December 5, 2006

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SUBJECT: WESTINGHOUSE AP1000 COMBINED LICENSE PRE-APPLICATION TECHNICAL REPORT 3 - REQUEST FOR ADDITIONAL INFORMATION (TAC NO. MD2358)

Dear Ms. Sterdis:

By letter dated June 14, 2006 (DCP/NRC1751), you submitted AP1000 Technical Report 3, "Extension of Nuclear Island Seismic Analyses to Soil Sites," which provided information and documentation on the seismic analyses that have been performed to extend applicability of the AP1000 to soil sites. The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the application and has determined that additional information is required. Our question are provided in the enclosure. We discussed these issues with your staff on November 27, 2006. Your staff indicated that you would attempt to provide your response by January 2, 2007.

Please contact me at (301) 415-1313, if you have any other questions on these issues.

Sincerely,

/RA/

Steven D. Bloom, Senior Project Manager
AP1000 Projects Branch 1
Division of New Reactor Licensing
Office of New Reactors

Project No. 740

Enclosure:
Request for Additional Information

cc w/encl: See next page

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REQUEST FOR ADDITIONAL INFORMATION

WESTINGHOUSE AP1000 DOCUMENT NO. APP-GW-S2R-010, REV 0

TECHNICAL REPORT 3 - EXTENSION OF NUCLEAR ISLAND SEISMIC ANALYSES

TO SOIL SITES

PROJECT NUMBER 740

TR3-1 The Introduction (p.1, paragraph 5) states "This document addresses seismic response spectra, soil sites, dynamic models, minor structural changes that are significant, seismic results and their impact on seismic design loads for the building structures." The staff notes that only the pressurizer compartment redesign is described in the report. Please describe in detail all the other "minor structural changes that are significant", and why these changes to the AP1000 design are necessary. Also identify the auditable documents that contain the applicable design/analysis calculations for each change.

TR3-2 The last second sentence of Item 2 in Page 3 of 154 states that the walls and basemat inside containment for this model is shown in DCD Figure 3.7.2-2. Since the height of the pressurizer cubical walls was reduced, this statement is no longer valid. Clarification is needed.

TR3-3 The fourth sentence of Item 4 in Page 4 of 154 states that plant design response spectra were developed from these analyses along with equivalent static accelerations for analysis of the building structures. Westinghouse is requested to define the term "plant design response spectra." Are these the response spectra at different floor levels?

TR3-4 The first sentence of the last paragraph in Page 8 of 154 should read "Key dimensions, such as the foundation size and thickness of the basemat, floor slabs, roofs and walls, of the seismic Category I building structures are shown in DCD Figures 3.7.1-14 and 3.7.2-12."

TR3-5 The second sentence of the third paragraph in Page 9 of 154 states that the (concrete) modulus of elasticity is reduced to 80% of its value to reduce stiffness to simulate cracking. Westinghouse is requested to clarify whether this reduced stiffness was used in both the dynamic seismic response analyses for generation of floor response spectra, and the equivalent static acceleration analyses for design of the structural members. If different stiffness assumptions were used, provide the technical basis for this decision. Also provide the technical basis for using 80%. Discuss this in relation to current industry guidance (e.g., ASCE 43-05, ASCE 4-98). Were any sensitivity studies conducted to determine the effect of varying the concrete stiffness on (1) the floor response spectra, and (2) the design of structural members?

Enclosure

TR3-6 The last sentence of the fourth paragraph in Page 9 of 154 states that the decision to move away from the use of the combined stick model is predicated on the use of the shell model for soil-structure interaction analyses, and to reflect the improvement in technology where the use of the shell models are reflective of the state of the art. Westinghouse needs to clarify which reinforced concrete structural model was used for calculate seismic responses of nuclear island structures founded on hard rock site: stick model or shell model?

TR3-7 The fourth sentence of the fourth paragraph in Page 10 of 154 states that since the water in the PCCS tank responds at a very low frequency (sloshing) and does not affect building response, the PCCS tank water mass is reduced to exclude the low frequency water sloshing mass. The staff requests Westinghouse to provide its detailed technical basis, with references and/or numerical results, for excluding the low-frequency, water sloshing mass. Westinghouse also needs to quantify the percentage of water mass in the PCCS tank that was excluded.

TR3-8 The first column of the third row of Table 4.2.4-1 in Page 40 of 154 provides a description of the seismic building model as “3D finite element coarse shell model of auxiliary and shield building (including steel containment vessel, polar crane, RCL, and pressurizer).” Westinghouse should clarify why the containment internal structures (superelement?) was excluded.

TR3-9 The core make-up tank is mentioned in Section 4.3. Westinghouse needs to provide a description of this tank in the report.

TR3-10 The staff’s review of Tables 4.4.1-1A and 4.4.1-1B found that Westinghouse used three soil/rock degradation models in its parametric studies for selecting site conditions: Seed and Idriss 1970 soil/rock degradation curves, Idriss 1990 soil degradation curves, and EPRI 1993 soil degradation curves. For example, Westinghouse used Seed and Idriss 1970 model for two horizontal motions and EPRI 1993 soil degradation model for two rocking motions when the parametric studies were performed for the AP1000 site selection. Westinghouse is requested to provide reasons and bases for using different soil degradation models for its parametric studies.

TR3-11 The last sentence of the third paragraph in Page 48 of 154 states that since the dominant AP1000 building frequencies are lower than for AP600, the shallower depth conditions would provide even less of an effect and thus using a depth-to-base rock of 120 ft is also appropriate. However, the last sentence of the first paragraph (Section 4.4.1) in Page 47 of 154 states that the soft rock case (V_s = 2500 ft/sec) for the AP600 has been replaced by firm rock (V_s = 3500 ft/sec) since the 2D SASSI parametric analyses show that the firm rock case is more significant than on AP600 due to the additional height of the shield building. Westinghouse needs to explain why the conclusion drawn for the AP1000 (the nuclear island structures with lower dominant building frequencies result in higher seismic response when founded on firm rock than on soft rock) is contradict to the conclusion drawn for the AP600 (the nuclear island structures with higher dominant building frequencies result in lower seismic response when founded on firm rock than on soft rock).

TR3-12 The fifth paragraph of Section 4.2.3 in Page 19 of 154 provides a description of how the grouping method was applied to define the seismic design response spectra. Appendix B provides tables showing the node grouping for various elevations of ASB and CIS. As indicated in Figures 4.2.3.3 and 4.2.3.4, and Table B-1, the grouping method was applied to the outside nodal points, but not the inside nodes. Westinghouse is requested to demonstrate that the resulted vertical seismic design response spectra are more conservative than those that would be obtained by grouping all of the nodes, including inside nodes.

TR3-13 The first row of the first column of Table 4.2.4-1 describes the shield and auxiliary building model as "3D finite element coarse shell model of auxiliary and shield building [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer). The staff's question is that should the CIS also be included in the model?

TR3-14 The third sentence of the first paragraph in Page 47 of 154 states that many results and conclusions from the AP600 soil studies are applicable for the AP1000. Westinghouse is requested to describe what results and conclusions from the AP600 soil studies, other than the three soil sites (the hard rock site, upper bound soft to medium soil, and soft to medium soil), are applicable to the AP1000.

TR3-15 In Page 48 of 154, Westinghouse illustrated that some effects (water table, soil layering, soil degradation model, etc.) are not significant to the seismic response of the nuclear island (NI) structures. Because these results are applied for the AP1000 design, the staff requests Westinghouse provide technical basis for making these conclusions. In addition, Westinghouse needs to demonstrate the combination of these effects is also insignificant to the seismic response of the NI structures.

TR3-16 The first sentence of the fourth paragraph in Page 50 of 154 states that maximum member forces are shown in Figures 4.4.1-2 through 4.4.1-5. These figures indicate that the equivalent static analysis always results in highest member forces when compared with SASSI results based on other site conditions. The staff requests Westinghouse to identify which site condition was selected to develop the equivalent static acceleration profile used to perform the equivalent static analysis. In addition, the staff's review of the report APP-GW-GLR-009, "Containment Vessel design Adjacent to Large Penetrations," found that the containment vessel was designed for seismic loads by applying equivalent static accelerations at each elevation based on the maximum acceleration from the fixed-base NI stick models tabulated in DCD Table 3.7.2-6. Based on the ZPAs shown in Table 4.4.1-2 and seismic loads shown in Figures 4.4.1-2 through 4.4.1-7, Westinghouse should demonstrate that the seismic loads used for the containment vessel design are the worst loading condition.

TR3-17 Wording in DCD Table 2-1 "Site Parameters" indicates that best estimate low-strain shear wave velocity shall be greater than 1,000 ft/sec and that variability across the site shall be less than 100 ft/sec (10%). It is presumed that this DCD commitment is based on SASSI results for a uniform half-space below the plant basemat. Westinghouse is requested to a include statement on maximum acceptable change in velocity profile within a depth equal to the width of the basemat in the definition of "Site Parameters."

TR3-18 Item 3 of page 83 of Page 154 indicates that if plant is founded on top of rock with velocity of 3,500 ft/sec and there are thin layers of soft materials overlying the rock, the site specific peak ground acceleration and spectra may be developed at the top of the competent rock and shown at the foundation level to be less than or equal to those given in Figures DCD 3.7.1 and 3.7.2. The hard rock design was based on the assumed rock shear velocity of 8,000 ft/sec. Westinghouse is requested to provide basis for changing the rock shear velocity.

TR3-19 The section of "DCD Subsection 2.5.2.3 - Sites with Geoscience Parameters Outside the Certified Design" states that final design verifications were based on 3D SASSI results with 2D results used to test sensitivity only. The final verification for a site not satisfying the site criteria should be based on 3D SASSI results. Westinghouse should justify how does one judge the adequacy of 2D SASSI results without performing 3D computations.

TR3-20 Comparison of Figure 6.1-4 to Figure 6.1-6, and comparison of the stick model results to the FE model results at the top of the SCV in Figure 6.1-6, raises a question about the connectivity of the bottom of the SCV stick to the CIS FE model, at node 130401. The staff requests Westinghouse to provide a detailed technical explanation for the following:

a. Why is the x-direction spectral peak at node 130412 reduced by 1/3 (approx. 4.2 vs. 6.3), while the y-direction spectral peak at node 130412 is only reduced by 1/11 (approx. 6.6 vs. 7.2)? What mechanism has caused the ratio of y to x to change from 1.09 for the stick model to 1.57 for the FE model?

b. Why does the vertical spectrum comparison in Figure 6.1-6 show (1) an increase in spectral peak for the FE model, compared to the stick model, and (2) a significant shift in the frequency of the peak?

TR3-21 The staff's review of Section 6.2 identified a number of items in need of clarification or explanation. The staff requests Westinghouse to address the following:

a. The fourth paragraph of page 91 of 154 states "In Section 6.3 a comparison of member forces obtained from seismic static and time history analyses is given." Please confirm that the reference should be to Section 6.4.

b. The last paragraph of page 91 of 154 states "For those local flexible structures that are amplified, apply an additional acceleration to these structures equal to the difference between the average uniform amplified component accelerations and rigid body component equivalent static accelerations. These accelerations are to be considered in local design of the flexible portion of the structure but do not need to be considered in areas of the structure away from the local flexibility. They can be applied in a series of individual load vectors." It is not obvious to the staff how this methodology has been implemented, and whether the effects of increased accelerations on locally flexible structures can be ignored in areas of the structure away from the locally flexible structures. The sum total of all the flexible masses times the corresponding acceleration increments may impose non-negligible additional loads on the overall structure, in the two horizontal directions and in the vertical direction. Therefore, Westinghouse is requested to (1) describe in greater detail the implementation of this methodology, including a numerical example; and (2) provide a quantitative technical basis for the conclusion that the effects of increased accelerations on locally flexible structures can be ignored in areas of the structure away from the locally flexible structures.

c. The top paragraph of Page 93 of 154 states "The vertical equivalent static seismic accelerations at (Shield Bldg) elevations 294.93 ft and 333.13 ft are obtained directly from the maximum time history results by taking the average of locations at opposite ends of a diameter. The vertical accelerations from the 3D finite element model at the shield building edges at these elevations are significantly influenced by the horizontal loading. If they are used for the vertical equivalent accelerations, the horizontal response would be double counted in the vertical direction." It is not obvious to the staff how this methodology has been implemented, and whether it is even appropriate. Therefore, Westinghouse is requested to submit a numerical example, based on elevation 333.13 ft of the Shield Building, to demonstrate the implementation of this methodology. In this example, please also include the vertical acceleration value that would be obtained if this methodology was NOT implemented.

d. Confirm that in Table 6.2-7, the referenced table numbers should be 6.2-3, 6.2-4, 6.2-5, and 6.2-6.

e. In Page 99, under the heading "Seismic Accelerations for Evaluation of Building Overturning," states "The dynamic response of the structure affecting overturning and basemat liftoff is primarily the first mode response at about 3 hertz on hard rock. This reduces to about 2.4 hertz on soil sites as shown in the 2D ANSYS and SASSI analyses. The higher auxiliary building accelerations of Table 6.2-2 are not considered in overturning since they are from higher frequency modes greater than 2.4 hertz. Amplified response of individual walls in the Auxiliary Building and the IRWST need not be considered since they are local responses that do not effect overturning." For the overturning analysis, the staff is concerned that the methodology employed may not predict an overall moment on the basemat that envelops the maximum overturning moment for all site conditions. Westinghouse is requested to provide its technical basis for the conservatism of the methodology employed.

TR3-22 Section 6.3 states "The maximum seismic deflections that were obtained from the time history analyses and SASSI analyses given in Tables 6.3-1 to 6.3-3 for the auxiliary and shield building, containment internal structure, and steel containment vessel." For the staff to properly evaluate this information, the following additional information is needed:

a. Are the deflections in the tables a consistent set, based on the worst-case time history result, or are they an envelop of maximum deflections from all the time history results?

b. How do these tabulated deflections compare to the corresponding deflections obtained from the equivalent static acceleration analyses? Please provide a tabulated comparison, and an explanation of any significant differences.

TR3-23 The staff review of Section 6.4 identified a number of items in need of clarification or explanation. The staff requests Westinghouse to address the following:

a. A comparison of equivalent static acceleration results to the worst-case time history results is presented for a small number of selected locations. It is not clear to the staff why these specific locations were selected for comparison, and whether they are representative of all other locations in the structural model. Therefore, Westinghouse is requested to (1) explain the basis for selecting these specific locations for presentation in the report, and (2) confirm that a comprehensive comparison was conducted in order to validate that the equivalent static acceleration results generally envelop the worst-case time history results, and that any under predictions are minor.

b. The staff noted that the only significant under-prediction documented in Section 6.4 is for T_y at ASB south elevation 107 ft. The equivalent static result is 76.7 ksf; the worst time history result is 89.5 ksf. This represents a 15% under-prediction. Please discuss whether this is the maximum under-prediction identified. If not, please explain the criteria applied to justify the acceptability of under-predictions, in reaching the conclusion that the equivalent static acceleration method of analysis provides an acceptable basis for structural design.

TR3-24 The description of Section 7.1 does not indicate whether the vertical spring/damper values were based on the rocking site stiffness value or the vertical site stiffness value and whether the horizontal/vertical parameters were determined from an assumed uniform half-space. Westinghouse should explain what are the differences in these parameters and how significant are these parameters on the computed results.

TR3-25 It is not obvious from the description provided in Section 7.1 if the nonlinear (zero tension) cases were run with the basemat width of 140 ft or 161 ft and if the runs were 2D or 3D cases.

TR3-26 The description provided in Section 7.2 indicates that spring/dashpot values were selected based on parameters for a uniform half-space. However, for a soil site with hard rock located at a depth of 120 ft below the basemat, the resulting SSI radiation damping value would be expected to be significantly lower than that for a uniform half-space solution. Westinghouse should evaluate what is the impact of this difference on the computed seismic response?

TR3-27 Section 7.1 indicates that direct integration was used to obtain computed results. Section 7.2 indicates that modal analysis was used to obtain solutions requiring the computation of equivalent modal damping accounting for both element and SSI damping. Westinghouse should describe how was the modal analysis method used to account for liftoff? Do the resulting modal damping values satisfy the limitations recommended in ASCE 4-98?

TR3-28 Westinghouse is requested to describe in Section 7 of this report that were the three directions of motion (H1, H2 and V) used to generate liftoff responses in all cases analyzed?

TR3-29 In Section 7.1, Westinghouse should explain why are comparisons of 2D SASSI-ANSYS results used to judge adequacy of the liftoff analyses?

TR3-30 Table 7.1 indicates that a damping of 30% was selected for the soft soil site. Westinghouse is requested to explain what is the basis for this selection? How does the viscous damping values shown in this table compare with the hysteretic material damping values typically found for iterated soils based on site responses?

TR3-31 As described in Section 7, if a soft/hard impedance mismatch occurs within the zone of influence of the basemat, the effective radiation damping may be severely reduced. Westinghouse should explain how would this impact computed responses?

TR3-32 The staff's review of the text and figures in Appendix C of AP1000 Document No. APP-GW-S2R-010, Revision 0, June 2006, "Extension of Nuclear Island Seismic Analyses to Soil Sites," identified the need for a number of clarifications and explanations of the results presented. The staff requests Westinghouse to address the following:

a. In paragraphs 4 and 5, a explanation is provided why the SASSI NI20 model produces higher results in the high frequency region than the ANSYS NI20 model, for a hard rock site condition. The explanation would appear to apply on a generic basis. However, comparison of Figures C-1 through C-6 to Figures C-7 through C-12, respectively, indicates that this effect is not generically demonstrated. Only the first three of the six locations demonstrate this behavior. Please (a) provide a detailed explanation why this effect occurs only at three locations, and not at all six locations; (b) describe how it was determined that the explanation provided in paragraph 4 and 5 is accurate; and (c) confirm that all other potential sources for the differences (e.g., modeling error) have been investigated and eliminated as the source of the difference.

b. Paragraph 2 states:

"Both finite element models give comparable results below 10 hertz. However, the results from the coarse model are not as good at high frequencies (above about 15 hertz). Therefore the hard rock FRS were generated from the fine NI10 model, and the coarse NI20 model was used for the soil site analyses where frequencies of interest are below 10 hertz."

Paragraph 6 states:

"In a few cases it is found that the soil cases analyzed in SASSI using the NI20 model give higher results than the hard rock case using the NI10 model for frequencies above 10 Hz (see for example Figure 4.4.3-9). Although these cases are believed to be due to conservatism in the SASSI results at high frequency, the SASSI results are used in developing the broadened envelope design response spectra."

Apparently, the hard rock results obtained from the NI10 ANSYS model do not always envelop the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz, as one might easily conclude from paragraph 2. From paragraph 6, it appears that there is considerable uncertainty about the validity of the SASSI results above 10 hertz. This is in contrast to the "matter-of-fact" statements made in paragraphs 4 and 5. Please clarify the Westinghouse position, including the technical basis, on the validity of SASSI NI20 model results above 10 hertz for all site conditions, including a hard rock site. Is the NI20 grid sufficiently refined to accurately predict response above 10 hertz? Have any SASSI soil site analyses been performed using a refined grid comparable to the NI10 model, to study the effect of element size on the solution results?

c. Explain what studies were performed to establish that the NI10 model refinement is sufficient to accurately account for high frequency response effects at all critical locations. It is not obvious from the results shown in Figure C-1 that convergence with element size has been achieved.

TR3-33 The staff's review of Appendix E identified a number of items in need of clarification or explanation. The staff requests Westinghouse to address the following:

a. Please explain why the MAX horizontal acceleration profiles shown in Figure E-2, for the Auxiliary Building, exhibit an erratic pattern of acceleration with increasing elevation, while the stick model results do not exhibit this behavior. Also explain why a vertical acceleration profile is not included in Figure E-2. Identify which acceleration profiles are used for the final design of the Auxiliary Building.

b. Please explain the very significant differences shown in Figure E-4, for the CIS, between the MAX horizontal and vertical acceleration profiles and the stick model acceleration profiles at the top of the CIS. Identify which acceleration profiles are used for the final design of the CIS.

c. Please explain why the ASB vertical acceleration profile for both MAX and stick model, shown in Figure E-1, exhibit essentially rigid behavior above elevation 290 ft. Also provide a detailed technical explanation for the significant reduction in the MAX vertical acceleration, compared to the stick model vertical acceleration, between elevations 260 ft and 290 ft. Identify which acceleration profiles are used for the final design of the ASB.

d. The last paragraph of Appendix E discusses accelerations used for overturning. The staff noted that no comparison figure is included in Appendix E, and also is not sure which acceleration profiles are used for the overturning case. Please provide this figure and also identify which acceleration profiles are used for the final design-basis overturning analysis.

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