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NUCLEAR ENERGY

10 CFR 50.4
10 CFR 52.79

March 25, 2010

UN#10-075

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. 216, Vibratory Ground Motion

Reference: Surinder Arora (NRC) to Robert Poche (UniStar Nuclear Energy), "FINAL RAI 216 RGS1 4336" email dated February 23, 2010

The purpose of this letter is to respond to the request for additional information (RAI) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated February 23, 2010 (Reference). This RAI addresses Vibratory Ground Motion as discussed in Section 2.5.2 of the Final Safety Analysis Report (FSAR), as submitted in Part 2 of the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 Combined License Application (COLA), Revision 6.

Enclosure 1 provides our responses to RAI 216, Questions 02.05.02-15 through 02.05.02-21. This response includes revised COLA content. Enclosure 2 provides the data files that support the response to Question 02.05.02-20.

Our responses do not include any new regulatory commitments. This letter does not contain any sensitive or proprietary information.

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NRD

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Wayne A. Massie at (410) 470-5503.

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

Executed on March 25, 2010

for Greg Gibson

Enclosures:

1) Response to NRC Request for Additional Information, RAI No. 216, Vibratory Ground Motion, Questions 02.05.02-15 through 02.05.02-21 Calvert Cliffs Nuclear Power Plant, Unit 3

2) Response to NRC Request for Additional Information, RAI No. 216, Vibratory Ground Motion, Question 02.05.02-20 Data Files Calvert Cliffs Nuclear Power Plant, Unit 3 (Compact Disc)

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
U.S. NRC Region I Office

GTG/RDS/mdf

Enclosure 1

Response to NRC Request for Additional Information,

RAI No. 216, Vibratory Ground Motion, Questions 02.05.02-15 through 02.05.02-21

Calvert Cliffs Nuclear Power Plant Unit 3

RAI No. 216

Question 02.05.02-15

The smooth 10^{-4} and 10^{-5} UHRS, provided in FSAR Table 2.5-23, are developed using controlling earthquake magnitude and distance values shown in FSAR Table 2.5-21 and the hard rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR-6728. Please specify which equation or combination of equations were used from NUREG/CR-6728.

Response

Equation (4-9) of NUREG/CR-6728 was used to develop smooth 10^{-4} and 10^{-5} high-frequency and low-frequency hard rock UHRS, weighting the single- and double-corner CEUS models equally.[1] The model coefficients are given in Table 4-3 of the NUREG. These spectra are shown in FSAR Figures 2.5-70 and 2.5-71 and were used to develop the amplification factors of FSAR Table 2.5-23.

COLA Impact

The COLA FSAR will not be revised as a result of this response.

[1] **NRC, 2001**. Technical Basis for Revision of Regulatory Guidance on Design Ground Motions, Hazard- and Risk-Consistent Ground Motion Spectra Guidelines, NUREG/CR-6728, U. S. Nuclear Regulatory Commission, 2001.

Question 02.05.02-16

According to FSAR Section 2.5.2.6, the horizontal GMRS (for each spectral frequency), is obtained by scaling the smooth rock 10^{-4} UHRS by the design factor specified in Regulatory Guide 1.208. RG 1.208 states that it is acceptable to use a value equal to 45 percent of the mean 10^{-5} UHRS if AR is greater than 4.2 (i.e. if the hazard curves are not approximated by a power law equation in the range of 1 E-04 to 1 E-05). Please indicate whether you used CAV (cumulative absolute velocity) filtering, which would result in an AR greater than 4.2.

Response

The CAV model was not used in the hazard calculations.

COLA Impact

The COLA FSAR will not be revised as a result of this response.

Question 02.05.02-17

FSAR Section 2.5.2-6 states that the GMRS was smoothed, particularly around 1.5 Hz. Please provide details regarding how this smoothing was performed.

Response

Smoothing was done for 0.4 Hz and between 1.25 Hz and 4 Hz by using a running average of the spectral amplitude at each frequency and the spectral amplitudes at each adjacent frequency, using the 38 frequencies at which spectral amplitudes were calculated (that is, the frequencies given in FSAR Table 2.5-22 or 2.5-23). Specifically, the final spectral amplitude for 0.4 Hz was the equally-weighted average of spectral amplitudes at 0.3 Hz, 0.4 Hz, and 0.5 Hz, the final spectral amplitude for 1.5 Hz was the equally-weighted average of spectral amplitudes at 1.25 Hz, 1.5 Hz, and 2 Hz, and similarly smoothed for the final spectral amplitudes of 1.25 Hz, 2 Hz, 3 Hz, and 4 Hz.

COLA Impact

The COLA FSAR will not be revised as a result of this response.

Question 02.05.02-18

FSAR Section 2.5.2.5.1.2 states that a value of 160 pcf (2592 kg/m^3) is used for the unit weight of the bedrock. However, FSAR Section 2.5.4.7.2 states that the rock unit weight estimated from the available literature is 162 pcf. Although the difference between these values is small, please clarify this inconsistency.

Response

The value for the unit weight of rock is given as 162 pcf in FSAR Section 2.5.4.7.3.2, "Shear Modulus Degradation Curves for Rock." In the absence of rock core samples for direct measurement of rock density at the CCNPP Unit 3 site this value was obtained from literature[2]. Based on results of testing 257 rock specimens from 27 localities across the U.S.[2], and statistical analysis of the data, an average unit weight of 162.3 pcf was reported for all the rock groups. For the purpose of analysis of site-specific amplification factors, an average rock unit weight of 162 pcf was considered reasonable for rocks beneath the CCNPP Unit 3 site and this value was used.

The value of 160 pcf given in FSAR Section 2.5.2.5.1.2, "Base Case Soil/Rock CCNPP Unit 3 and Uncertainties," was an approximation of this estimate.

COLA Impact

The eighth paragraph of FSAR Section 2.5.2.5.1.2, will be updated as follows in a future COLA revision:

> Unit weights for the soils beneath the site are in the range of about 115 to 120 pcf (pounds per cubic foot) (~~1765~~ <u>1842</u> kg/m^3 to ~~1929~~ <u>1922</u> kg/m^3). The bedrock unit weight was assigned a value of ~~160~~ <u>162</u> pcf (~~2592~~ <u>2595</u> kg/m^3) (Deere, 1966).

FSAR Section 2.5.2.8, will be updated to add the following reference in a future COLA revision:

> **Deere, 1966**. Engineering Classification and Index Properties of Intact Rock, University of Illinois, Prepared for Air Force Weapons Laboratory, Technical Report Number AFWL-TR-65-116, D. Deere and R. Miller, December 1966.

2 Deere, D.V. and Miller, R.P., (1966). Engineering Classification and Index Properties of Intact Rock," University of Illinois, Urbana, IL. Technical Report No. AFWL-TR-65-116, Prepared for Air Force Weapons Laboratory, Distributed by NTIS, December 1966.

Question 02.05.02-19

FSAR Section 2.5.2.5.1.2 states that site-specific RCTS-based shear modulus degradation and damping ratio curves were used for the final site amplification factor analysis for soils above a depth of 400 ft. However, FSAR Section 2.5.4.7.3.1 states that in the absence of actual data for the upper 400 ft of site soils, generic EPRI curves were adopted from EPRI TR-102293 (EPRI, 1993). Please clarify this discrepancy.

Response

UniStar Nuclear Energy substantially rewrote FSAR Sections 2.5.4 and 2.5.5 in October 2009. This update was submitted to the NRC in letter UN#09-427[3].

Updated FSAR Section 2.5.4.2.5.9 indicates that the shear modulus degradation and damping ratio curves used for the final Site amplification analysis are generic curves fitted to site-specific laboratory testing data.

The strain-dependent properties for the CCNPP Unit 3 project are developed by fitting generic curves to the site-specific data reported from Resonant Column Torsional Shear (RCTS) tests. EPRI curve selection for the upper 400 feet (ft) of the site soils was based on available soil characterization data from the site investigation.

A detailed description of the RCTS curve fitting process is provided in the report "Reconciliation of EPRI and RCTS Results, Calvert Cliffs Nuclear Power Plant Unit 3" and is included as COLA Part 11J.

COLA Impact

The third paragraph of FSAR Section 2.5.2.5.1.2, will be updated as follows in a future COLA revision:

> Initially, generic EPRI curves from EPRI TR-102293 (EPRI, 1993) were adopted to describe the strain dependencies of shear modulus and damping for all subsurface soils. The EPRI "sand" curves cover a depth range up to 1,000 ft (305 m). Since soils at the CCNPP Unit 3 site extend beyond 1,000 feet (305 m), similar curves were extrapolated from the EPRI curves, extending beyond 1000 ft (305 m), to obtain data for deeper soils. EPRI curves for the upper 400 ft (122 meters) of the site soils were based on available results from the site investigation <u>as described in Section 2.5.4.2.5.9</u>. Below 400 ft (122 m), a site-specific geologic profile was used as a basis for the soil profiles, including engineering judgment to arrive at the selected EPRI curves. The damping curves for soils were truncated at 15 percent for the initial site response analysis.

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3 G Gibson, (UniStar Nuclear Energy) to Document Control Desk (U.S. NRC), "Update to Calvert Cliffs Nuclear Power Plant, Unit 3 FSAR Sections 2.5.4 and 2.5.5," Letter UN#09-427, dated October 29, 2009

Question 02.05.02-20

FSAR Section 2.5.2.5.1.5 states that Random Vibration Technology (RVT) was used to calculate the site response. Please provide the model input parameters and modeling assumptions, so that the staff can verify the method and input and output parameters.

Response

The site response calculations for the site were performed using the Random Vibration Theory (RVT) approach. In many respects, the inputs and assumptions are the same for an RVT analysis and for a time history based analysis (that is, an analysis with the program SHAKE). Both the RVT and time-history (SHAKE) procedures assume a horizontally-layered half-space representation of the site and assume an equivalent-linear representation of dynamic response to vertically propagating shear waves. Starting from the same inputs (in the form of response spectra), both procedures will lead to similar estimates of site response[4]. The main advantage of the RVT approach is that it does not require the spectral matching of multiple time histories to a given rock response spectrum. Instead, the RVT approach uses a probabilistic representation of the ensemble of all input motions corresponding to that given response spectrum and then calculates the response spectrum of the ensemble of dynamic responses.

Site-response calculations were performed for three levels of bedrock motion (corresponding to mean annual frequencies of 1E-4, 1E-5, and 1E-6) and for high-frequency (HF) and low-frequency (LF) motions. Only the 1E-4 and 1E-5 high-frequency (HF) and low-frequency (LF) motions are used for Section 2.5.2. That is, four input motions were used for the development of the GMRS. For each of these input motions, site response was calculated for 60 site columns that were calculated as part of the site randomization step. Thus 240 analyses of site response were made for GMRS development.

The rock motion input to the RVT calculation is characterized by the rock spectrum, the strong-motion duration associated with that rock spectrum, and the equivalent-strain ratio to use in the equivalent-linear calculations (this input is required for both the time-history and RVT approaches). The duration is calculated from the controlling earthquake magnitude calculated from hazard deaggregation, using standard seismological relations between magnitude, seismic moment, corner frequency, and duration[4], and using stress-drop and crustal Vs values typical of the eastern United States. The effective strain ratio is calculated using the expression (M-1)/10[5]. Values of effective strain smaller than 0.5 or greater than 0.65 were brought into the 0.5-0.65 range, which is the range recommended by Kramer[6].

The four files labeled CALVERT_ROCK_INPUT*.INP, (where the asterisk stands for 1E-4_HF/LF or 1E-5_HF/LF) document the rock spectra (spectral accelerations in g, given for thirty-eight frequencies ranging from 0.10 Hz to 100 Hz), strong motion durations (sec), and effective strain ratios (dimensionless).

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4 Rathje, E.M., and M.C. Ozbey (2006). Site-Specific Validation of Random Vibration Theory-Based Seismic Site Response Analysis. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 132, No. 7, July.

5 Idriss, I. M., and Sun, J. I. (1992). SHAKE91: A computer program for conducting equivalent linear seismic response analyses of horizontally layered soil deposits, Dept. of Civil and Environmental Engineering, Center for Geotechnical Modeling, Univ. of California, Davis, Calif.

6 Kramer, Steven L. (1996). Geotechnical earthquake engineering. Prentice-Hall.

The sixty files labeled Calvert_randomization_GMRS_0001.opt1_2 through Calvert_randomization_GMRS_0060.opt1_2, contain stiffness curves (decimal values of G/Gmax) and damping curves (in percent) as a function of strain (percent), following the format of Option 1 of SHAKE91[5], and the soil type (with reference to the Option 1 input), thickness (in feet), initial estimate of damping (decimal), total unit weight (kips per cubic foot), and initial shear wave velocity (Vs in feet/sec) for each of the 166 layers within each randomized soil column following the format of Option 2 of SHAKE91.

FSAR Figures 2.5-78 through 2.5-85 were developed using these site soil columns and input parameters.

The sixty-four data files discussed above are contained in Enclosure 2.

COLA Impact

The COLA FSAR will not be revised as a result of this response.

Question 02.05.02-21

FSAR Section 2.5.2.5.1.5 states that two profiles were evaluated for site response: 1) the entire soil column, including 41 ft (12.5 m) of fill above the foundation of the nuclear island, and 2) a soil column that did not contain any soil above the base of the nuclear island foundation for the calculation of the GMRS. FSAR Section 2.5.2.5.1.5 further states that for the profile including fill, the shear-wave velocity for the fill material was assumed to be those of the subsurface strata I and IIa and the shear modulus degradation and damping curves were assumed to be those of subsurface strata I material. Please justify the use of these material properties for the fill.

Response

The text referenced in Question 02.05.02-21 is found in FSAR Section 2.5.2.5.1.2, and refers to a characterization of the site subsurface material properties originally developed for the project. This initial characterization was used both to develop the site-specific Ground Motion Response Spectra (GMRS) and to develop surface Foundation Input Response Spectra (FIRS) suitable for Emergency Power Generating Buildings (EPGB) and Essential Service Water Buildings (ESWB) located in the Nuclear Island (NI) area, considering a soil column consisting of assumed backfill properties for the top 40 feet. The basis for the assumed properties was that the backfill would be a granular material (like the Terrace Sand of the CCNPP Unit 3 site) with representative shear wave velocities.

Following submittal of COLA Revision 6, additional characterizations of the subsurface and backfill have been made and additional analysis of the site-specific amplification factors for ground motions affecting the EPGB, ESWB, and other Category I structures have been performed. The results of this additional characterization of the subsurface were provided to the NRC in the rewrite of FSAR Section 2.5.4[7]. The site-specific FIRS at all elevations of interest resulting from the amplification by the subsurface material have been analyzed and are currently incorporated into a revision of COLA FSAR Section 3.7.1[8].

COLA Impact

The last paragraph of FSAR Section 2.5.2.5.1.2 will be updated as follows in a future COLA revision:

Subsequent dynamic laboratory RCTS test results were used to obtain site-specific data on shear modulus and damping characteristics of in situ soils in the upper 400 ft (122 m) and of the backfill material as detailed in Section 2.5.4. ~~A total of 13 undisturbed soil samples, from depths of about 15 ft (4.6 m) to about 400 ft (122 m) below the existing ground surface, were assigned for RCTS testing.~~ The site-specific RCTS-based shear modulus degradation and damping ratio curves were used for ~~the~~ all final site amplification factor analysis. A subsurface soil profile~~Two profiles were evaluated: 1) the entire soil column, including 41 ft (12.5 m) of fill above the foundation of the nuclear island, and 2) a soil column~~ extending only to ~~that did not contain any soil above~~ the base of the nuclear island foundation, and including no backfill, was used for the

7 UNE letter UN#09-427, Letter Subject: "Update to Calvert Cliffs Nuclear Power Plant, Unit 3 FSAR Sections 2.5.4 and 2.5.5," October 9, 2009.

8 UNE letter UN#09-519, Letter Subject: "Update to Calvert Cliffs Nuclear Power Plant, Unit 3 FSAR Section 3.7 and response to FSAR Section 3.7 RAI sets 19, 25, 58, 63, 65, 112, 113, 139, 158, 159, 167, 168, 179, 180, 181, and 193," December 29, 2009.

calculation of the GMRS. For development of FIRS in Section 3.7.1, the soil profile appropriate for any given structure was developed from the material properties described and discussed in Section 2.5.4. For the profile including fill, the shear wave for the fill material was assumed to be those of the subsurface strata I and IIa and the shear modulus degradation and damping curves were assumed to be those of subsurface strata I material.

Enclosure 2

Response to NRC Request for Additional Information,

RAI No. 216, Vibratory Ground Motion, Question 02.05.02-20 Data Files

Calvert Cliffs Nuclear Power Plant Unit 3

(Compact Disc)