10^{1}
		0.125	1.11×10^{1}	1.52×10^{1}	1.80×10^{1}	1.59×10^{1}	1.29×10^{1}
		0.25	7.48	1.02×10^{1}	1.33×10^{1}	1.12×10^{1}	8.47
		0.375	4.36	6.23	8.75	7.27	5.12
		0.5	2.73	4.05	6.32	5.48	3.59
15	5	0.0625	4.24	5.71	4.29	2.04	1.44
		0.125	1.96	2.77	2.59	1.16	6.67×10^{-1}
		0.25	6.51×10^{-1}	1.18	1.57	6.59×10^{-1}	2.42×10^{-1}
		0.375	2.72×10^{-1}	6.48×10^{-1}	8.76×10^{-1}	4.54×10^{-1}	1.23×10^{-1}
		0.5	1.34×10^{-1}	3.60×10^{-1}	6.25×10^{-1}	3.38×10^{-1}	7.18×10^{-2}
	10	0.0625	5.64	8.47	7.49	4.61	3.38
		0.125	3.04	4.72	5.09	2.96	1.77
		0.25	1.12	2.24	2.53	1.57	7.06×10^{-1}
		0.375	5.05×10^{-1}	1.18	1.27	8.31×10^{-1}	3.42×10^{-1}
		0.5	2.60×10^{-1}	5.43×10^{-1}	8.58×10^{-1}	6.01×10^{-1}	2.02×10^{-1}
	20	0.0625	7.72	1.24×10^{1}	1.15×10^{1}	8.34	6.49
		0.125	4.49	7.31	8.21	5.31	3.59
		0.25	1.70	3.24	3.56	2.35	1.33
		0.375	8.24×10^{-1}	1.53	1.65	1.22	6.39×10^{-1}
		0.5	4.00×10^{-1}	6.96×10^{-1}	1.11	8.72×10^{-1}	3.82×10^{-1}
	50	0.0625	1.22×10^{1}	1.76×10^{1}	1.81×10^{1}	1.50×10^{1}	1.19×10^{1}
		0.125	7.13	1.17×10^{1}	1.27×10^{1}	9.36	6.57
		0.25	2.66	4.96	5.71	3.58	2.09
		0.375	1.23	2.04	2.23	1.65	9.14×10^{-1}
		0.5	5.64×10^{-1}	9.31×10^{-1}	1.57	1.20	5.90×10^{-1}

Table VII-2.7.5.4-13 Coefficient η_1 (Cont'd)

n	R/t	θ/π	$\lambda/(1+\lambda)$ 0.0	0.2	0.5	0.8	1.0
25	5	0.0625	2.53	3.34	2.28	6.71×10^{-1}	3.82×10^{-1}
		0.125	8.62×10^{-1}	1.47	1.32	3.59×10^{-1}	1.48×10^{-1}
		0.25	2.17×10^{-1}	5.79×10^{-1}	9.37×10^{-1}	2.18×10^{-1}	4.98×10^{-2}
		0.375	8.04×10^{-2}	2.83×10^{-1}	6.14×10^{-1}	1.62×10^{-1}	2.85×10^{-2}
		0.5	3.80×10^{-2}	1.42×10^{-1}	3.88×10^{-1}	1.22×10^{-1}	1.97×10^{-2}
	10	0.0625	3.64	6.12	4.82	2.50	1.53
		0.125	1.58	3.02	3.23	1.51	6.90×10^{-1}
		0.25	4.89×10^{-1}	1.37	1.83	8.74×10^{-1}	2.18×10^{-1}
		0.375	1.98×10^{-1}	7.68×10^{-1}	8.99×10^{-1}	5.14×10^{-1}	1.03×10^{-1}
		0.5	8.93×10^{-2}	3.44×10^{-1}	5.57×10^{-1}	3.70×10^{-1}	5.70×10^{-2}
	20	0.0625	5.17	7.20	8.56	5.36	3.59
		0.125	2.16	3.94	5.04	3.29	1.66
		0.25	8.11×10^{-1}	2.15	2.74	1.47	6.02×10^{-1}
		0.375	3.83×10^{-1}	1.12	1.06	6.82×10^{-1}	2.55×10^{-1}
		0.5	1.83×10^{-1}	4.44×10^{-1}	7.30×10^{-1}	4.95×10^{-1}	1.50×10^{-1}
	50	0.0625	6.95	6.70	9.57	9.94	6.48
		0.125	3.72	6.08	7.67	5.98	3.45
		0.25	1.28	2.20	3.66	2.36	1.18
		0.375	6.76×10^{-1}	1.39	1.49	9.43×10^{-1}	4.63×10^{-1}
		0.5	3.37×10^{-1}	5.12×10^{-1}	9.04×10^{-1}	6.88×10^{-1}	3.07×10^{-1}

Table VII-2.7.6.3-1 Coefficients to Calculate Circumferential Through-Wall Crack Length at Breakthrough

i	j	C_{0ji}	C_{1ji}	C_{2ji}	C_{3ji}	C_{4ji}
1	0	−4.4389	1.3948×10^{-1}	-4.5552×10^{-3}	7.1819×10^{-5}	-3.9347×10^{-7}
	1	−6.3664	-2.4794×10^{-2}	1.2443×10^{-3}	-2.4590×10^{-5}	1.3171×10^{-7}
	2	-4.0964×10^{-2}	1.3306×10^{-1}	-6.0515×10^{-3}	1.1912×10^{-4}	-8.4148×10^{-7}
2	0	1.3182×10^{-1}	-1.4849×10^{-2}	7.0766×10^{-4}	-1.3695×10^{-5}	9.9135×10^{-8}
	1	-5.0636×10^{-2}	2.7230×10^{-2}	-1.1904×10^{-3}	2.2609×10^{-5}	-1.6210×10^{-7}
	2	-9.7851×10^{-3}	-4.1773×10^{-3}	2.0644×10^{-4}	-4.1312×10^{-6}	3.1201×10^{-8}
3	0	4.9910	-6.8923×10^{-3}	-1.6961×10^{-3}	4.9094×10^{-5}	-4.6406×10^{-7}
	1	5.8976	-1.4469×10^{-1}	6.7543×10^{-3}	-1.3261×10^{-4}	1.0055×10^{-6}
	2	3.1234×10^{-1}	-1.1828×10^{-1}	5.0795×10^{-3}	-9.7685×10^{-5}	6.7186×10^{-7}

Table VII-2.7.6.3-2 Coefficients to Calculate Axial Through-Wall Crack Length at Breakthrough

A_i	B_{0i}	B_{1i}	B_{2i}	B_{3i}	B_{4i}
A_0	2.594	4.089	3.830×10^{-2}	-3.023×10^{-1}	5.566×10^{-2}
A_1	-1.815×10^{1}	6.041	-1.436×10^{1}	5.904	-8.479×10^{-1}
A_2	7.450×10^{1}	-8.364×10^{1}	8.852×10^{1}	-3.415×10^{1}	4.886
A_3	-1.387×10^{2}	1.935×10^{2}	-2.024×10^{2}	8.048×10^{1}	-1.184×10^{1}
A_4	1.286×10^{2}	-1.876×10^{2}	2.160×10^{2}	-9.042×10^{1}	1.381×10^{1}
A_5	-5.619×10^{1}	7.635×10^{1}	-1.075×10^{2}	4.850×10^{1}	−7.771
A_6	8.437	−7.963	1.916×10^{1}	−9.723	1.664

ARTICLE VII-3 HIGH-TEMPERATURE GAS-REACTOR–TYPE FACILITIES (25)

VII-3.1 SCOPE

This Article provides requirements for identifying and evaluating potentially active degradation mechanisms specific to high-temperature gas-reactor-type facilities. These and other unique requirements herein shall be used to supplement the RIM Program for high-temperature gas-reactor-type facilities.

(a) This Article shall be used only for high-temperature gas-reactor-type facilities.

(b) Section XI, Division 1, Article IWA-3000 shall be used as reference information to support this Article and is referenced by this Article.

(c) This Article shall be used only when ferritic components are limited to a maximum Design Temperature of 700°F (370°C) and austenitic components are limited to a maximum Design Temperature of 800°F (426°C). However, for SA-533 Type B Class 1 (UNS K12539 1) and SA-508 Grade 3, Class 1 (UNS K12042 1) the following operating limits shall apply:

Temperature, °F (°C)	Time, hr	Number of Excursions
≤700 (≤370)	Design life	Unlimited
700–800 (370–425)	3,000 cumulative	Unlimited
800–1,000 (425–540)	1,000 cumulative	3 occurrences

(25) VII-3.2 RIM PROGRAM — DEGRADATION MECHANISM ASSESSMENT

See Table VII-3.2-1.

VII-3.3 ACCEPTANCE STANDARDS

VII-3.3.1 Evaluation of Examination Results

VII-3.3.1.1 Preservice Volumetric and Surface Examinations

(a) General

(1) The preservice volumetric and surface examinations required by RIM-2.7.3 and performed in accordance with RIM-2.9 shall receive an NDE evaluation by comparing the examination results with the acceptance standards specified in (b).

(2) Acceptance of components for service shall be in accordance with (b) and (c).

(b) Acceptance

(1) A component whose volumetric or surface examination in accordance with RIM-2.7.3 meets the criteria of (-a), (-b), or (-c), shall be acceptable for service, provided the verified flaws are recorded in accordance with the requirements of RIM-1.4(i) and RIM-2.9.2(b) in terms of location, size, shape, orientation, and distribution within the component.

(-a) The volumetric or surface examination (see RIM-2.7.3) confirms the absence of flaws or identifies only flaws that have already been shown to meet the NDE acceptance standards of the Construction Code and Owner's Requirements for materials or welds, as applicable, documented in quality assurance records.

(-b) Volumetric examination detects flaws that are confirmed by surface or volumetric examination to be non-surface-connected and that do not exceed the acceptance standards of Table VII-3.3.3-1.

(-c) Volumetric examination detects flaws that are confirmed by surface or volumetric examination to be non-surface-connected and that are accepted by analytical evaluation in accordance with the provisions of VII-3.3.1.3(b)(4) to the end of the service lifetime of the component and reexamined in accordance with the requirements of RIM-2.7.6.3(a) and RIM-2.7.6.3(b).

(2) A component whose volumetric or surface examination (see RIM-2.7.3) detects flaws that do not meet the criteria established in (1) shall be unacceptable for service, unless the component is corrected by a repair/replacement activity in accordance with (c) to the extent necessary to meet the provisions of (1) prior to placement of the component in service.

(3) A component whose volumetric or surface examination (see RIM-2.7.3) detects flaws, other than those described in (2), that exceed the acceptance standards of Table VII-3.3.3-1 shall be unacceptable for service, unless the component is corrected by a repair/replacement activity to the extent necessary to meet the acceptance standards prior to placement of the component in service.

(c) Repair/Replacement Activity and Preservice Examination. The repair/replacement activity and preservice examination shall comply with the requirements of Article RIM-4. Preservice examination shall be conducted in accordance with the requirements of RIM-2.9. The recorded results shall demonstrate that the area subjected

Table VII-3.2-1
Degradation Mechanism Attributes and Attribute Criteria for High-Temperature Gas Reactors

Degradation Mechanism				
Type	**Subtype**	**Attribute Criteria**	**Degradation Features and Susceptible Regions**	**Table VII-3.3.3-1 Examination Category**
TF	TASCS	– single pipe and operating temperature >104°C (220°F), and – piping >DN 25 (NPS 1), and – pipe segment has a slope <45° from horizontal (includes elbow or tee into a vertical pipe), and – potential exists for low flow in a pipe section connected to a component allowing mixing of hot and cold fluids, or – potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or – potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or – Potential exists for two phase (steam/water) flow, or – potential exists for turbulent penetration in branch pipe connected to header piping containing hot fluid with high turbulent flow, and – calculated or measured ΔT > 28°C (50°F), and – Richardson Number >4.0 *OR* – Helium counterflow in dual pipe, and – Relatively high-velocity flow in the hotter pipe and relatively low velocity flow in the colder pipe, and – The difference between the fluid temperature in the hotter and colder pipes >900°C (1,620°F)	Cracks can initiate in welds, heat affected zones (HAZ), and base metal at the pipe inner surface Affected locations can include nozzles, branch pipe connections, safe ends, and regions of stress concentration TASCS can occur over extensive portions of the pipe inner surface Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	F, J, K
	TT	– operating temperature >132°C (270°F) for stainless steel, or – operating temperature >104°C (220°F) for carbon steel, AND – potential for relatively rapid temperature changes including: cold fluid injection into hot pipe segment, or hot fluid injection into cold pipe segment, AND – $\left\|\Delta T\right\|$ > 111°C (200°F) for stainless steel, or – $\left\|\Delta T\right\|$ > 83°C (150°F) for carbon steel, or – $\left\|\Delta T\right\|$ > ΔT allowable or – allowable cycles $<10^6$		
VF	FIV	– presence of attachments in a high velocity flow field, including: welded attachments, or attachments with small radii at the attachment junction *OR* – high velocity cross flow over S/G or H/X tube bundles, and – absence of vibration damping tube supports	Cracks can initiate in welds, HAZ, and base metal at the component inner or outer surface Affected locations can include welded attachments and regions of stress concentration Crack growth can be relatively fast, and through-wall cracks can occur within an inspection period	A, B, D, F, J, K, O as applicable NOTES: As approved by MANDEEP: – volumetric for part-through-wall cracks at the inner surface – surface for part-through-wall cracks at the outer surface and – leakage monitoring, leakage testing, or visual for through-wall cracks
	MF	– cyclic applied loads, and – presence of partial penetration welds, or – presence of small radii at the attachment junction *OR* – presence of attached vibration sources (e.g., pumps, compressors) and – no preoperational vibration testing or monitoring, or – no vibratory monitoring of vibration sources during operation		

Table VII-3.2-1
Degradation Mechanism Attributes and Attribute Criteria for High-Temperature Gas Reactors (Cont'd)

Degradation Mechanism				
Type	Subtype	Attribute Criteria	Degradation Features and Susceptible Regions	Table VII-3.3.3-1 Examination Category
VF (cont'd)	SF	– relative sliding motion between two contacting surfaces, and – absence of a solid lubricating system at the contacting surfaces	Cracking, pitting, spalling wear, or seizing can occur at the contact surfaces Cracking is expected to be localized and not grow through-wall	G-1, G-2, K
SCC	IGSCC	– BWR evaluated in accordance with existing facility IGSCC program per NRC Generic Letter 88-01 *OR* – material is austenitic stainless-steel weld or HAZ, and – operating temperature ≥93°C (200°F), and – susceptible material (carbon content ≥0.035%), and – oxygen or oxidizing species are present *OR* – material is Alloy 82 or 182, and – operating temperature ≥93°C (200°F), and – oxygen or oxidizing species are present *OR* – material is austenitic stainless-steel weld or HAZ, and – operating temperature <93°C (200°F), and – susceptible material (carbon content ≥0.035%), and – oxygen or oxidizing species are present, and – initiating contaminants (e.g., thiosulfate, fluoride, chloride) are present *OR* – material is in an aqueous environment, and – oxygen or oxidizing species are present, and – mechanically induced high residual stresses are present	Cracks can initiate in welds, and HAZ at the pipe inner surface Affected locations can include pipe welds, branch pipe connections, and safe end attachment welds Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	A, B, D, F, G-1, G-2, J, K, O
	TGSCC	– material is austenitic stainless steel, and – operating temperature >65°C (150°F), and – halides (e.g., fluoride, chloride) are present, or – caustic (NaOH) is present, and – oxygen or oxidizing species are present (only required to be present in conjunction w/halides, not required w/caustic)	Cracks can initiate in welds, HAZ, and base metal at the pipe inner surface Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	A, B, D, F, G-1, G-2, J, K, O
	ECSCC	– material is austenitic stainless steel, and – operating temperature >20°C (68°F), and – an outside piping surface is within five diameters of a probable leak path (e.g., valve stems) and is covered with nonmetallic insulation that is not in compliance with USNRC Reg. Guide 1.36, or – piping surface is exposed to wetting from chloride bearing environments (e.g., seawater, sea spray, brackish water, brine) during fabrication, storage, or operation	Cracks can initiate in welds, HAZ, and base metal at the pipe outer surface ECSCC can occur over extensive portions of the pipe inner or outer surface when exposed to wetting from chloride bearing environments during fabrication, storage or operation Crack growth is relatively slow, and through-wall cracking is not expected within an inspection period	J, K