RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

03/29/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 931-6467 REVISION 3**
SRP SECTION:	**03.08.03 – Concrete and Steel Internal Structures of Steel or Concrete Containments**
APPLICATION SECTION:	**03.08.03**
DATE OF RAI ISSUE:	**05/15/2012**

QUESTION NO. 03.08.03-88

The Executive Summary, Section 3.1, and Section 7.0 of MHI Technical Report (TR) MUAP-11020-P (R0) refer to some provisions of Chapter 21 of ACI 349-06. From the information provided it is not clear what provisions of Chapter 21 are included in the design of connection regions and connections. Therefore, the items listed below should be addressed.

1. Confirm whether all provisions of Chapter 21 (i.e., Sections 21.1 through 21.10) are followed or specifically identify which provisions are used in the design of connections and explain why the other sections of Chapter 21 are not used.

2. Section 7.0, Step 4, of MHI Technical Report (TR) MUAP-11020-P (R0) states that "the connection region will be designed in accordance with Section 3.0, which calls for detailing similar to ACI 349-06 Section 21.3.3...This detailing provides maximum tie bar spacing of 12 in." ACI 349-06 Section 21.3.3 applies to transverse reinforcement of flexural members of moment frames. According to the MHI-NRC meeting held on 3/12/12 at the NRC headquarters and documented in Agencywide Documents Access and Management System (ADAMS) under Accession Number ML120760065, changes to the tie bar spacings at the connection regions were made. The tie bar plates with a constant spacing of d/2 (d/2 = 24 inch for a 48 inch thick wall; d is the effective depth of a flexural member) will be used to tie the two SC wall faceplates together instead of tie bars (not plates) with a tie bar spacing of d/4. Explain the inconsistency between the 24 in. tie bar plate spacing that is being proposed and ACI 349-06 Section 21.3.3 tie bar spacing provision of 12 in.

3. Section 3.1, item (iv) indicates that the required out-of-plane shear strength (Vr out) of the connection region will be the larger of the following: (a) shear force calculated in accordance with ACI 349-06, Sections 21.3.4 and R21.3.4 and (b) shear force required to develop flexural capacity over a shear span ratio of 2, i.e., Mr/2T. When determining the required out-of-plane shear strength (of the connection region) in accordance with ACI 349 Sections 21.3.4 and R21.3.4, confirm that all of the provisions in Section 21.3 be followed. For example, Section 21.3.4.1 requires that the design shear force Ve shall be determined considering the forces acting on the member between faces of the joints and

the probable flexural moment strength Mpr. This moment utilizes 1.25fy of the steel. Also, according to Section 21.3.4.2, the required transverse reinforcement shall be proportioned to resist the shear force assuming Vc = 0 when two conditions are met: (a) the earthquake induced shear force represents ½ or more of the maximum required shear strength and (2) the factored axial compressive force is less than Agf'c/20.

ANSWER:

This answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-12197 (ML12235A511).

Response to 1

US-APWR containment internal structure (CIS) design follows all applicable American Concrete Institute (ACI) 349-06, Chapter 21, provisions. The internal structure design uses shear-wall and slab construction of heavy proportions, which ACI 349-06 Commentary, Section R21.2.1, confirms as the predominant structural system used in safety-related nuclear facilities. ACI 349-06, Sections 21.7, 21.9, and 21.10, requirements apply to the US-APWR containment internal structure shear-wall and slab systems. ACI 349-06, Sections 21.3, 21.4, and 21.5, do not apply because the US-APWR containment internal structure does not use moment frames.

As stated in Technical Report MUAP-11020, Rev. 1, Section 2.0, the full-strength steel concrete (SC) wall connections are planned for all SC wall connections in the containment internal structure (CIS). The full-strength connection design approach is presented in Technical Report MUAP-11020, Rev. 1.

As explained in Technical Report MUAP-11020, Rev. 1, page iii, the connected parts of the full-strength connection are designed to: (i) respond elastically with no significant damage due to safe-shutdown earthquake (SSE) loading; and (ii) undergo inelastic action and energy dissipation during beyond-design-basis earthquake loading, thus achieving ACI 349-06, Chapter 21, performance objectives.

The SC wall design outside of the full-strength connection is presented in Technical Report MUAP-11020, Rev. 1, Sections 3.1 and 3.2. Supplementary requirements, including those of ACI 349-06, Section 21.3.4.1, are imposed on the SC walls outside of the full strength connections in order to assure ductility. The SC walls use A572 Gr. 50 steel rectangular tie plates to provide out-of-plane shear strength and ductility. Details of these rectangular tie plates are presented in Technical Report MUAP-11019, Rev. 1, Sections 2.6 through 2.8. Transverse reinforcement detailing requirements of ACI 349-06, Section 21.3.3, are not imposed on SC wall design because the SC walls do not use A615 or A706 rebar stirrups or ties to provide out-of-plane shear strength and ductility. The out-of-plane shear strength and ductility of the SC wall to containment internal structures (CIS) basemat connection system was confirmed experimentally by the US-APWR Confirmatory Testing Program summarized in Technical Report MUAP-11013, Rev. 2, Appendix B.

As stated in Technical Report MUAP-11020, Rev. 1, Section 5.0, ACI 349-06, Section 21.5.3, is used to calculate the design joint shear strength of SC wall-to-SC wall connections. The conservatism of the joint shear strength equation was confirmed experimentally by the US-APWR Confirmatory Testing Program summarized in MUAP-11013, Rev. 2, Appendix B.

Response to 2

Technical Report MUAP-11020, Rev. 1, Section 7.0, Step 4, has been revised to remove the incorrect statement that Section 3.0 “calls for detailing similar to ACI 349-06, Section 21.3.3.” Technical Report MUAP-11020, Rev. 1, Section 3.0, does not call for transverse reinforcement detailing requirements similar to ACI 349-06, Section 21.3.3. Rather, Section 3.0 provides equations for calculating the required strengths for full-strength and overstrength connections. For full-strength connections, Section 3.1 explains that the required out-of-plane shear strength for the SC wall outside of the connection is the greater of a) V_e calculated in accordance with Section 21.3.4 and b) $M_r / 2T$. As explained in the last paragraph of Section 3.1 and Section 3.2, the SC walls outside of the connection must be designed and detailed for this required out-of-plane shear strength so that the governing failure mode for out-of-plane shear is ductile yielding in flexure. This is also the intent of the hoop and stirrup detailing requirements given in Section 21.3.3 for flexural members of reinforced concrete moment frames.

As stated in Technical Report MUAP-11019, Rev. 1, Section 2.6, the maximum spacing of the tie bars used in the SC walls is equal to overall section thickness *T* divided by 2. This spacing is selected in accordance with the general shear reinforcement spacing requirement given in ACI 349-06, Section 11.5.5.1, which was specified to ensure that flexural-shear cracks are intercepted by transverse reinforcement. The size of each tie bar cross section is calculated to provide the required out-of-plane shear strength for full-strength connections identified in Technical Report MUAP-11020, Rev. 1, Section 3.0.

The out-of-plane strength and ductility of the full-strength SC wall-connection systems was confirmed experimentally by the US-APWR Confirmatory Testing Program summarized in Technical Report MUAP-11013, Rev. 2, Appendix B.

Response to 3

US-APWR CIS design follows all applicable ACI 349-06, Chapter 21 provisions. ACI 349-06, Sections 21.7, 21.9, and 21.10, requirements apply to the CIS SC shear-wall and slab systems. ACI 349-06, Sections 21.3, 21.4, and 21.5, do not apply because the US-APWR CIS does not use moment frames.

In addition to ACI 349-06, Section 21.7, requirements, supplementary requirements are imposed on the SC walls outside of the full strength connections in order to ensure ductile behavior. Technical Report MUAP-11020, Rev. 1, Section 3.0, provides the tie bar size and spacing requirements to prevent out-of-plane shear failure before flexural yielding. These requirements includes required shear strength calculated in accordance with ACI 349-06, Section 21.3.4, which is a supplemental requirement that is included to assure that code intent and performance objectives are met, as stated above. The probable flexural moment (M_{pr}) is calculated using 125 percent of the steel reinforcement yield strength (f_y) when applying Section 21.3.4.1.

ACI 349-06, Section 21.3.4.2, is not followed because it applies only to the plastic hinge regions of flexural members in reinforced concrete moment frames. However, when checking the required SC wall transverse reinforcement in accordance with Technical Report MUAP-11019, Rev. 1, Section 8.1, V_c is automatically set equal to zero for the seismic loading combinations. Thus, the design procedure conservatively includes only the steel transverse reinforcement contribution to out-of-plane shear strength for all seismic (and seismic plus accident thermal) loading combinations.

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/Topical Report.

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