RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/27/2014

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 960-6709 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**09/24/2012**

QUESTION NO. 03.07.02-212:

The staff notes that Section 1.0 of MHI TR MUAP-12002 (R0), "Sliding Evaluation and Results," discusses structural gaps between buildings, but provides no details. To assist the staff in its evaluation of the sliding stability methodology, the staff requests the applicant to provide the following additional information related to structural gaps:

a) In order to judge the adequacy of the gaps, to document which structures are adjacent to each other, and to document the structures that share a common basemat, the applicant is requested to provide a figure that shows those information. The figure should include all of the Seismic Category I structures and non-Seismic Category I structures at the plant site, the boundary of the separate concrete basemats, and the magnitude of the gaps between adjacent basemats (below grade and above). The structures should include those within the MHI USAPWR design certification and those that are within the COL application scope.

b) Explain how the adequacy of gaps between the adjacent structures will be determined in view of the magnitude of sliding that may occur.

c) Describe how the seismic building response is combined with the potential sliding displacement, and how the total response of the two adjacent structures is compared (assuming out of phase motion) to ensure sufficient gaps exist with some factor of safety.

ANSWER:

This answer revises and replaces the previous MHI answer that was transmitted by Letter UAP-HF-12292 (ML12356A069).

a) A figure including a plan view and vertical sections for the Standard Plant structures is provided in Attachment 1. The exact locations of the structures within the Combined License (COL) Applicant's scope are site specific. Therefore these structures could not be included in the figure. Adequacy of the gaps between the site specific structures and the Standard Plant structures are to be addressed by the COL

Applicant. The requirement for the COL Applicant to confirm the adequacy of the gaps between site specific and Standard Plant structures by site-specific analyses of settlement and seismic sliding stability, as applicable, is reflected in DCD Subsection 3.8.5.5 and captured in DCD Section 3.8.6 including COL 3.8(24), COL 3.8(25), COL 3.8(26), COL 3.8(31), and COL 3.8(32).

b) The adequacy of the gaps between adjacent structures *(both below grade and above grade)* are addressed, in view of the potential sliding magnitude, as follows

   1. The access control building (AC/B) and the tank house weigh approximately 28,000 kips and 16,000 kips, respectively. The reactor building (R/B) complex weighs approximately 1,200,000 kips. Therefore, the AC/B and tank house weigh approximately 2.3 percent and 1.3 percent of the R/B complex, respectively. Thus, any sliding of the R/B complex toward the AC/B and/or the tank house will result in pushing these structures in the sliding direction of the R/B complex, with compression of the material in the gaps and subsequent reduction of the gap size. This gap size reduction is calculated as described in the answer to Question 212(c), amplified by a factor of safety of 2, added to other gap closures due to structure tilt and flexure, and verified for adequacy against the initial gap opening shown in Attachment 1. The maximum expected increase in pressure in the gap induced by sliding is considered in the design of adjacent basement walls.

   2. The gap between the R/B complex basemat and the turbine building (T/B) complex basemat is much larger (see Attachment 1), so there is no danger of contact between the structures' basemats due to gap closure. A potential issue is the increase in pressure in the backfill in the gap due to the two structures (R/B complex and T/B complex) sliding toward each other. The nonlinear sliding analysis provides a conservative estimate of the relative displacements of the R/B complex and the T/B complex and resulting gap closure (see the answer to Question c, below). This conservative estimate is then used to calculate the increase in pressure on the structural walls adjacent to the gap, due to compression of the backfill in the gap. These pressures are used for the design of structural below grade walls.

c) Gap closure due to seismic building response including potential sliding is calculated at the most critical point, located at the highest elevation in the gap. It is considered to consist of: (1) closure due to sliding, (2) closure due to long term tilt of the structures toward each other, and (3) closure due to dynamic flexure of the walls, assuming the worst case when the walls bend one towards the other during the SSE. This gap closure is calculated as described below.

   1. For the two lighter structures (AC/B and tank house) the maximum pressure in the gap due to R/B complex sliding toward these structures is conservatively estimated as the envelope of dynamic pressure and passive pressure. This is a conservative assessment, as mobilization of the entire passive pressure requires sliding displacements considerably larger than the maximum displacements induced by sliding. The passive pressures are calculated based on the Rankine earth pressure theory, modified to account for the presence of a rigid structure within the passive soil wedge. A series of conservative assumptions are used:

- Use upper bounds for the strength and unit weight of the engineered fill surrounding the AC/B and the tank house

- Use a lower bound for the stiffness of the backfill in the gap

- Assume low groundwater level, as passive pressures developed in unsaturated soil are larger than in saturated soil

- Consider the effect of out of phase motion by accounting for horizontal inertia forces induced by sliding in the adjacent buildings (AC/B and tank house), acting in the direction of increasing dynamic pressure.

The forces necessary to push the AC/B and the tank house away from the R/B complex are calculated considering conservatively that full passive pressure is mobilized in the backfill surrounding the two structures, and are as follows:

- For the AC/B: $P_{AC/B}$ = [93,340] kip

- For the tank house: P_{TH} = [63,525] kip

The minimum forces necessary to compress the backfill in the gaps between (1) the R/B complex and the AC/B, and (2) the R/B complex and the tank house by 0.75 inches (which is the maximum expected sliding distance for the R/B complex) are estimated for a reasonably minimum value of the deformation modulus of the backfill corresponding to a shear wave velocity, Vs = 300 ft/s. Other assumed properties for the backfill are: Poisson's ratio, μ = 0.3 and unit weight, γ = 125 pcf. A minimum value of the deformation modulus resulted as:

Therefore, the maximum gap closure due to sliding is $\Delta_{sliding}$ = 0.75 inches.

The gap closure due to long term tilt (Δ_{tilt}) is calculated based on the settlement during operation life of the plant, as a function of the tilt of each of the adjacent structure (s_1 and s_2 – in percents), and the lowest height of the two structures in contact, H. The maximum closure, at the roof level, is:

Additional gap closure above grade level, due to deflection of the walls produced by seismic loads, $\Delta_{dynamic}$, is calculated based on the results of soil-structure interaction (SSI) analyses. For the R/B complex, the following maximum displacements toward AC/B and tank house have been calculated in detail for walls adjacent to these two structures:

Dynamic displacements have not been calculated for the AC/B and the tank house. It is conservatively assumed that these displacements are two times larger than the ones calculated for the R/B complex at neighboring locations, i.e.,

A factor of safety of two is applied to the total gap closure, Δ, and the resulting value calculated according to equation (4) is checked against the initial gap opening:

$$\Delta = 2(\Delta_{sliding} + \Delta_{tilt} + \Delta_{dynamic}) \qquad (4)$$

The resulting values are: Δ ≈ [5.0] inches for the AC/B, and Δ ≈ [5.3] inches for the tank house. Both these values are well below the gap size, of 16 inches.

The gap between the R/B complex and the T/B is much larger, on the order of 13 feet (see Attachment 1 provided as part of the Answer to part a) of this question), therefore there is no concern regarding structure hammering. The gap closure due to sliding is calculated to estimate the increase in pressure on the structural walls adjacent to the gap, due to compression of the backfill in the gap. This gap closure is addressed as follows: For each of the two structures, nonlinear sliding analyses are performed for six generalized layered subgrade profiles and five acceleration time histories compatible with the certified seismic design response spectra (CSDRS). At each time instant, the total displacement for each structure is calculated as the vector sum of the sliding displacements in the X and Y directions. The nonlinear sliding analyses provide the maximum total displacements for each structure, each subgrade profile and each acceleration time history. The maximum expected sliding is calculated by statistical processing of results from different subgrade profiles and time histories, and represents the maximum value with exceedance probability of 2.5 percent (more details are provided in Section 5.4 of Technical Report MUAP 12002, Rev. 1). The gap closure is calculated as the absolute sum of the maximum expected values for the two structures (R/B complex and T/B complex). This calculation accounts for the possibility of the seismic waves to arrive in any direction, and for the two structures experiencing out of phase motions. Thus, the maximum gap closure due to sliding is $\Delta_{sliding}$=0.75+0.2=0.95 inches.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on PRA

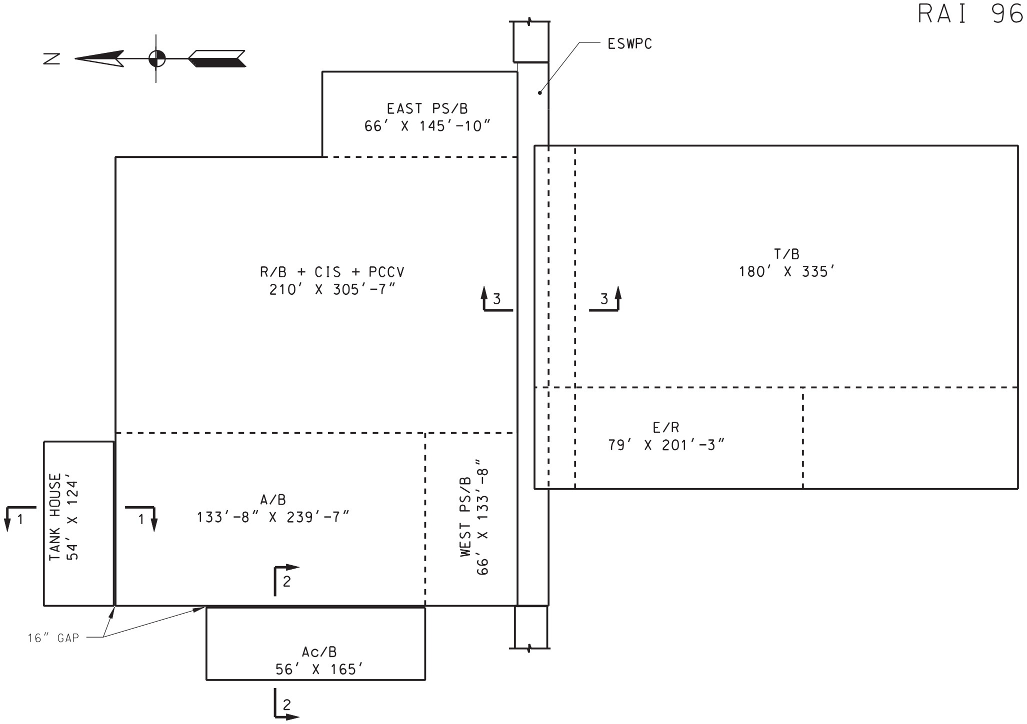
There is no impact on the PRA.

Impact on Technical/Topical Report

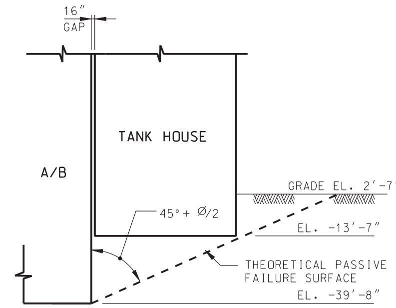
There is no impact on the Technical/Topical Report.

This completes MHI’s response to the NRC’s question.

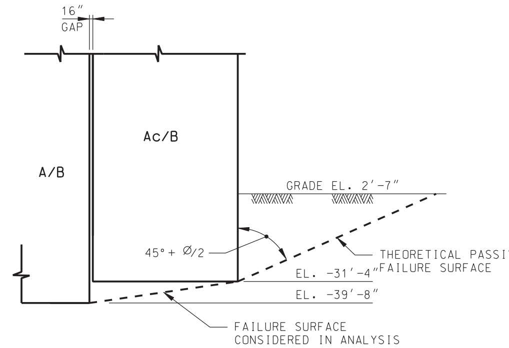
RAI 960-6709 QUESTION 03.07.02-212
ATTACHMENT 1



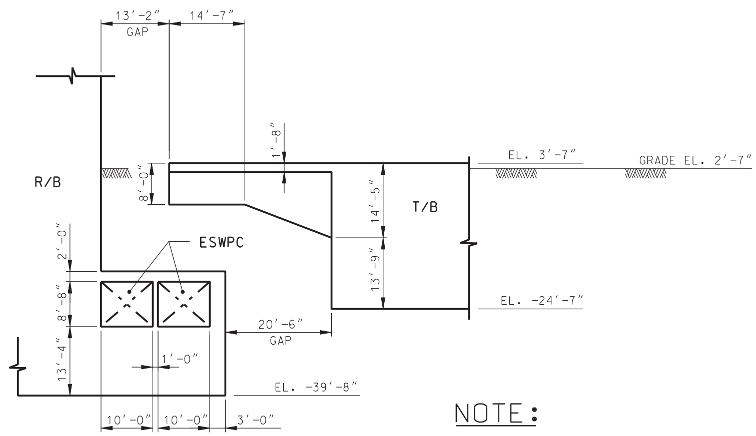
US-APWR STANDARD PLANT STRUCTURES - PLAN VIEW



SECTION 1-1



SECTION 2-2



SECTION 3-3

NOTE:

SECTIONS 1-1, 2-2 AND 3-3 REPRESENT BASEMATS OF VARIOUS PAIRS OF ADJACENT STANDARD PLANT STRUCTURES