MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

December 19, 2012

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-12292

Subject: MHI's Response to US-APWR DCD RAI No. 960-6709 (SRP 03.07.02)

References: 1) "Request for Additional Information No. 960-6709," dated September 24, 2012

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Response to Request for Additional Information No. 960-6709."

Enclosed are the responses to questions 03.07.02-212; 03.07.02-215; 03.07.02-216(a), (e), (g), and (h); 03.07.02-217(a-f); 03.07.02-220(c-e); contained within Reference 1. The responses to questions 03.07.02-213; 03.07.02-214; 03.07.02-216(b-d) and (f); 03.07.02-218; 03.07.02-219; 03.07.02-220(a-b) and (f-g); 03.07.02-221; 03.07.02-222; and 03.07.02-223, will be provided by March 21, 2013.

Please contact Mr. Joseph Tapia, General Manager of Licensing Department, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittal. His contact information is below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
Director, APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosures:

1. Response to Request for Additional Information No. 960-6709

D081
NRO

CC: J. A. Ciocco
J. Tapia

Contact Information

Joseph Tapia, General Manager of Licensing Department
Mitsubishi Nuclear Energy Systems, Inc.
1001 19th Street North, Suite 710
Arlington, VA 22209
E-mail: joseph_tapia@mnes-us.com
Telephone: (703) 908-8055

Enclosure 1

UAP-HF-12292
Docket No. 52-021

Response to Request for Additional Information No. 960-6709

December 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/19/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 960-6709**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.8.4, 3.8.5**
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:

a) A figure including a plan view and vertical sections for the Standard Plant structures is provided following this set of responses. This figure will be included in Section 5.5 of the TR. The exact locations of the structures within the 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 will be addressed by the COL applicant.

b) The adequacy of the gaps between adjacent structures will be addressed, in view of the potential sliding magnitude, as follows:

1. The Access Building and the Tank House weigh approximately 28,000 kips and 16,000 kips, respectively. The Reactor Building complex weighs about 1,200,000 kips. Therefore, the Access Building and Tank House weigh about 2.3% and 1.3% of the Reactor Building complex, respectively. Thus, any sliding of the Reactor Building (R/B) Complex toward the Access Building 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 calculated in Technical Report MUAP-10006, and verified 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 and the Turbine Building (T/B) is much larger (see Attachment 1), so there is no danger of contact between structures 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) sliding toward each other. The nonlinear sliding analysis will provide relative displacements of the R/B Complex and the T/B and resulting gap closure that will be 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 will be used for the design of structural walls.

c) Gap closure due to seismic building response including potential sliding is calculated as follows:

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 passive pressure. This is a conservative assessment, as mobilization of the entire passive pressure requires sliding displacements considerably larger than the maximum expected 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
- 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 adding horizontal inertia forces induced by sliding in the soil wedge and in the adjacent buildings (AC/B and Tank House), acting in the direction of increasing passive reaction.

The gap closure due to sliding is calculated as a function of the passive reaction pressure acting on the backfill material in the gap. A lower bound of the gap material stiffness is conservatively used. Additional gap closure above grade level, due to structure tilt and deflection is calculated based on the results of SSI analyses. A factor of safety of 2 is applied to the total gap closure and the resulting value is checked against the initial gap opening.

2. The gap between the R/B Complex and the T/B is addressed as follows: For each soil profile and each input acceleration time history, the gap closure is calculated as the square root of sum of squares (SRSS) of the maximum values of the total displacements for the two structures (R/B Complex and T/B). At each time instant, the total

displacement for each structure is the vector sum of the sliding displacements in the X and Y directions. The maximum total displacements occur, in general, at different time instants and in different directions for the two structures, and therefore the SRSS is a conservative addition method. This type of calculation accounts for the possibility of the seismic waves to arrive in any direction, and for the two structures experiencing out of phase motions. Adequacy of the SRSS method and the fact that it is conservative will be proven in Rev. 1 of the TR based on actual sliding analysis results.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on the technical Report. However, the report is being revised per the Seismic Closure Plan to address the staff's issue.

12/19/2012

US-APWR Design Certification
Mitsubishi Heavy Industries
Docket No. 52-021

RAI NO.:	NO. 960-6709
SRP SECTION:	03.07.02 – Seismic System Analysis
APPLICATION SECTION:	3.8.4, 3.8.5
DATE OF RAI ISSUE:	09/24/2012

QUESTION NO.: 03.07.02-215

Section 3.0 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," states that one of the objectives of this report is to, "Demonstrate acceptable seismic sliding of the Reactor Building (R/B) Complex and the Turbine Building (T/B) structures." It also states that possible sliding will be calculated during the safe-shutdown earthquake (SSE) using nonlinear time history analyses which will demonstrate that the amount of sliding, if any, is too small to cause any physical damage to the R/B Complex and T/B structures or to the structural connections. Currently, the criterion in SRP 3.8.5 indicates that there should be a factor of safety of 1.1 against sliding, rather than an evaluation of the effects of sliding on physical damage to structures and structural connections. The guidance in the SRP is intended to show that there is no sliding, including the consideration of the factor of safety. Therefore, the applicant is requested to provide the technical basis and justification for allowing some small displacement. The staff notes that the report does not include acceptance criteria for sliding. The staff requests the applicant to define the acceptance criteria it will use to evaluate sliding, and to provide the technical basis and justification for the acceptance criteria.

ANSWER:

In order to better describe the objective of the TR, the sentence "Demonstrate acceptable seismic sliding of the Reactor Building (R/B) Complex and the Turbine Building (T/B) structures" in Section 3.0 will be replaced by ""Demonstrate acceptable seismic *stability* of the Reactor Building (R/B) Complex and the Turbine Building (T/B) structures, for the cases where a minimum factor of safety for sliding of 1.1 computed using the conventional equivalent-static analytical approach is not met during the SSE"

The need to perform seismic sliding evaluation by means of nonlinear time history analysis is briefly discussed in Section 1.0 of the TR. As stated in Reference 12 of the TR:

> "In DC applications, however, it has been difficult to demonstrate seismic stability using simple calculations [*equivalent-static calculations - MHI note*]. The reason for this difficulty seems to be that, for the reasons mentioned in the introductory section, the seismic demands tend to be overestimated while

the seismic resistance tends to be conservatively underestimated. To overcome this difficulty, DC applicants have had to perform more realistic time-history seismic analyses that, in some instances, explicitly incorporated the nonlinearities caused by sliding, uplift and lateral soil pressure at the perimeter of embedded structures. The results of these analyses often indicate that small amounts of sliding or uplift may occur during a seismic ground motion. To meet the intent of the SRP, the safety review needs to determine, on a case-by-case basis, whether the small amounts of sliding or uplift are acceptable."

Specifically, the equivalent-static factor of safety for sliding may be less than the minimum accepted value for very short time intervals. It is the industry practice (e.g. References 4, 12, 13, 14 and 16 of the TR) to demonstrate acceptable sliding stability by estimating the foundation movement during small time intervals and demonstrating that the structure safety and functionality is not affected by these displacements.

Technically, this approach is no different from the approaches described in the SRP Acceptance Criteria of SRP 3.8.5.II.4 B (Second Section B) where the consideration of passive pressure implies a displacement of the structure. The wall displacement necessary to mobilize passive pressure is generally taken to be 0.005 to 0.01 H, where H is the height of concrete surface where the passive pressure occurs (Reference 1). For a 42 ft basement wall, this translates into a displacement of about 2½ to 5 inches. The dynamic analysis methodology currently being applied is based on a more accurate calculation of lateral displacements of the structures analyzed here than the ones implied by passive pressure theories that are based upon observations of other structures.

MHI methodology for sliding stability analysis follows the AP1000 approach, previously approved by NRC. As in the AP1000 method, the MHI method calculates seismic induced sliding by direct integration time history analysis and: (1) uses compression only sliding friction elements at the interface of basemat and soil, (2) considers basemat uplift in addition to sliding, (3) applies a seismic input increased by 10% in all directions to maintain a factor of safety against sliding of 1.1, and (4) does not account for the beneficial effect of passive soil reaction. Furthermore; (1) the sliding analysis model used by MHI is a 3D model, including horizontal accelerations in two orthogonal directions in addition to the vertical acceleration, and (2) the friction coefficient considered at the basemat-subgrade interface is 0.5 for both sliding and no-sliding conditions. Other conservative assumptions used by MHI are listed in Section 4.5 of the TR.

MHI is currently working with the design team to establish correct admissible values for the attached pipe connections (attached piping, between R/B and T/B; PS/B - PSFSV connections; connections between ESWPC and ESWPT, etc.). The acceptance criteria for sliding will be established based on these admissible values. These criteria along with their justification and technical basis will be provided in Section 1.0 of the TR. Conversely, it will be specified in the DCD that the design of attached pipe and attached adjacent structures must accommodate the displacements corresponding to these criteria.

Additional Reference:

1. Das, B.M., Principles of Geotechnical Engineering, 7th edition, Cengage Learning, 2010.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on the technical Report. However, the report is being revised per the Seismic Closure Plan to address the staff's issue.

12/19/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 960-6709

SRP SECTION: 03.07.02 – Seismic System Analysis

APPLICATION SECTION: 3.8.4, 3.8.5

DATE OF RAI ISSUE: 09/24/2012

QUESTION NO.: 03.07.02-216

Section 4.0 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," describes the methodology utilized to perform the sliding stability analyses. To assist the staff in evaluating whether the assumptions and modeling approach are consistent with the guidance in SRP Section 3.8.5; and can predict the magnitude of the sliding response, the staff requests the applicant to provide the following additional information:

a) In Section 4.1, "Assumptions," under Assumption number 1, the applicant stated that sliding is assumed to occur in some cases under safe-shutdown earthquake (SSE) but did not identify those cases. The applicant is requested to identify those cases and provide the basis for the assumption.

b) In Section 4.1, under Assumption number 2, the applicant indicated that it is assumed that a small amount of sliding will not modify the ground motion in the vicinity of the basemat. The applicant is requested to provide a quantitative measure of "small amount of sliding." The applicant also stated that, "this assumption is the accepted industry practice for such analyses." The applicant is requested to provide appropriate basis and references to demonstrate the industry practice for such analyses and that it has been accepted by the staff.

c) Regarding the use of the time histories from the SASSI soil-structure interaction (SSI) analyses and applying them in all three directions, the applicant is requested to provide a technical basis and justification for neglecting the rocking motions in relation to the two horizontal axes.

d) Since the soil ground motions from the SASSI SSI analysis is proposed to be used in the lumped-mass stick model (LMSM) sliding stability analysis, the dynamic characteristics between these two models should be consistent or conservative in the LMSM approach. Therefore, the applicant is requested to explain whether the ground motions from the SASSI SSI analyses to be used as input to the LMSM analyses will be based on the embedment case with no connection between the building side wall foundation and the vertical edge of the side soil or based on the connected case. In addition, the applicant is requested to confirm that the two model dynamic characteristics (SASSI and LMSM) are equivalent or that the more conservative ground motion (side soil/wall connection vs. no side soil/wall connection) will be used.

e) Based on the description presented in Sections 4.2.3 and 4.3 of the TR, the subgrade is modeled as a rigid surface and the basemat is modeled as a rigid surface. Contact elements are used between these two surfaces. The applicant is requested to discuss how the effect of dead weight is included in the nonlinear analysis to consider the potential uplift of the basemat; and to provide a technical basis and justification for the sliding stability model and the analysis results.

f) Assumption 4 in the TR indicates that embedment effects (active and passive pressures) are neglected during sliding. The applicant is requested to explain how the effects of surcharge loads due to adjacent structures will be considered in the sliding stability analyses.

g) The applicant in Assumption 5 stated that the maximum ground water level is considered for the sliding analysis. The applicant is requested to justify this assumption and demonstrate that the maximum ground water level case is conservative and will result in the minimum factor of safety (i.e., maximum seismic sliding force and minimum resistance).

h) Assumption 6 in the TR indicates that, "Dynamic soil pressures acting on basement walls before the initiation of sliding are assumed to be compensated by the difference between static and kinetic friction forces acting at the basemat level." Section 4.2.4 of the TR also discusses this item; however, it is not clearly explained. Therefore, the applicant is requested to describe this behavior, explain how the effects of these pressures are considered to be compensated by the difference between static and kinetic friction forces, and describe how this assumption is conservative and will be demonstrated, as stated in Section 4.2.4 of the TR.

ANSWER:

a) Assumption #1 will be removed from the TR. The intent of the TR is actually to implement analysis methodologies where sliding is allowed to occur.

e) The dead weight is included in the nonlinear sliding analysis through the mass of continuous elements used to model the basement and the concentrated masses modeling the superstructure. These masses accurately reproduce the actual masses in the Finite Element Model. The dead weight is reduced by the uplift force (due to groundwater), applied as an upward vertical pressure acting on the basemat.

The possibility of uplift is captured by the numerical model through the use of compression-only contact elements with finite stiffness. The stiffness of the contact elements is selected from the condition to avoid spurious rigid body vibrations, as explained in Section 4.3.2 of the TR. To illustrate the manner in which uplift is captured by the numerical model, figures with contours of calculated pressures at the basemat-subgrade interface, showing uplift (areas with zero pressure) during seismic shaking, will be presented in Rev. 1 of the TR, Section 5.2.5, along with an explanation of basemat uplift modeling by the analytical model.

g) This assumption has been verified, in terms of calculated seismic induced sliding displacement, through sensitivity analyses performed with analytical models developed prior to the revisions due to AIA. In summary, based on sensitivity analyses for two soil profiles and five seismic acceleration time histories, a lowering of the GWL from 1 foot below grade to 20 feet below grade resulted, on average, in a reduction of computed seismic sliding displacement by 55% to 70% for the R/B Complex and led to almost no sliding for the T/B. Results of similar analyses to be performed with updated analytical models will be presented in Rev. 1 of the TR, Section 5.2.6.

h) The sum of dynamic soil pressures acting before the initiation of sliding is a driving force, denoted in the following by F_D. This force is neglected in the sliding analysis. As discussed in Section 4.5 of the TR, the kinetic friction coefficient is conservatively used under both static and dynamic conditions. The difference between static friction forces and kinetic friction forces acting at the base of the structure is a resisting force, denoted in the following by ΔF, acting before the initiation of sliding. This force is also neglected in the sliding analysis. It is assumed in the TR that the force from the dynamic soil pressures, F_D, is compensated by the difference between the static friction force and the kinetic friction force, ΔF. Thus, when ΔF is shown to be larger than F_D for all input time histories and all soil profiles, the assumption that it is conservative to neglect both forces is validated.

The following methodology, including numerical values corresponding to acceleration time histories developed for the sliding analysis, will be included in Rev. 1 of the TR to validate this assumption. Calculations will be performed for dynamic soil pressures acting along the longest side, namely the North and South walls, of the R/B Complex. The methodology is as follows:

1. Obtain the horizontal ground acceleration for calculating dynamic soil pressure, a_{hX}, from the SASSI analyses. The value of a_{hX} is selected as the maximum value for all time steps, all earthquake time histories, and all soil profiles and averaged over the height of the basement walls. The dynamic soil force acting on the basement walls (calculated along the longest side of the R/B Complex using Wood's formula in Reference 5 of the TR) is calculated as:

$$F_D = a_{hX}\, C_v\, \gamma_{sat}\, H^2\, L / g \quad (1)$$

In equation (1), C_v is a coefficient depending of the Poisson's ratio (Reference 5 of the TR), γ_{sat} is the saturated unit weight of the engineered fill, H = 42'-3" is the depth of the basemat measured from plant grade, L = 409'-8" is the length of the North and South walls of the R/B Complex, and g is the acceleration of gravity.

2. Calculate the static stabilizing vertical force which is the buoyant weight of the structure (R/B Complex), W', assuming the maximum groundwater level at 1 foot below grade. Reduce this stabilizing vertical force by the vertical inertia force, which is calculated assuming that the vertical acceleration of the structure, a_v, acts downwards, $F_{vI} = a_v\, m$, where m is the total mass of the structure. The value of a_v is also obtained from the SASSI analysis results as the maximum value for all time steps, all earthquake time histories, and all soil profiles, and averaged over the entire structure. The minimum difference between the static friction force and the kinetic friction force acting at the basemat level is:

$$\Delta F_{min} = (\mu_s - \mu_k)\,(W' - F_{vI}) \quad (2)$$

In equation (2), $\mu_s = 0.7$ is the static friction coefficient and $\mu_k = 0.5$ is the kinetic friction coefficient.

3. Prove validity of Assumption #6 in the TR by showing that ΔF_{min} in equation (2) is larger than F_D in equation (1).

A similar analysis (Steps 1, 2 and 3 above) will be performed for the T/B.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on the technical Report. However, the report is being revised per the Seismic Closure Plan to address the staff's issue.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/19/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 960-6709**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.8.4, 3.8.5**
DATE OF RAI ISSUE:	**09/24/2012**

QUESTION NO.: 03.07.02-217

Section 4.2.1 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," describes the selection of the static and kinetic (sliding) coefficients of friction. To assist the staff in evaluating whether appropriate static and kinetic coefficient of friction values are utilized in accordance with the guidance in SRP Section 3.8.5, the staff requests the applicant to provide the following additional information:

a) Section 4.2.1 of the TR states, "The governing friction occurs between the mud mat and the underlying granular soil where a thin soil layer exists that is interlocked with the bottom of the mud mat." The applicant is requested to provide the technical basis and justification for the conclusion that the sliding interface would not be at the concrete to soil interface.

b) The TR indicates that any fine grain materials within a few feet below the basemat will be replaced by engineered fill. Engineered fill will be specified in the DCD as a well drained granular backfill with a minimum friction angle of $\Phi = 35°$. The applicant states that the minimum angle of internal friction will be specified in DCD Table 2.0-1 as a site requirement.

The staff notes that, regardless whether materials below the basemat are replaced by engineered fill, the DCD needs to specify the minimum angle of internal friction. Therefore, the applicant is requested to confirm that the minimum angle of internal friction for the in-situ soil, and any engineered fill, will be specified in DCD Tier 2, Section 2; and that in-situ soil will also be specified in DCD Tier 1.

c) Another potential sliding interface is at the location of any waterproofing material (e.g., waterproofing material between the mud mat and soil or between the basemat and mud mat).

Therefore, the applicant is requested to explain where waterproofing material is used; the type of waterproofing material; the coefficient of friction of the waterproofing material with respect to the adjacent material; and the basis for the coefficient of friction.

d) The TR indicates that the cold joint at the mud mat to bottom of foundation contact will be "raked" with a very rough surface (minimum amplitude greater than ¼ inch - as recommended in the Commentary to ACI 349-06 to maintain a minimum friction coefficient of 0.7. The applicant is requested to include this commitment in the DCD.

e) The kinetic coefficient of friction used for the sliding stability analysis is given as 0.5 for all subgrades. The value of the kinetic coefficient of friction is based on laboratory soil tests with samples from seven different types of sands. The applicant is requested to confirm that the kinetic coefficient of friction used for the design basis sliding stability analysis bounds the types of soils and soil properties/conditions considered for the US-APWR standard design.

f) Reference 13 in the TR could not be located. To complete its review, the staff requests the applicant to submit a copy of Reference 13: "Constant Volume Cyclic Simple Shear Testing, Proceedings of the 2nd International Conference on Microzonation, San Francisco, CA, Finn, W.D.L., Laid, Y.P. and Bhatia, S.K., pg 839-851, 1978

ANSWER:

a) The concrete-soil interface discussed in the TR is the interface between the mud mat and granular soil. For concrete, that is placed directly on the granular soil and penetrates in between the soil grains, the actual concrete soil interface is not smooth and the friction failure is forced to take place in the soil, immediately below the concrete. This is reflected by the fact that the recommended friction angle at contact between mass concrete and granular soil is the internal friction angle of the soil, ϕ (see e.g. Reference 10 of the TR).

b) The following requirements will be will be specified in the DCD:

- in-situ *granular soil* and engineered fill will have a minimum angle of internal friction of 35^0.
- any in-situ *fine grained* soil immediately below the basemat will be replaced by engineered fill. The engineered fill will be specified to be 4 to 6 inches thick with a maximum of 1 foot. This fill will be topped with a 3 to 4 inch mud mat.

c) No waterproofing membrane will be used below the basemats of US-APWR structures. Required concrete waterproofing will be ensured by using appropriate concrete admixtures.

d) A COL Item will be added in the DCD, as requested.

e) The kinetic friction coefficient for concrete-to-concrete and concrete-to-rock interfaces are discussed in section 4.2.1 of the TR based on test results reported in the literature. For interfaces involving soil, only granular soils are discussed in relation to friction coefficients used for sliding analysis (according to the Answer to Question 217b). Moreover, any friction failure for this type of interface occurs within the soil mass, as explained in the Answer to Question 217a. Therefore the laboratory test results discussed in this Answer only refer to granular soil.

The internal friction angle is the parameter of interest for assessing the shear strength properties of granular soil. The soils and soil property conditions considered for assessing friction coefficients include granular soils with shear wave velocities equal to, or larger than, 1000 feet/sec., i.e. dense granular soils, either natural soils or engineered fills. The soil samples used in the laboratory soil tests described in Reference 20 of the TR include various types of granular soils with friction angles between 28^0 and 48^0, which envelop the range of friction angles for dense granular soils (either natural, or engineered fill) considered for the US-APWR standard design.

f) Due to the copyright issue, a copy of Reference 13 in the TR cannot be submitted to NRC.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-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.

12/19/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 960-6709**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.8.4, 3.8.5**
DATE OF RAI ISSUE:	**09/24/2012**

QUESTION NO.: 03.07.02-220

Sections 4.3 and 4.4 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," describe the development of the finite element models and the lumped-mass stick model (LMSM). To assist the staff in evaluating whether the LMSM is equivalent to the more detailed finite element model, the staff requests the applicant to provide the following additional information:

a) Section 4.3.1 of the TR states, "There are two FE models for the R/B Complex considered: one detailed FE model which is used to validate the dynamic model; and one dynamic FE model, which is used for dynamic analyses in ANSYS, and these two models have correlation with each other. The dynamic FE model is the basis for correlation with the LMSM. Contact (or sliding) elements and a rigid basemat are added to the dynamic FE model for nonlinear sliding analyses. The dynamic FE model customized for sliding analyses is referred to herein as the FEM."

From this information, it appears to the staff that there are three models – 2 finite element models (FEMs) and 1 LMSM. The applicant is requested to provide a clear description (with figures, modal frequencies, and corresponding modal participation factors for the two horizontal and one vertical motions) of all the three models referred to in the above quoted paragraph, and clearly indicate the differences between them.

b) In addition, the applicant is requested to provide information which demonstrates that the LMSM is equivalent to the design basis seismic SSI model. This should include similar model information as described in Item a) above.

c) Section 4.2.1 of the TR appears to indicate that a static friction coefficient (μs) of 0.7 will be used and a kinetic friction coefficient of (μk) equal to 0.5 will be used. However, Section 4.5 of the TR indicates that one of the conclusions for the methodology is: "Use of the kinetic friction coefficient under static conditions (before initiation of sliding)." From the above, it is not clear which coefficient of friction values are used in the analyses. Therefore, the applicant is requested to clarify and provide a technical basis and justification whether both the static and kinetic coefficient of friction values will be used or if only the kinetic coefficient of friction will be used.

d) The applicant is requested to describe the specific ANSYS friction element type that will be used and define the quantitative values for the various parameters for this element.

e) To verify that the development of the LMSM is appropriately based on the first modes in the horizontal directions and the development of an equivalent fundamental frequency in the vertical direction from the FEM, the staff requests that the applicant provide a table showing the results of the modal analysis for the finite element model. The table should include for each mode the frequency, direction, effective mass, and percentage effective mass (of the total). The selection of the modes for matching in the LMSM should be shown to capture sufficient effective mass when compared to the total mass.

f) To confirm that the final (calibrated and fine-tuned) LMSMs for the Reactor Building (R/B) and Turbine Building (T/B) are adequate, the staff requests that the applicant provide a comparison of overall seismic demands predicted by the LMSMs and the detailed finite element models. The comparison should include the two shear forces, vertical (axial) force, and the two over-all bending moments at the base of the models, for a fixed base case with flat response spectral input.

g) To assist the staff in evaluating whether the base shear force from the LMSM for each of the 5 input motions is equivalent to the more detailed finite element model, the staff requests that the applicant compare the maximum forces at the base of the LMSMs with those from the SASSI soil-structure interaction (SSI) analyses used to develop each of the 5 input motions for the sliding stability analyses. In this study, sliding and lift off needs to be prevented in the LMSM analyses, for comparison to the SASSI results.

ANSWER:

c) The sentence "Only the kinetic friction coefficient will be used in the nonlinear sliding analyses for both static and sliding conditions" will be added in Section 4.1 - Assumption 6 and in Section 4.2.1 of the TR.

d) The following sentences will be added to the third paragraph of Section 4.3.2 of the TR:

> "The contact elements used for both the FEM and the LMSM in the ANSYS analyses are CONTA173 elements. The only material property prescribed for these elements is the coefficient of friction, $\mu = 0.5$ (the kinetic friction coefficient). The stiffness of the contact elements is controlled through the real constant FKN, and is calculated for each structure from the condition to avoid spurious rigid body vibrations *[the method for calculating necessary stiffness of the contact elements is explained in the 4th paragraph of Section 4.3.2 of the TR – MHI Note]*. The contact elements are placed at the bottom of the structure basemat. There is a target surface representing the subgrade, where the acceleration input motion is prescribed via a pilot node. TARGE170 elements are used in the ANSYS analyses for the target surface. The TARGET170 elements do not require any material properties or real constants".

e) Two tables will be presented in Rev. 1 of the TR, as requested. One table will be added in Section 5.2.3 for the R/B Complex, and one in Section 5.3.3, for the T/B.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

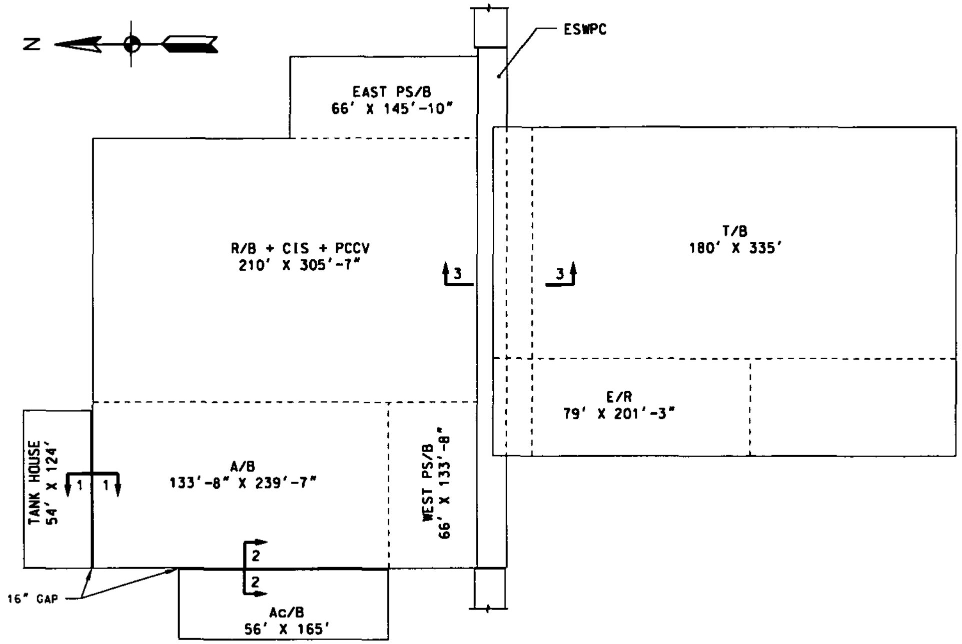
Impact on PRA

There is no impact on the PRA.

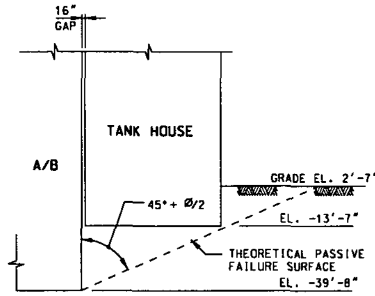
Impact on Technical/Topical Report

There is no impact on the technical Report. However, the report is being revised per the Seismic Closure Plan to address the staff's issue.

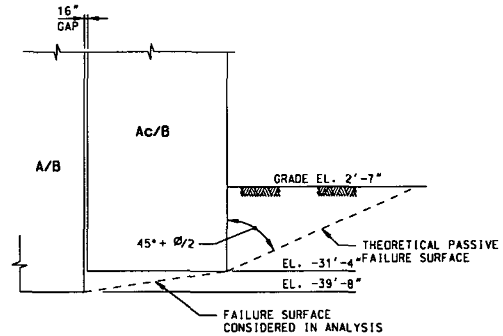
ATTACHMENT 1



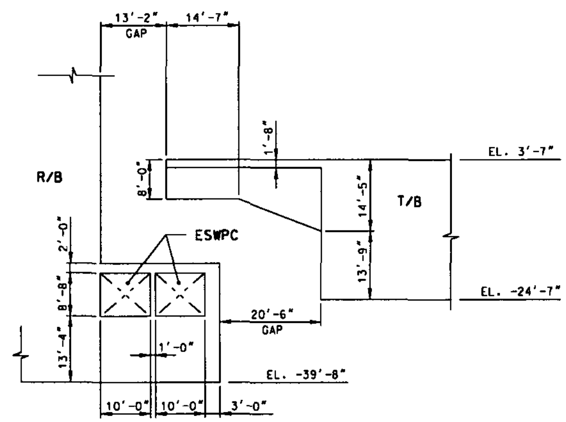
US-APWR STANDARD PLANT STRUCTURES - PLAN VIEW



SECTION 1-1



SECTION 2-2



SECTION 3-3