ArevaEPRDCPEm Resource

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Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 376, FSAR Ch. 3, Supplement 4
Attachments: RAI 376 Supplement 4 Response US EPR DC - DRAFT.pdf

Getachew,

AREVA NP Inc provided on June 24, 2010 a schedule in RAI 376 Supplement 3 for the responses to questions 03.08.03-21 and 22 (July 26, 2010). Attached is a draft response to supplement 4 to support interaction with the NRC on those questions. Let me know if the staff has questions or if the response to these questions can be sent as final.

Thanks,

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Response to

Request for Additional Information No. 376, Supplement 4

3/25/2010

U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.08.01 - Concrete Containment
SRP Section: 03.08.03 - Concrete and Steel Internal Structures of Steel or Concrete Containments
SRP Section: 03.08.05 - Foundations
Application Section: 3.8

QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)

Question 03.08.03-21:

Follow-up to RAI 155, Question 03.08.03-3

The RAI response to Items 1 through 3 relies upon comparison results which were not provided in the RAI response, but instead are contained in AREVA internal documents. To determine to what extent the use of ACI 349-01 meets the guidance in SRP 3.8.3.II.2 and RG 1.142 (which endorse ACI 349-97 with certain exceptions), and since the comparisons were not provided as part of the response, the staff requests AREVA to provide a summary of these comparisons that explain how: (a) design methodologies in ACI 349-01 and ACI 349-97 remain "substantially unchanged," with the exception of sway frame design; and (b) the design of sway frames per ACI 349-01 is a "significant improvement" over the methodology in ACI 349-97.

The response to Item 4 of this RAI explains that the strength reduction factor for shear in ACI 349-01 depends on whether the failure mode of a structural element is shear-controlled (φ=0.6) or bending-controlled (φ=0.85). In contrast, the strength reduction factor for shear strength in ACI 349-06 is the same in both cases. It is further indicated that the rationale for the relaxed provision in ACI 349-06 lies in the expected ductility demands in safety-related nuclear structures, which are typically lower than those in conventional building structures. The RAI response ascertains that, since the provision in ACI 349-01 is based on ACI 318 (code requirements for conventional building structures), then this provision is not necessary for safety-related nuclear structures. Finally, it is noted that while the load combinations in ACI 349-01 are different than those in ACI 349-06, Appendix C of the latter code still allows the use of the load combinations in the former code together with a strength reduction factor for shear equal to φ=0.85.

The staff believes that using isolated provisions (i.e., reduced shear strength reduction factor) of one code (ACI 349-06) together with the remaining provisions of another code (ACI 349-01) is not recommended since it may result in undesirable inconsistencies in the design. There may be other provisions in ACI 349-06 which could have an impact on the design but would not be utilized following the approach described by AREVA. Based on the preceding discussion, existing SRP 3.8 and applicable regulatory guides, and past precedent, the staff requests AREVA to identify one version of the ACI 349 code and to follow consistently the provisions of that code without making selected exceptions.

In addition, the RAI response indicates that the rationale for the elimination of the Section 9.3.4 (in ACI 349-01) requirement from ACI 349-06 is that ductility demands in safety-related nuclear structures are typically lower than those in conventional building structures. The staff emphasizes that this relaxed code provision is a significant departure from the ductile design philosophy utilized in the past, and cannot be accepted solely on the basis of a qualitative statement such as the one provided in the RAI response, especially considering that FSAR Section 3.8.3.4.4 (paragraph 5) indicates that "Seismic Category I concrete structural elements and their connections are detailed for ductility in accordance with ACI 349-2001, Chapter 21."

Therefore, AREVA is requested to identify which version of the ACI Code will be followed without reference to another code for exceptions. If ACI 349-06 is utilized for design and construction of reinforced concrete structures inside and outside the containment, provide a technical justification for any relaxation in the provisions of this code from those in ACI 349-97, which is endorsed by RG 1.142. This justification should provide the basis along with numerical data or test results where appropriate.

Response to Question 03.08.03-21:

The ACI 349-01 section on the design of sway frames allows three options for the calculation of moment magnifiers. These may be calculated by the following:

1. Direct input of values determined from the use of second order frame analysis.
2. Use of an approximated moment magnification factor based on the calculated value Q.
3. Use of an approximated moment magnification factor determined in accordance with methods provided in ACI 318-89 (i.e., ACI 349-97).

To better predict the moments in the frames, these values are combined with values calculated for non-sway frames. This calculation is performed because the practical frames will deflect under lateral loads (i.e., there is not a braced frame).

The section on sway frames includes a check of the frame for the classical case of side sway buckling under gravity loads, depending on the method used to compute the moment magnifiers.

While second order analysis methods have been allowed in prior versions of the code, this version is the first to use this method to better predict the moment increases in frame members. The use of a second order analysis allows a more direct solution for the slenderness effects.

The U.S. EPR common basemat structures utilize a shear wall design with limited numbers of interior columns. Column design uses a braced frame design for slenderness effects. Other structures may use the requirements for the design of sway frames.

The shear strength reduction factor is determined in accordance with ACI 349-01. U.S. EPR FSAR Tier 2, Sections 3.8.3.5, 3.8.4.4.1, 3.8.4.5, 3.8.5.4.1, and 3.8.5.5 will be revised to remove the exception allowing the use of shear strength reduction factors from ACI 349-06. The only exception to ACI 349-01 is for the design of anchorages according to ACI 349-06, Appendix D. The phi factors and load combinations of ACI 349-06, Appendix D, are consistent with ACI 349-01. The regulatory positions of RG 1.199 are applicable to anchorage design using ACI 349-06, Appendix D.

FSAR Impact:

U.S. EPR FSAR Tier 2, Sections 3.8.3.5, 3.8.4.4.1, 3.8.4.5, 3.8.5.4.1, and 3.8.5.5 will be revised as described in the response and indicated on the enclosed markup.

Question 03.08.03-22:

Follow-up to RAI 155, Question 03.08.03-5

The response to item 3 of this RAI confirms that all footnotes of Table Q1.5.7.1 in ANSI/AISC N690 are included in the design of the U.S. EPR. Furthermore, the design of all steel components, members, and connections follow the provisions of ANSI/AISC N690 (1994), including supplement 2 (2004), as referenced in FSAR Sections 3.8.3.2.1, 3.8.3.2.3, 3.8.3.3.2, 3.8.3.4, and Section 3.8.3.4.1. Finally, it is stated that footnotes in FSAR Sections 3.8.3.3.2 and 3.8.4.3.2 will be updated by deleting the text "The stress limit coefficient in shear must not exceed 1.4 in members and bolts" to avoid confusion. However, the staff notes that the markups included with the RAI response have been modified by adding an additional footnote 2 without deleting any text in footnote 1. If all the provisions of ANSI/AISC N690 (1994), including supplement 2 (2004), are being followed without exceptions then this should be clearly reflected in the FSAR. In particular, explain why certain footnotes are being selectively included in the FSAR and not others.

The response to item 4 of this RAI indicates that, for the load combinations described in FSAR Sections 3.8.2.3, 3.8.3.3, 3.8.4.3, and 3.8.5.3, the variation in the live loads (L) from zero to full value was not considered in the static model of the NI but was considered in local analysis and design. To determine if the load combinations utilized for the design of the U.S. EPR meet the acceptance criteria in SRP 3.8.2.II.3, 3.8.3.II.3, 3.8.4.II.3, and 3.8.5.II.3, and since the static model is used to obtain member forces for design, explain why full live load and no live load were not considered in the static model. Also, explain why a load factor of zero is not considered for loads where the use of the full value may reduce the effects of the other loads, as required in ACI 349. Information regarding this issue may be provided in conjunction with the response to the follow-up to RAI 3.8.1-7 Item 2.

Finally, the RAI response indicates that FSAR Sections 3.8.2.3.1, 3.8.3.3.1, and 3.8.4.3.1 will be updated to reflect the information presented in the RAI response. However, the staff notes that the markups included with the RAI response do not show these updates. Explain this inconsistency.

Response to Question 03.08.03-22:

The provisions of ANSI/AISC N690 (1994), including Supplement 2 (2004), are followed without exception. For clarity, the footnotes in U.S. EPR FSAR Tier 2, Sections 3.8.3.3.2 and 3.8.4.3.2 will be removed.

The full value of the live load is applied in the static model of the Nuclear Island (NI) for the load combinations containing live load. Variation in the global model of the live load factor between zero, one, and intermediate values, introduces a considerably large number of loading permutations that does not necessarily contribute to the validation of the performance of the defined critical structural elements. Local analyses that use variations in live load values combined with patterned loading conditions will be utilized to define the worse case loading condition for these individual structural components.

The same static model limitations prevent the identification of other global loads (not live load) that may reduce the effects of other loads on individual structural components. Any potential

reduction of load effects must be identified on a local basis. In cases where reduction effects exist, a load factor of zero is used in accordance with ACI 349-01, Section 9.2.3.

U.S. EPR FSAR Tier 2, Sections 3.8.2.3.1, 3.8.3.3.1, and 3.8.4.3.1 will be revised as described in the Response to RAI 155, Supplement 2, Question 03.08.03-5, Part 4, and are included in this response. For consistency, U.S. EPR FSAR Tier 2, Section 3.8.1.3.1 will also be revised and is included in this response.

FSAR Impact:

U.S. EPR FSAR Tier 2, Sections 3.8.1.3.1, 3.8.2.3.1, 3.8.3.3.1, 3.8.3.3.2, 3.8.4.3.1, and 3.8.4.3.2 will be revised as described in the response and as indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

- RG 1.199, November 2003~~.~~ (exception described in 3.8.1.4).

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 BPV Code, Section III, Division 2, Code for Concrete Containments and ACI Standard 359, and RG 1.136 (GDC 1, GDC 2, GDC 4, GDC 16, and GDC 50). RG 1.136 endorses the 2001 Edition of the ASME BPV 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 Code, inclusive of the exceptions taken in RG 1.136. Design loads and loading combinations for the concrete RCB are described in Sections 3.8.1.3.1 and 3.8.1.3.2.

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

3.8.1.3.1 Design Loads

The concrete RCB is designed for the following loads:

Service Loads

- Normal Loads – Normal loads are those loads encountered during normal plant operation and shutdown (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.
  - 03.08.03-22 – Live Loads (L) – Live loads include any normal loads that vary with intensity or point of application, including moveable equipment. Live load effects also refer to internal moments and forces due to live loads. ~~Live loads are applied, removed, or shifted in location to obtain the worst-case loading conditions.~~ 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 as appropriate for the loading condition.
  - Soil Loads or Lateral Earth Pressure (H) – There are no soil or lateral earth pressure loads on the RCB because it is surrounded by other Seismic Category I structures that shield it from these loads.
  - Hydrostatic Loads (F) – Hydrostatic loads due to water stored in pools and tanks are considered in the design of RB internal structures that exert reaction loads on the RCB and NI Common Basemat Structure foundation basemat. Hydrodynamic loads resulting from seismic excitation of fluids are included as a component of the safe shutdown earthquake (SSE) load. There are no

3.8.2.3.1 Design Loads

Steel portions of the RCB that are not backed by concrete are designed for the following loads:

The effects of missiles and external events such as hurricanes, tornados, aircraft hazards, and explosion pressure waves are not considered because the containment is protected from these effects by the RSB. RCB and RSB penetrations are protected by other Seismic Category I structures (i.e., Safeguards or FB).

Service Loads

- Normal loads – Normal loads are those loads encountered during normal plant operation and shutdown (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.

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  – Live loads (L) – Live loads include any normal loads that vary with intensity or point of application, including moveable equipment. Live load effects also refer to internal moments and forces due to live loads. ~~Live loads are applied, removed, or shifted in location to obtain the worst-case loading conditions.~~ 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 as appropriate for the loading condition.

  – Thermal loads (T_o) – Thermal loads consist of thermally induced forces and moments resulting from normal plant operation and environmental conditions. These are described in Section 3.8.1.3.1.

  – 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 included. Appropriate dynamic load factors are used when applying transient loads, such as water hammers.

  – 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 Standard SEI/ASCE 37. 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.

3.8.3.3.1 Design Loads

Loads on RB internal structures are in accordance with ACI 349-2001 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) 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.

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.

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- 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, or shifted in location to obtain the worst-case loading conditions.~~ 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 ~~400~~500 pounds per square foot is applied to ~~RB internal structures concrete floors, and 100 pounds per square foot live load 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.~~steel grating floors and platforms.~~ Live loads are applied to cranes and their supports for the lifting capacity and test load applied for the lifting device. Additional point loads are applied to concrete floors and concrete and steel floor beams in local design.

U = ~~(0.75)(1.4D + 1.4 F + 1.7L + 1.7T_o + 1.7R_o)~~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 + ~~F +~~ L + H + F + F_b + T_o + R_o + J + E'

U = D + ~~F +~~ L + H + F + F_b + J + F_a + 1.4P_a + T_a + R_a ~~+ F_a + 1.5P_a~~

U = D + ~~F +~~ L + H + F + F_b + J + E' + ~~T_a + R_a +~~ F_a + P_a + T_a + R_{ra} + ~~R_{rr} + R_{rj} + R_{rm} + E~~

~~[2]~~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, 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 + ~~F +~~ L + H + F + F_b + J

S = D + ~~F +~~ L + H + F + F_b + J + W ~~T_o + R_o~~

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

1.5S = D + ~~F +~~ 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) ~~1.7F + 1.7L~~

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

Y = ~~(~~1.3~~)~~(D + ~~F +~~ 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:

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$1.6S^{1} = D + F + L + H + F + F_b + T_o + R_o + J + W_t E'$

$1.6S^{1} = D + F + L + H + F + F_b + T_{ao} + R_{ao} + J + E' F_a + P_a$

$1.7 6S^{1} = D + F + L + H + F + F_b + J + F_a + T_a + R_a + F_a + P_a + R_{rr} + R_{rj} + R_{rm} + E'$

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

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

For factored load combinations, in computing the required section strength (S), the plastic section modulus of steel shapes may be used, except for those which do not meet the ANSI/AISC N690 criteria for compact sections.

- Factored load combinations for plastic design method:

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

$0.9Y = D + F + L + H + F + F_b + J + F_a + T_a + 1.25P_a + R_a + F_a + 1.5P_a$

$0.9Y = D + F + L + H + F + F_b + J + F_a + T_a + R_a + F_a + P_a + R_a + R_r + R_{rr} + R_{rj} + R_{rm} + E'$

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

3.8.3.4 Design and Analysis Procedures

Seismic Category I concrete structural elements and members are designed in accordance with ACI 349-2001 and its appendices (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 N690-1994 (R2004) (GDC 1).

Design of concrete embedments and anchors conforms to Appendix B of ACI 349-2001 06 (Appendix D 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). Ductility is provided by designing anchorage systems so that a steel failure mode controls the design.

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1. The stress limit coefficient in shear must not exceed 1.4 in members and bolts. The stress limit coefficient where axial compression exceeds 20 percent of normal allowable must be 1.5 for load combinations defined for 1.6S, and 1.6 for the load combination defined for 1.7S.

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 ~~2.0,~~ 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

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Limits for allowable stresses, strains, deformations, and other design criteria for reinforced concrete RB internal structures are in accordance with ACI 349-2001, and its appendices, including the exceptions specified in RG 1.142, ~~with the exception that the shear strength reduction factor of 0.85 is used as allowed in ACI 349-2006.~~ 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 ~~Appendix B of ACI 349-2006~~ACI 349-06 (Appendix D 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 (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 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 ACI 349-2001 and ANSI/AISC N690-1994 limits.

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

- 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 and RG 1.142, Revision 2, November 2001 for concrete structures, and in accordance with ANSI/AISC N690-1994 including Supplement 2 (2004) for steel structures (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, or shifted in location to obtain the worst-case loading conditions.~~ 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.

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  ~~In general, a live load of 400 pounds/ft^2 is applied to FB concrete floors, and 100 pounds/ft^2 live load is applied to concrete floors and to steel grating floors and platforms in other Seismic Category I structures.~~ 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

- Factored load combinations for the strength design method.

  $U = D + \sout{F +} L + H + F + F_b + T_o + R_o + J + E'$

  $U = D + \sout{F +} L + H + F + F_b + T_o + R_o + J + W_t$

  $U = D + \sout{F +} L + H + F + F_b + J + T_a + R_a + F_a + 1.4P_a$

  $U = D + \sout{F +} L + H + F + F_b + J + T_a + R_a + F_a + P_a \sout{+ R_r + R_{rj} + R_{rm}} + E'\sout{.}$

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

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.

- Service load combinations for the elastic working stress design method.[2]

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  $S = D + \sout{F +} L + H + F + F_b + J$

  $S = \sout{D + F + L + H} D + L + H + F + F_b + J + W$

  $1.5S = \sout{D + F + L + H} D + L + H + F + F_b + T_o + R_o + J$

  $1.5S = \sout{D + F + L + H + T_o + R_o} D + L + H + F + F_b + T_o + R_o + J + W\sout{.}$

- Service load combinations for the plastic design method.

  $Y = \sout{(1.7)(D + F + L + H)} 1.7(D + L + H + F + F_b + J)$

  $Y = \sout{(1.7)(D + F + L + H +} 1.7(D + L + H + F + F_b + J + W)$

  $Y = \sout{(1.3)(D + F +} 1.3(D + L + H + F + F_b + T_o + R_o\sout{)} + J)$

  $\sout{Y = (1.3)(D + F + L + H + W + T_o + R_o)}$

  $Y = 1.3(D + L + H + F + F_b + T_o + R_o + J + W)$

- Factored load combinations for the elastic working stress design method.[3]

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2. \sout{For primary plus secondary stress, the allowable limits are increased by a factor of 1.5.}

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

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

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

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

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(This load combination is used when the global non-transient sustained effects of T_a are considered).

1.7S = D + ~~F +~~ L + H + F + F_b + J + T_a + R_a + F_a + P_a + R_{rr} ~~+ R_{rj} + R_{rm}~~ + E'.

- Factored load combinations for the plastic design method.

  0.9Y = ~~1.1~~ (D + ~~F +~~ L + H ~~+~~ F + F_b + T_o + R_o + J ~~+~~ E')

  0.9Y = ~~1.1 (D + F + L + H + T_o + R_o~~ (D + L + H + F + F_b + T_o + R_o + J + W_t)

  0.9Y = ~~1.1~~ (D + ~~F +~~ L + H + F + F_b + J + T_a + R_a +F_a+ 1.25P_a)

  0.9Y = ~~1.1 (D + F + L + H + T_a + R_a +F_a+ P_a + R_{rr} + R_{rj}~~ (D + L + H + F + F_b + J + T_a + R_a + F_a+ P_a + R_{rm} + E').

3.8.4.4 Design and Analysis Procedures

Analysis and design procedures are similar for the various concrete and steel other Seismic Category I structures but vary somewhat from structure to structure. The general analysis and design procedures applicable to other Seismic Category I 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

3. ~~The stress limit coefficient in shear must not exceed 1.4 in members and bolts. The stress limit coefficient where axial compression exceeds 20 percent of normal allowable must be 1.5 for load combinations defined above for 1.6S, and 1.6 for the load combination defined above for 1.7S.~~

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 and its appendices (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.

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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. ~~, with the exception that the shear strength reduction factor of 0.85 is used as allowed in ACI 349-2006. Use of this shear strength reduction factor is acceptable because the loss of strength and stiffness due to cyclic inelastic loading in structural members of nuclear structures is smaller when compared to that of a conventional building structure, where a lower reduction factor is used.~~ The ductility requirements of ACI 349-2001 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 ~~Appendix B of~~ ACI 349-~~2001~~06 (Appendix D with exception stated in Section 3.8.1.2.1) and RG 1.199 (with exception described in Section 3.8.1.4.10). ~~Ductility is provided by designing anchorage systems such that a steel failure mode controls the design.~~ The requirements of Appendix C of ACI 349-2001 are followed for impulsive and impactive loading conditions (e.g., loading combinations that include pipe break missile impact loads 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) (GDC 1). Steel member design uses the allowable stress design methods of ANSI/AISC N690.

The design of bolted connections is in accordance with ANSI/AISC N690, Section Q1.16 and AISC 348-~~04~~00/~~2004~~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.

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.

between buried pipes and the buildings or structures to which pipes are anchored will be evaluated. At site locations where differential settlement is significant, flexible anchors may be used in lieu of rigid anchors. Support structures will be designed to resist the resulting axial loads, bending stresses, and shear stresses imposed by buried items on the structure.

Refer to 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 ~~2.0,~~ 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

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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 and its appendices, ~~with the exception that the shear strength reduction factor of 0.85 is used as allowed in ACI 349-2006~~ (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 ~~Appendix B of~~ ACI 349-~~2001~~06 (Appendix D with exception stated in Section 3.8.1.2.1) and RG 1.199 (with exception described in Section 3.8.1.4.10).

- EPGBs foundation basemats.
- ESWBs foundation basemats.

3.8.5.4.1 General Procedures Applicable to Seismic Category I Foundations

Concrete foundation basemats for Seismic Category I structures are analyzed as flat slabs on elastic supports to represent the underlying soil. The underlying soil medium is represented by FEM for SSI analyses for the NI and by soil springs for other Category I structures as described in subsequent sections. Loads are applied to the foundation basemats by the interfacing reinforced concrete walls and structural steel columns that comprise the building structures being supported, as well as by equipment supported directly on the foundations. Intersecting concrete walls also serve to stiffen the foundation basemat slabs to increase resistance to bending moments resulting from soil pressures under the slabs. Foundations are analyzed for the various factored loads and load combinations identified in Section 3.8.5.3.

Seismic Category I foundation basemat structures transfer vertical loads from the buildings to the subgrade by direct bearing of the basemats on the subgrade. Horizontal shears, such as those produced by wind, tornados, and earthquakes are transferred to the subgrade by friction along the bottom of the foundation basemat, shear key, or by passive earth pressure ~~(or both)~~. ~~Waterproofing membranes used under or within the Seismic Category I foundations will be evaluated on a site-specific basis, as described in Section 3.8.5.6.~~

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 and its appendices (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 BPV Code–2004 Edition, Section III, Division 2 for support and anchorage of the concrete RCB as described in Section 3.8.1.

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The design of concrete foundations for Seismic Category I structures is performed using the strength-design methods described in ACI 349-01~~, with the exception that a shear reduction factor of 0.85 is used as allowed in ACI 349-06 (Reference 39)~~. The ductility provisions of ACI 349-01 are satisfied to provide a steel reinforcing failure mode and to prevent concrete failure for design basis loadings.

3.8.5.4.5 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections ~~2.0,~~ 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

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Limits for allowable stresses, strains, deformations, and other design criteria for Seismic Category I concrete foundations are in accordance with ACI 349-01 and its appendices~~, with the exception that the shear reduction factor of 0.85 is used as allowed in ACI 349-06~~ (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 in accordance with the ASME BPV Code and RG 1.1~~-~~36 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 (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 limits, with the exceptions previously listed. Limits for allowable loads on concrete embedments and anchors are in accordance with Appendix ~~B~~D of ACI 349-~~20~~06 (Appendix D 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 BPV Code, Section III, Division 2.

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 3.8-12—Minimum Factors of Safety Against Overturning, Sliding, and Flotation for Foundations – NI Common Basemat Structure. ~~For the load combination containing seismic loads, the calculated minimum factors of safety are less than the values provided in NUREG-0800, for overturning and sliding of the NI Common Basemat Structure. The acceptability of these calculated values is further addressed in the following section for the NI Common Basemat Structure foundation basemat.~~

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