## RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**3/24/2014**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries**

**Docket No. 52-021**

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|---|---|
| **RAI NO.:** | **NO. 1060-7285 REVISION 4** |
| **SRP SECTION:** | **03.07.02 – Seismic System Analysis** |
| **APPLICATION SECTION:** | **3.7.2** |
| **DATE OF RAI ISSUE:** | **11/15/2013** |

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**QUESTION NO. 03.07.02-237:**

Section 02.4.1.1.1, “Finite Element Modeling,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant,” Revision 3, states in part:

> “Each node of the SASSI shell elements has five degrees of freedom that enable beam elements to transfer forces and bending moments to shell elements but not torsional moments. Therefore, massless beam elements are generated on the surface of the shell or solid elements as shown in Figure 02.4.1.1.1-7 and Figure 02.4.1.1.1-8 in order to provide adequate transfer of moments from beams in all three rotational degrees of freedom. For beams or columns connecting to slabs or walls in the R/B model, the effect of adding torsional stiffness to the slab and wall shell elements (Allman in-plane rotational stiffness in ANSYS SHELL63 element) is evaluated and the impact on the results is found to be negligible.”

The staff reviewed the cited figures, and is unable to completely understand the modeling techniques used to enforce moment transfer between beams and shells and between beams and solids. In Figures 02.4.1.1.1-7, "Connection of Beam to Solid Elements," and 02.4.1.1.1-8, "Connection of Beam to Shell Elements," rigid massless beams, called a massless tripod in the figures, connect the beam element to the shell or solid element, creating an eccentric constraint with respect to the beam element axis. The rigid massless beams are shown to be attached to the beam element at a finite distance along the beam axis, away from the beam/shell or beam/solid intersection point.

The staff requests the applicant to perform a simple analysis of a typical beam-to-solid connection utilizing the massless tripod approach. Describe the tripod model properties, and show that the desired moment transfer is accomplished.

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**ANSWER:**

A simple analysis of a typical beam-to-solid connection utilizing the massless tripod approach was done. An example is described as follows with the tripod model properties that are used in the Dynamic Finite Element model. One leg of the Steam Generator (SG) C lower support is selected to evaluate the moment transfer in a beam-to-solid connection

utilizing the massless tripod approach.  Figure 1 indicates the selected leg, colored red, with respect to the rest of Steam Generator C. The model properties for the Steam Generator C Support Leg beam elements are extracted from the Dynamic FE model and provided in Table 1. The Column with heading of "RC" in the Table indicates the real constant number or sectional property number for ANSYS beam elements Beam4 or Beam44. The corresponding element locations in the model are shown in Figure 2.  As shown in Table 1, the stiffness of the tripod elements, represented by the axial area (A ) and moments of inertia (Ixx, Iyy and Izz  in element local coordinate system), are significantly greater than the corresponding area and moments of inertia of the support leg.  Technical Report MUAP-10006, Rev. 3 describes how the tripod properties are determined.

Static analyses are performed on the Steam Generator C support, with and without the tripod connection, to ensure adequate rigidity and moment transfer between the beam elements of the support and the solid elements of the Containment Internal Structure (CIS).  Figure 3 provides the study analysis model to obtain the stiffness values of the Steam Generator C support leg. The numbers presented in the figure are the node numbers. The translational and rotational loads are applied separately at the top node (node 22194) as indicated by the red arrow in the figure. Two cases are analyzed statically. Case 1 analyzes the model with constraints imposed at Nodes 17630, 17660 and 17632 as shown in Figure 2. This case evaluates the flexibility of the leg including contribution from the tripod, which reflects the beam-solid connection modelling technique adopted in the Dynamic FE model of Reactor Building complex. Case 2 imposes fixed constraints at node 19631. The responses at the top node from this case will exclude any contribution from the tripod.

Table 2 presents results obtained from analyses of the two cases. The displacements at the top node, Node 22194, due to a 10 kip force applied separately in all three directions indicates the translational stiffness.  The rotations at the top node, Node 22194, due to a 10 kip-ft moment about all three axes applied individually reflects effect of the rotational stiffness. These values are compared between the two static analyses, to assess whether the massless tripod connection has adequate stiffness to properly transfer the moments. The ratios of responses, translational or rotational, from the two cases are shown in the last column of Table 2. The ratios vary from 1 to 1.026. It indicates approximately the same responses from the two cases.  The contribution from the flexibility of the tripod on the responses is negligible. The massless tripod connection has adequate stiffness to properly transfer the loads from the beam elements to the solid elements.

It should be noted that a formal study calculation package will be developed to document the calculation supporting this response.

Table 1  SG C Support Leg and Tripod Model Properties

| Beam | Type | Young's Modulus (ksf) | v | RC | A ($ft^2$) | $I_{ZZ}$ ($ft^4$) | $I_{YY}$ ($ft^4$) | $I_{XX}$ ($ft^4$) | ShearZ* | ShearY* |
|---|---|---|---|---|---|---|---|---|---|---|
| Tripod | BEAM4 | 4176000 | 0.3 | 2485 | 4.9677 | 97.754 | 97.754 | 195.51 | 1.2 | 1.2 |
| | | | | 2486 | 5.9724 | 169.87 | 169.87 | 339.74 | 1.2 | 1.2 |
| | | | | 2487 | 7.2115 | 299.06 | 299.06 | 598.12 | 1.2 | 1.2 |
| | | | | 2488 | 8.4589 | 482.64 | 482.64 | 965.28 | 1.2 | 1.2 |
| | | | | 2489 | 11.972 | 1368.3 | 1368.3 | 2736.7 | 1.2 | 1.2 |
| | | | | 2490 | 8.3955 | 471.86 | 471.86 | 943.71 | 1.2 | 1.2 |
| Support Leg | BEAM44 | 4209250 | 0.3 | 1956 | 0.50095 | 9.14E-02 | 9.14E-02 | 0.18271 | 1.8483 | 1.8483 |
| | | | | 1957 | 0.6975 | 7.14E-02 | 8.11E-02 | 0.15247 | 1.1769 | 1.1769 |

*Shear deflection constant defined as ratio of the axial area over shear area

Table 2  SG C Support Leg and Tripod Model Study Results

| DOF | Applied Load | Tripod Contribution (Case 1) | | No Tripod Contribution (Case 2) | | Ratio |
|---|---|---|---|---|---|---|
| | | Response | Stiffness | Response | Stiffness | |
| X | 10 kip | 0.040847 ft | 2.4482E+02 kip/ft | 0.040838 ft | 2.4487E+02 kip/ft | 1.0002 |
| Y | 10 kip | 0.040004 ft | 2.4998E+02 kip/ft | 0.039995 ft | 2.5003E+02 kip/ft | 1.0002 |
| Z | 10 kip | 0.000077 ft | 1.2987E+05 kip/ft | 0.000075 ft | 1.3333E+05 kip/ft | 1.026 |
| θX | 10 kip-ft | 0.000433 rad | 2.30947E+04 kip-ft/rad | 0.000432 rad | 2.31481E+04 kip-ft/rad | 1.002 |
| θY | 10 kip-ft | 0.000436 rad | 2.29358E+04 kip-ft/rad | 0.000436 rad | 2.29358E+04 kip-ft/rad | 1 |
| θZ | 10 kip-ft | 0.000564 rad | 1.77305E+04 kip-ft/rad | 0.000564 rad | 1.77305E+04 kip-ft/rad | 1 |

Figure 1  SG C Support Leg

Figure 2 SG C Support Leg Real Constant Numbers for the Beam Elements

Figure 3 Beam-Solid Connection Study Model

**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.

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