ArevaEPRDCPEm Resource

From: Miernicki, Michael
Sent: Wednesday, May 21, 2014 11:16 AM
To: ArevaEPRDCPEm Resource
Subject: FW: Response to U.S. EPR Design Certification Application FINAL RAI No. 583_CIB_7087, Chapter 3 (FSAR Rev 4 Review), Supplement 2
Attachments: RAI 583 Supplement 2 Response US EPR DC - Public.pdf

Michael J. Miernicki
Sr. Project Manager
NRC/NRR/DORL/LP-WB
301-415-2304

From: RYAN Tom (AREVA) [mailto:Tom.Ryan@areva.com]
Sent: Monday, March 10, 2014 10:19 AM
To: Miernicki, Michael
Cc: Wunder, George; HOTTLE Nathan (AREVA); GUCWA Len (EXTERNAL AREVA); UYEDA Graydon (AREVA); RANSOM Jim (AREVA); LEIGHLITER John (AREVA); WILLIFORD Dennis (AREVA); RYAN Tom (AREVA); ROMINE Judy (AREVA); DELANO Karen (AREVA); WILLS Tiffany (AREVA)
Subject: Response to U.S. EPR Design Certification Application FINAL RAI No. 583_CIB_7087, Chapter 3 (FSAR Rev 4 Review), Supplement 2

Mike,

AREVA provided a schedule for a technically correct and complete response to the one question in RAI No. 583 on June 3, 2013. AREVA provided a revised schedule for the final response to RAI 583 Question 03.08.03-25 on July 25, 2013.

The attached file, "RAI 583 Supplement 2 Response US EPR DC - PUBLIC.pdf," provides a final response to Question RAI 583 - 03.08.03-25. This response incorporates NRC feedback. Because the response file contains security-related sensitive information that should be withheld from public disclosure in accordance with 10 CFR 2.390, a public version is provided with the security-related sensitive information redacted. This email and attached file do not contain any security-related information. An un-redacted security-related version is provided under separate email.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to Question RAI 583 - 03.08.03-25.

The following table indicates the respective pages in the response document, "RAI 583 Response US EPR DC - PUBLIC.pdf" that contain AREVA's response to the subject question.

Question #	Start Page	End Page
RAI 583 — 03.08.03-25	3	106

This concludes the formal AREVA NP response to RAI 583, and there are no questions from this RAI for which AREVA has not provided responses.

Sincerely,

Tom Ryan
Manager, US EPR DCD
Regulatory Affairs
AREVA
7207 IBM Drive - CLT2B
Charlotte, NC 28262
Phone: 704-805-2643, Cell : 704-292-5627
Fax: 434-382-6657

From: HOTTLE Nathan (EP/PE)
Sent: Thursday, August 22, 2013 4:43 PM
To: Snyder, Amy (Amy.Snyder@nrc.gov)
Cc: michael.miernicki@nrc.gov; GUCWA Len (External RS/NB); RANSOM Jim (RS/NB); LEIGHLITER John (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB)
Subject: Response to U.S. EPR Design Certification Application FINAL RAI No. 583, Chapter 3 (FSAR Rev 4 Review)

Amy,

An advanced response to RAI 583 Question 03.08.03-25 was transmitted to you on June 11, 2013. We received comments from NRC staff on July 22nd. AREVA provided a revised schedule for the final response to RAI 583 Question 03.08.03-25 on July 25, 2013.

AREVA is in the process of evaluating the NRC staff comments and feedback and will provide a revised schedule for submittal of the final response to this question after AREVA has completed a full evaluation of changes necessary.

An updated schedule for the final response to RAI 583 Question 03.08.03-25 is provided below:

Question #	Final Response Date
RAI 583 — 03.08.03-25	TBD

Sincerely,

Nathan Hottle
AREVA Inc.
3315 Old Forest Road
Lynchburg, VA 24501
Phone 434-832-3864
Mobile 434-485-4239
nathan.hottle@areva.com

From: WILLIFORD Dennis (RS/NB)
Sent: Thursday, July 25, 2013 2:57 PM
To: Snyder, Amy
Cc: Michael.Miernicki@nrc.gov; ANDERSON Katherine (External AREVA NP INC.); DELANO Karen (RS/NB); LEIGHLITER John (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); LENTZ Tony (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application FINAL RAI No. 583, Chapter 3 (FSAR Rev 4 Review), Supplement 1

Amy,

AREVA NP Inc. provided a schedule for a technically correct and complete response to the one question in RAI No. 583 on June 3, 2013.

The schedule for a technically correct and complete final response to this question has been changed as provided below.

Question #	Final Response Date
RAI 583 — 03.08.03-25	**August 22, 2013**

Sincerely,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
7207 IBM Drive, Mail Code CLT 2B
Charlotte, NC 28262
Phone: 704-805-2223
Email: Dennis.Williford@areva.com
From: WILLIFORD Dennis (RS/NB)
Sent: Monday, June 03, 2013 4:46 PM
To: 'Snyder, Amy'
Cc: Michael.Miernicki@nrc.gov; ANDERSON Katherine (External AREVA NP INC.); DELANO Karen (RS/NB); LEIGHLITER John (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); LENTZ Tony (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application FINAL RAI No. 583, Chapter 3 (FSAR Rev 4 Review)

Amy,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 583 Response US EPR DC.pdf," provides a schedule since a technically correct and complete response to the single question cannot be provided at this time.

The following table indicates the respective pages in the response document, "RAI 583 Response US EPR DC.pdf," that contain AREVA NP's response to the subject question.

Question #	Start Page	End Page
RAI 583 — 03.08.03-25	2	2

The schedule for a technically correct and complete response to the question is provided below.

Question #	Advanced Response Date	NRC Comment Request Date	Final Response Date
RAI 583 — 03.08.03-25	June 11, 2013	July 11, 2013	July 25, 2013

Sincerely,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager

AREVA NP Inc.
7207 IBM Drive, Mail Code CLT 2B
Charlotte, NC 28262
Phone: 704-805-2223
Email: Dennis.Williford@areva.com

From: Snyder, Amy [mailto:Amy.Snyder@nrc.gov]
Sent: Thursday, May 02, 2013 12:11 PM
To: ZZ-DL-A-USEPR-DL
Cc: Terao, David; Scarbrough, Thomas; Miernicki, Michael; Segala, John; Xu, Jim
Subject: U.S. EPR Design Certification Application FINAL RAI No. 583, Chapte 3 (FSAR Rev 4 Review)

Attached please find the subject request for additional information (RAI). A draft RAI was provided to you on April 12, 2013 and modified by the staff after discussion with AREVA. A modified draft RAI was sent to AREVA on April. 29, 2013. On May 2, 2013, you informed us that the modified draft RAI does not contain proprietary information and that the modified draft RAI is clear and no further clarification is needed;   As result, the RAI sent on April 29, 2013 was not changed.

The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs,. For any RAIs that cannot be answered **within 30 days or June 3, 2013**, it is expected that a date for receipt of this information will be provided to the staff within the 30-day period so that the staff can assess how this information will impact the published schedule.

Thank You,

Amy

Amy Snyder, U.S. EPR Design Certification Lead Project Manager
Licensing Branch 1 (LB1)
Division of New Reactor Licensing
Office of New Reactors
U.S. Nuclear Regulatory Commission
Office: (301) 415-6822
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Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 4864

Mail Envelope Properties (9C2386A0C0BC584684916F7A0482B6CAFCB2DC61F2)

Subject: FW: Response to U.S. EPR Design Certification Application FINAL RAI No. 583_CIB_7087, Chapter 3 (FSAR Rev 4 Review), Supplement 2
Sent Date: 5/21/2014 11:16:21 AM
Received Date: 5/21/2014 11:16:21 AM
From: Miernicki, Michael

Created By: Michael.Miernicki@nrc.gov

Recipients:
"ArevaEPRDCPEm Resource" <ArevaEPRDCPEm.Resource@nrc.gov>
Tracking Status: None

Post Office: HQCLSTR02.nrc.gov

Files	**Size**	**Date & Time**
MESSAGE	7915	5/21/2014 11:16:21 AM
RAI 583 Supplement 2 Response US EPR DC - Public.pdf	547663	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Response to

Request for Additional Information No.583, Supplement 2

5/2/2013
U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.08.03 - Concrete and Steel Internal Structures of Steel or Concrete Containments
Application Section: 3.8.3
CIB Branch

Question 03.08.03-25:

In Section 3.8.3.2.1, the “ASME Boiler and Pressure Vessel Code – 2004 Edition, Section III, Division 1 – Nuclear Power Plant Components (GDC 1)” is designated as Tier 2*. Designating the entire 2004 Edition of the ASME B&PV Code, Section III as Tier 2* will present a major hardship for COL holders during plant construction when materials and components need to be procured to later Code editions and addenda. The edition and addenda to the ASME B&PV Code Section III for both Division 1 and 2 should be designated as Tier 2 information.

Response to Question 03.08.03-25:

References to the ASME Boiler and Pressure Vessel Code, Section III, Divisions 1 and 2 in U.S. EPR FSAR Tier 2, Section 3.8, will be revised to more narrowly define the specific reference. References to the ASME Boiler and Pressure Vessel Code, Section III, Division 1 will not be designated as Tier 2* because the use of this code is regulated by 10 CFR 50.55a.

References to the ASME Boiler and Pressure Vessel Code, Section III, Division 2 will be designated as Tier 2*, and will include the edition and addenda for structural design of the concrete containment. In addition, references to the following documents will be designated as Tier 2*, and will include the edition and addenda for structural design of safety-related structures:

- ACI 349/349R-01, “Code Requirements for Nuclear Safety-Related Concrete Structures,”
- ACI 349.1R-07, “Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures.”
- ACI 349-06, “Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary, Appendix D—Anchoring to Concrete.”
- ANSI/AISC N690-1994 (R2004), “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” including Supplement 2.
- ASTM STS-1-2006, "Steel Stacks," The American Society of Mechanical Engineers, 2006.

Conforming changes will be made in U.S. EPR FSAR Tier 2, Tables 1.8-2, 1.9-2, 3.2.2-1, and Sections 3.5, 3.7, 3.8, 6.2, and 6.3. The U.S. EPR FSAR Introduction, Table I-1 will be revised to update associated references to Tier 2* in U.S. EPR FSAR Tier 2. There will also be several editorial corrections made to ASME Code references in U.S. EPR FSAR Tier 2, Sections 3.5 and 3.8.

Also, based on precedent set in other design centers, for all FSAR Sections that include Tier 2* information, a statement will be placed at the end of the major FSAR Section denoting: *NRC Staff approval is required prior to implementing a change in this information marked in this Section; see FSAR Introduction Section.

FSAR Impact:

U.S. EPR FSAR, Introduction, Table I-1 and U.S. EPR FSAR, Tier 2, Tables 1.8-2, 1.9-2, 3.2.2-1, and Sections 3.5, 3.7, 3.8, 6.2 and 6.3 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

Table I-1—Summary of Tier 2* Information (Sheet 1 of 6)

Location	Description of Tier 2* Information	Expiration at First Full Power
~~Table 1.6-1~~	~~Maximum Fuel Rod Average Burn-up~~	~~No~~
~~Table 1.6-1~~	~~Piping Design Acceptance Criteria~~	~~Yes~~
Table 1.6-1	Instrumentation and Control Technical ~~and Topical Reports~~ Design Criteria	Yes
Table 1.8-2 Table 3.2.2-1 3.5.3 ~~3.5.3.2~~ ~~3.5.3.3~~ 3.5.4 3.8.1 3.8.3 3.8.4 3.8.5 3.8.6 ~~3.8.1.4.10~~ ~~3.8.1.5~~ ~~3.8.1.6.2~~ ~~3.8.3.3.1~~ ~~3.8.3.3.2~~ ~~3.8.3.4~~ ~~3.8.3.4.1~~ ~~3.8.3.4.2~~ ~~3.8.3.4.4~~ ~~3.8.3.5~~ ~~3.8.3.6.1~~ ~~3.8.3.6.2~~ ~~3.8.3.6.3~~ ~~3.8.4.3.1~~ ~~3.8.4.3.2~~ ~~3.8.4.4.1~~ ~~3.8.4.4.3~~ ~~3.8.4.4.4~~ ~~3.8.4.4.5~~ ~~3.8.4.5~~ ~~3.8.5.1.1~~ ~~3.8.5.3~~ ~~3.8.5.4.1~~ ~~3.8.5.5~~ ~~3.8.5.6.1~~ ~~3A.3.1~~	~~American Concrete Institute (ACI) 318,~~ ACI 349/349R-01~~,~~ ~~American National Standards Institute/American Institute of Steel Construction (ANSI/AISC) -690~~	Yes

Table I-1—Summary of Tier 2* Information
(Sheet 2 of 6)

Location	Description of Tier 2* Information	Expiration at First Full Power
3.8.3 3.8.4 3.8.6	ACI 349.1R-07	Yes
3.8.1 3.8.3 3.8.4 3.8.5 3.8.6	ACI 349-06, Appendix D—Anchoring To Concrete	Yes
3.5.3.2 3.5.3.3 3.5.4 3.8.2 3.8.3 3.8.4 3.8.5 3.8.6	ANSI/AISC N690-1994 (R2004) including Supplement 2	Yes
3.8.2 3.8.4 3.8.6	ASME STS-1	Yes
3.6.2.1	ASME Class 1, 2, and 3 piping Criteria Used to Define Break and Crack Location and Configuration	Yes
3.6.2.1.1.1	ASME Code Break Locations in Containment Penetration Areas	Yes
3.6.2.1.1.2	ASME Code Break Locations in Areas other Than Containment Penetration Areas	Yes
3.6.2.1.1.3	ASME Code Leakage Crack Locations in High-Energy Piping Systems	Yes
3.6.2.1.2.1	ASME Code Leakage Crack Locations in Fluid Systems in Containment Penetration Areas	Yes
3.6.2.1.2.2	ASME Code Leakage Crack Locations in Fluid Systems in Areas other than Containment Penetration Areas	Yes
3.6.2.1.2.3	ASME Code Moderate-Energy Fluid Systems in Close Proximity to High-Energy Fluid Systems	Yes
3.6.2.1.3.1	Piping Design Acceptance Criteria used for Circumferential Pipe Breaks	Yes
3.6.2.1.3.2	Piping Design Acceptance Criteria used for Longitudinal Pipe Breaks	Yes
3.6.2.1.3.3	Piping Design Acceptance Criteria used for Leakage Cracks	Yes
3.6.2.2	Guard Pipe Assembly Design Criteria	Yes

Table I-1—Summary of Tier 2* Information (Sheet 3 of 6)

Location	Description of Tier 2* Information	Expiration at First Full Power
3.6.2.4.2	Analysis of Essential System Piping Due to a Break in Attached Piping	Yes
3.6.2.4.3	Piping Design Acceptance Criteria used for Development of Pipe Whip Hinges	Yes
3.6.2.5.1.2	Piping Design Acceptance Criteria used for Pipe Whip Support Design	Yes
3.6.3.4.1	Piping Design Acceptance Criteria used for Geometry and Operating Condition	Yes
3.6.3.5.2	Piping Design Acceptance Criteria used for Leak Rate Determination Method for Main Coolant Loop and Surge Line	Yes
3.6.3.5.3	Piping Design Acceptance Criteria used for Leak Rate Determination Method for Main Steam Line	Yes
3.6.3.6.1.3	Piping Design Acceptance Criteria used for Axial Through-Wall Crack in a Straight Pipe	Yes
3.6.3.6.2.3	Piping Design Acceptance Criteria used for Axial Through-Wall Crack in a Straight Pipe	Yes
3.6.3.7	Piping Design Acceptance Criteria used for Leak Detection	Yes
3.7.2.8	Codes and Standards for Design of NAB	Yes
3.8	Defines Key Dimensions for NI Common Basemat Structure and other Seismic Category I Structures Shown in Figure 3B-1	Yes
3.5.3 3.5.4 3.8.1 3.8.2 3.8.3 3.8.4 3.8.5 3.8.6	ASME Code, Section III, Division 2, 2004 Edition	Yes
~~3.8~~	~~ASME Code Section III Div 2 for the RCB and the Liner~~	~~Yes~~
~~3.8.1.1.3~~	~~ASME Code Section III Div 2, CC-3810 for Liner Anchorage System~~	~~Yes~~
~~3.8.1.3~~	~~ASME Code Section III Div 2, CC-3000 for RCB~~	~~Yes~~
~~3.8.1.3~~	~~ASME Code Section III Div 2, CC-3230-1 for Construction Loads~~	~~Yes~~
~~3.8.1.4~~	~~ASME Code Section III Div 2, CC-3300 for RCB~~	~~Yes~~
~~3.8.1.4.10~~	~~ASME Code Section III Div 2, CC-3600 for Steel Liner Plate~~	~~Yes~~
~~3.8.1.5~~	~~ASME Code Section III Div 2, CC-3400 for RCB~~	~~Yes~~

Table I-1—Summary of Tier 2* Information (Sheet 4 of 6)

Location	Description of Tier 2* Information	Expiration at First Full Power
~~3.8.1.6~~	~~ASME Code Section III Div 2, CC-2000, CC-4000, CC-5000, CC-6000 and CC-9000~~	~~Yes~~
~~3.8.1.6.1~~	~~ASME Code Section III Div 2, CC-2230 for RCB~~	~~Yes~~
~~3.8.1.6.2~~	~~ASME Code Section III Div 2, CC-4333, CC-4300, and CC~~	~~Yes~~
~~3.8.1.6.3~~	~~ASME Code Section III Div 2, CC-2400 for Post-tensioning System~~	~~Yes~~
~~3.8.1.6.4~~	~~ASME Code Section III Div 2, CC-2520 for Liner~~	~~Yes~~
~~3.8.1.6.5~~	~~ASME Code Section III Div 2, CC-2000 for Embedments~~	~~Yes~~
~~3.8.1.7.1~~	~~ASME Code Section III Div 2, CC-6000 for the SIT~~	~~Yes~~
~~3.8.2.1.1~~	~~ASME Code Section III Div 1, NE-3000 for Hatches and Penetrations~~	~~Yes~~
~~3.8.2.1.2~~	~~ASME Code Section III Div 1, NC for Pipe and Sleeves~~	~~Yes~~
~~3.8.2.1.3~~	~~ASME Code Section III Div 1, NE for Electrical Penetration Sleeves~~	~~Yes~~
~~3.8.2.1.4~~	~~ASME Code Section III Div 1, NE for Penetration Sleeve~~	~~Yes~~
~~3.8.2.2.2~~	~~ASME Code Section III Div 1, NE-2000 for Materials, Appendix X and X-3000 for NDE~~	~~Yes~~
~~3.8.2.4~~	~~ASME Code Section III Div 1, NE-3222 for Buckling Strength~~	~~Yes~~
~~3.8.2.6~~	~~ASME Code Section III Div 1, NE-2000 for the Non-backed Steel~~	~~Yes~~
~~3.8.2.7~~	~~ASME Code Section III Div 1, NE-6000 for SIT~~	~~Yes~~
~~3.8.3.4.2~~	~~ASME Code Section III Div 1, NF for Supports~~	~~Yes~~
~~3.8.5.1.1~~	~~ASME Code Section III Div 2~~	~~Yes~~
~~3.8.5.2~~	~~ASME Code Section III Div 2~~	~~Yes~~
~~3.8.5.3~~	~~ASME Code Section III Div 2 with Clarifications~~	~~Yes~~
~~3.8.5.4.1~~	~~ASME Code Section III Div 2~~	~~Yes~~
~~3.8.6~~	~~2004 Edition of the ASME Code Section III Div 1~~	~~Yes~~
~~3.8.6~~	~~2004 Edition of the ASME Code Section III Div 2~~	~~Yes~~
3.9.3.3	ASME QME-1-2007 as accepted in Revision 3 to NRC Regulatory Guide 1.100	Yes
3.9.3.5	Piping Design Acceptance Criteria	Yes
3.9.6.1	ASME QME-1-2007 as accepted in Revision 3 to NRC Regulatory Guide 1.100	Yes
3.9.6.3.1.4	Acceptance Criteria for PST and IST MOVs	Yes
3.10.1.1	Equipment Seismic Qualification Methods and Standards	Yes

Table 1.8-2—U.S. EPR Combined License Information Items
Sheet 13 of 41

Item No.	Description	Section
3.8-9	A COL applicant that references the U.S. EPR design certification will describe site-specific foundations for Seismic Category I structures that are not described in this section.	3.8.5.1
3.8-10	A COL applicant that references the U.S. EPR design certification will evaluate site-specific methods for shear transfer between the foundation basemats and underlying soil for site-specific soil characteristics that are not within the envelope of the soil parameters specified in Section 2.5.4.2.	3.8.5.5
3.8-11	*[A COL applicant that references the U.S. EPR design certification will evaluate the use of epoxy coated rebar for foundations subjected to aggressive environments, as defined in ACI 349/349R-01, Chapter 4 (Reference 12). In addition, waterproofing and dampproofing systems of Seismic Category I foundations subjected to aggressive environments will be evaluated for use in aggressive environments. Also, the concrete of Seismic Category I foundations subjected to aggressive environments will meet the durability requirements of ACI 349/349R-01, Chapter 4 (Reference 12) or ASME Code, Section III, Division 2, Article CC-2231.7, as applicable.]**	3.8.5.6.1
3.8-12	A COL applicant that references the U.S. EPR design certification will describe the program to examine inaccessible portions of below-grade concrete structures for degradation and monitoring of groundwater chemistry.	3.8.5.7
3.8-13	A COL applicant that references the U.S. EPR design certification will identify site-specific settlement monitoring requirements for Seismic Category I foundations based on site-specific soil conditions.	3.8.5.7
3.8-14	A COL applicant that references the U.S. EPR design certification will describe the design and analysis procedures used for buried conduit and duct banks, and buried pipe and pipe ducts.	3.8.4.4.5
3.8-15	A COL applicant that references the U.S. EPR design certification will use results from site-specific investigations to determine the routing of buried pipe and pipe ducts.	3.8.4.4.5
3.8-16	A COL applicant that references the U.S. EPR design certification will perform geotechnical engineering analyses to determine if the surface load will cause lateral and/or vertical displacement of bearing soil for the buried pipe and pipe ducts and consider the effect of wide or extra heavy loads.	3.8.4.4.5
3.8-17	A COL applicant that references the U.S. EPR design certification will address examination of buried safety-related piping in accordance with ASME Section XI, IWA-5244, "Buried Components."	3.8.4.7

Table 1.8-2—U.S. EPR Combined License Information Items
Sheet 41 of 41

Item No.	Description	Section
19.1-10	~~A COL applicant that references the U.S. EPR design certification will, for equipment on the SEL, confirm that an acceptable seismic margin is achieved through the seismic qualification implementation program.~~A COL applicant that references the U.S. EPR design certification will, for equipment on the SEL, confirm that seismic margin is achieved through the seismic qualification implementation program by demonstrating HCLPF capacities as provided in Table 19.1-106.	19.1.5.1.1.3
19.2-1	A COL applicant that references the U.S. EPR design certification will develop and implement severe accident management guidelines using the Operating Strategies for Severe Accidents (OSSA) methodology described in U.S. EPR FSAR Section 19.2.5.	19.2.5
19.2-2	AREVA Technical Report ANP-10329 discusses the Phase 1, Phase 2, and Phase 3 actions that are performed to mitigate an ELAP event. A COL applicant that references the U.S. EPR design certification will address the actions listed in Table 19.2-6. The COL applicant will also address obtaining sufficient offsite resources to sustain core cooling, containment, and spent fuel pool cooling functions indefinitely.	19.2.8

*NRC Staff approval is required prior to implementing a change in this information marked in this table; see FSAR Introduction.

Table 1.9-2—U.S. EPR Conformance with Regulatory Guides
Sheet 12 of 19

RG / Rev	Description	U.S. EPR Assessment	FSAR Section(s)
1.142, R2	Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)	Y	3.5.3.2
			3.5.3.3
			3.8.3.2.5
			3.8.3.3.1
			3.8.4.2.5
			3.8.5.2
		EXCEPTION (ACI~~-~~ 349/ 349R-~~20~~01 edition used)	3.5.3.2
			3.5.3.3
			3.8.3.2.5
			3.8.3.3.1
			3.8.4.2.5
			3.8.5.2
1.143, R2	Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants	Y	3.2.1
			3.7.2
			3.10
			10.4.8
			11.2
			11.3
			11.4
1.145, R1 (reissued 02/ 1983)	Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants	Y	2.3.4
1.147, R14	Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1	Y	5.2.1.2
1.148, 03/1981	Functional Specification for Active Valve Assemblies in Systems Important to Safety in Nuclear Power Plants	Y	3.10.1.1
1.149, R3	Nuclear Power Plant Simulation Facilities for Use in Operator Training and License Examinations	N/A-COL	N/A
1.150, R1	Ultrasonic Testing of Reactor Vessel Welds During Preservice and Inservice Examinations	Y	5.2.4
1.151, 07/1983	Instrument Sensing Lines	Y	3.2.1
			7.1.3.4.9

Table 1.9-2—U.S. EPR Conformance with Regulatory Guides
Sheet 16 of 19

RG / Rev	Description	U.S. EPR Assessment	FSAR Section(s)
1.194, 06/2003	Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants	Y	2.3.4
1.195, 05/2003	Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors	Y	15.4.8
1.196, R1	Control Room Habitability at Light-Water Nuclear Power Reactors	Y	6.4
1.197, 06/2003	Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors	Y	6.4.5
1.198, 11/2003	Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites	N/A-COL	N/A
1.199, 11/2003	Anchoring Components and Structural Supports in Concrete	Y	3.8.1.2.5
			3.8.1.4.10
			3.8.3.2.5
			3.8.4.2.5
			3.8.5.2
		EXCEPTION (Appendix D to ACI ~~-~~349 ~~-20~~06 edition used)	3.8.1.2.5
			3.8.1.4.10
			3.8.3.2.5
			3.8.4.2.5
			3.8.5.2
1.200, R1	An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities	N/A-OTHER	N/A
1.201, R1	Guidelines for Categorizing Structures, Systems, and Components in Nuclear Power Plants According to Their Safety Significance	N/A-OTHER	N/A
1.202, 02/2005	Standard Format and Content of Decommissioning Cost Estimates for Nuclear Power Reactors	N/A-COL	N/A
1.203, 12/2005	Transient and Accident Analysis Methods	N/A-OTHER	N/A
1.204, 11/2005	Guidelines for Lightning Protection of Nuclear Power Plants	Y	7.1.3.4.20
			8.1.4.3
			8.3.1.2

Table 3.2.2-1—Classification Summary
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KKS System or Component Code	SSC Description	Safety Classification (Note 15)	Quality Group Classification	Seismic Category (Note 16)	10 CFR 50 Appendix B Program (Note 5)	Location (Note 17)	Comments/ Commercial Code
JNK	FPPS supply: Piping and Valve from FAL (30FAL16 AA102) to the IRWST	NS-AQ	D	II	Yes	UJA	ANSI/ASME B31.1[6]; Penetrates IRWST boundary RG 1.29[25]
30JNK11 AA009	IRWST Isolation Valve for SAHRS	S	B	I	Yes	UJH	ASME Class 2[2]
30JNK10 AA009/013	IRWST Isolation Valves for CVCS and FPPS	S	B	I	Yes	UJH	ASME Class 2[2]
30JNK10 AA010/011 30JNK11 AA010/011	MHSI Miniflow Line Check Valve	S	B	I	Yes	UJA	ASME Class 2[2]
30JNK10/11 AT004/ 005	IRWST Retaining Baskets	S	N/A	I	Yes	UJA	ANSI/AISC N690-1994(R2004)s2 [13]
30JNK00 BB001	IRWST Tank	S	N/A	I	Yes	UJA	*[ACI 349/349R-01[26]]**
30JNK10/20/30/40 AA001	IRWST Three-way Isolation Valves for SIS	S	B	I	Yes	UJH	ASME Class 2[2]
JNK	RCDT Overpressure Protection Line: Piping Downstream of RCDT to IRWST	S	C	I	Yes	UJA	ASME Class 3[3]
JNK	Reactor Building cavities Draining: Piping from FAL (30FAL16 AA003) to the IRWST	NS-AQ	D	II	Yes	UJA	ANSI/ASME B31.1[6]; Penetrates IRWST boundary RG 1.29[25]

Table 3.2.2-1—Classification Summary
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KKS System or Component Code	SSC Description	Safety Classification (Note 15)	Quality Group Classification	Seismic Category (Note 16)	10 CFR 50 Appendix B Program (Note 5)	Location (Note 17)	Comments/ Commercial Code
30JNK10/11 AT024/ 025	TSP Baskets	S	N/A	I	Yes	UJA	ANSI/AISC N690-1994(R2004)s2 [13]
LAR, LAS	**Emergency Feedwater System**						
30LAR11/21/31/41 AA007	Containment Isolation Check Valves	S	B	I	Yes	UJA	ASME Class 2[2]
30LAR14/24/34/44 AA001	Discharge Cross Connect Valves	S	C	I	Yes	UJH	ASME Class 3[3]
LAR	Discharge Header Piping and Valves	S	C	I	Yes	UJH	ASME Class 3[3]
30LAR04 AA001	DWDS Isolation Valve	S	C	I	Yes	4UJH	ASME Class 3[3]
30LAS11/21/31/41 AP001	EFW Pumps	S	C	I	Yes	UJH	ASME Class 3[3]
30LAR10/20/30/40 BB001	EFW Storage Pools	S	N/A	I	Yes	UJH	*[ACI 349/349R-01[26]]**
30LAR11/21/31/41 AA103	Flow Control Valves	S	C	I	Yes	UJH	ASME Class 3[3]
30LAR11/21/31/41 AA002	Min Flow Check Valves	S	C	I	Yes	UJH	ASME Class 3[3]
LAR	Piping between EFW discharge cross-connect header and Isolation Valve 30LAR55AA002	S	C	I	Yes	1UJH	ASME Class 3[3]

- RG 1.7 Regulatory Position C.2
- RG 1.143 Regulatory Position C.7
- RG 1.140 Regulatory Position C.1
- RG 1.21 Regulatory Position C.4
- NUREG-0737 Appendix B
- Staff Requirements Manual to SECY-93-087 Section II Q
- RG 1.45, Regulatory Position C 2.4
- RG 1.89 Regulatory Position C.1
- RG 1.97 Regulatory Position C

*26. [ACI 349/349R-01 refers to "Code Requirements for Nuclear Safety-Related Concrete Structures," 2001.]**

*NRC Staff approval is required prior to implementing a change in this information marked in this table; see FSAR Introduction.

concrete or steel enclosures are provided that are designed to withstand missile impact loads.

The externally generated missiles for which the U.S. EPR is designed are addressed in Section 3.5.1.

Section 3.3.2.3 describes the evaluation of the effects that the failure of structures or components not designed for tornado and hurricane loads, including missile impact, could have on nearby safety-related structures. Section 3.7.3 describes design requirements for Seismic Category II SSC, which are designed not to fail as a result of a safe shutdown earthquake and generate missiles that could affect the function of safety-related SSC.

Structures used to protect safety-related SSC meet the requirements of the following regulatory guides for externally generated missiles:

- Turbine generated missiles (RG 1.115).
- Tornado generated missiles (RG 1.117).
- Hurricane generated missiles (RG 1.221).
- Spent fuel storage facility (RG 1.13).
- Ultimate Heat Sink (RG 1.27).

3.5.3 Barrier Design Procedures

Missile barriers are designed to withstand local and overall effects of missile impact loadings. No credit is taken for non-safety-related structures providing shielding for safety-related structures from missile strikes.

Safety-related SSC are protected from missile penetration through the barrier, as well as from secondary missiles as a result of back-face scabbing. *[Concrete missile barriers subject to impactive loads are designed in accordance with the requirements of Appendix C to ACI 349/349R-01 (Reference 1).]** The Modified National Defense Research Committee Formulas referenced in ASCE No. 58, "Structural Analysis and Design of Nuclear Plant Facilities" (Reference 2) are used for the evaluation of missile penetration.

Steel missile barriers subject to impactive loads are designed in accordance with the recommendations of NUREG-0800, Reference 10. The Ballistic Research Laboratory (BRL) formula and the Stanford Research Institute (SRI) equation presented in ASCE No. 58, Reference 2, are used in the design of steel missile barriers to provide reasonable assurance that postulated missiles do not penetrate the barriers.

1.C, will be used to determine this residual velocity. The methodologies described in Sections 3.5.3.1.1 and 3.5.3.1.2 will be used for design of the concrete and steel portions of composite sections, respectively.

3.5.3.2 Overall Damage Prediction

Evaluations are performed on the overall response to missile impact of the barrier or portions within it. Structures or barriers subject to missile impact are analyzed to verify that they will not collapse or have excessive deformations that will impair the function of safe shutdown equipment. Non-linear, elasto-plastic response of structures may be assumed in the evaluation of the overall response of reinforced concrete and steel structures or barriers subjected to impactive or impulsive loads, provided the overall integrity of the structure is not impaired.

Evaluations of the overall damage from missile impact are performed by either considering missile impact in the elastic range of the structural element with other loadings applied and accounting for rebound effects of the impact, or by assuming that the inelastic capacity of the structural element resists missile impact loads. Section 3.8 provides additional information on loading combinations and analysis methods for reinforced concrete and structural steel. Inelastic impact analyses are performed by assuming that the full elastic capacity of the structural element is used to accommodate other loading conditions, and that the missile impact loads are accommodated inelastically based on the ductility of the structural element. Code requirements for ductility are met for missile impact evaluations.

Guidance provided in "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects," by R. P. Kennedy (Reference 5) is used for the evaluation of concrete missile barriers. *[Concrete missile barriers are designed in accordance with the requirements of ACI 349/349R-01, including Appendix C (Reference 1).]**

Steel missile barriers will be evaluated utilizing the equations as defined in ~~Section 3.5.3.1.3~~Section 3.5.3.1.2. *[Steel missile barriers are designed in accordance with the requirements of ANSI/AISC N690~~]*~~ (Reference 4).]**

The criteria recommended in Reference 10, SRP 3.5.3, and guidance provided in RG 1.142, are also used for design of concrete missile barriers. Procedures listed above are in agreement with methodology presented in "Impact Effect of Fragments Striking Structural Elements," Holmes and Narver, Inc., by R.A. Williamson and R.R. Alvy (Reference 6). Other procedures may also be used, provided the results obtained are comparable to those referenced. Ductility requirements specified in Section 3.5.3.3 are satisfied for concrete and steel structures that are subjected to impactive missile barrier loadings.

3.5.3.3 Ductility Requirements for Missile Barriers

Deformation under impactive and impulsive loads is controlled by limiting the ductility ratio, μ_d, which is defined as the ratio of maximum acceptable displacement, X_m, (or maximum strain, ε_m) to the displacement at the effective yield point, X_y, (or yield strain, ε_y) of the structural element. In addition to the specified deformation limits, the maximum deformation does not result in the loss of intended function of the structural element nor impair the safety-related function of other systems and components.

[Safety-related concrete structures, other than the Reactor Containment Building, are designed for impactive and impulsive loads in accordance with ACI 349/349R-01, (Reference 1),] with the exceptions noted in RG 1.142.~~]*~~*

*[The Reactor Containment Building is designed to the requirements (including those for impactive and impulsive loads) of the ASME Boiler & Pressure Vessel Code, Section III, Division 2, "Code for Concrete Containments" (Reference 7).]** Refer to ~~Reference 3.8.1~~Section 3.8.1 for more information on design of the post-tensioned concrete Reactor Containment Building.

[Safety-related steel structures are designed (including the design for impactive and impulsive loads) in accordance with ANSI/AISC N690,~~]~~ Reference 4.]**

The ductility limits for concrete and structural steel safety-related structures, other than the Reactor Containment Building, are given in Table 3.5-3—Allowable Ductility Ratios.

The effective yield displacement for reinforced concrete members is computed using a cross-sectional moment of inertia equal to $0.5(I_g + I_{cr})$.

Where:

I_{cr} = moment of inertia of cracked section transformed to concrete.

I_g = moment of gross concrete section about centroidal axis, neglecting reinforcement.

3.5.4 References

1. *[ACI 349~~-01~~/349R-01, ~~Appendix C,~~ "Code Requirements for Nuclear Safety Related Concrete Structures~~ and Commentary~~," American Concrete Institute, 2001.]**

2. ASCE Manual and Report on Engineering Practice No. 58, "Structural Analysis and Design of Nuclear Plant Facilities," ASCE Committee on Nuclear Structures and Materials, 1980.

3. Bechtel Power Corporation Topical Report, BC-TOP-9A, “Design of Structures for Missile Impact,” Rev. 2, 1974.

4. *[ANSI/AISC N690-1994 (R2004) including Supplement 2, “Specification for Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities,” American Institute of Steel Construction, 2004.]**

5. “A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects,” Paper No. NSS 5-940.1 by R. P. Kennedy Holmes and Narver, Inc., Nuclear Engineering and Design, Vol. 37, No. 2, North Holland Publishing Co., May 1976.

6. “Impact Effect of Fragments Striking Structural Elements,” R.A. Williamson and R.R. Alvy, Holmes and Narver, Inc., 1973.

7. *[ASME Boiler and Pressure Vessel Code, Section III, Division 2, “Code for Concrete Containments,” The American Society of Mechanical Engineers, 2004 Edition.]**

8. ASME Boiler and Pressure Vessel Code, Section III, Division 1, “Rules for Construction of Nuclear Facility Components,” The American Society of Mechanical Engineers, 2004 Edition.

9. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1: “Rules for Construction of Pressure Vessels,” The American Society of Mechanical Engineers, 2004 Edition.

10. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” Nuclear Regulatory Commission, March 2007.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

exception of sliding and overturning criteria. Because the TB does not have a safety function, it may slide or uplift provided that the gap between the TB and any Category I structure is adequate to prevent interaction. The effects of sliding, overturning, and any other calculated building displacements (e.g., building deflections, settlement) must be considered when demonstrating the gap adequacy between the TB and adjacent Category I structures. The separation between the TB and NI Common Basemat Structures is approximately 30 ft (see Figure 3B-1).]]

A COL applicant that references the U.S. EPR design certification will demonstrate that the response of the TB (including Switchgear Building on the common basemat) to an SSE event will not impair the ability of Seismic Category I systems, structures, or components to perform their design basis safety functions.

For COL applicants that incorporate the conceptual design for the TB presented in the U.S. EPR FSAR (i.e., [[the TB is analyzed to site-specific SSE load conditions and designed to the codes and standards associated with Seismic Category I structures so that the margin of safety is equivalent to that of a Category I structure with the exception of sliding and overturning criteria]]), this COL item is addressed by demonstrating that the gap between the TB and adjacent Category I structures is sufficient to prevent interaction. The effects of sliding, overturning, and any other calculated building displacements (e.g., building deflections, settlement) must be considered when demonstrating the gap adequacy between the TB and adjacent Category I structures.

Radioactive Waste Building

The RWB has no significant potential to seismically interact with either the NI Common Basemat Structures or with the nearest Seismic Category I structure not on the common basemat (i.e., the EPGB) therefore, the RWB is not evaluated for SSE. The RWB is a reinforced concrete shear wall structure with a low height-to-width ratio. It is designed according to RW-IIa criteria in RG 1.143; thus it is designed using the codes and standards, and load combinations associated with Category I structures (i.e., ACI~~-~~ 349/349R-01 (Reference 17), ~~AISC N-690)~~ANSI/AISC N-690 1994 including Supplement 2 (Reference 18) and analyzed for 1/2 SSE. This provides significant lateral force resistance capacity, thus catastrophic collapse of the RWB during an SSE event is unlikely. The NAB is a reinforced concrete structure located between the RWB and the NI. The NAB is designed using the codes associated with Category I structures and analyzed to full SSE, resulting in an inherently robust design. If the RWB were to collapse and impact the NAB, the damage to the NAB would be limited to local areas. Therefore, there is no potential for indirect interaction between the RWB and the NI structures.

Potential interaction between the RWB and EPGB is precluded by separation and by design and site selection and foundation design criteria for the RWB. The RWB is

13. GTSTRUDL, Version 32.

14. MTR/SASSI, Versions 9.2.2, 9.5HPC, 9.5, 9.5.1, 9.6HPC, and 9.6.

15. SHAKE91, Version 1.10.

16. ADINA, Version 8.4.

17. ACI 349-01/349-R01, "Code Requirements for Nuclear Safety-Related Concrete Structures," and Commentary, American Concrete Institute, Inc., 2001.

18. ANSI/AISC N690-1994 (R2004), "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2, American National Standards Institute, 2004.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

Table 3.7.2-30—Seismic Structural Interaction Criteria for Building Structures

Basis: Control Interaction through Prevention of Structure-to-Structure Impact[4]				
Structure	**Seismic Category**	**Design Code**	**Seismic Interaction Criteria**	**Seismic Interaction Evaluation**
Turbine / SBO	II	[[~~AISC N690~~ANSI/AISC N-690 1994 including Supplement 2]] [[ACI 349/349R-01]]	Site-specific SSE	[[COL applicant will demonstrate that there is no interaction potential]]
Access	II	[[~~AISC N690~~ANSI/AISC N-690 1994 including Supplement 2]] [[ACI 349/349R-01]]	Site-specific SSE	[[COL applicant will demonstrate that there is no interaction potential]]
NAB	II RS	ANSI/AISC N690-1994[3] ACI 349/349R-01[3]	SSE	The COL applicant will demonstrate that there is no interaction potential
RWB	RS	ANSI/AISC N690-1994[3] ACI 349/349R-01[3]	None[1]	No Interaction Potential

Notes:

1. The RWB, as a radwaste structure, is designed for the ½ SSE in accordance with the guidance for RW-IIa structures in RG 1.143.
2. Deleted.
3. ACI 349/349R-01 (Reference 17) and ~~AISC N690~~ANSI/AISC N-690 1994 including Supplement 2 (Reference 18) required due to Radwaste Seismic classification.
4. This table is not applicable to equipment and subsystems qualification criteria.

The NI Common Basemat Structure foundation basemat supports the RCB, and provides the only physical contact of the RCB with other structures. See Section 3.8.5 for a description of the NI Common Basemat Structure foundation basemat.

The RCB is a Seismic Category I, post-tensioned reinforced concrete shell structure consisting of an upright cylinder capped with a spherical dome. The dimensions of the RCB are approximately 162 feet outside diameter, by 153 feet inside diameter, by 218 feet high. The RCB is concentric with, and completely enclosed by, the RSB. No soil loadings are applied to the containment structure, and waterproofing materials are not required around the exterior surface of containment. A leak-tight steel liner plate covers the entire inner surface of the RCB, including the basemat (GDC 16).

[*The RCB is a concrete containment structure with a steel liner designed in accordance with the ASME Code, Section III, Division 2 (Reference 1)*]* (GDC 16). The RCB accommodates the calculated pressure and temperature conditions resulting from a loss of coolant accident (LOCA) without exceeding the design leakage rate and with sufficient margin (GDC 50). The RCB is designed for an internal pressure of 62.9 psig and a maximum temperature of 310~~309.2~~°F. The RCB is also designed for a negative internal pressure of -3.5 psig.

The equipment hatch and two airlocks provide access to the RB. A third opening provides access to the lower containment during construction. Section 3.8.2 provides a description of these sub-assemblies. The equipment hatch [ ] is located at [ ] and opens to the operating level of the RB internal structures. A personnel airlock is located at [ ] at the heavy load operating floor level and connects to a secure stair tower that serves various levels of the RCB. A construction access is located at [ ] An emergency airlock is located at [ ] and opens to the operating floor level from [ ]

The equipment hatch allows the entry of heavy components (e.g., the reactor pressure vessel, steam generators, reactor coolant pumps, and pressurizer) into the RB. The size of the hatch accommodates the entry of the reactor pressure vessel during construction and the entry of a replacement steam generator or pressurizer in one piece.

[*The steel liner plate is part of the concrete containment system and is designed in accordance with ASME Code, Section III, Division 2 (Reference 1).*]* The liner plate serves as a leak-tight membrane to prevent the uncontrolled release of radioactive materials to the environment (GDC 16). The steel liner plate is approximately 0.25 inch thick.

3.8.1.1.3 Liner Plate System

A carbon steel liner plate covers the entire inside surface of the RCB, excluding penetrations. The steel liner is 0.25 inch thick and is thickened locally around penetrations, large brackets, and at major attachments. Except for the bottom horizontal surface, angle and channel steel sections anchor the liner plate to the concrete containment structure. The in-containment refueling water storage tank (IRWST), including the containment sumps, are lined with 0.25 inch thick stainless steel liner plates that serve as additional corrosion protection for the underlying carbon steel liner. See Section 3.8.3 for a description of the IRWST.

Steel shapes reinforce the plate both longitudinally and laterally to provide rigidity during prefabrication, erection, and concrete placement. The steel shapes are welded to the liner plate and are fully embedded in the concrete to provide a rigid connection to the inside surface of the RCB concrete. The concrete foundation of the RB internal structures is poured on top of the liner plate at the basemat surface, embedding the lower region of the liner plate in the foundation. The liner plate is not used as a strength element to carry design basis loads; however, the liner supports the weight of wet concrete during the construction of the RCB.

[*Section CC-3810 of ASME Code, Section III, Division 2 (Reference 1) prescribes the criteria for design of liner anchorage system.*]* The U.S. EPR liner anchorage system is designed using an energy approach described in BC-TOP-1 ~~-01~~, Revision 1 (Reference 68), which addresses ASME criteria. The methodology considers the variation in liner yield strength analytically by converting liner strain to stress and membrane forces assuming the plate remains elastic. In addition, the variation of liner plate thickness is accounted for by considering a thicker panel (+16 percent) with outward curvature being adjacent to a nominal plate with inward curvature (refer to Figure 2 through 4 of Reference 68). The inward curvature is evaluated as no more than 1/8 inch during fabrication and erection of the liner plate as given in Reference 68. [*The weld offset is mitigated through quality control in accordance with ASME Code, Section III Division 2 (Reference 1) Subparagraph CC-4523.2*]*. The effects of concrete voids behind the liner are mitigated by the construction method employed. Lower concrete modulus is mitigated due to the code required over strength and the extensive performance testing required of the concrete mix. The variation of anchorage spacing is mitigated by quality control during the fabrication process. The anchorage system is designed with a safety factor so that the local crushing of the concrete is limited and a means of stress redistribution to obtain a maximum load capacity. The structural discontinuities areas, such as pipe penetration and openings, are designed as special regions.

Section 3.8.2 contains a description of the penetrations through the containment liner, including the equipment hatch, airlocks, piping penetration sleeves, electrical penetration sleeves, and the fuel transfer tube penetration sleeve.

No load transfer attachments are used at the bottom portion of the liner plate to transfer loads from the concrete RB internal structures into the lower portion of the NI Common Basemat Structure foundation basemat. RB internal structure lateral reaction loads are transferred through the liner plate. This is achieved by lateral bearing on the haunch wall at the bottom of the RB internal structures foundation where it is embedded in concrete above the NI Common Basemat Structure foundation basemat.

Structural attachments to the containment walls and dome include various pipe, HVAC, electrical, and equipment support brackets, as well as the polar crane rail supports. The liner plate is continuously welded to embedded plate areas and areas with thickened plates so that a continuous leak-tight barrier is maintained.

3.8.1.2 Applicable Codes, Standards, and Specifications

The following codes, standards, specifications, design criteria, regulations, and regulatory guides are used in the design, fabrication, construction, testing, and in-service inspection of the RCB (GDC 1, GDC 2, GDC 4, GDC 16, and GDC 50).

3.8.1.2.1 Codes and Standards

- ACI 117-90/117R-90, Specification for Tolerances for Concrete Construction and Materials (Reference 6).
- ACI 301-05, Specifications for Structural Concrete for Buildings (Reference 7).
- ACI 304R-00, Guide for Measuring, Mixing, Transporting, and Placing Concrete (Reference 8).
- ACI 305.1-06, Specification for Hot-Weather Concreting (Reference 9).
- ACI 306.1-90, Standard Specification for Cold-Weather Concreting (Reference 10).
- ACI 347-04, Guide to Form Work for Concrete (Reference 11).
- *[ACI 349~~-01~~/349R-01, Code Requirements for Nuclear Safety-Related Concrete Structures~~ and Commentary~~ (Reference 12)]** (exception described in Sections 3.8.4.4 and 3.8.4.5) ~~(Reference 12)~~.
- *[ACI 349-06~~/349R-06~~, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (Appendix D) (Reference 63) with the exception of Condition A strength reduction factors even when supplemental reinforcement is provided~~ (Reference 63)~~]**.
- ACI SP-2 (99), Manual of Concrete Inspection (Reference 13).

- ANSI/AWS D1.4-2005, Structural Welding Code - Reinforcing Steel (Reference 19).
- ASME Code.
  - Section II - Material Specifications.
  - [*Section III, Division 2 - Code for Concrete ~~Reactor Vessels and~~ Containments (Reference 1)*]*.
  - Section V - Nondestructive Examination.
  - Section VIII - Pressure Vessels.
  - Section IX - Welding and Brazing Qualifications.
  - Section XI – Rules for Inservice Inspection of Nuclear Power Plant Components.
- Acceptable ASME Code Cases per RG 1.84, Revision 33, August 2005.
- ASME NOG-1-04, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder) (Reference 21).

3.8.1.2.2 Specifications

Industry standards (e.g., those published by the ASTM) are used to specify material properties, testing procedures, fabrication, and construction methods. Section 3.8.1.6 lists the applicable standards used.

Structural specifications cover the areas related to the design of the RCB. These specifications emphasize the important points of the industry standards for the RCB and reduce the options that would otherwise be permitted by the industry standards. These specifications cover the following areas:

- Concrete material properties.
- Mixing, placing, and curing of concrete.
- Reinforcing steel and splices.
- Post-tensioning system.
- Liner plate system.

3.8.1.2.3 Design Criteria

The design of pressure retaining components of the RCB complies with:

- [*Article CC-2000 of the ASME Code, Section III, Division 2 (Reference 1)*]*.

- [*Article CC-3000 of the ASME Code, Section III, Division 2 (Reference 1)*]* (GDC 1, GDC 2, and GDC 16).
- ASME Code, Section XI, Subsection IWL, Requirements for Class CC Concrete Components of Light-Water Cooled Plants, 2004 Edition.
- ASME Code, Section XI, Subsection IWE, Requirements for Class MC and Metallic Liners of Class CC Concrete Components of Light-Water Cooled Power Plants, 2004 Edition.

3.8.1.2.4 Regulations

- 10 CFR 50 – Licensing of Production and Utilization Facilities.
- 10 CFR 50, Appendix A – General Design Criteria for Nuclear Power Plants (GDC 1, 2, 4, 16, and 50).
- 10 CFR 50, Appendix J – Primary Reactor Containment Leakage Testing for Water Cooled Power Reactors.
- 10 CFR 100 – Reactor Site Criteria.

3.8.1.2.5 NRC Regulatory Guides

Regulatory Guides applicable to the design and construction of the RCB:

- RG 1.7, Revision 3.
- RG1.35.1, July 1990.
- RG 1.84, Revision 33.
- RG 1.90, Revision 1.
- RG 1.94, Revision 1.
- RG 1.107, Revision 1.
- RG 1.136, Revision 3 (exception described in 3.8.1.3).
- RG 1.199, November 2003 (exception described in 3.8.1.4).
- RG 1.216, August 2010.

3.8.1.3 Loads and Load Combinations

The U.S. EPR standard plant design loads envelope includes the expected loads over a broad range of site conditions. [*Loads and load combinations for the RCB are in accordance with the requirements of Article CC-3000 of the ASME Code, Section III, Division 2~~,~~ (Reference 1)*]* ~~Code for Concrete Containments and ACI Standard 359~~, The ambient air temperatures listed below are for normal operation. Normal operation temperatures are given as a maximum value during summer and a minimum value during winter.

RB internal ambient temperatures:

- During normal operation:
  Equipment Area: 131°F (maximum), 59°F (minimum).
  Service Area: 86°F (maximum), 59°F (minimum).

- During normal shutdown: 86°F (maximum), 59°F (minimum).

RB annulus internal ambient temperatures:

- During normal operation: 113°F (maximum), 45°F (minimum).

– Pipe Reactions (R_o) – Pipe reactions are those loads applied by piping system supports during normal operating or shutdown conditions based on the critical transient or steady state conditions. The dead weight of the piping and its contents are not included. Appropriate dynamic load factors are used when applying transient loads, such as water hammers.

– Post-Tension Loads (J) – Post-tension loads are those loads developed from applying strain on the containment tendons.

– Relief Valve Loads (G) – Relief valve loads are those loads resulting from the actuation of a relief valve or other high-energy device.

– Pressure Variant Loads (P_v) – Pressure variant loads are those external pressure loads resulting from pressure variation either from inside or outside of containment.

– Construction Loads – Construction loads are those loads to which the structure may be subjected during construction of the plant. Construction loads will be applied to evaluate partially completed structures, temporary structures, and their respective individual members. [*Design load requirements during construction for buildings and other structures will be developed in accordance with Table CC-3230-1 of the Section III, Division 2, of the ASME Code (Reference 1)*]* and with SEI/ASCE 37-02. The magnitude and location of construction loads will be applied to generate the maximum load effects of dead, live, construction, environmental, and lateral earth pressure loads. Consideration will be given to the loads and load effects of construction methods, equipment operation, and sequence of construction.

– Test Loads – Test loads are those loads that are applied during structural integrity testing or leak-rate testing. This load category includes:

- Test Pressure Loads (P_t) – Test pressure loads are those loads resulting from the pressure exerted on the RCB during the SIT at 1.15 times the design pressure and during the leak-rate test at 1.0 times the DBA pressure.

- Unless a time-history analysis is performed to justify otherwise, the maximum values of load combinations including the loads P_a, T_a, R_a, R_{rr}, R_{rj}, R_{rm}, or G are used, including an appropriate dynamic load factor.

- [*For concrete members, U_S is defined as the required section strength for service loads based on the allowable stresses defined in Subarticle CC-3430 of the ASME Code, Section III, Division 2 (Reference 1)*]*, with additional guidance provided by NUREG-0800.

- [*For concrete members, U_F is defined as the required section strength for factored loads based on the allowable stresses defined in Subarticle CC-3420 of the ASME Code, Section III, Division 2 (Reference 1)*]*, with additional guidance provided by NUREG-0800.

- The following requirements are met for the design of concrete components for factored load conditions:

  – Primary forces must not bring the local section to a general yield state with respect to any component of section membrane strain or section flexural curvature. General yield state is the point beyond which additional section deformation occurs without an increase in section forces.

  – [*Under combined primary and secondary forces on a section, the development of a general yield state with respect to those membrane strains or flexural curvatures that correspond to secondary stress components is acceptable, and is subject to rebar strain limits specified in Subarticle CC 3420 of the ASME Code, Section III, Division 2 (Reference 1)*]*. The concept of a general yield state is not applicable to strains associated with radial shear stress.

- [*Primary and secondary forces are as defined in Subarticle CC-3130 of the ASME Code, Section III, Division 2 (Reference 1)*]*.

- [*Limitations on maximum concrete temperatures as defined in Subarticle CC-3440 of the ASME Code, Section III, Division 2 (Reference 1)*]* are observed.

- Loads and loading combinations encompass the soil cases described in Section 3.7.1, using the design criteria described in Section 3.7.1 and Section 3.7.2.

The following load combinations define the design limits for the Seismic Category I concrete RCB. These load combinations define the design limits for the Seismic Category I steel liner plate for the RCB, except that load factors are considered to be 1.0.

- Service load combinations (test loads).

  $U_S = D + L + H + F + F_b + J + P_t + T_t$

- Service load combinations (construction loads).

  $U_S = D + L + H + F + F_b + T_o + J + W$

- Service load combinations (normal loads).

  $U_S = D + L + H + F + F_b + T_o + R_o + J + G + P_v$

- Factored load combinations (severe environmental loads).

  $U_F = D + 1.3L + 1.3H + F + F_b + T_o + R_o + J + G + P_v + 1.5W$

- Factored load combinations (extreme environmental loads).

  $U_F = D + L + H + F + F_b + T_o + R_o + J + G + P_v + E'$

  $U_F = D + L + H + F + F_b + T_o + R_o + J + G + P_v + W_t$

- Factored load combinations (abnormal loads).

  $U_F = D + L + H + F + F_b + J + G + 1.5P_a + T_a + R_a$

  $U_F = D + L + H + F + F_b + J + G + P_a + T_a + 1.25R_a$

  $U_F = D + L + H + F + F_b + J + 1.25G + 1.25P_a + T_a + R_a$

- Factored load combinations (abnormal or severe environmental loads).

  $U_F = D + L + H + F + F_b + J + G + 1.25W + 1.25P_a + T_a + R_a$

  $U_F = D + L + H + F + F_b + T_o + J + G + F_a + W$

- Factored load combinations (abnormal or extreme environmental loads).

  $U_F = D + L + H + F + F_b + J + G + E' + P_a + T_a + R_a + R_r$

  $U_F = D + J + P_g1 + P_g2$

3.8.1.4 Design and Analysis Procedures

[*The analysis and design of the post-tensioned RCB comply with the requirements of Article CC-3300 of the ASME Code, Section III, Division 2 (Reference 1)*]* and RG 1.136 (GDC 1 and GDC 16).

Computer programs perform many of the computations required for the RCB analysis and design. In many cases, classical methods and manual techniques are also used for the analysis of localized areas of the containment structure and its subassemblies. Manual calculations are generally used for:

- Initial proportioning of the dome, wall, and base slab and determining tendon layout.

pressure load on containment penetrations. These analyses consider dead loads, pre-stressing loads, and the internal pressure load from the hydrogen burn event, and considered degradation of material properties due to the higher temperature resulting from hydrogen burn. [*RCB liner strains calculated for the pressure time histories during this hydrogen burn are within strain limits described by ~~RG 1.7 and~~ ASME Code, Section III, Division 2, Subarticle CC-3720 (Reference 1)*]* and RG 1.7.

Gaps are provided between the RCB and adjoining interior and exterior structures to accommodate deformation during pressurization and as a result of seismic movements.

Appendix 3E provides details of the design and reinforcement for the containment wall to foundation connection.

Appendix 3E provides details of the design and reinforcement for the containment cylinder wall and buttresses.

The following sections provide details of design and analysis of the RCB.

3.8.1.4.1 Computer Programs

The containment structure is included in an overall model developed for analysis of the NI Common Basemat Structure, which includes the RCB with the RB internal structures, the RSB, the SBs, the FB, and the NI Common Basemat Structure foundation basemat. The RCB is modeled and analyzed using the ANSYS computer program. ANSYS is a validated and verified, quality-controlled computer program that has been used for a number of years in the nuclear power industry. Refer to Chapter 17 for a description of the quality assurance program for the U.S. EPR design certification.

The ANSYS model is used to analyze the RCB for the loads defined in Section 3.8.1.3.1. The results from these load case analyses are combined and factored using the loading combinations defined in Section 3.8.1.3.2. The design of the RCB shell wall and dome is generally controlled by load combinations containing the ~~+62/-3 psig~~ design internal pressure load and SSE seismic loads.

The overall NI Common Basemat Structure analysis is performed using the ANSYS finite element computer program. The RCB is modeled in combination with the other structures of the NI Common Basemat Structure and basemat using a mesh of finite elements. The element mesh for the RCB consists of the dome and cylindrical shell wall, which interconnects with the overall NI Common Basemat Structure foundation basemat. No other structures physically connect to the containment structure; therefore, the foundation basemat is the only interfacing structure in the model. Section 3.8.5 describes the modeling of the NI Common Basemat Structure foundation basemat.

Transfer Analysis-Reactor Containment Building.

Structural forces were computed, with time, based on the heat transfer analysis using the ANSYS computer code. Figure 3.8-22—Temperature Gradient Through Cylinder Wall, Figure 3.8-23—Temperature Gradient Through Dome, and Figure 3.8-24—Temperature Gradient Through Basemat provide the generic results of this analysis. These results and those of the accident pressure analysis were reviewed in detail to establish critical time points for the development of load cases to be used in the structural analysis. Forces and moments at times 0 second, 1.39 hours, 24 hours and 100 hours were selected as critical for cylinder, dome, and basemat forces and moments. Additional internal pressure was added to the RCB due to the heating of the liner plate.

The RCB, including the steel liner, is designed to resist the effects of impulse loads and dynamic effects. Structural members designed to resist impulse loads and dynamic effects in the abnormal, extreme environmental, and abnormal and extreme environmental categories are allowed to exceed yield strain and displacement values. [*The allowable stresses applicable to the determination of section strength are as specified in Subsections CC-3400 and CC-3700 of the ASME Code, Section III, Division 2 (Reference 1)*]*. In determining tensile yield strength of reinforcing steel (i.e., f_y) the dynamic effect of the loading may be considered. [*The applicable design assumptions in Subsection CC-3930 of the ASME Code, Section III, Division 2 (Reference 1) are used in calculating the effects of impact or impulse.*]*

The ductility limits used in design for impact load do not exceed two-thirds the ductility determined at failure. The ductility limits used in design for impulse load do not exceed one-third the ductility determined at failure. See Section 3.8.5 for a description of additional requirements for missile barrier design and ductility requirements applicable to the design of the RCB.

3.8.1.4.5 Creep, Shrinkage, and Cracking of Concrete

Conservative values of concrete creep and shrinkage are used in the design of the RCB. Moments, forces, and shears are obtained on the basis of uncracked section properties in the static analysis. However, in sizing the reinforcing steel required, the concrete is not relied upon for resisting tension. Thermal moments are modified by mesh refinement and cracked-section analysis using analytical techniques. The ANSYS computer code and the RCB model thermal stress evaluation, based on results from the heat transfer analysis, were used to evaluate cracking due to accident thermal loading. The material properties, specifically E (Young's modulus), for the finite elements, were redefined as bilinear. This approximation allows the moment of inertia of a wall section to reduce in proportion to the amount of cracking developed due to the thermal loading. The threshold tensile value for cracking, maximum tension in the concrete, is taken as $4\sqrt{f'_c}$. Elements are not allowed to heal once cracked. Results from this analysis are used to factor the thermal moments from the RCB static analysis for the design of concrete sections.

Section 3.8.1.6.1 describes methods used to confirm that concrete properties satisfy design requirements.

3.8.1.4.6 Dynamic Soil Pressure

Soil loads are not applicable to the design of the RCB because the building is completely surrounded by other structures above the NI Common Basemat Structure foundation basemat.

3.8.1.4.7 Tangential Shear

[*The design and analysis procedures for tangential shear are in accordance with the ASME Code, Section III, Division 2 (Reference 1)*]* and RG 1.136.

Tangential shear is resisted by the vertical reinforcement and the horizontal hoop reinforcement in the RCB wall.

3.8.1.4.8 Variation in Physical Material Properties

In the design and analysis of the RCB, consideration is given to the effects of possible variations in the physical properties of materials on the analytical results. The properties used for analysis purposes were established based on past engineering experience with similar construction and materials. Values used are delineated in Table 3.8-2—Material Properties – Reactor Containment Building, Table 3.8-3—Tendon Frictional Losses, and Table 3.8-4—Thermal Properties – Reactor Containment Building. Additional reviews of materials and their effects on the analysis and design of the RCB will be included in design specification development and materials selection.

Losses due to elastic shortening, concrete creep and shrinkage, and relaxation of the post-tensioning cables were accounted for in the analysis. Table 3.8-5—Tendon Losses and Effective Forces with Time summarizes the losses and delineates the final wire stresses.

When designing the structure under full service and factored load conditions, allowable stress levels are used based on the minimum strength of the concrete and reinforcing materials used in construction of the containment to account for variations in physical properties. The containment is designed for the range of soil properties described in Section 3.7.1.

3.8.1.4.9 Penetrations

Large penetrations through the concrete RCB include the equipment hatch, two airlocks, and a construction opening, which are described in Section 3.8.1.1. The two airlocks are located in the containment buttresses, with one positioned at azimuth 0° and one positioned at azimuth 230°. The construction opening, which is a temporary opening permanently sealed using a metal pressure closure cap after construction, is also located at azimuth 230°. The equipment hatch is located in the cylindrical shell portion of containment at azimuth 150° between the buttress locations. The containment shell is thickened in the region surrounding the equipment hatch.

Submodels with refined element meshes and tendon configurations are used to analyze the containment vessel in the areas around the equipment hatch and in the buttress at azimuth 230° that contains the penetrations for an airlock and the construction opening. Displacements and loadings obtained from the full containment model are applied to the equipment hatch and buttress at azimuth 230° submodel to more accurately represent results in the regions around the large openings for the various loading conditions. The modulus of elasticity of the solid elements at the openings in the full containment model is reduced to one percent to consider the effect of the openings; however, the openings are explicitly included in the submodel. The modification of material properties at those solid elements was done based on the satisfactory match of displacement and stress contours between the full containment model and the equipment hatch and buttress sub-models.

Small penetration openings through the concrete RCB are defined as those having a diameter of less than approximately 6 feet. These are not considered to have a specific effect on the overall design of the RCB and are not included in the overall computer model of containment.

~~Appendix 3E provides details of the design and reinforcement in the equipment hatch area.~~

Section 3.8.2 provides design details of the steel portion of containment penetrations.

3.8.1.4.10 Steel Liner Plate and Anchors

[*The design of the steel liner plate is in accordance with Subarticle CC-3600 of the ASME Code, Section III, Division 2 (Reference 1).*]* The steel liner plate is not considered as a structural strength member when performing containment design basis analyses. The steel liner plate is designed to withstand the effects of imposed loads and to accommodate deformation of the concrete containment without jeopardizing leak-tight integrity (GDC 16). The steel liner plate is anchored to the concrete containment in a manner that does not preclude local flexural deformation between anchor points. [*Calculated strains and stresses for the steel liner plate do not exceed the values given in Table CC-3720-1 of the ASME Code, Section III, Division 2*

(Reference 1)]*. Strains associated with construction-related liner deformations may be excluded when calculating liner strains for service and factored load combinations as allowed by the code. The liner is anchored to the concrete containment around the outside perimeter of the sides of the embedded portion between elevation -25 feet, 7 inches and elevation -7 feet, 6.5 inches. Anchors are not provided on the inside surface of the liner. Overturning moments and sliding forces of the RB internal structures relative to the liner plate are resisted by the appropriate structural dead weight and lateral bearing.

The steel liner plate anchorage system is designed to accommodate design loads and deformations without loss of structural or leak-tight integrity (GDC 16). The steel liner plate anchorage system is designed so that a progressive failure of the anchorage system is prevented in the event of a defective or missing anchor. *[The steel liner plate is anchored to the concrete so that the liner strains do not exceed the strain allowable given in Paragraph CC-3720 of the ASME Code, Section III, Division 2 (Reference 1).]** The anchor size and spacing is designed so that the response of the steel liner plate is predictable for applicable loads and load combinations. The anchorage system is designed to accommodate the design in-plane shear loads and deformations exerted by the steel liner plate and normal loads applied to the liner surface. *[The allowable force and displacement capacity for the steel liner plate anchors does not exceed the values given in Table CC-3730-1 of the ASME Code, Section III, Division 2 (Reference 1).]** The load combinations specified in Section 3.8.1.3.2 are applicable to the steel liner plate anchors. *[Mechanical and displacement-limited loads are as defined in Subparagraph CC-3730(a) of the ASME Code, Section III, Division 2 (Reference 1).]** *[Concrete anchors are designed in accordance with ACI 349-06 (Appendix D) (Reference 63) with exception stated in Section 3.8.1.2.1]*~~)~~,~~]*~~ and with the guidelines of RG 1.199. The use of Appendix D to ACI 349-06 is an exception to RG 1.199, which endorses Appendix B to ACI 349~~-01~~/349R-01 for concrete anchorage design. Use of Appendix D to ACI 349-06 ~~(~~with exception stated in Section 3.8.1.2.1~~)~~ is acceptable as it results in an equivalent or conservative anchorage design when compared to that of Appendix B to ACI 349~~-01~~/349R-01.

Steel liner plate penetration assemblies, including nozzles, reinforcing plates, and penetration anchors are designed to accommodate design loads and deformations without loss of structural or leak-tight integrity (GDC 16). Effects such as temperature, concrete creep, and shrinkage are considered. Temporary and permanent brackets and attachments to the steel liner plate are designed to resist the design loads without loss of the liner integrity due to excessive deformation or load from the brackets or attachments.

Design of the steel liner plate and anchorage system is based on minimum strengths for the materials that are specified for fabrication of the steel components and their interface with the concrete containment. Deviations in the geometry of the liner plate due to fabrication and erection tolerances are considered in the design.

The materials of the liner and its stiffening and anchorage components that are exposed to the internal environment of containment are selected, designed, and detailed to withstand the effects of imposed loads and thermal conditions during design basis conditions.

3.8.1.4.11 Containment Ultimate Capacity

The Ultimate Pressure Capacity Deterministic Analyses for the RCB is performed in accordance with RG 1.136, RG 1.216 and guidance provided in SRP 3.8.1.II.4.K (Rev. 2)

Analysis results for the various containment elements are summarized in Table 3.8-6. These results are based on ANSYS non-linear finite element containment model with nominal stress-strain elasto-plastic materials properties under accident temperature and with cracked concrete section behavior.

The Ultimate Nominal Pressure Capacities for the cylinder and dome sections are calculated using the two degree slice FEM with simulated axisymmetric boundary conditions. The ultimate conditions in these cases are 0.8 percent strain level in tendon areas located away from discontinuities (according to SRP 3.8.1.II.4.K). The simplified cross-checking hand calculation confirms the FEM results.

The Ultimate Nominal Pressure Capacities for the ring and gusset sections are evaluated using the same FEM as above with non-linear analysis run until the first 0.8 percent strain level in the rebars in the critical sections.

Equipment Hatch

Non-Linear 3D FEM is used for the equipment hatch Ultimate Nominal Pressure Capacities evaluation. The non-linear steel properties for hatch, flanges, and sleeves are based on elastic-perfectly plastic model with bilinear kinematic hardening according to Von Mises yield criteria. Geometric nonlinearity is accounted for in the large displacement (stability) calculation. The results of calculations are summarized in Table 3.8-6.

The structural capacity of the equipment hatch is determined by finite element techniques.~~The equipment hatch is a spherical shell.~~ The stability analysis is performed in accordance with NE-3222.1(a)(1)~~NE-3133.4~~. The allowable pressure for buckling is 85.33~~85.67~~ psig. In accordance with NE-3222, the compressive allowable stress is increased by 150 percent for ASME Service Level D, which gives an ultimate capacity buckling pressure as presented in Table 3.8-6.~~of 128.5 psig.~~

Since the hatch performs a leak tightness role, [*the allowable strain criteria in accordance with ASME Code, Section III, Division~~.~~ 2, ~~Subsection CC,~~ Article CC-3720 (Reference 1)]** is conservatively used for the hatch ultimate pressure capacity evaluation. These allowable strains are: membrane strain of ε_C=0.5%, ε_T=0.3% and combined membrane + bending strain of ε_C=1.4%, ε_T=1%.

The estimated Ultimate Pressure Capacities are determined from the principal strain levels, which approach ultimate in the protruding sleeves while remaining below yield in the hatch and flange areas. Under ultimate internal pressure that exceeds 2.0 times the design pressure, the sealing strip between the clamps remains in compression and remains leak tight. ~~The radial ribs on the sleeve serve as buckling stiffeners for the hatch sleeve and are designed to carry axial force that exceeds 2.5 times the design pressure.~~ The hatch cover and protruding sleeve buckle at greater than 2.0 times the design pressure.

An ultimate pressure capacity evaluation has been performed for the other major containment penetrations including the construction opening closure, the containment dedicated spare penetration, the personnel airlocks, the fuel transfer tube, and the main steam and feedwater line penetrations.

The ultimate capacity is evaluated using the design basis accident temperature and the following criteria.

1. Structural Capacity- A pressure 2.5 times the containment design pressure (2.5 x 62.9 psig = 157.25~~155~~ psig) is applied to the penetration. [*The resulting strain levels are compared against the ~~ASME Subsection CC~~ factored strain allowable values in Table CC-3720-1 of the ASME Code, Section III, Division 2 (Reference 1).*]* The 2.5 times design pressure is considered adequate to demonstrate sufficient margin exists above the design pressure for the ultimate capacity evaluation.

2. Stability (or buckling) - A stability analysis is performed to determine the buckling pressure in accordance with ASME Subsection NE, paragraph NE-3222, where one-third of the basic compressive allowable stress is considered or the buckling pressure is determined in accordance with NE-3133. ASME Level D allowable buckling pressures are determined. [*Strain values are determined from application of the allowable buckling pressure in an analysis with non-linear material properties and evaluated against the ~~ASME Subsection CC~~ factored strain allowable values in Table CC-3720-1 of the ASME Code, Section III, Division 2 (Reference 1).*]*

3. Potential Leak Paths - The sealing mechanisms and strain levels in the metallic components at the ultimate capacity pressure are evaluated to demonstrate that no containment leak paths are created.

The minimum ratio of the ultimate capacity pressure (Pu) to the design pressure (Pd) and the controlling mode/location is presented in Table 3.8-6.

Construction Opening Closure

The structural capacity of the construction opening closure is determined by finite element analysis techniques. The construction opening closure is a spherical shell. The stability analysis is performed in accordance with NE-3133.4. The allowable pressure for buckling is 79 psig. The compressive allowable stress is increased by 150 percent for Service Level D. Therefore, the ultimate capacity buckling pressure is 118.5 psig.

The construction opening closure is a welded cap. [*The calculated strain values do not exceed the factored allowable strain values in ~~ASME~~ Table CC-3720-1 of the ASME Code, Section III, Division 2 (Reference 1).*]* Therefore, the leaktight integrity of the penetration is maintained at the evaluated pressures.

Containment Dedicated Spare Penetration

The capacity of the containment dedicated spare penetration sleeve is bounded by the main steam line penetration. The penetration closure capacity is bound by the construction opening closure as described in Section 3.8.2.4.1. Therefore, the ultimate capacity of the containment dedicated spare penetration does not govern the ultimate capacity of the U.S. EPR containment.

Personnel Airlocks

The structural capacity of the personnel airlocks is determined by finite element analysis techniques. The personnel airlocks consist of a complex geometry. The stability analysis is performed by a rigorous analysis in accordance with NE-3222.1(a)(1).

The basic allowable pressure for buckling is controlled by the capacity of the airlock door and is 79.3~~6~~ psig. The compressive allowable stress is increased by 150 percent for Service Level D. ~~Therefore, the~~The ultimate capacity buckling pressure determined is presented in Table 3.8-6~~119.4 psig~~.

[*The airlock leak tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ~~ASME~~ Table CC-3720-1 of the ASME Code, Section III, Division 2 (Reference 1).*]* The airlock seals are positive seating with the containment internal pressure. The airlock seals remain compressed with the strain limits considered for the metal components in the vicinity of the airlock door seals. Therefore, the leak tight integrity of the penetration is maintained at the containment ultimate capacity pressures.

Fuel Transfer Tube

The structural capacity of the fuel transfer tube is determined by finite element analysis techniques. [*The stability analysis of the fuel transfer tube is performed by a* *rigorous analysis in accordance with NE-3222.1(a)(1) and Code Case N-284-1.]** A non-linear finite element analysis is performed by incrementally applying pressure until the solution no longer converges. The allowable pressure for buckling is 270~~230~~ psig, which is greater than 2.5 x Pd (157.25~~155~~ psig). Therefore, the ultimate capacity results are reported at 2.5 Pd (157.25~~155~~ psig).

*[The fuel transfer tube leak tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ~~ASME~~ Table CC-3720-1 of the ASME Code, Section III, Division 2 (Reference 1).]** The fuel transfer tube has a blind flange on the containment side which has positive seating with the containment internal pressure. The fuel transfer tube flange remains seated with the strain limits considered for the metal components in the vicinity of the blind flange. Therefore, the leak tight integrity of the penetration is maintained at the containment ultimate capacity pressures.

Main Steam and Feedwater Line Penetrations

The structural capacity of the main steam and feedwater line penetrations is determined by finite element analysis techniques. Buckling is not a failure mechanism for the main steam and feedwater line penetrations because the penetrations act as short columns with a slenderness ratio (kl/r) less than 89 (structural steel). Therefore, the ultimate capacity results are reported at 2.5 Pd (157.25 psig).

*[The main steam and feedwater line penetrations leak tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ~~ASME~~ Table CC-3720-1 of the ASME Code, Section III, Division 2 (Reference 1).]** Therefore, the leak tight integrity of the penetration is maintained at the containment ultimate capacity pressure.

3.8.1.4.12 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.4, 2.5, 3.3, 3.5, 3.7, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design results are presented in Appendix 3E for Seismic Category I structure critical sections. A cross-reference between U.S. EPR FSAR sections and information required by SRP Section 3.8.4, Appendix C is provided in Table 3.8-17.

3.8.1.5 Structural Acceptance Criteria

[*The limits for RCB allowable stresses, strains, deformations and other design criteria are in accordance with the requirements of Subsection CC-3400 of the ASME Code, Section III, Division 2 (Reference 1),*]* RG 1.136, and RG 1.216 (GDC 1, GDC 2, GDC 4, GDC 16, and GDC 50). This applies to the overall containment vessel and subassemblies and appurtenances that serve a pressure retaining function, except as noted in Section 3.8.2. Specifically, allowable concrete stresses for factored loadings are in accordance with Subsection CC-3420 and those for service loads are in accordance with Subsection CC-3430.

[*The limits for stresses and strains in the liner plate and its anchorage components are in accordance with ASME Code, Section III, Division 2, Tables CC-3720-1 and CC-3730-1 (Reference 1).*]*

[*Limits for allowable loads on concrete embedments and anchors are in accordance with Appendix D of ACI-349-06 (Reference 63) ~~(~~with exceptions stated in Section 3.8.1.2.1~~, Codes)]*~~]** and guidance given in RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~.

Section 3.8.1.6 describes minimum requirements for concrete, reinforcing, post-tensioning tendons, and the liner plate system for the RCB.

A SIT is performed as described in Section 3.8.1.7.1.

[*The RCB is stamped to signify compliance with the ASME Code, Section III, Division 2 (Reference 1).*]*

An as-built report is prepared to summarize deviations from the approved design and confirm that the as-built RCB is capable of withstanding the design basis loads described in Section 3.8.1.3 without loss of structural integrity or safety-related functions.

3.8.1.6 Materials, Quality Control, and Special Construction Techniques

This section contains information relating to the materials, quality control program, and special construction techniques used in the fabrication and construction of the RCB. Materials and quality control satisfy the following requirements (GDC 1):

- [*ASME Code, Section III, Division 2, Code for Concrete Containments~~/ACI Standard 359~~, Articles CC-2000, CC-4000, CC-5000, CC-6000, and CC-9000 (Reference 1).*]*
- RG 1.107, Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures, Revision 1, February 1977.
- RG 1.136, Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments, Revision 3, March 2007.

[*Concrete and reinforcement forming and placement tolerance not specifically addressed in these references are in accordance with ACI 349~~-01~~/349R-01 (Reference 12)*]* and ACI 117-90.

3.8.1.6.1 Concrete Materials

Concrete Mix Design

[*The concrete mix design for the RCB conforms to the requirements specified in Subarticle CC-2230 of the ASME Code, Section III, Division 2 (Reference 1).*]*

Structural concrete used in the construction of the RCB shell wall and dome has a minimum compressive strength (i.e., f'_c) of 7000 psi at 90 days.

Concrete mix design is determined based on field testing of trial mixtures with actual materials used. Testing evaluates:

- Ultimate concrete strength, as well as early strength in support of an aggressive construction schedule.
- Creep and shrinkage characteristics.
- Concrete workability and consistency.
- Required concrete admixtures.
- Heat of hydration and required temperature control for large or thick concrete pours.
- Special exposure requirements when identified on design drawings.
- Thermal properties, diffusivity and a conductivity per CRD C36 (Reference 69) and CRD C44 (Reference 70), respectively.

Cement

Cement used for the concrete RCB conforms to the requirements of ASTM C150 (Reference 47) (Type I, Type II, Type IV or Type V) or ASTM C595 (Reference 48) (Type IP, Type IP [MS], or Type IP [MH]).

Low-alkali cement, as defined in ASTM C150, is used in concrete with aggregates that are potentially reactive per ASTM C33.

Aggregates

[*Aggregates used for the RCB meet the requirements specified in ASME Code, Section III, Division 2, Paragraph CC-2222 (Reference 1).*]*

Aggregates conform to the requirements of ASTM C33 (Reference 22).

ASTM Standards C1260 and C1293 (References 71 and 72) shall be used in testing aggregates for potential alkali-silica reactivity (ASR).

Admixtures

Air-entraining admixtures conform to the requirements of ASTM C260 (Reference 23).

Chemical admixtures conform to the requirements of ASTM C494 (Reference 24) or ASTM C1017 (Reference 25).

Fly ash and other pozzolanic admixtures conform to the requirements of ASTM C618 (Reference 26).

Grout fluidizers conform to the requirements of ASTM C937 (Reference 27).

Ground-granulated blast furnace slag used as an admixture is in accordance with the requirements of ASTM C989 (Reference 28).

Silica fume used as an admixture conforms to the requirements of ASTM C1240 (Reference 29).

Admixtures used in concrete mixtures in accordance with ASTM C845 (Reference 30) expansive cement is compatible with the cement and produce no deleterious effects.

Mix Water

[*Mix water used for the RCB is in accordance with the requirements of ASME Code, Section III, Division 2, Paragraph CC-2223 (Reference 1).*]*

Placement

Conveying, inspection, placement, and testing of concrete are performed in accordance with the following codes and standards:

- ACI 301-05, Specifications for Structural Concrete for Buildings.
- ACI 304R-00, Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete.
- ACI 305.1-06, Specification for Hot-Weather Concreting.
- ACI 306.1-90, Standard Specification for Cold-Weather Concreting.
- ACI 347-04, Recommended Practice for Concrete Formwork.
- ACI SP-2 (99), Manual of Concrete Inspection.
- ASTM C94, Specification for Ready-Mixed Concrete (Reference 38).

3.8.1.6.2 Reinforcing Steel and Splice Materials

Materials

[*Conventional reinforcing is used in the concrete RCB, which conforms to ~~ASTM A615 (Reference 31) or ASTM A706 (Reference 32), and~~ the criteria described in the ASME Code, Section III, Division 2, Subarticle CC-2330 (Reference 1)*]* and ASTM A615 (Reference 31) or ASTM A706 (Reference 32).

[*Welded splices and mechanical splices of reinforcing bars are used. Mechanical splices are threaded, swaged, or sleeved with ferrous filler metal. These devices are qualified and the qualifications are maintained in accordance with Subarticle CC-4333 of ASME Code, Section III, Division 2 (Reference 1).*]* [*These devices also meet the provisions of ACI 349~~-01~~/349R-01, Section 12.14.3 (Reference 12).*]*

Welding of reinforcement is as specified in approved splice details and is located as shown on approved reinforcing placement drawings. [*Welding conforms to ASME Code, Section III, Division 2, Subsection CC (Reference 1),*]* as supplemented by RG 1.136, and ANSI/AWS D1.4.~~]*~~

Materials used for bar-to-bar sleeves for mechanical cadweld-type rebar splices in the RCB conform to ASTM A513, (Reference 33) ASTM A519 (Reference 34), or ASTM A576 (Reference 35). For bar splice sleeves attached to the liner plate or structural steel shapes, the sleeves are carbon steel in accordance with ASTM A513, ASTM A519, or ASTM A576 (Grades 1008 through 1030).

[*Materials for mechanical threaded, swaged, or sleeved splicing systems are established in accordance with the ASME Code, Section III, Division 2, Subarticle ~~CB~~CC-4333 (Reference 1).*]*

Fabrication and Placement

[*Fabrication and placement of reinforcing bars for the RCB are in accordance with Subarticle CC-4300 of the ASME Code, Section III, Division 2 (Reference 1).*]*

3.8.1.6.3 Tendon System Materials

Tendons

The post-tensioning tendon system consists of load-carrying and non-load-carrying components. The load-carrying components include the post-tensioning wires that make up the tendons, and anchorage components composed of bearing plates, anchor heads, wedges, and shims. Non-load-carrying components include the tendon sheathing (including sheaths, conduits, trumpet assemblies, couplers, vent and drain nipples, and other appurtenances) and corrosion prevention materials.

[*Materials used for the RCB post-tensioning system (including post-tensioning steel, anchorage components, and non-load-carrying and accessory components) meet the requirements of Subarticle CC-2400 of the ASME Code, Section III, Division 2 (Reference 1)*.]*

The Freyssinet C-range post-tensioning system has the following properties:

- ASTM A416 (Reference 36), Grade 270, low-relaxation tendon material.
- Tendon ultimate strength $F_{pu} = 270$ ksi
- Tendon minimum yield strength $F_{py} = (0.9)(270) = 243$ ksi
- Modulus of elasticity of tendon material $E_{ps} = 28{,}000$ ksi
- Number of strands per tendon $N_{strands} = 55$
- Total area of each tendon $A_p = 12.76$ in^2

The materials used for the anchorage components are compatible with the tendon system. Tendon raceways consist of corrugated steel ducts and rigid metal conduit. These components are non-structural and are sealed to prevent the intrusion of concrete during construction.

Grouting of Tendons

[*Cement grout for the grouted tendons in the prestressing system in the RCB is selected based on the testing and material requirements of the ASME Code, Section III, Division 2 (Reference 1),]** as amended by RG 1.136, which endorses the Regulatory Positions of RG 1.107, Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures.~~]*~~

Greasing of Tendons

[*Grease for the greased test tendons in the prestressing system in the RCB is selected based on the testing and material requirements of the ASME Code, Section III, Division 2 (Reference 1)*.]*

3.8.1.6.4 Liner Plate System and Penetration Sleeve Materials

[*The 0.25 inch thick liner plate is SA-516, Grade 55, 60, 65 or 70 material, which conforms to Subarticle CC-2500 of the ASME Code, Section III, Division 2 (Reference 1)]** (GDC 16). Thickened liner plates are used at penetrations, brackets, and embedded assemblies.

Penetration assemblies and appurtenances that are either not backed by concrete or are embedded in concrete and surrounded by a compressible material to provide local flexibility conform to the material requirements of Subsection NE of the ASME Code, Section III, Division 1 (Reference 73) (GDC 16). Penetration sleeve materials are listed in Table 6.1-1.

Welding materials conform to the requirements of ASME Code, Section II. Welding activities meet the requirements of ASME Code, Sections III and IX.

[*Materials used for the carbon steel liner plate, carbon steel and low alloy steel attachments, and appurtenances subject to ASME Code Division 2 requirements, meet the fracture toughness requirements of Subsection CC-2520 of the ASME Code, Section III, Division 2 (Reference 1).*]*

~~[~~Materials used in ASME Code, Section III, Division 1 attachments and appurtenances meet the fracture toughness requirements of Subsection 2300 of the ASME Code, Section III, Division 1.~~]*~~

3.8.1.6.5 Steel Embedments

[*Steel embedment materials conform to the requirements of Subsection CC-2000 of the ASME Code, Section III, Division 2 (Reference 1).*]*

3.8.1.6.6 Corrosion Retarding Compounds

Corrosion retarding compounds used for the RCB are described in Section 6.1.2.

3.8.1.6.7 Quality Control

In addition to the quality control measures addressed in Section 3.8.1.6, refer to Chapter 17 for a description of the quality assurance program for the U.S. EPR (GDC 1).

3.8.1.6.8 Special Construction Techniques

Special techniques are not used for construction of the RCB. Modular construction methods are used to the extent practical for prefabricating portions of the containment liner, equipment hatch, airlocks, penetrations, reinforcing steel, tendon conduits, and concrete formwork. Such methods have been used extensively in the construction industry. Rigging is pre-engineered for heavy lifts of modular sections. Permanent and temporary stiffeners are used on liner plate sections to satisfy code requirements for structural integrity of the modular sections during rigging operations.

3.8.1.7 Testing and Inservice Inspection Requirements

3.8.1.7.1 Structural Integrity Test

Following construction, the RCB is proof-tested at 115 percent of the design pressure. During this test, deflection measurements and concrete crack inspections are made to confirm that the actual structural response is within the limits predicted by the design analyses (GDC 1).

[*The SIT procedure complies with the requirements for prototype containments of Article CC-6000 of the ASME Code, Section III, Division 2 (Reference 1)*,]* ~~(Reference 1)~~ and with Subsections IWL and IWE of Section XI of the ASME Code.

3.8.1.7.2 Long-Term Surveillance

The RCB is monitored periodically throughout its service life in accordance with 10 CFR 50.55a and 10 CFR 50, Appendix J, to evaluate the integrity of containment over time (GDC 1 and GDC 16). As part of this monitoring program, containment deformations and exterior surface conditions are determined while the building is pressurized. Initial measurements and in-service inspection meet the requirements of the following:

- ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Subsections IWE and IWL.
- Supplemental Inspection Requirements of 10 CFR 50.55a.
- ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Subsection IWL, does not contain specifications for inservice inspection of grouted tendons. For inservice inspection of grouted tendons, the guidelines of RG 1.90, Revision 1 are followed, with no exceptions.

The U.S. EPR containment differs in some aspects from the "reference containment" as defined in RG 1.90, Revision 1. The U.S. EPR containment ISI program will be developed using the concepts presented in RG 1.90, Revision 1. In accordance with RG 1.90, Revision 1, the tendons for the U.S. EPR will be included in an ISI program. The program will consist of:

- Force monitoring of ungrouted test tendons (supplemented by RG 1.35.1).
- Monitoring of deformations under pressure at prescribed locations (Alternative B of RG 1.90, Revision 1).
- Visual inspection of exposed structurally critical areas of the containment and containment prestressing system.
- A sample of sheathing filler grease from each of the ungrouted test tendons will be taken and analyzed according to the test methods and acceptance criteria of ASME Code Table IWL-2525-1.

  In addition, the amount of sheathing filler grease removed and replaced will be compared to assess grease leakage within the structure.

Sufficient physical access is provided in the annulus between the RCB and the RSB to perform inservice inspections on the outside of the containment. There is approximately 18 inches clearance between the upper containment ring beam and the RSB. Space is available inside of the RCB to perform inservice inspections of the liner plate. Gaps are provided between the liner and RB internal structures concrete structural elements, which provide space necessary to inspect the liner at wall and floor locations inside containment. Inservice inspection of the embedded portion of the containment liner and the surface of the concrete containment structure covered by the liner are exempted in accordance with Section III of the ASME Code for Class CC components.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

3.8.2 Steel Containment

The steel containment section describes major RCB penetrations and portions of penetrations not backed by structural concrete that are intended to resist pressure. Section 3.8.1 describes the concrete RCB.

3.8.2.1 Description of the Containment

Steel items that are part of the RCB pressure boundary and are not backed by concrete include the equipment hatch, airlocks, construction opening, piping penetration sleeves, electrical penetration sleeves, and fuel transfer tube penetration sleeve. Section 3.8.1.1 describes RCB steel items that are backed by concrete, such as the liner plate.

3.8.2.1.1 Equipment Hatch, Dedicated Spare Penetration, Airlocks, and Construction Opening

The equipment hatch, illustrated in Figure 3.8-25 is a welded steel assembly with a double-sealed, flanged, and bolted cover. The cover for the equipment hatch attaches to the hatch sleeve from inside of the RCB. The cover seats against the sealing surface of the penetration sleeve mating flange when subjected to internal pressure inside the RCB. The RCB penetration sleeve and the RSB penetration sleeve are connected by an expansion joint to allow for differential movement between the two walls, as shown in Figure 3.8-25. The equipment hatch opens into the Seismic Category I FB, which provides protection of the hatch from external environmental hazards (e.g., high wind, tornado and hurricane winds and missiles, and other site proximity hazards, including aircraft hazards and blasts). The equipment hatch sleeve has an inside diameter of approximately 27 feet, 3 inches.

The containment penetrations also include a 36-inch diameter spare containment penetration as shown in Figure 3.8-119. This penetration is dedicated for post-accident conditions as described in Section 19.2.3.3.8.

One personnel airlock and one emergency airlock are provided for personnel to access the RCB. Figure 3.8-26—Personnel Airlock, Emergency Airlock General Overview illustrates a typical arrangement for the airlocks. Each airlock is a welded steel assembly that has two doors, each with double seals. The airlocks open into containment so that internal pressure inside the RCB seats the doors against their sealing surfaces. The personnel airlock and emergency airlock are connected to the RSB wall by expansion joints to allow for differential movement.

The doors mechanically interlock so that one door can not be opened unless the second door is sealed during plant operation. Provisions are made for deliberately overriding the interlocks by the use of special tools and procedures for ease of access during plant maintenance. Each door is equipped with valves for equalizing the pressure across the doors. The doors are not operable unless the pressure is equalized. Pressure equalization is possible from the locations at which the associated door can be operated. The valves for the two doors interlock so that only one valve can open at a time and only when the opposite door is closed and sealed. Each door is designed to withstand and seal against design and testing pressures of the containment vessel when the other door is open. A visual indication outside each door shows whether the opposite door is open or closed. In the event that one door is accidentally left open, provisions outside each door allow remote closing and latching of the opposite door.

The personnel airlock at [ ] opens into a [ ] which is a Seismic Category I structure. The emergency airlock opens into the [ ], which is a Seismic Category I structure. Therefore, both airlocks are protected from external environmental hazards (e.g., high wind, tornado and hurricane winds and missiles, and other site proximity hazards, including aircraft hazards and blasts). The personnel airlock and the emergency airlock have inside diameters of approximately 10 feet, 2 inches.

The construction opening is located at [ ] and opens to the heavy load operating floor level from [ ] This passage serves as personnel and material access into the RB during construction. The construction opening has an outside diameter of approximately 9 feet, 6 inches. Upon completion of construction work, the cavity in the RCB is permanently sealed with a metal closure cap welded to an embedded sleeve. The construction opening is shown in Figure 3.8-123.

The equipment hatch, dedicated spare penetration, two airlocks, and construction opening closure cap and sleeve are designated as Class MC components in compliance with Article NE-3000 of the ASME Code, Section III, Division 1~~I~~, and are stamped pressure vessels designed and tested in accordance with this code~~]*~~ (GDC 1 and GDC 16).

3.8.2.1.2 Piping Penetration Sleeves

Piping penetrations through the RCB pressure boundary are divided into the following three general groups:

- High-energy penetrations:

  This type of penetration is used for high-energy piping. Examples of high-energy penetrations are those provided for the safety injection or chemical and volume control lines. High-energy piping penetrations consist of the following major steel items:

  - ~~[~~Process pipe – Process pipes are welded or seamless and are made of carbon or stainless steel. The pipes are welded to a connecting part centrally located in the annulus between the inner containment wall and the outer shield wall. The connecting part is welded to an embedded sleeve in the inner containment wall. This acts as an anchor for the penetration. The guard pipe is also connected to the connecting part. The process pipes conform to the requirements of ASME Code, Section III, Subsection NC and meet the requirements of the piping system they serve as described in Section 3.6.

  - Connecting part – Connecting parts are made from forged carbon or stainless steel and conform to ASME Code, Section III, Division 1, Subsection NC. The connecting process pipes and connecting part are each designed and analyzed to be capable of carrying loads in the event of failure of the process pipes as described in Sections 3.6 and 3.9.

  - Pipe sleeve – Pipe sleeves are made from carbon or stainless steel and consist of the portion of the penetration that projects into the RCB and supports the connecting part. Pipe sleeves conform to ASME Code, Section III, Division 1, Subsection NE (GDC 1).~~]*~~

- Main steam and feedwater penetrations:

  These penetrations are a special adaptation of the high-energy penetrations. The design is the same as the high-energy penetration except it has a guard pipe that fits tightly over the process pipe in the inner containment sleeve that is designed to dissipate heat and prevent the concrete from overheating. The protection pipes are connected to the RSB penetration sleeve by expansion bellows, as shown in Figures 3.8-120 and 3.8-27. The bellows allow differential movement and minimizes load transfer between the RCB and RSB.

- Standard piping penetration:

  This penetration type is used for moderate or low energy piping lines. The basic configuration consists of an inline flued head component attached to the inner containment embedded pipe sleeve. There is no guard pipe, but an expansion joint attached to the pipe and sleeve allows differential movement and minimizes load transfer between the RCB and RSB. These penetrations consist of:

- Process pipe and flued head – Process pipes are welded or seamless and are made of carbon or stainless steel. The pipes are welded to the flued head. Flued heads are made from forged carbon or stainless steel. {Process pipes and flued heads conform to Subsection NC of the ASME Code, Section III, Division 1, and}* meet the requirements of the piping system they serve as described in Section 3.6.

- Pipe Sleeve – Pipe sleeves are made from carbon or stainless steel and consist of the portion of the penetration that projects into the RCB and supports the flued head. {Pipe sleeves conform to ASME Code, Section III, Division 1, Subsection NE}* (GDC 16).

• Spare penetrations:

Spare penetrations are reserved for future use. Spare penetrations consist of the following major items:

- Solid closure plate or pipe cap – {Closure plates and pipe caps are made from carbon or stainless-steel and conform to the requirements of Subsection NC of the ASME Code, Section III, Division 1, Subsection NC.}*

- Pipe sleeve – {Pipe sleeves are made from carbon or stainless-steel and consist of the portion of the penetration that projects into the RCB. Pipe sleeves conform to ASME Code, Section III, Division 1, Subsection NE}* (GDC 16).

Typical details of piping penetrations are illustrated in Figure 3.8-27—Containment Penetration for Feedwater Pipe, Figure 3.8-28—Containment Penetrations for High Energy Pipes, Figure 3.8-29—Containment Standard Piping Penetrations – Single Pipe, Figure 3.8-30—Containment Standard Piping Penetrations – Multiple Pipes, and Figure 3.8-120—Containment Penetration for Main Steam Pipe.

3.8.2.1.3 Electrical Penetration Sleeves

Sleeves for electrical penetrations consist of the portion of penetrations that projects into the RCB and supports the electrical assembly. {Sleeves conform to ASME Code, Section III, Division 1, Subsection NE}* (GDC 16).

Typical details of electric penetrations are illustrated in Figure 3.8-121—Low Voltage Electrical Penetration Sleeve and in Figure 3.8-122—Medium Voltage Electrical Penetration Sleeve.

3.8.2.1.4 Fuel Transfer Tube Penetration Sleeve

The fuel transfer tube penetration is provided to transfer fuel between the refueling canal and the spent fuel pool during the refueling operations of the reactor. The penetration consists of an approximately 20 inch diameter stainless steel pipe installed inside a larger 36 inch diameter penetration sleeve that is anchored to the concrete RCB. ~~[~~The penetration sleeve conforms to Subsection NE of the ASME Code, Section III, Division 1~~]*~~ (GDC 16). The inner pipe acts as the transfer tube. Expansion joints are provided around the fuel transfer tube where it passes through the RB internal structures refueling canal concrete and the RSB and FB concrete to allow for differential movement between the structures and to maintain leak-tight boundaries for the refueling pools and the annulus ventilation system. Figure 3.8-31—Fuel Transfer Tube Penetration (Conceptual View) illustrates the fuel transfer tube penetration.

3.8.2.2 Applicable Codes, Standards, and Specifications

The following codes, standards, specifications, design criteria, regulations, and regulatory guides are used in the design, fabrication, construction, testing, and inservice inspection of steel portions of the RCB that are intended to resist pressure, but are not backed by structural concrete (GDC 1, GDC 2, GDC 4, GDC 16 and GDC 50).

The boundaries between the RCB and the steel pressure boundary component consist of those defined in ASME Code, Section III, Division I, Paragraph NE-1132. Section 3.8.1.2 describes codes, standards, and specifications applicable to the containment steel liner.

3.8.2.2.1 Codes and Standards

- [*ANSI/AISC N690~~-1994 (R2004)~~, Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2 (Reference 14).*]*
- ANSI/AWS D1.1-2000, Structural Welding Code – Steel.
- ANSI/AWS D1.6-1999, Structural Welding Code – Stainless Steel.
- ASME Code:
  - Section II – Material Specifications.
  - Section III, Division 1 – Rules for Construction of Nuclear ~~Power Plant~~Facility Components (Reference 73).
  - Section V – Nondestructive Examination.
  - Section VIII – Pressure Vessels.
  - Section IX – Welding and Brazing Qualifications.
- Acceptable ASME Code Cases per RG 1.84.

- [ASME STS-1, Steel Stacks (Reference 75).]*

3.8.2.2.2 Specifications

Industry standards such as those published by ASTM are used to define material properties, testing procedures, fabrication, and construction methods. ~~[~~The applicable ASTM standard specifications for materials are those permitted by Article NE-2000 of Section III, Division 1 of the ASME Code. Applicable ASTM standard specifications for nondestructive methods of examination are those referenced in Appendix X and Article X-3000 of Section III, Division 1 of the ASME Code.~~]*~~

Structural specifications cover the design of steel portions of the containment pressure boundary. These specifications cover the following areas:

- Equipment hatch, airlocks, and construction opening closure cap and sleeve.
- Piping penetration sleeves.
- Electrical penetration sleeves.
- Fuel transfer tube penetration sleeve.

3.8.2.2.3 Design Criteria

The design of steel pressure retaining components of the RCB that are not backed by concrete complies with the following:

- Article NE-3000 of the ASME Code, Section III, Division 1 (Reference 73) (GDC 1 and GDC 16).

3.8.2.2.4 Regulations

- 10 CFR 50, Licensing of Production and Utilization Facilities.
- 10 CFR 50, Appendix A – General Design Criteria for Nuclear Power Plants GDC 1, 2, 4, 16, and 50.
- 10 CFR 50, Appendix J – Primary Reactor Containment Leakage Testing for Water Cooled Power Reactors.

3.8.2.2.5 NRC Regulatory Guides

RGs applicable to the design and construction of steel portions of the RCB that resist pressure, but are not backed by structural concrete:

- RG 1.7, Revision 3.
- RG 1.57, Revision 1.

intensity limits defined by Articles NE-3221.1, NE-3221.2, NE-3221.3, and NE- 3221.4~~ of the ASME BPV Code~~. The stresses induced by the concrete displacements on ASME Code, Section III, Division 1, Subsection NE, Class MC components are displacement limited and hence secondary in nature. Therefore the qualification of the design for primary stress criteria does not consider the effects of concrete displacement. The concrete displacements are non-cyclical. Therefore, ratcheting and fatigue failure of the penetrations due to concrete displacements are not evaluated. [*The concrete displacements are considered for the qualification of the ASME Code, Section III, Division 2, Subsection CC sleeve components (Reference 1).*]*

Buckling analyses are performed for the equipment hatch, airlocks, construction opening, and high energy piping penetrations (main steam and feedwater). The equipment hatch and airlocks were~~was~~ qualified in accordance with NE-3222 and Code Case N-284-1. ~~The airlocks were qualified in accordance with NE-3222.~~ The construction opening is qualified in accordance with NE-3133. For high energy piping penetrations (main steam and feedwater); it was determined that buckling is not a failure mechanism for these penetrations.

Equipment Hatch

A rigorous buckling analysis was performed in accordance with NE-3222.1(a)(1). Three-dimensional (3D) finite element submodels of each appurtenance were prepared in ANSYS~~, Version 11.0~~. Material nonlinearities and large deformations were considered in accordance with NE-3222.1(a)(1). Material nonlinearity was simulated using the Bilinear Kinematic Hardening material model (BKIN) in ANSYS. Large deflection command NLGEOM in ANSYS was enabled to account for geometric nonlinearity.

In the analysis, the steel liner and ring plate were fixed while constant increments of pressure are applied on the external surface. Other loads, such as seismic and dead weight, do not have any significant effect on buckling of the equipment hatch and have not been applied. The applied pressure was increased until the solution began to diverge. At this point, the analysis was stopped and the critical buckling stress was reached.

~~[~~The maximum allowable buckling stress for Design and Levels A & B service limits was determined by NE-3222.1(a) to be one-third the value of the critical buckling stress. In accordance with NE-3222.2, the allowable limits for Level C and D service limits are 120 percent and 150 percent of the value given in NE-3222.1, respectively.~~]*~~ The applied pressure in each load condition was compared to the allowable limit to verify that the criterion is met.

*[Consideration of geometric imperfections in the equipment hatch is in accordance with RG 1.193 and ASME Code Case N-284-1.]**

3.8.2.4.3 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.4, 2.5, 3.3, 3.5, 3.7, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design results are presented in Appendix 3E for Seismic Category I structure critical sections. A cross-reference between U.S. EPR FSAR sections and information required by SRP Section 3.8.4, Appendix 3C is provided in Table 3.8-17.

3.8.2.5 Structural Acceptance Criteria

Structural acceptance criteria for steel containment items described in Section 3.8.2.1 are in accordance with Subsections NC and NE of the ASME Code, Section III, Division 1, including allowable stress limits, strain limits, deformation limits, and factors of safety. These are augmented by the requirements of RG 1.57 and RG 1.216 (GDC 1, GDC 2, GDC 4, GDC 16, and GDC 50). Containment steel items not backed by concrete that are intended to resist pressure will be designed to meet the acceptance criteria for the load combinations listed in Section 3.8.2.3.2.

Steel items that are an integral part of the RCB pressure boundary will be designed to meet minimum leakage rate requirements. The leakage rate must not exceed the acceptable value indicated in the applicable technical specification.

The design and analysis methods, as well as the type of construction materials, are chosen to allow assessment of the capability of steel items to function properly throughout the plant life.

A SIT is performed as described in Section 3.8.2.7. Surveillance testing provides assurance of the continuing ability of each item to meet its design functions. Surveillance requirements are addressed in Section 3.8.2.7.

Items that form part of the containment pressure boundary are stamped in accordance with the applicable section of the ASME Code used for their design or fabrication.

3.8.2.6 Materials, Quality Control, and Special Construction Techniques

~~[~~Steel items that are not backed by concrete that are part of the containment pressure boundary are fabricated from materials that meet the requirements specified in Article NE-2000 of Section III, Division 1 of the ASME Code, except as modified by applicable and acceptable ASME Code Cases~~]*~~ (GDC 1). SA-516 Grade 70 material is used for major steel components of the penetration assemblies. The materials are defined in Table 6.1-1.

Quality control for containment steel items conforms to Articles NE-2000, NE-4000, and NE-5000 of Section III, Division 1 of the ASME Code (GDC 1).

Section 3.8.1.6 provides a description of welding requirements for steel items for the RCB, quality control for steel items for the RCB, and materials used for penetration sleeves, steel embedments, and corrosion retarding compounds.

Use of neoprene-based seals are kept to a minimum because of the presence of fluoride or chloride ions and the increased potential for stress corrosion cracking.

The seals for the airlocks and the equipment hatch make use of elastomer seal material (Dupont Viton®, or equal) which is compressed by the action of the mechanical closure devices associated with each of the components. This material is recessed into two concentric grooves (double seals) around the perimeter of the airlock doors and around the equipment hatch flange penetration mating flange. This material is selected based on its ability to maintain elasticity at elevated temperatures for extended durations and to be in compliance with the materials tested for severe accident conditions as specified in NUREG/CR-5096 (Reference 64).

Steel items such as the equipment hatch, airlocks, fuel transfer tube, and penetrations are prefabricated and installed as subassemblies during construction. No special techniques are used for construction of containment steel items not backed by concrete. Section 3.8.1.6 provides additional information of modular construction techniques used for the RCB.

3.8.2.7 Testing and Inservice Inspection Requirements

~~[~~A SIT is performed for steel containment components not backed by concrete in accordance with Article NE-6000 of Subsection NE of the ASME Code, Section III, Division 1~~]*~~ (GDC 1).

Inservice inspections for the steel pressure retaining subassemblies follow the requirements of the ASME Code, Section XI, Subsection IWE with the additional requirements of 10 CFR 50.55a (GDC 1 and GDC 16). Section 6.2.6 describes the leakage tests and associated acceptance criteria.

Vendor testing and in-situ testing of the seals is conducted to provide assurance of the seal performance for normal operating conditions and for temperature and pressure conditions associated with a loss of coolant accident. Once this equipment is installed in containment, the air space between the two seals will be continuously maintained under a negative pressure by connection to the Leak-Off system. This system is also used to pressurize the air space between the seals for in-situ testing operations.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

3.8.3.2.1 Codes and Standards

- ACI 301-05, Specifications for Structural Concrete for Buildings.
- ACI 304R-00, Guide for Measuring, Mixing, Transporting, and Placing Concrete.
- ACI 305.1-06, Specification for Hot-Weather Concreting.
- ACI 306R-88 (Re-approved 2002), Cold-Weather Concreting (Reference 49).
- ACI 306.1-90 (Re-approved 2002), Standard Specification for Cold Weather Concreting.
- ACI 308R-01, Guide to Curing Concrete (Reference 50).
- ACI 308.1-98, Standard Specification for Curing Concrete (Reference 39).
- ACI 311.4R-05, Guide for Concrete Inspection (Reference 40).
- ACI 347-04, Guide to Formwork for Concrete.
- [A*CI 349~~-01~~/~~349-R01~~349R-01, Code Requirements for Nuclear Safety-Related Concrete Structures ~~and Commentary on Code Requirements for Nuclear Safety-Related Concrete Structures~~(Reference 12)*]* (exception described in 3.8.4.4 and 3.8.4.5) (GDC 1).
- *[ACI 349-06~~/349R-06~~, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (Appendix D) (Reference 63) with the exception of Condition A strength reduction factors even when supplemental reinforcement is provided ~~(Reference 63)~~.]**
- *[ACI 349.1R-07, Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures (Reference 41).]**
- AISC 303-00, Code of Standard Practice for Steel Buildings and Bridges (Reference 42).
- *[ANSI/AISC N690~~-1994~~, Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2~~, 2004~~ (Reference 14)]** (GDC 1).
- AISC 348-00/2000 RCSC, Specification for Structural Joints Using ASTM A325 and A490 Bolts (Reference 44).
- ANSI/AWS D1.1-2000, Structural Welding Code - Steel.
- ANSI/AWS D1.4-2005, Structural Welding Code - Reinforcing Steel.
- ANSI/AWS D1.6-1999, including January 6, 2005 update, Structural Welding Code – Stainless Steel.

- ANSI/AWS D1.8-2005, Structural Welding Code – Seismic Supplement (Reference 45).
- [*ASME Boiler and Pressure Vessel Code, Section III, Division 2 - Code for Concrete ~~Reactor Vessels and~~ Containments (Reference 1)*]* (GDC 1).
- ASME Boiler and Pressure Vessel Code, Section III, Division 1 – Rules for Construction of Nuclear ~~Power Plant~~Facility Components (Reference 73) (GDC 1).
- ASME NOG-1-04, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder).

3.8.3.2.2 Specifications

Industry standards (e.g., those published by the ASTM) are used to specify material properties, testing procedures, fabrication methods, and construction methods. Section 3.8.3.6 addresses the applicable standards used.

Structural specifications cover areas related to the design and construction of the RB internal structures. These specifications emphasize important points of the industry standards for these structures and reduce options that otherwise would be permitted by the industry standards. These specifications cover the following areas:

- Concrete material properties.
- Mixing, placing, and curing of concrete.
- Reinforcing steel and splices.
- Structural steel.
- Stainless steel liner plate and embedments.
- Miscellaneous and embedded steel.
- Anchor bolts.
- Expansion anchors.
- Polar crane.
- Miscellaneous cranes and hoists.

3.8.3.2.3 Design Criteria

- [*ACI 349~~-01~~/~~349-R01~~349R-01, Code Requirements for Nuclear Safety-Related Concrete Structures ~~and Commentary on Code Requirements for Nuclear Safety-Related Concrete Structures~~(Reference 12)*]* (GDC 1).

- *[ACI 349-06~~/349R-06~~, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (Appendix D) (Reference 63) with the exception of Condition A strength reduction factors even when supplemental reinforcement is provided ~~(Reference 63)~~]**.

- *[ANSI/AISC N690~~-1994~~, Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2 (Reference 14)* ~~(2004)~~*]** (GDC 1).

3.8.3.2.4 Regulations

- 10 CFR 50, Appendix A, General Design Criteria for Nuclear Power Plants, GDC 1, GDC 2, GDC 4, GDC 5, and GDC 50.
- 10 CFR 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants.
- 10 CFR 50, Appendix S, Earthquake Engineering Criteria for Nuclear Power Plants.

3.8.3.2.5 NRC Regulatory Guides

RGs applicable to the design and construction of RB internal structures:

- RG 1.61, Revision 1, March 2007 (exception described in 3.7.1).
- RG 1.69, December 1973.
- RG 1.136, Revision 3, March 2007 (exception described in 3.8.1.3).
- RG 1.142, Revision 2, November 2001 (exception described in 3.8.3.3).
- RG 1.160, Revision 2, March 1997.
- RG 1.199, November 2003 (exception described in 3.8.1.4).

3.8.3.3 Loads and Load Combinations

The U.S. EPR standard plant design loads envelope includes the loads over a broad range of site conditions (GDC 1, GDC 2, GDC 4, GDC 5 and GDC 50). The loads on RB internal structures are separated into the following categories:

- Normal loads.
- Severe environmental loads.
- Extreme environmental loads.
- Abnormal loads.

A COL applicant that references the U.S. EPR design certification will confirm that site-specific loads lie within the standard design envelope for RB internal structures, or perform additional analyses to verify structural adequacy.

Section 5.4.14 addresses the loads and loading combinations and design stress limits for the RCS component and pipe supports.

3.8.3.3.1 Design Loads

[*Loads on RB internal structures are in accordance with ACI 349* ~~*-2001*~~*/349R-01 (Reference 12)*]* and the guidelines of RG 1.142, Revision 2, November 2001 [*for concrete structures, and in accordance with ANSI/AISC N690* ~~*-1994*~~ *including Supplement 2* ~~*(2004)*~~ *(Reference 14) for steel structures.*]* RG 1.142 delineates the acceptability of ACI 349-1997 with exceptions. The U.S. EPR standard plant design is based on the 2001 edition of the code, with the exceptions noted above. Use of the 2001 edition of the code is acceptable as it incorporates needed updates to the 1997 version. This includes anchorage of wall reinforcing without the use of confined cores in certain situations, and is in keeping with RG 1.199, which adopted the 2001 version Appendix B with exceptions in the area of load combinations. In addition, the guide has supplementary recommendations in the areas of materials, installation, and inservice inspection. The guidelines of RG 1.199 are followed with the exception described in Section 3.8.1.4.10. This exception allows the use of Appendix D to ACI 349-06 ~~(~~with exception stated in Section 3.8.1.2.1~~)~~ for concrete anchorage design. This exception is acceptable as it results in an equivalent or conservative anchorage design when compared to that of Appendix B to ACI 349 ~~-01~~/349R-01.

Seismic Category I safety-related RB internal structures are designed for the following loads.

Normal Loads

Normal loads are those loads encountered during normal plant operation, startup, shutdown, and construction (GDC 4). This load category includes:

- Dead Loads (D)—Dead loads include the weight of the structure and any permanent equipment or material weights. Dead load effects also refer to internal moments and forces due to dead loads.
- Live Loads (L)—Live loads include any normal loads that vary with intensity or point of application (or both), including moveable equipment. Live load effects also refer to internal moments and forces due to live loads. Live loads are applied, removed, varied from zero to full value, or shifted in location to obtain the worst-case loading conditions. Impact forces due to moving loads are applied according to the loading condition. In general, a live load of 500 pounds per square foot is applied to RB internal structures concrete floors and a load of 175 pounds per square foot is applied to steel grating floors and platforms. Live loads are applied to

- Pipe break loads (R_r)—Local equipment and piping loads generated following a postulated pipe break. Unless a time-history analysis is performed to justify otherwise, these loadings include a dynamic load factor to account for the dynamic nature of the load. The pipe break load (R_r) is considered to act as three separate components (R_{rr}, R_{rj}, R_{rm}), which are defined in the following paragraphs. In determining an appropriate equivalent static load for R_{rr}, R_{rj}, and R_{rm}, elasto-plastic behavior may be assumed with appropriate ductility ratios, provided excessive deflections do not result in the loss of function of any safety-related SSC.
  - Pipe break reaction loads (R_{rr})—R_{rr} is defined as the equivalent static load on the structure generated by the reaction of the high-energy pipe during the postulated break.
  - Pipe break jet impingement loads (R_{rj})—R_{rj} is defined as the jet impingement equivalent static load on the structure generated by the postulated break.
  - Pipe break missile impact loads (R_{rm})—R_{rm} is defined as the missile impact equivalent static load on the structure generated by or during the postulated break, such as pipe whipping.

Other Loads

Other loads refer to postulated events or conditions that are not included in the design basis (GDC 4). These loading conditions and effects are evaluated without regard to the bounding conditions under which SSC perform design basis functions. This load category includes:

- Aircraft hazard (A)—Aircraft hazard refers to loads on a structure resulting from the impact of an aircraft. The evaluation of this loading condition is considered as part of the plant safeguards and security measures. There are no aircraft hazard loads on the RB internal structures since they are surrounded by other Seismic Category I structures that shield them from these loads.
- Explosion pressure wave (B)—Explosion pressure wave refers to loads on a structure resulting from an explosion in the vicinity of the structure. The evaluation of this loading condition is considered as part of the plant safeguards and security measures. There are no explosion pressure wave loads on the RB internal structures because they are surrounded by other Seismic Category I structures that shield them from these loads.
- Missile loads other than hurricane- or tornado-generated missiles—The RSB and the RCB protect the RB internal structures from impact of externally generated missiles. The RB internal concrete and steel structures are designed for internally generated missile loads as described in Section 3.5.

3.8.3.3.2 Load Combinations

[*Load combinations for design of RB internal structures are in accordance with ACI 349*~~*-2001*~~*/349R-01 (Reference 12)*]* and guidelines of RG 1.142, Revision 2, November

2001 [*for concrete structures, and in accordance with ANSI/AISC N690~~-1994~~ including Supplement 2 (Reference 14) ~~(2004)~~ for steel structures*]* (GDC 1, GDC 2, GDC 4, GDC 5 and GDC 50).

The NI Common Basemat Structure is a monolithic concrete structure. However, various portions of the structure have different classifications (i.e., RCB, RB internal structures, and other Seismic Category I structures) and correspondingly different design requirements, as shown in Figure 3.8-118. In some instances, the load combinations identified in ACI 349~~-2001~~/349R-01 do not include certain independent loadings which should be considered to account for potential structure-to-structure effects (i.e., the effect on one structure resulting from loadings applied to a separate, but monolithically connected, structure). To account for potential structure-to-structure effects, the loading combinations from ACI 349~~-2001~~/349R-01 are adjusted by including the necessary additional independent loadings. For concrete structures, the independent loadings added to the load combinations include buoyant force (F_b) and post-tension load (J). For steel structures, the independent loadings added to the load combinations include hydrostatic load (F), buoyant force (F_b), post-tension load (J), and soil load/lateral earth pressure (H). In load combinations where abnormal loads are considered, internal flood load (F_a) is added for both steel and concrete structures. The load factors for hydrostatic load (F), buoyant force (F_b), and post-tension load (J) are matched to that of the dead load (D) for each loading combination, while the load factors for soil load/lateral earth pressure (H) and internal flood load (F_a) are matched to that of the live load (L). Section 3.8.3.3.1 provides details regarding the loads considered for the design of the RB internal structures, while Section 3.8.1.3.1 provides the description of the post-tension load (J) which is included to account for the global effect of post-tension loads (J) on the NI Common Basemat.

The following definitions apply to load combinations for concrete and steel RB internal structures:

- [*For concrete members, U is defined as the section strength required to resist design loads based on the strength design methods described in ACI 349/349R-01 (Reference 12).*
- *For steel members, S is defined as the required section strength based on the elastic design methods and the allowable stresses defined in Part Q1 of ANSI/AISC N690 (Reference 14).*
- *For steel members, Y is defined as the section strength required to resist design loads based on plastic design methods described in Part Q2 of ANSI/AISC N690 (Reference 14).*]*

Loads and loading combinations encompass the soil cases described in Section 2.5, using the design criteria described in Section 3.7.1 and Section 3.7.2.

Concrete Reactor Containment Building Internal Structures

The following load combinations define the design limits for Seismic Category I concrete RB internal structures.

- Normal load combinations (for strength design method):

  $U = 1.4 (D + F + F_b + J) + 1.7 (L + H + R_o)$

  $U = 1.05(D + F + F_b + J) + 1.3(L + H + R_o) + 1.2T_o$

  $U = 1.4(D + F + F_b + J) + 1.7(L + H + R_o + W)$

  $U = 1.05(D + F + F_b + J) + 1.3(L + H + R_o + W) + 1.2T_o$

- Factored load combinations (for strength design method):

  $U = D + L + H + F + F_b + T_o + R_o + J + E'$

  $U = D + L + H + F + F_b + J + F_a + 1.4P_a + T_a + R_a$

  $U = D + L + H + F + F_b + J + E' + F_a + P_a + T_a + R_a + R_r$

  $U = D + L + H + F + F_b + T_o + R_o + J + W_t$

  $U = D + L + H + F + F_b + J + E' + F_a + P_a + T_a + R_a$

Steel Reactor Containment Building Internal Structures

The following load combinations define the design limits for Seismic Category I steel RB internal structures. [*For normal service load conditions, either the elastic working stress design methods of Section Q1 or the plastic design methods of Section Q2 of ANSI/AISC N690, including Supplement 2 (Reference 14), are used.*]* For factored load conditions, the elastic working stress design method is used.

- Service load combinations for elastic working stress design method:

  $S = D + L + H + F + F_b + J$

  $S = D + L + H + F + F_b + J + W$

  If thermal stresses due to T_o and R_o are present, the following load combination is also considered:

  $1.5S = D + L + H + F + F_b + T_o + R_{o + J}$

  $1.5S = D + L + H + F + F_b + T_o + R_{o + J + W}$

- Service load combinations for plastic design method:

$$Y = 1.7(D + L + H + F + F_b + J + W)$$

$$Y = 1.7(D + L + H + F + F_b + J)$$

$$Y = 1.3(D + L + H + F + F_b + T_o + R_{o + J})$$

$$Y = 1.3(D + L + H + F + F_b + T_o + R_{o + J + W})$$

- Factored load combinations for elastic working stress design method:

$$1.6S = D + L + H + F + F_b + T_o + R_o + J + W_t$$

$$1.6S = D + L + H + F + F_b + T_o + R_o + J + E'$$

$$1.6S = D + L + H + F + F_b + J + F_a + T_a + R_a + P_a$$

$$1.7S = D + L + H + F + F_b + J + F_a + T_a + R_a + P_a + R_r + E'$$

$$1.6S = D + L + H + F + F_b + J + F_a + T_a + P_a$$

- Factored load combinations for plastic design method:

$$0.9Y = D + L + H + F + F_b + T_o + R_o + J + E'$$

$$0.9Y = D + L + H + F + F_b + J + F_a + T_a + 1.25P_a + R_a$$

$$0.9Y = D + L + H + F + F_b + J + F_a + T_a + P_a + R_a + R_r + E'$$

$$0.9Y = D + L + H + F + F_b + T_o + R_o + J + W_t$$

3.8.3.4 Design and Analysis Procedures

[*Seismic Category I concrete structural elements and members are designed in accordance with ACI 349* ~~*2001*~~*/349R-01 and its appendices (Reference 12)*]* (GDC 1). Exceptions to the code found in RG 1.142 are incorporated into the design and are accommodated in the loading combinations described in Section 3.8.3.3.2 for concrete structures.

[*Seismic Category I steel members and assemblies are designed in accordance with the requirements of ANSI/AISC N690 (Reference 14)* ~~*1994 (R2004)*~~]* (GDC 1).

[*Design of concrete embedments and anchors conforms to ACI 349-06 (Appendix D) (Reference 63) with exception stated in Section 3.8.1.2.1*~~*)*~~]* and guidelines of RG 1.199 (with exception described in Section 3.8.1.4.10).~~]*~~

Section 5.4.14 describes the applicable design and analysis procedures used for the design of steel portions of the NSSS component supports which interface with the RB internal structures concrete and steel embedments.

considered where the live load (L) is varied between its maximum design value and zero.

- For load combinations including the loads P_a, T_a, R_a, R_{rr}, R_{rj}, or R_{rm}, the maximum values of these loads, including an appropriate dynamic load factor, are used unless a time-history analysis is performed to justify otherwise.

- For load combinations including loads R_{rr}, R_{rj}, and R_{rm}, the load combinations are first satisfied with these loads set to zero. However, when considering these concentrated loads, local section strength capacities may be exceeded under the effect of these concentrated loads, provided there is not a loss of intended function of the structural member or a loss of function of any safety-related SSC.

Concrete and steel structural elements and members are designed for axial tension and compression forces, bending moments, torsion, and in-plane and out-of-plane shear forces for the controlling loading combinations that are determined from the ANSYS computer analysis and local analyses. Internal structures behave within the elastic range under design basis loads. However, the ability of the structures to perform beyond yield is considered for abnormal loads associated with a pipe break, which results in rupture reactions, jet impingement and pipe whip, and for missile impact loads.

[*The strength-design methods described in ACI 349~~-2001~~/349R-01 and its appendices (Reference 12),*]* including the exceptions detailed in RG 1.142, [*are used for the design of concrete walls, floors and other structural elements for RB internal structures ~~(GDC 1)~~. The ductility requirements of this code are satisfied so that a steel reinforcing failure mode controls over concrete failure modes. The recommendations of Appendix C of ACI 349~~-2001~~/349R-01 are met for impulsive and impactive loading conditions (e.g., loading combinations that include pipe break missile impact loads).*]*

[*Steel member and assembly design utilizes the allowable stress design methods of ANSI/AISC N690~~-1994 (R2004)~~, including Supplement 2 (Reference 14)*]* (GDC 1). Steel items are maintained elastic for normal and extreme loadings in their respective combinations. Local yielding is permitted for abnormal loadings (e.g., pipe break accident loadings).

[*A local analysis and design of concrete members will be performed for impactive and impulsive loads according to ACI 349/349R-01, with exceptions noted in RG 1.142. A local analysis and design of steel members will be performed for impactive and impulsive loads according to ANSI/AISC N690 (Reference 14).*]*

It is acceptable to assume non-linear (elasto-plastic) response of structural members for evaluation of the response of reinforced concrete and steel structures subject to impactive or impulsive loads. Deformation under impactive and impulsive loads is controlled by limiting the ductility ratio, μ_d, which is defined as the ratio of maximum acceptable displacement, χ_m (or maximum strain, ε_m), to the displacement at the effective yield point, χ_y (or yield strain, ε_y), of the structural member. In addition to the specified deformation limits, maximum deformation will not result in the loss of intended function of the structural member nor impair the design basis safety function of other systems and components.

Regarding structural capacity, a structural member will retain its ability to perform its design basis function when ductility limits for concrete and steel members presented in Table 3.5-3 are satisfied. As deformation limits of the member may be governed by attached structures, systems and components (SSC), the member will also satisfy deformation limits imposed by attached SSC to prevent loss of design basis function.

3.8.3.4.2 Local Analysis and Design

Local analyses are performed for concrete and steel structural elements and members by using sub-models expanded from the overall analysis model and by using manual techniques, in combination with overall model analysis results. Sub-models are performed by refining the element mesh in the overall ANSYS model. Local discontinuities (e.g., openings, thickened areas, local loads, and changes in member cross-section) are included in the sub-models.

Local analysis and design consider the same member and element forces and moments as described for overall design. In addition, local effects (e.g., punching shear and transfer of anchorage loads to the structure) are considered. Local analyses also are used for design of secondary structures (e.g., platforms, equipment supports, crane supports).

[*The recommendations of ACI 349~~-2001~~/349R-01 and its appendices (Reference 12),*]* including the exceptions in RG 1.142, [*are followed for concrete element and member local design*]* (GDC 1).

[*Design of concrete embedments and anchors conforms to ACI 349-06 (Appendix D) (Reference 63)~~-~~ with exception stated in Section 3.8.1.2.1~~)~~*]*and guidelines of RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~.

[*ANSI/AISC N690~~-1994 (R2004)~~, including Supplement 2 (Reference 14), are followed for local steel member design*]* (GDC 1).

[*The design of bolted connections is in accordance with ANSI/AISC N690, Section Q1.16 (Reference 14)*]* and AISC 348-00/2000 RCSC. Bolted in connections are fully tensioned, regardless of design methodology, unless justified otherwise.

The design of welded connections is in accordance with ANSI/AWS D1.1-2000 and ANSI/AWS D1.6-99, including January 6, 2005 update.

[*The design of bolted connections in combination with welded connections is in accordance with Section Q.15.10 of ANSI/AISC N690 (Reference 14).*]*

Openings in walls and slabs of RB internal structures are shown on construction drawings. Openings in slabs are acceptable without analysis if they meet the criteria identified in ACI 349, Section 13.4.2. Round pipe sleeves are used in lieu of rectangular penetrations, where possible. Corners of rectangular openings in walls or slabs are provided with diagonal reinforcing to reduce cracking due to stress concentrations at these locations in accordance with ACI 349, Section 14.3.7.

~~Appendix 3E provides a description of analysis and design results for critical areas of the RB internal structures.~~

Section 5.4.14 describes the design of interfacing steel assemblies which support the NSSS components and attach to, or interact with, embedments in the concrete. ~~[~~Steel supports for the RCS components and piping, including the base plates at the face of concrete structures, are designed in accordance with ASME Code, Section III Division 1, Subsection NF.~~]*~~ [*Embedded portions of RCS component and pipe supports, which are beyond the jurisdictional boundary of the ASME Code, are designed in accordance with ACI 349-06 (Appendix D) (Reference 63) with exception stated in Section 3.8.1.2.1*~~)~~]*, RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~, [*and also in accordance with ANSI/AISC N690* ~~*1994 (R2004)*~~, *including Supplement 2 (Reference 14).*]*

3.8.3.4.3 Static Analysis and Design

Dead loads (D), live loads (L), hydrostatic loads (F), pipe reactions (R_o), and normal thermal loads (T_o) are considered in the analysis and design of RB internal structures for the static normal load concrete and service load steel loading combinations. Normal thermal loads are considered as self-relieving for the overall RB internal structures. Concrete and steel members are designed to accommodate these static loads within the elastic range of their section strength.

Static fluid pressure loads are considered for design of the walls and floors of the IRWST and refueling canal. Moving loads are considered for mobile plant equipment (e.g., the polar crane, refueling machine, and other cranes and hoists).

3.8.3.4.4 Seismic and Other Dynamic Analyses and Design

Seismic analyses and designs of the RB internal structures conform to the procedures described in Section 3.7.2. Seismic accelerations are determined from the dynamic FEM described in Section 3.7.2. These accelerations are applied to the static FEM model of the RB internal structures as static-equivalent loads at the elevations used in the dynamic FEM.

Seismic SSE (E') loads are obtained by multiplying the dead load and 25 percent of the design live load by the structural acceleration obtained from the seismic analysis of the structure. Seismic loads are also considered due to the mass of fluids in tanks and canals as described herein (Section 3.8.3.4.4). Consideration is given to the amplification of these accelerations due to local flexibility of structural elements and members. Construction loads are not included when determining seismic loads. Other temporary loads are evaluated for contributing to the seismic loads on a case-by-case basis.

Seismic loads from the three components of the earthquake are combined using the SRSS method, where resultants are obtained using the following formulas:

$P_R = +- \text{sqrt}(P_x^2 + P_y^2 + P_z^2)$

$M_R = +- \text{sqrt}(M_x^2 + M_y^2 + M_z^2)$

The number of permutations for design are $2^n = 2^2$ = (++, --, +-, -+).

The effects of local flexibilities in floor slabs and wall panels are considered to determine if additional seismic accelerations should be applied to their design beyond those determined from the seismic stick model. Local flexibility evaluations are performed by determining the natural frequency of the floor or wall panel and comparing this to the frequency of the zero period acceleration on the applicable response spectra. Additional acceleration is applied when the natural frequency of the panel results in higher accelerations than the zero period acceleration. In cases where local flexibilities are determined to be a factor, additional out-of-plane accelerations are applied to the inertia loads on these panels for determining out-of-plane bending and shear loads.

Additional seismic loads due to accidental torsion are considered as described in Section 3.7.2. This is to account for variations in material densities, member sizes, architectural variations, equipment loads, and other variations from the values used in the analysis and design of the RB internal structures. Due to these potential variations, an additional eccentricity of the mass is included at the floor elevations and is equivalent to five percent of the maximum building dimension.

[*Seismic Category I concrete structural elements and their connections are detailed for ductility in accordance with ACI 349 ~~2001~~/349R-01, Chapter 21 (Reference 12).*]*

Structural Stiffness Considerations

Conservative values of concrete creep and shrinkage based on past experience are used in the design of the RB internal structures. Moments, forces, and shears are obtained on the basis of uncracked section properties in the analysis. However, in sizing the reinforcing steel, the concrete is not relied upon for resisting tension. Thermal the crane. For analysis purposes, the critical load is defined as that of the reactor head. The design of the crane includes seismic restraints (up-kick lugs), which prevent the bridge and trolley from dislodging from their respective rails.

Refer to Section 9.1.5 for additional information on the polar crane.

Pipe Rupture Loads

Local analyses of the RB internal structures consider the following abnormal loads:

- Sub-compartment pressure loads (P_a).
- Pipe break thermal loads (T_a).
- Accident pipe reactions (R_a).
- Pipe break reaction, jet impingement, and missile loads (R_{rr}, R_{rj}, R_{rm}).
- Local flood loads (F_a).

These loads are applied to concrete and steel structures that enclose and support the RV, SGs, RCPs, PZR, RCS piping, MS and feedwater system piping, and other areas subject to abnormal loads.

Subcompartment pressure loads (P_a) are not applied to the overall ANSYS computer model because they do not result in global loadings on the RB internal structures. Subcompartment pressure loads are evaluated in local design of the concrete walls and floors for the applicable compartments. Subcompartment pressure loads resulting from a LOCA event are evaluated as time-dependent loads across concrete walls and floors that enclose the SGs, RCPs, PZR, and the RCS piping. Pipe breaks are not postulated in the reactor cavity. Concrete and steel members are designed to accommodate subcompartment pressure loads within the elastic range of the section strength.

Pipe break thermal loads (T_a) are considered in local analyses of concrete walls and floors. Accident thermal loads are evaluated as time-dependent loads across concrete walls and floors that enclose the SGs, RCPs, and the PZR. Concrete temperature is limited to 150°F for normal loading conditions. For short-term and accident thermal conditions, the concrete temperature is allowed to increase to 350°F for interior surfaces. Localized areas are allowed to reach 650°F from fluid jets in the event of a pipe failure. [*ACI 349~~-01~~/~~349-R01~~349R-01, Appendix A (Reference 12) and ACI 349.1R-07 (Reference 41) is the basis used for thermal design of concrete.*]*

Accident pipe reaction loads (R_a) are considered on the NSSS equipment and piping supports, including supports for the RV, SGs, RCPs, PZR, and RCS piping. These loads are applied to the overall ANSYS computer model by applying worst-case LOCA loads to these component supports in separate load cases to determine overall effects on the RB internal structures (GDC 4 and GDC 50). Worst-case accident pipe reaction loads are further evaluated in local designs of the component supports in the critical sections described in Appendix 3E. Concrete and steel members are designed to accommodate accident pipe reaction loads within the elastic range of their section strength.

Pipe break reaction, jet impingement, and missile loads (R_{rr}, R_{rj}, R_{rm}) are not applied to the overall ANSYS computer model because they do not result in global loadings on the RB internal structures. These loads are considered in local design of concrete walls and floors and steel members. As defined in Section 3.8.3.3.1 under the definitions of abnormal loads, dynamic load factors are applied when analyzing structures for the static equivalent of these loads. Elasto-plastic behavior may be assumed with appropriate ductility ratios, provided that excessive deflections do not result in the loss of function of any safety-related SSC. [*Appendix C of ACI 349 ~~2001~~/349R-01 (Reference 12) is used to determine pipe break reactions, jet impingement, and missile impact impulsive and impactive loads.*]* The design of the RB internal structures for these loads conforms to the procedures described in Section 3.5 for internally generated missiles. Section 3.5 also describes ductility limits that are met for impactive and impulsive loadings.

Local flood loads (F_a) are applied to walls and floors of the RB internal structures in the overall ANSYS computer model. Concrete and steel members are designed to accommodate these flood loads within the elastic range of their section strength.

3.8.3.4.5 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.4, 2.5, 3.3, 3.5, 3.7, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design results are presented in Appendix 3E for Seismic Category I structure critical sections. A cross-reference between U.S. EPR FSAR sections and information required by SRP Section 3.8.4, Appendix C is provided in Table 3.8-17.

3.8.3.5 Structural Acceptance Criteria

[*Limits for allowable stresses, strains, deformations, and other design criteria for reinforced concrete RB internal structures are in accordance with ACI 349~~-2001~~/349R-01, and its appendices (Reference 12),*]* including the exceptions specified in RG 1.142.~~,~~ The exceptions specified in RG 1.142 (GDC 1, GDC 2, GDC 4 and GDC 50) are considered.

[*Limits for allowable loads on concrete embedments and anchors are in accordance with ACI 349-06 (Appendix D) (Reference 63) with exception stated in Section 3.8.1.2.1~~)~~*]* and guidance given in RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~.

[*Limits for the allowable stresses, strains, deformations and other design criteria for structural steel RB internal structures are in accordance with ANSI/AISC N690 ~~1994~~, including Supplement 2 (Reference 14)*]* (GDC 1, GDC 2, GDC 4 and GDC 50).~~]*~~

Limits for allowable stresses, strains, and deformations on steel RCS component and pipe supports, including the base plates for these supports at the face of concrete structures, are in accordance with ASME Code, Section III, Division 1, Subsection NF.

The design of RB internal structures is generally controlled by load combinations containing SSE seismic loads. [*Stresses and strains are within the limits in ACI 349~~-2001~~349R-01 (Reference 12) and ANSI/AISC N690, including Supplement 2 ~~1994 limits~~ (Reference 14).*]*

~~Appendix 3E provides design results for critical areas of the RB internal structures.~~

An as-built report is prepared to summarize deviations from the approved design and confirm that the as-built RB internal structures are capable of withstanding the design basis loads described in Section 3.8.3.3 without loss of structural integrity or safety-related functions.

3.8.3.6 Materials, Quality Control, and Special Construction Techniques

This section contains information relating to the materials, quality control programs, and special construction techniques used in the fabrication and construction of concrete and steel internal structures of the RB internal structures (GDC 1).

3.8.3.6.1 Concrete Materials

[*Concrete materials for the RB internal structures conform to ACI 349~~-2001~~/349R-01, Chapter 5 (Reference 12),*]* as supplemented by RG 1.142, and ACI 301-05 (GDC 1).~~]*~~ Where required for radiation shielding, concrete conforms to RG 1.69.

Concrete Mix Design

Structural concrete used in the construction of the RB internal structures has a minimum compressive strength (i.e., f'_c) of 6000 psi at 90 days. The concrete density is between 140 pounds per cubic foot and 160 pounds per cubic foot. Poisson's ratio for the concrete is 0.17, unless otherwise justified.

Concrete mix design is determined based on field testing of trial mixtures with actual materials used.

Testing:

- Ultimate concrete strength, as well as early strength in support of an aggressive construction schedule.

- Concrete workability and consistency.
- Concrete admixtures.
- Heat of hydration and temperature control for large or thick concrete pours.
- Special exposure requirements when identified on design drawings.

Cement:

- Cement used for the concrete RB internal structures conforms to ASTM C150, ASTM C595 (excluding Types S and SA), or ASTM C845-04.
- Low-alkali cement, as defined in ASTM C150, is used in concrete with aggregates that are potentially reactive per ASTM C33.

Aggregates:

- [*Aggregates used for the RB internal structures conform to ACI 349 ~~2001~~/349R-01, Section 3.3 (Reference 12)*.]*
- Aggregates conform to ASTM C33.
- ASTM Standards C1260 and C1293 (References 71 and 72) shall be used in testing aggregates for potential alkali-silica reactivity (ASR).

Admixtures:

- Air-entraining admixtures conform to ASTM C260.
- Chemical admixtures conform to ASTM C494 or ASTM C1017.
- Fly ash and other pozzolanic admixtures conform to ASTM C618.
- Grout fluidizers conform to ASTM C937.
- Ground-granulated blast furnace slag used as an admixture conform to ASTM C989.
- Silica fume used as an admixture conforms to ASTM C1240.
- Admixtures used in concrete mixtures containing ASTM C845 expansive cement are compatible with the cement and produce no deleterious effects.

Mix Water:

- [*Mix water used for the RB internal structures conforms to ACI 349 ~~2001~~/349R-01, Section 3.4 (Reference 12)*.]*

Concrete Placement

Site-specific construction specifications address requirements and procedures for concrete placement. Construction specifications address the following:

- Desired volume of concrete pours and rate of deposition.
- Special forming requirements.
- Maximum height of pours.
- Temperature limitations; weather conditions and concrete mix, including methods for temperature control.
- Curing requirements and procedures.

Placement of concrete is performed with consideration given to the following codes:

- ACI 304R-00, Guide for Measuring, Mixing, Transporting, and Placing Concrete.
- ACI 305.1-06, Specification for Hot-Weather Concreting (Reference 9).
- ACI 306R-88 (Re-approved 2002), Cold-Weather Concreting.
- ACI 306.1-90 (Re-approved 2002), Standard Specification for Cold Weather Concreting.
- ACI 308R-01, Guide to Curing Concrete (Reference 52).
- ACI 308.1-98, Standard Specification for Curing Concrete.
- ACI 311.4R-05, Guide for Concrete Inspection.
- ACI 347-04, Guide to Formwork for Concrete.

3.8.3.6.2 Reinforcing Steel and Splice Materials

[*Reinforcing steel materials for the RB internal structures conform to ACI 349~~-2001~~/349R-01 (Reference 12)~~ (GDC 1)~~*.]*

Materials

- [*Reinforcing steel used in the concrete RB internal structures conforms to ASTM A615 or ASTM A706 and the additional items specified in ACI 349~~-2001~~/349R-01, Sections 3.5.1 through 3.5.4 (Reference 12)*.]*
- Smooth wire for spiral reinforcement conforms to ASTM A82 (Reference 51).
- Welded plain wire fabric reinforcement conforms to ASTM A185 (Reference 52).

- Welded deformed wire fabric reinforcement conforms to ASTM A497 (Reference 53).
- Welded splices and mechanical splices of reinforcing bars are used.
- Materials used for bar-to-bar sleeves for mechanical cadweld-type rebar splices in the RB internal structures conform to ASTM A513, ASTM A519, or ASTM A576.
- [*Material for threaded and swaged reinforcement splices are determined by the manufacturer and are qualified in accordance with provisions of ACI 349~~-01~~/349R-01, Section 12.14.3 (Reference 12).~~]*~~ These devices meet the provisions of Subarticle CC-4333 of the ASME Code, Section III, Division 2 (Reference 1).*]*

Fabrication and Placement

[*Fabrication and placement of reinforcing bars for RB internal structures is in accordance with ACI 349~~-2001~~/349R-01, Chapter 7 (Reference 12).*]*

[*Welding conforms to the ASME Code, Section III, Division 2, Subsection CC (Reference 1)*]*, as supplemented by RG 1.136 and AWS D1.4-2005 (GDC 1).

[*Mechanical splices are subject to the testing and acceptance criteria of ACI 349~~-2001~~/349R-01, Section 12.14.3 (Reference 12).*]*

3.8.3.6.3 Structural Steel

[*Structural steel materials for the RB internal structures conform to ANSI/AISC N690~~-1994~~ including Supplement 2 (Reference 14) ~~(2004)~~*]* and AISC 303-00 (GDC 1).

Materials

[*Seismic Category I structural steel conforms to ASTM material specifications identified in ANSI/AISC N690, Section Q1.4.1 (Reference 14).*]* Materials for structural steel members include those listed in Table 3.8-8.

High strength bolting materials conform to ASTM A325 (Reference 54), or ASTM A490 (Reference 55). Other bolting materials conform to ASTM A307 (Reference 56).

[*Structural bolts conform to the ASTM material specifications identified in ANSI/AISC N690, Section Q1.4.3 (Reference 14)*]*, or other materials identified in the AISC/RCSC.~~]*~~ Bolting materials for structural steel include those listed in Table 3.8-9. Anchor rods conform to the material specifications in ASTM F1554 (Reference 46).

Structural bolts utilize nuts and washers as recommended by ASTM for the particular bolting material and as identified in AISC/RCSC. Structural bolting nut and washer materials for structural steel include those listed in Table 3.8-10—Structural Bolting Nut and Washer Materials.

[*Structural steel, steel pipe, or tubing used in composite compression members in Seismic Category I concrete structures conforms to the specifications in Section 3.5.6 of ACI 349~~-2001~~/349R-01 (Reference 12)*.]*

Welding materials conform to ANSI/AWS D1.1-2000, or ANSI/AWS D1.6-99, including the January 6, 2005 update, except as modified by ANSI/AISC N690, Sections Q1.17.1 and Q1.17.2.1. The compatibility of filler metal with base metal is specified in Table 3.1 of AWS D1.1.

Fabrication and Erection

Fabrication and erection of structural steel, welding, and bolting conforms to the following codes:

- [*ANSI/AISC N690~~-1994~~, Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2 (Reference 14)~~(2004)~~*.]*
- AISC 348-00/2000 RCSC, Specification for Structural Joints Using ASTM A325 and A490 Bolts.
- ANSI/AWS D1.1-2000, Structural Welding Code – Steel.
- ANSI/AWS D1.6-1999, including January 6, 2005 update, Structural Welding Code – Stainless Steel.
- ANSI/AWS D1.8 2005, Structural Welding Code – Seismic Supplement.

3.8.3.6.4 Quality Control

In addition to the quality control procedures addressed in Section 3.8.3.6.1, Section 3.8.3.6.2, and Section 3.8.3.6.3, refer to Chapter 17 for a description of the quality assurance program for the U.S. EPR (GDC 1).

3.8.3.6.5 Special Construction Techniques

The RB internal structures are constructed using proven methods common to heavy industrial construction. Special, new, or unique construction techniques are not used.

Modular construction methods are used to the extent practical for prefabricating portions of the IRWST liner, refueling canal liner, reinforcing, concrete formwork, and other portions of the RB internal structures. Such methods have been used extensively in the construction industry. Rigging is pre-engineered for heavy lifts of modular sections. Permanent and temporary stiffeners are used on liner plate sections and other modularized items to satisfy code requirements for structural integrity of the modular sections during rigging operations.

Steel decking and plates and supporting steel beams may be used to form concrete floors. In these instances, the decking thickness is in addition to the floor thickness shown on the dimensional arrangement drawings, provided in Appendix 3B. The decking, plates, and beams may be left in place, in which case they are designed for applicable seismic loads and other loading conditions. Other types of formwork that may also be used is left in place and become a permanent part of the structure. Such items conform to code requirements and are designed to prevent their failure from affecting Seismic Category I SSC.

3.8.3.7 Testing and Inservice Inspection Requirements

Section 5.4.14 describes the tests and inspections for the RCS component supports.

Monitoring and maintenance of RB internal structures is performed in accordance with 10 CFR 50.65 and supplemented with the guidance in RG 1.160 (GDC 1).

Section 9.1.5 describes the tests and inspections for the polar crane. Physical access is provided to perform inservice inspections of the RB internal structures. Gaps are provided between the containment liner and concrete RB internal structures, which provide space necessary to inspect the liner at wall and floor locations inside containment.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

3.8.4 Other Seismic Category I Structures

3.8.4.1 Description of the Structures

Other Seismic Category I structures in the U.S. EPR include the following buildings and structures:

- Reactor Shield Building (RSB) and annulus – located on the Nuclear Island (NI) Common Basemat Structure foundation basemat.
- Fuel Building (FB) – located on the NI Common Basemat Structure foundation basemat.
- Safeguard Buildings (SB) 1, 2, 3, and 4 – located on the NI Common Basemat Structure foundation basemat.
- Vent Stack – supported on the roof slab of the Fuel Building.
- Emergency Power Generating Buildings (EPGB) 1 and 2, and 3 and 4 – two separate buildings.

- ACI 347-04 - Guide to Formwork for Concrete.
- [*ACI 349~~-01~~/~~349-R01~~349R-01 - Code Requirements for Nuclear Safety-Related Concrete Structures* ~~and Commentary on Code Requirements for Nuclear Safety-Related Concrete Structures~~(Reference 12)]* (exception described in 3.8.4.4 and 3.8.4.5) (GDC 1).
- [*ACI 349-06~~/349R-06~~, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (Appendix D) (Reference 63) with the exception of Condition A strength reduction factors even when supplemental reinforcement is provided ~~(Reference 63)~~.*]*
- [*ACI 349.1R-07 - Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures (Reference 41).*]*
- ACI 350-06 - Code Requirements for Environmental Engineering Concrete Structure (Reference 58).
- ACI 350.3-06 - Seismic Design of Liquid-Containing Concrete Structures (Reference 59).
- AISC 303-00 - Code of Standard Practice for Steel Buildings and Bridges.
- [*ANSI/AISC N690~~-1994~~ - Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2 (Reference 14)* ~~(2004)~~]* (GDC 1).
- ANSI/ANS-6.4-2006 - Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants (Reference 4).
- AISC 348-00/2000 RCSC - Specification for Structural Joints Using ASTM A325 and A490 Bolts.
- ANSI/AWS D1.1-2000 - Structural Welding Code – Steel.
- ANSI/AWS D1.4-2005 - Structural Welding Code - Reinforcing Steel.
- ANSI/AWS D1.6-99, including January 6, 2005 update - Structural Welding Code – Stainless Steel.
- ANSI/AWS D1.8 2005 - Structural Welding Code – Seismic Supplement.
- [*ASME Code, Section III, Division 2 – Code for Concrete ~~Reactor Vessels and~~ Containments (Reference 1)*]*.
- ASME NOG-1-2004 - Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girders).
- ASME B31.3 - 1996 - Process Piping, American Society of Mechanical Engineers (Reference 60).

- ASME B31.4 - 1992 - Liquid Transportation System for Hydrocarbon, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols (Reference 61).
- ASME B31.8 - 1995 - Gas Transportation and Distribution Piping Systems.
- [*ASME STS-1 - Steel Stacks (Reference 75).*]*

3.8.4.2.2 Specifications

Industry standards (e.g., those published by the ASTM) are used to specify material properties, testing procedures, fabrication methods, and construction methods.

Structural specifications cover areas related to the design and construction of other Seismic Category I structures. These specifications emphasize important points of the industry standards for these structures and reduce options that would otherwise be permitted by the industry standards. These specifications cover the following areas:

- Concrete material properties.
- Mixing, placing, and curing of concrete.
- Reinforcing steel and splices.
- Structural steel.
- Steel liner plate and embedments.
- Miscellaneous and embedded steel.
- Anchor bolts.
- Expansion anchors.
- Cranes and hoists.

3.8.4.2.3 Design Criteria

- [*ACI 349~~-01~~/~~349-R01~~349R-01 - Code Requirements for Nuclear Safety-Related Concrete Structures ~~and Commentary on Code Requirements for Nuclear Safety-Related Concrete Structures~~(Reference 12)*]* (GDC 1).
- [*ACI 349-06~~/349R-06~~, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary (Appendix D) (Reference 63) with the exception of Condition A strength reduction factors even when supplemental reinforcement is provided ~~(Reference 63)~~.*]*
- [*ANSI/AISC N690~~-1994~~ - Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2 (Reference 14)*~~(2004)~~]* (GDC 1).

- [ASME STS-1 - Steel Stacks (Reference 75).]*

3.8.4.2.4 Regulations

- 10 CFR 50, Appendix A - General Design Criteria for Nuclear Power Plants, GDC 1, GDC 2, GDC 4, and GDC 5.
- 10 CFR 50, Appendix B - Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants."
- 10 CFR 50, Appendix S - Earthquake Engineering Criteria for Nuclear Power Plants.

3.8.4.2.5 NRC Regulatory Guides

Regulatory Guides applicable to the design and construction of other Seismic Category I structures:

- RG 1.61, Revision 1, March 2007 (exception described in Section 3.7.1).
- RG 1.69, December 1973.
- RG 1.115, Revision 1, July 1977.
- RG 1.142, Revision 2, November 2001 (exception described in Section 3.8.3.3).
- RG 1.160, Revision 2, March 1997.
- RG 1.199, November 2003 (exception described in Section 3.8.1.4).

3.8.4.3 Loads and Load Combinations

The U.S. EPR design loads envelope includes the loads over a broad range of site conditions. The loads on other Seismic Category I structures are separated into the following categories:

- Normal loads.
- Severe environmental loads.
- Extreme environmental loads.
- Abnormal loads.

A COL applicant that references the U.S. EPR design certification will confirm that site-specific loads lie within the standard design envelope for other Seismic Category I structures, or perform additional analyses to verify structural adequacy.

3.8.4.3.1 Design Loads

[*Loads on other Seismic Category I structures are in accordance with ACI 349~~-2001~~/349R-01 (Reference 12)*]* and RG 1.142~~, Revision 2, November 2001~~ [*for concrete structures, and in accordance with ANSI/AISC N690~~-1994~~ including Supplement 2 (Reference 14) ~~(2004)~~ for steel structures and ASTM STS-1 (Reference 75)*]* (GDC 1, GDC 2, GDC 4, and GDC 5).

Other Seismic Category I structures are designed for the following loads, as described in Section 3.8.4.4:

Normal Loads

Normal loads are those loads encountered during normal plant operation, startup, shutdown, and construction (GDC 4). This load category includes:

- Dead loads (D)—Dead loads include the weight of the structure and any permanent equipment or material weights. Dead load effects also refer to internal moments and forces due to dead loads.

  For buried items, the dead load includes the weight of the soil overburden. The soil overburden load includes the weight of the overlying soil prism.

- Live loads (L)—Live loads include any normal loads that vary with intensity and point of application, including moveable equipment and precipitation loads. Live load effects also refer to internal moments and forces due to live loads. Live loads are applied, removed, varied from zero to full value, or shifted in location to obtain the worst-case loading conditions. Impact forces due to moving loads are applied for the loading condition.

  In general, a live load of 500 pounds per square foot is applied to FB concrete floors and a load of 175 pounds per square foot is applied to FB and SB steel grating floors and platforms. A live load of 300 pounds per square foot is applied to SB concrete floors. Finally, a live load of 100 pounds per square foot is applied to concrete floors, steel grating floors, and platforms in other Seismic Category I structures. Floor live loads may vary according to the function of individual floors. Truck loads, fuel cask shipment loads, and loads due to replacement of RCS components are considered as live loads in the loading and material handling bays of the FB. Live loads are applied to cranes and their supports for the lifting capacity and test loads applied for lifting devices. Additional point loads are applied to concrete floors and to concrete and steel beams in local design.

  The design live load for rainfall is based on a rate of 19.4 inches per hour, as described in Section 2.4.

  The design live load due to rain, snow, and ice is based on a ground load of 143 pounds per square foot, which corresponds to a roof load of 100 pounds per square foot, as described in Section 2.3. This value is postulated as a meteorological site parameter for the extreme winter precipitation load and includes the weight of the

- Missile loads other than hurricane- or tornado-generated missiles—The hurricane- and tornado-generated missile spectra presented in Table 3.5-1 is considered to bound other external missile loads for the U.S. EPR other Seismic Category I structures. Turbine missiles and conformance to RG 1.115 are addressed in Section 3.5. As described in Section 3.5.1.3, the impact of turbine missiles on other Seismic Category I structures is not considered safety significant based on the redundancy and the low probability of a turbine missile being generated. Other Seismic Category I concrete and steel structures are designed for internally generated missile loads as described in Section 3.5.

3.8.4.3.2 Loading Combinations

[*Load combinations for design of other Seismic Category I structures are in accordance with ACI 349 ~~2001~~/349R-01 (Reference 12)*]* and RG 1.142~~, Revision 2, November 2001~~ [*for concrete structures, and in accordance with ANSI/AISC N690 ~~1994~~ including Supplement 2 (Reference 14) ~~(2004)~~ for steel structures and ASME STS-1 (Reference 75)*]* (GDC 1, GDC 2, GDC 4, and GDC 5).

The NI Common Basemat Structure is a monolithic concrete structure. However, various portions of the structure have different classifications (i.e., RCB, RB internal structures, and other Seismic Category I structures) and correspondingly different design requirements, as shown in Figure 3.8-118. In some instances, the load combinations identified in ACI 349 ~~2001~~/349R-01 do not include certain independent loadings which should be considered to account for potential structure-to-structure effects (i.e., the effect on one structure resulting from loadings applied to a separate, but monolithically connected, structure). To account for potential structure-to-structure effects, the loading combinations from ACI 349 ~~2001~~/349R-01 are adjusted by including the necessary additional independent loadings. For concrete structures, the independent loadings added to the load combinations include buoyant force (F_b) and post-tension load (J). For steel structures, the independent loadings added to the load combinations include hydrostatic load (F), buoyant force (F_b), post-tension load (J), and soil load/lateral earth pressure (H). In load combinations where abnormal loads are considered, internal flood load (F_a) is added for both steel and concrete structures. The load factors for hydrostatic load (F), buoyant force (F_b), and post-tension load (J) are matched to that of the dead load (D) for each loading combination, while the load factors for soil load/lateral earth pressure (H) and internal flood load (F_a) are matched to that of the live load (L). Section 3.8.4.3.1 provides details regarding the loads considered for the design of other Seismic Category I structures, while Section 3.8.1.3.1 provides the description of the post-tension load (J) which is included to account for the global effect of post-tension loads (J) on the NI Common Basemat.

The following criteria apply for load combinations for concrete and steel Seismic Category I structures other than the RCB and RB internal structures:

- [*For concrete members, U is defined as the section strength required to resist design loads based on the strength design methods described in ACI 349/349R-01 (Reference 12).*

- *For steel members, S is defined as the required section strength based on the elastic design methods and the allowable stresses defined in Part Q1 of ANSI/AISC N690 (Reference 14).*

- *For steel members, Y is defined as the section strength required to resist design loads based on plastic design methods described in Part Q2 of ANSI/AISC N690 (Reference 14).*]*

Loads and loading combinations encompass the soil cases described in Section 3.7.1, using the design criteria described in Section 3.7.1 and Section 3.7.2.

Other Seismic Category I Structures – Concrete

The following load combinations define the design limits for concrete Seismic Category I structures, other than the RCB and RB internal structures:

- Service load combinations for the strength design method.

  $U = 1.4(D + F + F_b + J) + 1.7(L + H + R_o)$

  $U = 1.4(D + F + F_b + J) + 1.7(L + H + W + R_o)$

  $U = 1.05(D + F + F_b + J) + 1.3(L + H + R_o) + 1.2T_o$

  $U = 1.05(D + F + F_b + J) + 1.3(L + H + R_{o + W}) + 1.2T_o$

- Factored load combinations for the strength design method.

  $U = D + L + H + F + F_b + T_o + R_o + J + E'$

  $U = D + L + H + F + F_b + T_o + R_o + J + W_t$

  $U = D + L + H + F + F_b + J + T_a + R_a + F_a + 1.4P_a$

  $U = D + L + H + F + F_b + J + T_a + R_a + F_a + P_a + E'$

  $U = D + L + H + F + F_b + J + T_a + R_a + F_a + P_a + R_r + E'$

Other Seismic Category I Structures - Steel

The following load combinations define the design limits for steel Seismic Category I structures, other than the RCB and RB internal structures. [*For normal service load conditions, either the elastic working stress design methods of Section Q1 or the plastic design methods of Section Q2 of ANSI/AISC N690, including Supplement 2, are used (Reference 14).*]*

structures are explained below. The procedures specific to the following other Seismic Category I structures are also described.

- The RSB and annulus, FB, and SBs.
- The EPGBs.
- The ESWBs.
- Buried conduit and duct banks, and buried pipe and pipe ducts.

Design and analysis procedures described in the following sections also apply to the design of supports for Seismic Category I distribution systems (i.e., pipe supports, equipment supports, cable tray supports, conduit supports, HVAC duct supports, and other component supports) and to Seismic Category I platforms and miscellaneous steel structures located within other Seismic Category I buildings and structures.

3.8.4.4.1 General Procedures Applicable to Other Seismic Category I Structures

*[Other Seismic Category I concrete structural elements and members are designed in accordance with the requirements of ACI 349~~-2001~~/349R-01 and its appendices (Reference 12)]** (GDC 1). Exceptions to code requirements specified in RG 1.142 are incorporated into the design and are accommodated in the loading combinations described in Section 3.8.4.3.2 for concrete structures.

[The design of concrete walls, floors, and other structural elements for other Seismic Category I structures is performed using the strength-design methods described in ACI 349~~-2001~~/349R-01 (Reference 12). The ductility requirements of ACI 349~~-2001~~/349R-01 are satisfied to provide a steel reinforcing failure mode and prevent concrete failure for design basis loadings.

*The design of anchors and embedments conforms to the requirements of ACI 349-06 (Appendix D) (Reference 63) with exception stated in Section 3.8.1.2.1~~)~~]** and RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~. *~~[~~The requirements of Appendix C of ACI 349~~-2001~~/349R-01 (Reference 12) are followed for impulsive and impactive loading conditions (e.g., loading combinations that include pipe break missile impact loads, hurricane- or tornado-generated missile impact loads).*

*Other Seismic Category I steel members and assemblies are designed in accordance with ANSI/AISC N690~~-1994 (R2004~~, including Supplement 2 (Reference 14)) ~~(GDC 1)~~. Steel member design uses the allowable stress design methods of ANSI/AISC N690.]**

*[Application of ASME STS-1 (Reference 75) is allowable for the vent stack.]**

*[The design of bolted connections is in accordance with ANSI/AISC N690, Section Q1.16 (Reference 14)]** and AISC 348-00/2000 RCSC, ~~"~~Specification for

Structural Joints Using ASTM A325 and A490 Bolts."]* Bolted connections are designed to be fully tensioned (e.g., slip critical) unless justified otherwise.

The design of welded connections is in accordance with AWS D1.1 or AWS D1.6.

*[The design of bolted connections in combination with welded connections is in accordance with Section Q.15.10 of ANSI/AISC N690 (Reference 14).]**

Loads and load combinations defined in Section 3.8.4.3 are used to determine strength requirements of members and elements of other Seismic Category I structures. Abnormal pipe break accident loads only apply to limited areas of structures located on the NI Common Basemat Structure. The following criteria apply for load combinations for concrete and steel other Seismic Category I structures:

- Where any load reduces the effects of other loads, the corresponding coefficient for that load is 0.9 if it can be demonstrated that the load occurs simultaneously with other loads.
- Where the structural effects of differential settlement, creep, or shrinkage may be significant, they are included with the dead load (D) as applicable.
- For load combinations in which a reduction of the maximum design live load (L) has the potential to produce higher member loads and stresses, multiple cases are considered where the live load (L) is varied between its maximum design value and zero.
- Roofs with a slope of less than 0.25 inches per foot are analyzed for adequate stiffness to preclude progressive deflection as water ponding is created from the snow load or from rainfall on the surface. The analysis considers the potential blockage of the primary drainage system of the area that is subject to ponding loads. The analysis uses the larger of the snowmelt depth or rain load.
- For load combinations including the loads P_a, T_a, R_a, R_{rr}, R_{rj}, or R_{rm}, the maximum values of these loads, including a dynamic load factor, are used unless a time-history analysis is performed to justify otherwise.
- For load combinations including loads R_{rr}, R_{rj}, R_{rm}, or W_m, these load combinations are first satisfied with these loads set to zero. However, when considering these concentrated loads, local section strength capacities may be exceeded under the effect of these concentrated loads, provided there is not a loss of intended function of the structural member or a loss of function of any safety-related SSC.
- Tornado and hurricane loads are applied to roofs and exterior walls of other Seismic Category I structures. If tornado and hurricane pressure boundaries are not established at the exterior walls, interior walls are designed as tornado and hurricane pressure boundaries.
- For load combinations that include a tornado and hurricane load (W_t), the tornado and hurricane load parameter combinations described in Section 3.3 are used.

Concrete and steel structural elements and members are designed for axial tension and compression forces, bending moments, torsion, and in-plane and out-of-plane shear forces for the controlling loading combinations that are determined from analysis. Concrete and steel members and elements remain elastic for loadings other than impact. Local yielding is permitted for localized areas subjected to hurricane- and tornado-generated missile loads, pipe break accident loadings, and beyond design basis loadings. The structural integrity of members and elements is maintained for the loading combinations described in Section 3.8.4.3.

[*A local analysis and design of concrete members will be performed for impactive and impulsive loads according to ACI 349/349R-01 (Reference 12),*]* with exceptions noted in RG 1.142. [*A local analysis and design of steel members will be performed for impactive and impulsive loads according to ANSI/AISC N690 (Reference 14).*]*

It is acceptable to assume non-linear (elasto-plastic) response of structural members for evaluation of the response of reinforced concrete and steel structures subject to impactive or impulsive loads. Deformation under impactive and impulsive loads is controlled by limiting the ductility ratio, μ_d, which is defined as the ratio of maximum acceptable displacement, χ_m (or maximum strain, ε_m), to the displacement at the effective yield point, χ_y (or yield strain, ε_y), of the structural member. In addition to the specified deformation limits, maximum deformation will not result in the loss of intended function of the structural member nor impair the design basis safety function of other systems and components.

Regarding structural capacity, a structural member will retain its ability to perform its design basis function when ductility limits for concrete and steel members presented in Table 3.5-3 are satisfied. As deformation limits of the member may be governed by attached structures, systems and components (SSC), the member will also satisfy deformation limits imposed by attached SSC to prevent loss of design basis function.

Analysis and design of other Seismic Category I structures are performed using a combination of computer models and local analyses. Computer models are used to perform overall analysis of major structures. The loads and loading combinations described in Section 3.8.4.3 are applied to the overall computer model to design for global effects of the loadings. Local analyses and designs are performed using refined computer submodels and manual calculations. Local analyses and designs are used to account for local discontinuities (e.g., openings, thickened areas, local loads, punching shear checks, and changes in member cross-section). Local analyses are also used to determine designs for items such as component supports, embedments, anchors, platforms, and other miscellaneous structural items. Techniques used for major structures are described in Sections 3.8.4.4.2 through 3.8.4.4.5.

A finite element sub-model for the Main Steam/Feedwater (MS/FW) Valve Room portion of the Safeguard Building 1 (SB1) is developed in ANSYS to analyze and include localized loadings and pipe penetration locations that were not considered in the NI global model. The sub-model includes a portion of the geometry of SB1, a portion of the Reactor Shield Building (RSB), and small portions of the staircases that are part of the shield buildings for the Fuel Building and Safeguard Buildings 2/3.

To account for the effects of the NI global model on the MS/FW Valve Room submodeled region, the displacements of the nodes on the boundaries of the submodel are obtained from the NI global model results for each independent load. These displacements are applied to the submodel as boundary conditions for the respective independent load. The boundaries of the MS/FW Valve Room sub-model are established a distance from the MS/FW Valve Room such that the global results at the boundary node locations are not significantly affected by the additional localized loadings. Missing loads and loads that are applied to the NI global model in the region the submodel are also applied in the MS/FW Valve Room submodel. The submodel results are used to determine load combinations used in the analysis and design of MS/FW Valve Room critical section. Refer to Section 9.1.5 for design requirements applicable to cranes located in other Seismic Category I structures.

Openings in walls and slabs of other Seismic Category I structures are shown in construction drawings. Openings are acceptable without analysis if they meet the criteria identified in ACI 349/349R-01, Section 13.4.2. Round pipe sleeves are used in lieu of rectangular penetrations where possible. Corners of rectangular openings in walls and slabs are provided with diagonal reinforcing to reduce cracking due to stress concentration at these locations in accordance with ACI 349/349R-01, Section 14.3.7.

Appendix 3E describes analysis and design results for critical sections of other Seismic Category I structures.

Section 3.7.2 addresses design procedures applicable to non-safety-related structures to preclude adverse interaction effects on Seismic Category I structures.

Static Analysis and Design

Dead loads (D), live loads (L), hydrostatic loads (F), soil loads and lateral earth pressure loads (H), wind loads (W), pipe reactions (R_o), and normal thermal loads (T_o) are considered in the analysis and design of other Seismic Category I structures for the static normal load concrete and service load steel loading combinations. Concrete and steel members are designed to accommodate these static loads within the elastic range of their section strength. For concrete structures, uncracked section properties are used to proportion loadings to members. However ultimate strength design is used to reinforce concrete elements and members subjected to the normal factored loading combinations defined in Section 3.8.4.3.2.

architectural variations, equipment loads, and other variations from the values used in the analysis and design of other Seismic Category I structures. Due to these potential variations, an additional eccentricity of the mass is included at the floor elevations that are equivalent to 5 percent of the maximum building dimension.

[*Seismic Category I concrete structural elements and their connections are detailed for ductility in accordance with ACI 349~~-2001~~/349R-01*, Chapter 21 (Reference 12).]*

Structural Stiffness Considerations

Conservative values of concrete creep and shrinkage are used in the design of other Seismic Category I structures. Moments, forces, and shears are obtained on the basis of uncracked section properties in the analysis. However, in sizing the reinforcing steel required, the concrete is not relied upon for resisting tension. Thermal moments are modified by cracked-section analysis using analytical techniques, when the state of loading indicates the development of cracks.

The effect of local wall and floor slab flexibility is included where the analysis indicates the existence of this condition. The concrete section properties used in calculating the amplified seismic forces include an appropriate level cracking for the particular element under consideration. The amplified forces are also used in the design of the structural members that support the flexible element.

Section 3.8.4.6 describes methods used to confirm that concrete properties satisfy design requirements.

Seismic Structural Damping

Seismic analysis of other Seismic Category I structures uses the following SSE structural damping values as recommended by RG 1.61.

Structure Type	Percent of Critical Damping
• Welded Steel	4
• Bolted Steel, Slip Critical Connections	4
• Bolted Steel, Bearing Connections	7
• Reinforced Concrete	7

Hydrodynamic Loads

Hydrodynamic loads are applied to the walls and floors of the spent fuel pool and liquid storage tanks in the SBs and in the ESWBs to account for the impulsive and convective effects of the water moving and sloshing in the tanks as a result of seismic excitation. These loads are considered as part of the seismic SSE loads, and to have no effect on the overall structure of other Seismic Category I structures and are only considered in local analyses.

[*For concrete structures, the requirements of ACI 349/349R-01, Appendix A (Reference 12), ACI 349.1R-07 (Reference 41) , or thermal analysis computer programs or similar procedures are used to evaluate thermally induced forces and moments. When considering the combined effects of thermal stress and stress due to other loads, the analysis satisfies the requirements of Appendix A of ACI 349/349R-01.*]*

Pipe Rupture Loads

Other Seismic Category I structures will be evaluated for pipe rupture loads. Local analyses of other Seismic Category I structures consider the following abnormal loads for areas that house high-energy piping systems:

- Subcompartment pressure loads (P_a).
- Pipe break thermal loads (T_a).
- Accident pipe reactions (R_a).
- Pipe break reaction, jet impingement, and missile loads (R_{rr}, R_{rj}, R_{rm}).
- Local flood loads (F_a).

Subcompartment pressure loads (P_a) resulting from a LOCA event are evaluated as time-dependent loads across concrete walls and floors that enclose high-energy piping systems. Concrete and steel members are designed to accommodate subcompartment pressure loads within the elastic range of the section strength.

Pipe break thermal loads (T_a) are considered in local analyses of concrete walls and floors. Accident thermal loads are evaluated as time-dependent loads across concrete walls and floors that enclose high-energy piping systems subject to LOCA events. [*The thermal design of concrete is in accordance with ACI 349~~-01~~/~~349-R01~~349R-01, Appendix A (Reference 12) and ACI 349.1R-07 (Reference 41).*]*

Accident pipe reaction loads (R_a) are considered on piping supports, including supports for the MS and feed water piping. Concrete and steel members are designed to accommodate accident pipe reaction loads within the elastic range of their section strength.

Pipe break reaction, jet impingement, and missile loads (R_{rr}, R_{rj}, R_{rm}) are considered in local design of concrete walls and floors and steel members. Dynamic load factors are applied when analyzing structures for the static equivalent of these loads. Elasto-plastic behavior may be assumed with ductility ratios, provided that excessive deflections do not result in the loss of function of any safety-related SSC. [*Pipe break reactions, jet impingement, and missile impact impulsive and impactive loads are in accordance with Appendix C of ACI 349* ~~*-2001*~~*/349R-01 (Reference 12).*]* The design of other Seismic Category I structures for these loads conforms to the procedures described in Section 3.5 for internally generated missiles. Section 3.5 also describes ductility limits that are followed for impactive and impulsive loadings.

Flood loads (F_a) are applied to walls and floors in the local design of other Seismic Category I structures. Concrete and steel members are designed to accommodate these flood loads within the elastic range of their section strength.

Missile Impact Design

The design of Seismic Category I structures for internally generated and externally generated missiles conforms to the procedures described in Section 3.5.

[*Concrete missile barriers subject to missile impact loads are designed in accordance with Appendix C of ACI 349/349R-01 (Reference 12).*]* Steel missile barriers subject to missile impact loads are designed in accordance with the requirements of ASCE No. 58. Missile protection barriers that use composite sections will be evaluated for local damage using the residual velocity of the missile perforating the first element as the striking velocity of the missile for the next element in the section.

Seismic Category I structures, shields, and barriers designed to withstand the effects of missile impacts are evaluated for local damage in the impacted area, including an estimation of the depth of penetration and, in the case of concrete barriers, the potential for generation of secondary missiles by spalling or scabbing. Global and regional effects of missile impact are also evaluated for concrete and steel missile barriers.

Dynamic load factors are applied when analyzing structures for the static equivalent of missile impact loads. Elasto-plastic behavior may be assumed with ductility ratios, provided excessive deflections do not result in loss of function of any safety-related SSC.

Structures that are not classified as Seismic Category I structures are not relied upon to shield Seismic Category I structures from the effects of missile impact.

Flood Design

In addition to designing for the external flood loads described in Section 3.8.4.3.1, Seismic Category I structures are protected against external flooding by the following methods:

For uniformity of site characteristics, the required bearing demand will be the same as for the NI.

The equivalent SSI model includes modifications to the stiffness of the various composite beams at elevation 51 feet, 6 inches, as well as modifications to account for cracking. The stiffness of these composite beams is included in the model to capture out-of-plane response. Stiffness of the composite beams is not required in the static analysis model as only in-plane stresses in the concrete slab are determined.

For the composite beams and floor slab at elevation 51 feet, 6 inches, the corresponding floor accelerations from the MTR/SASSI analysis output are applied to tributary floor areas and walls to obtain the seismic loads associated with the out-of-plane loads. Dead load, live load, equipment loads, and piping loads are combined with the seismic loads. The composite beams are analyzed outside of the FEM. [*Structural design of the composite beams is in accordance with the provisions of ANSI/AISC N690 (Reference 14) ~~1994 (R2004)~~.*]*

The in-plane and out-of-plane results from the GT STRUDL equivalent static analysis are extracted and used to design reinforced concrete shear walls and slabs according to provisions of ACI 349 ~~01~~/349R-01. The evaluation of walls and slabs for external hazards (e.g., hurricane- or tornado generated missiles and blast loads) is also performed by local wall and slab analyses. Structural element reinforcement is designed to provide sufficient ductility.

Additional information on the seismic analysis approach for the EPGBs is contained in Section 3.7.2.

For the design of the EPGBs, some details for the composite beams and slabs at elevation 51 feet, 6 inches, particularly changes in beam sizes and floor openings, as well as certain aspects of mechanical design layout, are not reflected in the MTR/SASSI FEM used for SSI analyses. Inclusion of these details in the MTR/SASSI FEM are not expected to have any significant impact on the seismic forces used in the design of the EPGBs, but may impact the in-structure response spectra. Therefore, a subsequent analysis will be performed with these details in the FEM to confirm the seismic responses and in-structure response spectra presented in Section 3.7.2. The design of the EPGBs will conform to the structural acceptance criteria described in Section 3.8.4.5.

3.8.4.4.4 Essential Service Water Buildings

Reinforced concrete elements for the four ESWBs consist of slabs, beams, shear walls, and foundation basemat to transfer imposed loads to the supporting soil. Structural steel framing is used to support the missile barriers protecting the safety-related fans.

~~Similar to the EPGBs, the~~ The ESWBs are analyzed and designed using a 3D FEM representing the structure. The FEM is generated using the GT STRUDL computer code (Reference 74). The use of the model for both static and dynamic analyses, including extraction of results for design, is similar ~~almost identical~~ to the methods presented in Section 3.8.4.4.3. ~~Similarly, t~~The GT STRUDL model is used to provide an accurate representation of the structure for translation to an SSI model ~~(SASSI 2000)~~ for seismic analysis. As such, only model variations are addressed below.

In addition to structural dead loads, slab live loads, piping loads and equipment loads, the GT STRUDL FEM for the ESWBs includes the weight of non-structural fill, hydrostatic loads, hydrodynamic loads, and soil pressures (including surcharge pressures). The appropriate accelerations from the SSI analysis are applied to the tributary floor areas and walls to obtain the equivalent static seismic loads.

[*Dead load, live load, equipment loads, and piping loads are combined with the equivalent static seismic loads for structural design in accordance with the provisions of ACI 349 ~~-01~~/349R-01 (Reference 12)*,]* with supplemental guidance of RG 1.142, ACI 350-06, and ACI 350.3-06.~~]*~~ The evaluation of walls and slabs for external hazards (e.g., hurricane- or tornado-generated missiles) is performed by local analyses, including ductility evaluations. The elastic solution methodology of ASCE 4-98, Section 3.5.3.2 is used for the dynamic soil pressures associated with the 33~~21~~ feet embedment of the ESWBs.

Seismic induced lateral soil pressure on below grade walls are evaluated considering the following cases:

- The seismic soil pressure as equal to the sum of the static earth pressure plus the dynamic earth pressure calculated in accordance with ASCE 4-98, Section 3.5.3.2.
- The seismic soil pressure as equal to the passive earth pressure.

Additional information on the seismic analysis approach for the ESWBs is contained in Section 3.7.2.

3.8.4.4.5 Buried Conduit and Duct Banks, and Buried Pipe and Pipe Ducts

The design of buried conduit and duct banks, and buried pipe and pipe ducts is site-specific. Buried Seismic Category I conduit, electrical duct banks, pipe, and pipe ducts will be analyzed and designed in accordance with the specific requirements of the systems. In addition, these items will be designed for the effects of soil overburden, surcharge, groundwater, flood, seismic soil interaction, and other effects of burial. [*Concrete components of buried items will be designed in accordance with ACI 349~~-2001~~/349R-01 (Reference 12)*,]* including the exceptions specified in RG 1.142. [*Steel components of buried items will be designed in accordance with ANSI/AISC N690~~-1994 (R2004)~~, including Supplement 2 (Reference 14)*.]*

Refer to Appendix 3F~~the AREVA NP Inc., U.S. Piping Analysis and Pipe Support Design Topical Report (Reference 37)~~ for additional analysis and design procedures applicable to buried piping.

A COL applicant that references the U.S. EPR design certification will describe the design and analysis procedures used for buried conduit and duct banks, and buried pipe and pipe ducts.

A COL applicant that references the U.S. EPR design certification will use results from site-specific investigations to determine the routing of buried pipe and pipe ducts.

A COL applicant that references the U.S. EPR design certification will perform geotechnical engineering analyses to determine if the surface load will cause lateral or vertical displacement of bearing soil for the buried pipe and pipe ducts and consider the effect of wide or extra heavy loads.

3.8.4.4.6 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.4, 2.5, 3.3, 3.5, 3.7, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design results are presented in Appendix 3E for Seismic Category I structure critical sections. A cross-reference between U.S. EPR FSAR sections and information required by SRP Section 3.8.4, Appendix C is provided in Table 3.8-17.

3.8.4.5 Structural Acceptance Criteria

[*Limits for allowable stresses, strains, deformations and other design criteria for other Seismic Category I reinforced concrete structures are in accordance with ACI 349~~-2001~~/349R-01 and its appendices (Reference 12)]** (GDC 1, GDC 2, and GDC 4). Limits for concrete design include the exceptions specified in RG 1.142.

[*Limits for allowable loads on concrete embedments and anchors are in accordance with the requirements of ACI 349-06 (Appendix D) (Reference 63) with exception stated in Section 3.8.1.2.1~~)~~]** and RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~.

[*Limits for the allowable stresses, strains, deformations, and other design criteria for other structural steel Seismic Category I structures are in accordance with ANSI/AISC N690, ~~-1994 (R2004)~~ including Supplement 2 (Reference 14)]** (GDC 1, GDC 2, and GDC 4).~~]*~~

Allowable settlements for other Seismic Category I structures are described in Section 2.5.

The design of other Seismic Category I structures is generally controlled by load combinations containing SSE seismic loads. [*Stresses and strains are within the limits in ACI 349 ~~2001~~/349R-01 (Reference 12) ~~limits~~, with the exceptions previously listed, and ANSI/AISC N690 (Reference 14)~~ 1994 limits~~.*]*

Appendix 3E provides design results for critical sections of other Seismic Category I structures.

An as-built report is prepared to summarize deviations from the approved design and confirm that the as-built other Seismic Category I structures (RSB, SB, FB, EPGB, and ESWB) are capable of withstanding the design basis loads described in Section 3.8.4.3 without loss of structural integrity or safety-related functions.

Structural acceptance criteria for buried Seismic Category I pipe are addressed in Appendix 3F~~the AREVA NP Inc., U.S. Piping Analysis and Pipe Support Design Topical Report~~.

A COL applicant that references the U.S. EPR design certification will confirm that site-specific Seismic Category I buried conduit, electrical duct banks, pipe, and pipe ducts satisfy the criteria specified in Section 3.8.4.4.5 and those specified in Appendix 3F~~AREVA NP Topical Report ANP-10264NP-A~~.

3.8.4.6 Materials, Quality Control, and Special Construction Techniques

This section contains information relating to the materials, quality control programs, and special construction techniques used in the fabrication and construction of concrete and steel Seismic Category I structures other than the RCB and the RB internal structures.

Construction of concrete radiation shielding structures and certain elements of design that relate to problems unique to this type of structure is in accordance to RG 1.69. The requirements and recommended practices contained in ANSI/ANS-6.4-2006, are generally acceptable for the construction of radiation shielding structures, as amended by the applicable exceptions noted in RG 1.69.

3.8.4.6.1 Materials

Concrete, reinforcing steel, and structural steel materials for other Seismic Category I structures are the same as described in Section 3.8.3.6 (GDC 1), except as follows:

Structural concrete used in the construction of other Seismic Category I structures has the following compressive strengths (f'_c) at 90 days.

- The NI Common Basemat Structures, including RSB, FB and SBs (except for foundation basemat): 6,000 psi minimum.

Refer to Section 9.1.5 for testing and inservice inspection requirements applicable to cranes.

Physical access is provided to perform inservice inspections of exposed portions of other Seismic Category I structures.

Examination of inaccessible portions of below-grade concrete structures for degradation and monitoring of ground water chemistry are addressed in Section 3.8.5.7.

A COL applicant that references the U.S. EPR design certification will address examination of buried safety-related piping in accordance with ASME Code, Section XI, IWA-5244, Buried Components.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

3.8.5 Foundations

3.8.5.1 Description of the Foundations

Foundations for Seismic Category I structures are provided for the following buildings and structures:

- NI Common Basemat Structure foundation basemat.
- EPGB foundation basemats.
- ESWB foundation basemats. The ESWBs house the ESWCTs and the ESWPBs.

Foundations for buried items are included in Section 3.8.4. Section 3.7.2 addresses design requirements for Non-Seismic Category I structures to preclude adverse interaction effects on Seismic Category I structures.

Figure 3B-1 provides a site plan of the U.S. EPR standard plant showing the outline of the foundation basemats for the NI Common Basemat Structure, EPGBs, and ESWBs, along with the location of each foundation basemat.

Structures described within this section are not shared with any other power plant units (GDC 5).

A COL applicant that references the U.S. EPR design certification will describe site-specific foundations for Seismic Category I structures that are not described in this section.

3.8.5.1.1 Nuclear Island Common Basemat Structure Foundation Basemat

The NI Common Basemat Structure foundation basemat is a heavily reinforced concrete slab that supports the NI Common Basemat Structure Seismic Category I structures. The RCB and the RSB are located near the center of the NI Common Basemat Structure foundation basemat, and they are surrounded by the FB and the four SBs. The NI Common Basemat Structure foundation basemat is a cruciform shape that has outline dimensions of approximately 360 feet by 360 feet by 10 feet thick. The bottom of the NI Common Basemat Structure foundation basemat is founded approximately at elevation -41 feet and is embedded into the supporting soil approximately 40 feet. The NI Common Basemat Structure foundation basemat outline and section views are presented in Figures 3B-1, 3.8-11, 3.8-12, 3.8-13, 3.8-50, 3.8-51, 3.8-52, 3.8-63, 3.8-74, and 3.8-85.

The NI Common Basemat Structure foundation basemat provides anchorage of the vertical post-tensioning tendons in the RCB, which is described in Section 3.8.1. The portion of the NI Common Basemat Structure foundation basemat that is considered to provide support and anchorage for the RCB is the area under the circumference of the outer face of the RSB wall, as shown on Figure 3.8-11, Figure 3.8-12, Figure 3.8-13, and Figure 3.8-118. [*This portion of the NI Common Basemat Structure foundation basemat is designed in accordance with the ASME Code, Section III, Division 2 (Reference 1)*.]* A circular gallery is provided beneath the NI Common Basemat Structure foundation basemat for maintenance access to the bottom of the vertical post-tensioning tendons provided in the RCB shell wall. The tendon access gallery is approximately 20 feet wide by 18 feet high, including an approximately 72 inch thick foundation slab under the gallery structure. The tendon gallery, which is integrally cast with the basemat, acts as a shear key and transfers lateral and vertical loads from the basemat into the soil. [*The walls and slab of the tendon access gallery are designed according to ACI 349/349R-01 (Reference 12)*.]*

Sections 3.8.1 and 3.8.3 describe the interface of the RCB containment liner plate and upper internal basemat above the liner for supporting the RB internal structures. Section 3.8.4 describes the interface of the RSB, FB, and SBs with the NI Common Basemat Structure foundation basemat. Concrete walls and columns of these NI Common Basemat Structure Seismic Category I structures are anchored into the NI Common Basemat Structure foundation basemat with reinforcing bars to transmit vertical, horizontal, and bending moment loads into the basemat and to enhance the rigidity of the basemat.

Horizontal shear loads are transferred from the NI Common Basemat Structure foundation basemat to the underlying soil by friction between the bottom of the basemat, mud mat (or both), and the soil, and by passive earth pressure on the below-grade walls of the NI Common Basemat Structure Seismic Category I structures. In addition, the tendon gallery is classified as a Seismic Category I structure and analyzed in the north-south direction. Additional figures provided in Appendix 3E illustrates both the shear walls at the super-structure and foundation basemat interface and the foundation basemat reinforcement. Isometric views of the GT STRUDL model representing the overall structure are provided in Section 3.7.2.

3.8.5.2 Applicable Codes, Standards, and Specifications

Applicable codes, standards, specifications, design criteria, regulations, and regulatory guides that are used for the design, fabrication, construction, testing, and inservice inspection of Seismic Category I foundations are the same as those in Section 3.8.4.2 (GDC 1, GDC 2, GDC 4 and GDC 5).

In addition, [*the portion of the NI Common Basemat Structure foundation basemat under the RCB/RSB is designed in accordance with the ASME Code, Section III, Division 2 (Reference 1) for support and anchorage of the concrete RCB.*]*

3.8.5.3 Loads and Load Combinations

Loads and load combinations for Seismic Category I foundations are the same as those in Section 3.8.4.3.

In addition to the loads addressed in Section 3.8.4.3, the NI Common Basemat Structure foundation basemat is designed for the loads and load combinations from the RCB as described in Section 3.8.1.3. The NI Common Basemat Structure foundation basemat provides for anchorage of the RCB vertical post-tensioning tendons, and the portion of the basemat under the RCB/RSB is designed to accommodate loads from containment.

[*Loads and load combinations on Seismic Category I foundations are in accordance with ACI 349~~-01~~/349R-01 (Reference 12), ANSI/AISC N690, including Supplement 2 (Reference 14) for steel structures,*]* RG 1.142, and RG 1.199~~, and ANSI/AISC N690-1994, including Supplement 2 (2004) for steel structures~~ (GDC 1, GDC 2, GDC 4 and GDC 5).~~]*~~ [*Loads and load combinations on the portion of the NI Common Basemat Structure foundation basemat that supports the RCB/RSB are in accordance with the ASME Code, Section III, Division 2 (Reference 1)*]* and RG 1.136 (Exception: RG 1.136 endorses the 2001 Edition of the ASME Code with the 2003 addenda (including exceptions taken in RG 1.136). [*The U.S. EPR standard plant design is based on the 2004 Edition of the ASME Code, Section III, Division 2 (Reference 1)*]*, inclusive of the exceptions taken in RG 1.136).~~]*~~

The NI Common Basemat Structure is a monolithic concrete structure. However, various portions of the structure have different classifications (i.e., RCB, RB internal structures, and other Seismic Category I structures) and correspondingly different design requirements, as shown in Figure 3.8-118. In some instances, the load combinations identified in SRP Section 3.8.5 do not include certain independent earthquakes are transferred to the subgrade by friction along the bottom of the foundation basemat, shear key, or by passive earth pressure.

The stability evaluations for the NI, EPGB, and ESWB are based on SSI analysis results, as described in Section 3.7.2.3. The coefficient of passive soil pressure corresponding to the sidewall movements into the soil are estimated from the SSI analysis and are used to calculate the passive soil pressure resisting sidewall movement.

Passive soil pressure capacities are based on constitutive models, typically used for granular media, such as Drucker-Prager or Coulomb-Mohr. For soil sites, a granular backfill material is used against side walls and underneath the structures, if needed. Backfill shall be installed to meet 95 percent of the Modified Proctor density (ASTM D-1557 (Reference 66)). For rock sites, controlled low strength material, as described by ACI-229R (Reference 65), is specified on the faces of below grade walls. The tendon gallery acting as a shear key is backfilled with lean concrete. Cohesive materials will be addressed on a site-specific basis.

The wall pressures calculated from SSI analysis, elastic solution by Wood, and those required for sliding stability are considered in the design of embedded walls. Each soil case is analyzed, dynamically and statically, and design loads and controlling loads for each wall are used in the design.

The estimated maximum sidewall movement into the soil that results in the highest K_p value may not necessarily occur when the minimum factor of safety is calculated. Therefore, the minimum factor of safety is investigated using appropriate sidewall movements (using corresponding K_p) at the time of minimum sliding factor of safety.

Design and analysis procedures for Seismic Category I foundations are the same as those described in Sections 3.8.1.4 and 3.8.4.4 for the respective structures that apply loads on the foundations.

[*Seismic Category I concrete foundations are designed in accordance with ACI 349~~-01~~/349R-01 and its appendices (Reference 12)*]* (GDC 1). Exceptions to code requirements specified in RG 1.142 are incorporated into the design and are accommodated in the loading combinations described in Section 3.8.5.3. [*In addition, the portion of the NI Common Basemat Structure foundation basemat that supports the RCB/RSB is designed in accordance with the ASME Code, Section III, Division 2 (Reference 1) for support and anchorage of the concrete RCB*]* as described in Section 3.8.1.

[*The design of concrete foundations for Seismic Category I structures is performed using the strength-design methods described in ACI 349~~-01~~/349R-01 (Reference 12).*]* The ductility provisions of ACI 349~~-01~~/349R-01 are satisfied to provide a steel reinforcing failure mode and to prevent concrete failure for design basis loadings.

The effect of settlement on the ESWB structure considers a soft soil site consistent with a soft soil case as shown in Table 3.7.1-9. Soil springs are developed to consider both short term (elastic) and long term (heave and consolidation) effects. The 3D FEM of the ESWB basemat and superstructure are used in a static structural analysis with elastic soil springs applied in an elliptical distribution. The consolidation effects are approximated by further softening the elastic soil spring stiffness by a factor of two. A settlement load file is created considering 100 percent of the dead load, 25 percent of the live load, and 75 percent of the precipitation loads to determine locked-in forces and moments for all structural elements. The full Ec and section modulus is used in the ESWB settlement analysis. ~~A check is conducted to determine if the basemat concrete has cracked during development of the load file. If the basemat concrete has cracked, a cracked section modulus is used to develop the forces and moments.~~ The basemat design includes symmetrical main reinforcing steel in each direction and on each face to account for any additional lateral variability in the soil properties and to control development of any large cracks in the basemat.

The total differential settlement contour is developed for the ESWB as shown in Figure 3.8-136.

Detailed analysis and design procedures are described in the critical sections presented in Appendix 3E for the ESWBs.

3.8.5.4.5 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.4, 2.5, 3.3, 3.5, 3.7, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design results are presented in Appendix 3E for Seismic Category I structure critical sections. A cross-reference between U.S. EPR FSAR sections and information required by SRP Section 3.8.4 Appendix C is provided in Table 3.8-17.

3.8.5.5 Structural Acceptance Criteria

[*Limits for allowable stresses, strains, deformations, and other design criteria for Seismic Category I concrete foundations are in accordance with ACI 349~~-01~~/349R-01 and its appendices (Reference 12)*]* (GDC 1, GDC 2 and GDC 4). Limits for concrete design include the exceptions specified in RG 1.142. In addition, [*the portion of the NI Common Basemat Structure foundation basemat that supports the RCB/RSB is designed in accordance with the ASME Code, Section III, Division 2 (Reference 1)*]* and RG 1.136 for containment loadings as described in Section 3.8.1.

[*Limits for the allowable stresses, strains, deformations, and other design criteria for structural steel elements of Seismic Category I foundations are in accordance with ANSI/AISC N690~~-1994 (R2004)~~, including Supplement 2 (Reference 14)*]* (GDC 1, GDC 2 and GDC 4).

The design of Seismic Category I foundations is generally controlled by load combinations containing SSE seismic loads. [*Stresses and strains are within the ACI 349~~-01~~/349R-01 limits (Reference 12)*,]* with the exceptions previously listed. [*Limits for allowable loads on concrete embedments and anchors are in accordance with Appendix D of ACI 349-06 (Appendix D) (Reference 63)] with exception stated in Section 3.8.1.2.1~~)~~]** and guidance given in RG 1.199 ~~(~~with exception described in Section 3.8.1.4.10~~)~~.~~]*~~ [*Portions of the NI Common Basemat Structure foundation basemat that support the RCB/RSB are within the limits in accordance with ASME Code, Section III, Division 2 (Reference 1)]**.

Seismic Category I foundations are required to satisfy the factors of safety against overturning, sliding, and flotation defined in Table 3.8-11. The calculated minimum factors of safety for the NI Common Basemat Structure are provided in Table 3E.1-5—Minimum Factors of Safety for the Nuclear Island Common Basemat Structure.

Acceptance criteria for soil conditions for the media supporting Seismic Category I foundations are addressed in Section 2.5.

Acceptance criteria for tilt settlement for Seismic Category I foundations are addressed in Section 2.5.

The acceptance criteria for differential settlement of Seismic Category I foundations are based on the site- specific predicted angular distortion, as described in U.S. Army Engineering Manual 1110-1-1904 (Reference 67). Predicted angular distortion is compared to the angular distortion throughout the basemat in both the east-west and north-south directions in the differential settlement contours. If the predicted angular distortion of the basemat of Seismic Category I structures is less than the angular distortion shown, the site is considered acceptable. Otherwise, further analysis will be required to demonstrate that the structural design is adequate.

~~Additional acceptance criteria for critical areas of these structures are described in Appendix 3E.~~

An as-built report is prepared to summarize deviations from the approved design and confirm that the as-built Seismic Category I foundations are capable of withstanding the design basis loads described in Section 3.8.5.3 without loss of structural integrity or safety-related functions.

A COL applicant that references the U.S. EPR design certification will evaluate site-specific methods for shear transfer between the foundation basemats and underlying soil for site-specific soil characteristics that are not within the envelope of the soil parameters specified in Section 2.5.4.2.

3.8.5.6.1 Materials

Concrete, reinforcing steel, and structural steel materials for Seismic Category I foundations have been used in other nuclear facilities and are the same as described in Section 3.8.3.6 (GDC 1), except as follows:

- Materials for the portion of the foundation basemat that supports the RCB/RSB are the same as described in Section 3.8.1.6.
- Structural concrete used in the construction of Seismic Category I foundations has a minimum compressive strength of 4000 psi (f'_c) at 90 days.
- Waterproofing and dampproofing systems are addressed in Section 3.4.2.
- [*Concrete exposed to aggressive environments, as defined in ACI 349~~-01~~/349R-01, Chapter 4, shall meet the durability requirements of ACI 349~~-01~~/349R-01 Chapter 4 (Reference 12) or ASME Section III, Division 2, Article CC-2231.7 (Reference 1), as applicable. In addition, epoxy coated reinforcing steel will be considered, on a site specific basis, for use in foundations subjected to aggressive environments. For epoxy coated reinforcing steel, the required splice length is increased in accordance with ACI 349~~-01~~/349R-01 specifications.*
- *The waterproofing and dampproofing system of all below-grade Seismic Category I structures subjected to aggressive environments, as defined according to ACI 349~~-01~~/349R-01, Chapter 4, shall be evaluated for use in such environments.*]*

The waterproofing and dampproofing system will provide adequate frictional characteristics, as specified inTable 2.1-1. This characteristic will be demonstrated by vendor testing. The contact surface between the waterproofing or dampproofing system and the concrete will be finished in accordance with manufacturer recommendations.

*[A COL applicant that references the U.S. EPR design certification will evaluate the use of epoxy coated rebar for foundations subjected to aggressive environments, as defined in ACI 349~~-01~~/349R-01, Chapter 4 (Reference 12). In addition, waterproofing and dampproofing systems of Seismic Category I foundations subjected to aggressive environments will be evaluated for use in aggressive environments. Also, the concrete of Seismic Category I foundations subjected to aggressive environments will meet the durability requirements of ACI 349~~-01~~/349R-01, Chapter 4 (Reference 12) or ASME Code, Section III, Division 2, Article CC-2231.7, as applicable.]**

3.8.5.6.2 Quality Control

Quality control procedures for Seismic Category I foundations are the same as described in Section 3.8.3.6 (GDC 1).

3.8.5.6.3 Special Construction Techniques

Seismic Category I foundations are constructed using proven methods common to heavy industrial construction. No special, new, or unique construction techniques are used.

Modular construction methods are used to the extent practical for prefabricating portions of reinforcing and concrete formwork. Such methods have been used extensively in the construction industry. Rigging is pre-engineered for heavy lifts of modular sections.

3.8.5.7 Testing and Inservice Inspection Requirements

Monitoring and maintenance of Seismic Category I foundations is performed in accordance with 10 CFR 50.65 and supplemented with the guidance in RG 1.160 (GDC 1).

Additional testing and surveillance requirements for the portion of the foundation basemat that supports the RCB/RSB are the same as described in Section 3.8.1.7.2.

Physical access is provided to perform inservice inspections of exposed portions of Seismic Category I foundations.

A COL applicant that references the U.S. EPR design certification will identify site-specific settlement monitoring requirements for Seismic Category I foundations based on site-specific soil conditions.

If the monitoring program indicates actual settlement values are not following predicted settlement values during construction, condition specific evaluations or actions will be required. This may include adjusting the construction sequence or schedule, or evaluation of the existing conditions to demonstrate that the resulting moments and forces imposed on the structure are acceptable.

A COL applicant that references the U.S. EPR design certification will describe the program to examine inaccessible portions of below-grade concrete structures for degradation and monitoring of groundwater chemistry.

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

3.8.6 References

1. [*ASME Boiler and Pressure Vessel Code, Section III, Division 2, "Code for Concrete Containments," The American Society of Mechanical Engineers, ~~[~~2004 Edition*]*.

2. SEI/ASCE 37-02, "Design Loads on Structures During Construction," ~~2002,~~ American Society of Civil Engineers, 2002.

3. NUREG-0800, Standard Review Plan, Section 3.8.1, "Concrete Containment," Revision 2, March 2007.

4. ANSI/ANS 6.4-06, "Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants," American National Standards Institute, 2006.

5. NUREG/CR-6906, Appendix A, "Containment Integrity Research at Sandia National Laboratories – An Overview," 2006.

6. ACI 117-90/117R-90 "Standard Tolerances for Concrete Construction and Materials," American Concrete Institute, Inc., 1990.

7. ACI 301-05, "Specifications for Structural Concrete," American Concrete Institute, Inc., 2005.

8. ACI 304R-00, "Guide for Measuring, Mixing, Transporting, and Placing Concrete," American Concrete Institute, Inc., 2000.

9. ACI 305.1-06, "Specification for Hot-Weather Concreting," American Concrete Institute, Inc., 2006.

10. ACI 306.1-90, "Standard Specification for Cold-Weather Concreting," American Concrete ~~Containment~~Institute, Inc., 1990.

11. ACI 347-04, "Guide to Form Work for Concrete," American Concrete ~~Containment~~Institute, Inc., 2004.

12. [*ACI 349~~-01/349-R01~~349R-01, "Code Requirements for Nuclear Safety-Related Concrete Structures," ~~and Commentary,~~ American Concrete Institute, Inc., 2001.*]*

13. ACI SP-2 (99), "Manual of Concrete Inspection," American Concrete ~~Containment~~Institute, Inc., 1999.

14. [*ANSI/AISC N690-1994 (R2004), "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2, American National Standards Institute, 2004.*]*

15. ASCE Standard 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," American Society of Civil Engineers, 1998.

16. ASCE/SEI Standard 7-05, "Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers, 2005.

17. ASCE/SEI Standard 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," American Society of Civil Engineers, 2005.

18. ANSI/AWS D1.1-2000, "Structural Welding Code – Steel," American National Standards Institute, 2000.

34. ASTM A519-06, "Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing," American Society for Testing and Materials, 2006.

35. ASTM A576-06, "Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality," American Society for Testing and Materials, 2006.

36. ASTM A416-06, "Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete," American Society for Testing and Materials, 2006.

37. ~~ANP-10264NP-A, Revision 0, "U.S. EPR Piping Analysis and Pipe Support Design Topical Report," AREVA NP Inc., November 2008~~Deleted.

38. ASTM C94-06, "Standard Specification for Ready-Mixed Concrete." American Society for Testing and Materials, 2006.

39. ACI 308.1-98, "Standard Specification for Curing Concrete," American Concrete Institute, Inc., 1998.

40. ACI 311.4R-05, "Guide for Concrete Inspection," American Concrete Institute, Inc., 2005.

41. [*ACI 349.1R-07, "Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures," American Concrete Institute, Inc., 2007.*]*

42. AISC 303-00, "Code of Standard Practice for Steel Buildings and Bridges," American Institute of Steel Construction, Inc., 2000.

43. Deleted.

44. AISC 348-00, "Specification for Structural Joints Using ASTM A325 or A490 Bolts," American Institute of Steel Construction, 2000.

45. ANSI/AWS D1.8-2005, "Structural Welding Code – Seismic Supplement." American National Standards Institute, 2005.

46. ASTM F1554-07, "Standard Specification for Anchor Bolts, Steel, 36, 55, and 105 ksi Yield Strength," American Society for Testing and Materials, 2007.

47. ASTM C150-07, "Standard Specification for Portland Cement," American Society for Testing and Materials, 2007.

48. ASTM C595-07, "Standard Specification for Blended Hydraulic Cements," American Society for Testing and Materials, 2007.

49. ACI 306R-88, "Cold-Weather Concreting," American Concrete Institute, 1988.

50. ACI 308R-01, "Guide to Curing Concrete," American Concrete Institute, 2001.

51. ASTM A82-07, "Standard Specification for Steel Wire, Plain, for concrete Reinforcement," American Society for Testing and Materials, 2007.

All indicated changes are in response to RAI 583, Question 03.08.03-25

52. ASTM A185-07, "Standard Specification for Steel Welded Wire Reinforcement Plain for Concrete," American Society for Testing and Materials, 2007.

53. ASTM A497-07, "Standard Specification for Steel Welded Wire Reinforcement Deformed for Concrete," American Society for Testing and Materials, 2007.

54. ASTM 325-07, "Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength," American Society for Testing and Materials, 2007.

55. ASTM A490-06, "Standard Specification for Structural bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength," American Society for Testing and Materials, 2006.

56. ASTM A307-07, "Standard specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength," American Society for Testing and Materials, 2007.

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59. ACI 350.3-06, "Seismic Design of Liquid-Containing Concrete Structures," American Concrete Institute, 2006.

60. ASME B31.3, "Process Piping, American Society of Mechanical Engineers," American Society of Mechanical Engineers, 1996.

61. ASME B31.4, "Liquid Transportation System for Hydrocarbon, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols," American Society of Mechanical Engineers, 1992.

62. ASME B31.8, "Gas Transportation and Distribution Piping Systems," American Society of Mechanical Engineers, 1995.

63. [*ACI 349-06~~/349R-06~~, "Code Requirements for Nuclear Safety-Related Concrete Structures~~"~~ and Commentary, Appendix D—Anchoring To Concrete," American Concrete Institute, 2006.*]*

64. NUREG/CR-5096 - "Evaluation of Seals for Mechanical Penetrations of Containment Buildings," August 1998.

65. ACI 229R-99, "Controlled Low-Strength Materials," American Concrete Institute, 1999.

66. ASTM D-1557-09, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort," American Society for Testing and Materials, 2009.

All indicated changes are in response to RAI 583, Question 03.08.03-25

67. EM 1110-1-1904, “Settlement Analysis,” U.S. Army Engineering Manual, 1990.

68. Bechtel Power Corporation Topical Report, BC-TOP-1, Containment Building Liner Plate Design Report, Revision 1, December 1972.

69. CRD C36-73, “Method of Test for Thermal Diffusivity of Concrete,” U.S. Army Engineer Research and Development Center, December 1973.

70. CRD C44-63, “Method for Calculation of Thermal Conductivity of Concrete,” U.S. Army Engineer Research and Development Center, June 1963.

71. ASTM C1260-01, “Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method),” American Society for Testing and Materials, 2001.

72. ASTM C1293-01, “Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction,” American Society for Testing and Materials, 2001.

73. ASME Boiler and Pressure Vessel Code, Section III, Division 1, “Rules for Construction of Nuclear Facility Components,” The American Society of Mechanical Engineers, ~~[~~2004 Edition~~]*~~.

74. GT STRUDL Version 32.

75. [*ASTM STS-1-2006, "Steel Stacks," The American Society of Mechanical Engineers, 2006.*]*

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

2. *[Steel Analysis: ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2 (Reference 34).*

3. *Concrete Anchorages: ACI 349/349R-01, "Code Requirements for Nuclear Safety Related Concrete Structures" (Reference 33).]**

4. Damping Values: NRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, March 2007.

The debris interceptor components such as IRWST retaining baskets, trash racks, TSP baskets and sump strainers are categorized as Seismic Category I mechanical equipment in U.S. EPR FSAR, Tier 1, Table 2.2.2-1. The seismic qualification of this equipment is covered by ITAAC Item 3.3 in U.S. EPR FSAR, Tier 1, Table 2.2.2-3.

6.2.2.3 Design Evaluation

The design basis containment analysis for loss of coolant accidents and main steam line breaks, and the containment pressure and temperature responses for these events, is discussed in Section 6.2.1. As shown in Figure 6.2.1-12, Figure 6.2.1-16, and Figure 6.2.1-20, containment pressure decreases to half its peak in less than twenty-four hours after a LOCA. Analysis of heat removal capacity of the LHSI heat exchanger in support of containment heat removal is discussed in Section 6.2.1.1.3.

The evaluation of NPSH availability of the SIS pumps is discussed inSection 6.3.3.3.

The failure modes and effects analyses of the CONVECT System are described in Section 6.2.5. The failure modes and effects analyses of the SIS are listed in Table 6.3-6. The common mode failure is addressed by the qualification program and periodic testing.

6.2.2.4 Tests and Inspections

Tests and inspections of the CONVECT system are described in Section 6.2.5.4, while the tests and inspections of the IRWST and the SIS are described in Section 6.3.4.

6.2.2.5 Instrumentation Requirements

Instrumentation requirements of the CONVECT system are described in Section 6.2.5.5, while the instrumentation requirements of the IRWST and the SIS are described in Section 6.3.5.

Next File

22. "HVAC Air Duct Leakage Test Manual," Sheet Metal and Air Conditioning Contractors' National Association, 1985.

23. ANSI/ASME N510-1989, “Testing of Nuclear Air-Treatment Systems,” American National Standards Institute/The American Society of Mechanical Engineers, 1989.

24. ASME AG-1, “Code on Nuclear Air and Gas Treatment,” The American Society of Mechanical Engineers, 1997 (including the AG-1a-2000, “Housings” Addenda).

25. NRC Regulatory Guide 1.52, Rev. 3, “Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post Accident Engineered Safety Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants,” 2001.

26. ASTM D3803-1989, “Standard Test Method for Nuclear Grade Activated Carbon,” 1989.

27. ANSI/ASME N509-1989, “Nuclear Power Plant Air Cleaning Units and Components,” American National Standards Institute/The American Society of Mechanical Engineers, 1989.

28. ANP-10322P, Revision 0, “Qualification and Testing of the U.S. EPR Passive Autocatalytic Recombiner,” AREVA NP Inc., June 2012.

29. ANP-10268P-A, Revision 0, “U.S. EPR Severe Accident Evaluation Topical Report,” AREVA NP Inc, February, 2008.

30. U.S. NRC SECY-90-016 “Evolutionary Light Water Reactor (LWR) Certification Issues and their Relationship to Current Regulatory Requirements,” January 1990.

31. U.S. NRC SECY-93-087 “Policy, Technical, and Licensing Issue Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs,” April 1993.

32. NEA/CSNI/R(2000)7 “Flame Acceleration and Deflagration-to-Detonation Transition in Nuclear Safety,” August 2000.

33. *[ACI 349/349R-01, “Code Requirements for Nuclear Safety-Related Concrete Structures,” American Concrete Institute, Inc., 2001.*

*34. ANSI/AISC N690-1994 (R2004), “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” including Supplement 2, American National Standards Institute, 2004.]**

*NRC Staff approval is required prior to implementing a change in this information marked in this section; see FSAR Introduction.

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spreading area to provide gravity flooding of the spreading area with the IRWST water inventory. The core spreading area and the SAHRS are described in Section 19.2.3.3.

The debris interceptor components, including trash racks, retention baskets and ECCS strainers, are designed and analyzed per the provisions of ANSI/AISC N690-1994, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2 ~~(S2)~~. The structural qualification of the debris interceptors includes an evaluation of the structural integrity of the supports and anchorages as it relates to the abilities of the trash rack, retention baskets and ECCS strainers to perform their intended function.

The structural design details and structural evaluation of the debris interceptor components, including the anchorages of the components to the walls or the floor and the attachments of the screens, will be provided in a structural evaluation and stress margin report.

The following industry codes and standards are used for the structural qualification of the debris interceptor components.

1. Design Properties of Materials: ASME Boiler & Pressure Vessel Code, Section II, Part D, 2004 edition.

2. Steel Analysis: ANSI/AISC N690-1994,"Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement ~~No.~~ 2.

3. Concrete Anchorages: ACI 349 ~~01~~/349R-01, "Code Requirements for Nuclear Safety Related Concrete Structures ~~and Commentary.~~"

4. Damping Values: NRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, March 2007.

The debris interceptor components such as IRWST Retaining Baskets, trash racks, TSP Baskets and Sump Strainers are categorized as Seismic Category I Mechanical components in U.S. EPR FSAR, Tier 1, Table 2.2.2-1. These components are covered by ITAAC item 3.3 in U.S. EPR FSAR, Tier 1, Table 2.2.2-3.

6.3.2.3 Applicable Codes and Classifications

The SIS design complies with applicable industry codes and standards, and regulatory requirements, commensurate with the appropriate safety function for each of the individual components. Table 3.2.2-1 provides the seismic and other design classifications of the components in the SIS. Sections 3.9, 3.10, 3.11, 7.3, and 8.1.4 further address these requirements and their implementation for the U.S. EPR.