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Your ref: Docket No. 52-006
Our ref: DCP/NRC2241

August 28, 2008

Subject: AP1000 Response to Request for Additional Information (SRP3.9.2)

Westinghouse is submitting a revised response to the NRC request for additional information (RAI) on SRP Section 3.9.2. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

A revised response is provided for RAI-SRP3.9.2-EMB1-01 and -11. This response completes all requests received to date for SRP Section 3.9.2. A response to RAI-SRP3.9.2-EMB1-01 through -11 was submitted under letter DCP/NRC2163 dated June 20, 2008.

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Request for Additional Information on SRP Section 3.9.2

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NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3.9.2

RAI Response Number: RAI-SRP3.9.2-EMB1-01
Revision: 1

Question:

Describe the design and modeling of the core barrel/upper core plate as they relate to flow-induced vibration (FIV) structural dynamic analysis. What is the uncertainty that the model of the interface employed in the modal analysis is representative of the physical support?

Westinghouse Response:

The upper core plate is modeled as a part of the upper internals in the system model. The gaps between the upper core plate (and core shroud) slots and the alignment plates mounted on the core barrel are also modeled (see Figures 1 and 2).

To ensure that the entire range of possible gaps between the upper core plate and the core barrel alignment plates is evaluated, time-history analyses were performed with various sets of gaps (upper core plate, top core shroud plate, and core barrel lower supports). Table 6-9 in WCAP-15949-P, Rev 2 (Reference 1), shows the gaps modeled and the resulting loads. The resulting highest load was used in the structural analysis.

References:

1. Westinghouse Technical Report, WCAP-15949-P, Rev. 2, "AP1000 Reactor Internals Flow-Induced Vibration Assessment Program," June 22, 2007.

Design Control Document (DCD) Revision: ~~None.~~

<u>Additional text as shown below will be included in Section 3.9.2.3.</u>

3.9.2.3 Dynamic Response Analysis of Reactor Internals under Operational Flow Transients and Steady-State Conditions

The vibration characteristics and behavior due to flow-induced excitation are complex and not readily ascertained by analytical means alone. Assessment of vibrational response is done using a combination of analysis and testing. Comparisons of results obtained from reference plant vibration measurement programs have been used to confirm the validity of scale model tests and other prediction methods as well to confirm the adequacy of reference plant internals regarding flow induced vibration. The flow-induced vibration assessment is documented in WCAP-15949 (Reference 18).

Reactor components are excited by flowing coolant, which causes oscillatory pressures on the surfaces. The integration of these pressures over the applied area provides the forcing functions to be used in the dynamic analysis of the structures. In view of the complexities of the geometries and the random character of the pressure oscillations, a closed form solution of the vibration problem by the integration of the differential equations is not always practical and realistic.

The determination of forcing functions as a direct correlation of pressure oscillations cannot be practically performed independently of the dynamic characteristics of the reactor vessel internals structure. The main objective is to establish the characteristics of the forcing functions that determine the response of the structures.

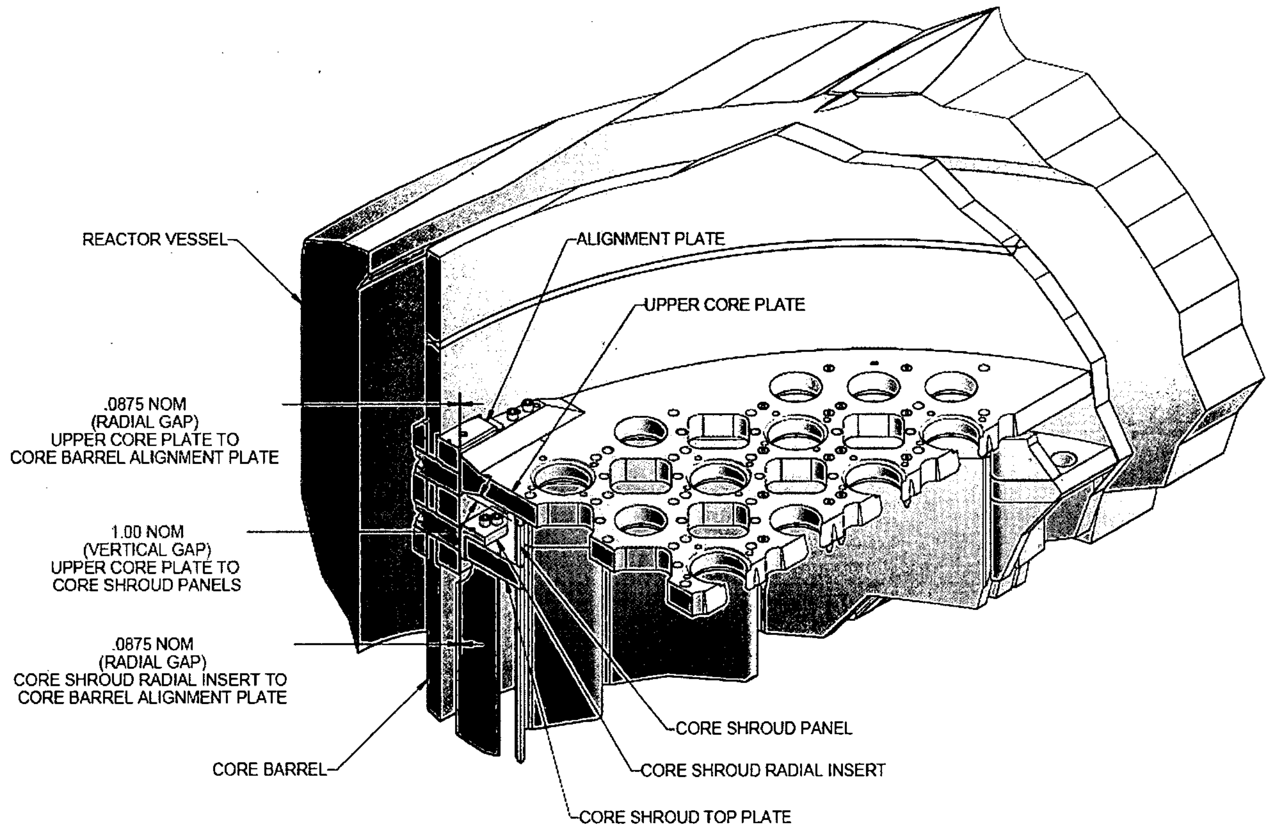
By studying the dynamic properties of the structure from previous analytical and experimental work, the characteristics of the forcing function are deduced. These studies indicate that the most important forcing functions are flow turbulence and pump-related excitation. The relevance of such excitation depends on factors that include the type and location of components and flow conditions.

The effects of these forcing functions have been studied in tests performed on models and reference plants. These effects will be factored into the analysis models used to evaluate flow-induced vibrations in the AP1000 reactor internals.

The structural analysis models include modeling of the gaps between the core barrel and reactor vessel, the core barrel and upper core plate, and core barrel and core shroud. To ensure that the range of possible gaps between the components is evaluated, time-history analyses are performed with various sets of gaps. The resulting loads are evaluated and the resulting highest load for each component is used in the structural analysis.

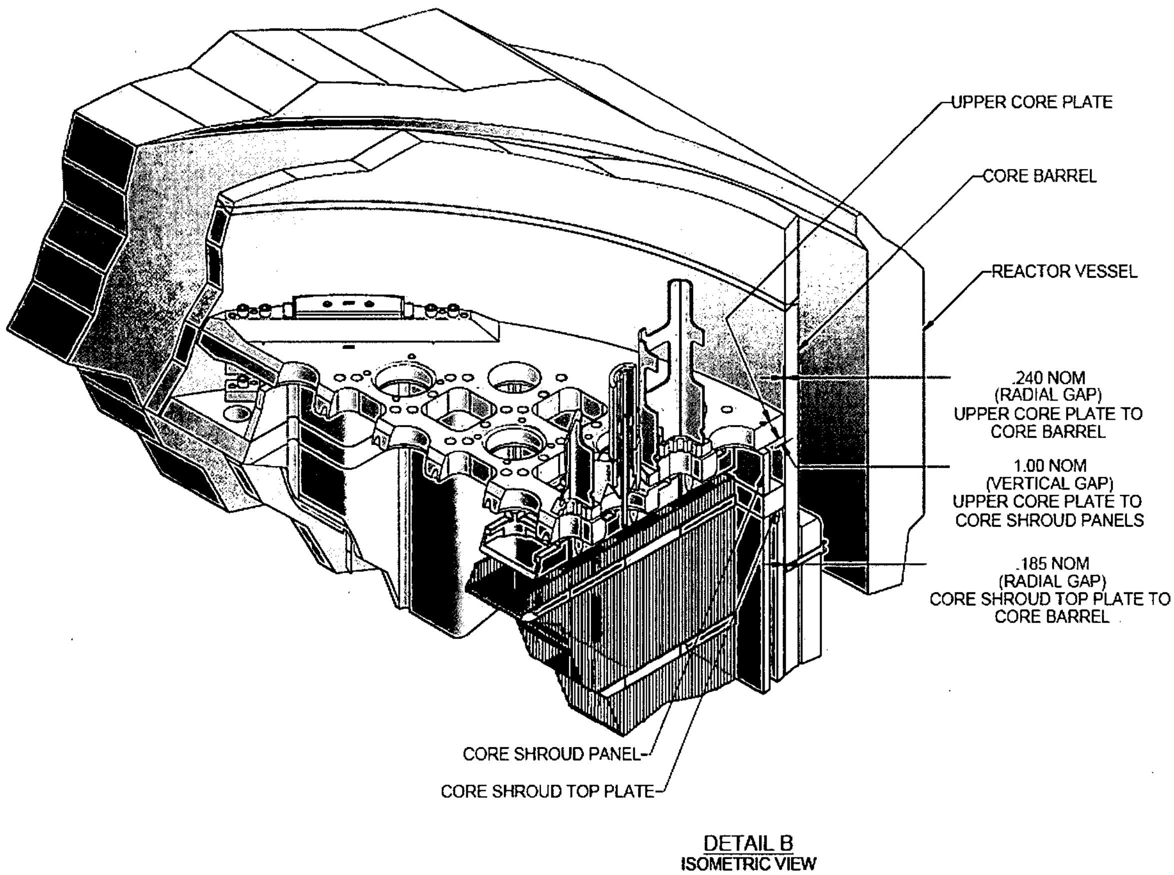
PRA Revision:
None

Technical Report (TR) Revision:
None



DETAIL A
ISOMETRIC VIEW

Figure 1



UPPER CORE PLATE
CORE BARREL
REACTOR VESSEL
.240 NOM
(RADIAL GAP)
UPPER CORE PLATE TO
CORE BARREL
1.00 NOM
(VERTICAL GAP)
UPPER CORE PLATE TO
CORE SHROUD PANELS
.185 NOM
(RADIAL GAP)
CORE SHROUD TOP PLATE TO
CORE BARREL
CORE SHROUD PANEL
CORE SHROUD TOP PLATE
DETAIL B
ISOMETRIC VIEW

Figure 2

RAI Response Number: RAI-SRP3.9.2-EMB1-11
Revision: 1

Question:

Discuss how the uncertainties associated with acoustic analysis have been factored in the results of the updated calculations. Section 5.1.3.1 of WCAP 15949 states:

"The impact of the results of the updated calculations has been addressed in the individual component analyses for the guide tube, upper support column, core barrel, and core shroud. The reactor internals were evaluated for the RCP startup conditions shown in Table 5-9a. The updated reactor conditions are shown in Table 5-9b. Note that the updated conditions are less severe since the time to reach hot standby is the same for the new and old conditions but the flow rates during heat-up are lower for the new conditions. Therefore, fluid velocities are lower for the updated startup conditions than for the evaluated startup conditions. Lower flow rates would result in lower flow turbulence loads."

In order to evaluate the impact on predicted pressure differences due to the design changes, an updated ACSTIC calculation was performed. However, simplifying assumptions were made in the acoustic modeling. Therefore the above conclusions are not necessarily valid unless adequate justification is provided that the uncertainties associated with the ACSTIC calculation have been taken into consideration.

Westinghouse Response:

The uncertainties associated with the ACSTIC calculation were considered by employing a general design basis in which the RCP-related responses are taken to be coincident with natural frequency if the natural frequency is within ±10 % of the RCP excitation frequency. The calculated maximum forces from this resonance condition were then utilized in the reactor internals component structural evaluation.

Design Control Document (DCD) Revision: ~~None.~~

Additional text as shown below will be included in Section 3.9.2.3.

3.9.2.3 Dynamic Response Analysis of Reactor Internals under Operational Flow Transients and Steady-State Conditions

The vibration characteristics and behavior due to flow-induced excitation are complex and not readily ascertained by analytical means alone. Assessment of vibrational response is done using a combination of analysis and testing. Comparisons of results obtained from reference plant vibration measurement programs have been used to confirm the validity of scale model tests and other prediction methods as well to confirm the adequacy of reference plant internals regarding

flow induced vibration. The flow-induced vibration assessment is documented in WCAP-15949 (Reference 18).
Reactor components are excited by flowing coolant, which causes oscillatory pressures on the surfaces. The integration of these pressures over the applied area provides the forcing functions to be used in the dynamic analysis of the structures. In view of the complexities of the geometries and the random character of the pressure oscillations, a closed form solution of the vibration problem by the integration of the differential equations is not always practical and realistic.

The determination of forcing functions as a direct correlation of pressure oscillations cannot be practically performed independently of the dynamic characteristics of the reactor vessel internals structure. The main objective is to establish the characteristics of the forcing functions that determine the response of the structures.

By studying the dynamic properties of the structure from previous analytical and experimental work, the characteristics of the forcing function are deduced. These studies indicate that the most important forcing functions are flow turbulence and pump-related excitation. The relevance of such excitation depends on factors that include the type and location of components and flow conditions.

The effects of these forcing functions have been studied in tests performed on models and reference plants. These effects will be factored into the analysis models used to evaluate flow-induced vibrations in the AP1000 reactor internals.

<u>Loads on the reactor vessel internals components result from the reactor coolant pump pulsations. Using a reactor coolant system analysis, the resulting pressure differences across the components are calculated for inclusion in the structural evaluation models. The uncertainties associated with these component loads are considered by employing a general design basis in which the reactor coolant pump related pressure pulsations are taken to be coincident with the component natural frequency if the natural frequency is within ±10% of the reactor coolant pump excitation frequency. The calculated maximum forces from this resonance condition are utilized in the component structural evaluation.</u>

PRA Revision:
None

Technical Report (TR) Revision:
None