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Seismic Hazard Review for the Systematic Evaluation Program - A Use of Probability in Decision Making

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ABSTRACT

This document presents the U. S. Nuclear Regulatory Commission (NRC) Geosciences Branch review and recommendations with respect to earthquake ground motion considerations in the Systematic Evaluation Program (SEP) Phases I and II. It evaluates the probabilistic estimates presented in the 5-volume report entitled "Seismic Hazard Analysis" (NUREG/CR-1582) and compares and modifies them to take into account deterministic estimates. It presents the NRC's Geosciences Branch first approach to utilizing complex state-of-the-art probabilistic studies in an area where probabilistic criteria have not yet been set and where decisions for specific plants have been previously made in a non-probabilistic way.

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INTRODUCTION

In the years 1978 through 1981, the NRC through the Systematic Evaluation Program embarked on its most comprehensive effort to date in the field of probabilistic evaluation of seismic hazard. This project was carried out for the NRC by Lawrence Livermore National Laboratories (LLNL) and its subcontractor TERA Corporation. It involved extensive solicitation of expert judgment, integration of this judgment into a probabilistic framework, sensitivity studies, review panels, and feedback. This program is described in the 5-volume report entitled "Seismic Hazard Analysis" (NUREG/CR-1582). Volume 1 of this report is an executive summary that provides a general overview and history of the project. Incorporation of these results and their use in the regulatory decision making framework is not discussed in the above report. The problem is a complex one. Simply stated, how does an agency use a state-of-the-art probabilistic study in an area in which probabilistic criteria have not been set and decisions for specific plants have been previously made in a nonprobabilistic way?

The attached reviews represent the efforts of the NRC's Geosciences Branch to come to grips with these problems. The initial review (dated June 23, 1980, and presented in Part I) evaluates the program in detail, shows comparisons to various deterministic techniques, and recommends a minimum level below which probabilistic spectra should not be used. The final review (dated May 20, 1981, and presented in Part II) presents an analysis of a second-round questionnaire given to the experts and an assessment of the conservatism of the staff's recommendation. It was concluded that "the recommended spectra can be generally associated with the higher end of the range of implicitly assumed seismic hazard that has been found acceptable using current criteria." This conclusion is supported by subsequent studies presented to the ACRS Subcommittee on Extreme External Phenomena on October 22, 1982.

The ability to make use of such a complex study in an area where NRC had no specific criteria was greatly facilitated by the close monitoring and involvement of the staff reviewers in the execution of the project. While separation of research and development from application may be appropriate in some areas, their close interaction in this project led to the immediate use of this new methodology in licensing decisions. A new and improved version of the methodology is currently being developed by LLNL that will take into account many of the lessons learned in the initial project. The systematic survey of expert judgment, their incorporation into a sound probabilistic methodology, and their use in the regulatory process should remain as ongoing high-priority items to assure rational and stable decision-making in the rapidly developing field of seismic hazard estimation for engineering purposes.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUN 2 3 1980

MEMORANDUM FOR: D. Crutchfield, Acting Chief
Systematic Evaluation Program Branch

THRU: James P. Knight, Assistant Director for
Components and Structures Engineering, DE

FROM: Robert E. Jackson, Chief
Geosciences Branch, DE

SUBJECT: INITIAL REVIEW AND RECOMMENDATIONS FOR SITE SPECIFIC SPECTRA AT SEP SITES

We have been working for the past two years with the SEP Branch and their consultants in order to provide preliminary recommendations regarding site specific spectra to be used in the SEP for evaluation of the seismic design adequacy of the selected plants.

The Branch recommendations are attached, however, it should be noted that they are subject to the limitations described in the sections entitled "Purpose and Scope" and "Recommendations." These recommendations were prepared by Dr. Leon Reiter based primarily on documents submitted in the Site Specific Spectra Program. We expect that our evaluation of items still forthcoming in the Site Specific Spectra Program may result in the following:

1. It is likely that there will be further changes in the return periods associated with the recommended spectra for the various sites. These return periods will still be able to be described as "of the order of 1000 or 10,000 years", which is the present description of the spectra and the level implicitly accepted by NRC in recent licensing decisions.

2. There will be no major change in the relative levels of seismic hazard between sites.

3. There will be little or no change in the "deterministic" comparisons for the various site used to evaluate the acceptability of the spectra recommended in the attached review.

4. There is a preliminary indication that a reduction in spectra at intermediate and low frequencies may be called for at rock sites (Dresden, Ginna, Haddam Neck and Millstone). Probabilistic predictions of peak velocities at these sites may also be affected.

JUN 2 3 1980

While it is difficult to predict the outcome of an innovative program that is still in progress it is our best estimate, based on the above, that this subsequent evaluation will not result in very large changes in spectra recommended for use in the evaluation of the SEP.

We recommend that you utilize these spectra in your reanalysis of the SEP facilities. We further recommend that a minimum spectra be established as discussed in the report. This recommendation is based on the innovative nature of the Site Specific Spectra Program and the need for continued review and maturation of the program. The site specific spectra provided are generally less than would result from a literal application of Appendix A to 10 CFR and the current Standard Review Plan throughout the frequency range of interest for nuclear power plants.

Since follow up work and sensitivity studies are continuing, we will monitor progress and provide a final recommendation in December 1980 upon completion and review of these elements of the program.

Robert E. Jackson

Robert E. Jackson, Chief
Geosciences Branch
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Enclosure:
As stated

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Initial Review and Recommendations for Site Specific Spectra at SEP Sites

Purpose and Scope

This review presents initial recommendations for Site Specific Spectra to be used in the reevaluation of SEP plants. It is based upon review of the following items.

(1) Draft Seismic Hazard Analysis: TERA - Lawrence Livermore Laboratory (LLL), 3 volumes, August 1979.

(2) Peer Review Comments to above reports, **Individual** comments by Dr. O. Nuttli, Dr. L. Sykes, Dr. D. Veneziano, Dr. A. Ang, (LLL Review Board); Fugro, URS Blume Assoc., Dr. A. Cornell, **Mr.** R. Holt, Commonwealth Edison (licensee sponsored reviews); Dr. L. Abramson (NRC, Applied Statistics Branch) Fall-Winter 1979.

(3) Response to Peer Review Site Specific Spectra Project (SSSP), TERA, May 1980.

(4) Draft Seismic Hazard Analysis: SSSP Sensitivity Results, TERA-LLL, May 1980.

(5) Attenuation Panel Feb. 1980, and comments on the panel meeting by Dr. O. Nuttli, Dr. M. Trifunac, Dr. R. McGuire, Dr. N. Donovan.

(6) Letter Report evaluation of Attenuation Panel by TERA, April 4, 1980.

(7) Letter Reports on Ossippee Attenuation Model by TERA, May 22, May 29, 1980

(8) Interim Summary of assessment of conservatisms by TERA, May 30, 1980.

(9) Evaluation of Ossippee Attenuation Models and alternatives by LLL, May 23, 1980.

(10) Seismic Hazard Evaluation for SEP plants (Draft) N. M. Newmark (May 30, 1980).

In addition to these documents there have been many discussions and telephone conversations with individuals at TERA, LLL, reviewers, attenuation panel members and Drs. Newmark and Hall.

Following is a list of other items and reviews which will be forthcoming and could have an impact upon the results.

1. Review of the Draft Seismic Hazard Analysis by the USGS.
2. Additional Review and comments by Drs. Newmark and Hall.
3. Review of all submissions by the licensees on their recommendations for site specific spectra (several have been reviewed).
4. Comparison of SSSP results with other eastern U. S. hazard analyses.
5. Feedback meeting with original expert group.
6. Recommendation from TERA-LLL and possible reanalysis based upon utilization of input from sensitivity results, attenuation panel and feedback meeting.

Recommendations

It is recommended that the following spectra presented in the Sensitivity Results (May 1980) be used as site specific free field spectra.

Eastern U. S. (Yankee Rowe, Connecticut Yankee, Millstone, Ginna, Oyster Creek) - "1000 year" spectra assuming no background and Ossippee Attenuation.

Central U. S. (Dresden, Palisades, LaCrosse, Big Rock Point) - "1000 yr" spectra assuming no background and Gupta-Nuttli Attenuation.

These spectra account for gross site conditions (soil or rock) and do not take into account any specific conditions which may result in amplification (LaCrosse, Yankee Rowe, Palisades).

It is also recommended that a minimum be established for which no spectra be allowed to go below. It is suggested that this minimum be the median (50th percentile) representation of real spectra for a magnitude 5.3 earthquake. This minimum exceeds the "1000" yr spectra for Big Rock Point, LaCrosse and Palisades at frequencies greater than 2 to 3 Hz.

The rationale for these recommendations are discussed below.

General Comments

The SSSP was conceived as a multi-method approach for determining site specific spectra (Bernreuter, 1979). It encompassed probabilistic approaches at predicting peak acceleration, peak velocities and uniform hazard spectra for different return periods and a empirical approach which includes calculation of 50th and 84th percentile spectra from ensembles of real data at different magnitudes, site conditions and distance ranges. The probabilistic approach utilized is basically that suggested by Cornell (1968) which has been modified to formally incorporate "expert" judgements. This approach is explained in detail in the documents referenced above and in Part 1 of the Executive Summary by TERA Corp.

The difference between so called "deterministic" approaches (for example, that found in the Standard Review Plan*) and probabilistic approaches are described below. In the deterministic approach (Figure 1) local (fault) and regional

*Although this approach is commonly called "deterministic" it is better described as "judgemental-empirical." A true deterministic approach would involve using the principles of physics to calculate ground motion due to a rupturing fault.

(tectonic province) source regions are specified geometrically (Step 1). The largest earthquake associated with each source is then defined from historical seismicity and/or geological estimates, and it is assumed to occur at a location in each source closest to the site in consideration (Step 2). The resultant ground motion (usually peak acceleration) at the site from each of these sources is then estimated utilizing magnitude-acceleration or intensity-acceleration relationships (Step 3). The largest of these is then considered the controlling ground motion and it determines the assumed earthquake loading at the site (Step 4). In the current NRC practice this earthquake loading (Safe Shutdown Earthquake) usually is peak acceleration used to anchor the standardized Regulatory Guide 1.60 spectrum. This method does not take into account the frequency of earthquake occurrence and allows no description of uncertainty.

In the probabilistic approach described in Figure 2, earthquake sources are determined (Step 1) as in the deterministic approach. Historical seismicity is then used to determine an earthquake recurrence model for each source (Step 2). This model is usually determined from a linear regression analysis relating earthquake size (magnitude or intensity) to frequency of occurrence. These recurrence models are terminated at the largest earthquake expected from each source. Most probabilistic models assume that earthquake occurrence follows a Poisson process or that these earthquakes occur randomly with respect to time and space within a given source. The ground motion (peak or spectral parameter) at the site from the different earthquakes at different distances is estimated using a set of magnitude (or intensity) - ground motion relationships that explicitly incorporate the dispersion of the data about such relationships (Step 3). Finally, integrating the effect of different size earthquakes from different locations in different sources with the recurrence information from Step 2, the probabilities that given levels of ground motion will not be exceeded within given time periods are calculated (Step 4).

The deterministic approach is strongly controlled by the choice of input parameters (source configuration, intensity-acceleration relationship, response spectra etc.). Sizeable changes in characterizationof safe shutdown earthquakes for Nuclear Power Plants in the past 5 to 10 years have resulted from staff adoption of the Regulatory Guide 1.60 spectrum and the Trifunac-Brady (1975) intensity-acceleration relationship. Probabilistic prediction can also be driven by the choice of input parameters. In the eastern U. S. these input parameters or their statistical representation cannot in many cases be unambiguously derived from the existing data. The innovative approach of the SSSP was to canvas expert opinion as to what the choice of these input parameters were, what range they might be expected to assume and what credibility could be attached to them. Each experts input was treated separately, spectra were computed for each expert at each site than a trial synthesis was performed combining all the experts at each site based upon their own self-ranking. The input parameters covered four areas: (1) the configuration of seismic source zones in the central and eastern U. S. (2) the largest earthquake expected in each of these zones (3) the earthquake activity rate and recurrence statistics associated with each zone and (4) methods for predicting ground motion in the eastern and central U. S. from an earthquake of a given size at a given distance.

Responses were received from 10 of the 14 expert polled. (The questionnaires were lengthy and required several days to answer in a comprehensive manner). These responses were almost exclusively directed at the first three areas. The significant lack of response in areas of ground motion made it necessary for TERA-LLL to develop its own ground motion determination scheme. Additional approaches were presented in the sensitivity results and an additional special "Attenuation Panel" was convened to discuss this difficult problem.

In addition to the ground motion problem, the extensive peer review conducted for the initial draft report identified other problem areas. The most significant of these were related to the way each expert's zonation was treated and the assumed dispersion of the data. These subjects were also treated in the sensitivity studies mentioned above. Specific discussions on each of these problem areas follow.

Specific Comments

Ground Motion Determination

The problem is to quantitatively predict ground motion east of the Rockies when there is practically no strong motion data recorded in this region. The existing data base (most Western U. S.) was recorded in areas where seismic wave attenuation and, to some extent, seismic sources are different. A method must be developed to predict this motion theoretically or make use of the historical (non-instrumental) felt reports from the eastern U. S. in conjunction with strong ground-motion data from the western U. S. The initial results (August 1979) utilized felt reports from the well-documented Southern Illinois Earthquake of 1968 and the assumption that ground motion associated with a given felt effect (site intensity) and epicentral distance will be the same in both east and west. The sensitivity studies (May 1980) examined the affects of assuming that the ground motion associated with a given felt effect and given earthquake size will be the same for both east and west. The studies accomplished this result for three felt-effect predictions; the 1968 Southern Illinois Earthquake, the 1940 Ossippee New Hampshire earthquake, and a modification of the Gupta-Nuttli (1976) relation based upon several central U. S. earthquakes. While the attenuation panel had mixed feelings there seemed to be some preference for this latter assumption. In conjunction with the sensitivity studies, the existing data set was also modified to prevent undue dependence upon a single earthquake and to eliminate strong motion records that were believed to represent only part of the actual shaking. In addition, studies of several other earthquake suggested a difference in attenuation of ground motion between the northeastern and central U. S. At distances greater than 100 kilometers, the effects of shaking appear less attenuated in the central U. S. when compared with that in the northeast. As a result of these considerations, we recommend that the 1980 model based upon the Ossippee earthquake be used as a basis for determining ground motion in the northeastern U. S.; while the 1980 model based upon the Gupta-Nuttli relationship be used as a basis for determining ground motion in the central U. S. The Ossippee attenuation was calculated several ways. In the original SSSP Sensitivity Results (May 1980) an average distance was first computed for each intensity level and then a regression was performed treating distance as the independent parameter and site intensity as the dependent parameter. A significant difference was observed when the averaging was omitted and the regression performed directly on the data (TERA Letter Reports, May 22 and May 29, 1980). It is not immediately clear which approach is more appropriate. Conceptually it appears better to avoid the averaging step. We feel, however, that at this time the original technique using the averaging step should be used. The reasons for this are (LLL Letter, May 23, 1980): (1) This method is analagous to that used by Gupta and Nuttli (1976) to derive their attenuation relationship. (2) the second method would predict ground motion significantly less at most distances than that proposed by the theoretical model of Nuttli (1979) while the original method falls much closer to his model.

The attenuation panel recommended greater use of such theoretical relationships for determining ground motion. Initial calculations show that when these theoretical relationships are incorporated into SSSP methodology peak accelerations for return periods of 1000 years appear to be similar to the Gupta-Nuttli and original Ossippee attenuations. While some small differences between central and northeastern attenuation can be expected we feel that at this time, reliance upon results produced utilizing a particular regression technique on one earthquake in the northeast which are significantly less than theoretical and empirical results for the central U. S. is imprudent. Clearly, however, determination of a proper attenuation relationship is an area that requires additional work.

Zoning

The initial treatment of experts input to configuration and credibility of seismic source zones allowed for the existence of a background zone consisting of the union (enevelope) of all the experts zones in a particular region. The extent to which this background zone was used depended upon the experts general level of belief (credibility) in the existence of these zones. As a result, this leads to tying one expert's results to others and the allowance of specific numbers of the larger earthquakes normally associated with a seismic zone being allowed to occur anywhere within the background. Various reviewers criticized this approach and some alternatives were suggested. The sensitivity studies computed spectra based upon the opposite extreme i.e. the assumption that each expert had 100% belief in his zone and no background need exist. These two computations bound the problem.

For SEP sites, the latter assumption results in a reduction in estimated seismic hazard. If a site were located in the middle of an active seismic zone such as New Madrid the assumption of no background would result in an increase in estimated seismic hazard. There are many arguments that may be made as to how this problem may be treated correctly. It seems clear that neither extreme is correct and some better way of accounting for credibility is warranted. TERA-LLL has argued that a true representation of credibility in such a complex problem may be very cumbersome computationally and prohibitively expensive. It is our recommendation that, barring such a computation spectra intermediate between these two assumptions be used at this time. As shown below the actual difference between spectra computed using the two extreme assumptions is not large and any error in estimating the intermediate spectra will not have a significant effect.

Dispersion of Data

In The August 1979 report the dispersion assumed about the final ground motion prediction was assumed to be log normal with σ=0.9 (base e). In addition the distribution was truncated at $\pm$ 2σ. This size of the dispersion was determined combining dispersions normally encountered in determining site intensity from earthquake size (epicentral intensity) and in converting this intensity to ground motion. These individual dispersions can be considered as due to randomness found in nature. Several reviewers argued however that treating these errors as independent and disregarding their cross correlation is overly conservative and that it increases the total dispersion beyond that resulting from true randomness. Where ground motion records due exist, e.g. Western U. S., the dispersion associated with ground motion from a given size of earthquake can usually be described with σ=0.6 to 0.7. Data points do not normally extend out beyond limits of $\pm$ 3σ. These criticisms are considered valid and it is recommended that the dispersion defined as σ=0.7, truncated at $\pm$ 3σ be accepted. Extension of the truncation point beyond 3σ will not have a significant effect upon the results.

Synthesis Curves

Some alternate methods were suggested to synthesize the results of the various expert judgements. The SSSP utilizes a self-ranking system. In the opinion of TERA Corporation, alternate methods would not have a significant effect upon the synthesized curves. By inspection it appears that the synthesis curves represent a median or somewhat higher than median representation of the individual spectra computed for each expert. It is recommended that this synthesis be used to describe the hazard.

Integration of Recommendations

In the sensitivity studies, uniform hazard spectra are presented for all the ground motion models recommended above, i.e. Ossippee (1980 model) for northeastern sites and Gupta-Nuttli (1980) for central U. S. sites.

All spectra are computed assuming no background and σ=0.9 $\pm$ 2σ truncation. These spectra are approximately equal to the recommended spectra of σ=0.7 $\pm$ 3σ truncation with a zoning assumption intermediate between a background and no background because: 1) The decrease in peak accelerations and peak velocities computed for representative individual experts from σ=0.9 ($\pm$ 2σ) to σ= 0.7 ($\pm$ 3σ) is on the average about 7 to 10% for the Gupta-Nuttli and Ossippee attenuations; (2) the increase in peak accelerations and peak velocities from no background to background is on the average about 15 to 20% for the August 1979 attenuation (the onlv comparison available). Although there is some preliminary indication of attenuation model dependence for the background-no background comparison these approximations are considered adequate given the precision of the spectra and the size of the differences.

Adequacy and Conservatism of the Recommended Spectra

While the "1000 year" spectra are recommended it is not possible to state with any certainty that the true return period (inverse of annual risk of exceedente) is 1000 years. Generally these estimates are believed to be conservative for the following reasons.

1. Strong motion data sets are in many ways biased toward high values. Non-triggered instruments or low-level records receive little attention. This is also true at great distances and for longer periods where noise may be contributing significantly to observed motion.
2. The assumption that earthquakes occur randomly within a given seismic source zone is conservative for large zones of low to moderate level seismicity such as those around most SEP sites. While the sources of central and eastern U. S. earthquakes remain hidden, most seismologists conclude that damaging earthquakes will eventually be associated with specific faults.
3. The uniform spectra represent composite risk from different source zones which may effect different frequency ranges. Under certain situations, exceeding the spectra at different frequencies implies the simultaneous occurrence of earthquakes in more than one source zone.
4. The assumption that intensities from large earthquakes attenuate at the same rate as intensities from small earthquakes is conservative.

Some non-conservative aspects of this and other studies are:

1. The strong-motion data set used mixes accelerograms recorded in the true free field with those recorded in the basements of buildings. Many engineers feel that the effect of large foundations in these buildings is to reduce high frequency motion.
2. The probabilistic spectra represent the chance of being exceeded more than once in a given return period. The probability of being exceeded twice or more, however, is small when compared to the probability of being exceeded only once.

Based upon consideration of all of the above and their estimated relative weights, we consider the true return period associated with these spectra to be longer than 1000 years. TERA in a recent reassessment of conservatism (Letter, May 30, 1980) concludes that those spectra presented in the Sensitivity Results as "1000 year spectra" can be conservatively represented as 5000 to 10,000 year loads. Additional work will better define what the return periods are. At the present time however, we believe that there is no way of indicating what these true return periods are or establishing rigourously defined confidence limits. In the past there has been implicit acceptance of design spectra that were assumed to have return periods of the order of 1000 or 10,000 years. It is our judgement that these spectra fall within this description.

The most important quality of these spectra is that, although no great confidence can be attached to the absolute probabilities (i.e. return periods), the systematic incorporation of expert opinion and uncertainty and the wide ranging sensitivity tests indicate greater stability when estimating relative hazard probabilities at these levels of ground motion. This would apply to estimating the equivalent levels of probabilities of exceedence at different sites and small relative differences in probabilities of exceedence at the same site. Thus, while we are not sure that the "1000 year spectra" really represent 1000, 5000 or 10,000 year return periods at all the sites we have greater confidence that they represent approximately equivalent levels of hazard whatever the true return period is. This is based in large part upon the relative consistency of effects associated with the sensitivity tests (SSSP Sensitivity Results, May 1980) and the synthesizing of wide ranges of expert judgement with respect to each region.

Comparison of Spectra with "Deterministic" Procedures

In order to further evaluate the adequacy and reasonableness of the recommended design spectra several comparisons with non-probabilistic techniques were performed.

Comparison with spectra determined using the tectonic province approach (Appendix A). In this approach (Figure 1) the largest historical earthquake that has occurred in the host province is assumed to occur near the plant while the largest historical earthquakes in adjacent provinces are assumed to occur in these provinces at locations closest to the site. The ground motion at the site from these earthquakes is estimated and this determines the seismic input to design. Tectonic province boundaries and earthquake sizes were estimated based upon recent licensing decisions. The configuration of the New Madrid Zone was also used assuming the more recent suggestions of Nuttli and Herrmann (1978). The assumptions for each site are listed in Table 1. Earthquake size is also given in terms of magnitude (m_b) and these are based upon recent individual determinations of the magnitudes from intensity data and the general relationship proposed by Nuttli and Herrmann (1978).

Utilizing these events, a series of theoretical and empirical equations were used to predict the peak accelerations and velocities at each site. In order to deal with differences in these equations, selected results representing the most appropriate theoretical and empirical relationships were averaged to arrive at final estimates of peak acceleration and velocity. Table 2 shows the controlling (largest) peaks estimated at each site. These are compared with the peak accelerations and velocities associated with the recommended uniform hazard (probabilistic) spectra.

The uniform hazard peak accelerations reach or exceed the deterministic peak accelerations at all sites except Palisades, LaCrosse and Big Rock Point. This is a reflection of the fact that these 3 sites lie in areas of low seismicity and estimated seismic hazard in the central stable region. The uniform hazard peak velocities exceed the deterministic peak velocities except at Dresden where it is less. This is a reflection of the fact that probabilistic techniques take into account larger than historical earthquakes. Sensitivity studies show that these have the largest effect upon peak velocities. This is reflected in the deterministic procedure for Dresden where the proximity of the New Madrid zone has a significant impact. In general it can be said that the 1000 year uniform hazard peaks bracket the deterministic peaks. Differences between the two sets of values result from the ability of the uniform hazard approach to overcome the artificial constraints often posed by the "tectonic province" approach. Thus, while the tectonic province approach would require Big Rock Point and Haddam Neck to utilize similar seismic input for design purposes, the probabilistic methodology takes into account the real difference in seismicity and perceived earthquake hazard at these sites.

The deterministic peak accelerations and velocities are converted to response spectra using the amplification factors suggested by Newmark and Hall (1978) in NUREG CR-0098. Figs. 3 thru 11 compare the recommended uniform hazard spectra with 50th and 84th percentile deterministic spectra. In the central U.S. the recommended spectra generally fall below or at the 50th percentile. In the eastern United States the uniform hazard spectra are approximately equivalent to the 84th percentile deterministic spectra. While the deterministic peaks are generally lower than the predicted peaks, use of the 84th percentile amplification factors usually more than compensate for the differences. Again the uniform hazard spectra more adequately reflect perceived relative hazard. The "tectonic province" approach can be made to achieve conservatism in this case by utilizing conservative amplification factors.

Figures 12 and 13 show the uniform spectra compared to Reg. Guide 1.60 spectra anchored at 0.1 and 0.2g. Following suggested Standard Review Plan procedures for new plants that is utilizing the trend of the means of Trifunac and Brady (1975) to anchor the Reg. Guide 1.60 spectra, would result in design spectra anchored at between 0.12 and 0.20g. The specific acceleration used would depend in large part upon the applicants submittal and the reviewer's conservatism. For the central U. S. the recommended spectra are mostly below the Reg. Guide spectrum anchored at 0.1g while for eastern U. S. the recommended spectra are at or above the Reg. Guide spectrum anchored at 0.1g. The average recommended spectrum would be roughly equivalent to the Reg. Guide 1.60 Spectrum anchored at a peak acceleration of about 0.1g. The observation that the average peak acceleration associated with the recommended spectra (Table 2) is about 0.15g illustrates the often discussed conservatism of the Reg. Guide spectrum. It was conservatively derived from earthquakes of different sizes recorded at different distances and different site conditions.

Comparison with Real Spectra

A more applicable comparison can be found in Figures 14 and 15. Here the recommended spectra are compared to the 50th and 84th Percentile levels of ensembles of response spectra derived from strong motion records recorded at nearby distances (usually 27 km or less) from earthquakes of magnitude

5.3 ± 0.5 in the western U. S. and Italy. At these distances differences in regional attenuation are not pronounced. At periods less than 0.3-0.5 seconds the recommended spectra fall in between the 50th and 84th percentile except for Palisades, LaCrossse and Big Rock Point which are slightly below the 50th Percentile. Differences again can be related to real differences in earth quake hazard.

There can be some concern however in that the recommended spectra may fall below some minimum level of ground motion from a nearby magnitude 5.3 (Intensity VII). While Intensity VIII or larger earthquakes have been restricted in historical time in the central and eastern U.S. to five or six locations, Intensity VII earthquakes have occurred in sufficient numbers and at sufficient locations such that we believe that they could occur anywhere in the U.S. at varying levels of certainty. It is prudent therefore to establish such a minimum level although a direct uniform hazard assessment would more accurately reflect relative earthquake hazard. It is recommended that this minimum be set at the 50th percentile of the plotted real spectra. While the 84th percentile has been used in deterministic techniques it is not suggested that it be used as a minimum since it is more a reflection of the dispersion of data resulting from the magnitude and distance range needed to gather an adequate number of records for statistical treatment.

As indicated above use of the 50th Percentile would have a small effect upon LaCrosse, Palisades and Big Rock Point.

Conclusions

Based upon review of the indicated documents and the comparison with "deterministic" procedures mentioned above, we believe that the site-specific uniform hazard response spectra suggested represent an adequate level of free field ground motion for use in the reevaluation of the SEP plants. The varying levels of these spectra more accurately reflect true variations in real seismic hazard than those derived utilizing the "deterministic" tectonic province approach. We also believe that it is prudent to establish some minimum level below which no spectra be allowed to fall. It is recommended that this be the 50th percentile of real data from a nearby magnitude 5.3 earthquake as shown in the comparative plots. Utilization of this minimum would have a small effect upon Palisades, LaCrosse and Big Rock Point. These spectra do not take into account specific site amplification factors that may be present at LaCrosse, Palisades or Yankee Rowe nor do they reflect consideration of additional studies still ongoing in the SSSP program. Those spectra presented were computed for 5% damping.

Table 1

Controlling Earthquakes used in the Tectonic Province Approach

Site	Local Earthquake (Host Province) (Average Epicentral Distance 10-15 km)	Distant Earthquakes (other than Host Provinces
Yankee Rowe	mb 5.3 (Intensity VII)	mb6.0 (Intensity VIII) from White Mt. zone (80 km)
Haddam Neck	mb 5.3 (Intensity VII)	mb 6.0 (Intensity VIII) from White Mt. Zone (130 km)
Millstone	mb5.3 (Intensity VII)	mb 6.0 (Intensity VIII) from White Mt. Zone (140 km)
Oyster Creek	mb 5.3 (Intensity VII)	mb 6.0 (Intensity VIII) from White Mt. Zone (375 km) mb 5.8 (Intensity VIII) from Southern Valley and Ridge (550 km)
Ginna	mb5.3 (Intensity VII-VIII)	mb 5.75 (Intensity VIII) from Clarenden-Linden Fault (55 km)
Dresden	mb 5.3 (Intensity VII-VIII)	mb 7.5 (Intensity XI-XII)from New Madrid Zone (280 km) *mb6.7 (Intensity X) from Wabash Zone (200 km)
Palisades	mb5.3 (Intensity VII-VIII)	mb7.5 (Intensity XI-XII) from New Madrid Zone (315 km) *mb6.7 (Intensity X) from Wabash Zone (300 km)
LaCrosse	mb5.3 (Intensity VII-VIII)	mb7.5 (Intensity XI-XII from New Madrid Zone (600 km) *mb6.7 (Intensity X) from Wabash Zone (530 km)
Big Rock Pt.	mb5.3 (Intensity VII-VIII)	mb7.5 (Intensity XI-XII) from New Madrid Zone (760 km) *mb6.7 (Intensity X) from Wabash Zone (650 km)

*Controlling event based upon Nuttli and Herrmann (1978) interpretation of Mississippi Embayment Seismic Zoning.

Table 2

Comparison of Predicted Peak Accelerations and Velocities Based upon Probabilistic* and Deterministic** Techniques

	Site	Peak Acceleration (cm/sec^2)		Peak Velocity (cm/sec)	
		Probabilistic	Deterministic	Probabilistic	Deterministic
1.	Yankee Rowe	195	123	22	11
2.	Hadden Neck	202	123	20	9
3.	MIllstone	184	123	18	9
4.	Oyster Creek	161	123	18	9
5.	Ginna	169	132	17	10
6.	Dresden	124	132	16	20
7.	Palisades	102	132	15	12
8.	LaCrosse	91	132	14	9
9.	Big Rock Point	81	132	11	9

*Probabilistic values are those associated with TERA-LLL's synthesis for the 1000 yr return period. Attenuation model used for sites 1-5 was 1980 Ossippee for sites 6-9 1980 Gupta-Nuttli. While explicit values assumed no background and a dispersion of σ=0.9 + 2σ This is estimated to be equivalent to intermediate background and a dispersion of σ=0.7, $\pm$ 3σ.

**Deterministic values were computed using Table 1 and averages of results from the following suites of predictive equations.

Local Events - all sites, suite (a)
Distant Events - northeastern sites (1,2,3,4), Suite (b),
central sites (6,7,8,9) Suite (c)
intermediate site (5) Suite (a).

The suites of equations are:

a. Herrmann (personal communication, 1980), TERA-LLL Aug, 1979, TERA-LLL 1980 Ossippee, TERA-LLL 1980 Gupta-Nuttli.
b. Herrmann (personal communication, 1980), TERA-LLL 1980 Ossippee
c. Herrmann (personal communication, 1980), TERA-LLL Aug. 1979, TERA-LLL 1980 Gupta-Nuttli.

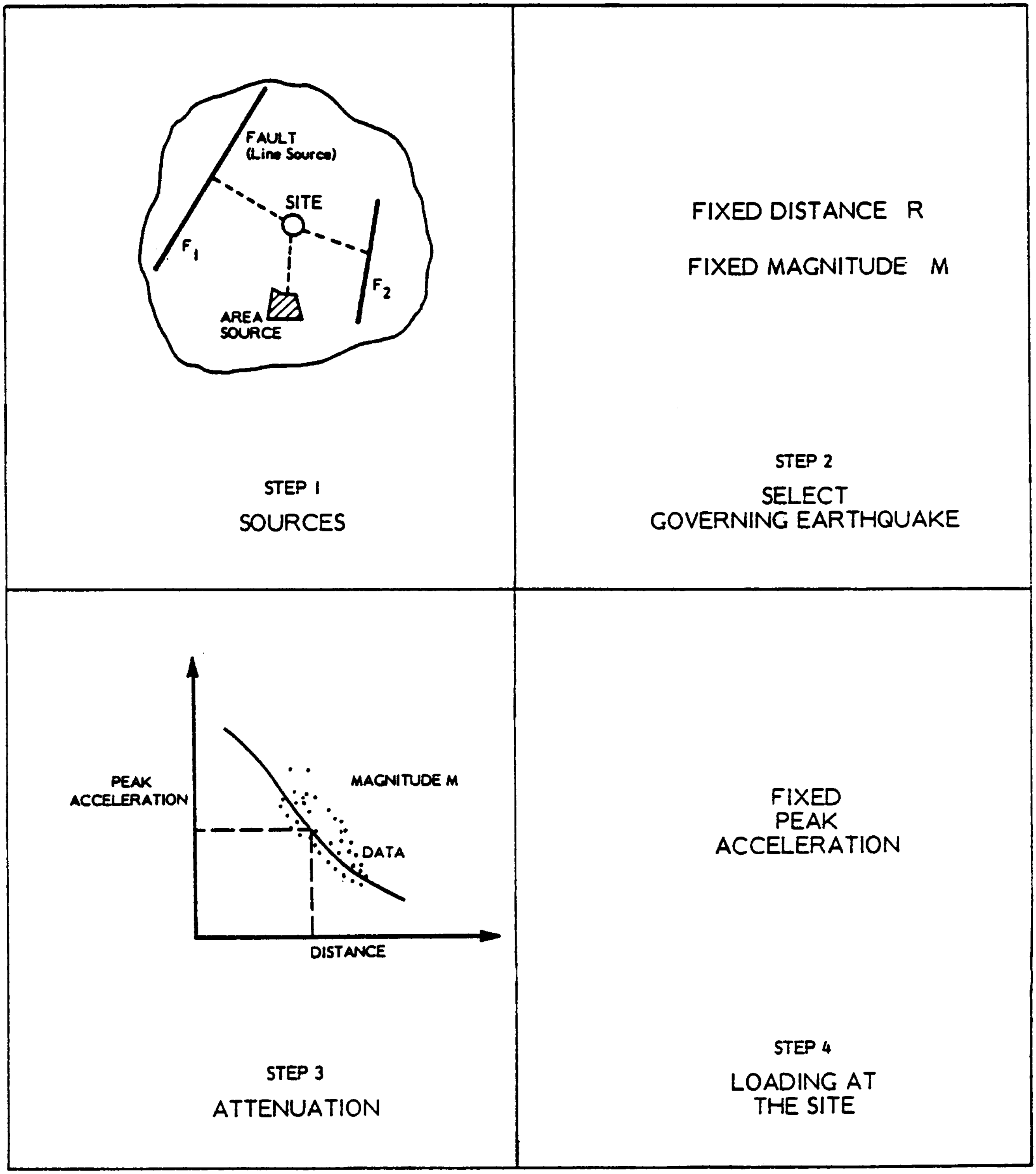


FIGURE 1

DETERMINISTIC APPROACH
TO LOADING AT THE SITE

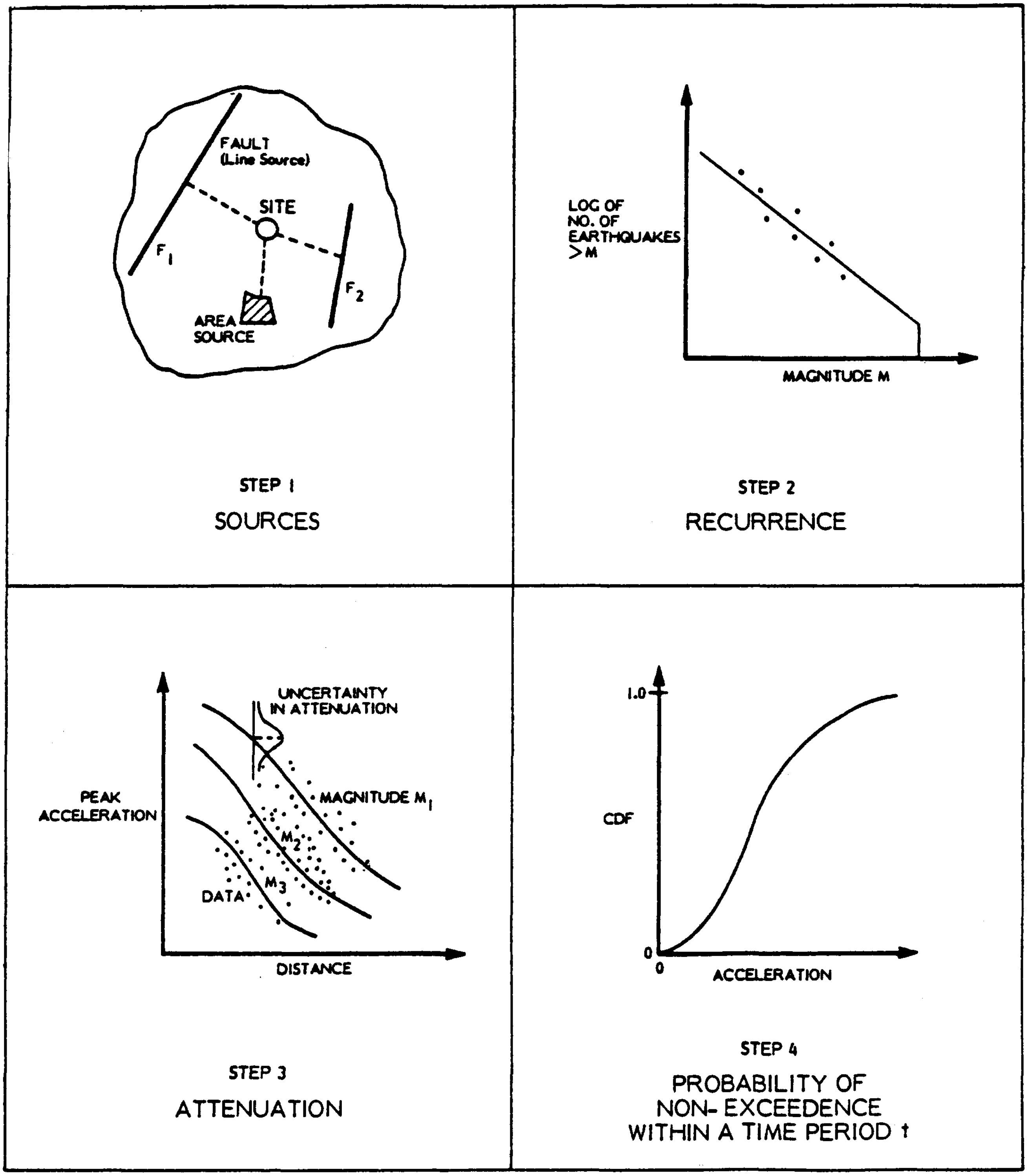
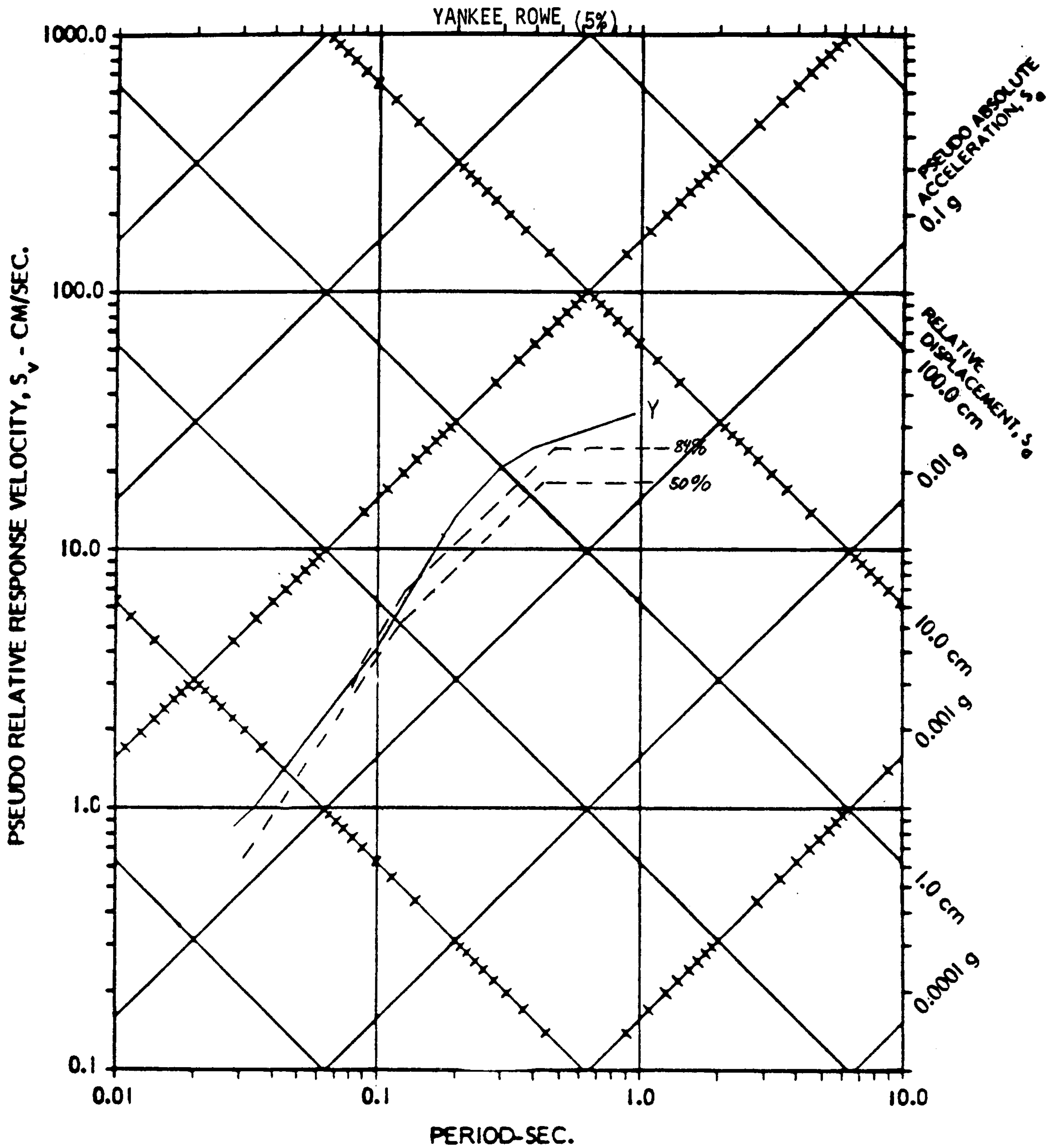


FIGURE 2

CURRENT APPROACH TO HAZARD
MAPPING FOR PEAK VALUES

Dec. 8, 1978

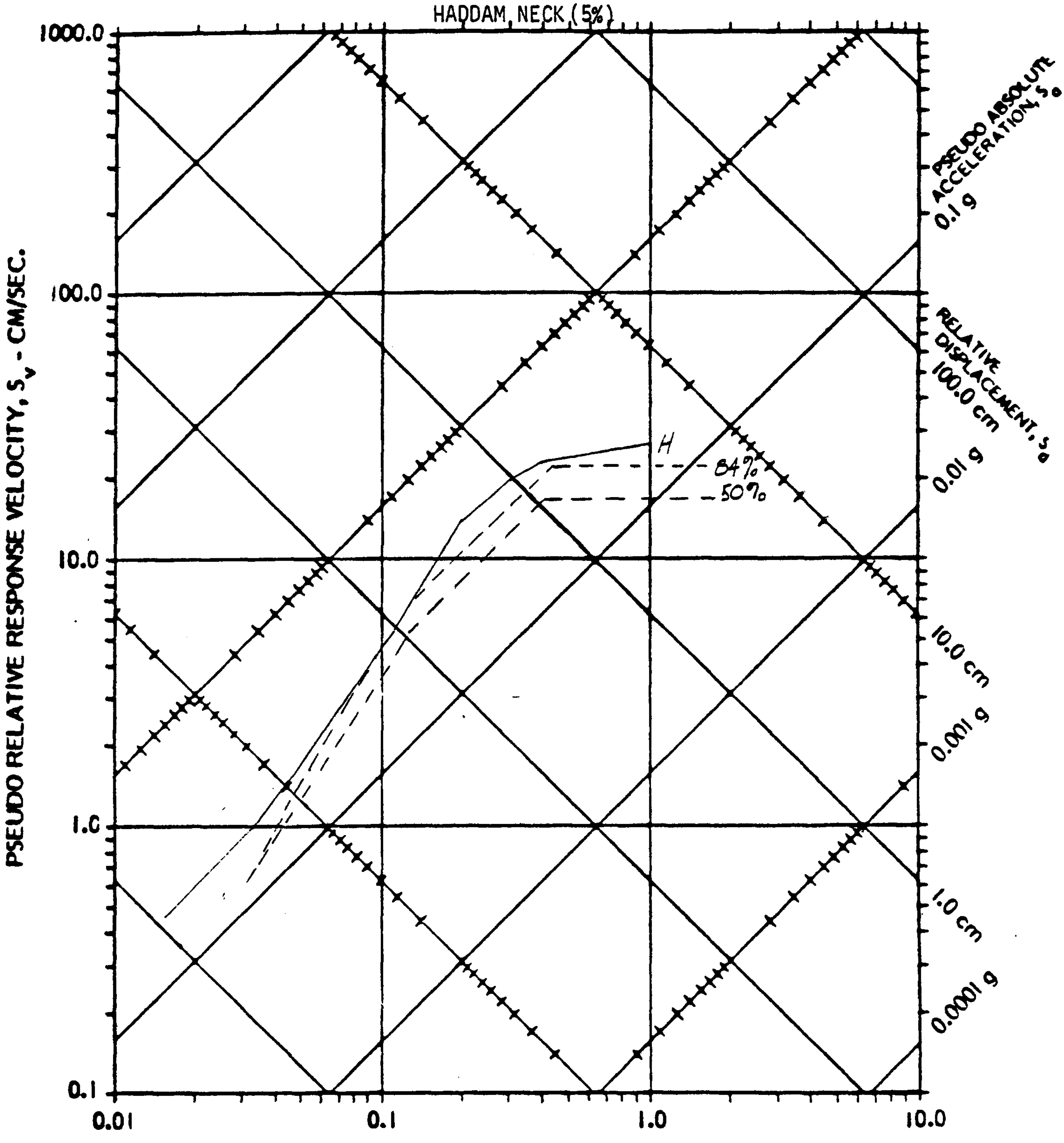


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

Y - Recommended probabilistic spectra.

Figure 3

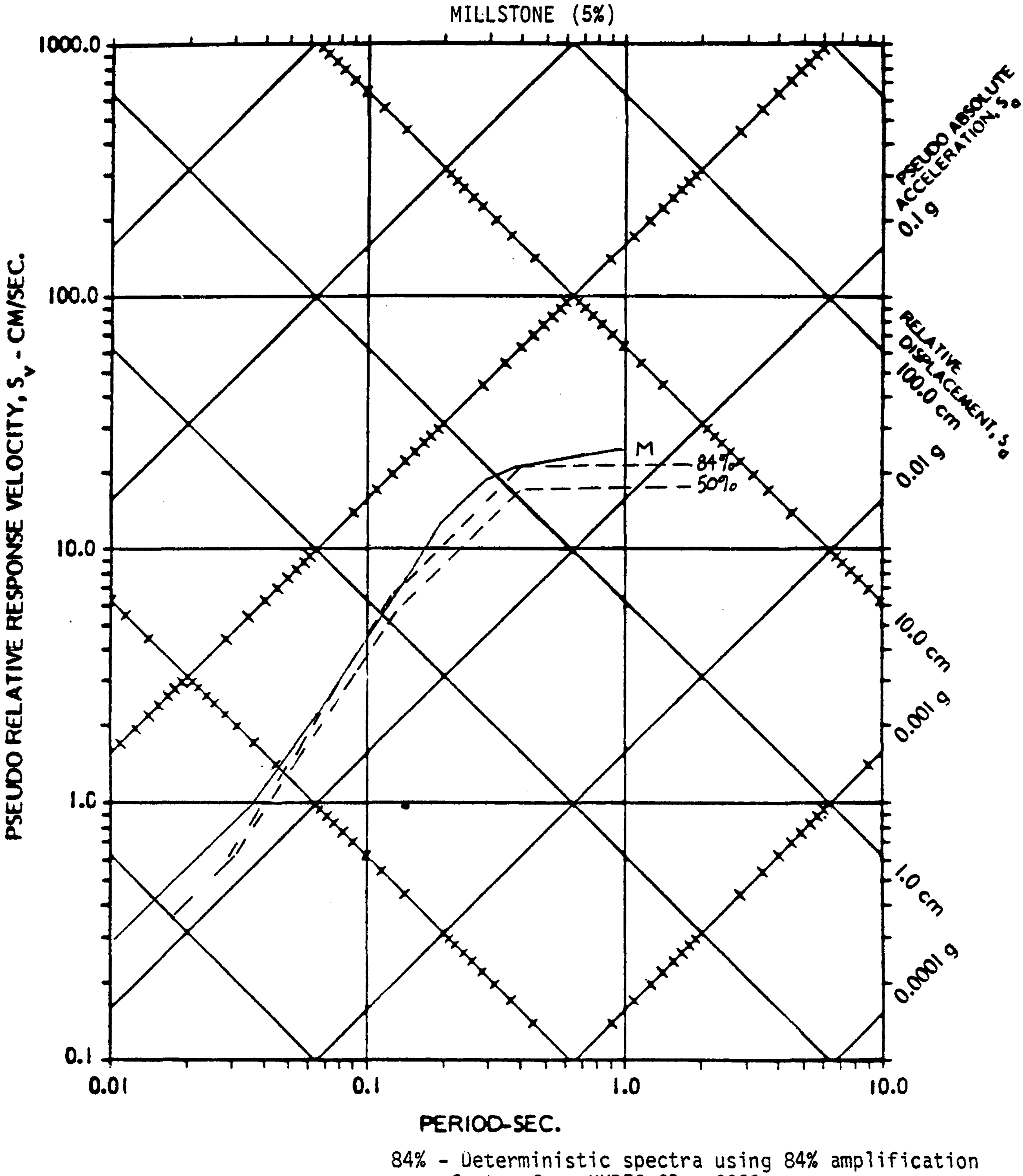


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spestra using 50% amplification factor from NUREG CR - 0098.

H - Recommended probabilistic spectra.

Figure 4

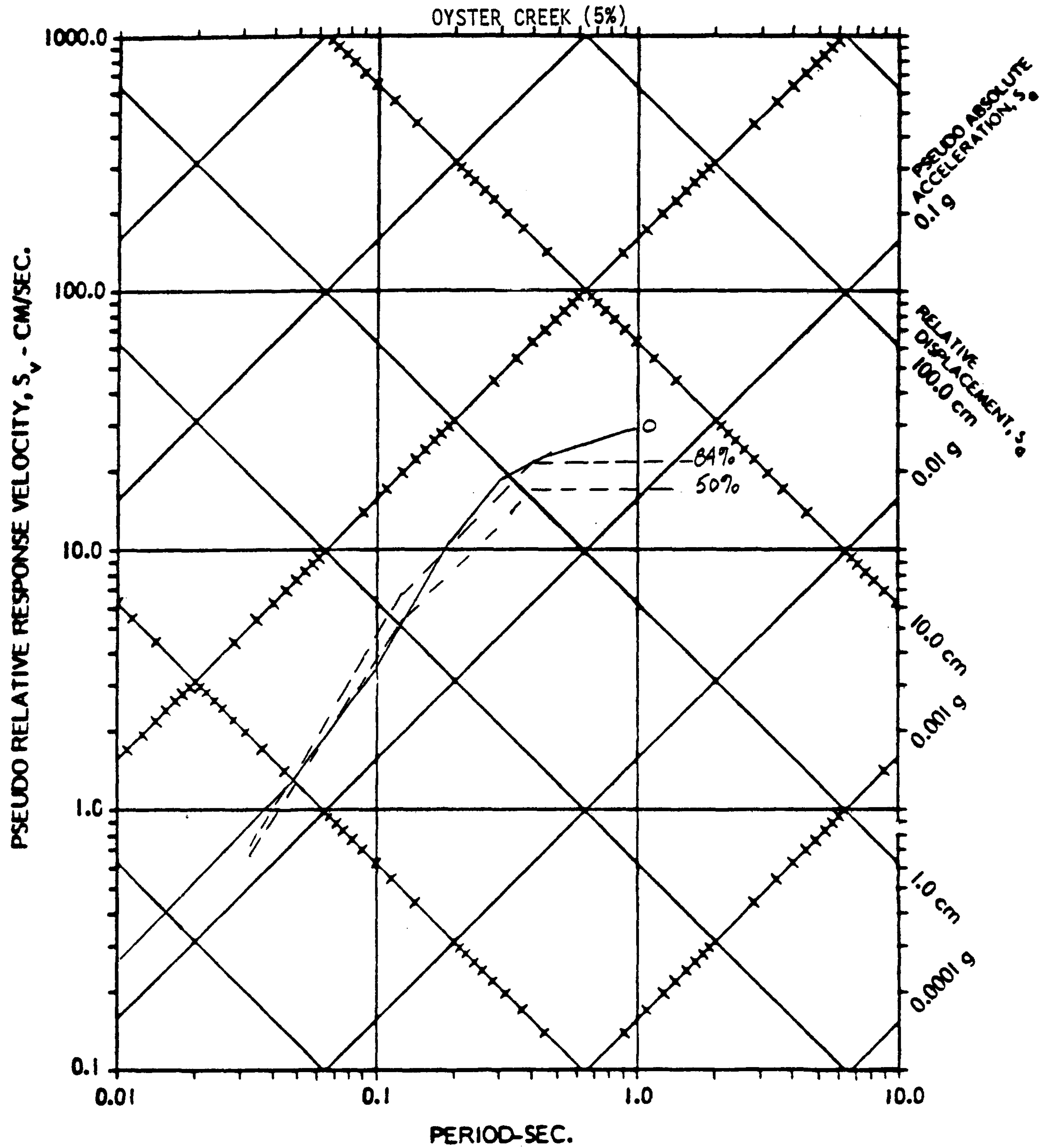


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

M - Recommended probabilistic spectra.

Figure 5

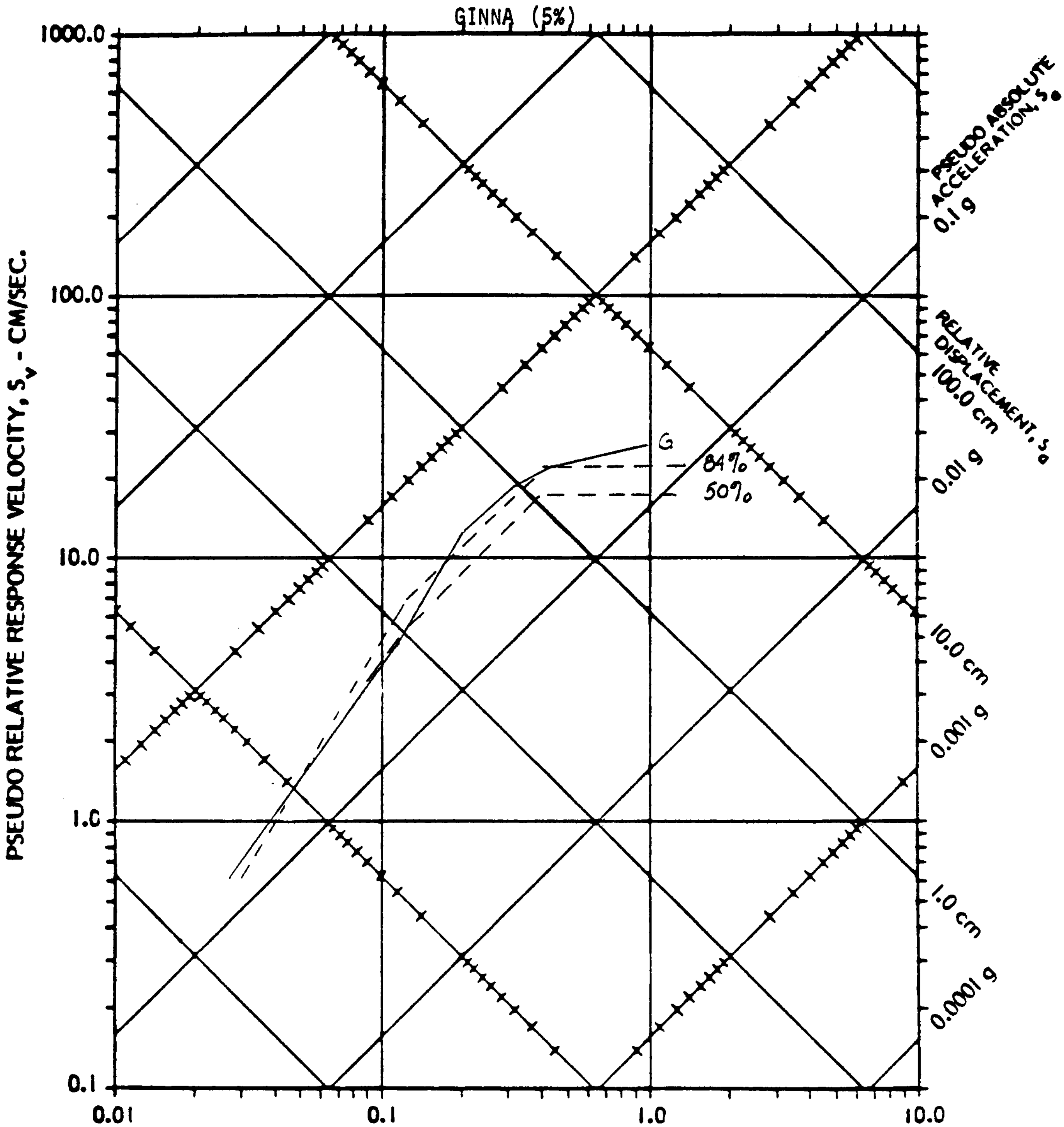


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

0 - Recommended probabilistic spectra.

Figure 6

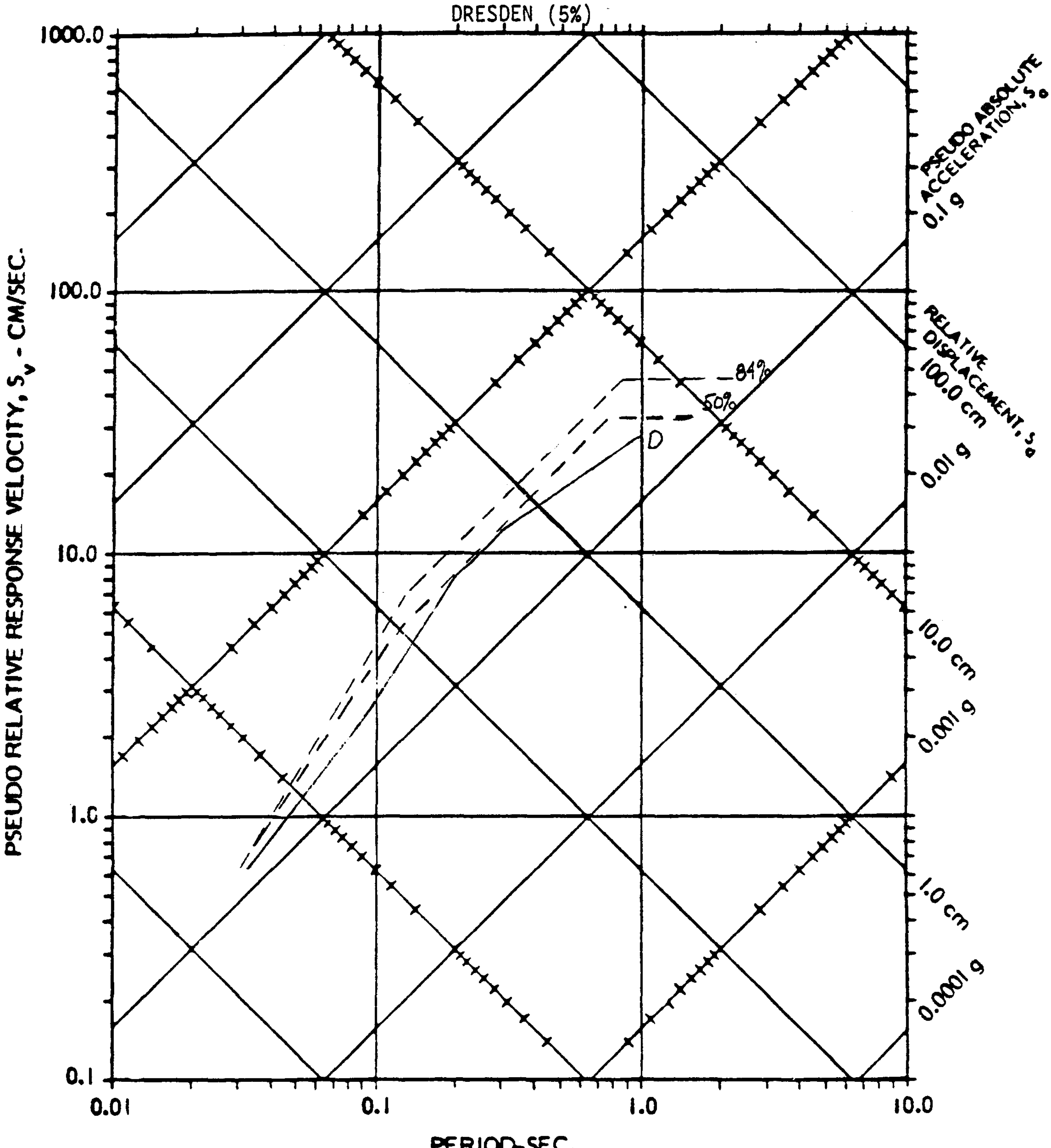


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

G - Recommended probabilistic spectra.

Figure 7

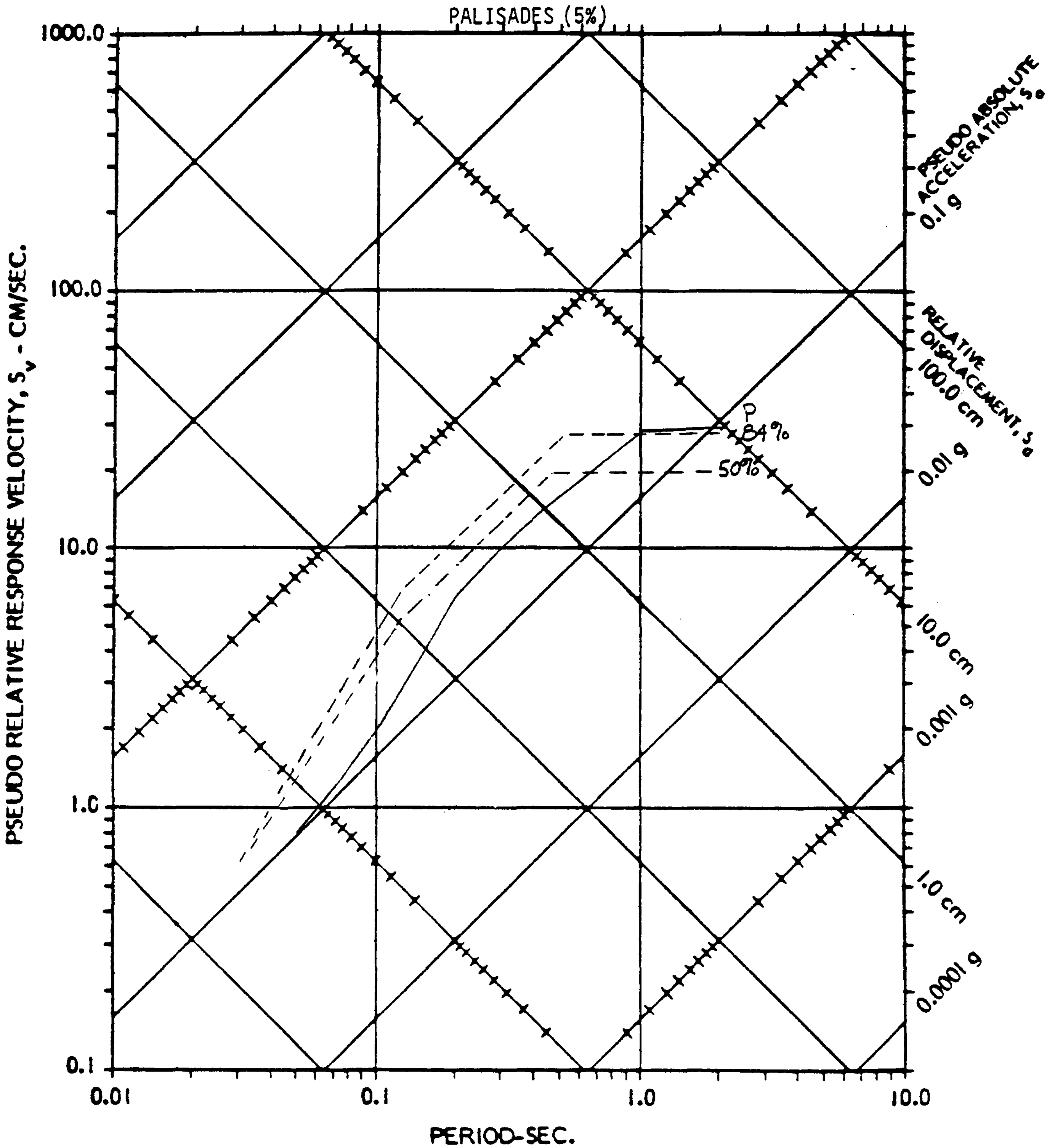


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

D - Recommended probabilistic spectra.

Figure 8

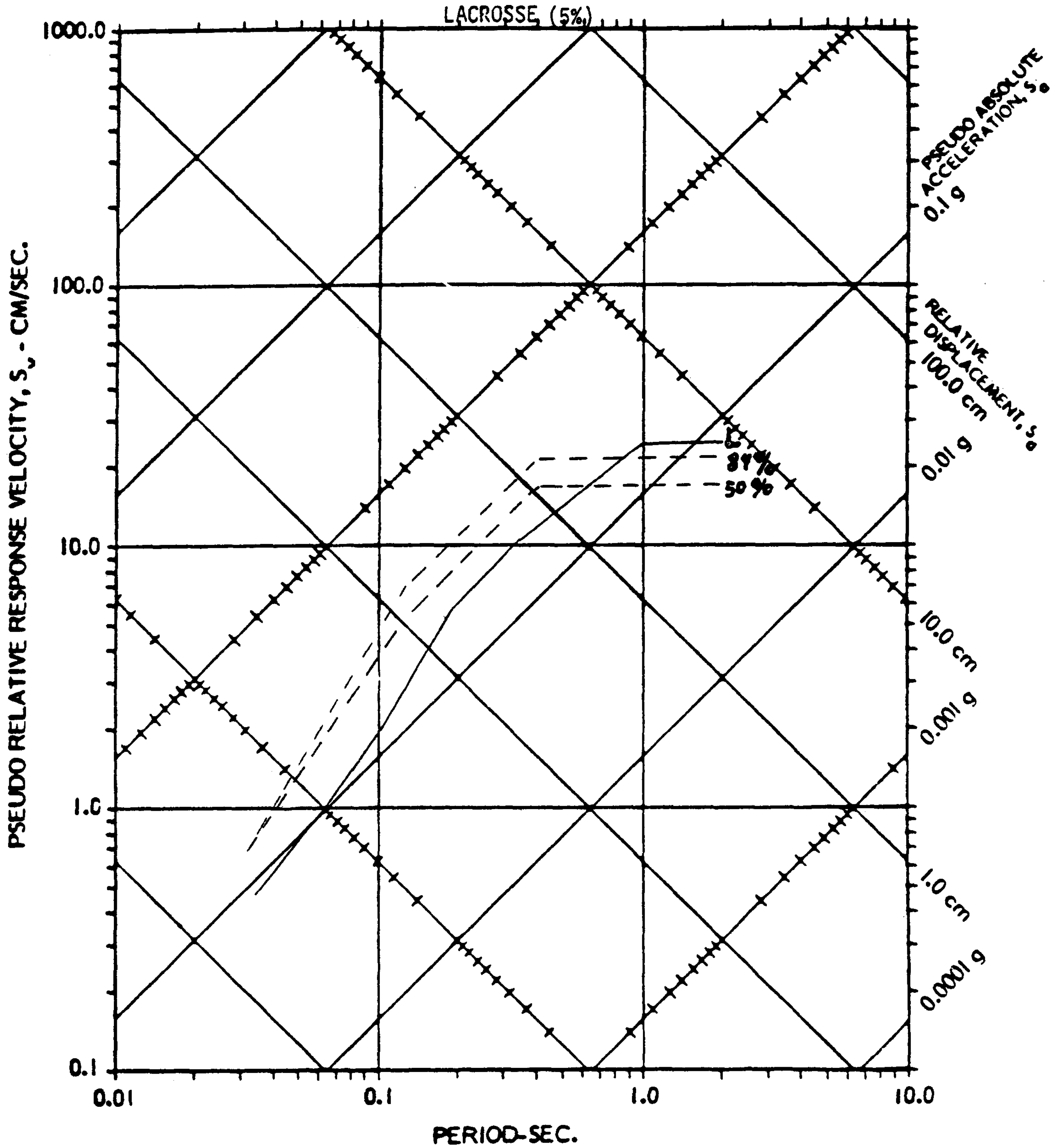


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

P - Recommended probabilistic spectra.

Figure 9

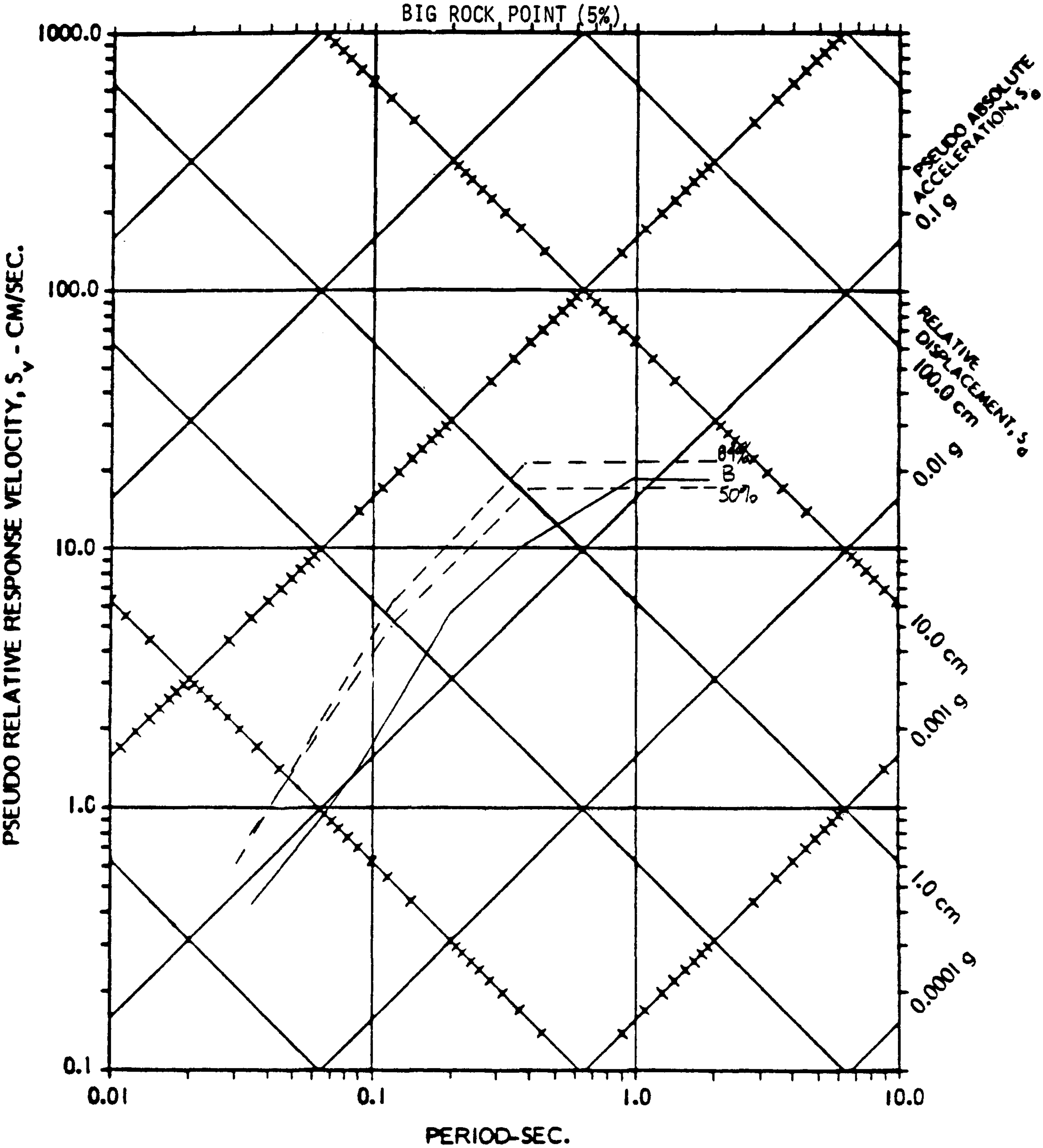


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

L - Recommended probabilistic spectra.

Figure 10



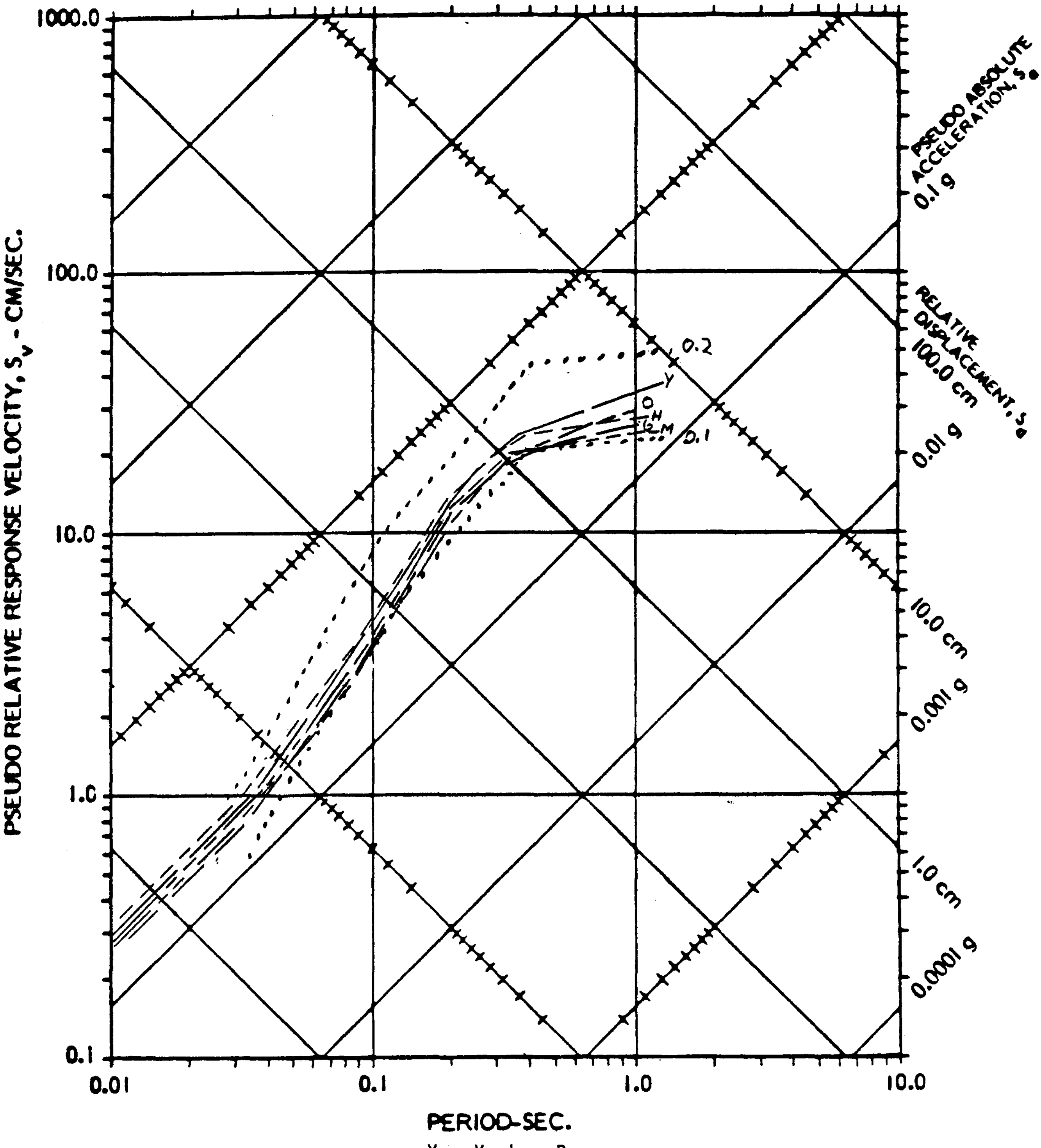
84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

50% - Deterministic spectra using 50% amplification factor from NUREG CR - 0098.

B - Recommended probabilistic spectra.

Figure 11

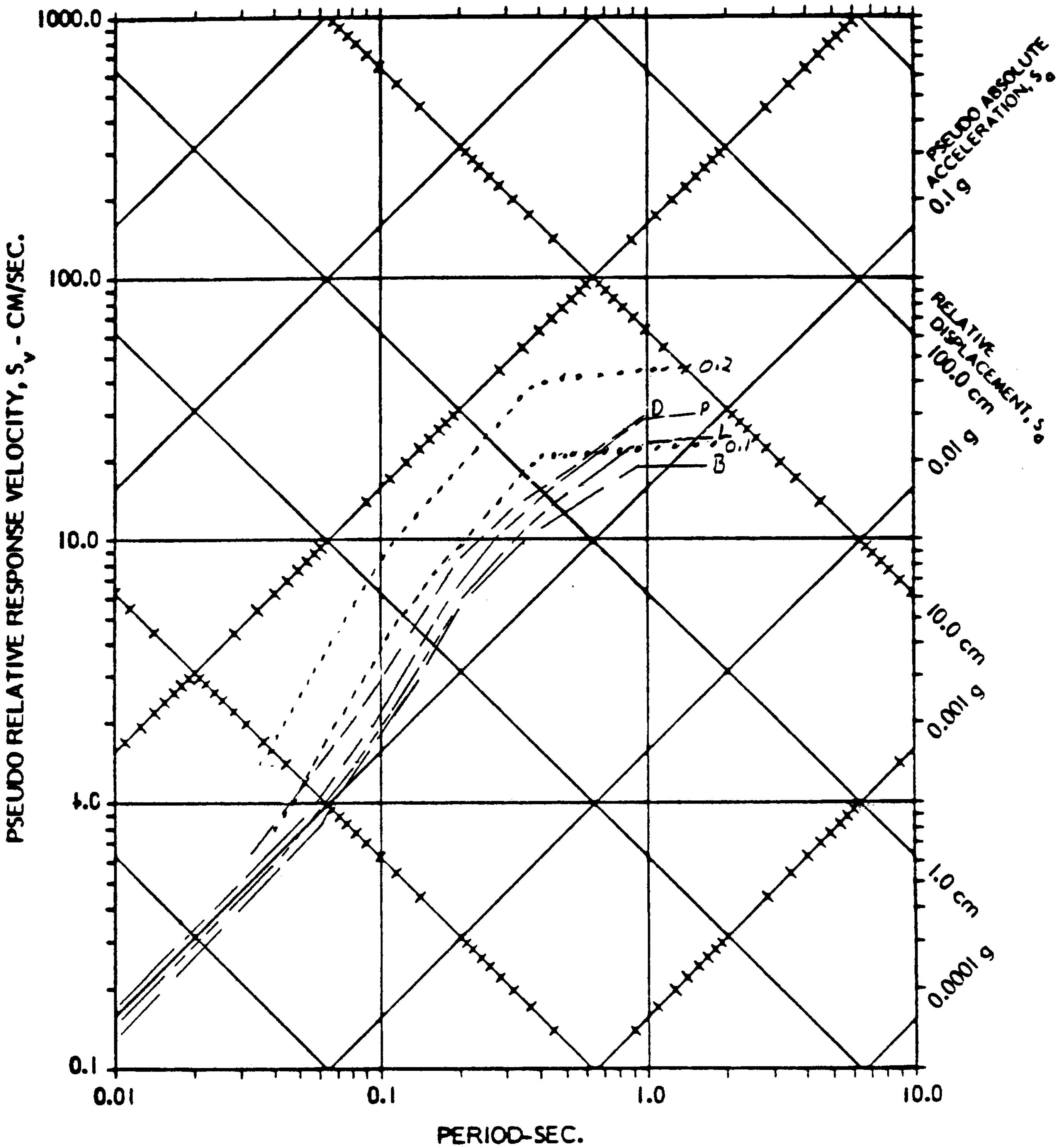
E.U.S. Recommended Probabilistic Spectra and Regulatory Guide 1.60 Spectra



Y - Yankee Rowe
O - Oyster Creek
H - Haddam Neck
G- Ginna
M- Millstone
0.1 - R.G. 1.60 anchored at 0.1g
0.2-R.G. 1.60 anchored at 0.2g

Figure 12

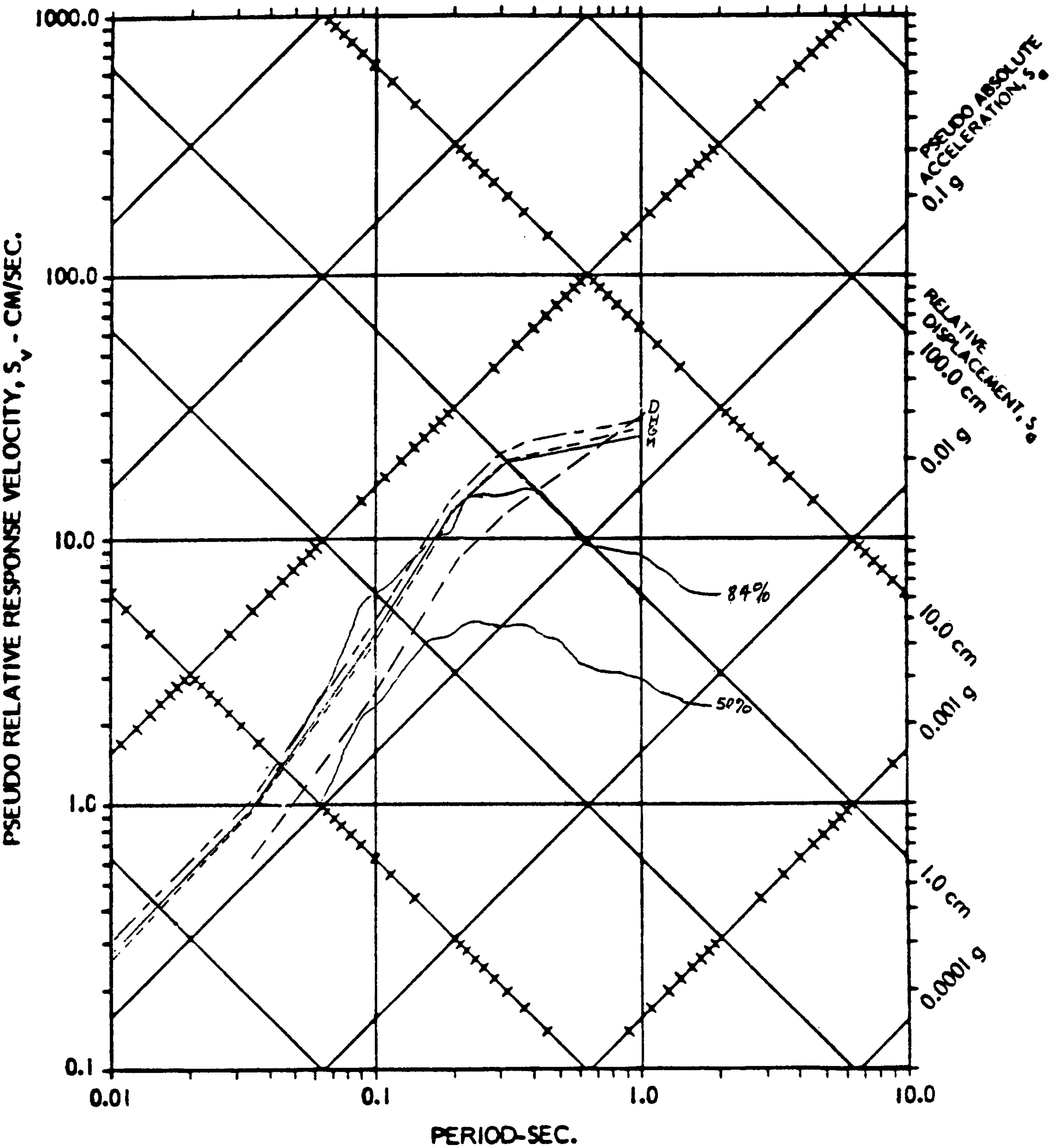
C.U.S. Recommended Probabilistic Spectra and
Regulatory Guide 1.60 Spectra



D - Dresden
P - Palisades
L - LaCrosse
B - Big Rock Point
0.1 - R.G. 1.60 anchored at 0.1g
0.2 - R.G. 1.60 anchored at 0.2g

Figure 13

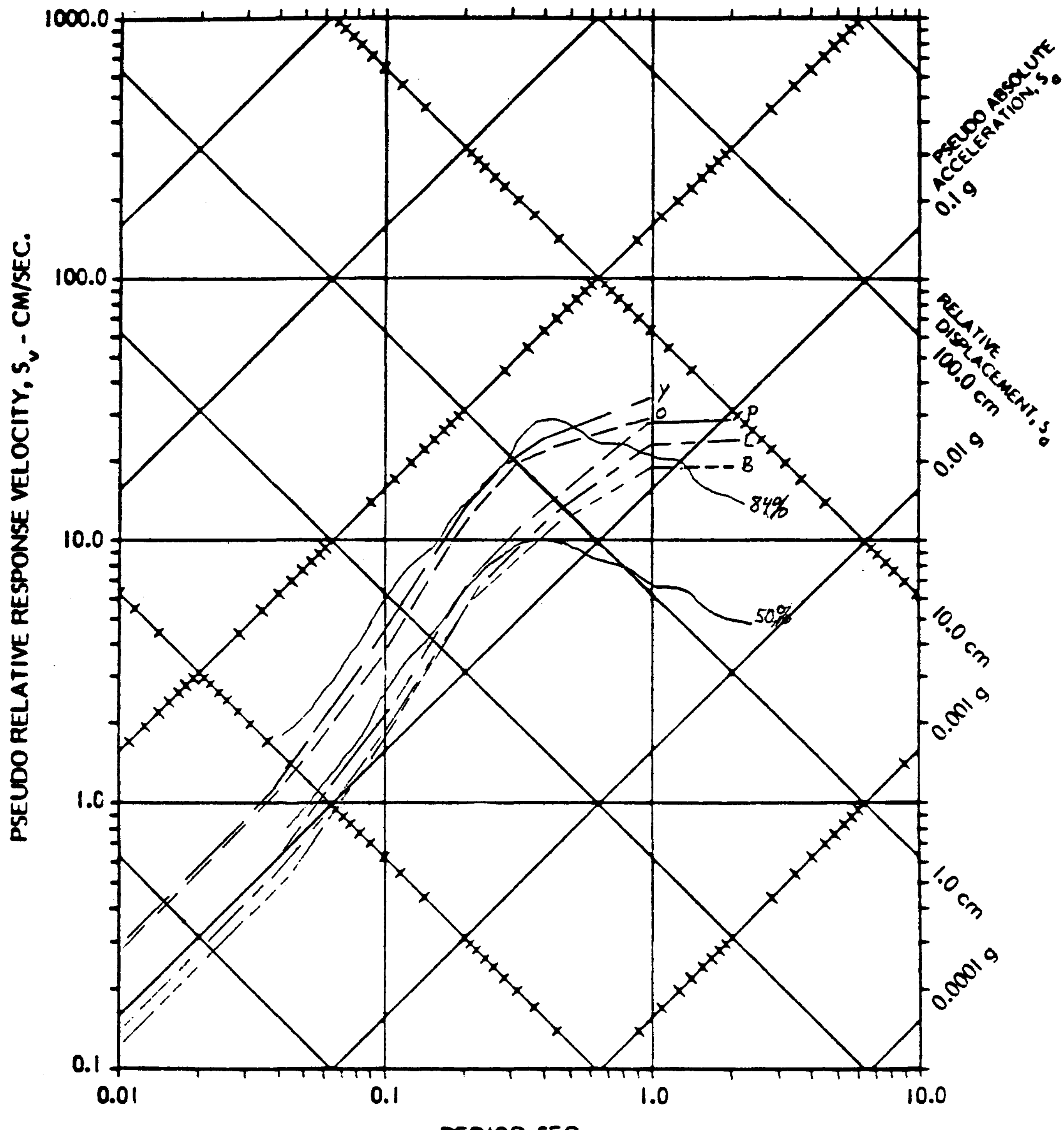
Recommended Probabilistic Spectra at Rock Sites and Recorded Spectra at Rock Sites



D-Dresden
H - Haddam Neck
G-Ginna
M-Millstone
84% - 84% spectra from nearby Mag. 5.3 ± .5 event.
50%-50% spectra from nearby Mag. 5.3 ± .5 event

Figure 14

Recommended Probabilistic Spectra at Soil Sites and
Recorded Spectra at Soil Sites



y - Yankee Rowe
O - Oyster Creek
P - Palisades
L - LaCrosse
B - Big Rock Point
84% - 84% spectra from nearby Mag. 5.3 ± .5 event
50% - 50% spectra from nearby Mag. 5.3 ± .5 event

Figure 15

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 20 1981

MEMORANDUM FOR: William Russell, Chief
Systematic Evaluation Program Branch
Division of Licensing

THRU: James P. Knight, Assistant Director
for Components and Structures Engineering
Division of Engineering

FROM: Robert E. Jackson, Chief
Geosciences Branch
Division of Engineering

SUBJECT: FINAL REVIEW AND RECOMMENDATIONS FOR SITE SPECIFIC SPECTRA AT SEP SITES

On April 24, 1981, we received the most important outstanding items related to the Site Specific Spectra Study, Drafts of Volumes 4 and 5 of Seismic Hazard Analysis (Lawrence Livermore Laboratories). Please find enclosed our final review of this study with respect to the SEP. This review and our recommendations were prepared by Dr. Leon Reiter of the Geosciences Branch and are attached to this memorandum. A summary of these recommendations is:

1. We reaffirm the spectra recommended in the "Initial Review and Recommendations for Site Specific Spectra at SEP Sites" (Memorandum from R. Jackson to D. Crutchfield, June 23, 1980).

2. We find no need to reduce the spectra at rock sites. This possibility was raised in the June 23, 1980 Memorandum.

3. We have not taken into account possible anomalous site conditions at Palisades, LaCrosse or Yankee Rowe.

4. Application of this study and its review recommendations to other sites or other programs should be examined on a case by case basis.

We consider the recommended spectra and the evaluation of their conservatism as described in the section entitled "Conservatism of Recommended Spectra" in the attached review to be consistent with the general SEP approach. The assessment of these spectra with respect to safety and design adequacy should be considered within the context of structural and mechanical performance of plant structures, piping and equipment.

MAY 2 0 1981

Based upon our ongoing review of site geology to satisfy SEP Topics II-4; Geology and Seismology, and II-4B: Proximity of Capable Structures to the Site, we do not anticipate that our final review of these topics will have any impact upon the recommended spectra.

Robert E. Jackson, Chief
Geosciences Branch
Division of Engineering

Enclosure:
As stated

cc: w/enclosure
R. Vollmer
D. Eisenhut
G. Lainas
W. Russell
T. Cheng
D. Crutchfield
F. Schauer
H. Levin
L. Wight, TERA Corp.
G. Lear
L. Heller
D. Bernreuter, LLNL
—GSB Personnel

FINAL REVIEW AND RECOMMENDATIONS FOR SITE SPECIFIC SPECTRA AT SEP SITES

Purpose and Scope

This review presents final recommendations for Site Specific Spectra to be used in the reevaluation of SEP plants. It supplements "Initial Review and Recommendations for Site Specific Spectra at SEP Sites" (Memorandum from R. Jackson to D. Crutchfield, June 23, 1980, and referred to below as Initial Review) and is based upon those items reviewed for the Initial Review plus the following documents.

(1) Seismic Hazard Analysis: Volume 4, NUREG/CR-1582, Application of Methodology, Results and Sensitivity Studies (Draft) D. L. Bernreuter, LLNL April 1981 NUREG/CR-1582. (Referred to below as Volume 4).

(2) Seismic Hazard Analysis: Volume 5, NUREG/CR-1582, Peer Review, Eastern Ground Motion Panel and Formal Feedback (Draft) D. L. Bernreuter LLNL, April 1981 (Referred to below as Volume 5).

(3) Final Report Seismic Hazard Analysis: Results, TERA Corporation, February 1981.

(4) Introduction tu Ground Motion Panel, TERA Corporation, February 1980.

(5) Second Round Questionnaire, TERA Corporation, September 1980.

(6) Seismic Hazard Analysis: Solicitation of Expert Opinion Second Round Questionnaire, TERA Corp., January 1981.

All of the above documents and many of those listed in the initial review will appear in their final form as text or appendices in volumes 4 and 5 of NUREG/CR-1582 Seismic Hazard Analysis. Two segments of this study, Volume 2, "A Methodology for the Eastern U.S.," and "Volume 3, "Solicitation of Expert Opinion," have already been published. Volume 1 of this series, which represents an executive summary of the study, has not yet been submitted. Items originally listed in the Initial Review which have not been received are:

(1) Review of the Draft Seismic Hazard Analysis by the USGS,

(2) Additional Review and Comments by Drs. Newmark and Hall.

Licensee submittals for individual SEP sites are being handled by the SEP Branch separately on a case by case basis.

Recommendations

In the Initial Review the following recommendation was made.

> "It is recommended that the following spectra presented in the Sensitivity Results (May 1980) be used as site specific free field spectra.
>
> Eastern U.S. (Yankee Rowe, Connecticut Yankee, Millstone, Ginna, Oyster Creek) - "1000 year" spectra assuming no background and Ossippee Attenuation.
>
> Central U.S. (Dresden, Palisades, LaCrosse, Big Rock Point) - "1000 yr" spectra assuming no background and Gupta-Nuttli Attenuation.

These spectra account for gross site conditions (soil or rock) and do not take into account any specific conditions which may result in amplification (LaCrosse, Yankee Rowe, Palisades).

It is also recommended that a minimum be established for which no spectra be allowed to go below. It is suggested that this minimum be the median (50th percentile) representation of real spectra for a magnitude 5.3 earthquake. This minimum exceeds the "1000" yr spectra for Big Rock Point, LaCrosse and Palisades at frequencies greater than 2 to 3 Hz."

Based upon review of the documents and information received since preparation of the Initial Review, we conclude that the recommended spectra as described above in the Initial Review are appropriate for use in the Systematic Evaluation Program. The rationale for this conclusion is discussed below.

Digitized response spectral values (5% damping) for each site and a scaling relationship which can be used to derive spectra at other damping values are attached to this review (Enclosure 1).

Basis for Previous Recommendation

As described in the Initial Review the above recommended spectra depend upon several important assumptions by the staff. They are:

(1) The appropriate ground motion model to be used in the Central-U.S. was that based upon a modification of the Gupta and Nuttli (1976) relation.

(2) The appropriate ground motion model to be used in the northeastern U.S. was that calculated from the 1940 Ossippee earthquake. The particular version of the Ossippee model to be used is that which was originally presented since it is more analagous to that used by Gupta and Nuttli (1976) for the central U.S. and falls closest to theoretical models of ground motion.

3) The appropriate zonation assumptions should be intermediate between those labeled "Background" and "No Background".

4) The appropriate dispersion assumed for ground motion estimation should be $\sigma = 0.7$ (natural logarithms) truncated at $\pm 3\sigma$.

5) The recommended spectra can be associated with return periods of the order of 1,000 to 10,000 years.

The additional review herein concentrates upon the appropriateness of the preceeding assumptions in light of the new material received.

Feedback and Second Round Questionnaire

The most important item received since the previous review centers about convening the experts for a round table discussion and the submittal by them of answers to a second-round questionnaire. At the meeting of the experts the results of the first questionnaire, calculated results, and sensitivity parameters were presented and discussed. This meeting was followed by submittal of a second round questionnaire which gave each expert the opportunity to modify his input to the study regarding the seismicity models used in the LLNL/TERA analysis. In addition each expert was asked to explicitly address those issues which were not adequately discussed previously and were shown to have an important effect upon the calculated spectra. It is important to point out that in the interim (between responding to the first and second questionnaires) there occurred an $m_{blg} = 5.2$ earthquake in Kentucky.

This was the largest event to occur in the U.S. east of the Rocky Mts. since the southern Illinois earthquake of 1968 and it provided an opportunity to test the effect of new information upon the experts' input and the calculated spectra.

Change in Seismicity Models

Most of the experts suggested some changes in their seismicity models. While many of these changes were minor, some had possible major impact upon the calculated results. One expert provided a significantly different seismic zonation than he previously had provided, several changed their upper magnitude cut-off and two experts suggested modified b values. Qualitative assessments of the impact of these changes on calculated results were originally made (Volume 5) indicating net changes in resulting ground motion for individual experts ranging from a 5% decrease to a 30% increase in the central U.S. and from a 15% decrease to a 15% increase in the eastern U.S. It was also felt that the effects of these individual changes in the input would lead to changes in the synthesis that would certainly be less than 15% in the central U.S. and less than 10% in the eastern U.S. LLNL recalculated results (Volume 5) for four of the experts. (The generic parameters were the same as those recommended in the Initial Review). The experts selected were those for whom most of the larger changes were indicated. Many of the changes were not as large as originally anticipated particularly for the expert who had large changes in zonation. As a result of the recalculations it was estimated (LLNL) that the change in any synthesis would be less than 10%. Based upon our examination of the individual results we believe that this can be even further restricted to less than about 5%. This net change in synthesis ground motion would be least (a very slight increase or decrease) in the eastern U.S. and reach an increase of perhaps several percent in the central U.S. It is important to note that probabilistic estimates remain quite stable in particular those based upon a syntheses of opinion even though some of the input parameters may vary significantly. This is due primarily to the balancing effects which result from the changes in different input parameters for the same expert and the balancing effects which result from changes in input parameters from different experts.

Feedback on Generic Assumptions

The experts were asked to provide their input on generic assumptions previously assumed in the study which were applied to all the inputs uniformly. With respect to the assumption of "background" vs. "no background" most of the experts (6) supported the original assumption of background (and zone supposition) while the others were either unsure, rejected this concept or offered no opinion on the subject.

With regard to the choice of the ground motion model the opinion was diversified. Different models including some which were not previously considered were recommended. There seemed to be a preference for intensity attenuation based upon several earthquakes and the use of different models for the central and northeastern regions. Some recommended the use of theoretical models. With respect to the uncertainty assumed in the ground motion model the experts recommended the use of standard deviations (σ) which ranged from $\sigma = 0.5$ to $\sigma = 0.9$ with some preference for the 0.6 to 0.7 range.

<u>Effect of Second Round Questionnaire Upon Conclusions of the Initial Review</u>

As indicated above the preferred model for calculating risk suggested in the Initial Review assumed Gupta-Nuttli intensity attenuation in the central U.S., Ossippee Intensity attenuation in the eastern U.S., a dispersion of $\sigma = 0.7 \pm 3\sigma$ and an intermediate position between "background" and "no background". Zone superposition was assumed to be coincident with the assumption of background. Since calculations were not carried specifically for this model of dispersion and background, existing models were examined and we concluded that the calculations based upon $\sigma = 0.9 \pm 2\sigma$ and no background would approximate the desired results. The higher level of ground motion (+7 to +10%) in the calculated result which was caused by assuming greater dispersion was balanced by the lower level of ground motion (-7 to -10%) in the calculated result which was caused by assuming no background.

With respect to generic assumptions in the Initial Review, input from the Second Round Questionnaire can be summarized as follows.

1) There is no preferred guidance from the experts as to which intensity attenuation relation should be used.

2) The use of a standard deviation of $\sigma = 0.6$ to $0.7 \pm 3\sigma$ (Second Round expert preference) as compared to the use of $\sigma = 0.9 \pm 2\sigma$ would result in a decrease of 10 to 15% in estimated ground motion at the level recommended in the Initial Review (Volume 5).

3) The use of a generic seismicity model which favored the use of background (Second Round expert preference) with respect to a model which assumed no background would result in an increase of about 10% or more in estimated ground motion at the level recommended in the Initial Review.

4) The use of revised inputs for seismicity and zonation would result in an estimated change of 5% or less in estimated ground motion at the level recommended for the various sites in the Initial Review.

Based upon the above discussion, we estimate that inclusion of input from the Second Round Questionnaire would lead to calculated site specific spectra which would be roughly similar to those recommended in the Initial Review differing at most by several (less than 10) percentage points. This is not to say however that an individual expert would not or could not provide input that would lead to calculated spectra that were different. Slight variations in the choice of attenuation model and ground motion dispersion alone could have a major impact upon the results. What these results do indicate however is the relative stability of integrated estimates synthesized from different individual input assumptions.

Comparison with Other Studies

The Final Report Seismic Hazard Analysis: Results, (TERA Corporation, 1981) includes a comparsion with several other seismic hazard studies. In general it was found that when using input taken from other studies with the TERA computer code, the same results were obtained and that the difference between these results and those obtained using input from the expert panel could be explained by differences in assumptions. One of the studies compared was a probabilistic assessment of ground motion carried out to assess the likelihood of liquefaction at LaCrosse (Dames and Moore, 1980). Taking into account the variations in input, the Dames and Moore (1980) study and that performed by TERA-LLNL are in close agreement.

An interesting comparison was also made utilizing a "pseudo-historical" analysis at Dresden and Yankee Rowe. In this analysis, no zonation is assumed and the probability of exceeding a given level of ground motion is determined entirely from the historical record. Lacking instrumental records the ground motion itself is estimated from a given attenuation model. These estimates are sensitive to the inclusion of rare events such as the 1811, 1812 New Madrid Series and have not been corrected for homogeneity or upper magnitude cutoff. They do however yield results that are generally within the range of ground motion estimates calculated from the inputs of the individual experts for these sites.

Adequacy of Spectra for Rock Sites

In the cover letter to the Initial Review it was indicated that a reduction in spectra at intermediate and low frequencies may be called for at rock sites (Dresden, Ginna, Haddam Neck and Millstone). The change (Table 5-2, Final Report Seismic Hazard Analysis: Results, TERA Corporation, 1981) was recommended by TERA Corporation based upon its restructuring (weighting) of the strong motion data set used in ground motion estimation primarily to avoid overemphasis upon the 1971 San Fernando Earthquake. While this restructuring may be valid for estimating ground motion as a function of magnitude and intensity or distance, LLNL has pointed out (Volume 4) that it also results in a significant reduction in the number of rock records since many such records resulted from the San Fernando Earthquake. We agree therefore with LLNL's assessment that the original nonweighted model is more appropriate for determining differences in ground motion between rock and soil sites and no reduction is called for.

Conservatism of Recommended Spectra

Our estimate in the Initial Review was that although the recommended spectra were labelled "1000 year" spectra the actual return periods associated with these spectra were longer. TERA Corporation had estimated these actual return periods to be closer to 5,000 or 10,000 years. While we were not sure what the precise estimates were we concluded that they were consistent with the previous implicit acceptance of design spectra that were assumed to have return periods of the order of 1,000 or 10,000 years. As a result of this final review we find no new information that changes our previous estimate.

Since other levels of ground motion-spectra could fit into this range of probabilities it is worthwhile reexamining the criteria by which the recommended spectra were found to be appropriate.

1. These spectra, whatever their true return periods actually are, represent approximately equivalent levels of seismic hazard at the different SEP sites currently being considered and represent a more consistent estimate to be used in seismic analysis than standard "deterministic" procedures. These "deterministic" procedures generally rely upon tectonic provinces and controlling earthquakes regardless of the size of the tectonic province or the frequency of earthquake occurrence. As a result, these procedures can lead to the acceptance of different levels of seismic hazard at different locations. The recommended spectra generally indicate a relatively greater earthquake hazard associated with sites in the northeast when compared to sites in the upper midwest.

2. When compared to the deterministic procedure recommended for use in the SEP in NUREG/CR-0098 the recommended spectra as a group bracket the 50th and 84th percentile deterministic spectra as calculated in the Initial Review.

3. When compared to non-probabilistic site specific spectra derived from real records, an approach currently being pursued with many OL reviews, the recommended spectra vary from the 84th percentile to the 50th percentile representation of a magnitude 5.3 earthquake. The 50th percentile of the

spectra from real records was specified in the Initial Review as the minimum which recommended spectra would not be allowed to fail. The 84th percentile is that level which has been used in OL reviews.

4. The recommended spectra form a band centered about the Regulatory Guide spectrum anchored at 0.1g. New plants licensed in these areas would most likely utilize peak accelerations of 0.12 to 0.20 g to anchor the Regulatory Guide Spectrum.

Based upon the above discussion we consider this approximate overlap of the higher of the recommended spectra with the mid to lower range of those spectra estimated applying current deterministic criteria to indicate that the recommended spectra can be generally associated with the higher end of the range of implicitly assumed seismic hazard that has been found acceptable using current criteria.

Lacking more defined levels of acceptable seismic hazard and a prescribed method for calculating this hazard, the use of individual and often non-quantifiable judgement cannot be avoided in assessing the results of this study so as to integrate it with other techniques into a decision-making framework.

Based upon the above comparison it is our position that the recommended spectra represent the appropriate levels of free field ground motion to be used in the SEP for the purpose of evaluating the seismic design adequacy of the selected plants.

Application of this study and its review recommendation to other sites or other programs should be examined on a case by case basis.

Anomalous Site Conditions

As was indicated in the Initial Review these spectra only account for gross site conditions (soil or rock). No attempt was made to consider soil amplification beyond that already inherent in the soil records used in the study. LaCrosse, Palisades, and Yankee Rowe have been identified as having site conditions which may be anomalous with respect to those site conditions associated with the soil records used in this study.

Enclosure 1

SEP 17 1980

DISTRIBUTION
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DE RDG
HLEVIN

MEMORANDUM FOR: Dennis M. Crutchfield, Chief
Systematic Evaluation Program Branch

FROM: Howard Levin, Technical Assistant
Division of Engineering

SUBJECT: DIGITIZED PSEUDO SPECTRAL ACCELERATION DATA FOR SEP PLANTS

Attached are digitized pseudo spectral acceleration values (5% damping) for the preliminary site specific ground response spectra transmitted to you in a letter from R. Jackson, dated June 23, 1980. Noted is a scaling relationship which can be used to convert from the 5% damped spectra to spectra in the range of 2% to 20%.

Howard Levin, Technical Assistant
Division of Engineering

cc: D. Eisenhut
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SYSTEMATIC EVALUATION PROGRAM
SITE SPECIFIC SPECTRA
PSEUDO SPECTRAL ACCELERATIONS (cm/sec^2)

Period	Yankee Rowe	Oyster Creek	Ginna	Haddam Neck	Millstone	Big Rock Pt.	LaCrosse	Palisades	Dresden
.04	208.00	172.61	178.85	215.91	196.23	122.29	122.29	122.29	134.40
.05	213.69	178.17	192.52	228.92	210.91	130.19	130.19	130.19	142.56
.08	247.74	206.77	230.16	279.47	253.44	152.05	152.05	152.05	164.92
.10	275.68	229.98	258.38	316.00	287.00	179.69	179.69	179.69	181.76
.20	434.80	363.77	388.92	475.17	433.65	213.50	213.50	214.77	270.73
.30	455.49	376.59	375.82	456.79	415.45	201.96	201.96	224.41	267.48
.40	408.76	339.90	328.79	395.71	360.53	171.68	195.71	218.32	249.33
1.0	224.32	180.98	165.10	183.25	165.68	122.90	151.98	174.57	185.13
2.0	93.80	64.12	60.85	67.56	59.84	59.65	77.51	91.85	33.98
PGA	195.20	161.33	168.65	202.48	184.16	102.50	.02.50	102.50	124.15
PGV*	22.48	18.41	16.92	19.66	17.82	11.39	13.50	15.18	16.05

CONVERSION TO OTHER DAMPING VALUES (RANGE 2% - 20%)

$$PSA_{x\%} = PSA_{5\%} \times 10^{(C_T x (\text{new damping}(x) - .05)}$$

Period	C_T
.04	**
.05	**
.065	-0.290
.08	-0.600
.10	-0.904
.13	-1.270
.20	-1.700
.30	-1.990
.40	-1.950
.75	-1.810
1.0	-1.960
2.0	-1.600

* Units =cm/sec
** Statistically Insignificant Coefficient, Use 5% PSA Value

REFERENCES

Bernreuter, D.L., "Methods to Develop Site Specific Spectra and a Review of the Important Parameters that Influence the Spectra," Lawrence Livermore National Laboratory, UCRL-52548, 1979.

Cornell, C.A. "Engineering Seismic Risk Analysis," Bulletin of the Seismological Society of America, 58, 1583-1606, 1968.

Dames and Moore, "Seismic Ground Motion Hazard at LaCrosse Boiling Water Reactor, Wisconsin, Draft Report," Docket 50-409, June 13, 1980.

Gupta, I.N. and O.W. Nuttli, "Spatial Attenuation of Intensities for Central U. S. Earthquakes," Bulletin of the Seismological Society of America, 66, 743-751, 1976.

Nuttli, O.W. and R. B. Herrmann, "Credible Earthquakes for the Central United States," Miscellaneous Paper S-73-1, State-of-the-Art Report 12, U.S. Army Engineer Waterways Experiment Station, Dec. 1978.

Trifunac, M.D. and A.G. Brady, "On the Correlation of Seismic Intensity Scales with the Peaks of Recorded Strong Ground Motion," Bulletin of the Seismological Society of America, 65, 139-162, 1975.

U.S. Nuclear Regulatory Commission, NUREG/CR-0098, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," N. M. Newmark and W. J. Hall. NM Newmark Consulting Engineering Services. 1978.

U. S. Nuclear Regulatory Commission, NUREG/CR-1582, "Seismic Hazard Analysis," 5 Volumes.

Volume 1, "Overview and Executive Summary," D.L. Bernreuter and C. Minichino. To be published 1983.

Volume 2, "A Methodology for the Eastern U.S.,"Lawrence Livermore National Laboratory/ TERA Corporation. August 1980.

Volume 3, "Solicitation of Expert Opinion", Lawrence Livermore National Laboratory/ TERA Corporation. August 1980.

Volume 4, "Application of Methodology, Results and Sensitivity Studies", D.L. Bernreuter, 1981. Lawrence Livermore National Laboratory.

Volume 5, "Review Panel, Ground Motion Panel and Feedback Results," D.L. Bernreuter, 1981. Lawrence Livermore National Laboratory.

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16. ABSTRACT (200 words or less)
This document presents the U. S. Nuclear Regulatory Commission (NRC) Geosciences Branch review and recommendations with respect to earthquake ground motion considerations in the Systematic Evaluation Program (SEP) Phases I and II. It evaluates the probabilistic estimates presented in the 5 volume report entitled "Seismic Hazard Analysis" (NUREG CR-1582) and compares and modifies them to take into account deterministic estimates. It presents the NRC's Geosciences Branch first approach to utilizing complex state-of-the-art probabilistic studies in an area where probabilistic criteria have not yet been set and where decisions for specific plants have been previously made in a non-probabilistic way.

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