ArevaEPRDCPEm Resource

From:	WILLIFORD Dennis (AREVA) [Dennis.Williford@areva.com]
Sent:	Friday, July 15, 2011 2:12 PM
To:	Tesfaye, Getachew
Cc:	BENNETT Kathy (AREVA); DELANO Karen (AREVA); ROMINE Judy (AREVA); RYAN Tom (AREVA)
Subject:	Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3, Supplement 5
Attachments:	RAI 463 Supplement 5 Response US EPR DC.pdf

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 463 on January 27, 2011. On March 29, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for Question 03.07.03-40. On April 8, 2011, AREVA NP submitted Supplement 2 to provide a final response to Question 03.07.03-40. AREVA NP submitted a revised schedule for Question 03.07.01-30 in Supplement 3 on April 28, 2011. On June 24, 2011, AREVA NP submitted Supplement 4 to provide a final response to Question 03.07.01-30.

The attached file, "RAI 463 Supplement 5 Response US EPR DC.pdf" provides a revised final response to Question 03.07.01-30 based on NRC staff comments. Appended to this file are the affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 463 Question 03.07.01-30.

The following table indicates the respective pages in the response document, "RAI 463 Supplement 5 Response US EPR DC.pdf," that contain AREVA NP's response to the subject question.

Question #	Start Page	End Page
RAI 463 — 03.07.01-30	2	2

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: Friday, June 24, 2011 9:55 AM
To: Tesfaye, Getachew
Cc: BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3, Supplement 4

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 463 on January 27, 2011. On March 29, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for Question 03.07.03-40. On April 8, 2011, AREVA NP submitted Supplement 2 to provide a final response to

Question 03.07.03-40. AREVA NP submitted a revised schedule for Question 03.07.01-30 in Supplement 3 on April 28, 2011.

The attached file, "RAI 463 Supplement 4 Response US EPR DC.pdf" provides a technically correct and complete final response to Question 03.07.01-30, as committed. Appended to this file are the affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 463 Question 03.07.01-30.

The following table indicates the respective pages in the response document, "RAI 463 Supplement 4 Response US EPR DC.pdf," that contain AREVA NP's response to the subject question.

Question #	Start Page	End Page
RAI 463 — 03.07.01-30	2	2

This concludes the formal AREVA NP response to RAI 463, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
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Charlotte, NC 28262
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Email: Dennis.Williford@areva.com

From: WELLS Russell (RS/NB)
Sent: Thursday, April 28, 2011 6:15 PM
To: 'Getachew Tesfaye'
Cc: CORNELL Veronica (External RS/NB); BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3, Supplement 3

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 463 on January 27, 2011. On March 29, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for Question 03.07.03-40. On April 8, 2011, AREVA NP submitted Supplement 2 to provide a final response to Question 03.07.03-40. The schedule for Question 03.07.01-30 is being revised.

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

Question #	Response Date
RAI 463 — 03.07.01-30	June 28, 2011

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
AREVA NP, Inc.
3315 Old Forest Road, P.O. Box 10935

Mail Stop OF-57
Lynchburg, VA 24506-0935
Phone: 434-832-3884 (work)
434-942-6375 (cell)
Fax: 434-382-3884
Russell.Wells@Areva.com

From: WELLS Russell (RS/NB)
Sent: Friday, April 08, 2011 1:26 PM
To: 'Tesfaye, Getachew'
Cc: CORNELL Veronica (External RS/NB); 'Miernicki, Michael'; BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3, Supplement 2

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 463 on January 27, 2011. On March 29, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for Question 03.07.03-40.

The attached file, “RAI 463 Supplement 2 Response US EPR DC.pdf” provides a technically correct and complete response to question 03.07.03-40, as committed.

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 RAI 463 Question 03.07.03-40.

The following table indicates the respective pages in the response document, “RAI 463 Supplement 2 Response US EPR DC.pdf,” that contain AREVA NP’s response to the subject question.

Question #	Start Page	End Page
RAI 463 — 03.07.03-40	2	4

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

Question #	Response Date
RAI 463 — 03.07.01-30	April 28, 2011

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
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3315 Old Forest Road, P.O. Box 10935
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Fax: 434-382-3884
Russell.Wells@Areva.com

From: WELLS Russell (RS/NB)
Sent: Tuesday, March 29, 2011 10:08 AM
To: 'Tesfaye, Getachew'
Cc: COLEMAN Sue (RS/NB); CORNELL Veronica (External RS/NB); BREDEL Daniel (EP/PE); BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); HALLINGER Pat (EXT); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); WILLIFORD Dennis (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3, Supplement 1

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 463 on January 27, 2011.

The schedule for Question 03.07.03-40 is being revised to allow additional time for AREVA NP to interact with the NRC. The schedule for the remaining question is unchanged.

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

Question #	Response Date
RAI 463 — 03.07.01-30	April 28, 2011
RAI 463 — 03.07.03-40	**April 28, 2011**

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
AREVA NP, Inc.
3315 Old Forest Road, P.O. Box 10935
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Russell.Wells@Areva.com

From: BRYAN Martin (External RS/NB)
Sent: Thursday, January 27, 2011 3:04 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 463 Response US EPR DC.pdf" provides a schedule since a technically correct and complete response to the 2 questions can not be provided at this time.

The following table indicates the respective pages in the response document, "RAI 463 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 463 — 03.07.01-30	2	2
RAI 463 — 03.07.03-40	3	3

A complete answer is not provided for the 2 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 463 — 03.07.01-30	April 28, 2011
RAI 463 — 03.07.03-40	March 29, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
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702 561-3528 cell
Martin.Bryan.ext@areva.com

From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Tuesday, December 21, 2010 11:14 AM
To: ZZ-DL-A-USEPR-DL
Cc: Chakravorty, Manas; Hawkins, Kimberly; Miernicki, Michael; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 463 (5280, 5281), FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on December 8, 2010, and discussed with your staff on December 16, 2010. No change is made to the Draft RAI as a result of that discussion. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs, excluding the time period of **December 24, 2010 thru January 3, 2011, to account for the holiday season** as discussed with AREVA NP Inc. For any RAIs that cannot be answered **within 45 days**, it is expected that a date for receipt of this information will be provided to the staff within the 40-day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 3247

Mail Envelope Properties (2FBE1051AEB2E748A0F98DF9EEE5A5D47EC000)

Subject: Response to U.S. EPR Design Certification Application RAI No. 463, FSAR Ch. 3, Supplement 5
Sent Date: 7/15/2011 2:12:23 PM
Received Date: 7/15/2011 2:12:26 PM
From: WILLIFORD Dennis (AREVA)

Created By: Dennis.Williford@areva.com

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Tracking Status: None

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Files	**Size**	**Date & Time**
MESSAGE	10443	7/15/2011 2:12:26 PM
RAI 463 Supplement 5 Response US EPR DC.pdf		158478

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

Response to

Request for Additional Information No. 463(5280, 5281), Revision 0

Supplement 5

12/21/2010

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.07.01 - Seismic Design Parameters
SRP Section: 03.07.03 - Seismic Subsystem Analysis

Application Section: 03.07

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

Question 03.07.01-30:

Follow Up to RAI 371, Question 03.07.01-29

In its response to the second part of Question 03.07.01-29**,** the applicant states that it evaluated the impact of the Bell Bend lower bound, best estimate, and upper bound cases on the seismic response of the RCS. The results of this evaluation were not provided as part of the response. The Bell Bend ground response spectra exceed that of the EUR hard soil spectra at frequency values above approximately 22 cps to 70 cps. Although much of the structural response of the RCS may take place at frequencies below 22 cps, the applicant has not demonstrated that the application of the Bell Bend spectra does not have an impact on the results of the RCS structural analysis including any amplified response spectra generated from this analysis for subsequent use. Thus it cannot be concluded that the certified design of the RCS meets the requirements of GDC 2. As a result, AREVA is requested to provide a comparison of the RCS structural response using the EUR governing cases with that of the Bell Bend lower bound, best estimate and upper bound cases including a comparison of RCS amplified response spectra, if applicable, which demonstrates that the EUR governing cases control the seismic design of the RCS. In its response, AREVA should describe the analysis methodology used to determine the Bell Bend RCS response. AREVA should also identify and justify the cutoff frequency used for this analysis. In addition, AREVA is requested to update U.S. EPR FSAR, Tier 2, Appendix 3C.4.2.2.1 to describe how the Bell Bend cases were analyzed and their impact, if any, on the seismic design of the RCS.

Response to Question 03.07.01-30:

The seismic soil cases “hfub”, “hflb,” and “hfbe” listed in U.S. EPR FSAR Tier 2, Table 3.7.1-6 are representative of Bell Bend upper bound, lower bound, and best estimate soil conditions, respectively. The Bell Bend soil cases are therefore included in the seismic design basis of the U.S. EPR standard plant design. U.S. EPR FSAR Tier 2, Table 3.7.1-6 incorporates the three high frequency cases. The Response to RAI 371, Question 03.07.01-29 was submitted prior to the U.S. EPR FSAR Tier 2, Table 3.7.1-6 revision.

U.S. EPR FSAR Tier 2, Sections 3C.4.2.2, 3C.4.2.2.1, and 3C.4.2.2.2 will be revised to indicate that the U.S. EPR FSAR Tier 2, Table 3.7.1-6 seismic cases are included in the seismic analysis of the reactor coolant system (RCS) four loop structural model.

The Response to RAI 371, Question 03.07.01-29 demonstrates that 99.5 percent of the effective mass for the RCS is accounted for below a frequency of 28 Hz. This indicates that a cut-off frequency of 35 Hz with missing mass included for higher frequencies is acceptable for the RCS seismic analysis. Recent discussions with the NRC have raised concerns about the adequacy of a 35 Hz cut-off frequency for the Bell Bend soil cases. To address these concerns, the cut-off frequencies are modified to be 70 Hz for the high frequency soil cases and 35 Hz for the generic cases with missing mass included at higher frequencies for all soil cases. The overall methodology for the RCS seismic analysis remains unchanged and is described in U.S. EPR FSAR Tier 2, Section 3C.4.2.2.1.

FSAR Impact:

U.S. EPR FSAR Tier 2, Sections 3C.4.2.2, 3C.4.2.2.1, and 3C.4.2.2.2 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

The integration time step used in these analyses is 0.0001 seconds.

3C.4.2.2 Seismic Analysis

03.07.01-30

As described in Section 3.7.1.3, the seismic design basis of the U.S. EPR includes twelve SSE cases. These twelve cases represent twelve combinations of soil profile and control motions, ranging from soft soil through medium soil to hard rock. The response of the Nuclear Island Common Basemat Structure at the basemat elevation obtained from soil-structure interaction analysis considering these twelvesoil cases serves as input to the seismic analyses of the RCS four loop structural model and the RPV isolated model.

3C.4.2.2.1 Reactor Coolant System Four Loop Structural Model Seismic Analysis

03.07.01-30

The Table 3.7.1-6 seismic soil cases included in the seismic design basis are applied as input motions to the RCS four loop structural model.The bounding seismic cases for the RCS are determined through a comparison of translational building spectra at the building elevations of importance to the RCS (basemat, bottom of RCP and SG support columns, RPV support ring, SG lower lateral support bumper\RCP lateral support, SG upper lateral support\pressurizer lateral bumpers, pressurizer bracket). Eight of the twelve initial seismic cases provide a bounding set of excitations for the RCS.

Basemat translational and rotational excitations (acceleration time histories) in the three global directions are applied to the RCS structural model, at the base of the RBIS, for each of the bounding seismic cases. Application of all eight of the seismic cases in the design basis seismic analysis of the RCS provides some coverage of uncertainties associated with the soil-structure interaction analysis and the model itself because each of the seismic cases tends to exhibit slightly different frequency characteristics, but relatively similar peak acceleration values, across much of the frequency range of interest to the RCS. To enhance this effect and to provide further coverage of uncertainties inherent in the analysis, the eight sets of seismic excitations are applied to three different configurations of the RCS model: the first model configuration has the modulus of elasticity for the RBIS elements set at 70 percent of the nominal value, the second model configuration has the modulus of elasticity for the RBIS elements set at its nominal value, and the third model configuration has the modulus of elasticity for the RBIS elements set at 130 percent of the nominal value.

The seismic loads for the stress and fatigue analysis of the RCS pressure boundary components are generated from computer analyses through application of these 24 seismic cases to an RCS four loop structural model with the gaps at the SG Lower Lateral Support (LLS) bumpers considered closed. Physically, the SG bumpers are designed to provide a nominal one-sixteenth inch gap at 100 percent normal operating conditions. To determine the effect that this non-linearity has on the seismic response of the RCS, all of the seismic cases are analyzed using both the linear and non-linear versions of the RCS four loop structural model and the results are compared To determine the effect that this non-linearity has on the seismic response of the RCS, the seismic cases are analyzed using linear and non-linear versions of the RCS four loop structural model with Rayleigh damping and direct step-by-step integration time history analyses. The results of these runs are compared to arrive at factors which are then applied to a linear modal superposition time history solution of the RCS four loop structural model, using modal damping values from Table 3.7.1-1 with effects of missing mass included beyond the cut-off frequency. The cut-off frequency is determined to be 70 Hz for high frequency (HF) cases and 35 Hz for generic cases with missing mass included at higher frequencies for all cases. A step-by-step method for performing the seismic analysis of the RCS four loop structural model is described as follows:

03.07.01-30

Basemat excitations for the eight bounding seismic cases are applied to the three versions of the linear RCS four loop structural model (RBIS modulus of elasticity equal to 70 percent of the nominal value, equal to the nominal value, and equal to 130 percent of the nominal value) and to the three versions of the non-linear RCS four loop structural model, for a total of 24 cases per model.

- The same Rayleigh proportional damping is applied in both the 24 linear and the 24 non-linear analyses. The formula shown in Equation 3C-11 is used to calculate a Rayleigh damping curve representative of the modal damping values obtained from analyzing the linear RCS four loop structural model for frequencies and mode shapes using composite modal damping, with damping values taken from Table 3.7.1-1.

The Rayleigh damping curve used in the comparative analyses is based on Rayleigh damping coefficients of α = 1.7 and β = 0.00055.

- The modal superposition time history solution technique, as described in Section 8.3 of Reference 5, is used to calculate the response of the linear RCS four loop structural model. In this scheme, the equations of motion are translated into the principal coordinate system in order to decouple the modes from one another and the individual equations of motion for each mode are solved time-for-time using the Wilson-θ integration scheme, as described in Section 8.2 of Reference 5. The cutoff frequency is 35 cps and the response due to high frequency modes is not implicitly calculated. The direct step-by-step integration time history solution technique is used to calculate the response of the non-linear RCS four loop structural model. The equations of motion in the global coordinate system are solved using the Wilson-θ integration scheme, as described in Section 8.2 of Reference 5. As this is a direct time-for-time solution of the equations of motion, the total response of the system is accounted for. The ratio of the responses from these two analyses therefore includes the effect of high frequency modes that are excluded from the linear analysis The cut-off frequencies for the seismic cases are 70 Hz for HF cases and 35 Hz for generic cases with missing mass included at higher frequencies for all cases. Modal damping values from Table 3.7.1-1 are used for the linear time history analysis.

03.07.01-30

- Loads at key locations obtained from the analysis of the linear RCS four loop structural model for a particular seismic case are compared to the corresponding loads from the analysis of the non-linear RCS four loop structural model for the same seismic case. The key locations evaluated are:
  - RPV HL and CL nozzles
  - RPV support pads
  - SG HL and crossover leg nozzles
  - SG tube support plates
  - SG shell at main feedwater elevation
  - SG shell at the top elevation
  - SG vertical column supports
  - SG lower lateral support bumpers
  - SG upper lateral support snubbers
  - SG upper lateral support struts
  - RCP suction and discharge nozzles
  - RCP vertical column supports
  - RCP lateral supports
  - PZR surge line nozzle
  - PZR shell at the top elevation
  - PZR lower bracket support
  - PZR lateral bumper
- Based on the comparisons in the previous step, bounding factors are calculated for the primary nozzles (including the HL surge line nozzle), the RCS piping (including the surge line), the individual RCS components, and each of the RCS component supports. Conservatively, none of the factors are taken as less than 1.0 (i.e. in those instances where the non-linear analyses produced lower loads than the linear analysis, the factors are taken as 1.0 rather than less than 1.0).

03.07.01-30

The response of the RCS is obtained from time history analysis of the linear RCS four loop structural model, considering the basemat excitations from all ~~24~~ seismic cases. ~~These time history analyses use modal superposition time history solution techniques with a 35 cps cutoff frequency, and modal damping as shown in Table 3.7.1-1.~~These

03.07.01-30

time history analyses use modal superposition time history solution techniques with a cut-off frequency determined to be 70 Hz for HF cases and 35 Hz for generic cases with missing mass included at higher frequencies for all cases and modal damping as shown in Table 3.7.1-1.

03.07.01-30

The integration time step for the seismic time history analyses of the linear RCS model is selected by the analysis code, BWSPAN, as the inverse of 30 times the cutoff period:. As an example, for a cut-off frequency of 35 Hz, the time step is determined by, 1/(30 * 35) = 0.00095 seconds. Several authors recommend an integration time step equal to one-tenth of the highest period of significance to the system (see for example Section 7.2 of Structural Dynamics by Craig (Reference 7) and Section 5.5.2 of Reference 6. Assuming that 35 cps represents a still significant frequency for the RCS, this approach would lead to an integration time step of 0.00286 seconds, which is noticeably larger than the 0.00095 seconds actually used in the analyses. The plots contained in Section 5.5.2 of Reference 6 indicate that the error introduced into the calculated response is negligible when the integration time step divided by the period is 0.03325. The error in the calculated response decreases as the period increases, indicating that the error introduced by an integration time step of 0.00095 seconds is extremely small for the lower modes of the system, which provide the majority of the system response.

03.07.01-30

The responses obtained from analysis of the RCS linear model for the ~~24~~ seismic cases are multiplied by the linear-to-non-linear factors described above before being used in the stress and fatigue analyses of the RCS components, piping and supports.

Seismic analysis of the RCS four loop structural model using any of the direct step-by-step time history solution techniques described in Appendix N of Section III to the ASME Boiler and Pressure Vessel Code (Reference 8) is an acceptable alternative to the process described above provided that RG 1.61 damping (represented by an appropriate Rayleigh damping curve) and a suitably small integration time step are used.

3C.4.2.2.2 Reactor Pressure Vessel Isolated Structural Model Seismic Analysis

The SSE cases described in Section 3.7.1.3 are considered in the seismic analysis of the RPV isolated structural model.

03.07.01-30

Basemat translational and rotational excitations (acceleration time histories) in the three global directions are applied to the RPV isolated structural model, at the base of the RBIS, for each of the seismic cases. Application of all ~~twelve of~~ the seismic cases in the design basis seismic analysis of the RPV isolated structural model provides some coverage of uncertainties associated with the soil-structure interaction analysis and the model itself because each of the seismic cases tends to exhibit slightly different frequency characteristics, but relatively similar peak acceleration values, across much

03.07.01-30

of the frequency range of interest to the RPV, its internals, and RPV CHE. To enhance this effect and to provide further coverage of uncertainties inherent in the analysis, the ~~twelve~~ sets of seismic excitations are applied to three different configurations of the RPV isolated structural model: the first model configuration has the modulus of elasticity for the RBIS elements set at 70 percent of the nominal value, the second model configuration has the modulus of elasticity for the RBIS elements set at its nominal value, and the third model configuration has the modulus of elasticity for the RBIS elements set at 130 percent of the nominal value.

The seismic loads for the primary stress analysis of the RPV, its internals, and RPV CHE are generated from computer analyses through application of these ~~36~~ seismic cases to the RPV isolated structural model with gaps at the locations indicated below explicitly represented in the model: 03.07.01-30

- Between the RPV and the upper support plate flange;
- Between the RPV and the core barrel flange;
- Between the RPV radial guides and the radial keys;
- Between the hold down spring, the upper support plate flange and the core barrel flange;
- Between the fuel assemblies in the central core area and the fuel assemblies in the peripheral core area; and
- Between the fuel assemblies in the peripheral core area and the heavy reflector.

Since the RPV isolated structural model is geometrically non-linear due to these gaps, the direct step-by-step integration time history solution technique with Rayleigh damping is utilized. The predicted seismic response that results from the use of a single Rayleigh damping curve is overly conservative due to the wide range of model element damping ratios (from 3 percent for pressure vessels up to 30 percent for fuel assemblies). Therefore, several sets of Rayleigh damping constants (α's and β's in Equation 3C-11) are determined and applied in the analysis in the same manner as described in Section 3C.4.2.1.

The integration time step used in these non-linear analyses is 0.0005 seconds. Such a small time step is required to ensure that the various gaps are properly accounted for in the solution. A time step study is performed where one SSE case is reanalyzed with the integration time step halved to 0.00025 seconds. The RCS response from this analysis is compared to that from the corresponding analysis with the original time step (0.0005 seconds). The maximum change in response is less than 6 percent, thereby validating the original integration time step (0.0005 seconds) as sufficient to allow convergence of the solution.

3C.4.3 Load Combinations

The load combinations used in the stress analyses of the RCS piping, components, component internals, and component supports are described in Section 3.9.3.

3C.5 Amplified Response Spectra Generation

03.07.01-30

Basemat acceleration time histories representing the SSE cases considered in the seismic analysis of the RCS four loop structural model are used to develop Amplified Response Spectra (ARS) at points of interest in the RCS. These include branch line nozzle locations on the RCS primary piping and componentsthe MFW line and MS line nozzles on the SGs. The ARS are peak broadened by 15 percent in each direction per the guidance provided in RG 1.122. The ARS is generated for the various damping levels needed for seismic analysis of the attached piping (see Table 3.7.1-1). ARS is generated using the computer code RESPECT (see Section 3C.6). RESPECT generates ARS using input basemat time histories and the RCS structural properties as obtained from the BWSPAN output from the seismic analysis of the RCS four loop structural model.

3C.6 Description of Computer Programs

The following computer programs are used in the loading analyses of the RCS four loop structural model and the RPV isolated structural model:

- BWHIST: This code converts pressure time histories generated by CRAFT2 and COMPAR2 into force time histories by integrating the pressures over the component area on which the pressure acts. BWHIST also orients the resulting force time history for direct input into BWSPAN. Earlier versions of BWHIST were certified by comparing the output from the analysis of sample problems to the results obtained from hand calculations for the same sample problems. As additional options were added to the code, test cases were run to confirm that results did not change from the previous version. BWHIST is a certified computer code that is maintained in a controlled location (users can only access an executable file, not the source code).

- BWSPAN: Information on this computer code is provided in Section 5.0 of Reference 1.

- BWSPEC: This code tabulates displacements, pipe and structure loads, support loads, and spring loads for selected locations using output from a BWSPAN analysis. Tabulations can be made for static, response spectrum, and time history load cases. Earlier versions of BWSPEC were certified by comparing the results it generated using BWSPAN output from sample problems to the actual output from BWSPAN. As additional options were added to the code, test cases were run to confirm that results did not change from the previous version. BWSPEC is a personal computer based code that is verified, by comparing its output to the BWSPAN output from which it is reading, each time it is executed.