SEISMIC DESIGN DECISION ANALYSIS

NSF-RA-E-75-301

PB 293817

Sponsored by National Science Foundation Research Applied to National Needs NSF Grant G1-27955

INTERNAL STUDY REPORT NO. 51

NUCLEAR POWER PLANTS AND THE OPERATING BASIS EARTHQUAKE - PHASE I

by

Betsy Schumacker

January 1975

Department of Civil Engineering Massachusetts Institute of Technology Cambridge, Massachusetts

-

REFORT DOCUMENTATION 1. Stream Council and the Operating Basis Earthquake Phase 01, (Setsmit Design Decision Analysis), Internal Study Report 51. 1. New Plants and the Operating Basis Earthquake Phase 01, (Setsmit Design Decision Analysis), Internal Study Report 51. 1. New Plants and the Operating Basis Earthquake Phase 01, (Setsmit Design Decision Analysis), Internal Study Report 51. 1. New Plants and the Operating Basis Earthquake Phase 01, (Setsmit Design Decision Analysis), Internal Study Report 51. 1. New Plants Basis 0. Schumacker 1. New Plants Basis 0. Provide Study Rep. 51. 9. Metament 0. Schumacker 1. Decision Basis 0. Schumacker 1. Decision Basis 0. Schumacker 1. Decision Basis 0. Schumacker 9. Decision Operating Operating News 12. Second Operating Operating News National Science and Research Applications (ASRA) National Science Poundation 13. Superventage News 13. Type of Recent & Period Decision 0. GI27955 14. Washington, D.C. 20550 14. 15. Superventage News 16. Advance Line: 200 wordd 16. Superventage News 16. News Hampshire, yor generally that no Plants simultaneously with the QUES. This study is concerned solely with the QUES on of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked an area operating the next Y years. The study is not concerned with structural response, News Massachuschts; Charlestown, Rubde Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The Operation of the plants were considered to be: Niscasset, Maine; Seabrook, New Hampshire; Vernon, Wermont; Reve, Messachuschts; Charlestown, Rubde Siand; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Isl	50272 -101			
The Bask Dole Presenting Design Decision Analysis), Internal Study Report January 1975 2. Autors) January 1975 2. Autors) Environing Organization Name and Address Massachusetts Institute of Technology Internal Study Rep. 51 Department of Civil Engineering Internal Study Rep. 51 Department Compariza	REPORT DOCUMENTATION 1- REPORT NO. PAGE NSF-RA-E-75-301	2.	Per 2	93817
2. Additional Display=100 Address	Nuclear Power Plants and the Operating Basis Eart 01, (Seismic Design Decision Analysis), Internal 51	hquake Phase Study Report	5. Report Date January 6.	/_1975
B. Schumacker Line and Advess Massachusetts Institute of Technology Department of Civil Engineering Cambridge, Massachusetts 02139 11. Contractic or Carotic Units Applied Science and Research Applications (ASRA) National Science Foundation 12. Spreading Organization None and Advess Applied Science Foundation 13. Spreading Organization None and Advess Applied Science Foundation 14. Contractic or Carotic Units 15. Supplementary Motes 14. Supplementary Motes 15. Supplementary Motes 16. Advinced Line 200 words) Nuclear power plants are affected by two earthquake levels in their design and oper- ation: the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the QBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study Mich looked at an area comprised of three seismic source zones and nine nuclear power plants. The location of the plants study. A computer program developed in Russia at the Institute of Geophysics for damage and loss studies was do compute the effect of an earthquake on these sites. The assumptions used in the description of the seismicity of the region are described in this report. The results from this phase of the study are presented. 10. December Advess Nuclear power plants a. Levelther/Oper-Ended twos b.	7. Author(s)		8. Performing O	rganization Rept. No.
b. Premonia Cognization Name and Address Assachusetts Institute of Technology Department of Civil Engineering Cambridge, Massachusetts O2139 12. Spearang Organization Name and Address Applied Science and Research Applications (ASRA) National Science Foundation 1800 G Street, N.W. Washington, D.C. 20550 13. Supplementary Notes 14. 14. 14. 14. 14. 15. Supplementary Notes 15. Supplementary Notes 16. Abstract (Lime 200 words) Nuclear power plants are affected by two earthquake levels in their design and oper- ation: the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously will the Question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three selsmic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Wermont; Rowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Geophysics for dame; the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the arthquake on these sites. The assumptions used in the description of the selsmicity of the region are described in this report. The results from this phase of the study are presented. 15. Decement Ambies a Descriptor and loss studies e. COBATI Field/Group Earthquakes Nathematical models Damage Additione/Open Ended Terms Damage and loss studies e. COBATI Field/Group Earthquake Component an Barthquake Component an Ender in this study are presented. Earthq	B. Schumacker		Internal	Study Rep. 51
Massachusetts Institute of Technology Department of Civil Engineering Cambridge, Massachusetts 02139 11. Contraction of Condition No. Condition No. Cond	9. Performing Organization Name and Address		10. Project/Tasl	k/Work Unit No.
Department of Civil Engineering 11. cmtenet() is Grant(Ci) No. Cambridge, Massachusetts 02139 (C) 12. Sementing Organization None and Adress (C) 13. Springer Cambridge, Massachusetts 02139 (C) 14. Additional Science Foundation (ASRA) 1800 G Street, N.W. (C) 1800 G Street, N.W. (SE) National Science and Research Applications (ASRA) (C) 15. Supplementary Notes (SE) 16. Addition Down plants are affected by two earthquake levels in their design and operation: the safe shutdown earthquake (SE) and the operating basis earthquake (OE). This study is concerned solely with the OBE and the probability that a plant, two Plants Simultaneously, or generally that n plants simultaneously will have to shutdown for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three selsint source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Vermont, Newe, Massachusetts; Unerestown, Rhode ISI and; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Geophysics for damage nuclear power plants 17. Document Analysis a Descriptors<	Massachusetts Institute of Technology			
Cambridge, Massachusetts 02139 12. Seconomic Organization Name act Advers: Applied Science and Research Applications (ASRA) National Science Foundation 1800 G Street, N.W. Washington, D.C. 20550 14. 15. Supplementary Notes 16. Astruct Lunct 200 words 17. Supplementary Notes 18. Supplementary Notes 18. Astruct Lunct 200 words 19. Type of Record & Period Covered 10. Clear power plants are affected by two earthquake levels in their design and oper- ation: the safe shutdown earthquake (SEE) and the operating Dasis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three seismic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Yermont; Rowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Geophysics for damage and loss studies 10. Decomment Anatyles a Develotere Earthquakes NIIS 20. Mathematical models Damage Audies 21. Mathematical models Damage Audies 22. Mathematical models Damage Audies 23. Mathematical models Damage Audies 24. Mathematical models Damage Audies 25. Mathematical models Damage Audies 26. Mathematical models Damage Audies Audies 27. Mathematical Audi	Department of Civil Engineering		11. Contract(C)	or Grant(G) No.
Go G127955 Generation Name and Address Applied Science and Research Applications (ASRA) National Science Foundation 180 of Street, N.W. Washington, D.C. 20550 Suppermentary Notes Address shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three seismic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Vermont; Kowe, Massachusetts; Dralestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The study are presented. This study were plants the description of the seismicity of the region are described in this report. The results from this phase of the study are presented. This study and besident the description of the seismicity of the region are described in this neport. The results from this phase of the seismicity of the region are described in this report. The results from this phase of the study are presented. This study as loseristors a describers and loss studies a describers anage and loss studies anage and loss studies Shutdowns butdentifier/Down Ended Terres Damage Studies and loss studies anage Studies and loss studies anage Studies and loss studies anage Studies Studies and loss studies	Cambridge, Massachusetts 02139		(C)	
12. Spentoring Organization Name and Actress Applied Science And Research Applications (ASRA) National Science Foundation 1800 G Street, N.W. 11. Type of Report & Pende Covered 18. Mathing to Science Foundation 1800 G Street, N.W. 14. 15. Supplementary Notes 14. 16. Abstract (Limit 200 words) Nuclear power plants are affected by two earthquake levels in their design and oper- ation: the safe Shutdown earthquake (SSE) and the operating basis carthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three selsmic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine, Seabrook, New Hampshire; Vernon, Vermont; Rowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Robde Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Geophysics for damage and loss studies was used to compute the effect of an earthquake on these sites. The assumptions used in the description of the seismicity of the region are described in this report. The results from this phase of the study are presented. 21. Mo. of Pages 22. Mol. 20. Security Class (This Report) 23. Security Class (This Report) 24. Mol. Of Note 22. (A-7) 25. Security Class			(G) GI279	955
	12 Engraving Organization Name and Address		12 7	
1800 G Street, N.W. IA. Washington, D.C. 20550 IA. Is. Supplementary Notes IA. Is. Anatreal (Unit 200 words) Nuclear power plants are affected by two earthquake levels in their design and operation: the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three serient: source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Vermont; Nowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Beophysics for damage and loss studies was used to compute the effect of an earthquake on these sites. The assumptions used in the description of the seismicity of the region are described in this report. The results from this phase of the study are presented. 17. Document Anatysis a Descriptors Shutdowns a. Longither/Open Edded Terms Damage b. Mentiffier/Open Flatts Shutdowns	Applied Science and Research Applications (ASRA) National Science Foundation		13. Type of Rep	on & Perioa Covered
Washington, D.C. 20550 15. Supplementary Notes Nuclear power plants are affected by two earthquake levels in their design and oper- ation: the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three seismic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Vermont; Rowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Geophysics for damage and loss studies was used to compute the effect of an earthquake on these sites. The assumptions used in the description of the seismicity of the region are described in this report. The results from this phase of the study are presented. 12. Document Analysis & Descriptors Earthquakes Mathematical models b. Identifiery/DeerEnded Terms Damage and loss studies 2. Descriptore Earthquakes Mathematical models b. Identifiery/DeerEnded Terms Damage and loss studies	1800 G Street, N.W.		14.	
15. Supplementary Notes 16. Abstreat (Limit: 200 words) Nuclear power plants are affected by two earthquake levels in their design and operation: the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three seismic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Vermont; Rowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. A computer program developed in Russia at the Institute of Geophysics for damage and loss studies was used to compute the effect of an earthquake on these sites. The assumptions used in the description of the setudy are presented. 17. Document Amstyle a Descriptore Earthquakes Mathematical models Damage Nuclear power plants Shutdowns 21. No. of Pages b. Identifiers/OpenEnded Terms 23. Sec instructions on Riverne 24. No. of Pages b. Identifiers/OpenEnded Terms 24. No. of Pages 24. No. of Pages <td>Washington, D.C. 20550</td> <td>,</td> <td></td> <td></td>	Washington, D.C. 20550	,		
16. Abstract (Limit: 200 words) Nuclear power plants are affected by two earthquake levels in their design and operation: the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shutdown for inspection during the next Y years. The study is not concerned with structural response, but solely with the question of whether shutdowns for inspection will be required. This report describes the first phase of this study which looked at an area comprised of three seismic source zones and nine nuclear power plants. The location of the plants were considered to be: Wiscasset, Maine; Seabrook, New Hampshire; Vernon, Vermont, Rowe, Massachusetts; Plymouth, Massachusetts; Charlestown, Rhode Island; Waterford, Connecticut; Haddam, Connecticut; and Shoreham, Long Island. The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. Computer program developed in Russia at the Institute of Geophysics for damage and loss studies was used to compute the effect of an earthquake on these sites. The assumptions used in the description of the seismicity of the region are described in this report. The results from this phase of the study are presented. 17. Document Analysis a. Descriptors Earthquakes Mathematical models Damage and loss studies e. COSATI Field/Group is. dentificer/Osen Ended terms Damage and loss studies e. Avainability Statement NTIS	15. Supplementary Notes			
17. Document Analysis a. Descriptors Earthquakes Mathematical models Damage Nuclear power plants Shutdowns Damage b. identifiers/Open-Ended Terms Damage and loss studies Earthquakes Damage c. COSATI Field/Group 19. Security Class (This Report) 21. No. of Pages 18. Availability Statement 20. Security Class (This Page) 22. Price NTIS 20. Security Class (This Page) 22. Price iee ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77 (Formerly NTIS-35)) c Commerce	16. Abstract (Limit: 200 words) Nuclear power plants are affected by two earthqua ation: the safe shutdown earthquake (SSE) and th This study is concerned solely with the OBE and th plants simultaneously, or generally that n plants for inspection during the next Y years. The study response, but solely with the question of whether required. This report describes the first phase comprised of three seismic source zones and nine the plants were considered to be: Wiscasset, Mat Vermont; Rowe, Massachusetts; Plymouth, Massachus Waterford, Connecticut; Haddam, Connecticut; and taken as a modified Mercalli intensity VI for eac the actual situation. Differences in plant capac study. A computer program developed in Russia at and loss studies was used to compute the effect of assumptions used in the description of the seism this report. The results from this phase of the	ake levels in the operating bathe probability s simultaneousl dy is not concer shutdowns for of this study nuclear power ine; Seabrook, setts; Charlest Shoreham, Long ch plant, even city were ignor t the Institute of an earthquak icity of the re study are pres	heir designs sis eartho that a p y will hav rned with inspection which lood plants. New Hamps own, Rhod Island. though th ed in this of Geoph e on thes gion are ented.	gn and oper- quake (OBE). lant, two ve to shutdown structural on will be ked at an area The location of hire; Vernon, e Island; The OBE was is may not be s initial ysics for damage e sites. The described in
Earthquakes Mathematical models Damage Nuclear power plants Shutdowns Damage b. identifiers/Open-Ended Terms Damage and loss studies Earthquakes c. COSATI Field/Group 19. Security Class (This Report) 21. No. of Pages 18. Availability Statement 19. Security Class (This Report) 21. No. of Pages NTIS 20. Security Class (This Page) 22. Price 19. Security Class (This Page) 22. Price 10. Security Class (This Page) 19. Security Class (This Page) 22. Price 10. Security Class (This Page) 19. Security Class (This Page) 22. Price 10. Security Class (This Page) 19. Security Class (This Page) 22. Price 10. Security Class (This Page) 10. Security Class (This Page) 22. Price 10. Security Class (This Page) 10. Security Class (This Page) 22. Price 10. Security Class (This Page) 10. Security Class (This Page) 22. Price 10. Security Class (This Page)	17. Document Analysis a. Descriptors			
Nuclear power plants Shutdowns b. identifiers/Open-Ended Terms Damage and loss studies Damage and loss studies c. COSATI Field/Group 19. Security Class (This Report) 21. No. of Pages 18. Availability Statement NTIS 20. Security Class (This Page) 22. Price PCAO2 19. Security Class (This Page) 22. Price PCAO2 20. Security Class (This Page) 19. Security Class (This Page) 22. Price PCAO2 20. Security Class (This Page) 19. Security Class (This Page) 22. Price PCAO2 20. Security Class (This Page) 10. Security Class (This Page) 19. Security Class (This Page) 22. Price PCAO2 10. Security Class (This Page) 19. Security Class (This Page) 22. Price PCAO2 10. Security Class (This Page) 19. Security NTIS-35) 10. Security NTIS-35) 10. Security Class (This Page) 19. Security NTIS-35) 10. Security NTIS-35)	Earthquakes Mathematica	l models		Damage
b. Identifiers/Open-Ended Terms Damage and loss studies c. COSATI Field/Group 18. Availability Statement NTIS 20. Security Class (This Report) 22. Price PCAD2 See Instructions on Reverse OPTIONAL FORM 272 (4-77 (Formerly NTIS-35) 14	Nuclear power plants Shutdowns			
c. COSATI Field/Group 18. Availability Statement NTIS 19. Security Class (This Report) 21. No. of Pages 22. Price 23. Price 24. Price 24. Price 24. Price 25. Price 26. Price 26. Price 26. Price 26. Price 27. Price 27. Price 27. Price 27. Price 27. Price 27. Price 28. Price 28. Price 29. Price 20. Security Class (This Page) 20. Security Class (This Page) 22. Price 23. Price 24. Price 24. Price 25. Price 26. Price 26. Price 26. Price 26. Price 27. Pric	b. Identifiers/Open-Ended Terms Damage and loss studies			
18. Availability Statement 19. Security Class (This Report) 21. No. of Pages NTIS 20. Security Class (This Page) 22. Price See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77 (Formerly NTIS-35)) L L Department of Commerce	c. COSATI Field/Group			
INFLO 20. Security Class (This Page) 22. Price Image: Price See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77 (Formerly NTIS-35)) i Department of Commerce	18. Availability Statement	19. Security Class (This	Report)	21. No. of Pages
See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77 (Formerly NTIS-35) CACACIAL CONTINUE (Formerly NTIS-35) Department of Commerce	CTIN	20 Security Class (This	Page)	22. Price
See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77 (Formerly NTIS-35) CPTIONAL FORM 272 (4-77 (Formerly NTIS-35) Department of Commerce		TOP BECOMINY CLESS (1915		PCAO2 Man
	See ANSI-Z39.18) See Instructions on Rev	/erse		OPTIONAL FORM 272 (4–77) (Formerly NTIS–35) Department of Commerce
	4			a permitte or commission

1

**

CAPITAL SYSTEMS GROUP, INC. 6110 EXECUTIVE BOULEVARD SUITE 250 ROCKVILLE, MARYLAND 20852

SEISMIC DESIGN DECISION ANALYSIS

Sponsored by National Science Foundation Research Applied to National Needs NSF Grant G1-27955

INTERNAL STUDY REPORT NO. 51

NUCLEAR POWER PLANTS AND THE OPERATING BASIS EARTHQUAKE - PHASE I

by

Betsy Schumacker

January 1975

Department of Civil Engineering Massachusetts Institute of Technology Cambridge, Massachusetts

> Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s)and do not necessarily reflect the views of the National Science Foundation.

Nuclear power plants are affected by two earthquake levels in their design and operation:

(1) the safe shutdown earthquake (SSE), and

(2) the operating basis earthquake (OBE).

For earthquakes in regions where there are no identified active faults, the safe shutdown earthquake is the maximum earthquake intensity which has occurred in the seismotectonic province in which the plant is located. The OBE earthquake has been defined in several ways over the years; most recently it has been defined as an intensity with 1/2 the peak acceleration of the safe shutdown earthquake. The OBE is used in two ways:

- (1) The plant and its equipment must be designed such that the stresses must stay within normal code-specified working stresses if an $a_o^=$ OBE occurs at the site, and
- (2) If an a_g> OBE occurs at the site, then the plant must shut down and be inspected to determine if it is safe for continuous operation.

If an earthquake occurs which generates ground motion greater than the safe shutdown level, the plant must be designed so that it can safely shut down even though damage may have occurred.

This study is concerned solely with the OBE and the probability that a plant, two plants simultaneously, or generally that n plants simultaneously will have to shut down for inspection during the next Y years. We are not concerned with structural response, but solely with the question of whether shut-downs for inspection will be required.

This question arose from the fact that many utility companies would like to see the OBE lowered, since the OBE at present controls the design of certain portions of a typical plant. (That is, the OBE plus the requirement of staying within normal working stresses is, for some of a plant, a more stringent design requirement than safe shut-down following on SSE.) On the other hand, if the OBE is lowered, then the likelihood of it being exceeded is increased and the probability that more than one plant could be affected is increased. The decision to study these probabilities was made for two reasons:

 This could turn into a very interesting and worthwhile application of some of the work developed in the SDDA project;

1.

(2) This would include an investigation of the feasibility of using a computer program developed in Russia at the Institute of Geophysics for damage and loss studies (see first four entries on reference list).

This report describes the first phase of this study. Later phases will look at plants in the entire northeast region (New England, New York, Pennsylvania, and New Jersey) and use the seismic source zones and occurrence data developed by Algermissen.

This initial phase of study looked at an area comprised of three seismic source zones and nine nuclear power plants. The power plants are located (or might in the future be located) at:

1. Wiscasset, Maine

- 2. Seabrook, New Hampshire
- 3. Vernon, Vermont
- 4. Rowe, Massachusetts
- 5. Plymouth, Massachusetts
- 6. Charlestown, Rhode Island
- 7. Waterford, Connecticut

8. Haddam, Connecticut

9. Shoreham, Long Island.

The OBE was taken as a modified Mercalli intensity VI for each plant, even though this may not be the actual situation. Differences in plant capacity were ignored in this initial study. The seismic source zones have the following frequency of occurrence and intensity range:

Zone A:	v = 15/250 per year;	V <u>≤</u> 1 <u>_</u> VIII.3
Zone B:	v = 6/250 per year;	V <u><</u> I <u>o</u> < VIII.3
Zone C:	v =33/250 per year;	V <u><</u> I <u>o</u> < VIII.7
Background:	$v = 8 \times 10^{-7} / yr/mi^{2}$	V <u>≤</u> I <u></u> ≤ VI.3

where I_0 is the maximum epicentral intensity for each source zone and ν is the annual rate of occurrence of earthquakes with $I_m \geq 5$ in each zone. These source zones were originally suggested by Richard Holt of Weston Geophysical, and the source zone parameters were developed by Professor Cornell from data supplied by Mr. Holt.

The area is shown in Figure 1. The plants are designated by a with the number inside corresponding to the number in the list above. The zones are labelled A, B, C except for the background zone. That zone consists of the triangular area bounded by the A, B, C zones.

As mentioned before, a Russian program (KKM program, for its authors: Keilis-Borok, Kronrod and Molchan) was used to compute the effect of an earthquake on these sites. The assumptions used in the description of the seismicity of the region are described in the next section of this report; the results from this phase of the study are given in the third section of this report.

ASSUMPTIONS

20

The following assumptions were made about the models and their parameters.

1. Magnitude-intensity relationship.

The relationship between magnitude and epicentral intensity was assumed to be

 $M = 1 + \frac{2}{3} I_{o}$.

2. The frequency-of-occurrence law.

The model for frequency-of-occurrence of earthquakes used in the KKM program is

 $\log N(M) = \alpha_{0} - \bigvee_{1} (M-M_{0}) \qquad \text{for } M \leq MLR$ $\log N(M) = \alpha_{0} - \bigvee_{1} (MLR-M_{0}) - \bigvee_{2}M \qquad \text{for } M > MLR.$

The slope of the magnitude-log of rate of occurrence curve was assumed constant; hence, there was no "point of bend" MLR or second slope χ_2 . Thus our model was simply the first equation,

 $\log N(M) = \alpha_{0} - \gamma_{1} (M-M_{0})$ where M₀ is merely that magnitude for which α_{0} is computed, and with M \leq MMAX₁ i=1,4 where MMAX₁ is the truncation point for the curve of magnitude vs. log of rate of occurrence curve for seismic zone **i**.

For purposes of the first phase of this study, it was desirable to use seismicity data which had already been used for seismic risk computations of sites in our area of interest. This would provide us with a check on the KKM program and on the interpretations of input specifications to this program. For this reason, rate-of-occurrence data was extrapolated from Figure 2 of SDDA Report No. 11. It became obvious (after a while) that the M_0 had to be chosen carefully in order to compute a slope χ_1 that gave a reasonable area (total rate of occurrence). This was due at least in part to having to "eyeball" the percentages for each level of intensity.

The parameters, then, were

	αο	<u>¥1</u>	Mo	MMAX
Zone A	-3.6904	.7028	5.0	6.53
Zone B	-4.0883	.7028	5.0	6.53
Zone C	-3.3479	.7028	5.0	6.8
Background	-4.8401	.9574	5.0	5.2

3. The model of isoseismals.

Shape and orientation:

Isoseismals, for the purposes of the first phase of this study, were assumed circular. Hence there was no variation in the orientation of the isoseismal - in essence, no orientation. Actually, the isoseismals were specified as ellipses with a major/minor axis ratio (elongation) of 1.0 and a fixed orientation with no corrections.

Areas:

The model for isoseismal area used in the KKM program is

log Q_c (e|g) = log \hat{Q}_c (e|g) + $\Delta Q(g)$ where log \hat{Q}_c is the mean value of the log of area $Q_c(e|g)$ and ΔQ is a random addition defined by a distribution function. The mean value

 $\hat{\mathbb{Q}}_{\textbf{C}}$ and the magnitude M of an earthquake are related by

 $\log \hat{Q}_{c} (M|g) = a_{c} (g) + b_{c} (g) M$

and the function for correction ΔQ is defined by σk where $b_c M + \sigma k \ge \varepsilon$.

For this study, then, the following parameter values were used:

 $b_c = 0.8$ $\sigma = 0.2$ k = 2.5 $a_c = -1.04$, -1.62, -2.20, -2.76 for intensities VI through IX

respectively. These values for a were computed based upon the relationship

 $I_{SITE} = 2.6 + I_0 - 1.3 \ln (R) \qquad R \ge 10 \text{ mi}$ $I_{SITE} = I_0 \qquad R < 10 \text{ mi}.$ The values for b_c and σ were obtained from SDDA Report No. 11.

Ground corrections:

The KKM program provides for corrections to the intensity of tremors at a point \tilde{g} due to local soil conditions. For this study, no corrections for local soil conditions were introduced

Effect of earthquake:

A treemor at a site of intensity c causes an effect expressed by a relationship of the form:

effect (t, g, e) = DAM (g) \cdot LAWD (g, c) where LAWD is a relationhip between damage and intensity (a DPM) for a specific site g and DAM is a base factor for damage.

For the purposes of the first phase of this study, the base factor DAM was defined as the same for all 9 sites and the damage/intensity relationship was 1.0 for all intensities; i.e., the same damage would occur for intensity VI as for VII, VIII and IX. This makes sense when this relationship is interpreted as saying that a plant would have to shut down no matter what the intensity as long as the intensity was VI or greater.

FINDINGS

0

The results obtained from this phase of the study are:

- 1. The annual probability of 1 or more plants being hit by intensity VI or greater is 9.87×10^{-3} .
- 2. The annual probability of 2 or more plants being hit by intensity VI or greater is 6.87×10^{-4} .
- 3. The annual probability of 3 or more plants being hit by intensity VI or greater is 8.04×10^{-5} .
- 4. The annual probability of Seabrook being hit by intensity VI or greater is $4.28 \ge 10^{-3}$. (This is of interest as a check, since this annual probability had been computed in earlier studies by Professor Cornell.)
- 5. The maximum number of plants which would be affected by a single earthquake is three. That is, with the assumed maximum magnitudes and attenuation law, it turns out that no more than 3 plants can experience an intensity VI or greater during a single earthquake.

REFERENCES

£1

 G. Molchan, V. Keilis-Borok, G. Vilkovich. "Seismicity and Principle Seismic Effects." Geophys. J. Roy. Astron. Soc., 1970, V. 21, pp. 323-35.

6

- M. Caputo, V.I. Keilis-Borok, T.L. Kronrod, G.M. Molchan, G. Panza, E. Piva,
 V.M. Podgaetskaja, D. Postpishl. "The Estimation of Seismic Risk for Central Italy." Computational Seismology, Vol. 6, 1974.
- L.V. Kantorovich, V.J. Keilis-Borok, G.M. Molchan. "Seismic Risk and Principles of Seismic Zoning." <u>Computational Seismology</u>, Vol. 6, 1974. Translated as Internal Study Report No. 43.
- V.I. Keilis-Borok, T.L. Kronrod, G.M. Molchan. "Algorithm for the Estimation of Seismic Risk." <u>Computational Seismology</u>, Vol. 6, 1974. Translated as Internal Study Report No. 46.
- 5. C.A. Cornell, H.A. Merz. "A Seismic Risk Analysis of Boston." SDDA Report No. 11, April, 1974.

