ArevaEPRDCPEm Resource

From: WELLS Russell D (AREVA NP INC) [Russell.Wells@areva.com]
Sent: Monday, February 23, 2009 3:53 PM
To: Getachew Tesfaye
Cc: Pederson Ronda M (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); SLIVA Dana (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 160, FSAR Ch 3
Attachments: RAI 160 Response US EPR DC.pdf

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 160 Response US EPR DC.pdf" provides a technically correct and complete response to 21 of the 23 questions.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which supports the response to RAI 160 Questions 03.09.02-10 and 03.09.02-14.

The following table indicates the respective pages in the response document, "RAI 160 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

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A complete answer is not provided for 2 of the 23 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 160 — 03.09.02-25	May 14, 2009

Sincerely,

(Russ Wells on behalf of)
Ronda Pederson

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Cc: Jai Rajan; Terri Spicher; Anthony Hsia; Michael Miernicki; Joseph Colaccino; Meena Khanna; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 160 (1403), FSARCh. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on December 18, 2008, and discussed with your staff on January 6, 2009. Draft RAI Questions 03.09.02-7, 03.09.02-8, 03.09.02-13, 03.09.02-19 thru 03.09.02-23, and 03.09.036 were deleted and Draft RAI Questions 03.09.02-18, 03.09.02-31 and 03.09.02-34 were modified 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. For any RAIs that cannot be answered within 30 days, 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.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
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Hearing Identifier: AREVA_EPR_DC_RAIs
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Response to

Request for Additional Information No. 160

01/23/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.09.02 - Dynamic Testing and Analysis of Systems Structures and Components
Application Section: RAI 3.9.2-1

QUESTIONS for Engineering Mechanics Branch 1 (AP1000/EPR Projects) (EMB1)

Question 03.09.02-9:

The applicant described the piping vibration testing in FSAR Tier 2, Section 3.9.2.1.1 and Section 3.9.2.1.2. Test specifications for monitoring piping system vibration and thermal expansion during testing are in accordance with ASME OM-S/G-2000. NUREG-0800, SRP 3.9.2 recommends that for new applications, piping test specifications should be in accordance with ASME OM-S/G-1990, "Standards and Guides For Operation of Nuclear Power Plants," Part 3, "Requirements for Preoperational and Initial Start-Up Vibration Testing of Nuclear Power Plant Piping Systems," and Part 7, "Requirements for Thermal Expansion Testing of Nuclear Power Plant Piping Systems." The staff did not find where the applicant justified the use of ASME OM-S/G-2000. The applicant is requested to justify the use of ASME OM-S/G-2000 instead of ASME OM-S/G-1990, including identification of any margin changes that result from use of the 2000 Code instead of the 1990 Code.

Response to Question 03.09.02-9:

Draft Revision 3 to SRP 3.9.2 refers to ASME OM-S/G-1990 in the text and lists ASME OM-S/G-1990 as reference 18. However, in the final version of Revision 3 of SRP 3.9.2, NRC revised the References section to change ASME OM-S/G-1990 to ASME OM-S/G-2000 but the text of the SRP was not changed. Additionally, NRC has accepted use of AMSE OM-S/G-2000 for license renewal and operating plants extended power uprates. Therefore, AREVA NP inferred that the NRC also intended to apply ASME OM-S/G-2000 to new reactor applications.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-10:

SRP 3.9.2, section I(1) recommends that the systems to be monitored should include:

A. all American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Class 1, 2, and 3 systems,

B. other high-energy piping systems inside Seismic Category I structures,

C. high-energy portions of systems whose failure could reduce the functioning of any Seismic Category I plant feature to an unacceptable safety level, and

D. Seismic Category I portions of moderate-energy piping systems located outside containment.

The applicant stated in FSAR Tier 2, Section 3.9.2.1 that testing is performed on the following piping systems and identified in FSAR Tier 2, Table 3.2.2-1:

A. ASME Code, Section III, Class 1, 2, and 3 piping systems tabulated in FSAR Tier 2, Table 3.2.2-1 — “Classification Summary”,

B. high-energy piping systems inside Seismic Category I structures,

C. high-energy piping systems whose failure would reduce the safety level of a Seismic Category I SSC,

D. Seismic Category I portions of moderate-energy piping systems located outside of containment.

FSAR Tier 2, Table 3.2.2-1 identifies the ASME Code, Section III, Class 1, 2, and 3 systems for the U.S. EPR. The staff reviewed FSAR Tier 2, Table 3.2.2-1 but did not find where the applicant identified the high and moderate piping systems recommended in SRP 3.9.2, section I(1), B, C and D. In addition, the staff was unable to determine if <u>all</u> ASME piping systems are included in the applicant’s testing program. The applicant is requested to identify high and moderate piping systems included in the testing program as recommended in SRP 3.9.2, section I(1), B,C and D and explain if <u>all</u> ASME piping systems are included in the applicant’s testing program.

Response to Question 03.09.02-10:

U.S. EPR FSAR Tier 2, Table 3.2.2-1 contains all the ASME Section III, Class 1, 2 and 3 piping systems for the U.S. EPR, as recommended by SRP 3.9.2, Section I(1), A. U.S. EPR FSAR Tier 2, Table 3.6.1-1 contains a listing of the high-energy piping systems inside Seismic Category I structures for the U.S. EPR, as recommended by SRP 3.9.2, Section I(1), B. In accordance with the guidance of SRP 3.9.2 Section I(1), C, U.S. EPR FSAR Tier 2, Table 3.6.1-3 lists those high-energy systems the failure of a portion of which (i.e., terminal end breaks) could potentially reduce the functioning of some Seismic Category I feature to an unacceptable safety level. Since Seismic Category I moderate-energy piping systems provided in U.S. EPR FSAR Tier 2, Table 3.6.1-1 are among the ASME Class 2 and Class 3 piping systems listed in U.S. EPR FSAR Tier 2, Table 3.2.2-1, those tables satisfy the guidance of SRP 3.9.2, Section I(1), D. In addition to the information provided above, as part of U.S. EPR FSAR Tier 2, Section 3.9.2.1, the structures, systems, and components (SSC) for which startup testing is performed are identified in U.S. EPR FSAR Tier 2, Section 14.2.1, which includes ASME Class 1, 2 and 3 piping systems.

U.S EPR FSAR Tier 2, Section 3.9.2.1 will be revised to add references to U.S. EPR FSAR Tier 2, Table 3.6.1-1 and Table 3.6.1-3.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.9.2.1 will be revised as described in the response and indicated on the enclosed markup.

Question 03.09.02-11:

In accordance with TMI Action Item II.D.1 of NUREG-0737, both PWR and BWR licensees and applicants are required to conduct testing to qualify the reactor coolant system (RCS) relief and safety valves and associated piping and supports under expected operating conditions for design-basis transients and accidents. Upon review of FSAR Tier 2, Section 3.9.2.1, the staff determined that the applicant's description of the testing or criteria specified for piping systems did not include relief or safety valve actuation such as pressure relief devices and automatic depressurization valves connected to the pressurizer, safety valves, power operated relief valves on the steam lines, and relief valves on the containment isolation lines. The applicant is requested to explain if the testing or criteria specified for piping systems includes relief or safety valve actuation such as pressure relief devices and automatic depressurization valves connected to the pressurizer, safety valves, power operated relief valves on the steam lines, and relief valves on the containment isolation lines.

Response to Question 03.09.02-11:

See the response to RAI 107, Question 03.09.03-12.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-12:

Upon review of FSAR Tier 2, Section 3.9.2.1, the staff determined that the applicant did not provide a list of selected locations in the piping system at which visual inspections and measurements (as needed) will be performed during testing as recommended in SRP 3.9.2 subsection II.1 (Acceptance Criteria) C. The applicant is requested to provide a list of selected locations in the piping system at which visual inspections and measurements (as needed) will be performed during testing.

Response to Question 03.09.02-12:

SRP 3.9.2, subsection II.1, Acceptance Criteria C states that an acceptable test program will include a list of selected locations in a piping system at which visual inspections and measurements will be performed during the tests. These locations will be at pipe supports, particularly supports with allowances for free thermal movements (e.g., spring and snubber supports). The criteria for determining these locations are described in U.S EPR FSAR Tier 2, Section 3.9.2.1. Additionally, this FSAR section states: “Specific information concerning the locations where visual inspection or measurements are to be taken is also addressed in the applicable test procedures.”

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-14:

Upon review of FSAR Tier 2, Section 3.9.2.1, the staff determined that the applicant did not provide a description of the thermal motion monitoring program acceptance criteria or how motion will be measured as recommended in SRP 3.9.2 subsection II.1 (Acceptance Criteria) E. The applicant is requested to describe the thermal motion monitoring program acceptance criteria and how motion will be measured.

Response to Question 03.09.02-14:

Part 7 of ASME OM-S/G describes the scope of piping systems to be monitored for thermal expansion during preoperational and initial start-up testing and the monitoring techniques that would satisfy the minimum requirements for testing and acceptance criteria. U.S EPR FSAR Tier 2, Section 3.9.2.1.2 will be revised to indicate that monitoring the thermal expansion of piping systems during preoperational and startup testing, including measurement of snubber movement and verification of adequate clearance and gaps, is performed in accordance with Part 7 of ASME OM-S/G.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.9.2.1.2 will be revised as described in the response and indicated on the enclosed markup.

Question 03.09.02-15:

The applicant stated in FSAR Tier 2, Section 3.9.2.1.1 that if excessive vibration levels are detected during testing, consideration is given to modifying the design specification to re-verify applicable code conformance using the measured vibration as input. If testing and subsequent analysis reveal that additional restraints are needed to reduce stresses to acceptable levels, they are installed. The staff determined that the applicant did not provide a description of steady state or transient vibration analysis or analytical methods for Level A or Level B system vibration loads in the FSAR or in Topical Report ANP-10264NP-A. The applicant is requested to explain how Level A and B vibration loading is addressed in the analysis of U.S. EPR piping systems and if excessive system vibration mitigation and corrective actions results in additional testing.

Response to Question 03.09.02-15:

The vibration monitoring evaluation method VMG-2, as described in Reference 3 of U.S. EPR FSAR Tier 2, Section 3.9.2.7, is used to evaluate the Level A and Level B vibrations in the U.S. EPR piping systems. VMG-2 is the method by which the vibration is evaluated, involving beam calculations of the piping to develop conservative criteria for vibration velocity and displacement based on limiting the stress to the fatigue stress limit.

As stated in U.S. EPR FSAR Tier 2, Section 3.9.2.1.1, in the event that vibrations arising from Level A or Level B loads in Phase I and Phase II tests are observed to be excessive when compared to those computed using the VMG-2 method, more detailed analyses based on VMG-1 methodology may be performed to demonstrate the acceptability of measured vibrations. If unacceptable results are obtained, appropriate corrective actions will be performed and included in the results of the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-16:

In FSAR Tier 2 Section 3.9.2.4, the applicant discussed the measurement of accelerations of representative trains of piping attached to the RCS, the main steam and main feedwater lines during startup testing. The applicant provided for measurement of discrete locations on the piping systems and key components such as valves and pumps installed along the length of the piping using hand held devices. The applicant intends to use these hand held devices during both steady-state and transient events. In discussing the use of hand held devices, the applicant references use of hand held devices during the 1970s and 1980s during start up testing of currently operating plants and that, while at design power ratings, these plants have experienced very few instances of excessive pipe vibrations. This previous use coupled with the few instances of excessive pipe vibrations at design power rating is used by the applicant to justify the handheld devices as proven and reliable methods of validation. The staff reviewed the applicant's description for using handheld devises during measurement of piping accelerations and could not reach a conclusion as to whether it is appropriate. The applicant is requested to provide clarification of how piping attached to the reactor cooling system (RCS) was selected for measurement, the required specifications for the handhelds, and discussion for the plans for their use in characterizing the piping system response relative to the analytical predictions.

Response to Question 03.09.02-16:

The representative piping systems attached to the RCS are monitored by hand held devices and are selected based upon their acoustic connection with the RCS system through acoustic pressure fluctuations. Specifications for hand held devices will be in accordance with the vendor recommendations at the time they are procured.

In accordance with the guidance of RG 1.20, Revision 3, the details of the vibration measurement program, including the specifications for the handheld devices, will be included in the comprehensive vibration assessment report which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-17:

In FSAR Tier 2 Section 3.9.2.4, the applicant stated representative trains of piping attached to the RCS, the main steam and main feedwater lines are monitored during startup testing. The applicant is requested to justify the use of representative trains instead of all lines encompassing the RCS in the assessment of flow-excited acoustic and structural resonances or other self-excited responses given that flow-excited acoustic and structural resonances are sensitive to small changes in the construction of even supposedly identical systems. The applicant should also discuss how pressure fluctuations would be measured and analyzed to determine loads on any safety related or critical structures. In addition, the staff determined that the applicant did not explain how, in the absence of monitoring, RCS components are determined not to be subject to flow-excited and structural resonances during the plant design life. Further, the applicant is also asked if other systems would be instrumented in order to identify the presence of any strongly excited internal acoustic resonances.

Response to Question 03.09.02-17:

Acoustic resonances, such as those caused by flow past a dead leg of closed relief valves, have the characteristic that the pressure-flow oscillations travel through the entire affected piping system with little attenuation. SRP 3.9.2 states that “instabilities in these flow fields can couple with acoustic and structural resonance causing high dynamic loads throughout the steam system and RPV.” Thus, the vibrations from acoustic resonances are readily identifiable throughout an affected piping system. This is a basis for monitoring only representative trains of piping systems.

In accordance with the guidance of RG 1.20, Revision 3, details of the vibration measurement, including use of the test results to compute loads on safety-related structures, will be included in the results from the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

As stated in U.S. EPR FSAR Tier 2, Section 3.9.2.4, the RCS, main steam, and main feedwater systems are measured for vibration during initial start-up testing. This section also states the main steam and main feedwater systems will be instrumented with permanent sensors during the operating life of the plant.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-18:

The applicant described the U.S. EPR interaction and separation design criteria in FSAR Tier 2, Sections 3.7.3.8.1 and 3.7.3.8.2 and in Section 4.4 of Topical Report (TR) ANP-10264(NP)-A, with supplemental information in Section 3.2.8 of the EPR FSAR. In Section 4.4.2 of the TR, the applicant stated that non-seismic piping and components may be located in the vicinity of safety-related piping without being qualified as Seismic Category II provided an impact evaluation is performed to verify that no possible adverse impacts will occur. In this evaluation, the non-seismic components are assumed to fall or overturn as a result of a seismic event. Any safety-related piping system or component which may be impacted by the non-seismic component is identified as an interaction target and evaluated to ensure that there is no loss of ability to perform its safety-related function. In TR Section 4.4.2, the applicant further stated that the following assumption is used to evaluate non-seismic/seismic interactions:

> All flanges on bolted connections on the non-seismic piping system are assumed to fail, thus allowing each section of piping to fall independently.

The applicant is requested to justify why this assumption is conservative with respect to the impact evaluation of target components.

Response to Question 03.09.02-18:

The information in ANP-10264(NP)-A, Section 4.4.2 was evaluated and approved by the NRC in Section 3.2.8 of the Final Safety Evaluation Report for ANP-10264NP-A, which states “All other non-seismic/seismic interaction criteria discussed in TR Sections 4.4.1 and 4.4.2 are found reasonable and acceptable to the staff.”

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-24:

The applicant stated in FSAR Tier 2, Section 3.9.2.4 that either an extensive measurement program or a complete inspection of the U.S. EPR RPV internals will be performed during hot functional testing (HFT) in accordance with RG 1.20 for non-prototype Category I designation. The applicant is requested to supply the following additional information to demonstrate that changing the current EPR prototype designation to the non-prototype Category I designation is in accordance with RG 1.20:

A. Provide details of the preoperational vibration and test program which is consistent with the NUREG 0800, SRP Section 3.9.2 subsection II.4 for a prototype. The information requested includes test conditions (e.g. flow conditions, power levels, and temperatures), transducer types, specifications and locations, and methods for preparing the data for comparisons to both the acceptance criteria and the analytical predictions from FSAR Tier 2 Section 3.9.2.3. The applicant is also requested to provide the vibration prediction, test acceptance criteria and bases, and permissible deviations from the criteria prior to the tests. Finally, the applicant should provide a listing of the major reactor internal components that would be subjected to flow induced vibration testing.

B. The applicant has expressed the intent to recategorize the U.S. EPR as a Non-prototype Category I with the Olkiluoto-3 reactor, currently under construction, as the prototype. If the applicant makes this reclassification, per RG 1.20, the applicant is requested to provide the detailed results of the comprehensive vibration assessment program conducted on the Olkiluoto-3 which is consistent with the requirements of RG 1.20 and should include a listing of the major reactor internal components that would be subjected to flow induced vibration testing.

Response to Question 03.09.02-24:

A. In accordance with the guidance of RG 1.20, Revision 3, details of the preoperational vibration and test program, including the requested information, will be included in the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

B. As stated in U.S. EPR FSAR Tier 2, Section 3.9.2.4, the U.S. EPR reactor pressure vessel (RPV) internals are classified as prototype design per RG 1.20. Additionally, as stated in U.S. EPR FSAR Tier 2, Section 3.9.2.4, if design changes to the RPV internals are required as a result of the hot functional testing and subsequent inspection at Olkiluoto-3, the appropriate classification of the U.S EPR RPV internals will be determined in accordance with RG 1.20. Accordingly, the associated experimental and/or analytical justification, including any required changes to the comprehensive vibration assessment program, will be provided to the NRC.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-25:

The applicant concluded in FSAR Tier 2, Section 3.9.2.4 that, based on operational experience, U.S. EPR SG components will not be subject to excessive vibration, and therefore no flow induced vibration analyses or startup testing is planned. However, changes in the U.S. EPR design due to increased power level introduce differences that may challenge the applicant's premise that flow induced vibration analyses or startup testing is not required. The applicant is requested to identify differences between the steam generator upper internals and flow conditions in the U.S. EPR design and those in the 'similar' plants cited by the applicant and explain why these differences will result in a similar, and problem-free vibration response such that no flow induced vibration (FIV) analyses or startup testing is required. When FIV response results from other reactors are used to predict EPR component responses, provide complete justifications for the structural and flow similarities between the EPR and the other reactors for each EPR reactor component. The structural justifications should include discussions of geometry, mass distribution, and boundary conditions, modal frequencies, mode shapes, modal masses, and modal damping. The fluid flow justifications should include discussions of pressure amplitudes, frequencies, spatial and time distributions and their correlations, the flow properties, the flow velocity vector fields, the flow regimes and the turbulent characteristics of the flow, and the potential FIV forcing functions and mechanisms.

Response to Question 03.09.02-25:

A response to this question will be provided by May 14, 2009.

Question 03.09.02-26:

The applicant stated in FSAR Tier 2 Section 3.9.2.4, that the U.S. EPR SG upper internals are non-safety-related components and will not experience excessive vibration. However, industry experience indicates that flow-induced resonances may occur in steam generator systems, particularly those caused by flow over side-branch openings in the steam lines, such as those in the standpipes connected to valves. As is noted in RG 1.20, flow-excited and structural resonances are sensitive to minor changes in arrangement, design, size and operating conditions. It is unclear to the staff if these sensitivities have been adequately addressed by the applicant. The applicant is requested to explain which U.S. EPR operating conditions could lead to resonance conditions in the SGs and discuss how the startup test plan will demonstrate that no flow-induced resonance effects will occur during the design life of the plant that could lead to excessive vibration and damage to components in the steam generation system.

Response to Question 03.09.02-26:

A response to this question will be provided by May 14, 2009.

Question 03.09.02-27:

In FSAR Tier 2 Section 3.9.2.3, the applicant described the required comprehensive analysis of the U.S. EPR RPV internals. The analysis is a combination of analytical and testing evaluations that considers various flow excitation mechanisms such as vortex shedding, leakage-flow-induced vibrations, turbulence buffeting, and acoustic sources due to pump operation and loop oscillations. In addition to these mechanisms, and to provide assurance that GDC 1 and 4 are fully met, SRP 3.9.2 recommends incorporating the response of the RPV internals due to the flow excited structural and/ or acoustic resonances (self-excited loads) into the analyses of any potential adverse flow conditions that may lead to a self-excited response. A self-excited response refers to the coupling of the structural and/or acoustic vibration with the forcing function. The staff did not find where the applicant addressed the response of the RPV internals due to the flow excited structural and/ or acoustic resonances in the analyses of any potential adverse flow conditions. The applicant is requested to provide a discussion of the analyses of these potential adverse flow conditions and the operating conditions that give rise to such flow conditions. The discussion should include the bias errors, uncertainties and any operational experience the applicant possesses or of which the applicant is cognizant, particularly for situations that have led to past failures, as it relates to the U.S. EPR.

Response to Question 03.09.02-27:

In accordance with the guidance of RG 1.20, Revision 3, the details of the assessment of acoustic resonances and self-excited response, along with discussion of the bias errors, uncertainties and operational experience, will be included in the results from the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-28:

The applicant stated at the conclusion of FSAR Tier 2 Section 3.9.2.3 that the vibration assessment program demonstrates that the vibration levels of the RPV internals conform to RG 1.20. The staff was unable to verify this conclusion based on the information provided by the applicant. The applicant is requested to supply the results of the analyses so that review of the dynamic properties of the structures and of the methods for obtaining the overall vibration and stress response from the forcing functions, and the vibration and stress models may be made. The results should include:

A. The applicant should provide the dynamics of the internal structures, including natural frequencies, mode shapes relevant to the vibration and stress response, damping factors, and the frequency response functions (FRF).

B. The methodology for combining the vibrations and stress response models with the forcing functions to obtain the overall stress and vibration response of the RPV internals.

C. The method for combining the uncertainties and bias errors and the effect of these on the resulting overall stress and vibration response prediction of the RPV internals.

D. The prediction of the overall stress and vibration response for the U.S. EPR RPV internals together with the comparisons to the criteria which demonstrate the stated conformance of the vibration levels with RG 1.20.

Response to Question 03.09.02-28:

A. In accordance with the guidance of RG 1.20, Revision 3, the requested information is addressed in the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2. Additionally, the flow-induced vibration (FIV) analyses provide details of the methodology and analysis inputs to the comprehensive vibration assessment program.

B. See Item A above.

C. In accordance with the guidance of RG 1.20, Revision 3, the discussion of the bias errors and uncertainties is part of the results from the comprehensive vibration assessment program. The combined effect of these uncertainties and bias errors on the response of the RPV internals will be assessed after hot functional testing when these inputs are confirmed with test measurements. A comparison of these analysis inputs and their incorporation into the revised prediction of the RPV internals to achieve an agreement between the analytical and test results will be included in the comprehensive vibration assessment program final report.

D. See item A above.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-29:

Due to the complex nature of fluid/structure interactions which result in the vibratory response of the reactor internals, the SRP Section 3.9.2.3 acceptance criteria recommends that small scale model tests and analysis are used to produce the full scale prediction of both the forcing functions and the structural response to the coolant flow. The applicant, in agreement with the SRP, intends to adjust the forcing functions determined as described above, through imposed agreement between full-scale analytical and U.S. EPR preoperational test results. The staff was unable to conclude that the applicants approach to developing the full scale response includes all the aspects of fluid/structure interactions. The applicant is requested to supply the following information, as recommended by SRP 3.9.2.3 acceptance criteria, that addresses the critical area of flow-excited acoustic and structural resonances or other self-excited response to vortex-induced vibration, turbulence and turbulence buffeting, flow separation, reattachment and impinging flow instabilities:

A. The scale model tests should be discussed with reference to dynamic similarity of the model tests to the full scale structures and operating conditions being analyzed. Additionally, the types and placement of the transducers employed in the small scale model test should be included in the discussion.

B. Because the analysis of the small scale models is used to baseline the analytical/computational procedures for use on the full scale structure, the analytical/computational models of the small scale structures and the analytical procedures employed should be discussed together with an assessment of the bias and uncertainties in the predictions.

C. Comparisons of the small scale model results and the analytical model results should be provided with discussion quality of the comparisons and the implications of the comparison on the use of the procedure on the full scale structure.

D. Discuss the analysis methodologies or software used in the modeling of both the full-scale and the scale model structures. Further, the methodology used to assess the accuracy, limitations and applicability of the software package or analysis procedure should be provided. The discussion of the analysis procedures should include the interaction of the various software packages/models such as providing inputs to each other or any required iterations between models.

E. The applicant stated that "during preoperational testing, the full-scale analytical results are confirmed…." Provide a basis and discussion of the acceptance criteria for confirmation of the results.

F. Because any disagreement between the full scale analysis and the full scale test results will be addressed by adjusting the inputs to the analysis, the identification of the parameters together with the methods and criteria for setting limits on the appropriate adjustment of those input parameters should be provided.

G. The applicant has not specified or referenced locations of transducers or test conditions.

Response to Question 03.09.02-29:

A. The requested information will be provided in the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

B. See Item A above.

C. See Item A above.

D. See Item A above.

E. The preoperational comprehensive vibration program report includes the types of instrumentation with the required sensitivities and other specifications needed to validate the full scale analytical evaluations. The locations of the instrumentation on the RPV internals and the acceptance criteria to be considered for the comparison between the full scale analytical and hot functional testing results will be provided in the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

F. See the response to Question 03.09.02-35.

G. See Item E above.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-30:

Upon review of FSAR Tier 2 Section 3.9.2.4, the staff did not find how the applicant determined which operating condition is the bounding case for the RPV internals vibratory response. The applicant is requested to justify why full-power, steady-state normal operating conditions are the most conservative to examine and justify the selection of the temperature conditions relative to anticipated operational modes of the plant. The applicant should address in particular any flow-excited acoustic and structural resonances or other self-excited response to vortex-induced vibration, turbulence and turbulence buffeting, flow separation, reattachment and impinging flow instabilities.

Response to Question 03.09.02-30:

From a high-cycle fatigue perspective, the full power steady state normal operating condition would be the most conservative condition to evaluate for the reactor pressure vessel (RPV) internals since this condition combines high flow rates and high temperature conditions over a long period of time. During plant heatup and cooldown transient conditions when different combinations of RCP operation are occurring, the response of the RPV internals to turbulence may exceed the full power steady state values but still be within the acceptable limits of base excitation for the fuel bundle. The relatively short duration of these operating configurations does not contribute significantly to the high cycle fatigue. In accordance with the guidance of RG 1.20, another RPV transient condition for consideration is a 10 percent overspeed increase of the reactor coolant pumps (RCP). This momentary increase in reactor coolant flow also increases the response of the RPV internals but does not have a significant effect on the high cycle fatigue. The 10 percent overspeed increase for the RCPs was considered in the flow-induced vibration (FIV) analysis of the upper internals (see response to Question 03.09.02-31).

The hot functional testing includes a variety of RCP combinations and primary fluid temperatures, which bounds the plant heatup and cooldown conditions. The vibratory behavior of the RPV lower internals are assessed with instrumentation of the RPV internals during hot functional testing to ascertain acceptable flow-induced vibration behavior during the transient conditions. Therefore, analytical evaluation of these transient conditions is not planned.

The FIV analyses for the U.S. EPR include the following components of the RPV lower internals:

- The RPV lower internal assembly including the core barrel, heavy reflector and lower core support plate, mass of the flow distribution device.
- Flow distribution device.
- Irradiation specimen basket assembly.

These components of the RPV lower internals were evaluated for excitation resulting from random turbulence and vortex-shedding, depending upon the susceptibility of the individual components of the RPV to these mechanisms. The RPV lower internal assembly model also considered the jet impingement effects that exist in the vicinity of the four inlet nozzles. The comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2, will provide a description of the scale model flow test, the scale model analysis, the effects on the full scale analyses, and the methods used therein to validate the design of the RPV lower internal assembly.

The comprehensive vibration program for the RPV lower internal assembly considers the normal acoustic loadings created from the RCPs or loop oscillations unique to the U.S. EPR design which are obtained with full scale testing. These impulse functions, once they have been measured during hot functional testing, will be incorporated into the comprehensive vibration assessment program final report.

The details of the assessment of acoustic resonances and self-excited response will be included in the comprehensive vibration assessment program. If unexpected acoustic loadings are observed in the reactor coolant system (RCS piping) (e.g., at standoff branch lines, etc.) during hot functional testing, these sources of excitation upon the RPV internals and piping systems are also considered. Depending upon the level of excitation created from this type of mechanism and the influence upon the other RCS components, appropriate corrective actions will be taken to eliminate these acoustic loadings.

See the response to Question 03.09.02-31 for justification of the full power steady state operating condition and RCS transient conditions for the upper internals of the RPV.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-31:

In the FSAR Tier 2, Section 3.9.2.3, the applicant stated that vibration of the U.S. EPR RPV upper internals may result from vortex shedding and fluid-elastic instability. The applicant further states that the instrument guide tubes (and hence the upper internals) are subjected to turbulence from flow through the fuel assembly outlet nozzle turbulence. Such turbulent flow may also excite vibrations. The applicant is requested to provide the flow induced vibration analyses for the mechanisms indicated in the SRP 3.9.2 (vortex-induced vibration, flow-excited acoustic resonance, fluid-elastic instability, turbulence buffeting, and other flow excitations such as flow separation, reattachment, and impinging flow instabilities) and any plans for testing to indicate acceptable behavior, including the acceptance criteria, details on the validations of the test plan and the instrumentation and test conditions that will be employed in the U.S. EPR preoperational testing to confirm the acceptable design of the upper internals.

Response to Question 03.09.02-31:

The U.S. EPR flow-induced vibration (FIV) analyses of the reactor pressure vessel (RPV) upper internals include assessment at the full power normal operating conditions. These full power steady state thermal-hydraulic inputs are increased by 10 percent to evaluate a 10 percent reactor coolant pump (RCP) overspeed transient condition. The FIV analyses included the following components:

- The CRGA column supports (including the upper housing column).
- The CRGA Internals (i.e., the tie rods, c-tubes, rod control cluster assemblies).
- The normal column supports.
- The level measurement probe columns supports (including the upper housing column).
- The instrumentation guide tubes.

These structures were evaluated at their most limiting locations in close proximity to the RPV outlet nozzles where the total flow through the reactor upper internals is the greatest with all the RCPs operating. The transient flow conditions developed in the upper internals during different combinations of RCP operation are bounded by operation at full power with all RCPs operating. The maldistribution of flow created in the RPV downcomer with combinations of one to three RCPs operating redistributes itself after entering the upper internals. Therefore, the heatup transient condition consistent with one to three RCP operation is not explicitly evaluated but is considered bounded by the full power steady state operating condition with the increase in the flow rate as described above.

The above RPV components were evaluated for fluid-elastic instability, random turbulence, vortex-shedding excitations. FIV analysis for flow separation, reattachment, and impinging flow instabilities is not necessary for these components because they are not susceptible to these sources of excitation. If unexpected acoustic loadings are observed in the reactor coolant system (RCS piping) (e.g., at standoff branch lines, etc.) during hot functional testing, these sources of excitation upon the RPV upper internals are also considered. Depending upon the level of excitation created from this type of mechanism and the influence upon these and other RCS components, appropriate corrective actions will be taken to eliminate these acoustic loadings. See the response to Question 03.09.02-17 for further discussions regarding this mechanism.

The analytical acceptance criteria employed with the FIV analysis of the RPV upper internal components are as follows:

Fluid-elastic Instability

The Fluid-elastic Stability Margin (FSM) is the ratio of the critical velocity at which an array of cylinders is predicted to become unstable to the equivalent mode shape weighted pitch velocity. An FSM greater than 1.0 implies that the array of cylinders is stable, while an FSM less than 1.0 implies that the array of cylinders will become unstable. The minimum acceptable FSM for design is 1.0. For the U.S. EPR, a conservative acceptance criterion for fluid-elastic instability of FSM greater than 1.3 is used.

Random Turbulence-Induced Vibration

The turbulence-induced vibration analysis was based on Powell's joint acceptance technique, which computes only the root mean square (rms) vibration amplitude and stresses. The displacements are computed in units of (inch, rms), the moments in units of (in-lbs, rms) and reaction loads at support locations in units of (lbs, rms). A statistical analysis technique was used to develop an rms fatigue curve for the tube using the ASME fatigue curve for austenitic steel, which was based on tests performed with sinusoidal loads. These curves were derived directly from the corresponding fatigue curves based on long-duration tests with deterministic loads, as published in the ASME Section III Boiler & Pressure Vessel Code. The rms fatigue curves were derived using the fatigue curves “A, B, & C” for the fatigue life calculations for the FIV analysis of high cycle fatigue loadings. The allowable stress for fatigue curve “A” at 10^{13} cycles is 4570 psi, rms and for fatigue curve “C” at 10^{13} cycles is 2800 psi, rms.

Because the computed displacement response to turbulence is based on a probability of excursions, the displacements (determined in units of inch, rms as stated above) are multiplied by a factor of 5 or 5 sigma, which represents an approximately 100 percent probability that the computed displacement will not be exceeded. For a control rod guide assembly (CRGA) column-to-column pitch of 11.973 inches and a column OD of 9.535 inches, the gap clearance between CRGA locations is

CRGA Gap Clearance = 11.973 – 9.535 = 2.438 inches

One-half of this value, 1.219 inches, was used as the acceptance criteria to prevent impacts between adjacent CRGAs. Therefore, the allowable displacement in units of inch, rms is 1.219 inch/5 sigma or 0.244 inch, rms for turbulence-induced vibration.

The allowable displacement limit of 0.244 inch, rms was conservatively applied to the other support columns (Normal and LMP) because the clearance between these components and the CRGA support columns is greater; therefore, this method is conservative. Similar logic is applied with the other RPV internal components.

Vortex-Shedding Induced Vibrations

The FIV analyses of the upper internals verified that vortex-shedding lock-in would not occur for the column supports and the instrumentation guide tubes. The analyses were performed in accordance with the guidance of the ASME Boiler & Pressure Vessel Code, Section III, Appendix N-1300 to avoid a resonance condition for an array of cylinders. The criteria to avoid lock-in are listed below and it is only necessary to meet any one of the applicable conditions to show that the structures are acceptable.

The reduced velocity for the fundamental vibration mode (n=1) satisfies the condition: $\frac{V}{f_1 D} < 1$

(a) The reduced damping (for a given vibration mode) is larger than 64: $C_n > 64$

(b) For a given vibration mode the two following conditions are verified: $\begin{cases} V/f_n D < 3.3 \\ C_n > 1.2 \end{cases}$

(c) For the structural frequencies, verify: $f_n < 0.7 f_s$ or $f_n > 1.3 f_s$, where f_n is the natural structural frequency of the n^{th} mode and f_s is the frequency of the periodic vortex shedding in either the lift or drag directions.

The acceptance criteria for the off resonant response of the support columns is such that the high cycle fatigue resulting from this FIV mechanism is acceptable and the mid-span displacements of the support columns are small enough such that impact with adjacent support columns is avoided. Because the response to vortex-shedding is sinusoidal, the allowable displacement and the allowable stress are in units of 0-peak. As computed for turbulence, the allowable displacement limit for all CRGA support columns is 1.219 inch (0-peak). The allowable high cycle fatigue stress is 23,300 psi (0-peak) at 10^{13} cycles for fatigue curve "A" for the off lock-in response of the structure. Similar logic is applied to the other RPV upper internal components.

The comprehensive vibration assessment program will include a description of the flow testing that is performed to [verify the design of the CRGA internals. Furthermore, instrumentation of the RPV upper internal components (including the CRGA internals) will be used to assess vibratory behavior of the RPV upper internals during hot functional testing.

The comprehensive vibration assessment program will describe the hot functional test plan, including the types of instrumentation with the required sensitivities and other specifications needed to validate the analytical evaluations, the locations of the instrumentation, and the acceptance criteria (degree of comparison between the analysis and hot functional testing). The comprehensive vibration assessment program will provide the results of the hot functional testing and the final analytical results with documentation of any adjustments required to obtain agreement with the test results.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-32:

As stated by the applicant in FSAR Tier 2, Section 3.9.2.3, the U.S. EPR RPV upper internals such as the incore instrumentation guide tubes and the control rod guide assemblies (CRGA) have been evaluated for flow induced vibration performance. The design of CRGA, in particular, has been optimized based on flow tests to minimize vibration levels and vortex formation. The applicant stated that the full-scale CRGA components have been shown analytically to have acceptable vibrational behavior but did not provide the supporting analysis. The applicant is requested to provide details of the analyses and testing that indicate acceptable behavior, including the acceptance criteria, details on the validations of the test plan and the instrumentation and test conditions that will be employed in the U.S. EPR preoperational testing to confirm the acceptable CRGA design.

Response to Question 03.09.02-32:

See the response to Question 03.09.02-31.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-33:

The applicant stated in FSAR Tier 2 Section 3.9.2.4 that during hot functional testing, various conditions to cover potential situations for flow induced vibration will be monitored with instrumentation placed at locations of the largest analytically predicted responses. The instrumentation on the RPV internals will measure component strains, displacements, accelerations and pressures at those specified locations. The staff did not find where the applicant identified the various conditions for flow induced vibration that form a conservative basis for determining the vibratory response of the tested components. The applicant is requested to explain the various conditions to cover potential situations for flow induced vibration (including flow-excited acoustic and structural resonances or other self-excited response to vortex-induced vibration, turbulence and turbulence buffeting, flow separation, reattachment and impinging flow instabilities) and provide the basis for selection of these conditions to ensure a conservative basis exists for determining the vibratory response of the tested components.

Response to Question 03.09.02-33:

The flow-induced vibration (FIV) analytical evaluations of the U.S. EPR reactor pressure vessel internals (RPVI) were performed at full power, steady state operating and transient conditions considering the susceptibility of these components to the applicable sources of flow excitations (see the responses to Questions 03.09.02-30 and 03.09.02-31).

The analytical evaluations provide a prediction of the maximum responses of the RPVI. The results of the analytical evaluations are used in the development of the hot functional test plan, to demonstrate that the location and sensitivity of the instrumentation installed on the RPV internals are adequate to measure the maximum response during hot functional testing. Depending on availability, the results of the hot functional testing at Olikiuoto-3 also may be used in conjunction with the current analytical results for the U.S. EPR to finalize the plans for instrumentation of the U.S. EPR RPVI for hot functional testing.

The hot functional test plan, including location, type and sensitivity of the instrumentation, will be provided in the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-34:

In the FSAR Tier 2 Section 3.9.2.4, the applicant stated that inspection of the RPV internals before and after the hot functional testing will be performed to ensure that the RPV internals are performing correctly. The applicant provided a list of systems in the accessible areas of the RPV internals to be visually inspected in FSAR Tier 2, Tables 3.9.2-1 through 3.9.2-5. The list consists mainly of fastening devices, bearing surfaces, interfaces between the RPV internal parts that are likely to experience relative motions and the inside of the RPV. This is in agreement with the recommendation in SRP 3.9.2 to perform such an inspection. However, the staff was unable to determine if the applicant's inspection program met SRP 3.9.2 recommendations described below:

A. The inspections discussed and listed in Tables 3.9.2-1 through 3.9.2-5 pertain to only visual inspections. The applicant is requested to discuss the types of non-destructive testing planned during the inspections process. It is noted that Tables 3.9.2-3 through 3.9.2-5 reference the storage stands. The applicant should clarify at which points in the testing process components will be removed, placed on storage stands, inspected, the method of inspection and the criteria which will be applied. The applicant should also discuss what actions will be taken as a result of these inspections.

B. In addition, the SRP recommends that walkdown inspections of the steam, feedwater, and condensate systems take place during hold points in the testing. The applicant should provide details of the planned walkdowns, what monitoring and testing equipment is required, and what actions will be taken as a result of these inspections.

Response to Question 03.09.02-34:

A. The comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2, will identify the type of non-destructive testing, the inspection process, and the acceptance criteria for this aspect of investigation. If unacceptable inspection results are obtained, appropriate corrective actions will be performed and included in the comprehensive vibration assessment program final report.

B. The comprehensive vibration assessment program will provide details of the walkdowns, the inspection process, and the acceptance criteria for this aspect of investigation undertaken to verify the integrity of the steam, feedwater, and condensate piping. If unacceptable inspection results are obtained, appropriate corrective actions will be performed and included in the comprehensive vibration assessment program final report.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-35:

In FSAR Tier 2 Section 3.9.2.6, the applicant described the correlation between reactor internals vibration test results and analytical results. The applicant stated comparison of the RPV internals dynamic analysis with the results of preoperational tests verifies that the analytical model provides appropriate results. If the analysis differs significantly from the measured values, the vibration responses are determined using the measured forcing functions as input to the analytical model. The staff could not determine if this approach includes consideration of other factors that could influence the difference between analytical results and test results. The applicant is requested to provide a detailed discussion of the basis for the comparison, including acceptance criteria used for determining the relevance of the analytical results and how the results of the analysis using the revised forcing functions are used.

Response to Question 03.09.02-35:

The acceptance criteria used to compare the analytical solution and the hot functional testing will be included in the comprehensive vibration assessment program, which is the responsibility of the COL holder as noted in U.S. EPR FSAR Tier 2, Table 1.8-2. The results of the hot functional testing and any modifications required to obtain the necessary agreement between the revised analytical solution and the hot functional testing, such as modifications to the forcing function or other analysis inputs, will be included in the comprehensive vibration assessment program final report.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-37:

FSAR Tier 2 Table 1.8-2 provides COL information items to be resolved or addressed by COL applicants. The applicant is requested to explain why the results from the vibration assessment program for the U.S. EPR RPV internals as shown in Item Number 3.9-1 of FSAR Tier 2 Table 1.8-2 are site specific and cannot be provided as part of the DCD but must be deferred until the COL application.

Response to Question 03.09.02-37:

As noted in U.S. EPR FSAR Tier 2, Table 1.8-2, this COL information item is the responsibility of the COL holder not the COL applicant. This information is contingent on preoperational vibration testing of the first U.S. EPR prior to hot functional testing and associated field testing consistent with the guidance of Regulatory Guide 1.20.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.02-38:

As stated by the applicant in Topical Report ANP-10264-NP-A, an alternate method of analyzing the effects of the SSE on a piping system is to use an equivalent static load method. When the equivalent static load method is used, justification will be provided that the use of a simplified model is realistic and the results are conservative. The applicant is requested to explain if the justification for use of equivalent static load method is required for the COL application and should be included in FSAR Tier 2 Table 1.8-2.

Response to Question 03.09.02-38:

The information requested in this question is addressed in Section 3.2.5, “Equivalent Static Load Method,” of the NRC Final Safety Evaluation Report (FSER) for ANP-10264-NP-A. As noted in FSER Section 3.2.5:

> “In accordance with SRP Section 3.9.2, II.2.A (ii), TR discusses the following conditions that should be met prior to using this method of analysis:
>
> - Justification is provided that the system can be realistically represented by a simple model and the method produces conservative results in terms of responses.
> - The design and associated simplified analysis account for the relative motion between all points of support.
> - To obtain an equivalent static load of equipment or component which can be represented by a simple model, a factor of 1.5 is applied to the peak acceleration of the applicable floor response spectrum.”

Therefore, the justification for use of the equivalent static load method for piping is a part of analysis methodology that must be utilized prior to performing such an analysis. It does not represent a specific future analysis or set of analyses that must be performed by the COL applicant. Therefore, a COL information item is not required.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

U.S. EPR Final Safety Analysis Report Markups

- The seismic qualification testing of Seismic Category I mechanical equipment is described in Section 3.10.
- The thermal and hydraulic design of the RPV internals is described in Section 4.4.
- Consideration of design loads from the dynamic effects of pipe rupture is described in Section 3.6.2 and Appendix 3C.
- The number of earthquake cycles to be considered in Seismic Category I subsystem and component design, as well as the seismic system analysis, is described in Sections 3.7.2 and 3.7.3.

3.9.2.1 Piping Vibration, Thermal Expansion, and Dynamic Effects

Pipes are subject to damage from a variety of events that can cause movement of the pipe or of ancillary components, such as supports or snubbers. These include routine operational events, such as vibrations caused by fluid flow or movement arising from differential thermal expansion. Transient operational events (e.g., valve closures and flow instabilities) can also induce pipe vibration or movement.

This section addresses the preoperational testing, initial fuel loading, and pre-critical testing to be performed to verify that: vibration and thermal expansion and contraction of piping systems meet design requirements; design of the piping systems tested will prevent excessive vibration; and snubbers, restraints, and supports function as intended during these events. The piping systems tested include:

- ASME Code, Section III, Class 1, 2, and 3 piping systems (Reference 1). Table 3.2.2-1—Classification Summary identifies the ASME Code, Section III, Class 1, 2, and 3 systems for the U.S. EPR. Analysis of the vibration of Class 1, 2, and 3 piping arising from seismic events is described in Sections 3.12 and Appendix 3C.
- High-energy piping systems inside Seismic Category I structures, or those whose failure would reduce the safety level of a Seismic Category I SSC (see ~~Table 3.2.2-1~~Table 3.6.1-1 and Table 3.6.1-3).

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- Seismic Category I portions of moderate-energy piping systems located outside of containment (see Table 3.2.2-1 and Table 3.6.1-1).

Piping systems are validated through a series of checks, inspections, and tests:

- During construction, pipe and equipment supports are checked for correct assembly and their initial positions under cold conditions are recorded. This phase also includes the initial operation of many system components as the systems are flushed to remove construction debris and meet cleanliness requirements.
- When the plant is first heated to normal operating temperatures the systems are operated in an integrated mode. Expansion data for piping systems are recorded, compared with the cold position data, and evaluated against system expansion

may be performed to demonstrate that the measured vibration does not cause the piping in question to exceed stress or fatigue acceptance criteria.

Level B loads are infrequent loads with a high probability of occurrence but which cause no damage or reduction in function. The vibrations arising from these loads are transient and are usually set in motion by rapid actuation of control, relief, and check valves, or from the rapid start or trip of a pump or turbine. These dynamic responses are tested or simulated during the preoperational testing. If excessive system vibration is evident during Phase I or Phase II tests arising from Level B loads, an evaluation is performed to determine the cause and to identify the corrective action. Alternatively, an analysis may be performed to demonstrate that the measured vibration does not cause the piping in question to exceed stress or fatigue acceptance criteria.

The systems and transients included in the test program are described in Section 3.9.1 and Section 14.2. The Phase I and Phase II tests do not address vibrations arising from Level C (Emergency) or Level D (Faulted) loads.

3.9.2.1.2 Piping Thermal Expansion Details

Thermal expansion testing verifies that the design of the piping systems tested prevents constrained thermal contraction and expansion during Normal and Upset transient events, and that the component supports (including spring hangers, snubbers, and struts) can accommodate the expansion of the piping for these modes of operation. In those systems where startup testing leads to unacceptable thermal expansion, the systems or their restraints are modified and retested.

03.09.02-14

Section 14.2.12 provides descriptions of selected planned piping thermal expansion measurement tests. Test specifications for monitoring the thermal expansion testing of piping systems during preoperational and startup testing, including measurement of snubber movement and verification of adequate clearance and gaps (including acceptance criteria) are in accordance with Part 7 of Reference 3. The standard also provides guidance for developing acceptance criteria, instrumentation, and measurement techniques, as well as corrective actions and methodologies for reconciling movements that differ from those specified by the acceptance criteria.

3.9.2.2 Seismic Analysis and Qualification of Seismic Category I Mechanical Equipment

This section describes the seismic system analysis and qualification of Seismic Category I systems, components, and equipment performed to confirm functional integrity and operability during and after a postulated seismic occurrence. Appendix 3A describes the design criteria for piping and supports (including cable trays and ventilation ducts). Additionally, Section 3.2 provides a list of Seismic Category I equipment.