January 23, 2007

MEMORANDUM TO: Rick Croteau, Deputy Director
Engineering Research Applications
Division of Fuel, Engineering & Radiological Research
Office of Nuclear Regulatory Research

THRU: Anthony H. Hsia, Branch Chief **/RA/ H. Graves for**
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SUBJECT: SUMMARY OF DECEMBER 20-21, 2006, CATEGORY 2 PUBLIC MEETING WITH NUCLEAR ENERGY INSTITUTE (NEI) TO DISCUSS SEISMIC ISSUES RELATED TO FUTURE REACTOR SITING

On December 20-21, 2006, a public meeting was held between the U.S. Nuclear Regulatory Commission (NRC) and Nuclear Energy Institute (NEI) at the EPRI Facility in Palo Alto, 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 spacial seismic wave incoherency that occurs as a result of natural scattering and wave passage effects in the surface of foundation material and (2) an NEI report and results on soil-structure-interaction (SSI) analyses using versions of the SASSI and CLASSI software that incorporate the proposed ITF in the analyses.

Below is a summary of the key outcomes from the meeting. These include two statements of common understanding and a list of action items. A more complete description of the discussions that occurred during the meeting related to technical issues and open action item is provided as Appendix A. A list of meeting attendees is included as Enclosure 1. Enclosure 2 is the meeting agenda. The presentation provided by Dr. Norman Abrahamson addressing topic (1) above is provided as Enclosure 3. The power point presentation provided by EPRI discussing topic (2) above is provided as Enclosure 4.

<u>The Proposed Incoherency Transfer Function</u>

Significant discussion related to the NEI recommended incoherency transfer function (ITF) occurred during this meeting. As a result of these discussions, a statement of common understanding was developed by NEI and the NRC staff and consultants. This statement of common understanding represents significant progress on this issue and is provided in its complete form below:

Common understanding:

During the 10-25-06/10-25-06 and 12-20-2006 NRC public meetings, the original coherency model proposed by NEI was discussed and evaluated. Whereas the

model appears to adequately represent the effect of coherency at soil sites, additional analyses on the Pinyon Flat rock data revealed that the previously proposed coherency model underestimated the coherency in the Pinyon Flat data set. Industry proposed to use a single coherency model to cover rock effects, soil effects, and embedment effects. The NRC finds the use of a single model acceptable provided that it is brought into line with the higher coherency observed at the Pinyon Flat rock site and at soil sites with embedment effects. The model needs to be revised so that the residual for rock sites in the high frequency range pertinent to rock sites is decreased. Based on the results presented to date and the assumptions made in the evaluation, the average residual values were found to vary between approximately 0.1 and 0.3 in the frequency range of 10 to 35 Hz.

- The industry believes that modifying the existing model to increase the coherency so that the calculated residual value is reduced by 0.1 averaged over the frequency range of 10 to 30 Hz is conservative for the horizontal plane-wave coherency model for all sites and all embedment depths. Based on the available data set and proposed hypothesis, the NRC is not convinced that this is necessarily a conservative estimate.

- Both the industry and the NRC understand the urgency of a timely decision regarding the use of the plane-wave coherency model. Therefore, the industry and the NRC are willing to accept a coherency model that leads to a reduction of 0.2 in the value of the residual averaged over the frequency range of 10 to 35 Hz. This position will hold until justification for a coherency model leading to lower values in this frequency range can be provided by further analysis of available data.

- The same approach will be followed for vertical ground motion.

- The industry expects to complete a report on the coherency function based on these assumptions by February 19, 2007.

Implementation in Soil-Structure Interaction Analyses

Significant discussion also occurred on the issue of implementation of the Incoherency Transfer Function in Soil-Structure Interaction (SSI) analyses. A common understanding as to the current status of the SSI modeling issues was jointly articulated as detailed below:

- The industry believes that CLASSI has been validated; therefore it can be used for validating SASSI.

- The industry believes that SASSI has been validated to provide the proper translational transfer functions; however, the validation of incoherence-induced torsional and rocking transfer functions is in progress. The basis of validation is the results of CLASSI.

- The industry will develop user guidance for SASSI users to ensure proper use of the code for incoherence.

- Each individual user of SASSI will need to be validated against CLASSI.

For clarity, it should be noted that this statement of common understanding relates to only industry's views of the status of ongoing SSI analyses and does not indicate any NRC views on the acceptance of ongoing SSI analyses. The statement indicates that NRC staff understand industry's stated views, and understand that industry will move forward based on these stated views. This is in contrast to the statement of common understanding related to the ITF, which details specific changes to the ITF that would make an updated form of the ITF acceptable to the NRC staff present at the meeting.

Action Items for Industry

A review at the end of day 2 of the meeting produced the following list of action items

1. Development of the coherency model to address the 0.2 residual for 10-35 Hz as detailed in the common understanding.

2. Presentation of new residuals for all cases (soft soil, soft rock, hard rock, and embedment).

3. Extension of the coherency function to the vertical direction.

4. Investigation of appropriate values for the alignment time lag (using alignment on the P and S wave arrival times).

5. Development of revised coherency model for horizontal and vertical as needed based on item 4.

6. Target date for new report of February 19th (items 1 and 2 are essential).

7. Provide 1) acceleration, velocity, and displacement time histories, 2) cross correlation between the acceleration, velocity and displacement, 3) the phase differences, and 4) the differences between the accelerations, velocities and displacements for two close together and two far apart points.

8. Complete validation of SASSI considering incoherency effects.

9. Use new incoherency model in SSI analyses to determine its effects on the structural responses, including the effects of both translational and rotational foundation motions.

10. Develop user guidelines for use of SASSI with incoherency to be published as part of an upcoming report.

APPENDIX A: SUMMARY OF THE MEETING

Introduction

Robert Kassawara (EPRI) first welcomed everyone to the EPRI offices and presented logistics. Andrew Murphy (NRC) then officially opened the meeting by welcoming all and discussing the scope of the agenda for the two days (Enclosure 2). It was noted by both parties that this is a working meeting and members of the public were invited to actively participate and not wait for a specific public comment period. It was agreed that the specific objectives of the meeting were: 1) to resolve open issues and reach agreement on specific steps to be taken to gain acceptance of the proposed ITF; 2) to close out existing issues and to review new modeling efforts in versions of the SSI programs SASSI and CLASSI software that incorporate the proposed ITF.

Objective 1: The Proposed Incoherency Transfer Function

Dr. Norm Abrahamson presented additional research results to address issues identified at the public meeting of October 23-24. As agreed upon, this information was provided as a separate appendix to the EPRI report 1014101 and will ultimately be incorporated into the final report. The appendix (Enclosure 3) contains information and results related to each of the tasks listed below in order.

To start the meeting, the open tasks from the October 23-24 meeting related to the incoherency transfer function (ITF) were reviewed. These were listed on page 1 of Enclosure 3 and are as follows:

1 Correct the timing/polarity of the Pinyon Flat data and use the data to check the plane-wave coherency model for a hard rock site.

2 Develop a revised coherency model for the coherency for embedded structures.

3 Evaluate the correlation of the Fourier amplitude spectrum (FAS) and the coherency.

4 Check the magnitude and site hardness dependence at higher frequencies.

5 Separate the EPRI Parkfield events and use the one with the better signal to noise ratio at high frequencies (>20Hz).

6 Provide the EPRI proprietary coherency model report referenced in EPRI report 1014101.

7 Provide the digital data base used to develop the coherency model.

Key discussion points on the above action items were as follows:

- It was noted that item 6, above, was closed out prior to the public meeting (NRC received the report) and the development of the data set (task 7) was still continuing.

- Task 2 was undertaken and the results were presented in Section 2 of Enclosure 3. A comparison between the surface and embedded models was provided as Figure 2.2. This model was as requested in the October public meeting. The embedded model was subsequently also discussed as compared to the new Pinyon Flat hard rock data.

- Task 3 was undertaken and the results were presented in Section 3 of Enclosure 3. This task originally resulted from analysis of a specific piece of data that suggested that high frequency coherency may be higher when there is more high frequency energy. After reviewing the results of analyses of the entire data set as presented in Enclosure 3, it was determined by the NRC staff and NRC consultants that there is not a correlation between the peak of the FAS and coherency because the residuals were not correlated with the normalized FAS.

- The results of Task 4 were presented as figures in Section 4 of Enclosure 3. While on the plot there does appear to be a dip in coherency at intermediate values of magnitude followed by an increase again at high magnitudes, Dr. Abrahamson noted that the trend was not statistically significant. In addition, none of the participants could offer a physical basis for a dip of this sort.. Dr. Veletsos asked if there is general agreement that it is acceptable to use very small motions to look at the impact at large earthquakes. Dr. Abrahamson noted that because (at close distances) bigger earthquakes deviate from the point source assumption and the coherency should theoretically come down as the waves are more likely to hit the site simultaneously from multiple directions. However, he noted that it is unclear the degree to which the coherency would come down because such data doesn't exist. He further noted that work for Diablo Canyon showed that increasing magnitude theoretically reduces the coherency significantly, but the faults need to be close to the receptor. There was not consensus among meeting participants as to whether the change would likely be significant. However, there was general acknowledgment that there was no clear physical basis for coherency increasing as magnitude increased. The meeting participants agree to close this item.

- The results of Task 5 were presented as figures in Section 5 of enclosure 3. A discussion of methods for determining signal to noise ratios ensued. Dr. Abrahamson explained his analysis techniques (using figures in Enclosure 3 as examples) and indicated that he used only recordings with acceptable signal to noise ratios in his coherency analyses. After discussion, it was determined by NRC staff and NRC consultants that this task could be closed.

- Review of the results of Task 1 constituted the bulk of the discussion. The results of this work is presented in Section 1 of Enclosure 3.

    - Dr. Abrahamson noted that there seemed to be timing issues of up to 0.2 seconds that lead to unusually low values of coherency. It was not clear as to why this was the case, but it may result from instrument installation problems. As a result it was necessary to align the data based on the signal; The P-wave signal was chosen for this purpose as it provides the least uncertainty in the start of the signal. Dr. Zerva questioned the impact of using the S-wave signal instead of the p-wave. It was determined that this would be an open issue.

- Because recordings were aligned on the P-wave for the Pinyon Flat database, they may over-predict coherency. To assess the magnitude of the potential bias, additional analyses using a delay time of 0.005 seconds based on equipment spacing and a typical P-wave velocity of 5km/sec was assumed. After discussion, NRC staff and their consultants concluded that because an assumed delay time would reduce the level of coherency calculated, the choice of delay time needs to be justified before the ITF is adjusted to take advantage of this reduction.
- At the request of Dr. Veletsos, Dr. Abrahamson explained the justification for removing some records from the database. The removed data accounted for approximately 1 to 2% of the overall database. Dr. Abrahamson also noted that he was able to add some new data that was recovered from out-of-date electronic media.
- When reviewing the Pinyon Flat data, there did appear to be a difference between hard rock and other materials in the level of incoherency at the surface. This was manifest as an under-prediction of coherency by the original surface model at shortest station spacing in the range of 10 to 40 Hz. The residual (difference between the actual data and the data predicted by the ITF) ranged from approximately 0.1 to 0.2, depending on the assumption of time delay (noted above). This change in incoherency appears to be similar in nature (and possibly amplitude) to that calculated at depth for other site conditions (site materials).

• In the discussion of Task 1, it was acknowledged that both the Pinyon Flat hard rock data and data recorded at standard embedment depths showed a higher level of coherency than the existing soil and soft rock surface incoherency model predicts. Given the divergence of hard rock results from previous analyses, the value of using one incoherency function versus several was discussed. It was agreed that use of a single coherency function targeted to the hard rock data was preferable for a number of reasons including: (1) hard rock sites are of principal interest, (2) there is no data at depth for hard rock, (3) it is difficult to have separate relationships for surface and embedded structures, (4) because there is only one hard rock site, the shear wave velocity at which the wave scattering behavior changes is unknown. Based on the available data, the use of a relationship based on hard rock sites will be conservative for other types of sites.

<u>The Proposed General Resolution to Objective 1</u>

Industry (NEI) proposed to develop a single ITF for all sites based on the Pinyon Flat hard rock data. This ITF would be based on conservative assumptions for open issues, provided that ITF could be revisited in the future as additional analyses or data became available. Ensuing discussion on this proposal between the NRC and industry focused on a model based on the Pinyon Flat hard rock data using the conservative assumption of infinite P-wave velocity (delay time=0 seconds). Based on the analyses provided by Dr. Abrahamson in Figure 1-19 in attachment 3 (in which the assumption of infinite velocity is used), discussion focused on changes that would lead to an increase from the existing model such that the residual values would be reduced by 0.2 on average over the frequency range of 10 to 35 Hz as suggested by the NRC consultants.

Based on the discussions detailed above, the following statement of common understanding was developed by industry and NRC representatives.

"**Common understanding:**

During the 10-25-06/10-25-06 and 12-20-2006 NRC public meetings, the original coherency model proposed by NEI was discussed and evaluated. Whereas the model appears to adequately represent the effect of coherency at soil sites, additional analyses on the Pinyon Flat rock data revealed that the previously proposed coherency model underestimated the coherency in the Pinyon Flat data set. Industry proposed to use a single coherency model to cover rock effects, soil effects, and embedment effects. The NRC finds the use of a single model acceptable provided that it is brought into line with the higher coherency observed at the Pinyon Flat rock site and at soil sites with embedment effects. The model needs to be revised so that the residual for rock sites in the high frequency range pertinent to rock sites is decreased. Based on the results presented to date and the assumptions made in the evaluation, the average residual values were found to vary between approximately 0.1 and 0.3 in the frequency range of 10 to 35 Hz.

- The industry believes that modifying the existing model to increase the coherency so that the calculated residual value is reduced by 0.1 averaged over the frequency range of 10 to 30 Hz is conservative for the horizontal plane-wave coherency model for all sites and all embedment depths. Based on the available data set and proposed hypothesis, the NRC is not convinced that this is necessarily a conservative estimate.

- Both the industry and the NRC understand the urgency of a timely decision regarding the use of the plane-wave coherency model. Therefore, the industry and the NRC are willing to accept a coherency model that leads to a reduction of 0.2 in the value of the residual averaged over the frequency range of 10 to 35 Hz. This position will hold until justification for a coherency model leading to lower values in this frequency range can be provided by further analysis of available data.

- The same approach will be followed for vertical ground motion.

- The industry expects to complete a report on the coherency function based on these assumptions by February 19, 2007."

<u>Objective 2: Implementation of an Incoherency Transfer Function in Soil-Structure-Interaction Software SASSI and CLASSI</u>

In this portion of the meeting, Greg Hardy first provided an introduction to the EPRI presentation on SSI (Enclosure 4) and led a discussion of open issues from the October 24-25 public meeting in Santa Ana. Next, Steve Short and Jim Johnson provided a team presentation of the

technical details and results of the most recent SSI analyses.

The discussions on open items from the October 24-25 public meeting, which related to the slides shown in Enclosure 4, were as follows:

- For action item #1, ARES Corporation under contract to EPRI, was to review the implications of a change in the coherency function at depth. It was noted that this item was to be partially addressed later in the SSI presentation. However, significant work using the ITF developed for embedded foundations was not undertaken as the new ITF was provided on December 9. This action item is now changed to a review of the hard-rock based ITF that will be developed based on the common understanding discussed above.

- For action item #2, Greg Hardy had conducted a conference call with Dr. Abrahamson and interested parties to address questions related to choices in the coherency evaluation that impact SSI. The conference call was conducted 11/6/06 and it resulted in a clarification of issues and a request that certain assumptions be explicitly stated in the upcoming report. The steps for resolution for this issue were agreed upon during the conference call. For resolution if this item, Drs. Constantino and Zerva forwarded written questions and Dr. Abrahamson provided written responses consistent with the discussions during the conference call. The responses were provided to Drs. Constantino and Zerva by the NRC during the meeting, thus not allowing full review. However, unless the written responses differ from those provided verbally during the conference call as determined by Drs. Constantino and Zerva, this item is closed.

- For action item #3, a number of changes to the ARES report were requested. These changes have been incorporated into the recent EPRI report.

- For action item #4, Dr. Constantino was to schedule a discussion with Bechtel to review issues related to their SASSI software. Dr. Constantino and Dr. Ostadon of Bechtel have met on this issue and the items of interest have been reviewed.

- For action item #5, ARES was to provide additional information on the main structural model results (frequencies, mode shapes, eigenfunction and participation factors up to approximately 30 Hz). The studies were completed and were presented (See Enclosure 4).

- For action item #6, ARES was to discuss with EPRI a path for generating documentation and providing a version of the CLASSI computer code with incoherency to the NRC for use in its reviews on this project. It was noted that the legal hurdles were cleared. A complete package is expected in late January, once documentation has been completed.

- For action item #7, potential inconsistences between SASSI and CLASSI results related to rotational responses were to be identified and resolved. Studies are currently underway and this remains an open item.

- Action item #8, identifying and implementing ways for industry to participate in efforts to

generate NRC/Industry common understanding on elements of the seismic qualification process, is still open. However, on December 14 NRC held a public meeting with industry to discuss open issues. Industry provided input/recommendations based on an NEI meeting held the day before. Industry has requested further interactions related to the upcoming SRP updates related to seismic analysis criteria in Section 3.7 of the SRP.

- For action item #9, plots of the free-field ground motion, SSI coherent and SSI incoherent Fourier Spectra for figures such as 5-80 and 5-81 in EPRI Report 1013504 were to be provided. These were developed and presented in the SSI presentation. (See Enclosure 4.)

During the presentation of the latest results from the ongoing SSI analyses (Enclosure 4), key discussion points were as follows:

- There was a discussion of how SSI takes account of the input motion variability. It was noted that in seismological terms, the incoherency is a phase shift that comes from lagged coherency. The SSI averages out the inputs to the structure. This is computationally more efficient than using alternate techniques. It was noted that a check was performed in which the spread of the function was used for a thousand monte carlo simulations. Dr. Zerva noted that this check was essentially a verification of the use of a random vibration approach.

- It was noted that if the ITF is used, it is essential that loading in the two directions are not correlated. This is true because the review of the incoherency function shows that the two directions are not correlated with respect to the degree of coherency. The requirement that the two directions are uncorrelated is already in place for other reasons.

- It was again agreed by all parties that in SSI analyses that incorporate incoherency, outriggers for the assessment of rotation and overturning effects must be included in any stick model used for analysis.

- A new element of the SSI presentation was a comparison of the industry results with Luco and Wong. Although the comparison does not initially appear close, it was noted by Dr. Zerva that Luco and Wong used a numerical model for development of the ITF (versus empirical data) due to limited data available at the time. The degree of scattering in the soil/rock media is contained in the gamma factor, which is highly uncertain. As a result, Luco is more accurate for longer separation distances than it is for short distances. Results were also compared using Luco and Mita. In general, comparison seems reasonable.

- There was discussion of the need to produce SASSI validation package for review (similar to CLASSI). Currently, problems in SASSI are evident when looking at torsion and rocking. It is unclear what the root of the problem is and work to resolve this is ongoing. There was agreement among industry that once the issues have been resolved, advice to other users needs to be put into the report. It was noted that because SASSI has many more ways to change the analyses, there are significant places for operator error.

- It was agreed that any parties that intend on using SASSI must first validate their results against the CLASSI case histories provided in the report. This validation must include rocking and torsion in addition to translation and should be provided.

- It was again iterated and agreed that analyses that incorporate incoherency must consider any structures or components that may be sensitive to rocking or torsion. This may include elements near the edge of the foundation and near the top fo buildings and may require analysis of additional elements beyond those specifically detailed in the Design Certification Documents for standard designs.

Based on the above discussions, a common understanding as to the current status of the SSI modeling issues was jointly articulated as detailed below:

- The industry believes that CLASSI has been validated; therefore it can be used for validating SASSI.

- The industry believes that SASSI has been validated to provide the proper translational transfer functions; however, the validation of incoherence-induced torsional and rocking transfer functions is in progress. The basis of validation is the results of CLASSI.

- The industry will develop user guidance for SASSI users to ensure proper use of the code for incoherence.

- Each individual user of SASSI will need to be validated against CLASSI.

Topic 3: Action Items for Industry

A review at the end of day 2 of the meeting produced the following list of action items:

1. Development of the coherency model to address the 0.2 residual for 10-35 Hz as detailed in the common understanding.

2. Presentation of new residuals for all cases (soft soil, soft rock, hard rock, and embedment).

3. Extension of the coherency function to the vertical direction.

4. Investigation of appropriate values for the alignment time lag (using alignment on the P and S wave arrival times).

5. Development of revised coherency model for horizontal and vertical as needed based on item 4.

6. Target date for new report of February 19th (items 1 and 2 are essential).

7. Provide 1) acceleration, velocity, and displacement time histories; 2) cross correlation between the acceleration, velocity and displacement; 3) the phase differences; and 4) the differences between the accelerations, velocities and displacements for two

ground motion input points that are close together and two that are far apart.

8. Complete validation of SASSI considering incoherency effects.

9. Use new incoherency model in SSI analyses to determine its effects on the structural responses, including the effects of both translational and rotational foundation motions.

10. Develop user guidelines for use of SASSI with incoherency to be published as part of an upcoming report.

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 Recent Research Results Related to the ITF
4. EPRI's Presentation Materials on the SSI analysis results

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