UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 16, 1994

Docket No. 52-003

Mr. Nic' ɪas J. Liparulo
Nuclear Safety and Regulatory Activities
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, Pennsylvania 15230

Dear Mr. Liparulo

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON THE AP600

As a result of its review of the June 1992 application for design certification of the AP600, and the January 21-22, 1994 meeting between Westinghouse and the Nuclear Regulatory Commission (NRC) on Seismic Analysis and Structural Design in Monroeville, Pennsylvania, the staff has determined that it needs additional information in order to complete its review. The additional information is needed in the areas of structural engineering (Q220.51-Q220.90)*, seismic design (Q230.50-Q230.95), and geology (Q231.15-Q2-31.32). Enclosed are the staff's questions. Please respond to this request within 60 days of the date of this letter.

You have requested that portions of the information submitted in the June 1992 application for design certification be exempt from mandatory public disclosure. While the staff has not completed its review of your request in accordance with the requirements of 10 CFR 2.790, that portion of the submitted information is being withheld from public disclosure pending the staff's final determination. The staff concludes that this request for additional information does not contain those portions of the information for which exemption is sought. However, the staff will withhold this letter from public disclosure for 30 calendar days from the date of this letter to allow Westinghouse the opportunity to verify the staff's conclusions. If, after that time, you do not request that all or portions of the information in the enclosures be withheld from public disclosure in accordance with 10 CFR 2.790, this letter will be placed in the NRC's Public Document Room.

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*The numbers in parenthesis designate the tracking numbers assigned to the questions.

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This request for additional information affects nine or fewer respondents, and therefore is not subject to review by the Office of Management and Budget under P.L. 96-511.

If you have any questions regarding this matter, please contact me at (301) 504-1114.

Sincerely,

Original Signed By:

Kristine M. Shembarger, Project Manager
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and License Renewal
Office of Nuclear Reactor Regulation

Enclosure:
As stated

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Westinghouse Electric Corporation

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AP600

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REQUEST FOR ADDITIONAL INFORMATION
ON THE WESTINGHOUSE AP600 DESIGN

Design of Category I Structures

220.51 The plant layout has changed several times, and seismic and structural models have been revised incrementally. It is not clear whether the latest model is consistent with the final certified design configuration. The calculated design stresses and forces may have been deduced from several independent results. Demonstrate that a consistent final model with complete design certification configuration exists.

220.52 Provide the validation package of INITEC's computer programs. In addition, verify the post-processed results that were developed to produce complete reinforcing steel requirements from the results of the ANSYS program.

220.53 Provide the rationale that the use of 6-foot thick foundation, especially the foundation mat underneath the containment vessel, is adequate. (Conventional containment building foundation is 10-foot thick)

220.54 Provide the rationale that the use of 3-foot thick outer walls for the nuclear island structure is adequate against lateral earth pressure (both static and dynamic).

220.55 Based on the staff's past licensing review experience, the unevenly distributed construction loads on the foundation mat, especially for the foundation mat with large dimensions and irregular shape, can be very significant and may cause severe foundation cracks. The use of a symmetrical reinforcement arrangement at the top and bottom surfaces of the foundation mat in the design can minimize the possibility of these cracks. Provide basis to demonstrate the design adequacy in coping with the unevenly distributed construction loads, if an unsymmetrical reinforcement pattern at the top and bottom surfaces of the foundation mat is used in the design.

220.56 Provide the following information pertaining to the finite element analysis model for the basemat: (a) the input seismic loads at the various nodes, (b) the spring connecting the internal structure to the basemat, and (c) the soil springs attached to the basemat.

220.57 Provide the basis for using a uniform Winkler spring in the foundation analyses instead of the expected variable stiffness from edge to center of foundation mat.

220.58 In the nuclear island foundation design, consider the seismic shear and moments due to the out-of-phase vibration between the shield building, containment shell, and structures.

Enclosure

220.59 Provide the radius and the thickness of the knuckle region and the dome in Section 3.8.2 of the SSAR.

220.60 Provide the basis for not considering the wind load in the Level A and C load combinations in which the external pressure is included (Table 3.8.2-1 of Revision 1 to the SSAR).

220.61 It is stated in Section 3.8.2.1.1 of the SSAR (pg. 3.8-1) that a flexible watertight and airtight seal is provided at Elevation 123' 3") between the containment shell and the shield building. Provide clarification for the following concerns:

a. What is the safety class and seismic category of this seal?

b. If the seal is a safety class item, explain how the seal will perform its function when the containment shell is displaced laterally inward and outward at the base of the foundation.

220.62 Provide descriptions for the polar crane system in Section 3.8.2.1. of the SSAR.

220.63 For the air baffle,

a. pertaining to the fatigue aspects of the containment shell design, provide information on the magnitude, distribution and number of cycles of the stresses induced by the wind,

b. consider the potential of tornado missiles generated by the air baffle and discuss whether or not the air deflector is protected against tornado missiles, and

c. provide detailed information of the flexible seal between the air baffle and the shield building roof.

220.64 Provide, in the SSAR, the critical locations for taking measurements during the pre-operational structural integrity test (SIT) of the steel containment and describe how this information is to be used to demonstrate the consistency between the observed and predicted responses.

220.65 Provide a list of potential sources of missiles and sources of high pressure resulting from a high energy line break between (a) the containment and operating floor and refueling cavity walls, (b) the secondary shield walls and the containment, and (c) the containment and the shield building.

220.66 Provide the basis for using the "1.0, 0.4, 0.4" method in lieu of the SRSS method for combining co-directional seismic responses resulting from the three components of the earthquake ground motion.

220.67 For loads and load combinations listed in SSAR Table 3.8.2-1, explain why the operating pressure "P_o" was not included in Load Combinations 6 and 7 (Service Level C) as specified in Equation (iii).(c).(2) in SRP Subsection 3.8.2.II.3.b.

220.68 With regard to the materials to be used for the containment shell, a stress-strain curve for SA-537 Class 2 material was presented that was reported to be obtained from Japanese data. The yield stress was shown to be 81.3 ksi. However, Table 2 of the ASME specification for SA-537 reports a minimum yield strength of 60 ksi for the same material. Clarify the correct properties to be used for design.

220.69 Describe how the containment was modeled and what computer code was used when the containment shell was analyzed for the non-axisymmetrical loads due to earthquake and crane loads.

220.70 Include, in the SSAR, a discussion of the use of structural modules at other locations (that was described during the January 20 and 21, 1994 meeting). Furthermore, it was stated during the meeting that Westinghouse planned to attach as much of the distribution systems (e.g., piping, HVAC, cable trays) as possible to the structural modules before final placement. Describe the plans and procedures regarding the attachment of distribution systems to the structural modules. In addition, provide a discussion on the design of the attachment points to the structural modules.

220.71 Describe plans, criteria, or specifications for fabrication, storage, transportation, handling, assembly, inspection, and QA/QC related to structural modules. This information, including goodness of fit, inspection and hold points, and sequence of construction, should be included in the SSAR.

220.72 What are the steps taken to address aging degradation of structural modules? Are there plans for accessibility for inservice inspection, maintenance, and repair or monitoring of modules during operation? For example, how is the leaktight integrity of the refueling cavity, fuel pool, and incontainment refueling water storate tank wall modules ensured throughout the 60 year design life?

220.73 Some of the designs of joints and connections, such as the welds joining adjacent modules, are not finalized. Finalize the designs and provide a description of the designs.

220.74 Describe the procedures for ensuring that the concrete can be effectively placed in the structural modules. In addition, discuss any plans to perform "mock-ups" to demonstrate the adequacy of these procedures.

220.75 Describe the experiences with the use of concrete filled steel structures with regard to ensuring the proper curing of concrete and the potential for corrosion resulting from entrapped moisture.

220.76 Justify the representation of the structural modules in the finite element model of the containment internal structures. The model contains plate elements with homogeneous properties in all directions based on the addition of concrete and steel areas adjusted for their modular ratio. This modelling approach was based on several tests on steel and concrete modules performed in Japan. However, the configurations tested were somewhat different and there is insufficient information to permit a realistic extrapolation.

220.77 For the modular construction design, provide detailed information in the SSAR regarding (a) the construction sequence, (b) the plan for inspection during fabrication, (c) the inspection plan for pouring concrete, (d) the measurements for controlling curing and corrosion, (e) the connection joint details, (f) the details at intersection of modular walls, (g) the connection between two modules, and (h) the connections between the modules and pour-in-place concrete elements.

220.78 For the modular construction design, provide the following information:

(a) a copy of the detailed design drawings for one of the common M-subunit modules,

(b) the Modular Design Criteria Document, and

(c) the current version of the construction procedures related to modular construction.

220.79 For the in-containment refueling water storage tank (IRWST), provide in the SSAR, figures and cross sections showing: (a) overall configuration of the tank, (b) the relationship between the tank walls, channel heads, concrete foundation and structural steel modules, and (c) areas covered by the stainless steel or cladding for preventing corrosion.

220.80 The last paragraph of Section 3.8.3.4 of the SSAR states that computer codes used are general purpose codes and the code development, verification, validation, configuration control, error reporting and resolution are according to the Quality Assurance requirements of SSAR Chapter 17. Specify, in the SSAR, which computer codes were used in the analysis of the containment internal structures.

220.81 Consider the effects of concrete cracking in the seismic analysis and design of the NI structures.

220.82 In Q220.16 dated October 1, 1992, the staff requested that the purpose of Note 3 of Tables 3.8.4-1 and ..8.4-2 of the SSAR should be clarified. In its response to this question dated January 8, 1993, Westinghouse stated that by applying Footnote 2 to Load Combination 2, SSAR Table 3.8.4-2 will include consideration of the equivalent of the load combination 1.2D+1.7W. The staff is concerned with the adequacy of this equivalence unless the live load "L" is always present in the combined load condition and the load combination "1.2D+1.7L+1.7W" is always more critical than 1.2D+1.7W. Address this concern.

220.83 For each seismic Category I structure, provide in the SSAR, a summary of design information using the format for design loads/results as indicated in Appendix C to Section 3.8.4 of the SRP.

220.84 Address, in the SSAR, the concerns and limitations documented in the following staff positions that were distributed at the January 20 and 21, 1994 meeting:

a. Staff Position on Shell Buckling Due to Internal Pressure

b. Staff Position on Application of ACI 349 Code - Steel Embedments

c. Staff Position on The Use of Standard ANSI/AISC N690, Nuclear Facilities - Steel Safety Related Structures For Design, Fabrication and Erection

d. Staff Position on The Calculations of Dynamic Lateral Earth Pressures on Earth Retaining Walls and Embedded Walls of Nuclear Power Plant Structures

220.85 Provide the basis for using an internal friction angle of 35 degrees and the angle of friction force of 17.5 degrees for the backfill soil.

220.86 For the design of the NI foundation, provide the detailed procedures for applying: (a) the structural seismic loads to the finite element foundation analysis model, (b) the springs attached to the bottom nodes of the basemat, and (c) the springs connecting the internal structures to the basemat.

220.87 For evaluating the dynamic stability of the NI structures against overturning, provide formulas for calculating the energy component due to embedment effect "W_p" and energy component due to buoyancy "W_b" in Section 3.8.5.5.4 of the SSAR.

220.88 To prevent the potential of rebar corrosion, evaluate, in the SSAR, the use of coated reforcing bars for the design of the NI foundation.

220.89 Identify the number of critical sections chosen for the detailed structural design and the basis for this selection. In addition, provide drawings indicating the reinforcement details of all selected critical sections in the SSAR.

220.90 For the nuclear island structures, provide, in the SSAR, the type and characteristics of water seals to be used at the penetrations (mechanical and electrical) and accesses located below the flood level for preventing and mitigating the external flooding effects.

Seismic Design

230.50 Seismic analyses for the AP600 design has been conducted since the late 1980s and the assumptions and building configurations have changed during these analyses. Some earlier analyses appear to be used to simplify the number of parametric runs to be considered in the later analyses. Provide a clear auditable trail for the final seismic calculations so that the assumptions made can be fully understood.

230.51 The seismic design bases for the AP600 standard design are essentially defined by a safe-shutdown earthquake (SSE) with peak ground acceleration of 0.3g and the soil profiles characterized in Section 2 of the SSAR (assuming no liquefaction and fault displacement at the plant site). If these generic design bases are not satisfied, design certification will no longer hold, and site-specific analyses and evaluations must be performed in accordance with the SRP. Provide a COL commitment, in the SSAR, to perform this reconciliation analysis.

230.52 For the evaluation of foundation mat uplift potential during a seismic event, the "hard rock" site condition should also be evaluated in determining seismic forces (vertical forces, sliding forces and overturning moment). The procedures for evaluating potential impact between foundation mat and supporting material due to uplift as a result of rocking, and load concentration at edges and corners, should also be evaluated.

230.53 According to the SSAR, only three soil conditions (shear wave velocity equal to 1000 ft/sec, 2500 ft/sec and 8000 ft/sec) were used in the seismic design of AP600 standard plant. Provide justification for not including the site conditions with other shear wave velocities, such as 1500 ft/sec and 3500 ft/sec and different depths from grade to bedrock.

230.54 According to the definition in Section 3.7 of the SSAR, the seismic analysis and design of the seismic Category II structures adjacent to the nuclear island should be performed using the same input and acceptance criteria as those for the seismic Category I structures. Justify the use of the Zone 3 requirements of the Uniform Building Code (UBC) for the analysis and design of these structures.

230.55 Justify the adequacy of using the SASSI computer code to calculate member forces for the structural design. According to the staff's experience and understanding, the SASSI analyses will produce inaccurate member forces.

230.56 Regarding the structure-to-structure interaction:

a. evaluate the potential pounding between the NI structures and the non-seismic Category I structures, and

b. evaluate the potential of structure-to-structure interaction through soil to ensure the integrity of both Category I and Category II structures.

230.57 One of the drawings displayed shows a physical connection between the containment shell and the shield building near the upper spring line. If the function of the connection is important, its integrity should be evaluated when the connection is subject to relative displacement (between the containment shell and the shield building) during a seismic event.

230.58 Provide the following information pertaining to the high frequency modes of the structures:

a. Provide justification to demonstrate that the time steps used in the time-history seismic analyses are small enough to account for the high-frequency modes that have significant mass participation factors.

b. Make "missing mass" corrections to the seismic analyses (horizontal as well as vertical) where significant high-frequency modes were left out. Note that the seismic forces computed without such "missing mass" correction (if applicable) would result in underprediction (example: a foundation mat design where seismic forces were used in the equivalent static analysis).

230.59 Provide, in the SSAR, a comparison between the SRSS method and the 1.0, 0.4, 0.4 method, or the bases for use of only the 1.0, 0.4, 0.4 method for the combination of seismic loads. Also Q220.67.

230.60 What is the accidental torsion in the overall seismic member forces to be used for the design? Provide, in the SSAR, a description of this torsion.

230.61 Provide, in the SSAR, a description to ensure the adequacy of the effects of the high-frequency structural modes containing significant modal mass in the seismic analysis/design of the nuclear island structures.

230.62 Justify the validity of performing a fixed-base seismic analysis for the site conditions with shear wave velocity equal to or greater than 8000 ft/sec.

230.63 The soil column properties for horizontal and vertical (P-wave) models are not consistent. Specifically, (a) the damping ratio for S & P wave motions are different, and (b) Poisson's ratio for soils above the ground water table appear to be too high. Provide an explanation to justify (a) the use of same properties for the horizontal and vertical models, and (b) the use of a high Poisson's ratio in the analysis.

230.64 As discussed during the January 20 and 21, 1994 meeting, the lateral soil pressure on the embedded walls of the NI structures are being calculated using the Mononobe-Okabe (M-O) method, which is considered appropriate for computing soil loads developed on simple retaining walls. Provide a discussion on the adequacy of using the M-O method to compute soil pressures the embedded walls of the NI structures where wall movement relative to the surrounding soil may not develop failure strains in the soil.

230.65 For calculating the lateral earth pressures on the embedded NI structure walls, provide justification for not considering the energy feedback between the nuclear island and immediately adjacent structures.

230.66 If Category II structures are adjacent to the nuclear island and will be driven by the nuclear island, justify the adequacy of using Zone 2A requirements of the Uniform Building Code for the design.

230.67 Clarify, in the SSAR, whether the lower bound shear wave velocity (Vs) of 1000 ft/sec for the soft site was considered as the true lower bound value and not the best estimate value in the SSI analysis of the NI structures. It is the NRC staff's understanding from the January 20 and 21, 1994 meeting that the velocity should be the true lower bound value.

230.68 Clarify, in the SSAR, whether concentric and dual systems will be utilized when the Zone 3 requirements of the Uniform Building Code are used for the design of the seismic Category II structures. It is the NRC staff's position that concentric and dual systems should not be utilized when the Zone 3 requirements are used for the design of the seismic Category II structures.

230.69 Include the shallow soil site conditions in the SSAR and in the seismic analysis of nuclear island structures. In addition, for these site conditions, the guidance in Section 3.7.1 of the SRP for specifying control motion should be followed.

230.70 Document, in the SSAR, the procedures for developing seismic response envelopes (e.g., floor response spectra).

230.71 Justify the adequacy of using the seismic responses (force, shear and moment) corresponding to the soft rock site condition instead of the seismic response envelopes for the foundation design for all site conditions.

230.72 The first paragraph of Section 3.7.1.2 of the SSAR (pg. 3.7-1) states that a "single" set of three mutually orthogonal, statistically independent, synthetic acceleration time histories is used as input in the dynamic analysis of seismic Category I structures. However, the criteria or limits (e.g., the limit of the correlation coefficient between any two of the acceleration time histories) for demonstrating the statistical independence between these acceleration time histories were not specified in the SSAR. Specify these criteria in the SSAR.

230.73 Section 3.2.1.1.2 of the SSAR (pg. 3.2-2) states that seismic Category II structures, systems and components are designed so that the SSE does not cause unacceptable structural failure of or interaction with the seismic Category I items. Section 3.7 of the SSAR (pg. 3.7-1) also states that the seismic design of the AP600 seismic Categories I and II structures, systems and components is based on the SSE. However, Section 3.7.2.8 (pg. 3.7-9) of the SSAR states that the seismic Category II structures are analyzed and designed to prevent their collapse under the SSE, and the seismic loads for the design of these structures are analyzed according to the Zone 3 requirements of the Uniform Building Code (UBC) using an importance factor of 1.0. Based on the above:

a. clarify the inconsistency between the statements made in the SSAR.

b. provide the basis to demonstrate that the design of seismic Category II structures that are located adjacent to the NI structures, based on the Zone 3 requirements of the UBC with an importance factor of 1.0, will ensure that the SSE will not cause unacceptable interaction with or failure of any seismic Category I items.

230.74 Provide ordinates and units for plots of the ground motion acceleration, velocity and displacement time histories shown in Figures 3.7.1-3 to 3.7.1-5 of the SSAR.

230.75 Regulatory Guide 1.61 indicates that 4% damping should be used for welded steel structures. The results from the tests performed in Japan indicate that damping for concrete filled structural modules is approximately 5%, not 7%. Justify the use of 7% damping in the seismic analysis of the containment internal structures.

230.76 Table 3.7.1-1 (pg. 3.7-28) of the SSAR specified that a constant damping of 20% was used for the SSE seismic analysis of the cable tray systems (including supports). Figure 3.7.1-13 (pg. 3.7-75) of the SSAR indicated that the damping ratio to be used for the SSE seismic analysis of cable tray systems depends on the amount of cable fill and the damping ratio of 20% specified in Table 3.7.1-1 is the maximum value for trays with cable fill of 50% to 100%. It is the staff's understanding, based on the cable tray tests previously performed by Bechtel Power Corporation (1978) and URS/John A. Blume & Associates, Engineers (1983), that the damping ratios of the cable tray systems depend on a number of factors such as cable tray type, percent of cable fill, hanger type, tray span, hanger length, cable ties, hanger and tray connections, number of trays, fittings, spray for fire protection, etc. Among these factors, lower percent of cable fill, cable ties and spray for fire protection will significantly reduce the resulted damping ratios of the cable tray systems. Based on the above, justify the use of the maximum constant damping ratio of 20% for the SSE seismic analysis of the cable tray systems.

230.77 Section 3.7.1.3 of the SSAR (pg. 3.7-2) states that for structures or components composed of different material types, the composite modal damping is calculated using the strain energy method. In order not to overestimate the structural responses, specify the limit of the modal damping in the SSAR.

230.78 Expand, in the SSAR, the descriptions of the three components (H1, H2 and H3) of the ground motion time histories used in the analyses to include indications of the time discretization (Nyquist frequency) being used and the appropriateness of this time step for the frequency ranges of interest.

230.79 From the review of Figures 3.7.1-14 and 3.7.1-15 of the SSAR, it appears that the soil shear degradation curves for the typical soil used in the analysis and design are based on the soil shear degradation model recommended by H.B. Seed and I.M. Idriss in 1970. A comparison of the shear degradation curves presented in Figures 3.7.1-14 and 3.7.1-15 in the SSAR with the current published industry results, such as the results published by I.M. Idriss and Geomatrix in 1990, shows that the Seed-Idriss 1970 curves overestimated the soil strain degradation. The staff anticipates that the use of the Seed-Idriss 1970 curves in the SSI analyses of the NI structures will underestimate the seismic structural responses. Provide the basis for using the Seed-Idriss 1970 curves in the SSI analyses.

230.80 Subsection 3.7.2.1 of the SSAR (pg. 3.7.2-3) indicates that separate seismic analyses are performed for the nuclear island (NI) for each of the soil profiles defined in Section 3.7.1.4 and the three sets of in-structure seismic responses are enveloped to obtain the seismic design envelope (design member forces, nodal accelerations, nodal displacements, and floor response spectra) used in the design and analysis of seismic Category I structures, components, and seismic subsystems. The staff is concerned that the seismic design of the structures, systems and components of the AP600 standard plant may not be sufficient because it considers only three generic site conditions characterized with soil shear wave velocities that are far apart from each other. An example of the staff's concern is shown in the floor response spectra (FRS) plots of Figure 3.7.2-25. As shown in these plots, the horizontal (EW component in particular) FRS envelope in the control room area may not cover the FRS from two possible intermediate site conditions, one with a shear wave velocity between 1000 ft/sec and 2400 ft/sec (approximately 1500 ft/sec) and the other with a shear wave velocity between 2400 ft/sec and 8000 ft/sec (approximately 3500 ft/sec). Justify the adequacy of using only three generic site conditions for the AP600 standard plant design.

230.81 Sections 3.7.2.1.1 and 3.7.2.1.2 of the SSAR state that the computer code "SAP" was used for performing seismic analyses (response spectrum analysis and time-history analysis) of seismic Category I structures and Reference 7 is used. However, the computer code "BSAP" is referenced in Reference 7. Clarify this inconsistency.

230.82 The first paragraph of Section 3.7.2.1.1 of the SSAR states that response spectrum analyses, using computer code SAP, are performed to obtain the seismic forces and moments for the structural design of the auxiliary building, the shield building, and the containment internal structures on the nuclear island (NI). However, in the third paragraph of the same section, it is stated that Table 2A.17 of the SSAR shows that the hard rock site governs the seismic response forces and moments for the AP600 seismic Category I structures (the auxiliary building, the shield building, and the containment internal structures). Based on the above,

a. describe which method of analysis was used to calculate the seismic forces and moments for the design of the containment vessel for each of the three design site conditions,

b. clarify the inconsistency between Table 2A.17 and Section 3.7.2.1.1, in which a statement is made that the seismic loads for the hard rock site do not always govern, and

c. provide the basis for making the statement in the last paragraph of Section 3.7.2.1.1 that, in such cases, the seismic forces used for the design of NI structures are obtained by multiplying the results from the hard rock response spectrum analysis at each elevation by the ratio of the soil case to the hard rock case member forces at that elevation.

230.83 The third paragraph of Section 3.7.2.1.1 of the SSAR states that response spectrum analyses are performed only for the hard rock site based on the comparison of seismic member forces obtained from the two-dimensional soil-structure interaction analyses presented in Appendix 2A to the SSAR. In the first paragraph of Section 3.7.2.1.2, it is stated that mode superposition time-history analyses using computer program SAP and complex frequency response analysis using computer program SASSI are performed to obtain the in-structure seismic responses (accelerations, displacements and floor response spectra) needed in the analysis and design of seismic subsystems. Which method was used to calculate the seismic response forces and moments for the soil site conditions?

230.84 In Section 3.7.2.1.1 of the SSAR, provide information and explanation to demonstrate:

a. that for site conditions with soil shear wave velocity equal or greater than 8000 ft/sec, the SSI effects between NI structures and soil foundation are negligible and the use of fixed base models is adequate for calculating seismic responses of the NI structures, and

b. that for structures with multimodes, the amplification procedures, described for cases where the responses of soil founded structures exceed the responses of rock (shear wave velocity equal or greater than 8000 ft/sec) founded structures, will provide reasonable results for the design of structures, systems and components.

230.85 In Section 3.7.2.3 of the SSAR, provide detailed descriptions to address the following:

a. How are the unit force and moment applied at the top of the specific finite element sections in order to compute the equivalent sectional properties for the 3D beam elements?

b. How were the containment air baffle and polar crane modeled for the seismic analyses?

230.86 In the SSAR, (a) provide justification for not considering the effects of energy feedback between the NI and the surrounding non-seismic Category I structures in the computation of soil pressures on the NI embedded walls, and (b) demonstrate that based on current plant layout, the physical interaction between the NI structures and other non-seismic Category I structures, if any, is negligible. (Section 3.7.2.4)

230.87 For the case of the three components of ground motion time histories applied separately in the analyses, it is stated in Section 3.7.2.6 of the SSAR that one of the three methods is used to combine the resulted responses from the three components. Method 1 combines the responses algebraically at each time step. Method 2 combines the maximum responses by the SSRS method. Method 3 combines the maximum responses linearly with the coefficients of 1.0, 0.4 and 0.4. Specify, in the SSAR, when and under what circumstance each of the three methods is to be applied.

230.88 Section 3.7.2.7 of the SSAR states that the modal responses of the response spectrum system structural analysis are combined using the SRSS method. When closely spaced modes are present, these modes are considered using either the grouping method, the 10-present method, or the double sum method. However, Section 3.7.2.2 of the SSAR states that the double sum method is used for modes below 34 Hz and the procedure given in Appendix A to Section 3.7.2 of the SRP is used for modes above 34 Hz. Provide clarification for the inconsistency.

230.89 Section 3.7.2.3.1 of the SSAR states that the eccentricities between the centroids (the neutral axis for axial and bending deformation), the centers of rigidity (the neutral axis for shear and torsional deformation), and the centers of mass of the structures are represented by a combination of two sticks in the seismic model. The first stick represents only the axial areas and is located at the centroid. The second stick represents beam element properties other than the axial areas and is located at the center of rigidity. The staff is concerned that the neutral axis for bending deformation should be located at the same centroid as for the axial area and should not be located at the shear rigidity center. Provide an explanation why the bending properties of the beam elements are included in the second stick instead of the first stick.

230.90 Because many different dynamic models (3D stick model, 3D finite element model, 3D stick model coupled with 3D finite element soil foundation model, etc.) and analysis methods (response spectrum analysis method using SAP computer code, time history analysis method using SAP computer code, time history analysis method using SASSI computer code, etc.) were used for the seismic analyses of NI structures, provide a detailed description in the SSAR to show which model combined with which analysis method was used for generating what kind of dynamic responses for the design.

230.91 The second paragraph of Section 3.7.2.1.2 of the SSAR (pg. 3.7-4) states that the individual building lumped-mass stick models are interconnected with rigid linking elements to form the overall dynamic model of the NI structures.

a. Clarify the purpose of using these rigid linking elements.

b. Provide a table listing the magnitude of the stiffness used for the rigid links that connect the shield building and the stick models of other NI structures at various elevations. Compare these stiffness with the actual stiffness of the elements that were represented by the rigid links. Also, list the computed response forces and moments in the rigid links and compare these forces and moments with the capacities of the actual structural elements that the rigid links representing. In addition, indicate how one can ensure that the forces and the moments in the adjoining structural elements were not underestimated because of the artificially high stiffness of the rigid links.

c. Indicate whether these rigid links were used only for the time history analysis in the time domain, or if they were also used for the response spectrum analysis.

230.92 Section 3.7.2.4 of the SSAR (pg. 3.7-8) states that the mass and stiffness contributed by the embedded portion of the NI periphery walls are subtracted from the modal properties of the lumped-mass stick model. Explain, in the SSAR, how the stiffness properties were subtracted.

230.93 Section 3.7.2.11 of the SSAR (pg. 3.7-10) states that the seismic analysis models of the NI structures incorporate the mass and stiffness eccentricities of the seismic Category I structures and the torsional degrees of freedom. Hence, additional accidental torsion is not added to the actual calculated torsional responses.

According to the guidelines of Section 3.7.2.II.11 of the SRP, when accounting for accidental torsion, an additional eccentricity of ±5 percent of the maximum building dimension at the level under consideration shall be assumed for both directions. Provide justification for not including the accidental torsion in the analysis and design.

230.94 Provide the criteria used for decoupling the subsystems from the primary structural systems. (Section 3.7.2.3)

230.95 Regulatory Guide (RG) 1.12 is currently being revised. The seismic instrumentation specified in the original RG 1.12 is out of date. More modern instrumentation, that is more easily operated and maintained and which produces data that can be more easily and rapidly analyzed, is available off the shelf. Provide justification why outdated instrumentation is used or modify the SSAR to include seismic instrumentation in accordance with the draft RG 1017, issued in November, 1992 for public comment.

Geology, Seismology and Geotechnical Engineering

231.15 What are the geography and demography limits for a site at which an AP600 plant could be located?

231.16 Indicate, in the SSAR, what specific design features of the AP600 standard plant allow for a flood level up to the plant grade elevation.

231.17 Incorporate, in the SSAR, the site qualification flow chart provided in Westinghouse's letter dated January 22, 1993 in response to Q231.1. Modify the flow chart to reflect additional factors that may go into the site selection process based on the issues identified in Q231.1 (e.g., inclusion of basemat location for comparison of response spectra, etc.)

231.18 Table 2.0-1 (Site Interface Parameters) in the SSAR makes a general statement, under the heading, "Bearing Strength," that soils must support the AP600 under all specified conditions. Further, it states that an average static bearing reaction of the AP600 is about 8000 pounds/square foot (psf), and that the maximum bearing reaction is about 11000 psf. It is not clear whether the term, "bearing strength" in Table 2.0-1 refers to the ultimate bearing capacity (related to the ultimate failure of the soil), or to the allowable bearing capacity (which is defined in two ways, i.e. (a) the ultimate bearing capacity divided by a suitable design safety factor, or (b) the allowable bearing capacity which may be limited by the foundation settlement criteria). Based on the above,

a. Clarify the above aspect in the SSAR wherever the term "bearing strength" is used.

b. Amplify the table by specifically stating whether the bearing reaction given in Table 2.0-1 is associated with the seismic response of the NI only, or if it is the allowable pressure when considering the appropriate loading combinations (such as dead, live and seismic loads).

c. Table 2.0-1 indicated that the maximum static bearing reaction at a corner is 11000 psf, while Section 2.5 of the SSAR indicates the corresponding figure is 12000 psf. Also, Westinghouse provided the latter (higher) figure in its November 30, 1992 response to Q220.17. Correct the apparent discrepancy.

d. Explain how the high bearing capacity requirement (up to 12000 psf) will be met for a soft soil site with a low shear wave velocity of 1000 fps.

231.19 Table 2.0-1 of the SSAR specifies a minimum shear wave velocity of 1000 feet/second (fps). During the January 20 and 21, 1994 meeting, Westinghouse clarified that the value of 1000 fps meant a minimum <u>best estimate</u> value of the low strain shear wave velocity. This criterion implies an acceptable lower bound shear wave velocity of about 707 fps assuming a 50% reduction of shear modulus specified in SRP 3.7.2 for parametric studies. If 1000 fps is a nominal value, it will be necessary to perform SSI analysis for a 707 fps soil shear wave velocity case. Based on the above, provide the following information:

a. Because no SSI analysis has been performed for shear wave velocities less than 1000 fps, modify Table 2.0-1 to indicate that 1000 fps refers to the lower bound shear wave velocity obtained by considering a 50% reduction from the best estimate value.

b. Similarly, at the other end of the spectrum where the shear wave velocity of soils/soft rock are just below that of hard rock, about 2500 fps or 3000 fps, the variability of the shear modulus must be considered by a factor of 2 per SRP 3.7.2. The staff does not accept Westinghouse's response to Q231.11 that such variation of the modulus by a factor of 2 is intended for sites that are not well investigated.

231.20 Section 2.5 of the SSAR states that, for sites where soil characteristics differ significantly from those used in the generic sensitivity analysis, a COL applicant may perform site-specific soil structure interaction analysis and compare the site-specific floor response spectra at four locations in the superstructure. In the January 8, 1993 response to Q231.3, Westinghouse stated that a comparison of the foundation level response spectra is provided indirectly from the response spectra comparison at the reactor vessel support, because the spectra at that location closely resemble those at the basemat due to the rigidity of the basemat and the internal structure. The intent of the staff question was to ensure compliance with Section 3.7.2 of the SRP, which requires that the spectral amplitude of the horizontal acceleration response spectra in the free field at the foundation depth shall be not less than 60% of the corresponding design response spectra at the grade level in the free field.

In order to facilitate verification of this compliance, include in the SSAR, the basemat location as one of those locations at which the COL applicant will make the necessary comparison.

231.21 SRP 3.7.2 guidance is that the spectral amplitude of the acceleration response spectra at the foundation level in the free field shall be not less than 60% of the corresponding design response spectra at the finished grade in the free field. However, the spectral amplitudes of the acceleration response spectra shown in Figures 2A-21 through 2A-24 show that the spectral amplitudes at the foundation depth do not satisfy this criterion. Section 2A.4 of the SSAR states that the dip in the amplitude of the response spectrum corresponds to the fundamental soil column frequencies at the depth where the response is calculated. However, the dip is very wide and deep over a frequency range from about 3 Hz to about 6.5 Hz.

a. In view of the above phenomenon, and referring to the response to Q231.10, justify not specifying the control motion at an actual or hypothetical rock outcrop in the above cases as well as other sites with one or more thin soil layers overlying rock.

b. The response spectral curves in the above mentioned figures do not match the legends given in the figures. Clarify the figures.

231.22 In the January 22, 1993 response to Q231.5 regarding the assumption of an upper bound value of 8000 feet per second (fps) for the shear wave velocity of the hard rock site, Westinghouse states that, for the hard rock site profile with shear wave velocity of 8000 fps (greater than 3500 fps), the nuclear island is analyzed as a fixed base structure. However, the decision to use fixed base analyses should not be based on a specified rock shear wave velocity, but on the relationship between the SSI frequency and the structural frequency of the NI.

Perform necessary SSI studies for the rock model (with rock shear wave velocity ranging from 8000 to 11000 fps discussed in Q231.5 to justify the use of fixed base analysis for the rock site with shear wave velocity of 8000 fps.

231.23 In the November 30, 1992 response to Q231.6 regarding the lateral earth pressure loads, Westinghouse states that the seismic Category I retaining structures and below grade exterior walls are designed for the worst case enveloping the lateral earth pressure, and that the SSAR will be suitably revised. Westinghouse's response does not clearly address the fact that the lateral earth pressures along the walls of the NI are a function of the lateral extent and character of the backfill soils. Based on the above,

a. Specify, in the SSAR, acceptable ranges of backfill properties (such as compacted soil density, minimum acceptable degree of compaction, range of sizes, etc.) for backfill soils to ensure that the design is adequate, and

b. Justify the use of the Mononobe-Okabe (MO) method for calculating the lateral soil loads on walls of the NI where wall movements relative to the surrounding soil may not develop failure strains in the soil.

231.24 In Section 2A.2 of the SSAR, it states that three depths to bedrock, four generic soil profiles, and a rock case were considered in order to encompass most of the potential site conditions. Further, in Section 2A.6 of the SSAR, (Item 4 on pg. 2A-9), it states that the soft soil profile was eliminated from the design soil profiles, because it gives an acceleration response only slightly higher than the enveloped response of the other three soil profiles at frequencies less than about 1.5 to 2 Hz.

a. Justify, with results of the parametric analyses performed, that the above cases adequately envelop the responses of several soil profiles that might be encountered at potential sites.

b. The elimination of a soft soil profile may mean that qualification of flexible piping systems and equipment, and evaluation of liquid sloshing effects cannot be performed using the AP600 generic floor response spectra. If this is the intent of the SSAR, this should be made clear in appropriate sections of the SSAR.

231.25 Because little experimental data is typically available for dynamic shear properties of rock materials, justify the appropriateness of the degraded shear wave velocity and hysteretic damping values given in Table 2A-5 of the SSAR. Also, indicate in the SSAR the sensitivity of the NI responses to these assumed properties to enable the COL applicant to judge the site selection process.

231.26 The properties of the soft-to-medium soil column given in Table 2A-6 of the SSAR show the shear wave velocity varying linearly from 1000 fps to 2400 fps. Typical variations at sandy soil sites are expected to be curvilinear, with most of the increase in soil stiffness occurring near the upper one-third part of the soil layer due to the nonlinear effects of depth of burial on stiffness. Because such variations may lead to significant differences in soil pressures over the depth of embedment of the NI, as well as changes in free-field ground motions at the foundation mat, provide a comparison of free-field motions at the foundation level obtained from SHAKE deconvolution analysis to indicate the sensitivity of response to this assumption.

231.27 Justify (giving the SHAKE analysis results) the statement made in Section 2A.4 of the SSAR that free field analyses of the profiles with intermediate and shallow depths to bedrock and water table are not necessary, because the input motion is specified at the surface.

231.28 The dynamic properties of the soil columns considered for free-field ground motion evaluation may not be consistent when considering both the horizontal (S-wave) and the vertical (P-wave) motions. The relation between S-wave and P-wave hysteretic damping ratio of the soil is not clear and may not be appropriate for real soils. Discuss the approach adopted for handling the coupled horizontal and vertical ground motions in the free-field and SSI calculations.

231.29 It appears that the Poisson ratio values selected for soils above the water table may not be consistent with values normally expected for silty sands of densities high enough to support a shear wave velocity of 1000 fps. Evaluate and discuss the effect of the assumed Poisson ratio values on the SSI responses.

231.30 No specific evaluations have been made on the potential impact of non-vertically incident ground motion on the NI responses. On this basis,

a. perform SASSI analyses to study the significance of such motions, and report the results in the SSAR, and

b. consider the impact of using different P and S wave hysteretic damping of site soils using the SASSI analysis.

231.31 For sites where the soil characteristics are outside the range considered in Appendix 2A.2 of the SSAR, why are the comparisons of the site specific soil-structure interaction analysis results to the design floor response spectra made at only a very limited number of locations?

231.32 What types of geosciences investigations must a COL applicant perform and what information is critical for making a decision as to the acceptability of a site for an AP600 plant?