ATTACHMENT 1

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

January 4, 1980

MEMORANDUM FOR: Olan D. Parr, Chief
Light Water Reactors Branch No. 3, DPM

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

SUBJECT: STAFF RESPONSE TO WILLIAM H. WARD'S LETTER ON SEISMIC ISSUES AT WOLF CREEK

Enclosed is the Staff response to William H. Ward's petition to the Commissioners requesting at least a partial suspension of the construction permit for the Wolf Creek Generating Station. This Staff response is an expanded background for the seismic issue mentioned in footnote 6 of the July 12, 1979 Director's Decision under 10 CFR 2.206. This Director's Decision by Victor Stello, Jr., IE, denied Mr. Ward's petition. It stated that the seismic issues contained in Mr. Ward's letter were previously considered by the Staff and do not alter the Safe Shutdown Earthquake at the Wolf Creek site. Based upon the enclosed evaluation of Mr. Ward's concerns and recent Staff licensing decisions, we conclude that the 0.12g Safe Shutdown Earthquake is adequately conservative and therefore recommend that Mr. Ward's request for at least a partial suspension of the construction permit for Wolf Creek be denied. Dr. Phyllis Sobel, Geophysicist, prepared this evaluation. She was assisted by Leon Reiter, Section Leader.

Original Signed by
R. E. Jackson

Robert E. Jackson, Chief
Geosciences Branch
Division of Systems Safety

Enclosure:
As stated

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R. Rothman
H. Lefevre
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D. Vassallo
H. Thornbury, IE
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STAFF RESPONSE TO WILLIAM H. WARD'S LETTER ON SEISMIC ISSUES AT WOLF CREEK

On June 29, 1979, William H. Ward, Attorney for the Mid-America Coalition for Energy Alternatives, wrote the NRC Commissioners to advise them of several seismic issues affecting the Wolf Creek site and to request at least a partial suspension of the construction permit (Attachment). It is the purpose of this Staff response to address Mr. Ward's concerns.

Concern 1. A report by the Kansas State Geological Survey (KSGS), NUREG/CR-0294, concludes that the 1867 Manhattan earthquake was at least intensity VII-VIII (MM). Mr. Ward states that this earthquake was used as the basis for the Safe Shutdown Earthquake (SSE) and that the SSE was based on the assumption that the 1867 Manhattan earthquake could occur on the Nemaha Ridge at its closest approach to the Wolf Creek site, 50 miles. In light of the new information developed by the KSGS, the .12g horizontal acceleration SSE does not now appear to be conservative to Mr. Ward.

Response. The Staff has reviewed the report by KSGS and still finds the 1867 Manhattan earthquake to be intensity VII (MM). The assignment of intensity VII-VIII is based upon an 1877 r[illegible]uefaction on a farm on the floodplain of the Kansas River. That observa[illegible]s assigned intensity VIII and placed close to the epicenter by the Kansas Geological Survey. Liquefaction is very dependent upon local site conditions and may occur in isoseismal areas that may otherwise be associated with intensities less than VIII. The staff agrees with the standard references, such as Earthquake History of the United States (1973), which list this earthquake as an intensity VII (MM).

In the Safety Evaluation Report (SER) for the Wolf Creek site, the Staff chose a Safe Shutdown Earthquake (SSE) of intensity VII (MM). This intensity was based on:

1. The maximum earthquake that could occur in the Nemaha Uplift at its closest approach to the Wolf Creek site.
2. The maximum random earthquake in the region (for example, the 1956 Catoosa, Oklahoma earthquake).

The Staff's analysis did not involve the direct use of the 1867 Manhattan earthquake since a larger earthquake (intensity greater than VIII and less than X) was assumed to occur on the Nemaha Uplift. This larger earthquake was already assumed to occur at the closest approach of the Humboldt Fault to the Wolf Creek site. Therefore, the results of the Staff's analysis (an SSE of intensity VII) are not modified by the KSGS results.

Concern 2. The size of the appropriate Wolf Creek SSE can be determined by reference to the SER for another of the SNUPPS units, Tyrone. Both Tyrone and Wolf Creek are located in the Central Stable Region Tectonic Province. The Tyrone SSE is 0.2g horizontal acceleration.

Response. The Staff's assessment of the SSE at both Wolf Creek and Tyrone considered both the maximum random earthquake and the maximum earthquake that could occur on a nearby structure. The staff has evaluated the SSE at Wolf Creek and Tyrone in light of more recent licensing decisions. As a result of this evaluation we see no evidence that the SSE at Wolf Creek is unconservative or that it is inconsistent with recent licensing decisions.

1. Random earthquake at Tyrone.

The Tyrone site is near the town of Durand in western Wisconsin. The site is in the Central Stable Region Tectonic Province. In the Tyrone SER (1975), the Staff considered the intensity VII-VIII Anna, Ohio earthquake of 1937 as the largest earthquake in the Central Stable Region which could not be reasonably associated with known geologic structure. Using the Trifunac-Brady (1975) empirical relation between intensity and ground acceleration, the mean vibratory ground acceleration corresponding to MM intensity VII-VIII is 0.2g. This evaluation of the largest random earthquake near the Tyrone site is conservative and similar to recent licensing decisions made for other sites in the Central Stable Region. The Staff, however, recognizes significant variations in the historic seismicity among subregions of this large structural tectonic province. Based on the low level of seismicity in the vicinity of the Tyrone site and had the licensee given sufficient supportive bases, the Staff may have considered an intensity lower than VII-VIII (MM) more appropriate for the random earthquake.

2. Maximum earthquake on the Midcontinent Geophysical Anomaly and its effects at the Tyrone site.

For the purpose of establishing the SSE at the Tyrone site, the Staff evaluated the effects of the maximum earthquake associated with the Midcontinent Geophysical Anomaly (MGA) on the Tyrone site (SER, 1975). The Staff assumed that an intensity VIII earthquake could occur on structures associated with the MGA. In the SER the Staff assumed that at its closest approach to the site, i.e. 45 miles, the intensity at the site due to attenuation would be reduced to intensity VII-VIII. Using current intensity-attenuation relationships for the Central Stable Region (Gupta and Nuttli, 1976) attenuation of the effects of the intensity VIII event at the closest point on the MGA to the Tyrone site, i.e. 45 miles, results in a site intensity less than VII. Using the Trifunac — Brady (1975) empirical relation between intensity and ground acceleration, the mean vibratory ground acceleration corresponding to MM intensity VII is 0.12g.

3. Random earthquake at Wolf Creek.

The Wolf Creek site lies in southeast Kansas in the Central Stable Region Tectonic Province. In the Wolf Creek SER, the Staff considered the maximum random earthquake to be intensity VII (MM). This position was reiterated in a more recent Staff decision in the same region-the Black Fox site in eastern Oklahoma (SER, 1977). The Staff recognized the low level of seismicity in the vicinity of the Black Fox site and considered the maximum random earthquake to be intensity VII.

4. Maximum earthquake on the Nemaha Uplift and its effects at the Wolf Creek site.

For the purpose of establishing the SSE at the Wolf Creek site, the Staff evaluated the effects of the maximum earthquake associated with the Nemaha Uplift (NU) on the Wolf Creek site (SER, 1975). The Staff assumed that intensities greater than VIII and less than X could occur on the Nemaha Uplift. In a more recent Staff decision for the Black Fox site (SER, 1977), the Staff found that an earthquake of intensity VIII was a more reasonable maximum event on the NU, based on similarity with other structures in the Central Stable Region which have associated seismicity. (This Staff decision was supported by the Black Fox Licensing Board Decision "Partial Initial Decision Authorizing Limited Work Authorization,' LBP-78-26, 8 NRC 102, 111 (1978), Aff'd ALAB - 573, Slip Op. at 40 (Dec. 7, 1979)). Using current intensity-attenuation relationships for the Central Stable Region (Gupta and Nuttli, 1976), attenuation of the effects of the intensity VIII event at the closest point on the NU to the Wolf Creek site, i.e. 50 miles, results in a site intensity less than VII.

Conclusion

Therefore, based upon our evaluation of the SER's for the most recent licensing decisions, we conclude that it is not necessary to have the same SSE at the Tyrone and Wolf Creek sites. Applying a current intensity-attenuation relation at both sites, a site intensity of VII is an adequately conservative value for the effects of the maximum earthquake on significant nearby structures. At the Tyrone site the maximum random earthquake was conservatively chosen to be intensity VII-VIII but the Staff could have considered a lower intensity based on the low level of seismicity in the vicinity of the site. At the Wolf Creek site credit was given for the lower level of seismicity in the vicinity of the site and the maximum random earthquake was considered to be intensity VII.

Analysis of NRC Sponsored Research Programs Affecting the Wolf Creek Site

The KSGS report mentioned in Ward's letter is part of a cooperative geologic, seismic, and geophysical research program by several state geological surveys that is seeking to define the structural setting and tectonic history of the Nemaha Uplift and the Midcontinent Geophysical Anomaly in order to provide the bases for a more realistic appraisal of the earthquake risks in the siting of nuclear facilities in the North American Mid-Continent. This information is used as a basis for continuing research and as input to the evaluation of seismic risk in the region within and around the Nemaha Uplift. The research effort thus far has increased our current data base and our understanding of earthquake phenomena in the vicinity of the Nemaha Uplift; however, this information has not indicated a need to modify any previous licensing decisions.

As part of this cooperative research program, the NRC is funding a five year detailed study of the sources of seismicity in the Nemaha Uplift area. The results of work completed in Phase I is currently being reviewed. Therefore, it is too early to assess the impact on nuclear power plant licensing. The total impact of the five year study cannot be assessed until the overall program is completed and synthesized with seismic monitoring data. The preliminary results are being considered in the development of a tectonic province or seismic zoning map of the eastern U. S.

ATTACHMENT 2

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

June 17, 1981

RECEIVED
JUN 2 3 1981
U.S. NUCLEAR REGULATORY COMMISSION

LS05-81-06-068

LETTER TO ALL SEP OWNERS
(EXCEPT SAN ONOFRE)

Gentlemen:

SUBJECT: SITE SPECIFIC GROUND RESPONSE SPECTRA FOR SEP PLANTS LOCATED IN THE EASTERN UNITED STATES

Reference: Letter to SEP Group II Plant (Big Rock Point, Dresden 1, Haddam Neck, La Crosse, Yankee Rowe) Licensees from D.G. Eisenhut, NRC dated August 4, 1980

Our letter dated August 4, 1980 (reference) issued the prelimiary version of site specific ground response spectra for the eastern United States SEP plants. Recently, these spectra have been finalized by the staff. Enclosure 1 includes the recommended ground response spectra (5% damping) for the eastern SEP sites. The bases of our final decision regarding the spectra and the digitized spectral acceleration values (5% damping) for these spectra are documented in Enclosure 2.

The site specific spectra (SSS) included in Enclosure 1 establish the ground motion acceleration values to be input into the structural reevaluation analyses to determine the resultant seismic loads. The geology reviews for Palisades, Ginna and Dresden 2 have been completed by the staff. The results of the review did not identify any geologic features that would affect the site specific spectra for those facilities. Based on our review to date for the remainder of the SEP facilities located in the eastern United States, we do not expect the SSS to be changed due to local geologic considerations.

Sincerely,

Dennis M. Crutchfield

Dennis M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Licensing

Enclosure:
As stated

cc w/enclosure:
See next page

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Mr. Frank Linder

LA CROSSE (BWR)
Docket No. 50-409

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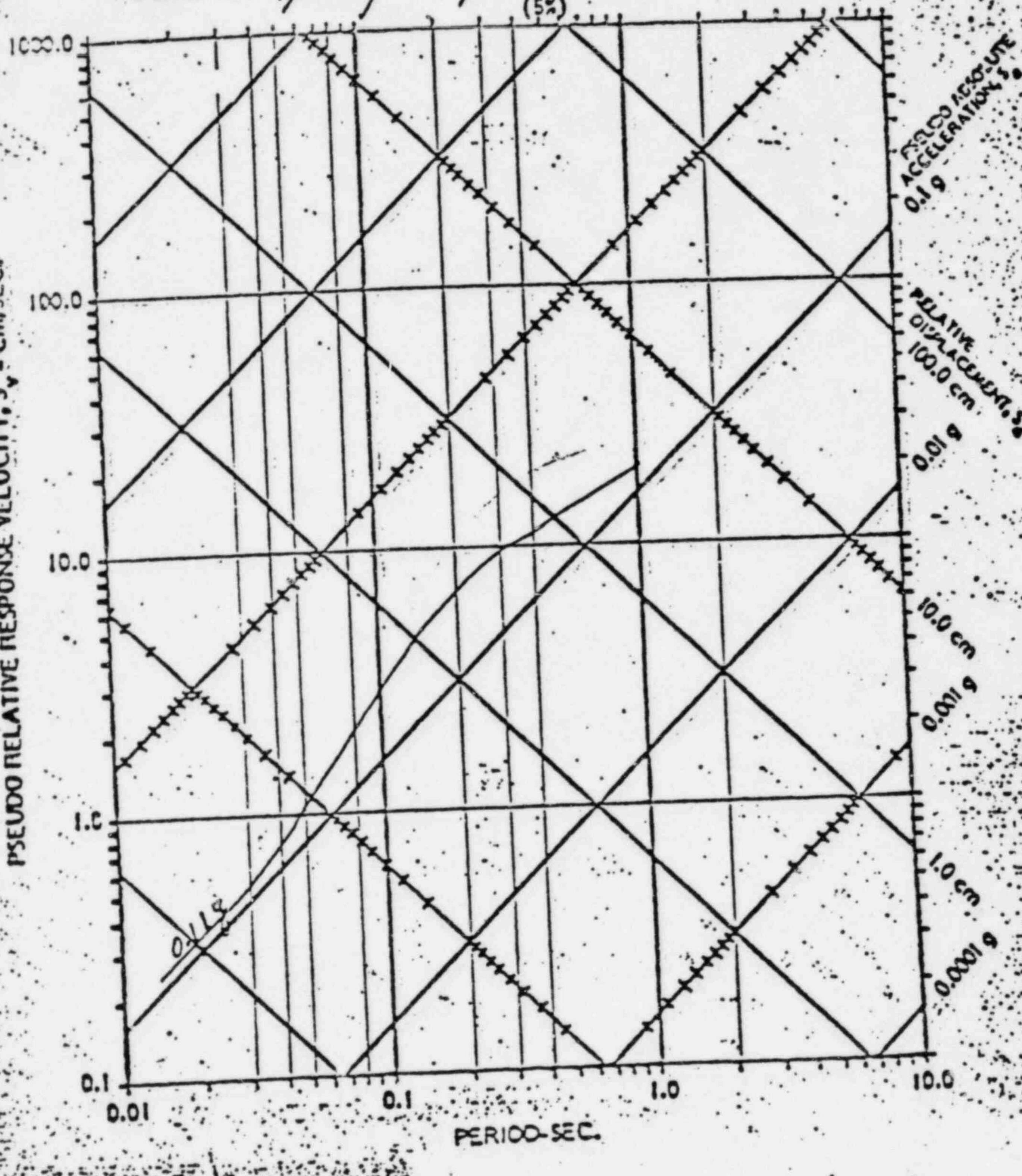
Attachment 1

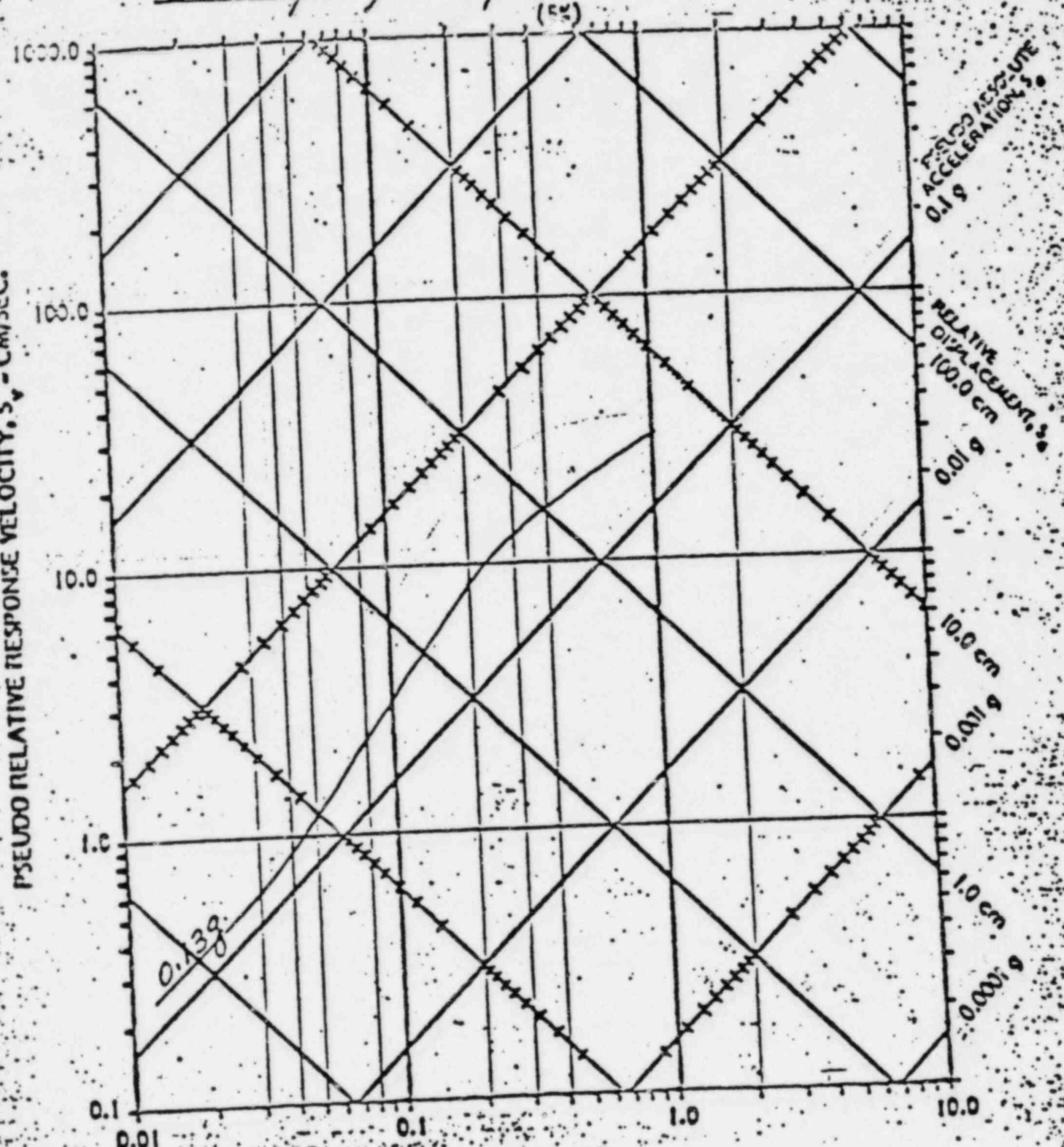
Site Specific Spectrum



Big Rock Point Site
(5% Damping)

Attachment 1

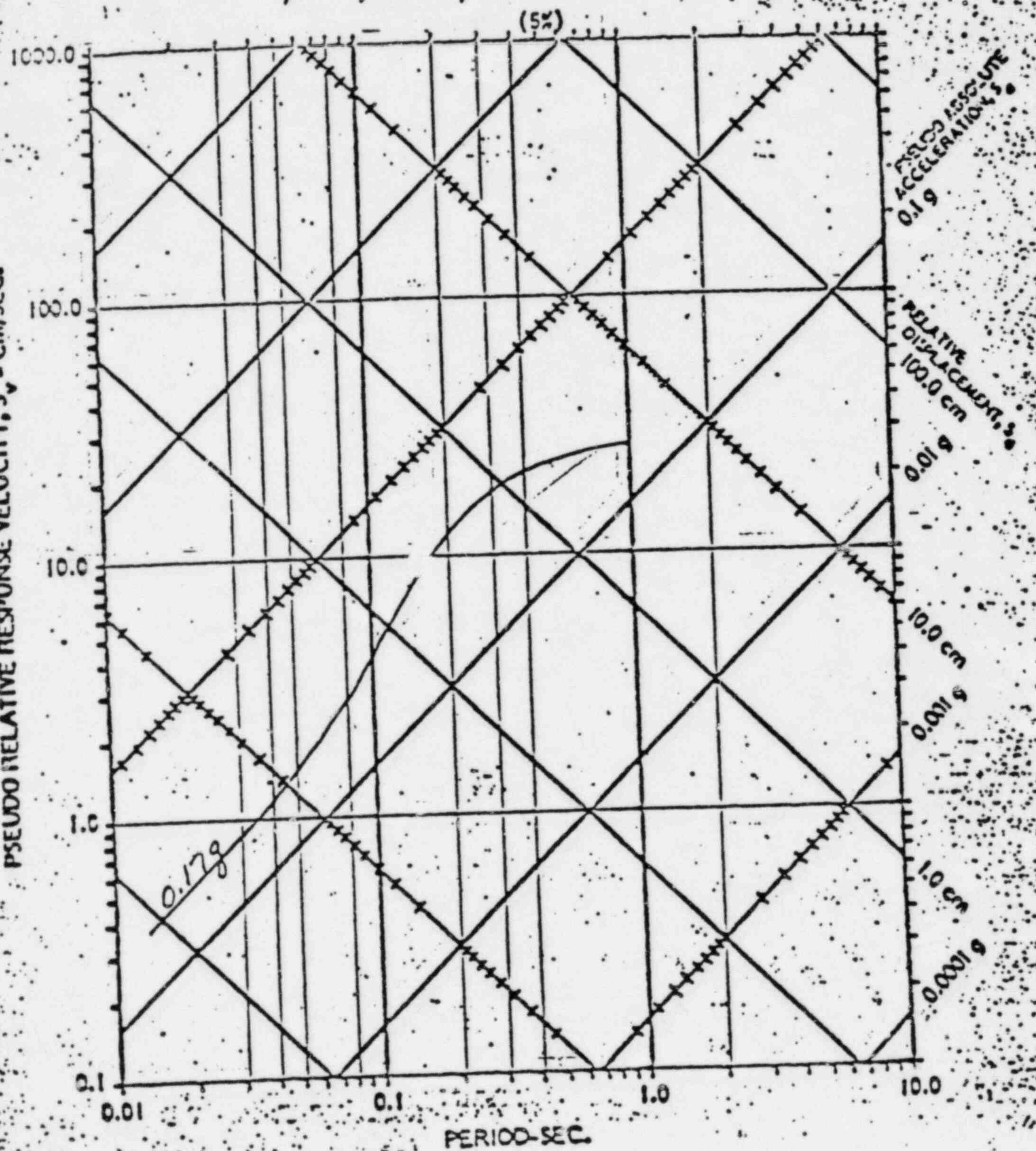
Site Specific Spectrum



Dresden Site
(5% Damping)

Attachment 1

Site Specific Spectrum

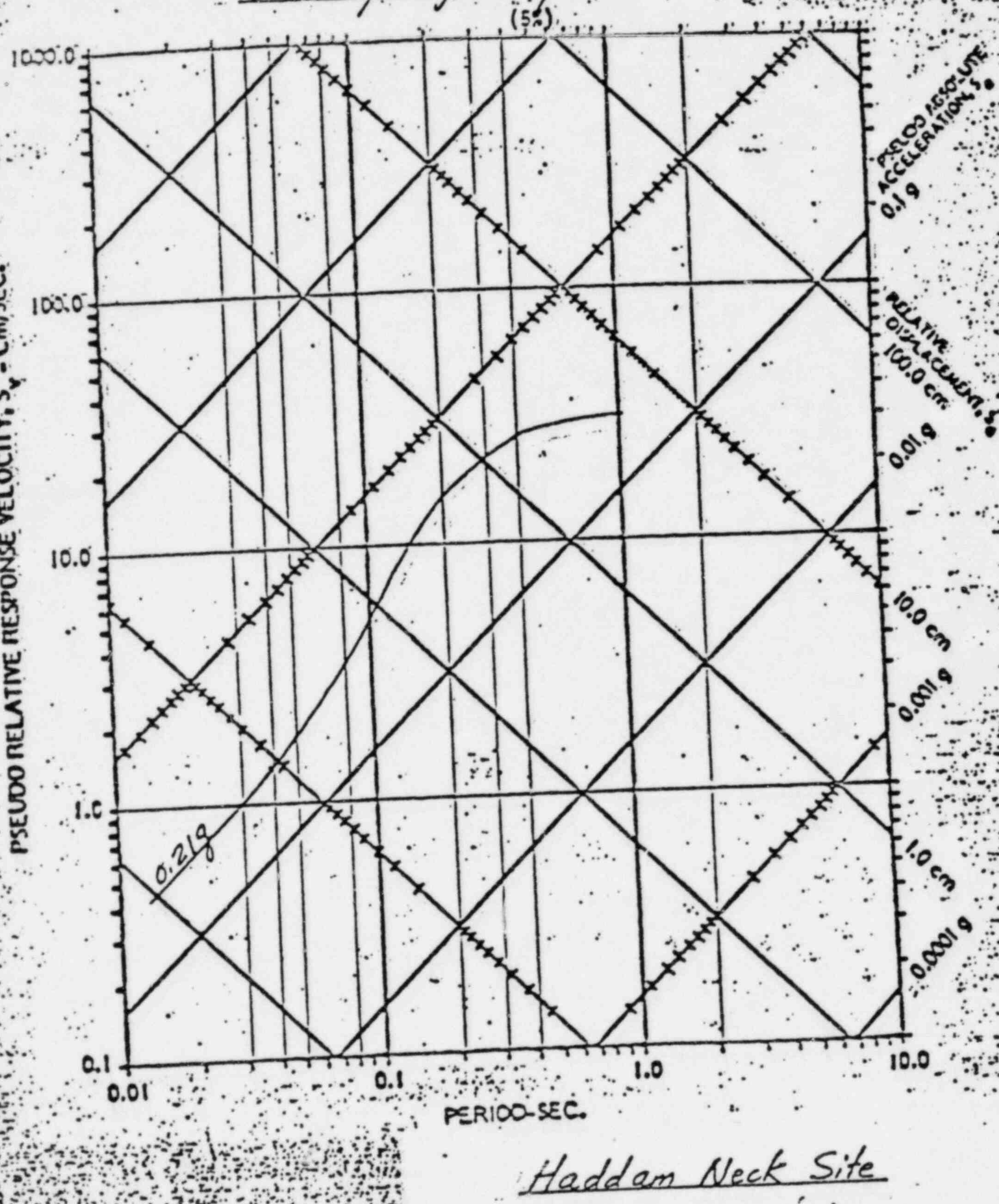


Ginna Site

(5% Damping)

Attachment 1

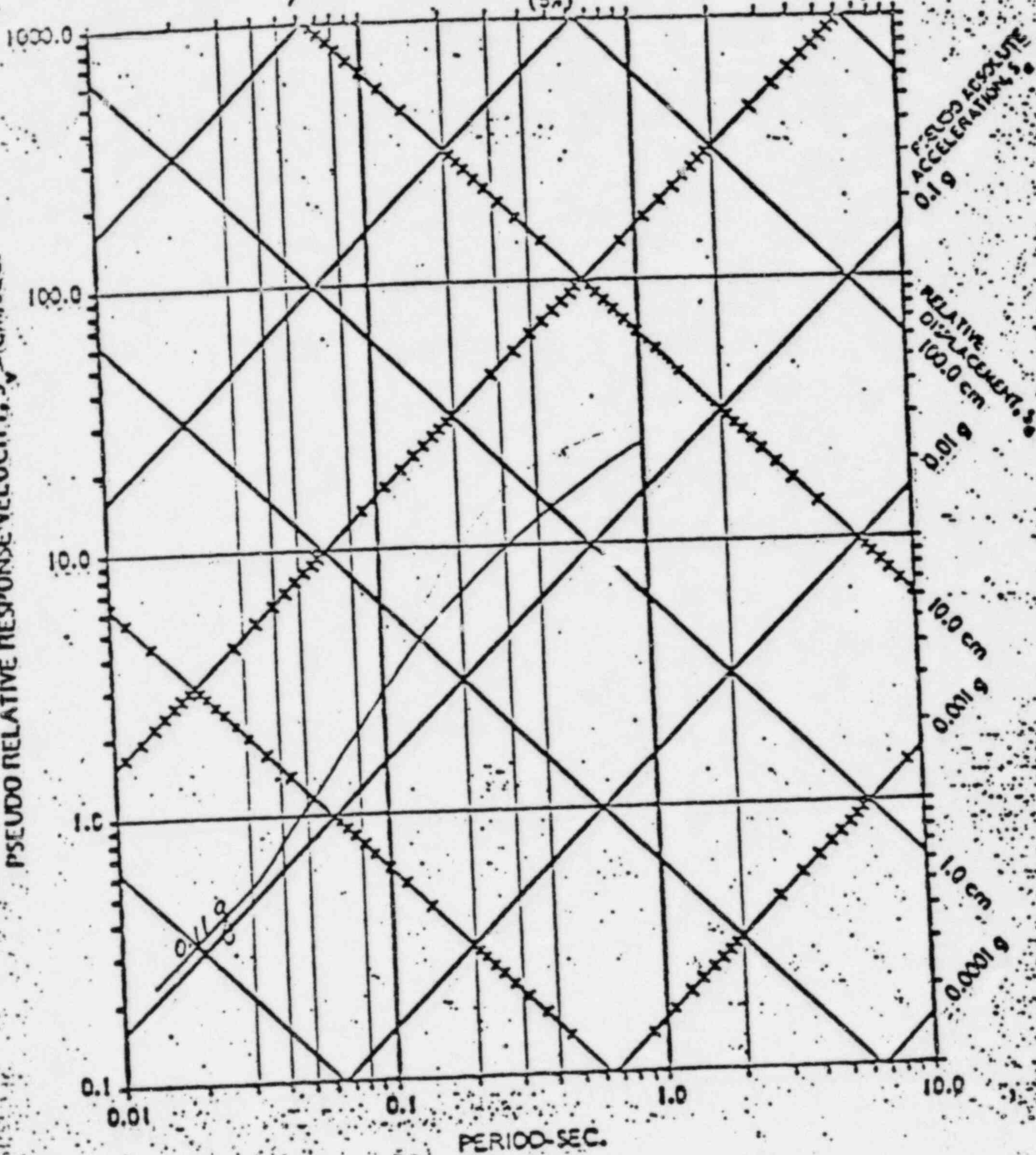
Site Specific Spectrum



Haddam Neck Site
(5% Damping)

Attachment 1

Site Specific Spectrum

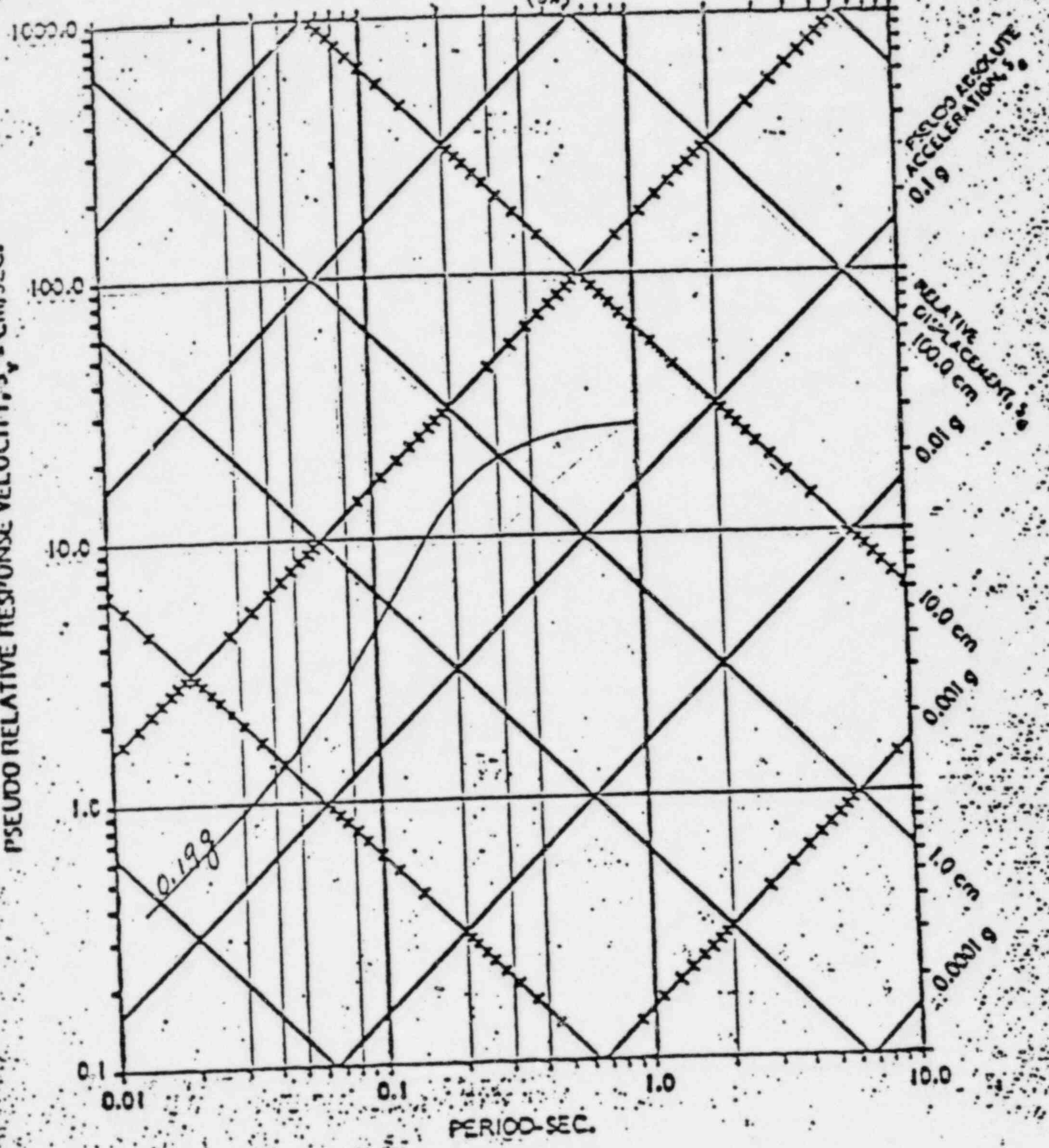


La Crosse Site

(5% Damping)

Attachment I

Site Spesific Spectram

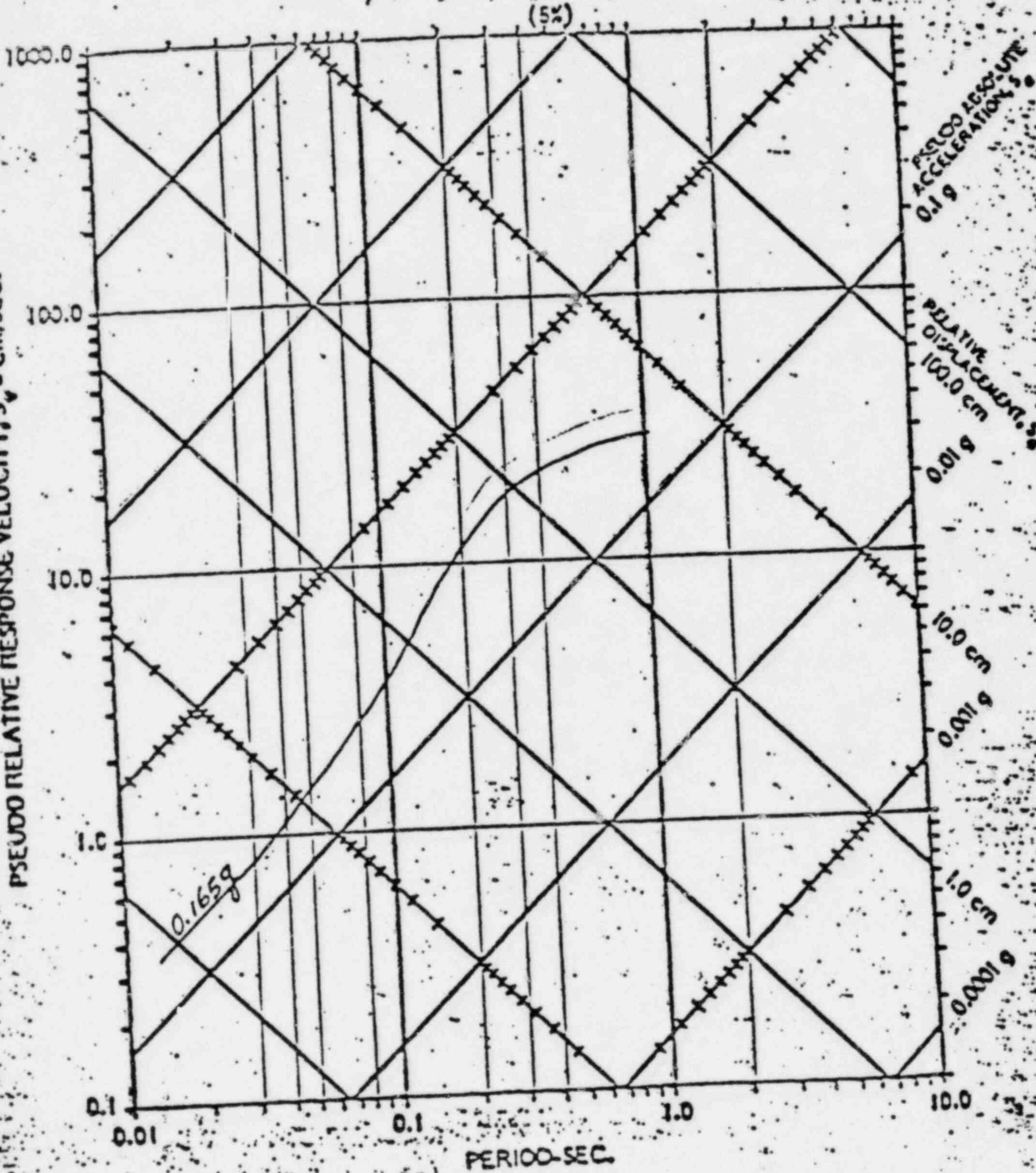


Millstone I Site

(5% Damping)

Attachment 1

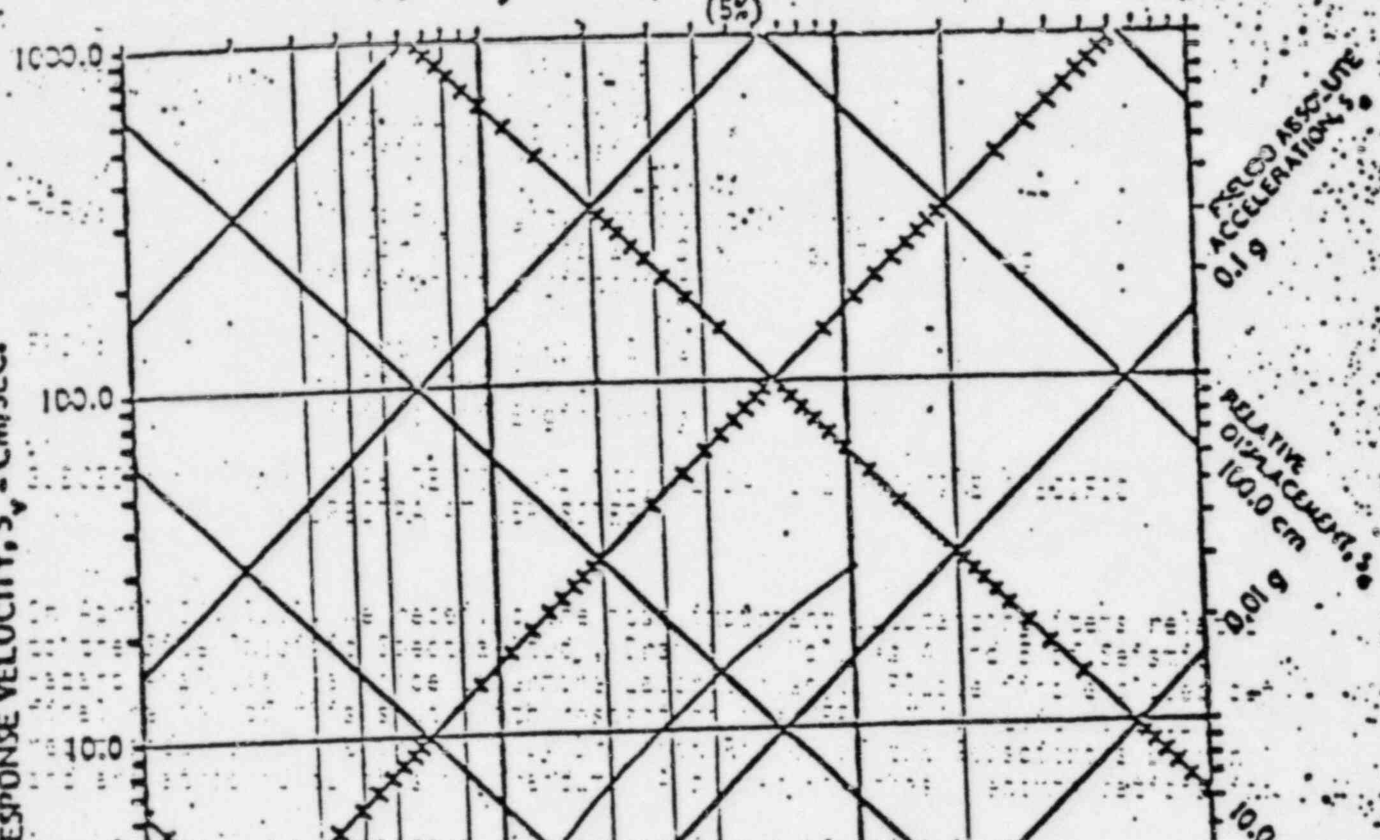
Site Specific Spectrum



Oyster Creek Site
(5% Damping)

Attachment 1

Site Specific Spectrum

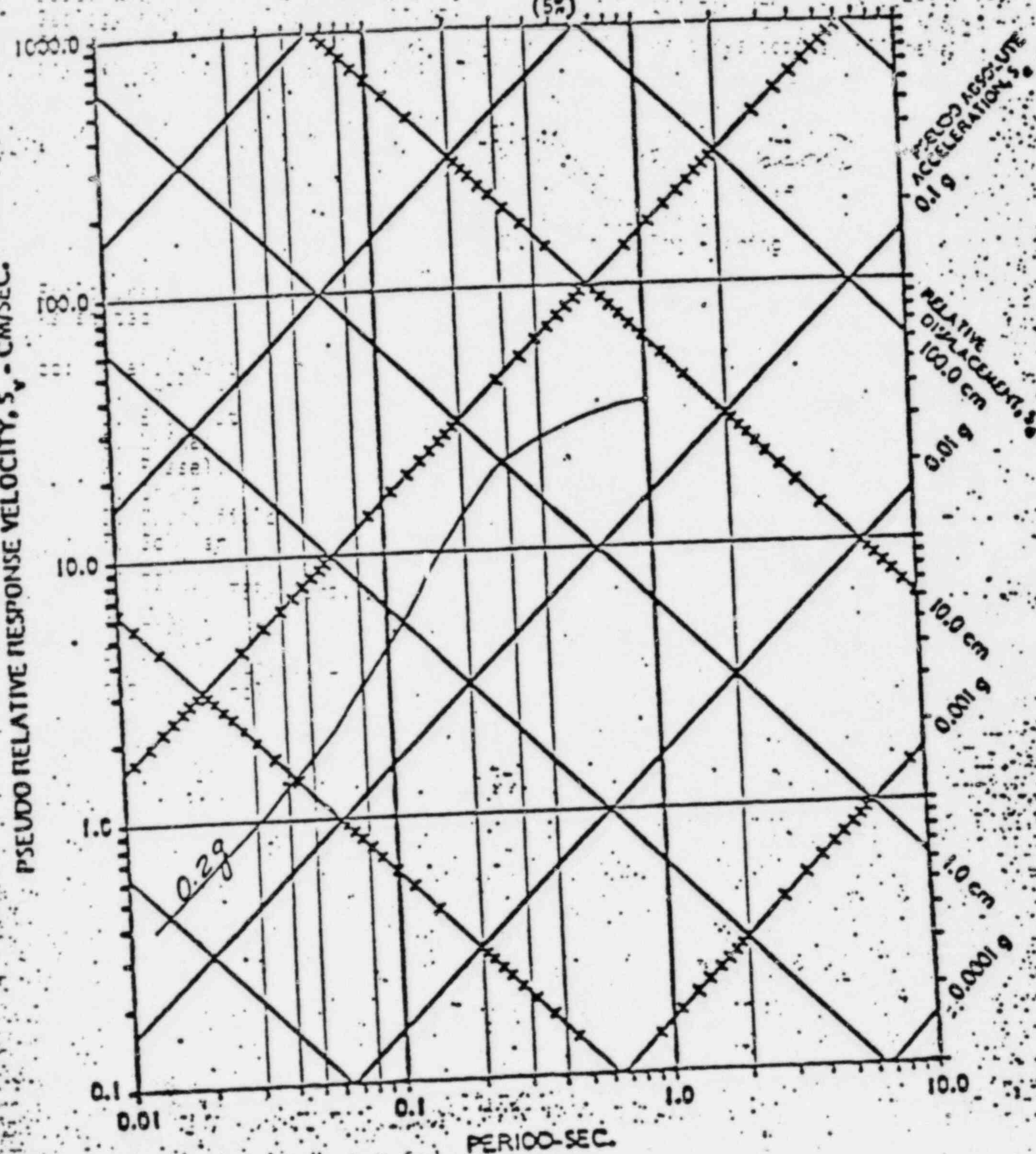


Palisades Site

(5% Damping)

Attachment 1

Site Specific Spectrum



Yankee Rowe Site
(5% Damping)

ATTACHMENT 3

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.

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PDR/LPDR

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
Division of Engineering

Enclosure:
As stated

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L. Wight, TERA
GSB Personnel

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 affects 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 its 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 only 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 exceedence) 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 synthsizing 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 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 $\sigma=0.9 \pm 2\sigma$ This is estimated to be equivalent to intermediate background and a dispersion of $\sigma=0.7$, $\pm 3\sigma$.

**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.

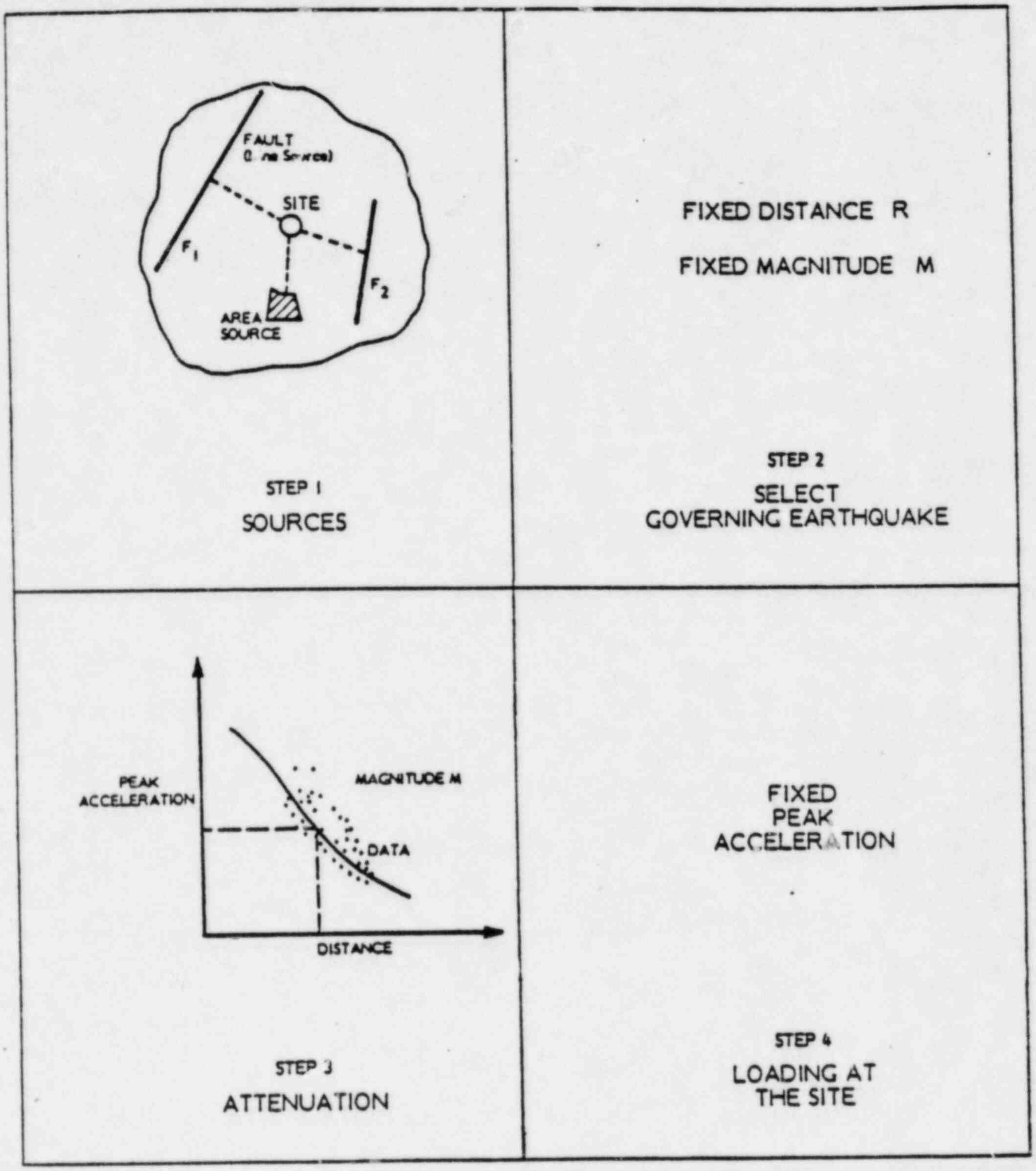


FIGURE 1

DETERMINISTIC APPROACH
TO LOADING AT THE SITE

TERA CORPORATION

Dec. 8, 1978

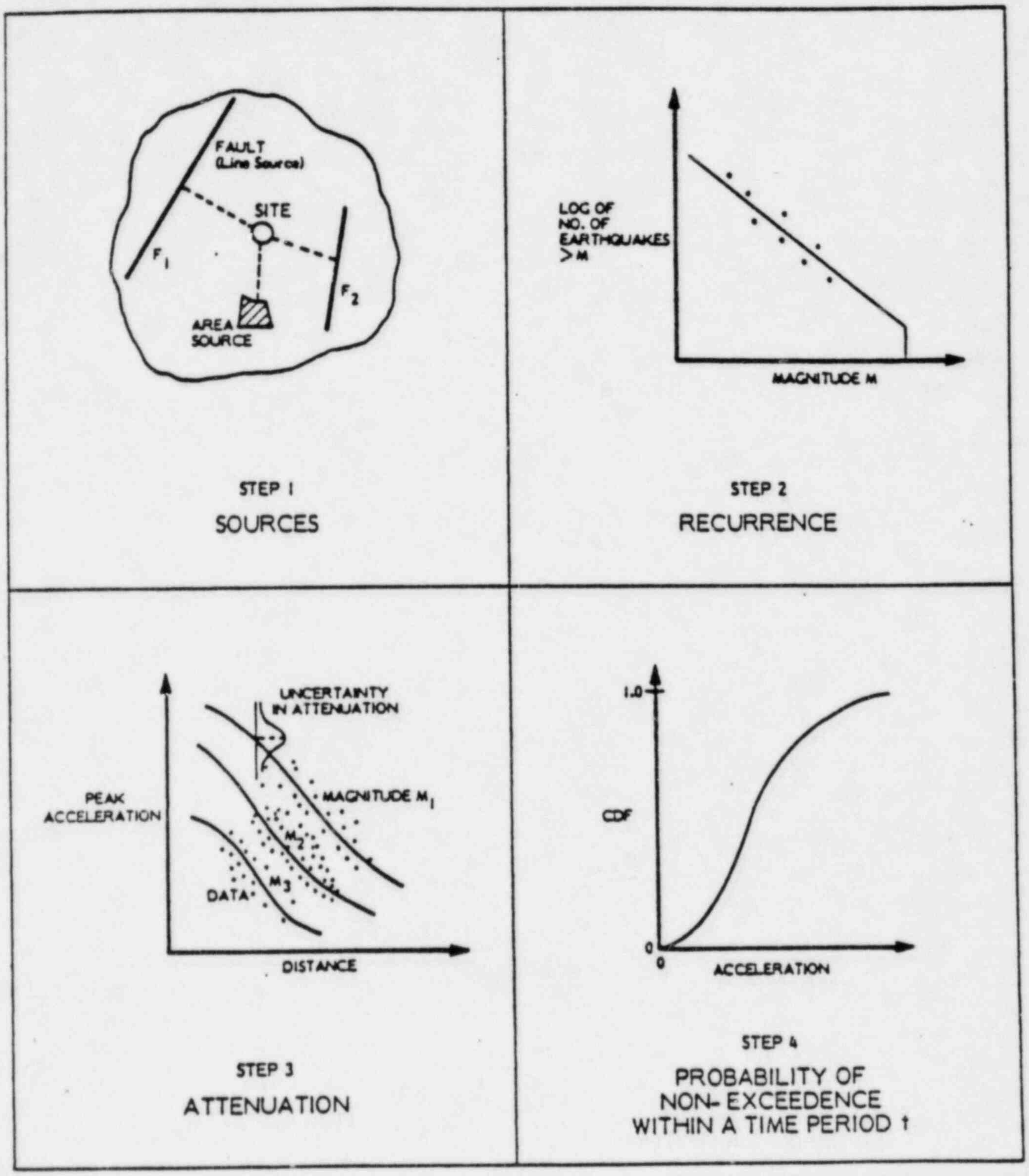


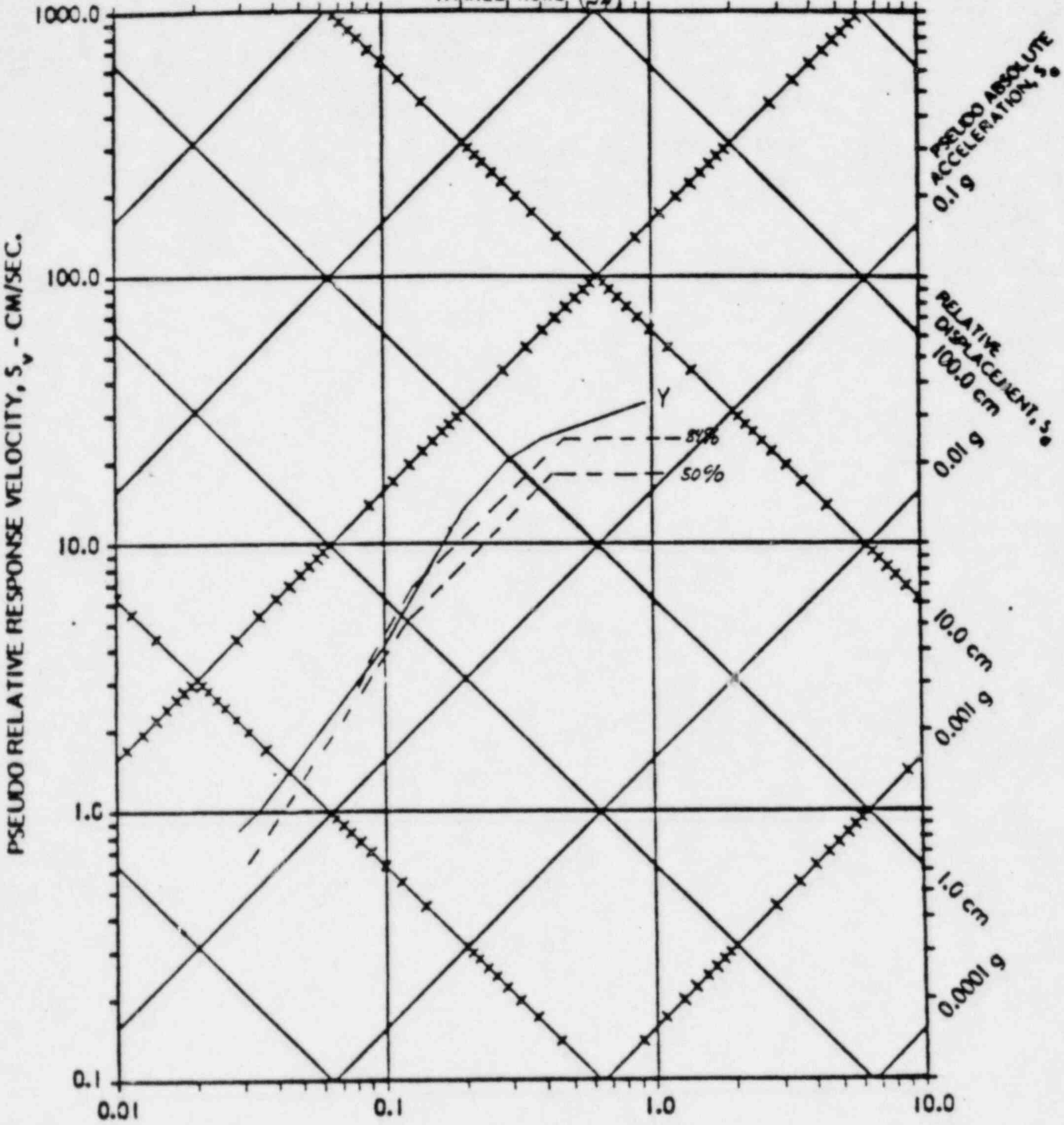
FIGURE 2

CURRENT APPROACH TO HAZARD
MAPPING FOR PEAK VALUES

Dec. 8, 1978

TERA CORPORATION

YANKEE ROWE (5%)

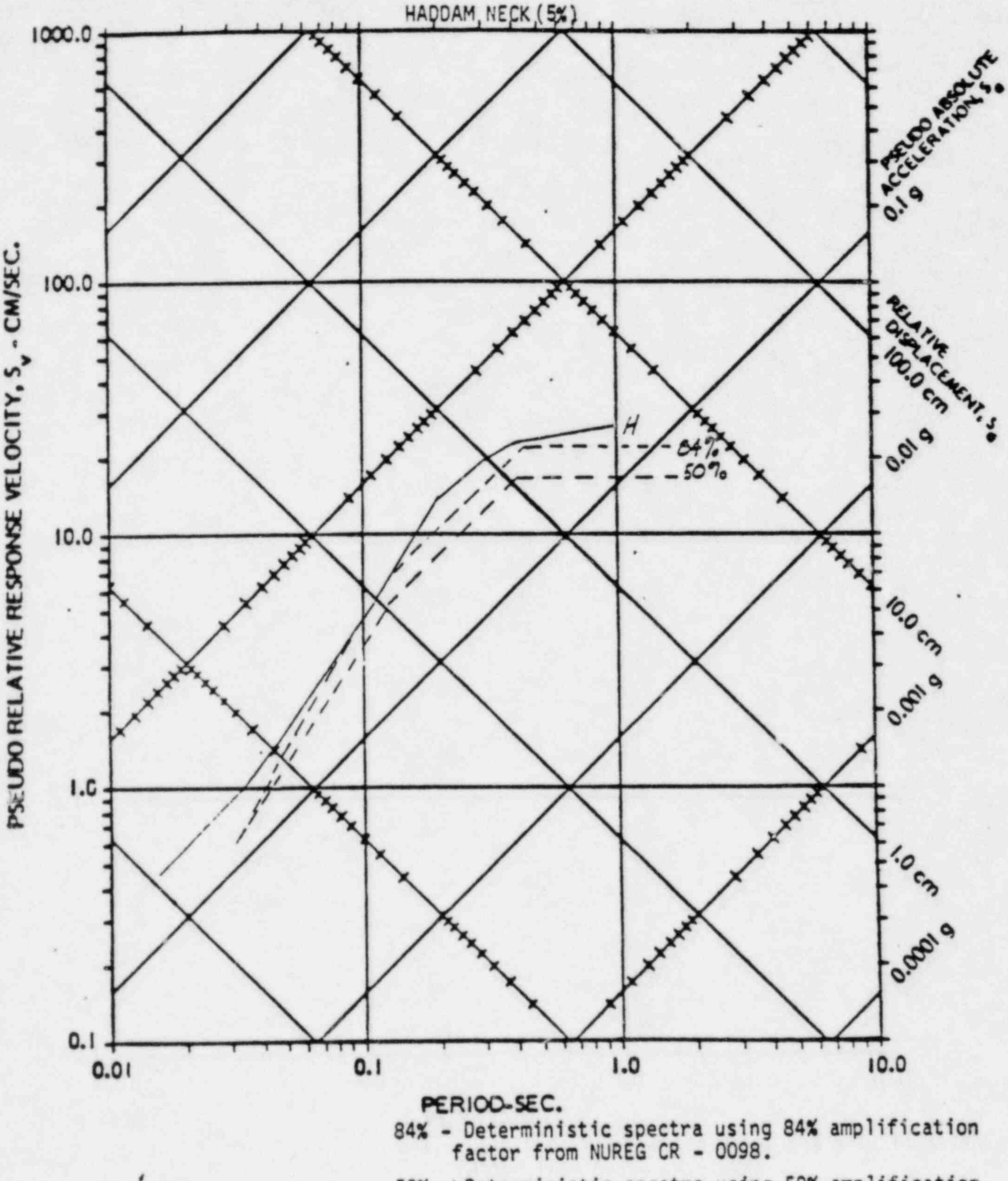


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

Y - Recommended probabilistic spectra.

Figure 3



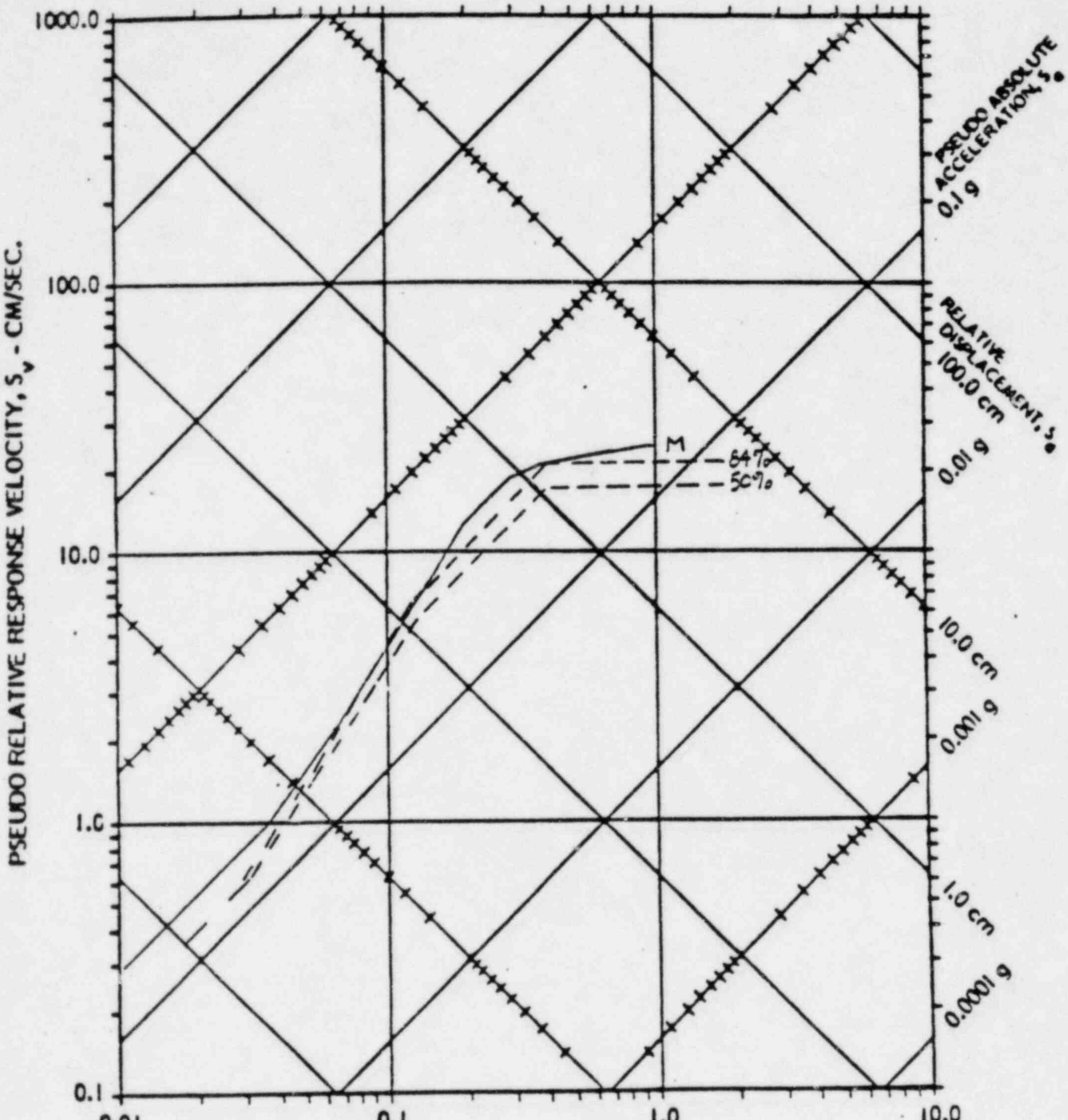
84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

H - Recommended probabilistic spectra.

Figure 4

MILLSTONE (5%)

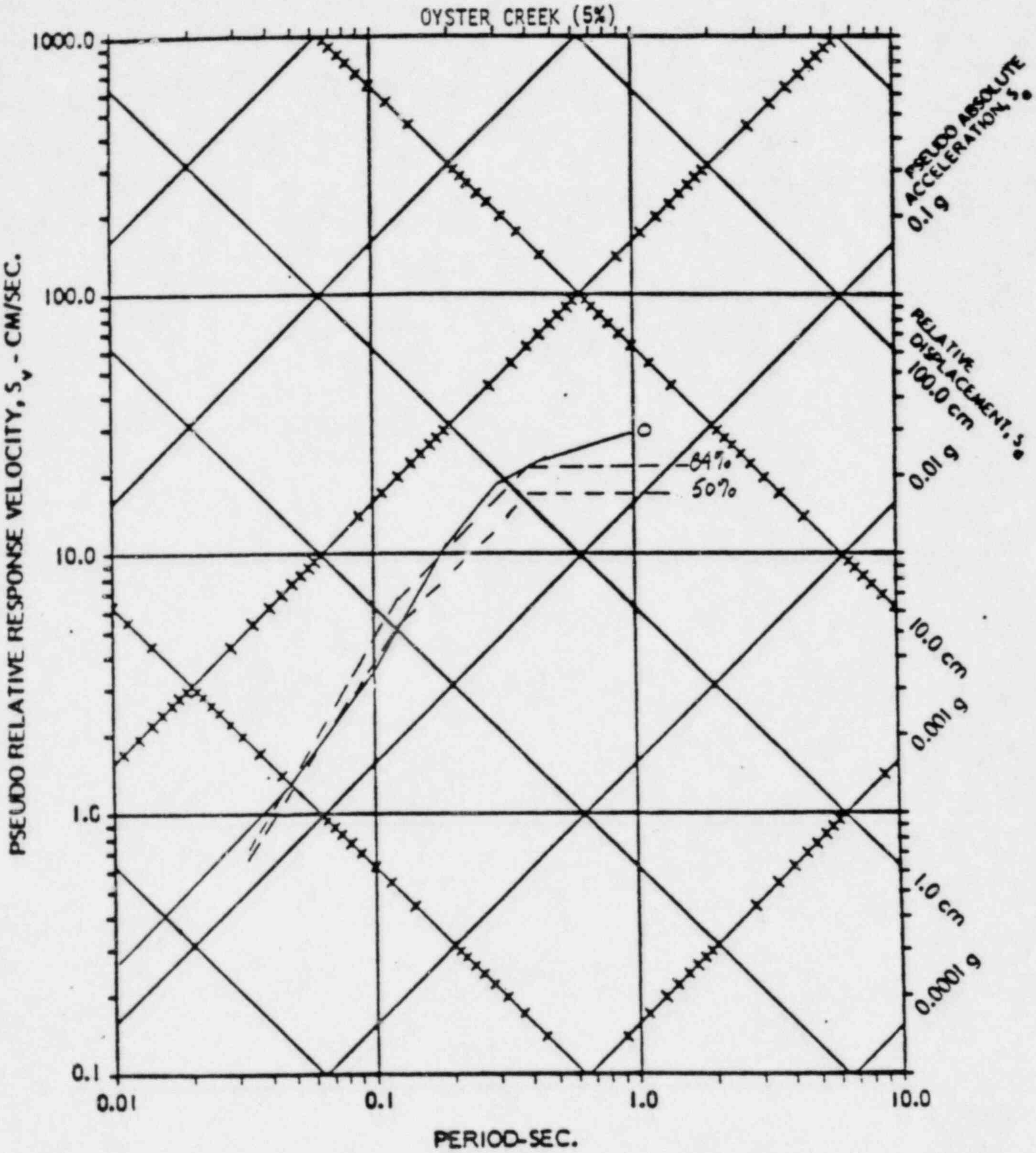


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

M - Recommended probabilistic spectra.

Figure 5

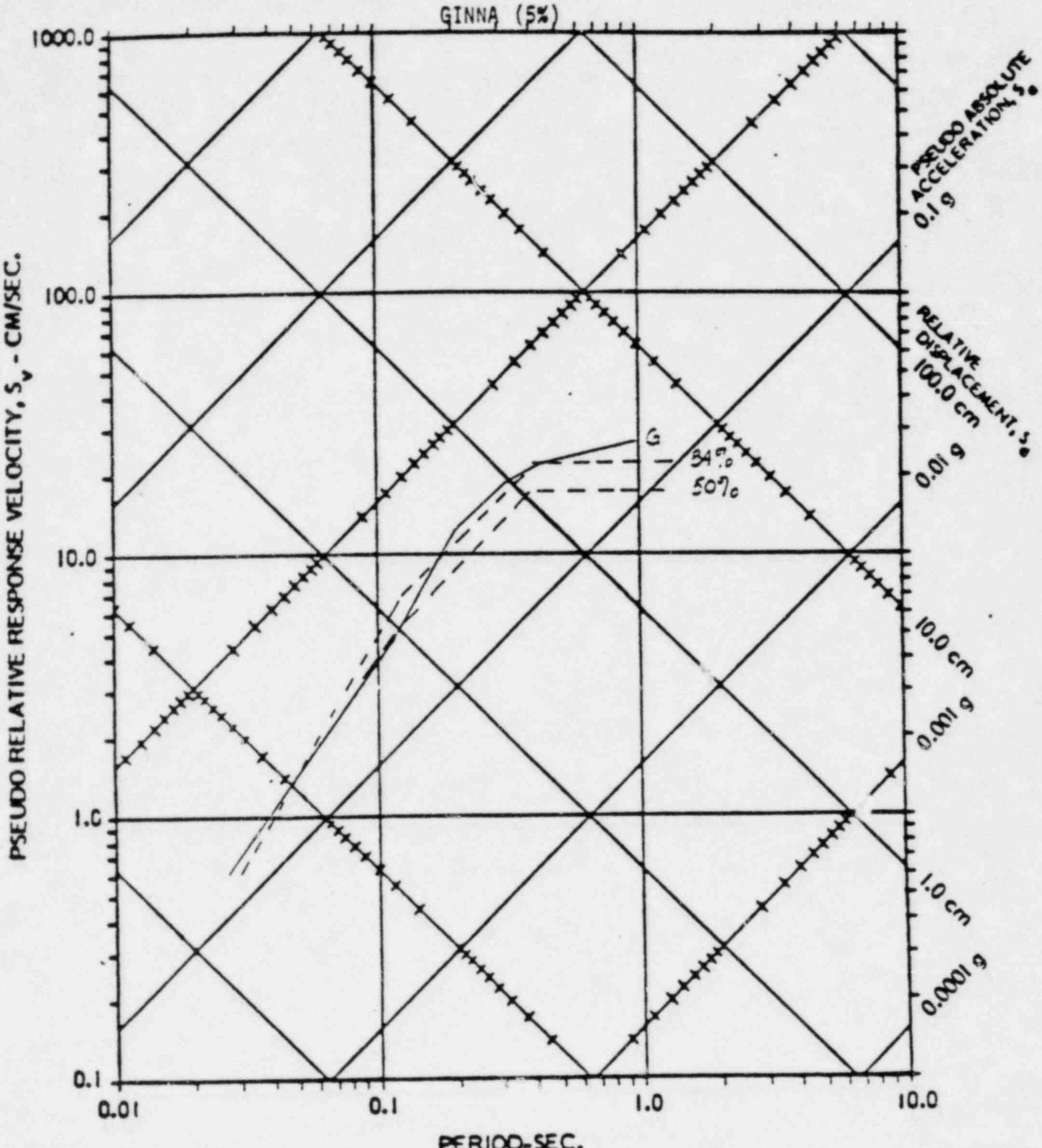


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

O - Recommended probabilistic spectra.

Figure 6

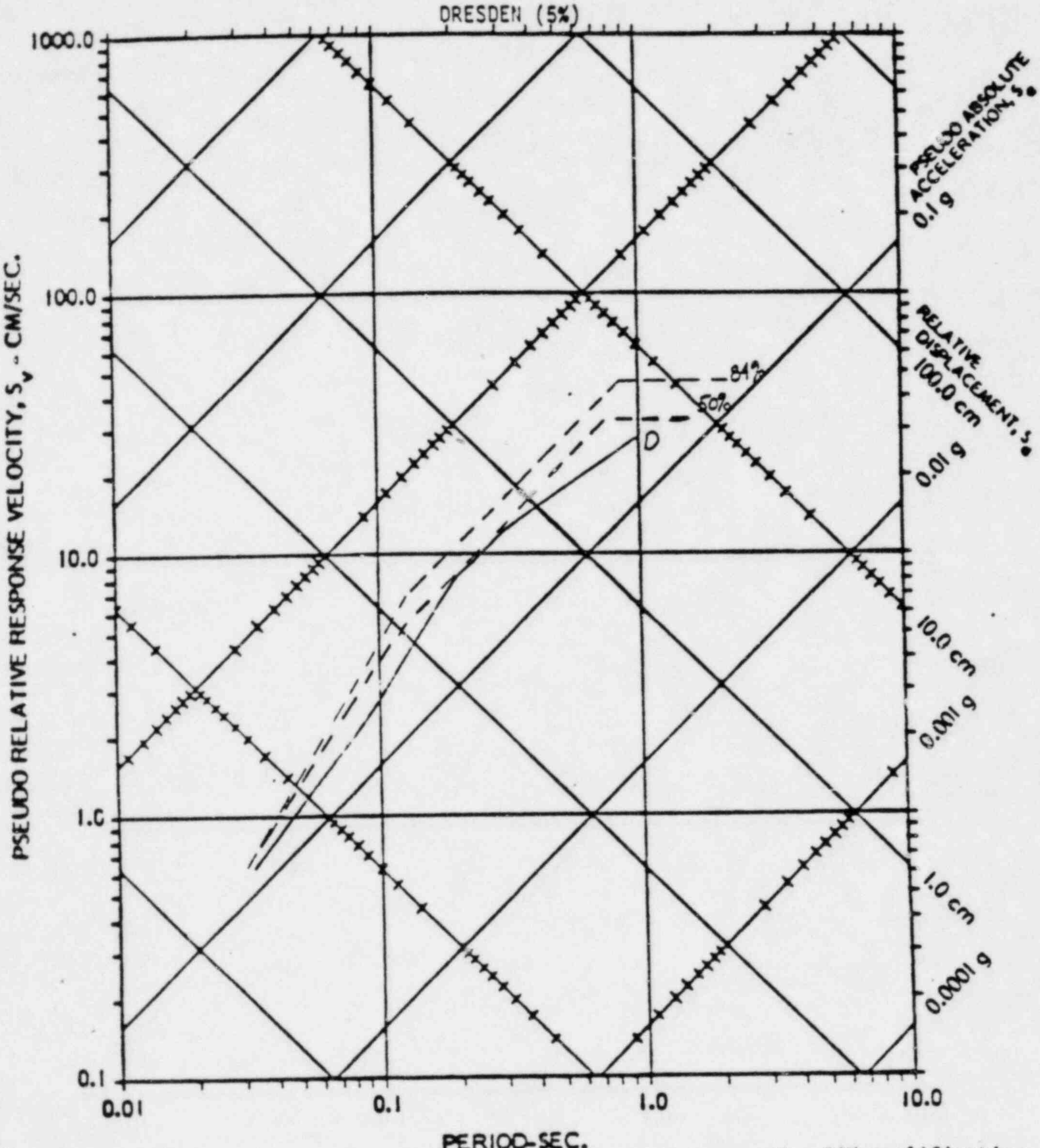


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

G - Recommended probabilistic spectra.

Figure 7

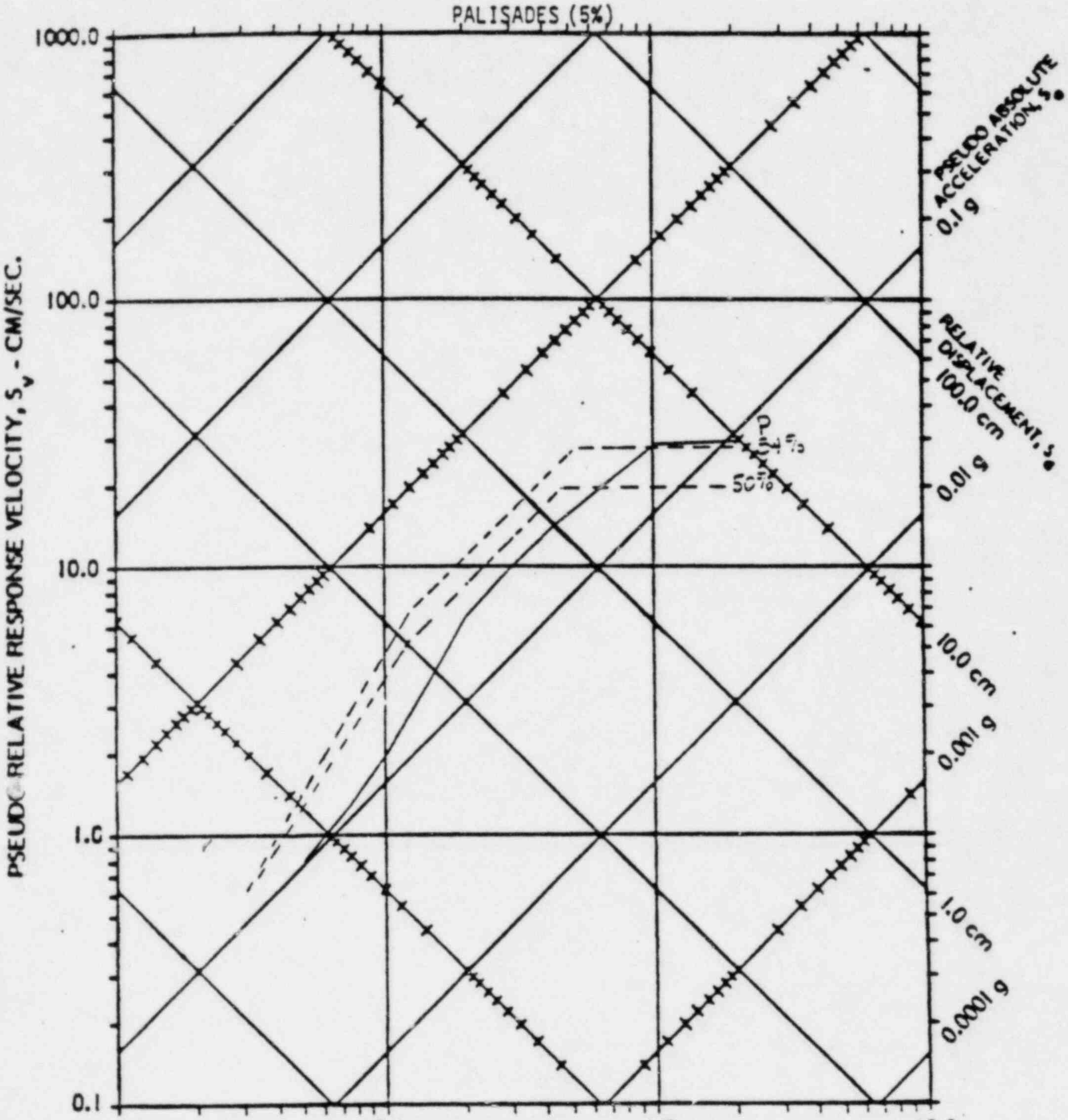


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

D - Recommended probabilistic spectra.

Figure 8

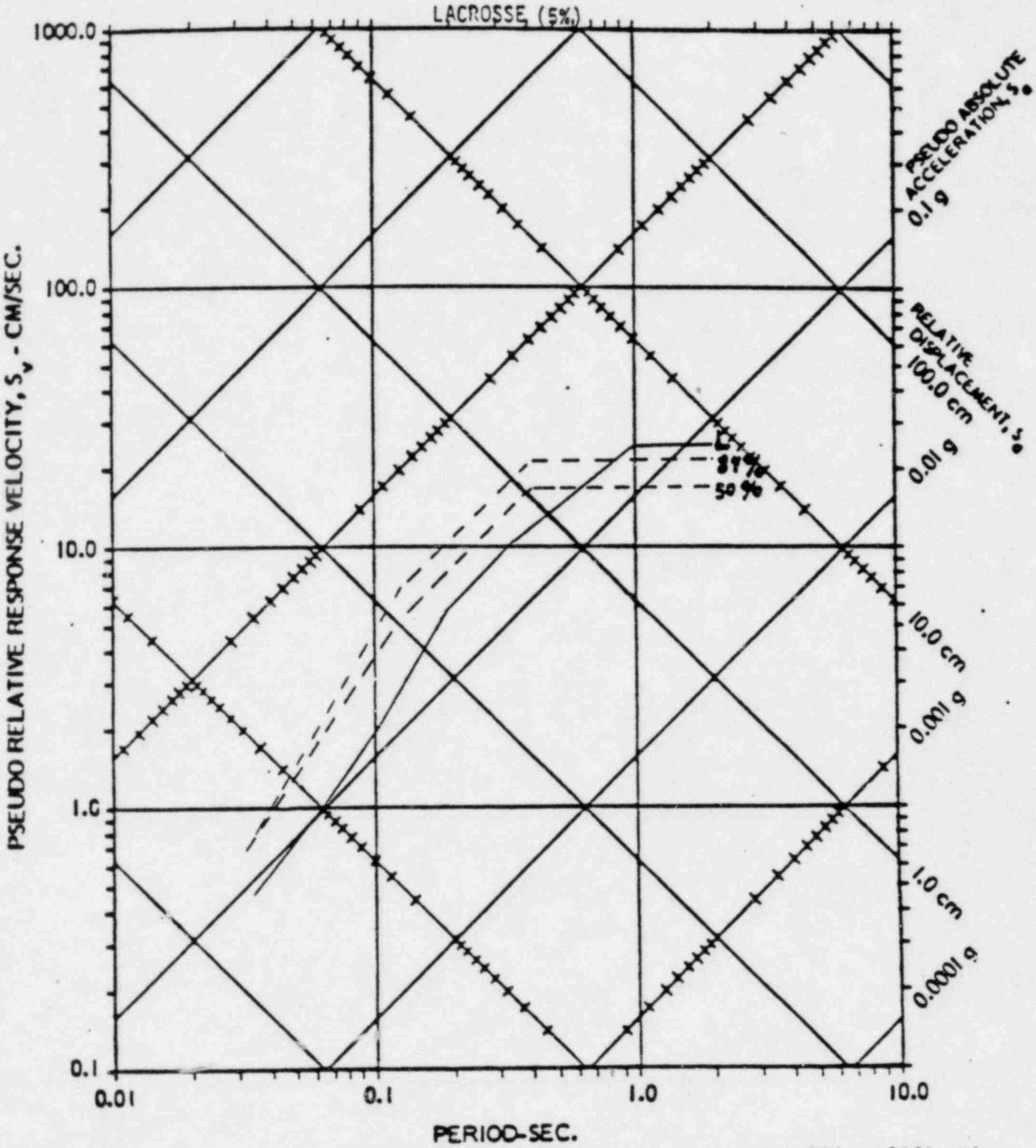


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

P - Recommended probabilistic spectra.

Figure 9

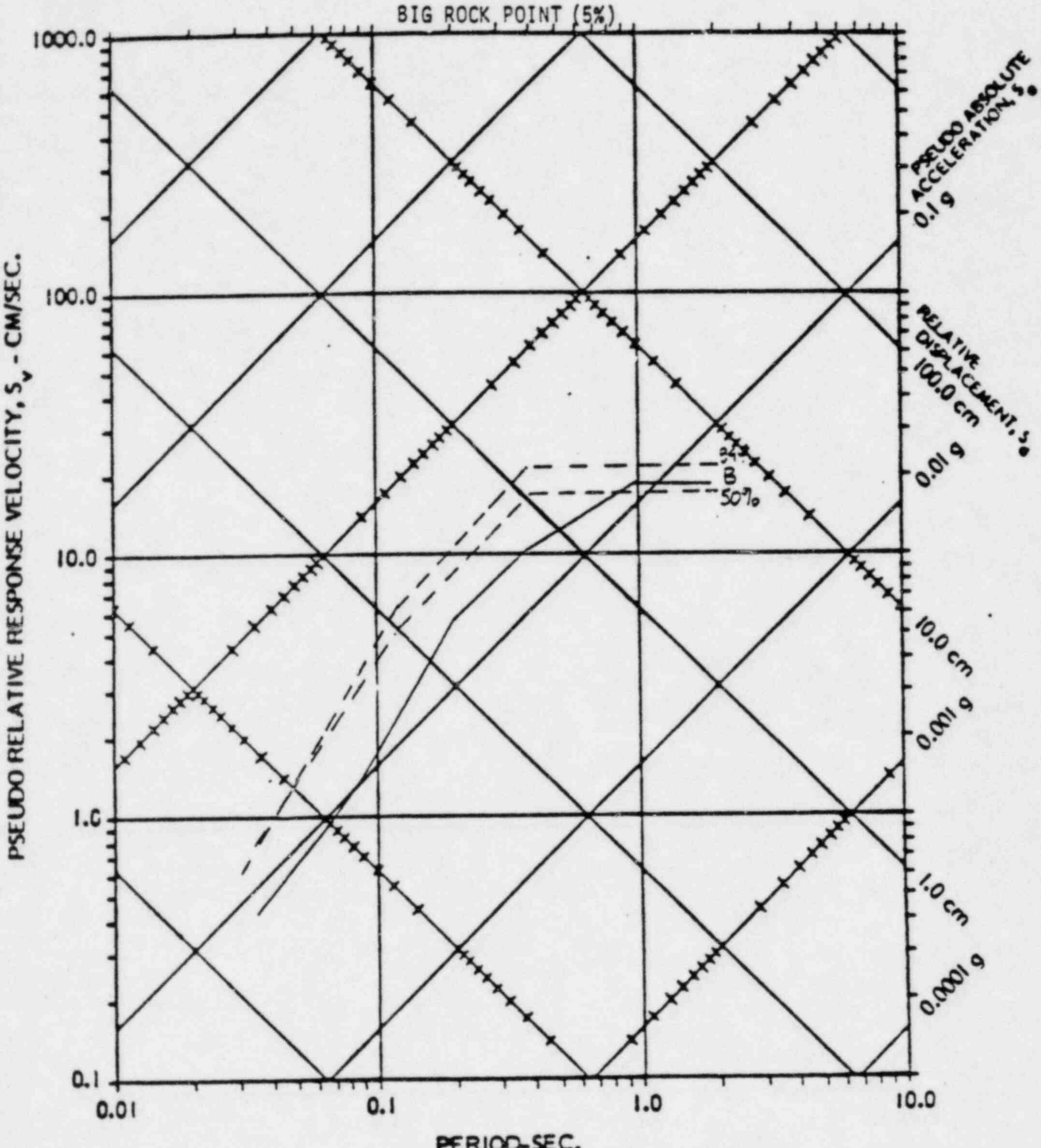


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

L - Recommended probabilistic spectra.

Figure 10



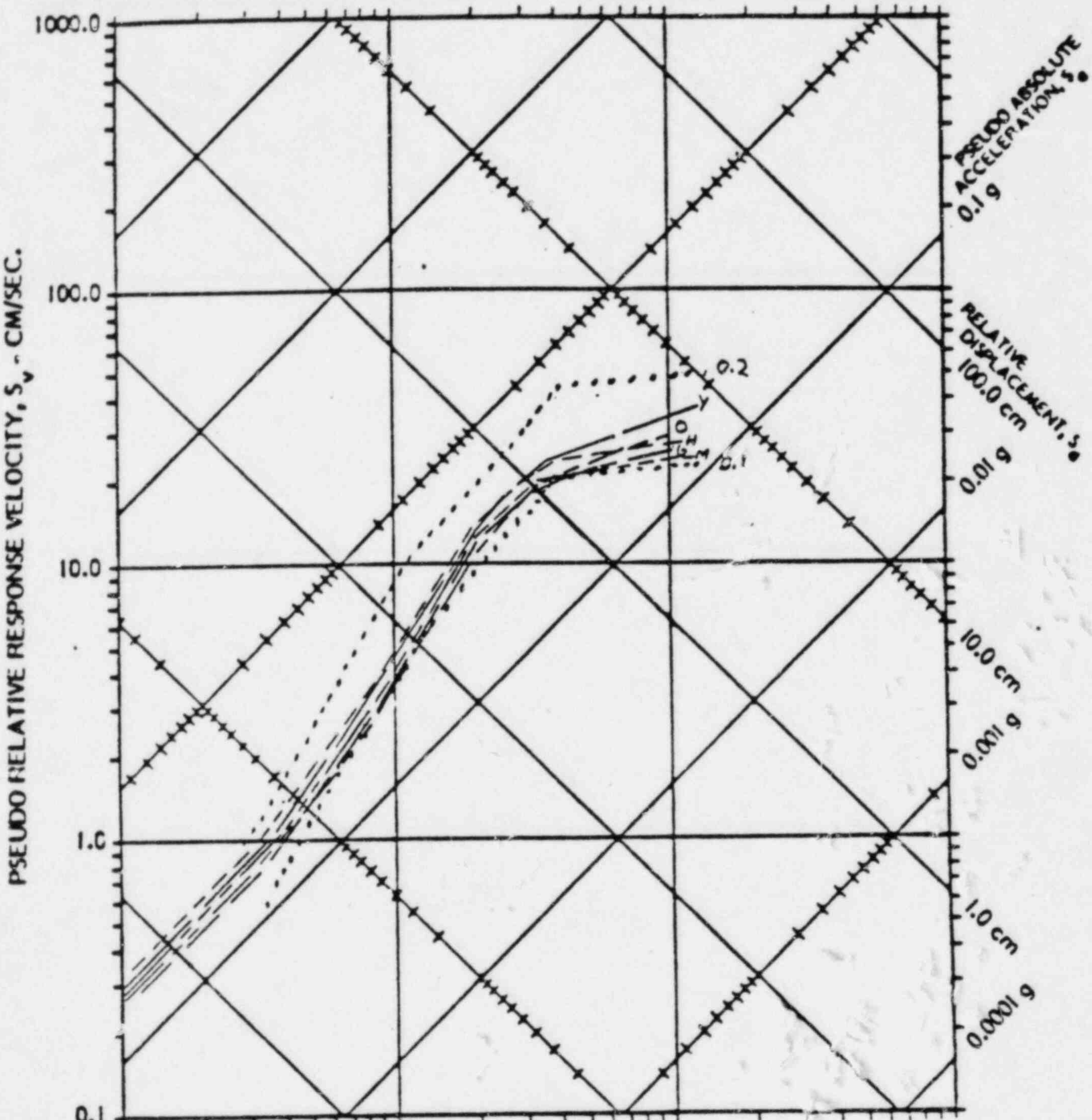
84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

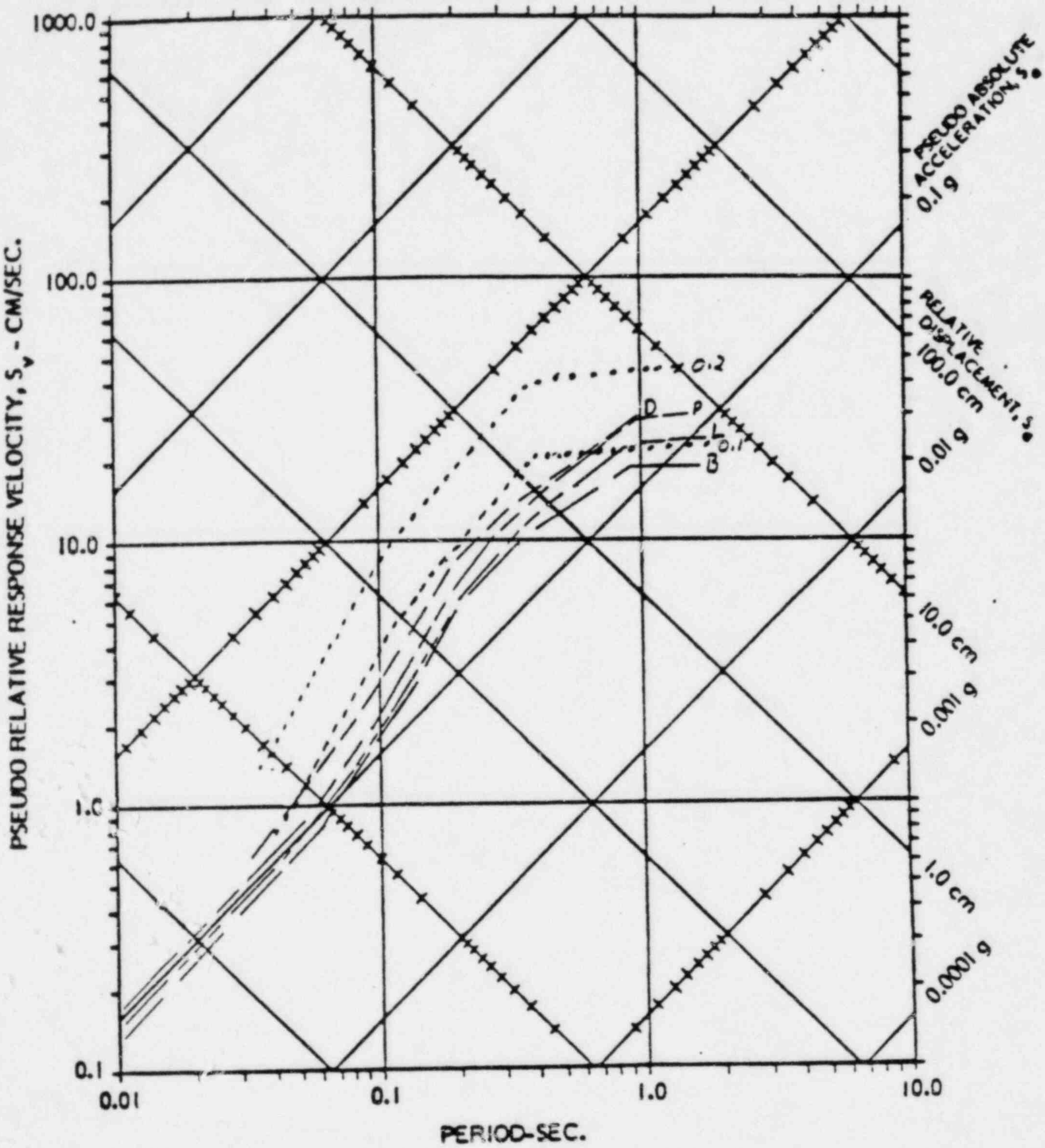


PERIOD-SEC.

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

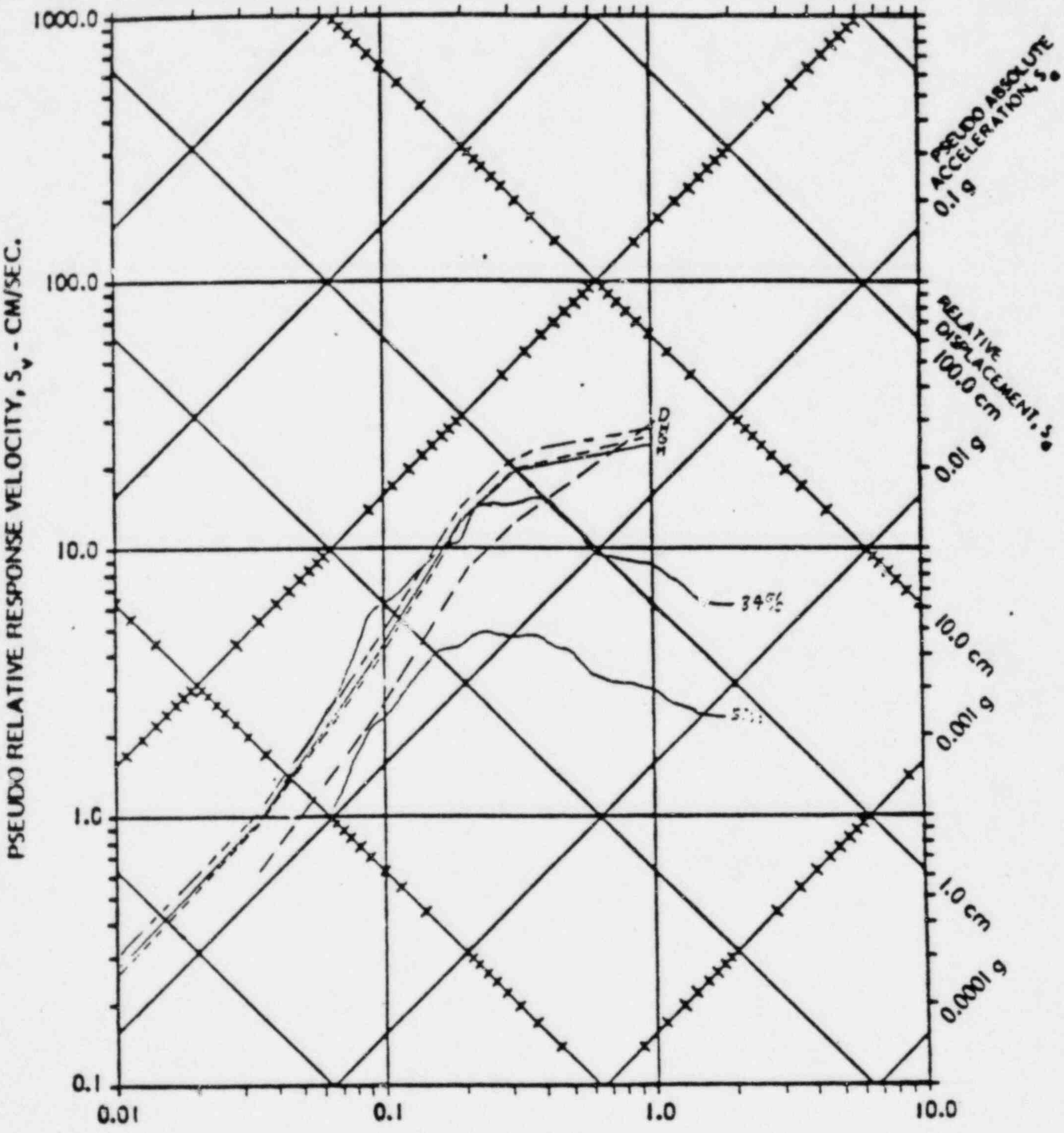
C.U.S. Recommended Probabilistic Spectra and
Regulatory Guide 1.60 Spectra



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

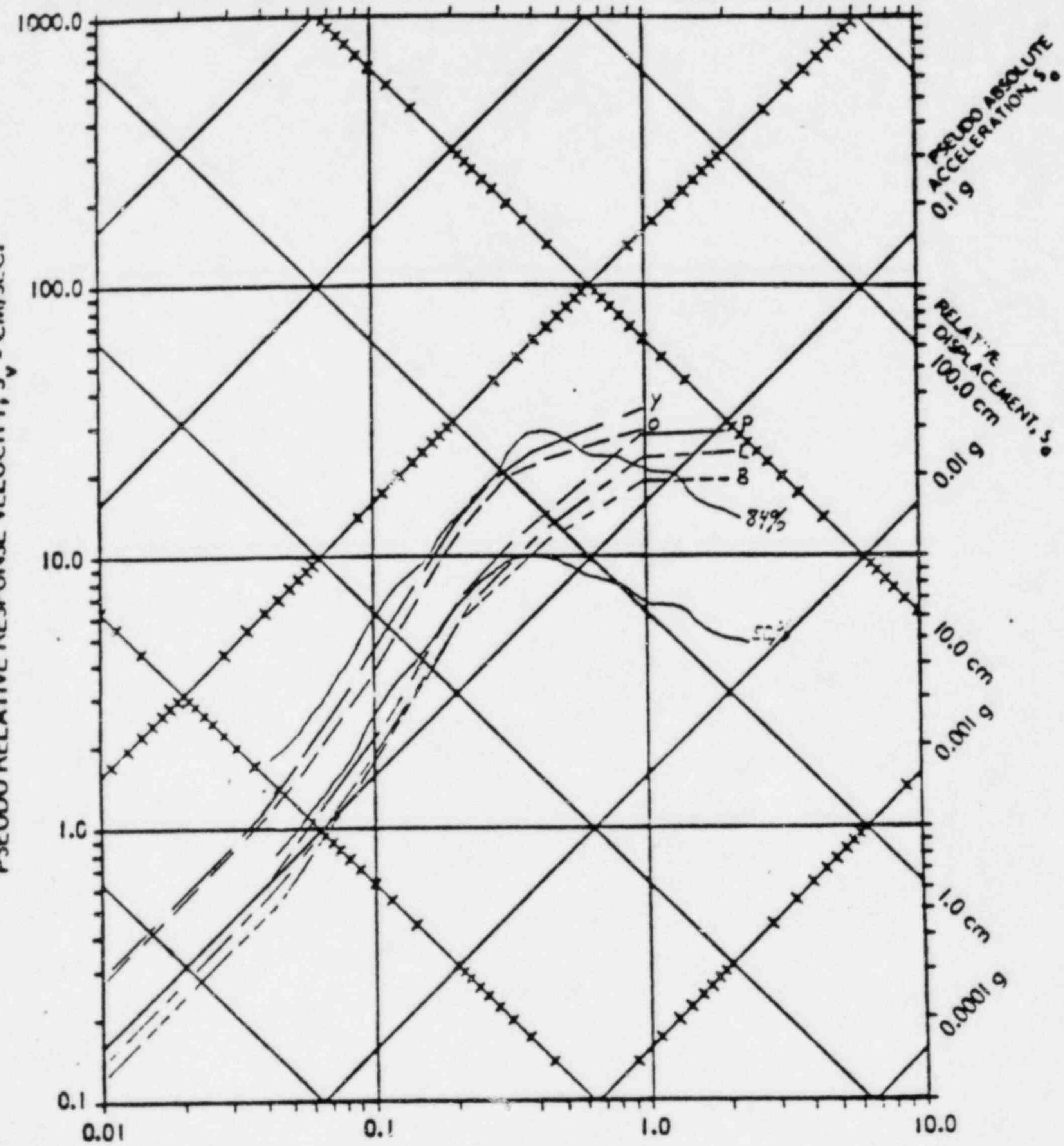
Recommended Probabilistic Spectra at Rock Sites and Recorded Spectra at Rock Sites



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



PERIOD-SEC.

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

Figure 15

ATTACHMENT 4

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.

~~8105290042~~ XA

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

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
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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 to 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 σ= 0.5 to σ= 0.9 with some preference for the 0.6 to 0.7 range.

Effect of Second Round Questionnaire Upon Conclusions of the Initial Review

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 σ= 0.7 $\pm$ 3σ 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 σ= 0.9 $\pm$ 2σ 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.

Attachment 5

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555
September 4, 1981

Docket No. 50-409
LS05-81-09-009

Mr. Frank Linder, General Manager
Dairyland Power Cooperative
Post Office Box 817
2615 East Avenue South
LaCrosse, Wisconsin 54601

Dear Mr. Linder:

SUBJECT: SEP TOPIC III-6, SEISMIC DESIGN CONSIDERATIONS
LACROSSE BOILING WATER REACTOR

In accordance with 10 CFR 50.54(f) of the Commission's Regulations, our letter to you dated August 4, 1980 requested that you submit plans and proceed with a seismic reevaluation program for LaCrosse Boiling Water Reactor and that you provide justification for your conclusion that continued operation is justified in the interim until the seismic reevaluation and any necessary upgrading, as results from this reevaluation, are complete. The staff has completed the review of the information supporting continued operation contained in your letters dated October 14, 1980 and June 12, 1981 and the letter from Craig Finnan, NES, to R.E. Shimshak, DPC, dated April 21, 1981. Furthermore, the staff and its consultant (Dr. W.J. Hall of University of Illinois) visited the site to evaluate the seismic resistance of the facility. As a result of this review, the staff has concluded that continued operation of the LaCrosse Boiling Water Reactor is justified under the following conditions:

(1) results of seismic analyses are submitted for NRC review on the schedule specified in your June 12, 1981 letter; and

(2) any modifications shown to be necessary as a result of the seismic analysis which are not implemented by January 1, 1983 were justified on a case by case basis with a schedule for implementation.

Enclosed is our Safety Evaluation Report.

Sincerely,

Dennis M. Crutchfield

Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Enclosure:
As stated

cc: See next page

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Town of Genoa
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BASES FOR CONTINUED OPERATION
LACROSSE BOILING WATER REACTOR

INTRODUCTION

In accordance with the Commission Regulation 10 CFR 50.54(f), a letter was issued on August 4, 1980 to Dairyland Power Cooperative requesting the licensee to provide justification for continued operation for the interim until the seismic reevaluation program is complete. In response to this letter, the licensee submitted its basis for continued operation on October 14, 1980. More recently, a telecopy of Craig Finnan's (NES) letter to R. E. Shimshak, DPC dated April 21, 1981 was received by the staff. In this letter, a response to certain staff's questions was discussed. On May 22, 1981 the staff and its consultant, Prof. W. J. Hall of University of Illinois, made a site visit to the plant to discuss with the DPC and its consultants the ongoing seismic analyses and related studies and the seismic retrofitting that is in progress. The staff's evaluation of the basis for continued operation follows.

Seismic Hazard Consideration

The staff, in its letter dated August 4, 1980, directed the licensee to conduct the seismic reevaluation of LaCrosse Nuclear Plant using the site specific spectrum (0.11g peak ground acceleration) as the free field ground motion. The adequacy of this site specific spectrum was confirmed by the staff through a letter dated June 17, 1981. This ground motion is equivalent to an earthquake with return period between 1,000 years and 10,000 years.

Seismic Resistance of Structures, Systems and Components

In 1974, the licensee completed a seismic analysis of the plant facilities (reactor building, reactor pressure vessel, main steam, main feedwater and recirculation pipings, and other fluid and electrical distribution systems) as part of basis for its FTOL application. Regulatory Guide 1.60 Spectrum scaled to 0.12g peak ground acceleration was used as input ground motion. This spectrum completely enveloped the site specific spectrum recommended by the staff, i.e., it is more conservative than the site specific spectrum. The results of this analysis are highlighted below:

- Positive safety margins of reactor building structures were identified

- Additional pipe restraints were found to be necessary for High Pressure Core Spray, Main Steam, Main Feedwater and Recirculation pipings from the results of analyses performed using 0.12g R. G. 1.60 Spectrum input ground motion. So far, a total of twenty-five restraints have been installed to High Pressure Core Spray system. The design of additional restraints in preparation for upgrading is currently underway.

- The structural model used for these analyses was not consistent with current staff criteria (2-D vs 3-D). However, the combination of stresses was by a more conservative absolute addition method. The use of a 2-D structural model with absolute summation of response is conservative and acceptable.

Since 1978, the following additional seismic issues have been addressed and resolved under the SEP seismic review. Furthermore, the licensee in response to NRC letters dated August 4, 1980 and April 24, 1981, has initiated a seismic reevaluation program that is scheduled for completion by January 1983.

- Soil liquefaction is not problematic for 0.12g peak ground acceleration at LaCrosse site. (NRC Safety Evaluation dated February 25, 1981.)

- In response to NRC "Anchorage and Support of Safety-Related Electrical Equipment" issues dated January 1, 1980 and July 28, 1980, a total of 43 items were inspected by the licensee and its consultants (DPC letter to NRC dated 5/30/80). All the items were satisfactorily anchored and supported or were upgraded (DPC letter to NRC dated 4/23/81).

In addition, the staff and their consultant verified during May 22, 1981 site visit that alternate sources of cooling water and power (including emergency gasoline motor driven pumps) have been provided to remove decay heat. The report of the staff's consultant regarding continued operation of the facility is attached (Enclosure 1).

<u>CONCLUSION</u>

Based on the acceptable results provided to date from the analyses of the plant structures, systems and components, the upgrading of high pressure core spray system, the proper anchorage and support of safety related electrical components, the addition of redundant cooling water supplies, and the inherent capacity of the remaining plant structures and systems as well as the low seismic hazard associated with the LaCrosse site, the staff concludes that the continued operation of LaCrosse Boiling Water Reactor during the seismic reevaluation of the facility and the implementation of any modification shown to be necessary as a result of seismic reanalysis is justified under the following conditions:

(1) results of seismic analysis are submitted for NRC review on the schedule specified in the licensee's June 12, 1981 letter; and

(2) any modifications shown to be necessary as a result of the seismic analysis which are not implemented by January 1, 1983 are justified on a case by case basis with a schedule for implementation.

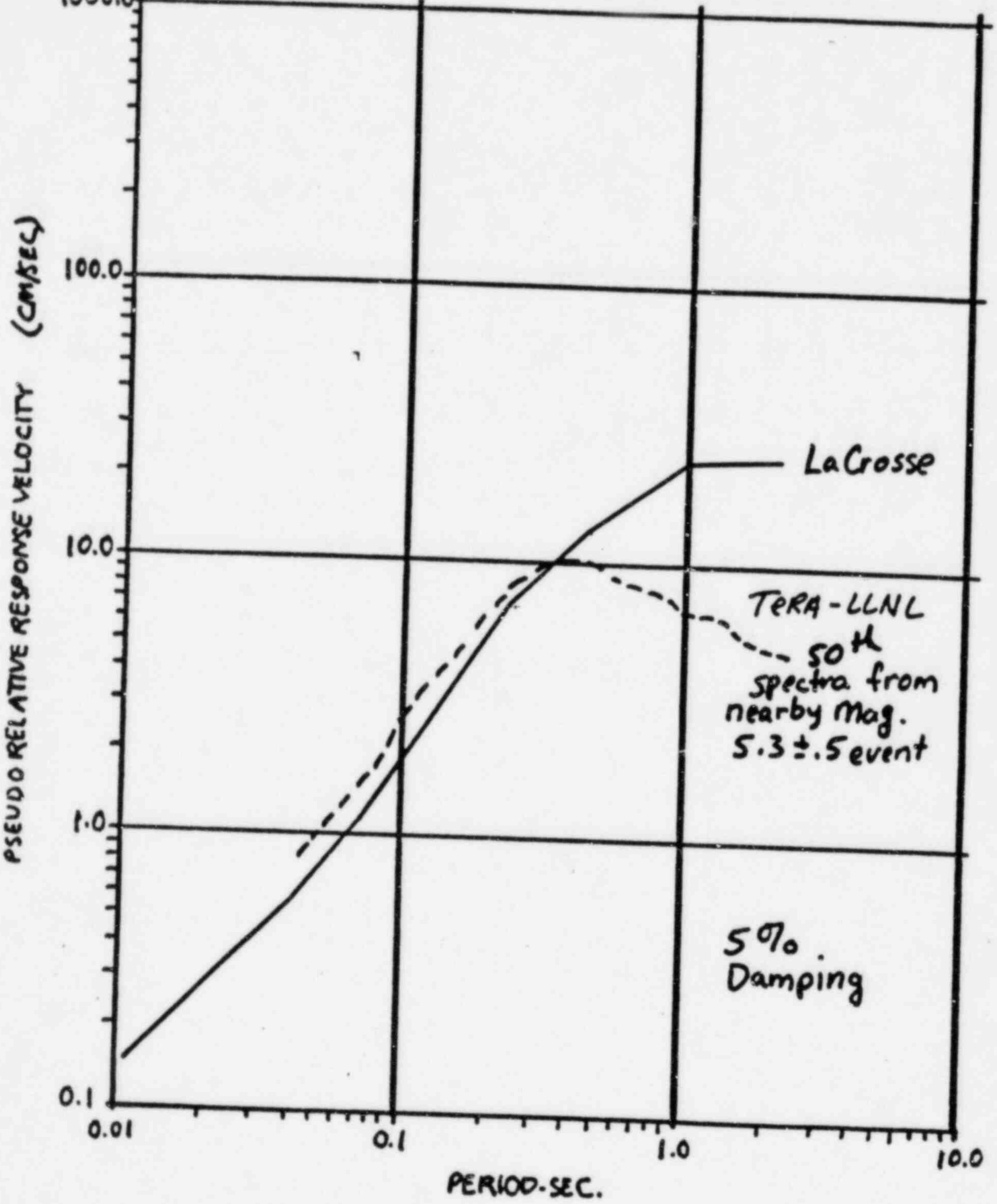

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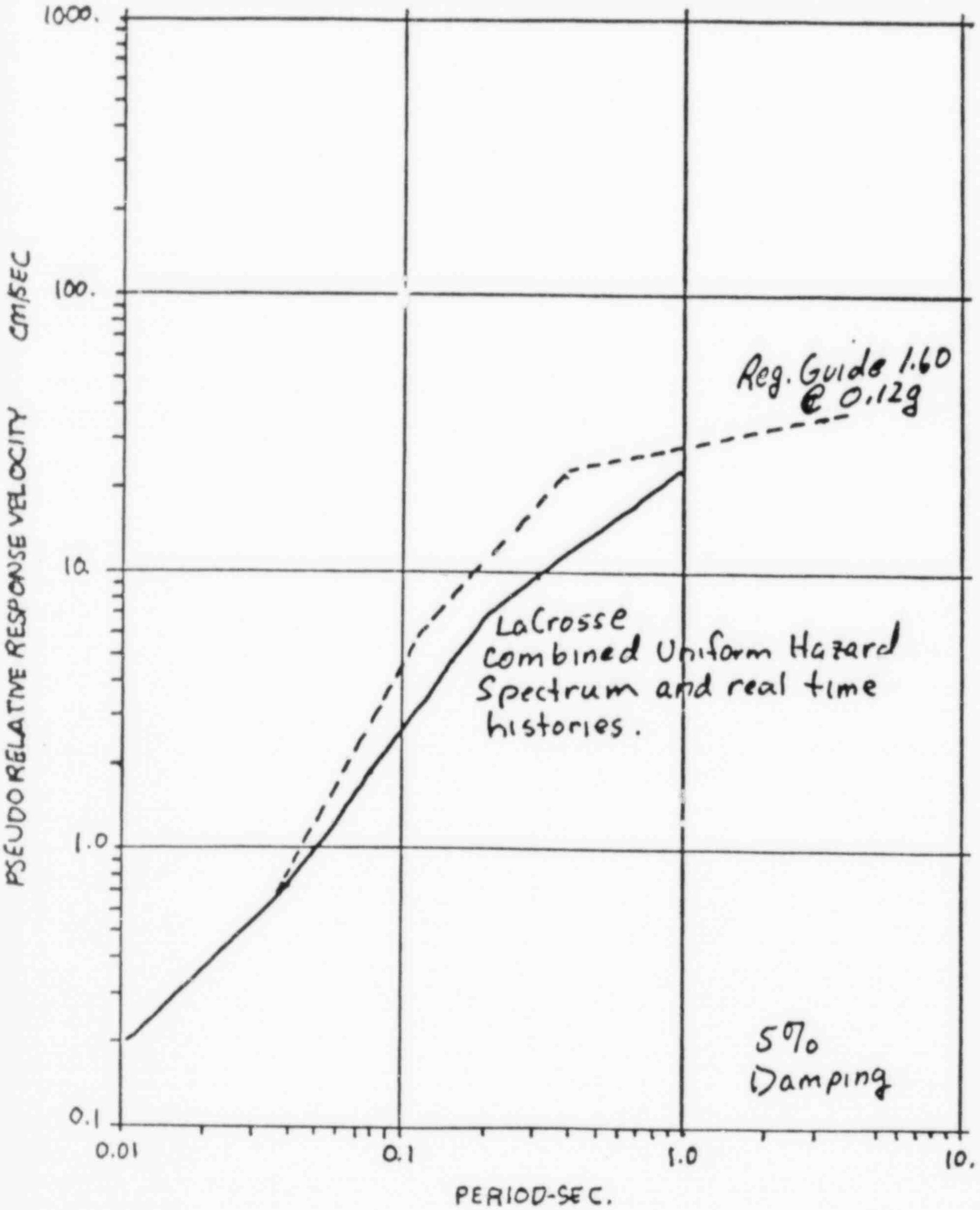
FIGURE 1



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LaCrosse
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histories.
5%
Damping

Figure 2

Big Rock Point

111-6

BRP-1

JUL 28 1980

Docket No. 50-155

Mr. David P. Hoffman
Nuclear Licensing Administrator
Consumers Power Company
212 West Michigan Avenue
Jackson, Michigan 49201

Dear Mr. Hoffman:

SUBJECT: ANCHORAGE AND SUPPORT OF SAFETY RELATED ELECTRICAL EQUIPMENT

References:
1. Letter from D. Eisenhut to SEP Licensees, dated January 1, 1980
2. Letter from R. Schaffstall to D. Crutchfield, dated July 3, 1980

Reference 1 identified a potential safety concern relative to the anchorage and support of safety related electrical equipment and requested that you initiate a program to resolve this issue including the installation of any required modifications by September 1, 1980. Reference 2 describes a program which was developed by the Systematic Evaluation Program Owners Group in response to comments made by members of the NRC staff at a May 14, 1980 meeting in Bethesda. As a result of your comments and our review of Reference 2, we are providing additional guidance to you as indicated in the Attachments.

Attachment 1 provides guidance as to the expected scope of your investigations and information which should be documented for our review. A suggested format for this documentation is provided in Attachment 2. Due to the lack of clarification relative to certain requirements of Reference 1 and in particular the issue of support of internally attached electrical components, we will permit an extension until December 31, 1980 for completion of this program. This shall include the installation of any modifications which may be required as a result of your investigations. Any modifications shall be made in accordance with 10 CFR 50.59 of the Commission Regulations. We request that formal documentation summarizing your program be submitted to this office by December 31, 1980.

Existing plant floor response spectra or floor response spectra computed or estimated from the NRC Site Specific Spectra Program are acceptable

8008080110
PDR/LPDR

for use in your evaluation. The conservatism of these loadings shall be verified when the final floor response spectra are available.

Sincerely,

Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Attachments:
As stated

cc w/attachments:
See next page

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

Docket No. 50-155

JUL 2 8 1980

Mr. David P. Hoffman
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Consumers Power Company
212 West Michigan Avenue
Jackson, Michigan 49201

Dear Mr. Hoffman:

SUBJECT: ANCHORAGE AND SUPPORT OF SAFETY RELATED ELECTRICAL EQUIPMENT

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Existing plant floor response spectra or floor response spectra computed or estimated from the NRC Site Specific Spectra Program are acceptable for use in your evaluation. The conservatism of these loadings shall be verified when the final floor response spectra are available.

Sincerely,

for Thomas V. Wambach
Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Attachments:
As stated

cc w/attachments:
See next page

Mr. David P. Hoffman

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Washington, D. C. 20555

Big Rock Point Nuclear Power Plant
ATTN: Mr. C. J. Hartman
Plant Superintendent
Charlevoix, Michigan 49720

Christa-Maria
Route 2, Box 108C
Charlevoix, Michigan 49720

William J. Scanlon, Esquire
2034 Pauline Boulevard
Ann Arbor, Michigan 48103

ATTACHMENT 1
ANCHORAGE AND SUPPORT OF SAFETY RELATED ELECTRICAL EQUIPMENT POINTS TO BE ADDRESSED BY SEP LICENSEES IN DECEMBER 31, 1980 SUBMITTAL

1. Information should be provided not only for the anchorage of electrical equipment but also the entire support that provides a load path (such as bracing and frames), as well as support for internally attached components. The latter is especially important for cabinet or panel type electrical equipment (such as control panels, instrument panels, etc.) which has internally supported components. An example of a potential improperly supported internal component would be a heavy component cantilevered off a front sheet metal panel without additional support to a stronger and stiffer location. These inadequate supports for internal components also should be identified and corrected before December 31, 1980.

2. In order to verify that an anchorage or a support of safety related electrical equipment has adequate capacity, provide justification by test, or analytical means. If expansion anchor bolts exist, justification provided previously for IE Bulletin 79-02 can be utilized if applicable. The acceptance criteria for substantiating these judgements should be provided, this may involve specifying the factor of safety and allowable stress limits used for design and justifying the overturning moment and shear force used.

3. Provide a table listing all (to include both floor and wall mounted) safety related electrical equipment in the plant. For each piece of equipment provide the information described in the attached table (attachment 2).

   These investigations of each piece of equipment should determine:

   a. Whether positive anchorage or support exists

   b. The type of anchorage

   c. Whether internally attached components are properly supported

   d. Identify non-seismic Category I equipment, the dislodgement of which during an earthquake may be detrimental to safety related equipment and render them inoperable. Inspection of the anchorages of such non-seismic Category I equipment should be conducted. If positive anchorages do not exist, they should be identified and modified before December 31, 1980.

4. Wherever modifications of anchorages or supports are required, these modifications should be implemented and thoroughly documented.

5. The seismic design of cable trays may be treated as a separate problem, because of its complexity. Each licensee or the SEP Owner's Group should provide a separate action plan for the resolution of this issue within 30 days of receipt of this letter.

ATTACHMENT 2

SUMMARY OF INVESTIGATION OF ANCHORAGE AND SUPPORT OF SAFETY RELATED ELECTRICAL EQUIPMENT AND NON-SEISMIC CATEGORY I ITEMS THAT MAY DAMAGE THIS EQUIPMENT

Equip. Name	Equip. ID	System in Which Installed	Location Bldg. & Elev.	Type of Anchorage*	Was Anchorage Modified Since Jan. 1, 1980	Internally Attached Components			Non-Seismic Cat I Items that could potentially interact with this equip.			I.D. of Document Supporting Conclusion
						Equip. Name & ID	Type of Support	Was Support Evaluated	Name & ID	Type of Support	Was Support Evaluated	

*Examples of Type of Anchorage:
1. Bolted to Equipment
2. Bolted to Concrete Wall
3. Bolted to Concrete Slab
4. Bolted to Block Wall
5. Welded to Embedded Channel

111-6

BRP-2

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

January 15, 1979

Docket No. 50-155

Consumers Power Company
ATTN: Mr. David A. Bixel
Nuclear Licensing Administrator
212 West Michigan Avenue
Jackson, Michigan 49201

Gentlemen:

RE: BIG ROCK POINT

As part of the Systematic Evaluation Program (SEP) the NRC staff has completed a search of your docket for pertinent information related to the seismic design bases of your facility. We find that your docket lacks sufficient information concerning the seismic design input and structural capability for safety-related structures, systems and equipment to withstand earthquake effects to enable us to complete our evaluation.

As you know, the major NRC regulations dealing with seismic design are 10 CFR Part 50, Appendix A (General Design Criterion 2) and 10 CFR Part 100, Appendix A. We recognize that both of these regulations were issued subsequent to the design of your facility. However, one of the objectives of the SEP is to compare the original design basis with current criteria. Currently, the information on the docket is not sufficiently complete to adequately address the potential hazard of earthquakes, nor to determine whether backfitting of additional seismic resistance would provide substantial additional protection required for safety.

We recognize that your facility possesses inherent structural capabilities to withstand earthquake effects. However, there is insufficient information docketed to adequately quantify such capability. We believe that a significant effort on your part may be required to assess the seismic safety margins of your facility. This matter has been generally discussed with your representatives, as part of the SEP, to assure that the issue will be properly resolved within the time frame of the SEP.

While the docket does not contain sufficient information on geologic and seismic input to allow a comparison to current criteria, seismic input information for your facility could be developed based on current criteria and a bounding conservative assessment; however, evaluation of various site specific response spectra methodologies may demonstrate a more realistic approach in determining seismic input. Staff effort in these methodologies is expected to lead to acceptable procedures for determining site specific spectra. We encourage you to closely follow the progress of our work aimed at the development of a seismic input for your facility.

Although we have undertaken this seismic input effort, we expect you to be responsible for a documented seismic design basis for your facility. In addition to seismic input, this would include analytical or other procedures for demonstrating that acceptable structural design criteria are satisfied. The staff expects to work with you in this effort, especially in the areas of definition of acceptable seismic structural design criteria and seismic input.

If you wish to follow such an approach, as suggested by the staff, please inform us within 30 days. Additionally, please provide, within the next 90 days, a description outlining your program for documenting a seismic design basis and a program schedule. To provide maximum assurance that both the scope and schedule are acceptable, we suggest that detailed working meetings for your facility in the next 90 days would be beneficial.

Sincerely,

for Victor Stello, Jr., Director
Division of Operating Reactors
Office of Nuclear Reactor Regulation

cc:
See next page

cc:
Mr. Paul A. Perry, Secretary
Consumers Power Company
212 West Michigan Avenue
Jackson, Michigan 49201

Judd L. Bacon, Esquire
Consumers Power Company
212 West Michigan Avenue
Jackson, Michigan 49201

Hunton & Williams
George C. Freeman, Jr., Esquire
P. O. Box 1535
Richmond, Virginia 23212

Peter W. Steketee, Esquire
505 Peoples Building
Grand Rapids, Michigan 49503

Charlevoix Public Library
107 Clinton Street
Charlevoix, Michigan 49720

III -6

HN-1

NORTHEAST UTILITIES

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THE CONNECTICUT LIGHT AND POWER COMPANY
THE HARTFORD ELECTRIC LIGHT COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

P.O. BOX 270
HARTFORD, CONNECTICUT 06101
(203) 666-6911

January 17, 1980

Docket No. 50-213

Director of Nuclear Reactor Regulation
Attn: Mr D. L. Ziemann, Chief
Operating Reactors Branch #2
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Reference: (1) Summary of Meeting Held on August 29, 1979, J. J. Shea to CYAPCO, dated September 26, 1979.

Gentlemen:

Haddam Neck Plant
Systematic Evaluation Program
Seismic Reevaluation

During a meeting held in CYAPCO offices on August 29, 1979, Connecticut Yankee Atomic Power Company (CYAPCO) representatives made a brief presentation regarding the status of the Seismic Reevaluation Program for the Haddam Neck Plant. At the end of the meeting, the Staff requested additional details concerning the program. As documented in Reference (1), it was originally CYAPCO's intention to provide a criteria document to the NRC Staff during November, 1979. This effort had been delayed, primarily because of the urgency associated with implementation of the TMI-related improvements and in complications associated with the development of site-specific spectra.

In response to the Staff request, the following information is hereby provided.

The CYAPCO proposed program is comprised of five distinct parts.

(1) Geology/Seismology

In response to the questions raised by the NRC Staff, CYAPCO has already begun an extensive research effort, with regard to the regional and site-specific geology/seismology. This effort is directed at reevaluating the geological basis which served as input in the original seismic design of the Haddam Neck Plant, in light of more recent geological information currently being discussed among the scientific community.

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(2) Site-Specific Spectra

Discussions with the Staff will continue in an effort to develop a mutually acceptable approach. This section will be addressed in a supplement to this submittal.

(3) Containment Model

CYAPCO proposes to analyze the seismic response and evaluate the structural capability of the containment structure at the Haddam Neck Plant for the effects of the safe-shutdown earthquake. Floor response spectra will also be generated for use in Part (4) below.

(4) Reactor Coolant System (RCS) Model

CYAPCO is proposing to analyze and evaluate the structural response of the RCS piping, RCS components, and the supports of RCS components (i.e., reactor vessel, steam generator, reactor coolant pump, pressurizer) for effects of the design basis earthquake.

(5) Other Structures

CYAPCO proposes to analyze and evaluate other structures which house equipment necessary to effect a safe-shutdown (screenwell, primary auxiliary building, control room, auxiliary feedwater pump room) following a seismic event and coincident loss of offsite power. Floor level response spectra will be generated at appropriate locations within the structures.

The efforts described above will result in an assessment of the integrity of the reactor coolant pressure boundary (RCPB) and in the generation of information necessary to assure the ability to effect a safe shutdown — the documented objectives of the SEP seismic evaluation.

CYAPCO and our consultants have expended considerable effort aimed at accomplishment of the objectives laid out in that meeting. Significant effort has been expended in reevaluating the seismic hazard at the Haddam Neck Plant, data gathering, modeling of important plant structures, and modeling of the reactor coolant system. Site visits have been made by our consultants to verify and supplement information on CYAPCO drawings, specifications, etc. Simplistic, preliminary calculations have been performed by our consultants on some structures to enable them to determine appropriate methods for final analyses, and reduce the time span required for those analyses. It is currently envisioned that development of mutually acceptable site-specific response spectra will govern the timetable for completion of this program.

Portions of the CYAPCO program are provided in Attachment 1, Seismic Reevaluation Program, Criteria Document. The attached material should be viewed as a draft, which will be finalized concurrent with the development of site-specific spectra and resolution of other technical aspects of the program not addressed in the attached draft. The sections attached address criteria for reassessment of the structural adequacy of safety-related structures and the reactor coolant system piping and components under SSE loads. The remaining sections are in various stages of development and will be provided as soon as they are available.

Consistent with statements made by senior management within the NRC Staff, since this program will involve a considerable amount of resources from each of our organizations, it is CYAPCO's intention to obtain the concurrence of the NRC Staff regarding this program, prior to its execution. Exempted from this statement would be those aspects of the effort, such as RCS modeling, which would not be significantly impacted by future negotiations on this subject.

We trust you find the above information response to your request.

Very truly yours,

CONNECTICUT YANKEE ATOMIC POWER COMPANY

W. G. Counsil

W. G. Counsil
Vice President

Attachment

DOCKET NO. 50-213

ATTACHMENT 1

HADDAM NECK PLANT

SEISMIC REEVALUATION PROGRAM

CRITERIA DOCUMENT

8001250470

PDR/LPDR

JANUARY, 1980

SECTION IV

PRIMARY COOLANT LOOP SYSTEM ANALYSIS

A. SCOPE

The purpose of this document is to present the analytical methods and stress criteria which will be used for the Connecticut Yankee primary coolant loop system seismic qualification program. The program will include static analysis of the primary piping/support system for normal operating thermal, pressure, and deadweight loads along with dynamic system analysis for seismic loads. Stress criteria will be presented for the piping, supports, and primary equipment.

B. BACKGROUND

In the years since the Connecticut Yankee generating station was designed seismic analysis methods have become more rigorous and the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, has been published reflecting changes in analysis, design, and quality control techniques. The purpose of this criteria document is to establish requirements for performing the upgrading seismic analyses of the primary coolant loop system with current technology.

The original design criteria used for analysis of this plant's primary piping system is the ANSI B31.1 Code for Pressure Piping. The reactor pressure vessel, steam generator, and reactor coolant pump were designed and analyzed to the rules of the ASME Code Section VIII.

For the purposes of this document, the reactor coolant loop piping shall be considered to consist of the hot legs, cold legs, crossover legs, and pressurizer surge line. The primary equipment considered in this document consists of control rod drive mechanism, reactor vessel internals, reactor pressure vessel, steam generator, reactor coolant pump, and pressurizer. The supports covered by the criteria in this document are those for the reactor pressure vessel, the steam generator, reactor coolant pump, and pressurizer.

C. LOADING CONDITIONS

The reactor coolant loop piping, supports, and components will be analyzed for the following loading conditions:

1. Normal condition operating pressure, deadweight, and temperature.
2. SSE Condition Seismic - Safe Shutdown Earthquake (SSE) combined with operating pressure and deadweight.

D. STRESS CRITERIA

1. Piping

The piping analysis that will be performed for the Connecticut Yankee evaluation is based on the rules of the ANSI B31.1-1973 Code, the Summer 1973 Addenda.

The loading combinations and associated stress limits to be used for the piping systems which are part of the seismic qualification program are given in Table 1. The stress limits used for the SSE condition correspond to faulted condition allowables. The piping stresses are to be calculated using formulas given in ANSI B31.1-1973, 1973 Summer Addenda.

The maximum loads that the primary coolant loop piping is permitted to transmit to the pressurizer, steam generator, reactor coolant pump, and reactor pressure vessel nozzles are listed in Table 2.

Since the loop isolation valves are much thicker and stronger than the attached piping, and since valves of this design have no history of gross failure of their pressure boundaries (as long as the stresses of the piping attached to the valve remain within the limits defined in this document) the valve integrity is assured.

2. Supports

For linear type supports (i.e., reactor coolant pump hangers), the basis used for the stress criteria in this section is the AISC steel construction manual. The other supports in the primary coolant loop system can be classified as plate and shell types. The stress criteria for the plate and shell supports that is outlined in this document are based on the ASME Code, Section III, Subsection NF.

The load combinations and stress limits for both the linear and plate and shell primary equipment supports are presented in Table 3. The information presented in the table will provide allowables for normal operating and seismic conditions.

3. Components

The basis of the stress criteria outlined in this section for the primary equipment is the ASME Code, Section III, Subsection NB. The load combinations and stress limits to be used with those combinations are presented in Table 4.

E. ANALYSIS PROCEDURES

1. General Procedures

The reactor coolant loop piping/support system will be evaluated with three-dimensional static or dynamic models, depending on the load requirements, which include the effects of the equipment supports and equipment. Static analysis of the piping systems will be performed using displacement techniques with lumped parameters and stiffness matrix representations of supports. It will assume that all components and piping behave in a linear elastic manner. The methods to be used for dynamic analysis depend upon which of two techniques is chosen, response spectra or time history. Details of the two dynamic analysis procedures are presented in the following two sections.

The primary equipment that will be evaluated as part of this program shall have dynamic analyses performed in accordance with the same procedures as those presented below for piping systems. In addition to the detailed models that are developed for the evaluations of the individual components, reduced models will be produced for use in the reactor coolant loop system analysis.

Analytical representations of the primary equipment supports shall be produced for inclusion in the reactor coolant loop system model. The loads that are generated by the reactor coolant loop system model shall be used to qualify the component supports.

2. Response Spectrum Analysis Procedures

If a decision is made to perform a response spectrum seismic analysis, a three-dimensional linear dynamic analytic model of the primary coolant loop system will be developed. The model will include analytical representations of the components, component supports, and associated piping. The boundaries of the model will be defined as the component support to containment concrete interface.

The analysis will be performed assuming that the seismic event is initiated with the plant at normal full power condition. The damping values that will be used are four percent (4%) of critical for the SSE condition. Since the components are supported at different floor elevations within the containment building, the response spectrum in each direction shall be an envelope of the applicable floor spectra.

The analysis shall be performed with a simultaneous input of the two horizontal components and one vertical component of the earthquake. The modal response for each item of interest (e.g., force, displacement, stress) shall be obtained by the square root of the sum of the squares method.

$$R_T = \left[\sum_{i=1}^{3} R_i^2 \right]^{1/2}$$

where: $R_i \quad \left[\sum_{j=1}^{N} R_{ij}^2 \right]^{1/2}$

where: R_T = total combined response at a point

R_i = value of combined response of direction i

R_{ij} = absolute value of response for direction i, mode j

N = total number of modes considered.

For systems having modes with closely spaced frequencies, the above method shall be modified to include the possible effect of these modes. Combined total response for systems which have such closely spaced modal frequencies will be obtained in accordance with Regulatory Guide 1.92, or as an acceptable alternative, the following method. The groups of closely spaced modes shall be chosen such that the difference between the frequencies of the first mode and the last mode of the group does not exceed ten percent (10%) of the lower frequency. Frequency groups are formed starting from the lowest frequency and working toward successively higher frequencies. No frequency should be included in more than one group. The resultant unidirectional response for systems having such closely spaced modal frequencies shall be obtained by the square root of the sum of: (a) the sum of the squares of all modes, and (b) the product of the responses of the modes in various groups of closely spaced modes and associated coupling factors, ε. The mathematical expression for this method (with "R" as the item of interest) is:

$$R_i^2 = \sum_{j=1} R_{ij}^2 + 2 \sum_{j=1}^{S} \sum_{K=M_j}^{N_j-1} \sum_{\ell=K+1}^{N_j} R_{iK} R_{i\ell} \varepsilon_{K\ell}, \text{ for: } \ell \neq K$$

where: S = number of groups of closely spaced modes

M_j = lowest model number associated with group j of closely spaced modes

N_j = highest model number associated with group j of closely spaced modes

$\varepsilon_{K\ell}$ = coupling factor with

$$\varepsilon_{K\ell} = \left[1 + \left[\frac{\omega_K^1 - \omega_\ell^1}{(\beta_K^1 \omega_K + \beta_\ell^1 \omega_\ell)}\right]^2\right]^{-1}$$

and:

$$\omega_K^1 = \omega_K \left[1 - (\beta_K^1)^2\right]^{1/2}$$

$$\beta_K^1 = \beta_K + \frac{2}{(\omega_K t_d)}$$

ω_K = frequency of closely spaced mode K (rad/sec)

β_K = fraction of critical damping in closely spaced mode K

t_d = duration of the earthquake (seconds)

The analyses performed for piping and supports will not include stresses resulting from SSE induced differential motion. These stresses are secondary in nature, based on ASME Code rules for piping (NB-3653, NB-3656, F-1360) and component supports (NF-3231). The SSE being a very low probability single occurrence event, is treated as a faulted condition.

The analysis of the components subjected to seismic loading will involve several steps that are similar to those outlined above for the system analysis. A three-dimensional linear elastic analystic representation of the component is developed. The component supports and attached primary coolant loop piping shall be represented by stiffness matrices. The analysis shall be performed with the simultaneous input of three response spectra, two horizontal and one vertical. Damping values of four percent (4%) for SSE will be used. The model combination techniques outlined for the system analysis shall also be used for the component analysis.

3. Time History Seismic Analysis Procedures

In the event that time history seismic analysis is required, the following procedures shall be used. A three-dimensional elastic non-linear model of the reactor coolant loop system shall be used. The model shall include a simplified representation of the containment interior concrete structure, the components, the component supports and the attached piping. The effects of the large auxiliary piping systems (e.g., main steam, feedwater) shall be accounted for with stiffness elements in the form of linear springs or stiffness matrices. Damping for the system model shall be provided using the Rayleigh method based on a computed model energy distribution.

If the analysis is performed by applying the three orthogonal earthquake time histories separately, the total response will be obtained by adding the three directional responses by algebraic summation. If the three time histories are applied simultaneously, direct integration will be used to determine the total response.

F. MODELING TECHNIQUES

The piping system components, and component supports are to be represented by an ordered set of data which numerically describes the physical system.

The spatial geometric description of the model is to be based upon the as-built isometric piping drawings and equipment drawings. Node point coordinates and incremental lengths of the members are determined from these drawings. Node point coordinates are input on network cards. Incremental member lengths are input on element cards. The geometrical properties along with the modulus of elasticity, E, the coefficient of thermal expansion, α, the average temperature changes from the ambient temperature, ΔT, and the weight per unit length, ω, are specified for each element. The supports are represented by stiffness matrices which define restraint characteristics of the supports.

A network model is to be made up of a number of sections, each having an overall transfer relationship formed from its group of elements. The linear elastic properties of the section are to be used to define the characteristic stiffness matrix for the section. Using the transfer relationship for a section, the loads required to suppress all deflections at the ends of the section arising from the thermal and boundary forces for the section are obtained. These loads are incorporated into the overall load vector.

After all the sections have been defined in this manner, the overall stiffness matrix (K) and associated load vector to suppress the deflection of all the network points is to be determined. The flexibility matrix is multiplied by the negative of the load vector to determine the network point deflections due to the thermal and boundary force effects. Using the general transfer relationship, the deflections and internal forces are then determined at all node points in the system. The support loads (F) are also computed by multiplying the stiffness matrix (K) by the displacement vector (δ) at the support point.

The models used in the static analyses are to be modified for use in the dynamic analyses by including the mass characteristics of the piping and equipment.

The lumping of the distributed mass of the piping systems is to be accomplished by locating the total mass at points in the system which will approximately represent the response of the distributed system. Effects of the equipment motion will be obtained by modeling the mass and the stiffness characteristics of the equipment in the overall system model when required. The supports are again represented by stiffness matrices in the system model for the dynamic analysis.

From the mathematical description of the system, the overall stiffness matrix (K) is to be developed from the individual element stiffness matrices using the transfer matrix (K_R) associated with mass degrees-of-freedom only. From the mass matrix and the reduced stiffness matrix, the natural frequencies and the normal modes are to be determined.

The effect of eccentric masses, such as valves and extended structures, are considered in the seismic piping analyses. These eccentric masses are modeled in the system analysis, and the torsional effects caused by them are evaluated and included in the total system response. The total response must meet the limits of the criteria applicable to the safety class of the piping.

TABLE 1

LOADING COMBINATIONS AND STRESS LIMITS FOR PIPING

LOADING COMBINATIONS	STRESS LIMITS
1. Normal:	
Design Pressure + Deadweight	$\leq S_h$
2. SSE:	
Operating Pressure + Deadweight + Maximum Potential Earthquake Loads (SSE)	$\leq 2.4\ S_h$

where: S_h = allowable stress from USAS B31.1 Code for Pressure Piping.

TABLE 2

STEAM GENERATOR LOADS INLET AND OUTLET NOZZLES

LOAD	FORCE (kips)			MOMENT (in-kips)		
	X	Y	Z	X	Y	Z
Thermal	160	100	25	1200	3000	15000
DW	20	- 20	10	70	100	150
Pressure	+1700	40	15	1500	1500	2000
SSE	250	200	120	6000	6200	7000

REACTOR COOLANT PUMP LOADS INLET NOZZLE

LOAD	FORCE (kips)			MOMENT (in-kips)		
	X	Y	Z	X	Y	Z
Thermal	100	30	30	8000	7000	3000
DW	+ 20	1	1	50	200	200
Pressure	+1700	30	20	1000	6000	3000
SSE	350	200	275	6000	13000	10000

REACTOR COOLANT PUMP LOADS OUTLET NOZZLE

LOAD	FORCE (kips)			MOMENT (in-kips)		
	X	Y	Z	X	Y	Z
Thermal	50	50	40	3000	3000	7000
DW	1	- 10	1	50	20	150
Pressure	+1400	10	10	1000	700	500
SSE	450	150	300	13000	1500	15000

NOTE: 1. All loads are ± unless noted.
2. Coordinate system.

X-Y Plane Vertical

Z By Right Hand Rule

TABLE 2 (Continued)

REACTOR PRESSURE VESSEL LOADS INLET NOZZLE

LOAD	FORCE (kips)			MOMENT (in-kips)		
	X	Y	Z	X	Y	Z
Thermal	50	100	30	5000	7000	5000
DW	1	- 20	1	200	60	800
Pressure	+1400	1	10	800	700	200
SSE	300	130	300	9000	13000	10300

REACTOR PRESSURE VESSEL LOADS OUTLET NOZZLE

LOAD	FORCE (kips)			MOMENT (in-kips)		
	X	Y	Z	X	Y	Z
Thermal	60	150	30	1000	4000	20000
DW	1	- 20	1	75	100	800
Pressure	1500	5	5	70	900	400
SSE	500	90	160	1600	14000	7000

PRESSURIZER SURGE NOZZLE

LOAD	FORCE (kips)			MOMENT (in-kips)		
	X	Y	Z	X	Y	Z
Thermal	3	7	7	1200	1000	400
DW	+ 30	1	1	15	10	35
SSE	3	5	5	250	350	350

NOTES: 1. All loads are ± unless noted.
2. Coordinate system.

X-Y Plane Vertical

Z, By Right Hand Rule

TABLE 3

LOADING COMBINATIONS AND STRESS LIMITS FOR SUPPORTS

LOADING COMBINATION	LINEAR TYPE SUPPORTS LIMITS[3]	PLATE AND SHELL SUPPORTS LIMITS
$P + D + T_D$	Working Stress[4]	$P_m \leq 1.0\ S_m$ $P_m + P_b \leq 1.5\ S_m$
$P + D + T_O + E^1$	Within lesser of $\frac{1.2\ F_y}{F_t}$ or $\frac{0.7\ S_u}{F_t}$ times working limits[4]	$P_m \leq 1.2\ F_y$[1] $P_m + P_b \leq 1.8\ F_y$[2]

1 Not to exceed $0.7\ S_u$

2 Not to exceed $1.05\ S_u$

3 Compressive axial member loads should be kept to less than 0.9 times the critical buckling load.

4 Working stress allowables per Appendix XVII of ASME III.

NOTES:

P	=	pressure
	=	deadweight
T_D	=	thermal-design temperature
T_O	=	thermal-operating temperature
E^1	=	SSE
F_y	=	material yield strength
F_t	=	allowable tensile stress per ASME Section III, Appendix XVII

TABLE 4

LOADING COMBINATIONS AND STRESS LIMITS FOR COMPONENTS

LOADING COMBINATION	STRESS LIMIT
Design Pressure + Deadweight	$P_m \leq S_m$
	$P_L\ (P_m) + P_B \leq 1.5\ S_m$
Operating Pressure + Deadweight + SSE	$P_m \leq 2.4\ S_m$[1]
	$P_L\ (P_m) + P_B \leq 3.6\ S_m$[2]

1 Not to exceed $0.7\ S_u$

2 Not to exceed $1.05\ S_u$

NOTES:

- P_m = general primary membrane stress
- P_L = primary local membrane stress
- P_B = primary bending stress
- S_m = allowable stress intensity per ASME, Section III
- S_u = ultimate stress at operating temperature

V. ANALYSIS AND EVALUATION OF PLANT STRUCTURES

1. Basic Approach

This section outlines criteria that form the basis for the reassessment of the structural adequacy of the safety-related structures to resist the SSE loads. The structures that will be included in the reevaluation are:

a) Containment Shell

b) Containment Internal Structure

c) Screenwall House

d) Primary Auxiliary Building

e) Service-Turbine Building Complex

f) Auxiliary Feedwater Building

All of these structures may be classified as seismic Category 1 structures except for some areas of the service-turbine building complex. The new diesel generator building, a recent addition to the plant, has been designed as a seismic Category 1 structure using currently accepted techniques and is not included in this reassessment.* All structures will be reevaluated using dynamic analyses. Where the preliminary evaluations indicate a considerable margin of safety with respect to the postulated seismic event, a simplified equivalent static procedure may be used.

The following documents establish acceptable methods, stresses and properties and are discussed in detail in the sections to follow:

USNRC Standard Review Plan - Sections 3.7.2, 3.8.3, 3.8.4

USNRC Regulatory Guides 1.60, 1.61, 1.92

ACI Codes 318-71, 349-76, 359-77

ASME B&PV Code, Section III Subsections NE, NF

AISC Specification for Design, Fabrication and Erection of Structural Steel for Buildings

Uniform Building Code - 79 Edition for Unreinforced Brick and Hollow Unit Masonry

Although the proposed criteria are essentially the current standard ones, they may subsequently be modified. If the proposed modification departs significantly from the present NRC positions, justifications will be documented to support any changes.

*The new diesel generator building was analyzed in 1974. A three dimensional space frame model was constructed and an evaluation made based on a Reg. Guide 160 input normalized to 0.17 G.

2. Time-History Motions

The seismic input has been described in terms of response spectra in Section III. The seismic input is also needed in terms of time-histories for the computation of floor response spectra as well as in the time-history analyses procedures for structural response computations.

Time-histories that will be developed for such purposes will match the design response spectra of Section III within the limits required by USNRC Standard Review Plan Section 3.7.1. The overall duration and the rise, strong motion and decay portions of the time-history will be consistent with the hypothesized SSE.

3. Material Properties

For the determination of the strength and stiffness of the structures under the postulated seismic conditions, the material properties will be taken as either those specified on the contract drawings and documents or the average of actual material properties obtained from tests at the time of construction. In lieu of construction test data, tests on selected cores or samples from existing construction may be performed to obtain actual material properties.

Table 1 lists the specified material properties for concrete, reinforcement and structural steel in various structures.

Damping in reinforced concrete and structural steel shall be taken as 5 percent of critical except 7 percent of critical damping may be used when the stresses induced in the structure by seismic, gravity, and operating loads (see section 6.1) are high (close to allowables, see section 6.2).

TABLE 1

SPECIFIED MATERIAL PROPERTIES

I. Containment & Internals Structure

A. Reinforced Concrete

1. f'_c = 3000 psi @ 28 days (dome concrete - f'_c = 5000 psi) @ 28 days)

2. Reinforcing Steel

(a) #14 & #18 (ASTM A408)

(1) Typical fy = 50,000 psi min

(2) Foundation Mat and Exterior Wall Dowels:
fy = 40,000 psi min

(b) #11 (ASTM A-15 & A-305)

(1) Typical: fy = 40,000 psi min

(2) Exterior Wall above elev. 31'-6" and dome:
fy = 50,000 psi min

(c) #10 and smaller: ASTM A-15 and A-305, intermediate grade,
fy = 40,000 psi min

B. Structural Steel

ASTM A-36, Fy = 36,000 psi min

II. Primary Auxilary Building, Turbine-Service Building Complex and Screenwell House

A. Reinforced Concrete

1. F'_c = 3000 psi @ 28 days

2. Reinforcing Steel: ASTM A-15 & A-305, intermediate grade,
fy - 40,000 psi min.

B. Structural Steel

ASTM A-36, Fy - 36,000 psi min

C. Unreinforced Brick and Hollow Unit Masonry:

S'_m = 1500 psi

III. Auxiliary Feedwater Building

A. Structural Steel

ASTM A-36, Fy = 36,000 psi min

4. Analytical Procedures

Linear elastic dynamic analyse. procedures are intended to be used for all structures. If nonlinear inelastic procedures are to be used for any structure a separate criterion will be developed for the non-linear analysis procedures and acceptance criterion.

The USNRC Standard Review Plan Section 3.7.2 shall be followed in those matters not explicitly covered by this document. The following dynamic analyses procedure may be used:

- o Response spectrum modal superposition
- o Time-history modal superposition
- o Time-history direct integration

Equivalent static procedure may also be used where justified.

4.1 Soil-Structure Interaction

Most of the structures at the CY plant are founded on rock (shear wave velocity, V_s > 3500 ft./sec.) Screenwell house is founded on lean concrete fill of 2 ft. to 20 ft. depth over rock. A small portion of Turbine Building is also founded on lean concrete fill of small depth over rock. A lightly loaded region of Service Building is founded on select compacted fill (soil) of about 10 ft. depth over rock.

Soil compliance effects in those portions of any structure founded on soil backfill will be considered. The seismic input for all structures will be as described in Section 2.

4.2 Structural Modeling

Dynamic structural models will be used to calculate the structural responses to the horizontal and vertical components of the ground motion. Material properties used in these models will be as defined in Section 4.3.

In general, the stiffness of reinforced concrete structural members will be calculated using gross cross-sections. Cracked sections will be used when necessary for a realistic assessment of the stiffness.

Mass calculations shall include the dead weight of the structures as well as the equipment. The mass of non-structural elements (e.g., partitioning) and small pieces of equipment (e.g., electrical cabinets) will be estimated as a uniform weight across the whole floor.

4.3 Coupling

Simplified models of the Nuclear Steam Supply System (NSSS) components will be coupled to the dynamic structural model of the Containment Internal structure. Responses at the equipment supports will be calculated for later use in NSSS qualification.

Structures which are physically connected by structural elements will be analyzed using coupled dynamic models except where it can be shown that coupling does not significantly influence relevant structural responses.

4.4 Torsion

Significant eccentricity between mass and stiffness will induce torsional response in a structure subjected to horizontal component of ground motion. Such eccentricity will be taken into account in the modeling of structures. In addition, to account for variation in location of mass and stiffness in the model and in the structure as well as possible torsional input into the structure, accidental eccentricity or equivalent will be considered.

For structures with rigid diaphragms or equivalent which are modeled by lumped mass models, accidental eccentricity shall be taken equal to 5% of the plan dimension normal to horizontal input component. Such accidental eccentricity will be additive to geometrical eccentricity that may exist at that level.

For other structures where accidental eccentricity cannot be accounted for in a simple manner, the responses to the horizontal input component shall be increased by 5% to account for the effects of accidental eccentricity.

Torsional responses shall be combined with translational responses on an absolute sum basis.

5. Floor Response Spectra

The peaks in the floor response spectra at structural frequencies are usually broadened to account for the uncertainties in these frequencies due to uncertainties in material properties, and approximations in modeling techniques and analyses procedures.

When minimum specified properties of structural materials are used in the model, the spectral peaks at structural frequencies will be broadened by 15% on each side of such frequencies.

If actual average structural material properties determined from test data are used in the models, a portion of this uncertainty is accounted for. The average material properties are usually higher than the minimum specified properties and leads to somewhat higher values for structural frequencies. In this case the spectral peaks at structural frequencies will be broadened by 5% on the high side and 15% on the low side of the structural frequencies.

Lesser peaks and valleys will be smoothed by free-hand enveloping.

6. Acceptance Criteria

6.1 Load Combination

The following load combination will be considered in evaluating the structure:

$$U = D + L' + O + E$$

where

U = total load to be resisted

L' = actual live load

O = operating temperature and pressure loads, if any

E = SSE load

D = dead weight

6.2 Allowable Stresses

The allowable stresses for reinforced concrete portions of structures will be per ACI Code 359-77 for the Containment Exterior and Internal structures and ACI Code 349-76 for other structures.

The stresses for steel portions of structures will be checked per Part 1 of AISC Specification, 1979 edition, except that the allowable stresses will be as delineated in NRC Standard Review Plan Section 3.8.3 and 3.8.4.

6.3 Structural Foundations

The structural foundations will have a factor of safety 1.1 against sliding and overturning for the following load combination:

$$U = D + L' + E$$

where U, D, L' and E are as defined in Section 6.1.

LBWR - 1

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

January 20, 1979

Docket No. 50-409

LICENSEE: Dairyland Power Cooperative

FACILITY: LaCrosse Boiling Water Reactor (LACBWR)

SUBJECT: SUMMARY OF JANUARY 9, 1979 MEETING REGARDING LIQUEFACTION POTENTIAL AT THE LACBWR SITE

Representatives of Dairyland Power Cooperative (DPC) and their consultants met with members of the NRC staff in Bethesda, Maryland, on January 9, 1979. A list of meeting attendees is attached. The purpose of the meeting was to discuss a recent liquefaction study for the LACBWR site that was conducted by the U. S. Army Engineer Waterways Experiment Station (WES). The study was conducted at the NRC's request as part of the Systematic Evaluation Program (SEP) review. A copy of the WES report, "Liquefaction Analysis for LaCrosse Nuclear Power Station", dated December 1978, is attached.

A summary of the important items discussed follows:

1. The NRC staff outlined the results of the WES report. The report indicates that based on the data used and the analyses performed the soils at the site could strain badly for an earthquake producing a surface level peak acceleration of 0.12g (the Full Term License (FTL) application is based on an SSE of 0.12g).

2. The staff has found the available soil data to be inadequate for an accurate assessment of liquefaction potential. Further, the staff believes that the assumptions used concerning seismicity were conservative.

3. The staff expressed their conclusion that no immediate hazard exists at the site, but that the data base needs to be supplemented to reach a final resolution of the liquefaction topic for the SEP review of LACBWR.

4. DPC took exception to the WES report. They maintained that it was not an accurate representation of the potential for liquefaction because of the conservative treatment of the data. Moreover, they believed the hazard to the plant was overstated in the report because of the large number of piles that are utilized at LACBWR to support safety related foundations.

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PDR

5. DPC further maintained that the liquefaction analysis submitted in support of their FTL application was a more realistic, yet adequately conservative assessment of the potential for liquefaction. This analysis was performed by Dames and Moore and indicates a higher margin of safety than the WES report.

6. After some discussion it was agreed that it would be appropriate to initiate a soils properties investigation program. This program could include obtaining undisturbed soil samples at the site, and conducting laboratory undrained cyclic triaxial tests and density tests to better define the soils properties.

7. DPC stated that soil samples could be obtained within a short time (one or two weeks) after the details of a sampling program were defined. The staff indicated that this time frame would be consistent with the overall objective of resolving this topic for LACBWR on about a six month schedule.

8. The staff and DPC agreed to meet again in about two weeks to discuss the particulars of an appropriate soils investigation program for the LACBWR site. In the interim, DPC will do some preliminary work toward defining such a program.

Jack S. Wetmore, Project Manager
Operating Reactors Branch #2
Division of Operating Reactors

Attachments:
1. List of Attendees
2. WES Report

cc:
See next page

cc
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MEETING SUMMARY DISTRIBUTION:

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R. Reid
T. Ippolito
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G. Knighton
D. Brinkman
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H. Smith
A. T. Cardone
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K. Herring
C. H. Hofmayer
R. G. LaGrange
H. Levin
B. D. Liaw
C. P. Woodhead
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R. F. Fraley, ACRS(16)
TERA
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ATTACHMENT 1

LIST OF ATTENDEES

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E. Trimmil
A. H. Yoli

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D. L. Ziemann
J. T. Greeves

ATTACHMENT 2

LIQUEFACTION ANALYSIS FOR LACROSS NUCLEAR POWER STATION

By

W. F. Marcuson, III

And

W. A. Bieganousky

December 1978

Prepared for

U. S. Nuclear Regulatory Commission
Washington, D. C.

Prepared by

Geotechnical Laboratory

U. S. Army Engineer Waterways Experiment Station

Vicksburg, Mississippi

Dupe of ~~8408220173~~

LIQUEFACTION ANALYSIS FOR LACROSS NUCLEAR POWER STATION

Introduction

Background

1. The United States Nuclear Regulatory Commission (NRC) requested that the Waterways Experiment Station (WES) review certain foundation conditions at the LaCross Nuclear Station, an operating nuclear power plant. This plant, which is located near LaCross, Wisconsin, is among the oldest in the country and was put into operation before the present Site Analysis Report review system came into effect. This report documents WES' review of the LaCross Nuclear Station. Specifically, the question examined was the earthquake safety of the pile foundation which supports the containment vessel. The piles are driven through low to medium relative density sands and terminate in a dense sand layer approximately 28 ft above bedrock.

Scope of work

2. The investigation of the foundation at the LaCross Nuclear Station included the following:

a. Review of Chapter 3, Soil Engineering Properties contained in the Application for Operating License for the LaCross Boiling Water Reactor by Dairyland Power Cooperative including portions of Appendix A, entitled "Field Exploration and Laboratory Tests,"[1] and associated design drawings.

b. The performance of a liquefaction analysis using the Seed-Idriss Simplified Procedure[2] assuming an earthquake with a peak acceleration of 0.12 and 0.2 g, respectively.

c. The performance of a liquefaction analysis using Seed's empirical method assuming both the 0.12 and 0.2 g earthquakes and comparison with a "rule of thumb" based on the Japanese experience at Niigata in 1964.

3. The objective of this study was to evaluate to the degree possible with the data available from prior field and laboratory studies by others, the seismic stability of the pile foundation which supports the containment vessel at the LaCross Nuclear Station.

Review of Previous Work

4. As stated earlier, portions of Reference 1 were reviewed to determine the soil profile under the containment vessel, including soil properties. Logs of Borings B-3 and B-4 drilled by Raymond International in July 1962 and Borings DM-1 and DM-3, drilled under Dames & Moore's supervision in 1973, were reviewed. Figure 1 shows an idealized soil profile in the vicinity of the reactor building. The ground surface is at elevation (el) 636 ft mean sea level (msl). The groundwater table was assumed at a depth of 13 ft. Top of bedrock is located at a depth of about 133 ft.

5. During construction, the soil was excavated to el 615 ft msl, and piles were driven below the reactor containment vessel. These piles terminated at el 535 ft. The piles were 50-ton cast in-place concrete piles with a tip diameter of 8 in., a butt diameter of 12 in. and an outer shell of 7-guage steel monotube, and were driven approximately 3-1/2 ft on centers. No mention was made of any internal reinforcing steel in the piles in the plans and reports provided to WES. A total of

approximately 230 piles were driven. The data provided indicate that the hammer used was a McKierman-Terry C-5 double-acting hammer with a rated striking energy of 16,000 ft-lb per blow. The piles were driven to at least a resistance of 6 blows per in. for the final 2 to 3 in. The number of blows in the last foot actually ranged from 75 to 330.

6. The soil below the reactor building (el 610) consisted of a fine to medium sand with occasional zones of clayey silt, coarse sand, and fine gravel, down to an elevation of approximately 535 ft. At el 535 ft, a 10-ft-thick fine to medium sand, with fine to medium gravels is encountered. Below this gravelly sandy layer, is an 18-ft-thick layer of sand which immediately overlies the bedrock.

7. Also shown on Figure 1 are the average blow counts, water content, dry and wet density, and shear-wave velocities for the six layers in the idealized soil profile. The reader is cautioned that the blow counts may or may not be Standard Penetration Test (SPT) N values. It was not explicitly stated in the available source of information how the penetration tests were conducted nor were they called "Standard Penetration Test" results. The values shown on Figure 1 are considered approximate average values for the layer. Both the blows per foot and the dry density values were obtained from an evaluation of the boring log data in Reference 1. The wet densities and shear-wave velocities which are shown on Figure 1 are estimates based on WES' experience and data presented in Reference 1.

8. Figure 2 is a plot of blows per foot versus depth. The data obtained in Boring B-3 are believed to have been obtained prior to pile

driving. The data obtained in Borings DM-1 and DM-3 are believed to have been obtained after pile driving. The reader is cautioned that a 1-to-1 comparison is impossible because the data obtained in Boring B-3 were obtained using a 2-in. split-spoon sampler while the data obtained in Borings DM-1 and DM-3 were obtained using the Dames & Moore sampler which is 3-1/4 in. in diameter. Figure 3 is the dry density information obtained from samples obtained from Borings DM-1 and DM-3.

9. Figure 4 is a plot of overburden pressure versus depth for the site. As stated previously, the water table was assumed at a depth of 13 ft. Below this depth both total and effective overburden pressures are shown.

10. The blow count values were assumed to be Standard Penetration Test N values and were used to compute relative density from the following equation:[3]

$$D_r = 11.7 + 0.76 \left[\left| 222(N) + 1600 - 53(\bar{\sigma}_o) - 50(C_u)^2 \right| \right]^{1/2} \quad (1)$$

where

D_r = Relative density

N = Standard Penetration Test N values

$\bar{\sigma}_o$ = Effective overburden pressure in psi

C_u = The coefficient of uniformity

Using equation 1, the relative density of the top 105 ft is predicted to be between 50 and 60 percent.

11. Review of the available data[1] indicate that the material has the minimum density of about 100 pcf and a maximum density of about 120 pcf. These tests were run on bulk samples obtained by combining representative materials encountered at the site. WES' experience indicates that when

materials are combined the maximum and minimum density generally increase. This increase can be as much as 8 pcf. Consequently, WES believes that a minimum density of 92 pcf and a maximum density of 112 pcf may be more realistic for the in situ material. The relative densities predicted by equation 1 appear to be more nearly the same as those which would be obtained using the WES' maximum and minimum density estimates and the in situ dry unit weights given in Figure 3. An analysis of pile geometry records supplied by NRC suggest an average density increase of approximately 1 pcf due to pile driving. This is based on the reduction of void ratio which would occur assuming the soil displaced by the pile went entirely into taking up the voids of the adjacent soil. This assumes no soil heave and does not account for any densification due to vibrations during driving. An increase of 1 pcf is not significant and is believed not to contribute substantially to the stability of the soils. Records of ground surface movement during pile driving were sought but no such information was provided. While it is possible that more densification may have occurred, there were no data made available to WES which would support this hypothesis.

12. Dames & Moore determined the liquefaction potential of the subsurface soil by performing 11 stress-controlled dynamic triaxial compression tests on representative samples of the material considered to be potentially susceptible to liquefaction during the SSE. Eight of the samples were reconstituted to approximately what Dames & Moore believed to be the in situ density. In addition, three reconstituted samples were tested at slightly greater densities than the average in situ value (as determined by Dames & Moore) in order to examine the influence of density variation on liquefaction potential. These tests were run at confining

pressures of 1000 and 2000 psf and the results of these triaxial tests are shown on Figures 5 and 6. The data points identified by 104, 111, and 112 (the dry density in pcf) on Figure 5 were for specimens consolidated to an effective confining pressure of 1000 psf. The data identified by 106 and 105 (dry density in pcf) on Figure 6 were obtained by consolidating the specimens to an effective confining pressure of 2000 psf.

Dynamic Strength of the Soil

13. In order to evaluate the liquefaction potential of the soil in question, the laboratory cyclic triaxial test results obtained by Dames & Moore were used. Figures 5 and 6 are reproductions of Dames & Moore's test results. The as-tested dry densities of the remolded specimens made from material taken from Boring 5 at a depth of about 8-1/2 ft are shown next to the data points for these tests on Figure 5. A curve has been drawn through the data points for a dry density of about 111 pcf. As stated previously, WES believes that this material is at an in situ dry density of about 102 pcf. Consequently, a curve more or less parallel to the 111-lb curve was drawn through a data point at 104 pcf. This curve (marked γ_d = 102 pcf) was used to evaluate the soil strength. On Figure 6, the remolded soil specimens taken from Boring 3 at a depth of 35.5 ft have been used. Adjacent to each data point, the as-tested density is listed. A curve is drawn through these data for a density of about 106 pcf. A curve more or less parallel to this curve has been drawn and labeled γ_d = 100 pcf, because WES believes the in situ density of the material at a depth of about 38.5 is 100 pcf. This curve was also used to evaluate the dynamic soil strength.

14. As will be mentioned later on in this report, the number of equivalent cycles of load for SSE was chosen to be 10 (see discussion of design earthquake on page 8). Figures 5 and 6 were entered at 10 cycles and the stress ratio required to cause 10 percent double-amplitude strain was determined. This stress ratio was multiplied by 1000 and 2000 psf as appropriate to determine the superimposed dynamic shear strength. These values are plotted on Figure 7. A line was drawn through these data points and labeled isotropic laboratory data. Isotropically consolidated cyclic triaxial test data must be corrected by a correction factor, C_r, to represent field conditions. This correction factor is based on the comparison of cyclic triaxial test results to cyclic simple shear and SHAKE table test results (References 2, 4, and 5). For this investigation, a C_r of 0.57 was used. Also shown on Figure 7 is a curve labeled field conditions. The ordinate of this curve is 0.57 times the ordinate for the curve labeled isotropic laboratory data. The field condition curve was used to evaluate the dynamic shear strength of the soil during this investigation.

Seed-Idriss Simplified Procedure

15. In order to evaluate the liquefaction potential of a site, the cyclic stresses generated by the earthquake must be determined. Reference 2 suggests that the average shear stress, τ_{ave}, generated by an earthquake can be determined by the formula:

$$\tau_{ave} = 0.65 \times \frac{\gamma H}{g} A_{max} \times r_d \qquad (2)$$

where

γ = the total unit weight of the soil

H = depth from the ground surface to the point in question in feet

g = acceleration of gravity

A_{max} = the peak acceleration at the ground surface generated by the earthquake in the same system of units as g

r_d = a rigidity factor

The constant 0.65 is a factor which corrects the maximum shear stress to an equivalent sinusoidal shear stress.

16. Using equation 2, τ_{ave} can be determined for any depth in the soil profile. The r_d factor used in this analysis is shown by the curve marked "analysis" on Figure 8.

Earthquake parameters

17. In order to conduct this analysis, the maximum acceleration generated by the design earthquake and the number of equivalent cycles of stress are required. The maximum acceleration was specified by the NRC as 0.12 and 0.2 g. Review of the geological and seismological studies conducted at LaCross predict that an earthquake of Modified Mercalli Intensity VIII in the epicentral region has occurred on the Keweenaw fault.[1] For analysis purposes, an earthquake with an intensity one unit greater than the largest recorded intensity was assumed. Thus, using a Modified Mercalli Intensity of IX and using the intensity-magnitude relationships shown on Figure 9 (Reference 6), a magnitude 6.6 earthquake is postulated. Figure 10 is a plot of number of equivalent cycles versus magnitude which was developed by Seed.[5] This plot was entered and 10 equivalent cycles, which are essentially an upper bound

to the data in the plot, were assumed appropriate. For the design earthquakes (SSEa, and SSEb) 10 cycles and peak ground surface acceleration values of 0.12 and 0.2 g were used, respectively.

Analysis

18. Because of the high N values obtained in the dense sand layer at a depth of about 105 to 115 ft, this zone is predicted to remain stable even under the so-called design earthquakes. There are no other data available from this layer. If one assumes that the dynamic soil strength of this zone was the same as that judged appropriate for the upper materials by WES on Figure 7, then liquefaction might be predicted. WES does not believe this will happen.

SSE, 0.12 g

19. Table 1 presents the information needed to calculate the average shear stress (τ_{ave}) for the soil profile using the Seed-Idriss method.[2] Also listed on Table 1 is the effective overburden pressure ($\bar{\sigma}_o$) needed to enter Figure 7 to determine the available soil strength. Both the values of dynamic shear strength and dynamic shear stress are listed as a function of depth on Table 2. The factor of safety against 10 percent double-amplitude strain has been defined as the dynamic shear strength divided by the average dynamic shear stress. This factor of safety is also listed on Table 2. It should be noted that the factor of safety below a depth of 35 ft (depth of excavation) varies from 0.99 to 1.15 and is below 1.1 to a depth of 100 ft. Factors of safety less than 1 were predicted in the soil between a depth of 35 and 45 ft. It should be emphasized that the state of knowledge is not adequately refined and the assumptions required to carry out the analysis, given

the limitations in the existing data base, are such that it is not believed justified to call this site safe even though factors of safety marginally greater than 1 were calculated. However, this analysis does not prove the site unsafe under this acceleration as it is possible that had more extensive data and more thorough documentation been available, the judgments concerning the in-situ density and cyclic shear strength would have been different.

<u>SSE, 0.2 g</u>

20. The information needed to calculate τ_{ave} at the LaCross site for the SSE with 0.2 g peak acceleration is given on Table 3. Also shown on Table 3 is the effective overburden pressure which was used to enter Figure 7 to determine the shear strength of the soil. Table 4 presents the average shear stress and dynamic shear strength as a function of depth for this SSE. Also shown on Table 4 are factors of safety (as previously defined) for this SSE. As can be seen, the factors of safety below a depth of 35 ft vary from 0.59 to 0.66. Clearly, this indicates failure, as failure is defined in this report. A doubling of the cyclic strength over that shown by the authors would be required to produce a factor of safety of 1.25. This level is often considered reasonable for safety in the type of analysis performed herein.

Empirical Liquefaction Analysis

21. Empirical data in the form of stress ratio and corrected N values for sites that have and have not liquefied during past earthquakes, have been developed and plotted on Figure 11 (Reference 5). On Figure 11, the Standard Penetration Test N values have been corrected to an effective

overburden pressure of 1 tsf. As a second means to evaluate the lique-faction potential at the LaCross Site, the average blows per foot as shown on Figure 1, were plotted against the stress ratio and compared to the data shown on Figure 11. The stress ratio τ_{ave} divided by $\bar{\sigma}_o$ where $\bar{\sigma}_o$ is equal to the effective overburden pressure is also tabulated on Tables 1 and 3 for the various depths in question.

22. The blows per foot were assumed to be SPT N values and were corrected to an overburden pressure of 1 tsf by the formula:

$$N_1 = C_N \times N \qquad (3)$$

where

N = Standard Penetration Test penetration resistance value measured in the field

N_1 = Standard Penetration Test N values corrected to an overburden pressure of 1 tsf

C_N = Correction factor

23. C_N was determined from Figure 12 (Re erences 5 and 7). Figure 12 was extrapolated back to zero using data in Peck, Hânson, and Thornburn.[7] Values of C_N and N_1 are also shown on Tables 1 and 3. These values have been superimposed on Figure 11. Most of the values show that liquefaction should not occur; however, liquefaction is predicted from 25 to 35 ft.

24. A similar analysis was conducted assuming a SSE with a peak acceleration of 0.2 g. The stress ratios, C_N , N , and N_1 , as a function of depth are tabulated on Table 3. These values are shown on Figure 13. These data indicate that liquefaction is possible if a SSE producing 0.2 g at the ground surface occurs. The data points to the far

right which indicate safe conditions are for the 10-ft-thick sand and gravel layer at a depth of about 105 ft where the piles end.

25. Based on the Japanese experience in the 16 June 1964 Niigata earthquake, a rule of thumb has been developed. This rule states that in order to be safe against liquefaction, the Standard Penetration Test N value should be at least two times the depth in meters.[8] A line has been drawn on Figure 2 indicating what the N value should be if it were greater than two times the depth in meters. Note that a large majority of the blows per foot fall on the unsafe side of this line. This is particularly important in this case since the peak acceleration at Niigata was approximately 0.16 g.

Summary and Conclusions

26. The liquefaction potential of the LaCross Site was evaluated for two earthquakes; namely, a SSE with a peak acceleration at the ground surface of 0.12 g, and a SSE with a peak acceleration at the ground surface of 0.2 g. The analysis was made by two methods; namely, the Seed-Idriss Simplified Procedure and an empirical procedure. Figure 14 is a summary plot of the dynamic shear stress as a function of depth for a peak acceleration of 0.12 g. Superimposed on this plot is a cyclic strength of the material assuming 10 equivalent cycles of loading. Note that liquefaction is predicted by the Seed-Idriss calculations between a depth of 32 and 48 ft and liquefaction is predicted by the empirical methods based on a depth of between 24 and 35 ft. Japanese experience at Niigata, Japan, also indicates that liquefaction would be predicted below a depth of 15 ft. As indicated in Appendix A, the piles could

support concentric static loads even after a loss of lateral support from to a depth of 48 ft. However, it would require dynamic structural analysis beyond the scope of this study to judge whether they would have sufficient bending resistance to withstand the transient eccentricity of the static vertical loading and the transient horizontal loads caused by the seismic excitation. In view of the fact that there appears to be no reinforcing bars in the top one-third of the pile[9] (as called for in some seismic design codes[10]), it is probable that the available bending resistance is modest.

27. Figure 15 is a summary plot of the dynamic shear stress as a function of depth for the soil profile assuming a peak acceleration of 0.2 g. Also shown on this plot is the dynamic shear strength of the soil assuming 10 equivalent cycles of loading. The Seed-Idriss Simplified Procedure predicts liquefaction below a depth of 25 ft. The empirical method predicts liquefaction between a depth of 25 and 60 ft and between a depth of 85 and 105 ft. If lateral support is lost in the depth ranges predicted by either method, the piles would be in danger of buckling failures as indicated in Appendix A.

28. Based on the judgments concerning the density and strength data and on analysis as presented herein, the soils below the reactor at the LaCross Site are predicted to strain badly if a SSE which produces 0.12 g at the surface of the soil occurs. The soils beneath the reactor vessel at the LaCross Site are predicted to experience excessive strains and liquefaction if the SSE with a peak acceleration at the ground surface of 0.2 g occurs. Because of the limitations in the current state of knowledge concerning liquefaction and because of the limited data available for use in this analysis, WES cannot conclude that the reactor

vessel foundation is safe if the 0.12 g SSE occurs and concludes that the reactor vessel foundation is unsafe if the 0.2 g SSE occurs.

References

1. Dairyland Power Cooperative, Application for Operating License for the LaCross Boiling Water Reactor.

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Table 1

LACROSSE SITE LIQUEFACTION CALCULATIONS FOR A PEAK ACCELERATION OF 0.12 G

Middepth Sublayer	Depth ft	Overburden Pressure σ_o ksf	Effective Overburden Presure $\bar{\sigma}_o$ ksf	Octahedral Stress σ_{oct} ksf	Effective Octahedral Stress $\bar{\sigma}_{oct}$ ksf	Relative Density D_d %	Maximum Acceleration A_{max} % G	0.65 A_{max}	Average Shear Stress τ_{ave} ksf	Stress Ratio $\frac{\tau_{ave}}{\bar{\sigma}_o}$	Correction Factor C_N	SPT N Value N	Corrected SPT N Value N_1
1	2.5	0.273	0.273	0.182	0.182	1.0	0.12	0.078	0.021	0.078	1.48	9	13
2	7.5	0.818	0.818	0.545	0.545	0.99	0.12	0.078	0.063	0.077	1.28	9	12
3	11.5	1.254	1.254	0.836	0.836	0.98	0.12	0.078	0.096	0.076	1.18	9	11
4	14.0	1.535	1.473	1.023	0.982	0.97	0.12	0.078	0.116	0.079	1.11	9	10
5	17.5	1.948	1.667	1.299	1.111	0.96	0.12	0.078	0.146	0.088	1.03	8	8
6	22.5	2.538	1.945	1.692	1.297	0.95	0.12	0.078	0.188	0.097	0.96	8	8
7	27.5	3.128	2.223	2.085	1.482	0.94	0.12	0.078	0.229	0.103	0.95	8	8
8	32.5	3.718	2.501	2.479	1.667	0.91	0.12	0.078	0.264	0.106	0.90	8	7
9	37.5	4.308	2.779	2.872	1.853	0.88	0.12	0.078	0.296	0.106	0.85	16	14
10	42.5	4.898	3.057	3.265	2.038	[illegible]	0.12	0.078	0.321	0.105	0.81	16	13
11	47.5	5.488	3.335	3.659	2.223	0.80	0.12	0.078	0.342	0.103	0.77	16	12
12	52.5	6.078	3.613	4.052	2.409	0.77	0.12	0.078	0.365	0.101	0.74	16	12
13	57.5	6.668	3.891	4.445	2.594	0.74	0.12	0.078	0.385	0.99	0.71	16	11
14	62.5	7.276	4.187	4.851	2.791	0.73	0.12	0.078	0.414	0.099	0.68	25	17
15	67.5	7.901	4.500	5.267	3.000	0.71	0.12	0.078	0.438	0.097	0.65	25	16
16	72.5	8.526	4.813	5.684	3.209	0.70	0.12	0.078	0.465	0.097	0.62	25	16
17	77.5	9.151	5.126	6.101	3.417	0.69	0.12	0.078	0.493	0.096	0.60	25	15
18	82.5	9.776	5.439	6.517	3.626	0.68	0.12	0.078	0.519	0.095	0.58		15
19	87.5	10.401	5.752	6.934	3.835	0.67	0.12	0.078	0.544	0.095	0.55	25	14
20	92.5	11.026	6.065	7.351	4.043	0.66	0.12	0.078	0.568	0.094	0.54	25	14
21	97.5	11.651	6.378	7.767	4.252	0.65	0.12	0.078	0.591	0.093	0.53	25	13
22	102.5	12.276	6.691	8.184	4.461	0.64	0.12	0.078	0.613	0.092	0.51	25	13
23	107.5	12.921	7.029	8.617	4.686	0.63	0.12	0.078	0.635	0.090	0.50		
24	112.5	13.601	7.392	9.067	4.928	0.62	0.12	0.078	0.658	0.089	0.48		
25	117.5	14.251	7.730	9.501	5.153	0.61	0.12	0.078	0.679	0.088	0.47	60	28
26	122.5	14.876	8.043	9.917	5.362	0.61	0.12	0.078	0.708	0.088	0.46	60	28
27	127.5	15.501	8.356	10.334	5.571	0.60	0.12	0.078	0.725	0.087	0.45	60	27
28	131.5	16.001	8.606	10.667	5.737	0.60	0.12	0.078	0.749	0.087	0.44	60	26

Table 2

RESULTS OF DYNAMIC ANALYSIS 0.12 g SSE

Depth ft	Dynamic Shear Strength psf	Average Shear Stress τ_{ave}	Factor of Safety
2.5	50	21	2.38
7.5	102	63	1.62
11.5	145	96	1.51
14.0	166	116	1.43
17.5	185	146	1.27
22.5	212	188	1.13
27.5	239	229	1.04
32.5	293	296	0.99
42.5	320	321	0.99
47.5	347	342	1.02
52.5	374	365	1.02
57.5	400	385	1.04
62.5	429	414	1.04
67.5	460	438	1.05
72.5	490	465	1.05
77.5	520	493	1.05
82.5	551	519	1.06
87.5	581	544	1.07
92.5	611	568	1.08
97.5	642	591	1.09
102.5	672	613	1.10

Table 3

LACROSS SITE LIQUEFACTION CALCULATIONS FOR A PEAK ACCELERATION OF 0.20 G

Middepth Sublayer	Depth ft	Overburden Pressure σ_o ksf	Effective Overburden Pressure $\bar{\sigma}_o$ ksf	Octahedral Stress σ_{oct} ksf	Effective Octahedral Stress $\bar{\sigma}_{oct}$ ksf	Relative Density R_d %	Maximum Acceleration A_{max} % g	0.65 A_{max}	Average Shear Stress τ_{ave} ksf	Stress Ratio $\frac{\tau_{ave}}{\bar{\sigma}_o}$	Correction Factor C_N	SPT N Value N	Corrected SPT N Value N_1
1	2.5	0.273	0.273	0.182	0.182	1.0	0.20	0.13	0.036	0.132	1.48	9	13
2	7.5	0.818	0.818	0.545	0.545	0.99	0.20	0.13	0.105	0.128	1.28	9	12
3	11.5	1.254	1.254	0.836	0.836	0.98	0.20	0.13	0.160	0.128	1.18	9	11
4	14.0	1.535	1.473	1.023	0.982	0.97	0.20	0.13	0.194	0.132	1.11	9	10
5	17.5	1.948	1.667	1.299	1.111	0.96	0.20	0.13	0.243	0.146	1.03	8	8
6	22.5	2.538	1.945	1.592	1.297	0.95	0.20	0.13	0.313	0.161	0.96	8	8
7	27.5	3.128	2.223	2.085	1.482	0.94	0.20	0.13	0.382	0.172	0.95	8	8
8	32.5	3.718	2.501	2.479	1.667	0.91	0.20	0.13	0.440	0.176	0.90	8	7
9	37.5	4.308	2.779	2.872	1.853	0.89	0.20	0.13	0.493	0.177	0.85	16	14
10	42.5	4.898	3.057	3.265	2.038	0.84	0.20	0.13	0.535	0.175	0.81	16	13
11	47.5	5.488	3.335	3.659	2.223	0.80	0.20	0.13	0.571	0.171	0.77	16	12
12	52.5	6.078	3.613	4.052	2.409	0.77	0.20	0.13	0.608	0.168	0.74	16	12
13	57.5	6.668	3.891	4.445	2.594	0.74	0.20	0.13	0.641	0.165	0.71	16	11
14	62.5	7.276	4.187	4.851	2.791	0.73	0.20	0.13	0.690	0.165	0.68	25	17
15	67.5	7.901	4.500	5.267	3.000	0.71	0.20	0.13	0.729	0.162	0.65	25	16
16	72.5	8.526	4.813	5.684	3.209	0.70	0.20	0.13	0.776	0.161	0.62	25	16
17	77.5	9.151	5.126	6.101	3.417	0.69	0.20	0.13	0.821	0.160	0.60	25	15
18	82.5	9.776	5.439	6.517	3.626	0.68	0.20	0.13	0.864	0.159	0.58	25	15
19	87.5	10.401	5.752	6.934	3.835	0.67	0.20	0.13	0.905	0.157	0.55	25	14
20	92.5	11.026	6.065	7.351	4.043	0.66	0.20	0.13	0.946	0.156	0.54	25	14
21	97.5	11.651	6.378	7.767	4.252	0.66	0.20	0.13	0.984	0.154	0.53	25	13
22	102.5	12.276	6.691	8.184	4.461	0.64	0.20	0.13	1.021	0.152	0.51	25	13
23	107.5	12.926	7.029	8.617	4.686	0.63	0.20	0.13	1.058	0.151	0.50		
24	112.5	13.601	7.392	9.067	4.928	0.62	0.20	0.13	1.097	0.148	0.48		
25	117.5	14.251	7.730	9.501	5.153	0.61	0.20	0.13	1.130	0.146	0.47	60	28
26	122.5	14.876	8.043	9.917	5.362	0.61	0.20	0.13	1.180	0.147	0.46	60	28
27	127.5	15.501	8.356	10.334	5.571	0.60	0.20	0.13	1.209	0.145	0.45	60	27
28	131.5	16.001	8.606	10.667	5.737	0.60	0.20	0.13	1.240	0.145	0.44	60	26

Table 4

DYNAMIC ANALYSIS FOR 0.20 g SSE

Depth ft	Dynamic Shear Stress psf	Average Shear Stress τ_{ave}	Factor of Safety
2.5	50	30	1.39
7.5	102	105	0.97
11.5	145	160	0.91
14.0	166	194	0.86
17.5	185	243	0.76
22.5	212	313	0.68
27.5	239	382	0.63
32.5	266	440	0.60
37.5	293	493	0.59
42.5	320	535	0.60
47.5	347	571	0.61
52.5	374	608	0.61
57.5	400	641	0.62
62.5	429	690	0.62
67.5	460	729	0.63
72.5	490	776	0.63
77.5	520	821	0.63
82.5	551	864	0.64
87.5	581	905	0.64
92.5	611	946	0.65
97.5	642	984	0.65
102.5	672	1021	0.66

Layer	N (blows/ft)	w%	γ_{dry} (pcf)	γ_{wet} (pcf)	V_s (fps)
① Hydraulic fill - Brown fine to medium Sand, occasional fine gravel (13' ▽ WATER TABLE)	9	6.8	102.0	109.0 * 118.2	200
② Brown or grey fine to medium fine Sand, some thin zones of black clayey silt (— Nominal bottom of excavation, 33')	8	19.5	96.0	118.0	250
③ Brown fine to medium Sand, occasional zones of coarse sand/fine gravel, with < 5% silt (68')	16		102.0	* 118.0	350
④ Brown fine to medium Sand, occasional zones of coarse sand/fine gravel, with < 5% silt (— Nominal base of piles, 105')	25		107.0	* 125.0	500
⑤ Brown fine or fine to medium Sand, fine to medium gravel (115')			118.0	* 135.0	800
⑥ Brown fine or fine to medium Sand, traces of silt, occasional gravel zones (135')	60		110.0	* 125.0	650
					2550

* Assumed based on Terzaghi & Peck

Figure 1. Idealized Soil Profile and Approximate Average Values Assigned to Each Layer for Analysis

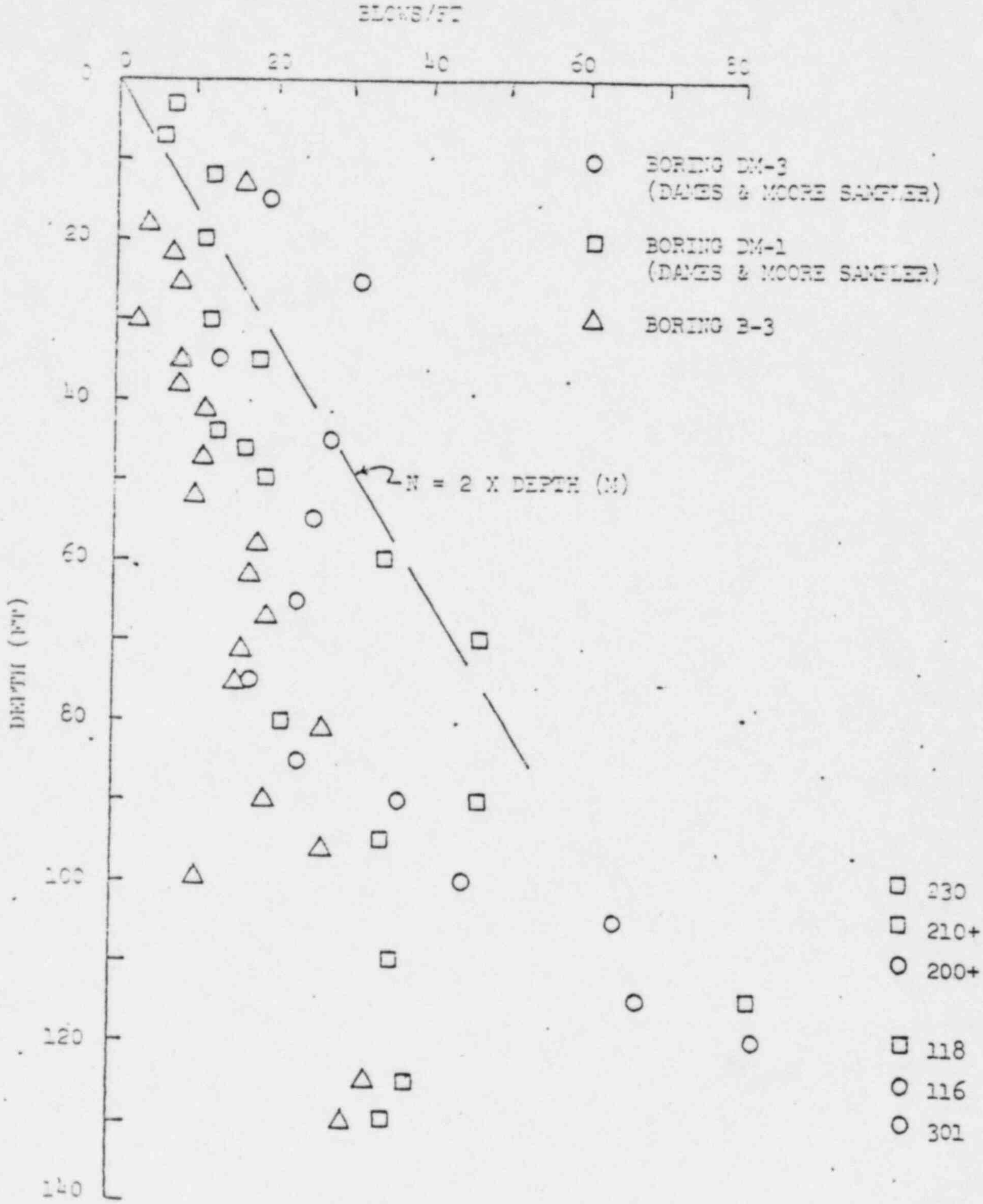

Figure 2. Blow Counts Presented as a Function of Depth

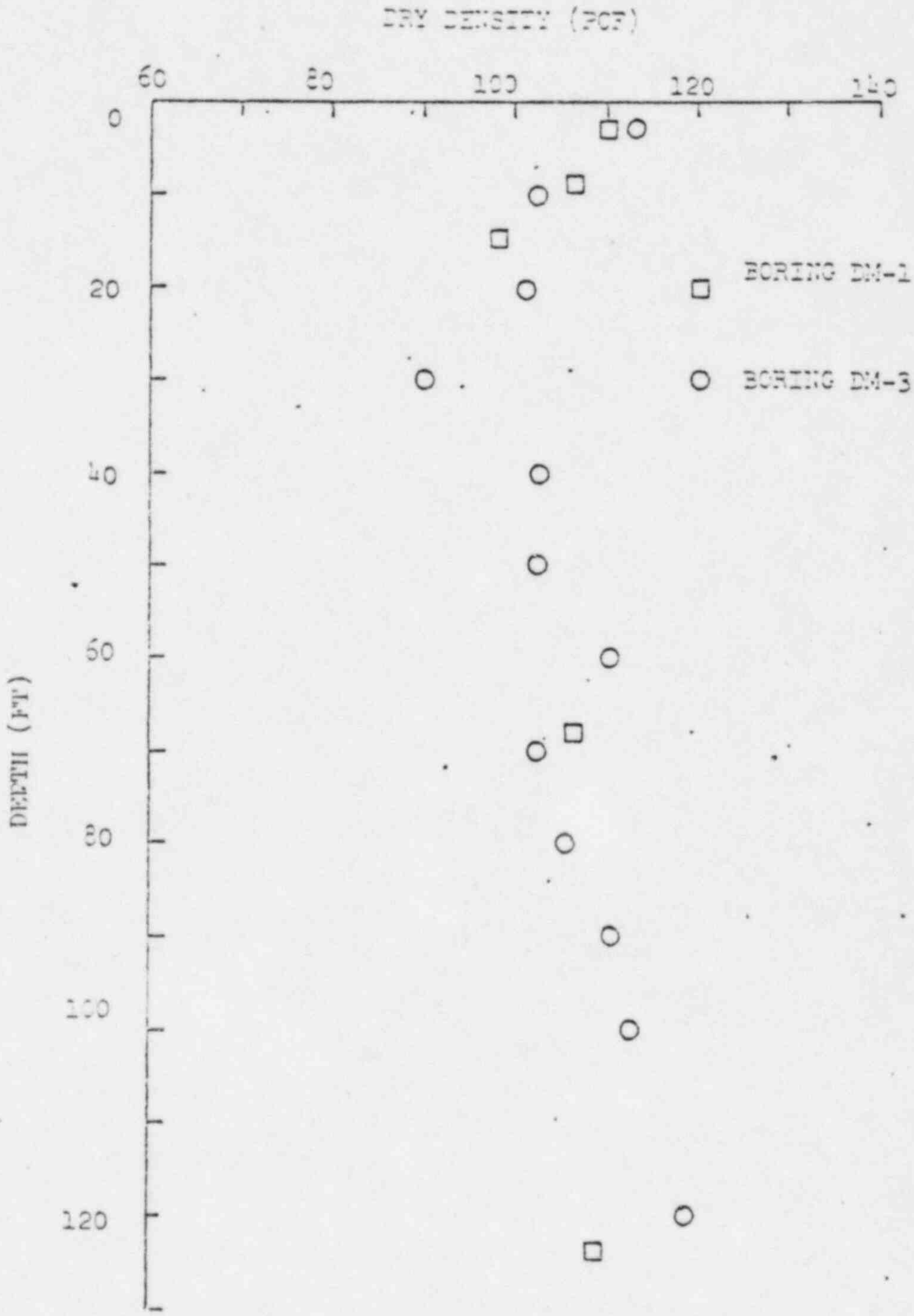

Figure 3. Dry Density as a Function of Depth

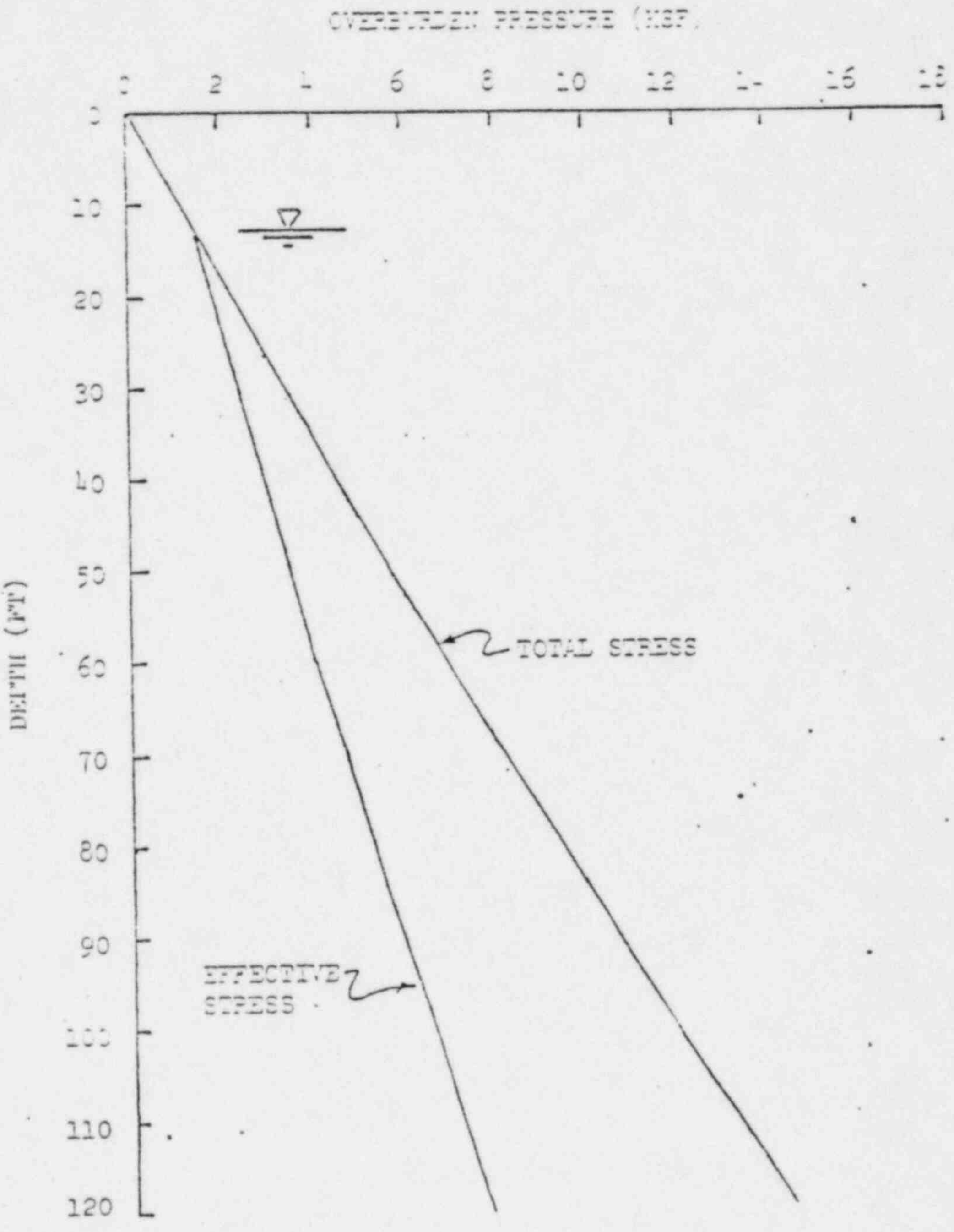

Figure 4. Overburden Pressure Versus Depth

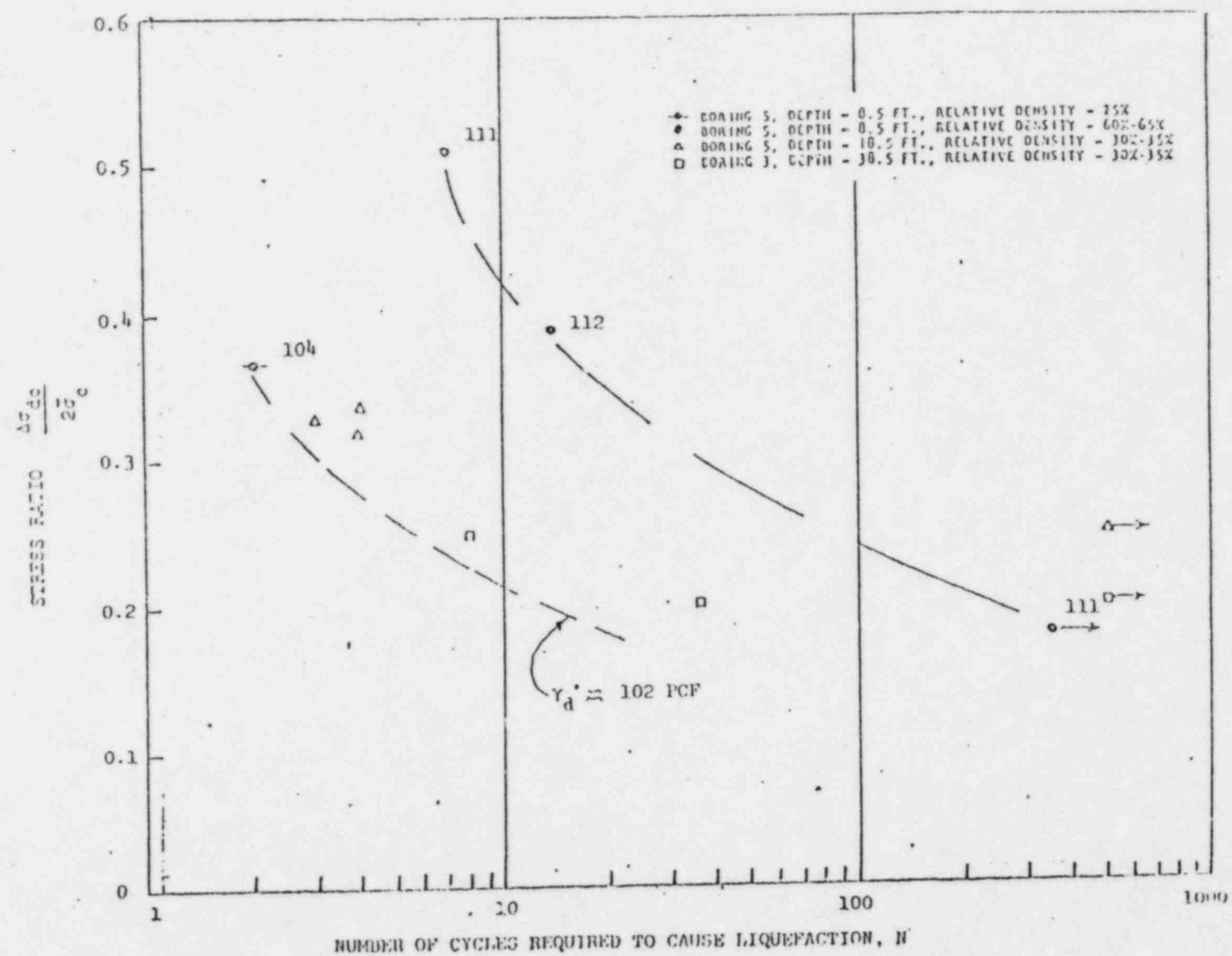

Figure 5. Cyclic Shear Strength Versus Number of Cycles to Liquefaction Based on Dames and Moore Laboratory Data, $\bar{\sigma}_c$ = 1000 psf

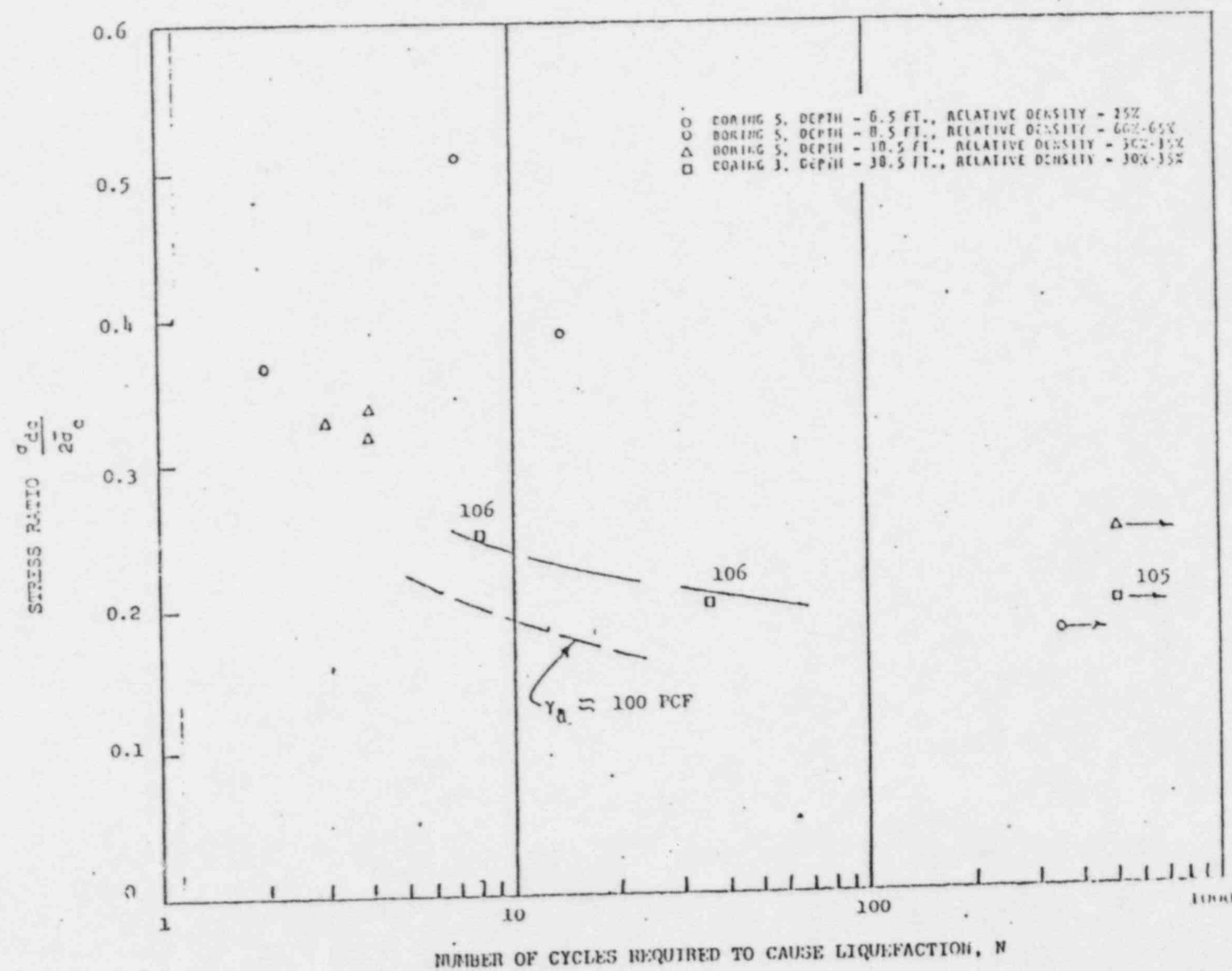

Figure 6. Cyclic Shear Strength Versus Number of Cycles to Liquefaction Based on Dames and Moore Laboratory Data, $\bar{\sigma}_c$ = 2000 psf

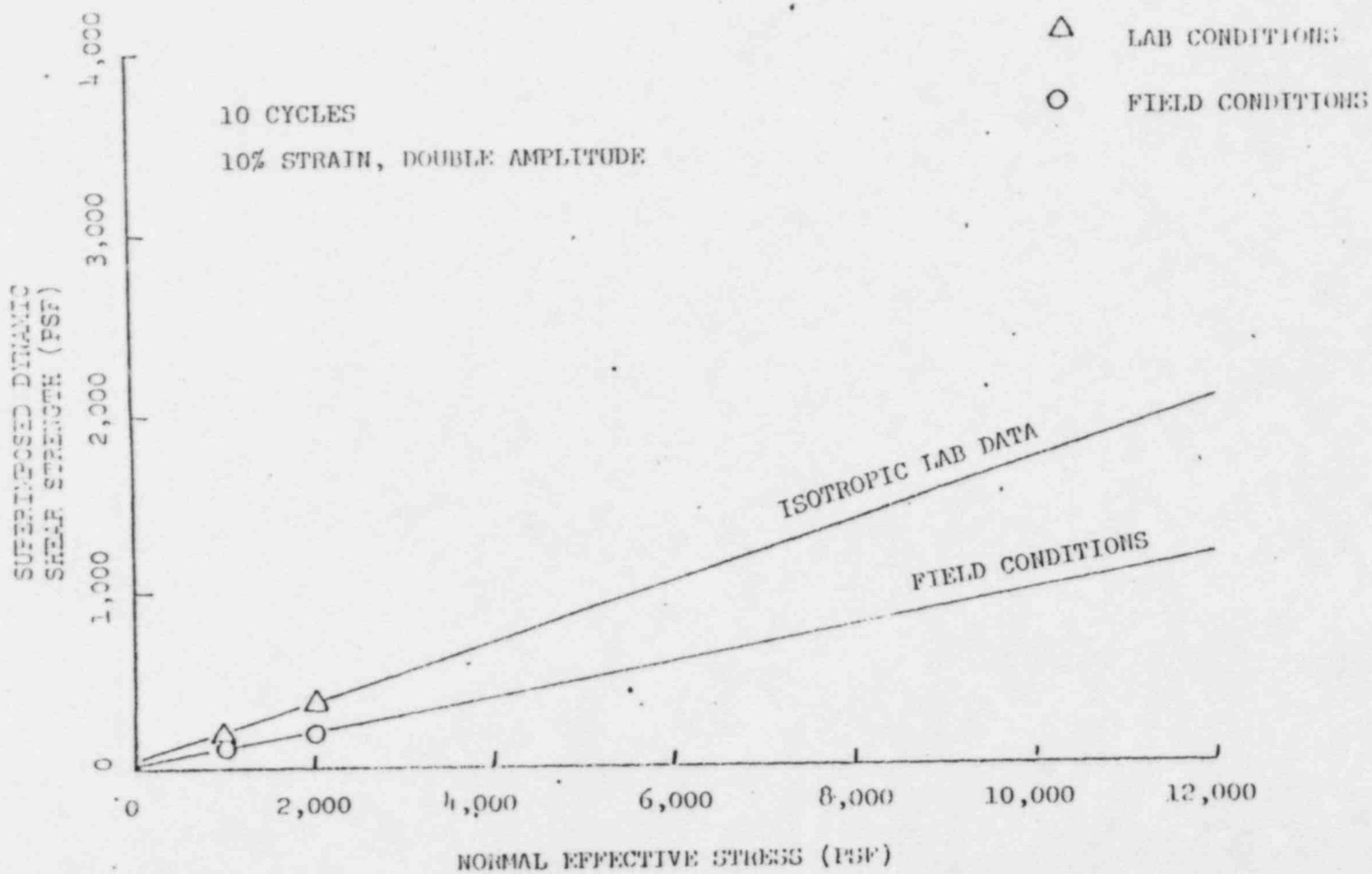

Figure 7. Superimposed Dynamic Shear Strength Versus Normal Effective Stress

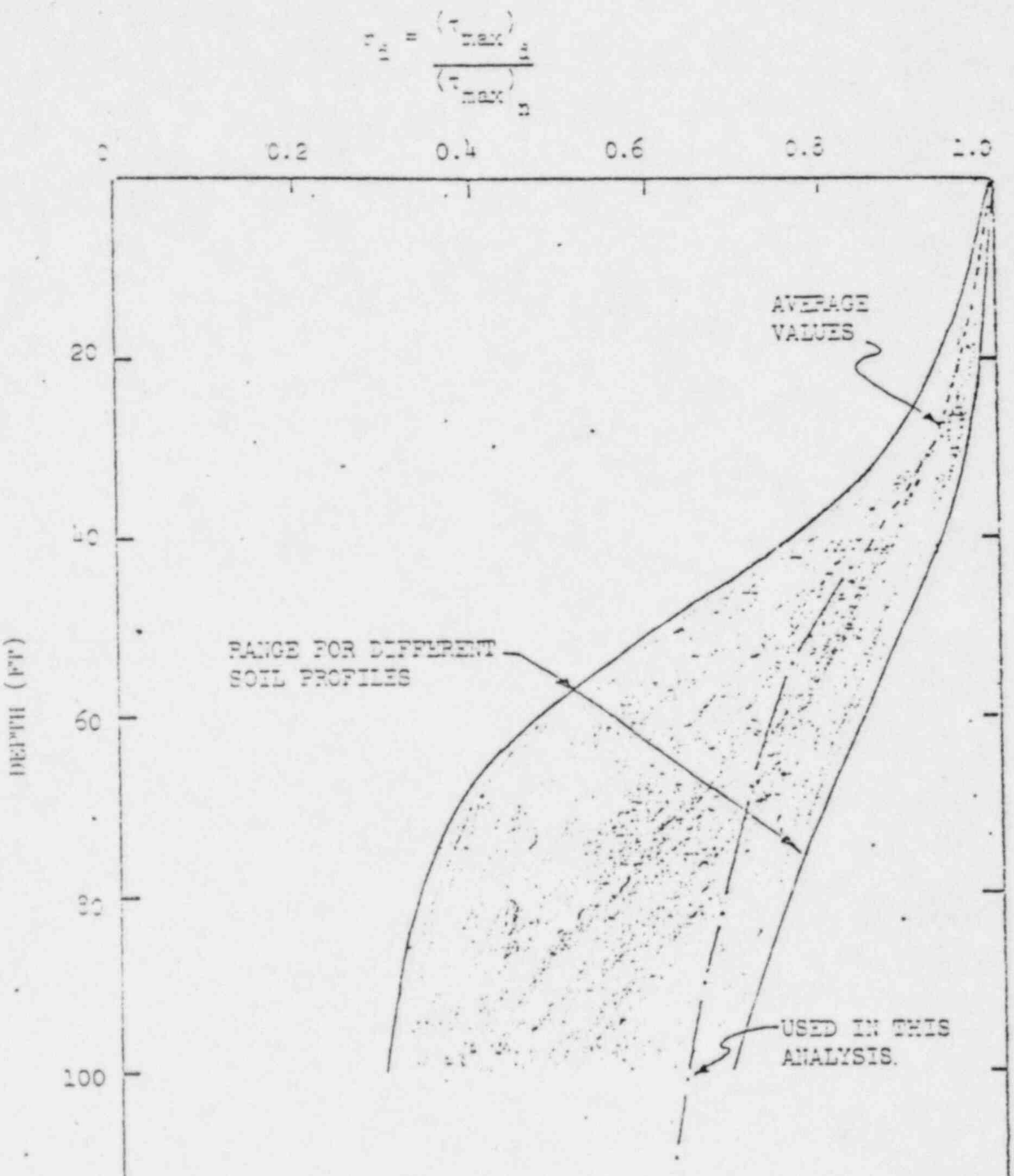

Figure 3. Rigidity Factor Versus Depth (after Reference 2)

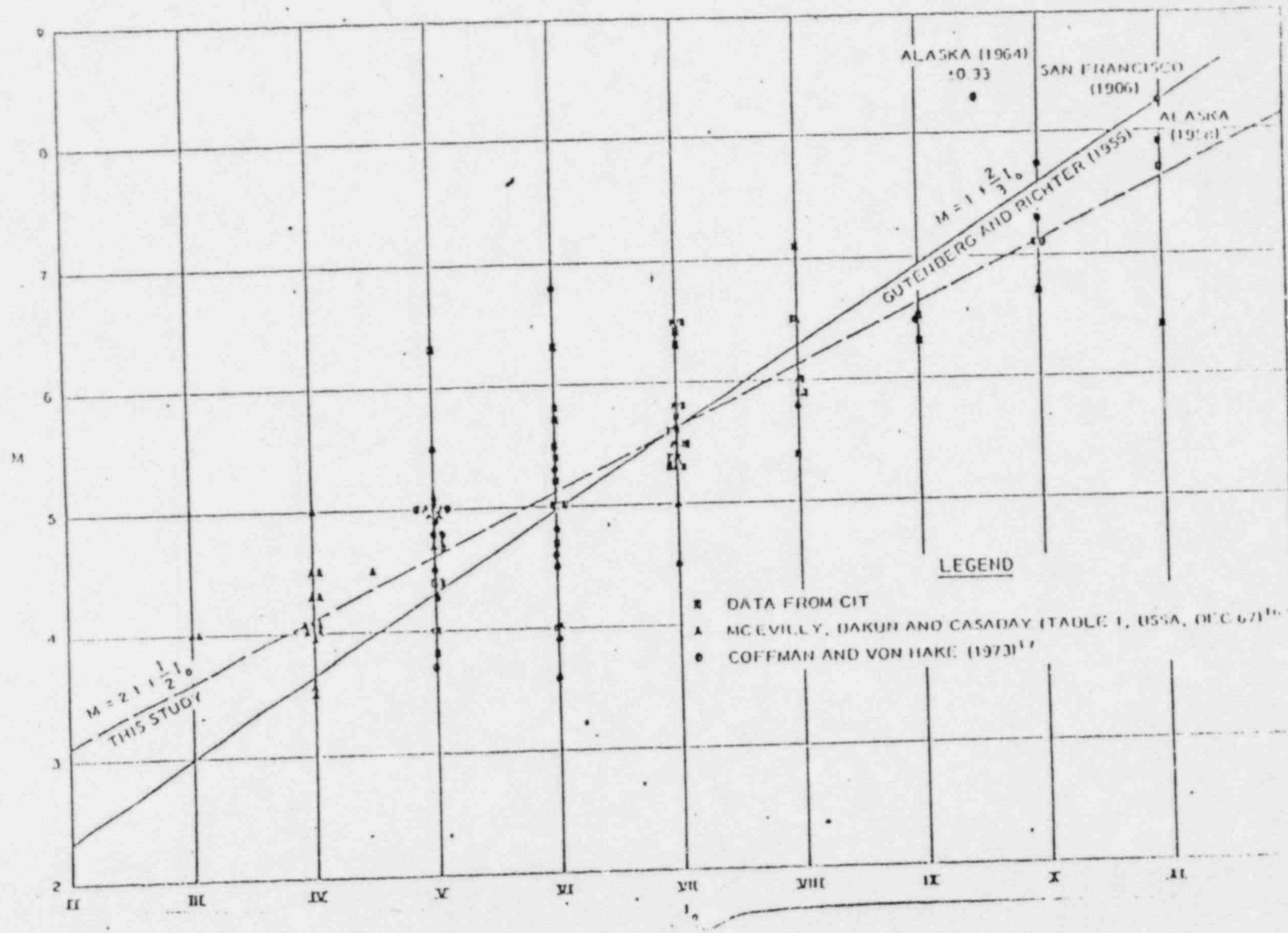

Figure 9. Relation Between Earthquake Magnitude and Intensity in Western United States (after Reference 6)

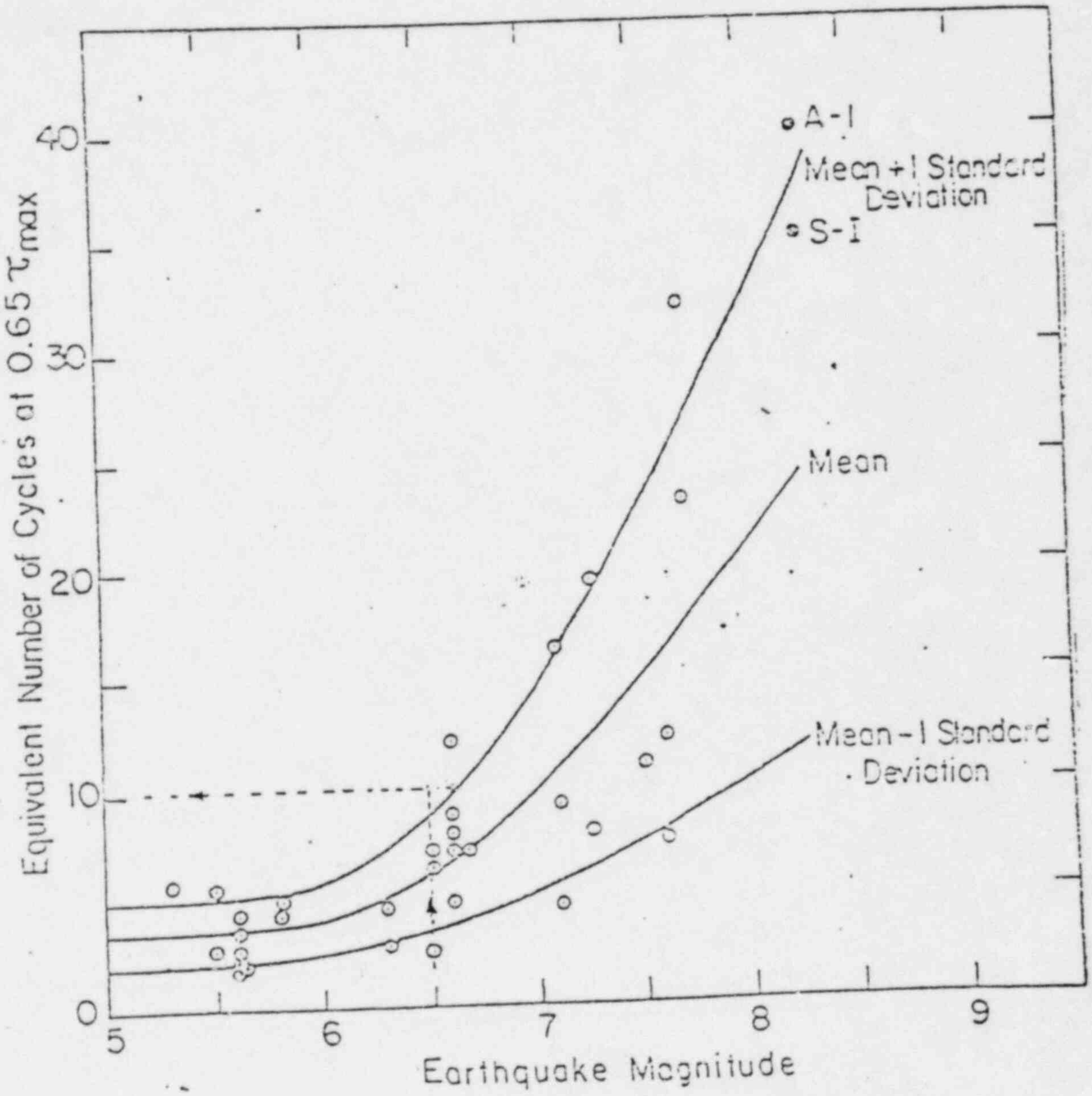

Figure 10. Equivalent Numbers of Uniform Stress Cycles Based on Strongest Components of Ground Motion

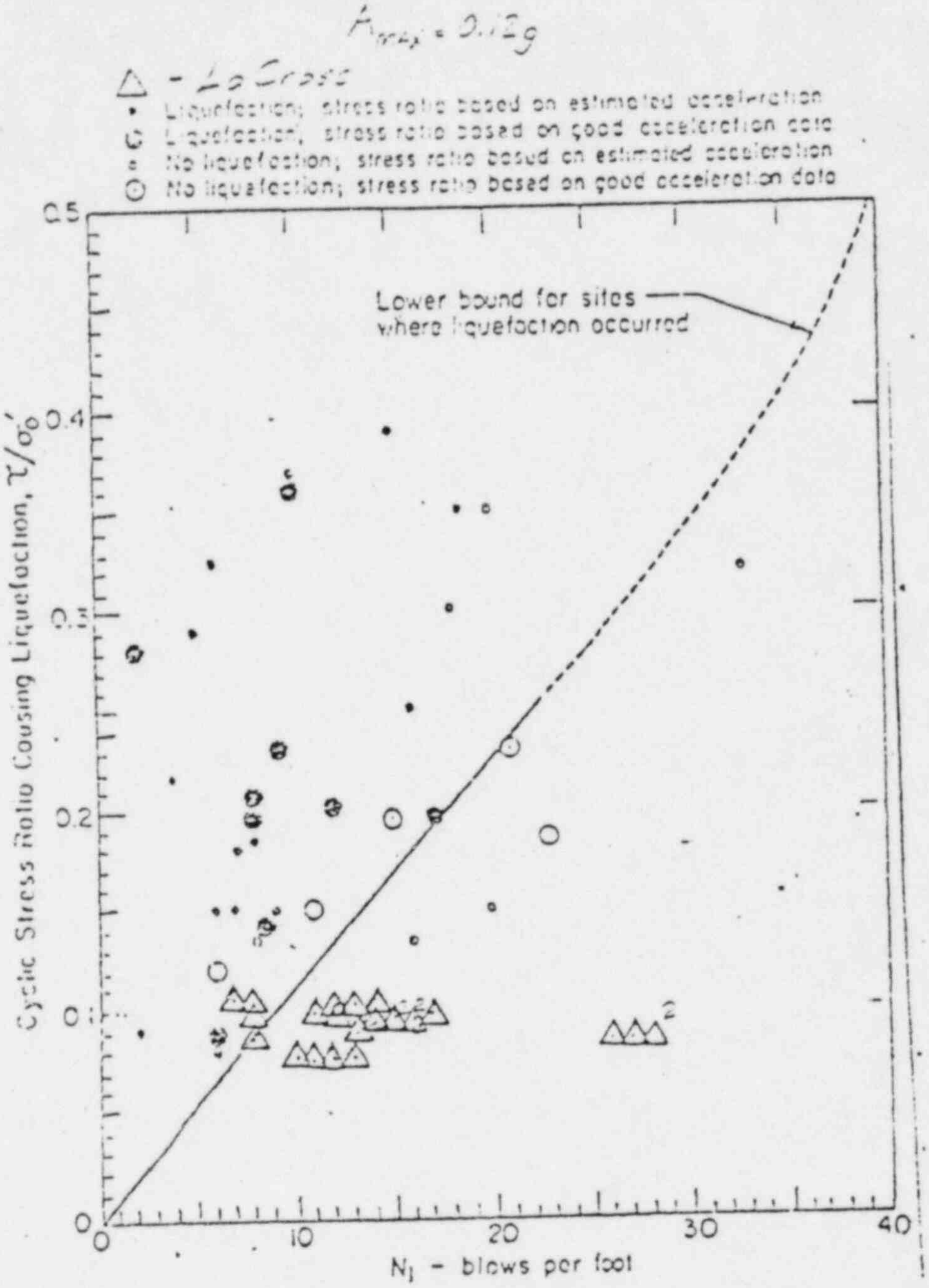

Figure 11. Correlation Between Stress Ratio Causing Liquefaction in the Field and Penetration Resistance of Sand

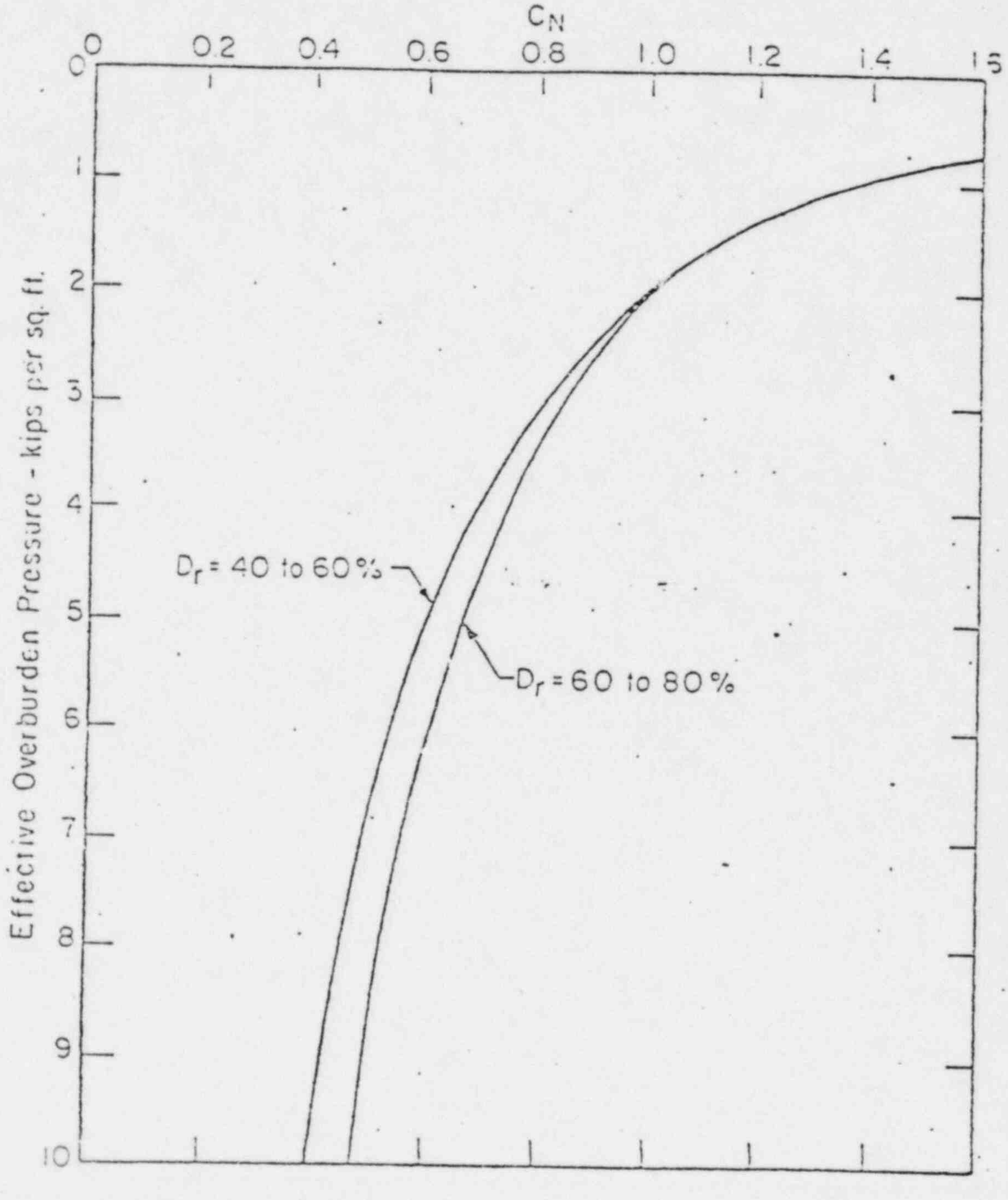

Figure 12. Recommended Curves for Determination of C_N Based on Averages for WES Tests (After Reference 5)

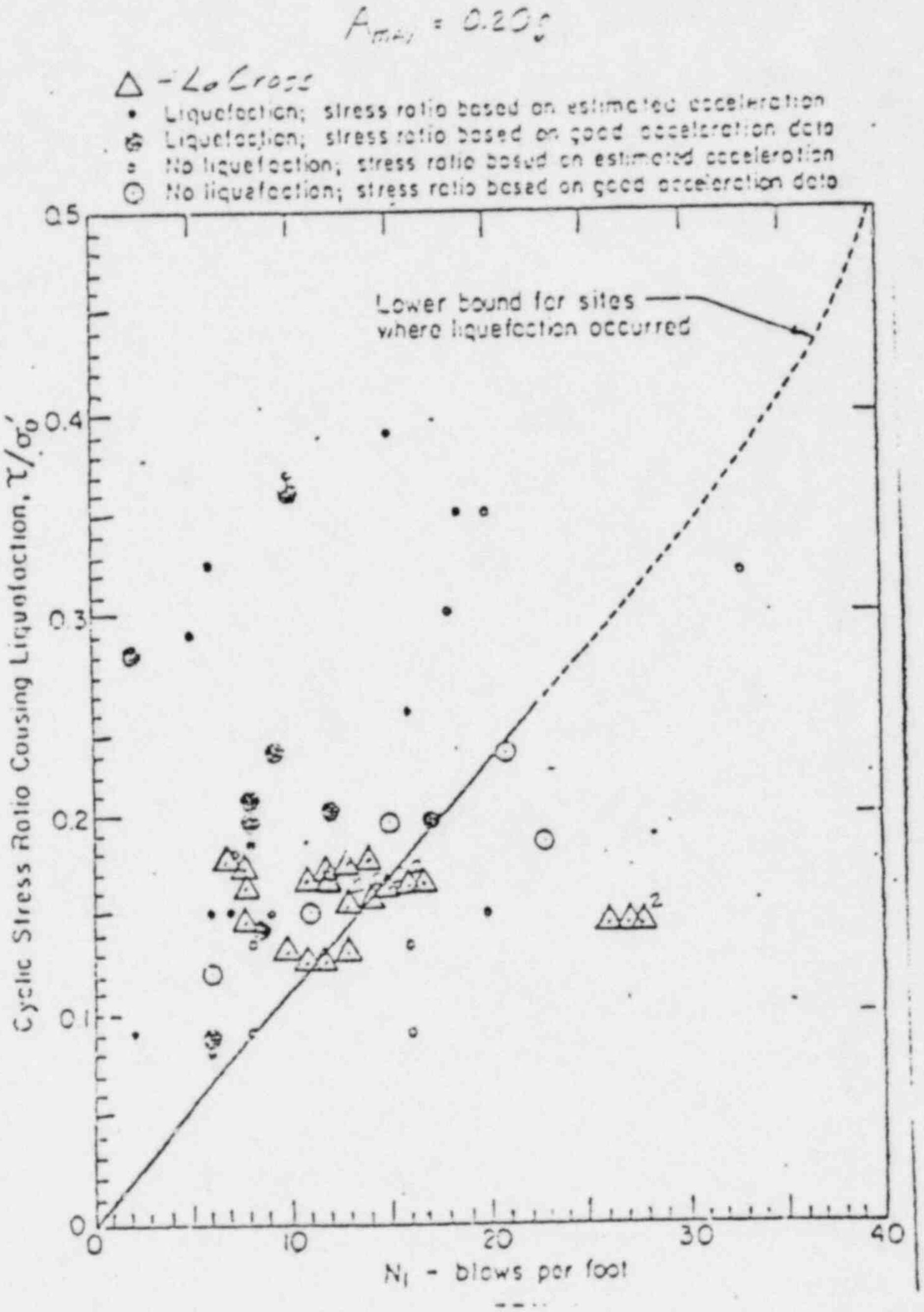

Figure 13. Correlation Between Stress Ratio Causing Liquefaction in the Field and Penetration Resistance of Sand

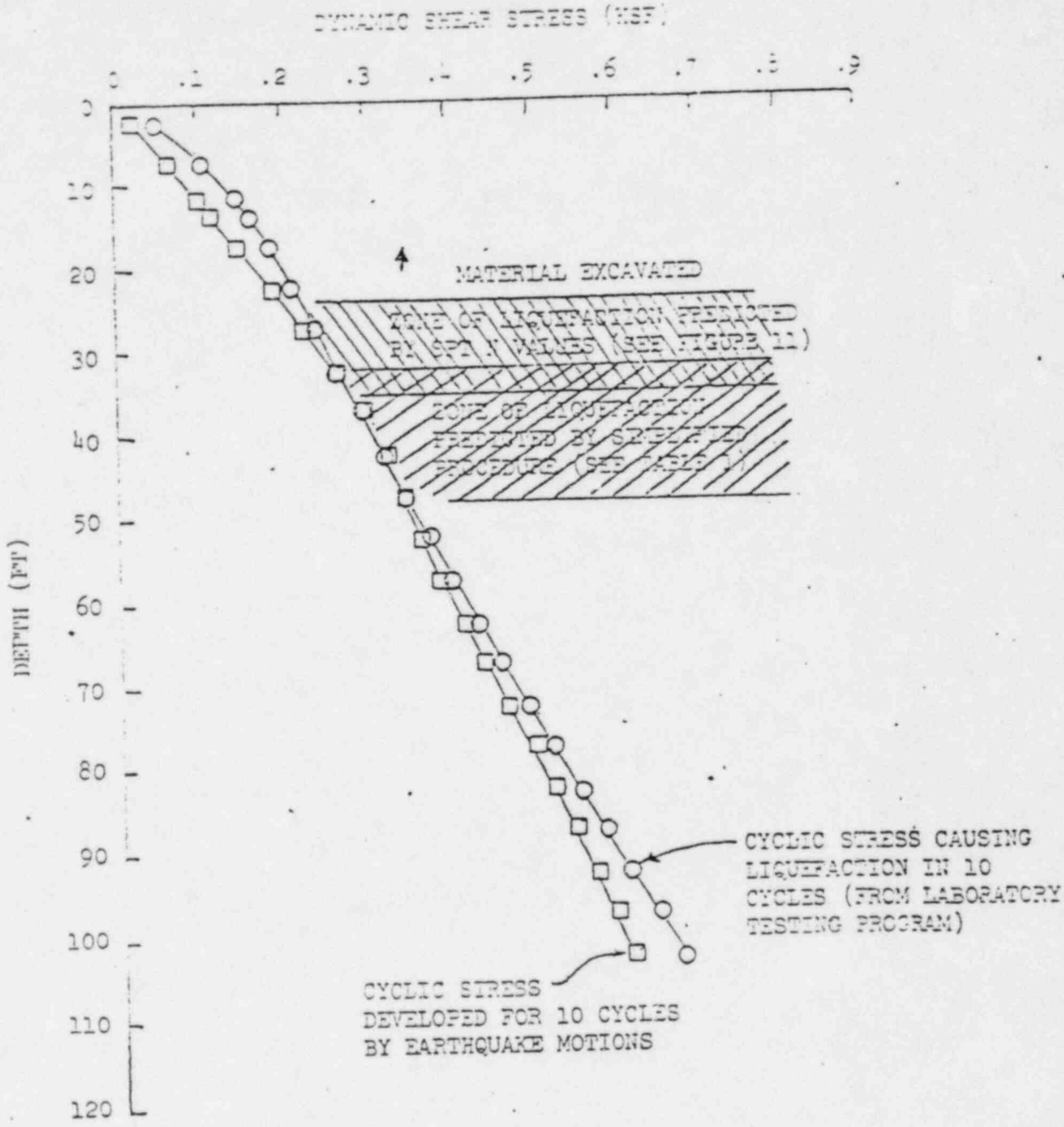

Figure 14. Results of SPT Empirical Study for SSE = 0.12 G

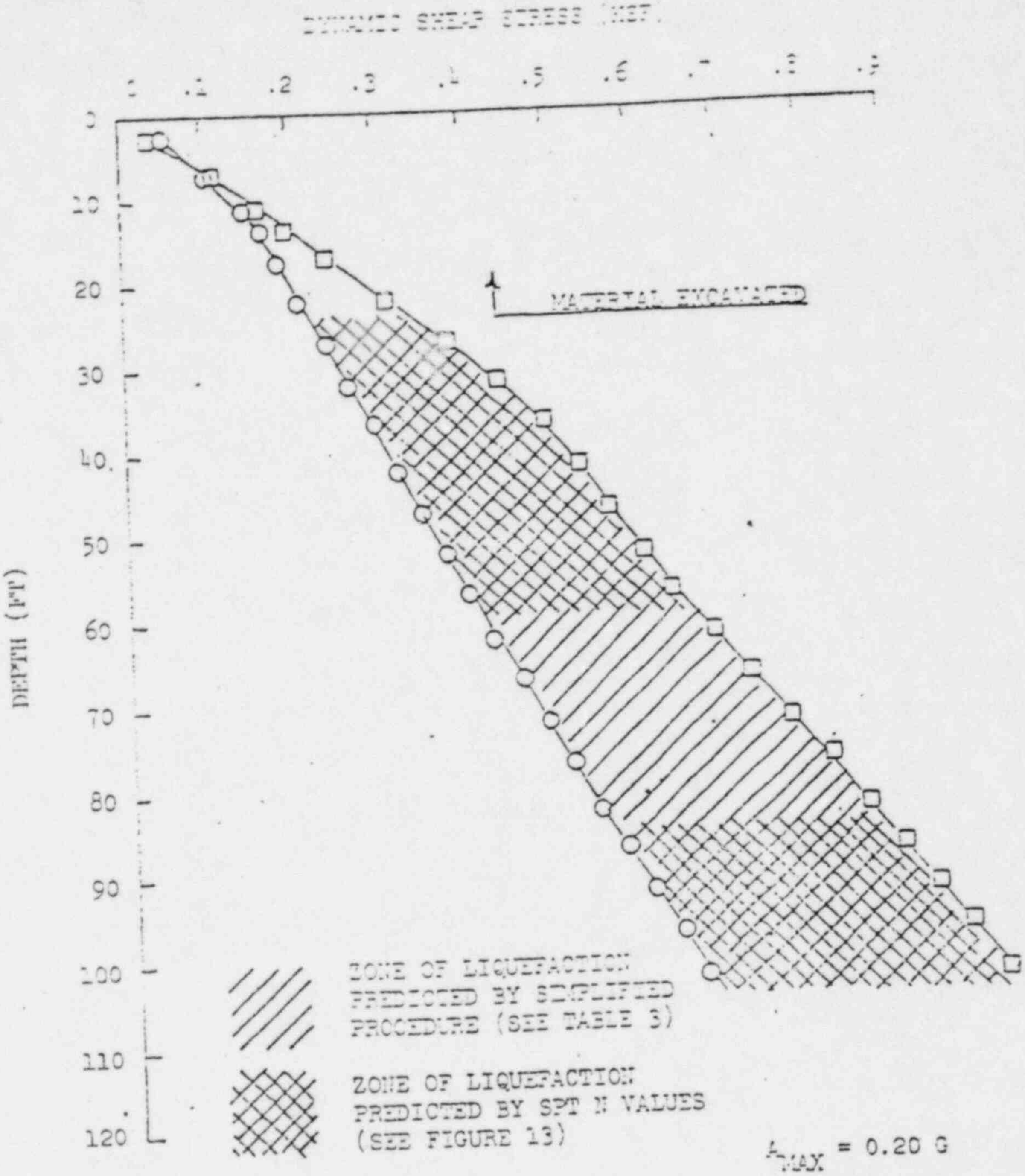

Figure 15. Results of SPT Empirical Study for SSE = 0.20 G

APPENDIX A

CALCULATION OF BUCKLING LOADS FOR PILES

While the containment vessel foundation mat is supported on piles on a bearing layer which, in WES' opinion, will not liquefy, these piles require lateral support above this layer to prevent buckling failure. If liquefaction occurs in some depth region along the pile, this support will be dimenished or absent. Further, as upward seepage from the liquefied zone develops, lateral support may be lost all the way from the zone to the base of the mat foundation. The Euler buckling load, P_{cr}, for a typical pile has been calculated as follows:

$$P_{cr} = \frac{2.05\pi^2 EI}{L^2}$$

where

E = Young's Modulus of the pile

I = Moment of inertia of the cross section about its neutral axis

L = Unsupported length

The following assumptions were made:

a. The pile was 9 in. in diameter. It actually had an 8 in. diameter at the tip and a 12 in. diameter at the butt.

b. The pile was made of a linear elastic material with a Young's Modulus of 3,000,000 psi. It actually was made of 3500 psi, 28-day strength, cast in-place concrete inside a thin steel shell.

c. The pile was fixed at the base of the mat foundation.

d. The pile was pinned at a depth, L, below the base of the mat.

For these assumptions, the relation of P_{cr} to L is shown on Figure A1.

These piles have been rated in Reference 10 to have a 51-ton static load capacity. Presumably, the piles have vertical loads considerably less than this value. At the rated load, the analysis indicates that the unsupported length at which buckling would take place is approximately 40 ft. On Figure 14 of the main text, the vertical distance from the mat to the bottom of the shaded zone is 24 ft or less. The piles appear capable of supporting their vertical working loads even if lateral support is lost in this region. However, there are also horizontal dynamic loads that act on the pile butts as a result of earthquake excitation which tend to bend the piles in themselves and make the vertical loads eccentric which would in turn cause further bending. Some rough calculations suggest that the bending capacity of the piles is low with respect to the moments which might occur. A more thorough investigation of the dynamic behiing problem is a complex but tractable structural dynamics problem beyond the scope of this study.

For the 0.2 g loading there is no point in performing such an analysis as Figure 15 of the main text indicates a possible unsupported length of over 80 ft. If loss of lateral support should occur over this length, as shown on Figure A1, the pile would buckle under its static load alone.

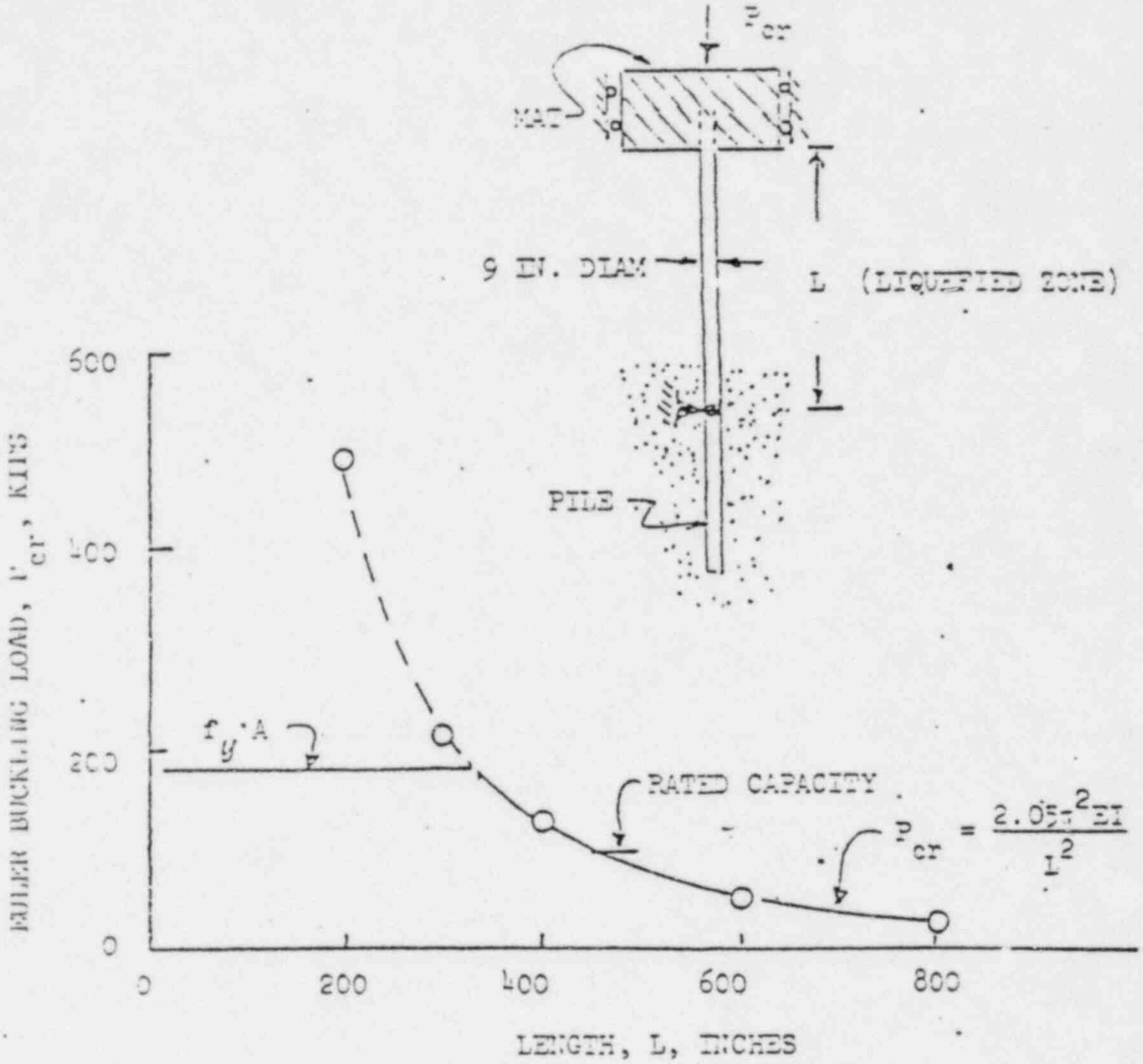

Figure A1. Buckling Resistance Versus Length of Unsupported Zone

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

LBWR-2

AUG 04 1980

Docket No. 50-409

Mr. Frank Linder
General Manager
Dairyland Power Cooperative
2615 East Avenue South
LaCrosse, Wisconsin 54601

Gentlemen:

RE: LACROSSE

Our letter to you dated January 15, 1979 requested that you initiate as part of the Systematic Evaluation Program (SEP) a program to demonstrate the seismic design adequacy of your facility. In relation to this request, we are aware of your efforts to develop a site specific ground response spectrum for your site; however, active structural/mechanical evaluations have not specifically been initiated. You are requested to submit, by September 15, 1980, details of your plans for proceeding with a seismic evaluation program and provide justification for why you conclude that continued operation is justified in the interim until the program is complete.

Your submittal should address the scope of review and evaluation criteria and provide a schedule for completion. The analytical portion of your program should be completed no later than January 1, 1982. Any modifications to the facility that may be necessary as a result of your evaluations should be installed by the following refueling outage, but no later than January 1, 1983. Any proposed changes to the facility as described in the safety analysis report shall be made in accordance with 10 CFR 50.59 of the Commission Regulations.

As a minimum, your program should provide for an evaluation of:

1. The integrity of the reactor coolant pressure boundary,

2. The integrity of fluid and electrical distribution systems related to safe shutdown and engineered safety features,

3. The integrity and functionability of mechanical and electrical equipment and engineered safety feature systems (including containment).

Although we have delayed until the end of 1980 a final decision relative to seismic input to maximize the potential benefits to be derived from use of site specific ground response spectra, we expect you to proceed with your seismic evaluation program. Based upon input that we have received from the Lawrence Livermore Laboratory/TERA Corporation Site Specific Spectra Project, the Systematic Evaluation Program licensees, NRC consultants and other sources, we have concluded that the ground response spectra shown in the Attachment 1 is an appropriate level at which to initiate your evaluations. Between now and the end of 1980 we plan to complete additional work that will allow us to finalize our decision. It does not appear likely that the ground response spectra shown in Attachment 1 will be modified to a large degree. Therefore, we strongly recommend that you use this ground response spectrum in your evaluations. The bases for our decision are documented in Attachment 2.

You are free to make an alternative proposal for use in the interim until the final NRC staff decision is made. We must emphasize that taking such an approach involves increased risk on your part because certain evaluations may have to be redone at a later time. Furthermore, limitations of NRC staff resources make review of alternative proposals impossible in the near term.

In accordance with 10 CFR 50.54(f) of the Commission's regulations you are requested to submit the information described above on the dates indicated above in order to enable the Commission to determine whether or not your license should be modified, suspended or revoked.

Sincerely,

Darrell G. Eisenhut

Darrell G. Eisenhut, Director
Division of Licensing
Office of Nuclear Reactor Regulation

Attachment:
As stated

cc: See next page

cc

Fritz Schubert, Esquire
Staff Attorney
Dairyland Power Cooperative
2615 East Avenue South
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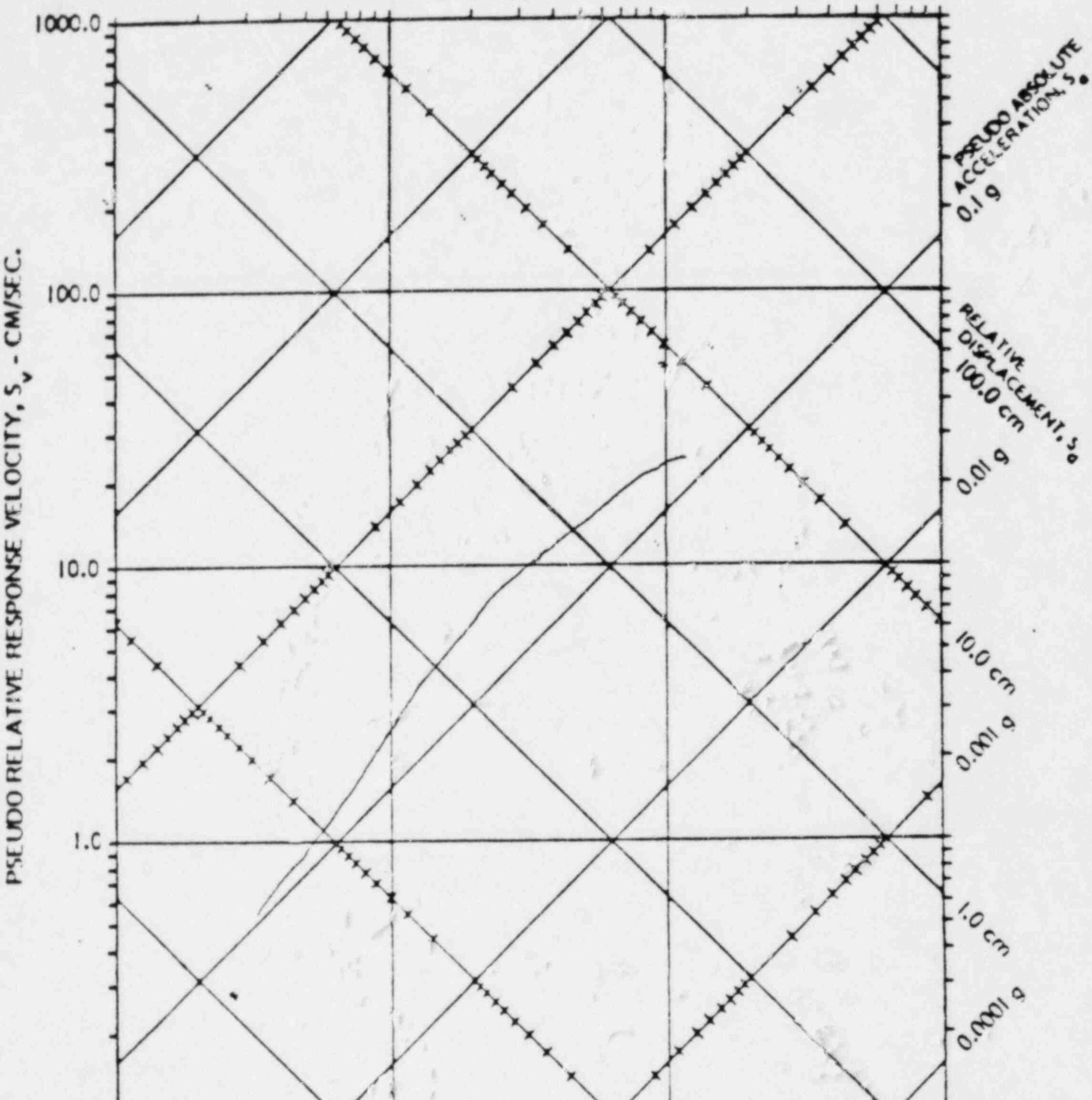
ATTACHMENT 1

LACROSSE



5% damping

Attachment 2

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

JUN 23 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.

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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
Division of Engineering

Enclosure:
As stated

cc: w/enclosure
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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.

he 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 affects 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 $\pm 2\sigma$. 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 $\pm 3\sigma$. These criticisms are considered valid and its recommended that the dispersion defined as σ=0.7, truncated at $\pm 3\sigma$ 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 only 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 exceedence) 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 appro imately equivalent levels of hazard whatever the true return period is. This is base in large part upon the relative consistency of effects associated with the sensitivity tests (SSSP Sensitivity Results, May 1980) and the synthsizing 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 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) Probabilistic	Peak Acceleration (cm/sec^2) Deterministic	Peak Velocity (cm/sec) Probabilistic	Peak Velocity (cm/sec) 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 + 2 σ This is estimated to be equivalent to intermediate background and a dispersion of σ=0.7, ± 3 σ.

**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.

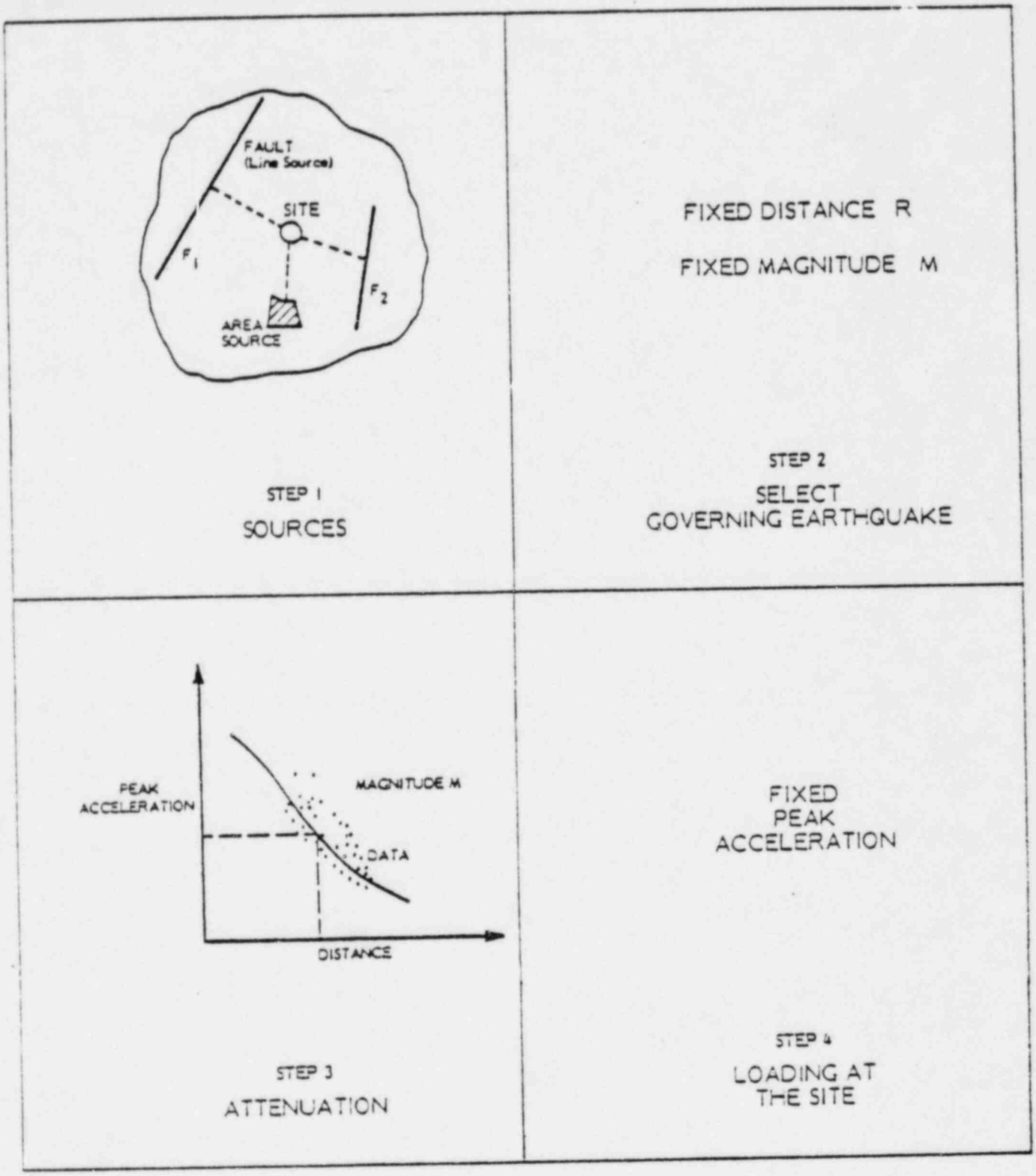


FIGURE 1

DETERMINISTIC APPROACH TO LOADING AT THE SITE

TERA CORPORATION

Dec. 8, 1978

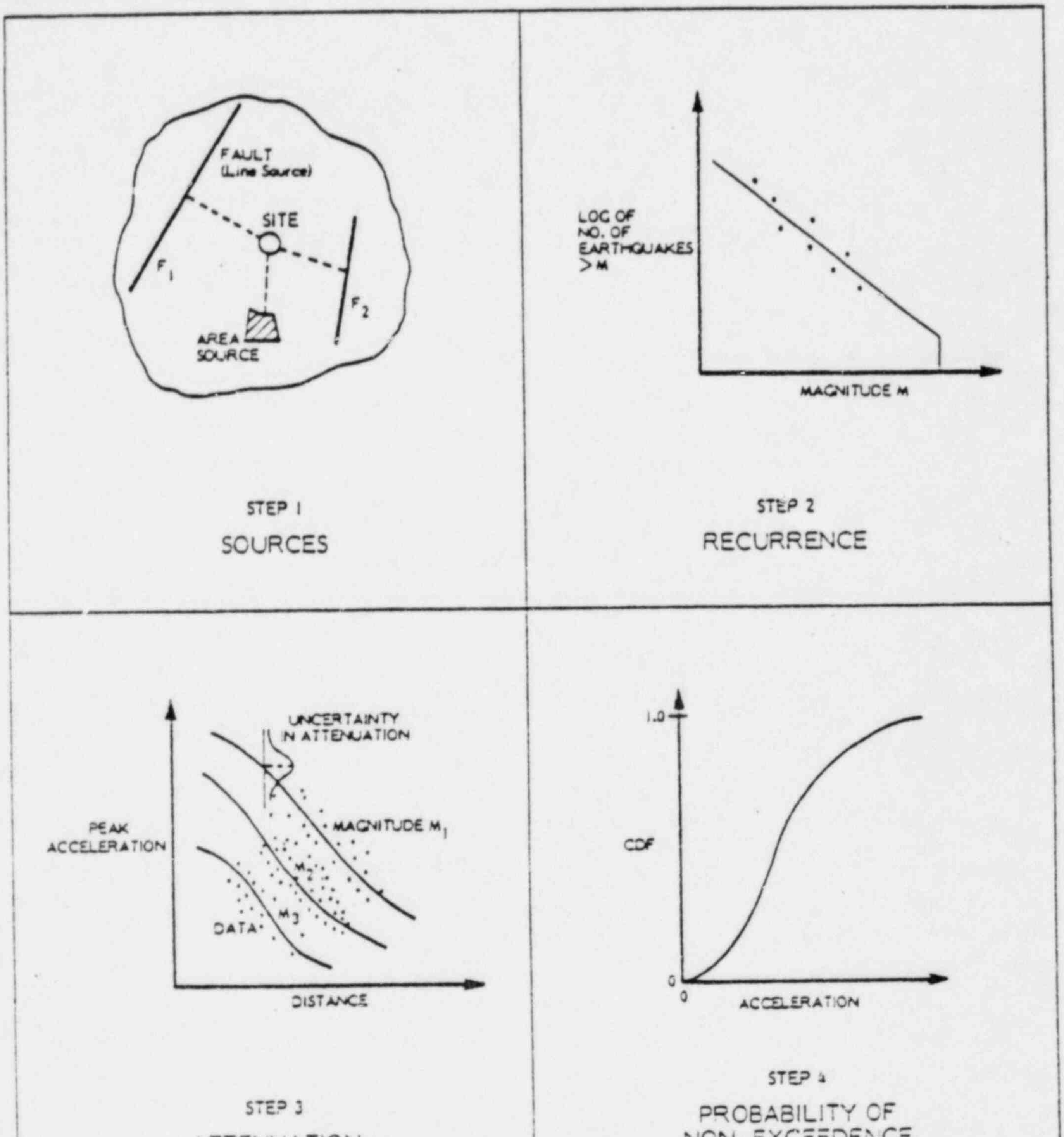
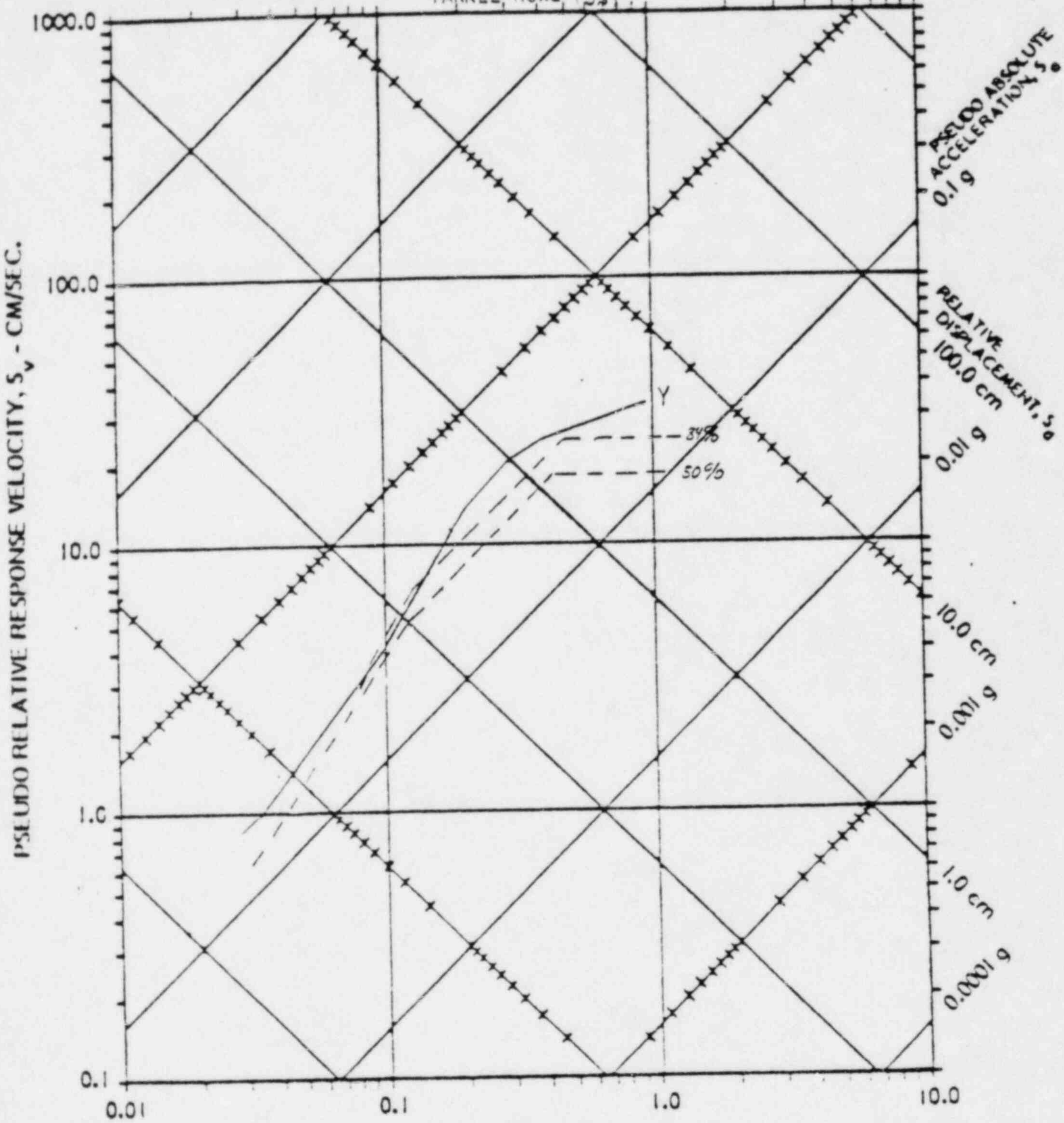


FIGURE 2

CURRENT APPROACH TO HAZARD
MAPPING FOR PEAK VALUES

Dec. 8, 1978

TERA CORPORATION

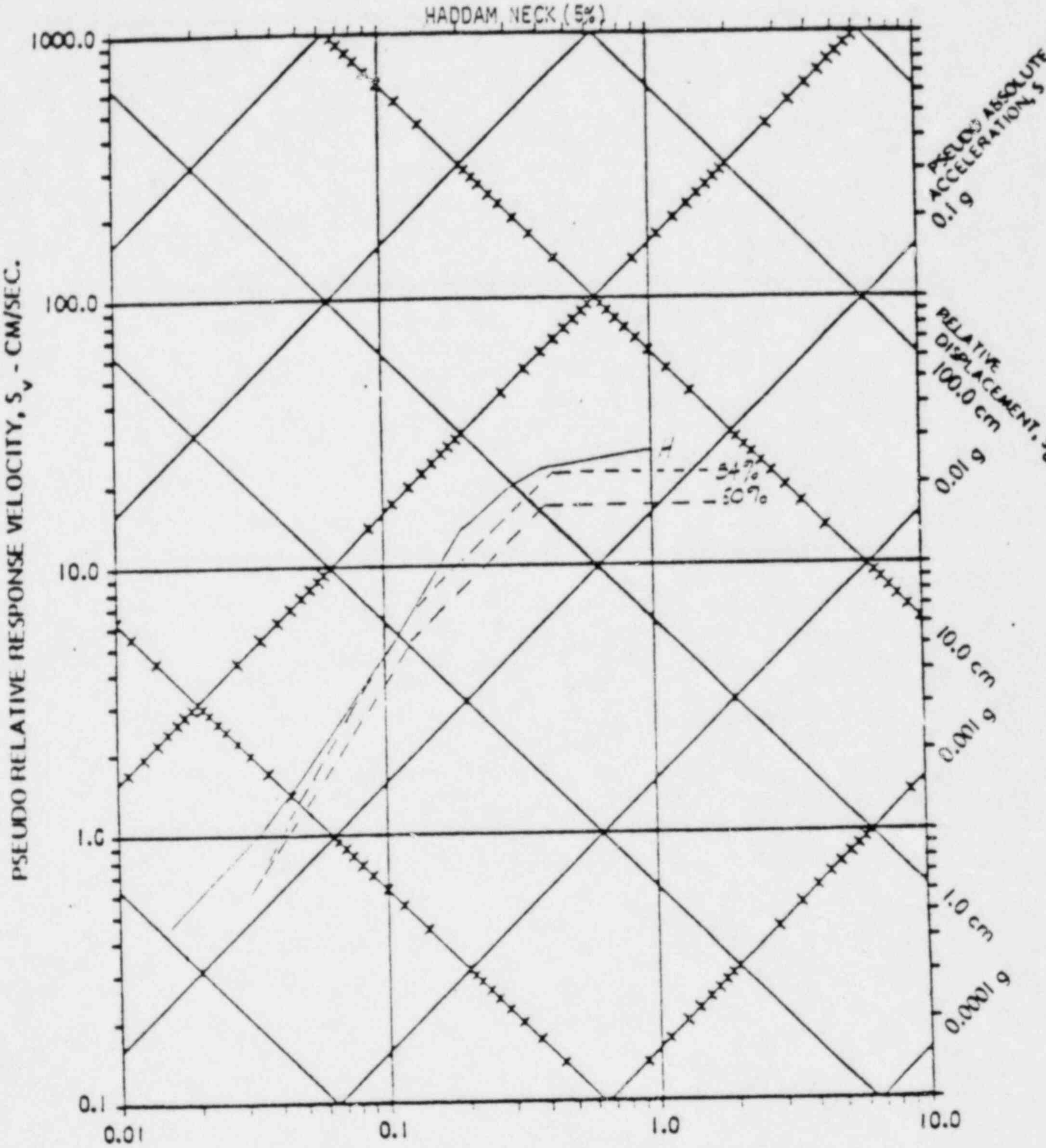


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

Y - Recommended probabilistic spectra. ————

Figure 3

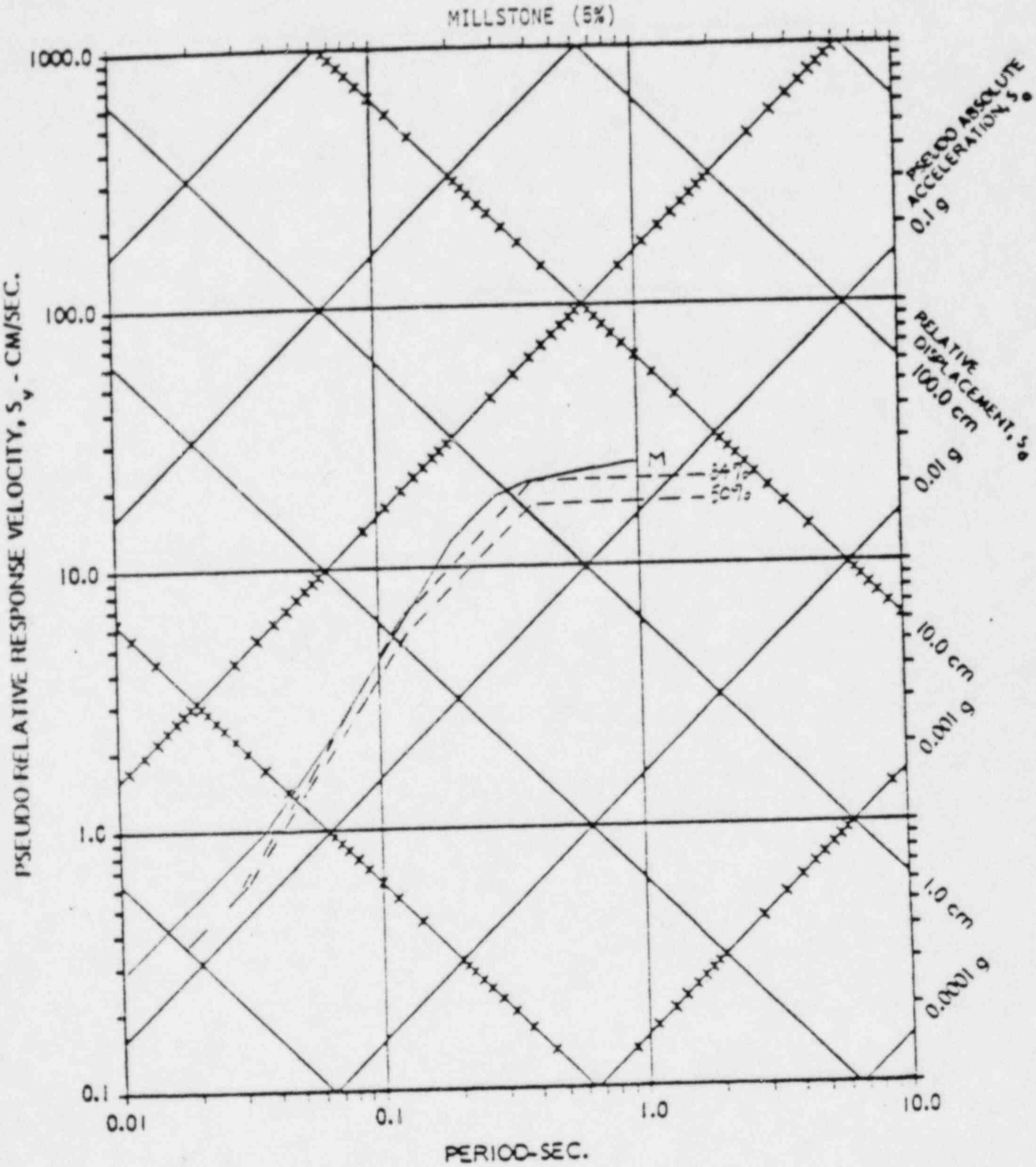


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

H - Recommended probabilistic spectra.

Figure 4

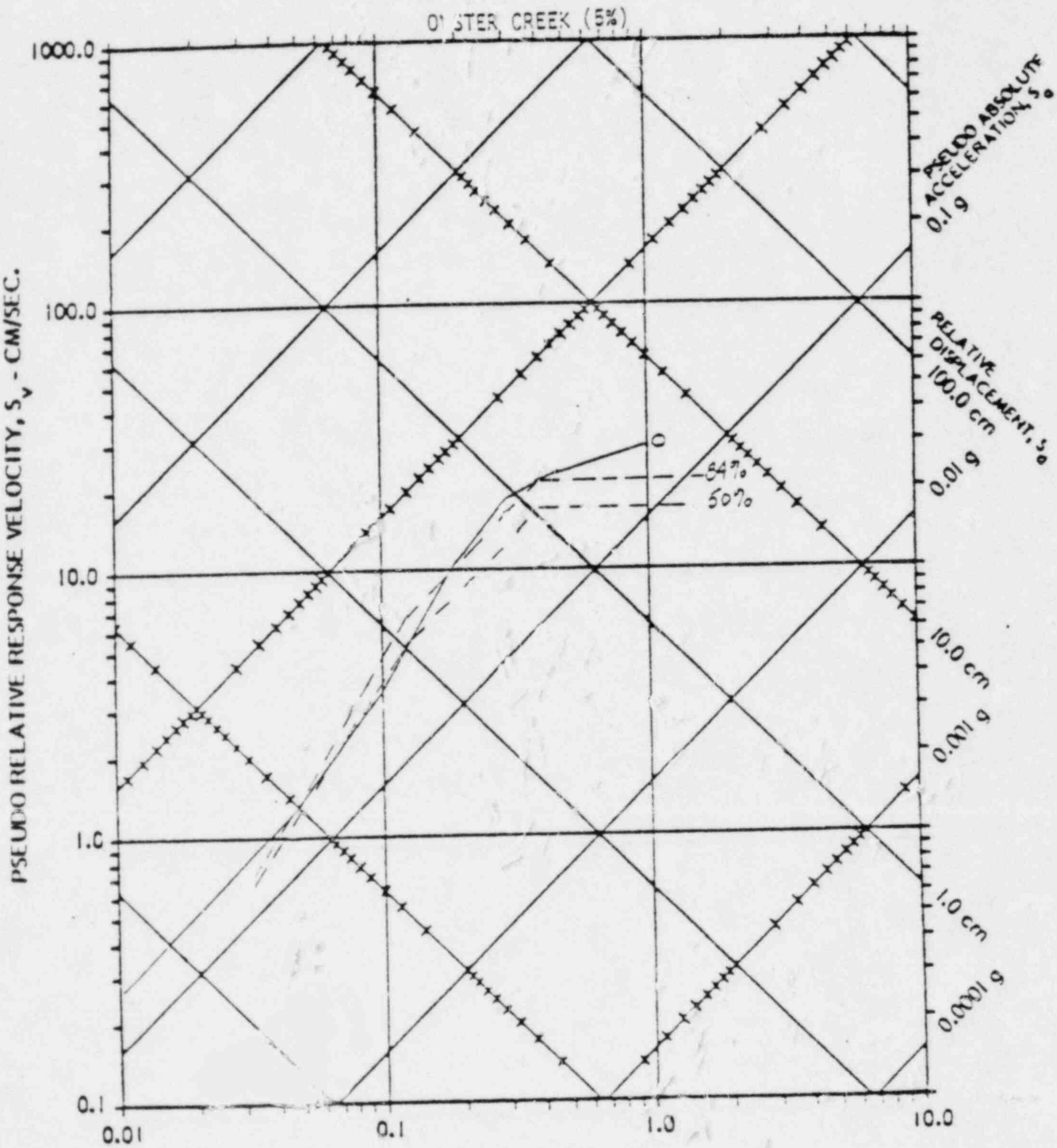


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

M - Recommended probabilistic spectra.

Figure 5

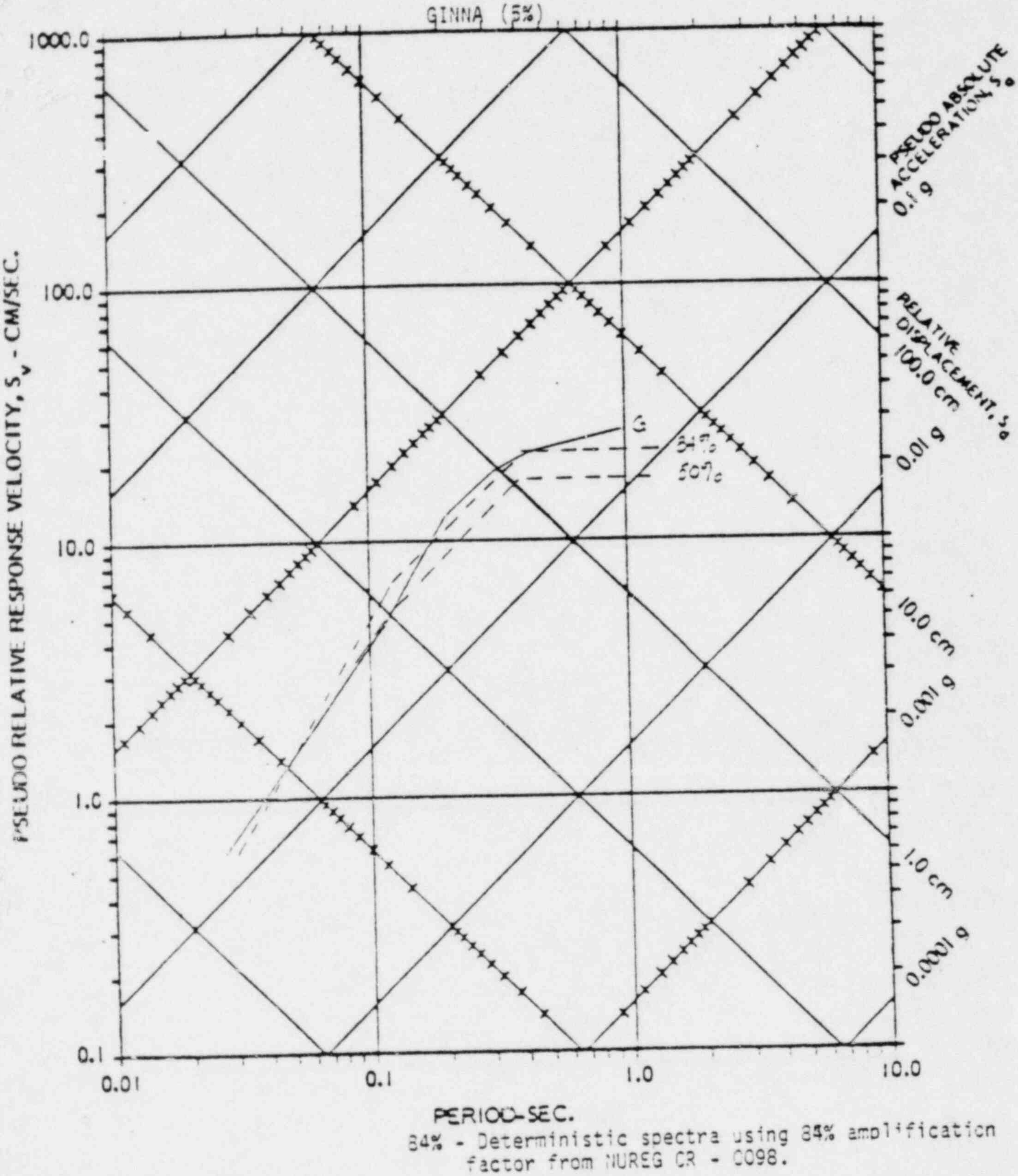


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

O - Recommended probabilistic spectra.

Figure 6

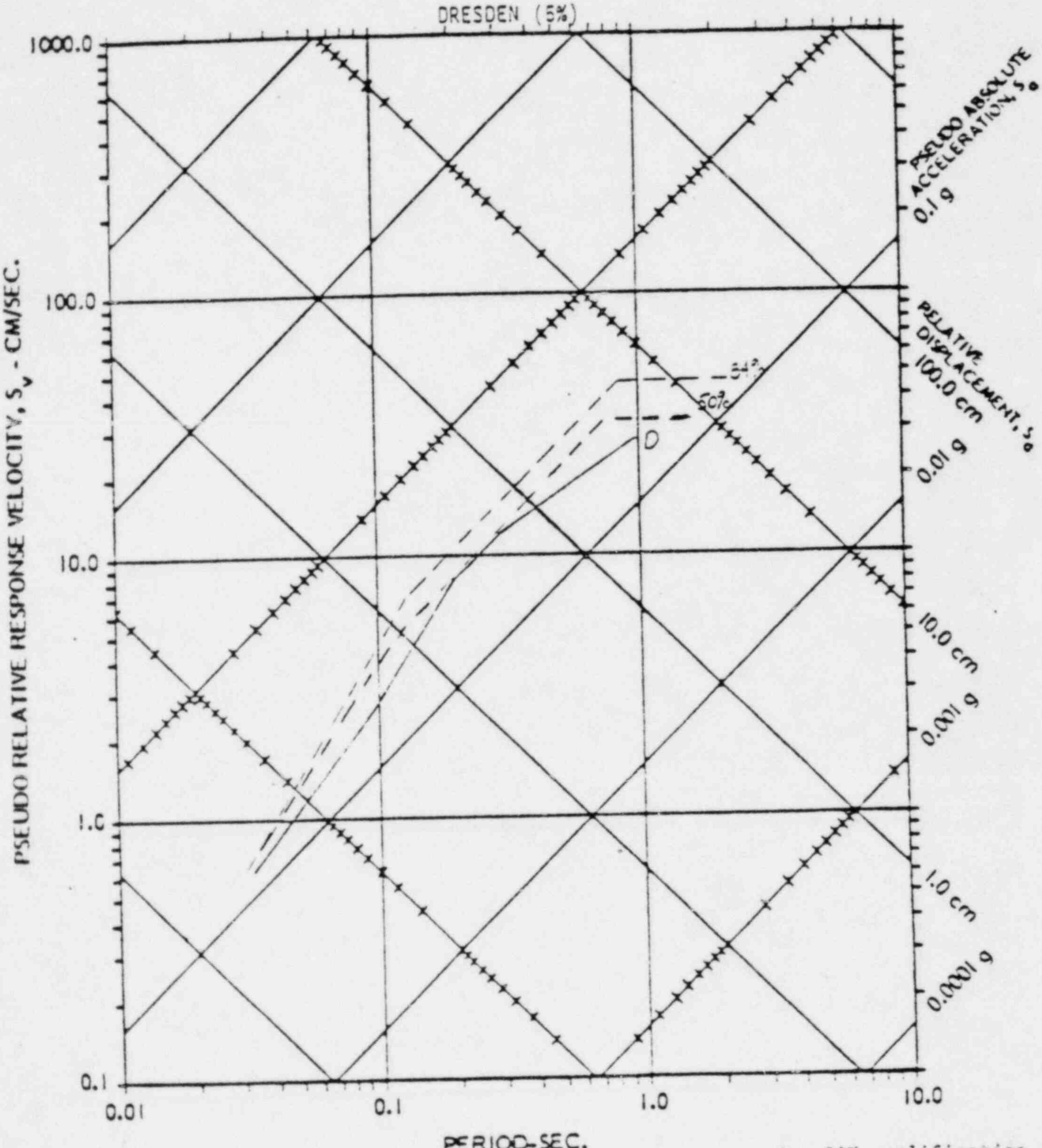


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

G - Recommended probabilistic spectra.

Figure 7

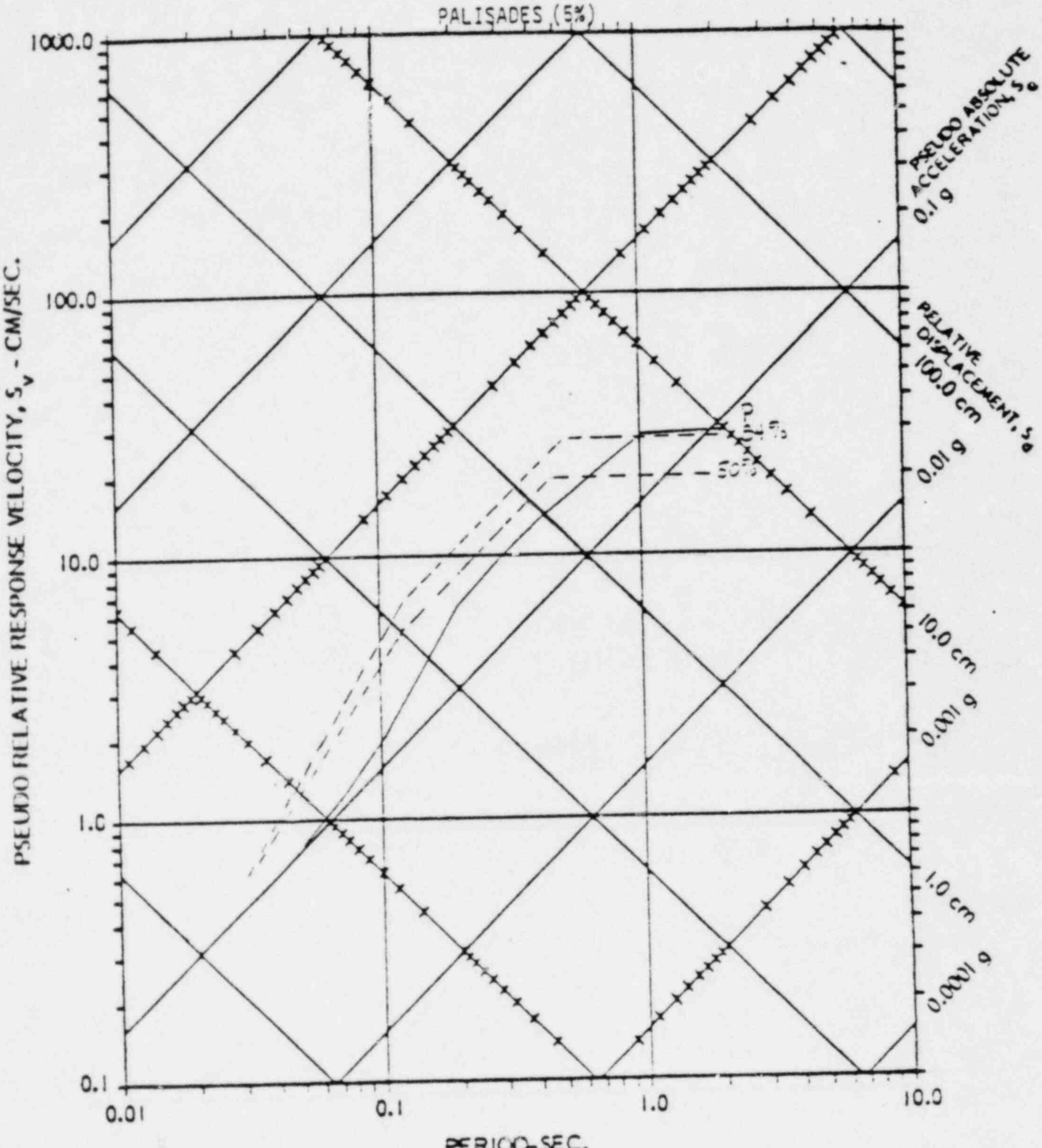


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

D - Recommended probabilistic spectra.

Figure 8

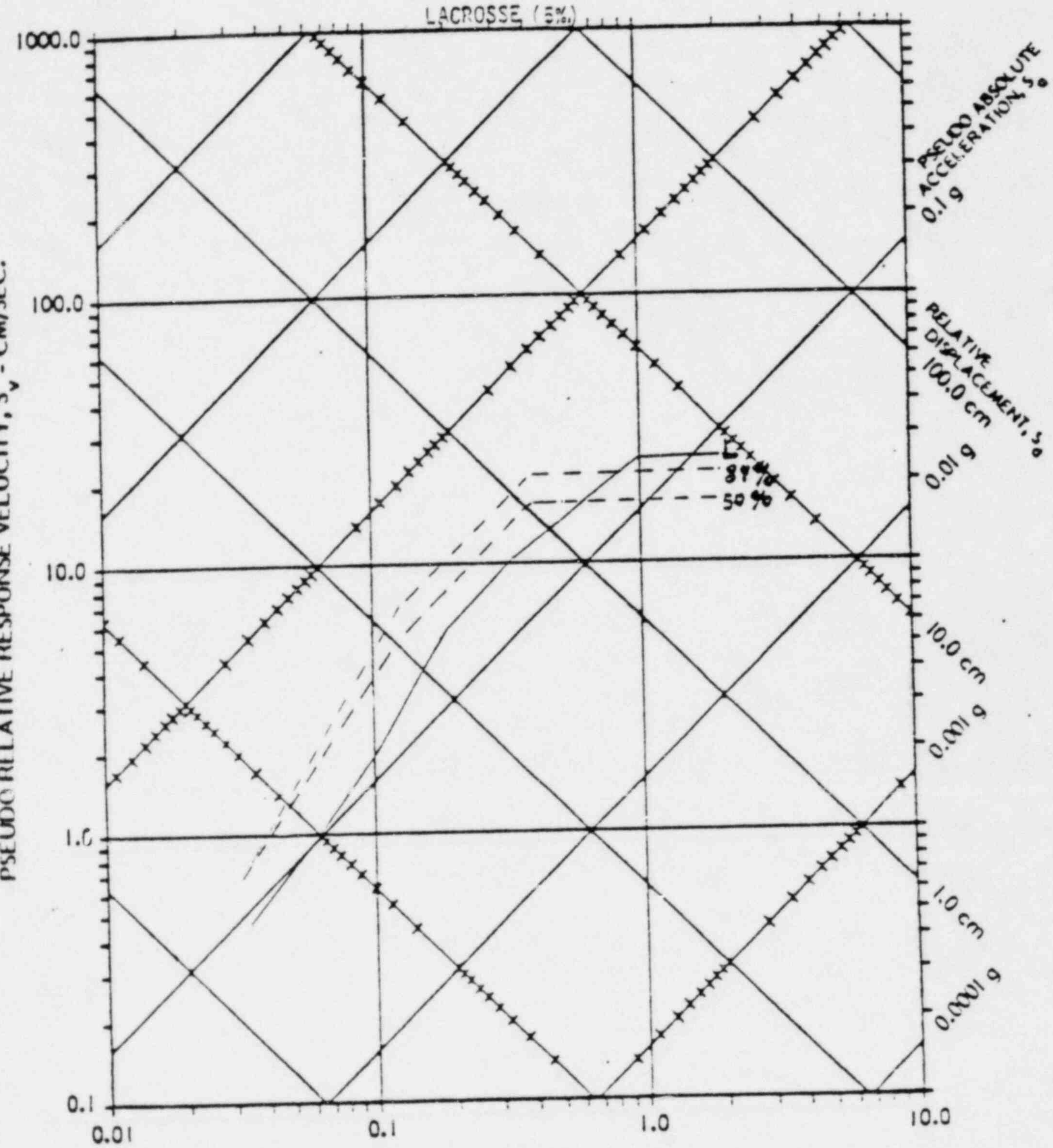


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

P - Recommended probabilistic spectra.

Figure 9

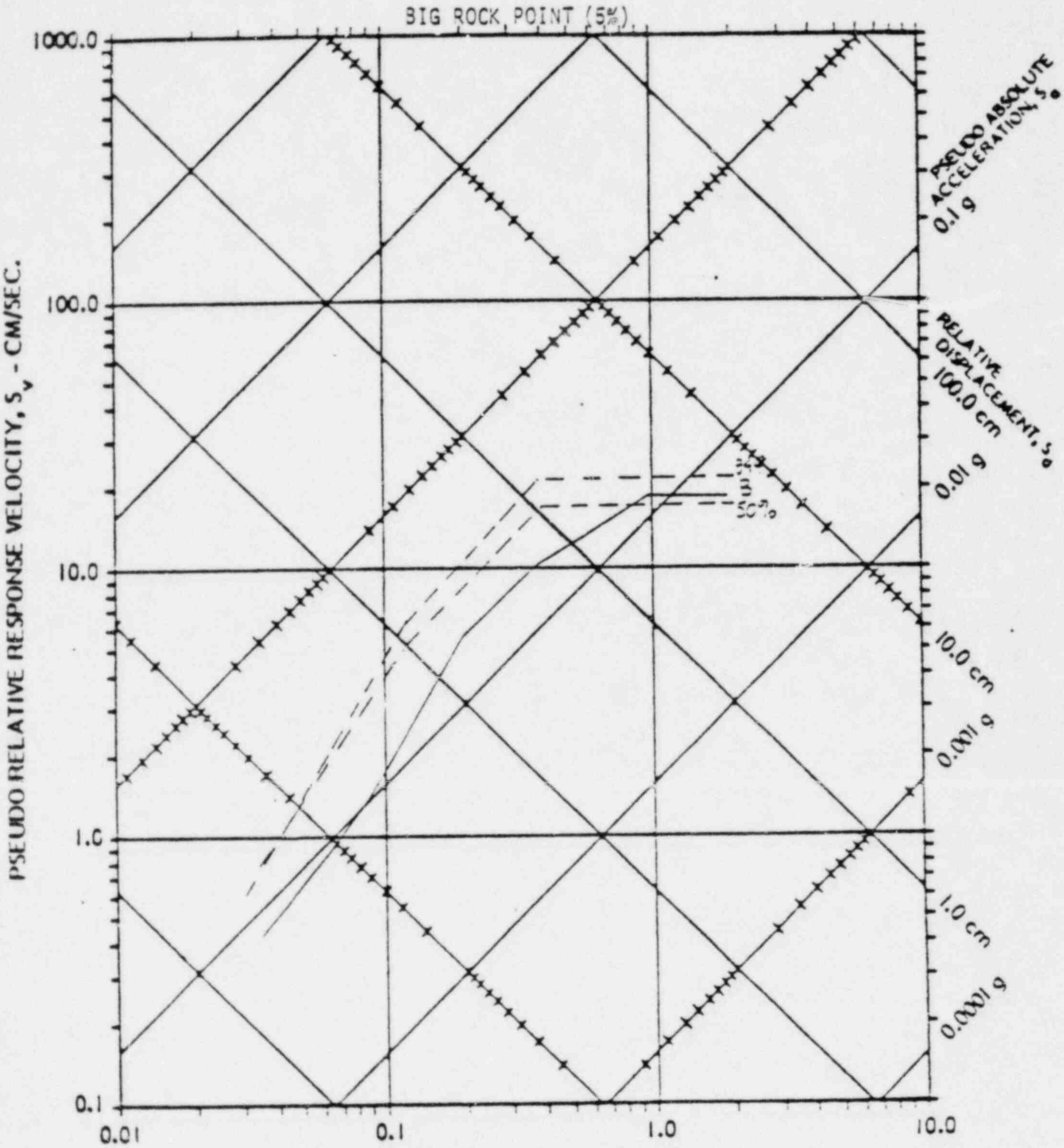


84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

L - Recommended probabilistic spectra.

Figure 10



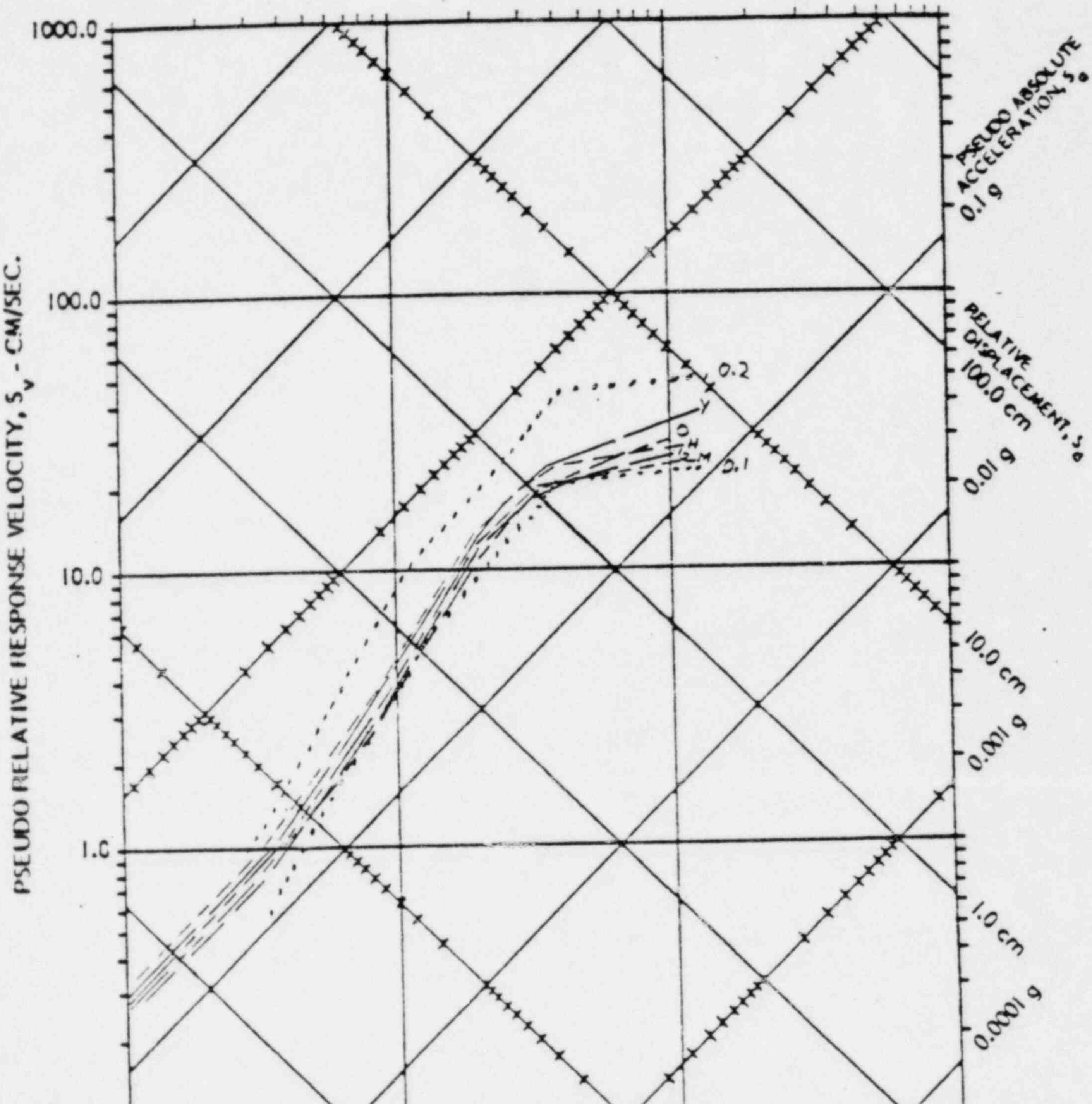
84% - Deterministic spectra using 84% amplification factor from NUREG CR - 0098.

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

B - Recommended probabilistic spectra.

Figure 11

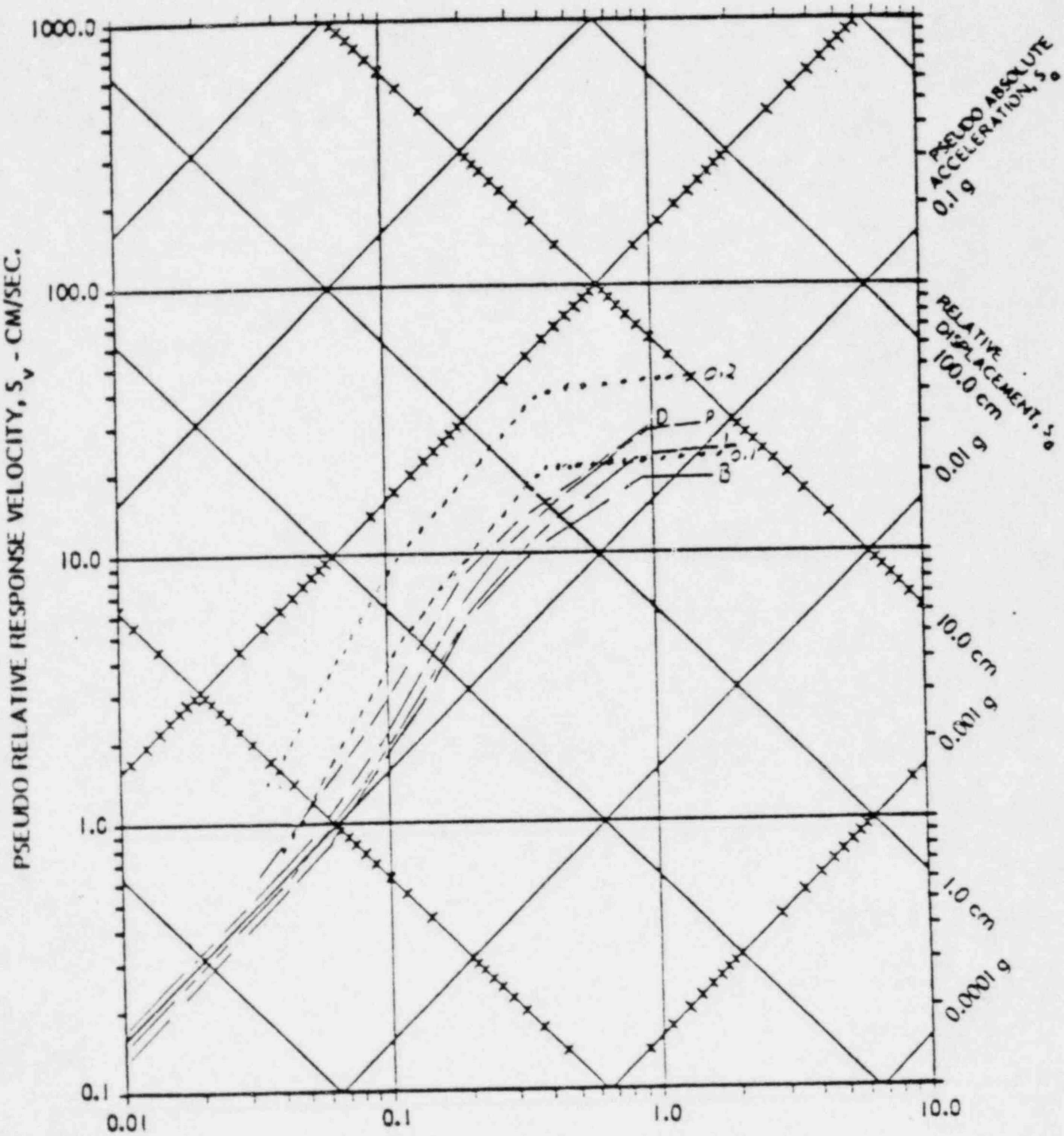
E.U.S. Recommended Probabilistic Spectra and Regulatory Guide 1.60 Spectra



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

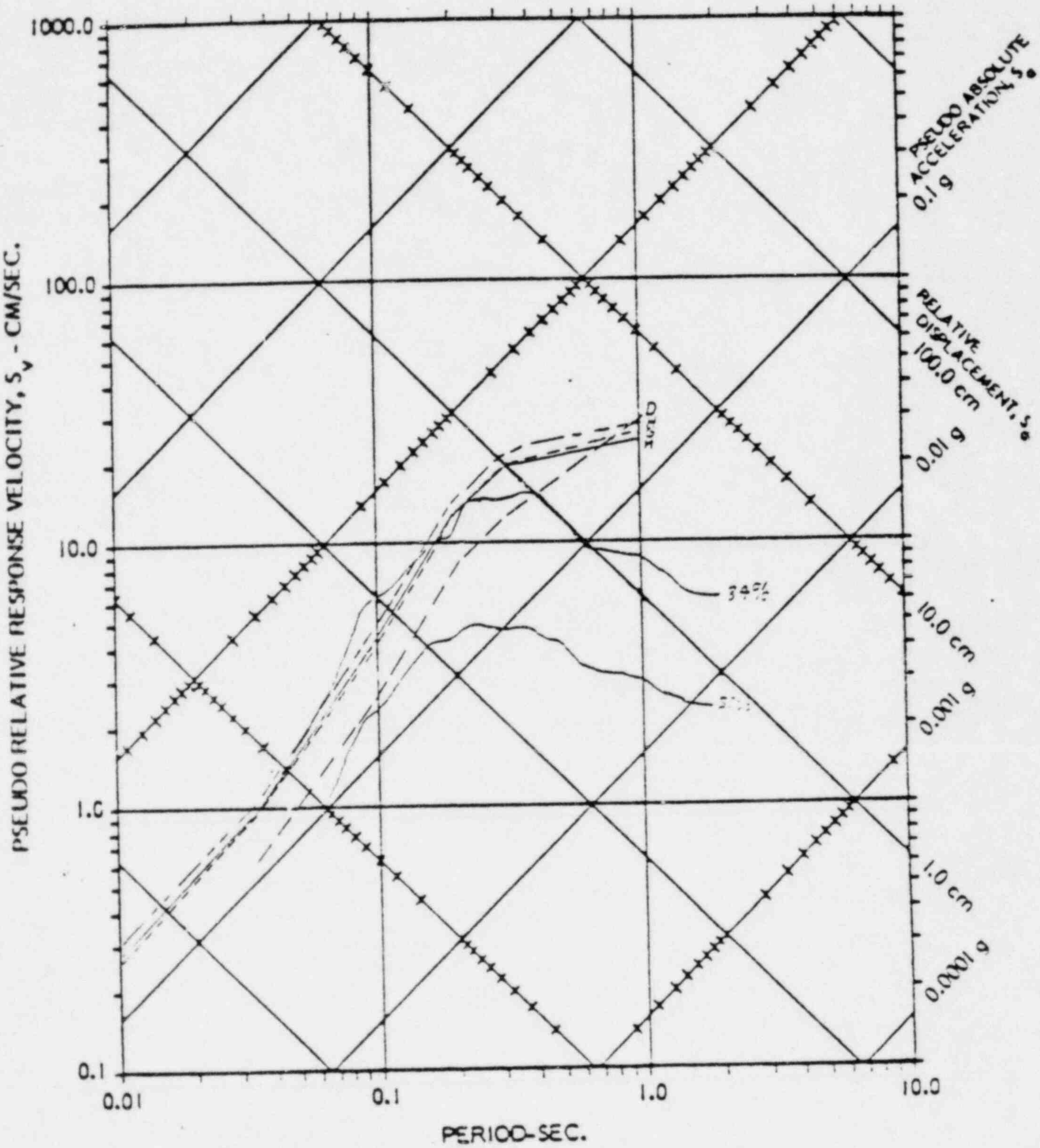
C.U.S. Recommended Probabilistic Spectra and
Regulatory Guide 1.60 Spectra



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

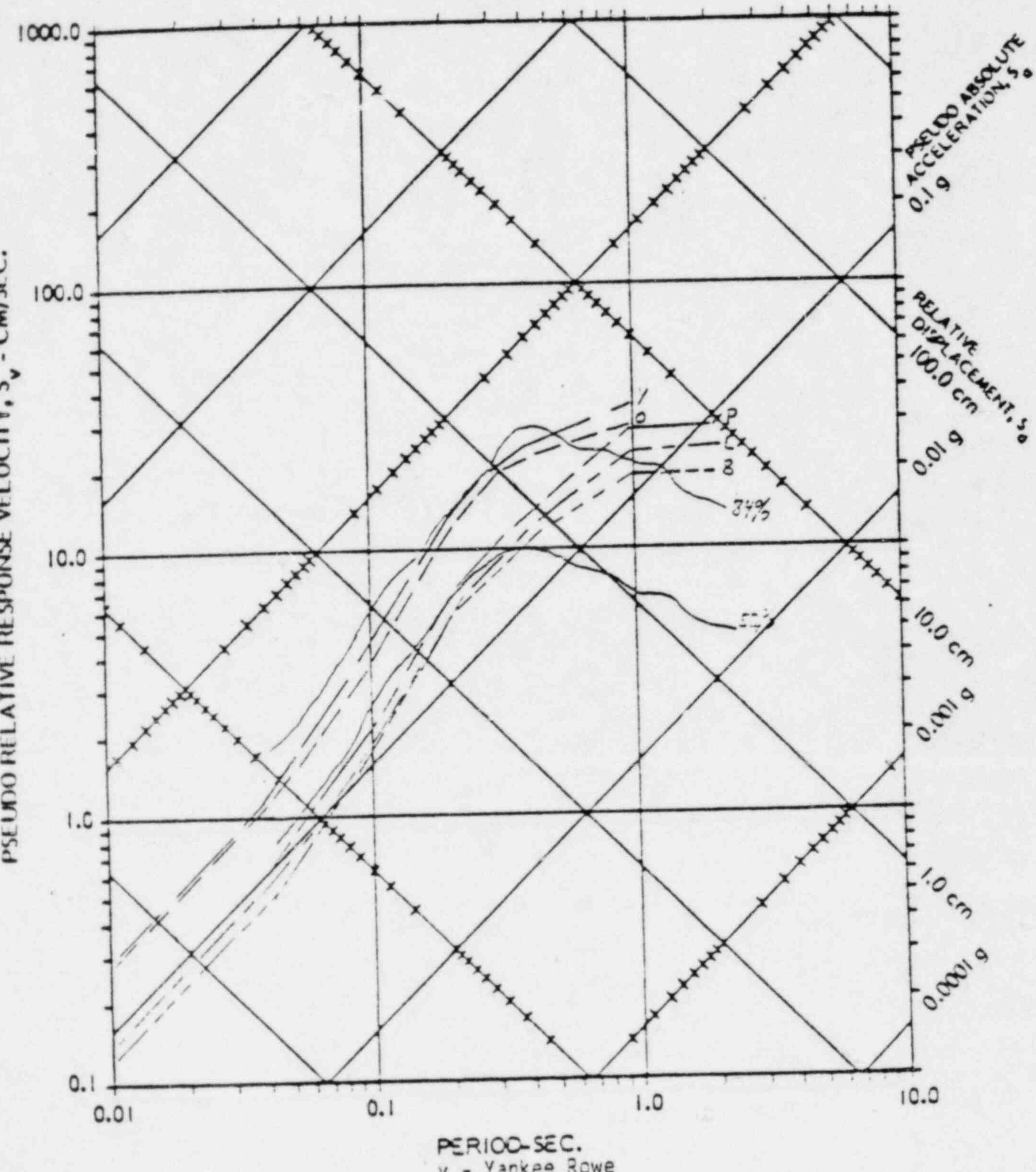
Recommended Probabilistic Spectra at Rock Sites and Recorded Spectra at Rock Sites



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

LBWR-3

DAIRYLAND POWER COOPERATIVE • P.O. BOX 817 • 2615 EAST AV SOUTH • LA CROSSE WISCONSIN 54601
(608) 788-4000

October 14, 1980

In reply, please refer to LAC-7181

DOCKET NO. 50-409

III-6

Director of Nuclear Reactor Regulation
ATTN: Mr. Dennis M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

SUBJECT: DAIRYLAND POWER COOPERATIVE
LA CROSSE BOILING WATER REACTOR (LACBWR)
PROVISIONAL OPERATING LICENSE NO. DPR-45
SEISMIC EVALUATION PROGRAM

Reference: (1) NRC Letter, Eisenhut to Linder, dated August 4, 1980.

Gentlemen:

Your letter, Reference 1, requested that we submit details of our plans for proceeding with a seismic evaluation program and provide justification for continued operation in the interim until the program is complete.

To date, Dairyland Power Cooperative (DPC) has undertaken substantial efforts to evaluate the integrity of the plant and systems essential to safety and safe shutdown.

In 1973, Dairyland Power Cooperative required structural evaluations to be prepared for the Full Term Operating License application. Gulf United Corporation evaluated the adequacy of major LACBWR structures and equipment to withstand the effects of an earthquake event. The Gulf United report (Technical Reference 1) used a ground response spectra, which was developed by Dames and Moore, based on a maximum horizontal ground acceleration of 0.12G for the Safe Shutdown Earthquake. The Gulf United report indicated that high stresses would be generated in some piping systems and building structures during a seismic event and Gulf United indicated that more detailed analyses would be required.

In 1974, DPC contracted Nuclear Energy Services (NES) to review the Gulf United report, provide the detailed seismic analyses on major primary system piping and design pipe restraints, if required. The seismic/stress analyses performed by NES are reported in Technical References 2 through 6 and included the recirculation piping, the

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S
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P

main steam and feedwater piping, and the high pressure core spray suction and discharge piping. NES also reanalyzed the LACBWR and Genoa 3 stacks for seismic effects. This work was reported in Technical Reference 7.

The NES analytical work confirmed that pipe restraints were necessary and DPC had decided to proceed with the design, fabrication and installation of the required pipe restraints. Shortly thereafter, the design work was stopped because the site specific spectra was questioned by the NRC and the potential for soil liquefaction was being evaluated by NRC.

It has recently been determined by NRC that soil liquefaction does not pose a problem at LACBWR and NRC also agreed that the 0.12G value used in previous analyses is acceptable and even conservative. The latter conclusion is based on a comparison of 0.12G ground response spectra developed by Dames and Moore and the LACBWR site specific spectra furnished by the NRC in Technical Reference 8. The ground response spectra developed by Dames and Moore clearly envelops the site specific spectra of Technical Reference 6. Therefore, all of the seismic evaluations of LACBWR structures and piping performed since 1974 by NES were based on a more conservative seismic spectra. It is DPC's intention that all future seismic work required for LACBWR will be based on the Technical Reference 8 seismic spectra.

Since 1978, NES has provided seismic/structural analyses work as required by DPC for the Systematic Evaluation Program. This work is being performed in accordance with the program submitted with this letter as Technical Reference 9. The overall seismic/structural evaluation of major structural components of the LACBWR Containment Building using the conservative ground response spectra of Technical Reference 1 has been completed. These major structural components of the Containment Building include the steel containment shell, the reactor pressure vessel, the outer and inner concrete shield walls, the concrete foundation mat and the pile foundation. The analysis indicated that the overall structural integrity of these major components will be maintained during the Safe Shutdown Earthquake.

Recently DPC has decided to upgrade the shutdown condenser system to an engineered safety system. Part of this upgrading effort consists of seismic analyses of the shutdown condenser, its support structure, and associated piping and valves. These analyses are currently being performed by NES.

As can be seen from the above discussion, DPC had started its own program of seismic/structural evaluations long before August 4, 1980 (Technical Reference 8) and in some cases even before the Systematic Evaluation Program began.

Summarizing this work to date:

1. Integrity of the reactor coolant pressure boundary: Structural analyses have been completed for the reactor pressure vessel, the main steam piping, the feedwater piping, and the recirculation piping.

2. Integrity of fluid and electrical distribution systems related to safe shutdown and engineered safety features: Structural analyses have been completed for the high pressure core spray suction and discharge piping. Analysis of the alternate core spray piping and shutdown condenser piping is currently in progress. Seismic pipe restraints for the high pressure core spray piping are currently being designed and fabricated for installation commencing early in November 1980 during the next scheduled refueling outage.

3. Integrity and functionability of mechanical and electrical equipment and engineered safety feature systems: Structural analyses of the Containment Building steel shell, outer shield wall, inner shield wall, concrete foundation and pile foundation is complete. Analysis of the LACBWR stack is complete. Analysis of the shutdown condenser and associated equipment is in progress.

As stated earlier, the previous analytical work performed for several major LACBWR piping systems indicated the need for additional pipe restraints. Since this work has been completed ahead of the Systematic Evaluation Program schedule, DPC has committed to a fabrication and installation program for the pipe restraints. DPC prefers to undertake this program now rather than wait for a 1982 outage, as proposed in Technical Reference 8. DPC has taken this position with the assumption that the ground response spectra shown in Technical Reference 8 is substantially correct and will not be revised in a more conservative direction by the NRC. It is estimated that an additional 24 months of analytical and evaluative work remain to satisfy the requests provided in your letter. This time table appears consistent with the progress of the Systematic Evaluation Program and the review of the Full Term Operating License.

Technical Reference 10 states that the NRC has determined that "the return period for an earthquake resulting in a peak acceleration of .12G would be at least 1,000 years and that the actual return period could be an order of magnitude higher. The LACBWR site is located in the Central Stable Region where historically the seismic activity is very low. Using seismicity data developed by the TERA Corporation for Lawrance Livermore Laboratory and the NRC, in conjunction with a computer program designed to perform seismic risk analysis, Dames & Moore has determined that the return period for an earthquake of this size is at least 10,000 years and more likely between 10,000 and 100,000 years."

Since the duration of the structural/seismic portion of the SEP is much shorter than the anticipated remaining life of the plant and since both DPC and NRC have agreed that the general level of seismic hazard is sufficiently low for LACBWR's anticipated remaining life, DPC feels continued operation of LACBWR is justified in the interim until the Systematic Evaluation Program is complete.

If there are any questions concerning this submittal, please contact us.

Very truly yours,

DAIRYLAND POWER COOPERATIVE

Frank Linder, General Manager

FL:RES:af

Enclosures

cc: J. G. Keppler, Reg. Dir., NRC-DRO III
NRC Resident Inspectors

Technical References:

1. Gulf United Report No. SS-1162, Seismic Evaluation of the La Crosse Boiling Water Reactor, January 1974; DPC Letter, Madgett to Giambusso, LAC-2788, dated October 9, 1974 (Application for FTOL).

*2. NES 81A0089, Seismic and Stress Analysis of LACBWR Recirculation Piping System.

*3. NES 81A0088, Seismic and Stress Analysis of LACBWR Main Steam Piping System.

*4. NES 81A0037, Seismic and Stress Analysis of LACBWR Feedwater Piping System.

*5. NES 81A0090, Seismic and Stress Analysis of LACBWR High Pressure Core Spray Suction Line Piping System.

*6. NES 81A0091, Seismic and Stress Analysis of High Pressure Core Spray Discharge Line Piping System.

7. NES 81A0092, Seismic and Structural Analysis of LACBWR and Genoa 3 Stacks, June 1976.

8. NRC Letter, D. G. Eisenhut to F. Linder, SEP Structural/ Seismic Evaluations, August 4, 1980.

9. NES Letters 5101-382, 5101-420, and 5101-481, R. A. Milos to R. E. Shimshak, Systematic Evaluation Program, Seismic and Structural Analysis, dated 9/7/78, 10/24/78 and 3/22/79 respectively (Transmitted with this letter).

10. Licensee's Answer to Order to Show Cause, dated March 25, 1980.

---

* DPC Letter, Linder to Director NRR, LAC-5478, dated September 27, 1978.

NUCLEAR ENERGY SERVICES, INC.
NES DIVISION
SHELTER ROCK ROAD
DANBURY, CONN. 06810
(203) 748-3581

RECD SEP 11 1978

September 7, 1978
Reference No. 5101-382

Mr. Richard E. Shimshak
LaCrosse Boiling Water Reactor
Dairyland Power Cooperative
P.O. Box 135
Genoa, WI 54632

Subject: Systematic Evaluation Program
Seismic Analysis Flow Chart

Dear Mr. Shimshak:

Enclosed is the SEP - Seismic Analysis Flow Chart, which we discussed last week at LACBWR. Confirming our telephone conversation today, Iqbal Husain is preparing a Task Plan covering the SEP - seismic analyses work and, in accordance with your instructions, he has started to model the Containment Building.

If we can be of further assistance, please call.

Very truly yours,

NUCLEAR ENERGY SERVICES, INC.
NES Division

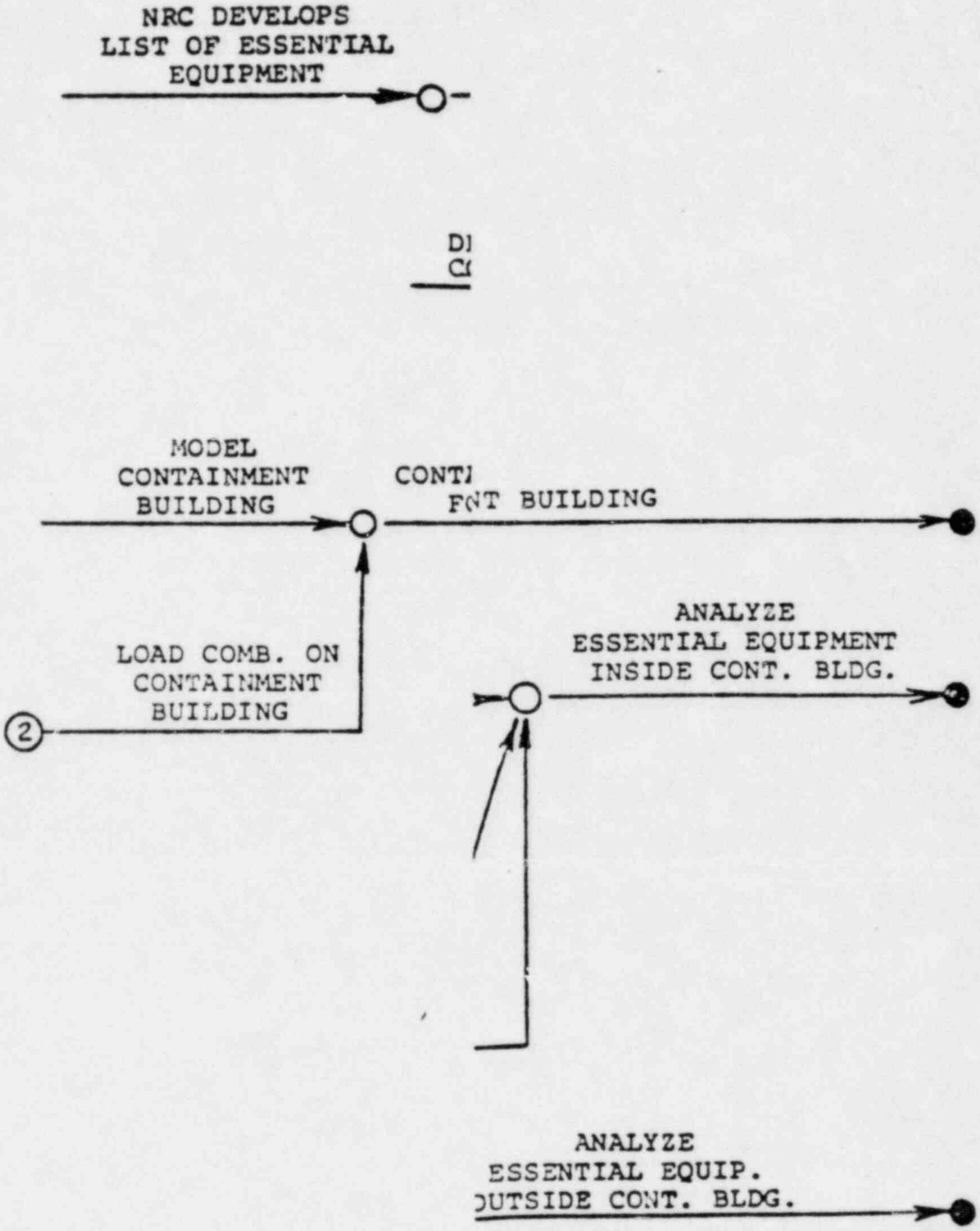
Richard Milos

Richard A. Milos
Project Manager

RAM/las
Enclosure

cc W. J. Manion
A. H. Yoli
I. Husain

SES FLOW CHART



R. Shimshak

RECD NOV - 2 1978

NES

NUCLEAR ENERGY SERVICES, INC.
NES DIVISION
SHELTER ROCK ROAD
DANBURY, CONN. 06810
(203) 748-3681

October 24, 1978
Reference No. 5101-420

Mr. Richard E. Shimshak
Dairyland Power Cooperative
La Crosse Boiling Water Reactor
P.O. Box 135
Genoa, WI 54632

Subject: Task Plan for the LACBWR-SEP Seismic and Structural Analysis

Dear Mr. Shimshak:

Enclosed is the Task Plan for the Seismic and Structural Evaluation of Major Building Structures, Equipment, Piping Systems and Components for the LACBWR Systematic Evaluation Program. Please review the enclosed Task Plan and send us your approval and/or comments.

If there are any questions, please do not hesitate to call.

Very truly yours,

NUCLEAR ENERGY SERVICES, INC.
NES Division

Richard Milos

Richard A. Milos
Project Manager

RAM/jam

Enclosure

cc: J. D. Parkyn
W. J. Manion
A. H. Yoli

Copies: Shimshak
NES Rdg. File
Parkyn
[illegible]
Townsley
[illegible]

TASK PLAN

FOR

SEISMIC AND STRUCTURAL EVALUATION OF MAJOR BUILDING STRUCTURES, EQUIPMENT, PIPING SYSTEMS AND COMPONENTS FOR THE LACBWR SYSTEMATIC EVALUATION PROGRAM

PREPARED UNDER PROJECT 5101

FOR

DAIRYLAND POWER COOPERATIVE

NUCLEAR ENERGY SERVICES, INC.
DANBURY, CONNECTICUT 06810

A. Objective

To perform seismic and structural analyses of essential building structures, equipment, piping systems and components for the LACBWR Systematic Evaluation Program.

B. Background

USNRC has initiated the Systematic Evaluation Program (SEP) for a number of older nuclear power plants. La Crosse Boiling Water Reactor is one of these plants. In the SEP it is required that essential building structures, equipment, piping systems and components be evaluated to verify their adequacy to withstand the normal loads (e.g. dead, live, pressure and thermal loads) as well as the loads associated with seismic and LOCA events. In an earlier response to the AEC/DL's request to review the effects of an earthquake event on LACBWR, Dairyland Power Cooperative requested Gulf United Nuclear Fuels Corporation to evaluate the adequacy of the major structures and equipment to withstand seismic loadings. The Gulf United (GU) Nuclear Fuels Corporation study used the ground response spectra (developed by Dames and Moore) which was based on a maximum horizontal ground acceleration of 0.12 G for the Safe Shutdown Earthquake (SSE). The Gulf United Study (Reference 1) indicated that high stresses would be generated in some piping systems (e.g. main steam) and building structures (e.g. the LACBWR stack) during a seismic event. To eliminate the possibility of a seismically induced loss of coolant accident, detailed seismic/stress analyses of the major LACBWR piping systems were subsequently performed and the design of necessary seismic support systems were initiated by NES (References 2 through 6).

In the SEP, however, NRC is asking LACBWR to evaluate the plant adequacy for a higher seismic input ground motion (>.12G) and to include the effects of other loads (dead, live, pressure, thermal, etc.) which were not considered in the GU study. Therefore some of the seismic/structural analysis work will have to be redone or modified.

NES proposes to perform the SEP seismic/structural analyses work in accordance with the flow chart shown on Figure 1 and the method of approach described in Section C of this task plan.

C. Method of Approach

As indicated on the seismic/structural analyses flow chart, on receiving the list of essential equipment (which is being developed by NRC), NES will prepare the applicable loads, load combinations and the corresponding structural acceptance criteria for each item of essential equipment. These loads, load combinations and the corresponding structural acceptance criteria will be based on the guidelines given in NRC Standard Review Plan Section 3.8.4 (Reference 7), applicable ASME, AISC and ACI codes (References 13 through 15) and current nuclear industry practice. The list of essential equipment, loads, load combinations and acceptance criteria will be reviewed and agreed on by NRC/DPC/NES prior to performing any detail analysis work.

NRC and their consultant Lawrence Livermore Laboratory (LLL) are currently reviewing the regional geological, seismological information and the LACBWR site soil data. NRC has requested the maximum seismic loading that the plant structure could withstand without making major structural modifications. This information along with the LLL recommendations will be used by NRC in developing the maximum ground acceleration and the site seismic spectra.

Since major modifications to the containment building would be very costly and would involve an extended shutdown, NES believes that it is the most important essential structure to analyze with respect to establishing the maximum tolerable seismic loading. Furthermore, the seismic response results of the containment building are required in evaluating the structural adequacy of other essential equipment, NES is currently developing the mathematical model for the seismic analysis of the containment building. The multi-degree of freedom lumped mass finite element mathematical model of the containment building is based on current industry practice and includes the soil structure interaction effects as well as that of the pile foundation: the seismic analysis will be performed using ground acceleration time history input base motion and the modal superposition methods of dynamic analysis. The characteristics of the base motion time history will be such that its spectra will envelope the ground response spectra given in NRC Regulatory Guide 1.60 (Reference 8). Appropriate damping values given in NRC Regulatory Guide 1.61 (Reference 9) will be used in the analysis. The effect of each of the three orthogonal spatial components (two horizontal and one vertical) of the earthquake will be based on procedure given in NRC regulatory Guide 1.92 (Reference 10).

The containment building structures will also be analyzed for other normal (dead and live loads) and abnormal loading conditions (pressure and thermal loads of LOCA) using appropriate finite element models and static or dynamic methods of structural analysis.

The response results of the seismic normal and abnormal loading conditions will be combined and compared with the allowable values in accordance with NRC standard review plan 3.8.4. The mathematical model, load combinations, analytical methodology, etc will be reviewed with DPC/NRC prior to performing the detail analyses work. From the above analyses the maximum ground acceleration that the plant could withstand without making major structural modifications to the containment building will be developed.

Based upon this DPC determined maximum ground acceleration value, LLL recommendations and NRC experience with other utilities participating in the SEP, NRC will select the maximum ground acceleration and site seismic spectra as indicated in the flow chart.

If major plant structural modifications are required to meet the NRC seismic criteria using conventional seismic analysis methods, NES will perform non-linear time history seismic analyses to take advantage of the additional material strength (reserve energy) available in the plastic range. Also wherever feasible probalitic combination of various loadings will be considered.

As indicated in the seismic analyses flow chart, mathematical models, load combinations, structural acceptance criteria, etc. will be similarly developed for essential equipment. These equipment and essential systems will be evaluated to verify their adequacy to survive and seismic and/or a LOCA event by using appropriate analytical methods, available environmental test results for similar equipment and/or in sites vibration testing. In the analytical methods, the floor response spectra or floor response time history results from the containment building seismic analysis will be used as input seismic motion. Information (models, input data, etc.) available from prior GU study and NES analyses work (Reference 1 through 6) will be utilized to reduce the effort required in the SEP analysis work. The seismic and structural analyses will be performed using STARDYNE, ANSYS and PIPESD computer codes (References 16 through 18).

D. Workscope

Since the SEP seismic/structural analysis work is quite extensive, the workscope for the analysis of each individual building structure equipment, and piping system will be furnished to DPC prior to starting the detail analysis work.

The workscope for the seismic/structural evaluation of the containment building which is being performed by NES is given below:

1. Prepare lumped mass mathematical of the containment building including soil structure interaction effects.

2. Develop member properties, lumped masses and base input motion

3. Perform seismic analysis.

4. Prepare finite element models of the containment building to evaluate the effects of other normal and abnormal loadings.

5. Prepare stiffness properties and input data for the normal and abnormal loading conditions.

6. Perform appropriate static/dynamic analysis of the finite element models.

7. Evaluate the effects of the combined seismic and other normal/abnormal loading conditions on the overall containment building structures and on the local critical areas such as pile foundation, containment to foundation interface, opening for the personnel lock, overhead tank, crane to support column, reactor vessel to pedestal connection, etc.

8. Develop the acceptable maximum horizontal ground acceleration values.

9. Prepare the detail analysis report.

E. Task Engineer

I. Husain will be Task Engineer for this workscope.

G. Schedule

The workscope items will be completed within five months.

H. References

1. GUS Report No. SS-1162, Seismic Evaluation of the LaCrosse Boiling Water Reactor

2. NES 81A0089, Seismic and Stress Analysis of LACBWR Recirculation Piping System.

3. NES 81A0088, Seismic and Stress Analysis of LACBWR Main Steam Piping System

4. NES 81A0087, Seismic and Stress Analysis of LACBWR Feedwater Piping System.

5. NES 81A0090, Seismic and Stress Analysis of LACBWR High Pressure Core Spray Suction Line Piping System.

6. NES 81A0091, Seismic and Stress Analysis of High Pressure Core Spray Discharge Line Piping System.

7. USNRC Standard Review Plan, Section 3.8.4.

8. USNRC Regulatory Guide 1.60 "Design Response Spectra for Seismic Design of Nuclear Power Plants" Rev. 1, December 1973.

9. USNRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants", October 1973.

10. USNRC Regulatory Guide 1.92, "Combination of Modes and Spatial Components in Seismic Response Analysis", Rev. 1, February, 1976.

11. USNRC Regulatory Guide 1.122 "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components", September 1976.

12. USNRC Regulatory Guide 1.57 "Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components", June 1973.

13. ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1974 Edition, Nuclear Power Plant Components.

14. "AISC, Steel Construction Manual", American Institute of Steel Construction, Inc., New York, Seventh Edition, 1970.

15. "Building Code Requirements for Reinforced Concrete (ACI 318-71)", American Concrete Institute, March 1973.

16. MRI/STARDYNE 3 - Static and Dynamic Structural Analysis Systems for Scope 3.4 Operating System User's Information Manual, Revision A, Control Data Corporation, August, 1976.

17. Swanson Analysis, Inc., "ANSYS - Engineering Analysis System User Information Manual", Revision D, Control Data Corporation, March, 1976.

18. URS/John A. Blume and Associates - "PIPESD" - Pipe Static, Dynamic and Thermal Transient Analysis System, Version 5.1, Revision F, Control Data Corporation, December 1977.

SEP - SEISMIC ANALYSES FLOW CHART

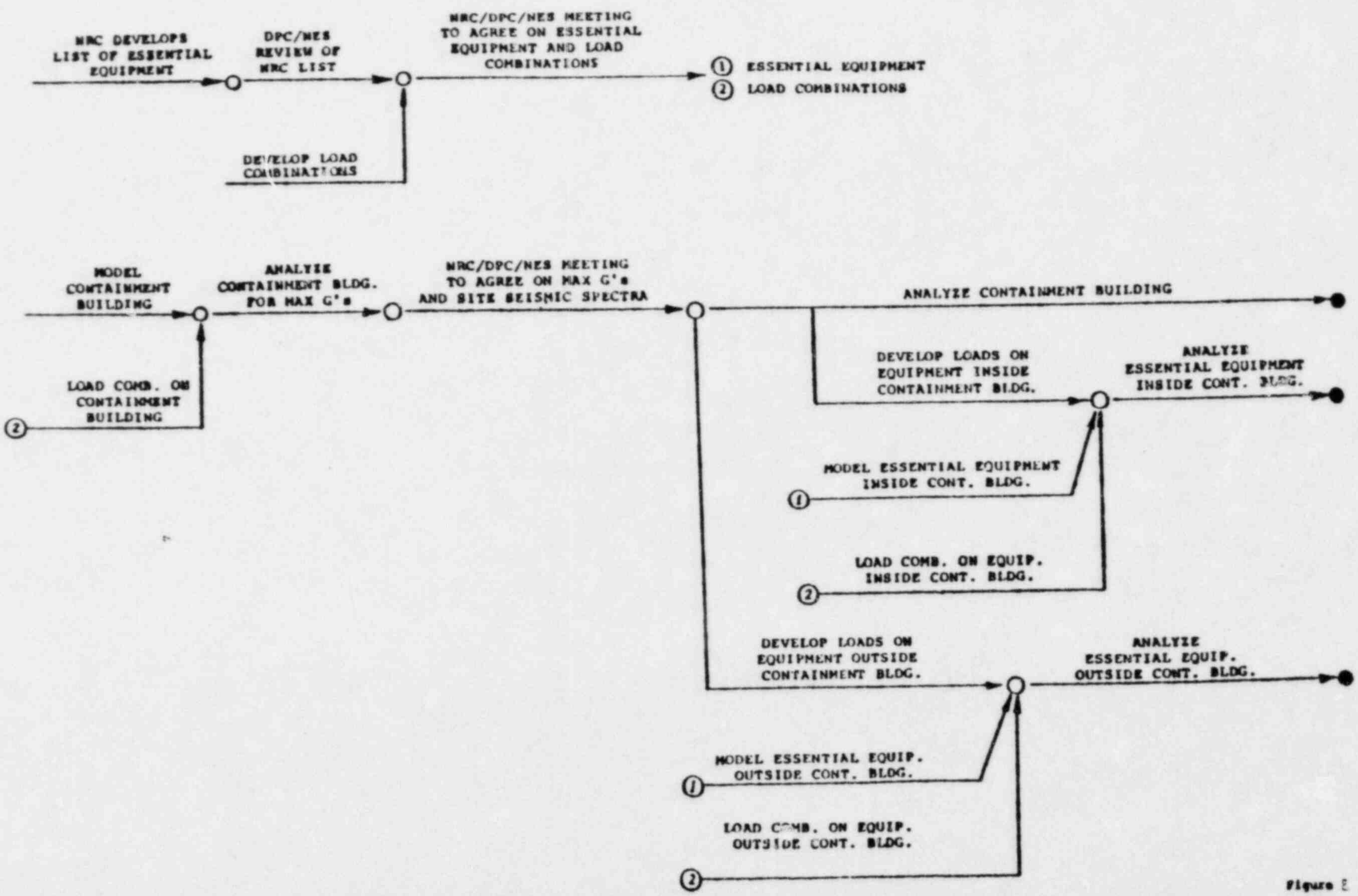


Figure 8

R. Shimshak
RECD MAR 26 1979

NUCLEAR ENERGY SERVICES, INC.
NES DIVISION
SHELTER ROCK ROAD
DANBURY, CONN. 06810
(203) 748-3581

NES notebook

Mr.Richard E. Shimshak
LaCrosse Boiling Water Reactor
Dairyland POwer Cooperative
P.O. Box 135
Genoa, Wi. 54632

March 22, 1979
Project/Task No.: 5101
Reference No.: 5101-481

Subject: SEP - Seismic and Structural Analysis

Reference: Telecon between R. E. Shimshak and R. A. Milos, Same Subject, on March 20, 1979

Dear Mr. Shimshak:

Enclosed is the revised SEP - Seismic Analysis Flow Chart which you requested in the referenced telecon. This flow chart was revised to indicate completion dates for the containment building model, the containment steel shell analysis and the complete containment building analysis to determine the maximum seismic loads which the containment building can survive. The flow chart also indicates the time intervals to complete other specific analyses, which will be required after the site specific spectra have been established and agreed to by DPC and NRC.

Enclosed also is a copy of the SEP - seismic and structural analyses Task Plan which was sent to you on October 24, 1978 with letter 5101-420.

If we can be of further assistance, please call.

Ve y truly yours,

NUCLEAR ENERGY SERVICES, INC.
NES Division

Richard Milos

Richard A. Milos
Project Manager

RAM:ma
Enc.

cc: W. J. Manion
A. H. Yoli
I. Husain

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SEP - SEISMIC ANALYSES FLOW CHART

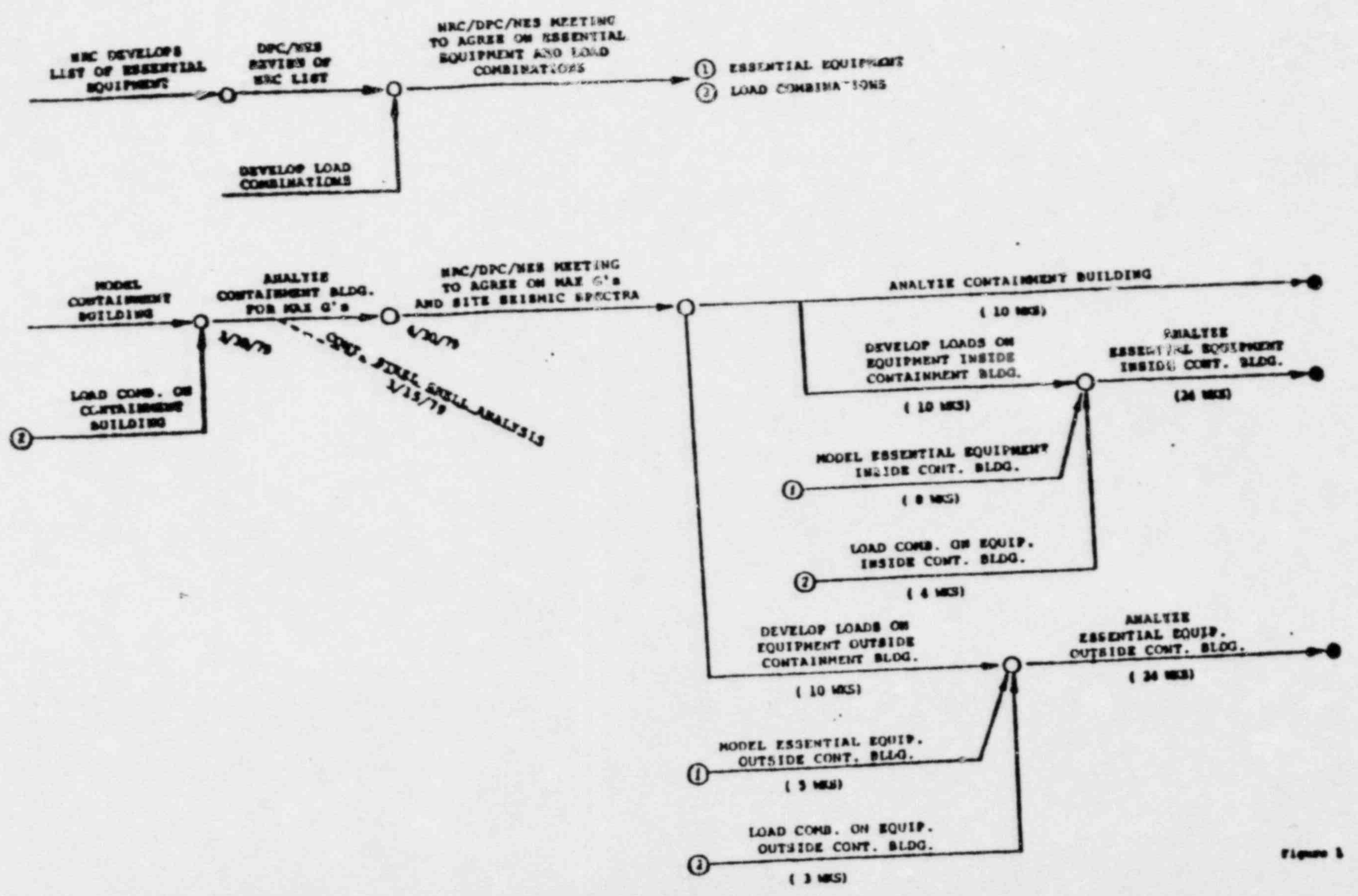

Figure 1

R. Shimshak
RECD MAR 26 1979

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Richard Milos

Richard A. Milos
Project Manager

RAM:ma
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SEP - SEISMIC ANALYSES FLOW CHART

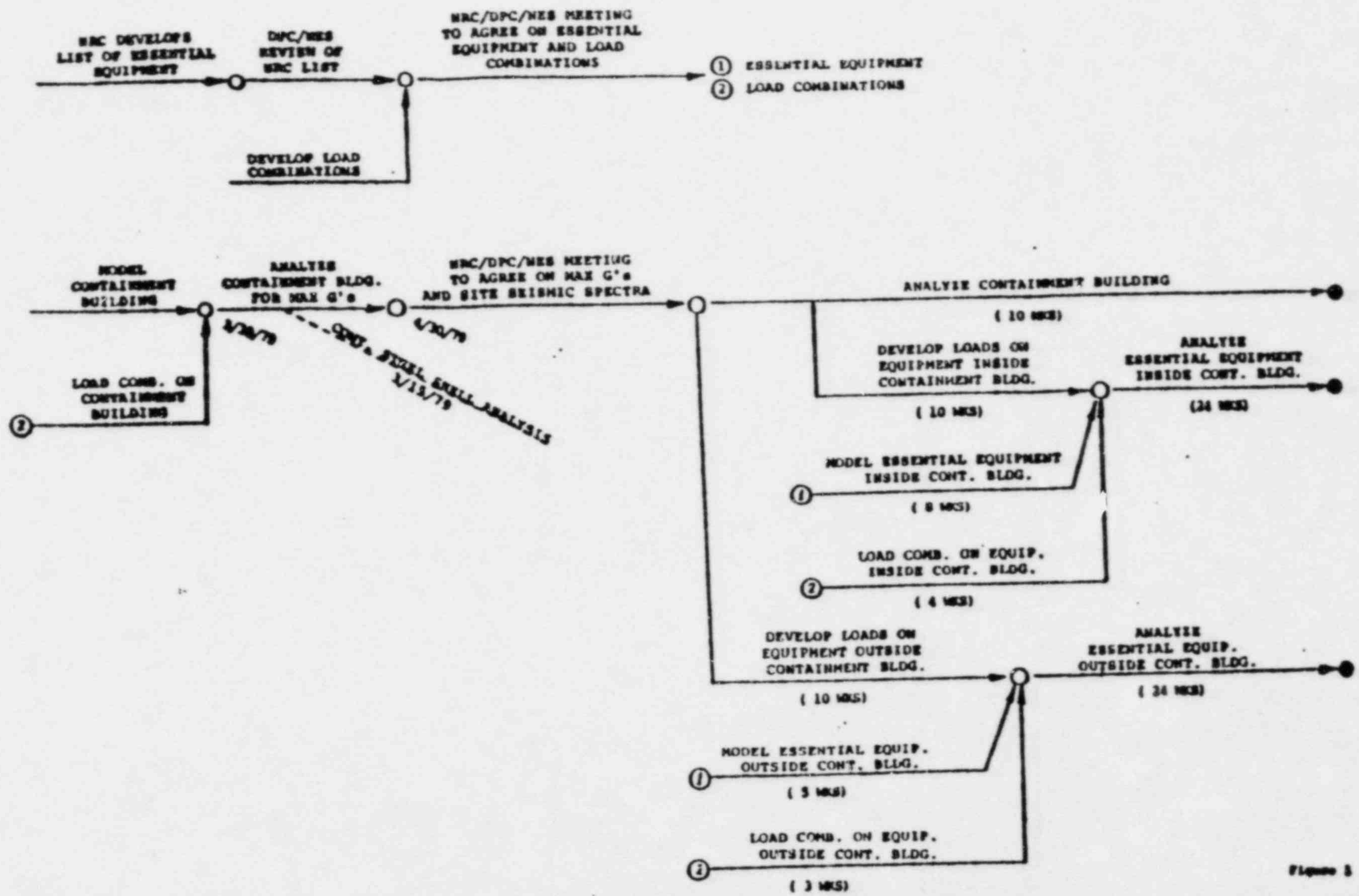

Figure 1

SO-3

III-6

Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

January 27, 1978

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Operating Reactors Branch #1
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Gentlemen:

Subject: Docket No. 50-206
Site Specific Earthquake
San Onofre Nuclear Generating Station
Unit 1

Enclosed for your review are 20 copies of the report "Simulation of Earthquake Ground Motions for San Onofre Nuclear Generating Station, Unit 1, Executive Summary", dated January 24, 1978. Copies of this report were requested in a meeting with the NRC on January 27, 1978. Based on discussion at that meeting, we are planning to meet with representatives of the Regulatory Staff on February 15, 1978 to further discuss the site specific earthquake program.

Should you have any questions concerning this matter, please let me know.

Very truly yours,

J. G. Haynes

J. G. Haynes
Chief of Nuclear Engineering

Enclosure

A001

SIMULATION OF EARTHQUAKE GROUND MOTIONS FOR SAN ONOFRE NUCLEAR GENERATING STATION - UNIT I

EXECUTIVE SUMMARY

January 24, 1978

THE PROBLEM

A study has been undertaken to estimate amplitude, duration and frequency content of ground motion at the San Onofre Nuclear Generating Station in the event of a major earthquake rupture along the hypothesized offshore zone of deformation. Our experience with past earthquakes indicates that rather complex physical processes are involved. When shear fracture initiates along a pre-existing fault, strain energy that is stored in the tectonically stressed earth is released. A portion of this released energy emanates from the fractured surface in the form of seismic waves. Several factors influence the production of seismic energy along the fault surface including the fracture strength of the subsurface materials, the amount of energy that is expended in creating new crack surface, the shear-carrying capacity of ruptured rock (sliding friction) and the spatial and temporal variations in these processes as the rupture spreads. Furthermore, shear fracture leads to a quadrupole (four-lobed) radiation pattern which is biased by the velocity of the spreading rupture and its inherent lack of coherence. The end product of the complex rupture process is to cause slip along the fractured surface. The time history of slip for each point along the fracture surface is a suitable and complete characterization of the production of seismic waves along the fault surface.

The outgoing seismic waves encounter a multiplicity of different rock types, each of which results in reflections, refractions and conversions to different wave types. These effects that arise from geologic heterogeneities are generally

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accentuated near the earth's surface where geologic complexities tend to be more pronounced. Earthquake waves are influenced most significantly by the general increase in wave speed with depth starting from the stress-free boundary at the earth's surface. The gradient in wave speed with depth tends to bend seismic energy toward the earth's surface where waves become trapped in the form of surface waves.

The amplitude or energy density of the seismic waves decreases with increasing distance from the fracture surface due to geometric spreading and material attenuation. Close to an earthquake rupture, geometric spreading causes some waves to decay with distance by less than $r^{-1/2}$ (the decay rate for trapped surface waves) while other waves decay by as much as r^{-2} where r denotes distance from the rupture surface. Material attenuation tends to preferentially diminish the energy in high frequency waves with the greatest effects in the shallowest layers. Soft, sedimentary layers can attenuate high-frequency waves ($\geq$ 10 Hz) by an order of magnitude in a short distance (less than one kilometer).

Thus, it is apparent that numerous inherent complexities are involved in estimating earthquake ground motions. These ground motions depend rather strongly on local geologic and tectonic conditions. Of fundamental importance are:

1. The characteristics of the earthquake rupture process that go into producing seismic energy.
2. The earth properties along the path between the observer and the rupture surface.
3. The distance and orientation of the fault with respect to the observer.

SOLUTION STRATEGY

The traditional earthquake engineering approach is to estimate ground motions using empirical relationships which are based on strong motion data recorded for past earthquakes. Because the past recordings were made under geologic and tectonic conditions that differ from the conditions present at San Onofre and because little strong motion data is available at distances of less than 10 km from the rupture surface, there would be, based on empirical data, significant uncertainty as to the nature of ground shaking that could occur at the plant from a major earthquake along the hypothesized zone of deformation approximately 8 km offshore from the site.

In order to establish a more credible basis for estimating ground shaking from a postulated earthquake offshore, we have proceeded with a program to develop and implement computer models for simulating the physical processes that would occur during such an earthquake. The goal has been to model the earthquake processes in three spatial dimensions over the frequency range from 0.5 to 20 Hz. The general strategy for accomplishing this goal has been as follows:

1. Implement the most advanced computer methods which are suited for modeling the spontaneous fracture process and the propagation of seismic waves in the earth. While numerical finite element or finite difference methods could model the fracture processes, the problem of propagating high frequency waves over several kilometers using these methods is beyond the capability of even the largest and fastest digital computers. On the other hand, no analytical method was available for propagating all of the waves that arise in earthquakes, even for an idealized earth that is horizontally layered. Consequently, such an analytical method had to be developed for the purpose of this work.

2. Characterize the physics of earthquakes for incorporation into the computer models. Some details of the physics of earthquakes are not well understood; for example, the processes by which the crack spreads in what appear to be irregular patterns—first rupturing along one segment, stopping, and then starting again along a slightly offset segment. Other physical processes are well understood

but beyond our ability to model; the principal example being the way in which earthquake waves encounter somewhat different rock types every few hundred meters. (Small heterogeneities that appear along a horizontal path are not only beyond our ability to model on the computer but also beyond our ability to measure in the field.) Fortunately, the most significant processes which contribute to ground motion can be modeled and the suitability of the various idealizations that are made to simplify the more complex behaviors can be tested by simulating earthquakes from the past. Sensitivity studies also aid in determining the importance of various complex physical processes.

3. Test and verify the computer model by simulating three past earthquakes, at least one of which is to be a large magnitude event for which strong ground motion was recorded for several seconds. Because the geologic conditions offshore of San Onofre indicate strike-slip faulting, preference was given to the selection of strike-slip earthquakes for the test events. The three events that were selected are Brawley (magnitude 4.9, 1976), Imperial Valley (magnitude 6.5 to 7.2, 1940) and Parkfield (magnitude 6.5, 1966).

4. Calculate site specific ground motions at San Onofre from a major earthquake along the hypothesized offshore zone of deformation. A sufficiently exhaustive parameter study was conducted to insure that the range of reasonably likely earthquake conditions has been covered and to reveal how ground motion depends on the various model parameters.

Thus, the general strategy has been to develop, test and implement computer models for simulating earthquake ground motions. This approach has been pursued as a means for estimating ground motions under geologic and tectonic conditions particular to San Onofre.

COMPUTER MODEL

The computer model that has been developed for simulating earthquakes is partitioned into three basic steps: fracture simulation, wave propagation and ground motion synthesis. The combined computer procedure, termed SISPEQ (Site Specific Earthquake), is visually depicted in Figure 1. Distinct computer models are implemented for treating each of the three basic steps as described below.

1. Fault Slip

A three-dimensional finite element code (SWIS) is used in conjunction with analytical solutions and laboratory experiments to provide information on how fault slip occurs during an earthquake. Experiments performed on compressed rock specimens indicate that shear fracture occurs when the shear stress exceeds some limiting value in the neighborhood of one kbar. (The actual failure strength depends on rock composition, loading rate, the presence of cracks, confining pressure, and interspersed fluid.) The fracture strength of rocks strongly influences the maximum velocity of particles on the fault surface near the crack tip. The suitability of SWIS for simulating spontaneous shear fracture has been demonstrated for idealized cases that have been modeled in the laboratory or modeled by analytical solutions. Results from SWIS calculations provide the basis for determining physically plausible characterizations for fault slip for use in earthquake simulations.

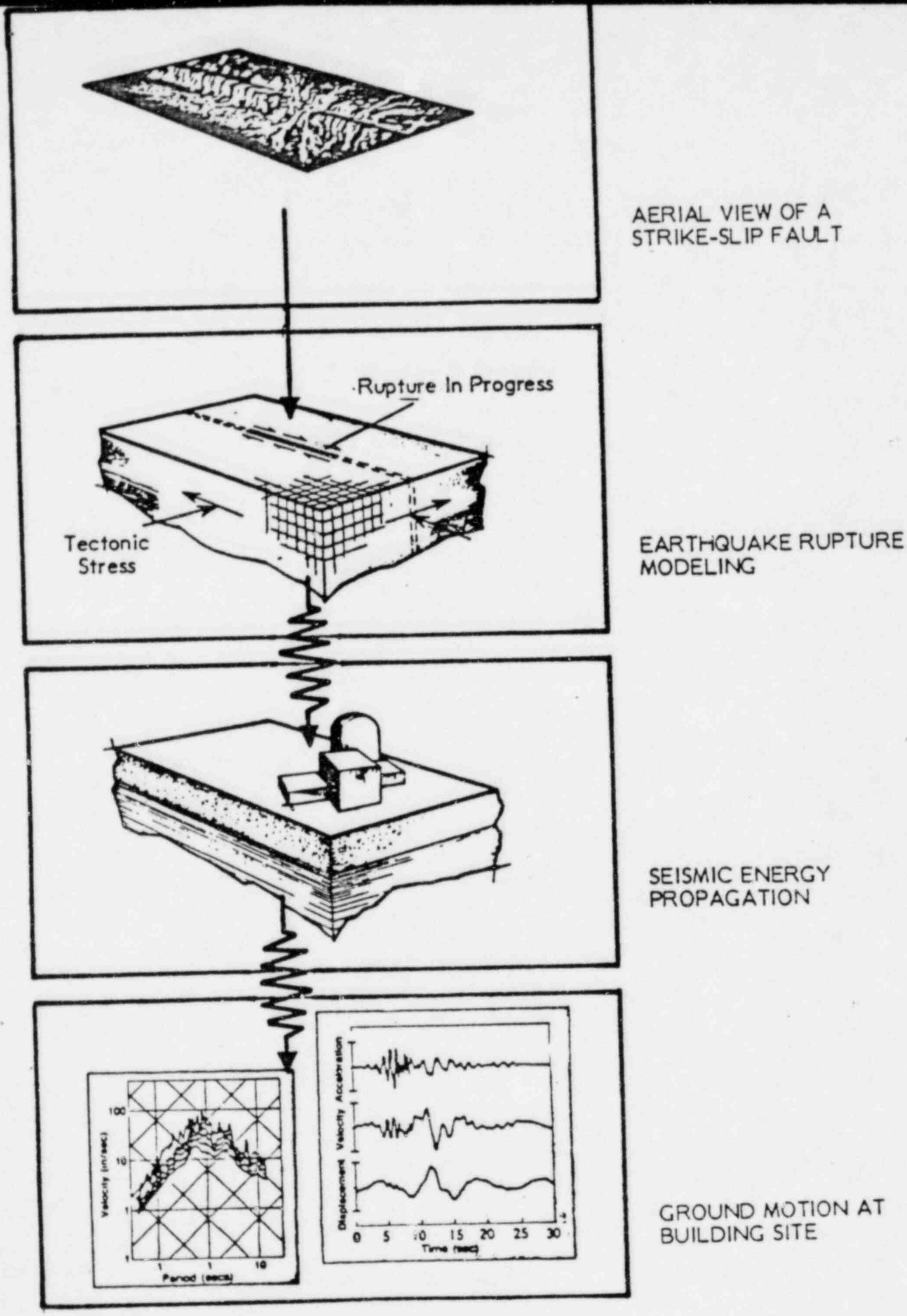

FIGURE 1

COMPUTER MODEL FOR SYNTHESIZING EARTHQUAKE GROUND MOTION

TERA CORPORATION

2. Wave Propagation

An analytical code (PROSE) has been developed to propagate seismic waves in horizontally layered, viscoelastic earth. The method utilizes a rather sophisticated procedure for inverting solutions, expressed as functions of horizontal wave number and frequency, into radial distance and time, respectively. This procedure is depicted in Figure 2. The resulting method accurately synthesizes the multiplicity of waves that arise in a horizontally layered medium over the frequency range from 0.1 to 20 Hz. Elementary solutions (Green's functions) are obtained using the appropriate geologic layering for wave contributions that result from rapid slip over small fault segments which are distributed over the surface of impending rupture. Several hundred of these elementary solutions (Green's functions) are obtained for a single earthquake to insure accurate simulation of the seismic energy that radiates from all portions of the rupture surface.

3. Ground Motion

The fault slip, which is prescribed based on calculations by SWIS, is combined with the wave propagation produced by PROSE to produce synthetic earthquake motions using a convolution code (FALTUNG). The prescription of fault slip is convolved, both in time and space over the rupture surface, with the elementary solutions from PROSE to produce synthetic ground motion at selected points on the earth's surface over the frequency range from 0.1 to 20 Hz. The procedure is illustrated in Figure 3.

EARTHQUAKE PARAMETERS

The earthquake calculations produce ground motions that depend on the characterization of fault slip and on the surrounding earth structure. The various parameters that define an earthquake simulation are itemized below along with a description of how values are assigned to the parameters. Information on how the various parameters influence the computed ground motion is presented in the subsequent section "Discussion of Results."

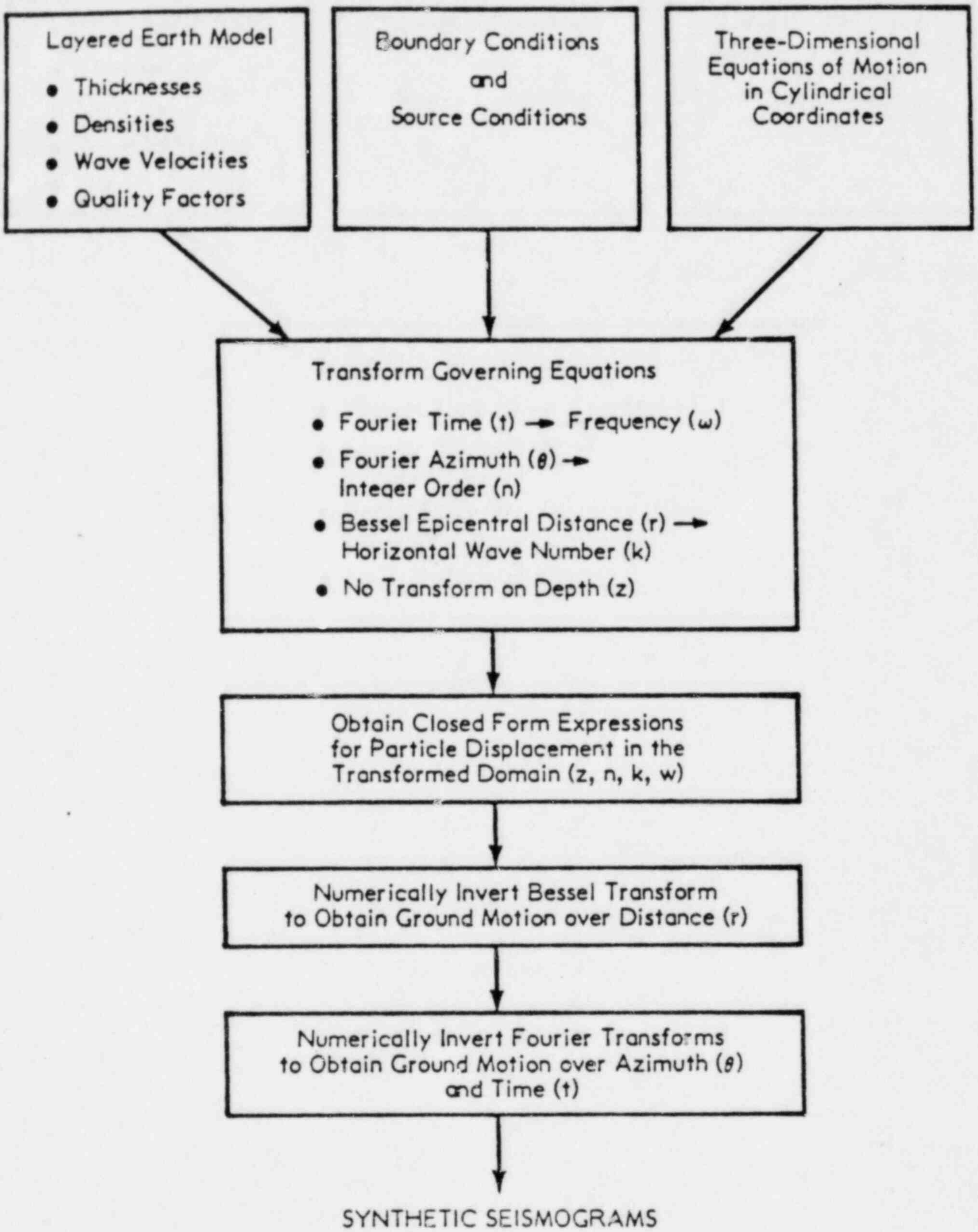

FIGURE 2

PROCEDURE FOR SYNTHESIZING THE PROPAGATION OF SEISMIC ENERGY (PROSE) IN HORIZONTALLY LAYERED EARTH

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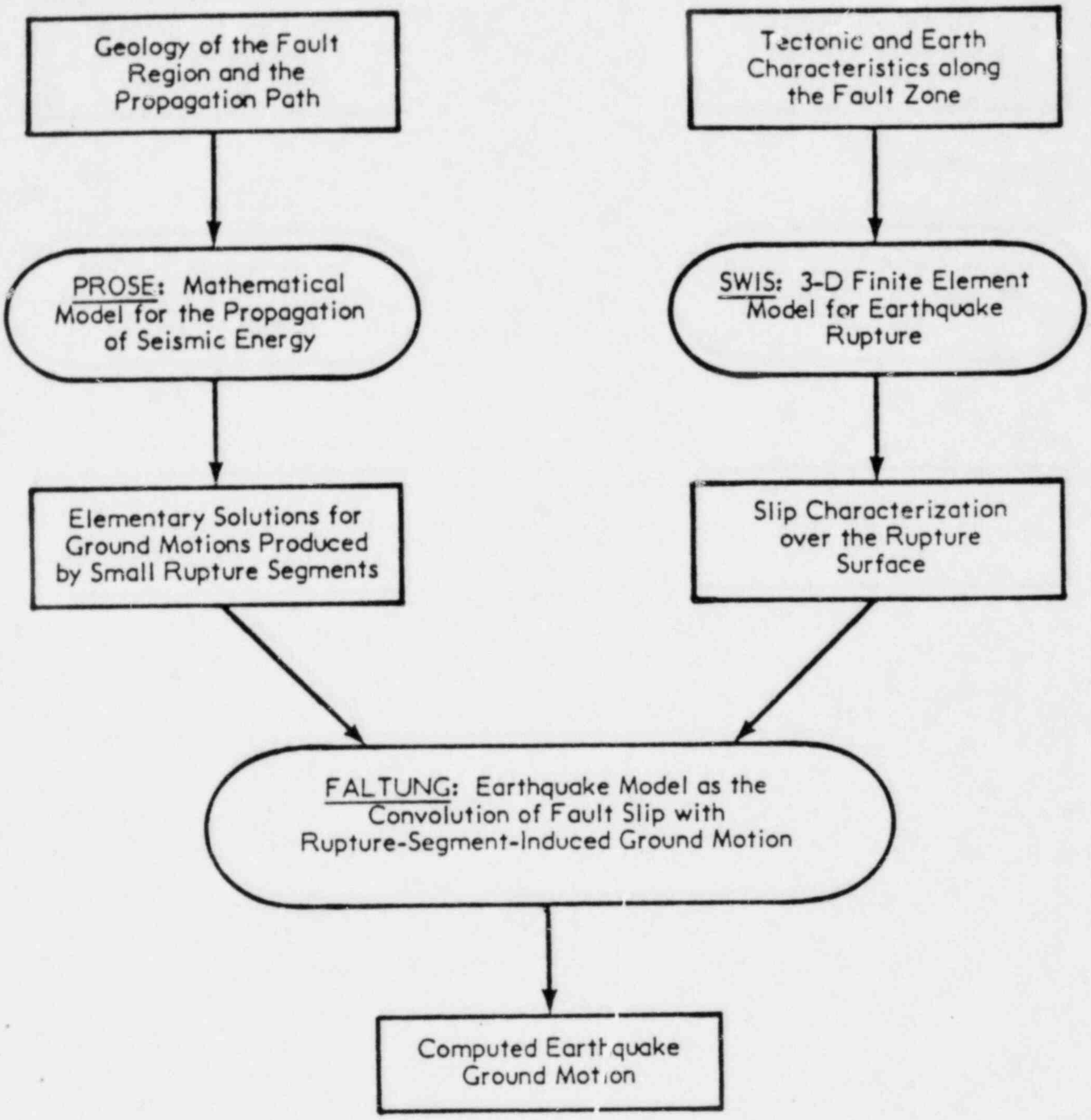

FIGURE 3

PROCEDURE FOR MODELING SITE SPECIFIC EARTHQUAKE GROUND MOTIONS (SISPEQ)

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1. Earth Structure

The earth's crustal structure is characterized by horizontal, viscoelastic layers to a depth in excess of 20 km. The material in each layer is characterized by layer thickness, density, shear-wave velocity, compressional wave velocity, and quality factor (Q). The layer thickness and wave velocities are extracted from field data, primarily seismic profiles. The density is estimated from the wave velocities and from geologic evidence on rock type. The quality factor for each layer is empirically related to the shear-wave velocity using both seismic evidence and laboratory data for guidelines. For cases in which conflicting evidence occurs, we have chosen to rely on that evidence with the largest quality factor, i.e., we use the smallest material attenuation that is consistent with the available data. These parameters for earth structure are used in the computations of elementary propagation functions by PROSE.

2. Rupture Extent

Elementary propagation functions are computed for a distribution of small rupture segments of the faulting surface(s) of interest. In subsequent ground motion calculations with FALTUNG, a particular rupture geometry is specified, which includes the lateral dimensions of the impending rupture surface(s) and the hypocenter—the point of first rupture. The hypocenter is generally positioned near the deepest extent of rupture, which does not exceed 14 km for our studies of strike-slip earthquakes in California. The shallowest extent of rupture ranges from 0 to 12 km and the rupture length ranges from 1 to 40 km.

3. Slip Characterization

The physics of spontaneous shear fracture is inherently contained in our characterization of fault slip. The fracture, which initiates at a point and spreads over the prescribed fault surface, is characterized for ground motion calculations in FALTUNG by a space-time representation of fault slip. The following parameters serve to characterize fault slip.

(a) Rupture Velocity: The rupture initiates at a point on the fault surface and spreads at a velocity which is taken as a fractional part of the local shear-wave velocity. Thus, the rupture may spread at different velocities in different layers. Sensitivity studies have been performed with rupture velocity varying from 50 percent to 90 percent of the shear wave velocity, the upper limit being set at the Rayleigh-wave velocity according to fracture mechanics. Also, test calculations have been performed for non-uniformly spreading ruptures to gain some insight into how fluctuations in rupture velocity might affect ground motions.

(b) Dynamic Stress Drop: Rather large particle accelerations conceivably occur at points on the fault where new crack surface is being produced due to concentrations in stress at the crack tip. Immediately following the production of a new crack surface, the shear stress drops, almost instantaneously, to a lower value. Based on laboratory experiments on rock, this drop in shear stress at the crack tip, which is termed dynamic stress drop, is expected to be in the vicinity of 1.0 kbar. This effect is characterized in the slip function by peaking of the slip velocity at rupture initiation. This rapid slip, which is related to the dynamic stress drop using simplified mechanics, occurs for a brief interval of time while the crack extends a few tens of meters. The duration of rapid slip (dynamic stress drop) is set to 1/40 sec. for all calculations in the study.

(c) Static Stress Drop: The static stress drop is a measure of the average difference in shear stress before and after an earthquake. The average final offset on the fault is linearly related to the static stress drop when the rupture area is held constant. Seismic data indicate that while static stress drop varies from below 10 bars to above 100 bars depending on the earthquake, the mean value for all plate boundary earthquakes is about 30 bars.

(d) Rise Time: Rise time is a word that has been coined in seismology for the duration of fault slip at a single point. SWIS calculations indicate that the "rise time" is controlled by the time it takes for information from non-sliding portions on the fault surface to propagate to points where sliding is occurring. On the average, the "rise time" appears to be the time it takes for the shear-wave velocity to traverse the fault width, which is the preferred value for our earthquake calculations.

(e) Spatial Variations: In an actual earthquake, slip characteristics inevitably vary in some complex manner over the fault surface. In an effort to minimize the number of earthquake parameters, the same slip function is used for all points on the rupture surface.

Thus, the slip function is characterized by four parameters; rupture velocity, dynamic stress drop, static stress drop (offset) and "rise time". The last three parameters govern the slip function once rupture initiates at a point as dictated by the rupture velocity. The dynamic stress drop controls the initial slope of the slip function (the initial slip velocity), the static stress drop provides the final offset and the rise time regulates how much time is available to make the transition from the initial slope to the final offset in the slip function. The major portion of the slip duration, between the initial slope and the final offset, occurs with a constant slip velocity as illustrated in Figure 4. This behavior is characteristic of the results of rupture calculations performed by SWIS.

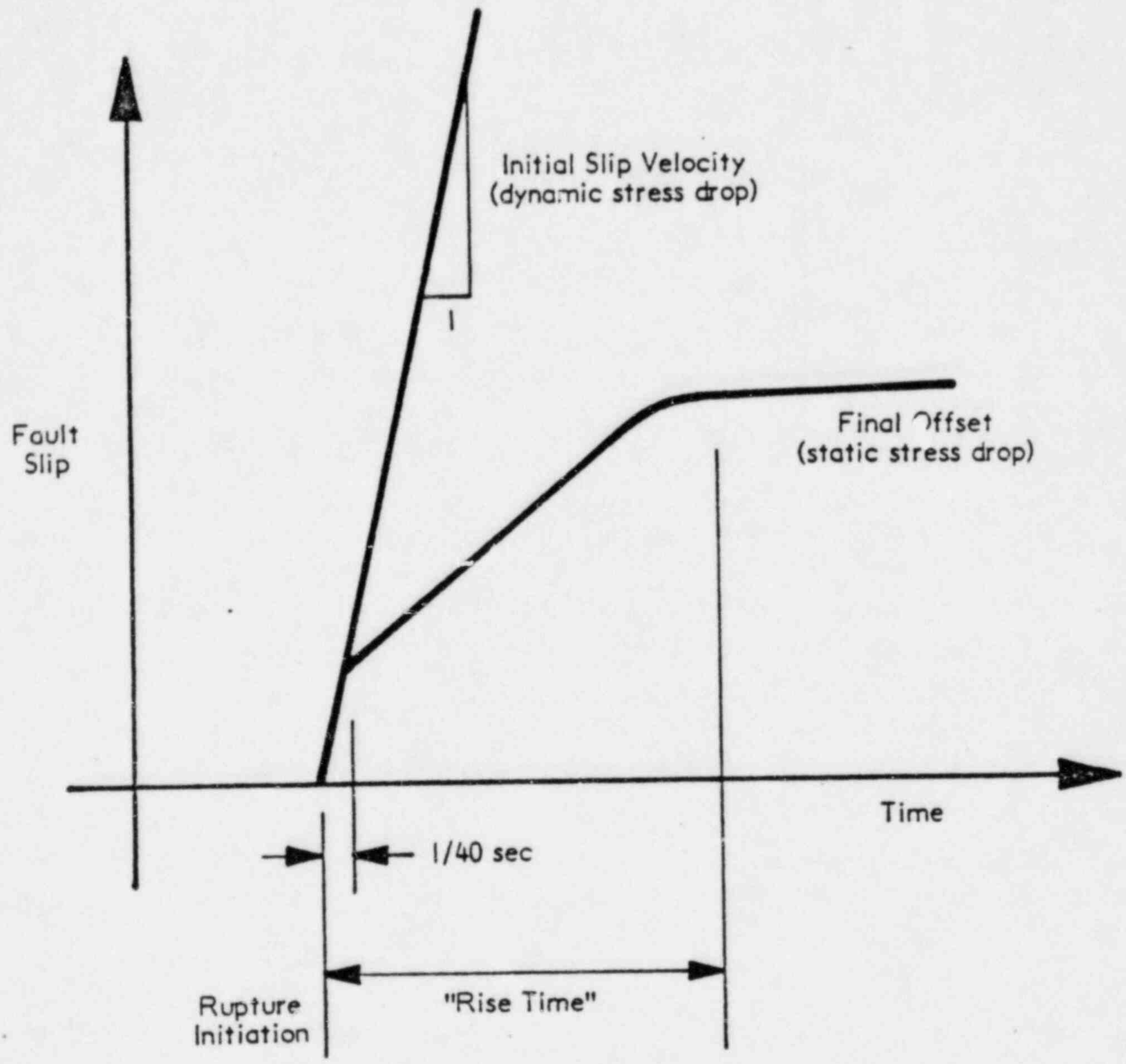

FIGURE 4

CHARACTERIZATION OF FAULT SLIP VS TIME

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VALIDATION STUDIES

The range of validity of the computer model has been tested by simulating three past earthquakes—Brawley (1976), Imperial Valley (1940) and Parkfield (1966). For all three earthquakes, best fits are obtained for a rupture velocity of 90 percent of the shear-wave velocity, a dynamic stress drop of 0.5 kbars and "rise time" set to the travel-time for shear waves to traverse the smallest fault. Specific information is provided below and in Table 1 for each earthquake studied.

Brawley - Ground motions are modeled at an epicentral distance of 33 km using a 1.8 km-square rupture surface at a hypocentral depth of 7 km. A sufficiently good match is obtained between computed and recorded ground motion to validate both the computer model and the geologic model for Imperial Valley. Sensitivity studies indicate that an adequate match with recorded signals depends critically on all the model parameters including the size and depth of the rupture.

Imperial Valley - Ground motions are computed at the El Centro recording station using a bilateral rupture which initiates 12.3 km to the southeast of the recording station. This rupture extends over a length of 48 km and width of 12 km. Although an adequate fit to the response spectra is obtained by a linear bilateral rupture, the fit to the coda is improved by use of a rupture propagating along the crooked path of the mapped surface break.

Parkfield - Comparisons of the observed and computed response spectra show excellent agreement for the horizontal components of Stations 5, 8 and 12, using a 32 km

TABLE I

EARTHQUAKE PARAMETERS

	Brawley	Imperial Valley	Parkfield
Rupture Extent (km)			
Length	1.8	48	32
Width	1.8	12	9
Deepest Extent	7.5	12	10.5
Hypocentral Depth	7.5	12	10.5
Distance (km) from Recording Station to:			
Epicenter	33	12.3	31.1 (Sta. 2) 32.5 (Sta. 5) 33.9 (Sta. 8) 36.2 (Sta. 12) 40.1 (Temblor)
Fault	33	6.6	0.2 (Sta. 2) 5.4 (Sta. 5) 8.8 (Sta. 8) 13.5 (Sta. 12) 9.5 (Temblor)
Slip Characteristics			
Ratio of Rupture Velocity to Shear-Wave Velocity	0.9	0.9	0.9
Dynamic Stress Drop (bars)	500	500	500
Static Stress Drop (bars)	140	90	24
Rise Time (sec)	0.3	2.4	2.7
Magnitude			
Seismic Moment (ergs)	3×10^{23}	0.36×10^{27}	0.39×10^{26}
Surface Wave Magnitude (M_s)	4.9	6.9	6.3

long rupture with a width of 9 km. The computed vertical components are uniformly high in the mid-frequency range but give good fits near the extreme frequencies of 0.1 and 20 Hz. Station 2 is so close to the fault that most of its response depends on local rupture properties which are not resolved in this study. The geologic structure on the N.E. side of the fault is not the same as on the S.W. side; however, the fit for the Temblor station is reasonably good. The fit to multiple observations at varying distances from the fault indicates that SISPEQ is successful in scaling ground motion with distance.

As discussed above, some aspects of fault slip may be complicated beyond our ability to understand in detail; however, rather uncomplicated characterizations can be used which explain earthquake data over a broad range of frequencies. Based on these studies we conclude that our computer models can provide useful estimates of the frequency content of site specific ground motions for earthquake design purposes.

POSTULATED GROUND MOTION AT SAN ONOFRE

The computer model was used to estimate ground motion at San Onofre from several postulated earthquakes along the hypothesized offshore zone of deformation using geologic layering representative of that region. Layer thicknesses and material velocities were obtained from a seismic refraction profile taken by Western Geophysical Company at a location about midway between the San Onofre station and the hypothesized offshore zone of deformation. Quality factors were assigned to each layer by applying the same velocity-attenuation formula used in the verification studies. Rupture parameters consistent with the verification studies were used to investigate the effect of varying the length and width of the rupture surface. In particular, the parameters were assigned values as follows; rupture velocity = 90 percent of the local shear-wave velocity, dynamic stress drop = 500 bars, static stress drop = 100 bars, and rise time = fault width divided by shear-wave velocity.

Several construed ruptures were synthesized. The most critical case involves a 40-km break that ruptures toward the plant and extends at least to a point opposite the plant. Such a rupture corresponds to about a magnitude 7 earthquake having a zero period (peak) acceleration of 0.41 g. Response spectra were computed and smoothed for six different 40-km rupture configurations. The envelope of these smoothed velocity response spectra is shown in Figure 5 along with the corresponding response spectra obtained using the methods of Housner, Newmark, and Regulatory Guide 1.60. All spectra are for two percent of critical damping. The envelope of the computed response spectra represents an upper bound for computer-generated magnitude 7 earthquakes using our best estimates for the various rupture parameters.

The sensitivity of computed response spectra to the various rupture parameters is discussed below.

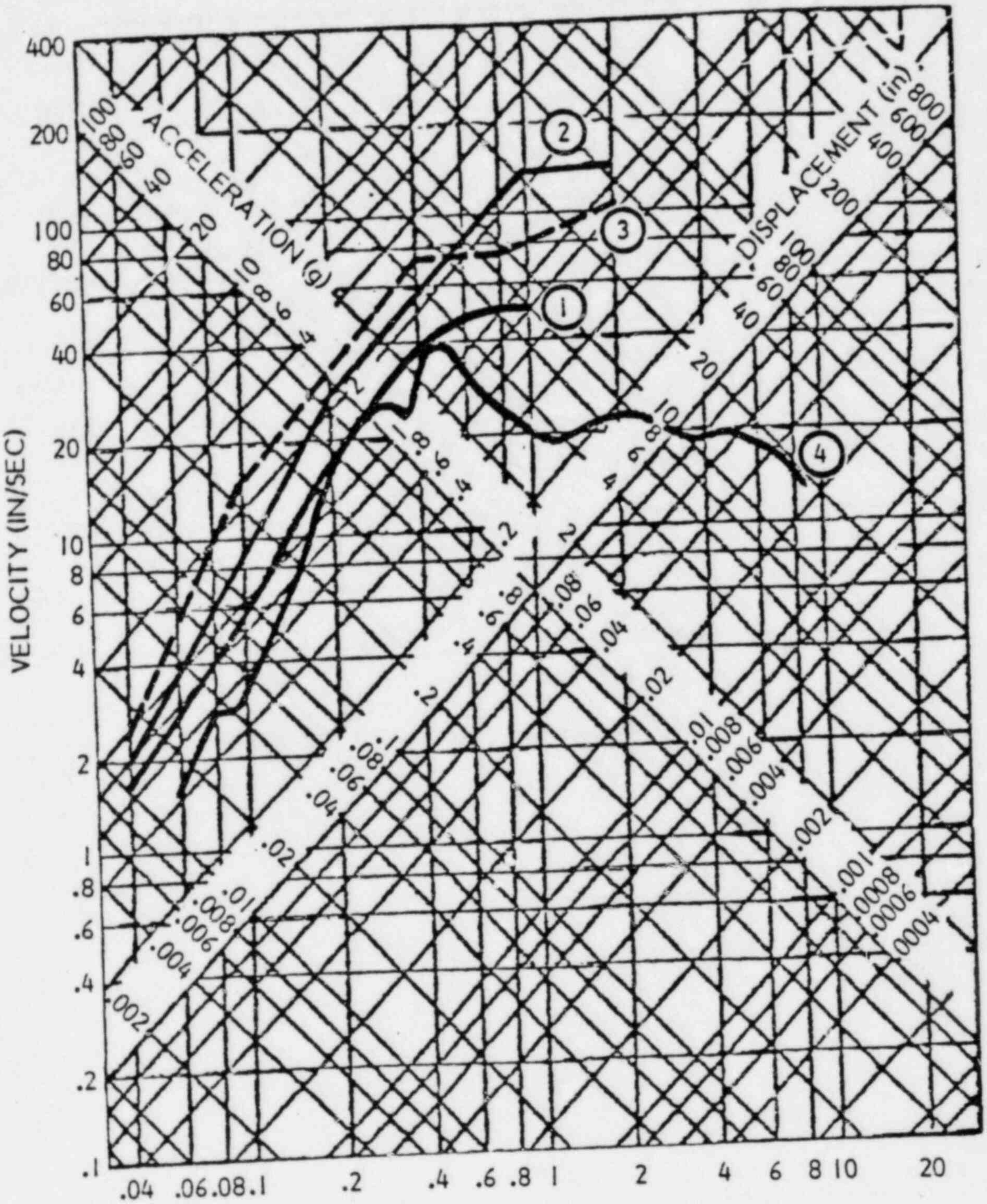
DISCUSSION OF RESULTS

Advanced computer methods have been developed and implemented for simulating hypothesized earthquake conditions at San Onofre. Whereas the mathematical procedures used in the study are quite sophisticated and complex, the mathematical description of the earthquake processes is not exceedingly complicated. The model employs four parameters to characterize slip along a specified rupture surface in an idealized horizontally layered earth. Each parameter in the model is motivated by current understanding of earthquake physics. A brief discussion follows on how the various parameters influence the computed ground motion at the San Onofre Nuclear Generating Station.

The properties of the geologic layering can have significant effects on the characteristics of the computed ground motions. Computed ground motions vary by more than a factor of two over some frequency bands when identical earthquake conditions are simulated in the three distinct earth structures of

FIGURE 5

ENVELOPE OF SMOOTHED VELOCITY RESPONSE SPECTRA COMPUTED FOR SAN ONOFRE VS. REGULATORY DESIGN SPECTRA



1 SONGS 1 DBE, HOUSNER 2%

2 SONGS 2 & 3 DBE, NEWMARK 2%

3 REGULATORY GUIDE 1.60 2%

4 SONGS SITE SPECIFIC EARTHQUAKE 2%

TERA CORPORATION

Parkfield, Imperial Valley, and San Onofre. This fact emphasizes the importance of using information on local subsurface properties for characterizing site-specific ground motions.

The hypothesized earthquake rupture at San Onofre was assumed to pass within 8 km of the power station. A 40-km rupture length was used to appraise potential earthquake motions at the plant even though our calculations indicate that the portion of the rupture beyond 20 km does not significantly influence high frequency shaking (above 5 Hz) at the plant in the presence of more local earthquake fracture. Motions at the plant were found not to be significantly influenced by the presence or absence of surface breakage; however, the deepest extent of the rupture is of some importance for anticipating high frequency shaking.

Sensitivity studies have been performed to determine how the computed ground motions depend on the four rupture parameters. Changes in rupture velocity lead to broad-band changes in computed ground motion. In general, the intensity of ground shaking increases with increasing rupture velocity. Alterations in dynamic stress drop influence the amplitude of shaking for periods shorter than 4.0 seconds; velocity response spectra vary almost linearly with dynamic stress drop for periods shorter than 1.0 second. Static stress drop, on the other hand, influences periods longer than 1.0 second; velocity response spectra vary linearly with static stress drop for periods longer than 4.0 seconds. Finally, the "rise time" influences the amplitude of ground shaking for periods longer than the "rise time" but less than about five times the "rise time." The general trend is for increased low frequency ground motions with decreasing "rise time."

In summary, the computed ground motions at San Onofre are based on our current understanding of the physics of earthquakes. The computer model has been tested on three past earthquakes. The rupture parameters that influence ground motions for frequencies above 1.0 Hz were found to be independent of the particular earthquake modeled within the resolving power of the computer model. This fact, combined with the physical consistency of the model, lends considerable credibility to the use of the computer model for predicting ground motions at San Onofre from a hypothesized offshore earthquake.

Y-1

Telephone 617 366-9011
TWX
710-390-0739

YANKEE ATOMIC ELECTRIC COMPANY

B.321
WYR 79-146

20 Turnpike Road Westborough, Massachusetts 01581

November 29, 1979

United States Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Office of Nuclear Reactor Regulation
Mr. Dennis L. Ziemann, Chief
Operating Reactors Branch #2
Division of Operating Reactors

Reference: (a) License No. DPR-3 (Docket No. 50-29)

Dear Sir:

Subject: Yankee Rowe SEP; Site Dependent Response Spectra

Enclosed as Figure 1 is the horizontal seismic response spectra for the Yankee Rowe Nuclear Power plant site.

The response spectra for the Yankee Rowe site were developed using only earthquakes determined to appropriately fulfill the prescribed earthquake ground motion potential at a site; namely, the magnitude of the SSE, the hypocentral distance, and the site foundation conditions. This approach, which is in accordance with the criteria of Appendix A, avoids many of the problems inherent with determining ground motion by scaling event size or epicentral distances. From recent seismological studies, it is known that the shape of the spectral excitation is dependent on earthquake size as well as frequency-dependent attenuation effects. The proper selection of accelerograms which are used to construct the response spectra void the errors resulting from scaling.

The seismicity evaluation for Yankee Rowe as prepared by Weston Geophysical was submitted to the NRC on February 23, 1979. This report entitled "Geology and Seismology, Yankee Rowe Nuclear Power Plant" considered the seismicity within the site tectonic province as well as adjacent tectonic provinces and structures to reach the conclusion "that an Intensity VI(MM) is an appropriately conservative estimate of the Safe Shutdown Earthquake". The Safe Shutdown Earthquake is best characterized by a magnitude of 4.5 in the report entitled "Eastern United States tectonic Structures and Provinces Significant to the Selection of a Safe Shutdown Earthquake" prepared by Weston Geophysical for the SEP Owner's Group and submitted to the NRC on October 16, 1979.

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The occurrence of a larger earthquake at a greater epicentral distance was also considered in the seismicity evaluation of the Rowe site. A magnitude range of 5.5 to 6.0 for an Intensity VIII(MM) earthquake associated with the Ossipee and Cape Ann plutons of the White Mountains Intrusive Series and a magnitude range of 5.0 to 5.5 for an Intensity VII(MM) earthquake associated with the Adirondack Uplift constitute the maximum risk to the Rowe site from a distant event.

Geological investigations of the site locale show that the Rowe plant is situated on glacial sediments in the lower elevation of a broad bedrock valley with the bedrock surface beneath the site dipping at 30° to 50° to the southeast. Seismic refraction surveys and test borings have identified the glacial deposits as dense till. In-situ velocity measurements (report transmitted to the NRC on April 5, 1979) have determined that the 70 to 140 feet of glacial till beneath the site has a compressional wave velocity of 6,700 to 7,000 ft/sec and a shear wave velocity of 1,700 to 2,200 ft/sec.

Using the seismicity and site conditions defined above, our strong motion data base was searched for accelerograms produced by earthquakes within the appropriate magnitude and epicentral distance ranges and recorded at sites whose geologic setting and/or foundation conditions (based on shear wave velocity data if available) resemble those at Rowe. The selected accelerograms were corrected for instrument response in accordance with state-of-the-art procedures to obtain response spectra for each available component.

The selected data for the magnitude 4.5 earthquake in the site province included 60 horizontal components (30 earthquakes). The earthquake magnitudes ranged from 4.4 to 5.4 (mean magnitude 4.8), and the epicentral distances ranged from 1.7 to 33.2 kilometers (mean epicentral distance 15.0 km). The selected accelerogram data set included 26 recordings from California (14 from 1975 Oroville earthquake sequence) and 34 recordings from the 1976 Friuli, Italy earthquake sequence. The mean response spectra for this data set is presented on Figure 2.

The data set of accelerograms recorded from moderate sized earthquakes at epicentral distances greater than 50 kilometers is limited because of low acceleration at greater distances. Selection from this data was restricted to those site conditions representative of Rowe. Eight (8) components (four earthquakes) met the seismicity-distance criteria; namely, a magnitude 5.5 to 6.0 earthquake associated with the Cape Ann or Ossipee plutons (epicentral distances 188 km and 178 km, respectively) or a magnitude 5.0 to 5.5 event associated with the Adirondack Province (minimum epicentral distance 70 km). These accelerograms, all from California earthquakes, have a magnitude range of 5.4 to 6.0 (mean magnitude 5.7) and an epicentral distance range of 53 to 85 km (mean epicentral distance 69 km). The shorter epicentral distances in the selected data set take into account the slower attenuation for eastern United States' earthquakes. The mean response spectra for the data set from distant sources are presented on Figure 3.

The horizontal seismic design response spectra recommended for the Rowe site (Figure 1) was obtained by enveloping the mean spectra derived for the site province (Figure 2) and for distance sources (Figure 3). The spectra developed for a seismic risk within the site province governs at periods less than .5 seconds while the spectra developed for seismic risk at distance sources governs at periods greater than .5 seconds.

A detailed report for the Site Dependent Response Spectra will be forwarded shortly. Should you have any questions relative to this matter, please contact us at your convenience.

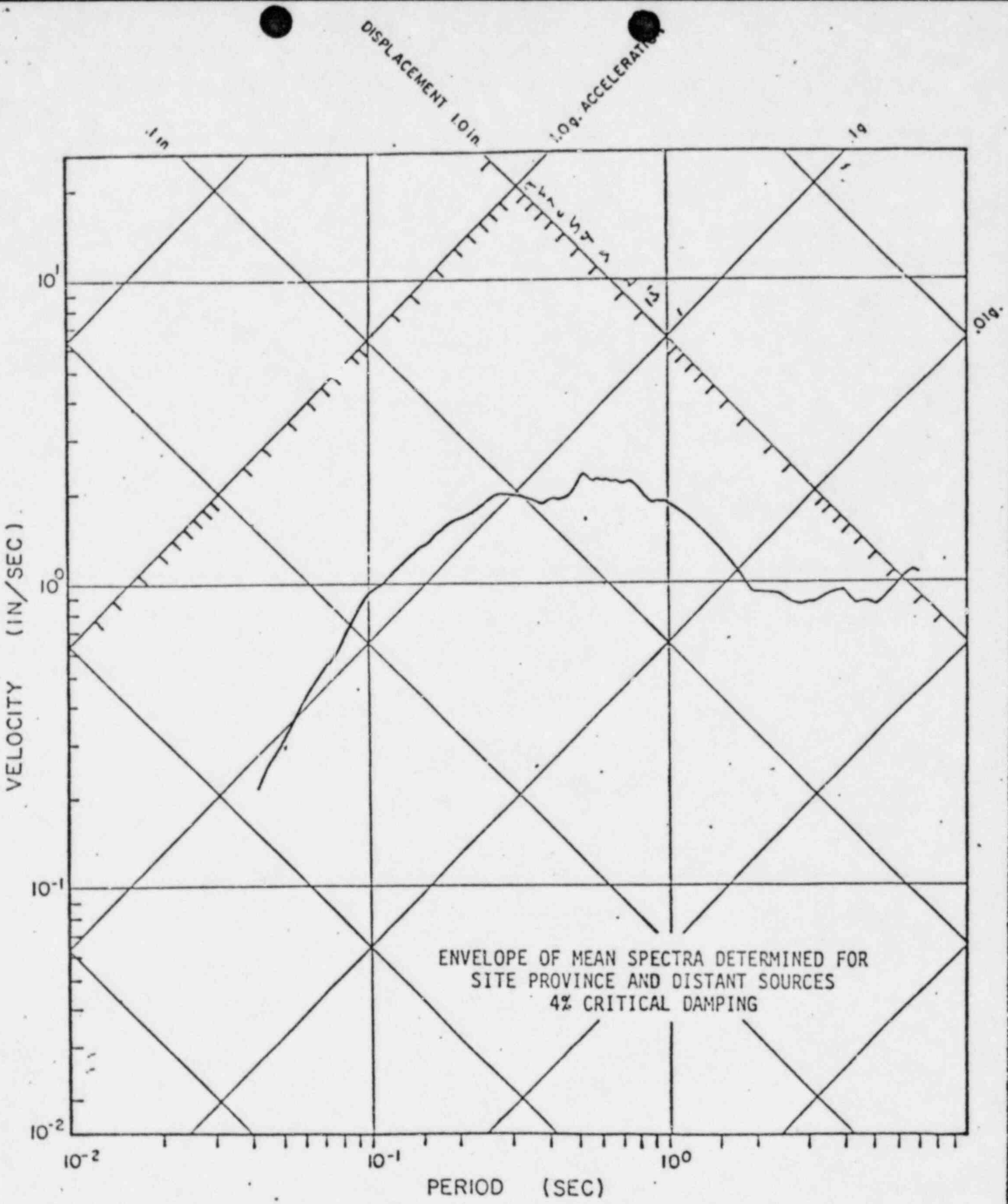
Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

Robert H. Groce
Senior Engineer - Licensing

JWS/kaf

Enclosure



HORIZONTAL SEISMIC DESIGN RESPONSE SPECTRA
YANKEE ROWE NUCLEAR POWER PLANT

Figure 1

Weston Geophysical

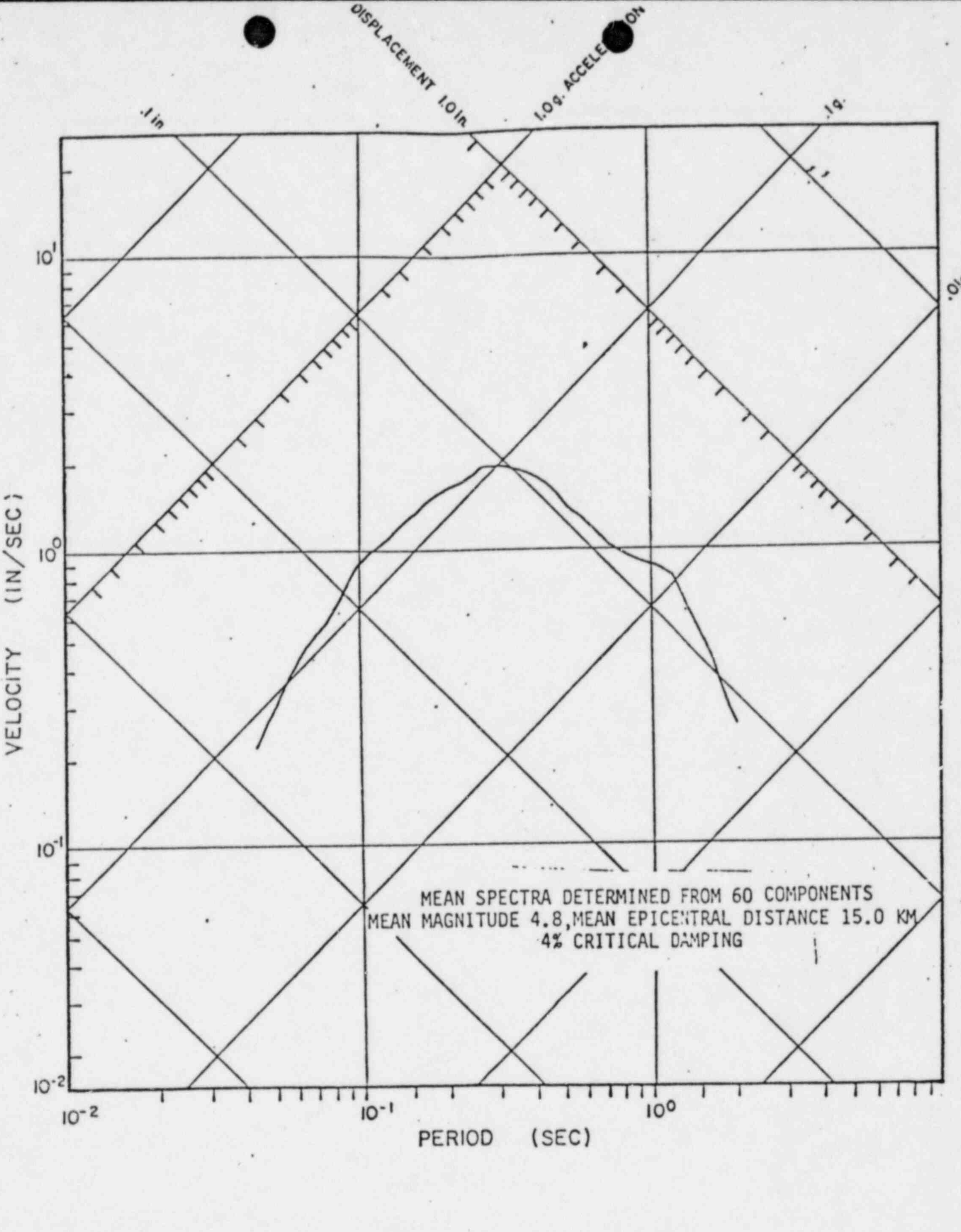


Figure 2

Weston Geophysical

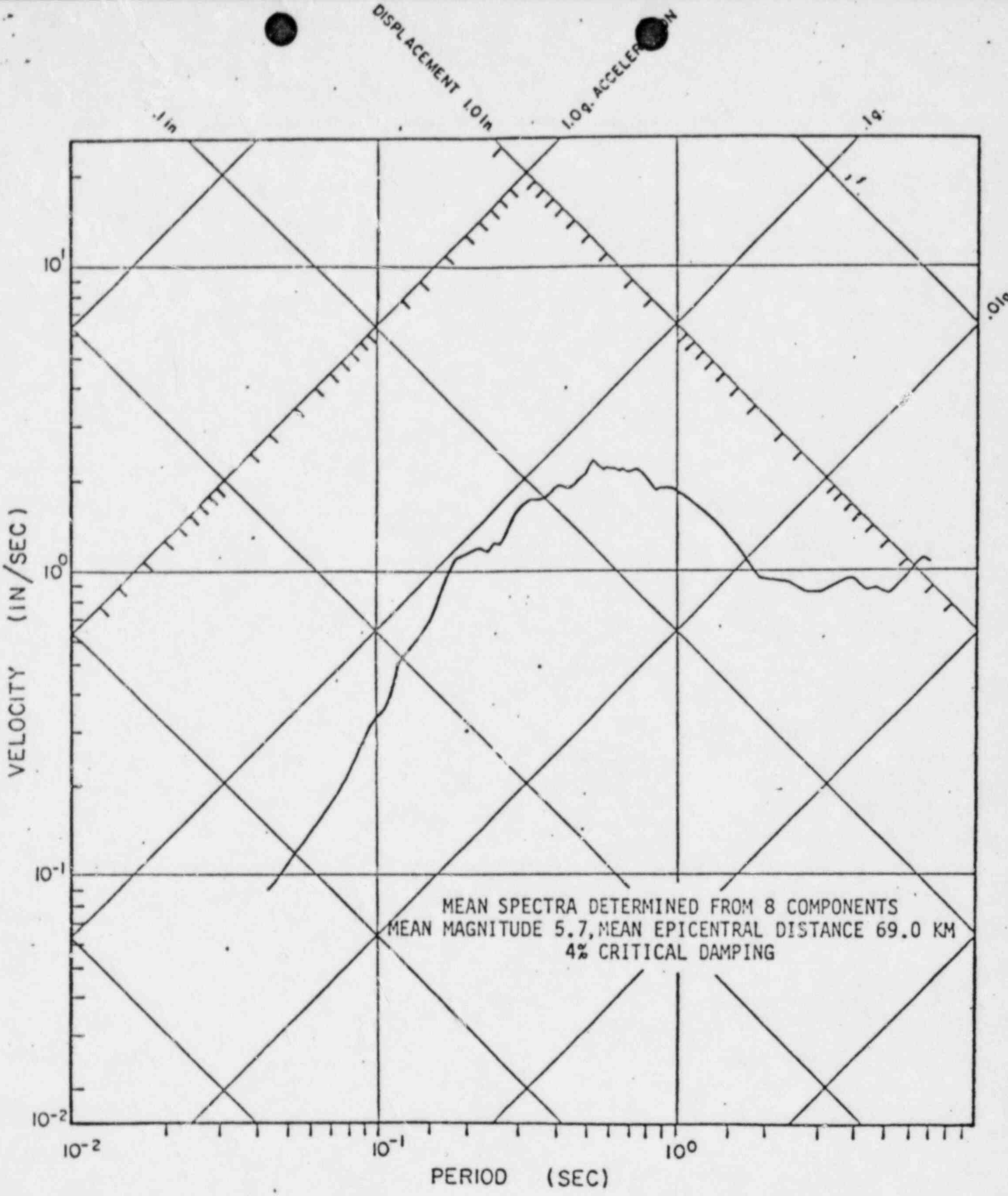


Figure 3

Weston Geophysical

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

(4)

SEP. 1 7 1980

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%.

Denny - What are you going to do with this? Send to utilities? Send back to SEP Branch

DE 9-29

Howard A. Levin
Howard Levin, Technical Assistant
Division of Engineering

We will Send to utilities.

cc: D. Eisenhut
R. Vollmer
J. Knight
R. Jackson
L. Reiter
J. Greeves
T. Cheng

8105290076 XA

CF

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	102.50	102.50	124.15
PG *	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

5

D. Crutchfield

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.

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

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 to 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 σ = 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 σ= 0.5 to σ= 0.9 with some preference for the 0.6 to 0.7 range.

Effect of Second Round Questionnaire Upon Conclusions of the Initial Review

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 σ= 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 σ= 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.

6

Enclosure 1

SEP 17 1980

DISTRIBUTION
CENTRAL FILE
NRR RDG
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
R. Vollmer
J. Knight
R. Jackson
L. Reiter
J. Greeves
T. Cheng

8105290016 XA

CF

OFFICE ➤	NRR/DE					
SURNAME ➤	HLevin:mg					
DATE ➤	9/17/80					

SYSTEMATIC EVALUATION PROGRAM
SITE SPECIFIC SPECTRA
PSEUDO SPECTRAL ACCELERATIONS (cm/sec^2)

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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	102.50	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
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.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

7

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

June 17, 1981

RECEIVED
JUN 2 3 1981
U.S. NUCLEAR REGULATORY COMMISSION

LS05-81-06-068

LETTER TO ALL SEP OWNERS
(EXCEPT SAN ONOFRE)

Gentlemen:

SUBJECT: SITE SPECIFIC GROUND RESPONSE SPECTRA FOR SEP PLANTS LOCATED IN THE EASTERN UNITED STATES

Reference: Letter to SEP Group II Plant (Big Rock Point, Dresden 1, Haddam Neck, La Crosse, Yankee Rowe) Licensees from D.G. Eisenhut, NRC dated August 4, 1980

Our letter dated August 4, 1980 (reference) issued the prelimiary version of site specific ground response spectra for the eastern United States SEP plants. Recently, these spectra have been finalized by the staff. Enclosure 1 includes the recommended ground response spectra (5% damping) for the eastern SEP sites. The bases of our final decision regarding the spectra and the digitized spectral acceleration values (5% damping) for these spectra are documented in Enclosure 2.

The site specific spectra (SSS) included in Enclosure 1 establish the ground motion acceleration values to be input into the structural reevaluation analyses to determine the resultant seismic loads. The geology reviews for Palisades, Ginna and Dresden 2 have been completed by the staff. The results of the review did not identify any geologic features that would affect the site specific spectra for those facilities. Based on our review to date for the remainder of the SEP facilities located in the eastern United States, we do not expect the SSS to be changed due to local geologic considerations.

Sincerely,

Dennis M. Crutchfield

Dennis M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Licensing

Enclosure:
As stated

cc w/enclosure:
See next page

Add: G. Staley - 1cy
D. Eisenhut - 1cy
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SE04
S 1/1

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DSu USE Ex (15-11-18-02 51-16-07-27 04-38) - 135 Cys

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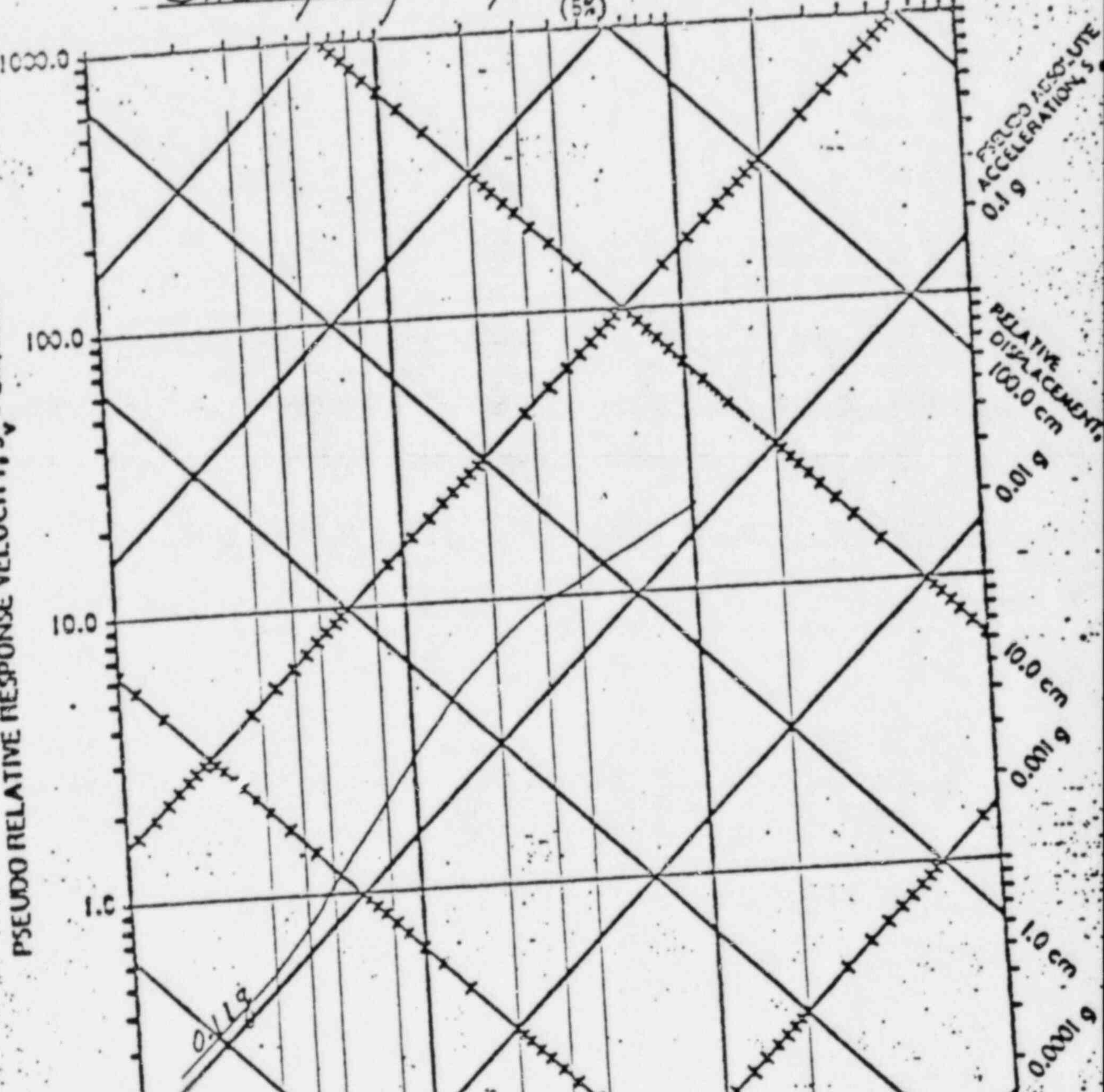
Attachment I

Site Specific Spectrum



Big Rock Point Site

(5% Damping)

Attachment 1

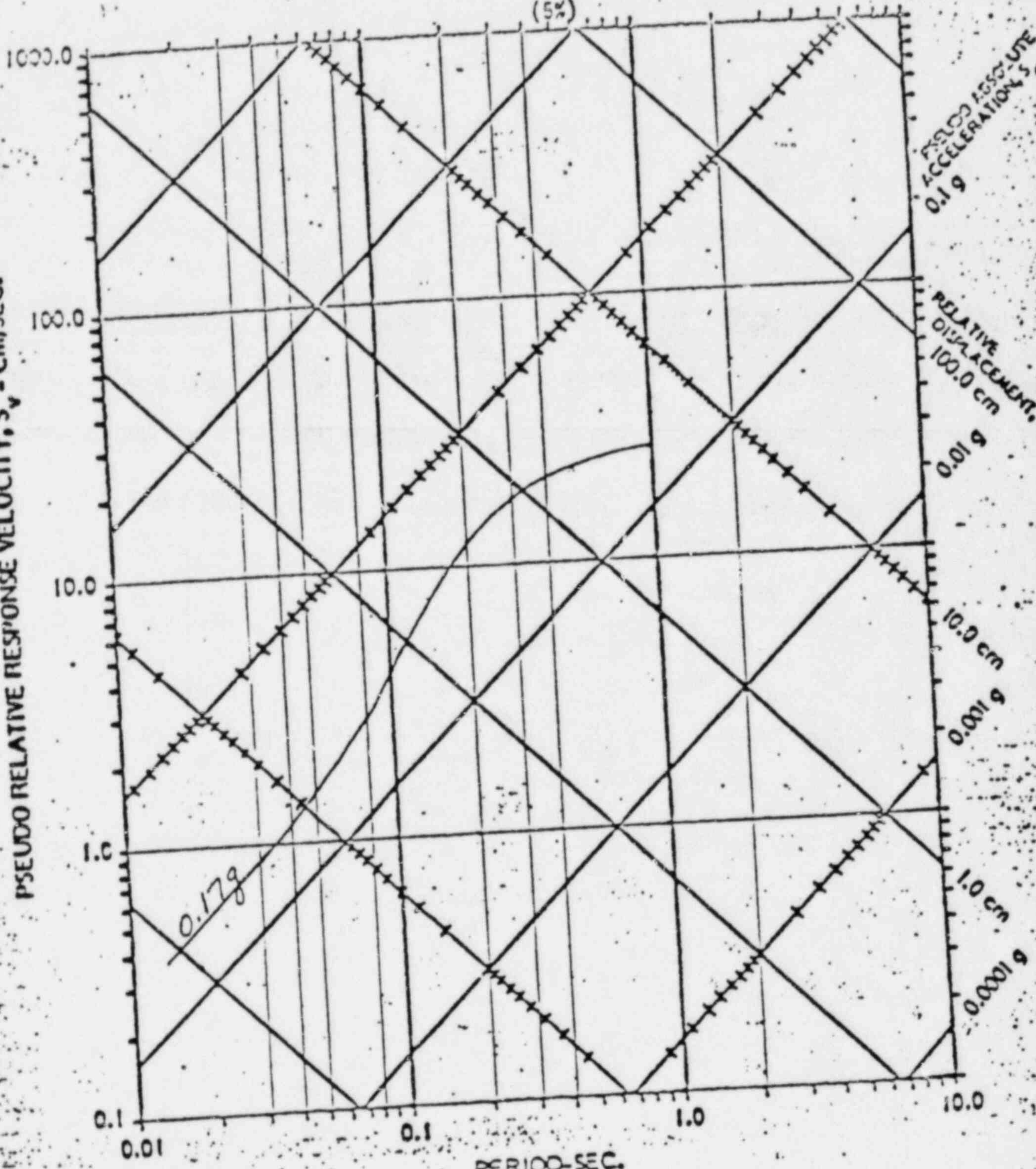
Site Specific Spectrum

Dresden Site

(5% Damping)

Attachment 1

Site Specific Spectrum

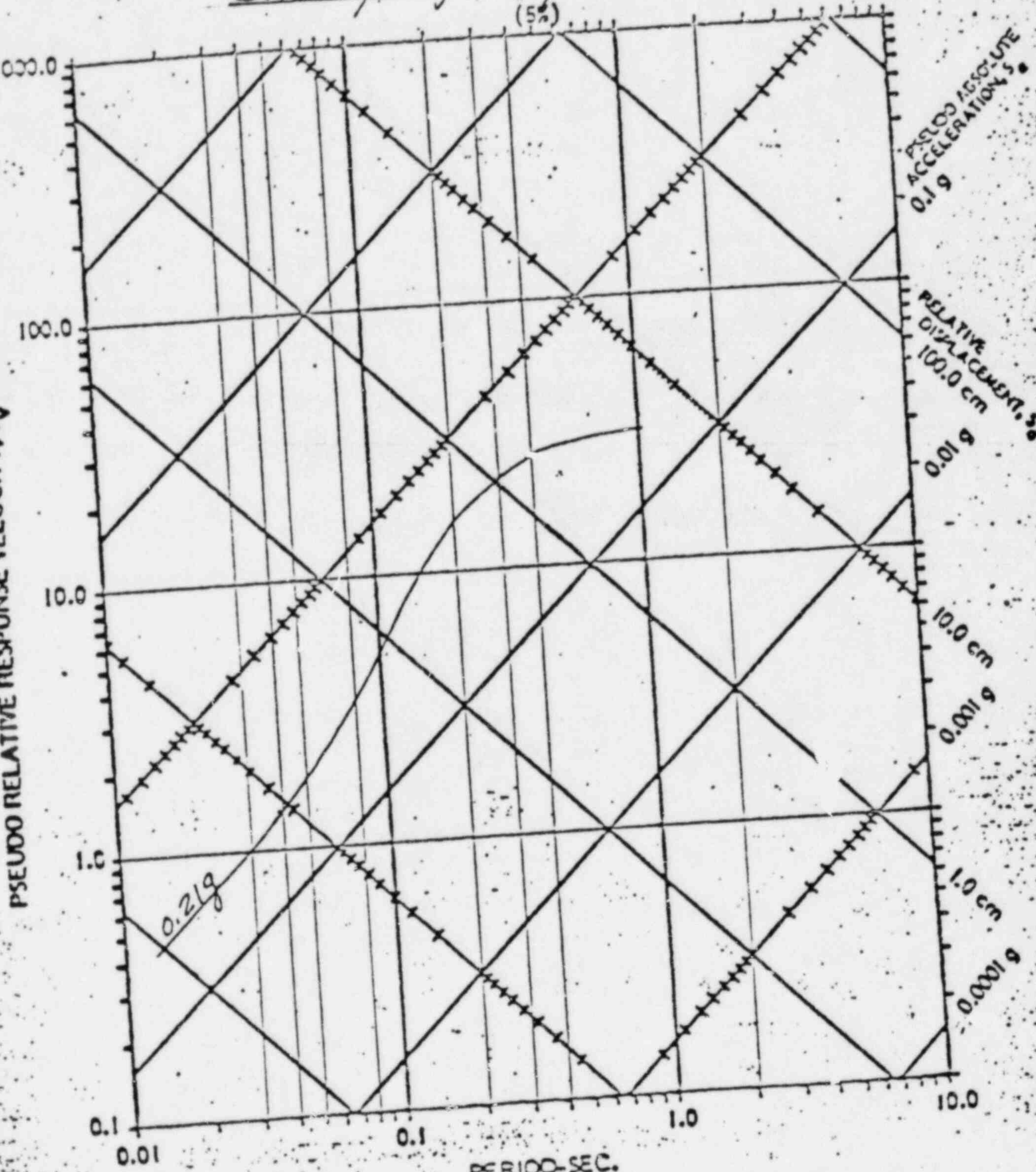


Ginna Site

(5% Damping)

Attachment 1

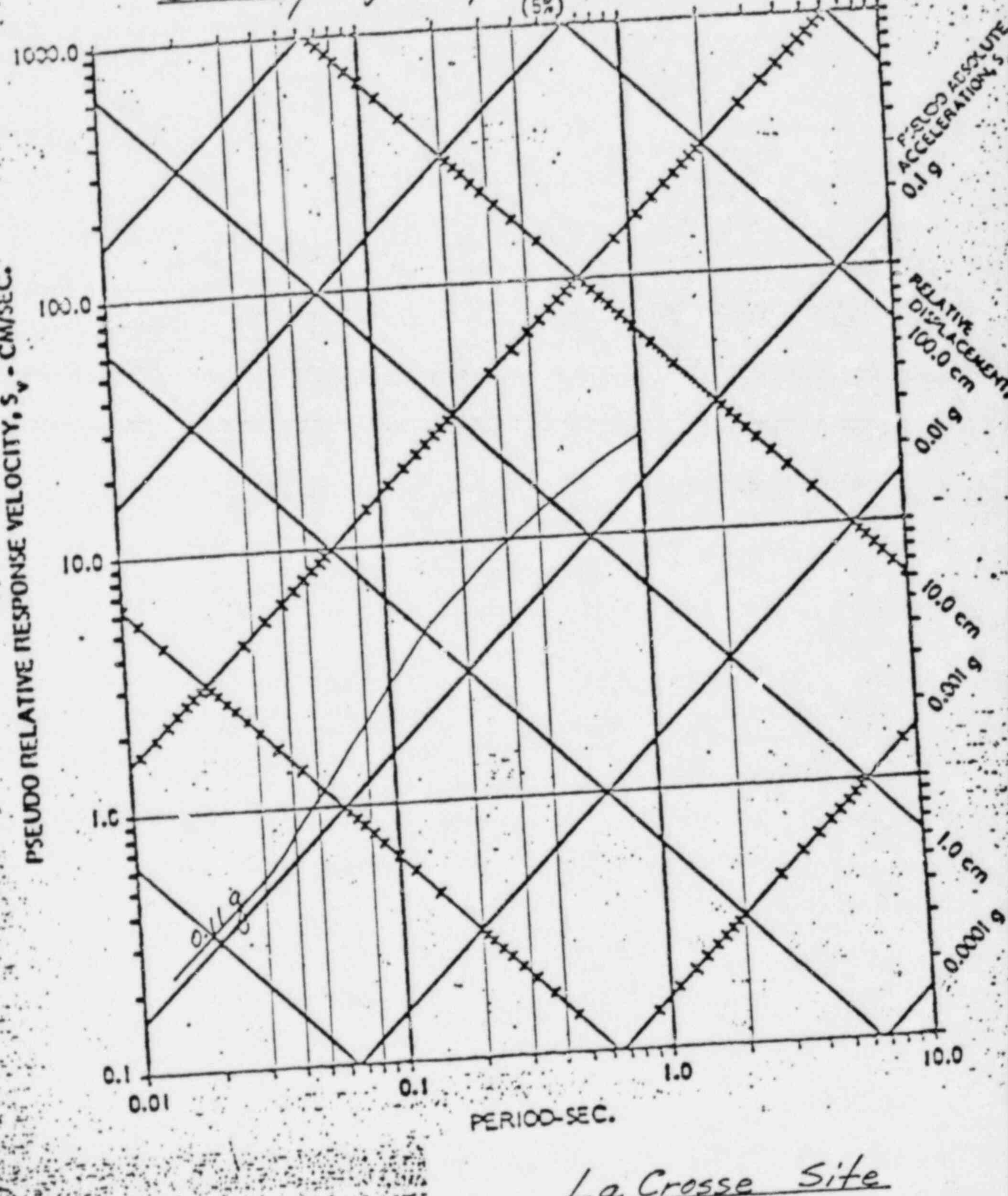
Site Specific Spectrum



Haddam Neck Site
(5% Damping)

Attachment I

Site Specific Spectrum

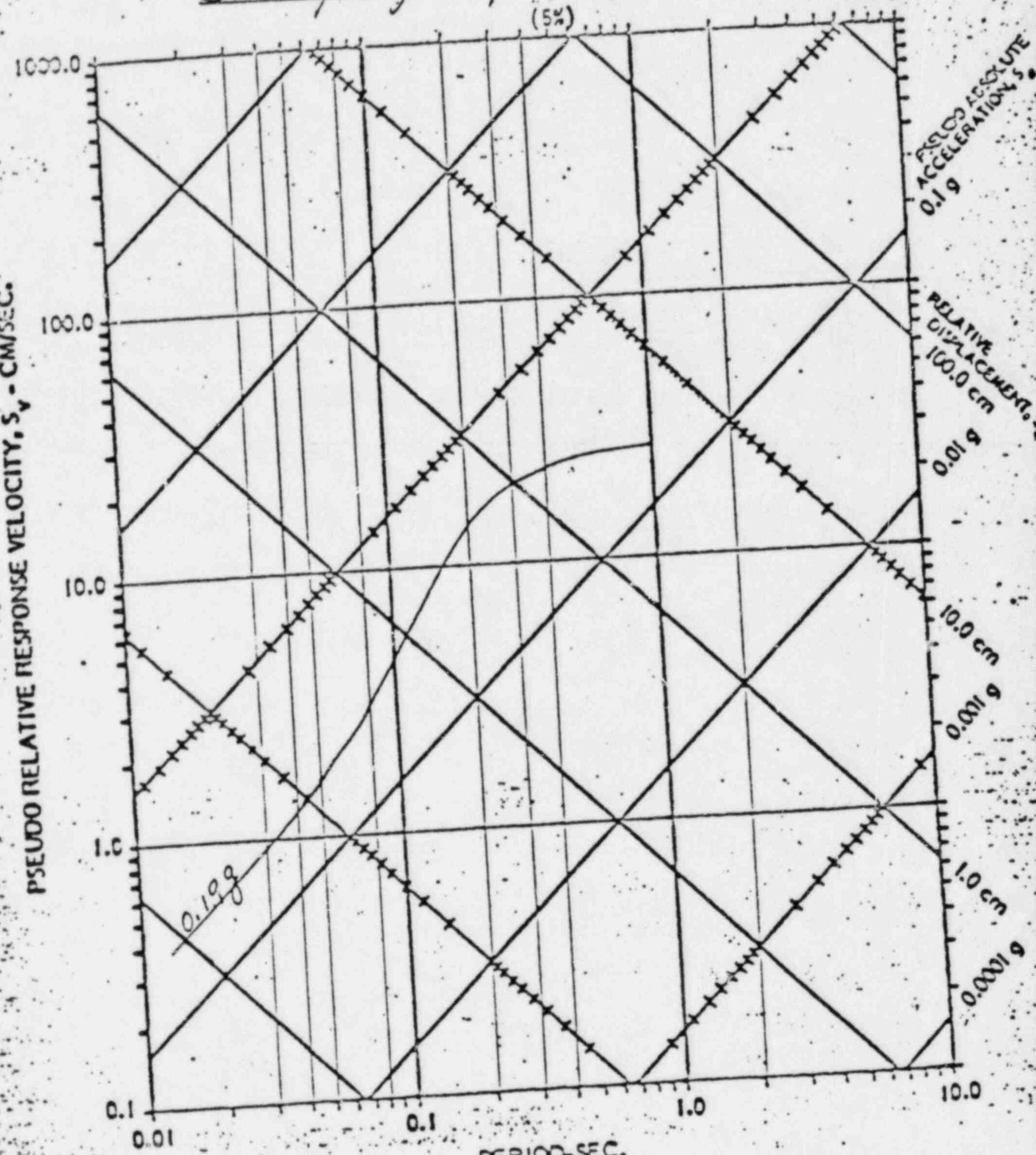


La Crosse Site

(5% Damping)

Attachment I

Site Specific Spectrum

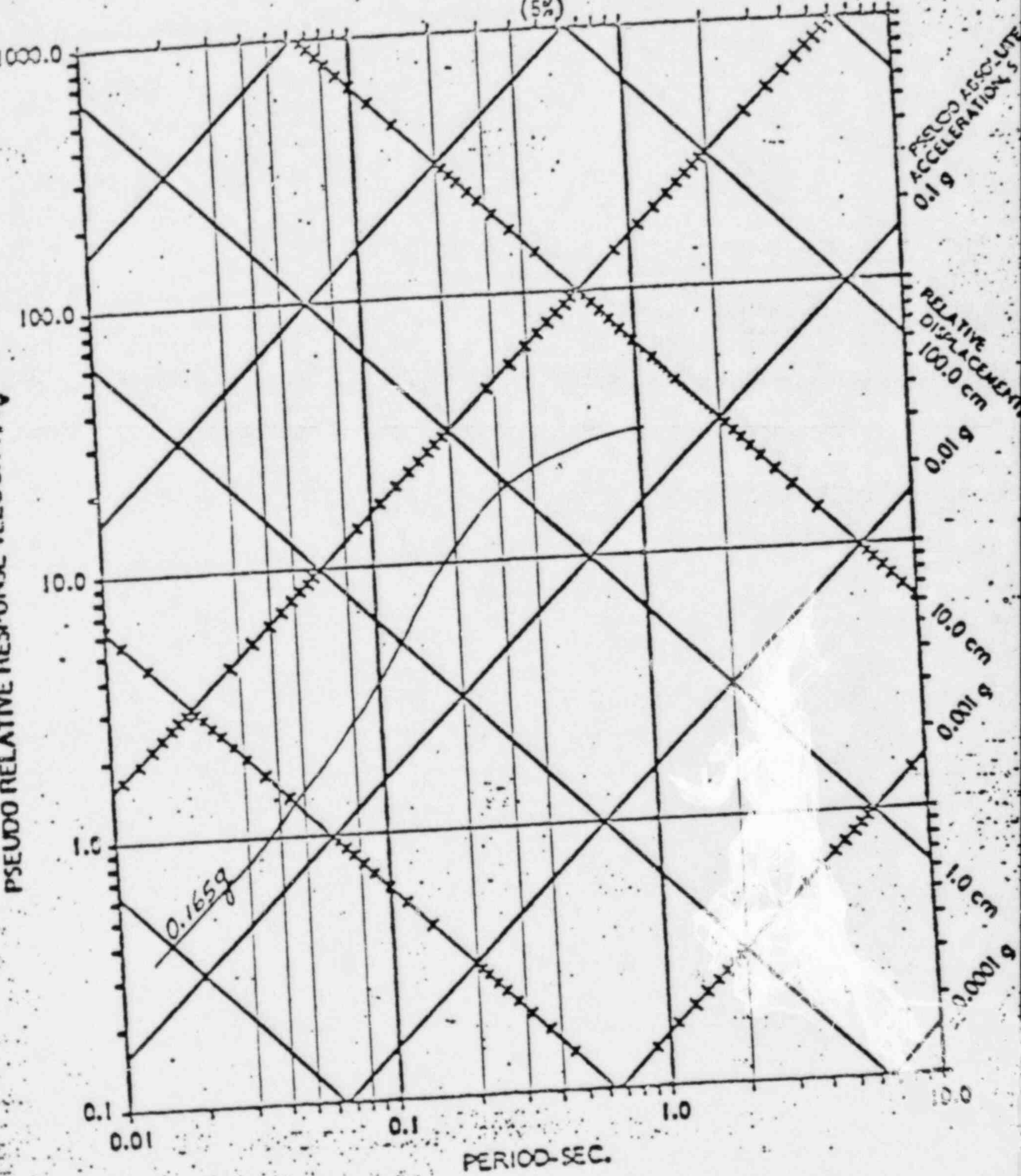


Millstone 1 Site

(5% Damping)

Attachment 1

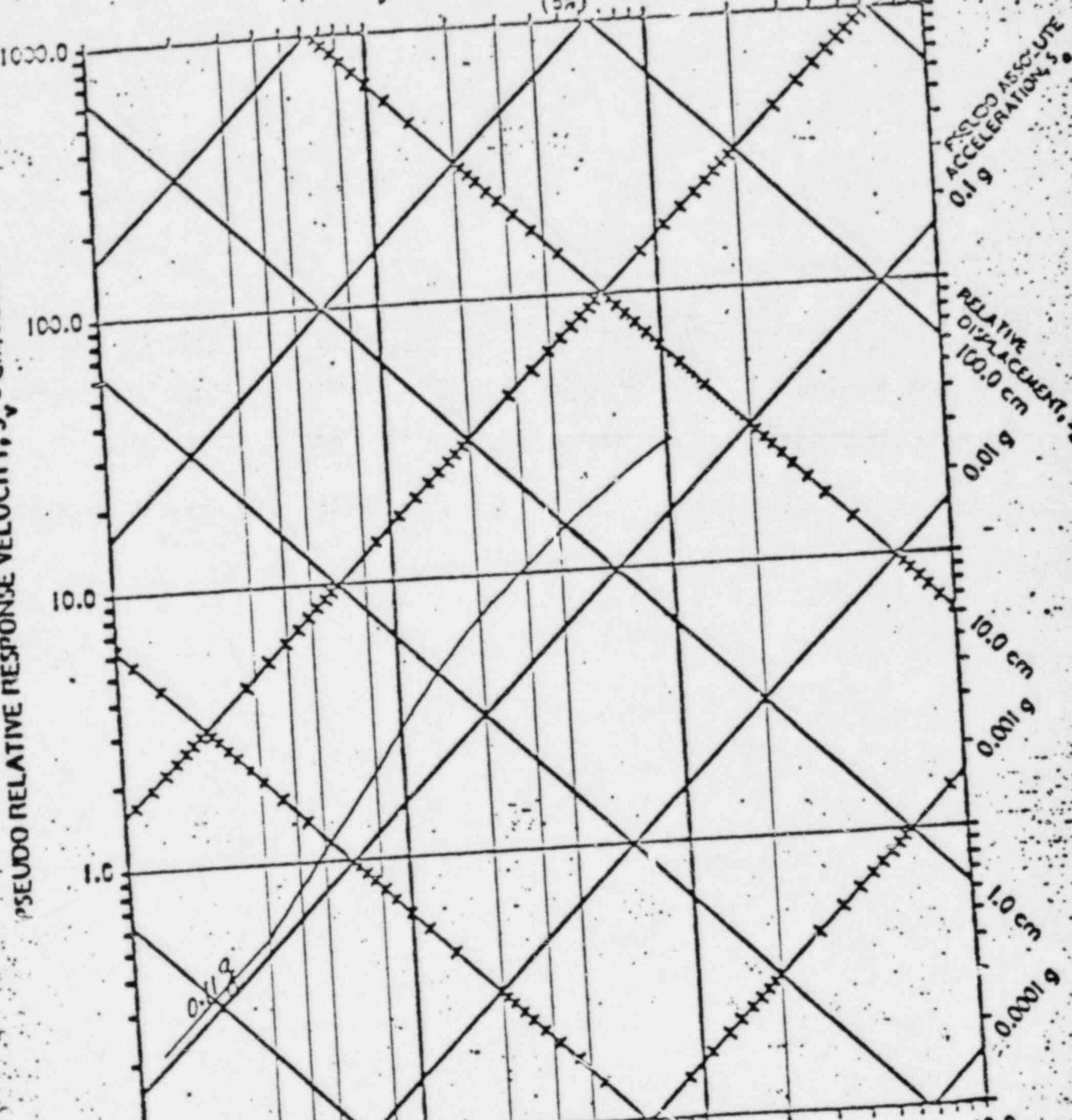
Site Specific Spectrum



Oyster Creek Site
(5% Damping)

Attachment 1

Site Specific Spectrum

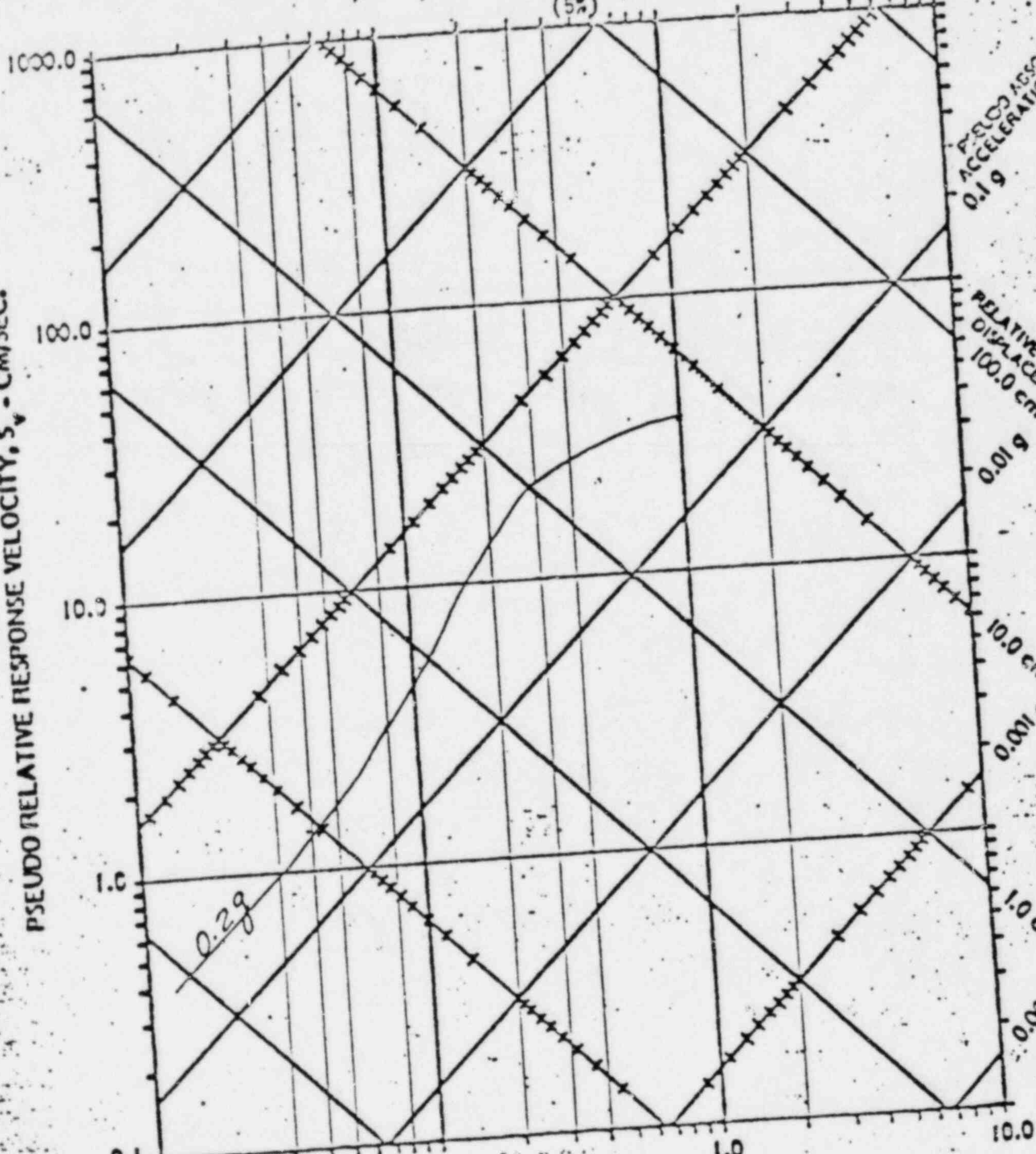


Palisades Site

(5% Damping)

Attachment 1

Site Specific Spectrum



Yankee Rowe Site
(5% Damping)

Attachment 2

UNITED STATES
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MAY 20 1981

MEMORANDUM FOR: William Russell, Chief
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THRU: James P. Knight, Assistant Director
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FROM: Robert E. Jackson, Chief
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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.

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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

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Enclosure:
As stated

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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 to 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 σ = 0.7 (natural logarithms) truncated at $\pm$? σ.

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 σ= 0.5 to σ= 0.9 with some preference for the 0.6 to 0.7 range.

Effect of Second Round Questionnaire Upon Conclusions of the Initial Review

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 σ= 0.7 $\pm$ 3σ 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 σ= 0.9 $\pm$ 2σ 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 1 7 1980

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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
R. Vollmer
J. Knight
R. Jackson
L. Reiter
J. Greeves
T. Cheng

Dupe of
~~# 8105290046~~ XA

OFFICE	NRR/DE					
SURNAME	HLevin:mg					
DATE	9/17/80					

SYSTEMATIC EVALUATION PROGRAM
SITE SPECIFIC SPECTRA
PSEUDO SPECTRAL ACCELERATIONS (cm/sec^2)

iod	Yankee Rowe	Oyster Creek	Ginna	Haddam Neck	Millstone	Big Rock Pt.	LaCrosse	Palisades	Dresde
4	208.00	172.61	178.85	215.91	196.23	122.29	122.29	122.29	134.4
5	213.69	178.17	192.52	228.92	210.91	130.19	130.19	130.19	142.5
8	247.74	206.77	230.16	279.47	253.44	152.05	152.05	152.05	164.9
0	275.68	229.98	258.38	316.00	287.00	179.69	179.69	179.69	181.7
0	434.80	363.77	388.92	475.17	433.65	213.50	213.50	214.77	270.7
0	455.49	376.59	375.82	456.79	415.45	201.96	201.96	224.41	257.4
0	408.76	339.90	328.79	395.71	360.53	171.68	195.71	218.32	249.3
	224.32	180.98	165.10	183.25	165.68	122.90	151.98	174.57	185.1
A	195.20	161.33	168.65	202.48	184.16	102.50	102.50	102.50	124.1
V*	22.48	18.41	16.92	19.66	17.02	11.39	13.50	15.18	16.0

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

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

riod	C_T
4	**
5	**
55	-0.290
3	-0.600
0	-0.904
3	-1.270
0	-1.700
0	-1.990
0	-1.950
5	-1.810
	-1.960

Units =cm/sec

Statistically Insignificant Coefficient, Use 5% PSA Value