RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

04/30/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 662-5131 REVISION 2**
SRP SECTION:	**03.08.03 – Concrete and Steel Internal Structures of Steel or Concrete Containments**
APPLICATION SECTION:	**3.8.3**
DATE OF RAI ISSUE:	**11/15/10**

QUESTION NO. 03.08.03-30:

The Amended Response to Question 03.08.03-08, (dated September 2009) contains changes to the text of the initial response to this question, revisions in the numbering of references, and, in some cases, replaces the references cited in MHI's initial response with other technical publications. The staff has reviewed the Amended Response for Question 3.8.3-08, including English translations of the technical papers furnished to the staff by MHI. According to MHI, these technical papers form the basis for the Japanese design codes for the SC modules, and thus form the basis for the suitability of the steel concrete (SC) module walls for the containment internal structures. In its review of the technical papers furnished in the Amended Response, the staff developed a number of questions and concerns that require further explanation or description by the applicant with respect to the design of the SC module wall assemblies used in the US-APWR.

Specifically, the applicant is requested to provide the following information:

1. For the results shown in typical strength and ductility tests it is of interest to know how the corresponding data points would appear for the actual full size USAPWR SC modules. MHI is requested to show that the parameters for the USAPWR SC modules are bounded by the test results. MHI can do this by placing the data points for the US-APWR SC modules in the figures of the test results.

2. MHI is requested to explain how the results of tests performed on scale model walls ranging from 1/10 to 1/5 of full scale are then applied to the design of the full size SC module walls. In particular, explain how important details such as steel plate thickness and the ratio of length of stud anchors to wall thickness for the scale model walls can be considered as representative of the steel plate thicknesses and stud lengths and walls thicknesses of the full size SC module walls. For example, for the tests of a 1/10 scale model of the entire containment internal structure reported in Reference 5 in the Amended Response, the steel plates (actually thin steel sheets) used in the tests are less than 1/16 inch thick. The applicant is requested to show how the results from a test with such thin steel sheets are applicable to the thicker steel plates used in the US-APWR SC module walls.

3. Provide the values of the shear span ratios for the full size SC modules used in the US-APWR containment internal structures.

4. Explain how the diameter and length of the studs used to anchor the steel faceplates to the concrete are determined. In addition, describe how the need for tie bars between steel faceplates is determined and how they are sized.

5. Is the specification for the US-APWR steel plate, ASTM A572, Grade 50, equivalent to the steel used in the tests, SS400 or SS490?

6. Describe the type of welds used in the support pullout tests report in Attachment 2 of MHI's Amended Response. Are these test welds equivalent to the welds used in the actual SC modules? If not, explain how the test results provide assurance that the design of the support anchorages, based on procedures developed from these tests will provide adequate structural strength and ductility in the anchorages.

7. What is the allowable range for the ratio of SC module wall thickness to steel faceplate thickness as used in the design of the US-APWR SC modules? Is the concept of minimum reinforcement ratio and 0.75 times the balanced reinforcement ratio for reinforced concrete (RC) applicable to the steel-concrete (SC) modules?

8. What is the ultimate shear strength of the actual full size SC module walls used in the US-APWR? What is the corresponding maximum value for the design shear?

9. How will the assessment of the serviceability of the SC module walls be carried out following an accident event that results in elevated temperatures in the compartment space? (This question was asked previously in RAI No. 322-1999 as Question 3.8.3-7.)

10. How is the condition and integrity of the concrete in the SC module wall assessed following a significant earthquake? What are the criteria to assure the structural integrity of these SC modules? If some portion or all of any SC module wall needed to be repaired or replaced, how would that be done?

It is also noted that MHI did not address the final portion of the original question in the RAI, namely, to confirm that the SC modules are used only for wall elements, and, further, that only ordinary reinforced concrete is used for all floor slabs. MHI is asked to confirm this observation.

ANSWER:

This answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-10358 (ML110100361).

Part 1

Technical Report MUAP-11005, Rev. 1, Appendices A through D, provide an overview of the experimental database for steel concrete (SC) composite structures that applies to the US-APWR. In these appendices, the test specimen parameters are compared to the design parameters for the US-APWR SC wall configurations as summarized in Table A-2 of Technical Report MUAP-11005, Rev. 1.

Appendix B of Technical Report MUAP-11013, Rev. 2, summarizes the confirmatory physical testing that was performed based on the configuration of the US-APWR SC walls.

Part 2

Technical Report MUAP-11013, Rev. 2, provides an overall methodology for the design of the containment internal structures (CIS), including SC walls, and confirming the adequacy and safety of the design methodology, including confirmatory analysis and physical testing. The design methodology is based on design equations that are based on the relationship between parameters such as plate thickness to wall thickness (reinforcement ratio), plate thickness to stud spacing, and so on. The behaviors demonstrated in the scale model tests are compared with the design equations, in terms of the relationship between the scaled parameters, to confirm that the methodology is conservative.

Technical Report MUAP-11005, Rev. 1, Section 2.2, summarizes the $1/6^{th}$ and $1/10^{th}$ scale test results and their significance to the US-APWR. These results are supplemented by additional physical tests. Technical Report MUAP-11005, Rev. 1, Appendices A through D, provides a detailed summary of additional scaled experimental tests and their applicability to the US-APWR design. Furthermore, Technical Report MUAP-11013, Rev. 2, Appendix B, summarizes the confirmatory physical testing that was performed based on the configuration of the US-APWR SC walls, including full scale tests.

Part 3

Representative shear span ratios for the US-APWR are found in Table 1. Shear span ratio is defined as the ratio of shear span (distance from concentrated load to support, *L*) to twice wall thickness (2*T*). For the table below the shear span is considered as the distance between floor slabs.

Table 1, Representative Shear Span Ratio

As explained in Technical Report MUAP-11020, Rev. 1, Section 3.1, the SC wall connections in the US-APWR CIS have been detailed so that flexural yielding governs the response for demand shear span ratios greater than 2. For demand shear span ratios less than 2, diagonal shear behavior dominates and shear strength will be much larger than that computed using the American Concrete Institute (ACI) code equations because of arching action as explained in Technical Report MUAP-11020, Rev. 1, Section 3.2.

Part 4

The design requirements for studs, including diameter and length, are specified in Technical Report MUAP-11019, Rev. 1, Section 2.2 through 2.5. The design requirements for tie bars, including size and spacing, are specified in Technical Report MUAP-11019, Rev. 1, Section 2.6 through 2.10.

Part 5

American Society of Testing and Materials (ASTM) A572 Gr. 50 steel specified for the US-APWR is equivalent to the SM490 steel used in the tests referenced in References 6, 9, and 12 of Technical Report MUAP-11005, Rev. 1. Both are high strength low alloy steel with a specified yield stress of about 50 ksi.

Part 6

The studs to be used on the US-APWR are to be secured to the steel faceplates by stud arc welding. Stud arc welding is standard practice for the attachment of headed studs.

Part 7

The reinforcement ratios (steel area to gross wall area) for the US-APWR CIS are between 0.015 and 0.045. The minimum horizontal reinforcement ratio specified for walls is 0.0025 (ACI 349-06, Section 14.3.3 for deformed bars larger than No. 5), 0.0015 for vertical reinforcement (ACI 349-06, Section 14.3.2 for deformed bars larger than No. 5) and 0.00333 for flexural members (ACI 349-06, Section 10.5.1). The SC modules meet these minimum reinforcement ratios. All SC walls in the US-APWR CIS have equal steel areas on both faces. As discussed in Technical Report MUAP-11019, Rev. 1, Sections 5.1 and 5.2, this ensures that the tension steel will yield before the concrete crushes when the wall is subjected to bending. Therefore the balanced reinforcement ratio limit is not applicable.

Part 8

The in-plane shear design strength equation for the US-APWR is defined in Technical Report MUAP-11019, Rev. 1, Section 7.3.

Technical Report MUAP-11005, Rev. 1, Appendix C, summarizes the in-plane shear tests of SC modules in the experimental database, including the demonstrated ultimate shear strength values at specimen failure. As shown in Technical Report MUAP-11005, Rev. 1, Figure C-4, the in-plane shear design strength equation conservatively predicts the in-plane shear strength.

Parts 9 &10

Please refer to Response to RAI 662-5131, Question 03.08.03-29, Part 6, for a discussion of condition assessment and repair/replacement of SC walls after accident or earthquake.

Ordinary reinforced concrete is used for all floor slabs in the CIS. SC modules are used only for wall elements in the CIS.

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.