ArevaEPRDCPEm Resource

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Sent: Friday, July 30, 2010 2:39 PM
To: Tesfaye, Getachew
Cc: DELANO Karen (AREVA); ROMINE Judy (AREVA); BENNETT Kathy (AREVA); VAN NOY Mark (EXTERNAL AREVA); CORNELL Veronica (EXTERNAL AREVA)
Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 384, FSAR Ch. 3
Attachments: RAI 384 Question 03.09.02-68 Response DRAFT - US EPR DC.pdf

Getachew,

To support the final response date for question 03.09.02-68 of August 30, 2010, a draft of the response is provided for your review. Let me know if the staff has questions or if the response can be sent as final.

Thanks,
Marty

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Response to

Request for Additional Information No. 384 (4350, 4351, 4469, 4498, 4527), Revision 0

5/20/10

U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.03.02 - Tornado Loads
SRP Section: 03.04.02 - Analysis Procedures
SRP Section: 03.08.04 - Other Seismic Category I Structures
SRP Section: 03.09.02 - Dynamic Testing and Analysis of Systems Structures and Components
SRP Section: 03.10 - Seismic and Dynamic Qualification of Mechanical and Electrical Equipment

Application Section: FSAR Chapter 3

QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)
QUESTIONS for Engineering Mechanics Branch 2 (ESBWR/ABWR Projects) (EMB2)

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Question 03.09.02-68:

Additional information needed regarding FSAR Section 5.4.2.3.1:

a. In FSAR Section 5.4.2.3.1, it is stated that the evaluation included analysis of the tube support system, research with tube vibration model tests and operating experience of similar SG designs in France.

   Provide the applicable details or reference documents relating to the vibration model tests and operating experience of similar SG designs in France, for staff review.

b. In FSAR Section 5.4.2.3.1, it is stated that the tube bundle was evaluated for fluid-elastic instability over the first 60 vibration modes by evaluating the ratio of the critical velocity to the effective cross-flow velocity to an allowable fluid-elastic stability margin of 1.3. The evaluation was performed using parameters including "Connors' constants" and damping for the straight and U-bend sections which were assessed through testing. The results indicated that fluid-elastic instability will not occur during full-power, steady-state, normal operating conditions.

   Provide the applicable details or reference documents to support the results indicating that fluid-elastic instability will not occur during full-power, steady-state and normal operating conditions for staff review.

c. In FSAR Section 5.4.2.3.1, it is stated that for flow-induced vibration resulting from random turbulence and vortex-shedding excitations, the resulting amplitudes and stresses were computed considering the cumulative effect of the first 60 vibration modes. The results were compared to allowable limits that would prevent high cycle fatigue failure and tube impacts with adjacent tubes. Both an un-degraded tube and a degraded tube with 40 percent through-wall wear flaws at the tube support locations were evaluated.

   Provide the applicable details or reference documents to support the statement that the allowable limits that would prevent high cycle fatigue failure and tube impacts would not be exceeded for staff review.

d. In FSAR Section 5.4.2.3.1, it is stated that consideration was given to possible excitation from the RCP acoustic pressure fluctuations resulting from the blade passing frequencies. The effects of this excitation mechanism on the tube bundle were shown to be negligible.

   Provide the applicable details or reference documents to support the statement that the effects from acoustic pressure fluctuations resulting from the blade passing frequencies would be negligible for staff review.

Response to Question 03.09.02-68:

Response for subpart (a.):

AREVA NP performed tube vibration testing to determine the damping ratio and Connors' Constant for U.S. EPR Steam Generator tube bundle design characteristics. This testing also evaluated the inclusive damping ratio, which takes into account damping associated with non-linear tube to tube-support-plate (TSP) interactions and secondary side fluid effects.

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Tube-to-TSP interaction damping ratio was determined using EVA 2 mockup tests. The EVA 2 mockup consisted of a cylindrical pressure vessel with a nominal diameter of 27.6 inches that are closed at both ends by ellipsoidal heads. Eighty U-tubes (eight rows of ten tubes each) were installed in a 1.08 inch square pitch pattern. Tube OD was 0.750 inch with a wall thickness of 0.043 inches. The straight section length for each tube was 86.7 inches. The smallest U-bend radius was 2.95 inches and the largest was 12.67 inches. Two quatrefoil-broached TSP were installed in the test section at 40.87 inches and 81.73 inches above the tube-sheet (TS). The five rows of U-bend sections were fixed by anti-vibration bars (AVB).

Secondary side two phase fluid damping ratio was based on industry data (References 1 through 4). An additional 2 percent damping was credited to tube elevations where the void fraction was between 60 percent and 90 percent.

The value of Connors' constant (β) depends on the type of tube bundle and the phase of secondary side fluid. Connors' coefficient values were developed from empirical data collected during experiments and mockup tests, particularly the SRM and EVA tests (References 1 through 4). Results of these tests are discussed in EPRI report NP-4559 (May 1986) and EPRI SG reference book (1985).

For straight tube sections, based on conservative values derived from experimental results, a Connors' constant (β) equal to 3.0 was determined. For the U-bend region, a lower bound value of 4.0 for the Connors' constant was determined. These values are derived from the following test results:

SRM test results:

Fluid-elastic instability was observed in a single phase flow regime to determine a Connors' constant (β) equal to 6.5 and a reduced damping of 3 percent.

EVA test results:

When fluid flow is a steam/water mixture, the Connors' constant (β) is at least equal to that measured in single phase flow condition. For the U-bend region, EVA tests showed that a Connors' constant (β) equal to 6.5 is the lower bound. However, due to damping coefficient measurement uncertainty, a supplementary margin was considered and a Connors' constant (β) equal to 4.0 was selected for the U-bend region of the tube bundle.

Response for subpart (b.):

The U.S. EPR steam generator tube bundle FIV analysis is available for NRC inspection.

Response for subpart (c.):

The U.S. EPR steam generator tube bundle FIV analysis is available for NRC inspection.

Response for subpart (d.):

The U.S. EPR steam generator tube bundle FIV analysis is available for NRC inspection.

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References:

1. K.M. Bourcher, C.E Taylor, and M. Yetisire, "Vibration and Impact Forces Due to Two-Phase Cross-Flow in U-Bend Region of Heat Exchangers," *Proceedings of Sixth International Conference on Flow-Induced Vibration*, London, UK, pp. 404-411.
2. M. J. Pettigrew, and C.E. Taylor, "Two Phase Flow-Induced Vibration," *Technology for the 90s*, ASME Special Publication, Edited by M. K. AuYang, 1993..
3. K. Hirota et al, "Dynamics of In-Line Tube Array in HCFC-123 Two-Phase Flow," *Proceedings 4th International Symposium in Fluid-Structure Interaction*, Vol. II, ASME AD, Vol. 53-2, pp. 399-420, Edited by M.P. Paidoussis, 1997.
4. M. K. Au-Yang, *Flow-Induced Vibration of Power and Process Plant Components, Figure 9-14.* New York: ASME Press, 2001.

FSAR Impact:

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

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