REQUEST FOR ADDITIONAL INFORMATION 662-5131 REVISION 2

11/15/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.08.03 - Concrete and Steel Internal Structures of Steel or Concrete Containments
Application Section: 3.8.3

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

03.08.03-26

03.08.03-26
The staff's evaluation of MHI's amended response to Question 03.08.03-1 is unchanged from that for the initial response. In that initial response MHI stated that "creep, shrinkage, and cracking of concrete are insignificant and are therefore not included in the stiffness calculation. The staff disagreed with this statement. Acceptance criteria 4.D of SRP 3.8.1 states that concrete cracking should be considered. In the response, MHI further stated that reducing the stiffness does not significantly affect the results of moment forces. MHI is requested to provide numerical data to support this claim. Also, in the response to Question 03.08.03-7 Part (c), MHI states that temperature gradient in SC modules will cause concrete to crack. If this statement is true, why is the concrete assumed to be uncracked in the stiffness calculation?

03.08.03-27

03.08.03-27
The staff's evaluation of MHI's amended response to Question 03.08.03-3 is unchanged from that for the initial response. In Part (a) of the question, MHI states that "This three level support system has increased … This response is described in details in Subsection 3.7.2.4". The staff was not able to find any description on this support system in Subsection 3.7.2.4. MHI is requested to provide this description in the DCD.
For Part (b), the information provided by MHI is acceptable in general. However, the figure provided in the answer causes another concern. It appears that the pins at the hinge joints will subject quite a large force on the heavy steam generator (SG). MHI is requested to provide a free-body diagram (sketch) of the SG showing the weight of SG and the reaction forces from the supports. Also, MHI is requested to provide the design calculation for the pin and the details of the connection of the support columns to the supporting concrete.

03.08.03-28

03.08.03-28
MHI's Amended Response to Question 03.08.03-05, (dated September 2009) is essentially unchanged from their initial response, dated 5/21/09. However, as stated in its evaluation of MHI's initial response to this question, the staff determined that the acceptability of the response to Question 3.8.3-5 was largely dependent on the

acceptability of MHI's response to Question 3.8.3-9. This dependency also exists for the Amended Response. It is noted that MHI's Amended Response for this question includes English translations of several Japanese technical papers.

The thrust of the initial Question 3.8.3-05 is for the applicant to demonstrate that the structural integrity of the SC module walls is assured when they are subjected to design loads at elevated temperatures caused by accidents or fire. The Amended Responses to Questions 3.8.3-05 and 3.8.3-09 have been reviewed by the staff, including a review of several technical papers that have been translated into English. As stated later in its evaluation of MHI's Amended Response to Question 3.8.3-09, the staff finds that, in general, these tests show that properly designed SC module walls (designed with adequate margins of safety) will retain adequate strength and ductility to resist the applied design loads when subjected to elevated temperatures due to accidents and/or fire. However, the staff continues to be concerned about the adequacy and completeness of the various tests conducted to show the structural soundness of the SC module walls when subjected to high temperatures in fires. The staff has therefore developed several questions that MHI is requested to address with regard to this aspect of the question.

Specifically, MHI is requested to furnish the following information:

1. Statements made in the Amended Response conclude that, in the aggregate, the results of all relevant tests conducted (in Japan) on fire resistance of the SC modules show that the fire resistance of the SC modules is equivalent to that of conventional reinforced concrete walls. This conclusion may not be entirely correct. Since the rebar in conventional reinforced concrete is enclosed within the concrete, it takes longer for the steel rebar to reach temperature at which loss of strength occurs then it does for the exposed steel faceplates. An important aspect of this issue is the fire resistance rating in terms of hours as per standard codes that are used to design buildings. The staff has found conflicting statements concerning the fire rating of the SC module type of structure. For example, in Reference 9, Part 2, it states that "We confirmed the structure studied in this work had a fire resistance time of over three hours as well as adequate flame and heat blocking capabilities." Compare that with the statement in Reference 9, Part 6, which states: "We presented an experimental program and results for experiments on heating of under load. For SC bearing walls that have high H/T values, a fire resistance time of two hours or more can be obtained by controlling the loading axial force ratio." It is noted that for critical structural elements such as columns and bearing walls in important structures it is required to have at least a three-hour rating. MHI is requested to show clearly that these SC modules, when acting as bearing walls and subject to in-plane and out-of-plane shear loads and bending moments, exhibit a fire resistance time of three hours.
2. In addition to addressing the staff's concerns in (1) above, MHI is requested to describe the design parameters that need to be controlled to assure satisfactory structural behavior during a fire, such as the ratio of shear rib cross-sectional area to shear stress per cross-sectional area of the steel plate between ribs, and the ratio of design strength to ultimate strength of the SC module wall.
3. The staff is unable to find any extended discussion of fire resistance of the SC modules in the US-APWR DCD. MHI is requested to address this area in a subsequent revision to the DCD, including a specification of the required fire resistance ratings for the SC module walls.

The staff notices that a draft standard for the design of SC modules for fire conditions exists in Korea. Is there a similar code in use in Japan, and was it used on the design of

the SC module walls for the US-APWR? If such a code was used for the US-APWR design, was it based on the results of tests cited in the technical reports sent to NRC in this Amended Response?

03.08.03-29

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The only change in the text of the Amended Response to Question 03.08.03-07 (dated September 2009) from that given in MHI's initial response is a renumbering of two references cited in Part (d) of the response, from Reference Nos. 6 and 7 to Reference Nos. 1 and 2. The staff reviewed the amended response, including the two technical papers that were translated into English. The staff finds that Parts (b) and (c) of the amended response are acceptable.

For Part (a) of the amended response: As stated in its initial evaluation the staff notices that all of the temperature plots begin with the calculated temperatures one (1) hour after the accident, and in all cases the maximum concrete temperature is shown to be 300F or less. However, it is not obvious that this temperature of 300F will not be exceeded at any time during the first hour following the accident. MHI is requested to show a typical temperature profile through one of the SC module walls for the first 60 minutes following the accident which shows that the temperature of the concrete surface does not, in fact, exceed at any time the 300F maximum shown for one (1) hour after the accident.

For Part (d) of the Amended Response: The staff reviewed the two referenced papers, Ref. 1 and Ref. 2 (in Attachment 1 of the Amended Response), and notices that the tests described in these technical papers appear to cover several conditions of temperature rise and support configurations for equipment supports embedded in the SC module walls. The tests provide support for MHI's claim that "By the experiments of References 1 and 2, it has been confirmed that steel faceplates and studs do not have any damage and the structural integrity of the SC modules is maintained during accidents which raise temperature such as LOCA and pipe rupture".

MHI is requested to provide information that addresses the following:

1. The response states that even for all accident conditions the maximum local concrete temperature does not exceed 300F. As stated above for Part (a) MHI is requested to show that the concrete at its interface with the steel faceplates does not exceed 300F during the first 60 minutes following the accident.
2. What type of welding in used to secure the studs to the steel faceplates in the pullout of support stud tests? Is this the same type of welding that will be used on the US-APWR?
3. How are shear stud diameter, length, and head size determined in the design of the US-APWR SC modules? Describe the tests that show the appropriateness of any formulas used to determine these parameters.
4. Show that the parameters that exist in the actual SC modules (such as actual wall thicknesses, steel plate thickness, stud sizes and spacing, etc.) are properly and adequately bounded by the corresponding parameters of the test specimens. For example, show how these values would appear in the various test result curves presented in these papers.
5. While the tests described in the technical papers show adequate performance for the maximum temperatures selected, it is important to know how significantly higher temperatures would affect the structural integrity of the SC modules. In particular, at what temperature of the concrete surface would significant reductions occur in the strength of the stud anchorages and steel faceplates?

6. How is the steam generated by the high temperature in the concrete accommodated? Are there any vent holes provided in the steel faceplates?

The staff finds that the MHI's amended response does not specifically address the question concerning the possible need to physically assess the condition of the concrete following any accident as required in ACI 349. MHI is requested to confirm whether thermocouples (or other temperature measuring device) will be installed at the interface between the faceplates and the concrete to assure that the calculated temperatures of the concrete are not exceeded during any accident. In addition, MHI is requested to describe the procedures that will be used to assess the condition of the concrete between the steel faceplates following any accident that results in elevated temperatures.

03.08.03-30

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 US-APWR SC modules. MHI is requested to show that the parameters for the US-APWR 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.

03.08.03-31

03.08.03-31

In its Amended Response to Question 03.08.03-09, (dated September 2009), MHI provided English translations of several Japanese technical papers that were cited in the response as providing answers to the staff's concerns expressed in the initial Question 3.8.3-09. The staff reviewed these technical papers, which papers addressed two topics:

1. Tests on Assemblies of Multiple Walls
2. Test on SC modules at Elevated Temperatures

The staff finds that the several test programs described in the technical reports provide demonstration that the structural behavior of multiple, inter-connected SC module walls designed in accordance with design codes developed using these test results will perform in a satisfactory manner. The staff has, however, developed several questions relating to this area, and these are presented in the staff's assessment of Question 3.8.3-08 above.

With regard to tests performed on SC modules at elevated temperatures, the staff developed a number of issues that need to be addressed, and has asked MHI to respond to these concerns in Question 3.8.3-28.

03.08.03-32

03.08.03-32

The staff's evaluation of MHI's amended response to Question 03.08.03-15 is unchanged from that for the initial response. In that response, MHI states that under the SSE loading the concrete of the SC modules does not crack. However, in the response to Question 03.08.03-7, MHI states that concrete of SC modules will crack under thermal load. Unless the SSE event occurs before the occurrence of thermal load, the concrete will crack and the concrete of SC modules under the SSE loading needs to be considered to be cracked.

MHI needs to provide evidence that the SSE event occurs before the occurrence of thermal load (with an appropriate margin of safety); otherwise, the concrete of the SC modules needs to be considered as cracked under the SSE load. MHI is requested to provide the actual timelines for each of the loads, and to provide the rationale supporting the assumptions for these timelines.