November17, 2006

MEMORANDUM TO: Scott A. Morris, Acting Deputy Director
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Division of Fuel, Engineering and Radiological Research
Office of Nuclear Regulatory Research

THRU: Anthony H. Hsia, Branch Chief **/RA/**
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SUBJECT: SUMMARY OF OCTOBER 24-25, 2006, CATEGORY 2 PUBLIC MEETING WITH NUCLEAR ENERGY INSTITUTE (NEI) TO DISCUSS SEISMIC ISSUES RELATED TO FUTURE REACTOR SITING

On October 24-25, 2006, a public meeting was held between the U.S. Nuclear Regulatory Commission (NRC) and Nuclear Energy Institute (NEI) at the ARES facility in Santa Ana, California. The purpose of this meeting was to discuss (1) an NEI recommended incoherency transfer function (ITF) that reduces high frequency ground motions by accounting for spatial seismic wave incoherency that occurs as a result of natural scattering and wave passage effects in the geologic foundation material (2) results on soil-structure-interaction (SSI) analyses using versions of the SASSI and CLASSI software that incorporate the proposed ITF in the analyses and (3) a proposed method for development of simplified response spectra-based incoherency relationship if time permits. A list of meeting attendees is included as Enclosure 1. The meeting agenda is provided as Enclosure 2. The power point presentation provided by Dr. Norm Abrahamson addressing topic (1) above is provided as Enclosure 3. The power point presentation provided by EPRI discussing topics (2) and (3) above is provided as Enclosure 4.

Andy Murphy (NRC) opened the meeting by welcoming all and discussing the scope of the agenda for the two days (Enclosure 2). It was noted that the NRC desire was to have RAIs on the task S2.1 A and B reports addressed as part of the presentation materials and the discussions. NEI representatives noted that resolution of the issues to be discussed is very important for utilities to file their COLs and that, in their view, the time-line for making plant siting decisions is getting critically short.

After introductions, it was agreed that the specific objectives of the meeting were: 1) to resolve RAIs and reach agreement on specific steps to be taken to gain acceptance of the proposed ITF; 2) to close out existing RAIs and to review new modeling efforts in versions of the SSI programs SASSI and CLASSI software that incorporate the proposed ITF. It was agreed that the potential for a simplified method for applying incoherency would be discussed if time permitted.

The meeting discussions focused on the following documents:

Electric Power Research Institute, and U.S. Department of Energy, "Program on Technology Innovation: Spatial Coherency Models for Soil-Structure Interaction," Draft Report 1014101, 2006.

Electric Power Research Institute, and U.S. Department of Energy, "Effect of Seismic Wave Incoherence on Foundation and Building Response," Draft Report 1013504, October 2006.

Summary of the Meeting

Topic 1: The Proposed Incoherency Transfer Function

Dr. Norm Abrahamson presented (Enclosure 3) information on the responses to the RAIs on EPRI Draft Report 1014101. He noted that the latest report sent to the NRC should be published by EPRI soon. The discussions were only in reference to EPRI report 1014101 and were limited to discussions of the model itself and any questions related to implementation in soil-structure-interaction (SSI) analyses will be presented in Topic 2.

Key discussion points were as follows:

- There are two physical mechanisms that lead to incoherency of waves. These are wave passage effects and natural scattering. The wave passage effects result from the wave fronts reaching different locations at different times. Natural scattering results from heterogeneity of the rock or soil impacting the waves as they travel through the medium. Because wave passage effects are more problematic in terms of determining the appropriate apparent wave velocity, and produce a relatively small effect related to natural scattering, they are not incorporated into the incoherency transfer function (ITF). The proposed ITF only incorporates natural scattering effects.

- Dr. Abrahamson expressed that data from the array at Pinyon Flat, a rock site, could be incorporated into the ITF analysis, which would significantly increase the amount of data from rock sites. He noted that the data would need to be corrected in some cases because some of the recording equipment showed a reversal of polarity between adjacent recordings on the array. It was noted that while analysis of the array data is ongoing, additional time is required because corrections to the array equipment with reversed polarity did not occur at the same time. Thus corrections to the data must be made on an event by event basis. It was agreed that NRC participants would accept the corrected data if the correction consisted only of a reversal of direction in cases where recordings from adjacent recording in the array indicate the problem.

- In the report and during the meeting, it was expressed that the type of material underlying a specific site of interest does not impact the resulting ITF in a statistically significant way when compared to the scatter between events at a single array; and for this reason a single ITF was used for both soil and rock sites. There was concern on the part of reviewers that this was inconsistent with past research in which shear wave velocity (Vs) was shown to be an important parameter. In response, it was noted that previous studies was focused on wave passage effects that would naturally be impacted by Vs and that this effect was found to be minimal compared to natural scattering. It was

decided that the Pinyon Flat database would be analyzed and the resulting complete database would be separated into at least 3 Vs groups for comparison purposes. If an increase in coherency is found for rock sites versus soil, either two ITFs can be developed or a single ITF could be developed that would be conservative for soil sites.

- In order to address the issue of embedded foundations. The residual (difference) between the incoherency predicted by the ITF and the data recorded at arrays with seismographs located at depth below the surface was determined. This comparison indicated that the proposed ITF may be unconservative at some depths of interest (10-20 m). It was decided that some correction to the ITF (of approximately 0.1 at depth) will be incorporated. This correction may either result in a single ITF that would be fit to data at depth, and as a result would be conservative at the surface. Alternately, a second ITF for foundations at depth may be developed.

- It was noted that in some plots provided it appears that the coherency drops with the peak spectral density. A focused study of the data will be undertaken to look at this issue. If this is systematically the case, it would indicate the existence of a fundamental scattering mechanism not yet identified and would have significant impact on the ability of ITFs to reduce seismic design levels in the high frequency range.

- The mean values are preferred for this work, though the median values are developed. The median values are slightly higher than the mean, so though the analyses are based on median values, they are close enough to the mean to be useful for the basis of the mean probability of failure or other performance criteria.

- Analysis results were presented for single sites under different magnitude events. These results showed no discernable trends. A similar lack of discernable trend occurred when results were separated by distance to the source.

- In general, it can be noted that many of the outstanding Requests for Additional Information (RAIs) were adequately addressed in the meeting and the task list below is a full accounting for the outstanding issues related to NRC acceptance of an incoherency function.

At the end of the discussion, the following tasks for Dr. Norm Abrahamson were agreed upon as a way forward to close the ITF issue:

- Data from Pinyon Flat site will be corrected, analyzed and incorporated into the ITF. The full database will then be separated into at least three Vs bins and compared to determine if a statistically significant difference exists within the current dataset.

- Because the proposed ITF is slightly unconservative for embedded foundations, an adjustment will be made. This correction will likely result in a single ITF that would be fit to data at depth, and as a result would be conservative at the surface; Alternately, a second ITF for foundations at depth may be developed.

- The data for individual events will be analyzed to determine if a correlation with peak Fourier amplitude spectrum exists.

- Provide an additional plot examining magnitude dependence at a higher frequency range

- Separate data from the two EPRI events and look at higher frequency motions for one event with better signal.

- Either provide copies of referenced reports or incorporate referenced information from unavailable reports into new reports

- Provide the data set digitally including: recorded time series, response spectra, coherencies, residuals, magnitude distance, array information

New information will be provided as a separate document from Dr. Norm Abrahamson and will be incorporated into the final report at a later time. In the short term, the new document will likely be characterized as an appendix to the EPRI report 1014101 not a revision of it. This information is to be forwarded by Dr. Norm Abrahamson by close of business November 27. A new meeting on this topic was tentatively set for December 20 and 21 in the San Francisco Bay area to close out the topic of ITF if possible and to have further discussions on the SSI implementation.

Topic 2: Implementation of an Incoherency Transfer Function in Soil-Structure-Interaction Software SASSI and CLASSI

In this portion of the meeting, Greg Hardy first provided an introduction to the ARES presentation which addressed the structural response RAIs (Enclosure 4). Next, Steve Short and Jim Johnson provided a team presentation of the technical details of the EPRI Report 1013504.

Key discussion points were as follows:

- The engineering sub-tasks of the S2.1 task were identified and agreed upon. These included defining the cases to be analyzed, developing the ground motion input, deriving the approach to include coherency function, conducting parametric studies, bench marking the computed incoherency, conducting SSI analyses, investigating a simplified approach, and providing documentation of the work.

- Generally, the technical approach is similar to that used in the 1980's with the exception of the incoherency function. The discussion of SSI centered on the analyses done by CLASSI and SASSI. The industry believes that obtaining the same results from these codes indicate that a simplified approach is viable using only these codes. The NRC feels that the codes are very similar and should, necessarily, produce very similar results. The NRC would have like to see comparisons from two codes based on different theoretical assumptions (e.g time-domain FE modeling versus frequency-domain modeling).

- The impact on response spectrum specifically for rock sites was discussed. The spectra used are typical as those for the COL applicants for rock sites; thus, any rock site with any significant seismicity will have the issues identified in these example spectra. The larger the peak of the motion the higher the reduction provided by incoherency.

- It was determined that both the incoherency and the SSI effects had significant impact on the high frequency motion for rock sites. There were some questions as to how much of the effect was due to incoherency versus SSI effects. There were also some related questions regarding the massless foundation used to assess incoherency effects. It was decided to provide the results in terms of Fourier spectra (instead of response spectra) and that the SSI versus incoherency effects would be separated as appropriate. ARES also agreed to provide additional information regarding the structural model for review purposes. The main frequencies, mode shapes, eigenvectors, and participation factors would be beneficial in understanding the structural responses presented throughout the report.

- There was general agreement that appropriate space for any simplified method is in the Fourier spectrum, not in the response spectrum. Earlier work in ASCE 4 was based on wave passage and the single RG1.60 spectrum. If the input spectrum changes (for example such as rock versus soil) the overall impact to soil is lower than to rock.

- There was consensus that if the coherency function changes to address the unconservatism at depths of 10 to 20 m, that the coherency would be changed at all elevations. This will introduce a conservatism at the surface but is probably the best option because (1) the data may not be sufficient to differentiate the coherency with depth and (2) generally the use of a single relationship for both depth and the surface is preferred. Some discussion will occur before the decision is finalized. The NEI/EPRI team will review in the near term and make a recommendation.

- The studies within Chapter 5 of the report have been done with three independent time histories simultaneously. Some early site permit (ESP) submittals have been required to re-analyze the results after changing the phasing on one horizontal direction to understand the difference that results. However, it is also possible to perform the analysis of each direction independently and use square-root-sum-of-the-squares (SRSS) to combine the results. The NRC will consider this issue which was noted to be a more general question which exists for any response analysis (with or without the incoherence effects).

- It was noted that there is less help from incoherence at the periphery due to the increased rocking and overturning. Thus sensitive equipment at the periphery should be analyzed using the higher response spectrums generated at their location. Location specific floor spectra need to be considered. Also base shear, shear wall analysis, etc, should be considered in light of the latest analysis methods.

- The current work focused on direct integration methods and used a more realistic structural model with eccentric and coupled masses. Locations on the edge of the foundation at height to measure rocking and torsion were also added. The new model shows rotation due to horizontal motion in addition to motions due to coherency. The changes were considered by the NRC to be a significant improvement over previous analyses provided. There was general consensus that, in the near future, direct integration methods are the preferred method of incorporating incoherency effects.

- There is a difference between the "direct" integration method and the original simplified methods proposed in which the ITFs were implemented in the input motions. While a

reduction of the input motions may be a basis for future simplified methods, (empirically-based) changes will need to be made. To that end there was discussion of development of a simplified approach based on the results provided. It was agreed that a simplified approach may be possible in the long term, but that it would require the analysis of a large number of case histories due to the empirical nature of the relationship and the complexities imposed by torsion and rocking. The adjustment to the simplified method (the simplified "updated" method) increases the low frequency motions to account for torsion and overturning. There was not general consensus that fixing a horizontal response spectra to account for vertical motions is the right way to go.

- Dr. Veletsos offered that the "approximate deterministic" approach he had helped develop in the past was valid for the evaluation of incoherence. Dr. Johnson noted that this same approach was used in CLASSI and has been described as one method of incorporating the "direct" approach. Based on this understanding, Dr. Veletsos stated that he is comfortable with this methodology. It was noted that this original paper by Dr. Veletsos should be referenced in the EPRI report.

- Relative to the embedment study in Appendix E, Dr. Zerva noted that since the process is a linear one between the surface and the embedded cases, it is not appropriate to make conclusions on the separation between the embedment effects and the incoherency effects. Dr. Johnson noted that there is a difference in the incoherency based on the inclusion of the vertical cylinder of nodes for the embedded case. The transfer functions (Page E 14 and E 15 of the EPRI Report 1013504) are not the same and that is demonstrated by the figures in the report.

At the end of the discussion, the following tasks were outlined:

- The ERPI Project team will review the implications of a change in the coherency function to address the low values at depths between 10 and 20 m (see Topic 1 task list). EPRI will develop a recommendation on how to address a potential variation in the coherency function with depth. Assuming that a change to the coherency function with depth is determined, new foundation and structure responses will be analyzed to demonstrate the effects of the changes as appropriate.

- Greg Hardy will arrange a conference call between Dr. Abrahamson and interested parties to discuss the following questions: If the basic site seismic hazard is defined from recorded ground motions using the entire strong motion window, why does the coherency evaluation consider only the plane S-wave contribution? Does the wave passage effect in the SSI calculation induce response in excess to that caused by the consideration of the plane wave coherency only? Does the wave passage effect in the SSI calculation induce response in excess to that caused by the consideration of the plane wave coherency only?

- Changes to the report will be made by ARES:
  a. To address a number of typos that were identified
  b. Wording will also be changed to state that the coherency function “was assumed to be independent of depth” not “was independent of depth”.
  c. Reference will be made to Dr. Veletsos earlier study on incoherency that

describes the "approximate deterministic" approach and a descriptive comparison of the Ares and Veletsos approaches will be made.

d. Chapter 4 will be amended to address the translation and rotation combination.

e. The use of random vibration theory in addition to SRSS to determine the combination of translation and rotation for edge translations will be considered (ARES) and changes to figures may be incorporated.

- Dr. Costantino will schedule a discussion with Bechtel on SASSI details relative to the input motion power spectral density (PSD) preservation and on load vectors.

- ARES will provide additional information on the main structural model results (frequencies, mode shapes, eigenfunctions and participation factors up to about 30 Hz) in order for the NRC consultants to fully understand the responses.

- ARES to discuss with EPRI a path generating documentation and a version of CLASSI (can be kept proprietary) with incoherency to the NRC for specific use in reviews on this project.

- Discuss and resolve the issue of whether both versions of SASSI and CLASSI get the increase in the low frequency region due to the rotations. A meeting was recommended between Bechtel and ARES needs to address this issue and come up with a resolution. There should be a problem that is done consistently with all codes. The resolution will be communicated to the NRC.

- Discuss/implement ways for industry to participate in an effort to generate an NRC/Industry consensus on elements of the seismic qualification process that have not been finalized, e.g.:
  a. Convolution for deep soil sites
  b. Site profile properties uncertainty usage for SSI analyses
  c. Minimum seismic design levels

- Plots of the free field ground motion, SSI coherent and SSI incoherent Fourier Spectra for figures such as 5-80 and 5-81 of the EPRI Report 1013504 to help demonstrate the effects of SSI (coherent or incoherent) on the seismic response of foundations and structures. This task was in response to several questions posed by an NRC consultant on separating the results of the incoherency responses.

- Dr. Veletsos indicated he would be sending written comments and requests on this EPRI report #1013504 to NRC; however, Andy Murphy stated that these comments could be treated as Staff comments and not RAIs.

- If EPRI has an SSI course (including how SASSI works), the NRC staff should be notified.

After asking for public comments or questions, the meeting was adjourned.

Enclosures:
1. List of Attendees
2. Agenda
3. Dr. Abrahamson's Presentation Materials on the ITF
4. ARES's Presentation Materials on the SSI analysis results

After asking for public comments or questions, the meeting was adjourned.

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Memo: ML063210313, Enclosure 1: ML063210300, Enclosure , ML063210421

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Santa Ana, California
Tuesday, October 24,2006

AGENDA

8:30 am	Introductions and Opening Remarks	NRC and EPRI
9:00 am	Discussions of Report S2.1 (a) - “Effect of Seismic Wave Incoherence on Foundation and Building Response	NRC and EPRI
10:30 am	Break	
10:45 am	Discussions of Report S2.1 (b) - “Spatial Coherency Models for Soil-Structure Interaction” and RAI responses	EPRI
12:00 pm	Lunch	
1:00 pm	NRC Staff Comments/Identification of Issues	NRC
2:00 pm	Break	
2:15 pm	Open Discussion and NEI/Industry Responses and Plans to Address NRC Comments	All
5:00 pm	Adjourn	

Santa Ana, California
Wednesday, October 25,2006

AGENDA

8:30 am	Summary of Tuesday Meeting	NRC and EPRI
9:00 am	Continued Discussions of S2.1 (a) and RAI Responses	EPRI
10:30 am	Break	
10:45 am	NRC Staff Comments/Identification of Issues	NRC
12:00 pm	Lunch	
1:00 pm	Continuation of NRC Comments, Open Discussion and NEI/Industry Responses and Plans to Address NRC Comments	NRC and EPRI
2:30 pm	Break	
2:45 pm	Summary of Meeting Action Items	NRC and NEI
4:00 pm	Adjourn	