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

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 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-SEB1-17 R5

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,

D. P. Lindgren /For

Robert Sisk, Manager
Licensing and Customer Interface
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/Enclosure

1. Response to Request for Additional Information on SRP Section TR85

D063
NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section TR85

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-17
Revision: 5

Question:

In Section 2.5, the first paragraph (Page 19 of 83) states that in the expected basemat construction sequence, concrete for the mat is placed in a single placement. The last sentence of the same paragraph states that once the shield building and auxiliary building walls are completed to Elevation 82'-6", the load path changes and loads are resisted by the basemat stiffened by the shear walls. The staff identified the following issues:

a. Since the size of the basemat is 256 feet by 161 feet, provide a detailed description of how the single placement is to be placed (e.g., by layers or by areas, time period between pouring of layers or areas, if by areas - type of joint detail to ensure proper connection, etc.).

b. Explain how the "single placement" can be completed and considered as a "single placement," if any unexpected incidents (such as malfunction of concrete mixer, etc.) occur.

c. Provide the basis of how the residual stress at the junction between the shear walls and the shield building is calculated (detailed calculation procedure needs to be provided) and designed for, if the auxiliary building shear walls are to be constructed up to Elevation 82'-6" first and then construction of the shield building.

d. Describe what construction techniques and design provisions are needed to address issues related to the use of a single massive concrete pour of the entire basemat. The response should also address concerns related to the effects of heat generation, restraint, and volume changes associated with a large single massive pour, and how the cracking of the concrete basemat will be avoided.

e. Where in the DCD is the requirement for the COL applicant to follow the construction sequences considered by Westinghouse in the design of the NI structures? If the COL applicant proposes to use a construction sequence that is substantially different than that studied by Westinghouse, the COL applicant should be required to demonstrate that their proposed sequence does not cause a problem.

Additional Request (Revision 1):

The RAI response states that the acceptability of the construction sequence used by the COL applicant is addressed by an ITAAC. However, the ITAAC could not be located; therefore, Westinghouse is requested to identify the ITAAC to be included in DCD Tier 1.

Additional Request (Revision 2):

The staff reviewed the RAI response provided in Westinghouse letter dated 12/2/08. The staff concurs that DCD Rev. 17 Section 3.8.5.4.2 has been revised to update the information for the three construction sequences that were evaluated to demonstrate construction flexibility within certain limits. However, a statement in the RAI response indicates that the acceptability of the construction sequence used by the COL applicant is addressed by the settlement analyses described in DCD subsection 2.5.6.4 which provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. Since DCD subsection 2.5.6.4 does not exist, explain what subsection this should refer to. If the intent was to refer to DCD subsection 2.5.4.3 - Settlement, then the information contained in this subsection does not explain how this settlement criteria ensures that the construction sequences evaluated and described in DCD Section 3.8.5.4.2 will be satisfied. To facilitate the resolution of this issue, it would be appropriate to include in the DCD the construction sequence limitations that were assumed in the set of construction sequence analyses described in the RAI response.

Additional Request (Revision 3):
(Follow-up RAIs dated 4/27/09 [note: this was based on review of the Rev 1 response])

The staff concurs (note: this was based on review of Rev 1) that DCD Rev. 17, Section 3.8.5.4.2, has been revised to update the information for the three construction sequences that were evaluated to demonstrate construction flexibility within certain limits. However, a statement in the RAI response indicates that the acceptability of the construction sequence used by the COL applicant is addressed by the settlement analyses described in DCD subsection 2.5.6.4 which provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. Since DCD subsection 2.5.6.4 does not exist, explain what subsection this should refer to. If the intent was to refer to DCD subsection 2.5.4.3 - Settlement, then the information contained in this subsection does not explain how these settlement criteria ensure that the construction sequences evaluated and described in DCD Section 3.8.5.4.2 will be satisfied. To facilitate the resolution of this issue, it would be more appropriate to include in the DCD the construction sequence limitations that were assumed in the set of construction sequence analyses described in the RAI response.

Additional Request (Revision 4):

The Westinghouse RAI response revised subsection 2.5.4.6.11 - Settlement of Nuclear Island, to state that, "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 (see subsection 3.8.5.4.2 for analyses of settlement during construction and the required limitations on construction sequence by the Combined License

applicant). Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1."

The staff finds that this revision does not make it clear that in addition to meeting the settlement criteria presented in Table 2.5-1, the construction sequence limitations presented in subsection 3.8.5.4.2 must also be satisfied by the COL applicant. Westinghouse is requested to include such a clear statement in DCD Section 2.5.

Additional Request (Revision 5):

The staff reviewed the Westinghouse response to RAI-TR85-SEB1-17, Rev. 4 and determined that more information is needed.

In the response, the proposed seventh paragraph of DCD Subsection 3.8.5.4.2 states, "The analyses of alternate construction scenarios show that member forces in the basemat are acceptable subject to the limits shown below, imposed for soft soil sites, on the relative level of construction of the buildings. Construction of the AP1000, when located at a soil site, will satisfy the limits shown below or a site specific analysis of settlement and member forces will be completed. These limits do not apply to AP1000 units with a soil profile that satisfies the requirements for soft rock, firm rock, or hard rock shown in Subsection 3.7.1.4".

Although the construction sequence limits were developed based on analyses for soft soil sites, there is no technical basis showing that construction sequence limits are not needed for soft or firm rock sites. Therefore, provide the technical basis for excluding soft and firm rock sites from the proposed construction sequence limits, or, revise the corresponding sections of DCD to include soft and firm rock sites as well. Also, correct the first sentence of the proposed seventh paragraph (quoted above) to make it clear that for each of the alternate construction scenarios, the softest soil site properties were used in the analyses.

Westinghouse Response (Revision 1):

The reference to the ITAAC has been replaced in the response to item (e) by a reference to the Combined License applicant's information on settlement.

a. Site specific placement plans will be developed to address the placement of concrete for the NI basemat. Those plans will address the conditions outlined below:

   The concrete for the NI basemat will be placed in a single continuous placement operation. It is expected that the batch plant equipment and materials on site (site dependent) for this operation will consist of the following equipment or equal in order to support this placement:

   - 12 cubic yard central mix batch plant (main plant)

- 10 or 12 cubic yard backup/auxiliary batch plant
- All coarse and fine aggregates stockpiled on-site to support the placement
- All admixtures (water reducer, plasticizer, air entraining agent, etc.) on-site to support the placement.
- All cement and fly ash stored on-site (batch plant silos and supplemental storage blimps) or reliability of re-supply during the placement verified.
- If ice is required, adequate supplies will be stored on-site or reliability of re-supply during the placement verified.
- Adequate concrete trucks including back-up trucks on-site to support the placement.
- Adequate personnel and truck drivers assigned to the batch plants to support multiple shift operations.

For the main batch plant, sustained maximum production is expected to reach 250 cubic yards per hour and average production is expected to exceed 200 cubic yards per hour allowing for decreased production periods at the beginning and at the end of the concrete placement. The placement plan shall be based on the use of one plant being able to successfully complete the placement, however the back-up plant may be used during the placement. Initial plans indicate that the placement will take approximately 36 hours.

Concrete will be placed by conventional placement equipment (i.e., pumps, conveyors, buckets, etc.) suitable for the site conditions. Telebelts (conveyors mounted on hydraulic cranes) or conventional conveyors may be used in concert with concrete pumps dependent on the site. Back-up equipment will be provided. Concrete will be placed in a "stair-step" pattern to minimize the exposed working face. Multiple concrete placing crews will be used to balance the concrete placement with the expected rate of concrete supply.

b. In theory a single placement could be interrupted for any one of several reasons. Possible causes of placement interruption based on experience at other projects are listed below together with the associated preventative or mitigating action being planned in each case for the AP1000 NI basemat.

Reason for Interruption	Preventative or Mitigating Action
Bad Weather	Placement to be made only after comprehensive site specific favorable weather forecast. Contingency plans will be in place for unexpected weather conditions.
Breakdown of Batch Plant	Back-up Batch Plant capacity on or nearby the site that satisfies Quality Control and Quality Assurance requirements of the Project. Critical system such as power supply to the batch plant will also have backup.

Breakdown of Concrete Trucks	Backup trucks will be provided.
Breakdown of Concrete Placement Equipment	Backup equipment will be provided.
Inadequate Quantities of Batch Constituents	Sufficient materials will be stored on site to provide for the required concrete quantity plus allowances for extra concrete that may be required for rejected concrete, waste and spillage and low estimated quantities.
Power Failure – unable to operate batch plant	Redundant source of power on site such as a portable diesel generator
Failure of Formwork	Field Engineers will check the formwork prior to the placement. Carpenters will be assigned to monitor the formwork during the placement.
Construction Accident	Enhanced Safety training and briefing of all supervisors and craft labor prior to the placement

In the unlikely event that a major interruption occurs in spite of the above cited Preventative or Mitigating Actions, the duration and cause of the delay and the associated effect on the integrity of the NI basemat will be evaluated. Depending on the level of the impact on the integrity, remediation actions could range from (a) removal, cleaning and green cutting of a new mating surface to (b) complete removal and subsequent placement of a portion of the placement and insertion of a new unplanned construction joint to be designed at the time of the occurrence.

c. The "residual stresses" are evaluated as "locked-in" stresses considering the immediate and long term settlements, the loading history consistent with the construction sequence, and the increasing foundation mat and superstructure stiffness as construction elements are placed and integrated into the structure.

The response to RAI-TR85-SEB1-19 presents details of the computational process and how the resulting forces and moments are considered in the design. The generic analysis includes the effects of three construction sequences, namely, a base case, a delayed Auxiliary building case and a delayed Shield building case.

d. While the quantity of concrete in the NI basemat is relatively large when compared to walls and floor slabs throughout the Nuclear Island, it is not large by normal modern construction practices. The American Concrete Institute (ACI) Code, including ACI 207.1R-05, "Guide to Mass Concrete" and ACI 207.2R-95 (reapproved 2002) "Effect of Restraint, Volume Change and Reinforcement on Cracking of Mass Concrete," has been considered in the design and planning of the NI basemat placement. The most significant issue is the heat of hydration associated with large placement which, in theory, could lead to deleterious cracking if not addressed in the design and construction

operation. Depending on the site location and conditions, the concrete temperature will be monitored and the concrete mix will be designed to minimize the heat of hydration, associated temperature rise and subsequent drop and the related tendency for cracking. Measures available for dealing with the heat of hydration, to be worked out on a site by site basis depending on the time of the year and location of the site, include the following:

Aggregate Size and cement fineness
Overall placement procedure
Use of chilled water and/or ice
Enhanced quantity of flyash (pozzolanic)
Use of chilled aggregate
Immediate commencement of curing after finishing
Use of misting equipment
Additives such as water reducers & retarders
Evaporative cooling (water spray) of aggregates

e. DCD 3.8.5.4.2 describes three construction sequences that were evaluated for a soft soil site to demonstrate construction flexibility within broad limits. The acceptability of the construction sequence used by the COL applicant is addressed by the settlement analyses described in DCD subsections 2.5.4.3 and 2.5.4.6.11 which provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. When the predicted settlement exceeds these values, the Combined License applicant will describe any special construction provisions to accommodate the predicted settlement.

- A base construction sequence which assumes no unscheduled delays.
- A delayed shield building case which assumes a delay in the placement of concrete in the shield building while construction continues in the auxiliary building.
- A delayed auxiliary building case which assumes a delay in the construction of the auxiliary building while concrete placement for the shield building continues.

The analyses of alternate construction scenarios show that member forces in the basemat are acceptable subject to the following limits imposed for soft soil sites on the relative level of construction of the buildings prior to completion of both buildings at elevation 82′ -6″:

- Concrete may not be placed above elevation 84′ -0″ for the shield building or containment internal structure.

- Concrete may not be placed above elevation 117′ -6″ in the auxiliary building, except in the CA20 structural module where it may be placed to elevation 135' - 3".

Westinghouse Response (Revision 2):

The response has been revised to correct the reference to DCD subsection 2.5.4.6.11 instead of 2.5.6.4. This subsection states: "Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1." The construction sequence limitations assumed in the analyses are already described in DCD Rev 17 subsection 3.8.5.4.2.

The majority of sites will satisfy the values of Table 2.5-1. The special construction requirements will only apply at unusual very soft sites. Any additional discussion of this should be in the Combined License applications for such sites.

Westinghouse Response (Revision 3):

A reference to DCD subsection 2.5.4.3 has been added in the response to Item (e) above.

A revision is shown to the DCD subsection 2.5.4.6.11 referencing the construction sequence limitations that were assumed in the set of analyses described in the RAI response and described in DCD Section 3.8.5.4.2.

Westinghouse Response (Revision 4):

DCD Section 3.8.5.4.2 contains the following limitation on the construction sequence.

> prior to completion of both buildings (shield building and auxiliary building) at elevation 82′ -6″:
>
> - Concrete may not be placed above elevation 84′ -0″ for the shield building or containment internal structure.
> - Concrete may not be placed above elevation 117′ -6″ in the auxiliary building, except in the CA20 structural module, where it may be placed to elevation 135′-3″.

DCD Subsection 2.5.4.6.11 will be revised to clarify the reference to construction sequence limits in Subsection 3.8.5.4.2. Subsection 3.8.5.4.2 will be revised to clarify the applicability of the construction sequence limits.

These construction sequence limits were developed for a soft soil case. Based on consideration of the elastic settlement due to dead load, construction sequence limits are not

required for soil properties that satisfy the requirements for rock sites in DCD Subsection 3.7.1. Construction at hard rock sites was approved in the certified design without construction sequence limits. The proposed DCD change excludes limits for soft, firm, or hard rock sites.

Westinghouse Response (Revision 5):

The limiting of the proposed construction sequence limits to soil sites was first applied in the AP600 Design Certification. The evaluation which supports the construction limits is described in the AP600 Design Control Document as being developed for soil site conditions. By implication these limits do not apply to rock sites. The DCD mark-up provided below clarifies explicitly that the construction sequence limits apply to soil sites with shear wave velocities below 7,500 feet per second. As explained in RAI-SRP3.7.1-SEB1-02, Revision 3, the shear wave velocity at the bottom of the basemat can drop to 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths. In RAI-SRP2.5-RGS1-21 Revision 1 the criterion for shear wave velocity at the bottom of the basemat equal to or higher than 7,500 fps is included in a Tier 1 Table.

References:

1. ACI 207.1R-05, "Guide to Mass Concrete"
2. ACI 207.2R-95 (Re-approved 2002), "Effect of Restraint, Volume Change and Reinforcement on Cracking of Mass Concrete"

Design Control Document (DCD) Revision:

The revisions described in Revision 0 of this response are incorporated in DCD Rev 17. The following additional changes are required for Revisions 3, ~~and~~ 4, and 5 of this response.

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. Subsection 3.8.5.4.2 includes analyses of settlement during construction completed to support the design certification and the required limitations on construction sequence for some sites. The limitations on construction sequence impose limits on the placement of concrete for the shield building and the auxiliary building prior to completion of both buildings at elevation 82′ -6″. Special construction requirements will be described, if required, to accommodate site specific settlement predicted to exceed the values shown in Table 2.5-1.

Revise the seventh paragraph of Subsection 3.8.5.4.2 and the subsequent bulleted items as follows:

The analyses of alternate construction scenarios considered the softest material properties satisfying the shear wave velocity limit of 1000 feet per second. These analyses show that member forces in the basemat are acceptable subject to the ~~following~~ limits shown below on the relative level of construction of the buildings. Construction of the AP1000 will satisfy the limits shown below or a site specific analysis of settlement and member forces will be completed. These limits do not apply to AP1000 units with a soil profile where the shear wave velocity exceeds 7500 feet per second,

P~~p~~rior to completion of both the shield building and auxiliary building~~s~~ at elevation 82′ -6″:

- Concrete may not be placed above elevation 84′ -0″ for the shield building or containment internal structure.
- Concrete may not be placed above elevation 117′ -6″ in the auxiliary building, except in the CA20 structural module, where it may be placed to elevation 135′-3″.

PRA Revision:

None

Technical Report (TR) Revision:

No changes to Revision 1 of the Technical Report.