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. 458, Supplement 8

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. References 2, 3, and 4 provided a schedule for technically correct and complete responses to RAI No. 458. Reference 5 provided a technically correct and complete response to 3 (Questions 03.09.01-13, 03.09.01-14, and 03.09.01-15) of the 12 questions. Reference 6 provided a revised schedule for the remaining 9 questions. Reference 7 provided a technically correct and complete final response to 2 of the 9 remaining questions (Questions 03.09.02-146 and 03.09.02-148). Reference 8 provided a technically correct and complete final response to 3 of the 7 remaining questions (Questions 03.09.02-150, 03.09.02-153, and 03.09.02-154). Reference 9 provided a revised schedule for the 4 remaining questions.

Enclosed is a technically correct and complete final response to 3 of the 4 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. Proprietary and non-proprietary versions of the enclosure to this letter are provided.

The following table indicates the respective pages in the enclosed response that contain AREVA NP's final response to the subject questions.

Question #	Start Page	End Page
RAI 458 — 03.09.02-147	2	3
RAI 458 — 03.09.02-149	4	8
RAI 458 — 03.09.02-151	9	9

Also enclosed are affected pages of ANP-10306P, "Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals Technical Report," Revision 0 in redline-strikeout format which support the response to RAI 458 Questions 03.09.02-147, 03.09.02-149, and 03.09.02-151.

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NRO

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

Question #	Response Date
RAI 458 — 03.09.02-152	August 12, 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. 458 (5149,5152), FSAR Ch. 3," November 5, 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. 458, FSAR Ch. 3," December 6, 2010.

Ref. 3: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 1," March 21, 2011.

Ref. 4: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 2," April 19, 2011.

Ref. 5: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 3," May 26, 2011.

Ref. 6: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 4," June 7, 2011.

Ref. 7: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 5," June 30, 2011.

Ref. 8: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 6," July 8, 2011.

Ref. 9: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 458, FSAR Ch. 3, Supplement 7," July 12, 2011.

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, New Plants Regulatory Affairs 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 Request for Additional Information No. 458, Revision 0, Supplement 8," 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(d) 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 26th

day of July , 2011.

Kathleen A. Bennett

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2015
Registration No. 110864

KATHLEEN A. BENNETT
Notary Public
Commonwealth of Virginia
110864
My Commission Expires Aug 31, 2015

Response to

Request for Additional Information No. 458(5149, 5152), Revision 0, Supplement 8

11/05/2010

U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.09.01 - Special Topics for Mechanical Components
SRP Section: 03.09.02 - Dynamic Testing and Analysis of Systems Structures and Components
Application Section: 3.9

QUESTIONS for Engineering Mechanics Branch 1 (AP1000/EPR Projects) (EMB1)
QUESTIONS for Engineering Mechanics Branch 2 (ESBWR/ABWR Projects) (EMB2)

Question 03.09.02-147:

In CVAP Section 4.6.3.1, AREVA discussed the damping applied to the control rod guide assembly (CRGA) internals. The discussion is not clear as to the total damping employed in the analysis. Further, AREVA is requested to discuss the damping mechanisms included in the total damping and the contribution of each mechanism to the total. If the structural component is greater than 1 percent, AREVA is further requested to strongly support the higher values of structural damping with measurements per the recommendations of RG 1.20. Revise CVAP Section 4.6.3.1 to include the requested information.

Response to Question 03.09.02-147:

As stated in Technical Report ANP-10306P, Section 4.6.3.1, the total damping applied to the analysis for random turbulence of the control rod guide assemblies (CRGA) (e.g., the tie rods, c-tubes, and rod control cluster assemblies) is equal to [ ] percent viscous (or [ ] percent structural). This damping magnitude is consistent with the damping inherent to the material, or the hysteresis, damping.

The total damping values used for the evaluation of lock-in conditions associated with vortex shedding excitation is reviewed in this paragraph. As shown in Technical Report ANP-10306P, Table 4-22 and Table 4-23, the justification that vortex shedding lock-in will not occur for the CRGA tie rods and c-tubes is demonstrated by ASME Code Section III, Appendix N-1324.1, Criteria (d), 2004. A damping value for these criteria is not required to assess the potential for lock-in since the resonant condition is avoided. Vortex shedding lock-in for the CRGA control rod cluster assemblies is suppressed by ASME Code Section III, Appendix N-1324.1, Criteria (c), as shown in Technical Report ANP-10306P, Table 4-24. For the CRGA control rod clusters assemblies, the total viscous damping value determined for the five modal frequencies are shown in Table 03.09.02-147-1. These viscous damping values are used to determine the reduced damping value (C_n), which is compared in ASME Code Section III, Appendix N-1324.1, Criteria (c). Table 03.09.02-147-1 shows the reduced damping.

Table 03.09.02-147-1 will be included in Technical Report ANP-10306P as Table 4-34. Additional clarifications regarding the damping will be provided in Technical Report ANP-10306P, Section 4.6.3.1.

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 be revised as described in the response and shown in the attached markup.

Table 03.09.02-147-1—Vortex-Shedding Lock-in Damping Values for CRGA Control Rod Absorber (Viscous)

[ ]

Notes:

1. The viscous fluid damping is determined from the following relationship and taken from Reference 1, Equation 8-23:

$$\zeta_{fluid} = C_{lift}\left(\frac{1}{8\pi}\right)\left(\frac{V}{f \cdot D}\right)\left(\frac{\rho \cdot D^2}{m_t}\right)$$

2. $\zeta(hysteresis)$ is the damping of the material resulting from hysteresis.
3. $\zeta(structural)$ is the damping created by the non-linear interaction of the control rod absorber and the guide plates.
4. The reduced damping (C_n) is determined from the relationship in ASME Code Section III, Appendix N-1324.1.

References:

1. Blevins, Robert D. Flow-Induced Vibration, Second Edition, 2001.

Question 03.09.02-149:

The applicant is requested to:

A. Verify that the effect of the uncertainties and bias errors on the calculations do not result in a possible range of lock-in occurring for the RPV internals.

B. Provide tables of resonant frequencies, flow rate, shedding frequency (for the upper internals) together with any possible range of lock-in and the effect of uncertainty on the lock-in parameters per the recommendation of RG 1.20.

C. Revise the CVAP to include the requested information.

Response to Question 03.09.02-149:

Response to Part (a):

Though vortex shedding is an important mechanism for single cylinders exposed to cross flow, it is generally not important unless the spacing of a bank of tubes (in this case, cylinders) is large with pitch-to-diameter (P/D) ratios greater than 2.0, as stated in the ASME Operation and Maintenance Guide, Part 11, Non-Mandatory Appendix A, Section A-2, 2009. For closely spaced arrays of cylinders with the P/D spacing less than about 1.5, the distinct frequency associated with vortex shedding degenerates into broadband turbulence. The control rod guide assembly (CRGA) array of cylinders has a P/D ratio equal to [ ] The span wise variation of the velocity profile along the length of the support columns, shown in Figure 03.09.02-149-1 and Figure 03.09.02-149-2, can reduce the strength of the lock-in. The upper internals of the reactor pressure vessel (RPV) were evaluated for lock-in, using the design criteria and methods outlined in ASME Code Section III, Appendix N-1324.1.

The Technical Report ANP-10306P, Table 4-19 will be revised to include the specific results obtained in the evaluation of the lock-in condition to allow direct comparison to the acceptance criteria. As shown in Technical Report ANP-10306P, Table 4-19, the results of the evaluation for lock-in using the design criteria established in ASME Code Section III, Appendix N-1324.1 demonstrate that lock-in is either avoided or suppressed for the column supports and the instrumentation guide tube.

Technical Report ANP-10306P, Section 4.5.3 will be revised to add a table comparing the natural frequencies and the vortex-shedding frequencies of the column supports. The results provided in this comparison are determined considering the most limiting flow conditions for the 10 percent reactor coolant pump (RCP) overspeed transient condition and the maximum gap or pitch velocity of approximately [ ] inch/sec that occurs at a single location along the length of the column supports, which are conservative. Figure 03.09.02-149-1 and Figure 03.09.02-149-2 show the velocity profile along the length of the CRGA and level measurement probe (LMP)/normal column supports, respectively. The vortex shedding frequencies for the column supports are based on a Strouhal number of 0.46, derived from the limiting pitch velocity ([ ] inch/sec) and the P/D ratio for the CRGA columns (see Technical Report ANP-10306P, Section 4.5.1.1.2 for additional information). This value for the Strouhal number is approximately equal to the upper bound value for a single cylinder (0.47) and (0.5) for an array of cylinders.

Technical Report ANP-10306P will be revised to include the tabular comparison of natural frequencies and vortex shedding frequencies described in this response, which shows that separation exists between the fundamental frequency of the CRGA column support and its vortex shedding frequency. A comparison of the more limiting vortex shedding frequency in the drag direction (f_d = [ ] Hz) to the fundamental frequency of the CRGA (f_1 = [ ] Hz) demonstrates that the flow conditions would have to increase by a factor of [ ] in order for a resonant condition to manifest itself. Based on this margin, the uncertainties and bias errors that may exist in the calculations are not significant enough for lock-in to occur for the CRGA column support.

For the instrumentation guide tube, frequency comparison shows that separation exists between its fundamental frequency and its vortex shedding frequency. A comparison of the more limiting shedding frequency in the drag direction (f_d = [ ] Hz) to the fundamental frequency of the guide tube (f_1 = [ ] Hz) demonstrates that the flow conditions would have to increase by a factor of [ ] in order for a resonant condition to occur. Based on this margin, the uncertainties and bias errors that may exist in the calculations are not significant enough for lock-in to occur for the instrumentation guide tube.

The normal and LMP column supports have similar natural frequencies and shedding frequencies. Therefore, these columns are described together in this response. The comparison of fundamental frequency of these column supports (f_1 = [ ] Hz and f_1 = [ ] Hz) and their vortex shedding frequency in the drag direction (f_d = [ ] Hz) show that the two frequencies are close. Lock-in is not possible for these column supports because the damping suppresses this condition as shown in Technical Report ANP-10306P, Table 4-19 (condition 3). A damping ratio of [ ] percent is evaluated for the first modal frequency of these column supports and is determined from the relationships in Technical Report ANP-10306P, Section 4.5.1.1.2. As stated in Technical Report ANP-10306P, Section 4.5.1.1.2, a regression analysis of an extensive compilation of damping data was used to create the correlation for damping. There is a limited degree of margin against lock-in for the column supports, however, these structures are not susceptible to lock-in for the following reasons:

1. The P/D ratio of 1.26 in the upper internals is not large enough for the distinct vortex shedding frequency to become organized.
2. The span wise variation of the cross flow velocity along the length of the column supports inhibits the formation of the vortices along the full length of the supports, preventing a lock-in condition from fully developing.

If these components are susceptible to lock-in, the hot functional testing (HFT) and instrumentation defined in Technical Report ANP-10306P, Section 5.0 for the LMP and normal column supports are capable of detection. If this occurs, appropriate actions will be taken to eliminate this susceptibility for lock-in from the design.

Response to (b & c):

Technical Report ANP-10306P, Section 4.5.3 will be revised to add a Table 4-32 showing a comparison of the natural frequencies and vortex shedding frequencies for the column supports.

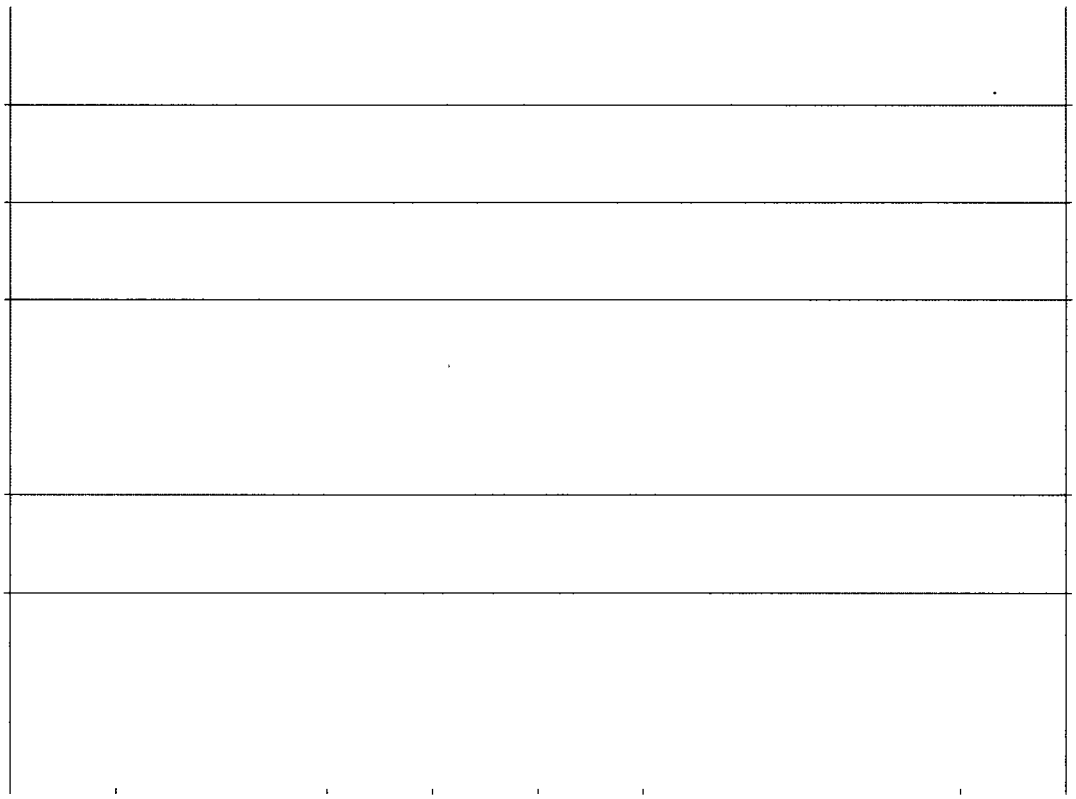
FSAR Impact:

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, Section 4.5.3 will be revised as described in the response and shown in the attached markup.

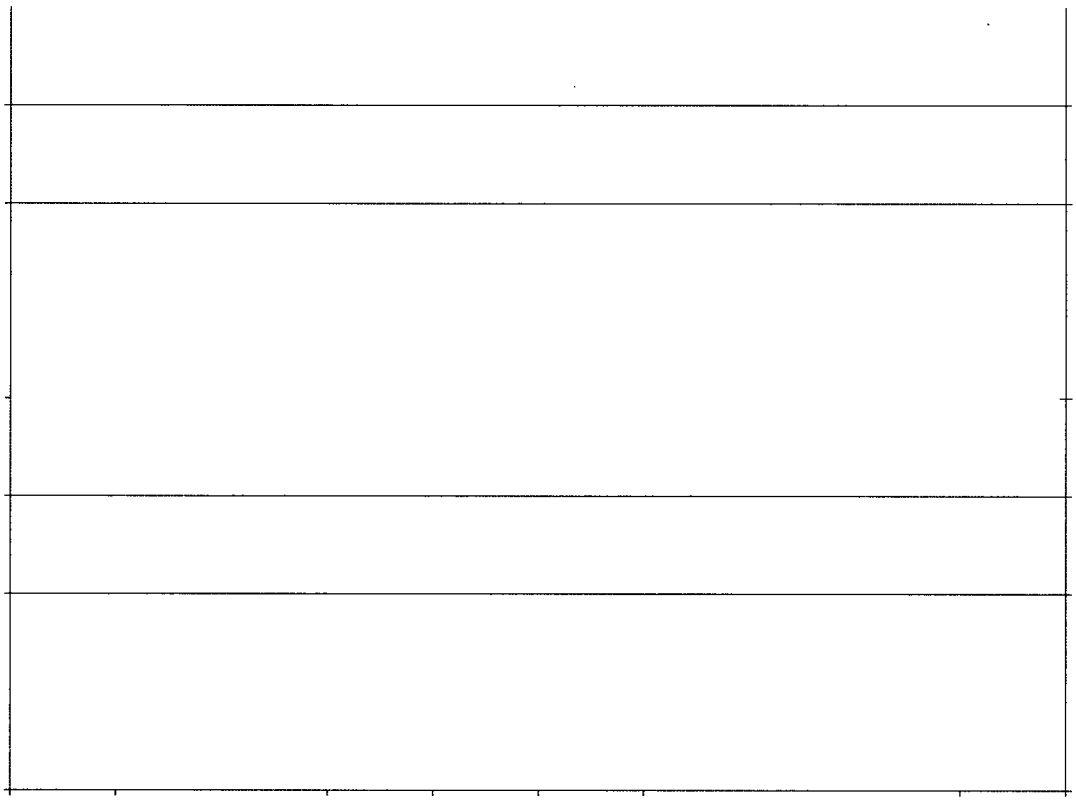
Figure 03.09.02-149-1—Velocity and Density Distribution for CRGA Support Column



Notes:

1. Representative of the full power, steady state normal operating condition.
2. The thermal hydraulic conditions in this figure are representative of location S6 in Technical Report ANP-10306P, Figure 5-10.
3. This velocity and density profile was also applied to the instrumentation guide tube.

Figure 03.09.02-149-2—Velocity and Density Distribution for LMP Support Column



Notes:

1. Representative of the full power, steady state normal operating condition.
2. The thermal hydraulic conditions in this figure are representative of location T7 in Technical Report ANP-10306P, Figure 5-10.
3. This velocity and density profile was also applied to the normal column support.

Question 03.09.02-151:

Provide justification for neglecting the tones associated with the RCP in the analysis of the RPV upper internals (extends RAI 03.09.021-101). Revise the CVAP to include the requested information.

Response to Question 03.09.02-151:

Technical Report ANP-10306P, Section 4.5 will be revised to address reactor coolant pump (RCP) acoustic pressure fluctuations and to include tables that compare the natural frequencies of the support columns, the forcing frequencies of the RCP acoustic pressure fluctuations, the static force, and the amplification factor for each forcing frequency. The stress induced in the support columns by this source of excitation will be added to Technical Report ANP-10306P, Table 4-20.

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, Section 4.5 and Table 4-20 will be revised as described in the response and shown in the attached markup.

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

- CRGA column supports.
- Normal column supports.
- Level measurements probe column supports.
- Instrumentation guide tubes.

The UCP and the USP are not susceptible to significant excitation from turbulence or any other FIV mechanisms. First, the rigidity offered by the column supports and the thickness of these plates increases the plate frequencies, making them less susceptible to turbulence. Second, the turbulence in the parallel flow through the UCP does not have the ability to become coherent with these high frequencies. Therefore, there is minimal potential to excite the modal frequencies of the UCP and USP.

The acoustic pressure fluctuations associated with loop acoustics will not have the ability to create significant excitation of the column supports (e.g., the CRGA columns, normal columns, LMP columns). The long wave length associated with the low frequency characteristics of loop acoustics makes the relatively slender structures of these upper internal components immune to this source of acoustic pressure fluctuations.

03.09.02-151

~~Additionally, t~~The narrow band acoustic pressure fluctuations associated with the RCP rotational speed ([ ] Hz) and the pump blade passing frequency ([ ] Hz)~~,~~ are typically less than 1 psi (0-peak). The long wave length associated with these pressure fluctuations make the relatively slender structures of these upper internal components immune to this source of acoustic pressure fluctuations. However, due to the close proximity of some of the harmonic frequencies of the RCP and the column supports, harmonic forced vibrations analysis of the column supports was performed. The column supports and the instrumentation guide tube are evaluated for a [0.14] psi (0-peak) amplitude of pressure at the first shaft and blade passing frequency of the RCPs. The pressure fluctuations associated with the higher order harmonics are typically one order of magnitude less than the magnitude for the first shaft and blade passing frequency and therefore, a [0.014] psi (0-peak) amplitude of pressure was evaluated for the second and third order harmonics of the shaft and blade passing frequencies. ~~as well as the other potential sources of acoustic pressure fluctuations (e.g., acoustic resonance and loop acoustics), are dissipated after passing through the fuel bundle. Therefore, there is minimal potential to excite the modal frequencies of the UCP and the USP.~~

The measures identified in Section 4.2.5.2.2 (and Appendix A.2.1) regarding the screening criteria to identify sources of acoustic resonances in the reactor coolant piping system will verify that the UCP, the USP, and the column supports will not be excited by acoustic mechanisms.

The flow-induced vibration phenomena of concern for the column supports, which are cylindrical structures exposed to cross flows in the upper plenum include:

- Vortex-shedding induced vibration.
- Fluid-elastic instability.

A conservative correlation length of ([ ]), which is typically representative of tube bundles is applied to the column supports. For the CRGAs, the corresponding correlation length is ~ [ ] inch, which is a relatively large value. The structural damping coefficient is set to two times the viscous damping coefficient ([ ]) to achieve the equivalent structural damping at resonance.

4.5.1.1.5 RCP Acoustic Pressure Fluctuations

The largest amplitude and resulting acoustic pressure typically occurs with the first blade passing frequency and will vary between -ΔP/2 and +ΔP/2 in a distance equal to the wave length of the acoustic pressure fluctuation. The wave length (λ) of the acoustic pressure fluctuations depends on its frequency and will vary for each RCP tone, but in general are very long wave lengths. Referring to Figure 4-59, the pressure differential (Δp) that would be imparted to these cylindrical structures with a diameter, d, by an acoustic pressure fluctuation with a magnitude equal to $\pm p_o$ and a wave length, λ, is equal to:

$$\Delta p = \frac{2 p_o d}{\lambda} \text{ psi}$$

and creates a harmonic force on the cylinder equal to:

$$F = d\Delta p = \left(\frac{2d}{\lambda}\right) p_o d \text{ per unit length}$$

The characteristics of the acoustic pressure fluctuations and the static loads that are created by the normal impingement of the RCP acoustic pressure fluctuations are provided in Table 4-30. The amplification factors used with these static forces to generate the harmonic excitation forces are provided in Table 4-31. The amplification factors were determined with the methods and damping ratios reported in Section 4.5.1.1.2.

Significant excitation of the support columns is not expected due to acoustic waves that may propagate along the length of the support columns. The acoustic pressure wave will vary between $-p_o$ and $+p_o$ in a distance equal to ½ of its wavelength. Because the height of the support columns is relatively short compared to this wavelength, the phase relationship between the fundamental mode shape of the column supports and the acoustic pressure wave does not exhibit adequate compatibility to impart a significant harmonic force to the support columns. The higher order modes of the support columns would exhibit even less compatibility with this harmonic excitation force.

03.09.02-151

4.5.2.3 Vortex-Shedding Induced Vibrations and RCP Acoustic Pressure Fluctuations

03.09.02-151

Acceptance Criteria for Displacements

The acceptance criterion for the off resonant response of the column supports assures that the mid-span displacements of the column supports are small enough to avoid impact with adjacent column supports. Because the response to vortex-shedding and the RCP acoustic pressure fluctuations is harmonic, the allowable displacement and the allowable stress are in units of 0-peak. As computed for turbulence, the allowable displacement limit for all CRGA column supports is [ ] inch (0-peak).

03.09.02-151

Acceptance Criteria for High Cycle Fatigue

The ASME fatigue curve "~~A~~C" shown in Figure 4-21 is applied to ~~the off-lock in~~ the response of the structure. The allowable high cycle fatigue stress of [ ] (0-peak) at 10^{11} cycles for fatigue curve "~~A~~C."

03.09.02-151

4.5.3 Response of the Column Supports

The primary fluid velocity and density throughout the RV upper internals is determined with a three dimensional CFD model ~~one-dimensional thermal hydraulic model~~ for the full power normal operating condition. The U.S. EPR upper plenum thermal hydraulic model is qualified based on benchmarking with flow tests performed with the ROMEO mock-up which simulates the upper internals at a scale of 1:5.2. ~~The magnitude of velocity and density that is evaluated for the column supports is representative of a location near the hot leg outlet nozzles (V = [37.6] ft/sec and ρ = [40.8] lbm/ft³). This~~The worst located column support is evaluated. As noted in Section 4.5.1, the cross flow velocity distribution along the length of the column supports is increased by 10 percent to account for the RCP over-speed transient conditions. ~~The distribution of velocity at the hot leg nozzle elevation is projected upon the corresponding flow area of the column supports to provide a velocity profile for the analysis.~~

~~Since the time at which the full scale analysis of the column supports were originally evaluated, the velocity profile along the length of the column supports has been refined using three-dimensional thermal hydraulic modeling and analysis of the flow distribution in the upper plenum. AREVA plans to revise the FIV analysis of these column supports to consider the refined velocity distribution and to remove other conservatisms in the current evaluation. The revised analysis is expected to improve the accuracy of the results to provide better agreement between the pre-operational evaluation and the hot functional test results. A preliminary assessment for the column supports, considering the revised thermal hydraulic conditions, shows a lower response to flow excitations resulting from turbulence for the column supports.~~

The FIV analysis of the column supports and the instrumentation guide tube for the limiting RCP transient condition is performed for fluid-elastic instability. The method by which the full power

Table 4-19—Evaluation for Vortex-Shedding Lock-in for the Column Supports

03.09.02-149

Note(s) for Table 4-19:

1. The vortex-shedding frequencies of the column support during the limiting RCP transient with three RCPs operating at cold shutdown conditions are bounded by the vortex-shedding frequencies for the 100 percent power normal operating conditions.
2. See Section 4.5.1.1.2 for details regarding the acceptance criteria for the lock-in condition as provided by the ASME Section III, Appendix N, Paragraph N-1324.1.

03.09.02-149

Table 4-20—Summary of FIV Results for the RV Upper Internal Column Supports (100% Power, Steady State, Normal Operating Conditions)

Notes for Table 4-20:

1. The stresses reported in this table are based on a conservative FSRF of 3.0 which bounds the computed values for the structural discontinuities of the lower and upper flanges. The full penetration welds used to join the column support parts do not require an FSRF per the ASME Section III requirements; however, a FSRF was conservatively applied.

03.09.02-151

The measures identified in Section 4.2.5.2.2 for the lower internals will verify that sources of acoustic resonance in the RCS piping do not exist. This type of narrow band acoustic pressure fluctuation can not be transmitted to the RV upper internals or the RV head through the narrow bypass flow channels between the CB outlet nozzle and the RV outlet nozzle or through the RV head dome spray nozzles to create excitation of the CRGA or the RCCAs.

4.6.3.1 Analysis Methodology and FIV Design Inputs

The analytical methodology implemented for the full scale FIV evaluation of the CRGA internal components is identical to that described for the CRGA column supports in Section 4.5.1.1. There are unique differences in the design inputs for the CRGA internal components, which are defined in this section.

Thermal Hydraulic Inputs

The thermal-hydraulic inputs that are used in the full scale evaluation of the CRGA internals are tabulated in Table 4-21 and are representative of full power normal operating conditions. The thermal-hydraulic inputs are developed from a one dimensional thermal hydraulic model, and the magnitudes are considered nominal. The maximum axial flow velocity through the CRGA column support ([ ] ft/sec) is conservatively applied as the cross flow in the CRGA regions above the c-tubes.

Damping for ~~Vortex-Shedding and~~ Random Turbulence Vibrations ← 03.09.02-147

A viscous damping coefficient of [ ] is applied to the CRGA internal components, which is representative of the damping inherent to the material or the hysteresis damping. The structural damping coefficient is set to two times the viscous damping coefficient to achieve the equivalent structural damping at resonance.

Damping for Vortex-Shedding Vibrations (including lock-in conditions)

A total viscous damping value of 0.5% is applied to the tie rods and c-tubes. For the CRGA control rod clusters assemblies, the total viscous damping created by the fluid, hysteresis, and the non-linear interaction of the control rod absorber and the guide plates is itemized in Table 4-34 for the first five modal frequencies. These sources of damping are used to determine the reduced damping value (C_n), which is compared in ASME Code Section III, Appendix N-1324.1, Criteria (c).

Design Inputs for Turbulent Forcing Function ← 03.09.02-147

The single phase PSD function, as proposed by Pettigrew and Gorman and also recommended by Reference 9a, is applied to the CRGA internal components. This PSD is shown in Figure 4-34 and discussed in detail in Section 4.5.1.1.4.

Table 4-30—U.S. EPR RCP Shaft and Blade Passing Frequencies (Design)

Note(s) for Table 4-30:

1. The wave lengths in this table are based upon a sonic velocity of 2902 ft/sec consistent with the full power normal operating conditions.

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Table 4-31—Static Forces Acting on the Support Columns

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Table 4-32—Comparison of Natural & Vortex-Shedding Frequencies for the Column Supports

[ ]

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Table 4-33—Comparison of Natural Frequencies and Forcing Frequencies for the RCP Acoustic Pressure Fluctuations and the Dynamic Amplification Factors

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Table 4-34—Reduced Damping for the CRGA Control Rod Absorber (Viscous)

[ ]

Notes:

1. The viscous fluid damping is determined from the following relationship and taken from Reference 2, Equation 8-23:

$$\zeta_{fluid} = C_{lift}\left(\frac{1}{8\pi}\right)\left(\frac{V}{f \cdot D}\right)\left(\frac{\rho \cdot D^2}{m_t}\right)$$

2. $\zeta(hysteresis)$ is the damping of the material resulting from hysteresis.
3. $\zeta(structural)$ is the damping created by the non-linear interaction of the control rod absorber and the guide plates.
4. The reduced damping (C_n) is determined from the relationship in ASME Code Section III, Appendix N-1324.1.

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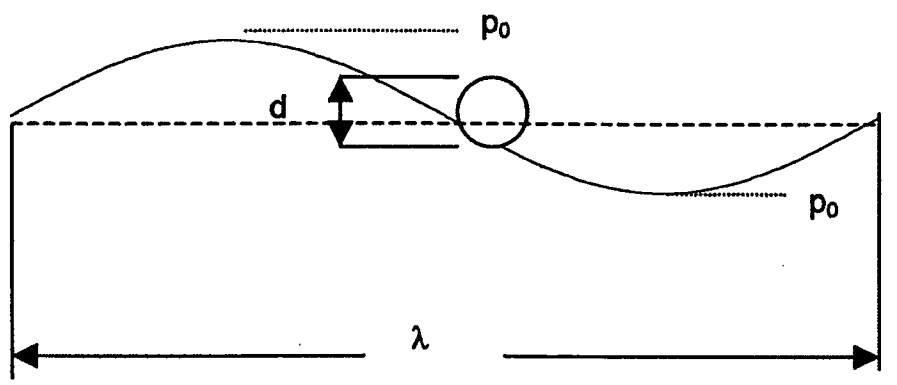
Figure 4-59—Acoustic Wave Impinging Normally on a Cylinder



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