MITSUBISHI HEAVY INDUSTRIES, LTD.
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February 22, 2010

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

Attention: Mr. Jeffery A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-10049

Subject: MHI's Response to US-APWR DCD Draft Open Items RGS1 2.5.4 Revision 2.

Reference:
1) "Draft Open Items RGS1 2.5.4, SRP Section: 02.05.04 – Stability of Subsurface Materials and Foundations," dated April 20, 2009.
2) "MHI's Response to US-APWR DCD Draft Open Items RSG1 2.5.4", MHI Ref: UAP-HF-09321, dated June 22, 2009

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document as listed in Enclosure.

Enclosed is the response to 1 Open Item contained within Reference 1. Supplemental information has been added to the original response (Reference 2) to clarify why the dynamic bearing capacity value became smaller than the value originally in Revision 1 of the DCD.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittal. His contact information is provided below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. "Response to Draft Open Items RGS1 2.5.4, Revision 1"

CC: J. A. Ciocco
C. K. Paulson

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Enclosure 1

UAP-HF-10049
Docket No. 52-021

Response to Draft Open Items RGS1 2.5.4,
Revision 1

February, 2010

2/22/2010

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

OPEN ITEM NO.: **RGS1 2.5.4**

SRP SECTION: **02.05.04 – STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS**

APPLICATION SECTION: **02.05.04**

DATE OF OPEN ITEM ISSUE: **4/20/2009**

OPEN ITEM NO. : [02.05.04-01] This question is related to the applicant's response to RAI 02.05.04-1.

In part (c) of its response to RAI 02.05.04-1, the applicant provided further explanation regarding the liquefaction potential requirement and stated that it intends to revise the DCD. Therefore, the staff considers part (c) of RAI 02.05.04-1 to be resolved. However, the staff determines that the information provided in response to parts (a) and (b) of RAI 02.05.04-1 is insufficient. The need to provide additional information to clarify parts (a) and (b) of RAI 02.05.04-1 is **Open Item (OI) 02.05.04-1**.

QUESTION NO. : 02.05.04-01

Related to tables 2.1-1 (Tier 1) and 2.0-1 (Tier 2) "Key Site Parameters":

a) Clarify your use of "average" static and dynamic bearing capacity rather than a minimum value. Please explain how the dynamic bearing pressure was determined.

b) Clarify why there is not a parameter value for settlement in Tier 1 and a description in Tier 2, Section 2.5.4.

ANSWER:

a) The terms "average static bearing capacity" and "average dynamic bearing capacity" on Sheet 5 of DCD Tier 1, Table 2.1-1, and DCD Tier 2, Table 2.0-1, are to be corrected to "minimum allowable static bearing capacity" and "minimum allowable dynamic bearing capacity." As corrected, these tables specify the maximum allowable bearing pressure demands for evaluation of the capacity of the site subgrade to support the US-APWR Reactor Building (R/B) complex foundation. The COL Applicant demonstrates adequate safety factors for bearing capacity by comparing these allowable bearing pressure demands with the ultimate capacity of the site at the bottom elevation of the R/B complex foundation. The DCD specifies an allowable static bearing capacity of 15 ksf based on the value of the average bearing pressure of 11.3 ksf calculated for the common foundation mat of R/B complex under combined dead load (*DL*) and live load (*LL*). A value of 15 ksf is specified for the static bearing capacity to provide an additional margin of safety in the site bearing capacity evaluations. This value also envelops the static bearing pressures calculated under the foundations of all other US-APWR standard plant seismic Category I & II structures.

The allowable dynamic bearing capacity is specified based on the foundation bearing pressures calculated under the foundation basemat of the R/B complex due to the combined action of the static and seismic loads. The value of 95 ksf specified in Revision 1 of the US APWR DCD for dynamic bearing capacity was based on a preliminary foundation uplift analysis that used factored loads to calculate the maximum bearing pressure under the foundation under seismic loading conditions. The magnitudes of the SSE loads used in the original foundation uplift analysis were developed from the results of the seismic response analyses in a conservative manner as described in the response to Question 3.8.4-11 in RAI 342-2000. In addition, the magnitude of these seismic loads were increased by more than 10% to account for accidental torsion and to conservatively introduce additional margin of safety in the design. The use of factored seismic loads resulted in overestimated uplift of the foundation and considerably higher dynamic bearing pressures.

This conservatism incorporated in the original estimate of the maximum dynamic bearing pressure is eliminated in the subsequent foundation uplift analyses by using non-factored foundation seismic loads obtained directly from the results of the seismic response analyses. The maximum results of the soil-structure interaction analyses for the forces and moments in the springs modeling the different subgrade stiffness conditions were enveloped and used as input seismic loads for the revised foundation uplift analyses. The use of non-factored foundation loads and overturning moments helped reduce the previously introduced conservatism in the estimation of the foundation uplift and resulted in a lower value of the maximum foundation bearing pressure under seismic loading conditions.

The results of the seismic response analyses, described in Subsection 3.7.2 of the DCD, are used to incorporate the effects of the eccentricity of the foundation load on the dynamic bearing pressure. The maximum eccentricity of the foundation load in north-south and east-west directions (e_{NS} and e_{EW}) are calculated for each of the four subgrade conditions using the seismic response analyses results for the foundation reaction forces and moments, as follows:

$$e_{NS} = \frac{M_{NS}}{DL + 0.25 \cdot LL \pm E_v} \qquad e_{EW} = \frac{M_{EW}}{DL + 0.25 \cdot LL \pm E_v}$$

where: M_{NS} and M_{EW} are the base reaction moments in north-south and east-west direction due to seismic loads and E_V is the vertical seismic force. For each of the four generic soil cases, the responses in three directions of the earthquake, north-south (S_{NS}), east-west (S_{ew}) and vertical (S_V) are combined using the Newmark 100-40-40 method as follows:

LC1: $DL + 0.25\ LL + S_{NS} + 0.4\ S_{EW} + 0.4\ S_V$

LC2: $DL + 0.25\ LL + S_{NS} + 0.4\ S_{EW} - 0.4\ S_V$

LC3: $DL + 0.25\ LL + 0.4\ S_{NS} + S_{EW} + 0.4\ S_V$

LC4: $DL + 0.25\ LL + 0.4\ S_{NS} + S_{EW} - 0.4\ S_V$

LC5: $DL + 0.25\ LL + 0.4\ S_{NS} + 0.4\ S_{EW} + S_V$

LC6: $DL + 0.25\ LL + 0.4\ S_{NS} + 0.4\ S_{EW} - S_V$

In the cases where e_{NS} > 1/6 L_{NS} and e_{EW} > 1/6 L_{EW} (L = length), the effect of the contact area reduction due to foundation uplift is investigated using the Highter and Anders equations for calculation of effective contact area of a rectangular foundation with two-way eccentricity that are provided in Section 3.12 of Principles of Foundation Engineering, 6th Edition, Braja M. Das, Thomson Engineering, 2006. The average dynamic bearing pressure acting on the effective contact area are calculated and used to select the critical load cases that result in maximum bearing pressures. The table below summarizes the results of the hand calculations.

The hand calculations indicate that the seismic response results for Medium 1 generic soil case provide the most critical results for the maximum dynamic bearing pressures. Finite element (FE) uplift analyses are performed for LC3 and LC4 load cases to calculate maximum bearing pressures. Compression-only springs are used to model the stiffness of the Medium 1 generic subgrade. The maximum dynamic bearing pressure of 53.0 ksf is obtained from the results of FE uplift analyses of LC3. A value of 60 ksf is specified for the dynamic bearing capacity to provide an additional margin of safety in the site bearing capacity evaluations. The DCD will be changed to reflect the 60 ksf dynamic bearing capacity within Table 2.1-1 of Tier 1, Section 2.1 and Table 2.0-1 of Tier 2, Section 2.0.

The COL Applicant can use lower values for maximum dynamic bearing pressure demands to evaluate the bearing capacity of the site based on results of site-specific bearing pressure analyses using as input site-specific seismic loads and subgrade stiffness. This is addressed by COL Item 3.7(7).

Load Combination	Generic Soil Case			
	Soft	Medium 1	Medium 2	Hard Rock
LC1	$e_{NS} / L_{NS} = 0.09$	$e_{NS} / L_{NS} = 0.16$	$e_{NS} / L_{NS} = 0.13$	$e_{NS} / L_{NS} = 0.13$
	$e_{EW} / L_{EW} = 0.05$	$e_{EW} / L_{EW} = 0.09$	$e_{EW} / L_{EW} = 0.08$	$e_{EW} / L_{EW} = 0.08$
	$q_{ave} = 11.4$ ksf	$q_{ave} = 11.8$ ksf	$q_{ave} = 11.9$ ksf	$q_{ave} = 12.0$ ksf
LC2	$e_{NS} / L_{NS} = 0.12$	$e_{NS} / L_{NS} = 0.22$	$e_{NS} / L_{NS} = 0.18$	$e_{NS} / L_{NS} = 0.19$
	$e_{EW} / L_{EW} = 0.07$	$e_{EW} / L_{EW} = 0.13$	$e_{EW} / L_{EW} = 0.11$	$e_{EW} / L_{EW} = 0.11$
	$q_{ave} = 9.0$ ksf	$q_{ave} = 18.2$ ksf	$q_{ave} = 15.4$ ksf	$q_{ave} = 19.3$ ksf
LC3	$e_{NS} / L_{NS} = 0.04$	$e_{NS} / L_{NS} = 0.06$	$e_{NS} / L_{NS} = 0.05$	$e_{NS} / L_{NS} = 0.05$
	$e_{EW} / L_{EW} = 0.14$	$e_{EW} / L_{EW} = 0.24$	$e_{EW} / L_{EW} = 0.21$	$e_{EW} / L_{EW} = 0.20$
	$q_{ave} = 11.4$ ksf	$q_{ave} = 24.3$ ksf	$q_{ave} = 21.3$ ksf	$q_{ave} = 17.4$ ksf
LC4	$e_{NS} / L_{NS} = 0.05$	$e_{NS} / L_{NS} = 0.09$	$e_{NS} / L_{NS} = 0.07$	$e_{NS} / L_{NS} = 0.07$
	$e_{EW} / L_{EW} = 0.17$	$e_{EW} / L_{EW} = 0.32$	$e_{EW} / L_{EW} = 0.29$	$e_{EW} / L_{EW} = 0.28$
	$q_{ave} = 13.9$ ksf	$q_{ave} = 24.1$ ksf	$q_{ave} = 20.6$ ksf	$q_{ave} = 14.4$ ksf
LC5	$e_{NS} / L_{NS} = 0.03$	$e_{NS} / L_{NS} = 0.05$	$e_{NS} / L_{NS} = 0.04$	$e_{NS} / L_{NS} = 0.04$
	$e_{EW} / L_{EW} = 0.05$	$e_{EW} / L_{EW} = 0.08$	$e_{EW} / L_{EW} = 0.07$	$e_{EW} / L_{EW} = 0.06$
	$q_{ave} = 13.2$ ksf	$q_{ave} = 14.2$ ksf	$q_{ave} = 14.4$ ksf	$q_{ave} = 14.7$ ksf
LC6	$e_{NS} / L_{NS} = 0.06$	$e_{NS} / L_{NS} = 0.12$	$e_{NS} / L_{NS} = 0.10$	$e_{NS} / L_{NS} = 0.11$
	$e_{EW} / L_{EW} = 0.09$	$e_{EW} / L_{EW} = 0.18$	$e_{EW} / L_{EW} = 0.16$	$e_{EW} / L_{EW} = 0.16$
	$q_{ave} = 7.2$ ksf	$q_{ave} = 11.5$ ksf	$q_{ave} = 6.0$ ksf	$q_{ave} = 5.8$ ksf

b) Table 2.1-1 in DCD Tier 1 and Table 2.0-1 in DCD Tier 2 will be revised to include the following parameters for settlement:

- Total settlement of R/B complex foundation of 6.0 in.
- Differential settlement of 2.0 in. across the R/B complex basemat foundation.
- Maximum differential settlement between buildings of 0.5 in. under static loading.
- Maximum tilt of the R/B complex basemat foundation generated during operational life of the plant of 1/2000.

The parameters listed above serve as guidelines to COL Applicant on foundation settlements under static design load combination (*DL+LL*) that are acceptable without further evaluation. The last settlement criterion imposes a limit to the settlements of the foundation generated after the start of operation of the plant that are due to long term consolidation, heave and creep of the subgrade soils. It is the responsibility of the COL Applicant to provide any special construction or operational provisions to accommodate site-specific settlements that exceed the values provided in the DCD.

The total and differential settlement parameters of R/B complex foundation are indicators of sufficient stiffness and acceptable uniformity of the subgrade. The maximum differential settlement between the buildings is specified to ensure the structural integrity of the pipes connected to the building. The COL Applicant can justify higher values by performing site-specific analyses to demonstrate that the relative displacement between the buildings will not compromise the structural integrity of the important to safety pipes connected to the building. The parameter controlling the differential settlement of the R/B complex due to long term consolidation, heave and creep of the subgrade soils is defined based on the maximum tilt specifications that ensure uninterrupted function of the important to safety equipment.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 1, Section 2.1, changes to be incorporated.

- Change the first and second columns of the sixth and seventh rows below the column title in Table 2.1-1 (Sheet 5 of 5) to the following:

Subsurface stability – minimum allowable static bearing capacity	15,000 lb/ft^2
Subsurface stability – minimum allowable dynamic bearing capacity, normal conditions plus SSE	60,000 lb/ft^2

- Add the following rows at the end of Table 2.1-1 (Sheet 5 of 5):

Total settlement of R/B complex foundation(11)	6.0 in.
Differential settlement across R/B complex foundation(11)	2.0 in.
Maximum differential settlement between buildings(11)	0.5 in.
Maximum tilt of R/B complex foundation generated during operational life of the plant(11)	1/ 2000

- Add the following note at the end of Table 2.1-1 (Sheet 5 of 5)

  11. Acceptable parameters for settlement without further evaluation.

- Move Table 2.1-1 notes to Sheet 6 of 6 (or as determined by other changes to Table 2.1-1 during DCD revision).

See Attachment 2 for the mark-up of DCD Tier 2, Section 2.0, changes to be incorporated.

- Change the first and second columns of the sixth and seventh rows below the column title in Table 2.0-1 (Sheet 5 of 5) to the following:

Subsurface stability – minimum allowable static bearing capacity	15,000 lb/ft^2
Subsurface stability –minimum allowable dynamic bearing capacity, normal conditions plus SSE	60,000 lb/ft^2

- Add the following rows at the end of Table 2.0-1 (Sheet 5 of 5):

Total settlement of R/B complex foundation(11)	6.0 in.
Differential settlement across R/B complex foundation(11)	2.0 in.
Maximum differential settlement between buildings(11)	0.5 in.
Maximum tilt of R/B complex foundation generated during operational life of the plant(11)	1/ 2000

- Add the following note at the end of Table 2.0-1 (Sheet 5 of 5)

  11. Acceptable parameters for settlement without further evaluation.

- Move Table 2.0-1 notes to Sheet 6 of 6 (or as determined by other changes to Table 2.0-1 during DCD revision).

Impact on COLA

There is no impact on COLA.

Impact on PRA

There is no impact on PRA.

This completes MHI's response to the NRC's open item.

ATTACHMENT 1
to OI RGS1 02.05.04

Table 2.1-1 Key Site Parameters
(Sheet 5 of 65)

Geology, Seismology, and Geotechnical Engineering	
Parameter Description	**Parameter Value**
Maximum slope for foundation-bearing stratum	20° from horizontal in untruncated strata
Safe-shutdown earthquake (SSE) ground motion	0.3 g peak ground acceleration
SSE (certified seismic design) horizontal ground response spectra	Regulatory Guide (RG) 1.60, enhanced spectra in high frequency range (see Figure 3.7.1-1)
SSE (certified seismic design) vertical ground response spectra	RG 1.60, enhanced spectra in high frequency range (see Figure 3.7.1-2)
Potential for surface tectonic deformation at site	None within the exclusion area boundary
Subsurface stability – minimum allowable ~~average~~ static bearing capacity	15,000 lb/ft^2
Subsurface stability – minimum allowable ~~average~~ dynamic bearing capacity, normal conditions plus SSE	60,000 ~~95,000~~ lb/ft^2
Subsurface stability – minimum shear wave velocity at SSE input at ground surface	1,000 ft/s
Subsurface stability – shear wave velocity for defining firm rock	3,500 ft/s
Subsurface stability – shear wave velocity for defining firm to hard rock	6,500 ft/s
Subsurface stability – shear wave velocity for defining hard rock	8,000 ft/s
Subsurface stability – liquefaction potential	None (for seismic category I structures)
Total settlement of R/B complex foundation(11)	6.0 in.
Differential settlement across R/B complex foundation(11)	2.0 in.
Maximum differential settlement between buildings(11)	0.5 in.
Maximum tilt of R/B complex foundation generated during operational life of the plant(11)	1/2000.

Table 2.1-1 Key Site Parameters
(Sheet 6 of 6)

NOTES:

1. The specified missiles are assumed to have a vertical speed component equal to 2/3 of the horizontal speed.
2. These dispersion factors are chosen as the maximum values at all intake points.
3. These dispersion factors are chosen as the maximum values at all inleak points.
4. These dispersion factors are used for a loss-of-coolant accident (LOCA) and a rod ejection accident.
5. These dispersion factors are used for a steam generator tube rupture, a steam system piping failure, a reactor coolant pump rotor seizure and a rod ejection accident.
6. These dispersion factors are used for a fuel handling accident occurring in the fuel storage and handling area.
7. These dispersion factors are used for a failure of small lines carrying primary coolant outside containment.
8. These dispersion factors are used for a fuel-handling accident inside the containment.
9. These dispersion factors are used for a LOCA.
10. These dispersion factors are used for a rod ejection accident.
11. Acceptable parameters for settlement without further evaluation.

ATTACHMENT 2
to OI RGS1 02.05.04

Table 2.0-1 Key Site Parameters
(Sheet 5 of 6)

Geology, Seismology, and Geotechnical Engineering	
Parameter Description	**Parameter Value**
Maximum slope for foundation-bearing stratum	20° from horizontal in untruncated strata
Safe-shutdown earthquake (SSE) ground motion	0.3 g peak ground acceleration
SSE (certified seismic design) horizontal ground response spectra	Regulatory Guide (RG) 1.60, enhanced spectra in high frequency range (see Figure 3.7.1-1)
SSE (certified seismic design) vertical ground response spectra	RG 1.60, enhanced spectra in high frequency range (see Figure 3.7.1-2)
Potential for surface tectonic deformation at site	None within the exclusion area boundary
Subsurface stability – minimum allowable ~~average~~ static bearing capacity	15,000 lb/ft^2
Subsurface stability – minimum allowable ~~average~~ dynamic bearing capacity, normal conditions plus SSE	60,000 ~~95,000~~ lb/ft^2
Subsurface stability – minimum shear wave velocity at SSE input at ground surface	1,000 ft/s
Subsurface stability – shear wave velocity for defining firm rock	3,500 ft/s
Subsurface stability – shear wave velocity for defining firm to hard rock	6,500 ft/s
Subsurface stability – shear wave velocity for defining hard rock	8,000 ft/s
Subsurface stability – liquefaction potential	None (for seismic category I structures)
Total settlement of R/B complex foundation(11)	6.0 in.
Differential settlement across R/B complex foundation(11)	2.0 in.
Maximum differential settlement between buildings(11)	0.5 in.
Maximum tilt of R/B complex foundation generated during operational life of the plant(11)	1/2000

Table 2.1-1 Key Site Parameters
(Sheet 6 of 6)

NOTES:

1. The specified missiles are assumed to have a vertical speed component equal to 2/3 of the horizontal speed.
2. These dispersion factors are chosen as the maximum values at all intake points.
3. These dispersion factors are chosen as the maximum values at all inleak points.
4. These dispersion factors are used for a loss-of-coolant accident (LOCA) and a rod ejection accident.
5. These dispersion factors are used for a steam generator tube rupture, a steam system piping failure, a reactor coolant pump rotor seizure and a rod ejection accident.
6. These dispersion factors are used for a fuel handling accident occurring in the fuel storage and handling area.
7. These dispersion factors are used for a failure of small lines carrying primary coolant outside containment.
8. These dispersion factors are used for a fuel-handling accident inside the containment.
9. These dispersion factors are used for a LOCA.
10. These dispersion factors are used for a rod ejection accident.
11. Acceptable parameters for settlement without further evaluation.