REQUEST FOR ADDITIONAL INFORMATION 223-1996 REVISION 0

2/26/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.08.01 - Concrete Containment
Application Section: 3.8.1

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

03.08.01-1

3.8.1-1

In DCD, Subsection 3.8.1.3.2.2 on Hydrogen Burn (Page 3.8-7), it states "For the US-APWR project, based on a DBA pressure P_a of 68 psig and a corresponding design test pressure of 1.15 x P_a, the above minimum requirement of D + 45 psig is met by virtue of the design and does not require design evaluation."

In the DCD Subsection 19.2.3.3.2, in addressing the pressures from a hydrogen burn, it is stated that "The maximum pressure in the containment under the adiabatic isochoric complete combustion condition is 136 psia. This pressure is lower than the containment ultimate pressure 216 psia and the requirement of 10 CFR 50.44(c)(5) is met."

The applicant is requested to provide values of P_{g1} = Pressure resulting from an accident that releases hydrogen generated from 100% fuel clad metal-water reaction, and P_{g2} = Pressure resulting from uncontrolled hydrogen burning, as stated in R.G. 1.136 5. CC-3000 Design, used in Factored Load Category of $D+P_{g1}+P_{g2.}$ The applicant is requested to demonstrate that the PCCV liner strains resulting from the factored loads for the hydrogen burn condition (136 psia) are within the limits placed on the liner strains in the ASME Code, Subarticle CC-3720.

Additionally, R.G. 1.136 5.B states: "Subarticle CC-3720 of the Code should be followed when the containment structure is exposed to the loading conditions listed below. These loading conditions should include the effect of temperature. For prestressed concrete containment the effects of prestress should also be considered." The applicant is therefore requested to include the effects of temperature and prestressing in demonstrating that the liner strains resulting from the hydrogen burn condition are within the ASME Code.

3.8.1-2

In DCD Subsection 3.8.1.4.1.1, the second paragraph (Page 3.8-9) states "The mesh discretization is chosen to assure adequate representation of the controlling stresses for key elements of the design…..".

The applicant is requested to provide the following information.

(a) What are the criteria used to size the element to assure adequate representation of the controlling stresses for key elements of the design?
(b) Per ASCE 4-98 subsection 3.1.1.3.2 (Page 10 of the Standard), the finite element model shall produce responses that are not significantly affected by further refinement in the element mesh and shape. Was a convergence study performed? If yes, provide the convergence criteria used in the study and the convergence curve/data from the study. If not, provide the rationale for not performing a convergence study.

3.8.1-3
In DCD Subsection 3.8.1.4.3, the 3rd paragraph states: "The resulting estimated ultimate pressure capacity of PCCV based on these hand calculations is 201 psig (approximately 3.0 Pd)**,** and is bounded by the SNL model pressure and yield strain test results."

The applicant is requested to provide the following clarification:

(a) Is the estimated failure of 201 psig (~ 3.0 Pd) based on the ultimate failure of the PCCV rather than the 'functional failure' of a liner tear? If it is the former, what is the estimated failure based on the 'functional failure' as defined in Ref. 3.8-16 (e.g. liner tearing at a discontinuity, etc.). The 'functional failure' value will be a lower bound to the ultimate capacity of the PCCV containment structure. Both values ('functional failure' and ultimate structural failure) are needed to provide a range of pressure capacities in which the PCCV containment will reach its ultimate capacity.
(b) According to the SRP 3.8.1, Rev.2 pg 3.8.1-16, the evaluation of the internal pressure capacity must also address major containment penetrations. The analysis provided does not mention this consideration for penetrations. Provide a clarification as to why penetrations were not considered in evaluating the ultimate pressure capacity of the PCCV.

3.8.1-4

This RAI deleted.

3.8.1-5

In DCD Subsection 3.8.1.4.1.1, the fourth paragraph (Page 3.8-9) states "In designing the PCCV superstructure, individual nodal spring stiffnesses are applied at the supporting FE model boundary (i.e., the basemat/soil interface) to represent the properties of elastic soil springs with tension capability because the SRSS method based on elastic analyses is used to evaluate the seismic load for the three components of the earthquake. The design forces due to the seismic load obtained by the SRSS method are beyond those obtained from inelastic analysis, at the PCCV shell/mat interface. The associated redistribution effects are found to be insignificant."

The applicant is requested to provide the following information:

(a) The soil spring in DCD Subsection 3.8.1.4.1.1 has tension capability which is different from the soil spring described in DCD Subsection 3.8.5.4.2 (Page

3.8-72) where the soil spring does not have tension capability. Provide information on how these two soil springs were calculated and their values.

(b) Throughout DCD Section 3.8, there are different springs used to model the supporting soil: vertical springs with tension capability in this DCD Subsection 3.8.1.4.1.1, vertical springs without tension capability in DCD Subsection 3.8.5.4.2; horizontal springs in DCD Subsection 3.8.5.4.2; and horizontal springs with rotational degree of freedoms in DCD Subsection 3.8.5.4.3. Provide the rationale for having these different springs. Tabulate all the analyses as columns with the type or types of soil springs used in the analyses as rows, and identify the analyses that their results were controlling and used for the design of structures.

(c) In DCD Subsection 3.8.5.4.2, the fourth paragraph (Page 3.8-72) states"The SSE loads are applied as equivalent static loads using the assumption that while the maximum response from one direction occurs, the responses from the other two directions are 40% of the maximum." The staff notes that this combination method is the 100-40-40 method, which is different from the SRSS method that was used in this DCD Subsection 3.8.5.4.2. Explain which combination method was actually used in the design, and the reason for choosing that method over the other.

(d) The meaning of the sentence, as quoted, "The design forces due to the seismic load obtained by the SRSS method are beyond those obtained from inelastic analysis, at the PCCV shell/mat interface." is unclear. Please clarify the meaning of that sentence. Describe the inelastic analysis performed. Does the word "beyond" in "the design forces from the SRSS method are beyond those obtained from inelastic analysis" mean "greater"? Regardless whether your answer to the above question is yes or no, provide the rationale for the answer.

(E) Explain what is meant by the words "The associated redistribution effects." Provide data to substantiate the claim that the redistribution effects are insignificant.

3.8.1-6

In DCD Subsection 3.8.1.4.1.1, the last paragraph (Page 3.8-10) states "The PCCV buttresses are modeled in the three-dimensional global FE analysis model described above so that the discontinuity effects of the normal shell and the thickened buttress can be evaluated."

The applicant is requested to provide the following information:

(a) Describe how the PCCV buttresses were modeled. What types of elements were used, solid elements or shell elements? How are the stresses calculated by the FE program split into the primary and secondary components when checking against the ASME code allowable?

(b) Describe how the discontinuity effects were evaluated.

3.8.1-7

In DCD Subsection 3.8.1.4.1.2, the first paragraph (Page 3.8-10) states "The average and equivalent linear gradients considering thermal stress of the liner plate are applied to the FE model of the PCCV."

The applicant is requested to provide the following information:

(a) Explain the meaning of "the average and equivalent linear gradients considering thermal stress".
(b) Provide the thermal gradients across the thickness of the PCCV cylindrical walls, the basemat, and the dome that were used for the design, and describe how these thermal gradients were obtained.

3.8.1-8

In DCD Subsection 3.8.1.4.2.1, the first paragraph (Page 3.8-11) states "The analysis used to calculate the dynamic response of the PCCV resulting from dynamic loads such as earthquake and hydrodynamic loads considers the potential effects of concrete cracking where significant."

The applicant is requested to describe how the effects of concrete cracking were considered in the dynamic analysis for the PCCV, and provide the technical basis for that consideration.

3.8.1-9

In DCD Subsection 3.8.1.4.2.1, the second paragraph (Page 3.8-11) states "Thermal forces and moments are reduced according to the concrete cracking depth."

The applicant is requested to provide the following information:

(a) How are thermal forces and moments reduced according to the concrete cracking depth?
(b) How is the concrete cracking depth calculated?

3.8.1-10

In DCD Subsection 3.8.1.4.2.1, the third bullet in the second paragraph (Page 3.8-11) states "The redistribution of section forces and moments that occurs due to concrete cracking is taken into account."

The applicant is requested to provide information on how the section forces and moments were redistributed when the concrete is cracked.

3.8.1-11

In DCD Subsection 3.8.1.4.6, the paragraph (Page 3.8-14) states: "A Design Report of the PCCV is provided separately from the DCD. In accordance with ASME Code, Section III (Reference 3.8-2), Subarticle NCA-3350, the Design Report has sufficient detail to show that the applicable stress limitations are satisfied when components are subjected to the design loading conditions."

The applicant is requested to provide a summary of the 'Design Report of the PCCV' showing how the PCCV Concrete Containment design meets the stress limitations subjected to design loading conditions. The summary should include the main parts and the major elements of the containment and provide the margins to the design limits.

3.8.1-12

In DCD Subsection 3.8.1.6 (pg. 3.8-24 and 25) it states "Another site-specific specification shall be produced for the PCCV personnel airlocks and equipment hatch. This specification refers to the ASME Code, Section III, Division 1 (Reference 3.8-2), which is applicable to metallic material not backed by concrete for load carrying purposes (refer to Subarticle CC-2112 for the delineation of jurisdiction). Fracture toughness requirements for materials for locks and hatch and other penetration assemblies subject to Division 1 of the ASME Code, Section III are in accordance with Article NE-2300 (Reference 3.8-2)."

The applicant is requested to provide the following clarification:

(a) In the second sentence of the quoted DCD Subsection 3.8.1.6 material above, Reference 3.8-2 is for Division 2 and not for Division 1. An additional reference is needed in DCD Section 3.8.7 which refers to ASME Section III, Division 1 and then correctly referenced.

(b) In the last sentence of the quoted DCD Subsection 3.8.1.6 material above, Reference 3.8-2 is for Division 2, not Division 1. Reference number 3.8-2 needs to be changed to the correct reference for ASME Section III, Division 1.

3.8.1-13

It is not clear from the information given in DCD Subsection 3.8.1.7 as to the exact nature and timing of the tests to be conducted upon completion of the PCCV and its major penetration assemblies (equipment hatch and personnel airlocks). The statement that the SIT test meets the requirements for leakage rate testing given in RG 1.206 needs to be more specific and clarified. In addition, Article CC-3000 of the ASME Code cited in DC Subsection 3.8.1.7 for preoperational testing is titled "Design", and does not appear to contain any specific provisions for preoperational testing.

The applicant is requested to provide the following information:

1. A description of the SIT and associated leakage rate testing, including the timing of these tests, that is required for the PCCV and major penetrations (equipment hatch and personnel airlocks).
2. A description of what is included in preoperational testing.
3. The specific Subarticle in CC-3000 of the ASME code that contains requirements for preoperational testing.

3.8.1-14

DCD Tier 2, Section 3.8, Revision 1 was reviewed by the staff. Most of the changes made to the DCD Revision 0 are editorial. A few of the changes are technical in their content. The staff finds that, in general, the changes in DCD Tier 2, Section 3.8 do not alter the meaning and intent of DCD Revision 0. However, there are several changes made in DCD Rev. 1 which need clarification or explanation by the applicant.

The applicant is requested to address the following:

1. Page 86 of 196 in the Change List, the change on p. 3.8-12 of DCD, Subsection 3.8.1.4.3. 2nd Paragraph, 3rd Sentence is not clear. The original wording "…..any penetration or discontinuity)" seems appropriate. The intent of changing to "….any penetration of discontinuity)" is not clear. Additionally, it appears that the change was not actually made. If the change is to be made in the future, clarify the intent of this new wording.

2. Page 98 of 196 in the Change List, the change on p. 3.8-45 of the DCD, Subsection 3.8.4, 4th & 5th Paragraphs. Suggest deleting "…..designed to the site-specific SSE….." just prior to the three bullets in the revised section. This is covered in the paragraph following the bullets.

3. Page 101 of 196 in the Change List, the change on p. 3.8-62 of the DCD, Subsection 3.8.4.4.4, 1st Paragraph, the new inserted paragraph states, in part "…..except structural steel in-plane stress limits are permitted to reach 1.0 F_y." Provide the references for Codes, Standards and Specifications or the technical basis that permit the structural steel in-plane stress to reach 1.0 F_y.

4. Page 109 of 196 in the Change List lists replacements of several figures in the DCD. Some of the new (replacement) figures have some information missing that was on the original figures. It is suggested that these omissions be corrected. The affected figures are as follows:

   (a) P. 3.8-182 of the DCD, Figure 3.8.3-6 (Sheet 6 of 7). The callouts for the Primary Shield Wall and Secondary Shield Wall are missing.
   (b) P. 3.8-200 of the DCD, Figure 3.8.4-3 (Sheet 1 of 2). The cross section markers on the plan view are missing for Sections 1 through 4.
   (c) P. 3.8-201 of the DCD, Figure 3.8.4-3 (Sheet 2 of 2). The cross section marker for Section 2 appears to be missing.
   (d) P. 3.8-210 of the DCD, Figure 3.8.4-11. The column line identifications are missing.
   (e) P. 3.8-211 of the DCD, Figure 3.8.4-12. The column line identifications are missing.
   (f) P. 3.8-215 of the DCD, Figure 3.8.5-1. The cross section markers for the E-W and N-S cross-sections are missing.