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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002665

October 19, 2009

Subject: AP1000 Response to Request for Additional Information (SRP 3)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 3. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP3.8.3-SEB1-03 R1

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, Manager
Licensing and Customer Interface
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/Enclosure

1. Response to Request for Additional Information on SRP Section 3

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3

RAI Response Number: RAI-SRP3.8.3-SEB1-03
Revision: 1

Question:

DCD Section 3.8.3.4.1 covers the seismic analyses of the containment internal structures (CIS). Subsection 3.8.3.4.1.1 describes the development of the 3D lumped-mass stick model of the CIS based on the structural properties obtained from a 3D finite element model using 3D shell elements. Subsection 3.8.3.4.1.2 describes the stiffness assumptions for local seismic analyses of the in-containment refueling water storage tank (IRWST). No description is provided for the model development and analysis, including the stiffness assumptions, for the global seismic analysis of the CIS. Prior revisions of the DCD did provide a description of this subject in a separate subsection; however, DCD Rev. 16 removed all of this information. Westinghouse is requested to provide a description of the CIS model, the stiffness assumptions utilized, and basis for the selection of the stiffness for the CIS and auxiliary building modules. In addition, DCD Table 3.8.3-2 was revised to utilize the "Monolithic Case 3" concrete stiffness representation of the CIS in the 3D finite element analysis using the equivalent static and response spectra analyses. Westinghouse is requested to explain why the CIS stiffness values were revised from the monolithic case 1 to monolithic case 3, and what is the technical basis for not evaluating the range of possible stiffness values between Cases 1 to 3.

If your response to this request for additional information will reference Revision 17 to the AP1000 DCD, please provide an exact reference.

Additional Request (Revision 1):

NRC Staff requests that in the Structural Modules for CIS DCD section that the information removed from DCD Section 3.8 be returned to the DCD and revised stiffness values be included in the DCD.

Westinghouse Response:

Section 3.8.3.4.1.2 was removed since stiffness assumptions for global seismic analyses are part of Section 3.7, Seismic Design. Description is provided for model development and analysis for the containment internal structures (CIS) in DCD Section 3.7.2.3.1 (Rev. 16 &17). Further, Technical Report 03 (Reference 1) was written to provide more details of the seismic analyses for soil sites than provided in the DCD. It is noted that DCD subsection 3.8.3.4.1.1 (Rev. 17), Finite Element Model is not up to date since it discusses 3D lumped-mass stick model of the CIS that is no longer used, a shell model is now used. The first sentence of the first paragraph of this subsection is removed, and reference is made to DCD Section 3.7 and 3G.

The stiffness assumptions for the global seismic analysis of the CIS and auxiliary building modules is discussed in DCD Section 3.7.2.3 (Rev. 16 & 17) and DCD Section 3.7.2.3.1 (Rev. 16 & 17). It is stated in DCD Section 3.7.2.3:

> "The finite element models of the coupled shield and auxiliary buildings, and the containment internal structures are based on the gross concrete section with the modulus based on the specified compressive strength of concrete reduced by a factor of 0.8 to consider the effect of cracking as recommended in Table 6-5 of FEMA 356 (Reference 5)."

In DCD Section 3.7.2.3 it is stated:

> "The properties of the concrete-filled structural modules are computed using the combined gross concrete section and the transformed steel face plates of the structural modules. The modulus is reduced by a factor of 0.8 to consider the effect of cracking."

The concrete stiffness was changed to Monolithic Case 3 to be consistent with the local seismic analyses of in-containment refueling water storage tank discussed in DCD Section 3.8.3.4.1.2 (Rev. 16 & 17). Foot note 2 was added to Table 3.8.3-2 to refer to DCD Section 3.7 for the specifics related to the global containment internal structures seismic analyses.

Westinghouse Response (Revision 1):

The first paragraph of DCD subsection 3.8.3.4.1.1 is changed in the Revision 0 response to reflect that the three dimensional lumped mass stick model of the CIS is no longer used. The structural modules are modeled within the 3D finite element shell models described in DCD subsection 3.7 and Appendix 3G. For consistency with DCD Section 3.7.2.3 a sentence will be added related to the reduction of concrete modulus by a factor of 0.8 to reflect cracking.

References:

1. APP-GW-S2R-010 (Technical Report 03), "Extension of Nuclear Island Seismic Analyses to Soil Sites.

Design Control Document (DCD) Revision: (Revision 0, 1)

Modify the second paragraph of subsection 3.8.3.4 as shown below:

Methods of analysis for the structural modules are similar to the methods used for reinforced concrete. Table 3.8.3-2 summarizes the finite element analyses of the containment internal structures and identifies the purpose of each analysis and the stiffness assumptions for the concrete filled steel modules. For static loads the analyses use the monolithic (uncracked) stiffness of each concrete element. The elastic modulus is taken as 0.80 times the value calculated based on the ACI Code. This reduced elastic modulus considers a small degree of cracking as described in the seismic analyses in subsection 3.7.2.3. For thermal and dynamic loads the analyses consider the extent of concrete cracking as described in later subsections. Stiffnesses are established based on analyses of the behavior and review of the test data related to concrete-filled structural modules. The stiffnesses directly affect the member forces resulting from restraint of thermal growth. The in-plane shear stiffness of the module influences the fundamental horizontal natural frequencies of the containment internal structures in the nuclear island seismic analyses described in subsection 3.7.2. The out-of-plane flexural stiffness of the module influences the local wall frequencies in the seismic and hydrodynamic analyses of the in-containment refueling water storage tank. Member forces are evaluated against the strength of the section calculated as a reinforced concrete section with zero strength assigned to the concrete in tension.

Modify the second bullet in the last paragraph of subsection 3.8.3.4 as shown below:

- Case 2 considers the full thickness of the wall as uncracked concrete. This stiffness value is shown for comparison purposes. It is applicable for loads that do not result in significant cracking of the concrete and is the basis for the stiffness of the reinforced concrete walls in the nuclear island seismic analyses (prior to the reduction in concrete stiffness by a factor of 0.8). This stiffness was used in the harmonic analyses of the internal structures described in subsection 3.8.3.4.2.2.

Modify the first paragraph of subsection 3.8.3.4.1.1 (Rev. 17) as shown below:

3.8.3.4.1.1 Finite Element Model

~~The three-dimensional (3D) lumped-mass stick model of the containment internal structure is developed based on the structural properties obtained from a 3D finite element model.~~ The structural modules are simulated within the finite element model using 3D shell elements. Equivalent shell element thickness and modulus of elasticity of the structural modules are computed as shown below. The shell element properties are computed using the combined gross concrete section and the transformed steel faceplates of the structural modules. This representation models the composite behavior of the steel and concrete. The modulus of concrete, E_C, is reduced by a factor of 0.8 to consider the effect of cracking as recommended in Table 6-5 of FEMA 356 (Reference 5 given in DCD Section 3.7.6). See Section 3.7 and Appendix 3G for further discussion of the CIS finite element model.

Modify Table 3.8.3-2 as follows:

Table 3.8.3-2

SUMMARY OF CONTAINMENT INTERNAL STRUCTURES MODELS AND ANALYSIS METHODS

Computer Program and Model	Analysis Method	Purpose	Concrete Stiffness [(1)]
3D ANSYS finite element of containment internal structures	~~Equivalent static and Response Spectra analyses~~~~[(2)]~~Static	To obtain the in-plane and out-of-plane mechanical ~~seismic~~ forces for the design of floors and walls (dead, live, hydrostatic, pressure)	Monolithic Case ~~3~~1 with Ec reduced by factor of 0.8.
3D ANSYS finite element of containment internal structures ~~fixed at elevation 98′ 0″~~	Response Spectra analyses[(2)]~~Static analyses~~	To obtain the in-plane and out-of-plane seismic forces for the design of floors and walls~~To obtain member forces in boundaries of IRWST for static loads (dead, live, hydrostatic, pressure)~~	Monolithic Case 1 with Ec reduced by factor of 0.8.
3D ANSYS finite element of containment internal structures ~~fixed at elevation 98′ 0″~~	Static analyses	To obtain the in-plane and out-of-plane member forces ~~in boundaries of IRWST~~ for thermal loads	Cracked Case 3
The following AP600 analyses are used as background to develop the AP1000 design loads.			
3D ANSYS finite element of containment internal structures fixed at elevation 103′-0″	Harmonic analyses	To evaluate natural frequencies potentially excited by hydrodynamic loads	Uncracked Case 2
	Time history analyses	To obtain dynamic response of IRWST boundary for hydrodynamic loads	Monolithic and cracked Cases 1 & 3

Note:

1. See Table 3.8.3-1 for stiffness case description.
2. See Section 3.7 for discussion of the containment internal structures seismic analyses.

PRA Revision:

None

Technical Report (TR) Revision:
None