ArevaEPRDCPEm Resource

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Sent: Friday, January 23, 2009 3:52 PM
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Subject: U.S. EPR Design Certification Application RAI No. 160 (1403), FSAR Ch. 3
Attachments: RAI_160_EMB1_1403.doc

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,
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Hearing Identifier: AREVA_EPR_DC_RAIs
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Request for Additional Information No. 160 (1403), Revision 0

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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)

03.09.02-7 and 03.09.02-8

[Intentionally deleted.]

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.

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.

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.

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.

03.09.02-13

[Intentionally deleted.]

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.

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.

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.

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.

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.

03.09.02-19 through 03.09.02-23

[Intentionally deleted.]

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

03.09.02-36

[Intentionally deleted.]

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.

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.