J. Kimball

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Docket No.: 50-155

MEMORANDUM FOR: Robert Jackson, Chief
Geosciences Branch
Division of Engineering

FROM: George Lear, Chief
Hydrologic and Geotechnical Engineering Branch
Division of Engineering

SUBJECT: EVALUATION OF GEOTECHNICAL DATA FOR DEVELOPING SEISMIC DESIGN BASIS FOR THE SITE

Plant Name: Big Rock Point Nuclear Power Plant (BRP)
Docket Number: 50-155
Responsible Branch: SEPB, T. Cheng, LPM

Soil conditions at the Big Rock Point power plant (40 ft overburden over bedrock) indicate possible ground motion amplification which might exceed the previously recommended spectrum, which was developed as part of the Systematic Evaluation Program (SEP). Attached is our evaluation of the geotechnical data available for the BRP site which presents the typical section and design parameters for use in studies to determine whether the previously recommended seismic design spectrum is appropriate.

This memorandum was prepared by Banad Jagannath, Geotechnical Reviewer of my branch and he may be reached at extension 28368.

Original signed by George Lear

George Lear, Chief
Hydrologic and Geotechnical
Engineering Branch
Division of Engineering

Enclosure:
As stated

cc: See page 2

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Big Rock Point Nuclear Power Plant
Docket No. 50-155
Geotechnical Evaluation of the Site

Prepared by B. Jagannath, GES, HGEB, DE

The Licensee of the Big Rock Point Power Plant, one of the Systematic Evaluation Program (SEP) plants, has petitioned for a license for modifications/additions to the Spent Fuel Pool at the plant. As part of the seismic safety margin study of the plant, available geotechnical data has been evaluated by the staff to establish the site profile.

1. Geotechnical Data Available

   The evaluation is based on the following:

   1) 'Soil Report', Big Rock Point Plant, Charlevoix, Michigan, by Soil Testing Services, Inc., March 7, 1960 (Reference 1).

   2) "Geophysical Cross-Hole Survey", Big Rock Point Nuclear Power Plant, Charlevoix, Michigan, January 1979. (Reference 2).

The first set of data, Soils Report (1960), presents the geotechnical investigation and analyses performed in connection with the construction of the power plant. The investigation consisted of drilling seven borings and performing laboratory tests on soil samples recovered from the borings. The site was classified as relatively seismically in-active and hence dynamic characteristics of the soil and rock at the site were not determined.

The second set of data, Geophysical Cross-Hole Survey Report (1979), presents the geophysical investigations performed to establish the dynamic properties of the materials at the site. This investigation consisted of drilling three borings and performing cross-hole tests to determine the compressional and shear wave velocities of the soil and rock at the site. The report presents details of the test and measured values of shear and compressional wave velocities as a function of depth.

2. Evaluation of Site Data

The site has approximately 40 ft thick soil overburden overlying limestone bedrock; the overburden is composed of:

- 7 to 10 ft thick, medium dense to dense, fine to coarse sand with some gravel and limestone chips, and varying amount of silt. This is a glacial outwash deposit. Standard penetration test (ASTM D1586) blow count ranged from 8 to 33. The soil is predomonantly cohesionless. The ground water table is controlled by the adjoining lake level and is at an approximate depth of 8 ft below ground surface.

- 30 to 35 ft thick, fine to coarse sand with some clay, trace of silt and gravel. This is a very stiff cohesive glacial till. The standard penetration test blow count ranged from 19 to 162. Sand lenses were occasionally encountered in this stratum.

- The bedrock is limestone. The upper 15 to 17 ft of this is highly fractured and weathered fossiliferous limestone with seams of clay. The core recovery in this zone ranged from 0 to 90 percent and the RQD (Rock Quality Designation) ratio ranged form 0 to 26.

  This highly fractured limestone zone is underlain by approximtely 75 ft thick massive limestone with occasional seams of clay. The core recovery in this ranged from 40 to 100 percent and the RQD ratio ranged from 0 to 84.

  This massive limestone is underlain by approximately 50 ft thick, highly fractured limestone with Vugs. The core recovery in this zone ranged from 10 to 100 percent and the RQD ratio was 0.

  The fractured vuggy zone is underlain by massive limestone. The core recovery in this zone ranged from 52 to 100 percent and the RQD ratios ranged from 55 to 90. The deepest boring at the site (201 ft deep) was terminated in this stratum.

Recommended Site Profile

The soil and rock parameters needed for the evaluation of amplification effects at the plant are: bulk density, shear wave velocity and Poisson's ratio.

Bulk density was determined by laboratory tests on soil and rock samples recovered form borigns. In site compressional and shear wave velocities were measured in the cross-hole test. Posisson's ratio was computed

Table 1

Recommended Design Parameters for Dynamic Analysis

Layer	Avg Thickness Feet	Bulk Density Lbs/ft^3	Shear Wave Velocity Ft/sec.	Poisson's Ratio
Sand & Gravel	8	130	840	0.42
Sand, Gravel & Clay (TILL)	32	147	1860	0.45
Limestone (Weathered & Fractured)	16	150	4200	0.42
Competent Limestone	75	155	5360	0.40
Vuggy Limestone	50	130	4080	0.46
Competent Limestone	*Boring terminated in this layer.	155	6000	0.40

*Groundwater table is at the top of the till.

References

1. "Soil Report, Big Rock Point, Charlevoix, Michigan" by Soil Testing Services, Inc., - March 1960.

2. "Geophysical Cross-Hole Survey, Big Rock Point Nuclear Power Plant, Charlevoix, Michigan," by D'Appolonia - January 1979.

April 27, 1979

→ Reiter

SECY-79-300

UNITED STATES
NUCLEAR REGULATORY COMMISSION

INFORMATION REPORT

For: The Commissioners

From: Robert B. Minogue, Director
Office of Standards Development

Thru: Lee V. Gossick, Executive Director for Operations

Subject: IDENTIFICATION OF ISSUES PERTAINING TO SEISMIC AND GEOLOGIC SITING REGULATION, POLICY, AND PRACTICE FOR NUCLEAR POWER PLANTS

Purpose: To inform the Commission of the status of the staff's reassessment of Appendix A "Seismic and Geologic Siting Criteria For Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria."

Background: This paper is a sequel to SECY 77-288A, which described current licensing practice and regulatory requirements in the seismic and geologic siting area. Appendix A to Part 100 sets forth a framework that guides the staff in its evaluation of the adequacy of applicants' investigations of geologic and earthquake phenomena and proposed plant design parameters. The bases for Appendix A were established in the late 60's and it became effective in December 1973. Since then, with advances in the sciences of seismology and geology along with the occurrence of some issues in licensing cases not foreseen in the development of Appendix A, a number of significant difficulties have arisen in the application of this regulation. As a result of these difficulties, the staff began a reassessment of Appendix A. This stage of the staff reassessment involved identifying problem areas needing resolution.

Issues identified in the enclosures have been synthesized from comments by the staff, meetings with the Seismic Subcommittee of the Advisory Committee on Reactor Safeguards and its consultants, interested persons who responded to a staff FEDERAL REGISTER notice on January 19, 1978 (eighteen comments were received), and other sources. Enclosure E describes in more detail the background for this paper and sources of information used.

Discussion: Issues that have been identified have been divided into three categories and presented in Enclosures A, B, and C. Enclosure A contains issues that stem directly from geoscience requirements put forth in Appendix A. Enclosure B contains issues arising from engineering requirements in Appendix A, procedures for providing an interface of these requirements with geologic and

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seismic input and with matters involving scientific and engineering conservatism. Enclosure C contains broad policy and technical issues bearing on the implementation of Appendix A and its revision. Enclosure F, memo from Minogue to Commissioner Mason, dated October 8, 1976, provides further information on seismic issues (Operating Basis Earthquake Concept).

In making geoscience assessments, there is a need for considerable latitude and judgement. This latitude and judgement is required because of limitations in data, the state of the art of geologic and seismic analyses, and the rapid evolution taking place in the geosciences in terms of accumulating knowledge and in modifying concepts. This appears to have been recognized when Appendix A was developed. However, having geoscience assessments detailed and cast in Appendix A, a regulation, has created difficulty for applicants and the staff in terms of inhibiting the use of needed judgement and latitude. Also, it has inhibited flexibility in applying basic principles to new situations and the use of evolving methods of analyses in the licensing process. Additionally, various sections of Appendix A lack clarity and are subject to different interpretations and dispute. Also, some sections in the Appendix do not provide sufficient information for implementation. As a result of being both overly detailed in some areas and not detailed enough in others, the Appendix has been the source of licensing delays and debate, has inhibited the use of some types of analyses and has inhibited the development of regulatory guidance.

In other siting areas, such as hydrology, regulatory guidance has been handled effectively through the use of regulatory guides and a program for their continuous updating. Many problems encountered in implementing Appendix A could best be alleviated through the use of regulatory guides and a program for continuous updating. The best course of action appears to be that Appendix A be revised to express the general intent of geologic and seismic assessments and that details presently in Appendix A be incorporated into a set of "1st generation" regulatory guides which would provide at least the equivalent of what is now in Appendix A. The "1st generation" guides could then be updated and supplemented with further guides to keep pace with advances in the state of the art and staff experience gained in the review of license applications.

The subsequent stage of the staff reassessment is discussed in Enclosure D. In brief, the next stage will consist of a value-impact analysis of issues, the development of a revised regulation and supplemental regulatory guides, as was stated in the prior paragraph, and the development of a policy paper making specific recommendations for rule making.

Coordination: The enclosures to this paper were prepared jointly by the Offices of NRR and OSD. The Office of NRR concurs in this paper; the Offices of I&E, RES and OELD, and the Seismic Subcommittee of the ACRS were consulted. OELD has no legal objections to this paper.

Robert B. Minogue

Robert B. Minogue, Director
Office of Standards Development

Enclosures:

A. Geoscience Issues Originating from Appendix A to 10 CFR Part 100
B. Engineering Design Issues Related to Vibratory Ground Motion
C. Broad Policy and Technical Issues Bearing on the Implementation and Revision of Appendix A
D. Summary of Subsequent Stage in the Assessment of Current Seismic and Geologic Siting Criteria, Policy, and Practice
E. Background and Sources of Information Used in this Paper
F. Memo from R.B. Minogue to Commissioner Mason, 10/8/76, "The Relationship between Safe Shutdown Earthquakes and Operating Basis Earthquakes"

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B. Revision of Appendix A to 10 CFR Part 100 and Development of Supplemental Guides

ENCLOSURE E: BACKGROUND AND SOURCES OF INFORMATION USED IN THIS PAPER

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ENCLOSURE A

ENCLOSURE A

GEOSCIENCE ISSUES ORIGINATING FROM APPENDIX A TO 10 CFR PART 100

1. INTRODUCTION

General Design Criterion 2 of Appendix A to 10 CFR Part 50 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, and tornadoes, without loss of capability to perform their functions. Appendix A to 10 CFR Part 100, Seismic and Geologic Siting Criteria for Nuclear Power Plants, sets forth criteria pertaining to site investigations to assess the effects of earthquakes and other geologic phenomena to meet the requirements of General Design Criterion 2. Appendix A sets forth considerations which guide the Commission in its evaluation of: (1) the suitability of a proposed site; (2) the suitability of plant design bases established in consideration of site characteristics; and (3) reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public. When Appendix A was developed, it was recognized that limitations in data and the state of the art would necessitate future modifications as data increased and the state of the art advanced (see SCOPE of Appendix A and Statement of Considerations).

Appendix A criteria, procedures and methods are directed toward the following major objectives:

a. The estimation of the severity of ground shaking at a site due to potential earthquakes for use in nuclear power plant design;

b. The assessment of the potential for ground rupture that could affect plant structures due to fault movement;

c. The evaluation of the effect on the site of phenomena associated with earthquakes such as seismically generated sea waves and ground failure; and

d. The assessment of the potential for other geologic hazards at a site such as landslides and subsidence.

The principal issues discussed in this enclosure relate to tectonic provinces, tectonic structures, capable faults, and specification of the Safe Shutdown Earthquake and Operating Basis Earthquake. These concepts have been put forth in Appendix A to achieve the above objectives. Difficulties have arisen with regard to the application of these concepts.

An additional issue that has been identified but is not discussed further in this paper concerns volcanic hazards. Appendix A states that volcanic hazards are to be addressed on a case-by-case basis; however, it has been suggested that generic regulatory guidance be provided.

1.1 Impacts of Issues

Issues identified in this enclosure have far-reaching impacts on siting policy and practice, plant design and construction, and ultimately on safety margins presently applied in these areas. Major impacts are summarized below.

Impaired efficiency of licensing process (delays)

Seismic difficulties in cases and debate over requirements in Appendix A have led to considerable delays. The extent of impact in this area is difficult to quantify. However, NUREG-0292, "Nuclear Power Plant Licensing: Opportunities for Improvement," indicates considerable schedule slippage due to delays in geology/seismology reviews. In the reviews of Indian Point 2 and 3, WPPSS 1 and 4, Skagit, Pebble Springs, and Pilgrim 2, debate over satisfying Appendix A requirements caused delays in excess of a year. In addition, faulting on the site, and perceived difficulties by the applicant in meeting the requirements of Appendix A was the reason given for the withdrawal of the Sears Island proposed site.

Expenditure of manpower

Because of difficulties encountered, considerable manpower is required for case review, preparation and response to interrogatories, preparation of testimony, and appearance at hearings. Often problems requiring considerable manpower stem from difficulties in making geologic or seismic assessments because of limitations in data and the state of the art. However, difficulties have been encountered which arise more from attempts to meet requirements in Appendix A than from a given seismic or geologic assessment. For example, the Indian Point 2 and 3 case before the ASLAB (Atomic Safety and Licensing Appeal Board) dealt with many fundamental issues stemming from Appendix A requirements and involved approximately 12 members of the staff (technical review and legal) over a 2-year period.

Restricted ability to use advances in science and engineering

The staff is inhibited in certain parts of its review from using state-of-the-art analysis because Appendix A, as a regulation, cannot be easily modified to accommodate developments in science or engineering methodology. The future development of the review process is also inhibited because results of NRC research or state-of-the-art procedures and methods, which might be incorporated into regulatory guides, are often not compatible with the requirements of Appendix A. The NRC has spent millions of dollars for research and contract support work in the earth science area. Much of this work has been necessitated by difficulties in applying the requirements of Appendix A to cases. As an important example, the NRC is sponsoring geologic and seismic research over a period of 5 years in the approximate amount of $3.5 million to find a definitive means of implementing the tectonic province concept (a basic concept introduced in Appendix A to determine seismic potential, but not developed). Even if such a means is found, Appendix A is worded such that the results of this research could be incorporated into the licensing process only by further rulemaking.

The validity of various procedures employed in the geologic and seismic review process has been increasingly questioned by experts in the earth science community familiar with these current procedures. In particular, the concepts of tectonic province and capable faulting, stated as regulations, have been criticized by experts because they imply that certain procedures involving interpretation and professional judgment are definitive with respect to their solutions to a particular problem.

Impacts on backfitting

Evolution of staff practice in an attempt to meet requirements in Appendix A and to incorporate state-of-the-art procedures have raised questions concerning the need for backfitting of previously licensed facilities. For example, a number of TVA plants were recently reassessed as to their adequacy in light of evolving staff practice in assessing earthquake ground motion (response spectra, intensity-acceleration relationships). Because Appendix A lacks guidance on a quantitative measure of conservatism to be met, it inhibits staff reassessments of existing facilities in terms of assessing whether design or construction modifications are needed, and creates uncertainty for applicants, as to whether plants having construction permits will receive operating licenses in light of new data.

Difficulties for applicants created by the regulation

Appendix A was developed prior to the present-day concepts of early site review, limited work authorization and alternative site review. Because the present regulation emphasizes a case-by-case approach, it is not compatible with the application of these new concepts which use a generic approach. Uncertainty for applicants concerning the licensing process is caused by a lack of clear guidance in the regulation regarding what constitutes acceptability for various aspects and stages of the current review process. Additionally, there are instances where the regulation has fostered nonuniformity and redundancy in SAR submittals, particularly with regard to defining tectonic provinces. A number of differing tectonic province schemes have been submitted by applicants that meet the requirements in Appendix A but are of questionable value for sites located in the same geographic area. On the other hand, for sites in the same area, the same tectonic province scheme is resubmitted with extensive documentation that is already available in other SARs.

Impacts on safety

The issues identified in this enclosure have impact on the margin of safety presently being applied in seismic design. The degree of this impact is hard to ascertain in a rigorous sense. Some issues bear on increasing while others bear on decreasing margins of safety presently applied. Most issues relate to the application of professional judgment and experience, and differing opinions exist as to the adequacy of determinations and the level of conservatism achieved. Our understanding of the impact of issues on safety is limited because safety margins and overall conservatism are not quantitatively defined.

2. ISSUES

2.1 Tectonic Provinces And Associated Concepts

Four principal conceptual elements contained in Appendix A govern the determination of the maximum intensity of ground shaking due to earthquakes to be considered appropriate at a site. These four elements are the concepts of tectonic province, tectonic structure, capable fault (discussed in Section 2.3), and "reasonable" correlation of seismicity with geologic structure. A tectonic province is defined in Appendix A as:

> "a region of the North American continent characterized by a relative consistency of the geologic structural features contained therein."

The concept of tectonic province was developed to provide an appropriate design basis for earthquakes whose cause is presently indeterminate. The staff interprets this concept as employed in Appendix A to imply regions of uniform earthquake hazard.

A tectonic structure is defined as:

> "a large-scale dislocation or distortion within the earth's crust. Its extent is measured in miles."

The concept of tectonic structure is employed in Appendix A to ensure consideration of structure which might localize seismicity in the vicinity of a site, and therefore, might require special attention in assessing the seismic design bases.

What constitutes a reasonable correlation between seismicity and structure is not defined in Appendix A. However, Appendix A requires:

> "correlation of epicenters or locations of highest intensity of historically reported earthquakes, where possible, with tectonic structures any part of which is located within 200 miles of the site. Epicenters or locations of highest intensity which cannot be reasonably correlated with tectonic structures shall be identified with tectonic provinces any part of which is located within 200 miles of the site."

Epicenters that cannot be reasonably correlated represent events which then must be assumed to have the potential for occurring randomly within a tectonic province.

The definition of tectonic province contained in Appendix A mentions only geologic structural features but implies that areas of uniform seismic potential will be delineated. Use of information restricted solely to geologic structure and without regard for its geochronological or seismological significance has led to a variety of tectonic province schemes, particularly in the East. Some of these schemes conform to the classical Paleozoic (250-600 million years before the present) geological provinces depicted on most maps. However, these maps, such as those by King (1969, 1974), Eardley (1962) and Rodgers (1970), were not developed with any attention to the possible distribution of seismically active structures. In fact, a study sponsored by the regulatory staff of the Atomic Energy Commission and carried out by the U.S. Geological Survey (Hadley and Devine, 1974), and motivated by concern about this issue, shows that there is a very limited correlation between the classical Paleozoic structural provinces and earthquake activity. Other schemes proposed by applicants and based on Paleozoic geology may meet the definition in Appendix A but suffer from the limited correlation between earthquakes and Paleozoic structure. The type of assessment called for in Appendix A does not provide adequately for vitally important factors bearing on the determination of a tectonic province and the earthquake ground motion for a given site. These factors are:

a. Seismicity

The pattern, frequency, and intensity of historic and instrumentally recorded seismicity is probably the best and most direct indicator of present-day tectonic activity in the East. As such, it is clearly the most relevant parameter for defining areas of uniform seismic hazard. However, as presently written, Appendix A doesn't speak to the application of this data base to the tectonic province concept.

b. Post-Paleozoic tectonics

The post-Paleozoic and particularly neotectonic (15 million years and younger) development of a region is important to the assessment of tectonic provinces. In areas of relatively high seismicity on a world-wide basis, there is a good correlation between earthquakes and structures formed during this period. Additionally, the theory of plate tectonics indicates that the current pattern of tectonic driving forces that affects the stress pattern in the North American continent occurred during post-Paleozoic time. In the eastern U. S., post-Paleozoic deformational effects are not as pervasive or well exposed as are those of the Paleozoic. These subtle effects have not generally been considered in the past mapping of tectonic elements to be of the same level of importance as older deformational features. In part, this is caused by a bias in mapping toward large-scale geologic structures.

c. Advances in Scientific Understanding

Since Appendix A was first drafted in 1966, took much of its current form in 1969, and was formally adopted in 1973, progress has been made in our understanding of intraplate seismicity, and the expansion of the data base is proceeding at a rapid pace. Important information has been collected and synthesized on stress distribution and relief, seismic sources, deep crustal structures, and microseismicity. Because of its incorporation of detail in the form of a regulation, Appendix A does not permit such advances in science to be readily incorporated into the licensing process.

Reliance solely on geologic structure to define areas of uniform earthquake hazard, as Appendix A can be construed, is an over simplified approach and has led to a number of problems. The selection of the appropriate geologic structures as boundaries of tectonic provinces is controversial in almost every case. Lack of guidance in this area has permitted applicants and the staff to consider widely varying province configurations for sites located in the same geographic area and has led to assessments of uncertain value with regard to conservatism and scientific validity.

To date, the NRC has not succeeded in developing a tectonic province siting map, and in fact efforts to do so have brought about further complexities. Controversy about size and distribution of tectonic provinces has led to the recommendation (e.g., the ASLAB in their conclusions on Indian Point) that NRC establish such a generic map for siting purposes. Although several Federal agencies have adopted maps to establish the seismic design basis for various types of structures, it would not appear appropriate to apply these to nuclear reactors. For the Commission to do so, a number of fundamental policy issues must first be addressed. All the state-of-the-art seismic zoning maps being developed rely to some degree on probabilistic considerations. At present, there is no consistent NRC policy in the geoscience area regarding the use of probabilistic methods for nuclear power plants. Furthermore, adoption of any particular map based on probabilistic considerations will necessarily require that a specific level of conservatism or confidence be defined. To date, no policy has been established stating the specific level of conservatism required in the geoscience area. Even when these issues have been addressed, the adoption of a tectonic province map based on any factors other than "consistency of geologic structure" will run contrary to a literal interpretation of the present regulation.

Appendix A allows for more conservative assessments than might normally result from using the tectonic province procedures set forth in the regulation in areas having "complex geology" and "high seismicity" or "where geologic and seismic data warrant." "Complex geology" and "high seismicity" are relative terms and are not defined in Appendix A; thus they become items subject to dispute. Additionally, situations where "geological and seismological data warrant" consideration of larger earthquakes are undefined in Appendix A and, again, are open to dispute. Appendix A also requires the most severe earthquakes associated with structures and provinces be identified considering the historical earthquakes that can be associated with the structures and provinces and "other relevant factors." No guidance is given as to what is meant by "other relevant factors."

2.2 Correlation of Seismicity and Tectonic Structure

Fundamental problems arise in the application of Appendix A because of a lack of guidance regarding the concept of tectonic structure and correlation with seismicity. The definition of tectonic structure given in Appendix A is broad and little guidance is given as to how it is to be interpreted. Section IV (Required Investigations) does mention the need to evaluate tectonic structure "whether buried or expresseu at the surface," implying that tectonic structure may include features that are interpretive and not necessarily susceptible to traditional methods of surface geologic mapping. This view that tectonic structure may be interpretative rather than demonstrated is generally held in the geologic community, and was originally intended in Appendix A. This point, however, has been subject to argument, and disagreement has arisen in the course of the licensing process as to whether a particular geologic feature was correctly or incorrectly interpreted to be a tectonic structure according to the intent of Appendix A. One interpretation of the definition found in Appendix A would be that the only features that may be considered tectonic structures (and therefore potential earthquake sources) are those whose physical characteristics are susceptible to mapping by direct methods of investigation such as by boring or trenching. Such a narrow definition of a tectonic structure could be interpreted to exclude from consideration geophysical, geologic, and seismologic data that indirectly indicate the existence of buried structure but that do not define the structure as completely as surface mapping might. A narrow definition may result in an erroneous assessment of the presence or absence of particular structure or structural style and its influence on the distribution of earthquakes. Patterns and rates of historic seismicity yield, in some cases, compelling evidence for the existence or lack of existence of a structure capable of generating earthquakes. Other sources of reliable and potentially useful data which might be excluded by a restricted interpretation of Appendix A include photoimagery, magnetic, gravity, and heat flow measurements, geodetic surveys, and microearthquake activity. Appendix A lacks explicit guidance in this respect and therefore can result in licensing delays.

As noted above, what constitutes a reasonable correlation between seismicity and a tectonic structure is not defined in Appendix A and no guidance is given. The degree of correlation between earthquakes and structures may vary from a demonstrated causal relationship, to a close spatial proximity of earthquakes with structures, to an entirely interpretive relationship between the two. According to Appendix A, a "reasonable correlation" between earthquakes and structure must be determined. The staff interprets "reasonable" to require that a sound scientific basis be established to correlate particular earthquakes with tectonic structure or to establish within the strength of seismicity data that an unidentified causative structure exists. The scientific basis may be a complex series of geological and seismological arguments. Because Appendix A offers no guidance, application of this interpretation has been controversial in several instances. Narrower interpretations of "reasonable correlation" have been raised which would require that the epicenter of the earthquake be very accurately known, that it fall on a well-mapped and physically well-defined geologic structure, and that a causative relationship be demonstrated. Such precision is rarely obtained at the present time. A slightly less narrow interpretation might permit the general association of a certain earthquake with a specific structure if its epicenter were near that structure, but not on it, and if the structure were well enough known that a mechanism for generating earthquakes could be accepted. The broader interpretation, which the staff favors, would consider the correlation of particular earthquakes with zones of crustal weakness that are not necessarily specifically defined by known structures but are inferred on the basis of geophysical data, geologic data, tectonic history, and seismicity, and for which credible causative mechanisms may be established. The above interpretations, as well as others falling within the range mentioned, are all scientifically acceptable as methods of correlation, but the degree of conservatism is different for each case. Appendix A is deterministic and does not specify the degree of conservatism to be applied (i.e., in terms of explicitly defining conservatism through specifying acceptable probabilities of earthquake recurrence, or specifying a quantitative rationale for the margins of safety associated with deterministic procedures); therefore, the acceptance of a correlation becomes one of professional judgment based on available information. Because of differences in professional views, controversy leading to litigation has arisen over whether a correlation exists and whether it is acceptable.

A further problem with Appendix A is the lack of guidance on the assessment of seismic zones. It is becoming widely accepted among earth scientists that zones and clusters of seismicity in the eastern United States can be very useful in evaluating areas of present-day crustal instability and potentially high earthquake hazard. Many of these zones and clusters are clearly and persistently anomalous with respect to regional background seismicity, broad-scale geologic structure, and known tectonic history. In several cases anomalous seismicity can be related to geologic and geophysical data which also suggest local instability relative to surrounding regions. These kinds of anomalous seismicity data have been used in the same sense as other remote sensing data such as aeromagnetics, gravity, and heat flow data, to reasonably correlate large historical earthquakes with geologic structure. The present regulation provides no specific guidance on the use of seismicity as a means of indirectly identifying tectonic structures and in assessing seismic potential of a region.

At present no regulatory guidance exists as to the use of microearthquake surveys and stress measurements in the identification and assessment of seismically active structures. During the last several years, it has been recognized that microearthquake and stress measurement data are becoming valuable in identifying and assessing zones of crustal weakness and instability. Because regulatory requirements do not mention the use of these data, questions arise as to when and how they should be used in performing investigations and specifically what weight should be given to them.

Related problems that arise after a correlation between an earthquake and structure has been accepted concern the size of an earthquake that may be generated. Guidance given in Appendix A for assessing the size of an earthquake that may be generated by a structure is basically limited to assessing capable faults. Appendix A lacks specific guidance in assessing tectonic structures that appear to be correlated with earthquakes but with which no capable faults have been identified. Generally, in the West, the seismic potential of seismically active structures is determined by considering historical and instrumental earthquake frequency and size, along with the inferred potential derived from observations of fault length, displacement, and regional geologic history. In the East it is not clear how seismic potential should be assessed. This is because of the paucity of data on large earthquakes and the general absence of recent surface displacement in the eastern United States. It is questionable whether the types of assessments used in the West are applicable to assessing structures in the East, given the significant differences between the East and West with regard to such factors as rates of tectonic activity and tectonic settings; although some distinctions between the East and West were explicitly recognized in earlier drafts of Appendix A, these were dropped in the final revision.

Additionally, Appendix A does not provide guidance for assessing seismically active structures in the nearfield. There have been several cases where this problem has become important. Broadly defined, the nearfield is that area in such proximity to an earthquake source such that elastic waves generated by an earthquake are different in terms of frequency content and prominent wave type than these waves arriving at a more distant site. The extent of the area is dependent on source dimensions, attenuation, earthquake depth, and magnitude. Very few seismic records are available for earthquakes occurring in this area. Thus, the question arises as to how to evaluate nearfield effects given these variables and the lack of instrumental data.

2.3 Capable Fault

The term "capable fault" defined in Appendix A was unique to the regulation, i.e., it was not previously used in the earth science profession. It was established as a measure of the likelihood that a fault could cause surface rupture and/or localize earthquake activity. The term has since gained world-wide use in the geologic and seismologic profession as a more precise definition for "active fault." Four basic elements are used in Appendix A to establish whether or not a fault is a "capable fault." These are (a) movement on a fault within the past 35,000 years or multiple movements within the past 500,000 years, (b) a correlation with "macro-seismicity," (c) a relationship to a known "capable fault," and, for non-capability, (d) a structural association with geologically old structures.

The capable fault concept is derived from observations of highly active faults located in the western United States where there is relatively high, ongoing tectonic activity represented by rugged topography, high rates of crustal deformation, and large and frequent earthquakes. Although it was developed with western geology in mind, Appendix A applies this concept uniformly across the entire United States, including the area east of the Rockies where rates of tectonic activity are relatively low. In an effort to quantify in rule language, for licensing, a complex scientific concept, the concept does not permit reasonable accommodation of new work relevant to assessing fault hazards. The types of work that are relevant to this problem and that are becoming increasingly more widely accepted include probabilistic analyses, calculations of recurrence rates for earthquakes and fault movement, microearthquake monitoring, stress analyses and strain measurements. The question has been raised whether the present definition of capable fault should be modified to include the above methods.

The characteristics of most recent fault movement defining a capable fault were chosen to provide some measure of the hazard posed by surface faulting. They are not based on a rigorous assessment of deformational activity of faults as manifested by a certain level of earthquake activity related to rates of fault movement. They were, however, chosen and accepted as being conservative, based on empirical knowledge of numerous active faults with histories of surface displacement and large earthquakes. Because the numerical age values are specifically stated in Appendix A, the determination of fault capability may appear to be straightforward.

In practice, however, earth scientists have not always been able to acquire "absolute" age data (radiometric age dates, etc.) to meet these criteria and often such assessments involve considerable professional judgment and indirect or relative methods of dating (the use of rates of denudation, regional geologic history, geomorphology, etc.). In the absence of definitive guidance in Appendix A on the extent of investigation needed to adequately assess capability of a fault and the level of certainty needed to conclude a fault is capable, disagreement among geological experts has arisen.

Difficulty arises in applying the recurrent movement criterion in the definition of capable fault. For faults with extensive amounts of offset (tens of feet) and for minor offset (less than several inches), the implementation of Appendix A is generally easily accomplished, i.e. large total offsets imply multiple movements and small total offsets usually imply a single movement. However, for intermediate amounts of offset between these two extremes, a determination of whether a single or recurrent movement has occurred is difficult to ascertain.

As indicated, the fault movement criteria were not originally based on a quantified consideration of rates of fault displacement; however, the numerical values assigned imply certain rates of earthquake activity. There is an inconsistency in Appendix A in that the rate of activity of a fault defined by the age of last movement criteria does not necessarily correspond to an explicit rate of activity as may be inferred from the seismicity element of the capable fault criteria.

The term macro-seismicity is unique to Appendix A and is used in Appendix A as if it were a clearly defined term in the earth sciences. The term is undefined in Appendix A and is not a generally recognized term. Macro-seismicity means either large (with respect to earthquake size and/or rate of earthquake activity) or long (in terms of persistency) earthquake activity. The staff has interpreted this to imply profound deep-seated tectonic activity. In current staff practice, macro-seismicity is considered to be a level of seismicity that implies significant, sustained, and coherent tectonic activity representative of major deformational movement within the earth's crust. Originally, a specific earthquake magnitude was intended as a threshold in defining macro-seismicity; this is not stated or implied in Appendix A.

In the definition of capable fault, the requirement concerning macro-seismicity states:

> "macro-seismicity [shall be] instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault."

In this regard, Appendix A provides no direction for establishing such a direct relationship. Appendix A provides no guidance as to what constitutes "records of sufficient precision" and only speaks to the use of instrumentally determined earthquakes without mentioning the use of historical earthquakes in such an assessment.

According to Appendix A, if a fault is structurally related to a capable fault, it also must be considered capable. The only guidance on structural relationships provided in Appendix A is that movement on one structure could reasonably be expected to be accompanied by movement on the other. Two types of relationships are possible: first, where there is a direct physical connection to a capable fault; second, where there is a genetic relationship between faults properly oriented in the same stress field. For either situation, there may be cases where movement on one fault could reasonably be expected to be accompanied by movement on the other. The requirement has been interpreted as only involving a direct connection to a known capable fault. The direct physical connection of faults is often extremely difficult to show and the data required to define these conditions are not specified in Appendix A. Since Appendix A is unclear in this regard, professional judgment must be used in making such determinations. Moreover, this clearly goes to the question of level of conservatism.

Also in need of clarification is one of the attributes used in defining a "fault" in Appendix A, i.e. the inclusion of ". . . any associated monoclinal flexure or other similar geologic structural feature." It is not clear how this characteristic should be used in assessing the length of faulting, the earthquake generating potential, or the potential for surface displacement of the fault.

Appendix A further states in the "notwithstanding" clause in the last paragraph of the definition of capable fault that a fault that can be demonstrated to be structurally associated with other structural features that are geologically old is not capable. It appears that this statement was intended to apply mainly to the eastern U. S., but the concept may have a more general application. The statement implies that faults that can be shown to have formed in response to a tectonic regime that has ceased to exist, or has been substantially modified, need not be considered capable even if the fault exhibits one of the characteristics of capability. It also could be interpreted to mean that faults in regions that have not experienced known Quaternary or younger tectonism should nevertheless be considered capable if such faults exhibit the characteristics of capability. Also, given the general observation of the antiquity of faults in the eastern U. S. and the significant differences between eastern and western U. S. tectonic settings, it is questionable whether it is the intent of Appendix A to require extensive investigations of faults in the eastern U. S.

Movements or deformations of the Earth's crust can be of either a profound deep-seated nature (tectonic) or of a more superficial nature (non-tectonic). The latter include near-surface stress release, ice-shove features, growth faults, etc. The movement criteria in the definition of capable fault were intended to deal with tectonic deformation. It has been previously argued in a petition for rulemaking that Appendix A is not clear with regard to differentiating the types of fault movement. The petition was denied because the staff considered Appendix A clear on this point. The issue is included in this enclosure because it was raised in a number of public comments.

A fundamental issue inherent in Appendix A is the concept of designing for surface displacement. Sections V (b) and VI (b) discuss the need to design for surface faulting. In order to accomplish and evaluate such designs the geoscientist must provide the engineer with an assessment of the precise location and expected amount of surface displacement near or beneath a facility. Such a determination cannot be accomplished with a high level of certainty with our present understanding of fault behavior. Although Appendix A does not include an explicit prohibition on use of a site which would require designing for surface displacement, the extensive investigations and analysis required by Appendix A would in effect result in such a prohibition. Present engineering and environmental practice contained in Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," states that sites located within 5 miles of a capable fault are generally not suitable and that sites that include capable faults are not suitable for nuclear power stations. The suggestion has been made that Appendix A state an explicit prohibition on siting near capable faults.

2.4 Specification of Safe Shutdown Earthquake (SSE) and Operating Basis Earthquake (OBE) Vibratory Ground Motion

This section treats the methodology for specifying vibratory ground motion from earthquakes. The overall procedure involves (1) taking an earthquake of some size (magnitude or epicentral intensity), (2) assuming that event to occur at some defined location relative to the site, (3) determining an acceleration level at the site representative of this earthquake, and (4) specifying design ground motion corresponding to that acceleration level and representative of the postulated earthquake description. Appendix A calls for the specification of two earthquakes for design. The SSE is an earthquake based upon evaluation of the maximum earthquake potential of a region. The OBE is an earthquake that could reasonably be expected to affect a plant during its operating life time. Several issues have been identified covering a wide range of topics of varying significance in the overall problem of specifying vibratory ground motion for use in engineering design. Other closely related technical issues are discussed in sections 2.1 through 2.5 of Enclosure B.

Appendix A calls for specification of earthquake size in terms of magnitude or epicentral intensity. Appendix A contains the additional requirement that the magnitude be specified on a Richter scale. In certain parts of the country, other magnitude scales have traditionally been used to indicate earthquake size. In such cases, the Appendix A requirement can impose an unnecessary constraint since a method for converting from the scale traditionally used to the Richter scale is not always available.

Alternatively, Appendix A permits that earthquake size may be expressed in terms of intensity on the Modified Mercalli Scale. Prior to 1934, nearly all earthquakes were rated according to intensity because instrumental data were not available. Some larger earthquakes (post-1927) and a few great earthquakes (post-1900) have instrumental data. The classification of earthquakes on an intensity scale is highly subjective. In particular, older events for which reports are limited may depend critically on the skills, objectivity, and biases of one or two observers. Questions frequently arise about the sizes and locations of some of these historical earthquakes. Such questions impact on considerations of the seismic design for particular nuclear power plants. As a result, the staff, applicants and the U.S. Geological Survey on a case-by-case basis have had to review the original data sources of earthquakes to reassess earthquake intensities and locations. There is needed for a reevaluation of earthquake intensities and locations of generic scope to establish a more accurate data base.

After establishing the sizes of earthquakes, the next step in the Appendix A methodology is to provide a representation of ground motion from a series of earthquakes postulated to occur according to various sets of conditions. Thus, in establishing the SSE, Appendix A requires that earthquakes equal in size to the largest historical earthquakes associated with tectonic structures or with tectonic provinces be postulated to occur on those structures or in those provinces at the points of closest approach to the site. For the tectonic province in which the site is located, the point of closest approach is at the site itself. If this were taken literally, the site would always be in the nearfield of the postulated earthquake and special considerations would need to be given to nearfield effects. In practice, Appendix A has been interpreted to mean that the maximum intensity historically reported in the province, in which the site is located, should be placed at the site, but not treated as nearfield. This interpretation is implied in Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants." This interpretation hinges on the low probability that the plant will be in the nearfield of a randomly occurring earthquake of the postulated size, and on extensive investigations in the site vicinity to identify potential earthquake sources. This practice does not appear consistent with a literal interpretation of Appendix A.

Ground motion in the Appendix A methodology is represented by an acceleration level in combination with response spectra (currently defined by Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"). Two issues arise directly from Appendix A requirements in this area. First, Appendix A specifies a minimum acceleration level for the SSE. Appendix A currently sets this level at 0.1g, but higher levels were considered in its development. The ACRS has recently (last several years) questioned whether this minimum level should be raised. The reasons put forth for such an increase are: (1) it would provide additional conservatism in consideration of uncertainties in the data base and would simplify case review; and (2) it would help alleviate problems with backfitting arising from the trend in recent years toward higher SSE acceleration levels in the eastern U. S. because the design levels would be higher. The second issue arises from the requirement that ground motion be represented by response spectra corresponding to the accelerations at the foundation levels of plant structures. Difficulty arises here as to what is meant by foundation level. The term foundation level may either imply some elevation below the ground surface or the strata upon which the plant is founded whether it be at the surface or below ground. The latter interpretation was intended; however, the present wording in Appendix A is not clear. Also, according to some investigators, difficulties arise here because nearly all the available data on ground motion are from measurements made at or near ground surface. In addition, some finite element method techniques developed to analyze variation of motion with depth and soil-structure interaction effects produce physically unrealistic results when the input motion is specified at foundation level at depth. The source of the discrepancy is the specification of a generalized motion at depth in the soil (i.e., foundation level below ground surface) where it could not naturally occur. To avoid this problem in practice, Appendix A has been interpreted to require that the generalized motion be specified at the ground surface and the motion at depth is derived according to the techniques noted earlier. However, it is unclear whether this practice is consistent with a literal interpretation of Appendix A.

The discussion thus far has focused primarily on problems in specifying the SSE. Problems also arise from requirements for the OBE, which have been found to be ambiguous, internally inconsistent, or contradictory (See Section 2.2 of Enclosure B for discussion of OBE engineering issues, and Enclosure F, memo from Minogue to Commissioner Mason, dated October 8, 1976, which provides further information on the OBE concept). The difficulty here arises from the definition of the OBE provided in Appendix A, its interpretation by different scientific and engineering disciplines, and the procedures described for determining the OBE acceleration level. The OBE is defined as an earthquake reasonably expected to affect the site during the plant's operating life. To some disciplines (geology/seismology), this implies a probabilistic assessment over the 40 year lifespan of a plant.

To engineering disciplines an earthquake expected during the life of a facility implies an event whose likelihood is great enough that (economic considerations would dictate that) a structure must be designed to accommodate it. For structures involving substantial capital investment, this is an event in the range of 300 to 500 years. Elsewhere in Appendix A the maximum acceleration corresponding to the OBE is required to be at least half that of the SSE, tying the OBE to the deterministic methodology of the SSE. Based on earthquake data, for most of the U. S. an acceleration level of one-half that of the SSE does not correspond to an event reasonably expected during a 40 year period (i.e. nominal operating life), but rather to an earthquake having a much longer return period (in the range of 300 to 1,000 years for most plants). Alternatively, in some seismically active areas of the U. S. an acceleration level of one-half the SSE may not represent a conservative estimate of an expected event because of the higher frequency of occurrence of earthquakes. To better meet the definition (as opposed to the requirement just noted) of the OBE as specified in Appendix A, the staff has accepted OBE acceleration values of less than half those of the SSE for a few sites. Such exceptions are permitted within the scope of Appendix A when supporting data to justify the departure are provided. In such cases, the staff has required probabilistic analyses of earthquake hazard to justify departures. However, it is unclear whether the allowance of such departures was the intent of Appendix A.

One additional aspect of the OBE issue is Appendix A requires that, if ground motion in excess of that corresponding to the OBE occurs, the plant be shutdown and inspected. There are several problems in applying this requirement. First, there is an overriding question, as to the determination of what constitutes exceedance of an OBE. Exceedance of the OBE can be defined in several ways, for example, exceedance of the freefield OBE acceleration level, exceedance of design response spectra at different elevations in a plant, exceedance of response spectra at a single frequency or several frequencies by a certain amount. There is a need to establish definitive guidance in this area. Second, no NRC specific criteria for inspection in the event of an OBE have been developed. Third, given the increased use of probabilistic analysis in determining the OBE, OBE acceleration values could be set at any level even below the .05g minimum set forth in Appendix A (OBE = ½ x .1g SSE minimum = .05g). It would not be practical to permit the OBE acceleration level used in plant design to be so low that the ground motion often would be exceeded. Criteria for identifying the permissible risk here do not exist. Such low OBE values could result in large areas having OBE values exceeded during an earthquake and, because of the requirements for shutdown, could cause blackouts.

ENCLOSURE B

ENCLOSURE B

ENGINEERING DESIGN ISSUES RELATED TO VIBRATORY GROUND MOTION

1. INTRODUCTION

In addition to the issues discussed in Enclosure A that arise in the application of Appendix A, there is another category of technical issues that relate to seismic design methodology. Included in this category are issues that derive from the interface with engineering design requirements of "ground motion" as determined in accordance with Appendix A methodology. The issues identified in this enclosure, in general, represent areas that are either not dealt with or afforded very limited discussion in Appendix A. They arise mainly from efforts by the NRC staff to provide information and procedures that supplement the regulation. These issues involve matters for which the state of the art is rapidly advancing and where the supporting data base is continually being expanded by acquisition of new information. They frequently require the exercise of engineering judgment. Such judgments are intimately tied with issues of conservatism and consistency in review.

The issues identified here have been the source of frequent and costly impacts on the licensing process, in terms of staff resources, engineering costs, and adverse safety impact in other areas, such as that caused by excessive stiffness of some systems. Some of the impacts of these issues are similar to those identified for issues discussed in Enclosure A. The acquisition and assessment of new geological and seismological data during the review process and, in particular, between the Construction Permit and Operating License phases of review have produced significant delays in licensing actions and, in some cases, costly reanalysis or changes in design. In other cases, licensing delays result from extended litigation and debate over the appropriateness of a methodology that provides an interface between ground motion and engineering design.

2. ENGINEERING REQUIREMENTS IN THE REGULATION

Certain engineering design aspects of nuclear power plants are briefly treated in Appendix A. This treatment was placed in this site evaluation-related Appendix to contribute to an understanding of the ultimate use of the siting assessments covered, and was not intended as a definitive treatment of the engineering aspects of seismic design. Several of the engineering concepts addressed in the regulation have been the subject of controversy because of their limited discussion.

Questions have been raised as to whether a regulation primarily intended for seismic and geologic siting evaluations can, or should, discuss engineering considerations. Also, the question has been raised whether the regulation should address the hydrologic aspects of siting. The hydrologic review procedures have been supported by a series of regulatory guides which provide details in this area.

2.1 Specification of Vibratory Ground Motion

Appendix A describes procedures for determining maximum vibratory ground motion at a site for use as an engineering design basis. These procedures were developed when relatively simple seismic design methods were standard practice. Now, complex methods are used in place of the earlier practices. These techniques have not, however, eliminated the controversy that is often associated with assigning a design basis for vibratory ground motion, and several questions remain to be addressed. Specific areas in which difficulty arises are discussed below.

2.1.1 <u>Site Specific vs Generalized Response Spectra</u>

Appendix A requires the development of response spectra for seismic design. Appendix A does not, however, provide a detailed procedure for deriving the response spectra. Regulatory guides and the Standard Review Plan (SRP) provide a supplement to Appendix A that is needed to complete the determination of vibratory ground motion. The staff has developed Regulatory Guide 1.60, which specifies broad-band spectra to be used. These spectra represent the normalized mean-plus-one-standard-deviation responses of records from 33 earthquakes of various magnitudes, recorded at various distances, and on varying site conditions. The staff at one time attempted to develop a site-specific method to derive response spectra (Agbabian-Jacobsen Associates, 1970, "A Study of Earthquake Input Motions for Seismic Design") but was unsuccessful. Difficulty was encountered because of limited data and in obtaining general acceptance.

Thus, following current practice, the SSE and OBE seismic design bases at a site are described by the Regulatory Guide 1.60 spectra appropriately scaled to represent the earthquake hazard at the site consistent with Appendix A criteria. Because Regulatory Guide 1.60 is a smoothed spectrum that contains energy at all frequencies, it gives unrealistically high values of motion at certain frequencies when used as input at the foundation level in some soil-structure interaction analyses. To avoid this, the input must be controlled at the free surface or a site specific spectrum must be used.

To alleviate the above problems, the staff encourages the use of site-dependent spectra because of improved analytical methods and the increased number of strong motion earthquake records. Such site-dependent analyses are stressed in a proposed revision of the SRP. In practice, site-dependent spectra are needed for certain analyses used to investigate liquefaction and, in some cases, in the design of embankment dams.

An additional question is whether there is enough data to develop site-dependent spectra for sites in the East. However, the same question can be raised regarding the applicability of Regulatory Guide 1.60 in the eastern U. S. since the response spectra do not include any eastern earthquakes.

2.1.2 Variation of Ground Motion with Depth

Appendix A requires that response spectra corresponding to the maximum vibratory accelerations at the elevations of the foundations be defined. Many methods have been proposed to achieve this requirement. Appendix A does not provide detailed guidance in this matter; therefore, regulatory guides and the SRP have attempted to complete the needed guidance.

Whether the vibratory ground motion for soil sites is specified at foundation levels or the ground surface, consideration of the variation of motion with depth is needed for defining design input for finite element soil-structure interaction models, liquefaction studies, and response analyses for earth structures. The present methods for considering the variation of ground motion with depth include computer modeling techniques with varying degrees of complexity. The one dimensional shear beam analysis (SHAKE), which is frequently used, has a number of limitations: (1) it treats all wave types as vertically propagating shear waves, thus neglecting the effects of other seismic wave types that are included in the ground motion; (2) because it is an equivalent linear elastic method, it is not applicable when large strains occur; (3) for some soil profiles, results can be unrealistic when generalized broad-band response spectra such as Regulatory Guide 1.60 are input at depth, and (4) the analysis is limited in that it does not account for certain geologic variations such as nonhorizontal layering and topography.

Some finite element methods have the advantage of permitting consideration of the effects of additional seismic wave types, such as surface waves and nonvertically incident waves. Usually these methods require specification of input motion at the base or at the side of the soil model. However, since nearly all earthquake data have been recorded at or near the surface, there is uncertainty in the form of the base motion to be used for such analyses.

It is the general view of the staff that use of site-dependent methods to estimate variation in ground motion with depth should be encouraged where data permits. Use of such procedures raises the question as to when does the data permit such analyses.

2.1.3 Specification of Time History

Appendix A requires specifying seismic input in terms of response spectra corresponding to the maximum vibratory accelerations to be expected at a site. In addition to response spectra, a time history of vibratory ground motion is frequently needed to perform various design analyses. Any number of time histories may be developed that satisfy Regulatory Guide 1.60 response spectra requirements within any given tolerance. Some of these may be more conservative than others because the frequency of motion of the actual accelerogram may be distributed so as to result in canceling modes of vibration that are of significance in power plant design. The question has been raised as to the need for explicit regulatory guidance in the use of time histories.

2.1.4 Duration of Shaking

The duration of strong earthquake motion is important in characterizing vibratory ground motion. It is a measure of the number of stress cycles that are applied to the structure and soil medium. Appendix A requires that the duration of shaking caused by earthquakes be given consideration in design. There is some lack of consistency in present practice in the treatment of duration. That is, the length of time and number of cycles of strong ground motion used is different for different analyses, e.g., in performing liquefaction analysis, structural over-turning analyses, and fatigue analysis.

The problem associated with duration of shaking is to define it in a complete and consistent manner. Several definitions of duration have been suggested by various investigators, but each involves uncertainties and limitations. The definition of duration could strongly influence trends from studies based on statistical analyses of strong motion.

2.2 OBE Use in Engineering

Additional questions, other than geologic-seismic ones, have been raised about the way vibratory ground motion representing the OBE is used in engineering design. The regulation requires that the effects of the OBE vibratory ground motion be considered in combination with normal operating loads. In practice, loads arising from the OBE are combined with loads from other severe natural events. For example, the OBE is combined with the load from the standard project flood to evaluate seismically induced dam failure.

Viewed as applied to engineering design, the design basis for the SSE is specified in Appendix A to assure that the plant design adequately protects the public health and safety in the event of an extreme earthquake. The plant may well not be operational as a power plant following an SSE. The OBE is established as the most severe earthquake following which the plant can safely be operated without special inspections. Engineering codes and design practice apply these two earthquake levels differently. Category I structures, systems and components, must maintain their safety function for earthquake levels up to the and including the SSE. On the other hand, the engineering design objective with the OBE is that the plant is capable of being safe in operation after experiencing an event less than or equal to the OBE.

As these events are applied to design, in use of the ASME Boiler and Pressure Vessel Code, the SSE is normally applied as a faulted condition, meaning that stress levels allowed by the code which would result in permanent general deformation are permitted except when deformation would lead to loss of safety function. The OBE, on the otherhand, is considered as an Upset Condition or Design Condition in application of the code and is used in conjunction with lower allowable stress levels at which no general deformation would occur (elastic regime). In addition, to differences of allowable stresses for the OBE and SSE, there are other differences in design analysis methods in the application of Faulted and Upset Conditions. Many designers see the SSE as being the basic seismic design basis with the OBE playing more the role of a cross-check basis using different analysis procedures and different limits to assure the adequacy of the margin provided by the SSE design over a wide range. Viewed from this perspective (which is the perspective of the engineering parts of Appendix A) the OBE is more an engineering safety factor applied to design analysis rather than being seen as a seismic event.

Because of the way some loads are combined, the associated damping used, and the stress levels allowed in current engineering design practice, situations occur where the loads arising from the OBE in combination with other loads are higher than loads for the SSE. In such cases, the determination of the OBE acceleration level becomes significant and the SSE loses significance in engineering design. The problem has been exacerbated by the arbitrary Appendix A requirement that the OBE acceleration level be half that of the SSE. Because the OBE acceleration level is used in a number of engineering analyses in different and complex ways, the significance of this parameter to the overall safety margin of a nuclear power plant is difficult to assess and has not been determined. The question has been raised as to whether the OBE is needed at all or alternatively whether the separate uses of the OBE should be differentiated. There is a need for a detailed consideration of all uses of the OBE acceleration in engineering design, margins of safety that may be affected, and the extent to which geosciences and/or engineering assessments should affect determination of the OBE acceleration level. It is important to note that the data base is sufficiently large to permit the determination of the OBE probabilistically in many cases (See discussion in Section 2.4 enclosure A).

2.3 Consideration of Aftershocks

Aftershocks are smaller earthquakes following a major event. Aftershock effects are required to be considered by Appendix A and it is permissible to allow strain limits in excess of the yield strain for the SSE loading. In practice, however, structural stresses due to the SSE are not allowed to exceed yield stresses except in localized areas; therefore, aftershock effects are not taken into account. Should the SSE stresses be allowed to go beyond yield, considerations regarding low cycle fatigue and ductility demands during the aftershock must be properly accounted for in the design of systems and components. However, some plants have been designed to undergo a certain degree of inelastic deformation of structures. Such local yielding is not allowed to place structures, systems, or components in danger of failure. This has been felt to be a safe practice since earthquakes approaching the SSE in severity are not likely to occur because of the low frequency of their observed occurrence.

2.4 Consideration of Potential Damage from Earthquakes Less than the SSE

Appendix A emphasizes design of safety-related structures, systems, and components for only two levels of vibratory ground motion: the OBE and SSE (with the exception of aftershocks). Appendix A does not consider the probability of intermediate levels of shaking. In areas where the frequency of occurrence of strong motion is high, the plant site may experience a number of strong earthquakes approaching the OBE or between the OBE and SSE during its lifetime. At present, limited consideration is given in design to the number of earthquake events (in fatigue analysis) the plant might experience and the finite probability of yielding due to these events. In attempting to design for such earthquakes, the same pitfalls discussed in consideration of aftershocks exist. A compromise is required between design for a broad spectrum of unlikely events and optimum design for normal operation. Design for a single limiting event (the SSE) and inspection and evaluation for earthquakes in excess of some specified limit (the OBE), when and if they occur, may be the most sound regulatory approach.

2.5 Use of Probability for Considering Combinations of Loads

Appendix A requires consideration be given to seismic and other concurrent loads in the design of safety related structures, systems and components. Appendix A is stated deterministically and does not give any guidance concerning consideration of the probability of occurrence and failure as a result of the applied loads. At present, loads are combined according to regulatory guides, ASME, and ACI codes. The staff considers the application of these load factors conservative. However, they lack a rigourous probabilistic basis.

2.6 Need for Seismic Scram

Appendix A notes that consideration is being given to the need for instrumentation to automatically shutdown (scram) a plant in the event of an earthquake that exceeds a predetermined intensity. The question of whether to have seismic scram instrumentation at commercial nuclear power plants has been a long standing dispute between the ACRS and the staff, and is an ACRS generic issue. The staff sponsored assessments of seismic scram (Lawrence Livermore Laboratory, UCRL-51619, "Evaluation of the Use of Seismic Scram Systems for Power Reactors" and Lawrence Livermore Laboratory, UCRL-52156, "Advisability of Seismic Scram") which confirmed the staff view that such instrumentation is not advisable. Subsequently, the ACRS was notified (memo from E. Case to M. Bender, dated May 19, 1977) that the staff considers the generic matter resolved, does not intend to require seismic scram instrumentation and does not plan to expend further effort or resources on additional studies. However, the ACRS has noted that the LLL study dealt with low-level earthquake intensity scram and has requested the staff to explore high-level earthquake intensity scram, such as that in use in Japan. The issue remains an unresolved ACRS generic issue pending a visit to Japan in the spring of 1979 by members of the staff and ACRS.

3. ISSUES REGARDING CONSERVATISM

3.1 Deterministic vs Probabilistic Approach

The tectonic province concept as used in Appendix A can be thought of as having a combination of both deterministic and probabilistic characteristics. It is deterministic in the sense that the distribution and size of future earthquakes may be predicted from a given set of observed and interpreted conditions, i.e., for areas containing consistent geological features, there is a consistency of earthquake potential. From this assumption that earthquake activity is consistent over a region, it follows that the frequency of earthquakes to be expected can be determined based on the number of events in a given region during a given interval of time; this is a probabilistic concept. In the development of the tectonic province concept, the use of probabilistic analysis was not emphasized. Probabilistic approaches were not considered to be sufficiently reliable because; (1) the historic record of earthquake data is short, necessitating extrapolation beyond the data base to determine low probability events; (2) the data base is inhomogeneous, i.e., the data base varies in completeness both spatially and temporally; (3) knowledge is lacking to identify earthquake source regions, a preliminary step in such determinations; and (4) information to reliably estimate the maximum earthquakes in such regions (also a prerequisite) is deficient. Because of these limitations, SSE level earthquakes for design estimated probabilistically would have large associated uncertainty.

Today, a number of arguments have been brought forth in favor of using a probabilistic analysis: (1) the present Appendix A approach suffers from the same shortcomings mentioned above; (2) unlike a probabilistic approach, which allows for a quantified and consistent treatment of uncertainty, the present approach does not lend itself to such treatment; (3) the present approach does not lend itself to consideration of backfitting, which requires assessment of significance; (4) the staff is frequently called on to make probabilistic determinations to assess adequacy at hearings and before the ACRS; and (5) probabilistic approaches have been adopted and are becoming more widely adopted to determine earthquake hazard to establish the seismic design for all types of structures (e.g., LNG facilities, general structures covered by the ATC building code).

Given these considerations, the issue has been raised as to whether the Appendix A methodology should be changed to emphasize probabilistic techniques for assessing earthquake hazard.

3.2 Empirical Relations Between Earthquake Size and Ground Motion Parameters

As discussed in Enclosure A, Appendix A requires that ground motion from earthquakes, postulated to occur according to the methodology defined in the regulation, be specified in terms of an acceleration level. However, specific procedures relating information on earthquake size and distance to acceleration are not contained in Appendix A. Numerous empirical relations between earthquake size (magnitude or intensity), distance, and acceleration level have been published. The data show wide scattering. Published relationships have been derived using different data sets, data from differing geologic regions, and varying procedures for data reduction.

It can be expected that as additional data become available the state of the art will continue to advance and still different relationships will be found. As the data base has evolved, different relationships have been developed and used to assess the acceleration levels at nuclear power plant sites. As a result, new plants assigned the same size earthquake as old plants have been designed for higher acceleration levels. An issue which has arisen is whether plants already designed and/or built should be reassessed in consideration of new data and new relationships relating earthquake size to acceleration level.

To ensure some level of consistency in more recent reviews, the staff has adopted specific relationships between earthquake size, distance, and acceleration level. Thus, in its Standard Review Plan, the staff has adopted as licensing practice the mean value of the intensity-acceleration relationship developed by Trifunac and Brady, where size is expressed as intensity, and the Schnabel and Seed relationship, where size is expressed as magnitude. Issues have been raised over whether these relationships are appropriate and, in particular, whether mean values derived from these relationships represent the proper level of conservatism.

A more fundamental issue has been raised as to whether the Appendix A methodology places too much emphasis on a single vibratory ground motion parameter: acceleration level. The totality of vibratory ground motion from an earthquake cannot be specified in terms of any one parameter. While Appendix A recognizes this in its requirement that ground motion corresponding to the SSE and OBE be represented by response spectra, these response spectra and the required investigative procedures are keyed to acceleration level. Questions have been raised over whether more complete descriptions of the ground motions from earthquakes, postulated to occur according to Appendix A, should be provided for use in assessing the engineering design.

3.3 General Lack of Definition of Overall Seismic Design Conservatism

An overriding issue is the lack of definition of some level of conservatism proper for seismic design. A major purpose of Appendix A is to set forth criteria for investigators to determine the vibratory ground motion at a site to use in seismic design; that is, to determine the input into the seismic design methodology. However, Appendix A does not define an explicit level of conservatism appropriate to this input. Rather, it defines a deterministic methodology to arrive at this input implicit in which is the premise that if the procedures are followed an acceptable level of conservatism will result. The lack of an explicit definition of an appropriate level of conservatism for the seismic input has led to difficulties in the licensing process. It places an undue burden on individual reviewers to define what is acceptable, which can lead to nonuniform application of Appendix A and unwarranted inconsistencies between sites.

The staff has on occasion been pressed in hearings to assess levels of conservatism associated with design earthquakes (i.e., using probabilistic analysis and defining the probability of exceeding the design earthquake). Such an assessment is not called for in Appendix A; nevertheless the level of conservatism becomes a focus of debate.

Because of the lack of overall definition of an appropriate level of seismic design conservatism, elements in the seismic design chain are reviewed in isolation from other elements, such as the siting and various engineering areas. Questions have been raised as to whether this results in compounding or counter-productive conservatisms; whether uncertainties in one element are compensated in design margins of another element, such as whether the use of means of empirical relations (e.g., intensity-acceleration relations) in assessing earthquake vibratory ground motion are adequately compensated (given significant uncertainity in such relations) by engineering safety margins; and whether increasing conservatism in one element might in fact reduce margins in another area such that overall conservatism decreases, as may result from stiffening of structures to resist seismic loads where they would better remain flexible to withstand thermal and other stresses. A major research effort sponsored by the Office of Nuclear Regulatory Research is in progress to assess the conservatisms in overall seismic design.

ENCLOSURE C

ENCLOSURE C

BROAD POLICY AND TECHNICAL ISSUES BEARING ON THE IMPLEMENTATION AND REVISION OF APPENDIX A

1. INTRODUCTION

The issues identified in this enclosure cover a wide range of topics that are related in various ways to the implementation of Appendix A. These issues have been raised within the NRC and by representatives of other government agencies, industry and the public. The issues discussed below have impacts on present and future siting policy to varying degrees. Some issues are obviously vitally important, such as whether Appendix A should be revised and, if so, to what extent. Others, such as issues pertaining to the relationship between NRC siting policy and other national policy, are important in terms of considerations regarding revision to Appendix A, but are not central to this stage of the staff's reassessment (i.e., identification of issues arising in the application of Appendix A).

2. IMPEDIMENTS TO IMPLEMENTING APPENDIX A IN THE LEGAL CONTEXT

In addition to the difficulties that arise for technical and scientific reasons, significant impacts on applicants and the staff have occurred because Appendix A is difficult to implement in a legal context. The development of Appendix A was itself precipitated by the Malibu hearings in the mid-sixties. In this licensing action, a hearing board and the Atomic Emergy Commission had difficulties bringing the case to conclusion because of problems in assessing the magnitude of hazard associated with faulting in the absence of professional standards in this area. Appendix A represents a detailed codification of technical subject matter much of which is not exacting and requires technical judgment and latitude in its application. Difficult tradeoffs are required between the need to avoid case-by-case litigation of recurring issues and the need for review flexibility in this fast moving technical area.

3. INTERFACE OF ISSUES WITH OTHER NRC POLICY

3.1 Lack of Policy Statements Concerning Early Site Reviews, Limited Work Authorization, and Alternative Site Reviews

At present, no policy has been established regarding the requirements for geologic and seismic information needed for issuance of a limited work authorization and for alternative site review, and only limited guidance has been given regarding information required for an early site review. With regard to early site reviews, more detailed guidance is needed concerning the options available to an applicant in terms of level of detail required for preliminary geologic and seismologic investigations. The question has been raised whether the NRC should provide an applicant the option of accepting a conservative and preapproved seismic design value rather than conduct the type of extensive regional analyses presently required. Such an option would reinforce the need for publication of an NRC seismic zoning map and more explicit policy concerning early determinations of vibratory ground motion at a site.

3.2 Seismic Design of Fuel Cycle Facilities

The consequences of failure of a fuel cycle facility are considered less than that of a nuclear power plant. Therefore, less stringent seismic and geologic siting and design requirements are considered appropriate. Use of Appendix A requirements and conservatisms for fuel cycle facilities implies either that undue conservatism is being applied in designing fuel cycle facilities or puts in question the level of conservatism adequate for nuclear power plants. Because Appendix A lacks an explicit level of conservatism based on a rigorous assessment of consequences, requirements for fuel cycle facilities cannot be readily determined based on scaling down requirements in Appendix A. The lack of an explicit level of conservatism based on the consequences of failure as a result of earthquakes, for instance, does not permit a quantitative determination as to the appropriate level of conservatism to be applied for fuel cycle facilities with respect to these consequences. Regulations and regulatory guides presently being developed for fuel cycle facilities are turning to probabilistic analysis procedures to determine design earthquakes (e.g., for independent spent fuel storage facilities). This allows for the specification of the level of conservatism required. Such methods are being widely accepted (e.g., ATC-seismic codes for large buildings, LNG regulations) and maps are available to facilitate determining the earthquake potential at a site and seismic design input. As discussed previously, the use of probabilistic procedures in determining seismic input for nuclear power plants is an issue in itself. The use of such analysis for fuel cycle facilities while excluding its use for nuclear power plants can be interpreted as an apparent inconsistency in policy. However, probabilistic analysis is being used for fuel cycle facilities because of the lower risk associated with such facilities compared to nuclear power plants which allows for designing for lower earthquake levels in the range where the data can be assessed with greater confidence.

3.3 Consider~~tion of Seismic Design of Nonradiological Safety Structures, Systems and Components

Requirements in Appendix A only address structures, systems and components that are considered safety related. It has been suggested that the NRC should require some level of earthquake-resistant design for non-safety related systems for the following reasons: (1) because of the complexity of interaction between safety and non-safety structures, systems, and components, elements of uncertainty may be introduced as to the overall adequacy of design; (2) there are some systems, components, and structures associated with nuclear facilities that pose nonradiological risk to the public health and safety. As an example, the failure of an ultimate heat sink dam could result in loss of life as a result of flooding. Present practice is to classify as safety related only those dams that may lead to radiological hazards. Under present NRC regulation, requirements are absent for the seismic design of systems, structures, and components not classified as related to radiological safety, but which may pose non-radiological hazards. The overall issue has been extensively discussed in the past, e.g., SECY-76-399, SECY-77-222, SECY-78-358 and is presently under assessment as a separate topical issue outside the staff assessment of Appendix A. The issue is mentioned here only as it relates to the seismic area.

4. ISSUES PERTAINING TO NATIONAL POLICIES AND PRACTICES

4.1 Consistency of NRC Seismic and Geologic Siting Policy and Practice with Other National Policies and Practices

4.1.1 Earthquake Hazards Reduction Act of 1977 (EHRA)

Several aspects of EHRA have significance with respect to our present seismic and geologic siting policy and practice and particularly to considerations for revision of Appendix A. The Act calls for increased earthquake research on and the development of new methods and procedures for design and construction to mitigate earthquake hazards. The Act specifically gives priority to the development of methods and procedures for earthquake-resistant design and construction for nuclear power plants. Authorizations to be appropriated under the Act are considerable; therefore significant advances in technological knowledge in this area are expected. As such, this places a significant priority on ensuring that present NRC policy and practice as well as regulatory requirements be amenable to readily assimilating information developed from research carried out under the Act. As previously discussed, one significant issue identified is that, because Appendix A is a regulation and is detailed, procedures and methods contained in the regulation cannot be readily modified to assimilate advances in the state of the art.

Another objective of the Act bearing on revision to Appendix A, is that the Act gives priority to the development and implementation of earthquake prediction. Appendix A was developed prior to many recent advances in earthquake prediction concepts and methodology. At present no NRC policy exists concerning what action, if any, may be required if an earthquake prediction is made for the area of a nuclear power plant.

4.1.2 Presidential Directives

4.1.2.1 Executive Order - Improving Government Regulations

On March 23, 1978, the President signed an executive order entitled: "Improving Government Regulations." Several aspects of the executive order bear on problems previously identified in the application of Appendix A and on procedural considerations that should be made in deliberating on possible revisions to the regulation. The latter will be treated in the next phase of the staff effort as noted in Enclosure D. This discussion is limited to the aspects of the executive order bearing on currently identified problems.

First, the executive order calls for the language of a regulation to be simple and clear as possible, that is, understandable to those subject to its provisions. Appendix A is a technical regulation directed at technical experts but written and structured in a very complicated manner difficult for the technical experts to follow.

Second, the executive order calls for regulations that do not impose unnecessary burdens on those affected by it (i.e., individuals, the public, private organizations, States, and local government). As noted previously, issues have been raised concerning the requirements of Appendix A placing an undue burden on applicants through excessive conservatism associated with some requirements and lack of clarity in some requirements, and ultimately on the public.

4.1.2.2 National Energy Policy

The National Energy Plan bears both directly and indirectly on NRC seismic and geologic policy and practice. The Plan bears indirectly on the seismic and geologic siting area in that it calls for overall improvement in the licensing process (i.e., establishing reasonable and objective criteria for licensing, reduction in extensive licensing procedures where standard design is involved, and overall reduction in delays and licensing time).

The Plan bears directly on seismic and geologic siting policy and practice in that it requests the Commission to develop firm siting criteria with clear guidelines to prevent future siting in potentially hazardous locations. The President in his energy address on April 20, 1977, specifically stated that new plants should not be located near earthquake fault zones. This policy is consistent with general NRC staff site suitability practice. However, Appendix A does not contain any explicit prohibition for construction on a capable fault.

4.1.3 Draft Congressional Legislation

Two bills introduced before the 95th Congress have bearing on our present siting policy and practice in this area: HR882, Nuclear Energy Reappraisal Act and HR11704, Nuclear Siting and Licensing Act. Although both bills were not reported out of committee, nevertheless, they illustrate past and present Congressional concerns that have a bearing on Appendix A and the geological/seismological licensing review. HR882 called for an assessment of the NRC licensing process, which has permitted nuclear power plants to be built over geologic faults. As noted previously, regulatory criteria prohibiting siting near hazardous faults has been identified as an issue. HR11704 pertained to this area of siting in that it called for the establishment of an early review permit, emphasis on standardized design, and a combined construction permit and operating license to reduce licensing time. Thus, one of the important goals in modifying present policy and practice, and regulatory requirements is the reduction of licensing time. Specific issues revolving around this have been identified (e.g., establishing detailed early site review policy in the geologic and seismic siting area).

4.1.4 Comparison of NRC and Other Federal Agency Critical Facility Seismic and Geologic Siting Policy and Practice

The staff has reviewed seismic and geologic siting criteria in use or under development by other Federal agencies to determine differences in approaches to provide a broader perspective on issues related to potential revisions to Appendix A. It should be noted that comparison of policy and practice cannot be readily made because different structures are involved, which require somewhat different siting and design approaches.

The staff has examined those earth science criteria for critical structures listed on the enclosed Table. Major differences in criteria are:

(1) The definition of a hazardous fault differs in terms of terminology used, the ages used to define a fault as a hazardous one, the use of

seismicity levels in defining a hazardous fault, the inclusion in criteria of prohibitions on siting near hazardous faults, and the reliance on probabilistic assessments to assess potential future fault movements.

(2) The procedures used to define seismic input for design differs in terms of the degree of reliance on maps to identify seismic source regions, use of probabilistic procedures, the procedures used to define regions to assess regional earthquake potential and the use of differing ground motion parameters for design input.

Generally, it appears the criteria are moving towards seismic and geologic assessments that require probabilistic analysis and the definition of acceptable levels of risk (dependent on the hazard associated with a particular facility) in quantitative terms.

5. EXTENT AND NATURE OF REVISIONS TO APPENDIX A

The foregoing discussions in this and previous enclosures have identified numerous issues that arise directly and indirectly from the application of Appendix A in its present form. Many issues raised deal with fundamental problems identified when Appendix A was in early stages of development (a decade ago), and during the initial public comment period when Appendix A was issued as a proposed rule in 1971. Because of the fundamental nature of difficulties it is clear at this time some form of revision to Appendix A is warranted. A number of options have been considered:

a. Minor revisions (word changes, expansion for clarity) to present regulation;

b. Substantial expansion of regulation (add detail to sections that are difficult to interpret because of their general nature);

c. Simplifying the regulation (deleting sections) and simultaneously providing more detailed information in regulatory guides;

d. Rescinding Appendix A and rely entirely on regulatory guides to provide detailed guidance on the subjects covered as has been done successfully in the hydrology area.

The staff consensus is that option C is the most desirable way to proceed. Accordingly, the next stage of the staff effort will be directed toward: (1) revising the regulation in a more simplified form; (2) supplementing the revised Appendix A with a series of regulatory guides to be issued concurrently with the revised regulation; (3) assessing through a value/impact analysis the resolution of issues identified in this paper; and (4) developing a program for continuous updating of regulatory guidance. Enclosure D describes more fully the subsequent stage of the staff effort.

LIST OF EARTH SCIENCE CRITERIA FOR CRITICAL STRUCTURES

AGENCY	FACILITY	TITLE	USE
NRC	Nuclear Power Plants	Seismic and Geologic Siting Criteria for Nuclear Power Plants; 10 CFR Part 100, Appendix A - November 1973	Regulation for licensing
COE	Dams	Earthquake Design and Analysis for Corps of Engineer Dams; Reg #1110-2-1806 April 1977	Guidance for staff and contractors
DOT	LNG Facilities	Liquefied Natural Gas Facilities (LNG), Federal Safety Standards; 49 CFR Part 193 - April 1977	Proposed draft regulation for licensing
VA	Hospital Facilities	Earthquake Resistant Design Requirements for VA Hospital Facilities; Handbook H-08-8 - May 1977	Guidance for staff and contractors
BR	Dams	USBR Design Earthquake Selection Procedures; - November 1977	Guidance for staff and contractors
EPA	Hazardous Waste Facilities	Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; 40 CFR Part 250 - February 1978	Working draft regulation for licensing
AIC (NSF/NBS)	Buildings	Tentative Provisions for the Development of Seismic Regulations for Buildings - June 1978	Tentative provisions

Enclosure "C"

ENCLOSURE D

ENCLOSURE D

SUMMARY OF SUBSEQUENT STAGE IN THE ASSESSMENT OF CURRENT SEISMIC AND GEOLOGIC SITING CRITERIA, POLICY, AND PRACTICE

A. PRELIMINARY VALUE-IMPACT STATEMENT (PVIS)

1. Objectives

The next phase of the staff assessment is a preliminary value-impact analysis of issues identified to structure the revised Appendix A and associated guides and then follow-on guides. The objectives of this phase include:

a. Using value-impact assessment to consider the resolution of issues identified. This will involve consideration of alternative ways of resolving technical and procedural issues through an assessment of values and impacts, i.e., considerations of tradeoffs in meeting objectives. During this stage, the specific recommendations made by the staff, ACRS and their consultants, and public comments will be addressed.

b. Using the PVIS as the working document to explore resolution of issues prior to actually revising Appendix A in order to: (1) establish the intent as to how the regulation should be revised; (2) establish a common reference of intent to review changes to the regulation; (3) avoid missing substantive issues that need resolution; and (4) minimize the review of word changes to the regulation (i.e., to minimize the number of drafts and work required to derive an acceptable revised regulation).

c. Using the PVIS to establish the framework for the supplemental regulatory guides.

d. Documenting clearly what, how, and why decisions were reached.

e. Forming the supplementary statement (statement of consideration) for revision of Appendix A and other policy and practice.

2. Preliminary Value-Impact Process

It is the staff's intent to perform the analysis in accordance with guidance already established by OSD, NRR (NRR office Letter No. 16) and by the Commission (Secretary Memorandum January 23, 1978). Details of the analysis are contained in the above guidelines and will not be repeated here. Special considerations will be given to those areas listed below.

a. Executive Order - Improving Government Regulations

b. Congressional Bills and Directives

c. Other Acts (EHRA, NEPA, NSLP)

d. Other Agency regulations (LNG, Dams, ATC)

e. National Energy Plan

f. Early site review

g. Standardized design

h. Backfitting

i. Use of Research

j. Impact on other facilities under NRC jurisdiction

3. Results of Preliminary Value-Impact Analysis

The results of our analysis will include:

a. Recommendations to the Commission on the resolution of issues;

b. Recommendations to the Commission for rulemaking and establishment of regulatory guidance.

c. Recommendations for obtaining further public input;

d. Common ground for all to assess the revised regulation.

B. REVISION OF APPENDIX A TO 10 CFR PART 100 AND DEVELOPMENT OF SUPPLEMENTAL GUIDES

On the basis of decisions reached in performing the preliminary value-impact analysis, a revised regulation and regulatory guides will be developed for promulgation for rulemaking and public comment. At the earliest, the revised regulation and supplemental regulatory guides could be promulgated in FY 1980.

ENCLOSURE E

ENCLOSURE E

BACKGROUND AND SOURCES OF INFORMATION USED IN THIS PAPER

I. BACKGROUND

A. Historical Perspective

Prior to 1973, when Appendix A "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria" became effective, regulatory requirements in the geologic and seismic siting area were contained in 10 CFR Part 50, "General Design Criteria," and in 10 CFR Part 100, These regulations provided merely broad requirements in the seismic and geologic siting area. A need for more definitive regulatory criteria in the earth science area arose from the difficulties encountered in licensing review of the siting of several nuclear power plants in California in the early sixties. The types of difficulties encountered included: (1) the lack of standards to assess adverse seismic and geologic conditions at a site; (2) the need for guidance to applicants as to the type of investigatory procedures to follow; (3) the absence of review procedures for the staff; (4) the lack of a framework to make legal determinations and to assess compliance; and (5) protracted delays and considerable debate in the licensing process over technical issues.

As a means of resolving the above difficulties, work was initiated in 1966 to draft seismic and geologic siting criteria which lead to a semi-formal siting document developed in March 1969. In 1971, Appendix A was published for public comment, and in late 1973 the regulation became effective. Appendix A in final form represented a compilation of procedures and methods developed primarily from experience gained during the review of early sites. It also reflected a synthesis of a broad spectrum of professional views and ideas.

In developing Appendix A, it was recognized that the criteria were based on limited available data and that revision would be appropriate as the state of the art improved and additional information became available. Such a statement is expressed in the PURPOSE of the regulation.

B. Review of the Application of Appendix A

Extensive experience has been gained in the application of Appendix A and difficulties in applying the regulation have arisen. Many of the problems Appendix A was intended to resolve were not resolved.

As a result of problems encountered, in 1976 the staff began a reevaluation of the regulation. As a means of ascertaining the extent of problem areas, the staff held several meetings and prepared a "straw man" revised draft of Appendix A. The "straw man" draft differed primarily from the regulation in the arrangement of sections and the incorporation of additional wording to increase clarity. This draft was circulated to staff for comment. Comments received were numerous and indicated a need for an in-depth reassessment.

Concurrently with the staff review of Appendix A, a broader review was underway of overall siting policy. In Policy Paper SECY-76-286 dated May 25, 1976, the staff informed the Commission of this overall review. That paper also informed the Commission that the seismic and geologic siting criteria were under separate review. Subsequently, in Policy Paper SECY-76-286A dated December 14, 1976, the staff outlined topics in the seismic and geologic siting area being considered.

By letter dated January 27, 1977, the Secretary of the Commission requested a proposed policy statement on seismic requirements. During the preparation of the requested paper, the Secretary issued a new memorandum dated June 30, 1977, requesting the following: (1) that the staff address only present siting policy and practice; (2) that SD and NRR in a followup paper describe and analyze major issues not covered in other siting papers; and (3) that SD and NRR prepare an alternative siting statement to present siting policy.

In response to the first directive, the staff prepared an Information Report (SECY-77-288A), dated August 18, 1977. That paper described current seismic and geologic siting policy and practice for nuclear power plants, its historical development, and outlined the staff's subsequent papers. Thus, SECY-77-288A established the framework for this paper and subsequent papers.

Following the preparation of SECY-77-288A, issues pertaining to overall seismic and geologic siting policy and practice were solicited and compiled from technical and legal staff. Additionally, on December 15, 1977 and January 26-27, 1978, meetings were held with the Seismic Subcommittee of the Advisory Committee on Reactor Safeguards (ACRS) and their consultants. The purpose of these meetings was to obtain their views on problem areas identified by the staff and to solicit any additional problems. Following the last meeting, the staff received reports from ACRS consultants. Also on January 19, 1978, the staff published a notice in the FEDERAL REGISTER requesting public comment on issues pertaining to Appendix A. The public comment period ended March 1, 1978. Eighteen public comments were received in response to the notice, and one public comment was received at the second ACRS meeting. Source documents used in the identification of issues are summarized below.

II. SOURCES OF INFORMATION

A. Staff Sources

Our review has consisted of discussions, meetings and solicitation of procedural and technical issues from the staff (i.e., geoscientists, hydrologists, and engineers in OSD, NRR, RES, and I&E whose responsibilities fall under Appendix A) and from both the Regulations and Hearing Divisions of OELD. Formal comments on issues were received from:

1. J. C. Stepp, Chief, Geosciences Branch, DSE, NRR, memo to L. Beratan, dated 11/22/77. Geoscience staff recommendations for revisions to Appendix A.
2. V. Stello, Jr., Director, DOR, NRR, memo to L. Beratan, dated 12/6/77, request for engineering and hydrology input into the revision of Appendix A, 10 CFR Part 100.

3. L. Hulman, Chief, Hydrology - Meteorology Branch, DSE, NRR, memo to L. Beratan, dated 12/14/77, proposed revision to 10 CFR Part 100, Appendix A - "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

4. I. Sihweil, Chief, ESB, DSS, NRR, dated 11/10/77 input into the revision of Appendix A, 10 CFR Part 100.

5. Comments were also received from the above sources as well as other staff sources (NRR, I&E, OSD, RES, OELD) during the revision of the strawman draft, draft issue papers, and during several meetings of the staff. Additionally, information was obtained from the staff during the ACRS seismic subcommittee meetings.

B. Advisory Committee on Reactor Safeguards

Source information examined from the ACRS includes: generic reports; reports on specific sites in which generic items were mentioned; comments by the seismic subcommittee and their consultants during and in response to three days of meetings on Appendix A. Specific documents include:

1. Site reports:

(a) Comments by J. C. Maxwell, consultant for ACRS, on Skagit, dated 8/30/77.

(b) ACRS reports on Perkins and Cherokee, including D. Okrent's remarks, dated 4/14/77.

(c) ACRS report on North Anna dated 1/17/77.

2. Generic reports:

(a) ACRS generic report #4, on seismic scram, 4/16/76.

(b) Minutes and consultant reports at the 178th ACRS Meeting, 2/6-8/75.

3. Information obtained during the Seismic Subcommittee meeting with the staff on Appendix A, 12/15/77, 1/27-28/78.

(a) Transcript of the above meeting (approximately six hundred pages).

(b) Consultant letter reports by:

A. H-S. Ang

John D. Maxwell

H. Bolton Seed

Shailer S. Philbrick

Merit P. White

James T. Wilson (2 letters)

Zenon Zudans

(c) Letter report by David Okrent.

C. Formal Public and Industry Comments

Formal comments on problems in the application of Appendix A were obtained in response to a staff Federal Register notice published on 1/19/78. The public comment period ended 3/1/78. Additionally, one public comment was received during the ACRS seismic subcommittee meeting. Also, at the request of the AIF, two days of meeting were held with NRR to discuss problems and recommendations for change. Specific sources follow:

1. Public comments in response to staff notice.

   (1) Weston Geophysical Research, Inc.

   (2) Arizona Public Service Co.

   (3) LeBoeuf, Lamb, Leiby and MacRae

   (4) Pacific Gas and Electric Co.

   (5) D'Appolonia Consulting Engineers, Inc.

   (6) Lindvall, Richter, and Associates

   (7) California Division of Mines and Geology

   (8) EBASCO Services, Inc.

   (9) Southern California Edison Co.

   (10) Los Angles Dept. of Water and Power

   (11) General Electric Co.

   (12) New York State Geological Survey

   (13) Law Engineering Testing Co.

   (14) Stone & Webster

   (15) Dames & Moore

   (16) Sargent & Lundy Engineers

   (17) Commonwealth Edison

   (18) Nathan M. Newmark Consulting Engineering Services

2. Public Comment at ACRS Seismic Subcommittee Meeting

   (a) Central Maine Power Company

3. Comment by AIF

   a. Letter from J. Ward to H. Denton, dated 6/15/76, summarizing comments presented at 5/12/76 meeting.

   b. Verbal comments received at 1/9/78 meeting.

D. Comments by the USGS

The staff has solicited formal comments on Appendix A from the USGS. Formal written comments are still pending; however, we have had several discussions with USGS staff on Appendix A, on 9/30/77 with James Devine and with members of the USGS Nuclear Advisory Group in formal and in informal session on 12/77. Comments received in these discussions have been considered in our compilation of issues.

E. Additional Sources

Numerous other sources have been considered in our compilation of issues. Included here are discussions with professional peers, review of papers presented at professional meetings, scientific publications discussing Appendix A, documents relating to NRC policy and practice, documents related to interfacing issues, and the Appendix A historical file.

ENCLOSURE F

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

OCT 8 1976

MEMORANDUM FOR: Commissioner Mason

FROM: Robert B. Minogue, Director
Office of Standards Development

THRU: Executive Director for Operations

SUBJECT: THE RELATIONSHIP BETWEEN SAFE SHUTDOWN EARTHQUAKES AND OPERATING BASIS EARTHQUAKES

In response to your request this memorandum summarizes for your information and that of the other Commissioners the technical issues involved in the interrelationship between the safe shutdown earthquake (SSE) and operating basis earthquake (OBE) in their determination and application to design.

NRC regulations (Appendix A to Part 100) identify two levels of earthquake severity to be applied to reactor seismic design. These are called the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE).

These earthquakes can be and are regarded and defined as either geologic events or as engineering design requirements. These two perspectives are often difficult to relate to one another. Both points of view are explicit in Appendix A.

Viewed geologically, the SSE is the most severe earthquake which can affect the site. The OBE is the most severe earthquake which is reasonably likely to occur during the operating lifetime of the plant.

Appendix A defines in detail the elements of the geologic and seismologic investigation of proposed sites. Deterministic procedures are given to establish the safe shutdown earthquake. These procedures require consideration of (a) the seismology of the region in which the site is located, (b) the regional and local geology, and (c) the nature of the materials underlying the site. If the structural geology of an area is understood, Appendix A procedures for determining the SSE usually have the effect of placing greater emphasis on structural geology than on historic seismicity, largely because of the limited historic record.

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The intent of these procedures is to identify the maximum earthquake which can affect the site. There is, of course, some probability of exceeding the SSE. This problem is because of the uncertainties arising from our limited understanding of the frequency and severity of large scale earthquake phenomena and the limitations of geologic and geophysical investigations, rather than lack of validity of the concept of a limiting earthquake. In a sense, then, the likelihood of exceeding the SSE is a measure of the state-of-the-art of geologic and seismologic understanding; it probably is on the order of perhaps 10^{-6} in any given year for any site, but with a very wide error band.

The operating basis earthquake, although an infrequent and major earthquake, is a much more likely geologic event. The recurrence interval frequently considered applicable to the OBE is in the range of 300 to 1,000 years. Although in engineering practice the OBE is usually established as a fraction of the SSE, in many parts of the country there is a sufficient record of historic seismic events to provide a basis for a probabilistic assessment of the OBE if these events are considered in light of the regional structural geology.

Appendix A does not prescribe specific geologic procedures for establishing the OBE (although it does specify a minimum level). An ANSI standard* has been drafted describing a method of probabilistic assessment of the OBE. Probabilistic analysis was used for establishing the OBE for the Koshkonong Nuclear Power Plant. The application for a construction permit has been reviewed and accepted by ACRS.

This approach of two levels of severity of a natural phenomenon is not unique to earthquakes. There is a good analogy between the concept of the SSE and OBE and that of the Probable Maximum Flood (PMF) and Standard Project Flood (SPF) used by the U. S. Army Corps of Engineers (and NRC). The level of likelihood of these two flood discharge levels is substantially the same as the SSE and OBE, respectively.

Viewed as applied to engineering design, the design basis for the SSE is specified in Appendix A to assure that the plant design adequately protects the public health and safety in the event of an extreme earthquake. The OBE is established as the most severe earthquake following which the plant can safely be operated without special inspections.

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*"Guidelines for Determining the Vibratory Ground Motion for the Design Earthquake for Nuclear Facilities", ANS 2.1 Working Group Draft, January 1, 1976.

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Engineering codes and design practice apply these two earthquake levels differently. Category I structures, systems, and components*, must maintain their safety function for earthquake levels up to and including the SSE. That is, although the plant, as a power generating facility, may be severely damaged in this extreme event, it must go through the earthquake without undue hazard to the public and following the earthquake the reactor must be capable of being shut down and kept in a safe shutdown condition. On the other hand, the engineering design objective with the OBE is that the plant is capable of being safe in operation after experiencing an event less than or equal to the OBE.

As an example of how these events are applied to design, in use of the ASME Boiler and Pressure Vessel Code, the SSE is normally applied as a Faulted Condition, meaning that stress levels allowed by the Code which would result in permanent general deformation are permitted except when deformation would lead to loss of safety function. On the other hand the OBE is considered as an Upset Condition or Design Condition in applicatio of the Code and is used in conjunction with lower allowable stress levels at which no general deformation would occur. In addition to differences of allowable stresses, there are other differences in design analysis methods in the application of Faulted and Upset Conditions. Many seismic designers see the SSE as being the basic seismic design basis with the OBE playing more the role of a cross-check basis using different analysis procedures and different limits to assure the adequacy of the margin provided by the SSE design over a wide range. Viewed from this perspective the OBE is more of an engineering safety factor applied to design analysis rather than being seen as a seismic event.

To provide such a safety factor, Appendix A to Part 100 contains the statement that the "Maximum vibratory ground acceleration of the Operating Bases Earthquakes shall be at least one-half the maximum vibratory ground acceleration of the Safe Shutdown Earthquake." This is a somewhat arbitrary relationship which assures that the stresses associated with design load combinations plus the OBE loading on systems essential to safe operation will not result in general yielding of the materials (i.e. will remain in the elastic regime).

On the other hand, if viewed as a seismic event the acceleration associated with the OBE may range from as low as 1/10 the SSE to as high as 80 or 90%. In parts of the country where the structural geology is not well understood, current practice would lead to OBE's typically about 1/2 the SSE; that is, roughly one Intensity unit lower.

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*Defined and listed in Regulatory Guide 1.29, "Seismic Design Classification

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The shaking associated with actual earthquakes is a very complex vibratory motion with wide variations in frequency content, amplitude, and duration depending on the type of initiating crustal movement and the transmission of the motion through the earth. Normal engineering practice is to define the vibratory motion input as it affects the facility with a composite response spectrum based on a number of earthquake records. Usually this response spectrum is reduced to a time-motion record (a synthetic seismogram) for application to design. This engineering definition of vibratory motion input is quite complex and contains a number of elements of arbitrary conservatism. A group of Regulatory Guides* has been issued which provides a complete definition of the vibratory motion input for reactor facilities. The only distinction between the SSE and the OBE in the application of these response spectra to design is a scaling by the comparative accelerations.

There are a number of specific issues and problem areas that are related to the determination and application of these two events which are identified and briefly described below. Attachment I is a detailed staff analysis discussing the subject at greater length, prepared with the assistance of the NRR Division of Site Safety and Environmental Analysis.

1. Is the OBE a safety-related event in the strictest sense?

Many people do not regard the OBE as a safety-related event. Design of the plant to withstand the SSE without undue public hazard is felt to meet the safety need. The decision whether or not to continue operation of the plant after an earthquake is seen as a decision of the utility. If an earthquake should occur, the safety of the plant for continued operation could be established by a suitable, possibly quite extensive, inspection program without requiring design to an OBE level. As originally published for comment Appendix A reflected this perspective by making the establishment of an OBE optional. Perhaps the best argument for regarding the OBE as a safety-related question is a recognition that in the aftermath of a major earthquake needs for power would be significant. Prompt continued reactor operation might be a community requirement. Another argument sometimes advanced is that the widespread shaking of the earthquake affects reactor systems in complex interactive modes which are not easily foreseeable. This makes it appropriate to require some level of general earthquake design within the elastic response range; but in fact application of OBE design to structures, systems, and components not also covered by SSE design is quite rare.

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*Regulatory Guides 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"; 1.61, "Damping Values for Seismic Design of Nuclear Power Plants"; 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis"; and 1.122, "Floor Design Response Spectra Development for Seismic Design of Floor-Supported Equipment or Components".

2. Should the CBE be established as a seismic event or as an engineering safety factor?

A widely-held engineering view is that the analysis of a seismic load in the range of from 1/3 to 1/2 the SSE provides the best engineering verificatic of seismic design, and that the CBE should be established in this range at a value such that the seismic design is determined by the SSE, not the CBE, since the CBE is seen as a design check. Note that other non-seismic factors may control the design overall. On the other hand, if determined probabilistically as a geologic event, the CBE would not necessarily be within this range, and may or may not determine seismic design.

3. What vibratory motion characteristics should be assumed for the CBE?

The complex multi-frequency shaking of an earthquake is normally represented for design purposes by a highly conservative smoothed response spectrum. The same response spectrum shape is normally used for both the SSE and CBE design, adjusted only as to acceleration. Since the CBE is an earthquake of lower intensity and likely shorter duration, a less conservative response spectrum might well be appropriate.

4. How should isolated acceleration peaks be treated?

It is not unusual in an earthquake to have a high amplitude acceleration peak of limited duration and little impact on the response of a complex structure. For example, such a peak (1.25 g) was measured at the Pacoima Dam in the San Fernando earthquake in 1971. Current practice is to base the engineering design on a response spectrum which implicitly assumes sustained shaking (and in effect disregards isolated peaks) based on the general engineering consensus that isolated peaks do not have any significant effect on structures.

5. What inspections should be carried out following an earthquake exceeding the CBE?

Appendix A does not provide guidance on this matter. It is very difficult before the fact to identify in a generic way exactly what inspection program would be appropriate after an earthquake. Conversely, following an earthquake observable effects on the facility could reasonably be expected to indicate the areas requiring inspection and the types of inspection needed. The staff position has been that the level and extent of inspection following an earthquake should be based on observed damage and a comparison between the smoothed response spectrum used as a design basis and the response spectrum corresponding to the motion actually experienced by the facility.

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The actual shaking can be determined by seismic instrumentation required on all nuclear power plants to measure earthquake input. An ANSI committee which developed a standard defining seismic instrumentation requirements to measure input* is now well along on a standard which defines a basis for assessing "exceedance" of the design response spectrum in a real event**, to provide a basis for decision on level and type of inspection based on the actual facility response.

Robert B. Minogue

Robert B. Minogue, Director
Office of Standards Development

Attachment:
Detailed Staff Analysis

cc: Chairman Rowden
Commissioner Gilinsky
Commissioner Kennedy
Office of the Secretary

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*ANSI N18.5, "Earthquake Instrumentation Criteria for Nuclear Power Plants", endorsed and amplified in Regulatory Guide 1.12, "Instrumentation for Earthquakes".

**ANSI N643 (ANS 2.10), "Guidelines for Retrieval, Review, Processing, and Evaluation for Records Obtained from Seismic Instrumentation".

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ATTACHMENT I

STAFF REPORT ON BASES FOR SELECTION OF SAFE SHUTDOWN EARTHQUAKES (SSE'S) AND OPERATING BASIS EARTHQUAKES (OBE'S) AND THE RELATIONSHIP BETWEEN THE TWO

I. PRESENT SITUATION WITH REGARD TO THE BASES FOR SELECTION OF SSE

The Safe Shutdown Earthquake (SSE) is that earthquake which is based on an evaluation of the maximum earthquake potential in the region of the nuclear power plant site. The evaluation is based on a consideration of the regional and local geology and seismology and on the specific characteristics of the material on which the power plant will be located.

For selection of the SSE, Part 100 Appendix A describes two distinct geological/seismological situations within which somewhat different procedures are required for determining the SSE: (1) when the seismicity can be related to geologic structures and/or capable faults and (2) when seismicity cannot be related to geologic structures and/or capable faults.

A. Situation One: When Earthquake Generating Structure Can Be Identified

The first situation, in which seismicity can be related to geologic structures and/or capable faults, is more typical of the western United States, which is a region of complex geology and high seismicity. The following four steps represent current staff procedure for establishing maximum SSE acceleration in this situation:

1. Determination of tectonic structures. An assessment of the earthquake history of the area in which a nuclear power plant will be located is made. This assessment includes the frequency of occurrence, and the maximum earthquake of record. Tectonic structures in the area that have associated seismicity are identified. By definition tectonic structures are large scale dislocations or distortions of the earth's crust and may or may not encompass capable faults. For example, the San Andreas fault zone of California and the Cincinnati Arch are both considered to be tectonic structures. One represents a rupture of the earth's crust, and the other a large flexure. If the maximum historic earthquake occurs on a tectonic structure either near or upon which the power plant will be situated, the earthquake is treated as though it took place at the proposed power plant site.

2. Determination of Capable Faults. By means of historic records and geological investigations, capable faults which could conceivably affect the site are identified. Table I from Section IV of Appendix A to 10 CFR 100 presents a minimum fault length versus distance from site, for consideration of the fault in establishing the SSE. For capable faults, the characteristics of the fault must be known. These characteristics are determined from historic records and by geologic investigation they include the length of the fault, amount and nature of displacement on the fault, physical properties of rock and soil associated with the fault, and information on past movements of the fault.

3. Determination of maximum earthquake. Since a fault does not usually rupture along its entire length, an effective rupture length must be established. Current staff practice is to assume that approximately 40% of the total fault length will be involved in any single event.

Given this rupture length, an earthquake magnitude is determined for the fault. Empirical relationships between rupture length, earthquake magnitude, and displacement have been developed and are used for this purpose. The relationship developed on AEC contract by Bonilla and Buchanan (1970) for this purpose is most widely used, although others (Algermissen (1969) and Ambraseys and Tchalenko (1968)) are sometimes employed. This maximum earthquake has always been larger than the maximum historic earthquake associated with the fault; however, the maximum historic earthquake would be used if it were the larger of the two.

4. Determination of maximum acceleration at site. The maximum earthquake intensity is assumed to occur on the portion of the fault or tectonic structure closest to the plant site. Given the earthquake and the distance to the site, the acceleration at the site is determined using attenuation relationships developed by Schnabel and Seed (1973). Other relationships (Hofmann (1974), Housner (1965), Donovan (1973)) are also sometimes used. The largest acceleration resulting at the site from the earthquakes on the various capable faults is then used as the maximum vibratory acceleration for the SSE. Appendix A requires that this acceleration be at least one-tenth the acceleration of gravity (0.1g).

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B. Situation Two: When the Cause of Historic Earthquakes Cannot be Related to Known Geologic Structures

The second situation, in which seismicity cannot be related to geologic structure and/or capable faults, is typical of the eastern United States, where it has generally not yet been possible to relate seismicity to tectonic structures or capable faults in many areas. In this case, tectonic provinces are used in the establishment of the SSE. The following steps present current staff procedure in this situation.

1. Determination of tectonic province. A tectonic province is (as defined in Appendix A) a region of the North American continent characterized by a relative consistency of the geologic structural features. There is no definitive generally accepted identification of such provinces in the United States. Several province maps exist (by King (1969), Eardley (1962), Hadley-Devine (1974)) and are used for general guidance, but the basic determination of such a province, if required, is made on a case-by-case basis.

2. Determination of maximum earthquake. Since in the second situation we are concerned with a region in which seismicity is not related to known geologic structures, the maximum historic earthquake of the region is treated as though it could occur anywhere in the tectonic province (i.e., at the plant site). Geological evidence, a high level of seismicity or a short historical record, may dictate the use of an earthquake intensity greater than that of the maximum historic earthquake of the tectonic province.

   When an adjacent tectonic province has experienced an earthquake greater than those of the tectonic province in which the power plant is to be located, the maximum recorded earthquake of the adjacent province is treated as though it occurred on the border of the two provinces at the point closest to the power plant site. The effect of such an earthquake on the plant site is determined as described below.

3. Determination of maximum acceleration at site. Most historic earthquakes in the eastern United States are recorded in terms of Modified Mercalli intensity (I_{MM}), and the maximum earthquake for the site is also specified in I_{MM}. A maximum acceleration is derived from this intensity. A number of correlations of acceleration and intensity have been developed by various authorities. Commonly used is the relationship developed by Trifunac and Brady (1975). A relationship from Neumann (1954) is also sometimes used.

For maximum earhtquakes presumed to occur at the border of adjacent tectonic provinces, the intensity of that earthquake is converted to a Richter magnitude using relationships developed by Richter (1958) or Nuttli (1974). Given this magnitude, the maximum acceleration is calculated in the same manner as for earthquakes associated with known faults, using the same attenuation relationships.

In the case of the Charleston SC 1886 and New Madrid MO 1811-1812 earthquakes, the recorded intensity contours are used to determine the intensity at the site, and the site acceleration is determined from relationships such as Trifunac and Brady (1975) or Neumann (1954).

II. SSE DESIGN RESPONSE SPECTRA

To define the SSE precisely for engineering design purposes, the maximum horizontal ground acceleration associated with the SSE for a given nuclear power plant site is established by the applicant and approved by the NRC. After agreeing on the maximum ground acceleration for a given site, Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," scaled to the SSE acceleration, is normally used for establishing the free field ground vibratory motion associated with the SSE for the site. The applicant also has the option of using site-dependent design response spectra in place of those given in Regulatory Guide 1.60.

It is pointed out in Regulatory Guide 1.60 that the acceptable design response spectrum procedure for nuclear power plants is a procedure developed as a result of two statistical studies of response spectra from past earthquakes. A summary of the two studies and the recommended design procedure is contained in the paper entitled "Seismic Design Spectra for Nuclear Power Plants" by Nathan M. Newmark, John A. Blume and Kanwar K. Kapur (ASCE, Journal of the Power Division, November 1973). In a study by John A. Blume, a total of 33 different earthquake records were considered, with the peak ground accelerations for these earthquakes ranging from 0.11g to 0.51g. A total of 28 records were used in a study by Nathan M. Newmark, with the maximum ground accelerations in the horizontal direction ranging from 0.03g to 1.25g. Response spectra were calculated for each record for varying degrees of damping and mean spectra were derived from statistical analyses. The results of the two studies were combined and a single spectrum was recommended for design purposes, using a mean plus one standard deviation as the design spectrum probability level.

It can be seen therefore that the characteristics of the actual earthquake records used by Blume and Newmark, such as their frequency content and the duration of their motions, are inherent in the design spectra found in Regulatory Guide 1.60. Since a number of conditions are enveloped in Regulatory Guide 1.60, the development of smoothed site dependent spectra from a single earthquake record would be less conservative because it covers only one condition.

It is important to emphasize that the peak ground accelerations of the earthquakes used in the Blume and Newmark studies are maximum motions observed independent of the duration of ground shaking at those levels. This introduces a degree of conservatism into design spectra, since it is well established in earthquake engineering that the most damaging ground motions are typically those levels of motion (frequently of lower amplitude than the peaks) that are maintained for longer periods of time.

III. PRESENT SITUATION WITH REGARD TO THE BASES FOR SELECTION OF THE OBE

The Operating Basis Earthquake, as defined in 10 CFR Part 100, Appendix A, is that earthquake which, considering the regional and local geology and seismology and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant. It is that earthquake which produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.

The minimum value of the acceleration level for the OBE is currently specified in Appendix A to 10 CFR Part 100 as at least one-half the acceleration determined for the SSE and this is the value normally specified. For sites not in highly seismic areas, ~~this requirement~~ is controlling in the selection of OBE. In these areas, earthquake accelerations which can reasonably be expected to occur in the life of the plant will usually be less than one-half the SSE acceleration.

For sites in highly seismic regions (mainly in the western United States) a complete description of the OBE is developed. Geologic structure capable faults, or tectonic provinces with which historical earthquake activity has been associated are considered as possible source mechanisms. Probability calculations such as those described by Algermissen and Perkins (1972, 1976) can be used to help estimate the acceleration level that can reasonably be expected to affect the plant during its operating life (approximately forty years). This acceleration may be greater than one-hal the SSE acceleration for some sites.

To define the CBE precisely for engineering design purposes, the same response spectrum as that for the SSE is used, scaled only as to acceleration.

The philosophy behind establishing the CBE to be not less than one-half SSE is as follows:

1. The stress level in the safety-related structures, systems, and components is allowed to reach yield level when the plant is subjected to a SSE in combination with other applicable loads, provided the necessary safety functions are maintained. For the CBE, all structures, systems, and components necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional and well within elastic limits when subjected to the CBE in combination with normal operating loads. The usual range of allowable elastic stress is from 0.45 to 0.6 of the yield stress. The choice of the CBE to be one-half SSE is consistent with the ratio of the yield stress (allowed for SSE) to the allowable elastic stress (allowed for CBE).

2. Appendix A to 10 CFR Part 100 requires that the nuclear power plant be shut down if the vibratory ground motion exceeds that of the CBE. This requirement indicates the advisability of an CBE which is large enough so that during a strong earthquake all the nuclear power plants in a large geographical area are not shut down and the public left without electric power.

(It should be noted that another application of the CBE arises when seismic effects are considered in combination with other natural phenomena. For example, in determining the design basis for certain structures of the ultimate heat sink, the CBE is considered in combination with waterflow based on severe historical events in the region of the structure. This application of the CBE is basically not germane to the issues of SSE/CBE interrelationship discussed in this paper).

IV. PRESENT SITUATION WITH REGARD TO ENGINEERING DESIGN METHODOLOGY USED FOR SEISMIC DESIGN OF PLANTS SUBJECTED TO SSE AND CBE

The attached diagram outlines the documented seismic design methodology being used today in the engineering design of nuclear power plants relative to the SSE and CBE.

Appendix A to 10 CFR Part 100 requires that vibratory motions of the SSE and CBE be defined by response spectra of the foundation level of the plant. These spectra are obtained by deconvolving the three-directional spectra specified in Regulatory Guide 1.60, which are free field spectra. For these free field spectra Regulatory Guide 1.60 specifies two horizontal spectra having the same amplification factor and a vertical spectrum having amplification factors which range from the same to 2/3 of the amplification factor used for the horizontal spectra. In the process of deconvolving, time histories compatible with the free field spectra are generated. Engineering analysis of the site is performed to find the compatible bedrock motions. These bedrock motions are used in soil structure interaction to find the plant foundation motions. The foundation level motions (represented by spectra or time-histories) are in turn used in the structural model of the nuclear power plant to find stresses and displacements in various elements of the plant and the floor design response spectra to be used subsequently in the design of floor-supported equipment and components. Sometimes structure-to-structure interaction analysis must be performed if two or more structures are in close proximity of each other. This anslysis may further modify the foundation level design input into a nuclear power plant structure.

V. IMPORTANT ISSUES CONCERNING SELECTION OF THE SSE

A. There is a paucity of data for use in determining the magnitude of the earthquake associated with a given fault length. certain types of earthquake source mechanisms (such as overthrust faults and reverse faulting resulting from compressional failures) generally have higher effective stresses across the fault, leading to greater energy releases and thus greater magnitudes than would be expected for a strike-slip or normal dip-slip fault. There is some feeling that the more frequently used empirical relationships are dominated by data for the reverse-type faults, leading to undully conservative magnitudes for other faults.

These empirical relationships contain an additional conservative bias due to difficulties in determining the rupture lengths of faults associated with past earthquakes. Since portions of the fault may be buried beneath landslides or a deep alluvial soil layer, estimates of rupture lengths associated with past earthquakes tend to be shorter than the actual rupture lengths. The relationships developed using these rupture lengths will then predict unduly conservative (large) earthquake magnitudes for well-established fault length and postulated rupture length.

B. In establishing the maximum acceleration for a site, there are differences of opinion among seismology experts regarding the maximum possible near-field (close to the fault) acceleration that can be generated. That is, there is some physical upper limit on near-field acceleration, regardless of earthquake magnitude; the disagreement is on the value for this upper limit.

C. Very high isolated peak accelerations have been measured but are not used in scaling and applying Regulatory Guide 1.60 design spectra. These maximum accelerations are usually of short duration and do not have time to build up damaging energy. Near-peak accelerations maintained for longer durations will be more damaging. The duration of strong motion is particularly significant for design stresses near the yield point (as is the case with the SSE).

D. Determination of tectonic provinces is a point of contention between the staff and industry. In general, staff practice is to use relatively large tectonic provinces to ensure conservative design. However, there is a great deal of technical argument from industry to use smaller tectonic provinces.

E. Determination of maximum acceleration from intensity creates difficulties in that intensity is a subjective measure of ground motion. Also, direct information about the duration of strong motion is lost when using intensity as a measure. This is a difficult problem since almost all earthquake data for the eastern United States is in terms of Modified Mercalli intensity.

VI. IMPORTANT ISSUES WITH RESPECT TO RELATIONSHIP BETWEEN OBE AND SSE

A. The OBE can be considered to be not safety-related and therefore appropriately chosen by the applicant as a matter of economic judgement. In such a case the guiding factor for the applicant to choose a certain g-level for the OBE would be the cost of shutting down and restarting the plant after an OBE occurs. If the applicant chooses too low a level for the OBE, he might incur heavy costs of shutting down and restarting the plant several times during the life of the plant. Further, if the plant generally has an inadequate seismic design basis he may incur extensive costs due to earthquake damage to power generation and transmission equipment. (As an example damage to utility systems in the San Fernando earthquake amounted to about $100,000,000).

Regulatory Guide 1.12 specifies that various seismic instruments be used to ascertain whether the OBE has been exceeded during an earthquake. When instrumentation shows that the peak acceleration or the response spectra experienced at the foundation of the containment building or in the free field exceed the OBE acceleration level or response spectra, the plant is required to be shut down pending permission to resume operation. To determine whether or not the plant can safely resume operations, visual field inspection of safety-related items, which may include nondestructive testing if need is indicated, is implemented and the measured responses from both the peak-recording and strong-motion accelerographs are compared with those assumed in the design. Considerable cost and time is involved in this process of inspection and verification, which includes such items as (1) inspecting the piping for any movement or rubbing, (2) inspecting the structures and equipment for abnormal displacement, (3) reviewing the recorded data on plant operating parameters for any abnormal operation of equipment during event, and (4) comparing the recorded responses with the design basis. To compare the responses, the earthquake data mus be retrieved from the instruments, digitized, and used in the compu analyses. Usually technical specifications of the licensees are used to accomplish the inspection and comparison of the responses.

B. Some members of the staff feel that the OBE should be established based on probabilistic methods, rather than being specified as a fraction of the SSE. This could be done by choosing an earthquak recurrence interval to obtain a sufficiently small probability of exceedance during the operating life of the plant, and modifying or eliminating the requirement that the OBE be at least one-half the SSE. One difficulty with this approach is in how to select an appropriate recurrence interval. Also, there is very little earthquake data for the eastern United States, creating problems in determining the earthquake severity for a given r currence interval. There is some feeling that the historic records for North America are too short for use in predicting geologic phenome The staff has a wide range of opinions on how such an approach should be used. There have been cases for which an OBE less than one-half SSE has been accepted by the staff as the earthquake which could reasonably be expected to affect the plant during its operating life.

C. Some feel that the minimum OBE should be set somewhere in the range of one-third to one-fourth of the SSE. It is their contention that, with an OBE equal to one-half of the SSE, the design of many components in a nuclear power plant is governed by load combinations involving the OBE rather than by combinations which include the SSE. While reducing the OBE/SSE ratio might in some cases, reverse the situation, in other cases it will not. What really controls the design are the choices of load factors, loading combinations, and allowable stresses used. The OBE is onl one of the loadings but in many cases the combination of nonseism loads has the controlling effect on the design. To overcome this problem, the load combination questions and allowable stresses would have to be revised to give different weightings to the loads involved. Differences of opinion exist within the staff on whether or not this should be done.

VII. IMPORTANT ISSUES WITH THE SEISMIC DESIGN METHODOLOGY

A. Regulatory Guide 1.60 is based only on limited data. There is room for improvement in the shape and amplitude of the free field design response spectra as a function of magnitude and distance.

B. Regulatory Guide 1.61, which gives the damping values to be used in the seismic analysis of the nuclear power plants is based on limited test data and engineering judgement. Room for improvement also exists here, because a slight difference in damping values can make a substantial difference in the resulting stresses in various components of the plant.

C. Regulatory Guide 1.60 specifies that the same amplification factors be used for the two horizontal spectra, and gives a separate set of amplification factors for the vertical spectrum. There is some feeling that the amplification factors for the second horizontal spectrum and the vertical spectrum can be less than those given in Regulatory Guide 1.60.

D. The shape of the spectra as given in Regulatory Guide 1.60 is not suitable for soil liquification analysis, according to some views. A site-compatible spectrum is more appropriate for these analyses.

E. Soil is a nonlinear material when subjected to the dynamic motion of earthquakes. At present most of the soil-structures interaction analyses and site analyses for deconvolving the time-history motions are based on the elastic (linear) properties of the soil. There must be a substantial improvement in the state-of-the-art before nonlinear analyses for soils can be incorporated into the design methodology.

F. In carrying out the structure-to-structure interaction analyses, the major problem encountered is the same as in soil-structure interaction analyses, i.e., the elastic rather than inelastic properties of the soil are used in the analyses.

G. There are two usual kinds of analyses which are performed on structures subjected to earthquake motions: (1) response spectrum analysis and (2) time-history analysis.

The major question raised about the response spectrum technique is how to combine the modal response and the effects of three components of earthquakes. Regulatory Guide 1.92 specifies procedures based on the present state-of-the-art.

If time-history technique is used and a simultaneous analysis of the three directions is performed, the problems of modal combination and three components of earthquakes are eliminated. However, the procedure requires a computer with very large memory capacity, therefore it is not being widely used at present.

E. Regulatory Guide 1.122 specifies procedures to broaden and smooth the floor response spectra. The guide also provides the procedure to combine the three floor response spectra for a given direction. The questions raised about the guide include the amount of broadening and the procedure to combine the three spectra for a given direction. The guide is based on the present state-of-the-art and can be improved in the future.

VIII. REFERENCES

10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants"

Regulatory Guide 1.12, "Instrumentation for Earthquakes"

Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"

Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants"

Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis"

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Enclosure

SEISMIC DESIGN METHODOLOGY

-Pertinent Regulations, Standards, and Guidelines-