ArevaEPRDCPEm Resource

From: WELLS Russell D (AREVA NP INC) [Russell.Wells@areva.com]
Sent: Wednesday, August 12, 2009 4:42 PM
To: Tesfaye, Getachew
Cc: Pederson Ronda M (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 245, FSAR Ch 3
Attachments: RAI 245 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 245 Response US EPR DC.pdf" provides a technically correct and complete response to 9 of the 22 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 245 Question 03.09.02-40.

The following table indicates the respective pages in the response document, "RAI 245 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 13 of the 22 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 245 — 03.09.02-42 (items 1 and 3)	December 3, 2009

RAI 245 — 03.09.02-44	December 3, 2009
RAI 245 — 03.09.02-45	December 3, 2009
RAI 245 — 03.09.02-46	December 3, 2009
RAI 245 — 03.09.02-47	December 3, 2009
RAI 245 — 03.09.02-48	December 3, 2009
RAI 245 — 03.09.02-49	December 3, 2009
RAI 245 — 03.09.02-50	December 3, 2009
RAI 245 — 03.09.02-51	December 3, 2009
RAI 245 — 03.09.02-53	December 3, 2009
RAI 245 — 03.09.02-54	December 3, 2009
RAI 245 — 03.09.02-59	December 3, 2009
RAI 245 — 03.09.04-2	November 13, 2009

Sincerely,

(Russ Wells on behalf of)

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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Friday, July 10, 2009 7:36 PM
To: ZZ-DL-A-USEPR-DL
Cc: Spicher, Terri; Dixon-Herrity, Jennifer; Patel, Jay; Miernicki, Michael; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 245 (2981, 3036),FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on June 5, 2009, and discussed with your staff on June 25, 2009. Draft RAI Questions 03.09.02 -53 was modified as a result of that discussion. In addition, the staff has modified Question 03.09.02-49 (shown with yellow highlight) to ensure clarity. 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
Email Number: 727

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Subject: Response to U.S. EPR Design Certification Application RAI No. 245, FSAR Ch 3
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From: WELLS Russell D (AREVA NP INC)

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Response to

Request for Additional Information No. 245 (2981, 3036), Revision 0

7/10/2009

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
SRP Section: 03.09.04 - Control Rod Drive Systems
Application Section: 3.9

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

Question 03.09.02-40:

Follow-up to RAI Question 03.09.02-12

In **RAI Question 03.09.02-12**, the staff requested the applicant to provide a list of selected locations in the piping system at which visual inspections and measurements (as needed) will be performed during testing. The applicant responded to **RAI Question 03.09.02-12** in their Response to Request for Additional Information No. 160, Revision 0, by stating that 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." The staff could not identify the locations in test procedures cited by the applicant. Based on the applicant's response, the staff determined that a list of the selected locations as required and requested has not been provided. Therefore, the staff is initiating a follow-up RAI requesting the locations where visual inspections or measurements will be taken.

Response to Question 03.09.02-40:

There are several tests that will require monitoring vibration, thermal expansion, and dynamic effects as part of the initial test program (ITP) (e.g., U.S. EPR FSAR Tier 2, Section 14.2, Tests 035, 164, 165, etc.). The ITP plan will include a list of locations in the specific piping systems that are selected for visual inspection and other measurements during the vibration, thermal expansion, and dynamic effects testing program, as recommended by SRP 3.9.2. This is consistent with SRP Acceptance Criteria 1 which states:

> "Relevant requirements of GDCs 1, 2, 4, 14, and 15 are met if vibration, thermal expansion, and dynamic effects testing are conducted during startup functional testing for specified high- and moderate-energy piping and their supports and restraints. The purposes of these tests are to confirm that the piping, components, restraints, and supports have been designed to withstand the dynamic loadings and operational transient conditions encountered during service as required by the code and to confirm that no unacceptable restraint of normal thermal motion occurs."

SRP Acceptance Criteria Item 1.C notes that an acceptable test program includes a list of selected locations in the piping system where visual inspections and measurements (as needed) will be performed during the tests.

In addition, the ITP plan will include acceptance criteria for the deflection, pressure, and/or other appropriate criteria to be obtained during the tests to determine if the stress and fatigue limits are within design levels.

To clarify that the recommendations of SRP 3.9.2 are incorporated in the ITP plan, U.S. EPR FSAR Tier 2, Section 3.9.2.1 will be revised to state that the list of locations for visual inspection and other measurements, as well as acceptance criteria, are part of the ITP plan.

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 03.09.02-41:

Follow-up to RAI Question 03.09.02-15

In **RAI Question 03.09.02-15**, the staff requested the applicant 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. The applicant responded to **RAI Question 03.09.02-15** in their Response to Request for Additional Information No. 160, Revision 0 by stating that 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. The staff reviewed the applicant's response and could not determine if the applicant will perform additional testing after corrective action is taken. In addition, a reference to a comprehensive vibration program that includes piping vibration assessment was not identified in U.S. EPR FSAR Tier 2, Table 1.8-2. Therefore, the staff is initiating this RAI to request that further information be provided regarding additional testing after corrective action is taken.

Response to Question 03.09.02-41:

If unacceptable results are obtained, corrective actions will be performed and included in the results of the comprehensive vibration assessment program for piping and steam generator upper internals, and additional testing will be performed after corrective action is taken.

FSAR Impact:

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

Question 03.09.02-42:

Follow-up to RAI Question 03.09.02-16

In **RAI Question 03.09.02-16**, the staff requested the applicant 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. The applicant responded to **RAI Question 03.09.02-16** in their Response to Request for Additional Information No. 160, Revision 0, by stating that 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. Regarding clarification of how the piping systems are selected, the applicant stated that the representative piping systems are selected based upon their acoustic connection with the RCS system through acoustic pressure fluctuations.

The staff noted that the applicant was also requested to provide the “required specifications” for the handhelds. The “required specifications” refers to requirements that will be used to identify an appropriate device. The “required specifications” for measurement devices is set by the intended use; that is, the environment operated in and the phenomenon that is intended to be measured. The actual device procured may be equal to or better than this “required specification.” Further, to evaluate the appropriateness of the device requirements and their use in this application, the applicant was requested to provide discussion of the plans for their using in characterizing the piping system response relative to the analytical predictions. To propose the use of the device, the applicant must possess a more detailed conception of how the handheld device use will enable adequate description of the vibratory response of the piping systems attached to the RCS. In addition, a reference to a comprehensive vibration program that includes a review of vibration measurement devices for piping was not identified in U.S. EPR FSAR Tier 2, Table 1.8-2. Therefore, the staff is initiating this RAI requesting further clarification of how:

1. piping attached to the reactor cooling system (RCS) was selected for measurement

2. the required specifications for the handhelds

3. discussion for the plans for their use in characterizing the piping system response relative to the analytical predictions.

Response to Question 03.09.02-42:

1. A response to this question will be provided by December 3, 2009.
2. Specifications for the handhelds will be determined as part of the initial test program.
3. A response to this question will be provided by December 3, 2009.

FSAR Impact:

1. A response to this question will be provided by December 3, 2009.
2. The U.S. EPR FSAR will not be changed as a result of this question.
3. A response to this question will be provided by December 3, 2009.

Question 03.09.02-43:

Follow-up to RAI Question 03.09.02-17

In **RAI Question 03.09.02-17**, the staff requested the applicant 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 staff reviewed the applicant's response and was unable to determine how a problem will be localized. As a follow-up, this RAI is initiated and requests the applicant to explain how they will localize a problem area so that corrective action can be taken. Further, flow excited acoustic resonances are sensitive to small changes in plant construction and operating conditions. The applicant has only indicated plans to test "representative" piping trains at full-power conditions. Sensitivity to small changes suggests that so-called representative piping trains will not be "representative." Additionally, at conditions just below and just above that range of conditions where the lock-in occurs, local vibratory response can be high without coupling system wide. Measurements schemes that depend upon system wide response to determine unacceptably high response may not detect locally high levels. In addition, the applicant is requested to describe plans for assuring that measuring representative piping systems will capture excessive vibration in the remaining piping systems.

Response to Question 03.09.02-43:

This response describes the screening methodology for flow excited acoustic resonance in the design of the reactor coolant system (RCS) and attached piping. To prevent the RCS system from experiencing dynamic loads, piping systems attached to the RCS will be designed so that the generation of the sources of flow excitation in the cavities of safety relief valves, standoff pipes for valves, and branch lines is not possible.

This response describes the evaluation of acoustic resonances caused by shear wave resonance of valve standpipes (i.e., dead leg of closed relief valve) in the RCS and piping systems attached to RCS components (i.e., components such as reactor vessel (RV), steam generators (SGs), pressurizer (PZR)) and describes the potentially damaging effects of these acoustic resonances. The screening methodology can be incorporated into the design of piping and valve components to preclude the possibility of the shear wave resonance from occurring. By utilizing the relationship between the Strouhal number and standpipe dimensions, the acoustic resonance excitation in the RCS and the piping systems attached to the RCS can be effectively eliminated.

Shear wave resonance of valve cavities occurs when the standing acoustic wave in the valve's cavity couples with the vortices shedding off of the leading edge of the valve cavity's mouth (see Figure 03.09.02-43-1). When the vortex shedding frequency becomes close to or equal to the acoustic frequency of the cavity, then high oscillating pressures may develop. The resulting resonance pressure-flow oscillation can travel through the entire affected piping system with little attenuation. The oscillating pressure amplitudes inside the valve can be much greater than the main piping line dynamic pressure. If these acoustic instabilities in the flow fields resonate with the structural frequencies of the RCS internal components, then high dynamic loads can be created that normally result in high cycle fatigue failure.

An accepted method of predicting conditions conducive to acoustic resonance in piping systems and an explanation of these phenomena is presented in Reference 1. As noted in Reference 1, flow past a standoff pipe or relief valves will separate near the leading edge forming a shear layer downstream.

The flow-induced oscillations in terms of the non-dimensional frequency can be expressed in the following analytical form:

Equation 1: $f = \frac{SU}{d}, \quad where$

$S \equiv Strouhal\ \ number$

$U \equiv free\ \ stream\ \ velocity$

$d \equiv diameter\ \ of\ \ the\ \ branch$

These alternating flows into and out of the cavity result in compression of the vertical column and will excite the acoustic depth modes with the frequency defined as follows:

Equation 2: $f = \frac{NC}{4L}, \ where$

$N = \text{acoustic mode numbers} = 1,3,5,...$

$C = \text{acoustic velocity in flowing stream}$

$L = \text{stub length (or the standpipe height for safety relief valves)}$

When the vortex shedding excitation frequency and the first acoustic modal frequency coincide, an acoustic resonance condition is created that is physically observed as a loud noise. Equating these two frequencies and solving for the Strouhal number, the following expression is obtained:

Equation 3: $S = \frac{Cd}{4LU}$

These pulsations can be further amplified by the main pipe resonance if the standing wave has a maximum velocity near the side branch entrance. The acoustic impedances will match with that frequency, and the side branch resonance will couple with the main pipe resonance. This scenario may cause significant vibration of the safety relief valves or other structures in the piping systems whose structural frequencies are coincident with the acoustic and vortex-shedding frequencies. This condition may also cause safety relief valves to leak and chatter. Conversely, if the side branch is located near a main piping velocity node (pressure maximum), an impedance mismatch occurs and the stub standing wave will attenuate.

To prevent the generation of noise and the subsequent acoustic resonant condition, testing was performed by Baldwin and Simmons and combined with field data for 40 valves to conclude that the lowest (most conservative) Strouhal number where no coupling should occur is about 0.6. Substituting U/C = M (Mach number) into the expression for the Strouhal number and setting the Strouhal number equal to 0.6 yields the following design relationship where acoustic

resonance conditions will not occur. The Mach number is a function of the fluid composition, state point and local free stream velocity:

Equation 4: $\frac{d}{L} > 2.4M$

The maximum allowable length-to-diameter ratio of the cavity is defined by the Mach number of the flow past the side branch. A lower L/d ratio provides a greater range of resistance to vortex dynamic problems.

By following this design criterion, the Strouhal number of no less than 0.6 is maintained for maximum flow velocity in plant operating conditions. At other power levels or other plant operating conditions, the Strouhal number would not be lower than 0.6, and the possibility for the onset of resonance is eliminated. This can be observed in Equation 3, where the free stream velocity term is in the denominator.

Additional research indicates the blend radius (r) at the mouth of the cavity is also important depending on the forged piping connection being a sweepolet, vesselet, or other type: the critical flow velocity scales with blend radius (r) + standpipe inside diameter (d). The modified diameter (d+ r) can be viewed as the equivalent d after the blend radius is taken into consideration. Therefore, Equation 1 can be further refined to be:

Equation 5: $f = \frac{SU}{(d+r)}$

To prevent the RCS from experiencing dynamic loads created by sources of acoustic resonances, piping systems attached to the RCS will be designed such that the generation of flow excitation in the cavities of safety relief valves, standoff pipes for valves and branch lines, etc. is not possible. The methods described in this response will be used in the design and analysis of piping systems attached to the RCS to prevent the generation of this source of flow excitation. If standoff pipes are found to be susceptible to acoustic resonance, as determined by a Strouhal number between 0.3 and 0.6, through the entire operating range of flow, then measures will be taken to redesign the piping so that acoustic resonance will not occur. There are other options in the design, such as the position of the safety relief valve on the main piping line, that can be adjusted to effectively eliminate the shear wave resonance, and other resonance suppression techniques can be deployed if an acoustic resonance problem is identified.

The final piping design of the main steam system (MSS), main feedwater system (MFWS), and the other piping systems attached to the RCS has not been completed. Therefore, the evaluation of standoff pipes for the valves, standoff branch lines, or other cavities that have the potential to create acoustic resonance will be evaluated later in the design process for these piping systems.

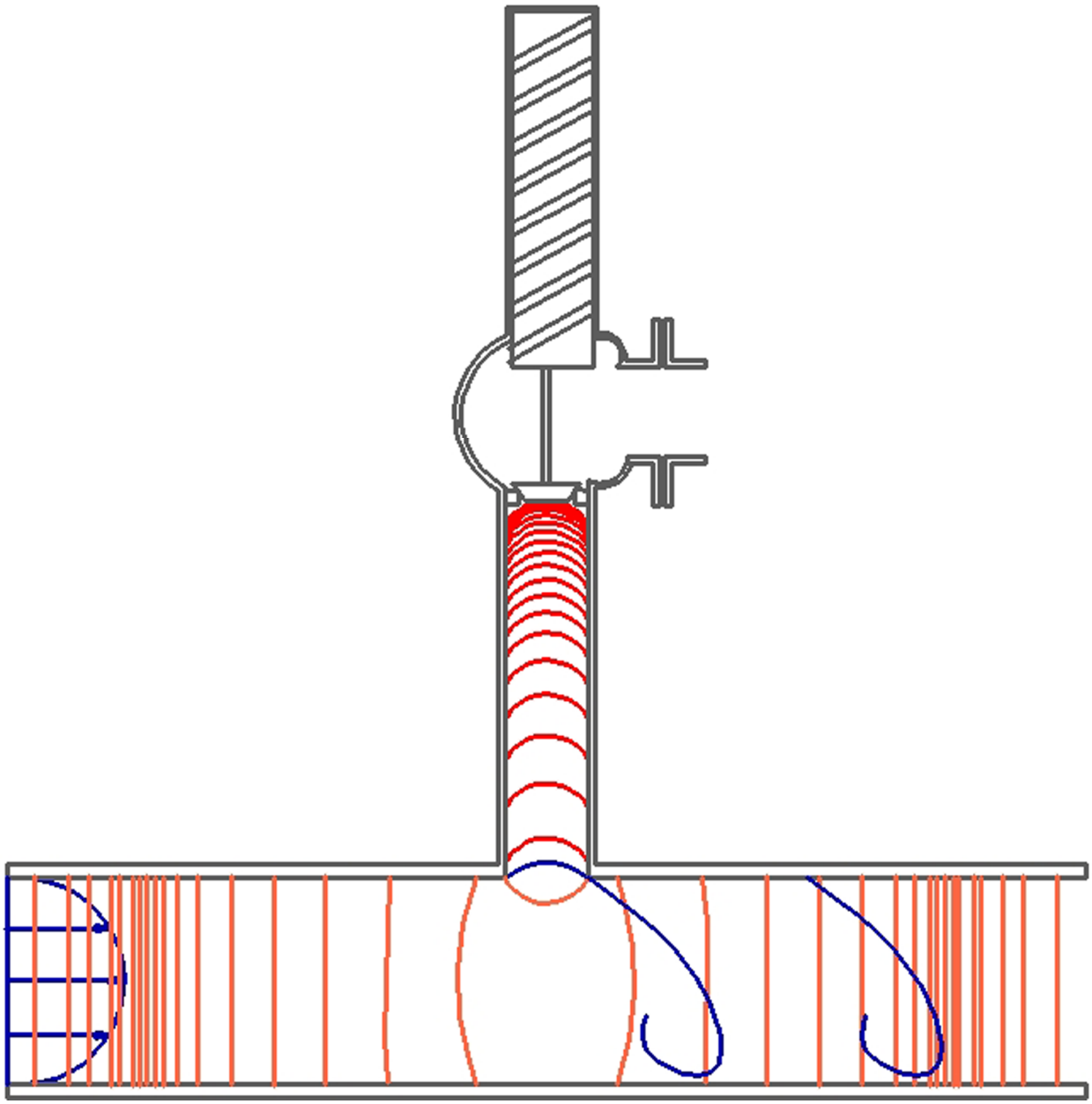
References for Question 03.09.02-43:

1. R.M. Baldwin and H.R. Simmons, “Flow-Induced Vibration in Safety Relief Valves,” ASME Journal of Pressure Vessel Technology, Volume 108/267, August 1986.

FSAR Impact:

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

Figure 03.09.02-43-1—Interaction of Flow over a Cavity



Question 03.09.02-44:

Follow-up to RAI Question 03.09.02-17

An additional follow-up to RAI 03.09.02-17 is required. The applicant stated in the response to **RAI Question 03.09.02-17** that U.S. EPR FSAR Tier 2, Section 3.9.2.4 describes that 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. The staff agrees that if the main steam and main feedwater systems are permanently instrumented and should be capable of identifying acoustic resonances throughout the affected system.

The applicant was requested to discuss how pressure fluctuations would be measured and analyzed to determine loads on any safety related or critical structures. The applicant responded by stating that the details of the vibration measurement, including the use of test results, would be addressed by the COL holder. The staff noted that this position and discussion of the planned pressure instrumentation and the plans for analyzing the pressures to compute loads are not dependent upon the results from the comprehensive RPV vibration assessment program referenced in U.S. EPR FSAR Tier 2, Table 1.8-2, Item 3.9-1. Therefore the staff determined that the applicant is required to provide additional information to complete the review of how pressure fluctuations would be measured and analyzed**.** Therefore, the staff is initiating this RAI requesting further information on the measurement and analysis of pressure fluctuations**.**

Response to Question 03.09.02-44:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-45:

Follow-up to RAI Question 03.09.02-24

In **RAI Question 03.09.02-24**, the staff requested the applicant to:

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.

The applicant responded to **RAI Question 03.09.02-24(a)** in their Response to Request for Additional Information No. 160, Revision 0 by stating that, 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.

The applicant responded to **RAI Question 03.09.02-24(b)** in their Response to Request for Additional Information No. 160, Revision 0 by stating that 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.

The staff noted that the applicant's response to **RAI Question 03.09.02-24(a)** deferred details of the preoperational vibration and test program to the COL holder. The applicant's response to **RAI Question 03.09.02-24(b)** deferred designation of the design as prototype or non-prototype contingent upon the comprehensive vibration assessment program conducted on the as yet unbuilt Olkiluoto-3 plant. However, the requested information in **RAI Question 03.09.02-24(a)** and (b) is inconsistent with what is required and should be available for determining compliance with regulation. The requested information on the vibration assessment program and the prototype design or the justification of classification of the U.S. EPR as non-prototype is needed to complete the DCD review to meet 10 CFR 52.47 to meet 10 CFR 52.47. This requested information has not been provided and therefore this RAI is initiated as a follow-up to request this information.

Response to Question 03.09.02-45:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-46:

Follow-up to RAI Question 03.09.02-27

In **RAI Question 03.09.02-27**, the staff requested the applicant 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.

The applicant responded to **RAI Question 03.09.02-27** in their Response to Request for Additional Information No. 160, Revision 0 by stating that 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. The staff requests the applicant to provide the comprehensive vibration assessment program for review by the NRC staff as part of the FSAR to meet 10 CFR 52.47. Therefore, this follow-up RAI is initiated requesting the program for review.

Response to Question 03.09.02-46:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-47:

Follow-up to RAI Question 03.09.02-28

In **RAI Question 03.09.02-28**, the staff requested the applicant 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 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.

The applicant responded to each item in **RAI Question 03.09.02-28** in their Response to Request for Additional Information No. 160, Revision 0 as follows:

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.

The staff reviewed the applicant's response to **RAI Question 03.09.02-28** and concluded that the applicant needs to provide the comprehensive vibration assessment program for review by the NRC staff as part of the FSAR to meet 10 CFR 52.47. Therefore, this follow-up RAI is initiated requesting a review of the program.

Response to Question 03.09.02-47:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-48:

Follow-up to RAI Question 03.09.02-29

In **RAI Question 03.09.02-29**, the staff requested the applicant 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.

The applicant responded to **RAI Question 03.09.02-29** in their Response to Request for Additional Information No. 160, Revision 0 as follows for each item: 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.

The staff reviewed the applicant's response to **RAI Question 03.09.02-29** and concluded that the applicant needs to provide the comprehensive vibration assessment program for review by the NRC staff as part of the FSAR to meet 10 CFR 52.47. Therefore, this follow-up RAI is initiated requesting a review of the program.

Response to Question 03.09.02-48:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-49:

Follow-up to RAI Question 03.09.02-30

The applicant stated in its response to RAI 03.09.02-30 that because transient evaluation of the RPV lower internals to transient conditions will occur during hot functional testing, no analytical evaluation of these transient conditions is planned. The analysis and testing portions of the comprehensive vibration assessment program are intended to compliment, not supplant, each other. The applicant is requested to provide justification for relying solely on the hot functional testing to determine the safety of the plant response to transients and to explain in detail why transient analysis is not performed.

Further, the applicant has stated that if acoustic loadings are observed in the reactor coolant system during hot functional testing, appropriate corrective actions will be taken to eliminate these acoustic loadings. If testing and analysis is conducted only at the full-power, steady-state operating state, as noted above, flow-excited and self-excited response occurring at other flow conditions may be missed. In this follow-up RAI, the applicant is requested to provide the details of their plans to ensure that these conditions are identified and mitigated. Rev 3 of Reg Guide 1.20 states that the applicant should perform a vibration and stress analysis for those steady-state and anticipated transient conditions that correspond to preoperational, initial startup test, and normal operating conditions.

Response to Question 03.09.02-49:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-50:

Follow-up to RAI Question 03.09.02-31

In **RAI Question 03.09.02-31**, the staff requested the applicant provide a comparison of the U.S. EPR and the German Konvoi plants support columns including the impedances of the mounting arrangements and a comparative analysis or testing that demonstrates the applicability of the German Konvoi experience to the U.S. EPR. The comparison should address placement of the instrumentation and the test conditions intended to evaluate the support columns in the U.S. EPR with those used by the German Konvoi plants.

The staff reviewed the applicant's response to **RAI Question 03.09.02-31** and concurs that the criteria for the FIV analysis of the RPV upper internals has been provided. The acceptance criteria for the random turbulence-induced vibration and for vortex-shedding induced vibrations were acceptable. However, in this follow-up RAI, the applicant is requested to identify the references for the fluid-elastic instability criteria.

Additionally, the applicant was also requested to describe "…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." The applicant deferred this discussion to 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, Item 3.9.1. The staff concludes that the applicant needs to provide the comprehensive vibration assessment program for review by the NRC staff as part of the FSAR to meet 10 CFR 52.47. Therefore, this follow-up RAI is initiated requesting a review of the program in addition to identification of the reference for the fluid-elastic instability criteria.

Response to Question 03.09.02-50:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-51:

Follow-up to RAI Question 03.09.02-32

In **RAI Question 03.09.02-32**, the staff requested 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.

The applicant responded to **RAI Question 03.09.02-32** in their Response to Request for Additional Information No. 160, Revision 0 by stating that the information is provided in the response to **RAI Question 03.09.02-31**, which stated that the applicant deferred this discussion to 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, Item 3.9.1.

Also, in the applicant's response to **RAI Question 03.09.02-32,** they stated in FSAR Tier 2, Section 3.9.2.3 that the full-scale CRGA components have been shown analytically to have acceptable vibrational behavior. This description indicates that the analysis is complete and conclusions indicate that the CRGA design is acceptable. In **RAI Question 03.09.02-32** the applicant was requested to provide details of the analyses. The applicant did not provide this information and the staff initiates this follow-up RAI to request details of the analyses.

Response to Question 03.09.02-51:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-52:

Follow-up to RAI Question 03.09.02-33

In **RAI Question 03.09.02-33**, the staff requested the applicant 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.

The staff reviewed the applicant's response to **RAI Question 03.09.02-33** and noted that the applicant stated that 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. In **RAI Question 03.09.02-33** the applicant was requested to provide the basis for determining the vibratory response of the tested components. This is a request for the flow-induced vibration (FIV) analytical evaluations of the U.S. EPR reactor pressure vessel internals (RPVI) that were performed. The applicant did not provide this information and consequently the staff is initiating this follow-up RAI.

Response to Question 03.09.02-52:

The analytical evaluations for the U.S. EPR reactor pressure vessel (RPV) internals are available for NRC inspection. As noted in the response to RAI 160, Question 03.09.02-33, the basis for determining the vibratory response of the tested components will be provided in the comprehensive vibration assessment program which will describe the hot functional test plan, including location, type, and sensitivity of the instrumentation.

FSAR Impact:

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

Question 03.09.02-53:

Follow-up to RAI Question 03.09.02-34

In **RAI Question 3.9.34**, the staff requested the applicant to discuss the types of non-destructive testing planned during the inspections process, if walkdowns are included, what monitoring and testing equipment is required, and what actions will be taken as a result of these inspections. 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, and inspected.

The staff reviewed the applicant's response to **RAI Question 03.09.02-34** and concluded that the applicant has deferred providing details of the nondestructive testing until after development 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, Item 3.9.1. The staff concludes that the applicant needs to provide the comprehensive vibration assessment program for review by the NRC staff as part of the FSAR to meet 10 CFR 52.47. Therefore, this follow-up RAI is initiated requesting a review of the program.

Response to Question 03.09.02-53:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-54:

Follow-up to RAI Question 03.09.02-35

In **RAI Question 03.09.02-35**, the staff requested the applicant 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.

The staff reviewed the applicant's response to **RAI Question 03.09.02-35** and concurs that it is appropriate that 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.

However, prior to the development of the testing program, factors that can influence accurate and meaningful comparison between analytical predictions used in design of the system and test results should be indentified. The applicant was requested to provide a discussion of these factors that influence the comparison of the test results to the analysis and how they will be incorporated into the testing program. The information requested has not been provided and consequently the staff is initiating this follow-up RAI.

Response to Question 03.09.02-54:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-55:

Follow-up to RAI Question 03.09.02-37

In **RAI Question 03.09.02-37** the staff requested the applicant 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 FSAR but must be deferred until the COL application.

The applicant responded to **RAI Question 03.09.02-37** in their Response to Request for Additional Information No. 160, Revision 0 by stating that this COL information item is the responsibility of the COL holder not the COL applicant and 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. The staff concludes that the applicant needs to provide the comprehensive vibration assessment program for review by the NRC staff as part of the FSAR to meet 10 CFR 52.47. Therefore, this follow-up RAI is initiated requesting a review of the program.

Response to Question 03.09.02-55:

Details of the comprehensive vibration program will be provided in the Response to Question 03.09.02-54, which is scheduled to be submitted to the NRC by December 3, 2009. Results from the vibration assessment program are the responsibility of the COL holder because these results are 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. Therefore, no change is required to COL Information Item number 3.9-1 of 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 03.09.02-56:

In FSAR Tier 2 Section 1.8, table 1.8-2, AREVA states the COL Item No. 3.9-1, with regard to section 03.09.02.04,: "A COL applicant that references the U.S. EPR design certification will submit the results from the vibration assessment program for the U.S. EPR RPV internals, in accordance with RG 1.20." The staff understands that Areva is proposing to have COL applicants (or Holders in this case) provide all the details of the vibration assessment program required in section 03.09.02.04 of RG 1.20 and NUREG 0800 section 03.09.02. However, the staff concern is that COL applicants must address all COL Items whether final action is taken before or after the license is issued. If the information is not provided, COL applicants need to meet RG 1.206 and let the staff know when and how the information will be provided. Given that it is acknowledged that the action will occur following the vibration assessment program, to allow the staff to perform necessary inspection of the report results ensuring the U.S. EPR RPV internals vibration assessment program has been properly designed and executed, the staff finds that an ITAAC in the EPR FSAR Tier 1 is necessary. The staff requests the applicant to add an appropriate ITAAC in EPR FSAR Tier 1 to address the issue.

Response to Question 03.09.02-56:

ITAAC exist in the U.S EPR FSAR to verify that the reactor pressure vessel (RPV) internals will withstand the effects of flow-induced vibration. Refer to U.S. EPR FSAR Tier 1, Section 2.2.1, "Reactor Coolant System," Item 3.8 and U.S. EPR FSAR Tier 1, Table 2.2.1-5, Item 3.8. This ITAAC wording was clarified in the Response to RAI 149, Question 03.09.05-3.

FSAR Impact:

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

Question 03.09.02-57:

Follow-up to RAI Question 03.09.02-25

In its response to RAI Question 03.09.02-25, AREVA states that a flow-induced vibration (FIV) analysis had been performed of the U.S. EPR steam separator design, which determined that the steam separators are not subjected to excessive vibration. The NRC staff requests that AREVA provide this analysis for review, including the analysis of potential FIV effects on the steam dryer and other internal parts in the U.S. EPR steam generator. Also, AREVA is requested to include FIV analysis information in DCD, Tier 2 Section 3.9.2.

Response to Question 03.09.02-57:

Analytical evaluations for the U.S. EPR upper and lower steam generator (SG) internals are available for NRC inspection. Because these analyses contain proprietary information, their methodology and results will be described in the comprehensive vibration assessment program for the SG upper internals and piping, which will be detailed in the Response to Question 03.09.02-54 scheduled to be provided to the NRC by December 3, 2009.

FSAR Impact:

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

Question 03.09.02-58:

Follow-up to RAI Question 03.09.02-25

In its response to RAI Question 03.09.02-25, AREVA states that excessive vibrations due to acoustic resonances as a result of flow in attached piping systems are eliminated by verifying that the piping systems are screened for this phenomenon in the design phase. The NRC staff requests that AREVA provide the methodology used in screening the U.S. EPR steam system design for potential flow-excited and structural resonances, and the results of its implementation of the methodology for the U.S. EPR design. The staff also requests that AREVA discuss the performance of scale model testing to confirm the validity of the methodology in predicting resonance in the U.S. EPR steam system. . Also, AREVA is requested to include the methodology and scale modeling testing information in DCD, Tier 2 Section 3.9.2.

Response to Question 03.09.02-58:

The methodology used in screening for sources of acoustic resonance in the U.S. EPR is described in Reference 1 (also see the Response to RAI 160, Question 03.09.02-25). The Response to Question 03.09.02-43 expands on the design criteria described in Reference 1 to provide an overview of the methodology to be incorporated into the design criteria for the reactor coolant system (RCS) piping as well as the design of piping attached to the steam generator (SG). This design objective and its evaluation will be included in the comprehensive vibration assessment program for the steam generator (SG) and applicable piping systems (RCS, main steam system (MSS), and feedwater system (MFWS)). Implementation of the methodology will be performed later in the design process.

The screening methodology provided in the Response to Question 03.09.02-43 is based on testing of 40 in-service valves and standoff branch lines and is the method typically followed by the industry when screening for this source of excitation. Scale model testing was not a part of the confirming the validity of the methodology.

References for Question 03.09.02-58:

1. R.M. Baldwin and H.R. Simmons, “Flow-Induced Vibration in Safety Relief Valves,” ASME Journal of Pressure Vessel Technology, Volume 108/267, August 1986.

FSAR Impact:

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

Question 03.09.02-59:

Follow-up to RAI Question 03.09.02-25

In its response to **RAI Question 03.09.02-25**, AREVA provides design information comparing the U.S. EPR steam dryers to those in other similar plants in Table 03.09.02-25-1, "Comparison of U.S. EPR SG Steam Dryers to Other Operating Plants." The NRC staff requests that AREVA provide a comparison of the structural capability of the U.S. EPR steam generator internal parts with those in other similar plants. The staff also requests that AREVA provide a comparison of the U.S. EPR steam system design, layout, branch line size and locations, steam velocity, and other applicable parameters that could affect potential flow-excited and structural resonances in the steam system with those parameters in similar plants. Also, AREVA is requested to include this information in DCD, Tier 2 Section 3.9.2.

Response to Question 03.09.02-59:

A response to this question will be provided by December 3, 2009.

Question 03.09.02-60:

Follow-up to RAI Question 03.09.02-26

AREVA refers to its response to **RAI Question 03.09.02-25** in responding to **RAI Question 03.09.02-26**. The NRC staff does not consider AREVA's response to **RAI Question 03.09.02-25** to be sufficient to resolve **RAI Question 03.09.02-26**. For example, AREVA did not address the consideration of sensitivities in the arrangement, design, size, and operating conditions of the U.S. EPR steam system that can influence flow-excited and structural resonances. Further, AREVA did not explain which U.S. EPR operating conditions could lead to resonance conditions in the steam generators, or 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. The NRC staff requests that AREVA address these considerations in its response to this RAI and include in DCD, Tier 2 Section 3.9.2.

Response to Question 03.09.02-60:

See the Response to Question 03.09.02-40. Tests performed as part of the initial test program (ITP) described in U.S. EPR FSAR Tier 2, Section 14.2 (e.g., Test 164 and Test 165) 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.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.9.2.1 was revised in response to Question 03.09.02-40.

Question 03.09.04-2:

Follow-up to RAI Question 03.09.04-1a

In **RAI 03.09.04-1a**, the staff requested the applicant to provide a reference that documents CRDM qualification to operate in the RPV environment for 60 years. The applicant in their response indicated that the Primary Stress Analysis will provide justification for the 60 year design life. The NRC staff finds this response acceptable. The applicant went on to explain that endurance testing was based on nine million steps. The NRC staff requests the applicant to provide the basis for enveloping the number of cycles or steps for the 60 year design life.

Response to Question 03.09.04-2:

A response to this question will be provided by November 13, 2009.

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acceptance criteria. Piping systems are checked for expansion-induced damage and for improperly restrained expansion and contraction. Clearances at gapped restraints are monitored during thermal expansion and contraction of the tested systems to identify any unanticipated contact between the fluid systems and their restraints. Snubber and deadweight support spring travel are also monitored to confirm that they will prevent unanticipated loading of the system.

- Performance tests are run on systems to verify operation and to check the performance of critical pumps, valves, controls, and auxiliary equipment. This phase of testing includes transient tests to identify unacceptable movement, noise, vibration, and damage caused by rapid valve opening and closing, safety valve discharge, pump operation, and other operational transients. During this phase, the piping and piping restraints are observed for vibration and expansion response and the automatic safety devices, control devices, and other major equipment are observed for indications of overstress, excessive vibration, overheating, and noise. Each system test includes critical valve operation during anticipated transients.

The initial test program is described in Section 14.2. The vibration, thermal expansion, and dynamic effects elements of this test program, summarized below, are performed during Phase I, Preoperational Testing, and Phase II, Initial Fuel Loading and Pre-Critical Testing. The initial test program includes the selected flow modes of operation and the transients to be simulated during testing, per RG 1.68. Test procedures for the initial test program describe the methods for establishing and measuring the reference values, including information on the instrumentation. Specific information concerning the locations where visual inspection or measurements are to be taken is also addressed in the applicable test procedures. These procedures also include details on the pipe monitoring displacement transducers or scratch plates, and strain gage or load cell locations. Information accuracy, measurement range requirements, and the criteria for evaluating the data are also addressed in the test procedures.

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The initial test program plan includes a list of locations in the specific piping systems that are selected for visual inspection and other measurements during the vibration, thermal expansion, and dynamic effects testing program. In addition, acceptance criteria for the deflection, pressure, and other appropriate criteria to be obtained during the tests is included in the initial test program plan to determine if the stress and fatigue limits are within design levels.

Phase I – Preoperational Testing

The piping systems to be tested are those described above (i.e., ASME Class 1, 2, and 3 pipes; high-energy pipes that involve seismic Category I structures; and seismic Category I portions of moderate-energy piping systems located outside containment). This testing includes ASME instrumentation lines up to the first support in each of the three orthogonal directions from the process pipe or equipment connection point.