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GUIDELINES FOR EARTHQUAKE GROUND MOTION DEFINITION FOR THE EASTERN UNITED STATES*

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Abstract

Guidelines for the determination of earthquake ground-motion definition for the eastern United States are established in this paper. Both far-field and near-field guidelines are given. The guidelines were based on an extensive review of the current procedures for specifying ground motion in the United States. Both empirical and theoretical procedures were used in establishing the guidelines because of the low seismicity in the eastern United States. Only a few large to great (M > 7.5) sized earthquakes have occurred in this region, no evidence of tectonic surface ruptures related to historic or Holocene earthquakes have been found, and no currently active plate boundaries of any kind are known in this region. Very little instrumented data has been gathered in the East. Theoretical procedures are proposed so that in regions of almost no data a reasonable level of seismic ground motion activity can be assumed. The guidelines are to be used to develop the Safe Shutdown Earthquake, SSE. A new procedure for establishing the Operating Basis Earthquake, OBE, is proposed, in particular for the eastern United States. The OBE would be developed using a probabilistic assessment of the geological conditions and the recurrence of seismic events at a site. These guidelines should be useful in development of seismic design requirements for future reactors.

INTRODUCTION

For the last two years, the Seismic Design Technology Program at Oak Ridge National Laboratory concentrated on the development of guidelines for ground motion definition for the eastern United States and near-field ground-motion spectra that cover a range of damping values. The objectives of the program was to develop and update procedures for predicting ground motion for nuclear plants. To meet these objectives a report was prepared entitled *Guidelines for Ground Motion Definition for the Eastern United States*, ORNL-6138. A summary of the guidelines are described in this paper.

The seismic design problem varies considerably in the United States because of the markedly different seismicity in the East and West. In the western United States, particularly in California and Nevada, the seismicity is relatively high. More large- and moderate-sized earthquakes have occurred in these two states than in any other part of the continental United States. Tectonic surface ruptures related to historic earthquakes (0–200 years before present) and Holocene earthquakes (0–10,000 years before present) are common. In addition, the active plate boundary represented by the 1000-km-long San Andreas fault system makes part of the western United States very different from other seismically active parts of the country. By contrast, the eastern United States has almost none of the characteristics exhibited in the western United States. Seismicity is low; large- to great-sized earthquakes occurred only in 1811, 1812, and 1886, and no evidence of tectonic surface ruptures related to historic or Holocene earthquakes has been found. Also, no currently active plate boundaries of any kind are known there.

Planning and engineering of structures in the eastern United States should be based on knowledge about the causes of seismicity in the East. Although epicenters in the East are broadly scattered, important historical seismicity is concentrated in only a few zones. Focal depths extend from near the surface to mid-crustal depths of about 20 km, which indicates the depth range of seismogenic structure. A plausible explanation for some eastern seismicity is that the larger earthquakes are caused by reactivation of ancient fault systems that were formed as early as the Precambrian time. These fault systems could be zones of weakness that are subject to movement when stresses are of sufficient magnitude and are oriented in an appropriate direction.

*Research sponsored by the Office of Breeder Technology Projects, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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*Work performed under the Structural Design Technology Program sponsored by the U.S. Department of Energy Office of Breeder Technology Projects.

The possibility of earthquake damage is one among many factors that affect planning and design decisions. Ultimately, the degree to which the earthquake threat influences decisions comes down to a judgment about its relative importance. Formation of this judgment depends on estimates of the likelihood of earthquake occurrence and the severity of earthquake effects. To a certain extent, such estimates can be derived from the historical record of seismicity, but this record is clearly inadequate in many areas because it is so short compared with the recurrence time of major earthquakes. This problem of incompleteness of the historical record is acute in the eastern United States, where the rate of occurrence of major earthquakes is very low relative to that in the West. A major earthquake occurs somewhere in the eastern United States only about every 50–100 years. One might think that the relatively low seismicity of the East makes the earthquake threat in that region insignificant compared with the other factors, and many people do take this view. However, the low seismicity of the East compared with the West is offset by some very important differences between the regions:

- Lower attenuation of seismic waves in the East causes shaking to extend over much larger areas for earthquakes of comparable magnitude. Higher population density in the East means greater exposure to damage.
- Lower earthquake awareness in the East has led to lower standards of design for and preparedness for earthquakes.

There are no easy solutions or quick fixes in dealing with the earthquake threat to the eastern United States, and much study must still be done to understand the geologic origin of the eastern United States seismicity.

However, the design of critical structures must continue and the possibility that and earthquake may strongly shake the structures must be taken into account. The guideline for development of safe shutdown earthquake for the eastern United States is shown in Fig. 1. The guideline for near-field ground motion will be discussed later since most seismic engineers would specify a site for a critical structure well away from the site of known seismic activity. The general procedure used for seismic design of nuclear power plants, including breeder reactors, is given in the Code of Federal Regulations, 10 CFR 100, Appendix A. The procedure exists for establishing a safe shutdown earthquake (SSE) which is based on the maximum ground motion at the site, and an operating basis earthquake (OBE), which, in general, is based on at least one-half ground acceleration magnitude of the SSE. Both of these design earthquakes are to be represented by response spectra.

There is a fundamental factor that distinguishes seismic and, indeed, all natural and external hazards as possible accident initiators from accident initiators that arise from causes within the plant:

> The public is at risk from earthquakes whether or not the nuclear plant exists [1].

A more accurate assessment of the seismic risk would be to assume that the risk to the public when the nuclear power plant does not exist as the background seismic risk. The additional risk due to the nuclear plant would be called the incremental seismic risk. As an alternative or supplement to the present thinking on safety, the acceptable incremental seismic risk could be specified in terms of some "small" percentage of the background seismic risk. This approach has a number of advantages:

- Engineers familiar with the seismic design of nuclear and conventional facilities can give many examples of how the design of nuclear power plants is much more conservative than the design of conventional facilities.
- A comparison of background and incremental seismic risk would provide the public, the NRC, and utilities with precisely the information needed for decision on whether or not reducing the incremental seismic risk is very effective in reducing the total public seismic risk.
- The comparison between background and incremental seismic risk will be more credible than a comparison of nuclear seismic risk with a numerical goal.
- Both background and incremental seismic risks are involuntary.

Such a consideration of incremental seismic risk for nuclear power plants would still require design for the SSE. A proposed design procedure for the OBE will be given in the last section of this paper.

GROUND-MOTION GUIDELINES FOR A SAFE SHUTDOWN EARTHQUAKE IN THE EASTERN UNITED STATES

In the guidelines there are three different methods that can be used to develop the ground-motion definition for a site. The choice of the method to be used should be made by an oversight committee of senior engineers and earth scientists. The committee is needed because of the diversity of opinions by "experts" on almost any variable or parameter associated with seismicity [2]. A panel of geologists and seismologists should provide expertise to interpret available geological and seismological data.

The first method, which is the most conservative, is based on using the maximum assumed historical seismic event in the tectonic region of the site or in tectonic regions near the site. The region in which the site is located will control the maximum ground acceleration for the facility design. Another procedure is to use a seismic source zone map which shows zones where the maximum ground motion is considered the same over each zone. From these maps can be found the maximum magnitude for each zone. Another place to look for maximum earthquake values are earthquake catalogs such as the Earthquake History of the United States [3]. These sources will give the ground-motion definition in magnitude and Modified Mercalli Intensity (MMI) values. Since most of the historical data in the East have been developed into MMI values and m_b body wave magnitudes, relationships between these values and ground-motion

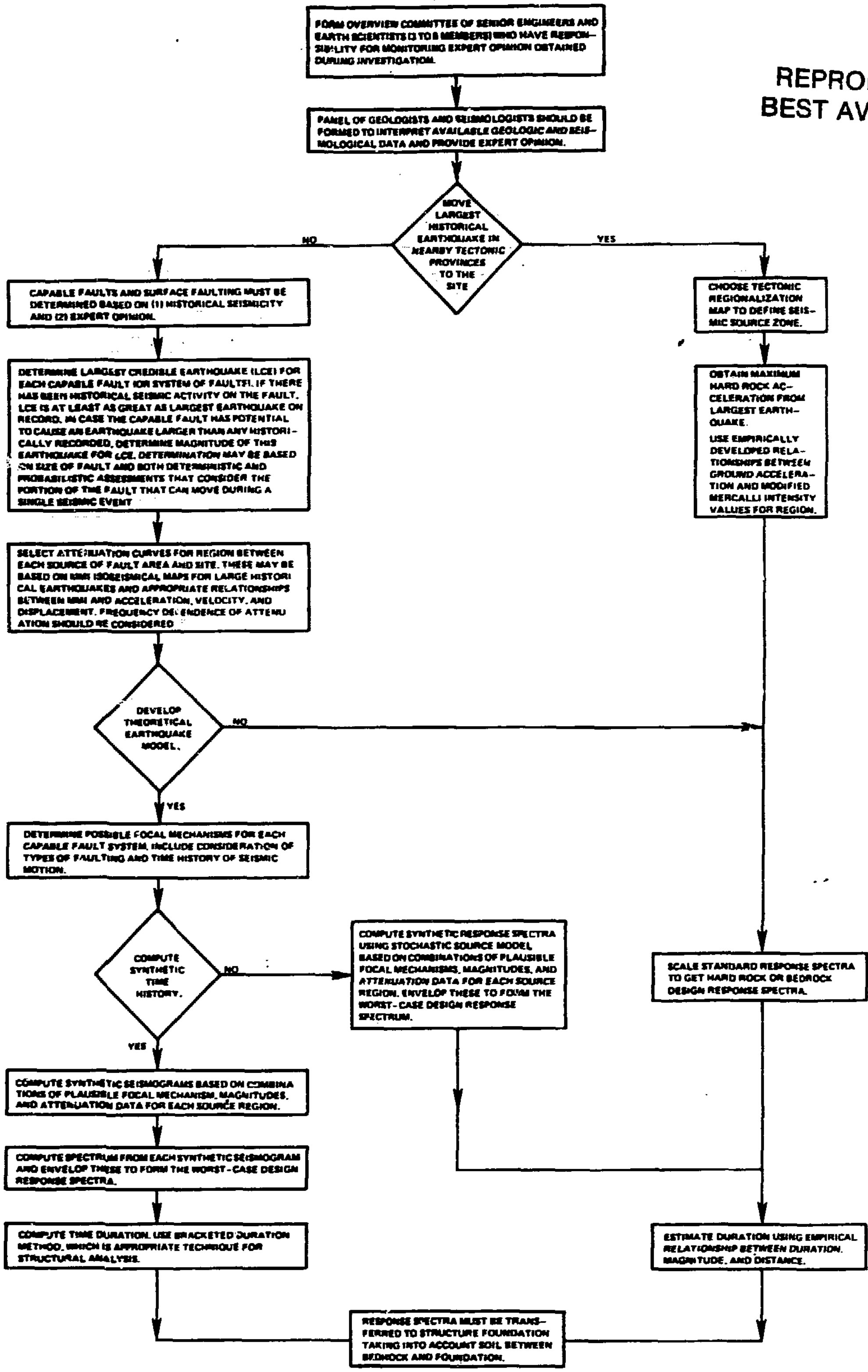

Fig. 1. Ground-motion guidelines for a safe shutdown earthquake in the eastern United States.

parameters (acceleration, velocity, displacement — both horizontal and vertical) must be used to calculate the maximum ground-motion parameters. The response spectra for the site can be developed by scaling a standard response spectra by the maximum ground acceleration, velocity, and displacement at the site.

The method described above develops the ground-motion parameters for the so-called "floating earthquake." This concept assumes that ground motion at the site occurs as if the structure were located on or over the epicenter of the largest assumed historical earthquake that has ever occurred in the tectonic region or seismic source zone. An alternative to the use of the largest assumed historical event is the "site-specific" earthquake. The series of steps associated with this definition for the ground motion is given in the following discussion and is based on using a combination of historical data and theoretical considerations or "expert opinion" to develop the ground-motion definition for site-specific spectra.

In the eastern United States, the low level of seismic activity and the lack of instrumented records makes it difficult to develop design spectra using historical data alone. The capable faults that affect the site must be determined as well as any surface faulting. The capable fault can be based on known historical seismicity or geologic evidence of past activity.

For each capable fault, the largest credible earthquake (LCE) must be determined. If there has been historical seismic activity along the fault, the LCE must be at least as great as the largest historical earthquake recorded for the fault. In case the fault has the potential to cause an earthquake larger than any historically recorded, the magnitude of this earthquake for the potentially largest LCE must be determined. This determination may be based on the size of the fault or by other theoretical methods [4]. The potential magnitude can be approximated by the seismic moment ($M_0 = \mu \overline{D} WL$, where L is fault length, $\overline{D}$ is average dislocation, W is fault width, and μ is rigidity). Relations between seismic moment and the other magnitude parameters for earthquakes such as m_b can be used to give an estimate of earthquake size or magnitude based on geological studies to measure the source parameters. For past historical worldwide earthquakes, the relation between seismic moment, source parameters, and magnitudes or size are shown in Table 1.

Calculations of seismic moment can be made for any faults discovered or known in a region; they can even be made for very large old faults. Such a calculation could lead to an overly conservative estimate of the earthquake size. However, by using recurrence relations, probabilistic analysis and expert opinion, a decision on the conservatism of the calculated earthquake size can be made. An earthquake that is too large based on these probabilistic studies or has too low a probability of occurrence should be considered too conservative. The recurrence relations represents the expected rates of seismic energy release within the region or seismic source zone based on a statistical interpretation of the past seismic record. The result of probability calculations should normally be in terms of probability of occurrence of intensity or magnitude and/or peak ground acceleration. Also using probabilistic analyses annual exceedence probability versus ground-motion parameter curves can be developed for any seismic zone. The probability procedures discussed above can be used for a seismic region to help determine the conservatism of the calculated ground-motion values.

Attenuation relationships between each source or fault and the site must be selected for the ground-motion acceleration, velocity, and displacement. Relations for attenuation of intensity values (MMI) from the source to the site can be used along with relations for and conversion of these intensity values to ground-motion parameters to develop the values at the site.

At this stage the choice can be made about the nature of the availability of acceleration time histories. If it is desirable not to develop a theoretical earthquake, the next step is the development of the site design response spectra by scaling a standard response spectra by the maximum ground-motion parameters. Both vertical and horizontal spectra are to be developed. If the choice is made to develop theoretical earthquakes, the following methodology is proposed. The calculational procedure can follow several paths, one being theoretical and the other semitheoretical or semiempirical. The theoretical earthquake is based on having a source mechanism, and a geometrical spreading and attenuation mechanism in the computational procedure. The source mechanism is the kinematic model for the slip or movement of the fault displacement during an earthquake as a function of time and position on the fault plane or the focal mechanisms for a source region. The attenuation and spreading mechanism allows calculation at the site of interest of the displacement as a function of time.

The semitheoretical procedure is based on using a theoretical attenuation relationship in which the source amplitude function is statistically fitted to data for the region. The spreading and attenuation mechanism or function was chosen in a theoretical form. These models may be used to calculate the acceleration at a site versus frequency. Also displacement and velocity can be calculated using these models. To develop a time history using these models a standard calculational procedure [5] which simulates earthquake motions compatible with a prescribed response spectra can be used.

For each source region or fault near the site of interest, these "theoretical" procedures should be used to calculate ground-motion time histories. Then select the worst-case time histories and calculate response spectra from each one. It is recommended that the duration be developed using the so-called "Trifunac-Brady

Table 1. Earthquake source parameters

Event	Date	M[a]	M_s[b]	M_w[c]	M_o[d] (10^2/dyn cm)	L[e] (km)	D[f] (km)	Slip type[g]	U[h] (m)	T[i] (s)	T*[j] (s)	v_r[k] (km s^{-1})	Δσ[l] (bar)	E_s[m] (10^{22} erg)	E_f[n] (10^{22} erg)	Remarks
San Francisco	4/18/06		8.25	7.9	10	430	15	RS	5-7					200	300	
Kanto	9/1/23	7.9	8.2	7.9	7.6	130	70	RT	2.1	7	10		21			
						85	55	RT	6.7							o
Tango	3/27/27	7.5	7.75		0.46	35	13	LS	3	6	2.5	2.3	115	10	4	
North Izu	11/25/30	7.0	7.1		0.2	20	11	LS	3		1.7		150	2	3	
Saitama	9/21/33	7.0	6.75		0.068	20	10	LS	1	?	1.6	2.3	59			
Sanriku	3/2/33	8.3	8.3	8.4	43	185	100	N	3.3	7	12	3.2	42			
Long Beach	3/11/33		6.25		0.028	30	15	RS	0.2	2	2.5	2.3	7			
Imperial Valley	5/19/40		7.1		0.48	70	11	RS	2		3.2		55	1	1.5	
Tottori	9/10/43	7.4	7.4		0.36	33	13	RS	2.5	3	4.0	2.3	99			
Tonankai	12/7/44	7.0	8.2	8.1	15	120	80	T	3.1		9.2		39			
Mikawa	1/12/45	7.1	7.1		0.087	12	11	RT	2.2		1.3		140			
Nankai	12/20/46	8.1	8.2	8.1	15	120	80	T	3.1		9.2		39			
						300	70-120	RT	4-6							o
						320	50-140	T	5-18							o
Fukui	1/28/48	7.3	7.3		0.33	30	13	LS	2	2	1.9	2.3	100			
Tokachi-Oki	3/4/52	8.1	8.3	8.1	17	180	100	T	1.9		14		17			
Kern County	7/21/52		7.7		2	60	18	LT	4.6	1	3.6		140			
Fairview	12/16/54		7.1		0.13	36	6	RN	2		1.7		100	6	7	
Chile	5/22/60		8.3	9.5	2400	800	200	T	21		36	3.5	91			
						1000	120	T	20							o
Kitamino	8/19/61	7.0	7.0		0.09	12	10	RT	2.5	2	1.3	3.0	170			
Wasaka Bay	3/27/63	6.9	6.9		0.033	20	8	RS	0.6	2	1.5	2.3	40			
North Atlantic I	8/3/63		6.7		0.12	32	11	RS	1		2.2		44			
Kurile Islands	10/13/63		8.2	8.5	75	250	140	T	3		17	3.5	28			
North Atlantic II	11/17/63		6.5		0.038	27	9	RS	0.48		1.8		24			
Spain	3/15/64		7.1		0.13	95	10	T	0.42		3.6	1.4	11			
Alaska	3/28/64		8.5	9.2	520	500	300	T	7		35	3.5	22	300	1000	o
						600	200	LT	16							
						800	175-290	LT	20							o
Niigata	1/16/64	7.5	7.4		3.2	80	30	T	3.3		5.3		66	11	50	
Rat Island I	2/4/65		7.9	8.7	140	500	150	T	2.5		25	4.0	17			
Rat Island II	3/30/65		7.5		3.4	50	80	N	1.2		5.8		33			
Parkfield	6/28/66		6.4		0.032	26	7	RS	0.6	0.7	1.6	2.7	32			
Aleutian	7/4/66		7.2		0.226	35	12	RS	1.6		2.4		64			
Truckee	9/12/66		5.9		0.0083	10	10	RS	0.3		1.2		20			
Peru	10/17/66		7.5	8.1	20	80	140	T	2.6		9.6		41			
Turkey	7/22/67		7.1		0.83	80	20	RS	1.7		4.7		32			

Table 1. Continued

Event	Date	M^{a}	$M_s^{\,b}$	$M_w^{\,c}$	$M_o^{\,d}$ (10^2/dyn cm)	L^{e} (km)	D^{f} (km)	Slip type[g]	U^{h} (m)	T^{i} (s)	T^{*j} (s)	$v_r^{\,k}$ (km s^{-1})	$\Delta\sigma^{l}$ (bar)	$E_s^{\,m}$ (10^{22} erg)	$E_f^{\,n}$ (10^{22} erg)	Remarks
Borrego	4/9/68		6.7		0.063	33	11	RS	0.58		2.2		22			
Tokachi-Oki	5/16/68	7.9	8.0	8.2	28	150	100	RT	4.1		12	3.5	37			
Saitama	7/1/68	6.1	5.8		0.019	10	6		0.92	1	0.9	3.4	100			
Iran	8/31/68		7.3		1	80	20	LS	2.1		4.7		38			
Portugal	2/28/69		8.0		5.5	80	50	T	2.5		6.1		53			
Kurile Islands	8/11/69		7.8	8.2	22	180	85	T	2.9		12	3.5	28			
Gifu	9/9/69	6.6	6.6		0.035	18	10	LS	0.6	1	1.7	2.5	35			
Peru	5/31/70		7.8	7.9	10	130	70	N	1.6		8.7	2.5	28			
San Fernando	2/9/71		6.6		0.12	20	14	LT	1.4	1	2.0	2.4	62			
Nemuro-Oki	6/17/73	7.4	7.7		6.7	60	100	T	1.6		7.5		35			
China	7/27/76		8.0	7.5	2	150	15	RS	2.7							

[a] Magnitude from local data [e.g., magnitude in "Rika-nenpyo" (*Annual Table of Scientific Constants*, Maruzen Publishing Co., Tokyo) for the Japanese earthquakes].

[b] Surface wave magnitude.

[c] Magnitude calculated from the seismic moment.

[d] Seismic moment in 10^2/dyn cm.

[e] Fault length.

[f] Fault depth (definition should be slightly changed for a buried fault).

[g] N, normal; T, reverse; S, strike-slip; RS, right-lateral; LS, left-lateral; RT, reverse with right lateral; and LT, reverse with left-lateral.

[h] Final slip (average).

[i] Rise time (linear ramp time function).

[j] Theoretical rise time.

[k] Rupture velocity.

[l] Stress-drop.

[m] Energy of seismic waves (approximate).

[n] Strain-energy change in faulting (approximate).

[o] Geodetic model, principally related to land movements.

Source: K. Kasahara, *Earthquake Mechanics*, Cambridge University Press, New York, 1981.

duration" [6] method corrected for the eastern United States.

Here another choice can be made to directly develop a synthetic response spectra. Synthetic response spectra can be developed for each plausible focal mechanism using magnitudes, source parameters, and attenuation data. A response spectra can be developed for each focal mechanism and source region close to the site. Then these response spectra can be enveloped to develop the worst case design response spectra. Again the Trifunac-Brady duration [6] method can be used to develop the duration period.

The above procedures are used to develop the SSE that is assumed to occur at a breeder or light water reactor site as shown in Fig. 1. Methods for development of the ground-motion definition for the eastern United States are presented which should prove to meet the needs for this development.

GUIDELINES FOR ANALYTICAL PROCEDURES FOR PREDICTING NEAR-FIELD RESPONSES SPECTRA THAT COVER A RANGE OF DAMPING VALUES

The labels "far-field" and "near-field" can be misleading and misunderstood. For the western United States in the field of seismicity, a certain distance is currently used to define near-field, usually 20 km from the source of the earthquake vibratory ground motion. However, the real near-field depends on the geological surroundings of the specific site being analyzed. A theoretical but pleasing definition is as follows [7]: the far-field is simply all positions that are more than a few wavelengths away from the source, and the near-field is all positions within a small fraction of a wavelength from the source. The wavelengths of interest are those of the compressional and shear waves. These wavelengths can be approximately calculated by

$$\text{compressional wavelength} = \frac{2\pi\alpha}{\omega} ,$$

$$\text{shear wavelength} = \frac{2\pi\beta}{\omega} ,$$

where ω is the frequency of the wave, α is the compressional wave velocity, and β is the shear wave velocity. The calculation of the true wavelengths could be difficult and approximate because of variation in the wave velocity with depth in the earth and local soil or geological conditions [8]. Also, the wavelength depends upon the frequency of the wave, and in earthquakes there are spectra of wave-frequency combinations. However, these simple formulas will give guidance for future theoretical work.

The current practice in development or prediction of near-field response spectra in the western United States is to use a regression analysis of a multitude of different response parameters on instrumental data taken during seismic events. The response spectral amplitudes consist of separate regression analyses of pseudovelocities at frequencies between 0.067 and 25.0 Hz. Response spectra corresponding to certain percentiles are formed in these analyses. In some cases, response spectra from the regression analysis model and spectra from measured records are compared to indicate the adequacy of the regression analysis. These types of analyses are given in Refs. 8-10 for 5%-damped pseudovelocities.

The guidelines for near-field response spectra is shown in Fig. 2. In the guidelines there are two methods to be used to develop the response spectra. One is based on the availability of near-field data and the other is a theoretical procedure. It is well known that there are few recorded near-field data from the eastern United States for use in statistical analysis [10]. However, the 1982 aftershocks of the New Brunswick and New Hampshire earthquakes gave near-field strong motion data for $m_b > 4$. As is seen in Fig. 2, if near-field data or strong-motion data for a tectonic region are available, the procedure used in Refs. 8-10 will be used to develop near-field response spectra.

For tectonic provinces or seismic source zones where no strong motion data has been collected by instrumentation, as is the case in much of the eastern United States regions, simulation studies should be done to develop synthetic seismograms or response spectra for strong motion. The current state-of-the-art allows theoretical or synthetic amplitude spectra to be calculated for simple source mechanisms. To develop synthetic response spectra for a tectonic or seismic source region, it should be closely matched to the actual geological structure and to the region's capable faults.

The first step should be a geological study of the tectonic or source region of interest to estimate the geological parameters. All capable faults [11] and the potential for surface faulting must be determined. The capable faults are to be determined form historical seismicity and expert opinion. If there has been historical seismic activity along the fault or in the seismic source zone, the needed potential source parameters such as the seismic moment, and fault length, width, and slip can be calculated. Geological investigations can also be used to estimate the static source parameters.

The next step is to determine the source mechanisms for each capable fault in the fault system. As discussed before, the source mechanism is the kinematic mathematical model for the movement along the fault versus time. Kinematic mathematical models have been developed for fault motion [4,7,12-15] and the best known are the Haskell [16] and Brune [17] models. Recent theoretical developments have allowed researchers to construct fairly realistic seismic models and generate computer simulations of ground motion. Semitheroetical procedures can also be used to calculate the near-field response spectra and use a simulation method [5] to develop the time history. Another choice is to directly develop a synthetic response spectra using the "Trifunac-Brady duration" method [6] and simulation [5] method to develop a synthetic time history.

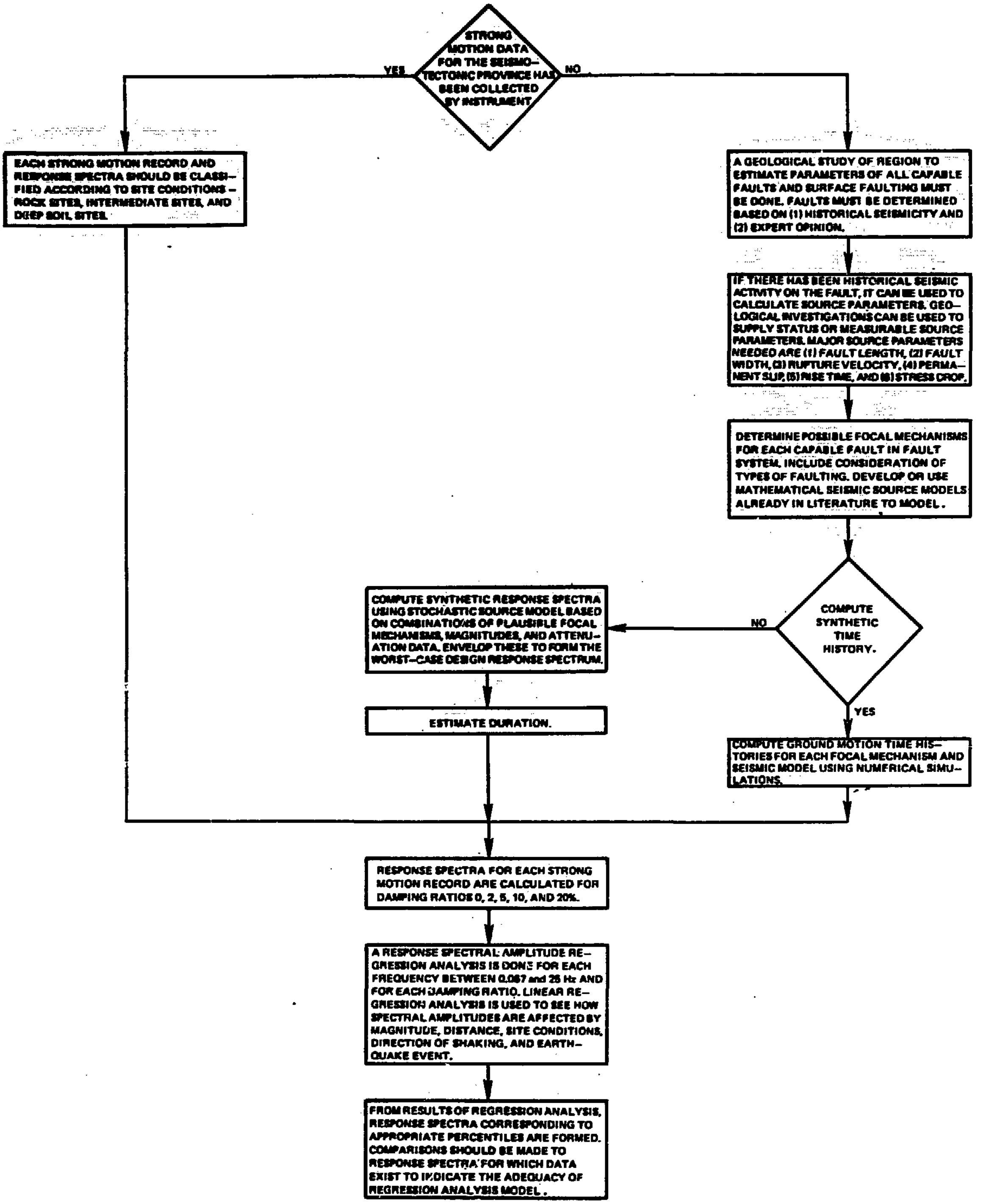

Fig. 2. Guidelines for near-field response spectra.

After the ground motion has been calculated for each capable fault, response spectra for each time history can be developed for a range of damping values of 0 to 20%. These calculated time histories and response spectra can be used directly for the specific site for which they were calculated. If a regression model for the eastern United States is required, the simulated response spectra for this specific site, along with others calculated for the East, can be used in a response spectral amplitude regression analysis.

As shown in Fig. 2, a procedure for calculation of near-field motion is given, which may be useful where near-field motion is needed for giving both site-specific data and statistically calculated response spectra for the East.

OPERATING BASIS EARTHQUAKE

The seismic design procedure for reactor plants in the United States is given in Code of Federal Regulatic.., 10 CFR 100, Appendix A [11]. It require.. establishing a safe shutdown earthquake (SSE) which is based on the maximum ground motion at the site and an operating basis earthquake (OBE) which, in general, is based on at least one half the ground acceleration magnitude of the SSE.

The OBE should be set based on the geological conditions at the site and the recurrence of seismic events in the area. One difficulty with 10 CFR 100, Appendix A is that it contains contradictory statements regarding the operating basis earthquake. In the criteria the operating basis earthquake is defined as an earthquake which can reasonably be expected to affect the site during the operating life of the plant. This seems to imply an exposure time of 40 years nominal operating life of a nuclear power plant. However, another section of the criteria requires that the acceleration level of the operating basis earthquake be at least one-half that of the safe shutdown earthquake. Only in areas of very high seismicity do these two distinct criteria for specifying the OBE acceleration level become comparable. Based on the above discussion of the OBE, it should be determined through probabilistic analysis of the seismicity in the region. The OBE should be set to specific exposure time rather than 0.5 SSE. For example, a 10% probability of exceedence in a 50-year design life (50 years exposure) would be consistent with 475-year return rate or recurrence interval. Thus, specifying a 475-year recurrence interval for the OBE would be conservative for a seismic event which could reasonably be expected to affect the reactor site during the operating life of the plant.

A departure from setting the OBE to one-half the SSE is permitted within the guidelines of 10 CFR 100, Appendix A [11] which states: if an applicant believes that the particular seismology and geology of a site indicate that some of these criteria, or portions thereof, need not be satisfied, the specific sections of these criteria should be identified in the license application and supporting data to justify clearly such departures should be presented.

Probabilistic seismic analysis is being used in the design of many critical structures and is an excepted practice today. The setting of the OBE by probabilistic analysis will be more realistic for the operating life of the plant without effecting the safety of the public since the plant is designed to withstand the SSE without undue risk to the public.

CLOSURE

Guidelines for ground-motion definition both near-field and far-field for the eastern United States have been developed, with specific recommendations where they can be made. A proposed "new" method for the development of the operating basis earthquake is given and is felt that it is realistic for the eastern region of the country. These guidelines should prove useful in development of seismic design requirements for future reactors.

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