AREVA

October 18, 2011
NRC:11:107

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 30

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: Letter, Sandra Sloan, (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 422, Supplement 29," September 27, 2011, NRC:11:104.

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. Reference 2 provided a technically correct and complete final response to 4 of the 11 remaining questions and a history of the prior supplemental responses.

Enclosed is a technically correct and complete final response to 1 of the 7 remaining questions of RAI 422, as shown in the below table. A revised response is also being provided to Questions 03.09.02-87 and 03.09.02-112, which were originally submitted to NRC in Reference 2.

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 question.

Question #	Start Page	End Page
RAI 422 — 03.09.02-87	2	3
RAI 422 — 03.09.02-104	4	9
RAI 422 — 03.09.02-112	10	11

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The schedule for the technically correct and complete final response to the remaining 6 questions is unchanged and is provided below.

Question #	Response Date
RAI 422 — 03.09.02-99	November 22, 2011
RAI 422 — 03.09.02-103	November 22, 2011
RAI 422 — 03.09.02-107	November 22, 2011
RAI 422 — 03.09.02-108	November 22, 2011
RAI 422 — 03.09.02-114	November 22, 2011
RAI 422 — 03.09.02-119	November 22, 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

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. 422, Revision 0, Supplement 30," 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(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 10th

day of October, 2011.

Kathleen A. Bennett

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

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

Response to

Request for Additional Information No. 422(4792)

Supplement 30

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 03.09.02-87:

Follow-up to RAI 245, Question 03.09.02-45(a)

The staff issued RAI 03.09.02-45(a) requesting the applicant to provide details of the preoperational vibration and test program so that a determination could be made as to whether the applicant followed the recommendations in SRP 3.9.2 Subsection II Acceptance Criteria (4) for a prototype reactor. As stated in the SRP, requirements of GDCs 1 and 4 are met if the preoperational vibration and stress test program for the internals of a prototype reactor conform to the requirements for a prototype test as specified in RG 1.20. In addition, the test program to demonstrate design adequacy of the reactor internals should include those criteria described in letters A through I of Subsection II Acceptance Criteria (4). The applicant responded to RAI 03.09.02-45(a) in the response to RAI 245, by referring to the CVAP Technical Report ANP-10306P, which is described as conforming to the guidance of RG 1.20, Revision 3. The staff noted that the CVAP does not discuss the criteria described in letters A through I of SRP 3.9.2 SRP Subsection II Acceptance Criteria (4) and omits recommendations for vibration predictions, test acceptance criteria and bases, and permissible deviations from the criteria required before testing, as recommended in SRP 3.9.2 Subsection II.4 letter "G". The staff determined that the proposed CVAP test plan did not meet all recommendations of SRP 3.9.2 Subsection II Acceptance Criteria (4) and therefore could not determine if requirements of GDCs 1 and 4 are met. Therefore, this item remains open.

Response to Question 03.09.02-87:

The criteria of SRP 3.9.2 Subsection II Acceptance Criteria (4), Letter G for vibration predictions, test acceptance criteria and bases, and permissible deviations from the criteria required before testing are met as described in Technical Report ANP-10306P, Comprehensive Vibration Assessment Program for U.S. EPR Reactor Internals, Section 4.0 and Section 5.5.

Technical Report ANP-10306P, Section 4.0 provides analytical predictions and applicable acceptance criteria and bases for the components of the reactor vessel (RV) internals that may be affected by flow-induced vibration (FIV). The results of the predictive analysis provided in Section 4.0 show that fluid-elastic instability, acoustic resonance, and vortex lock-in are highly unlikely. The predicted displacements and stresses due to random turbulence for the full-scale model are provided and also fulfill the analytical acceptance criteria established in Technical Report ANP-10306P.

The overall acceptance criteria for the HFT is an accuracy between the results obtained with the analytical prediction and the full-scale test to within a factor or 2.0, as stated in Technical Report ANP-10306P, Section 5.5.

Technical Report ANP-10306P, Section 5.5 will be revised and Section 5.6 will be added to provide further explanation of the test acceptance criteria and bases, and the permissible deviations from the criteria.

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.

Question 03.09.02-104:

This is related to RAI 03.09.02-47 (a).

The staff noted that the applicant described viscous damping was the only mechanism found to contribute to the shell modes. The contribution of viscous damping over the frequency band of 2.5 to 10 Hz was calculated using formulation by R. J. Gibert. The staff noted that the cited reference has not been used by other applicants. The applicant is requested to provide documentation that the methodology is an approved industry approach accepted by the NRC or an alternate source for this calculation.

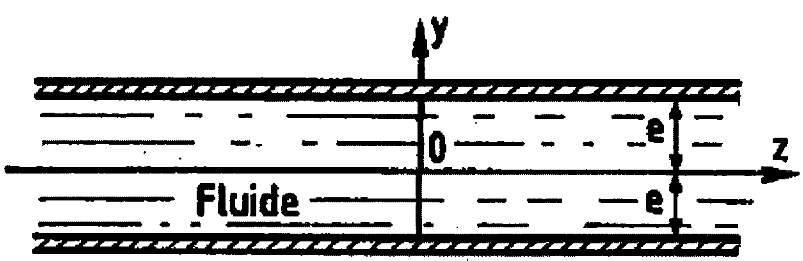
Response to Question 03.09.02-104:

The formula for shell-type mode damping as proposed by R.J. Gibert is selected because it adequately corresponds with the damping associated with the flexural vibration of fluid-coupled plates. The full derivation of the solution and the equation for the viscous damping, as reported in Technical Report ANP-10306P, Section 4.2.5.3.4, including all hypotheses and simplifications, is provided in Chapter 15 of Reference [1].

As requested by the NRC during a teleconference held on December 16, 2010, the methodology for this damping is translated from French to English to assist in the review of the Technical Report ANP-10306P. The following methodology for shell-type damping is a translation of Example 15.2.4 from Reference [1].

Damping of Two Vibrating Plates Coupled by a Viscous Fluid Gap

Consider two plates vibrating harmonically in pure flexion with a circular frequency (ω) and the dimensionless wave number (λ) vibrating out-of-phase with each other. Their deformed shape is equal to $Xo\cos(\lambda z/e)$



The two plates are separated by a gap filled with a viscous, incompressible fluid. The total thickness of the gap is equal to 2e. This model can also be used for a situation where a flexible plate and a rigid plate are coupled, provided that only half the total fluid thickness is considered.

a) Solve the Equations for Fluid Motion

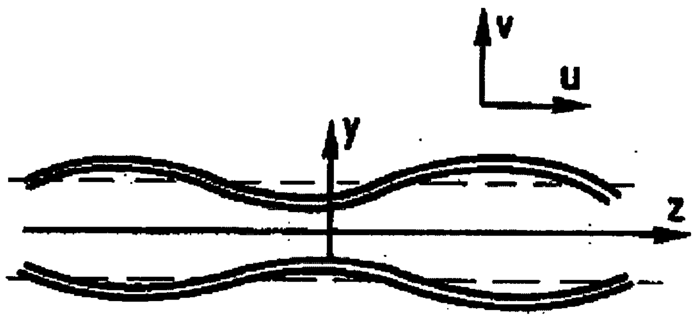
$$\rho_f\omega^2 X_f + gradp - i\mu\omega\Delta X_f = 0$$
$$divX_f = 0$$
(Equation 15.12 of Reference 1)

The fluid motion has two components that are defined as follows:

$$X_f = \begin{pmatrix} u(y)\sin(\lambda z / e) \\ v(y)\cos(\lambda z / e) \end{pmatrix},$$

Where the upper component is parallel to plates and the lower component is normal to plates.

The fluid pressure (p) is defined as follows: $p = \rho_f q(y)\cos(\lambda z / e)$



Substitution into equation 15.12 yields the following system of equations:

$$\frac{\lambda}{e}u + \frac{dv}{dy} = 0$$

$$i\omega\left[\left[i\omega + \upsilon\left(\frac{\lambda}{e}\right)^2\right]u - \upsilon\frac{d^2u}{dy^2}\right] - \frac{\lambda}{e}q = 0$$ (System of Equations 15.13 of Reference 1)

$$i\omega\left[\left[i\omega + \upsilon\left(\frac{\lambda}{e}\right)^2\right]v - \upsilon\frac{d^2u}{dy^2}\right] + \frac{dq}{dy} = 0$$

where the kinematic viscosity $(v) = \dfrac{\mu}{\rho_f}$

Note that the author has dropped the spatial dependency terms in the above expressions.

The boundary conditions which correspond to continuity at the fluid/structure interface are:

y=e yield u=0, v=X_0

y=-e yield u=0, v=-X_0

By eliminating the expressions "u" and "q" in equation (15.13) and retaining "v" as the remaining unknown variable, the following expression is obtained:

$$\frac{d^4v}{dy^4}-2\left(\frac{\lambda}{e}\right)^2\frac{d^2v}{dy^2}+\left(\frac{\lambda}{e}\right)^4 v-\frac{i\omega}{\upsilon}\left[\frac{d^2v}{dy^2}-\left(\frac{\lambda}{e}\right)^2 v\right]=0 \qquad \textit{(Equ. 15.14)}$$

Because of the symmetry that exists in the boundary conditions, the anti-symmetric solution for v(y) is obtained using the following expression:

$$\upsilon(y)=A\sinh\left(\frac{\lambda}{e}y\right)+B\sinh\left(\frac{\alpha}{e}y\right)$$

provided the following condition for "α" is respected:

$$\alpha^2=\lambda^2+\frac{i\omega e^2}{\upsilon}$$

Applying the boundary conditions for y=e yields:

$$\upsilon=X_0$$
$$\frac{d\upsilon}{dy}=0$$

$$\Rightarrow \begin{array}{l} A\sinh(\lambda)+B\sinh(\alpha)=X_0 \\ \lambda A\cosh(\lambda)+\alpha B\sinh(\alpha)=0 \end{array}$$

This allows the unknown coefficients A and B to be obtained, thereby yielding the velocity component "v":

$$\upsilon(y)=X_0\frac{\alpha\cosh(\alpha)\sinh(\lambda y/e)-\lambda\cosh(\lambda)\sinh(\alpha y/e)}{\alpha\sinh(\lambda)\cosh(\alpha)-\lambda\cosh(\lambda)\sinh(\alpha)}$$

According to the second expression in the system of equation (equation 15.13), the pressure term (q) is equal to:

$$q(e)=q(-e)=i\omega v\frac{e^2}{\lambda^2}\left(\frac{d^3\upsilon}{dy^3}\right)_{y=e}$$

Note that the continuity equation is also used here but, was not mentioned by the author:

$$=-i\omega\frac{\alpha\upsilon X_0}{\lambda e}(\alpha^2-\lambda^2)\frac{\cosh(\alpha)\cosh(\lambda)}{\alpha\sinh(\lambda)\cosh(\alpha)-\lambda\cosh(\lambda)\sinh(\alpha)}$$

$$=\frac{\omega^2X_0e}{\lambda}\frac{\alpha}{\alpha\tanh(\lambda)-\lambda\tanh(\alpha)}$$

b) Evaluate The Generalized Force (Per Unit Area) Exerted By The Fluid Onto The Plates Undergoing Flexural Motion

Because the tangential displacement of the plate is null, the generalized force per unit area is defined as follows:

$$F_\Sigma = \frac{\lambda}{2\pi e}\int_0^{2\pi e/\lambda}\left[f_n(e,z)\right] + fn(-e,z)\cos(\lambda z/e)dz$$

(Note from translator): The author has dropped the structural amplitude term X_0. This is inconsequential for the rest of the derivation because only the ratio of imaginary part / real part of generalized force is sought.

(Note from translator): Here the author references previous theoretical developments not strictly needed here. He uses the fact that the normal force (f_n) per unit area exerted by the fluid onto the structure is equal the pressure minus two times the normal velocity gradient times the fluid dynamic velocity (μ).

$$F_\Sigma = \frac{\lambda}{2\pi e}\int_0^{2\pi e/\lambda}\rho_f\left[q(e)+q(-e)\right]\cos^2(\lambda z/e)dz$$

$$-2\mu\frac{i\omega\lambda}{2\pi e}\int_0^{2\pi e/\lambda}\left[\left(\frac{d\upsilon}{dy}\right)_e+\left(\frac{d\upsilon}{dy}\right)_{-e}\right]\cos^2(\lambda z/e)dz$$

The second term is zero because of the null velocity gradient at fluid-structure interface so, only the pressure term needs to be estimated.

$$= \frac{\lambda}{2\pi e}\int_0^{2\pi e/\lambda}\rho_f\left[q(e)+q(-e)\right]\cos^2(\lambda z/e)dz = \rho_f q(e)$$

$$F_\Sigma = \rho_f e\omega^2 X_o\frac{\alpha/\lambda}{\alpha\tanh(\lambda)-\lambda\tanh(\alpha)}$$

Because α is complex-valued, F_Σ has a real part and an imaginary part, which corresponds to a force that is in phase or has a 90° lag with respect to structural motion. Deriving each part leads to complicated mathematical expression.

c) Examine the Case Where the Fluid Layer is not too Thin

When the fluid layer is not too thin then, $\frac{\omega e^2}{\nu} >> 1$

This is the case for shell modes of interest for the U.S. EPR. Considering a frequency range of [ ] to [ ] Hz, a gap thickness of [ ] mm[ ] inch) and a fluid kinematic viscosity of water at 300°C (572°F) of about 1.1 x 10-7m²/s (1.7 x 10-4 inch2/sec) leads to ratio of about 1800.

With this simplification, it is also assumed that the flexural wavelength is large compared to the fluid layer thickness or:

λ<<1

This is also the case for the shell modes of interest for the U.S. EPR, because the shortest flexural wavelength (n=5) is still more than 100 times larger than the fluid gap thickness).

Based on the aforementioned hypothesis, an approximate expression can be obtained for α.

$$\alpha \cong \frac{1+i}{\sqrt{2}}\sqrt{\frac{\omega e^2}{\nu}} \quad (|\alpha|>>1)$$

This in turn leads to:

$$F_\Sigma \cong \rho_f e\omega^2 X_o \frac{1/\lambda^2}{1-1/\alpha} \cong \rho_f e\omega^2 X_0 (1/\lambda^2)(1+1/\alpha)$$

From above:

The real part is: $(F_\Sigma)_r = \rho_f \dfrac{e\omega^2 X_0}{\lambda^2}$

The imaginary part is: $(F_\Sigma)_i = -(F_\Sigma)_r \sqrt{\dfrac{\nu}{2\omega e^2}}$

The expression:

$$\frac{(F_\Sigma)_r}{\omega^2 X_0} = \rho_f \frac{e}{\lambda^2}$$

corresponds with the added mass by unitary corresponding to the inertial effect of the fluid.

$(F_\Sigma)_i$ corresponds with the dissipative effect related to the viscous losses in the fluid. This term is small compared to the previous one.

$\dfrac{\nu}{\omega e^2}$ <<1 is indeed the *Stokes number* associated with the gap.

The viscous effect term is not proportional to the forcing frequency (ω). This means that the fluid viscous effect on the plate is not proportional to the structural velocity of the plates.

For the case of a coupled fluid-structure eigenmode having a mode shape identical to that considered previously, presume that the added fluid mass is the primary contributor to the coupled mode generalized mass. This is the case for the shell modes of interest for the U.S. EPR, for which modal frequencies in wet conditions are at least 10 times lower than in dry conditions, which means that the fluid contribution to the wet modal mass is at least 100 times larger than the structural contribution.

By letting "ω_o" denote the resonance circular frequency, the fluid viscous effect produce an equivalent reduced damping that can be expressed as:

$$\varepsilon_o = \frac{1}{2}\frac{(F_\Sigma)_i}{(F_\Sigma)r} \Rightarrow \varepsilon_o = \frac{1}{2}\sqrt{\frac{\nu}{2\omega_o e^2}}$$

d) Numerical Application of Expression for Damping

Using the expression obtained above for damping and considering the following attributes for the [ ] Hz shell mode of the U.S. EPR, yields the following critical damping ratio:

water gap (e) = [ ] mm [ ] inches)

kinematic viscosity (ν) =1.1 x 10^{7}m²/s (1.7 x 10^{4} inch^2/s)

resonant shell mode frequency equal to [ ] Hz.

[ ]

which, agrees with the value reported in Technical Report ANP-10306P, Section 4.2.5.3.4.

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.

References:

1. Vibrations des structures – Interactions avec les fluides – Sources d'excitations aléatoires - R.J. GIBERT – Eyrolles Editions, 1988.

Question 03.09.02-112:

This is related to RAI 03.09.02-48 (b).

The applicant is requested to provide a discussion and of the application of a frequency bias and uncertainty in their FEA predictions and the specifics about the locations, models, and reason for placement of transducers for the water filled modal testing (as originally requested in RAI 03.09.02-29b).

Response to Question 03.09.02-112:

The modal analyses of the HYDRAVIB mockup uses the material properties established in RCCM code (French equivalent to the ASME Section III code) and the nominal (design) dimensions of the components at the 1/8.168 scale. Therefore, no bias or uncertainties are incorporated into the analytical evaluations that determine the natural frequencies and mode shapes of the HYDRAVIB components.

The uncertainty in the turbulent response that could be attributed to the forcing function for random turbulence that is obtained from the flow test described in Technical Report ANP-10306P, Section 4.2.2.4 and its application to the finite element model of the HYDRAVIB is reviewed in this paragraph. The response to Question 03.09.02-114 provides a review of the raw data obtained from the dynamic pressure measurements that was used in part to develop the forcing function for turbulence. As stated in that response, a best estimate approach was used to define the empirical definition of the PSDs and no attempt was made to introduce conservatisms. As shown with the PSDs provided in Technical Report ANP-10306P, Figures 4-12, 4-13, 4-14, 4-29, 4-34, the distribution of turbulent energy in the PSD decays with increasing frequency. Therefore, a low estimation of the natural frequencies with the numerical solution will create a conservative estimate of the response to turbulence. A high estimation of the natural frequencies with the analytical model will provide an unconservative response. However, the differences in the 1-sigma (or 1-rms) response resulting from the variation of the natural frequencies will be insignificant since the response is determined from the integration of the response PSD curve. Thus, a slight shift in frequency of the peak response either to the left or right on the response PSD curve when integrated with respect to frequency will yield approximately the same area under the curve or approximately the same rms response.

A comparison of the natural frequencies and the response to turbulence of the components of the HYDRAVIB mockup that were obtained with the flow test and the results obtained from the numerical solutions is provided in Technical Report ANP-10306P, Section 4.2.4 and shows that an acceptable agreement is attained without the consideration of frequency bias and the uncertainties associated with the forcing function for random turbulence.

The instrumentation installed on the HYDRAVIB mockup is identified in Technical Report ANP-10306P, Figure 4-3 and Figure 4-4. The locations of accelerometers, displacement sensors, and strain gages were selected based on confirming the theoretical mode shapes and frequencies that were substantiated with the flow tests. Technical Report ANP-10306P, Section 4.2.1.2 provides additional rationale for the selection and location of the instrumentation installed on the HYDRAVIB mockup.

Refer to the response to RAI 422, Question 03.09.02-108 for a review of the bias errors and uncertainties in the calculations of the natural frequencies and the response to turbulence that is expected in the full scale analytical solution.

Refer to the response to RAI 422, Question 03.09.02-87 and the changes identified for the Technical Report ANP-10306P that are prescribed in that response for a review of the bias errors and uncertainties and how they will be considered during the acquisition of test data during hot functional testing of the full scale design.

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.

ANP-10306NP Technical Report Markups

5.4.3 Process for Determining Frequency, Modal Content and the Maximum Values of Response

The initial reduction of the data is performed during the test to determine whether or not the responses are within the acceptable limits. Spectrum analysis is used to analyze the natural frequencies and the vibratory characteristics of each component to compare to the results from the pre-operational vibration assessment program (See Section 4.0). The maximum stress values are also calculated to confirm the structural integrity.

5.4.4 Bias Errors and Random Uncertainties

Bias error and uncertainties depend on the accuracy of both the acquisition system and the method used for the reduction of data. The accuracy of the data acquisition is primarily a function of instrument error and the accuracy of the data reduction is a function of the number of data samples, the bandwidth, etc. These bias errors and random uncertainties are defined by the specification for the data acquisition system and signal processing equipment. The total instrument errors are calculated using a root sum of the squares (RSS) method prior to hot functional testing. Sampling and averaging methods described in Section 5.4.1 combined with high quality sensors and modern digital recording minimize the random and bias errors.

5.5 Acceptance Criteria for the Tests

The RMS response of the RV internal component is determined by calculation from the captured time waveform or from the integration of the PSD for specific frequency bands for each of the transducers mounted on the RV internals. This vibration amplitude and stress response is compared to the pre-operational theoretical values and the acceptance criteria identified for each component in Section 4.0. The stresses must show sufficient safety margins based upon the design fatigue curves presented in Figure 4-21. Further, the theoretical and measured values for the natural frequencies of the RV internal components are compared to verify that the structural modeling has accurately accounted for the hydrodynamic mass and stiffness of the components.

The acceptance criteria will account for transducer location, operating conditions for each test, uncertainties and biases, and margins to be added for conservatisms to ensure that the allowable fatigue stress will not be exceeded. The best estimate stress values determined in Section 4.0 will be used as a basis for comparison with the measured values for evaluating the accuracy of the FIV predictive methods. The peak stresses as well as the distribution of stresses throughout the component are determined by the analytical solutions. Due to practical considerations, such as situations where peak stresses occur at welds or at threaded joints where strain gages cannot be positioned, difficulties in accessing a desired location of peak stress, or difficulties in routing of instrument cables, the instrumentation may have to be located in non-peak stress positions. In these cases, adjustments will be made to scale the measured strains and resulting stresses to the peak stresses for the component. These biases and uncertainties will be taken into consideration when establishing the acceptance criteria for the HFT instrumentation.

Question
03.09.02-87

The impact of the uncertainties and bias associated with the instrumentation and other equipment that will be used to perform the HFT with the acceptance criteria defined above is not known at this time. When the instrumentation and data acquisition system have been designed, this bias and uncertainty will be incorporated in a manner that will not diminish the criteria established above.

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The HFT is acceptable if there is no evidence of excitation to the RV internal components due to fluid-elastic instability, acoustic resonance, and vortex-shedding lock-in. Because of the characteristics of the RCS design, vibrations of the RV internals are expected to be created primarily from random turbulence and acoustic pressure fluctuations associated with the RCP vane passing frequencies and the low frequency loop acoustics. Accuracy within a factor of 2.0 is expected for the vibrations induced by turbulence. Because the magnitude of the acoustic pressure fluctuations are verified at the time of HFT, it is difficult to estimate the degree of accuracy expected for the vibration associated with this source of excitation.

~~If deviation between the theoretical prediction and the measured values is observed, then these differences are evaluated for impact on the integrity of the RV internals. If necessary, appropriate changes are made to the theoretical evaluation to obtain an agreement in the response of the RV internals that are deemed critical to the integrity of the RV internals. This could include revising the structural model to consider a different hydrodynamic mass and stiffness, damping ratios, or to correct for the magnitude and coherence of the forcing function through the current definitions for the PSDs, correlation length or convective velocities.~~

~~As discussed in Section 4.2.7 and Section 4.2.8, the response of the lower internals is primarily dominated by the pendulum mode [(~ 8 Hz),] and this mode has the most dynamic influence on the excitation of the fuel bundle. The flow excitations of the CB shell modes do not create significant stress in the CB member, and they do not create excitation to the fuel bundle. Greater attention is given to the FIV inputs that are most influential in obtaining agreement with the response of the pendulum mode of the lower internals. Similar reasoning is applied to the other RV internal components.~~

5.6 Evaluation Plan for the Test Data

Tables of the maximum allowable test values will be generated for the sensors for use in the detailed test procedures. These maximum allowable test values will be developed based upon consideration of the bias and uncertainties of the instrumentation described in the acceptance criteria of Section 5.5. These maximum allowable test values will provide guidance for the test operators when they are conducting the HFT and allow the operators to determine the margins between the sensor values being measured and the allowable values as the tests are progressing.

If deviation between the theoretical prediction and the measured values is observed, then these differences will be evaluated for impact on the integrity of the RV internals. If necessary, appropriate changes will be made to the theoretical evaluation to obtain an agreement in the

Question 03.09.02-87

response of the RV internals that are deemed critical to the integrity of the RV internals. This could include revising the structural model to consider a different hydrodynamic mass and stiffness, damping ratios, or to correct for the magnitude and coherence of the forcing function through the current definitions of the PSDs, correlation length or convective velocities.

As described in Sections 4.2.7 and 4.2.8, the response of the lower internals is primarily dominated by the pendulum mode [(~ 8 Hz)], and this mode has the most dynamic influence on the excitation of the fuel bundle. The flow excitations of the CB shell modes do not create significant stress in the CB members or excitation of the fuel bundle. Greater attention is given to the FIV inputs that are most influential in obtaining agreement with the response of the pendulum mode of the lower internals. Similar reasoning is applied to the other RV internal components.

Question 03.09.02-87