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UniStar
NUCLEAR ENERGY

10 CFR 50.4
10 CFR 52.79

September 14, 2009

UN#09-371

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Response to Request for Additional Information for the
Calvert Cliffs Nuclear Power Plant, Unit 3
RAI No. 58, Seismic Design Parameters, Question 03.07.01-6
RAI No. 139, Seismic System Analysis; Questions 03.07.02-28 and 03.07.02-29

References:
1) John Rycyna (NRC) to Robert Poche (UniStar Nuclear Energy), "RAI No 58 SEB2 1966.doc (PUBLIC)" email dated February 17, 2009

2) John Rycyna (NRC) to Robert Poche (UniStar Nuclear Energy), "RAI No 139 SEB2 2715.doc" email dated August 13, 2009

3) UniStar Nuclear Energy Letter UN#09-364, from Greg Gibson to Document Control Desk, U.S. NRC, Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 58, Seismic Design Parameters, Questions 03.07.01-3 and 03.07.01-5, dated August 27, 2009

The purpose of this letter is to respond to the requests for additional information (RAIs) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated February 17, 2009 (Reference 1) and August 13, 2009 (Reference 2). These RAIs address

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Seismic Design and Analysis, as discussed in Section 3.7 of the Final Safety Analysis Report, as submitted in Part 2 of the CCNPP Unit 3 Combined License Application (COLA), Revision 5.

Enclosure 1 provides the current status of responses to the RAI questions for Seismic Analysis RAI Nos. 58, 65, and 112.

Enclosure 2 provides our responses to RAI No. 58, Question 03.07.01-6, as committed in Reference 3 and RAI No. 139, Questions 03.07.02-28 and 03.07.02-29.

Our responses do not include any new regulatory commitments and do not impact COLA content.

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Michael J. Yox at (410) 495-2436.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on September 14, 2009

for Greg Gibson

Enclosures: 1) Response Summary for Requests for Additional Information, RAI No. 58, Seismic Design Parameters; RAI No. 65, Seismic System Analysis; and RAI No. 112, Seismic Design Parameters; Calvert Cliffs Nuclear Power Plant Unit 3

2) Response to NRC Request for Additional Information, RAI No. 58, Seismic Design Parameters, Question 03.07.01-6; and RAI No. 139, System Analysis, Questions 03.07.02-28 and 03.07.02-29, Calvert Cliffs Nuclear Power Plant, Unit 3

cc: Surinder Arora, NRC Project Manager, U.S. EPR Projects Branch
Laura Quinn, NRC Environmental Project Manager, U.S. EPR COL Application
Getachew Tesfaye, NRC Project Manager, U.S. EPR DC Application (w/o enclosure)
Loren Plisco, Deputy Regional Administrator, NRC Region II (w/o enclosure)
Silas Kennedy, U.S. NRC Resident Inspector, CCNPP, Units 1 and 2
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GTG/TD/mdf

Enclosure 1

Response Summary for Requests for Additional Information, RAI No. 58, Seismic Design Parameters, RAI No. 65, Seismic System Analysis, and RAI No. 112, Seismic Design Parameters; Calvert Cliffs Nuclear Power Plant Unit 3

Response Summary for Requests for Additional Information

RAI Set 58 Question	Description of RAI Item	Response Date
03.07.01-1	Justify assumptions of rigid basemat in SSI analysis of Nuclear Island including lower bound soil properties (where shear wave velocity is less than 1000 fps)	September 15, 2009
	Identify impact on the SSI analysis results and on the design of the foundation mat and supported superstructure.	September 15, 2009
03.07.01-2	See UniStar Nuclear Energy letter UN#09-320, dated July 15, 2009	Response submitted
03.07.01-3	For EPGB and ESWB, provide methodology to calculate FIRS at grade elevation computed from the GMRS which were determined at an applicable elevation 41 ft below grade. See UniStar Nuclear Energy letter UN#09-364, dated August 27, 2009	Response submitted
	Describe computer codes, soil column model, and the basis for the shear wave velocity of the structural backfill that supports both the EPGB and ESWB and the impact of this backfill on the development of the FIRS.	December 29, 2009
	Provide in the FSAR the spectra at the foundation level of each structure meeting Appendix S requirements.	December 29, 2009
	Provide in the FSAR a comparison of the FIRS at the foundation level of each structure meeting the requirements of Appendix S to the CSDRS provided in the U.S. EPR FSAR.	December 29, 2009
	Provide the basis for not performing confirmatory analysis for the EPGB and ESWB similar to that for NI. See UniStar Nuclear Energy letter UN#09-329, dated July 29, 2009.	Response submitted
03.07.01-4	See UniStar Nuclear Energy letter UN#09-320, dated July 15, 2009	Response submitted
03.07.01-5	For Ultimate Heat Sink Electrical Building, provide and include in the FSAR the horizontal and vertical spectra depicting design spectra and applicable envelope. See UniStar Nuclear Energy letter UN#09-364, dated August 27, 2009	Response submitted

Response Summary for Requests for Additional Information

RAI Set 58 Question	Description of RAI Item	Response Date
	Provide in the FSAR a reconciliation of the design response spectrum with the horizontal foundation input response spectra (FIRS) for this structure which meets the minimum requirements of 10 CFR Part 50, Appendix S.	December 29, 2009
	Include a description of how the FIRS are developed including the soil model, soil properties, backfill properties, computer programs and analysis assumptions.	December 29, 2009
03.07.01-6	Provide in the FSAR how the design response spectrum and assumed soil properties used in the analysis of the UHS MWIS will be reconciled with the FIRS that meets the requirements of Appendix S and the final soil properties determined from the site final geotechnical studies.	This Letter – See Enclosure 2
	Include in the FSAR a comparison of the FIRS with the design response spectra used in the analysis.	December 29, 2009
	Include a description of how the FIRS are developed including the soil model, soil properties, computer programs, and analysis assumptions.	December 29, 2009
03.07.01-7	Provide in the FSAR a discussion of the site-specific spectra that were considered for buried utilities.	December 29, 2009
	Provide justification for the use of the EUR soft soil spectrum including possible displacement and velocity differences that may exist with the use of this spectrum as opposed to using a site specific spectrum.	December 29, 2009
	Provide a comparison of the EUR soft soil spectrum with appropriate site specific spectra that are applicable to buried utilities.	December 29, 2009
03.07.01-8	See UniStar Nuclear Energy letter UN#09-228, dated May 1, 2009	Response submitted
03.07.01-9	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.01-10	State explicitly or by reference design ground motion time histories for Nuclear Island, EPGB and ESWB structures.	September 15, 2009

Response Summary for Requests for Additional Information

RAI Set 58 Question	Description of RAI Item	Response Date
	What are the site specific design ground motions and their bases that apply to these structures? Provide this information in Section 3.7.1.1.2 of the FSAR.	December 29, 2009

RAI Set 65 Question	Description of RAI Item	Response Date
03.07.02-1	See UniStar Nuclear Energy letter UN#09-228, dated May 1, 2009	Response submitted
03.07.02-2	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-3	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-4	Provide results of SSI analysis for Ultimate Heat Sink Electrical Building that meet the acceptance criteria 4.A.vii of SRP 3.7.1 and acceptance criteria 4 of SRP 3.7.2 using subgrade model of final soil and backfill properties or justify alternative.	December 29, 2009
	Include SSSI effects from UHS MWIS.	December 29, 2009
	Reconcile with the results of assumed seismic response and ISRS.	December 29, 2009
03.07.02-5	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-6	Describe how the SSI analysis performed for Ultimate Heat Sink Makeup Water Intake Structure (UHS MWIS) meets the acceptance criteria and 4.A.vii of SRP 3.7.1 or justify alternative.	December 29, 2009
	Provide a figure depicting the soil-structure model used for the seismic analysis.	December 29, 2009

Response Summary for Requests for Additional Information

RAI Set 65 Question	Description of RAI Item	Response Date
	Provide the basis for the assumed soil properties and profile used to calculate the frequency independent impedance functions. See UniStar Nuclear Energy letter UN#09-339, dated August 13, 2009	Response submitted
	Provide the method and formulas used to calculate the values of the soil springs under the foundation as well as the lateral soil springs that represent the embedment effects. See UniStar Nuclear Energy letter UN#09-339, dated August 13, 2009	Response submitted
	State whether the soil properties used in the analysis are strain dependent or simply the low strain values. If these are low strain values, justify their use and quantify the impact of not using strain dependent properties on the results of the analysis. If the soil properties are strain dependent, describe how the final soil properties are determined in the analysis. See UniStar Nuclear Energy letter UN#09-339, dated August 13, 2009	Response submitted
	For large values of Poisson's ratio, the dynamic stiffness and damping are frequency dependent. Provide justification for assuming that the impedance functions of the supporting foundation are frequency independent. See UniStar Nuclear Energy letter UN#09-339, dated August 13, 2009	Response submitted
	Confirm that the control motion is applied at the base of the soil structure analysis model. See UniStar Nuclear Energy letter UN#09-339, dated August 13, 2009	Response submitted
	Provide a reconciliation of the final soil properties and the foundation input response spectra (FIRS) that are based on these properties with the seismic analysis results described in the FSAR.	December 29, 2009
03.07.02-7	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-8	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-9	See UniStar Nuclear Energy letter UN#09-126, dated March 19, 2009	Response submitted

Response Summary for Requests for Additional Information

RAI Set 65 Question	Description of RAI Item	Response Date
03.07.02-10	See UniStar Nuclear Energy letter UN#09-228, dated May 1, 2009	Response submitted
03.07.02-11	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-12	Provide results of a structure-to-structure interaction analysis between UHS MWIS and EB.	December 29, 2009
03.07.02-13	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-14	See UniStar Nuclear Energy letter UN#09-228, dated May 1, 2009	Response submitted
03.07.02-15	See UniStar Nuclear Energy letter UN#09-320, dated July 15, 2009	Response submitted
03.07.02-16	See UniStar Nuclear Energy letter UN#09-126, dated March 19, 2009	Response submitted

Response Summary for Requests for Additional Information

RAI Set 65 Question	Description of RAI Item	Response Date
03.07.02-17	The interaction of non-seismic Category I structures with Seismic Category I systems is described in FSAR Section 3.7.2.8. In this section on page 3.0-41, it states that fire protection SSCs are categorized as either Seismic Category II-SSE, meaning the SSC must remain functional during and after a Safe Shutdown Earthquake (SSE), or Seismic Category II, meaning the SSC must remain intact after an SSE without deleterious interaction with a Seismic Category I or Seismic Category II-SSE SSC. In the U.S. EPR FSAR on page 3.7-95, it states that Seismic Category II is designed to the same criteria as Seismic Category I structures. In SRP 3.7.2, SRP Acceptance Criteria 8, which addresses the interaction of non-Category I structures with Category I SSCs, it states that when non-Category I structures are designed to prevent failure under SSE conditions; the margin of safety shall be equivalent to that of the Seismic Category I structure. • Describe how this margin of safety is achieved for the Seismic Category II-SSE and Seismic Category II portions of the fire protection system. Include in your response the seismic inputs, loading combinations, codes and acceptance criteria. What are the differences in the method of design for these two seismic categories? • Describe the basis and provide figures in the FSAR of the design response spectra used to analyze above ground seismic Category II and seismic Category II-SSE fire protection SSCs including the fire protection tanks. • What are the methods of analysis and acceptance criteria for both the buried and above ground portions of the fire protection system that are Seismic Category II-SSE that will ensure that these portions of the system will remain functional following an SSE event? • What are the modeling and analysis methods used for the fire protection tanks and to what extent do the fire protection tanks meet the acceptance criteria of SRP 3.7.3, SRP Acceptance Criteria 14.A. thru J? When the tank analysis does not meet the acceptance criteria, provide the technical justification for not doing so.	October 16, 2009
03.07.02-18	Clarify the seismic classification of fire protection tank and building. See UniStar Nuclear Energy letter UN#09-329, dated July 29, 2009.	Response submitted
	Reconcile the U.S. EPR seismic analysis for NAB with the site-specific soil properties and foundation input response spectra (FIRS)	September 15, 2009

Response Summary for Requests for Additional Information

RAI Set 65 Question	Description of RAI Item	Response Date
	Demonstrate in the FSAR that the displacement of this structure relative to the nuclear island common basemat structure is enveloped by the results of the U.S. EPR analysis.	September 15, 2009
03.07.02-19	In FSAR Section 3.7.2.8 on page 3.0-42 it states that the conventional seismic switchgear building, conventional seismic grids systems control building, the conventional seismic circulating water intake structure and the Seismic Category II retaining wall surrounding the CCNPP Unit 3 intake channel could potentially interact with Seismic Category I SSCs. For each of the above structures, describe in the FSAR how the seismic interaction acceptance criteria of SRP 3.7.2, SRP Acceptance Criteria 8 are met, or justify an alternative. If they are intended to meet criterion B, provide the technical basis for the determination that the collapse of the non-Category I structure is acceptable. For criterion C, confirm that the structure will be analyzed and designed to have a margin of safety equivalent to that of a Category I structure and state how this will be accomplished.	October 16, 2009
03.07.02-20	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-21	See UniStar Nuclear Energy letter UN#09-228, dated May 1, 2009	Response submitted
03.07.02-22	See UniStar Nuclear Energy letter UN#09-126, dated March 19, 2009	Response submitted
03.07.02-23	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted
03.07.02-24	Per COLA item 3.7-1, address that the seismic response of the nuclear island common base mat structures, seismic Category II structures, the Nuclear Auxiliary Building and the Radioactive Waste Processing Building is within the parameters of Section 3.7 of U.S. EPR FSAR.	September 15, 2009
	Provide a summary for each structure, either directly or by reference, which describes how the COL item is met.	September 15, 2009
03.07.02-25	See UniStar Nuclear Energy letter UN#09-228, dated May 1, 2009	Response submitted
03.07.02-26	See UniStar Nuclear Energy letter UN#09-291, dated June 12, 2009.	Response submitted

Response Summary for Requests for Additional Information

RAI Set 112 Question	Description of RAI Item	Response Date
03.07.01-11	Provide a definition of site SSE and explain how it meets regulation requirements.	September 15, 2009
	Consistent with the site SSE, provide the FIRS in the free field at the foundation level of each structure meeting the requirements of Appendix S, and describe how each is determined.	September 15, 20092 (NI) December 15, 2009 (EPGB, ESWB)
	For the U.S. EPR Certified Design structures, provide a comparison of the results of the site seismic) analyses using the FIRS input motion defined at the foundation level of each structure, with the analyses results documented in the U.S. EPR FSAR.	September 15, 20092 (NI) December 15, 2009 (EPGB, ESWB)
	For the EPGS and ESWS, describe how the effect of structure-soil-structure interaction has been accounted for in the analysis of these buildings.	December 29, 2009 (EPGB, ESWB)

Enclosure 2

Response to NRC Request for Additional Information, RAI No. 58, Seismic Design Parameters, Questions 03.07.01-6, and RAI No. 139, System Analysis; Questions 03.07.02-28 and 03.07.02-29, Calvert Cliffs Nuclear Power Plant, Unit 3

RAI No. 58

Question 03.07.01-6

FSAR Section 3.7.1.1.1 on page 3.0-32 states that the design response spectrum used to analyze the Ultimate Heat Sink (UHS) Makeup Water Intake Structure (MWIS) is the European Utility Requirements (EUR) soft soil spectrum scaled down to a ZPA of .15 g. The acceptability of using the scaled down EUR soft soil spectrum is based on comparison of the horizontal ground motion response spectra (GMRS) and a RG 1.60 spectrum scaled down to a zero period acceleration (ZPA) of 0.10 g. It then states that upon completion of the final geotechnical site investigation, it will be confirmed that the GMRS is a conservative representation of the foundation input response spectra (FIRS) for the UHS MWIS. The horizontal component of the FIRS for this structure must meet the requirements of 10 CFR Part 50, Appendix S and have a minimum ZPA of 0.10 g. Provide in the FSAR how the design response spectrum and assumed soil properties used in the analysis of the UHS MWIS will be reconciled with the FIRS that meets the requirements of Appendix S and the final soil properties determined from the site final geotechnical studies. Include in the FSAR a comparison of the FIRS with the design response spectrum used in the analysis. Also include a description of how the FIRS are developed including the soil model, soil properties, computer programs, and analysis assumptions.

Response

As summarized in Enclosure 1, the following portion of this RAI question is addressed herein:

Provide in the FSAR how the design response spectrum and assumed soil properties used in the analysis of the UHS MWIS will be reconciled with the FIRS that meets the requirements of Appendix S and the final soil properties determined from the site final geotechnical studies.

UHS MWIS design spectrum as currently reported in FSAR Revision 5

As described in FSAR Section 3.7.1.1.1, a conservative design response spectrum was used for the preliminary analysis of the Ultimate Heat Sink (UHS) Makeup Water Intake Structure (MWIS). This spectrum is shown in FSAR Figure 3.7-38, and corresponds to the European Utility Requirements (EUR) soft soil spectrum scaled down to a zero period acceleration (ZPA) of 0.15 g. The spectrum shown in Figure 3.7-38 will be replaced by a figure similar to Figure 1.

Reconciliation of Design spectrum for UHS MWIS and FIRS

Figure 1 depicts the Calvert Cliffs Site SSE spectrum, which replaces the design spectrum described above and will be used as design spectrum for the Soil Structure Interaction (SSI) analysis of the UHS MWIS. Details regarding the development of Calvert Cliffs Site Safe Shutdown Earthquake (SSE) spectrum are discussed in response to RAI 58 Question 03.07.01-4[1]. This spectrum meets the requirements of 10 CFR Part 50, Appendix S Section IV (a)(1)(i). Figure 1 compares the site SSE spectrum, with RG 1.60

[1] UniStar Nuclear Energy Letter UN#09-320, from Greg Gibson (UniStar Nuclear Energy) to Document Control Desk, U.S. NRC, Response to Request for Additional Information for the Calvert Cliffs Nuclear Plant, Unit 3, RAI No. 58, Seismic Design Parameters, RAI No. 63, Seismic Subsystem Analysis, and RAI No. 65, Seismic System Analysis, dated July 15, 2009.

spectrum with Peak Ground Acceleration (PGA) of 0.1 g, using the NI foundation input response spectra (FIRS) as representative horizontal and vertical FIRS for UHS MWIS (i.e., new Ground Motion Response Spectra (GMRS) with PGA of 0.0755 g for NI reported in Table 2.5-22 and Figure 2.5-87 of enclosure to UniStar letter UN#08-027[2]).

Once the detailed sub-surface investigation at the location of the UHS MWIS is completed, reconciliation of Calvert Cliffs Site SSE spectrum and the FIRS for UHS MWIS will be conducted according to the following steps:

1. Horizontal and vertical FIRS will be calculated at the foundation level of UHS MWIS (El. 26.5'). The performance-based procedure described in NRC Regulatory Guide 1.208 (2007) will be used in this step.

2. It will be demonstrated that the Horizontal and Vertical FIRS from step 1 above are enveloped by Calvert Cliffs Site SSE spectrum.

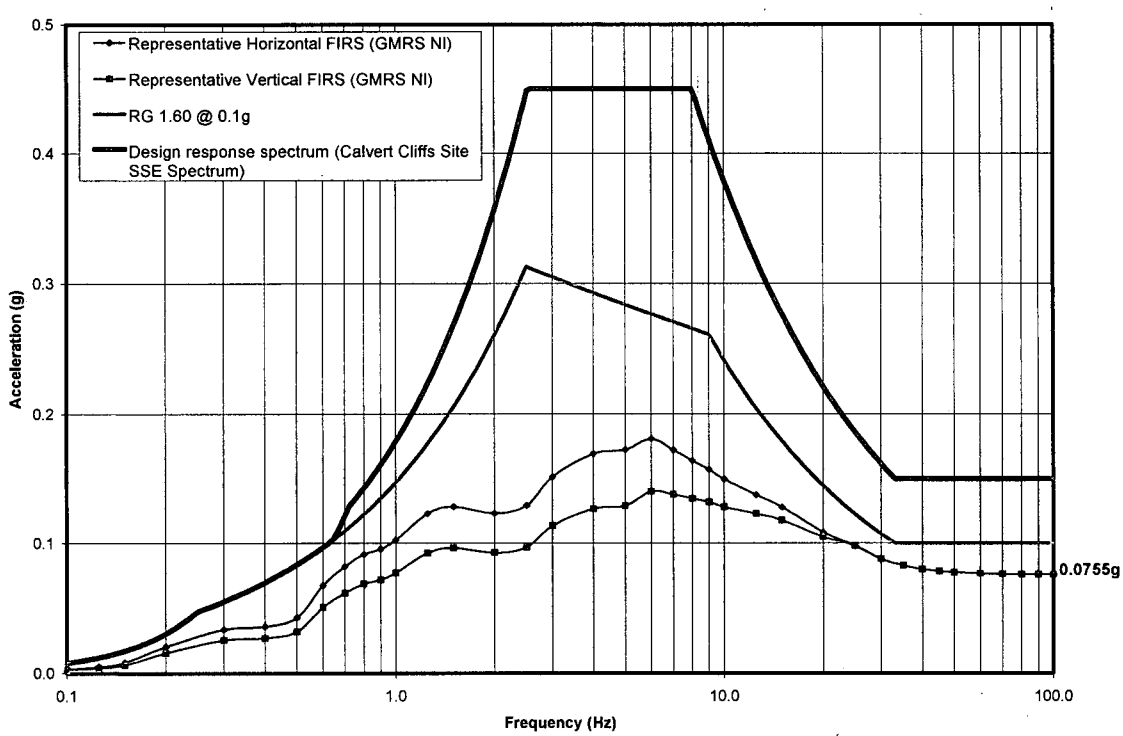

Figure 1: UHS MWIS design spectrum (Calvert Cliffs Site SSE 5% damping spectrum)

[2] UniStar Nuclear Energy Letter UN#08-027, from George Vanderheyden (UniStar Nuclear Energy) to Document Control Desk, U.S. NRC, Submittal of Supplemental Information for the Calvert Cliffs Nuclear Plant, Unit 3, Combined License Application, Updated Information for Ground Motion Response Spectrum, dated July 31, 2008.

COLA Impact

FSAR Subsections 3.7.1 and 3.7.2 will be updated once the horizontal and vertical FIRS at the location of the UHS MWIS are available, following completion of the sub-surface investigation and the seismic reconciliation of the UHS MWIS per the response schedule for this RAI in Enclosure 1.

RAI No. 139

Question 03.07.02-28

Follow-up 1 to Question 03.07.02-16 (RAI No. 65)

The staff reviewed the response to RAI No. 65, Question 03.07.02-16 and the proposed change to the CCNPP Unit 3 FSAR (UniStar letter No. UN#09-126, dated March 19, 2009) for the Ultimate Heat Sink (UHS) Makeup Water Intake Structure, and found them acceptable based on the fact that the time history method used meets the guidance provided in Regulatory Guide (RG) 1.92. However, in the March 19 RAI response, the proposed revision to FSAR Section 3.7.2.7 states that the combination of modal responses does not apply to the UHS Electrical Building (EB). Instead, because of its small cross-section size and significant stiffness, the response of the UHS EB is based on the ground motion Zero Period Acceleration (ZPA). Please include in FSAR Section 3.7.2.7 additional technical justification for the assumed seismic response of the UHS EB, or include references to other FSAR Sections where such technical justification may have been provided.

Response

The seismic reconciliation analysis for the Ultimate Heat Sink (UHS) Electrical Building (EB) will be performed using SASSI with the Calvert Cliffs Site SSE spectrum, as described in response to RAI 58 Question 03.07.01-5[3], as the design input. The SSI analysis will include the structure-soil-structure interaction effects from UHS Makeup Water Intake Structure.

The description of the reconciliation analysis will be provided with responses to RAI 58 Question 03.07.01-5 and RAI 65 Question 03.07.02-4 per schedule provided in Enclosure 1. The relevant sections of the FSAR will be updated accordingly.

COLA Impact

FSAR Sections 3.7.1 and 3.7.2 will be revised following the completion of SASSI analysis for UHS EB and will be provided with responses to RAI 58 Question 03.07.01-5 and RAI 65 Question 03.07.02-4 per schedule provided in Enclosure 1.

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[3] UniStar Nuclear Energy Letter UN#09-364, from Greg Gibson (UniStar Nuclear Energy) to Document Control Desk, U.S. NRC, Response to Request for Additional Information for the Calvert Cliffs Nuclear Plant, Unit 3, RAI No. 58, Seismic Design Parameters, dated August 27, 2009.

RAI No. 139

Question 03.07.02-29

Follow-up 1 to Question 03.07-02-22 (RAI No. 65)

The staff reviewed the response to RAI No. 65, Question 03.07.02-22 (UniStar letter No. UN#09-126, dated March 19, 2009) regarding the distribution of foundation stiffness to the basemat nodes, and concluded that the response included only a concept of how the springs are calculated for the tributary areas, and did not provide enough information as to how this was accomplished for the Ultimate Heat Sink (UHS) Makeup Water Intake Structure (MWIS). Provide a specific example showing how the methodology is applied to the UHS MWIS, including how the nodes are distributed in the foundation, and how the tributary area is determined for each node. Also, the March 19 RAI response stated that the stiffness values are amplified to account for embedment effects using factors given in Table C3.3-1 of American Society of Civil Engineers (ASCE) 4-98, "Seismic Analysis of Safety-Related Nuclear Structures," which is applicable to circular foundations. In the forthcoming response to RAI No. 65, Question 03.07.02-6, which will address issues regarding the Soil Structure Interaction (SSI) analysis of this structure, provide discussion of how embedment effects are determined, including justification for the use of Table C3.3.1 for the UHS MWIS, which has a rectangular foundation and is not embedded on all sides, and how the stiffness of the soil is calculated.

Response

How are the nodes distributed in the foundation?

FSAR Figures 3.8-5 and 3E.4-3 show the finite element mesh for basemat of the Ultimate Heat Sink (UHS) Makeup Water Intake Structure (MWIS). These figures illustrate how the joints (or nodes) are distributed.

How is tributary area determined for each node?

The finite element mesh for the UHS MWIS basemat is extracted from the complete model for determination of tributary area associated with each node. In this sub-model, joints are restrained against vertical displacement. A unit pressure (1 ksf) is applied to the basemat elements, and static analysis is performed. The tributary area associated with a joint is equal to the vertical reaction at that joint. This methodology is illustrated by the example below. Consider the finite element mesh for a basemat as shown in Figure 2.

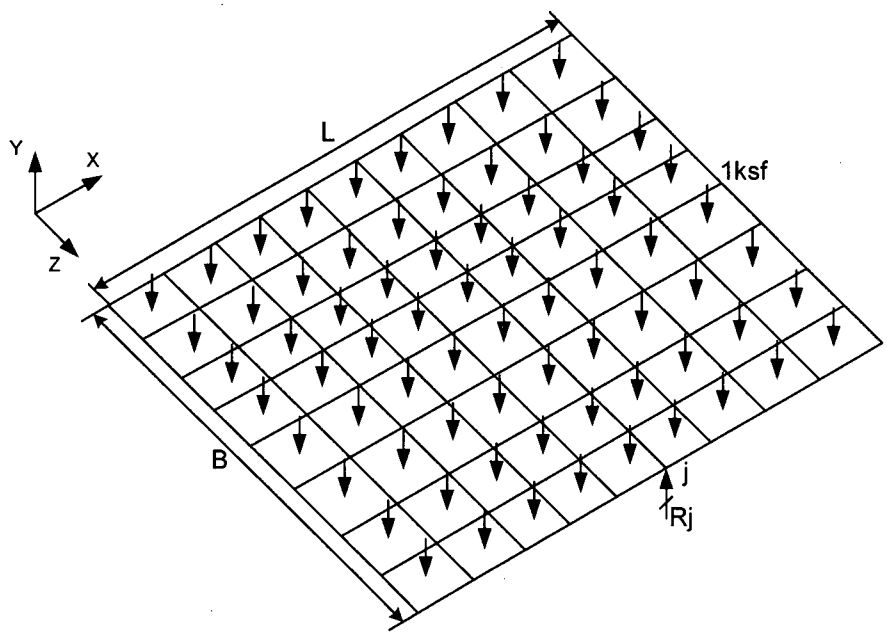

Figure 2: Tributary Area Calculation

The tributary area for joint 'j', $A_j = R_j / 1ksf$ where R_j is the vertical reaction (in kips) from the static analysis. L and B represent the plan dimensions of the basemat.

How is lumped foundation stiffness distributed to basemat nodes?

The lumped foundation stiffnesses for UHS MWIS are calculated using the equations and figures presented in response to RAI 65 Question 03.07.02-6[4]. For the seismic analysis of UHS MWIS, the lumped stiffnesses were distributed based on the methodology described below. For this example, consider that the calculated lumped translational stiffnesses are K_X, K_Y, and K_Z, and calculated lumped rotational stiffnesses are $K_{\psi X}$, $K_{\psi Y}$, and $K_{\psi Z}$, where X and Z represent the two horizontal directions and Y is the vertical direction (see Figures 2 and 3).

I. <u>Distribution of Vertical and Rocking Stiffnesses:</u>

(a) The vertical spring stiffness at each joint is calculated by multiplying the lumped vertical stiffness (K_Y) by the ratio of the joint tributary area (A_j) to total basemat area (A_B = L×B).

$$K_{Yj} = K_Y \frac{A_j}{A_B} \qquad (1)$$

[4] UniStar Nuclear Energy Letter UN#09-339, from Greg Gibson (UniStar Nuclear Energy) to Document Control Desk, U.S. NRC, Response to Request for Additional Information for the Calvert Cliffs Nuclear Plant, Unit 3, RAI No. 65, Seismic System Analysis, dated August 13, 2009.

(b) The distributed vertical stiffness produces inherent rocking stiffness about both horizontal axes ($K_{I\psi X}$ and $K_{I\psi Z}$), which are calculated as

$$K_{I\psi X} = \int\left(\frac{K_Y}{A}\right)z^2 dA = K_Y \frac{I_X}{A} = K_Y r_X^2 \tag{2a}$$

$$K_{I\psi Z} = \int\left(\frac{K_Y}{A}\right)x^2 dA = K_Y \frac{I_Z}{A} = K_Y r_Z^2 \tag{2b}$$

where I_X and I_Z represent the moment of inertias of the basemat about X and Z axes, and r_X and r_Z represent the radii of gyration about X and Z axes, respectively.

(c) The rocking stiffnesses determined in item (b) above are less than the calculated lumped rocking stiffnesses, and therefore, rocking deficits about both horizontal axes (i.e., $K_{\psi X}$-$K_{I\psi X}$ and $K_{\psi Z}$-$K_{I\psi Z}$) are calculated. These rocking stiffness deficits are distributed to each joint using rotational springs in proportion to joint tributary area, similar to distribution of vertical stiffness defined in Equation 1.

II. <u>Distribution of Horizontal and Torsional Stiffnesses:</u> The element type SBHQ6 used in the finite element analysis of UHS MWIS has a fictitious torsional degree of freedom, as described in GT STRUDL User Manual. Therefore, the lumped torsional stiffness ($K_{\psi Y}$) cannot be directly distributed based on the joint tributary areas. The following methodology was adopted to distribute horizontal and torsional stiffnesses.

(a) A small fraction (α) of the total horizontal stiffness in each direction was distributed to the four corner joints of the basemat (see Figure 3). The remaining stiffness {i.e., $(1-\alpha)K_X$, $(1-\alpha)K_Z$} was then distributed to the rest of the basemat joints in proportion to their tributary areas (see Figure 3.)

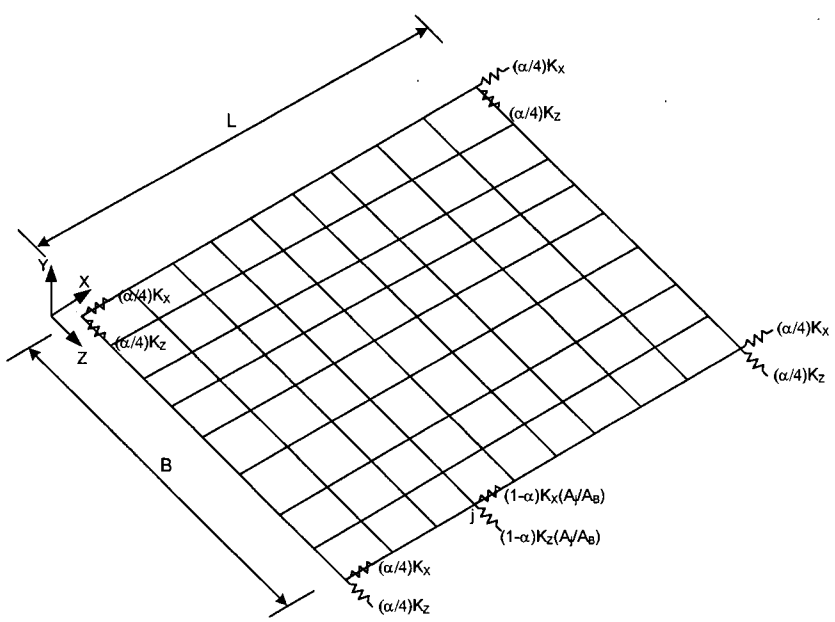

Figure 3: Horizontal and Torsional Stiffness Distribution

(b) The total torsional stiffness ($K_{\psi Y}$) is the summation of stiffness contribution from the corner nodes ($K_{\psi Y_corner}$) and the inner nodes ($K_{\psi Y_inner}$), where

$$K_{\psi Y_corner} = \frac{\alpha}{4}\left(K_X B^2 + K_Z L^2\right) \quad (3a)$$

$$K_{\psi Y_inner} = (1-\alpha)\left(K_X r_X^2 + K_Z r_Z^2\right) \quad (3b)$$

The value of α is determined such that $K_{\psi Y}$ equals $K_{\psi Y_corner}+K_{\psi Y_inner}$, as indicated by Equation 4.

$$K_{\psi Y} = \frac{\alpha}{4}\left(K_X B^2 + K_Z L^2\right) + (1-\alpha)\left(K_X r_X^2 + K_Z r_Z^2\right) \quad (4)$$

The methodology was validated by back-calculating the lumped stiffnesses from distributed values and comparing them with the actual lumped stiffnesses. A close match was confirmed.

In the forthcoming response to RAI No. 65, Question 03.07.02-6, which will address issues regarding the Soil Structure Interaction (SSI) analysis of this structure, provide discussion of how embedment effects are determined, including justification for the use of Table C3.3.1 for the UHS MWIS, which has a rectangular foundation and is not embedded on all sides, and how the stiffness of the soil is calculated.

The response to RAI 65 Question 03.07.02-6[4] provides the equations and figures used to calculate the lumped foundation impedances, along with a discussion on the inclusion of embedment effects. However, a justification for the use of Table C3.3-1 of ASCE 4-98 is not provided in that response. Therefore, the justification is provided here.

It is acknowledged that Table C3.3-1 of ASCE 4-98 gives the embedment factors for circular footings. The text by Richart et al (Vibrations of Soils and Foundations, 1970, Prentice-Hall, Inc.) states that "the equations and diagrams for geometrical damping developed by vibrations of a rigid circular footing on the elastic half-space may also be used to provide estimates for the geometrical damping developed by footings with rectangular plan form". Table 3.3-3 of ASCE 4-98 uses a similar approach and provides the equivalent radii for calculation of lumped damping coefficients for rectangular basemats. This approximation is accurate for rectangular foundations that are approximately square. The basemat of UHS MWIS is 59'-0"×60'-0" in plan, and therefore, the equivalent circular representation for calculation of lumped foundation impedances provides reasonable accuracy.

As described in response to RAI 65 Question 03.07.02-6[4], the seismic analysis of UHS MWIS will be performed using SASSI. The analysis will meet the acceptance criteria 4.A.vii of SRP 3.7.1. The reconciliation of the seismic analysis results will be provided with the response to RAI 65 Question 03.07.02-6 per schedule provided in Enclosure 1. The relevant sections of FSAR will be updated accordingly.

COLA Impact

FSAR Sections 3.7.1 and 3.7.2 will be updated following the completion of SASSI analysis for UHS MWIS, and will be provided with the response to RAI 65 Question 03.07.02-6 per schedule provided in Enclosure 1.