AUDIT RESULTS SUMMARY
(Prepared by BNL, 07/25/06)

ESBWR DCD Section 3.8

NRC Audit
at
GE, San Jose, CA
July 11-14, 2006

(1) Status of 76 RAI Responses Not Received -

GE reviewed twenty (20) draft responses with the staff. The staff provided verbal feedback for use by GE in developing its formal responses.

(2) RAI Responses Acceptable to Staff Prior to Audit
3.8-56 (adequacy of DCD markup confirmed at audit))
3.8-105

(3) RAI Responses Discussed with GE - Post-Audit Status Update

RAI Response	Post-Audit Status
3.8-3	Open; Supplemental response needed from GE
3.8-6	Open; Supplemental response needed from GE
3.8-13	Open; Supplemental response needed from GE
3.8-14	Open; Staff needs to review ACI 349-01 Fig RA-1
3.8-18	Open; Supplemental response needed from GE
3.8-19	Open; Staff to review GE report at next audit
3.8-20	Open; Staff to complete review of GE report at next audit
3.8-23	Open; GE currently revising the applicable report; Staff follow-up
3.8-25	Open; GE assessing how to respond; Staff follow-up
3.8-26	Open; Related to RAI 3.8-25
3.8-27	Acceptable
3.8-40	Open; Related to RAI 3.8-3
3.8-41	Open; Supplemental response needed from GE
3.8-46	Open; Supplemental response needed from GE
3.8-47	Acceptable
3.8-48	Open; Supplemental response needed from GE
3.8-49	Open; Staff to review applicable GE report at next audit
3.8-51	Open; Supplemental response needed from GE
3.8-63	Open; Supplemental response needed from GE
3.8-64	Open; Supplemental response needed from GE
3.8-82	Open; Supplemental response needed from GE
3.8-83	Acceptable
3.8-87	Open; Supplemental response needed from GE

3.8-90	Open; Supplemental response needed from GE
3.8-91	Open; Supplemental response needed from GE
3.8-100	Open; Supplemental response needed from GE
3.8-104	Open; Supplemental response needed from GE
3.8-106	Open; Supplemental response needed from GE

(4) GE Post-Audit Action Items:

RAI Response	GE Action Required
3.8-3	GE will provide in the DCD, details for the reinforcement around a major reinforced concrete containment vessel (RCCV) penetration (most likely MS & FW penetrations and a representative hatch through the RCCV. GE will provide in an RAI response (with an associated COL Action Item (AI) conceptual design details for the reactor pressure vessel (RPV) stabilizer and refueling seal. For attachments to outside of RCCV, a description will be provided in the DCD to explain that embedment plates will be designed for the RCCV when the component or commodity supports will be designed at the COL stage or confirmed by the COL holder.
3.8-6	GE will supplement response to indicate that during operation there are no components considered as live load which means anything inside containment would have been included in the dead load definition. During outages, items that may be brought inside containment would be under “administrative control” which means that they would be checked for removal from inside containment prior to resumption of operation. Also, as indicated above the effect of using the 25 percent was found to be negligible.
3.8-13	During the audit GE provided comparisons of the basemat deformation and basemat moments for soft soil and hard rock springs for dead load. The basemat deformation and moments for the soft soil springs were larger than that for the hard rock springs across the entire basemat. Therefore, GE concluded that the basemat design is considered to be performed under the worst conditions. In response to the audit team’s request, GE provided similar comparisons for the load combination of LOCA + SSE. The comparisons also showed that the moments across the mat for the soft soil springs were always larger than the moments for the hard rock springs. However, the audit team observed that under the load combination of LOCA + SSE there is a small uplift on the south side of the mat. GE explained during the audit that these results also included dead load. This means that the soil springs in this area are in tension, which is not possible. GE will address the issue of tensile springs and whether the tensile region would grow.

GE needs to include its supplemental response given at the audit in its formal RAI response. GE will re-run the analysis for DL + LOCA + SSE without the soil springs in the area that showed uplifting in order to demonstrate that this effect is not significant. GE is to confirm that the SSE load analyzed above considers 3 directional SSE, not just one or two horizontal directions.

3.8-18 GE will revise response to (1) include principal stresses for critical locations from the SIT pressure tests, and (2) address the need to consider reduced shear wall stiffness, based on past tests and industry methods.

3.8-23 GE indicated that the analysis and results for the external pressure loading on the drywell head are being revised to be consistent with ASME Code Case 284-1 and NRC staff positions in RG 1.193. In discussion of how water sloshing and inertia effects were considered, GE indicated that the treatment of water sloshing and inertia effects will be described in the next “release B” package of RAI responses (also see discussion under RAI 3.8-51 below).

3.8-25 Discussion was held to clarify the concerns with the modeling approach used for the liner. In the NASTRAN model the liner modulus of elasticity is reduced to 1/10,000 its actual value to prevent any stiffness contribution to the overall model. The grid point spacing of the liner does not match the actual anchorage spacing. This could affect the calculation of the correct strains in the liner and the reaction loads calculated for evaluation of the anchorage. The liner is designed using the strain at the connection of the rigid links and liner. The concern remains that the liner could penetrate the concrete surface and the anchorage spacing does not match the actual anchor spacing. As part of the response, GE indicated that the anchorage of the liner would meet requirements in ACI 349-01 for anchorage. This would have to be included as a referenced code/standard and also the corresponding RG 1.199 and 1.142. Reference was made to the Bechtel Topical Report BC-TOP-1 for the approach used to design the liner.

GE needs to evaluate the concerns identified above related to the potential for the liner to penetrate the concrete surface, and the liner grid spacing versus the actual spacing, and also explain how the forces on the anchors are determined if 1/10,000 E is used for the liner in the NASTRAN model.

GE will revise DCD Section 3.8.1 to reference to ACI 349-01, RG 1.142, and RG 1.199.

3.8-26 Covered under RAI 3.8-25.

3.8-40 Covered under RAI 3.8-3.

3.8-41 For vent wall and diaphragm floor, GE needs to demonstrate why the

approach is conservative. If the infill concrete is considered in the analysis then the frequency would increase which could lead to higher accelerations for seismic and/or hydrodynamic loads depending on where the frequency lies in the response spectrum curves. For the NASTRAN model, a DLF of 2.0 is used (not response spectra) so this concern would not apply. However, for the models which develop floor response spectra (seismic and hydrodynamic loads) it may be important. For LOCA thermal analysis, the infill concrete is considered. For other thermal analyses, this issue still needs to be addressed.

3.8-46 GE provided supplemental documentation which demonstrates that the axisymmetric SRV loads govern over the non-axisymmetric loads. Once some editorial corrections in their document are made, the response is acceptable. The commitment for fatigue evaluation for steel structures inside containment and the number of events and cycles for all applicable loads need to be specified in the DCD. The commitment to perform fatigue evaluation for steel structures inside containment is considered to be a COL Action Item to be confirmed. GE indicated that the combination method for seismic loads and for the various hydrodynamic loads is algebraic combination (+ and -) which considers all permutations of loads. GE to revise DCD to indicate that in addition to hydrodynamic building pressure loads on the building structural boundaries and response spectra, there are also direct pressure loads on submerged structures/components and components above the suppression pool surface.

GE to submit supplemental RAI response and revise DCD to reflect all of the above items.

3.8-48 An axisymmetric model using the ANSYS computer code was used to analyze hydrodynamic loads in order to generate floor response spectra. For axisymmetric loads the harmonic n=0 was used while for non-axisymmetric loading, n=1 (cosine shape) was used. GE indicated that for the non-axisymmetric loading n=1 was sufficient without higher harmonics because the structural shell wall is a reinforced concrete structure for which higher harmonics would not have a significant effect. GE showed the response spectra for those loads which were truncated at 100 Hz and demonstrated that the spectral amplitudes diminish at frequencies above 100 Hz. Therefore, leaving the 100 Hz as the cutoff is conservative. GE does not have examples of design specifications for distributions systems and equipment. These would be developed at a later date following the criteria contained in the DCD. This would be considered a COL Action Item to be confirmed. Details of the pressure distributions are provided in DCD Appendix B.

GE to provide supplemental response to capture explanation given by EA

for part (b); and to clarify part (d) by editing the last sentence of this response to read "... since the spectrum values at higher frequencies are lower than the value at the cut off frequency."

GE also needs to explain how the correct asymmetric pressure distribution can be applied to the ANSYS axi-symmetric model using only the n=1 harmonic. This produces negative pressure (i.e., external pressure) on one side of the axi-symmetric structure.

3.8-51 GE indicated that the impulsive (rigid) portion of the water in all pools was included in the models as dead weight. The convective (sloshing) effect of the water was considered for all pools except for the GDCS pool. In the case of the GDCS pool, calculations were provided which demonstrate that the convective (sloshing) pressures are much smaller than the impulsive pressures. In addition, the convective and impulsive pressures are combined by the SRSS method which further diminish the effect of the sloshing pressures for this pool.

GE will revise the DCD to describe application of impulsive and convective loads for all pools except the GDCS pool, where it was shown that the convective load was sufficiently small.

3.8-63 The audit team requested GE to provide information on clearances between the buildings and the technical bases for these clearances. GE provided details of the clearances between the RB/FB, CB and Access Tunnel. To avoid seismic response interaction between the Access Tunnel and RB/FB and CB, a 100 mm gap is kept between them. GE provided plots of the displacement of the RB/FB and CB which demonstrates that this gap width is sufficient. GE also provided drawings showing that the gap is filled with soft material (e.g, polystyrene board).

GE will include supplemental response given at the audit in its formal RAI response. GE also to indicate that a minimum 100 mm gap will be provided between all independent structures. GE needs to confirm that this gap was demonstrated to be sufficient based on current seismic analyses and will be confirmed again when all analyses are completed.

3.8-64 GE was requested to add a subsection under 3.8.4.5 for the EBAS Building.

The audit team reviewed selected portions of 26A6655, FB Structural Design Report, Revision 1, November 2005, containing the structural design details of the Fuel Building and additional supplemental information provided by GE at the audit. The structural design of reinforced concrete frame members is performed in accordance with ACI 349-01 and the steel frame members are designed in accordance with ANSI/AISC N690-1994s2 (2004). In the supplemental information provided at the audit, GE indicated that evaluations for deformation for design loads "are not strictly performed" since the deformations due to

design loads “are not so large.” In support of this position, GE provided the calculated displacements for an FB and CB frame member due to horizontal seismic load. The selected calculations support GE’s position; however, further information is needed to conclude that GE’s approach is applicable to the design of all frame members.

GE will include supplement response given at the audit in its formal RAI response. In addition, GE needs to strengthen the response regarding why deformation for design loads “are not strictly performed.” Need to characterize the term “not so large” and broaden the response to address all frame members.

During the course of the review of the FB Design Report, the audit team noted that the evaluation of the automobile tornado missile is performed at the detailed design stage. GE indicated that this missile was evaluated for the structures and they would provide further information on this subject.

3.8-82 The audit team reviewed GE Report 26A6655, Fuel Building Structural Design Report, Rev 1, November 11, 2005. The audit team found that the combined force and moment tables in the report did not tabulate results for all the load combinations discussed in the report. GE was requested to provide load combination results for the FB and RB external walls subject to W and Wt load combinations and compare with seismic results to demonstrate that they don’t govern the design. During the audit GE provided a comparison between Load Combination 3 and 4 for exterior wall design. These comparisons only addressed load combinations with wind and thermal loads and did not address the staff’s concern. GE agreed to supplement this response to clarify the process and illustrate the results at four selected elements on the exterior walls of the RB/FB. GE will provide results at the four selected locations for load combinations with tornado wind, seismic and thermal loads.

GE needs to supplement this response to clarify the process for checking all load combinations for all building elements against allowable stresses.

3.8-87 The audit team reviewed selected portions of GE Report 26A6651, RB Structural Design Report, Revision 1, November 2005, containing the structural design details of the Reactor Building. How the seismic loads are applied in the NASTRAN model and the assumptions used to define the soil springs are discussed under other RAI responses. Results of the audit teams review of the base mat design are discussed under RAIs 3.8-90, 3.8-91 and 3.8-100.

The audit team requested GE to provide the total load on the foundation in the NASTRAN analysis due to seismic effects and compare to the total loads on the rigid foundation obtained in the seismic analysis.

3.8-90 The audit team requested GE to consider non-uniform soil conditions under the mat. The audit team noted that such studies were done for AP600.

3.8-91 The audit team requested GE to look at the details of the mat design and determine what additional information to put in the DCD to describe the "well-established" methods.

The audit team reviewed the details of the mat reinforcement below the RCCV and requested GE to explain the transition from radial and hoop reinforcement to orthogonal reinforcement and whether sufficient development length was provided in the transition zone. GE explained that circumferential rebars are continuous in the transition region. Radial rebars are terminated at the end of the transition region assuring the required development length. N-S and E-W bars are either continuous or are terminated at the end of the transition region assuring the required development length. GE explained that in section design calculations, both cases of orthogonal rebars and radial-circumferential rebars are evaluated for the region.

In order to confirm the size and quantity of designed steel reinforcement, the total factored moment and shear forces were needed by the NRC audit team. This information was not included in RB Structural Design Report (26A6651 Rev 1). GE was requested to provide this information for three identified critical elements and to demonstrate how the individual load cases are combined to arrive at the total loads and how these total loads are applied to critical sections. Since the SSPD processor cannot directly provide this information, GE provided a table of maximum stress ratios that includes the three locations in the basemat. The staff used the basemat steel area provided at these locations and calculated the approximate capacity for one section and concluded that the reinforcement provided is reasonably conservative and consistent with the stress ratios provided by GE.

GE needs to supplement the response to describe the details of the mat reinforcement beneath the RCCV where the reinforcement transitions from a circumferential/radial pattern to an orthogonal pattern. GE needs to demonstrate that adequate development length for the reinforcement is provided.

In order to confirm the size and quantity of designed steel reinforcement, the total factored moment and shear forces were needed by the NRC audit team. This information was not included in RB Structural Design Report (26A6651 Rev 1). GE needs to provide this information for three identified critical elements. GE needs to demonstrate how the individual load cases are combined to arrive at the total loads and how these total loads are applied to critical sections.

3.8-100 The audit team reviewed the plan of the base mat design and observed that the portion of the mat where the thickness is 5.1 m occurs beneath the RPV region. GE explained that this region is fully constrained by the thick cylindrical wall of the RPV pedestal and is limited in size as compared to the total basemat. Therefore, GE believes that the effect of the thickened mat in this region on the basemat design is negligible. Since the audit team plans to perform some confirmatory analyses of the basemat, some parametric studies can be performed to confirm this assumption.

GE will include supplement response given at the audit in its formal RAI response.

3.8-104 GE explained during the audit that there is no concern about disparity of element sizes excluding regions of large stress or high stress gradients in the case of elastic analysis. GE referenced the MSC/NASTRAN Common Question and Answer section which provided a response to the question: "What are the accuracy checks for static stress analysis." In ESBWR design stresses of elements which have large aspect ratios are compared with those of rectangular elements around the triangular elements to check the reasonableness of the results. As an example, GE presented plots of the stresses of the drywell top slab under Drywell unit pressure. There were no unique stresses on these figures. For this structure, GE also presented a local FEM model that will be created that will use rectangular elements. GE also presented figures depicting the refined local FEM models that will be used to design the RCCV wall around large penetrations. The triangular elements which have large height-to-base aspect ratios in the global model are eliminated.

GE will include the information discussed during the audit in its formal RAI response.

3.8-106 The audit team noted that the response appears to indicate that there is a net upward force on the foundation mat due to unit drywell pressure, and that it is partly resisted by the springs under the FB. This needs to be clarified, as one would expect a zero net force on the foundation mat due to unit drywell pressure.

GE needs to sum the forces on the springs for the unit drywell pressure analysis to demonstrate that there is zero net force on the foundation mat due to unit drywell pressure.

(4) NRC Post-Audit Action Items:

RAI Response	NRC Action Required
3.8-14	Staff needs to review ACI 349-01 Fig RA-1

3.8-19	At the next audit, the Staff will review GE Calculation Report 26A6625, Revision 1, October 2005, which documents the non-linear analyses for the thermal loads taking into account concrete cracking and the redistribution of section forces due to concrete cracking.
3.8-20	At the next audit, the Staff will complete review of GE Report 26A6651, RB Structural Design Report, Revision 1, November 2005, which contains the structural design details of the Reactor Building.
3.8-49	At the next audit, the Staff will review GE Report 26A6558, General Civil Design Criteria, Revision 0, August 2005, which contains design criteria for ESBWR structures.