AREVA

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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Response to U.S. EPR Design Certification Application RAI No. 422, Supplement 21

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. Reference 2 provided a schedule for technically correct and complete responses to RAI No. 422. Reference 3 provided a technically correct and complete response to 2 (Questions 03.09.02-86 and 03.09.02-143) of the 63 questions. Reference 4 provided a revised schedule for a technically correct and complete response to the remaining 61 questions based on additional evaluations. Reference 5 provided a revised schedule for a technically correct and complete response to 6 of the remaining 61 questions based on additional evaluations. Reference 6 provided a revised schedule for a technically correct and complete response to 16 of the remaining 61 questions to allow additional time for AREVA NP to interact with the NRC. Reference 7 provided a technically correct and complete response to 11 (Questions 03.09.02-125, 03.09.02-128, 03.09.02-129, 03.09.02-130, 03.09.02-132, 03.09.02-133, 03.09.02-135, 03.09.02-136, 03.09.02-137, 03.09.02-139, and 03.09.02-141) of the remaining 61 questions. Reference 8 provided a revised schedule for a technically correct and complete response to 13 of the remaining 50 questions to allow additional time for AREVA NP to interact with the NRC. Reference 9 provided a revised schedule for a technically correct and complete response to 5 of the remaining 50 questions to allow additional time for AREVA NP to address NRC comments. Reference 10 provided a revised schedule for a technically correct and complete response to 3 of the remaining 50 questions based on additional evaluations. Reference 11 provided a revised schedule for a technically correct and complete response to 13 of the remaining 50 questions to allow additional time for AREVA NP to interact with the NRC. Reference 12 provided a revised schedule for a technically correct and complete response to 13 of the remaining 50 questions based on additional evaluations. Reference 13 provided a revised schedule for a technically correct and complete response to 16 of the remaining 50 questions based on additional evaluations. Reference 14 provided a revised schedule for a technically correct and complete response to 18 of the remaining 50 questions to allow additional time for AREVA NP to interact with the NRC. Reference 15 provided a technically correct and complete response to 1 (Question 03.09.02-126) of the remaining 50 questions. Reference 16 provided a technically correct and complete response to 8 (Questions 03.09.02-89, -91, -92, -93, -95, -96, -97, 142) of the remaining 49 questions. Reference 17 provided a revised schedule for a technically correct and complete response to 32 of the remaining 41 questions to allow additional time for AREVA NP to interact with the NRC. Reference 18 provided a revised schedule for a technically correct and complete response to 6 of the remaining 41 questions to allow additional time for AREVA NP to interact with the NRC. Reference 19 provided a revised schedule for a technically correct and complete response to 3 of the remaining 41 questions to allow additional time for AREVA NP to interact with the NRC. Reference 20 provided a revised schedule for a technically correct and complete final response to 29 of the remaining 41 questions to allow additional time for AREVA NP to

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interact with the NRC. Reference 21 provided a technically correct and complete response to 3 (Questions 03.09.02-105, -106, -123) of the remaining 41 questions. Reference 22 provided a revised schedule for a technically correct and complete final response to 9 of the remaining 38 questions.

The attached file, "RAI 422 Supplement 21 Response US EPR DC - Proprietary.pdf" provides a technically correct and complete final response to 5 of the 38 remaining questions. AREVA NP considers some of the material contained in the attached response to be proprietary. As required by 10 CFR 2.390(b), an affidavit is attached to support the withholding of the information from public disclosure.

The following table indicates the respective pages in the response document, "RAI 422 Supplement 21 Response US EPR DC - Proprietary.pdf," that contain AREVA NP's final response to the subject questions.

Question #	Start Page	End Page
RAI 422 — 03.09.02-90	2	3
RAI 422 — 03.09.02-94	4	4
RAI 422 — 03.09.02-124	5	5
RAI 422 — 03.09.02-138	6	6
RAI 422 — 03.09.02-144	7	8

The schedule for the technically correct and complete final response to the remaining 33 questions is unchanged and is provided below.

Question #	Response Date
RAI 422 — 03.09.02-82	June 15, 2011
RAI 422 — 03.09.02-84	June 15, 2011
RAI 422 — 03.09.02-85	June 15, 2011
RAI 422 — 03.09.02-87	July 13, 2011
RAI 422 — 03.09.02-88	July 13, 2011
RAI 422 — 03.09.02-98	June 15, 2011
RAI 422 — 03.09.02-99	June 15, 2011
RAI 422 — 03.09.02-100	June 15, 2011
RAI 422 — 03.09.02-101	June 15, 2011
RAI 422 — 03.09.02-102	June 15, 2011
RAI 422 — 03.09.02-103	June 15, 2011
RAI 422 — 03.09.02-104	June 15, 2011
RAI 422 — 03.09.02-107	June 15, 2011
RAI 422 — 03.09.02-108	June 15, 2011
RAI 422 — 03.09.02-109	June 15, 2011
RAI 422 — 03.09.02-110	June 15, 2011
RAI 422 — 03.09.02-111	June 15, 2011
RAI 422 — 03.09.02-112	June 15, 2011
RAI 422 — 03.09.02-113	June 15, 2011
RAI 422 — 03.09.02-114	June 15, 2011
RAI 422 — 03.09.02-115	June 15, 2011

Question #	Response Date
RAI 422 — 03.09.02-116	June 15, 2011
RAI 422 — 03.09.02-117	June 15, 2011
RAI 422 — 03.09.02-118	June 15, 2011
RAI 422 — 03.09.02-119	June 15, 2011
RAI 422 — 03.09.02-120	June 15, 2011
RAI 422 — 03.09.02-121	June 15, 2011
RAI 422 — 03.09.02-122	June 15, 2011
RAI 422 — 03.09.02-127	July 13, 2011
RAI 422 — 03.09.02-131	June 15, 2011
RAI 422 — 03.09.02-134	July 13, 2011
RAI 422 — 03.09.02-140	July 13, 2011
RAI 422 — 03.09.02-145	June 15, 2011

If you have any questions related to this submittal, please contact me by telephone at 434-832-2369 or by e-mail to sandra.sloan@areva.com.

Sincerely,

Sandra M. Sloan

Sandra M. Sloan, Manager
New Plants Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: G. Tesfaye
Docket No. 52-020

References

Ref. 1: E-mail, Getachew Tesfaye (NRC) to Martin C. Bryan (AREVA NP Inc.), "U.S. EPR Design Certification Application RAI No. 422 (4792), FSAR Ch. 3," August 3, 2010.

Ref. 2: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3," September 2, 2010.

Ref. 3: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 1," September 9, 2010.

Ref. 4: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 2," September 27, 2010.

Ref. 5: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 3," November 2, 2010.

Ref. 6: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 4," November 22, 2010.

Ref. 7: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 5," December 22, 2010.

Ref. 8: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 6," January 12, 2011.

Ref. 9: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 7," January 13, 2011.

Ref. 10: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 8," January 27, 2011.

Ref. 11: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 9," February 8, 2011.

Ref. 12: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 10," February 10, 2011.

Ref. 13: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 11," February 17, 2011.

Ref. 14: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 12," March 16, 2011.

Ref. 15: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "PROPRIETARY Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 13," March 24, 2011.

Ref. 16: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 14," March 30, 2011.

Ref. 17: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 15," March 31, 2011.

Ref. 18: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 16," April 13, 2011.

Ref. 19: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 17," April 20, 2011.

Ref. 20: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 18," May 11, 2011.

Ref. 21: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 19," May 20, 2011.

Ref. 22: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, FSAR Ch. 3, Supplement 20," May 25, 2011.

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, Regulatory Affairs for New Plants, for AREVA NP Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in, "Response to U.S. EPR Design Certification Application RAI No. 422, Supplement 21," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information".

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Sandra M. Sloan

SUBSCRIBED before me this 1st day of June, 2011.

Kathleen A. Bennett

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2011
Reg. #110864

KATHLEEN ANN BENNETT
Notary Public
Commonwealth of Virginia
110864
My Commission Expires Aug 31, 2011

Response to

Request for Additional Information No. 422, Supplement 21

8/3/2010

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: 3.9.2

QUESTIONS for Engineering Mechanics Branch 2 (ESBWR/ABWR Projects) (EMB2)

Question 03.09.02-90:

This is related to RAI 03.09.02-59.

The applicant stated that the primary steam separators are a new design and that the applicant has performed a flow induced vibration analysis to demonstrate the integrity of these separators. The upper frequency limit of this analysis is 350 Hz. The applicant is requested to provide the basis for the 350 Hz upper frequency limit used in the flow induced vibration analysis to demonstrate the integrity of these separators.

Response to Question 03.09.02-90:

A cut-off frequency of 350 Hz identified the first seven modal frequencies of the primary steam separators with the seventh mode at [ ] Hz. Typically, the response to random turbulence decays as the natural frequency increases, as shown in the power spectral density (PSD) curve in Technical Report ANP-10306P, Figure B-6 and the response PSD in Technical Report ANP-10306P, Figures B-7 and B-8. Figure B-7 shows that the steam separator response at the [ ] Hz frequency is approximately one order of magnitude less than at the frequency of [ ] Hz. Figure B-8 shows a similar but more pronounced pattern. There is a difference in response of at least five orders of magnitude between the [ ] Hz and the [ ] Hz frequencies. Therefore, evaluating these seven modal frequencies is sufficient to capture any appreciable response of the separators to random turbulence.

The PSD in Technical Report ANP-10306P, Figure B-6 is defined with a range of dimensionless frequency between zero and five, which corresponds to a frequency range of zero to approximately 170 Hz. Figure 03.09.02-90-1 shows the dimensional pressure PSD for the frequency range of 0 to 250 Hz, which bounds the frequencies that were evaluated in the analysis of the steam separators. This figure will be added to Technical Report ANP-10306P.

FSAR Impact:

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

Technical Report Impact:

ANP-10306P, "Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals Technical Report," will be revised as described in the response and shown in the attached markup.

Figure 03.09.02-90-1—Pressure PSD for Pipe-Separator Assembly

Question 03.09.02-94:

This is related to RAI 03.09.02-59.

The applicant described the fatigue acceptance criteria in CVAP section B.3.2.2 and stated that a fatigue strength reduction factor (FSRF) of 1.0 is applied to unflawed cross sections and 4.0 is applied to flawed cross sections. The applicant is requested to describe how flawed sections are defined and how an FSRF of 1.0 is conservative when applied to such sections. These details must be provided to assess the conservatism of the criteria.

Response to Question 03.09.02-94:

The fatigue strength reduction factor (FSRF) is a factor applied to the stress intensity to account for the stress amplification effect of a local structural discontinuity on the fatigue strength. An FSRF of 1.0 was applied at cross sections that are removed from any structural discontinuity. An FSRF of 4.0 was applied at cross sections of local structural discontinuities, particularly geometrical transitions, of the primary separator piping to conservatively account for stress amplification effects.

The stress results in Technical Report ANP-10306P, Table B-3 are for the most limiting locations and do not include the stress amplification effects of the structural discontinuities of the primary separator. Applying a conservative value of 4.0 for the FSRF, a maximum alternating stress of [ ] psi, rms is obtained, which is much less than the allowable stress at [ ] psi, rms at 10^{13} cycles.

The term "flawed" is a misnomenclature for this application. Technical Report ANP-10306P, Vibration Assessment Program for U.S. EPR Reactor Internals, Appendix B.3.2.2 will be revised to clarify the use of the FSRF.

FSAR Impact:

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

Technical Report Impact:

ANP-10306P, "Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals Technical Report," will be revised as described in the response and shown in the attached markup.

Question 03.09.02-124:

This is related to RAI 03.09.02-48d, (follow-up RAI to 03.09.02-29).

In RAI Question 03.09.02-29 letter (d), the staff requested the applicant to discuss the analysis methodologies or software used in the modeling of both the full scale and the scale model structures, including the methodology used to assess the accuracy, limitations and applicability of the software package or analysis procedure. The applicant described the use of the PCRANDOM software in CVAP Section 4.3.2 for the flow distribution device (FDD). The modal responses of the column supports were determined at full power operating temperatures and conditions using the applicant's CASS structural analysis program. The applicant stated that the limitations and accuracy verification against the classical closed form solutions are documented in the applicant NP Inc certification reports for the CASS software. The applicant employs AREVA NP computer code PCSTAB2 to perform the fluid-elastic instability analysis. These software codes are internally developed and maintained analysis software programs, therefore the applicant is requested to supply evidence that they have been used in a previously accepted NRC applications.

Response to Question 03.09.02-124:

The computer programs CASS, PCRandom, PCStab2, and EBDynamics used to perform flow induced vibration (FIV) analysis of various structural shapes have not been used in a previously accepted NRC application. The computer programs CASS and EBDynamics are described in U.S. EPR FSAR Tier 2, Appendix 3C. Technical Report ANP 10306P, Sections 4.3.2.1.1 and 4.5.1.1.3 include descriptions of computer programs PCRandom and PCStab2, respectively. U.S. EPR FSAR Tier 2, Appendix 3C will be revised to add a description of the computer programs PCRandom and PCStab2.

The certification reports for these PC programs are available for NRC inspection and audit.

FSAR Impact:

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

Technical Report Impact:

ANP-10306P, "Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals Technical Report," will not be changed as a result of this question.

Question 03.09.02-138:

This is related to RAI 03.09.02-49.

The applicant stated that the piping system design is not completed, but provides assurance that the design process discussed in CVAP Section A.2.1 will prevent the flow excitation of acoustic resonances in the piping system. The mechanism discussed is due to shear wave resonance from flow over the cavities in safety relief valves, standoff pipes for valves and branch lines coupling with the acoustic modes of the piping branch. The staff noted that the applicant is extending the range of Strouhal number to 0.3 to 0.63 based on their response to RAI 03.09.02-65. The staff accepts that the applicant's design practice will make acoustic resonances in the RCS and piping attached to the RSG unlikely and thus, for the conditions of plant operation through normal full power operation, will be met when the applicant provides a piping design which meets this Strouhal number standard. In addition, the applicant stated that sensitivities in the arrangement, design and operating conditions on the degree of margin to acoustic resonance will be considered later in the design process. The applicant is requested to verify that these requirements are included in the design ITAAC for these piping systems.

Response to Question 03.09.02-138:

ASME Code Section III requires that the assessment of piping system vibrations is considered during the design process.

U.S. EPR FSAR Tier 1, Table 2.2.1-5, Item 3.20 addresses the design of reactor coolant system (RCS) piping in accordance with ASME Code Section III.

As described in the Response to RAI 331, Question 03.09.02-65, the Strouhal number range used to screen for acoustic resonance is extended from 0.3 to 0.6 to 0.3 to 0.63. Technical Report ANP-10306P will be revised to reflect the modified screening criteria as indicated in the markups provided with the Response to RAI 331, Question 03.09.02-65.

FSAR Impact:

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

Technical Report Impact:

ANP-10306P, "Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals Technical Report," will not be changed as a result of this question.

Question 03.09.02-144

The applicant stated that only representative trains of piping systems are monitored as part of the CVAP. The staff requested an explanation of how a problem area will be identified so that corrective action can be taken, or describe how measuring representative piping systems will determine that excessive vibration is not occurring in non-instrumented piping systems. The applicant explained in their response to Question 03.09.02-64, in Response to Request for Additional Information No. 331, Supplement 2, that if an acoustic resonance occurs on one line, the same is expected at nearly the same flow conditions in the other representative lines. In the event that a resonant response is measured, the piping will be identified by determining the characteristic dimensions, e.g. diameter and length, required for the resonant frequency to occur. These characteristic parameters will be used to identify the piping that is in resonance.

The staff reviewed this approach and noted that the applicant's definition of a representative piping system requires meeting the criteria described below:

1. It must be part of the same overall plant system (e.g. Main Steam System)
2. It must have the same components and similar piping routing – particularly for branch piping.
3. The main piping must have the same diameter and have essentially the same flow conditions.
4. Distances to the first upstream elbow and distances between standpipes need to be essentially the same.
5. Branch piping needs to have the same length and diameter in the systems.

The applicant is requested to provide the criteria and /or metrics employed to determine when piping meets the "essentially the same" criteria used in determining distance to the upstream elbow, distance between standpipe and flow conditions and clarify if elbows are required to have the same orientation relative to the branch line.

Response to Question 03.09.02-144

The orientation of elbows relative to the branch line does not impact the propagation of acoustic waves or effects of acoustic wave reflections. Therefore, the orientation of elbows is not a criterion for determining similarity of pipe systems.

The diameter should be within tolerances typical of piping classes.

The distance to the upstream elbow and distance between standpipes do impact acoustic resonance phenomenon due to impact on Strouhal numbers, frequencies as well as amplitudes of standing waves as the result of interference. In order to keep piping systems tuned to comparable acoustic behavior, the allowable deviations of distances is based on construction tolerances of the piping system.

The flow conditions of piping system lines are considered "essentially the same" when they are within 2 percent of the design conditions.

The representative piping that will be instrumented is the one that is most likely to develop acoustic resonance. Sensitivity to acoustic resonance determination is based on detailed analysis, considering Strouhal numbers and other pertinent acoustic factors as outlined in the Technical Report ANP-10306P.

FSAR Impact:

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

Technical Report Impact:

ANP-10306P, "Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals Technical Report," Revision 0 will not be changed as a result of this question.

U.S. EPR Final Safety Analysis Report Markups

3C.6 Description of Computer Programs

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

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

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

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

- CASS: This code performs structural analysis of general structures subjected to static and dynamic loading using finite element analysis techniques and is typically used to perform modal analysis of structures. CASS is a purchased code that runs on a personal computer that is verified, by comparing the results from analysis of a sample problem to the classical solution of the same problem, each time it is executed.

- COMPAR2: This code performs hydraulics analysis of fluid systems (generally containment cavities). The system is modeled as a series of control volumes and flow paths, so that the behavior of a pressure wave caused by a pipe break can be predicted. Pressure time histories can be obtained for any structure included in the model. COMPAR2 is the AREVA NP version of COMPARE-MOD1, which is described in NUREG-0609 as being applicable and conservative for use in Asymmetric Cavity Pressurization analyses. No difference exists between these two codes except that COMPAR2 provides an additional output file containing a tabulation of nodal pressures for subsequent input to BWHIST. COMPAR2 is certified, by comparing results obtained from analyses of test configurations to actual test data and to hand calculations. COMPAR2 is a certified computer code that is maintained in a controlled location (users can only access an executable file, not the source code).

- CRAFT2: This code performs hydraulics analysis of fluid systems including piping and components. The system is modeled as a series of control volumes and flow paths such that the behavior of a pressure wave caused by a pipe break can be predicted. Pressure time histories can be obtained at changes in area or changes in flow direction. The NRC has approved CRAFT2 for use in simulating the effect of pipe ruptures on the RCS (Reference 4). CRAFT2 is certified, by comparing results obtained from analyses of test configurations to actual test data and to hand calculations. As additional options were added to the code, test cases were run to confirm that results did not change from the previous version. CRAFT2 is a certified computer code that is maintained in a controlled location (users can only access an executable file, not the source code).

- EBDynamics: This code performs dynamic analysis of general structures and fluids subjected to dynamic loading and is typically used to find the time domain solution of coupled fluid-structure problems. EBDynamics is a personal computer based program that is verified, by comparing the results from analysis of a sample problem to the classical solution of the same problem, each time it is executed.

03.09.02-124

- PCRandom: This code performs flow induced vibration analysis for random turbulence of structural shapes exposed to either parallel or cross flow thermal hydraulic conditions. The program finds the response of a structure to a pressure power spectral density function, based on finite element implementation of the acceptance integral method, and then integrates the response PSD with respect to the frequency to obtain the root mean square response at the selected finite element nodal locations. PCRandom is a personal computer based code that is verified, by comparing the results from analysis of a sample problem with the classical solution of the same problem, each time it is executed.

- PCStab2: This code performs flow induced vibration analysis for fluid-elastic instability of steam generator tube bundles or an array of cylindrical shapes. This program determines the fluid-elastic stability margin, which is the ratio of the critical velocity to the mode shaped weighted pitch velocity, at finite element node locations. PCStab2 is a personal computer based code that is verified, by comparing the results from analysis of a sample problem with the classical solution of the same problem, each time it is executed.

- P91232: This code calculates through-wall gradient temperatures and stresses given pipe or nozzle geometry and thermal characteristics (i.e., time dependant fluid temperature and film coefficients or flow rates). P91232 is a personal computer based code that is verified, by comparing results from analysis of sample problems to hand calculated results, each time it is executed.

- RESPECT: This code generates ARS given the frequency and mode characteristics of the system in question (from BWSPAN) and the acceleration time history applicable to the base of the structure. RESPECT is used to generate seismic ARS at the branch nozzle locations in a model of a piping system. Earlier versions of RESPECT were certified by comparing the output obtained from analysis of sample problems to results obtained from hand calculations for the same sample problems. As additional options were added to the code, test cases were run to confirm that results did not change from the previous version. RESPECT is a

Comprehensive Vibration Assessment Program for the U.S. EPR™ Reactor Internals Technical Report Markups

Structural Damping

The total damping coefficient is a composite of the following damping mechanisms:

- The structural damping associated with the hysteresis of the material.
- The structural damping created by the non-linear interactions of the lateral supports of the steam separator.
- The hydrodynamic damping of steam mixture.

A conservative viscous damping ratio of [ ] is applied to the pipe-separator assembly. The uniform structural damping coefficient is set to two times the viscous damping coefficient to achieve an equivalent viscous damping at resonance.

Correlation Length and Convective Velocity

For extremely turbulent flow conditions in confined channels, the correlation length (λ) of the forcing function acting along the length of the pipe-separator assembly is equal to approximately 40 percent of the hydraulic radius (Reference 4, Equation 8.65). For extremely turbulent flow conditions in confined channels, the convective velocity is approximately equal to 100 percent of the axial flow velocity (Reference 4, Equation 8.58).

Pressure PSD

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The pressure PSD that is applied to the pipe-separator assembly was measured from turbulent flow testing (without cavitation) in extremely turbulent single phase flows in confined channels where there are no well-defined boundary layers, such as those encountered in industrial piping systems with elbow, valves, and changes in cross sections. The pressure PSD is taken from Reference 4, Equation 8.70 and graphically presented in Figure B-~~5~~6. The upper bound curve shown in this figure is used for the evaluation performed for the piping-separator assembly. Figure B-9 provides the dimensional pressure PSD for a frequency range of 0 to 250 Hz, which bounds the frequencies that were evaluated in the analysis of the steam separators.

The structural model for the steam separators evaluated the nominal (design) dimensions of the components to determine the natural frequencies and mode shapes of these components. As such, the analytical model does not specifically consider the manufactured tolerances associated with the geometry of the structures and the differences in material properties values established in the ASME code and the as-built values. The rationale used to disposition the bias and uncertainty of the modal frequencies of the RPV lower internal assembly described in Section 4.2.2.1 is identical for the steam separators. Since the fluid-structure coupling mechanism for random turbulence is weak, the slight variation in the natural frequencies that would be attributed to manufactured tolerances and variation of the material properties will not significantly alter the forcing function and the response of the steam separators. The uncertainty in the response of the separators associated with these tolerances in the natural frequencies is estimated to be less than ± 5 percent of the amplitude of vibration.

B.3.2 FIV Acceptance Criteria

B.3.2.1 Acceptance Criteria for Displacements

The acceptance criterion for displacements due to turbulence-induced vibration is based on one-half the gap clearance between adjacent separators. Because the clearance between the entrance pipes is smaller than the clearance between the separators, the minimum acceptable displacement is conservatively based upon the clearance between the entrance pipes. The nominal pitch between the entrance piping is approximately [ ] inches and the nominal pipe OD is approximately [ ] inch. One-half of the gap clearance is:

C_{min} = (Pitch – OD) /2 = [ ] inch

Because the computed displacement response (inch, rms) to turbulence is based on a probability of excursions, C_{min} as calculated above, it is divided by a factor of 5 or 5 sigma, which is representative of approximately a 100 percent probability that this allowable displacement will not be exceeded. The acceptable displacement for vibration induced by flow turbulence is [ ] inch, rms.

B.3.2.2 Acceptance Criteria for Fatigue

The criterion established in Section 4.2.6.2 using fatigue curve "AC" is applied to the primary steam separator. ~~Because the PL + Pb + Q stress range is below 27.2 ksi and the mean stress is low, Fatigue curve "A" is applicable.~~ An allowable stress of [ ], at 10^{13} cycles is conservatively used and neglects corrections to this value resulting from the difference in the elastic modulus between the fatigue curve and the pipe-separator assembly.

An FSRF of 1.0 is applied at cross sections that are removed from any structural discontinuity. An FSRF of 4.0 is conservatively applied at cross sections of local structural discontinuities, particularly the geometrical transitions, of the primary separator piping to conservatively accounts for their stress amplification effects.~~A FSRF of 1.0 is applied to unflawed cross sections in the fatigue analysis and an FSRF of 4.0 is conservatively applied to flawed cross sections.~~

B.3.3 Response of the Pipe-Separator Assembly to Random Turbulence

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B.3.3.1 Displacement RPSD for the Pipe-Separator

The linear-log scale plots for the in-plane and the out-of-plane dimensional response PSDs of the pipe-separator assembly are shown respectively in Figure B-7 and Figure B-8. These figures predict the response for the first seven natural frequencies of the pipe-separator assembly considering a cut-off frequency of 350 Hz. Note that mode 4 (~ [ ] Hz) is an axial mode of the structure and does not create a translational response. As expected, the majority of the response occurs from the fundamental frequency (beam mode, [ ] Hz).

Figure B-9—Pressure PSD for Pipe-Separator Assembly

Notes:

1. The dimensional pressure PSD in this figure is developed from the dimensionless PSD identified with Figure B-6, whose dimensionless frequency has a range of F=0 to F=5 (or approximately 170 Hz). The range of frequency depicted in this figure (0 to 250 Hz) corresponds to the dimensionless frequency range of F=0 to 7.4. The dimensional PSD in this figure was extrapolated to 250 Hz considering the same slope or decay of turbulent energy between F=1 and F=5, as shown in Figure B-6.

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Table B-3—Pipe-Separator Stress (RMS Response)

Note(s) for Table B-3

1. The stresses reported in this table do not include the stress amplification effects of the structural discontinuities of the primary separator. Applying a conservative value of 4.0 for the FSRF, a maximum alternating stress of [ ] is obtained, which is much less than the allowable stress at [ ] at 10^{13} cycles.

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