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Subject: AP1000 Response to Request for Additional Information (TR85)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on TR85. 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-TR85-SEB1-36 R4

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,

R. F. Ziesing
Director, U.S. Licensing

/Enclosure

1. Response to Request for Additional Information on TR85

D063
NRD

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ENCLOSURE 1

Response to Request for Additional Information on TR 85

RAI Response Number: RAI-TR85-SEB1-36
Revision: 4

Question:

Section 5.1 presents the proposed revisions to DCD Tier 2, Table 2-1, which contains the Site Parameters including those for the soil media. Section 5.2 presents the proposed revisions to DCD Tier 1, Table 5.0-1, which also contains the Site Parameters for the soil. Considering that now the foundation of the AP1000 design has been extended to soil sites, both tables should include the additional items listed below or justification provided for not including the items.

a) Minimum required soil friction angle for soils below and adjacent to the NI. A minimum value of 35 degrees was used in the foundation stability calculations.

b) Settlement Criteria - maximum settlement at key locations (e.g., the corners of the basemat and west side of the shield building), maximum average settlement considering these key locations, maximum differential displacement (e.g., between key locations), and maximum differential displacement between any adjacent structures. Considering the relatively thin 6'-0" basemat for the NI, this criteria is considered important to ensure that there will not be significant settlement which might compromise the structural integrity of the NI basemat and foundation. Also, meeting differential settlement criteria would maintain adequate gap with adjacent structures under seismic loadings to preclude impact. The approach or basis for the selected settlement values should be described.

Additional Request (Revision 1):

The proposed revision to the DCD does not clearly state what is required regarding the evaluation for settlement. As an example, Sections 2.5.4.3 and 2.5.4.6.11 state that "Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values in Table 2.5-1." Therefore, Westinghouse is requested to explain whether the intent of the settlement criteria in the proposed revision to the DCD is to require that the Combined License applicant calculate predicted settlements before construction activities begin. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. These predicted displacements would then be compared to the proposed acceptable settlement values (considered in design), which are presented in Table 2.5-1 of the RAI response. If the predicted displacements exceed the limits of acceptable settlement, then a detailed evaluation and plan needs to be developed before proceeding with the construction. As construction begins, actual measured settlements would then be compared to the predicted settlement values and if exceeded, then a detailed evaluation and plan needs to be developed before proceeding with the construction. If this is the intent of the DCD settlement criteria, then revise DCD Tier 2, Section 2.5.4 including Section 2.5.4.6 - Combined License Information, and DCD Tier 1, Section 5 - Site Parameters to clearly describe the settlement criteria requirements in terms of the items discussed above. Otherwise, provide the technical basis for not doing so.

Additional Request (Revision 2):

Based on the information provided in Revision 1 to this RAI response, Westinghouse is requested to provide the staff with the following information:

(a) If acceptable soil sites are already known to cause potential settlements of as much as one foot as previous studies have indicated, it can be expected that construction settlements will in fact exceed the listed limitations of 3 inches for most soil sites. Buildings of the size and dead load of the NI can be routinely expected to settle well in excess of 3 inches, even at relatively stiff soil sites. Therefore, explain why Table TR85-SEB1-36-1 and the corresponding mark-up of DCD Table 2.5-1 do not present the larger, more realistic and expected settlement value for the NI. Also, explain what should be the components of the detailed plan that the COL applicant needs to implement when the predicted settlements in fact exceed 3 inches.

(b) As is well known in geotechnical engineering, the ability to predict settlements at deep soil sites is difficult at best, with much uncertainty in predictions, even when making conservative assumptions of soil properties. If any of the predicted settlements are indicated to be less than three inches for the total settlement as well as less than the other values presented in Table 2.5-1, and measured settlements during construction are found to seriously exceed these values before completion of construction, what should be the impact on the follow-on construction process and what is the requirement for the COL applicant?

Additional Request (Revision 3):

The staff reviewed the response provided in Westinghouse letter dated July 21, 2009 regarding the settlement criteria for the NI. The information provided in the RAI response and the proposed mark-up to DCD Tier 2, related to settlement have been found to be acceptable. However, as requested in the original RAI and supplemental RAIs, the settlement criteria contained in the proposed mark-up to DCD Tier 2, Table 2.5-1, should also be presented in DCD Tier 1, Table 5.0-1 – Site Parameters.

Additional Request (Revision 4):

During the review of the Vogtle COL application the NRC identified a concern about the characterization of the evaluation alternatives for sites that do not satisfy parameters for limits of acceptable settlement. The mark-up of the DCD previously included in the RAI response uses the term suggested with regard to the evaluation alternatives. This term is ambiguous and does not provide assurance that COL applicant will use the alternatives listed.

Westinghouse Response:

a) The minimum required soil friction angle has been added to both Tables 2-1 and 5.0-1 in accordance with Westinghouse's response to RAI-TR-SEB1-37.

b) DCD subsection 2.5.4.6.11 requires the Combined License applicant to evaluate settlement at soil sites. These evaluations may be performed assuming rigid basemat behavior of the nuclear island and the adjacent buildings.

The effect of settlement on the nuclear island basemat during construction has been considered in the design of the nuclear island as described in Section 2.5 of the report and in DCD subsection 3.8.5.4.2. These analyses consider the flexibility of the basemat during construction. They consider a soft soil site with properties selected to maximize the settlement during construction. These analyses show total settlements of about one foot. The analyses demonstrate that even this significant settlement does not compromise the structural integrity of the NI basemat and foundation.

Westinghouse has established guidance on settlement for the Combined License applicant shown in Table TR85-SEB1-36-1. If site specific settlement analyses predict settlement below the values in this table, the site is acceptable without additional evaluation. If the analyses predict greater settlement, additional evaluation will be performed. This may include specification of the initial building elevations, specification of the stage of construction and settlement for making connections of systems between buildings, etc. It would also include review of the effect of the rotation of buildings and its effect on the gap between adjacent structures. These analyses would provide the basis for review of settlement measurements during construction and subsequent operation.

Acceptable differential settlement between buildings without additional evaluation is identified as 3 inches between the Nuclear Island and the Turbine Building, the Annex Building, and the Radwaste Building. The 3 inches is measured from the center of the Containment Building to the center of the Turbine Building, center of the Annex Building, or the center of the Radwaste Building. Each building, including the Nuclear Island, also has a settlement criterion of no more than ½ inch in 50 feet in any direction. The Nuclear Island has a maximum absolute settlement value of 3 inches.

TABLE TR85-SEB1-36-1
Limits of Acceptable Settlement Without Additional Evaluation

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential between Nuclear Island and Turbine Building.	Differential between Nuclear Island and Other Buildings
½ inch 50 ft	3 inches	½ inch	½ inch

Westinghouse Response to Revision 1:

The intent of the settlement criteria in the proposed revision to the DCD is to require that the Combined License applicant calculate predicted settlements and provide them in the Combined

License application. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. The predicted settlements will be based on conservative assumptions of soil properties. The predicted settlements would be compared to the settlement values in Table 2.5-1 of the DCD that are considered acceptable without further evaluation. If the predicted settlements exceed the limits of acceptable settlement, a detailed evaluation and plan will be described by the Combined License applicant before proceeding with the construction. As construction begins at a soil site, actual measured settlements would then be compared to the predicted settlement values and any exceedances would require additional investigation before proceeding with the construction.

A revision is shown below to DCD Tier 2, Section 2.5.4 including Section 2.5.4.6 - Combined License Information to clearly describe the settlement criteria requirements in terms of the items discussed above. This is Tier 2 information and does not require a revision to the DCD Tier 1, Section 5 - Site Parameters

Westinghouse Response to Revision 2:

(a) Table TR85-SEB1-36-1 contains triggers values that require the COL applicant to further investigate the site for the effects of long-term, rotational settlement. The limit values have been updated in this revision of the RAI to account for discussions of the May 4-8, 2009 Audit meeting, and are listed as follows and provided in Table TR85-SEB1-36-2, updated from Revision 1:

- Total for Nuclear Island Foundation Mat – 6 inches
- Differential between NI and adjacent buildings – 3 inches

TABLE TR85-SEB1-36-2
Limits of Acceptable Settlement Without Additional Evaluation

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential between Nuclear Island and Turbine Building.	Differential between Nuclear Island and Other Buildings
½ inch 50 ft	6 inches	3 inches	3 inches

In the case that the COL applicant's site specific predicted settlement analysis yields results exceeding these limit values, the following alternatives are presented:

1. Evaluate the impact of the elevated estimated settlement values on the critical components of the AP1000 including, but not limited to, piping spanning between the Nuclear Island and the adjacent structures, the equipment support pads, the construction gap between the NI and adjacent buildings, and the stresses on the basemat (along with influences to the underlying soil).

2. Submit a construction sequence to control the predicted settlement behavior. A revised sequence should follow the specific schedule to distribute construction loads as necessary in order to obtain acceptable values. Depending on soil conditions, a significant amount of the settlement could occur during construction, and can be controlled through the construction sequence.

3. Provide a uniform excavation and engineered backfill to manage static building rotation and differential settlement between the Nuclear Island and adjacent structures.

4. Implement an active settlement monitoring system throughout the entire construction sequence as well as a long-term (plant operation) plan. By monitoring the settlement throughout construction, the COL applicant will be able to modify the construction sequences of adjacent buildings to conform to the site's settlement characteristics and minimize differential settlement. For soil sites, the potential heave or rebound of the excavation bottom, the effect of dewatering and the effect of foundation loading during construction should be monitored by the COL applicant. The monitoring system shall consist of three primary elements as follows:

   - Piezometers to measure pore pressures in a soil layer prone to consolidation type settlement. Vibrating wire piezometers are preferred for this purpose as they are adequately sensitive and responsive and easily record positive and negative changes on a real time basis.

   - Settlement monuments placed directly on concrete, preferably on the Mud Mat for early construction monitoring and on the corners of the structures at grade once the Mud Mat monuments have been covered by backfill to be used for long term monitoring. Monuments at grade are to be accessible with conventional surveying equipment

   - Settlement telltales if monuments are not practical or if fills are used over consolidation type soils and it is necessary to monitor settlement of the consolidation type in-situ soils independent of the consolidation of the engineered fill soil. Most soil sites will not need this particular form of monitoring.

   Develop graphs and plots of the field measurements to:

   - Show Movement (settlement or heave) versus Time
   - Estimate Construction Loads versus Time
   - Measure Ground water levels from the dewatering activities versus Time

   This data should be maintained during construction and post-construction as needed depending on the field measurement results.

(b) If the actual settlement values obtained at any given stage of construction are significantly higher than the predicted values or those in Table TR85-SEB1-36 (Revision 1), whichever is higher, the COL applicant shall execute any applicable option(s) provided in section (b) of this RAI response to minimize differential settlement and assure adequate seismic gaps and proper installation of safety related systems and components.

Westinghouse Response to Revision 3:

The settlement criteria from Tier 2 are added to Tier 1 Table 5.0-1. These settlement criteria are not an absolute requirement. A site that does not meet the settlement criteria requires additional evaluation.

Westinghouse Response to Revision 4:

In response to the NRC concern about the characterization of the evaluation alternatives for sites that do not satisfy parameters for limits of acceptable settlement, the word "Suggested" is removed from the DCD mark-up for Subsection 2.5.4.3 as shown below.

References: None

Design Control Document (DCD) Revision:

The revisions to the DCD identified in Revision 0 of this response have been incorporated in DCD Revision 17. The following revisions are to DCD Rev 17 and include the changes made in Revision 1, 2, ~~and~~ 3, and 4 of this response.

Revise the Soil parameters in Tier 1 Table 5.0-1 as follows: (This mark-up does not show changes included in the response to other RAIs and open items)

Table 5.0-1 (cont.) Site Parameters	
Soil	
Average Allowable Static Soil Bearing Capacity	The allowable bearing capacity, including a factor of safety appropriate for the design load combination, shall be greater than or equal to the average bearing demand of 8,900 lb/ft^2 over the footprint of the nuclear island at its excavation depth.
Maximum Allowable Dynamic Bearing Capacity for Normal Plus Safe Shutdown Earthquake (SSE)	The allowable bearing capacity, including a factor of safety appropriate for the design load combination, shall be greater than or equal to the maximum bearing demand of 35,000 lb/ft^2 at the edge of the nuclear island at its excavation depth, or site-specific analyses demonstrate factor of safety appropriate for normal plus safe shutdown earthquake loads.

Table 5.0-1 (cont.) Site Parameters		
Limits Of Acceptable Settlement Without Additional Evaluation[a]	Differential Across Nuclear Island Foundation Mat	1/2 inch in 50 ft
	Total for Nuclear Island Foundation Mat	6 inches
	Differential Between Nuclear Island and Turbine Building[b]	3 inches
	Differential Between Nuclear Island and Other Buildings[b]	3 inches
	[a] Additional evaluation may include evaluation of the impact of the elevated estimated settlement values on the critical components of the AP1000, determining a construction sequence to control the predicted settlement behavior, or developing an active settlement monitoring system throughout the entire construction sequence as well as a long-term (plant operation) plan.	
	[b] Differential settlement is measured at center of Nuclear Island and center of adjacent structures.	

Table 5.0-1 (cont.) Site Parameters	
Lateral Variability	Soils supporting the nuclear island should not have extreme variations in subgrade stiffness. This may be demonstrated by one of the following: 1. Soils supporting the nuclear island are uniform in accordance with Regulatory Guide 1.132 if the geologic and stratigraphic features at depths less than 120 feet below grade can be correlated from one boring or sounding location to the next with relatively smooth variations in thicknesses or properties of the geologic units, or 2. Site-specific assessment of subsurface conditions demonstrates that the bearing pressures below the footprint of the nuclear island do not exceed 120% of those from the generic analyses of the nuclear island at a uniform site, or 3. Site-specific analysis of the nuclear island basemat demonstrates that the site specific demand is within the capacity of the basemat. As an example of sites that are considered uniform, the variation of shear wave velocity in the material below the foundation to a depth of 120 feet below finished grade within the nuclear island footprint and 40 feet beyond the boundaries of the nuclear island footprint meets the criteria in the case outlined below. Case 1: For a layer with a low strain shear wave velocity greater than or equal to 2500 feet per second, the layer should have approximately uniform thickness, should have a dip not greater than 20 degrees, and should have less than 20 percent variation in the shear wave velocity from the average velocity in any layer.
Shear Wave Velocity	Greater than or equal to 1000 ft/sec based on minimum low-strain soil properties over the footprint of the nuclear island at its excavation depth
Liquefaction Potential	Negligible

Revise Tier 2, subsection 2.5.4.3 as follows: (Revision 4 of this response removes the word suggested from the line following the second paragraph.)

2.5.4.3 Settlement

The Combined License applicant will address short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the nuclear island foundation and adjacent buildings consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure.

The AP1000 does not rely on structures, systems, or components located outside the nuclear island to provide safety-related functions. Differential settlement between the nuclear island foundation and the foundations of adjacent buildings does not have an adverse effect on the safety-related functions of structures, systems, and components. Differential settlement under the nuclear island foundation could cause the basemat and buildings to tilt. Much of this settlement occurs during civil construction prior to final installation of the equipment. Differential settlement of a few inches across the width of the nuclear island would not have an adverse effect on the safety-related functions of structures, systems, and components. Table 2.5-1 provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period or otherwise justified. The predicted settlements will be based on conservative assumptions of soil properties. If the predicted settlements exceed the limits of Table 2.5-1, a detailed evaluation and construction plan will be described by the Combined License applicant. During construction and plant operation at a soil site, settlements would be measured and compared to the predicted settlement values and any exceedances would require additional investigation. ~~When the predicted settlement exceeds these values, the Combined License applicant will describe any special construction provisions to accommodate the predicted settlement.~~

~~Suggested a~~Alternatives for the additional evaluations are provided as follows:

1. Evaluate the impact of the elevated estimated settlement values on the critical components of the AP1000 including, but not limited to, piping spanning between the Nuclear Island and the adjacent structures, the equipment support pads, the construction gap between the NI and adjacent buildings, and the stresses on the basemat (along with influences to the underlying soil).

2. Submit a construction sequence to control the predicted settlement behavior. A revised sequence should follow the specific schedule to distribute construction loads as necessary in order to obtain acceptable values. Depending on soil conditions, a significant amount of the settlement could occur during construction, and can be controlled through the construction sequence.

3. Provide a uniform excavation and engineered backfill to manage static building rotation and differential settlement between the Nuclear Island and adjacent structures.

4. Implement an active settlement monitoring system throughout the entire construction sequence as well as a long-term (plant operation) plan. By monitoring the settlement throughout construction, the COL applicant will be able to modify the construction sequences of adjacent buildings to conform to the site's settlement characteristics and minimize differential settlement. For soil sites, the potential heave or rebound of the excavation bottom, the effect of dewatering and the effect of foundation loading during construction should be monitored by the COL applicant. The monitoring system shall consist of three primary elements as follows:

- Piezometers to measure pore pressures in a soil layer prone to consolidation type settlement. Vibrating wire piezometers are preferred for this purpose as they are adequately sensitive and responsive and easily record positive and negative changes on a real time basis.

- Settlement monuments placed directly on concrete, preferably on the Mud Mat for early construction monitoring and on the corners of the structures at grade once the Mud Mat monuments have been covered by backfill to be used for long term monitoring. Monuments at grade are to be accessible with conventional surveying equipment

- Settlement telltales if monuments are not practical or if fills are used over consolidation type soils and it is necessary to monitor settlement of the consolidation type in-situ soils independent of the consolidation of the engineered fill soil. Most soil sites will not need this particular form of monitoring.

Develop graphs and plots of the field measurements to:

- Show Movement (settlement or heave) versus Time
- Estimate Construction Loads versus Time
- Measure Ground water levels from the dewatering activities versus Time

This data should be maintained during construction and post-construction as needed depending on the field measurement results.

The revisions to DCD Subsection 2.5.4.6.11 shown below were included in Revision 0 of this response and have been incorporated into DCD Revision 17.

2.5.4.6.11 Settlement of Nuclear Island – Data will be provided on short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the nuclear island foundation and adjacent buildings consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure. Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1.

Table 2.5-1

LIMITS OF ACCEPTABLE SETTLEMENT WITHOUT ADDITIONAL EVALUATION

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential Between Nuclear Island and Turbine Building*	Differential Between Nuclear Island and Other Buildings*
1/2 inch 50ft	~~3~~6 inches	~~1/2~~3 inches	~~1/2~~3 inches

* Differential settlement is measured at center of Nuclear Island and center of adjacent structures.

PRA Revision:

None

Technical Report (TR) Revision:

None