Partial Release

April 26, 1982

SECY-82-175

For: The Commissioners

ADJUDICATORY ISSUE
(Notation Vote)

From: Sheldon L. Trubatch
Acting Assistant General Counsel

Subject: REVIEW OF ALAB-667
(IN THE MATTER OF PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, ET AL.)

Facility: Seabrook Station, Units 1 and 2.

Petition For Review: New England Coalition on Nuclear Pollution.

Purpose: To inform the Commission of an Appeal Board decision for which a petition for review has been filed.

Review Time Expires: May 7, 1982 (as extended).

Summary: In ALAB-667, the Appeal Board, at the Commission's direction, 1/ reopened the record in this proceeding to reconsider two aspects of the seismic design basis for this facility, and subsequently reaffirmed its previous decision on these issues. The issues remanded by the Commission were:

1. the factual validity of Dr. Chinnery's methodology for predicting earthquake recurrence times as a function of earthquake intensities; and

2. the consistency between Appendix A and staff's methodology for correlating vibratory motion with the Safe Shutdown Earthquake (SSE) and, in particular, the

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1/ Public Service Company of New Hampshire, et al. (Seabrook Station, Units 1 and 2), CLI-80-33, 12 NRC 295 (1980).

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relation between the average of the maximum ground accelerations and the maximum effective acceleration.

The Appeal Board found that the evidence on several elements of Dr. Chinnery's methodology demonstrated that it is not a credible means of predicting seismic motion at a particular site. Regarding the staff's methodology, the Appeal Board found that use of the average peak acceleration as the anchor point for the response spectrum for Seabrook provided a maximum characterization of the range of ground motions which could be expected at that site in the event of an SSE. Intervenor New England Coalition on Nuclear Pollution (NECNP) has petitioned for review on several grounds. The permittee Public Service Company of New Hampshire (PSCNH) and the NRC staff opposed review.

Background:

To place this Appeal Board decision in context, it is useful first to review briefly the events leading to the Commission's decision to initiate this remand proceeding. The Licensing Board authorized issuance of the construction permits for Seabrook in 1976. LBP-76-26, 3 NRC 857. Regarding seismic design of the facility, the Licensing Board found that the Safe Shutdown Earthquake (SSE) for the Seabrook site would have an intensity of VIII on the Modified Mercalli scale (MMI VIII) and that the corresponding vibratory ground motion could be accommodated by the facility if its seismic design was based on a response spectrum anchored to a ground acceleration of 0.25g. LBP-76-30, supra, 3 NRC at 868-71, 919-22. NECNP maintained that the SSE should have a Modified Mercalli intensity of at least MMI IX, and that even for an SSE of MMI VIII the anchor point acceleration should be at least 0.4g. NECNP's contention that the magnitude of the SSE was underestimated rested in part on Dr. Michael Chinnery's methodology for predicting the recurrence time of earthquakes of various intensities. Dr. Chinnery predicted the frequency of occurrence of larger-than-historical earthquakes by a method of statistical analysis. He found that a graph of historic earthquake intensity as a function of probability of occurrence yields an approximately straight line. He then assumed that the straight line could be

linearly extended to higher intensities to predict the frequency of occurrence of larger-than-historical earthquakes.

NECNP's contention that the anchor point acceleration was underestimated rested in part on testimony by Dr. Mihailo Trifunac. Dr. Trifunac noted that there is a variation by a factor of ten in the maximum ground accelerations associated with earthquakes of MMI VIII. Accordingly, he believed that the use of the average of these accelerations was not a conservative anchor point but that a reasonable value for the design horizontal acceleration should be the average of 0.25g plus one standard deviation for a total of 0.4g.

In ALAB-422, a majority of the Appeal Board found Dr. Chinnery's probabilistic methodology to be technically deficient and inconsistent with 10 CFR Part 100, Appendix A. 6 NRC 33, 57-60. The technical deficiencies identified by the Board were Dr. Chinnery's assumptions that: (1) there is no limit to the intensity of earthquakes to be expected in any given area so that data from areas that have experienced very large earthquakes can be applied to determine the probability of earthquakes in other areas that have not experienced such large earthquakes; and (2) that the plot of earthquake probability as a function of intensity can be linearly extrapolated to predict the probability of occurrence of larger-than-historical earthquakes. The inconsistency with Appendix A identified by the Board was Dr. Chinnery's use of seismic data from tectonic provinces other than the province containing the site where there was no demonstration of geologic similarity of tectonic provinces considered.

Regarding Dr. Trifunac's testimony that 0.4g would be an appropriate anchor point for the response spectrum, the Appeal Board found that the record supported the applicant's and staff's lower value of 0.25g. Staff's witness, Dr. Newmark, testified that the high acceleration values observed in ground motion caused by earthquakes of MMI VIII were associated with high frequency waves that could not significantly affect a structure as massive as a nuclear power plant. The Board found that the rules did not require consideration of accelerations due to such

waves because where the rules use the phrase "maximum acceleration" they must be interpreted to mean "effective" maximum acceleration. Accordingly, the Board found that use of the average peak acceleration was reasonable because the seismic design did not have to include the ineffective high-frequency waves.

Mr. Farrar dissented from the majority opinion in ALAB-422. ALAB-561, 10 NRC 410 (1979). Regarding Dr. Chinnery's methodology, Mr. Farrar found nothing in Appendix A that would exclude it. As for the technical merits of Dr. Chinnery's methodology, Mr. Farrar found nothing in the record casting doubt on the validity of his thesis. ALAB-561, supra, 10 NRC at 421-28. As for the anchor point acceleration corresponding to the SSE, Mr. Farrar was concerned that the peak acceleration values varied by a factor of 10 for earthquakes of intensity MMI VIII. He found nothing in the record to establish a demonstrable relation between the average of the peak accelerations associated with earthquakes of intensity MMI VIII and the maximum effective acceleration that should be associated with an SSE of MMI VIII.

In response, the Appeal Board majority noted, among other things, that Dr. Chinnery's methodology is invalid because it rests on the unsupported assumption that there is no upper limit on the intensity of an earthquake possible at the Seabrook site. ALAB-561, supra, 10 NRC at 436-e. As for the assignment of the anchor point acceleration, the majority stated that Mr. Farrar appeared to endorse the use of Fourier analysis to determine the maximum effective accelerations. The majority found that the lack of data rendered the procedure impossible in this case. Id. at 436-f-g.

On May 29, 1980, in response to NECNP's petition for review, the Commission conducted an oral briefing by the parties on these seismic issues. Subsequently, in CLI-80-33, 12 NRC 295 (1980), the Commission concluded that Dr. Chinnery's methodology was consistent with Appendix A, and the Commission remanded to the Appeal Board for further proceedings on the two issues identified above. As noted above, the Appeal

Board subsequently reaffirmed its earlier decision.

Sheldon L. Trubatch
Acting Assistant General
Counsel

Attachments:

1. ALAB-667
2. Petition for Review
3. Applicants' Answer
4. NRC Staff's Opposition

Commissioners' comments should be provided directly to the Office of the Secretary by c.o.b. Friday May 7, 1982.

Commission Staff Office comments, if any, should be submitted to the Commissioners NLT Friday April 30, 1982, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional time for analytical review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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ATTACHMENT 1

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING APPEAL BOARD

Administrative Judges:

Alan S. Rosenthal, Chairman
Dr. John H. Buck
Dr. W. Reed Johnson

emp

MAR 3 1982

In the Matter of	)	
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE ET AL.	)	Docket Nos. 50-443 50-444
(Seabrook Station, Units 1 and 2)	)	

Mr. William S. Jordan and Ms. Lynne Barnabei, Washington, D. C., for the intervenor, New England Coalition on Nuclear Pollution.

Messrs. Thomas G. Dignan, Jr., and R. K. Gad III, Boston, Massachusetts, for the applicants, Public Service Company of New Hampshire et al.

Mr. Roy P. Lessy for the Nuclear Regulatory Commission staff.

DECISION ON REMAND

March 3, 1982

(ALAB-667)

On September 25, 1980, by a divided vote the Commission remanded to us this construction permit proceeding involving the Seabrook nuclear facility in New Hampshire. CLI-80-33, 12 NRC 295. The instructions given us were (1) to reopen the record to receive additional evidence on certain seismic issues; and (2) in the light of that evidence, to reconsider the conclusions we

reached on those issues in ALAB-422, 6 NRC 33, 54-65 (1977) and ALAB-561, 10 NRC 410, 436-a et seq. (1979).

In compliance with that directive, we held a further evidentiary hearing last April, in which the applicants, the intervenor New England Coalition on Nuclear Pollution and the NRC staff participated. On the basis of the disclosures at that hearing, together with the proposed findings of fact of the respective parties, we have reconsidered our prior conclusions. For the reasons stated in this opinion, we find no cause to disturb them.

I

A. The background of the seismic remand was summarized in ALAB-623, 12 NRC 670, 672-675 (1980), in which we denied the Coalition's motion to suspend the Seabrook construction permits pendente lite. For convenience, we repeat that summary here.

1. In an initial decision issued in 1976, the Licensing Board authorized the issuance of construction permits for the Seabrook facility. LBP-76-26, 3 NRC 857.[1/] The decision

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1/ On the strength of that authorization, the permits were issued on July 7, 1976. Their effectiveness was later twice suspended for periods of time for reasons unrelated to the matters now before us. With respect to the first suspension, see ALAB-366, 5 NRC 39, as modified in CLI-77-8, 5 NRC 503 (1977); ALAB-423, 6 NRC 115 (1977). As to the second suspension, see CLI-78-14, 7 NRC 952, 957-60 (1978); CLI-78-17, 8 NRC 179 (1978).

prompted appeals by several of the parties, including the Coalition. A principal question presented by the Coalition's appeal was addressed to the Licensing Board's application of the seismic and geologic siting criteria for nuclear power plants which are contained in Appendix A to 10 CFR Part 100.

At the root of those criteria is the "Safe Shutdown Earthquake" (SSE) concept. As recently reemphasized:[2/]

> The SSE for a particular site is that earthquake "which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material" and "which could cause the maximum vibratory ground motion at the site . . . . ." 10 CFR Part 100, Appendix A, §III(c), §V(a). The nuclear power plant must be designed so that, should the SSE occur, "certain [specified safety] structures, systems, and components will remain functional". Id., §VI(a). . . .
>
> In short, the SSE is the earthquake postulated for the purpose of determining the adequacy of the seismic design of the facility. The plant has to be capable of being safely shutdown despite the effects of whatever vibratory ground motion might be experienced at the site as a result of the SSE. (One of the elements of the SSE determination is, of course, an ascertainment of the amount of such motion (Id., V(a)).)

Before the Licensing Board, the applicants and the NRC staff had adduced evidence in support of their position that the Seabrook

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2/ Dairyland Power Coop. (La Crosse Boiling Water Reactor), ALAB-618, 12 NRC 551, 552 (1980).

SSE had a maximum Intensity of VIII (measured on the Modified Mercalli scale) and that the vibratory ground motion (acceleration) which might be experienced at the site as a result of that earthquake would not exceed 0.25g.[3/] For its part, the Coalition had asserted (1) that the SSE should at a minimum be a Modified Mercalli Intensity IX; and (2) that, even for an Intensity VIII SSE, an acceleration value of approximately 0.4g should be assigned. For these propositions the Coalition had relied inter alia upon, respectively, (1) the probabilistic hypothesis advanced by one of its witnesses, Dr. Michael A. Chinnery; and (2) the testimony of another Coalition witness, Dr. Mihailo Trifunac. On the basis of its appraisal of the record, in its initial decision the Licensing Board had resolved the issue in favor of the applicants and the staff. In other words, it had found that the Seabrook facility need be designed so as to be capable of being shutdown safely in the event of a Modified Mercalli Intensity VIII earthquake producing an acceleration at the site of 0.25g. LBP-76-36, supra, 3 NRC at 868-71, 919-22.

Challenging this result, the Coalition complained to us of the rejection of the contrary conclusions of Dr. Chinnery and

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3/ The acceleration associated with an earthquake is expressed in terms of a percentage of "g" (one g represents the gravitational acceleration of a free falling body).

Dr. Trifunac. By a divided vote, this Board turned the challenge aside. As the majority saw it, Dr. Chinnery's probabilistic theory was both technically deficient and inconsistent with Appendix A to 10 CFR Part 100. ALAB-422, supra, 6 NRC at 57-60. With respect to the matter of the maximum acceleration which an Intensity VIII earthquake might occasion at the Seabrook site, the majority determined that the analytic approach of the staff's principal witness (Dr. Nathan M. Newmark) -- which had led to the assignment of the 0.25g value -- was preferable to that of Dr. Trifunac. Id. at 62-64.

Viewing the matter differently, Mr. Farrar[4/] noted his dissent from this disposition of the seismic question and thus from the affirmance of the Licensing Board's authorization of the issuance of the Seabrook construction permits. 6 NRC at 106 et seq.[5/] Instead of filing a full opinion at that time, however, he confined himself to a summary statement of his own conclusions with the notation that he would later file a supplemental opinion detailing the reasoning underlying his position.

4/ By reason of his resignation in 1980 from full-time service on the Appeal Panel, Mr. Farrar no longer is a member of this Board.

5/ All other issues raised by the Coalition and the other appellants were resolved in ALAB-422 in the applicants' favor. Jurisdiction was retained, however, over one question which this Board had raised sua sponte -- a question which did not bear upon whether the facility should be built. 6 NRC at 104-05.

2. On August 10, 1977, the Coalition filed a petition for Commission review of ALAB-422. On September 15, 1977, the Commission announced that it would defer its determination whether to grant review on the seismic issues to await Mr. Farrar's supplemental opinion.[6/] That opinion was rendered in August 1979 and prompted a response the following month from the Appeal Board majority. ALAB-561, 10 NRC 410.

Acting on a Commission invitation, the Coalition filed a supplemental memorandum on September 26, 1979 in support of that portion of its petition for review of ALAB-422 which dealt with the seismic issues. The Commission was advised, inter alia, that, subsequent to his testimony before the Licensing Board, Dr. Chinnery had undertaken certain seismological studies under NRC contract and had reported the results of those studies to the NRC staff in 1978 and 1979. According to the Coalition (supplemental memorandum, pp. 10-11), Dr. Chinnery's reports provided a sufficient answer to the criticism which had been leveled in ALAB-422 against his probabilistic analysis (and reiterated in the Appeal Board majority's response in ALAB-561 to Mr. Farrar's full dissent).

6/ The remainder of ALAB-422 was affirmed in CLI-78-1, 7 NRC 1 (1978).

Following its receipt of the rejoinders of the other parties to the Coalition's supplemental memorandum, the Commission called for an oral briefing by the parties, which took place on May 29, 1980. At that briefing, the Commission heard (albeit not under oath) from Dr. Chinnery, as well as from a panel of staff members and a technical representative of the applicants.

In the wake of the briefing, the Coalition requested that the adjudicatory record be supplemented by the inclusion of the two reports Dr. Chinnery had prepared for the NRC and the stenographic transcript of the oral presentations. This request was opposed by the applicants and the NRC staff on the principal ground that the Commission's Rules of Practice precluded the granting of such relief.

In its remand order, CLI-80-33, supra, the Commission denied the Coalition's request for the reason that it was both granting review of ALAB-422 and ALAB-561 and calling upon this Board to reopen the record on the matters dealt with in the Chinnery reports and at the briefing.[7/] With respect to the earthquake intensity question, the Commission concluded that (1) the majority of this Board had erroneously determined that Dr. Chinnery's methodology was inconsistent with Appendix A to 10 CFR Part 100;

7/ The briefing had covered both the earthquake intensity and the acceleration questions.

and (2) the "factual validity of Dr. Chinnery's hypothesis" required "greater exploration on the record" in light of the substantial time interval since his testimony before the Licensing Board in 1975 and the "subsequent publication of Dr. Chinnery's works and general increase in seismic knowledge". 12 NRC at 296-297. Regarding the acceleration question, the Commission perceived a need for additional evidence as to "the consistency of Appendix A and staff's methodology for correlating vibratory motion with the SSE". Id. at 298.

B. At the hearing on remand, Dr. Chinnery and Dr. Trifunac once again testified.[8/] In addition, testimony was received from Richard J. Holt on behalf of the applicants and a panel of staff witnesses comprised of James P. Knight, Robert E. Jackson and Dr. Leon Reiter. Following the hearing, the parties filed proposed findings of fact in accordance with an agreed schedule approved by us. The last such submission was received in August.

8/ At the Coalition's request, Dr. Trifunac was called as a Board witness because of his then status as a consultant to the Advisory Committee on Reactor Safeguards. Given that status, he preferred not to appear as a witness for a party to the proceeding. As before the Licensing Board, Dr. Chinnery testified on behalf of the Coalition.

In Part II of this opinion, infra, we deal with the first of the questions identified in the Commission's remand order: the acceptability of Dr. Chinnery's methodology for determining the intensity value which should be assigned to the Seabrook SSE. Then, in Part III, we shall move on to consider the second question: whether the staff's methodology for correlating vibratory motion with the SSE is consistent with Appendix A to 10 CFR Part 100.

II

As was noted in ALAB-422, supra, 6 NRC at 57, Dr. Chinnery is not satisfied with the determination of the seismic design of nuclear facilities based upon the size of the largest recorded historical earthquake in the particular area. Rather, as he sees it, one should go beyond the reported historical earthquakes in that area and, through a form of statistical analysis, endeavor to ascertain the likelihood of occurrence of an earthquake of yet greater intensity.

In his prepared testimony furnished to the Licensing Board in 1975,[9/] Dr. Chinnery discussed the ingredients of his probabilistic approach as applied to the Seabrook site. As he explained, his first step was to ascertain from a review of historical earth-

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9/ NECNP Exh. 10, admitted into evidence fol. Tr. 3101. As employed herein, "Tr." refers to the transcript of the proceedings below and "R.Tr." to the transcript of the hearing on remand which we conducted.

quake data, the number of earthquakes of Intensities III through IX which had occurred in three regions of the United States -- Boston-New Hampshire, Mississippi Valley and Southeastern United States.[10/] For each of those regions, he then plotted the probability per year of the occurrence of an earthquake of each intensity level between III and IX.[11/] According to Dr. Chinnery, this produced essentially straight line graphs with roughly the same slopes for all three areas for earthquakes of or greater than Intensity IV. This led him to conclude that the probability of an earthquake at or above the Intensity IX level could be ascertained by a linear extrapolation of the three curves and, most particularly, that for the Boston-New Hampshire region. Using such an extrapolation, Dr. Chinnery arrived at the further conclusion that "the probability of an Intensity IX or greater event [in New England] lies somewhere between 0 and 10^{-3} per year," which was coupled with the observation that "my assessment of the evidence leads to a number near the high end of this range."[12/]

10/ In the case of the Boston-New Hampshire region, Dr. Chinnery found no earthquake of greater than Intensity VII. Id. at p. 1.

11/ Id. at Figure 1.

12/ Id. at p. 4.

In his prepared testimony submitted to us in connection with our hearing on the remand,[13] Dr. Chinnery elaborated upon his theory. As part of that elaboration, he illuminated the basic philosophy underlying his probabilistic approach in a discussion entitled "Frequency -- Intensity Relationship:"[14]

> The characterization of the seismicity of a province in terms of the rates of occurrence of earthquakes of different sizes is usually accomplished using frequency-magnitude or frequency-intensity relationships. In the present case we use the latter, since only intensities are quoted in the Smith catalog. In addition, we use cumulative frequency-intensity counts, i.e., we count the number of earthquakes larger than or equal to a given intensity value during a given period.
>
> The extraction of frequency-intensity data from a catalog such as Smith's must be carried out with care, since the completeness of the catalog at lower intensities is likely to be a strong function of population density, and therefore of time. We use the approach described in Chinnery and Rodgers 1973 (Exhibit 1) here.

13/ That submittal took the form of Direct Testimony (denominated a "Statement") and Rebuttal Testimony, both admitted into evidence fol. R.Tr. 218. The Direct Testimony was accompanied by, inter alia, two papers published by Dr. Chinnery:

Exhibit 1 - Chinnery and Rodgers, Earthquake Statistics in Southern New England, 44 Earthquake Notes 89 (1973).

Exhibit 2 - Chinnery, A Comparison of the Seismicity of Three Regions of the Eastern U.S., 69 Bull. of the Seismological Society of America 757 (1979).

They will be hereinafter identified as Chinnery Exhs. 1 and 2.

14/ Direct Testimony, at pp. 7-8.

Having extracted and plotted the data for the Boston-New Hampshire seismic zone, we have three important questions to consider:

(i) can the data be represented by a linear frequency-intensity relationship?

(ii) if so, what is the slope of the linear relationship?

(iii) is there some upper bound to the intensity of earthquakes that can be expected in this seismic zone? Let us consider each of these in turn.

In addition to those questions, the justification for the use made by Dr. Chinnery of the historical data to determine the likelihood of occurrence of an earthquake of greater size necessitates consideration of a fourth question as well: whether there is validity to his required assumption that that data can be linearly extrapolated to include larger seismic events.

Each of the four questions was addressed at the remand hearing. In Part A, we summarize the testimony of the parties; following that, in Part B, Dr. Chinnery's methodology will be examined against the background of that testimony.

A. Summary of the evidence presented by the parties

1. Representation of seismic data by a linear frequency-intensity relationship.

In his direct testimony (at p. 10), Dr. Chinnery stated that "[t]he vast majority of seismologists have accepted the linearity of frequency-magnitude[15/] data as a working hypothesis";[16/] he went on to acknowledge, however, that that hypothesis "has no clearly developed theoretical basis". With regard to the "linearity" of frequency-intensity relationships, he testified that there has been "much less" discussion but that, "of what scientific literature there is, the vast bulk assumes that [such] relationships are linear."[17/] On cross-examination,

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15/ Emphasis supplied. As will be later discussed (pp. 28-29, infra), "Magnitude" refers to the size of an earthquake as measured by an instrumental method. "Intensity", on the other hand, refers to earthquake size as subjectively measured by its observed effects. The intensity concept was first employed long before the availability of seismic instrumentation.

16/ Dr. Chinnery's employment of the term "linearity" in this context is open to misunderstanding. The relationship between earthquake frequency and magnitude is generally expressed by the equation $\text{Log } N_C = A - bM$, in which N_C is the number of earthquakes of magnitude M or greater per unit time. Because, as shall be seen (p. 29, infra), M is a logarithmic scale, graphical representation of this equation would be a log-log curve. It is the log-log relationship that Dr. Chinnery assumes to be linear.

17/ On this score, Dr. Chinnery's employment of "linearity" is even more troublesome. The plots he used to show a frequency-intensity relationship are plots of equations in the form of $\text{Log } N_C = a - bI$. If I is a linear scale, then the plot is log linear. But if I is a logarithmic scale as assumed by Dr. Chinnery in his 1973 paper (Chinnery Exh. 1), then the plot is log-log. In either case, the equation makes the fundamental assumption that I is a uniform scale (see fn. 19, infra).

(FOOTNOTE CONTINUED ON NEXT PAGE)

however, he conceded that most of the scientists utilizing the linear frequency-intensity hypothesis do so for the purpose of classifying seismic regions, and not as a method of predicting maximum earthquake intensity (R.Tr. 64).

Notwithstanding these considerations, Dr. Chinnery has elected (see Chinnery Exh. 1) to "use intensities throughout" because of "the nature of the historical data".[18/] And, as he sees it, there is no need to justify analytically his assumption that the frequency-intensity relationship is a linear one. The assigned reason was that it has a recognized empirical foundation (R.Tr. 302-03).[19/]

17/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE)

The nature of the plots are of more than passing academic interest. The shape of a plotted curve depends strongly on the type of graph used to make the plot. Dr. Chinnery agreed that his data points would have produced a sharply-curved line if plotted against linear axes (R.Tr. 261).

18/ This, of course, refers to the fact that, except for very recent years, seismic data were exclusively reported in terms of the effects of earthquakes, i.e., intensity.

19/ Nonetheless, Dr. Chinnery did endeavor, see Chinnery Exh. 1, pp. 93-95, to formulate a relationship between earthquake frequency and intensity by a two-step analytic process. He first noted that "it appears in general to be possible to relate the maximum epicentral Intensity I to the local magnitude M by a linear algebraic expression $M = 1 + 2/3\ I$ taken from a paper by B. Gutenberg and C.F. Richter (Bull. of Seismological Society of America, Vol. 46, No. 2, 1956)". From this,

(FOOTNOTE CONTINUED ON NEXT PAGE)

By way of illustration, Dr. Chinnery took historical earthquake data from four areas of the United States[20] to plot Log N_C per year vs. intensity curves.[21] These plots are shown in Figure 1 on the following page, which is a reproduction of a figure in his 1979 paper (see Chinnery Exh. 2, Figure 8 at p. 766). It is his thesis that these plots show that the Log N_C per year vs. intensity is linear for the range Intensity IV and above.[22]

19/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE)

Dr. Chinnery concluded that "[i]f a linear relationship exists between magnitude and intensity * * * then clearly we can write Log N_C = c - dI."

The only mention in the 1956 paper by Gutenberg and Richter of a possible linear relationship between magnitude and intensity is at p. 131, where they state that "[i]n Figure 5 the data for I_o and M are correlated. The resulting empirical equation M = 1 + 2/3 I_o differs only slightly from the corresponding equation in Paper 1." In his later book Elementary Seismology (1958), Richter notes at p. 140 that, in such equations, "[I]ntensity grades must be treated as true numerical quantities which they are not." (See also pp. 29-33, infra.)

20/ The areas used were Mississippi Valley, Southeastern United States, Southern New England and Boston-New Hampshire.

21/ As earlier noted (fn. 16, supra), N_C represents the number of earthquakes producing an Intensity I or greater during a particular time period.

22/ Noting the fact that low intensity data are incomplete and that the higher intensity data may be too sparse to be reliable, Dr. Chinnery also presented straight line representations of the data in each region (i.e., of the form Log N_C = a - bI). The slopes of these lines, determined for the four regions mainly by the frequency of earthquakes of Intensities IV to VII, lie in the range 0.54 to 0.60 (Chinnery Exh. 2, at p. 765).

FIGURE 1

766 MICHAEL A. CHINNERY

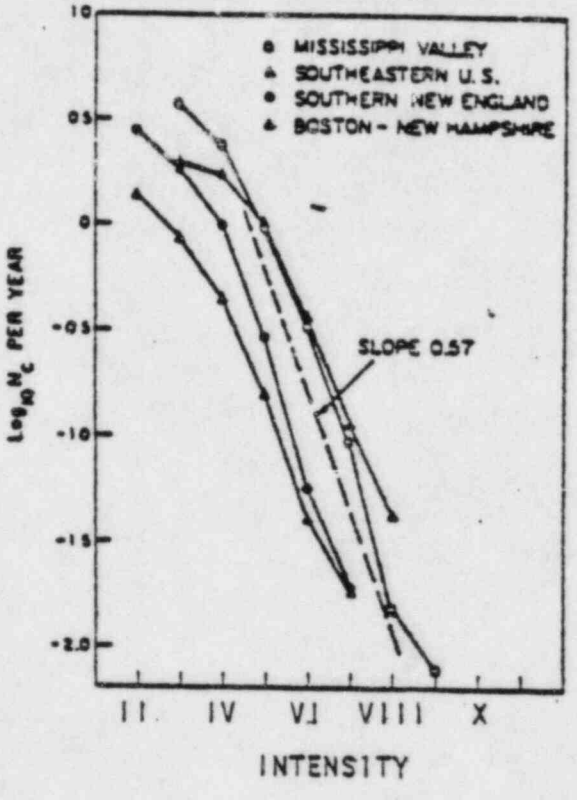

Figure 8. Comparison of the frequency-intensity data from Figures 2, 4, and 7.

[Chinnery Exh. 2, Figure 8]

Dr. Chinnery's data used in plotting the curves were not taken from the same period of time for each region -- nor for the same length of time for each curve.[23/] He stated with regard to the Southeastern United States region that he wished "to get away from the worst of the aftershocks" of the large earthquake of 1886 (Charleston); accordingly, he arbitrarily started with the year 1900 (R.Tr. 183). Respecting the Mississippi Valley region, "the large earthquakes there happened in 1811, 1812 (New Madrid) so I can go back further and there my intensity file goes back to 1870" (ibid). However, data for Intensities VI through IX are listed in his Table 2 as beginning in 1840. He admitted that the 1800 cut-off for the New England data was arbitrary (R.Tr. 59).

23/ The actual time periods used by Dr. Chinnery were (Exh. 2, at pp. 760, 761, 764):

	III	IV	V	VI or great
Southeastern United States	1930-1969	1900-1969	1900-1969	1900-1969
Mississippi Valley	1900-1969	1870-1969	1840-1969	1840-1969
Southern New England	1928-1959	1900-1959	1860-1959	1800-1959
Boston-New Hampshire	1928-1959	1900-1959	1860-1959	1800-1959

Dr. Chinnery also conceded that he had excluded data on Intensity III and below and had not investigated the sensitivity of the purported linearity of the N_c - intensity relationship to the omission of this data. Moreover, he had used data from Smith's Earthquake Catalogue without determining the accuracy of the data or whether late work had resulted in changes in the intensity values used by Smith (R.Tr. 54-55; see also fn. 44, infra).

The staff and applicants' witnesses were critical of Dr. Chinnery's conclusion that a linear representation of the frequency-intensity data is the most desirable way to display this information. They noted that many other functional relationships (e.g., truncated linear, bilinear and higher order) have been used to represent these data (Reiter, fol. R.Tr. 493, at p. 4; Holt, fol. R.Tr. 349, at p. 3). Dr. Reiter observed:

> Yegian (1979) has discussed these [relationships] in recent summary of probabilistic approaches to seismic hazard analysis. New forms of frequency magnitude relationships are continually being proposed. An examination of the six issues of the Bulletin of the Seismological Society of America for 1980 alone indicates three different generic approaches to determining the relationship between earthquake magnitude or intensity and frequency. (Bloom and Erdmann, 1980; Berrill and Davis, 1980; and Makjanic, 1980). The linear assumption is a first order or rough approximation which may be adequate for generalized arguments but clearly requires great scrutiny and possibly higher order terms in detailed descriptions such as return periods for earthquakes of high intensities.

Reiter at p. 5.

For his part, Mr. Holt stated that Dr. Chinnery's arbitrary choice of time frames for the various seismic regions eliminated years of earthquake data that, if included, would produce drastic changes in Dr. Chinnery's results (Holt, fol. R. Tr. 349, at p. 2). Specifically, had that data been included, for each of the areas selected by Dr. Chinnery the consequence would have been curves which were non-linear at the high intensity end:

> For the three cited cases, Mississippi Valley, Charleston, La Malbaie, the high intensity end of the curve does not follow a linear pattern; it does not have a "stable" slope. There are several possible explanations for this:
>
> > The observation period fortuitously includes the large earthquakes and if we looked at a much longer time period their probability level would be much lower (or their return period much longer). This is the explanation Dr. Chinnery has chosen when he uses the "linearity" of the smaller events.
> >
> > The points may be fitted by another type curve or there are different slopes for the smaller earthquakes than for the larger earthquakes; for the European area different slopes can be fit to different regions (Karnik, 1969) and, in some regions, two slopes fit the data much better than one.
> >
> > The curve changes slope with time and/or the earthquakes are not uniformly distributed in time and therefore not predictable at any probability level from the limited time base we have.

Id. at p. 3.

In the same vein, Dr. Reiter pointed out that "* * * you can fit many many straight lines, many many higher order curves, bi-linear curves to that data set" (R.Tr. 512).

2. Uniform slope or "b" value

Dr. Chinnery testified that the only study concerning the variation of the slopes of the frequency-intensity relationship from region to region was his own 1979 paper.24/ In that paper, he concluded that, in the four eastern United States areas there studied, the "frequency-intensity plots that we have considered show a remarkable uniformity. All show a pronounced linearity, and have slopes which are consistent with a value of about 0.57."25/

24/ Direct Testimony, at p. 11. That paper accompanied the testimony as Exhibit 2 (see fn. 13, supra).

25/ In this regard, Dr. Chinnery stated that the slope of his linear projection for the Boston-New Hampshire region was determined by the slope for the data for the other eastern United States regions because the data for the Boston-New Hampshire region were very sparse (R.Tr. 48-49). On cross-examination, he acknowledged that the Intensity VII data point (derived from three events in a 160-year period) that he plotted as slightly above his graph line was in error. That data point should have been lower, reflecting a single event in that period. He indicated, however, that this error would not affect his conclusions (R.Tr. 128-9, 139).

In rebuttal, Dr. Reiter maintained that other studies of the linear relationship between earthquake frequency and intensity show "a wide range of b values has been reported." 26/ For example, a study by Algermesian and Perkins (1976) computed b values for 71 regions in the United States and found them to range from 0.24 to 0.76. 27/ Dr. Reiter asserted that even a variation of the value of b from 0.45 to 0.57 results "in a variation of about 0.8 in site intensity associated with a return period of 10,000 years * * * which utilizing the trend of the means of Trifunac and Brady (1975) * * * implies 75% increase in ground acceleration." 28/

Figure 5 contained in Mr. Holt's testimony is a plot of frequency vs. intensity for two regions in South Carolina and was taken from a paper published in 1977 by A.C. Tarr. 29/ One curve on the plot shows the data for the highly seismic region in the vicinity of Charleston; 30/ the other reflects the data for the rest of that state. The slope of the first curve -- for the smaller, more seismically active, region -- is markedly different (less steep) than the slope of the second.

26/ Reiter, fol. R.Tr. 493, at p. 5.

27/ Ibid.

28/ Id. at p. 6.

29/ Holt, fol. R.Tr. 349, at p. 13.

30/ An area which provided many of the seismic events included in Dr. Chinnery's Southeastern United States region. See Chinnery Exh. 2 at p. 760.

3. Existence of an upper bound to the intensity of earthquakes that can be expected in a seismic zone

Dr. Chinnery admitted that "the question of the existence of upper bounds to maximum earthquake intensity (less than the scale maximum of XII) remains unanswered" (Chinnery Exh. 2, at p. 771). But he believes "that a rational conservative approach to the estimation of the seismic risk at a site would include the possibility of events with Intensity X or more anywhere in Eastern United States." Ibid. This conclusion rested on extrapolation of the frequency-intensity data to intensities higher than those historically recorded. We discuss such extrapolation in Section 4, infra, pp. 26-28.

On the other hand, Mr. Holt asserted that Dr. Chinnery's curves of earthquake frequency vs. intensity "do not tell us that there is or is not a regional 'upper-limit' earthquake." He maintained that "in any given region the available stress and nature of existing earthquake structures may be such that only a small or intermediate earthquake will be produced." Mr. Holt also testified that there is no geologic evidence of large earthquakes in New England -- as there is in areas known to be seismically active. In particular, he pointed to the area around New Madrid, Missouri (Holt, fol. R.Tr. 349, at pp. 4-5; see also Appendix 3 to his testimony).

Dr. Reiter agreed with this assessment, adding that most seismologists believe that estimates of maximum likely earthquakes in a given area can be obtained only by the use of a combination of "instrumental and historical seismicity, local and regional tectonic history, geologic structure, stress measurements and, when possible, fault parameters such as dimension and slip rate" -- none of which tools had been alluded to in Dr. Chinnery's direct testimony (Reiter, fol. R.Tr. 493, at pp. 6-7).

In his rebuttal testimony (at pp. 11-12), Dr. Chinnery expanded somewhat on his theories concerning the upper bounds to earthquake sizes. He pointed out that a recent paper by Liu and Kanamori (1980) "examined 5 mid-plate earthquakes and their results * * *." These events had estimated fault dimensions ranging from $10km^2$ to $100km^2$, with seismic moments 31/ found to be between 10^{25} and 10^{26} dyne-cm. The corresponding stress drops 32/ were found to range from 100 to 1000 bars -- unusually high compared to the interplate earthquakes which, according to

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31/ Because earthquakes are caused by rupture and sliding along fault surfaces in the earth, the net effects of an earthquake can be measured in terms of the amount of slip and the area (i.e., the length times depth of the fault) over which it took place. The product of the slip (u), the fault area (A) and the rigidity (μ) of the surrounding rocks is taken to be the "seismic moment" (M_o); i.e., $M_o = u \mu A$.

32/ "Stress drop" is the change (decrease) in the rock stresses on either side of the fault before and after the earthquake.

Dr. Chinnery, have stress drops in the range of 10 to 100 bars. Dr. Chinnery concluded from this that mid-plate earthquakes may have small dimensions but, because of their stress drops, may have magnitudes in the range of 7 to 7.5 (which he equates to an epicentral Intensity of X.) He added that "in my opinion there is no sound geological basis for saying that New England is in some way an unusual mid-plate region"; i.e., he thought that area to be similar to the five areas studied by Liu and Kanamori. On this basis, Dr. Chinnery reached the "professional judgment" that

> a magnitude 7 (M_S) earthquake may well occur rarely in the Boston-New Hampshire zone, at a depth that may be as little as 5 to 10 km. Furthermore, I feel it will be a long time before we get enough new information that we will be able to revise this estimate. As near as I can estimate, a magnitude 7 earthquake at a depth of 10 km would lead to a surface intensity of at least X.

Id. at p. 13.

On cross-examination, however, Dr. Chinnery stated that his value of magnitude 7 to 7.5 M_S for the earthquakes in the Liu and Kanamori study was obtained by his own method of estimation and had not taken into account the much lower magnitude values (M_S 5.5 to 6.3) of the mid-plate earthquakes actually presented in the Liu and Kanamori paper.33/ Although he had calculated Modified

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33/ R.Tr. 164. Dr. Chinnery's exact statement was: "what you were pointing out is absolutely right, that is, they have magnitude values already in that paper which I obviously didn't go [sic], I went through too fast to see."

Mercalli values equivalent to M_S 7 to 7.5 for the purposes of his rebuttal testimony and had read other papers which gave relationships between various magnitudes and intensity values, he declined to give any estimate of the Modified Mercalli values which would correspond to earthquakes in the range of M_S 5.5 to 6.3 (R.Tr. 166-170).

By way of response to Dr. Chinnery, Dr. Reiter observed that actual measurements of stress drop had been made for earthquakes in New England using techniques similar to those of Liu and Kanamori, which had provided results of less than 50 bars (R.Tr. 556-7). And Mr. Jackson offered his observation that the rocks in New England are heavily jointed and cracked and, thus, would more likely produce small fault areas and earthquakes (R.Tr. 562-3). Although Mr. Jackson admitted his observations were made near the surface, and not at the depth of 10 km or so at which fault ruptures might occur (id.), he noted that geologists would generally expect to find uniformity in depth of rock structure (R.Tr. 565). In any event, Mr. Jackson believed that his observation on rock structure in New England was supported by the finding of low stress drops for earthquakes measured in the region (R.Tr. 587-8).

Regarding the possibility of an upper bound of earthquakes, Mr. Holt cited another intraplate region, England and Scotland,

where, in a thousand years of data, the largest earthquake intensity measured has been Intensity VII. (R.Tr. 401). He went on to state that there was no geological evidence of large earthquakes in the New England area, such as capable faults. This is in marked contrast to the Mississippi Valley (New Madrid) region, where numerous signs of early intense earthquakes are to be found. (Holt, fol. R.Tr. 349, at pp. 4-5, Appendix 3).[34/]

4. The extrapolation of the relationship between earthquake frequency and intensity to earthquake intensities greater than any historically recorded in the area under consideration

On the basis of his assumptions that there is a "linear" relationship between the frequency of earthquake occurrence and intensity, and that the slope of the line representing this relationship is constant throughout the eastern United States, Dr. Chinnery asserted that the relationship can be linearly extrapolated to predict the frequency of occurrence of earthquakes larger than those historically recorded (Direct Testimony, p. 12). For New England, he expressed the opinion that the linear rela-

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34/ There is no residual evidence of past earthquakes in the Charleston, South Carolina region, due (at least in part) to the deep overburden found there (R.Tr. 406).

tionship indicated by his data could be extended on a conservative basis to at least Intensity X. Id. at p. 13. The single articulated basis for this opinion was that five out of 10 seismologists had suggested that the largest earthquake to be expected in the Cape Ann area of Massachusetts (which is in the Boston-New Hampshire zone as described by him) might possibly be as high as Intensity X. Id. at pp. 12-13. In Exhibit 2 to his Direct Testimony, Dr. Chinnery maintained that, in the higher seismic areas of Charleston (Southeastern United States) and New Madrid (Mississippi Valley), the extrapolation would be valid to Intensities IX and X, respectively. (Chinnery Exh. 2, p. 771).

On this matter, as well, staff and applicant witnesses took issue with Dr. Chinnery's thesis (see e.g., Reiter, fol. R.Tr. 493, at pp. 8-9; Holt, fol. R.Tr. 349, at pp. 2-3). That disagreement centere upon his limited use of the available data. Dr. Chinnery had relied on the data given in Smith's Catalogue of Earthquakes, even though he admitted that much of the catalogue data was questionable (Direct Testimony, at pp. 4, 7; Rebuttal Testimony, at p. 14). Further, he had not investigated the accuracy of the Smith data that he had employed nor had he taken into account the re-evaluation in other studies of some of the seismic events he had utilized (R.Tr. 53-55; 128-133).

With respect to the linear extrapolation of the Modified Mercalli scale beyond Intensity VIII, Dr. Reiter emphasized that:

> While Intensity VII earthquakes have occurred in many parts of the Central and Eastern U.S., Intensity VIII earthquakes have occurred in much fewer locations. Intensity IX or greater events have only occurred at four locations in eastern North America, the New Madrid Missouri Zone, Charleston South Carolina, La Malbaie, Quebec and the Grand Banks off of Newfoundland.

Reiter, fol. R.Tr. 493, at p. 8.

In the same vein, the frequency-intensity curves to which he alluded in his testimony (see p. 19, supra) persuaded Mr. Holt that "the curve in the historical time period is not linear at the high intensity end" (Holt, fol. R.Tr. 349, at p. 3).

B. Analysis of the evidence

1. An evaluation of the evidence adduced respecting Dr. Chinnery's probabilistic hypothesis requires some understanding of the two recognized bases for measuring the size of an earthquake -- magnitude and intensity.

a. Defining earthquake size in terms of magnitude is a relatively recent development, the concept having originated in 1931 in Japan and then further developed for California earthquakes by Charles Richter in 1935.[35/] Magnitude is determined

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35/ Bolt, Earthquakes - A Primer (1978), at 104.

by instrumental measurements and is understood to be

> the logarithm to base ten of the maximum seismic wave amplitude (in thousandths of a millimeter) recorded on a standard seismograph at a distance of 100 kilometers from the earthquake epicenter.36/

Thus, each additional unit of magnitude as represented on the scale devised by Dr. Richter (and named after him) reflects a ten-fold increase in the amplitude of the earthquake waves.37/

Although the original Richter Magnitude scale was essentially a local one with application to Southern California earthquakes alone, this measurement method is now employed worldwide with the aid of various types of seismographs.38/

b. In contrast, earthquake intensity -- as now reflected on the Modified Mercalli scale -- is not instrumentally measured. Indeed, the intensity concept originated long before instruments had been devised for the measurement of earth movement; i.e., at a time when the size of an earthquake could be assessed only in terms of its observed effects. Measurements in intensity terms thus have a markedly subjective element; this becomes clear from the generally accepted standards utilized in determining the value on the Modified Mercalli scale which should

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36/ Ibid.

37/ Ibid.

38/ Ibid.

be assigned to the earthquake.[39/] It is also apparent from those standards that, although the steps in the scale from I to XII represent progressively larger earth motion, no basis

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39/ As described in Richter, Elementary Seismology (1958), at 136-38:

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls, Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle--CFR).

(FOOTNOTE CONTINUED ON NEXT PAGE)

exists for an assumption that the increase from step to step either is uniform or follows any particular mode of variation.

39/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE)

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments--CFR). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations--CFR.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides.

(FOOTNOTE CONTINUED ON NEXT PAGE)

2. In short, the Modified Mercalli scale uses the effects on man and man-made structures to give a word picture of the size

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39/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE)

Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

of the earthquake causing those effects. It provides a useful means for determining the characteristics of the magnitude of seismic events for which no instrumental data are available. Nonetheless, the scale must be used with caution, for the ground motion and damage associated with any given earthquake may vary greatly depending upon local conditions (e.g., whether the situs of the earthquake has a rock or, instead, a soil foundation).40/

When questioned by us respecting the basis for his assumptions that the Modified Mercalli scale is consistently uniform throughout its range, Dr. Chinnery acknowledged that "scientifically it [intensity] is very hard to use and to define." He further stated in his 1973 paper (Chinnery Exh. 1) that

> there's a plot of some data of magnitude against intensity and I'm not saying it proves very much.
>
> There is clearly a lot of scatter there nevertheless * * * . Now, that * * * diagram in my '73 paper goes up to Intensity VIII. Whether the intensity scale continues to be linear beyond that I agree is a problem.

R.Tr. 223.

40/ In his prepared testimony at p. 1 and p. 4, Mr. Holt discussed this point and, in Appendix 1 to that testimony, provided numerous illustrative examples. See also Bolt, supra fn. 35, at 101-102, for the observation that landslides, which are used as an indication of Intensity X earthquakes, can be caused by very slight seismic activity, depending on the terrain.

Apart from his use of the intensity scale levels as if they reflected true numerical quantities, which they manifestly do not, Dr. Chinnery's approach is replete with questionable scientific methodology. We have already noted his arbitrary selection of time periods when comparing various geologic areas of the United States. See pp. 17-20, supra. A yet more troublesome problem stems from Dr. Chinnery's selection of the four regions to be studied for the purposes of his analysis -- a choice which necessarily has a decided bearing upon the reliability of his results and their usefulness in assigning earthquake risk.

Two of those selected regions are relatively large in area: Southeastern United States (307,000 km^2) and Mississippi Valley (250,000 km^2).41/ Within those regions, there are much smaller areas of very high seismicity -- Charleston and New Madrid, respectively -- which have contributed a large percentage of the seismic events which have taken place in the region.42/ Yet, in plotting his frequency-intensity curves for those regions, he used data from the entire region. See pp. 15-17, supra. As we have seen, however, there is uncontroverted evidence that, at least in South Carolina, the slope of the curve is significantly

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41/ Chinnery Exh. 2, at pp. 758, 760.

42/ R.Tr. 279; Holt, fol. R.Tr. 349, Fig. 5A; Chinnery Exh. 2 at pp. 759, 761.

influenced by whether the data employed are from a region of high, or instead low, seismicity. See p. 21, supra.

The two other selected regions are considerably smaller in overall area: Southern New England (100,000 km^2) and Boston-New Hampshire (27,000 km^2).[43/] More importantly, a much greater percentage of those regions are seismically active. This is especially true of the Boston-New Hampshire region which is entirely encompassed within the Southern New England region and, as its boundaries were arbitrarily drawn by Dr. Chinnery, is very irregular in shape and appears to include the principal seismic areas in eastern Massachusetts and the southern portion of New Hampshire. It might be noted that Dr. Chinnery acknowledged that he had selected that region because it had "somewhat more seismicity than the rest of New England" (R.Tr. 278). It thus would appear that, in making that selection, he employed different criteria than that which undergirded his choice of the other three regions. In these circumstances, it is of little, if any, significance that Dr. Chinnery's frequency-intensity curves for the four regions have similar slopes.

43/ Chinnery Exh. 2 at p. 761.

Moreover, as earlier noted (p. 24, supra), in using the paper by Liu and Kanamori to support his belief that there is no limit on the intensities of mid-plate earthquakes, Dr. Chinnery disregarded the earthquake magnitudes found by the authors and instead substituted much higher values of his own. Still further, his claim that the New England area is geologically and seismologically similar to the five mid-plate areas studied by Liu and Kanamori is without foundation (R.Tr. 145). In this connection, it is noteworthy that Dr. Chinnery conceded that he had made no analysis himself of relevant seismic records nor had he calculated stress drops for any New England earthquakes (R.Tr. 171); that the only stress measurements he knew of were taken in drill holes at depths of no more than 2000 feet, (R.Tr. 199); and that, because he had not personally kept up with the record of intensities of recent New England earthquakes, he did not know if they indicated small area,high stress events (R.Tr. 201-202). Nor had he examined the spectra obtained from New England earthquakes to see how they compared with earthquake spectra in other areas (R.Tr. 202-203).[44/] These admissions obtain

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44/ In this connection, as earlier noted (fn. 25, supra) Dr. Chinnery now accepts the recent reevaluation which reduced the number of Intensity VII events which have occurred in the Boston-New Hampshire region from three to one (an 1817 earthquake has been downgraded from VII to VI and two Intensity VII events which took place a few days apart in December 1940 near Ossipee, New

(FOOTNOTE CONTINUED ON NEXT PAGE)

yet greater significance when taken in conjunction with the statement made by him in response to questions by the Licensing Board concerning the possibility that the New England earthquakes might not show surface faulting because their focus might be deeper than that of California earthquakes:

> No. As I said, I personally suspect that it's because they are smaller. The stresses which are built up in an area like New England are almost certainly much higher than the stresses which are built up in California. And it's like a very small, very intent bomb, if you like. We can contain a lot of energy within a small space in an environment like New England. This is not possible in California; earthquakes are very much larger, it's not surprising that they very nearly always penetrate the surface in California.

Tr. 4048-49.

44/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE)

Hampshire are now treated as having been a single earthquake and its aftershock). Nevertheless, as also noted, Dr. Chinnery expressed the view that this reduction does not affect the slope of his line for this region, which had been founded on a VII data point which assumed three events of that intensity.

We think otherwise. The computation of the VII data point on the basis of a single event, instead of three events, produces a value of Log N_C equal to -2.2 rather than -1.72 and that value lies well below Dr. Chinnery's proposed linear curve (see Chinnery Exh. 2, Fig. 7, at p. 765). Moreover, the treatment of the Ossipee events as a single Intensity VII earthquake (R.Tr. 139, 272) requires a reduction in the cumulative number of events included in the Intensities VI and V data points (which encompass all events of that or greater intensity). Using the corrected data, all of the points beyond Intensity V plotted on Dr. Chinnery's Boston-New Hampshire graph (Fig. 7) fall below his straight line and the apparent slope of the plotted data is no longer consistent with his linear projection.

Even were there not these infirmities in Dr. Chinnery's methodology, it still would not provide a basis for determining the SSE for the Seabrook site. As plotted by Dr. Chinnery, the magnitude of the frequency vs. intensity curve (i.e., the position of the line relative to the vertical axis) is dependent upon the total number of events in the particular region providing the data base, without regard to the area of that region. As reflected by the curves found in Figure 1, supra, p. 16, one consequence is that the number of events of a given intensity to be expected per year in the Mississippi Valley and Southeastern United States regions would exceed (by a factor of approximately 10) those in the Boston-New Hampshire region.

Nonetheless, upon our inquiry Dr. Chinnery stated that he was not prepared to assign a factor-of-10 greater seismic risk to a hypothetical nuclear power plant site in western Alabama (within the Southeastern United States region) than he would assign to a specific site within the Boston-New Hampshire region (R.Tr. 280-285). He explained that, in order to equate the areal seismic risk with that existing at a certain site within the area, one would have to make a subjective assessment of the areal data and be informed as to the particular characteristics of that site (R.Tr. 286-88). Accordingly, Dr. Chinnery explicitly acknowledged that his methodology could only be employed to determine the seismic risk in the region in which the Seabrook site is located and

that his testimony therefore did not address the probability of earthquake intensity at the site itself (R.Tr. 288-89). In these circumstances, there is little basis for the Coalition's claim (at p. 33 of its proposed findings of fact) that the areal earthquake probability which Dr. Chinnery had computed for the Boston-New Hampshire region perforce must be applied to the Seabrook site.

In sum, we are compelled to conclude that Dr. Chinnery's methodology has not been shown to be a credible means of predicting the intensity of seismic motion at a particular site. Leaving aside the just discussed admitted limitations affecting its usefulness, we have seen that, had he employed relatively uniform criteria in the selection of regions and time periods for the purposes of his probabilistic analysis, the results would have been materially different from those which he presented and would have refuted his postulated linear frequency-intensity relationship. Once again, his thesis that the Seabrook facility should be designed to withstand an earthquake of an intensity greater than any historically recorded earthquake in the New England region rests entirely upon his assertion of such a

linear relationship.[45/]

45/ Contrary to the Coalition's claim in its proposed findings, we find nothing in the record to indicate that Dr. Chinnery's methodology has received peer acceptance. More particularly, we do not agree that Dr. Trifunac's testimony endorsed Dr. Chinnery's proposed linear projection as a means of forecasting recurrence rates of earthquakes higher than those historically recorded. See R.Tr. 750-52.

Nor can we adopt the Coalition's proposed finding that certain testimony of Mr. Holt establishes that Intensity XII should be assigned to the Seabrook SSE. In this testimony, Mr. Holt referred to an apparent correlation between earthquakes which occurred off of Cape Ann, Massachusetts in 1727 and 1755 and the existence in that area of an intrusive (pluton) with northeasterly trending incapable faults. (R.Tr. 381-92; 425-28). He also took note of the similar coincidence of an intrusive and a fault in the New Madrid area, where seismic events possibly as high as Intensity XII occurred in 1811-12 (R.Tr. 403-04). Leaving aside the fact that the Holt theory respecting the significance of intrusives is not accepted by the United States Geological Survey (R.Tr. 430, 552-553) -- or, insofar as we are aware, by any other authorities --, it does not point to the conclusion which the Coalition would draw from it. This is because Mr. Holt (1) additionally alluded to a significant seismological difference between the Cape Ann and New Madrid areas (R.Tr. 405); and (2) expressed the opinion that the coincidence of an intrusive and a fault in the Cape Ann area would not occasion an earthquake greater than magnitude 6 (which represents an intensity of approximately VIII) (R.Tr. 388-89). In this connection, it should be noted that the Cape Ann earthquakes have never been thought to have exceeded Intensity VIII and that at least the 1755 one is now regarded in many quarters as of Intensity VII. See ALAB-422, supra, 6 NRC at 57, 62. Further, Coalition counsel did not endeavor to cross-examine Mr. Holt respecting his stated belief that, his intrusive theory notwithstanding, the maximum earthquake to be expected in the Cape Ann area is an Intensity VIII.

III.

We now turn to the second question before us: whether the staff's methodology for correlating vibratory ground motion (acceleration) with the safe shutdown earthquake is consistent with the requirements of Appendix A to 10 CFR Part 100. See p. 9, supra. By a divided vote, we had given an affirmative response to that question in ALAB-422, supra. In calling upon us to consider it further on the remand, the Commission did not discuss the analysis which led to that response. Rather, it simply stated that "more evidence" should be taken on the question and that, "[i]n particular, the parties should provide a discussion of the relation between the mean of the maximum ground accelerations and the maximum effective ground acceleration." CLI-80-33, supra, 12 NRC at 298.

In the circumstances, it may reasonably be presumed that the concern which prompted the Commission's remand on the acceleration issue had its roots in Mr. Farrar's view, in dissent from the majority conclusion in ALAB-422, that the staff's approach to the correlation of earthquake intensity and acceleration levels does not comport with Appendix A. See ALAB-561, supra, 10 NRC at 431. On that premise, to place the evidence adduced on remand in its proper context, we start with a review of what was said in

ALAB-422 and ALAB-561 on the subject based upon the content of the record which had been developed before the Licensing Board.

A. As seen from those decisions, the witnesses testifying below on the intensity-acceleration correlation did not disagree respecting the arithmetic mean value of the acceleration peaks which would be associated with an Intensity VIII earthquake.[46/] Employing the same basic data (much of which had been collected by Dr. Trifunac himself), the witnesses all expressed the opinion that that value was not in excess of 0.25g. ALAB-422, 6 NRC at 62.

The controversy centered instead upon whether a 0.25g mean value should be used in the design of the Seabrook facility. As summarized in ALAB-422, id. at 62-63:

> Dr. Trifunac pointed out that there is a wide variation in the value of the acceleration peaks included in the calculation of the mean. He noted that the standard deviation was approximately 50 percent of the mean value. He therefore suggested that the "reasonable upper bound" for the design horizontal acceleration should be the mean value plus one standard deviation, or approximately 0.4g. (NECNP Exh. 8, p. 3).

46/ As the term has uniformly been used in this proceeding, "mean" refers to the arithmetic mean or average of the values under consideration.

> The other witnesses uniformly expressed the contrary view that 0.25g was an acceptable design value for the Seabrook facility. Dr. Newmark testified without contradiction that the highest acceleration peaks are associated with the highest frequency ground waves. These high frequency waves would be fully recorded by the relatively small and compact seismographs, but yet would have no significant effect on the large massive structures of a nuclear facility (Newmark Dir. Test., fol. Tr. 2813, p. 7). Thus, included in the mean of the acceleration peaks are a number of high frequency peaks which can be discounted insofar as this facility is concerned.

Our analysis of these divergent opinions culminated in an affirmance of the Licensing Board's acceptance of the 0.25g value. Several factors prompted that result.

First we read Section VI(a) of Appendix A as requiring the employment for design purposes of the effective "maximum vibratory acceleration at the elevations of the foundations of the nuclear power plant." On this interpretation, we saw no regulatory bar to the exclusion from consideration of high frequency waves which would have no discernible impact upon the facility (i.e., were not "effective") -- which in turn would make resort to the mean of the peak accelerations sufficiently conservative. Id. at 63.

Second, we referred to a table supplied by Dr. Trifunac in conjunction with his testimony below, which provided data

for peak accelerations as a function of intensity in the western United States.[47] That table reflected a mean horizontal peak acceleration for an Intensity VIII earthquake of approximately 0.167g with a standard deviation of slightly more than 0.08g -- i.e., a combined value of almost precisely 0.25g. These data thus lent support for the 0.25g design value consistent with Dr. Trifunac's view that, because it serves to compensate for the fact that the maximum peak acceleration exceeds the mean, a standard deviation should be added to the latter. Id. at 63-64.

In this connection, we took note of the reason assigned by Dr. Trifunac for adopting a mean value of 0.25g rather than 0.167g: that peak accelerations at hard rock sites (such as Seabrook) are considerably greater than those at alluvium sites.[48] As we saw it, however, that explanation was countered by the additional consideration that the record further disclosed that the increased peak accelerations at hard rock sites are occasioned by high frequency ground waves which do not affect heavy concrete structures. Id. at 64.

47/ The table now appears as Table 3 in Trifunac and Brady, On the Correlation of Seismic Intensity Scales With the Peaks of Recorded Strong Ground Motion, 65 Bull. of the Seismological Society of America 139, 146 (1975). This article is discussed further, infra, p. 48.

48/ The data in his table had been derived from accelerations associated with varying geological conditions.

For his part, both in his brief dissent to ALAB-422 and in the later elaboration of his views in ALAB-561, Mr. Farrar agreed that Appendix A is concerned with the greatest "effective" vibratory acceleration which might result from the occurrence of an earthquake of the predicted intensity. 6 NRC at 113; 10 NRC at 431-32. He also acknowledged that "the evidence seemingly left no room for doubt that the extremely high frequency waves which can cause the highest accelerations are of such short duration and low energy that they will have no real consequences". 10 NRC at 432. Nonetheless, in his judgment, the utilization of the mean of the peak accelerations was forbidden by Appendix A. Pointing to the fact that the record disclosed that the peak acceleration values being averaged differ from each other by as much as a factor of ten, he expressed the view that "the average of all of them has no demonstrable relationship to the maximum effective acceleration that occurred during the one earthquake where damaging accelerations were the highest". Id. at 434.

For this reason, Mr. Farrar rejected not only the majority's acceptance of the approach of the applicants and staff, but also that of the intervenor Coalition. (On the latter score, he opined that "taking the 'mean of the peaks plus one standard deviation' * * * suffers (although to a lesser extent) from the same defective rationale as does use of the mean itself". Ibid). Rather,

what he thought to be required was a different kind of analysis, said to have received our approval in Consolidated Edison Co. (Indian Point Station, Units 1, 2 and 3), ALAB-436, 6 NRC 547, 584-85 (1977). Specifically, he would have called for an evaluation of the frequency spectrum associated with individual peak accelerations on seismograms for the purpose of obtaining "the highest magnitude associated with the frequencies in the damaging range. The magnitude thus determined would serve as the value representative of the particular intensity in question; in other words, it would be correlated with the intensity scale in the same manner that the 'mean of the peaks' currently is". 10 NRC at 436-h, fn. 12.

The majority's rejoinder to this thesis was that there are insufficient available base data applicable to the New England region to permit its adoption. In this connection, it noted that only one New England earthquake (the 1755 Cape Ann event) is generally acknowledged to have been possibly of intensity VIII. Id. at 436-g, 436-h. Further, the majority reiterated its belief that the methodology of the staff and applicant is not proscribed by Appendix A and that the addition of the error factor (standard deviation) advocated by the Coalition was unwarranted. Id. at 436-h.

B. Against this background, we proceed to the additional evidence adduced on the remand on the question whether the staff's methodology for correlating vibratory ground motion with the safe shutdown earthquake comports with Appendix A requirements. On this issue, as on the intensity question, the staff presented the testimony of a panel of witnesses consisting of Messrs. Knight and Jackson and Dr. Reiter. Dr. Trifunac testified as a Board witness.[49/]

In essence, the staff witnesses elaborated upon the description of staff procedures which had been provided the Licensing Board several years ago (i.e., there does not appear to have been a significant alteration in those procedures during the intervening period).[50/] Once the safe shutdown earthquake for the particular reactor site has been ascertained (in this instance a seismic event of Intensity VIII), the next step is the determination of the peak acceleration which is associated with that earthquake.

49/ The applicants' witness on the intensity question (Mr. Holt) did not appear as a witness on the acceleration issue although some of his prepared testimony touched upon that issue.

50/ In part, these procedures are outlined in Regulatory Guide 1.60 (Revision 1, December 1973), entitled "Design Response Spectra for Seismic Design of Nuclear Power Plants."

For this purpose, the staff now utilizes a relationship between intensity and peak accelerations which had been suggested by Trifunac and Brady in an article published in 1975.[51] In that article, the authors had employed the largest data base then available with regard to earthquakes in the western United States to calculate the mean value of peak acceleration in each intensity class. They then drew a straight line to indicate a trend for the calculated means of the acceleration values.[52] Although not expressly stated in the article, Figure 3 and Table 1 therein[53] reflect that the trend line would indicate a peak acceleration value of 0.25g for Intensity VIII. As previously noted, however, the recorded data indicated that the actual mean of the peak accelerations for that intensity level was 0.167g, with a standard deviation of approximately 0.08g. See pp. 43-44, supra; see also R.Tr. 645, 649. This discrepancy may explain the admonition in the article that "these average trends [should not] be used to derive the expected peak values of ground motion in terms of Modified Mercalli intensities." Rather, according

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51/ See fn. 47, supra. The entire content of the article was before the Licensing Board as an appendix to his testimony (introduced into evidence as NECNP Exhibit 8 at Tr. 3101).

52/ Trifunac and Brady, supra fn. 47, at 140.

53/ Id. at 143.

to Drs. Trifunac and Brady, "if a result of this type is desired, we do recommend that [all available data on ground acceleration, velocity and displacement] be considered and that the peak values be selected on the basis of a pre-defined degree of conservatism."[54/]

Having selected a peak acceleration for the SSE on the basis of the trend line of Trifunac and Brady (despite the authors' admonition not to do so), the third step in the staff methodology is the selection of a response spectrum.[55/] This spectrum determines the level of response to ground motion that is to be expected over the entire range of frequencies. For Seabrook, the shape of

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54/ Id. at 149.

55/ A response spectrum is the result of an analytical procedure whereby a number of one-degree-of-freedom harmonic oscillators, each having the same degree of damping but with different natural frequencies, are driven by the time-dependent motion characteristic of a real or postulated seismic event. For a particular event and degree of damping there will be a time-dependent response which varies for oscillators of the different frequencies. The maximum values of the response of the oscillators in terms of acceleration, velocity and displacement, may be plotted as a function of the frequency of the oscillators being excited. Such a plot can be produced for any one of the three parameters taken individually. Because of the relationship among acceleration, velocity and displacement under harmonic motion, a tripartite plot showing the maximum responses in acceleration, velocity and displacement as a function of oscillator frequency may also be prepared (see e.g., Regulatory Guide 1.60, supra fn. 50, Figure 1). Pacific Gas and Electric Co. (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-644, 13 NRC 903, 924 fn. 40 (1981).

the response spectrum used was that of the standard spectrum of Regulatory Guide 1.60, supra fn. 50. As described by Dr. Reiter, that spectrum "is essentially the mean plus one sigma spectral shape derived after normalizing a series of earthquake records to the same peak acceleration or high frequency response." Reiter, fol. Tr. 493, at p. 18. The very high frequency (at least 30 cycles per second), or anchor point, of the spectrum was set by the staff to be equivalent to the peak acceleration that had been selected for the Seabrook SSE (i.e., 0.25g for Intensity VIII).

In summary, as applied at Seabrook, the staff's methodology progressed from characterization of a safe shutdown earthquake for the site, through the selection of a peak acceleration for that earthquake, to the formulation of a response spectrum — the latter being a device which is intended to establish, at every frequency, the maximum level of response to ground motion representative of the SSE.

What we are called upon to decide, then, is whether this approach comports with the Appendix A requirement that the seismic design of a nuclear power facility take account of the maximum effective vibratory acceleration which might accompany the determined SSE for that facility (as seen from the background statement, pp. 41-46, supra, there is no present disagreement that the Appendix

is concerned solely with ground motion which might have an impact on the facility's safety-related structures and components).[56/]

As we see it, resolution of that issue necessitates going beyond the foreshortened statement posed to us by the Commission of "the relation between the mean of the maximum ground accelerations and the maximum effective ground acceleration" (see p. 41, supra).

56/ At this juncture, it may be helpful to recite the two pertinent portions of Appendix A.

V. SEISMIC AND GEOLOGICAL DESIGN BASES

(a) Determination of Design Basis for Vibratory Ground Motion.

(1) Determination of Safe Shutdown Earthquake.

* * * * *

(iv) The earthquake producing the maximum vibratory acceleration at the site, as determined from paragraph (a)(1)(i) through (iii) of this section shall be designated the Safe Shutdown Earthquake for vibratory ground motion, except as noted in paragraph (a)(1)(v) of this section. The characteristics of the Safe Shutdown Earthquake shall be derived from more than one earthquake determined from paragraph (a)(1)(i) through (iii) of this section, where necessary to assure that the maximum vibratory acceleration at the site throughout the frequency range of interest is included. * * *

VI. APPLICATION TO ENGINEERING DESIGN

(a) Vibratory ground motion-(1) Safe Shutdown Earthquake. The vibratory ground motion produced by the Safe Shutdown Earthquake shall be defined by response spectra corresponding to the maximum vibratory accelerations at the elevations of the foundations of the nuclear power plant structures determine [sic] pursuant to paragraph (a)(1) of Section V. * * *

For the selection of a peak acceleration is but a step along the way. The staff's ultimate representation of the SSE is the response spectrum, which perforce encompasses a measure of the motion of the SSE at all frequencies. The peak acceleration value is employed simply to anchor that spectrum, and should be viewed in that context. (See Jackson, fol. R.Tr. 493, at p. 10; Reiter, fol. R.Tr. 493, at p. 18). In this regard, the selection of a peak acceleration and the use of it to determine the anchor point of a standard spectrum is but one of many ways to arrive at a response spectrum characteristic of the SSE (Reiter, at p. 19; R.Tr. 635).[57/]

Thus, in the last analysis, the acceptability of the staff's methodology in terms of Appendix A hinges upon whether that methodology does, in fact, produce a response spectrum at Seabrook which properly reflects the maximum vibratory acceleration, throughout the frequency range of interest, for the Intensity VIII event which has been selected for the SSE.

The staff witnesses testified that they used the Trifunac and Brady relationship between acceleration and intensity to select an anchor point acceleration because the combination of that anchor point acceleration and the Regulatory Guide 1.60 spectrum shape provides a conservative result (that is, it

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57/ Dr. Reiter noted that, were more data available, it would be preferable to have response spectra obtained for the SSE directly, rather than going to the intermediary step of a peak acceleration. (Reiter, fol. R.Tr. 493, at p. 19).

exceeds, by about one standard deviation, the spectrum that actually would be expected should the SSE be experienced at the site). Jackson, fol. R.Tr. 493, at pp. 14-15; R.Tr. 705-708. As a demonstration that this is so, they presented a comparison of the Seabrook response spectrum with several response spectra representative of Intensity VIII (Reiter, fol. R.Tr. 493, at pp. 15, 23-25, Figures 1, 2 & 3). The Seabrook spectra exceeded these spectra, and exceeded the mean plus one standard deviation (i.e., one sigma) spectra where that was displayed. The testimony of applicants' witness Holt also demonstrated that the Seabrook spectrum exceeds the "one plus sigma" spectrum determined from a worldwide set of strong motion records for a range of epicentral Intensities, VII to XI, with a mean value IX (the Seabrook Intensity is VIII) (Holt, fol. R.Tr. 349, at pp. 6-7, Figures 9, 10, Table 1).

Finally, the Seabrook spectrum was subject to a test of its conservatism by the method favored by Dr. Trifunac.[58/] He used probabilistic methods to determine Uniform Risk Spectra - spectra for which there is a constant probability that the plotted value will be exceeded in a 50 year period. To obtain probabilistic estimates of the seismicity at the Seabrook site, Dr. Trifunac used the projection of Dr. Chinnery (modified to yield events per 1000 km^2), and a pessimistic version of that projection. For the former, Dr. Trifunac computed that there would be less than a 5%

58/ Trifunac, fol. R.Tr. 729, at 8-9, Figs. 3 and 4.

chance of the Seabrook spectrum being exceeded in 50 years, even if the maximum earthquake intensity for the region was assumed to be XII.[59] Using the pessimistic seismicity estimate, those probabilities were assessed at less than 5% and less than 30%, for assumed regional maximum Intensities of VIII and XII respectively.

From these results, Dr. Trifunac himself concluded that:

> The above probabilistic calculations suggest that the proposed SSE design spectra for Seabrook site (corresponding to 0.25g peak acceleration) may be acceptable. However, before I can finalize this conclusion, I would have to carry out additional and more detailed calculations to find whether [his model of seismicity] is indeed a "sufficiently pessimistic" representation of possible seismicity during the next 50 years.[60]

59/ Dr. Trifunac agreed that an earthquake which resulted in motions which exceeded the design response spectrum at some frequency range would not necessarily lead to an accident. R.Tr. 760. See also Reiter, fol. R.Tr. 493, at pp. 24-25.

60/ Trifunac, fol. R.Tr. 729, at p. 10. Our review of Dr. Trifunac's method indicates that it already contains certain conservatisms (i.e., is pessimistic). For example, Figure 1 of his current testimony indicates a mean value of peak acceleration for an Intensity VIII event of about 0.3g. Table 1 of the Holt testimony (see p. 53, supra) gives the mean value of 13 earthquakes in the Intensity range VII to XI as about 0.14g, and the mean plus one sigma value about 0.2g. See also, p. 48, supra.

On the basis of all of the foregoing evidence, it is reasonable to conclude that the methodology employed by the staff at Seabrook, which included using the appropriate mean peak acceleration of Trifunac and Brady as the anchor point for a Regulatory Guide 1.60 spectrum, provides an upper level, or maximum, characterization of the range of ground motion to be expected in the event of an Intensity VIII event. This being so, we are satisfied that the methodology does not offend Appendix A.

For the foregoing reasons, we reaffirm our determination in ALAB-422, supra, that the Seabrook safe shutdown earthquake is of Intensity VIII with an associated maximum vibratory ground motion of 0.25g.

It is so ORDERED.

FOR THE APPEAL BOARD

C. Jean Shoemaker
Secretary to the
Appeal Board

ATTACHMENT 2

UNITED STATES OF AMERICA

before the

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NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, et al.	)	Docket Nos. 50-443 50-444
(Seabrook Station, Units 1 & 2)	)	

NEW ENGLAND COALITION ON NUCLEAR POLLUTION
PETITION FOR REVIEW OF ALAB-667

Pursuant to 10 CFR 2.786(b), the New England Coalition on Nuclear Pollution ("NECNP" or "the Coalition") petitions the Nuclear Regulatory Commission to review the decision by the Atomic Safety and Licensing Appeal Board in ALAB-667, issued March 3, 1982.1/ This Petition derives from gross errors in the Appeal Board's handling of the proceeding below and from the need for Commission involvement and guidance in the area of determining seismic design criteria for nuclear reactors in the entire Eastern United States.

I. Background and Summary of the Decision

The decision that is the subject of this Petition for Review stems from a Commission Order reversing a previous Appeal Board decision and holding that the probabilistic method of estimating earthquake return periods for various regions, which had been presented below by Dr. Michael Chinnery of the Massachusetts Institute of Technology and which would result in the choice of a higher intensity safe shutdown earthquake (SSE), was consistent

1/ Public Service Company of New Hampshire (Seabrook Station, & 2), Docket Nos. 50-443, 50-444, ____NRC____.

with 10 CFR Part 100, Appendix A. The Commission directed the Appeal Board to take further evidence on "the factual validity of Dr. Chinnery's hypothesis," and on the consistency of Appendix A and the Staff's methodology for correlating vibratory ground motion with the SSE. 2/

With respect to Dr. Chinnery's methodology, the Appeal Board found on remand that it "has not been shown to be a credible means of predicting the intensity of seismic motion at a particular site." ALAB-667 at 39. This decision was based on two independent conclusions: (1) that Dr. Chinnery's methodology allows the probabilistic prediction of earthquake recurrence times only for the region surrounding the Seabrook site and, therefore, it cannot be used to predict the probability of earthquake intensities for the site itself, and (2) that the methodology is invalid as a matter of scientific fact for various reasons. The decision also depends upon a rejection of the proposition, established through the testimony of the Applicant's witness, that earthquakes substantially larger than Intensity VIII, the SSE, may occur quite close to the Seabrook site.

With respect to the Staff's method of correlating vibratory ground motion with the SSE, the Board concluded that it "provides an upper level, or maximum, characterization of the range of ground motion to be expected in the event of an Intensity VIII event," and "does not offend Appendix A." ALAB-667 at 55. This decision appears to be based primarily on the fact that the Staff's result compares favorably with the result of other methods and on the fact that Dr. Trufunac thought the pro-

2/ Public Service Company of New Hampshire (Seabrook Station, Units 1 & 2), CLI-80-33, 12 NRC 295(1980).

bability of an earthquake exceeding the design basis during the life of the plant "may be acceptable."

II. Errors As To Which Review is Sought

The Appeal Board's decision in ALAB-667 purports to review the evidence with respect to these two issues and then to reach reasoned decisions on the basis of that evidence, and presumably on the basis of applicable standards for evaluating scientific evidence of this type. In fact, the decision does no such thing. To the contrary, the Appeal Board treated virtually every honest qualifying statement by Dr. Chinnery as a damaging admission, while accepting the most tenuous and unsupported assertions by the Staff and Applicant at face value. Similarly, the Board accepted the Staff's defense of its methodology for correlating vibratory ground motion with the SSE while ignoring both (1) the unrefuted testimony of Dr. Trifunac demonstrating the lack of a rational basis for the Staff's approach and (2) the fundamental principle of conservatism that the Commission itself has decreed is particularly applicable to this decision on seismic issues. CLI-80-33, supra, 12 NRC at 297.

This pervasive one-sided treatment of the evidence in this proceeding may be the necessary result of the Board's attempt to evaluate the issues without reference to any standard by which to judge the evidence, the validity of Dr. Chinnery's hypothesis, or the acceptability of the results of the Staff's methodology for correlating vibratory ground motion with the SSE. As a result, the Board's decision is arbitrary and capricious in that it cannot be based on relevant factors and does not

constitute reasoned decisionmaking required of administrative agencies. Mobil Oil Corp. v. Department of Energy, 610 F.2d 796, 801 (Temp. Emer. Ct. App. 1979), Greater Boston Television Co. v. Federal Communications Commission, 444 F.2d 841, 851-53 (D.C. Cir. 1970), cert. denied 91 S. Ct. 2229, 2233 (1971). We set out below the particulars of this and other errors of fact and law. In each case, we state where these issues were previously raised before the Appeal Board.

A. The Board erred as a matter of law in ruling that factual questions concerning the uncertainties in the Staff and Applicant methods for determining the SSE were beyond the scope of the proceeding and denied NECNP the opportunity to address and establish those uncertainties so that they could be compared with any uncertainties found in Dr. Chinnery's method. As a result, the Board had no standards by which to judge Dr. Chinnery's methodology, and no basis for knowing whether, despite its flaws, it was superior to the Staff and Applicant approaches. Order Denying Motions to Compel, filed February 12, 1981. Accordingly, the decision is arbitrary and capricious, particularly since it necessarily constitutes a judgment that the Staff's approach is superior to Dr. Chinnery's.

B. The Board erred in failing to accept or develop a rational standard for judging the threshhold "validity" of Dr. Chinnery's hypothesis in the absence of a comparative approach, again rendering its decision arbitrary and capricious and without a rational foundation, and precluding effective administrative or judicial review. NECNP Proposed Findings at 10-12.

C. The Board erred in ruling that Dr. Chinnery's methodology is invalid for determining the SSE because it provides probability estimates only for the region surrounding Seabrook and not for the site itself. ALAB-667 at 38-39. In so doing, the Board violated Appendix A, which requires, inter alia, that the maximum potential earthquake in the tectonic region containing the site be assumed to occur at the site. That mandate applies whether the maximum earthquake is based on the largest historic earthquake, whose actual probability is utterly unknown, or whether it is based on a rational means of estimating the probability of occurrence of earthquakes of given intensities. NECNP Proposed Findings at 48-50.

D. The Board erred as a matter of law and Commission policy in crediting Staff testimony to the effect that efforts similar to Dr. Chinnery's have produced a wide variation in slopes of the function used to predict or assess earthquake return times, but ignoring the fact that Dr. Chinnery's probabilities, while at the non-conservative end of that range, are still more conservative than the results of the Staff and Applicant approaches. ALAB-667 at 21. In so doing, the Board violated the requirement to take a conservative approach in licensing decisions, particularly with respect to seismic issues. NECNP Proposed Findings at 18-19.

E. Similarly, the Board erred as a matter of law and policy in crediting Staff and Applicant testimony that challenged Dr. Chinnery's methodology on geologic grounds, while ignoring or discounting applicant testimony demonstrating that there are geologic reasons to believe that an earthquake as large as Intensity XII can occur very near the Seabrook site. ALAB-667

at 22-23, 25-26. Again, the Board violated the Commission's mandate for conservatism in licensing decisions. NECNP Proposed Findings at 4-9.

F. The Board erred as a matter of law and procedure in relying on a publication critical of the use of Intensity grades to characterize earthquakes, without providing NECNP with any notice that it intended to do so or giving Dr. Chinnery the opportunity to explain why their use is nonetheless valid in this context, as he would have done. ALAB-667 at 15, n. 19. This issue has not previously been raised since NECNP had no knowledge that the Board would rely on extra-record material.

G. The Board erred as a matter of law and policy in ignoring the serious issue of whether Reg. Guide 1.60 can be used as it is by the Staff, when there is no rational basis for doing so and the approach is contrary to the basis on which Reg. Guide 1.60 was developed. NECNP Proposed Findings at 42-43.

H. The Board erred as a matter of law and policy in basing its decision in part on Dr. Trifunac's rough 5% probability estimate of the probability of exceeding the Seabrook design spectrum during the life of the plant. This is invalid because it violates the conservatism mandate and, more importantly, because it is a decision reached in a vacuum, with no policy direction from the Commission or other basis for accepting a probability that amounts to one chance in twenty that the plant's design basis will be exceeded during its 40 year life. ALAB-667 at 54, NECNP Proposed Findings at 45-46.

I. The Board erred as a matter of law and procedure in failing to strike portions of Staff and Applicant testimony

objected to by NECNP as beyond the scope of the proceeding under the Board's own order establishing that the proceeding was limited to the validity of Dr. Chinnery's methodology. The testimony in question concerned the application of Dr. Chinnery's methodology, the probability of earthquake occurrence at the site rather than in the tectonic region, and inherent conservatisms in the design of Seabrook. NECNP had no opportunity to respond to any of this testimony or to prepare a case in those areas, particularly in light of the Board's narrow ruling on the scope of the proceeding. The failure to strike this testimony is also extremely prejudicial, since the themes that this testimony promotes pervade the decision. NECNP Proposed Findings at 46-50.

III. The Commission Should Exercise Review

This case involves fundamental questions of law and policy that bear on the very validity of the Commission's decisionmaking process. It also involves serious questions of the fairness of Commission proceedings.

The most serious issue, which is raised by points II(a), (B), and (H) above, is the lack of any standards by which the Board reached its judgments. Dr. Chinnery's methodology was not judged against any ideal method of estimating earthquake probabilities or against any accepted method of determining the SSE, such as that used by the Staff. Instead, it was judged in a vacuum, so that the Board's factual conclusions, even if correct, are essentially meaningless. Several examples illustrate this point:

1. The Board discounted Dr. Chinnery's methodology because he drew his data from various different time periods. However, there is no record basis for a conclusion that this methodology is inherently invalid, and there is no standard against which it can be evaluated to reach such a conclusion. ALAB-667 at 17-19, 34.

2. The Board attacked Dr. Chinnery's failure to reconsider his conclusions based on new data, ignoring the fact that Dr. Chinnery's conclusions did not depend on those data. ALAB-667 at 36-37, n. 44. For some reason the Board believed this undermined the validity of Dr. Chinnery's methodology, although there is no standard by which to reach this conclusion, or even by which to compare Dr. Chinnery's use of data to similar actions by the Staff. Even if these were serious flaws, they would not render the Chinnery hypothesis invalid for this proceeding if the hypothesis as a whole is no more seriously flawed than the Staff and Applicant approaches.

3. Operating in a vacuum, the Board accepted Staff testimony that the data could be used to develop highly complex relationships, ignoring the scientific principle espoused by Dr. Chinnery and uncontradicted in the record that the simplest relationship consistent with the data must be used in the absence of a compelling scientific or theoretical basis for a more complex relationship. ALAB-667 at 18. Not only did the Board have no basis for this judgment, it rejected in this instance one of the few standards offered by any party. The error is particularly egregious because it also constitutes a rejection of a fundamentally conservative, well-founded scientific approach in favor of what amounts to gross speculation.

4. The Board rejected Dr. Chinnery's conservative and scientifically based conclusion that the state of scientific knowledge does not permit a firm conclusion that an earthquake of Intensity X or greater cannot occur in the Seabrook area, with no basis for determining whether the basis for Dr. Chinnery's conclusion was equivalent to or stronger than those of the Staff or Applicant. Since NECNP was precluded from addressing Staff and Applicant uncertainties, a fair comparison was impossible. ALAB-667 at 27.

The second major issue, although closely related, is predominantly one of procedure - the manifest unfairness of allowing two parties to criticize the methods espoused by NECNP, while denying NECNP the right to present similar criticism and to develop a record that would have demonstrated that our method is at least the equal of the Staff's and the Applicants. A

clear example here is the Board's utter failure to deal with the fact that neither the Staff nor the Applicant could have predicted the two major Mississippi Valley and Charleston earthquakes before they occurred. That fact, alone, demonstrates a fatal weakness in the Staff and Applicant methods, yet the Board ignored it in criticizing Dr. Chinnery. This prejudicial approach is apparent i several areas of the decision. ALAB-657 at 21, 22-23, 25-26, 27, 28-34. See Part II (E) above.

Third, Commission review is required here to provide guidance and assure integrity and consistency in future seismic decisions, particularly those involving sites in the Eastern United States. Given that probabilistic methodology is consistent with Appendix A, as previously decided by the Commission, it is crucial to determine whether the resulting probability estimates relate to tectonic provinces, as envisioned by the regulation, or to particular sites, as the Board seems to believe. Similarly, it is essential that the Commission address acceptable probability levels, including the 5% in 40 years standard apparently adopted by the Board, and that it examine the use of Reg. Guide 1.60 in light of the fact tht it is used by the Staff in a manner contrary to the original intent. Even if the result is acceptable at Seabrook, that may be purely coincidental, so that Dr. Trifunac's criticisms must be considered before the Staff's approach is used elsewhere. See Part II (C), (G), and (H) above.

Fourth, conservatism is at the very heart of the licensing process, particularly here, where decisions are based primarily on informed judgment rather than actual knowledge or empirical conclusions. The Commission must act here to assure that its

tribunals do not stray from that mandate and to provide a clearer definition so that the difficulties encountered by the Appeal Board do not arise in the future. See Points II (D), and (E) above.

Finally, points II (F) and (I) raise serious issues of procedural fairness. It is unthinkable that the Board should rule on one hand that the scope of the proceeding is severely restricted, while later admitting prejudicial testimony that goes far beyond that scope. Similarly, it is unthinkable that the Board should be allowed to rely on extra-record material.

Conclusion

In order to protect the integrity of the Commission's proceedings, assure rational decisionmaking, and provide essential guidance in the development of seismic design criteria for nuclear reactors, the Commission should grant review of ALAB-667 and require that the record be completed and the decision reconsidered pursuant to relevant factors and accordant standard for judgment.

Respectfully submitted,

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UNITED STATES OF AMERICA

before the

NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, et al.	)	Docket Nos. 50-443 50-444
(Seabrook Station, Units 1 & 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that a copy of "New England on Nuclear Pollution Petition for Review of ALAB-667" was mailed first class postage prepaid this 23rd day of March, 1982 to the following:

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U.S. Nuclear Regulatory
Commission
Washington, D.C. 20555

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ATTACHMENT 3

UNITED STATES OF AMERICA

before the

NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, et al.	)	Docket Nos. 50-443 50-444
(Seabrook Station, Units 1 and 2)	)	

APPLICANTS' ANSWER TO NEW ENGLAND COALITION ON NUCLEAR POLLUTION PETITION FOR REVIEW OF ALAB-667

Background

In an initial decision authorizing issuance of the Seabrook construction permits, handed down on June 29, 1976, LBP-76-26, 3 NRC 857, an Atomic Safety and Licensing Board held the seismic design criteria of Seabrook to be adequate. 3 NRC at 868-71, 919-22. In so doing, the Licensing Board rejected the thesis of Michael A. Chinnery, Ph.D., that Seabrook's seismic design criteria should account for the possibility that an earthquake with an epicentral intensity of MMI IX in the "seismic zone" containing the Seabrook site had a probability of approximately 10^{-3} per year or greater. 3 NRC at 920. The Licensing Board also rejected the contention of the intervenor NECNP that, even

assuming that the proper SSE to be chosen for Seabrook was of an epicentral intensity of MMI VIII, the appropriate zero period acceleration to be used as the design criterion was 0.4g as opposed to the 0.25g actually selected by the NRC Staff. 3 NRC at 871, 921-22.

On July 26, 1977, the Appeal Board affirmed those findings and rulings of the Licensing Board, ALAB-422, 6 NRC 33, 57-60, 62-64, over the dissent of then Member Farrar, 6 NRC at 106, 111-13, who reserved the right to set forth at a later date "the full reasoning underlying [his] position", id. at 106. In affirming the Licensing Board, this Appeal Board rejected Dr. Chinnery's "probabilistic theory" as "both technically deficient and inconsistent with [10 CFR 100] Appendix A." 6 NRC at 60. NECNP's 0.4g contention was rejected and the 0.25g criterion accepted as reasonable on the basis of the testimony of the applicant and Staff witnesses, 6 NRC at 62-63, and as being buttressed by data presented by Dr. Mihailo Trifunac, 6 NRC at 63-64.

NECNP petitioned the Commission for review of both of these holdings; the Commission deferred review pending receipt of the promised "full reasoning" of Member Farrar. That "full reasoning" was issued two years later on August 3, 1979, ALAB-561,

10 NRC 410-36,[1] and failed to persuade the majority, see 10 NRC 436-a--h.

One more year later, on September 25, 1980, after an extraordinary session in which Dr. Chinnery, inter alia, was permitted to address the Commission not under oath, the Commission issued an order[2] with respect to the NECNP petition for review. CLI-80-33, 12 NRC 295. The Commission found, 12 NRC at 297, the Chinnery methodology not to be inconsistent with Appendix A. Next, the Commission found that a greater exploration on the record as to the "factual validity of Dr. Chinnery's hypothesis" was required and directed the Appeal Board to "reopen the record to take additional evidence on Dr. Chinnery's methodology and reconsider its opinion on this matter." Id. In addition, the Appeal Board was directed to "reopen the record to take more evidence on the consistency of Appendix A and Staff's methodology for correlating vibratory ground motion with the SSE," and to "reconsider its opinion on this matter". 12 NRC at 298.

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[1] It is ironic to note that Mr. Farrar originally based his view that Seabrook's SSE should be MMI IV on the convergence of three lines of evidence: (1) the Chinnery theory, (2) the Smith catalog assignment of MMI IX to the 1755 Cape Ann event, and (3) the supposed similarity of the Montreal geology to New England coupled with the MMI IX Montreal event. 6 NRC at 112-13. Since that time it is conceded by everyone with expertise that Smith overrated the 1755 event, and the Montreal event has been officially downgraded by Canadian authorities to MMI VIII. It is not clear that absent the convergence of the three lines, Member Farrar would have dissented.

[2] The vote was 2-1. Commissioner Hendrie had disqualified himself and there was a vacancy. Commissioners Bradford and Gilinsky voted to grant review. Commissioner Ahearne voted to deny review.

In due course, an evidentiary hearing was convened and held on April 6-9, 1981. On March 3, 1982, after full briefing of the issues, the Appeal Board issued ALAB-667, as to which the petition at bar seeks review.

In ALAB-667 the Appeal Board reaffirmed its prior conclusion as to the appropriateness of the Seabrook seismic design criteria. With respect to the two specific issues remanded to it made the following ultimate findings:

1. "In sum, we are compelled to conclude that Dr. Chinnery's methodology has not been shown to be a credible means of predicting the intensity of seismic motion at a particular site. Leaving aside the just discussed admitted limitations affecting its usefulness, we have seen that, had he employed relatively uniform criteria in the selection of regions and time periods for the purposes of his probabilistic analysis, the results would have been materially different from those which he presented and would have refuted his postulated linear frequency-intensity relationship." ALAB-667 at 39.

2. "On the basis of all of the foregoing evidence it is reasonable to conclude that the methodology employed by the staff at Seabrook, which included using the appropriate mean peak acceleration of Trifunac and Brady as the anchor point for a Regulatory Guide 1.60 spectrum, provides an upper level, or maximum, characterization of the range of ground motion to be expected in the event of an Intensity VIII event. This being so, we are satisfied that the methodology does not offend Appendix A." ALAB-667 at 55.

ARGUMENT

A. The Commission Should Not Review ALAB-667 Insofar as it Again Rejected The Chinnery Thesis

ALAB-667 marks the third time an adjudicatory board of this agency has rejected Dr. Chinnery's theory as a matter of fact. The question now presented is whether or not Dr. Chinnery should have yet another bite at the Seabrook seismic apple. He should not.

Dr. Chinnery managed in his oral presentation before the Commission on May 29, 1980, to convince a majority of the three sitting Commissioners that his theory was consistent with 10 CFR 100, Appendix A. Under oath on cross-examination the opposite appeared true:

> "Q All right. Now keeping that in mind, I come back, aren't you proposing the alteration of the Appendix A or modification to use your word to include a concept that it does not even include?
>
> "A Yes." R. Tr. at 18.
>
> * * *
>
> "Q Now, would you try my question, which is, is this another place where you would have us alter the language of Appendix A?"
>
> [Colloquy of board and counsel.]
>
> "A Mr. Dignan, I think altering the language of Appendix A would make it much clearer what the intent of the concept of a tectonic province is. I do not believe personally that you can define a tectonic province in A in a way which can be used to determine the safe shutdown of an earthquake without determining the seismicity of that province." R. Tr. 30-31.
>
> * * *

"Q And indeed what you wish to have the Commission do as a result of this proceeding is change Appendix A, isn't that right?

"A I have again mentioned this in many places.

"MR. DIGNAN: Mr. Chairman, I think I am entitled to a direct answer to that question.

"CHAIRMAN ROSENTHAL: I think, Dr. Chinnery, that question should be answered yes or no and then you will have an opportunity --

"THE WITNESS: May I have an opportunity to --

"CHAIRMAN ROSENTHAL: Elaborate on it. If Mr. Dignan doesn't give you the opportunity, I think someone else undoubtedly will.

"THE WITNESS: Thank you. Yes. My intent is that at some point in the future I would like to see the regulations changed. In the meantime before that point arises, I would like to see a somewhat more broad interpretation of the current regulations." R. Tr. 625-26.

In short, from Dr. Chinnery's own mouth, we now have the admission that his theory is not consistent with the Commission's regulations. In light of this, the Appeal Board's rejection of that theory for the second time is clearly not an issue worthy of Commission review.

B. The Commission Should Not Review ALAB-667 Insofar as it Upheld the Staff's Methodology

The record herein presents no case for review of the second issue decided by the Appeal Board.

The Staff's overall conclusion as to the acceptability of the Seabrook seismic design is uncontradicted in this record. Dr. Trifunac concluded that insofar as he had analyzed the

problem, the design "may be acceptable"; the reason for the "may be" was that he needed to do additional work (which he did not do). Trifunac 10.[3/] Dr. Chinnery adopted the Trifunac conclusion. Tr. 46. Dr. Trifunac characterized the Staff methodology, assuming the correct SSE is MMI VIII, to be "conservative". Tr. 794-95. He said if the SSE were a MMI X, it still would be conservative "in a crude fashion". Tr. 796. Finally, he deemed it "acceptable" under Appendix A. Tr. 762, 797-98. Thus, the evidentiary record is bereft of any legally significant conflict on this issue.

C. The Remainder of The Petition Presents No Issue Worthy of Review

NECNP complains of the denial of its motion to strike testimony. Nothing is less worthy of appellate review than a denial of a motion to strike; the grant of such a motion might in some circumstances be prejudicial; the denial never is. The issue of alleged reliance on extra record material is equally unworthy of review. It is an issue having no significance beyond the case and, indeed, the only reliance on extra record material

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3/ Dr. Trifunac's analysis showed that, given Dr. Chinnery's hypothesis but limiting it to a maximum intensity of VIII, the probability that the Seabrook design criteria (i.e., the Reg. Guide 1.60 spectral shape anchored at 0.25g) would be exceeded is substantially less than .05. Trifunac, Fig. 3. Indeed, the probability of such an occurrence is .05 or less even if Dr. Chinnery's hypothesis is accepted together with his hypothesis of no upper bound on earthquake intensity. Id. The probability of exceeding the design criteria in the range of relevant frequencies (1-15 cps; period = .07 - 1.0 sec.) is even lower.

complained of, ALAB-667 at n.19, was used only as a cumulative reason for rejecting a statement of Dr. Chinnery as to the conclusions to be drawn from the work of another.

NECNP complains of the Appeal Board's ruling that this proceeding was not one for the purpose of comparing methodologies. The ruling was correct. The Commission instructed the Appeal Board to take up the validity of Dr. Chinnery's theory; no direction was given to go beyond that issue and, in light of its rejection, there is no need to do so. Equally without merit is the complaint that the Staff and Applicants could not have predicted the major southern earthquakes before they occurred. The Staff and Applicants are not trying to prove they can predict earthquakes; only Dr. Chinnery claimed that ability.

CONCLUSION

The Petition should be denied.

Respectfully submitted,

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April 1, 1982

CERTIFICATE OF SERVICE

I, Thomas G. Dignan, Jr., one of the attorneys for the applicants herein, hereby certify that on April 1, 1982, I made service of the within document by mailing copies thereof, postage prepaid, to:

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Washington, D.C. 20555

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ATTACHMENT 4

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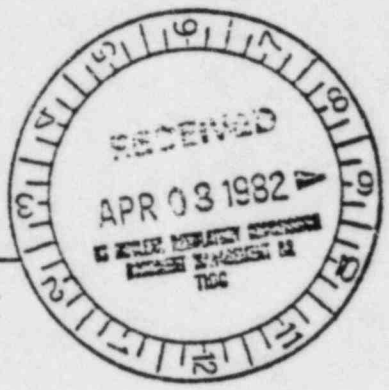

RESPONSE OF THE NRC STAFF IN OPPOSITION TO NEW ENGLAND COALITION FOR NUCLEAR POLLUTION'S PETITION FOR COMMISSION REVIEW OF ALAB-667

Roy P. Lessy
Deputy Assistant Chief
Hearing Counsel

April 7, 1982.

DESIGNATED ORIGINAL

Certified By

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I. INTRODUCTION

On March 3, 1982, the Atomic Safety and Licensing Appeal Board issued ALAB-667, a "Decision On Remand" with respect to the two seismic issues remanded by the Commission to the Appeal Board in the construction permit phase of this proceeding.[1/] CLI-80-33, 12 NRC 295 (September 25, 1980) (hereafter "remand order.") In its remand order, the Commission directed the Appeal Board to reopen the record, and reconsider its previous views[2/] with respect to two discrete seismic issues, viz.: (1) the "factual validity" of the methodology of Dr. Michael Chinnery,[3/] that there is an empirical relationship between earthquake intensity and earthquake recurrence time; and (2), whether the Staff's methodology for correlating vibratory ground motion (acceleration) is consistent with Appendix A to 10 C.F.R. Part 100.

1/ The operating license phase of this proceeding is now underway with petitions for intervention and requests for a hearing pending before a board designated to rule on such petitions.

2/ See ALAB-422, 6 NRC 33, 54-65 (1977) and ALAB-561, 10 NRC 410, 436 et seq. (1979).

3/ Dr. Chinnery was an expert witness testifying on behalf of the petitioner, New England Coalition on Nuclear Pollution ("NECNP").

Subsecuent to an evidentiary hearing held before the Appeal Board during the week of April 6th, 1981, the Appeal Board concluded "that Dr. Chinnery's methodology has not been shown to be a credible means of predicting the intensity of seismic motion at a particular [nuclear power plant] site" (ALAB-667, Slip Op. at 39). Thus, the Appeal Board concluded that the present seismic design of Seabrook of Modified Mercalli Intensity VIII, with an associated maximum vibratory ground motion of 0.25g, Regulatory Guide 1.60, is acceptable. Finally, the Appeal Board concluded that the Staff's methodology for correlating vibratory ground motion, which included using the appropriate mean peak acceleration of Trifunac and Brady as the anchor point for a Regulatory Guide 1.60 response spectrum, was consistent with (i.e., "did not offend") Appendix A to 10 C.F.R. Part 100 (Slip Op. at 55).

On March 22, 1982, NECNP filed the instant petition for Commission review under the authority of 10 C.F.R. § 2.786(b). Under the provisions of 10 C.F.R. § 2.786, a party to a proceeding may file a petition for review of an Atomic Safety and Licensing Appeal Board decision with the Commission on the ground that the decision is erroneous with respect to an important question of fact, law or policy, involves an important procedural issue, or otherwise raises important questions of public policy. It is the view of the NRC Staff that none of these requisite elements are raised by the instant petition for review of ALAB-667. Accordingly, and for the reasons discussed below, the petition for review should be denied.

II. DISCUSSION

A. Standards Utilized By The Appeal Board

NECNP contends that "[t]he most serious issue . . . is the lack of any standards by which the Board reached its judgments" (Petition, p. 7).

Thus, NECNP argues that this constitutes "an arbitrary and capricious" approach, ". . . without a rational foundation" (Petition, p. 4).

Initially it must be noted that NECNP has failed to address the requirements of the governing regulation, as to why this assignment of error constitutes an important matter of law or policy that could significantly affect the environment, the public health and safety, or otherwise raise important questions of public policy. See 10 C.F.R. § 2.786(b)(4)(i). Moreover, NECNP has failed to recognize the standards by which Dr. Chinnery's methodology was, in fact, evaluated by the Appeal Board. Four discrete steps were utilized by the Appeal Board in reaching a judgment, as directed by the Commission in its remand order, of "the factual validity" of Dr. Chinnery's methodology.

The first step was to describe the methodology as consisting of four basic assumptions, each of which must be correct assumptions in order for the results of the methodology to be accurate[4/] (See Chinnery Tr. 90-91). The second step employed by the Appeal Board was to assess the validity of the four assumptions as tested by other expert testimony, the cross-examination of Dr. Chinnery by the other parties, as well as the examination of Dr. Chinnery by the Appeal Board. This step, in essence, probed Dr. Chinnery's justifications for making the assumptions, the reasonableness of the assumptions, and the utilization of the assumptions within the overall methodology. See Slip. Op. at pp. 12-20 (linearity assumption);

4/ The four assumptions are: (1) in any seismic region during a given period of time, there is a linear relationship between epicentral intensity of earthquakes and their frequency of occurrence; (2) this will yield a universal slope consistent with 0.57; (3) there exists no upper bound to earthquake size in any area; and (4) frequency intensity data may be extrapolated linearly to predict the probability of occurrence of larger than historical earthquakes.

pp. 20-22 (uniform slope); pp. 22-26 (upper bounds to maximum earthquake intensity); pp. 26-28 (linear extrapolation beyond historical data).

The third step employed by the Appeal Board was to summarize and delineate in detail the results of its analysis of Dr. Chinnery's assumptions. See Slip Op. pp. 28-34. As a fourth step, the Appeal Board examined the use of scientific data by Dr. Chinnery, i.e., his scientific method (See Slip. Op. pp. 34-39). Only after evaluating Dr. Chinnery's methodology utilizing these four steps, did the Appeal Board render its conclusions with regard to the factual validity of Dr. Chinnery's methodology. The Staff submits that the four-step standards employed by the Appeal Board in responding to the Commission's remand were thorough, well-articulated in ALAB-667, and totally appropriate. Thus, Commission review is not warranted.

B. The Scope of the Hearing

NECNP next contends, as a ground for Commission review, that the Appeal Board erred in ruling that questions concerning alleged uncertainties in the Staff and Applicant methods for determining the SSE were beyond the scope of the hearing (Petition, p. 4). Again, NECNP has failed to address the requirements of the controlling regulation, 10 C.F.R. § 2.786(b).

In responding to this claim, it is important to note that when the Commission ordered the record reopened in this proceeding in September of 1979, it did so with respect to two discrete seismic issues as discussed above. These two issues were but a subset of at least four seismic issues that had been litigated by NECNP before the Appeal Board in 1976-77. See ALAB-422, 6 NRC 33 at 54-65 (1977). Certain other seismic issues, based on arguments advanced by NECNP concerning the "tectonic provinces" approach used by the Staff under Appendix A, and the intensity

of the 1755 Cape Anne earthquake were not reopened by the Commission. However, well after most prehearing matters in the remanded proceeding had been ruled upon, and after the parties had identified the scope of their proffered testimony, NECNP claimed that the hearing should be expanded to examine not only the validity of Dr. Chinnery's methodology, but also should include an adjudication and examination of the relative validity of each party's methods for ascertaining the appropriate intensity earthquake. Since the Staff was a party, such an inquiry would have necessitated a detailed examination of the tectonic province approach and the selection of the Safe Shutdown Earthquake under Appendix A to 10 C.F.R. Part 100. Such issues were beyond the scope of the Commission's remand. Faced with this request by NECNP to expand the issues for hearing -- a request which certainly would have resulted in delay -- the Appeal Board determined that the scope of the hearing should be limited to the remanded issues. See "Memorandum and Order" (February 12, 1981) (unpublished). The Appeal Board did not rule that the "weighing" of all such competing methodologies was inconceivable. Rather, it stated that "It is neither necessary nor appropriate to decide at this juncture whether the Coalition has correctly forecast our next step should the Chinnery approach be found, after the further evidence is received, to be acceptable." Id., p. 7, n.10. The Staff submits that such a ruling was correct, was well within the discretion of the Appeal Board, and clearly forms no basis for Commission review.

C. Conservatism in Licensing

NECNP seeks Commission review on the ground that Dr. Chinnery's methodology is more conservative than the approaches of the Staff and Applicant and that conservatism requires the adoption of the Chinnery approach

(Petition, pp. 5, 9). It is important for the Commission to note that neither NECNP witness, Dr. Chinnery, nor Board witness, (formerly NECNP witness, now an ACRS consultant) Dr. Mihailo Trifunac criticized the adequacy or safety of the present seismic design of Seabrook of Modified Mercalli Intensity VIII, 0.25g, Reg. Guide 1.60. To this should be added the fact that the seismic design of Seabrook is as high as that of any nuclear power plant east of the Rocky Mountains. Yet Dr. Chinnery's methodology, taken literally, would have most, if not all, nuclear power plants designed to withstand an earthquake of Modified Mercalli X-XII (See Tr. 77-78 (Chinnery)). This assertion is based, in part, on Dr. Chinnery's assumption that there should be a universal slope in the frequency-intensity relationship for all regions of the U.S.A. of 0.57, in spite of the fact that a wide range of slopes for the U.S., from 0.24 to 0.76 had been reported (Slip. Op. pp. 20-21). Moreover, the Appeal Board noted that Dr. Chinnery's assertion of a uniform slope was based only on one study that he had performed, (Slip. Op. p. 20), whereas evidence indicated that a modest variation in slope could produce significant differences. Thus, given these facts, the Appeal Board did not accept NECNP's proffered conclusion that Dr. Chinnery's analysis must be accepted simply because it may yield a more conservative result. Rather, the Appeal Board based its conclusions upon the four-step analysis previously described. Accordingly, Commission review of this matter is not warranted.

D. Geologic Testimony

NECNP contends that Commission review is required because the Appeal Board cited expert geologic testimony by Staff and Applicant witnesses. In evaluating this claim, it should be initially noted that Dr. Chinnery's methodology is primarily probabilistic (i.e., mathematical) in nature and

does not consider geologic or local characteristics of surface and subsurface material.

The purpose of Dr. Chinnery's methodology is to determine the Safe Shutdown Earthquake ("SSE"). The SSE is defined in 10 C.F.R. Part 100, Appendix A, III(C) as

> . . . that earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material . .

Thus, not only is use of geologic data permissible in evaluating a methodology to determine the SSE, the use of such data, where available, is required by Appendix A. See also, 10 C.F.R. Part 100, Appendix A, § IV. Therefore, it was not erroneous for the Appeal Board to consider geologic testimony in evaluating Dr. Chinnery's methodology, and Commission review is not warranted.

E. Miscellaneous Procedural Matters

As discussed previously, 10 C.F.R. § 2.786 provides for Commission review of procedural issues that are characterized as "important" or serious. The procedural issues delineated by NECNP fall well-short of such a threshold.

For example, NECNP requests Commission review of ALAB-667 because the Appeal Board, in footnote 19 (p. 14), made a single reference to a basic, if not the basic textbook in seismology, "Elementary Seismology" (1958) by C.F. Richter (Petition, p. 6). As explained by the Appeal Board in footnote 19, Dr. Chinnery in Exhibit 1 to his pre-filed direct testimony quoted a portion of a 1956 paper by C.F. Richter (and B. Gutenberg) on the relationship between Modified Mercalli Intensity grades to other numerical quantities. The Appeal Board, after setting

forth Dr. Chinnery's reliance on the 1956 Richter paper, then quoted a basic textbook by Richter, published two years later in 1958. The later quote modified Richter's position which Dr. Chinnery had relied on. As the substance of the matter was treated at length later in the opinion (Slip Op. pp. 29-33), it was not prejudicial for the Appeal Board to update in a footnote a secondary source relied upon by Dr. Chinnery.

NECNP also contends that Commission review is warranted because the Appeal Board failed to grant NECNP's motion to strike portions of Applicant and Staff testimony (Petition, pp. 6-7). In fact, the Appeal Board denied all motions to strike testimony made at the hearing by the Applicant, the Staff and Applicant jointly, and by NECNP. The Appeal Board reasoned that since that proceeding was not before a lay jury but before a Board versed in the technical area, objections to testimony should go to weight, not admissibility. See Tr. 175. The Staff submits that this approach to such motions, as utilized by the Appeal Board, did not harm NECNP.[5/] NECNP's further argument that it had "no opportunity" to respond to such testimony is not supported by the record. NECNP was afforded opportunities to identify and counter such testimony in the discovery phase of the proceeding, during cross-examination, and by the filing of rebuttal testimony. Therefore, it is clear that Commission review of these procedural matters is not warranted.

F. Specific Applicability of the Chinnery Methodology

The Appeal Board quoted Dr. Chinnery as testifying that his methodology did not reach the question of earthquake intensity at a particular site, but only in broad regions (Slip. Op. pp. 38-39). Indeed, Dr. Chinnery, at the

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5/ It also appears from a reading of the "Decision on Remand" that very little, if any, weight was given by the Appeal Board to testimony subject to such motions.

hearing was not clear how, or to what extent his regional predictions of earthquake probability could be made site specific. See Tr. 285-89 (Chinnery). The Appeal Board, in evaluating Dr. Chinnery's methodology, referenced this testimony.

NECNP, however, claims that this was error because it believes the answer to Dr. Chinnery's uncertainty as to the computation of site specific probabilities is to use that portion of Appendix A which requires, while utilizing the tectonic province approach (not used by Dr. Chinnery), placing the largest historical earthquake in the province, at the site. NECNP's proposal would involve mixing methodologies,[6/] and appears to go beyond Dr. Chinnery's own testimony on Tr. 285-86, 289. In fact, Dr. Chinnery testified generally that deriving precise numbers of risk from his methodology is "clearly nonsense" (Chinnery, Tr. 92). Thus, the Appeal Board did not err in quoting the limitations of his methodology which Dr. Chinnery acknowledged.

G. Staff Use of Reg. Guide 1.60 and Dr. Trifunac's Probability Estimate

NECNP has requested Commission review (Petition, p. 6) on two matters relating to the second-remanded issue, the Staff's methodology for correlating vibratory ground motion. First, NECNP merely disagrees with the finding of the Appeal Board that the Staff's use of Reg. Guide 1.60 is consistent with Appendix A. This assignment of error by NECNP is somewhat surprising in light of the express testimony of Board witness (formerly NECNP witness) Dr. Trifunac that the Staff's methodology "would be one acceptable way of rationally interpreting Appendix A" (Trifunac, Tr. 762). Moreover, Dr. Trifunac also agreed with

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6/ See "Proposed Findings of Fact, Conclusions of Law, And Supporting Argument The NRC Staff On Remanded Seismic Issues," p. 22 et seq. (June 16, 1981).

the Staff that the very highest frequency peaks on an accelogram are not of concern for purposes of seismic design of nuclear power plants because the amount of energy that would be delivered to the structures from such peaks, regardless of the peak value, is not sufficient to cause damage (Knight, Tr. 719; Reiter Tr. 669, Jackson 15; see Trifunac Tr. 762).

Finally, NECNP objects to the Appeal Board's citation of the fact that Dr. Trifunac had no objection to the present seismic design of Seabrook based upon certain uniform risk spectra probability estimates included in Dr. Trifunac's testimony (Petition, p. 7). In assessing the Staff's methodology, the Board examined the question of whether the Staff's methodology in fact produced a response spectrum at Seabrook which properly reflects the maximum vibratory acceleration for the selected SSE. The Board therefore compared the present seismic design of Seabrook with the results of other response spectra developed by the Staff and Applicant witnesses and Board witness Trifunac. The results of these analyses uniformly indicated that the present seismic design of Seabrook is safe and conservative. However, the Appeal Board did not endorse or adopt any design basis probabilities (including Dr. Trifunac's 5% exceedance probability) in that analysis, as NECNP has indicated. Thus, Commission review of this matter is not warranted.

III. CONCLUSION

For the reasons stated above, the Staff believes that NECNP's petition for Commission review of ALAB-667 should be denied.

Respectfully submitted,

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Assistant Chief Hearing Counsel

Dated at Bethesda, Maryland
this 7th day of April, 1982.