REQUEST FOR ADDITIONAL INFORMATION 491-3733 REVISION 0

11/23/2009

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)

03.08.03-16

In its response to Question 3.8.3-01 (of RAI 322-1999 hereinafter unless indicated otherwise), MHI states that for the US-APWR steel-concrete (SC) modules, creep, shrinkage, and cracking are insignificant, and therefore these effects are not included in the calculations of the member stiffness. MHI states further that since member forces are statically obtained using an equivalent elastic stiffness, reducing this equivalent elastic stiffness (due to creep, shrinkage, and cracking) does not significantly affect the magnitude of these member forces. Thus, these effects (creep, etc.), are considered to be negligible and are not included in the calculations.

In the response, MHI states that “creep, shrinkage, and cracking of concrete are insignificant and are therefore not included in the stiffness calculation.” The staff disagrees with this statement. SRP Acceptance Criteria 4.D of SRP 3.8.1 states that concrete cracking should be considered. In the response, MHI further states that reducing the stiffness does not significantly affect the results of moment forces. The applicant is requested to provide numerical data to support this claim. Also, in the response to RAI 3.8.3-07 Part (c), MHI states that the temperature gradient in the SC modules will cause the concrete to crack. If this statement is true, the applicant is requested to provide justification for assuming the concrete to be uncracked in the stiffness calculation.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-17

In its response to Question 3.8.3-3, MHI states that in order to reduce the seismic effects of the US-APWR steam generators (SG) they chose to use a three level lateral support system. This three level support system is described in the response. The response also includes a sketch that shows how the pin-joint detail used for the SG support columns provides for thermal movement.

In Part (a) of their response, 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. The applicant is requested to provide a description of the response, cited above, in the DCD.

For Part (b) of their response, 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 would be subjected to a large force from the heavy steam generator (SG). The applicant 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 calculations for the pins at the hinge joints and the details of the connection of the support columns to the supporting concrete.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-18

In its response to Question 3.8.3-5, MHI confirmed that for the steel-concrete (SC) modules, the two parallel steel faceplates, which act as reinforcement for the concrete wall, are exposed to the local environment. MHI discusses three topics to demonstrate the structural integrity of the SC modules when subjected to elevated temperatures caused by fire and/or accident, and when subject to corrosive environment which might cause degradation of the faceplates. These three topics are: (1) Elevated Temperature due to Fire; (2) Elevated Temperature due to Accident; and (3) Corrosion. In (1) above, MHI states that the fire resistance of the SC modules is equivalent to that of a conventionally reinforced concrete wall. MHI refers to their detailed reply to Question 3.8.3-9 to substantiate this claim. In a similar manner, in (2) above, MHI cites their reply to Question 3.8.3-9 to substantiate their position that the structural integrity of the SC modules are assured when subjected to accident conditions in the prestressed concrete containment vessel (PCCV). Regarding item (3) above MHI states that the steel faceplates in the SC modules will be painted to prevent corrosion, in the same manner as done for conventional steel structures.

MHI's response states that their response to Question 3.8.3-9 essentially forms the response to this Question 3.8.3-5, with the exception of the response to Part (3) regarding corrosion protection. The staff finds that the response to Part (3) to be a reasonable approach in providing corrosion resistance for exposed surfaces on the steel faceplates, namely, to paint these surfaces with a suitable coating such as that used in conventional buildings of steel construction. The NRC staff also agrees with MHI's position that adequate corrosion resistance is provided for SC modules exposed to water by applying a stainless steel plate which is roll-bonded to the underlying carbon steel faceplate. However, since the staff finds that MHI's response to Question 3.8.3-9 to be unacceptable, the responses for this Question 3.8.3-5, Parts (2) and (3) are also unacceptable. MHI is requested to address issues raised in the staff evaluation of Question 3.8.3-9 in order to resolve the open status of this Question 3.8.3-5.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-19

In its response to this Question 3.8.3-6, MHI provides a brief paragraph which describes, in general terms, the plan needed to install the SC modules. The response includes a flow chart diagram (Fig.1) that shows the major steps involved in shop fabricating the SC modules and installing them in the PCCV. Another figure (Fig 2) is included which shows an exploded isometric view of the various SC modules in the overall containment internal structure.

The staff finds the information given in MHI's response to Question 3.8.3-6 to be rather general, and does not provide sufficiently detailed information on the special module construction techniques needed for the SC module concept that one would expect in the referenced supplement to the DCD. MHI's response to Question 3.8.3-10 provides some further detailed information that relates directly to this Question 3.8.3-6. However, as stated in the staff's evaluation of MHI's response to Question 3.8.3-10, that response also falls short of providing much of the detailed information requested by the NRC staff in its RAI. The applicant is requested to provide a greater level of detail concerning the fabrication and construction of the SC modules.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-20

MHI's response to Question 3.8.3-7 is organized to match the subsections of the NRC staff's RAI, namely, a), b), c), and d).

For Part a) of the question, MHI presents temperature profiles following an accident for typical steel concrete (SC) modules at several locations in the containment internal structure. The locations include walls around the steam generators (SG), part of the wall at the refueling cavity, and a wall along the Radioactive Waste Storage Pit (RWSP). A table is included in the response that shows the Average Temperature and Equivalent Linear Temperature Gradients for the various locations chosen. For all locations the wall temperatures level out at about 190°F in 30 days after the accident.

For Part b) of the question, the response includes a table showing forces, moments and thermal stresses due to the temperature profiles and gradients in Part (a) above. Several pages are presented to show the various FEM models used in the analysis.

For Part c) of the question, MHI includes a table showing the maximum tensile and compressive stresses in the concrete in the SC modules resulting from the thermal gradients in (a) above. It is noted in MHI's response that since the values in tension stress exceed the tensile strength of the concrete, cracking will occur in these SC module walls due to these thermal loads.

For Part d) of the question, MHI discusses the maximum temperatures following a pipe break in the SG compartment SC module wall and for wall around the refueling cavity. These temperatures are 570°F and 580°F, respectively. It is stated that the maximum local temperature of the concrete interface between the concrete and faceplates is 300°F. MHI cites two technical papers in Japanese technical journals which report experiments at elevated temperatures are said to confirm that the steel faceplates and studs do not have any damage in these conditions and that the structural integrity of the SC modules is maintained during accidents such as LOCA and pipe rupture.

The staff notes that in Part a) of the response, MHI presents several temperature plots in the SC module walls for several locations and for both summer and winter conditions. 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 300°F or less. However, it is not obvious that this temperature will not exceed 300°F during the first hour following the accident. MHI is requested to provide a typical temperature profile through one of the SC module walls for the first 60 minutes that will show that the temperature of the concrete surface does not, in fact, exceed at any time the 300°F level shown for one (1) hour after the accident.

Part b) of the response is acceptable.

In Part c) of the response, MHI presents maximum thermal gradients and tension stress in the concrete portion of the SC module, and states that since the stresses exceed the tensile strength of the concrete the concrete will crack. This cracking of the concrete is an important result that affects the seismic response of the structure and is addressed in the staff's follow-up Question No. 3.8.3-15 in this RAI.

For Part d) of the response, MHI states that even for all accident conditions the maximum local concrete temperature does not exceed 300°F. The tests referenced in the response have been conducted in Japan and are reported in Japanese publications. The translated versions of these reports provided to NRC in the updated RAI response dated 9/17/2009 are still being reviewed. The staff's evaluation of the acceptability of this aspect of the response is therefore pending completion of the review of these translations.

MHI's response does not specifically address the question concerning the possible need to physically assess the condition of the concrete following the accidents as is stated in ACI 349. The applicant 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.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-21

In response to Question 3.8.3-10, MHI organized its response along four (4) topics: (1) Manufacturing of SC Module; (2) Transportation of SC Module; (3) Installation; and (4) Pouring Concrete for a SC Module.

For Part (1), MHI states, in a general way, that in manufacturing of the SC modules special care will be taken to confirm the welding workability at the shop and the plant site, as well as to assure the installation of pipe penetrations, supports for components, etc.

For Part (2), MHI presents a brief discussion of transportation weight of the SC module prefabricated assemblies and that the center of gravity will be well marked on each assembly. It is stated that the SC module is to be transported by sea, and it is necessary to consider weather conditions, and that any salt residue must be thoroughly removed. A more detailed description is given for special measures to be taken to protect any SC modules utilizing stainless steel cladding.

For Part (3), MHI refers to their answer to Question 3.8.3-6 for information on installation of the SC modules.

For Part (4), MHI presents a detailed description of the steps to be taken to assure that the concrete placed into the SC modules completely fills the wall cavity and is free of voids and honey-combing. These include use of tell-tale holes that are drilled in several places in the faceplates to indicate when the concrete mix reaches that location. Additional precautions to be taken to assure high quality, sound concrete include minimal use of water in the mix, use of well-graded aggregate, and compaction of the concrete with vibrators.

The staff finds that with the exception of MHI's statements in Part (4) of their response and that portion of the reply for Part (2) covering precautions taken to protect the stainless steel clad SC module assemblies, the response is quite general and lacks the level of detail requested in the RAI. The staff's request for additional information identified the specific items to be addressed by MHI and the level of detail expected in the response. For example, the staff requested detailed information for special requirements placed on fabrication, shipping, handling, and installation of the modules, especially those steps needed to avoid over-stressing the prefabricated steel assemblies, excessive distortion of the faceplates, and any other degrading mechanism. Also, there is little discussion concerning shipment of the shop fabricated steel form modules. What little discussion is presented only addresses, in a general way, shipment of the modules by sea. While sea transport is important (if applicable), it is equally important to provide details of special measures to be taken for overland transportation of the modules, especially with regard to vibrational loads during transit of the assemblies. In addition, more information is needed on the use of tell-tale holes in the faceplates, such as size and spacing of these holes, and a demonstration that this technique effectively assures virtually total absence of voids/honey-combing. The applicant is requested to provide more detailed information for all phases of the construction of the SC modules, similar to that given in MHI's response to Part (4) of this question, and addressing the staff's comments above.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-22

In its response to Question 3.8.3-11, MHI states that the clad plates for SC modules are manufactured by bonding the base carbon steel plate with the stainless steel overlay plates by a rolling process, and that no welding is used in this process. The response also states that the stainless steel cladding plates are not considered as contributing to the structural strength of the wall, nor are they considered in the heat transfer calculations made.

The staff finds that the information given in MHI's response to Question 3.8.3-11 adequately addresses the staff's concerns covered in the RAI. However, MHI is requested to provide the details of the welded joint between adjoining clad plate assemblies.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-23

In its response to Question 3.8.3-12, MHI states that the faceplates of adjacent SC modules are connected by single full penetrating welds. Generally, the faceplates of SC modules are welded using backing metal. MHI states further that visual inspection will be made for all welding portions, and that radiographic, ultrasonic, and liquid penetrant testing will be provided as required. Fillet or full penetration welds are used to satisfy the requirements of design of each module.

The applicant is requested to provide the following information:

1. In general, the staff finds that the response to this question somewhat vague. For example, what quality control measures are to be taken to assure that these critical welds between the SC module faceplates meet appropriate acceptance criteria?. The response also states that radiographic (RT) and ultrasonic (UT) inspections may be employed, as required, but it does not say when or where such quality control (QC) inspections are to be performed. MHI is requested to specify where and when these RT and UT tests are to be applied. Also, are the backing bars at weld joint between SC module faceplates left in place, or are they removed? If they are left there, MHI Is asked to describe how the welding inspection is done.

The response to that part of the question dealing with the nature of the joint between the faceplates and the embedded steel in the basemat states that the bottom steel plate of the SC module assembly is welded to the SC assembly in the shop. In viewing the figure showing this detail, it appears to the staff that the SC module assembly needs to be installed prior to completing the final pours of the concrete basemat. The applicant is requested to confirm this and to describe the measures taken to assure sound bonding between all steel and concrete interfaces.

The applicant is further requested to describe the sequence of construction operations in this area. This description should address the installation and welding details of the ¼ in steel liner plate on the top of the basemat concrete, and its connection to the thicker embedded plates attached to the SC modules.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-24

In response to Question 3.8.3-14, MHI furnished a new figure that shows the detail of the joint between the bottom of the SC modules and the PCCV basemat and the ¼-inch steel liner on the top of the basement**.** MHI explains the manner in which the embedded plate at the bottom of the SC module and the development length of the reinforcing bars in the PCCV basemat that anchor the steel faceplates of the SC module is designed for this area. It is stated that the approach used assumes that the anchor assembly strength exceeds the tensile strength of the steel faceplates in the SC module.

The staff finds that the information given in Figure 1 of the response adequately shows the details of this critical area of the containment internal structures. However, as noted in the staff's evaluation of Question 3.8.3-12, it appears that the final concrete pours in the PCCV basemat must be done after the SC modules are installed. The applicant is requested to provide an explanation as to how the soundness of the concrete in the PCCV basemat is assured and determined in this detail.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.

03.08.03-25

In its response to Question 3.8.3-15, MHI states that an analysis of the containment internal structure comprised of SC Modules for Safe Shutdown Earthquake (SSE) load conditions determined that the resulting shear forces and moments do not cause cracking at the base of the containment internal structure. Based on this check, MHI maintains that the effects of concrete cracking were determined to have only an insignificant effect on the seismic response of the overall the containment internal structure.

The staff notices that while MHI states in their response that under the SSE loading the concrete of the SC modules does not crack. However, in their response to Question 3.8.3-7, MHI states that the concrete of SC modules will crack under thermal load. Unless the SSE event occurs before the occurrence of thermal load, the concrete may be cracked prior to or concurrent with the SSE, and such cracking of the concrete of SC modules under the SSE loading needs to be considered in the analysis. The applicant is requested to provide evidence that it is not possible that SSE events could occur after the occurrence of thermal load; otherwise, the concrete of SC modules needs to be considered as cracked under SSE load, and a re-analyses must be conducted.

Reference: MHI response to RAI 322-1999, dated 9/17/2009, MHI Ref: UAP-HF-09449, ML092670583.