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July 28, 1988

NS-NRC-88-3362

June 1, 1988
53 FR 20038
(3)

Mr. Robert Baer
Division of Engineering
U.S.Nuclear Regulatory Commission
Washington, DC 20555

Subject: Westinghouse Comments on the Proposed Resolution for Unresolved Safety Issue (USI) A-40, "Seismic Design Criteria"

Dear Mr. Baer:

Westinghouse has reviewed all of the documents included in the proposed resolution to USI A-40 issued by the Commission, including the specific questions on Soil-Structure Interaction (SSI) and has prepared a series of comments/responses. These are being transmitted to you in response to the Commission's request published in the Federal Register 53 FR 20038, dated June 1, 1988. The Westinghouse comments on the proposed resolution are contained in Attachment A and the responses to the questions regarding SSI are contained in Attachment B.

Following is a summary of the Westinghouse comments.

- o Number of Required Artificial Time Histories for a Seismic Analysis

  In general, multiple seismic time history analyses need not be performed to demonstrate seismic adequacy and qualification. The only situations when multiple time histories should be considered are when the seismic event is to be combined algebraically with a design basis accident event within the time domain, or gross material inelastic analyses are performed. One set of seismic time histories associated with the three orthogonal directions is sufficient for performing elastic non-linear system analyses if the time histories meet certain conditions.

- o Power Spectral Density as a Measure of Energy

  Westinghouse does not agree with the position that meeting additional justification requirements associated with the

letter sent 9/26/88

use of single time history will have a minor industry impact. The use of power spectral density (PSD) requirements will place an added burden on the industry that will not be minor. We recommend that PSD not be imposed at this time because the added conservatism imposed on the design of a nuclear power plant has not been adequately defined.

- o Duration of an Earthquake Time History

  The process of selecting a suitable time history also involves selecting the appropriate time history duration. Use of unnecessarily long duration time histories may result in the waste of computational resources without any significant contribution to the accuracy of the results. A time history should be long enough so that the resultant response spectra does not change significantly if the time history duration is increased.

- o High Frequency Mode Combinations

  In Appendix A to SRP Section 3.7.2, acceptable methodologies to account for high frequency modes are given. One acceptable procedure is given for incorporating responses associated with high frequency modes and it is recommended that examples of other acceptable methods be given through reference. In Attachment A to this letter, four such references are provided.

- o Low Frequency Mode Combinations

  The Standard Review Plan should be revised to reflect the acceptability of the algebraic sum method for modal combinations as discussed in NUREG-1061, Volume 4, "Report of the U.S.Nuclear Regulatory Commission Piping Review Committee", December, 1984.

Questions or further discussion regarding these comments are welcome, and should be directed to the undersigned.

Sincerely,

Robert D. Wiesemann for

W. J. Johnson, Mgr.
Nuclear Safety Department

0126C/WFG/072788

ATTACHMENT A

COMMENTS- U.S. NRC PROPOSED RESOLUTION
OF UNRESOLVED SAFETY ISSUE (USI) A-40
SEISMIC DESIGN CRITERIA
(PROPOSED REVISIONS TO NUREG-0800)

1. Number of Required Artificial Time Histories for a Seismic Analysis

NRC PROPOSED POSITION

In Section 3.7.1 (I.1.b and II.1.b) the design time histories to be used in a seismic analysis are discussed and the following recommandations concerning multiple time histories are given:

- Multiple seismic time histories may be used in lieu of the use of a single time history. "As a minimum, five time histories should bs used for analyses."

- Multiple real earthquake time history analyses are appropriate when non-linear analyses are performed.

WESTINGHOUSE COMMENTS

In general, multiple seismic time history analyses need not be performed to demonstrate seismic adequacy and qualification. The only situations when multiple time histories should be considered, are when the seismic event is to be combined algebraically with a design basis accident event within the time domain, or gross material inelastic analyses are performed. One set of seismic time histories associated with the three orthogonal directions (eg., north-south; east-west; vertical) is sufficient for performing elastic non-linear system analyses if the time histories meet the following conditions:

- Produce seismic response levels consistent with the seismic event response spectra defined for the site,

- Produce non-linear impact loads consistent with the defined seismic event,

- Are of sufficient duration and frequency content to reflect the possible different phase response in the non-linear support as measured by statistically independant parameters and associated response spectra.

Westinghouse has developed this approach, and can provide the NRC with a procedure to review and consider for incorporation into the standard review plan if so requested.

It is unrealistic, and unwarranted, to use five sets of time histories to perform a seismic analysis. This will have a significant impact on industry by increasing the cost due to increased computation and documentation effort without significantly increasing the accuracy or safety margins of the analysis or design.

The use of real earthquakes to perform seismic analyses is not feasible in most cases since the site seismic requirements reflect the seismology of the area and not a particular seismic event. Care should be taken when suggesting actual earthquakes be employed.

2. Power Spectral Density as a Measure of Energy

NRC PROPOSED POSITION

New requirements are placed on the analyst to demonstrate that the time histories being employed have sufficient energy. For example, in Section 3.7.1 (I.1.b and II.1.b) the following was noted:

- In addition to a comparison to requirsd response spectra, it is also required that a single time history used in a seismic analysis also "be further justified by satisfying a target power spectral density (PSD) requirement ... ."

- PSD functions generated from the multiple "time histories can be used to demonstrate adequacy of the number of time histories used and to exhibit that there is no significant lack of energy at frequency bands or frequencies of interest.

WESTINGHOUSE COMMENTS

It is stated in NUREG-1233 (Draft) that meeting additional justification requirements associated with the use of single time-history will have minor industry impact. Westinghouse does not agree. The use of PSD requirements will place added burden on the industry that will not be minor. It is not recommended that PSD be imposed at this time for the following reasons:

- The added conservatism imposed on the design of a nuclear power plant has not been adequately defined. It could be substantial and should be studied further by the NRC.

- The basis for the PSD has been developed. However, few of the general purpose computer codes used by the nuclear industry for equipment design contain algorithms needed to implement this analysis method. The "target" PSD functions should be studied further, and applied to additional cases. Since the modes used to describe energy distribution differ significantly between PSD and required response spectra (RRS) algorithms, a definitive correlation methodology between the two methods must be developed before ths PSD procedure can be used. To date, most evaluations of earthquake input characteristics have been evaluated using RRS methods, whereas little published work is available to the general engineering profession discussing PSD characteristics of earthquakes. Only when this work has been completsd and subjected to industry review will it be possible to define consistent "target" PSD and RRS functions.

- o The analyst should not be required to consider both enveloping of the required response spectra, and meeting the PSD requirements. If PSD provides a more realistic measure of an earthquake event, then the seismic design criteria including site seismic requirements should be modified so that all the seismic requirements are defined using the PSD concept, and not a mixture of response spectra and PSD.

On page 3.7.2-15, Section 5., it is stated at the end of third paragraph: "Justification should be provided for the statistical relationship between input ground response spectra and output floor response spectra." Does this imply the use of PSD parameters or some other method. This should be clarified, and the method of justification described in more detail.

3. Duration of an Earthquake Time History

NRC PROPOSED POSITION

The proposed revision includes the following acceptance criteria for the duration of an earthquake ground motion time history (see page 2.5.2-14).

"Total duration of the motion is acceptable when it is as conservative as values determined using current studies such as References 23, 24, and 27."

WESTINGHOUSE COMMENTS

The process of selecting a suitable time history also involves selecting the appropriate time history duration. Use of unnecessary long duration time histories may result in the waste of computational resources without any significant contribution to the accuracy of the results. A time history should be long enough so that the resultant response spectra does not change significantly if the time history duration is increased. The issue is discussed in detail in References 1 thru 4.

Reference 1 recommends, as a minimum requirement, the use of a 6 second duration for the purpose of generating synthesized time history motions. Although recorded long duration earthquakes tend to excite a much wider range of frequencies, this effect is factored in the nuclear power plant design by using a design response spectra that envelops Regulatory Guide 1.60 spectra.

Also, according to Reference 3, the minimum duration of the strong seismic motion may generally be taken as 6 seconds. A build-up duration of about 4 seconds is recommended to precede the strong motion. The reference recommends the extension of strong motion duration to 10 seconds in order to evaluate whether significant response increases occur.

The study described in Reference 4 concluded that it is necessary to increase the response magnitude by about 20% if a 5 second time history is used. For a 10 second input, an increase of 10% is sufficient; and for a 15 second input, no adjustment is necessary.

Therefore, it is recommended that a more definitive acceptance criteria specifying a total duration of 10 to 15 seconds, with at least 6 seconds of strong motion, be included in the Standard Review Plan. Choice of a shorter time history, with appropriate justification, should also be acceptable.

References:

1. Lin, C.-W., "Criteria for the Generation of Spectra Consistent Time Histories", Transactions of the 4th SMiRT Conference, San Francisco, August 1977.

2. Lin, C.-W., "Time History Input Development for the Seismic Analysis of Piping Systems", Transactions, ASCE, May 1980.

3. ASME Boiler and Pressure Vessel Code, Appendix N.

4. Li, D. and Lin, C.-W., "A Statistical Analysis of 2-D.O.F. Systems to the Time History Inputs with Different Durations", 1988 ASME Pressure Vessels and Piping Conference, Pittsburgh, June 1988.

4. High Frequency Mode Combinations

NRC PROPOSED POSITION

In Appendix A to SRP Section 3.7.2, acceptable methodologies to account for high frequency modes are given. One acceptable procedure is given for incorporating responses associated with high frequency modes. It is recommended that examples of other acceptable methods be given through references.

WESTINGHUSE COMMENTS

Given below are four such references:

Envelope Seismic Spectra Analysis

1. Vashi, K. M., "Computation of Seismic Response from Higher Frequency Modes," Transactions of the ASME 103, Journal of PVT, 2/81, pp. 16-19.

2. Park, I. B., and E. R. Johnson, "Computationally Efficient Methods for Seismic Response from Flexible and Rigid Modes," PVP-Vol. 81, 1984, PVP Conference, 6/84, San Antonio Texas.

3. Vashi, K. M. "Seismic Spectral Analysis for Structures Subject to Non-Uniform Excitation," ASME Paper 83-PVP-69.

4. Leimback, K. R., H. Lauren, and H. P. Sterkel, "Computation of Rigid Body Effects and Harmonic Excitation with KWUROHR", Proceedings of SMIRT-6, Paper K9/6, 1981.

Seismic Multi-Spectra Analysis

Papers 3 and 4 above.

5. Low Frequency Mode Combinations

NRC PROPOSED POSITION

In describing an acceptable procedure in Appendix A to SRP Section 3.7.2, mode combinations are to be in accordance with the methods given in Reg. Guide 1.92.

WESTINGHOUSE COMMENTS

The Standard Review Plan should be revised to reflect the acceptability of the algebraic sum method for modal combinations as discussed in NUREG-1061, Volume 4, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee," December, 1984. The driving force behind this recommended change is that the procedures in Reg. Guide 1.92 are over conservative and lead to excessive numbers of pipe support snubbers when applied to a piping system containing a relatively light secondary system which is tuned to a relatively heavy primary system. Refer to the paper by Soekman and Kelly, "Equipment Response Spectra for Nuclear Power Plant Systems," Nuclear Engineering and Design 57 (1980).

ATTACHMENT B

SOIL-STRUCTURE INTERACTION

The reviewers of the USI A-40 proposed resolution were asked to comment on specific questions related to Soil-Structure Interaction (SSI) in areas such as the control motion and analysis methodologies. These questions were included in Enclosure 7 in the package issued for public comments. The Westinghouse response to these questions is as follows:

Question 1

Lotung data indicates that, for that site, the deconvolution procedure did not predict consistent results to reflect observed variation of motion along the depth. Therefore, for proposed acceptance criteria in SRP Section 3.7.2.II, (primarily, for Alternate 1), should a limitation be included, such as no more than 40% reduction be allowed from the surface motion (e.g., Ref. 4 contains such a limitation) on the deconvolved motion at the foundation level in the free field for certain site conditions?

W Response

In early 1980's, the Senior Seismic Review Team (SSRT), headed by N. M. Newmark, provided guidelines to the U.S. NRC Division of Licensing for the Systematic Evaluation Program (SEP) SSI review (Ref. 1). It was recommended that the structural input motions at the foundation level, however developed and justified, under no conditions should be less than 75 percent of the free-field surface motion. The analytical techniques have significantly improved in recent years. The ASCE Standard 4-86, "Seismic Analysis of Safety-Related Nuclear Structures" (Ref. 2) considered these improvements. It recommends that the reduction of the response spectra at the foundation depth should be limited to 60 percent of the corresponding design ground response spectra at all frequencies.

Westinghouse agrees with the proposed limitation that no more than 40% reduction be allowed from the surface motion. This limitation will account for the uncertainties due to assumed wave types, angle of incidence, soil non-linearity, etc.

Question 2

A number of post test correlation studies of the Lotung facility found that the calculated soil damping values had to be reduced to match the observed results. Therefore, should a limitation be placed on the soil damping values used in the SSI analysis, particularly when a simplified half-space approach is used?

W Response

It was recommended by SSRT (Ref. 1) that the radiation damping be limited to 75 percent of the theoretical values calculated by using text book formulas (Ref. 3) for frequency independent soil systems. Westinghouse

agrees with this recommendation. For the layered systems, values computed from an acceptable computer program should be used. Furthermore, the composite modal damping in the soil-structure analysis system should be limited to 20 percent, if the modal superposition approach is used. For higher composite damping, the direct integration approach should be used.

Question 3

Similarly, should a limitation be placed on low strain values of soil used to determine the soil properties (e.g., shear modulus and damping) used in the SSI analysis?

W Response

No comment.

Question 4

Should the requirement of enveloping results of the two methods of SSI be retained in proposed Alternate 1 of the acceptance criteria in SRP Section 3.7.2.II, in light of the limitation which may be placed on the ground motion reduction and soil material properties?

W Response

There are two categories of SSI analytical techniques, the direct method and the substructure approach. The direct method analyzes the idealized soil-structure system in a single step, whereas the substructure approach treats the problem in a series of steps, typically three. The latter may employ elastic half space technique or the finite element approach. Both techniques involve a great deal of interpretive judgement. However, the current analysis procedures represent major advances in computational ability. Considering the limitations on input ground motion and soil damping recommended in the previous paragraphs, the enveloping of the results of the two methods would impose a severe penalty. It is recommended that this requirement of enveloping results of the two methods of SSI analysis be deleted.

References

1. Letter from N. M. Newmark, Chairman, SSRT, to Mr. W. T. Russel, Chief U.S. NRC Systematic Evaluation Program, dated December 8, 1980.

2. ASCE Standard 4-86, "Seismic analysis of Safety-Related Nuclear Structures", September 1986.

3. Richart, Hall, and Woods, "Vibration of Soils and Foundations", Prentice-Hall Inc., 1970.