UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of	)	
PUBLIC SERVICE COMPANY	)	Docket No. 50-443
OF NEW HAMPSHIRE, ET. AL	)	50-449
(Seabrook Station, Units 1 & 2	)	

COMMENTS

by

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March 20, 1981

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INTRODUCTION

The proposed characteristics of strong earthquake ground motion for seismic design of the Seabrook nuclear power plant may be summarized as follows:

1. Safe Shut Down Earthquake (SSE) will not exceed MMI=VIII at the site.
2. Maximum peak acceleration which will result from MMI=VIII at the site is 0.25g (where g=981 cm/sec^2).
3. Design Response Spectrum shapes are consistent with the Reg. Guide 1.60 spectra recommended by the U.S.N.R.C.. At short periods (high frequencies, $f \geq 30$ Hz) these spectra approach the peak absolute ground acceleration equal to 0.25g.
4. From geological view point the site can be classified as a rock site.

In its recent order, CLI-80-30, 12 NRC 295, 298 (1980), the Atomic Safety and Licensing Appeal Board states:

> "The Appeal Board shall also reopen the record to take more evidence on the consistency of Appendix A and staff's methodology for correlating vibratory motion with the SSE. In particular, the parties should provide a discussion of the relation between the mean of the maximum ground acceleration and the maximum effective ground acceleration."

In response to this order, in the following I will discuss some aspects of selecting the seismic design criteria at this site and will try to test the adequacy of the above proposed design levels. As will be seen from the subsequent pages I will analyze the end product only by using the methods which to me, at present, appear to be the most suitable. In this respect I will employ my own interpretation of the minimum requirements contained in the Appendix A.

SELECTED COMMENTS ON A DETERMINISTIC INTERPRETATION OF APPENDIX A AND THE ASSOCIATED DIFFICULTIES.

By some, Appendix A (together with the associated Regulatory Guides) is interpreted to lead to detailed step by step instructions on how the future strong earthquake is to be estimated for the design of nuclear power plants. With this viewpoint, it is possible to compartmentalize all required operations and to develop "standard" procedures, which, if carefully documented, may precisely outline the needed tasks and their ultimate output, the design response spectra. From an administrative, licensing and design viewpoints this approach at least formally, appears inviting, since, through precisely documented procedures, it leads directly to the results. Such precisely outlined and executed procedures, however, may not always lead to an accurate description of the physical nature of the problem; if the uncertainties associated with various operations are not properly reflected in the distribution of the estimated output values.

For Eastern U.S., for example, a typical analysis essentially begins by specifying "the largest credible" earthquake shaking at a site (usually measured in terms of the Modified Mercalli Intensity, MMI). The difficulties associated with this first step sometimes result from a naive expectation that the past seismicity, geology and tectonics in the area can somehow be employed to compute the largest credible site intensity. I believe that many licensing difficulties could be avoided by recognizing that it is sufficient to evaluate the maximum intensities by means of a distribution function, rather than through a selection of a precise yet not necessarily an accurate point estimate.

The next task then consists of relating the assigned site intensity of shaking to an amplitude of peak ground acceleration. Here one finds a considerable spread of the recorded peak acceleration for the same site intensity, shown in Figure 1. This figure illustrates how the distributions of peaks $P(a \leq a_0)$ might look like. The dashed straight lines, approximating this unknown distribution, have been plotted here by using the Table VI in Trifunac (1976). It is seen, for example, that the 80% confidence interval for recorded peak accelerations for the site intensity MMI=VIII is from ~0.15g to ~0.70g. The point to be noted here is that when a peak acceleration is presented it must be viewed with this wide distribution in mind.

In Figure 1 and elsewhere in this discussion "peak acceleration" will mean the largest absolute amplitude of acceleration function versus time recorded during the complete strong earthquake motion. For linear response analysis using response superposition technique this is the only correct use of peak acceleration, since the computed response spectra asymptotically approach this peak value as the period of the single degree of freedom oscillator approaches zero. I believe that the term "effective peak acceleration" should not be considered at all, since, so far, no one has precisely defined what is meant by this expression. From the past experience, I found that it is usually smaller than the recorded acceleration, that its interpretation varies from one experts to the next, and that it somehow reconciles the past analyses with recent or new recorded data. From several cases of its usage that I have seen it appears that it avoids the physical basis of the problem and allows unwarranted freedom for expert judgement.

The third and often the last step in specifying the design earthquake motions at a site is to use the appropriate peak acceleration to scale the amplitudes of the standard shape of the response spectrum given by the Regulatory Guide 1.60. Unfortunately the shape of this response spectrum does not represent the correct average plus one standard deviation or average spectrum envelope, since, prior to analysis for spectral shapes, all spectral amplitudes have been normalized by the corresponding peak acceleration. This normalization leads to the zero standard deviation of spectral amplitudes at the short period end. When multiplied by the average peak ground acceleration the resulting spectrum amplitudes are close to the average spectral amplitudes at the short period end, and as T increases approach the average plus one standard deviation spectrum from below. If multiplied by the average plus one standard deviation the resulting spectra overestimate the actual average plus one standard deviation of spectral amplitudes at all T. In spite of these difficulties, the above procedures can yield an adequate seismic design basis in the range of intermediate and small response amplitudes where the detailed and more refined analysis is not essential.

It is further noted that in the critical re-evaluation of the existing design spectra, the detailed review and justification of the tasks involved in the above step by step methodology cannot be expected to resolve all difficulties, since this methodology itself represents an approximation.

A PROBABILISTIC INTERPRETATION OF APPENDIX A

To formulate an independent basis for evaluation of the seismic design response spectra at Seabrook site (Reg. Guide 1.60 spectra with short period amplitudes at 0.25g) the following procedure is considered:

1. Describe seismicity at and surrounding the plant site by a

stationary uniform Poisson sequence of earthquakes in time and space, such that the number, N^*, of earthquakes of given maximum (epicentral) intensity, I, is given by

$$\log_{10} N = a - bI$$

where a and b are constants that can be evaluated for the site.

2. Compute the Uniform Risk Spectra (URS) at the site for the seismicity given by 1 above and for the local site specific geologic conditions, following the procedures presented by Anderson and Trifunac (1977).

3. Compare the derived URS amplitudes with the proposed Seabrook design spectra, evaluate the differences and discuss the adequacy of the proposed design spectra.

Figure 2 presents the data on the expected number of earthquakes (per year) with different epicentral intensities I on MMI scale, in the area of about 27000 km^2 identified as Boston-New Hampshire region (Chinnery, 1979). The outside (left) scale on the vertical axis gives the logarithm of the number of earthquakes per year for the entire region of 27000 km^2. The right (inside) scale on the y-axis gives the logarithm of the number of earthquakes per year per 1000 km^2 assuming the total area of 27000 km^2. Open circles represent N_c (number of earthquakes greater than and equal to I). The full circles represent N the number of earthquakes of intensity which corresponds to the x-coordinate of the point.

The seismicity model

$$\log_{10} N_c = 2.15 - 0.59I \quad (1)$$

---

* Number of earthquakes per year per 1000 km^2

corresponds to the one discussed by Chinnery (1979). The model

$$\log_{10} N_c = 1.52 - 0.48I \qquad (2)$$

represents an example of a "pessimistic" interpretation of $\log_{10} N_c$ versus MMI data, available so far, in that it most probably overestimates the frequency of earthquake occurrence for earthquakes with MMI ≥ VII.

For calculation of URS following Anderson and Trifunac (1977), equation (1) is transformed to

$$\log_{10} N = 0.59 - 0.59I \quad . \qquad (3)$$

Perusal of figure 5 on the page 763 of Chinnery (1979) shows that the distribution of epicenters within the zone corresponding to the Boston-New Hampshire region is not uniform. To further add to the "pessimistic" nature of the model (2) I will assume, arbitrarily, that all these events have occurred in a small area A = 13500 km^2. With this, equation (2) leads to

$$\log_{10} N = 0.22 - 0.48I \qquad (4)$$

To apply the method of Anderson and Trifunac (1977), it is convenient to choose the maximum intensity which can occur in each source region. By performing a series of calculations for different maximum intensities it is possible to show how this parameter influences the end result.

To compute the URS at the site I assumed that the whole region surrounding the site can be represented by a uniform diffused zone as defined by Anderson and Trifunac (1977). In the case of model (3) this is equivalent to a redistribution of the past seismicity into a uniform seismicity per area surrounding the site. For the model (4) this is equivalent to postulating a future seismicity per unit area which is comparable to the most active sub areas of the Boston-New Hampshire region during the past 50 to 150 years. Since the model (4) assumes that this will occur uniformly at the Seabrook site and all surrounding areas, this model represents a "pessimistic" prediction of future-seismicity, which would be considerably higher than what has been observed there so far.

Figures 3 and 4 summarize the results of computed URS of Pseudo Relative Velocity (PSV) at a rock site (h=0 km, where h represents the depth of sediments beneath the site), for horizontal ground motion and for structural damping of ζ =0.05. Each figure shows two groups (each consisting of three URS spectra) of curves for p=0.05 and p=0.30. Here p represents the probability that these spectra will be exceeded at least once during the next 50 years. Each group contains three URS curves corresponding to the three cases analyzed and for the maximum intensity in the area assumed to be VIII, X or XII. Both figures also show the SSE spectra proposed for the Seabrook site and corresponding to 0.25g peak acceleration and ζ =0.05.

Figure 3 shows that these calculations suggest the probability of exceeding the proposed Seabrook design spectra during the next 50 years is less than 0.05, assuming no limit on the maximum epicentral intensity in the region. Assuming that the largest possible intensities are X and then VIII the probability of exceeding the SSE spectra for Seabrook is further reduced. This also means that for the seismicity represented by the model in equation (3), during the next 50 years the probability that the peak acceleration equal to 0.25g will be exceeded is less than (I_{max} = VIII and X) or equal to 0.05 (if I_{max} = XII).

Results in Figure 4 show that if the site seismicity is equal to that described by equation (4) that the probabilities of exceeding the proposed SSE spectra at Seabrook Site are as follows:

Maximum area intensity	Probability of exceeding Seabrook Spectra
I_{max} = VIII	< 0.05
I_{max} = X	< 0.15
I_{max} = XII	< 0.30

The differences between the shapes of URS for this site and the proposed SSE spectra exemplify the ability of the URS method to reflect the site specific conditions which in this case are primarily influenced by the nature of the rock site (this tends to increase the high frequency URS amplitudes relative to the fixed shape of Reg. Guide 1.60 spectrum) and the nature of the $\log_{10} N$ versus MMI.

CONCLUSIONS

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 the above model of seismicity in equation (4) is indeed a "sufficiently pessimistic" representation of possible seismicity during the next 50 years.

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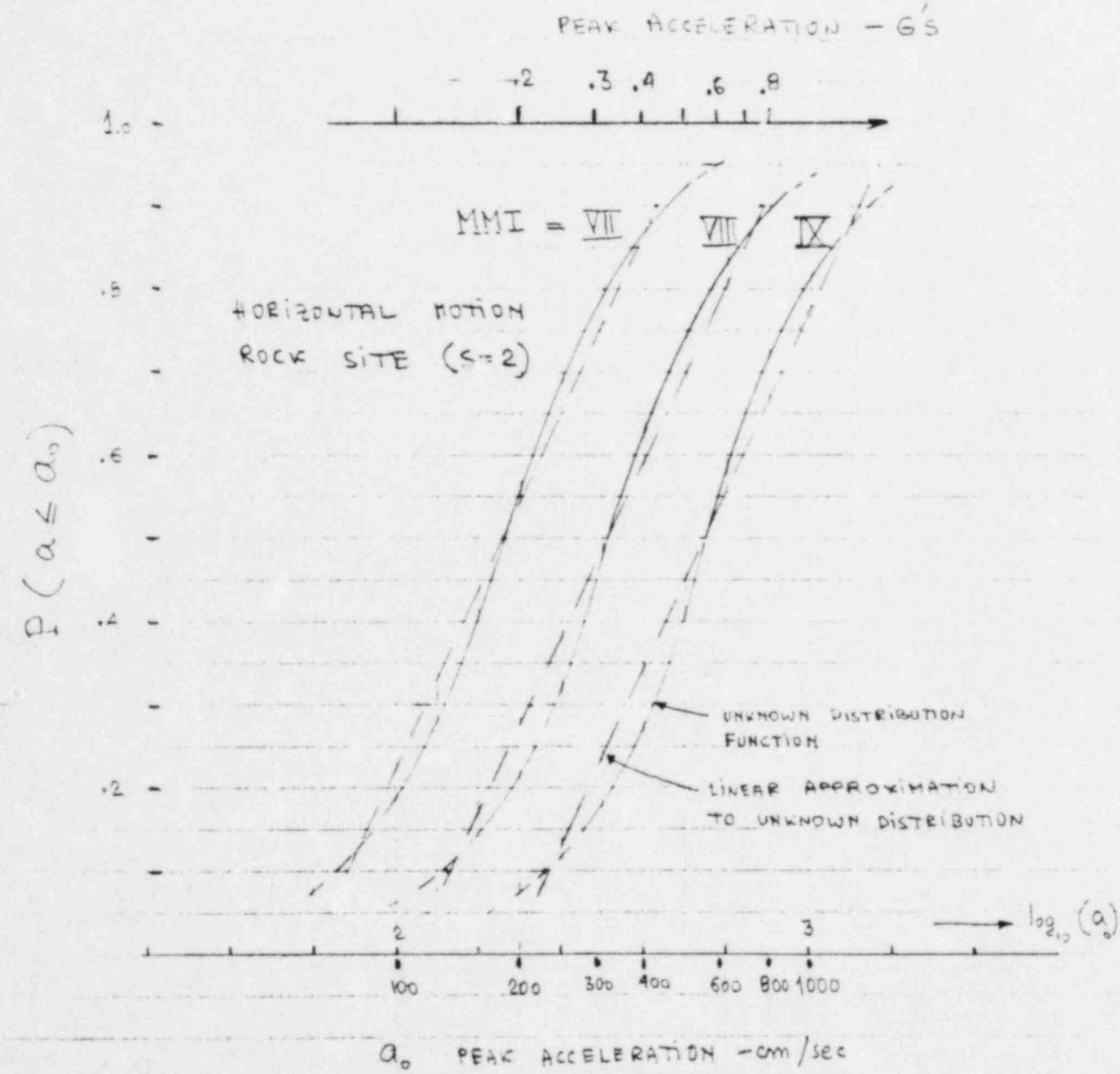
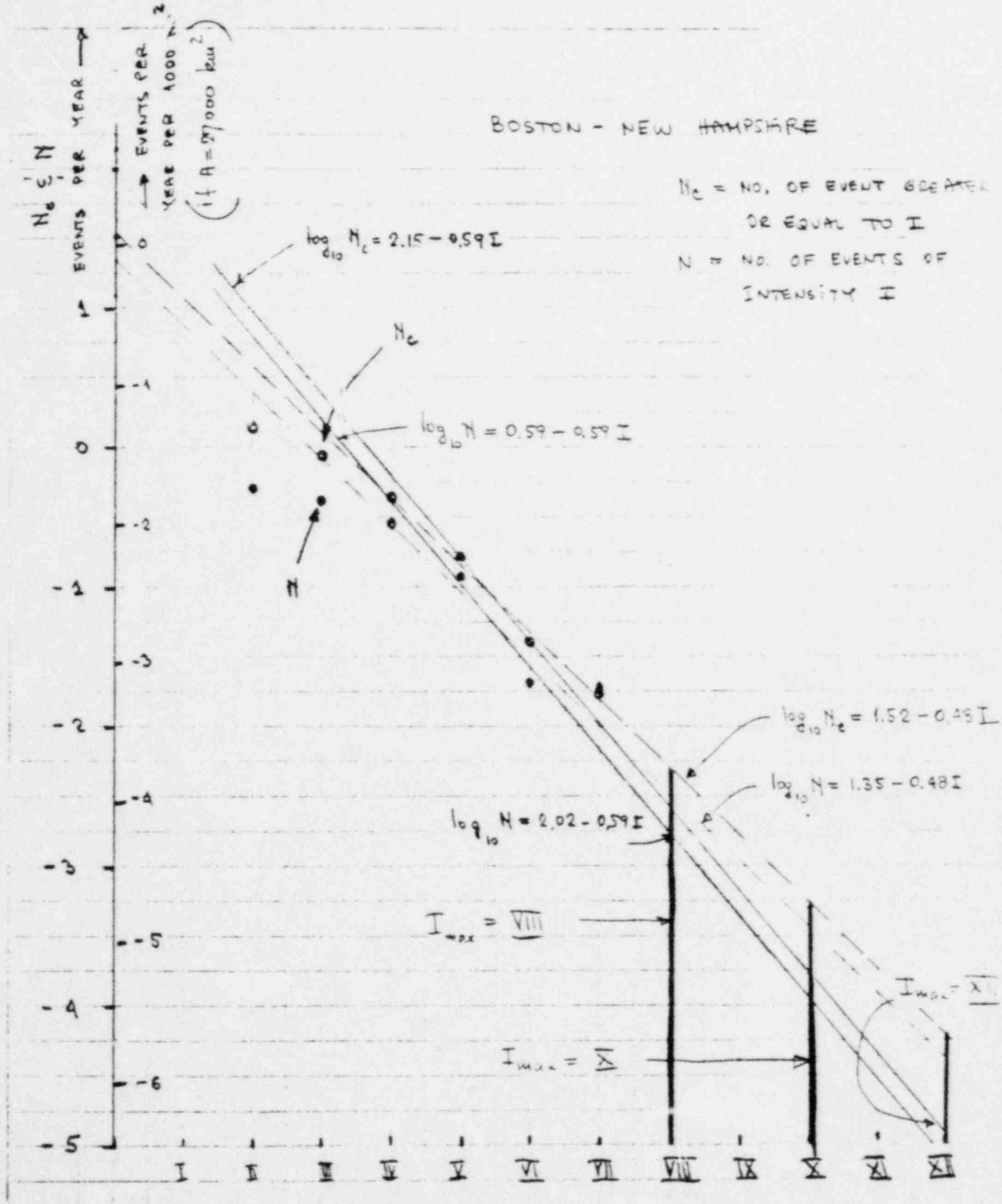

PEAK ACCELERATION - G'S
.2 .3 .4 .6 .8
1.0
.8
.6
.4
.2
MMI = VII
VIII
IX
HORIZONTAL MOTION
ROCK SITE (S=2)
P (a ≤ a₀)
UNKNOWN DISTRIBUTION FUNCTION
LINEAR APPROXIMATION TO UNKNOWN DISTRIBUTION
2
3
log₁₀ (a₀)
100 200 300 400 600 800 1000
a₀ PEAK ACCELERATION - cm/sec

Figure 1



BOSTON - NEW HAMPSHIRE
Nc = NO. OF EVENT GREATER OR EQUAL TO I
N = NO. OF EVENTS OF INTENSITY I
Nc & N EVENTS PER YEAR
EVENTS PER YEAR PER 1000 km²
(if A = 27,000 km²)
log10 Nc = 2.15 - 0.59 I
Nc
log10 N = 0.59 - 0.59 I
N
log10 Nc = 1.52 - 0.48 I
log10 N = 1.35 - 0.48 I
log10 N = 2.02 - 0.59 I
Imax = VIII
Imax = X
Imax = XII
MMI

Figure 2

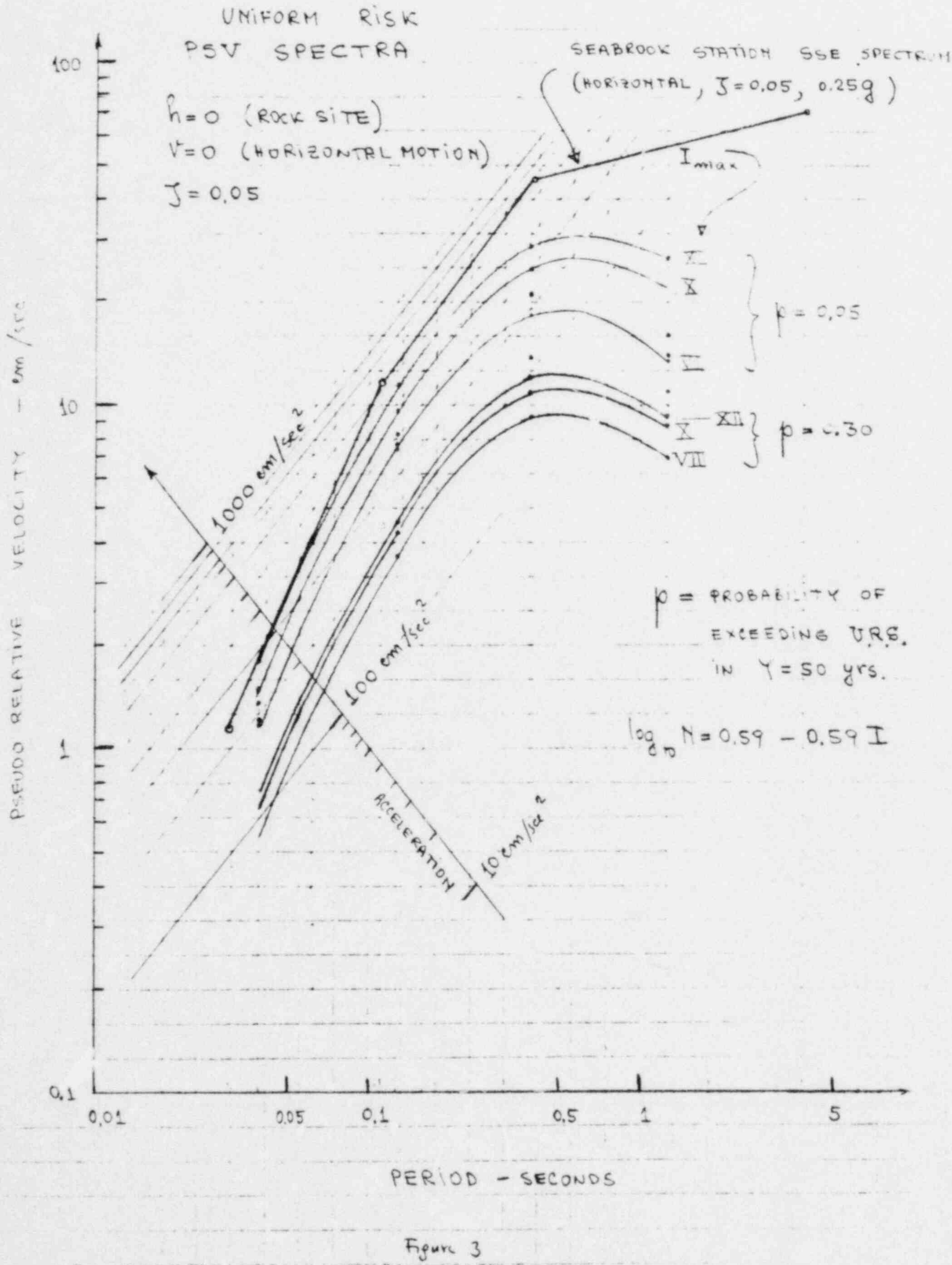

UNIFORM RISK
PSV SPECTRA
h=0 (ROCK SITE)
V=0 (HORIZONTAL MOTION)
ζ = 0.05
SEABROOK STATION SSE SPECTRUM
(HORIZONTAL, ζ=0.05, 0.25g)
I_{max}
XI
X
VI
p = 0.05
XII
X
VII
p = 0.30
1000 cm/sec²
100 cm/sec²
10 cm/sec²
ACCELERATION
p = PROBABILITY OF EXCEEDING U.R.S. IN Y = 50 yrs.
$\log_{10} N = 0.59 - 0.59 I$
PSEUDO RELATIVE VELOCITY - cm/sec
100
10
1
0.1
0.01
0.05
0.1
0.5
1
5
PERIOD - SECONDS

Figure 3

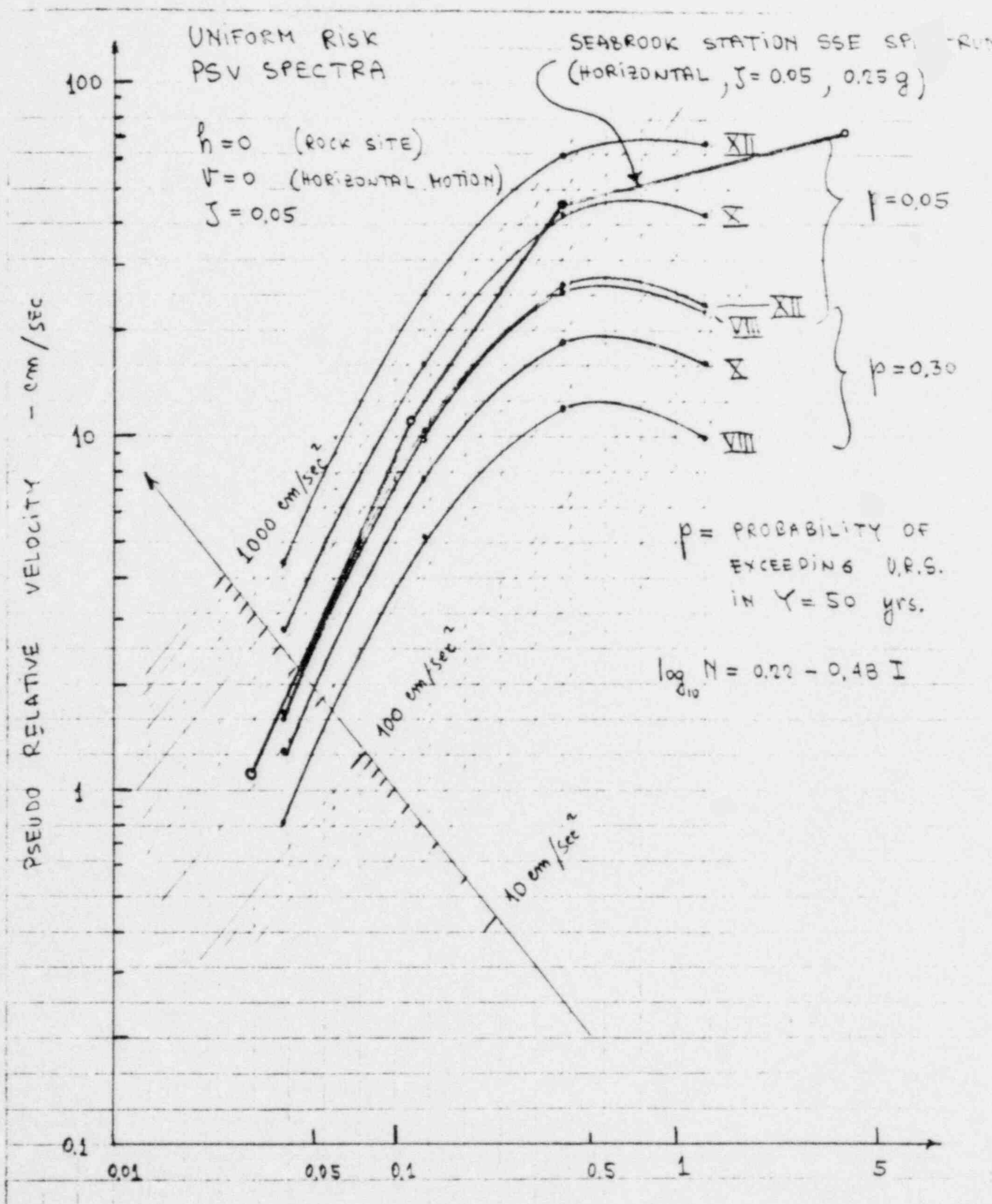

UNIFORM RISK
PSV SPECTRA
SEABROOK STATION SSE SP... RUM
(HORIZONTAL, ζ = 0.05, 0.25 g)
h = 0 (ROCK SITE)
V = 0 (HORIZONTAL MOTION)
ζ = 0.05
XII
X
XII
VIII
X
VIII
p = 0.05
p = 0.30
p = PROBABILITY OF EXCEEDING U.R.S. IN Y = 50 yrs.
log10 N = 0.22 - 0.48 I
1000 cm/sec²
100 cm/sec²
10 cm/sec²
100
10
1
0.1
0.01
0.05
0.1
0.5
1
5
PSEUDO RELATIVE VELOCITY - cm/SEC
PERIOD - SECONDS

Figure 4

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(Seabrook Station, Units 1 and 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of Letter from M.D. Trifunac to R.P. Lessy enclosing "COMMENTS BY PROF. MIHAILO D. TRIFUNAC" in the above-captioned proceeding have been served on the following by deposit in the United States mail, first class, or, as indicated by an asterisk, through deposit in the Nuclear Regulatory Commission's internal mail system, this 23rd day of March, 1981:

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