LILCO, July 16, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of LONG ISLAND LIGHTING COMPANY (Shoreham Nuclear Power Station, Unit 1)	))))))	Docket No. 50-322-OL-4 (Low Power)

TESTIMONY OF JOHN T. CHRISTIAN,
AHMED E. MELIGI AND ROBERT C. WIESEL
ON BEHALF OF LONG ISLAND LIGHTING COMPANY

I. Witness Qualifications

Q.1. Please state your name and business address.

A. (Christian) My name is John T. Christian and my address is Stone & Webster Engineering Corporation, 245 Summer Street, Boston, Massachusetts.

(Meligi) My name is Ahmed E. Meligi and my address is Sargent & Lundy, 55 East Monroe, Chicago, Illinois.

(Wiesel) My name is Robert C. Wiesel and my address is Stone & Webster Engineering Corporation, 245 Summer Street, Boston, Massachusetts.

Q.2. Dr. Christian, what is your position with Stone & Webster?

A. (Christian) I am a senior consulting engineer in Stone & Webster's consulting group.

Q.3. How long have you been in this position?

A. (Christian) Since October 1980.

Q.4. What are your duties and responsibilities as a senior consulting engineer?

A. (Christian) At SWEC a senior consulting engineer provides technical advice, guidance, analysis, and leadership across one or more disciplines. He is not assigned to a particular engineering division and works on a variety of projects and assignments as his services are needed. I serve as such a consultant on problems involving geotechnical engineering, earthquake engineering, numerical modeling, computer applications, seismic hazard studies, and related areas. I provide consulting service to various clients and to projects within SWEC. I also serve on several internal committees and boards dealing with computer matters at Stone & Webster and am involved in development of offshore technology.

Q.5. Prior to your appointment as a senior consulting engineer, what other positions have you held with Stone & Webster?

A. (Christian) I began work with Stone & Webster in June 1973 as a consultant to the Geotechnical Division. In November 1976, I was appointed as a consulting engineer and in October 1980 I was appointed to my present position, Senior Consulting Engineer.

As a consultant in the Geotechnical Division, I provided consulting services within Stone & Webster and to outside clients on matters relating to geotechnical engineering, earthquake engineering, numerical modeling, and computer applications. My responsibilities as a Consulting Engineer were substantially similar to my present ones.

A list of projects in which I have participated and a brief description of those projects is included in my resume which is attached (Attachment 1).

Q.6. What positions did you hold prior to your employment with Stone & Webster?

A. (Christian) From July 1966 through July 1973, I was employed as an assistant professor and associate professor of civil engineering at the Massachusetts

Institute of Technology, Cambridge, Massachusetts. I was responsible for research and teaching, primarily in the areas of geotechnical engineering and computer application. Specific topics included the application of finite elements methods to problems in geotechnical engineering, including consolidation, behavior of braced excavations, stability of slopes, inelastic deformation of soil, earthquake problems, and flow through soils. I also performed research on the behavior of levees on the Atchafalaya River, development of computer-aided slope stability analysis, and earthquake engineering. During my tenure at MIT, I provided consulting services to Stone & Webster Engineering Corporation (July 1969 - July 1973) and T. William Lambe and Associates, Cambridge, Massachusetts (July 1966 - July 1969). This consulting work generally involved field, laboratory, and analytical work on a variety of geotechnical projects, including nuclear power plants, earth dams, foundations, and slope stability analyses.

From September 1963 to July 1966, I earned a Doctor of Philosophy degree in civil engineering from the Massachusetts Institute of Technology as a National Science Foundation graduate fellow. Prior to that time, I had performed work for T. William Lambe and Associates as both an employee and a consultant in the area of geotechnical engineering. I also served as an officer in the United States Air Force. A complete description of my employment history is included in my resume.

Q.7. Dr. Christian, what is your educational background?

A. (Christian) I hold a Doctor of Philosophy, Master of Science and Bachelor of Science in Civil Engineering from the Massachusetts Institute of Technology.

Q.8. Do you belong to any professional societies?

A. (Christian) Yes. I am a member of a large number of professional societies, including the American Society of Civil Engineers (ASCE). I am a member of the Executive Committee of the Geotechnical Engineering Division of ASCE and a past or present member of several committees of that division, including those on Soil Dynamics, Safety and Reliability, Computer Applications and Numerical Methods, and Publications. I am a member of the Seismological Society of America, the Earthquake Engineering Research Institute, in which I have served on the research committee, the International Society of Soil Mechanics and Foundation Engineering, the British Geotechnical Society, and the Boston Society of Civil Engineers. A complete list of the professional societies to which I belong and the honors and awards which I have received are included in my resume. I am a Registered Professional Engineer in the Commonwealth of Massachusetts and the State of Maine.

Q.9. Mr. Meligi, what is your position with Sargent & Lundy?

A. (Meligi) My title is Head, Component Qualification Division.

Q.10. How long have you been in this position?

A. (Meligi) Since September, 1981.

Q.11. What are your duties and responsibilities as Head of the Component Qualification Division?

A. (Meligi) I am responsible for developing and implementing comprehensive qualification programs for assuring the operability, functionability and structural integrity of power plant components and component supports during all postulated loading (dynamic and static) and environmental plant conditions. The components include equipment (mechanical; electrical; heating, ventilation and air conditioning (HVAC); controls; instrumentation; HVAC ducts; and penetration assemblies) for nuclear and fossil plants. I also direct and review the activities related to optimal design/analysis methods for the reliability of components, special analysis of fluid mechanics, heat transfer, creep-fatigue, fracture mechanics, structural dynamics, vibrations, and material problems. A copy of my resume is attached (Attachment 2).

As Head of the Component Qualification Division, I am in charge of over 130 qualified individuals devoted to all activities related to the qualification of nuclear plant components. The scope of work of this division includes writing seismic test plans, witnessing seismic tests, performing analytical seismic qualifications, and reviewing seismic qualification reports. In the course of conducting our assignments we have been in charge of seismically qualifying more than 12 GM-EMD diesel generators for several other utilities that are similar to the 2.5 MW sets installed at Shoreham. We have also performed seismic qualification for other types of diesels. These assignments provided us with the knowledge and experience to respond to LILCO's request to perform a seismic survivability study on the EMD diesels.

Q.12. What previous positions have you held with Sargent & Lundy?

A. (Meligi) I was hired in April, 1971 as a seismic analyst in the Engineering Mechanics Division (EMD) of

Sargent & Lundy. My assignments were to establish the seismic qualification criteria for nuclear power plant equipment, to specify the seismic requirements in the procurement specifications, and to review vendor's seismic qualification reports. I was promoted to Assistant Supervisor in 1972, to Supervisor in 1973, and to the Head of the Component Analysis Section in 1974. In this capacity I was in charge of over 40 engineers who handle all seismic qualification activities for safety-related components in the nuclear plants designed by Sargent & Lundy. In 1979 I was promoted to be an Assistant Head of the Engineering Mechanics Division. Later in 1981, the Component Qualification Division was formed, drawing from the Component Analysis Section of EMD, electrical engineers from our Electrical Department, and other control and HVAC engineers. I was appointed Head of this Division.

Q.13. What is your employment experience prior to Sargent & Lundy?

A. (Meligi) I worked as a Project Engineer in Helwan Aircraft factories in designing automatic control systems for three years (1965-1968). Then, I joined Strato Engineering Company, a consultant firm for aerospace engineering in Burbank, California, as a Senior Engineer in charge of flutter and vibration analysis and flight tests evaluations for one and a half years (1968-1969). In 1970-1971, I taught engineering mechanics courses in Michigan Tech.

Q.14. Mr. Meligi, what is your educational background?

A. (Meligi) I hold a Bachelor of Science in Aeronautical Engineering from Cairo University, Egypt, and a Master of Science in Engineering Mechanics from Michigan Technological University.

Q.15. Do you belong to any professional societies?

A. (Meligi) I am a Registered Professional Engineer in Illinois, member of the American Society of Mechanical Engineers (ASME), American Nuclear Society (ANS), Institute of Environmental Sciences (IES), and Egyptian American Scholars. I am the Secretary of the Special Working Group on Dynamic Analysis and member of the Working Group on Component Supports Committees of the ASME Section III. I am also a member of the ANSI Committee on Operability of ASME Class 2 and 3 pumps.

Q.16. Mr. Wiesel, what is your position with Stone & Webster?

A. (Wiesel) I am a Senior Structural Engineer in the Structural Division.

Q.17. What are your duties and responsibilities as a Senior Structural Engineer?

A. (Wiesel) I am currently the Supervisor of Projects for the Structural Division. My duties and responsibilities include the technical supervision of the structural engineering staff assigned to the Shoreham Nuclear Power Station project and other Stone & Webster nuclear projects. I am directly involved in the establishment of the technical methods and procedures utilized by the structural engineers assigned to our current nuclear projects. Based on the licensing requirements involved, such activities typically include seismic analysis and the design of nuclear plant structural elements.

Prior to my February 1, 1984 appointment as Supervisor of Projects, I held the position of Lead Structural Engineer for the Shoreham Project. In this position, I was directly responsible for the analysis and design of structural elements and development of construction drawings and specification for Shoreham. Included in this area would be the seismic analysis and design of structures, cable tray supports, conduit supports, and equipment foundations. I assumed this position in March of 1980.

Q.18. What other positions have you held for Stone & Webster?

A. (Wiesel) I joined Stone & Webster in June 1972 as an Engineer in the Structural Division. In that position, I was assigned to a number of nuclear and fossil fueled power projects. During such assignments, I was involved in the seismic analysis and design of nuclear safety related structures and equipment supports. A copy of my resume is attached (Attachment 3).

Q.19. Mr. Wiesel, what is your educational background?

A. (Wiesel) I hold a Master of Science in Civil Engineering from Northeastern University and a Bachelor of Science in Civil Engineering from the University of Massachusetts.

Q.20. Are you a member of any professional organizations?

A. (Wiesel) I am a Registered Professional Engineer in the Commonwealth of Massachusetts and the State of New York.

Q.21. Gentlemen, what is the purpose of your testimony?

A. (Christian, Meligi, Wiesel) The purpose of this testimony is to describe the seismic capabilities of the General Motors EMD diesels currently installed on site. Sargent & Lundy was engaged to study the seismic capability of the machines themselves and their associated mechanical and electrical equipment. LILCO asked Stone & Webster to review several other aspects of seismic capabilities of these machines, including the integrity of the mountings for the diesel generators and its associated switchgear, seismic capability of the fuel line for the diesel generators, and the stability of the soil upon which the diesel generators rest.

II. Sargent & Lundy Study

Q.22. You mentioned earlier that Sargent & Lundy performed a seismic survivability study on the EMD diesels at Shoreham. What do you mean by the term "seismic survivability"?

A. (Meligi) Seismic survivability is defined as the ability of a mechanical or electrical component to undergo a seismic event and remain structurally intact and be capable of performing its intended function subsequent to the event.

Q.23. How does seismic survivability differ from seismic qualification?

A. (Meligi) The seismic qualification of a piece of equipment is an effort which starts at the early stages of the equipment design. This is done by defining the seismic qualification requirements: the level, directions, and the frequency contents of the seismic input. The designer in turn attempts to incorporate these requirements in the design. Later, a qualification program (test, analysis, or combination of both) is conducted to demonstrate that the equipment is capable of performing its intended function. The program is usually rigorous, conservative, detailed, and well documented. Verifying the seismic survivability is usually a backfit effort for an already installed piece of equipment. It utilizes good engineering judgment backed up by sufficient engineering evidence and calculations. The information used in the calculations and the judgment is obtained from the available documents, accessible as-built data from walk-downs, and communications with the manufacturer. The objective of both techniques is to demonstrate and verify the seismic capability of a piece of equipment.

Q.24. Please describe how Sargent & Lundy conducted the study of the seismic survivability of the GM EMD diesels.

A. (Meligi) The seismic survivablity study of the GM EMD diesels was conducted in three phases:

Phase I consisted of a site visit and gathering of essential information to provide the basis of the evaluation and analyses for the study.

Phase II consisted of preparation of the base and elevated response spectra curves, as well as the analyses, review and comparative studies addressing the structural integrity and operability of engine, generator, components and devices. A report was prepared at the end of this phase and is included as Attachment 4 to this testimony.

Phase III consisted of the confirmatory work.

Q.25. Would you please describe the activities conducted during Phase I in more detail?

A. (Meligi) The purpose of Phase I was to gather the information we needed to conduct our study. Among the activities involved were:

1. Obtaining the acceleration time history for the foundation below the engine skid assembly and electrical switchgear assemblies.

2. Obtaining information concerning the EMD diesel generator system, including identifying information for all electrical and mechanical equipment found on the engine assembly.

3. Obtaining mounting details for items known to be different from those with which Sargent & Lundy was already familiar.

4. Investigating and recommending simple modifications for the electrical switchgear panels, cooling piping system, and radiator, as well as diesel generator enclosures which, based on our experience, would simplify and improve the results.

In the course of site visits and discussions with LILCO, we gathered any other pertinent information that would aid in the study.

Q.26 Please describe activities conducted in Phase II.

A. (Meligi) The objective of the activities performed in Phase II was to investigate the structural integrity and operability of (1) the diesel engine, (2) its accessory items, and (3) electrical equipment. These activities included:

1. Collecting additional technical information and data as required, based on the field trip in Phase I.

2. Performing a comparative study of all LILCO's diesel generator components and devices with those stored in the Sargent & Lundy data base. Because Sargent & Lundy has previously qualified diesel generators very similar to the Shoreham engines for nuclear service, we already had available significant information about the seismic capabilities of many of the components of these engines.

3. Determining the bounding acceleration levels for the electrical devices (switchgear) to ensure that the acceleration levels produced by the design basis earthquake at Shoreham are bounded by the data already available to Sargent & Lundy.

4. Reviewing the structural integrity and operability of equipment on the Shoreham engines that Sargent & Lundy had not previously analyzed in its prior work on EMD diesel generators.

5. Reviewing the structural integrity and operability of the generator using analytical techniques.

6. Reviewing the structural integrity of the large metal enclosure around the engine.

7. Reviewing the structural integrity of the common switchgear housing panels.

8. Reviewing the structural integrity of the electric start system.

9. Demonstrating the operability of the engine and associated components.

Q.27. Please explain how you make the comparison mentioned in items 2 and 3 above.

A. (Meligi) LILCO supplied Sargent & Lundy with the ground motion acceleration as a function of time for the safe shutdown earthquake (SSE) that was developed by Stone & Webster for Shoreham. Based on this ground motion acceleration time history data, base response spectra curves were developed. A base response spectrum curve is a plot of the maximum responses of simple equipment over a wide range of frequencies when subjected to the acceleration time history. Different damping values for this simple equipment produce a different response and, consequently, different response spectra curves. These base spectra curves were compared with curves previously developed by Sargent & Lundy which were used to qualify similar engines and components. This comparison revealed that the LILCO curves are bounded by the Sargent & Lundy curves throughout in the frequency range of interest. In other words, the response spectra for the Shoreham plant at the location of the EMD engines is less severe than the response spectra used by Sargent & Lundy to qualify similar diesels. Thus, if the Shoreham engines have components that are similar to components on previously qualified machines, we can conclude that these components would withstand an SSE at Shoreham.

Response spectra for different elevations on electrical panels were also developed for Shoreham because the response at these elevations may be amplified from the response at the base of the equipment. These elevated spectra curves were compared to existing Sargent & Lundy elevated spectra. This comparison demonstrated that the Shoreham elevated spectra are bounded by the Sargent & Lundy curves. Details of these comparisons and the analyses for the extraction of elevated spectra curves are given in Appendices A.1, C.1(a) and C.1(b) of our report (Attachment 4).

Q.28. In describing your Phase II activities, you indicated that you checked the structural integrity of the engine and its components. What do you mean by structural integrity?

A. (Meligi) Structural integrity is the ability of any structure (including equipment and components) to sustain postulated loads without exceeding the allowable stresses set by the applicable codes, standards, and good practices. Our review of the EMD diesels ensured that equipment and components (active and nonactive) that are needed for diesel operation, as well as equipment whose failure could degrade the integrity of these equipment and components, have the appropriate structural integrity.

Q.29. You also indicated that you investigated the op- e ability of equipment. What do you mean by operability?

A. (Meligi) Operability is the ability of a piece of equipment to perform its required function after the time it is subjected to the postulated loads. Only active mechanical equipment and electrical equipment essential to the operation of the diesels are required to have their operability verified.

Active mechanical equipment is equipment that must perform a mechanical motion during the course of accomplishing a system function. Nonactive mechanical equipment (such as piping) must maintain its pressure boundary and/or structural integrity but does not have to perform mechanical motion.

Q.30. You indicated that you analyzed three categories of components: (1) accessory items, (2) the diesel engine and (3) electrical equipment. With respect to accessory items, please describe how you conducted your analysis.

A. (Meligi) Accessory components are those items that are not an integral part of the engine assembly. This includes all of the components that are not directly bolted to the engine. These components were analyzed by performing calculations using an upperbound response spectrum that would cover the spectra for Shoreham. These calculations are found in Appendix B of our report (Attachment 4). These calculations demonstrated that the stresses and deflections are within allowable limits. Therefore, we concluded that the structural integrity and operability of the equipment will be maintained during a seismic event of the magnitude of the SSE.

All accessory items, with some exceptions, were found to be suitable to withstand an SSE level earthquake and remain operable following the event. These conclusions are based on our analysis or evaluation of each accessory item in the system. For the exceptions noted above, Sargent & Lundy has made recommendations for modifications which, if implemented, will result in those components being able to withstand the SSE. Our recommendations are discussed in response to questions 35 through 37 below.

Q.31. With respect to the diesel engine itself, please explain how you performed the seismic analysis.

A. (Meligi) The evaluation of the EMD engines was performed using a combination of analysis and test results. Our evaluation is set out in Appendix D of the attached report (Attachment 4). I will summarize our approach here.

1. <u>Test</u>. The engine block and all of its internal components were qualified in conformance with IEEE-344 (1975), Section 7, paragraph 7.5, "Shock Testing." This standard states that shock testing performed in conformance with various military standards, "for example MIL-S-901C," that can be shown to have sufficiently high

accelerations, "far higher than earthquake levels," and that can be shown to be of sufficient duration can be used for qualification purposes. General Motors EMD diesels of the type in use at Shoreham have been subjected to shock tests by the U.S. Navy. These tests were carried out in conformance with MIL-S-901C. The acceleration levels measured during the test far exceed the zero period acceleration (ZPA) levels that would be experienced at Shoreham during an SSE. Zero period acceleration levels are acceleration levels associated with high frequency response. (The period is the inverse of the frequency; as frequency increases the period approaches zero.) Equipment that has a natural frequency above 33 cycles per second is considered a rigid structure because it does not have an amplified response; it experiences only the ZPA. Since the engine (including the block and all internal components) is a rigid structure, the fact that the shock test levels far exceed the ZPA levels at Shoreham allows us to reach conclusions about the seismic capabilities of the engine. Combining the shock test results with analysis showing the magnitude of inertial loading imposed on the diesels during operation, we concluded that the engine block and internal components would withstand the SSE at Shoreham.

2. Analysis. In order to supplement the shock test data and address any external components attached to the engine which may have predominant frequencies in the flexible range (below 33 Hz), we used an analysis performed by General Motors for EMD diesels. In this analysis, detailed frequency calculations were performed and correlations made between the shock levels and given responses to an input of 3 g in the horizontal and 1 g in the vertical. This was done for each item found to have a fundamental material frequency in the flexible range (below 33 Hz).

It should be noted that in order for the engine and engine components to survive the loads induced by normal operation of the engine, they have been designed to have natural frequencies outside the engine vibration range and well above the seismic frequency range. This means that the engines and components have inherent seismic capabilities.

Q.32. Please summarize the results of your analysis of the seismic capabilities of the diesel engine.

A. (Meligi) The engine assembly and all of its integral components were found to be able to experience an SSE level earthquake and function properly following the event. All of the components that were considered to be part of the engine assembly are listed on pages D.1.34 through D.1.42 in Appendix D of our report.

Q.33. With respect to electrical equipment, please describe how you performed your analysis.

A. (Meligi) A detailed finite element analysis was performed on the worst case electrical panel to prove the structural integrity of the panels. The worst case panel was selected based on the geometric configuration and careful inspection which led us to believe that it will have the weakest dynamic characteristics of all of the engine panels.

To verify the operability of electrical equipment, elevated response spectra were obtained at device locations. These elevated response spectra were shown to be bounded by the similar spectra used by Sargent & Lundy in qualifying other EMD diesels. Sargent & Lundy's data base was reviewed to obtain seismic information for those electrical devices installed on Shoreham that were similar to devices previously analyzed by Sargent & Lundy.

The seismic survivability of the remaining electrical equipment was addressed using confidence levels for the NUREG/CR-2405, "Subsystem Fragility." This study makes use of statistical techniques to obtain confidence levels in the equipment's ability to survive an earthquake on a generic basis. Using the study and applying it to the remaining components on the Shoreham EMDs, we found a 99% confidence level that both structural integrity and operability of the components would be maintained. A list of electrical devices and the method of analysis used can be found on pages C.2.3 through C.2.15 of our report.

In addition to the above evaluations, a detailed check of the mounting bolts on many of the instruments was performed. All of the bolts were found to be acceptable and would remain intact during an SSE event.

Q.34. What were the results of your analysis of electrical equipment?

A. (Meligi) Electrical components and devices on the Shoreham EMD diesels will withstand the SSE.

Q.35. Your report contains a number of recommendations. Please explain those recommendations.

A. (Meligi) The recommendations made by Sargent & Lundy fall into two categories. First, as noted in response to question 30 above, we made recommendations that were necessary to ensure the structural integrity and operability of the EMD diesel generator units. These recommendations are found on pages 5-7 (Recommendations A through F) of our report. Second, we recommended that certain confirmatory calculations be made to give added confidence in the seismic capabilities of certain components that were addressed in the report using engineering judgment or conservative assumptions. These recommendations are found on page 7 (Recommendation G) of our report.

Q.36. Has any action been taken on the first set of recommendations?

A. (Meligi) With respect to the first category of recommendations, Sargent & Lundy has prepared detailed construction and installation drawings for the modifications that were found to be required. The modified components have been analyzed and found to be within accepted allowable limits. LILCO has accepted our recommendations and intends to implement them once LILCO's exemption request has been approved.

Q.37. What is the status of the second category of recommendations?

A. (Meligi) With respect to the second category of components, confirmatory calculations have been performed and the results confirm the conclusions stated in our report. All of the equipment was found to remain structurally intact and operable following an SSE level earthquake.

Q.38. Please summarize your overall conclusions with respect to the seismic survivablity of the four GM EMD diesels installed at Shoreham.

A. (Meligi) Once the recommendations discussed above are implemented, the diesel generators at Shoreham will survive an SSE level earthquake and remain operable following the event. From our past experience with equipment qualifications, diesel generator equipment in particular, the required seismic levels at Shoreham are much less severe than at many other plants. Although the units were not seismically qualified when built, the high vibration environment created by the normal operation of the engines results in inherent seismic capabilities being designed into the units. The EMD units were also structurally designed to be moved from location to location without sustaining any appreciable damage. This means that the units are much stronger than a comparable stationary unit would be. Based on our study of the Shoreham EMD diesel generators, the equipment is adequate to withstand an SSE level earthquake.

III. Stone & Webster Analysis

Q.39. Dr. Christian and Mr. Wiesel, on what basis were the areas of your analysis selected?

A. (Christian and Wiesel) As already described, LILCO engaged Sargent & Lundy to perform an analysis of the seismic capabilities of the diesel generators themselves, including their ability to operate after an earthquake. LILCO asked SWEC to perform an analysis of any aspects of the seismic capabilities of the machines not covered by Sargent & Lundy that might be pertinent to their ability to operate under seismic conditions. We looked at the mounting of the EMD diesels and associated switchgear, the fuel line connection, and the soils beneath the diesels.

Q.40. How are the EMD diesels mounted?

A. (Christian and Wiesel) Each of the EMD diesels is mounted on a steel frame or skid. This skid provides support for the diesel engine, the generator, and all associated equipment. The skid in turn rests on wooden timbers (similar to railroad ties) that are sunk into a bed of crushed stone which is approximately 24 inches deep.

Q.41. How did you perform the analysis of the mounting of the diesel generators?

A. (Wiesel) A static analysis of the support of the EMD diesels was performed. The analysis consisted of two parts: a sliding analysis and overturning analysis.

The sliding analysis was performed to determine whether the steel skid supporting the diesels would slide on the timbers upon which it rests in the event of an earthquake. This analysis was done by comparing the earthquake-induced forces that would cause the unit to slide to the support systems' capability to resist those sliding forces. The forces that would cause sliding were determined by multiplying the appropriate accelerations caused by an earthquake by the various weights included in the system. Since the Shoreham plant uses a design basis earthquake (Safe Shutdown Earthquake or SSE) with a 0.2 g horizontal acceleration, the weight of the diesel was multiplied by the ground acceleration of 0.2 g. For example, the weight of the enclosure structure was multiplied by 0.35 g to reflect the amplification of the ground acceleration through the enclosure structure. This amplified acceleration was obtained from the Sargent & Lundy analysis.

The system's capability to resist sliding was determined by multiplying the coefficient of friction for steel on timber by the normal force applied to the support. To provide a conservative analysis, the normal force was reduced by an amount equal to the component weight multiplied by the vertical acceleration. The ratio of the resisting force to the sliding force results in the factor of safety against sliding. Our analysis determined that the resisting force exceeds the sliding force with an adequate safety factor to ensure that sliding of the EMD diesels would not occur during an SSE.

In a similar analysis, the factor of safety against overturning was determined. The inertia forces, which were determined as outlined above, were applied through the component center of gravity to determine the system overturning moment. The resisting moment was calculated by multiplying the system weight by the distance from the center of gravity to the assumed point of overturning. The ratio of the resisting moment to the overturning moment provides the factor of safety against overturning. Again, to be conservative, the component weight was reduced by an amount equal to the weight multiplied by the vertical acceleration. Our analysis concluded that the EMD diesels would not overturn in the event of an SSE.

Q.42. How did you perform your analysis of the capabilities of the switchgear mounting?

A. (Wiesel) The analysis of the diesel switchgear mounting was the same type of analysis as performed on the EMD diesels. It included an assessment of the potential for the sliding and overturning of the switchgear. The analysis indicates that adequate factor of safety exists to prevent sliding or overturning for a minimum ground input of 0.13 g.

Q.43. How did you perform your analysis of the capabilities of the diesel fuel oil line?

A. (Wiesel) A Stone & Webster engineer experienced in the analysis and design of piping systems performed a field walkdown of the fuel oil line installation. The scope of the field walkdown was to evaluate the piping arrangement and support system. This initial evaluation of the piping system's ability to withstand earthquake effects was based on the engineer's judgment and experience in dealing with the analysis and support of piping systems. As a result of this evaluation, a recommendation was made to bury the piping system to improve its ability to withstand a seismic event.

Q.44. Has LILCO implemented this recommendation?

A. (Wiesel) LILCO has decided to accept SWEC's recommendation and will bury the fuel line. Stone & Webster will review this modification including the connection to the diesel to ensure that the installation has the appropriate seismic capability. This modification will be made once LILCO's exemption request is approved.

Q.45. You also mentioned that Stone & Webster performed an assessment of the stability of the soil upon which the EMD diesel generators rest. What steps did this involve?

A. (Christian) In the soils area, we looked at two issues. First, we analyzed the potential for the sliding of the diesel generators on the ground under seismic conditions. Second, we assessed the potential for soil liquefaction.

Q.46. How did you perform your assessment of the potential for the sliding of the diesel generators?

A. (Christian) We considered two possible modes of sliding: one with the failure surface at the contact between the wooden beams and the gravel, and the other with the failure surface passing below this through the gravel and soil. The coefficient of friction was taken as 0.5 for the first case, and friction angles of 35 degrees and 40 degrees were used for the soil and gravel, respectively. Psuedo-static analyses were done using the horizontal and vertical seismic coefficients computed from the analysis of the diesel generators and their associated switchgear discussed by Mr. Wiesel.

These analyses demonstrated an adequate factor of safety against sliding in all cases in the event of an SSE.

Q.47. How did you assess the potential for soil liquefaction under the diesel generators during a seismic event?

A. (Christian) This analysis used soil information obtained from borings made in the vicinity of the EMD diesel generators. Seed's procedure, which is the commonly accepted method of analyzing soil data for liquefaction potential, was used. This starts from the results of the Standard Penetration Tests (SPT) that were performed in each boring. In the Standard Penetration Test, a standard sampling tube (called a "split spoon") is attached to the bottom of the drill rod and the assembly of drill rod and sampler is driven into the soil at the bottom of the boring by repeatedly dropping a 140 pound weight through 30 inches to impact on the top of the drill rod. The number of blows required to drive the sampler one foot into the soil is called the SPT value or the blow count. After the test has been done at one depth in the boring, the boring is advanced to a new depth, and a new SPT is done on the soil at that depth.

In Seed's method the blow counts are modified to account for the depth of the test and location of the water table. The prescribed peak accleration, magnitude of the earthquake, and depth of the sample are then used to find the shear stresses that the earthquake will induce in the soil.

Based on observed behavior in previous earthquakes in various parts of the world, Seed has developed criteria whereby the combination of the modified blow count and induced earthquake loading can be used to determine whether liquefaction is likely.

In the present case the Seed analysis was done for each SPT in each of the four borings near the EMD diesels.

As a check on the Seed analysis, an independent analysis, based on Dobry's method, was done. In this approach, the shear strains caused by the earthquake are compared to limits derived from empirical observation of past earthquakes. The method does not have as large an empirical data base and is not as widely accepted as Seed's.

Q.48. What are the results of your soil liquifaction analysis?

A. (Christian) The soil has a substantial ability to resist liquefaction. The weakest region is a zone extending from the groundwater table at a depth of about 10 feet to a depth of 15 to 20 feet. The calculations indicate that these soils can withstand up to 0.13 g without liquefaction. The check calculation using the threshold strain approach (Dobry's method) indicated the soils at a depth between 10 feet and 26 feet could resist between 0.10 g and 0.16 g. These results indicate that we can predict that liquefaction will not occur in earthquakes up to 0.13 g. This does not mean that above 0.13 g liquefaction will occur; it only means that we cannot predict with confidence that it will not occur. This level of seismic capability is significant because it exceeds the Operating Basis Earthquake for Shoreham, which is 0.1 g.

Q.49. Is it significant that you cannot predict that soil liquefaction or sliding of the switchgear will not occur above 0.13 g?

A. (Christian) No. Let me explain my answer by putting the risk of exceeding a 0.13 g earthquake in perspective.

It is our understanding that the EMD diesels will be relied upon for a relatively short period of time. Therefore, it is appropriate to evaluate the hazard that an earthquake with ground acceleration exceeding 0.13 g will be felt at the site during that short period of time. For analysis purposes, we have conservatively assumed that time to be one year. Based on existing estimates of annual return periods for earthquakes of different sizes for the Shoreham area, we can find the annual probability of occurrence of an event with a peak horizontal acceleration of 0.2 g or greater. This probability is then used to find the probability of observing such an event during the 40 year life of the plant. From the same estimate of annual return period we can find the annual probability of observing an event with acceleration of 0.13 g or greater. This turns out to be less than one-tenth of the probability of a 0.2 g earthquake occurring in 40 years.

As noted in FSAR § 2.5.2.5.7, Shoreham is in an area of low seismicity. The seismic hazard posed by operating the plant during low power testing as proposed by LILCO is an order of magnitude lower than this already low hazard.

It should be noted that the absolute values of the probabilities for earthquakes of various sizes can be affected by different assumptions made in performing the original calculations of seismic hazard, but the <u>relative</u> probability between the 0.2 g event over 40 years and the 0.13 g event over one year is affected very little by these factors. In other words, the statement that the probability of a 0.13 g event in one year is less than one-tenth the probability of a 0.2 g event in 40 years is valid even if different assumptions and calculations are made in estimating the annual probabilites themselves.

Q.50. Gentlemen, could you please summarize your testimony concerning the GM EMD diesels?

A. (Christian and Wiesel) The diesel generator installation has a resistance to sliding and overturning well in excess of that needed to resist the Safe Shutdown Earthquake. The switchgear installation has a resistance to sliding and overturning in excess of that needed to resist earthquakes at least 0.13 g. The soils in the vicinity of the temporary diesel generators and switchgear will resist liquefaction for earthquakes up to 0.13 g.

The probability of an earthquake of 0.13 g or more occurring at the Shoreham site during the time the EMD diesels will be relied upon is less than one-tenth the probability of the Safe Shutdown Earthquake occurring during the 40 year life of the plant.

We conclude that there is adequate seismic resistance of the foundations and underlying soils for the EMD diesel generator installation. Once Stone & Webster's recommendation for the fuel line is implemented, it will also have adequate seismic resistance.

February 1984

CHRISTIAN, JOHN T.

SENIOR CONSULTING ENGINEER
CONSULTING GROUP

EDUCATION

Massachusetts Institute of Technology - Bachelor of Science in Civil Engineering 1958
Massachusetts Institute of Technology - Master of Science in Civil Engineering 1959
Massachusetts Institute of Technology - Doctor of Philosophy in Civil Engineering 1966

LICENSES AND REGISTRATIONS

Professional Engineer - Massachusetts, Maine

EXPERIENCE SUMMARY

Dr. Christian has had extensive experience in foundation engineering, earth dam analysis and design, engineering mechanics, and earthquake engineering and is one of the leading authorities in the use of computer methods in geotechnical engineering. His activities in geotechnical engineering have ranged from the preliminary design stage to the construction stage. He has done geotechnical and seismological work on nuclear power plants in a variety of locations, including probabilistic assessments of seismic hazard. In addition to nuclear power plants, Dr. Christian has worked on offshore caissons, offshore mooring facilities, earth dams for storage of fuel oil and water, offshore piplines, underground rock openings, slope stability studies, highway embankments, oil field subsidence, and foundation investigations for conventional buildings. He has done seismological evaluations and analytical studies of earthquake effects including soil amplification, liquefaction, and soil structure interaction. He has conducted earthquake studies of earth and rock fill dams. He has developed finite element programs for a variety of applications. He has conducted studies of flow of water through dams and other geological structures. He has also had experience in the interpretation of field data from soil instrumentation. He is the co-editor of a book on Numerical Methods in Geotechnical Engineering. He has developed standards for documenting computer programs and has implemented procedures for controlling the quality and accuracy of computerized calculations at Stone & Webster. He is a member of the Corporate Computer and Software Oversight Committee and Chairman of the Computer Disaster Recovery Committee.

Dr. Christian has taught and done research in geotechnical engineering at the graduate level. He developed several computer programs and has published numerous papers and reports based on his research and practical experience. He has been a Visiting Lecturer at the Massachusetts Institute of Technology.

Prior to joining Stone & Webster Engineering Corporation, Dr. Christian was Associate Professor of Civil Engineering at the Massachusetts Institute of Technology and a private consultant. He has worked in the U.S.A., Brazil, Malaysia, Canada, The Netherlands, Finland, and Venezuela and has been involved in projects in Italy, Libya, and Turkey.

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers - Fellow

Executive Committee, Geotechnical Engineering Division - Secretary

National Convention, Boston, 1979 - Technical Program Committee and Session Allocation Board - Chairman

Committee on Coordination within ASCE, Technical Council on Computer Practices - Member

Committee on Computer Applications and Numerical Methods, Geotechnical Engineering Division - Member and Past Chairman

Awards Committee, Geotechnical Engineering Division - Member

Committee on Definitions and Standards, Geotechnical Engineering Division - Member

Session Programs Committee, Geotechnical Engineering Division - Past Chairman

Publications Committee, Geotechnical Engineering Division - Past Member

Committee on Reliability and Probabilistic Concepts, Geotechnical Engineering Division - Past Member

Committee on Soil Dynamics, Geotechnical Engineering Division - Past Member

Past Geotechnical Engineering Division Correspondent - ASCE News

Boston Society of Civil Engineers Section/American Society of Civil Engineers - Past Chairman Computer Group and currently Member of Computer Group Executive Committee

Boston Society of Civil Engineers Section/American Society of Civil Engineers - Seismic Design Advisory Committee - Member

International Society of Soil Mechanics and Foundation Engineering - Member

U.S. Committee on Large Dams of International Commission on Large Dams - Member

Committee on Methods of Numerical Analysis of Dams - Member

American Association for the Advancement of Science - Member

Seismological Society of America - Member

Universities Council on Earthquake Engineering Research - Member

Earthquake Engineering Research Institute - Member

Committee on Research - Past Member

Joint Committee on Tall Buildings - IABSE/ASCE - Past Editor for Committee 11 - Foundations

Transportation Research Board - Committee A2K05 - Mechanics of Earth Masses and Layered Systems - Past Member

International Committee on Numerical Methods in Geomechanics - Member

International Journal for Numerical and Analytical Methods in Geomechanics - Member of Advisory Board

Accreditation Board for Engineering and Technology - ASCE Member of Engineering Accreditation Visiting Committee

Association for Computing Machinery - Member

British Geotechnical Society - Member

Institute of Electrical and Electronic Engineers - Computer Society - Member

Advisory Committee for the Department of Civil Engineering, University of New Hampshire - Chairman

HONORS AND AWARDS

Chi Epsilon, National Civil Engineering Honor Society - M.I.T. - 1955

Tau Beta Pi National Engineering Honor Society - M.I.T. - 1956

Sigma Xi National Scientific Research Honor Society - M.I.T. - 1966

U.S. Air Force Commendation Medal - 1963

Desmond Fitzgerald Medal - Boston Society of Civil Engineers Section, American Society of Civil Engineers - 1973

Outstanding Correspondent Award - ASCE News - 1978

BOOK

Numerical Methods in Geotechnical Engineering, co-editor with C. S. Desai, McGraw-Hill, New York, 1977.

PUBLICATIONS

"Thixotropic Characteristics of a Laurentian Clay," S.M. Thesis, M.I.T. - 1959.

"Plane - Strain Deformation Analysis of Soil," Ph.D. Thesis, M.I.T. - 1966 (also M.I.T. Department of Civil Engineering Report R66-33).

"Two Dimensional Analysis of Stress and Strain in Soils," Report No. 1, "Iteration Procedure for Saturated Elastic Porous Material," M.I.T. Department of Civil Engineering Report R65-46, June 1965.

"Analysis of Stress Distribution beneath Embankments," M.I.T. Department of Civil Engineering Report R66-53, September 1966. (Co-authors T.W. Lambe and R.C. Hirschfeld).

"Numerical Methods of Calculating Time - Dependent Settlement and Heave of Embankments," M.I.T. Department of Civil Engineering Report to U.S. Department of Transportation, September, 1967.

"Settlement of Strip Load on Elastic-Plastic Soil," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 94, No. SM2, March, 1968, pp. 431-445. (Co-authors K. Hoeg and R.V. Whitman).

"Undrained Stress Distribution by Numerical Methods," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 94, No. SM6, November, 1968, pp. 13331345.

"The Selection of Foundation Soil Properties for Levee Design," M.I.T. Department of Civil Engineering Report R69-17, December, 1968. (Co-authors include B. J. Watt, T. W. Lambe, C. C. Ladd, and others).

"Prediction of the Deformation of a Levee on a Soft Foundation," M.I.T. Department of Civil Engineering Report R69-18, December, 1968, (Co-authors include B. J. Watt, T. W. Lambe, and others).

"Extended LEASE - I, an ICES Subsystem," M.I.T. Department of Civil Engineering Report R69-21, April, 1969. (Co-author Cecila C. Hsiung).

"A Model for Progressive Failure in One Dimension," M.I.T. Department of Civil Engineering Report, December 1969. (Co-author R. V. Whitman).

Discussion of "Applications of Limit Plasticity in Soil Mechanics," by W. D. Liam Finn, Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 94, No. SM3, May 1968, pp. 796-798.

"Plane Strain Consolidation by Finite Elements," M.I.T. Department of Civil Engineering Report R69-60, August 1969. (Co-author Jan Willem Boehmer).

"A One-Dimensional Model for Progressive Failure," Proceedings, Seventh International Conference on Soil Mechanics and Foundation Engineering, August 1969, Mexico City, Vol. II, pp. 541-545. (Co-author R.V. Whitman).

"ICES LEASE - I, A Problem Oriented Language for Slope Stability Analysis, User's Manual," M.I.T. Department of Civil Engineering Report R69-22, April 1969. (Co-author W.A. Bailey).

"Highway Engineering Computer Systems Application," M.I.T. Department of Civil Engineering Report R69-63, September 1969. (Co-authors J. H. Suhrbier, E. E. Newman, and R. W. Wells).

"Stress - Strain Models for Frictional Materials," M.I.T. Department of Civil Engineering Report R70-18, April 1970. (Co-authors A. J. Hagmann and D. J. D'Appolonia).

"Plane Strain Consolidation by Finite Elements," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 96, No. SM4, July 1970, pp. 1435-1457. (Co-author Jan Willem Boehmer).

"The Effects of Soil Parameters and Boundary Conditions on the Consolidation of an Elastic Layer," M.I.T. Department of Civil Engineering Report to Office of High Speed Ground Transportation, U.S. D.O.T., No. FRA-RT 71-77, August 1970. (Co-author Jan Willem Boehmer).

"The Initiation of Failure in Slopes in Overconsolidated Clays and Clay Shales," M.I.T. Department of Civil Engineering Report to U.S. Army Engineer Nuclear Cratering Group, NCG Technical Report No. 29, November 1970. (Co-authors I.V. Constantopoulos and R.V. Whitman).

"NETFLO Documentation," M.I.T. Department of Civil Engineering Report R7117, April 1971.

"Bearing Capacity of Anisotropic Cohesive Soil," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 97, No. SM5, May 1971, pp. 753-769. (Co-author E.H. Davis).

"Parametric Analyses of Soil-Structure Interaction for a Reactor Building," First International Symposium on Structural Mechanics in Reactor Technology, Berlin, September 1971. (Co-authors R. V. Whitman and J. M. Biggs).

"Bearing Capacity and Stability Analysis," M.I.T. Department of Civil Engineering Report R71-24, September 1971.

"Finite Element Deformation Analyses," M.I.T. Department of Civil Engineering Report R71-25, September 1971.

"Consolidation," M.I.T. Department of Civil Engineering Report R71-32, September 1971.

"Finite Element Analyses of Large Strains in Soil," M.I.T. Department of Civil Engineering Report R71-37, September 1971. (Co-author Rodrigo Molina Fernandez).

"Consolidation at Constant Rate of Strain," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 97, No. SM10, October 1971, pp. 1393-1413. (Co-authors A. E. Z. Wissa, E. H. Davis, and S. Heiberg).

"The Use of Computers in Education and Research," Panel - The Computer Revolution in Soil Engineering, ASCE Annual and National Environmental Engineering Meeting, St. Louis, Missouri, October 1971.

"Stress Conditions in NGI Simple Shear Test," Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 98, No. 1, January 1972, pp. 155-160. (Co-authors A. S. Lucks, K. Hoeg, and G. Brandow).

"Finite Element Program FEECON for Undrained Analysis of Granular Embankments on Soft Clay Foundations," M.I.T. Department of Civil Engineering Report R72-9, January 1972. (Co-authors R. M. Simon and C. C. Ladd).

"Settlement Prediction for Foundations Resting on a Nonhomogeneous Elastic Half-Space," presented at Spring Meeting, Texas Section, ASCE, Fort Worth, Texas, April 1972. (Co-author W. D. Carrier III).

"Undrained Visco-Elastic Analysis of Soil Deformations," Proceedings, Symposium on Applications of the Finite Element Method to Problems in Geotechnical Engineering, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi, May 1972, pp. 533-579. (Co-author B. J. Watt).

"Finite Element Analysis of Elasto-Plastic Soils," M.I.T. Department of Civil Engineering Report R7221, June 1972. (Co-author W. A. Marr, Jr.).

"The Consolidation of a Layer Under a Strip Load," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol., 96, No. SM7, July 1972, pp. 693707. (Co-authors Jan Willem Boehmer and Philippe P. Martin).

"Soil-Foundation Interaction for Tall Buildings," State-of-the-Art Report, Technical Committee 11, ASCE-IABSE International Conference on Tall Buildings, August 1972, Preprints: Report Vol. Ia-11, pp. 121-137.

"Tolerance of Buildings to Differential Settlements," M.I.T. Department of Civil Engineering Report R72-79, December 1972, (Co-authors Rebecca Grant and Erick H. Vanmarcke).

"Relative Motion of Two Surface Points during an Earthquake," M.I.T. Department of Civil Engineering Report R73-83, January 1973.

"Analysis of an Inhomogeneous Elastic Halfspace," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 99, No. SM3, March 1973, pp. 301-306. (Co-author W. D. Carrier III).

"Rigid Circular Plate Resting on a Nonhomogeneous Elastic Halfspace," Geo technque, Vol. 23, No. 1, March 1973, pp. 67-84. (Co-author W. D. Carrier III).

"Errors in Simulating Excavation in Elastic Media by Finite Elements," Soils and Foundations. Vol.13, No. 1, March 1973, pp. 110. (Co-author I. H. Wong)

"Engineering Computer Documentation Standards," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 99, No. SM3, March 1973, pp. 249-266. (Co-Authors Committee on Computer Applications).

"A Comparison of Linear and Exact Nonlinear Analysis of Soil Amplification," Fifth World Conference on Earthquake Engineering, Rome, June 1973, Paper 225. (Co-authors I. V. Constantopoulos and J. M. Roesset).

"Recent Technical Developments in Shallow Foundations," Lecture Series on "Shallow Foundations," Soil Mechanics and Foundations Group of the Philadelphia Section of the American Society of Civil Engineers, 1973.

"Undrained Creep of Atchafalaya Levee Foundation Clays," M.I.T. Department of Civil Engineering Report R73-16, 1973 (Co-Authors L.Edgers and C.C. Ladd).

"Large Diameter Underwater Pipeline for Nuclear Power Plant Designed against Soil Liquefaction," Paper 2094, Offshore Technology Conference, May 1974. (Co-authors P. K. Taylor, John K. C. Yen, and D. R. Erali).

"Slope Stability Analysis by Computer," lecture presented to Metropolitan Section American Society of Civil Engineers, April 1974.

"Analysis of Undrained Behavior of Loads on Clay," Analysis and Design in Geotechnical Engineering, Specialty Conference, Geotechnical Engineering Division, ASCE, Austin, Texas, June 1974, Vol. I, pp. 51-84. (Co-authors R. N. Simon and C. C. Ladd).

"Shear Wave Velocity and Modulus of a Marine Clay," Journal of the Boston Society of Civil Engineers, Vol. 61, No. 1, January 1974, pp. 12-25. (Co-authors P. J. Trudeau and R. V. Whitman).

"Differential Settlement of Buildings," Journal of the Geotechnical Engineering Division, ASCE, Vol. 100, No. 679, September 1974, pp. 973-991. (Co-authors Rebecca Grant and Erik H. Vanmarcke).

Technical Comment on "Settlement of Venice," Science, Vol. 185, No. 4157, September 27, 1974, pp. 1185. (Co-author R. C. Hirschfeld).

"Use of Incremental Plasticity Relations in Finite Element Analysis of Deformation of Frictional Soils," presented at Annual Meeting of the Society for Engineering Science, Duke University, November 1974.

"Geotechnical Considerations for Siting Nuclear Power Plants," Fifth Symposium on Earthquake Engineering, Roorkee, India, November 1974, Session A. (Co-author V. R. Nivargikar).

"Evaluation of Structure Response Supported on Deep Soil Deposits," Fifth Symposium on Earthquake Engineering, Roorkee, India, November 1974, Session C. (Co-author V. R. Nivargikar).

"Seismic Design Considerations," presented to ASME, Joint Philadelphia and Delaware Sections, Nuclear Engineering Division, 1974, ASME B&PV Code, Section III Course, December 1974 and December 1975.

"A Standard for Computer Program Distribution," Journal of the Geotechnical Engineering Division, ASCE, Vol. 102, No. GT10, October 1975, pp. 1049-1057. (Co-authors Committee on Computer Applications).

"Choice among Procedures for Dynamic Finite Element Analysis," ASCE National Convention, Denver, Colorado, November 1975.

"Shear Strength of Soils and Cyclic Loading," ASCE National Convention, Denver, Colorado, November 1975, also Journal of the Geotechnical Engineering Division, ASCE, Vol. 102, No. GT9, September 1976, pp. 887-894. (Co-author Gonzalo Castro).

"Statistics of Liquefaction and SPT Results," Journal of the Geotechnical Engineering Division, ASCE, Vol. 101, No. GT11, November 1975, pp. 1135-1150. (Co-author W. F. Swiger).

"Uncertainties in Soil Structure Interaction," Second ASCE Specialty Conference on Structural Design of Nuclear Power Plant Facilities, New Orleans, Louisiana, December 1975, pp. II-105 - II-124.

"Seismological Considerations," Course on Soil Dynamics for Earthquake Design, International Centre for Computer Aided Design, Lecture Series N. 2/76, Santa Margherita, Italy, January 1976.

"Stress-Strain Properties," Course on Soil Dynamics for Earthquake Design, International Centre for Computer Aided Design, Lecture Series N. 2/76, Santa Margherita, Italy, January 1976.

"Liquefaction," Course on Soil Dynamics for Earthquake Design, International Centre for Computer Aided Design, Lecture Series N. 2/76, Santa Margherita, Italy, January 1976.

"Analysis of Offshore Concrete Caisson Dikes Under Cyclic Loading," Second International Conference on Numerical Methods in Geomechanics, Blacksburg, Virginia, June 1976, Vol. II, pp. 979-990. (Co-author J. M. E. Audibert).

"Computerized Analysis of Rock Slope Stability," Proceedings, Specialty Conference on Rock Engineering for Foundations and Slopes, ASCE, Boulder, Colorado, August 1976, Vol. I, pp. 415-438. (Co-authors D. S. Campbell and H. H. Einstein).

"Consolidation with Internal Pressure Generation," Journal of the Geotechnical Engineering Division, ASCE, Vol. 102, No. GT10, October 1976, pp. 1111-1115.

"Non-Linear Behavior in Soil-Structure Interaction," Journal of the Geotechnical Engineering Division, ASCE, Vol. 102, No. GT11, November 1976, pp. 1159-1170. (Co-authors E. Kausel and J. M. Roesset).

"Relative Motion of Two Points during an Earthquake," Journal of the Geotechnical Engineering Division, ASCE, Vol. 102, No. GT11, November 1976, pp. 1191-1194.

"Soil-Foundation-Structure Interaction," No. 6 in Analysis and Design of Building Foundations, H. Y. Fang, ed., Envo Publishing Co., Lehigh Valley, Pa., 1976, pp. 149-179.

"Consolidation with Triangular Pressure Distribution," Journal of the Geotechnical Engineering Division, ASCE, Vol. 103, No. GT2, February 1977, pp. 133-136.

"Resonant Period Effects in the Gediz, Turkey, Earthquake of 1970," Earthquake Engineering and Structural Dynamics, Vol. 4, No. 2, April-June 1977, pp. 157-179. (Co-authors S. S. Tezcan, H. B. Seed, R. V. Whitman, N. Serff, M. T. Durgunoglu, and M. Yegian).

"An Improved Algorithm for Nonlinear Soil Amplification," Proceedings, Fourth International Conference on Stuctural Mechanics in Reactor Technology, San Francisco, August 1977, paper K1/14 (Co-authors E. Jausel and F. J. LaPlante).

"Incremental Plasticity Analysis of Frictional Soils," International Journal for Numerical and Analytical Methods in Geomechanics, Vol. 1, No. 4, October -December, 1977, pp. 343-375. (Co-authors A. J. Hagmann and W. A. Marr, Jr.).

"Probabilistic Evaluation of OBE for Nuclear Plant," session on "The Use of Probabilities in Earthquake Engineering," ASCE Fall Convention and Exhibit, San Francisco, California, October 1977, pp. 37-60. (Co-authors R. W. Borjeson and P. T. Tringale) - also Journal of the Geotechnical Engineering Division, ASCE, Vol. 104, No. GT7, July 1978 pp. 907-919.

"Janbu, Bjerrum, and Kjaernsli's Chart Reinterpreted," Canadian Geotechnical Journal, Vol. 15, No. 1, February 1978, pp. 123-128. (Co-author W. D. Carrier III).

"Dynamic Behavior of Soil-Structure Systems," lecture 2 in BSCES/ASCE Geotechnical Lecture Series on "Design of Foundations for Dynamic and Repeated Loads," March 1978.

"Professional Viewpoint on Documentation Standards," Conference on Computing in Civil Engineering, Atlanta, Georgia, June 1978.

"Seismically Induced Sliding of Massive Structures," ASCE National Convention and Exhibit, Conference on Civil Engineering and Nuclear Power, Boston, Massachusetts, April 1979, also Journal of the Geotechnical Engineering Division, ASCE, Vol. 105, No. GT12, December 1979, pp. 1471-1488. (Co-authors E. A. Kausel, A. S. Lucks, L. Edgers, W. F. Swiger).

"Probabilistic Soil Dynamics: State-of-the Art," ASCE National Convention and Exposition, Boston, Massachusetts, April 1979, Session on Reliability and Geotechnical Engineering, pp. 136-161, also Journal of the Geotechnical Engineering Division, ASCE, Vol. 106, No. GT4, April 1980, pp. 385-397.

"Soil Mechanics of Offshore Permanent Displacements," presented at ASCE National Convention and Exposition, Boston, Massachusetts, April 1979. (Co-authors W. A. Marr, Jr., J. Hedberg, J. W. Boehmer).

"Permanent Displacement Analysis for Oosterschelde," presented at ASCE National Convention and Exposition, Boston, Massachusetts, April 1979. (Co-authors W. A. Marr, Jr., T. Y. Chang, J. W. Boehmer).

Foundation Design, (editor and partial author) Chapter SC-7, Planning and Design of Tall Buildings, Council on Tall Buildings and Urban Habitat, Volume SC, "Tall Building Systems and Concepts," 1980, pp. 257-340.

"Flow Nets from Finite Element Data," International Journal for Numerical and Analytical Methods in Geomechanics, Vol. 4, No. 2, April-June 1980, pp. 191-196.

"Flow Nets by the Finite Element Method," Ground Water, Vol. 18, No. 2, March - April 1980, pp. 178-181.

"User Needs: A View from Industry," Workshop on Limit Equilibrium, Plasticity and Generalized Stress - Strain in Geotechnical Engineering, Montreal, Quebec, May 1980, published by ASCE, pp. 61-67.

"Report on Working Group One," Workshop on Limit Equilibrium, Plasticity and Generalized Stress - Strain in Geotechnical Engineering, Montreal, Quebec, May 1980, published by ASCE, pp.93-101.

"A Summary of Generalized Stress - Strain Applications," presented at ASCE National Convention, Hollywood-by-the-Sea, Florida, October 1980, to be published by ASCE in 1982.

Discussion of "State of the Art: Laboratory Strength Testing of Soils," by A.S. Saada and F. C. Townsend, Symposium on Laboratory Shear Strength of Soil, Chicago, Illinois, June 1980, published as ASTM STP740, R. N. Yong and F. C. Townsend, editors, 1981, pp. 638-640.

"Comparison of Japanese Design Earthquake Response Spectra with those Prescribed by U.S. NRC Regulatory Guide 1.60," Nuclear Engineering and Design, Vol. 61, 1980, pp. 369-382.

"The Use of Computers in Practice," Proceedings, 22nd U.S. Symposium on Rock Mechanics, Cambridge, Ma., June 1981, pp. 493-500.

"Permanent Displacements Due to Cyclic Wave Loading," Journal of the Geotechnical Engineering Division, ASCE, Vol. 107, No. GT8, August 1981, pp. 1129-1149. (Co-author W. A. Marr, Jr.).

"Instrumentation Corrections to Wave Velocity Data," Journal of the Geotechnical Engineering Division, ASCE, Vol. 107, No. GT10, October 1981, pp. 1419-1423. (Co-authors J. R. Hall, Jr., E. A. Kausel, and J. C. Wolfgang).

"The Application of Generalized Stress-Strain Relations," Application of Generalized Stress-Strain in Geotechnical Engineering, ASCE symposium, October, 1980, pp. 182-204.

"Seismic Hazard in Northeastern United States," International Conference on Soil Dynamics and Earthquake Engineering," Southhampton, England, July, 1982. Revised version published in Soil Dynamics and Earthquake Engineering, Vol. 3, No. 1, 1984, pp. 8-18. (Co-Authors H. K. Acharga and A. S. Lucks).

"Finite Element Analysis of Permanent Settlements Due to Storm Loadings on Offshore Structures," Proceedings, International Conference on Finite Element Methods, Shanghai, China, 1982, Volume II, pp. 16-22 (Co-Author T. Y. H. Chang).

"Soil-Structure Interaction Problems," Proceedings, Fourth International Conference on Numerical Methods in Geomechanics, Edmonton, Alberta, 1982, Volume III. (Co-Author J. R. Hall, Jr.)

"Geotechnical Use of Finite Element Analysis", presented at ASCE Convention, Houston, Texas, October 1983.

LANGUAGES

Portugese
Some Spanish, French, and German

DETAILED EXPERIENCE RECORD
CHRISTIAN, JOHN T. 13488

STONE & WEBSTER ENGINEERING CORPORATION, BOSTON, MA (June 1973 to Present)

Appointments:

Senior Consulting Engineer - Oct 1980
Consulting Engineer - Nov 1976
Consultant, Geotechnical Division - June 1973

Engineering Department Staff (Nov 1976 to Present)

Directly responsible to Chairman of the Board for developing and carrying out program to qualify and document engineering software. Responsible for budget review and control of computer related development, maintenance, and documentation in Engineering Department. Member of group reviewing, sponsoring, and recommending developments in interactive computer graphics.

Member of Corporate Computer Software and Hardware Oversight Committee responsible for reviewing all hardware and software development and purchases. Chairman, Computer Disaster Recovery Committee, responsible for developing policies for recovery from computer disasters.

Deputy Manager, Strategic Business Plan for Offshore development.

Teollisunden Voima Oy (Industrial Power Co.) - Finland (Oct-Dec 1983)

Analysis of probabilistic seismic hazard at Alkiluoto, Finland, for existing nuclear power plant and proposed additions.

Puget Sound Power and Light Company (Nov 1982 to Present)

Upper Baker and Lower Baker Dams

Geotechnical consultant on seismic reanalysis of two concrete dams and rock fill West Pass Dike. Responsible for geotechnical and analytical work on West Pass Dike.

Trengganu Gas Processing Plant, Petronas, Malaysian National Oil Company (March 1982 to Present)

Geotechnical review and study of alternative schemes for marine structures to export liquid petroleum gas. Participate in review of computer systems and pipeline specifications.

Surry Power Station - Units 1 and 2, Virginia Electric and Power Company (March 1979-Dec 1979)

Seismic risk studies and dynamic soil structure interaction studies for reevaluation of pipe stresses due to earthquakes. Justification of analytical methodology to U.S. NRC.

Beaver Valley Power Station - Unit 1, Duquesne Light Company (March 1979-Dec 1979)

Seismic risk studies and dynamic soil structure interaction studies for reevaluation of pipe stresses due to earthquakes. Justification of analytical methodology to U.S. NRC.

Commonwealth of Massachusetts - Metropolitan District Commission/Hansen, Holley, & Biggs (1980)

Study of possible damage to adjacent structures during construction of sewer and pumping stations.

Dravo - Van Houten Consulting Engineers, Bintulu Port Development (1981-1982)

Evaluation of soil densification designs and proposals and consulting advice on densification. Consulting on remedial action to remedy soft foundation conditions under break water.

Lawrence Livermore Laboratory (Jan 1979-Dec 1979)

Study of methods of soil-structure interaction analysis.

Nine Mile Point Nuclear Power Station - Unit 2, Niagara Mohawk Power Corporation (1975 to Present)

Evaluation and review of rock squeeze hazard, field geophysical measurements, and other geological problems.

Power Authority of the State of New York, Greene County

Review of soil structure interaction.

Wisconsin Electric Power Company, Koshkonong, Wood County, and Haven Sites

Seismicity analysis and seismic risk analysis in addition to review of geotechnical work.

San Diego Gas & Electric Company, Sundesert Nuclear Plant

Review of geotechnical work and engineering mechanics analyses.

Atomic Energy Organization of Iran, Rud-e Karun Site Study

Geotechnical and seismological studies.

Yankee Atomic Power Company, Charlestown Nuclear Power Plant

Review and consulting on liquefaction analysis and seismicity studies.

Stone & Webster Standard Nuclear Power Plant Project

Lead Geotechnical Engineer; developed geotechnical design consideration and parameters.

Rijkswaterstaat Deltadienst, The Hague, Netherlands

Consultation, analytical studies, evaluation of design, and selection of soil properties for large caisson in North Sea. Consultant on evaluation of test section and final design. Member of Consultants Group.

North Anna Nuclear Power Station - Units 1, 2, 3, and 4
Virginia Electric and Power Company

Seismic stability analysis of intake structures and pump houses. Participated in study of fault at North Anna, investigation of effects of reservoir filling, and studies of settlement of stuctures and embankments.

Surry Power Station - Units 3 and 4, Virginia Electric and Power Company

Site investigation, soils evaluation, and seismic studies for Surry Units 3 and 4, including liquefaction studies and defense of safe shutdown chosen for design. Work included preparation of appropriate sections of SAR.

Millstone - Unit 3, Northeast Utilities Service Company

Study of soil amplification of earthquake effects for Millstone, Unit 3 and statistical evaluation of earthquake risk at same site.

Montague Nuclear Power Plant, Northeast Utilities Service Company

Participation in development of safe shutdown earthquake for Montague nuclear power plant and in foundation design of cooling towers.

Jamesport and Shoreham Sites, Long Island Lighting Company

Liquefaction study for Jamesport nuclear power plant including earthquake amplification effects. Review of geotechnical studies. Review of seismic analysis.

Design of embedment requirements for offshore pipelines for Shoreham nuclear power plant, including evaluation of wave effects on liquefaction of sand and flotation of pipes. Liquefaction and stability studies for intake structures and canal slopes.

Beaver Valley Power Station, Duquesne Light Company

Evaluation of liquefaction potential for Beaver Valley Power Station and justification of design before U.S. NRC. Study of relative motion of building during earthquakes.

Continuing Education - Stone & Webster Engineering Corporation

Continuing education in geotechnical engineering, including continuing education of personnel in Geotechnical Division as well as explanation of geotechnical concepts to persons in other fields. Responsibilities include presentation of lectures, arrangement for lectures by others, and development of programs.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA (July 1966-July 1973)

Assistant Professor and Associate Professor of Civil Engineering

Research and teaching are primarily in the areas of geotechnical engineering and computer application. Specific topics include the application of finite element methods to problems in geotechnical engineering, including consolidation, behavior of braced excavations, stability of slopes, inelastic deformations of soil, earthquake problems, and flow through soils. Other research was done into the field behavior of levees on the Atchafalaya River, development of computer aided slope stability analysis, and earthquake engineering. Teaching has included running and participating in special short courses for engineering. Recent work included participation in seismic design studies for urban areas.

CONSULTANT IN GEOTECHNICAL ENGINEERING (July 1969-July 1973)

Stone & Webster Engineering Corporation, Boston, Massachusetts

Investigation and analysis of earthquake effects on stability and performance on North Anna Dam, then under construction.

Implementation of computerized stability and finite element analysis for geotechnical projects.

Investigation of surge pressures on inlet tunnels at Northfield Mountain Pumped Storage Project, Massachusetts.

Analysis of motions at Upper Baker Dam, Oregon.

Development of Preliminary Safety Analysis Report for extension of Surry Nuclear Power Station for presentation to AEC.

Consultation on numerous aspects of seismic risk and seismic design for power plants.

Dames & Moore, Cranford, New Jersey

Design and analysis of breakwater for offshore nuclear power plant.

Woodward-Moorhouse & Associates, Clifton, New Jersey

Study of effects of underwater embankment in reducing damage to liquid natural gas pipeline as the result of ship collision. Development of artificial time-history of design earthquakes.

Development of computerized slope stability analysis of rock slopes.

Joseph S. Ward & Associates, Caldwell, New Jersey

Prediction of deformations in foundation of float-glass plant.

Goldberg-Zoino & Associates, Newton, Massachusetts

Seismic amplification and soil liquefaction studies for additional structures at Vermont Yankee Nuclear Power Plant.

Geotechnical Engineers, Inc., Winchester, Massachusetts

Finite element study of deformations and possible cracking in proposed earth dam.

Panama Canal Company, Canal Zone

Study of stability of proposed rock cut.

Hansen, Holley, & Biggs, Cambridge, Massachusetts

Analysis of soil-structure interaction for ENEL No. 4 Nuclear Power Plant at Piacenza, Italy, for Gibbs & Hill. Development of soil parameters for soil-structure interaction for Aquirre nuclear power plant structures for Jackson & Moreland.

Weston Geophysical Research, Weston, Massachusetts

Soil amplification effects on earthquake for proposed Hanford nuclear power plant addition.

Haley & Aldrich, Cambridge, Massachusetts

Analysis of movement of sheeting at excavation for John Hancock Tower, Boston.

New England Concrete Pipe Corporation, Newton, Massachusetts

Expert witness on lateral movement of retaining wall in garage.

C. A. Maguire & Associates, Waltham, Massachusetts

Review of analysis of static soil-structure interaction for proposed Charles River Dam Locks and development of new computer methods of performing analysis.

T. WILLIAM LAMBE & ASSOCIATES, CAMBRIDGE, MA (July 1966-July 1969)

Consulting Soil Engineer

Creole Petroleum Corporation, Caracas, Venezuela

Studies of the subsidence of oil field at Lake Maracaibo, Venezuela, and of means of predicting the ultimate magnitude of settlement.

Analysis and design on proposed dam for storage of fuel oil, including deformation, seepage, and stability analyses.

Borden Chemical Company, Plant City, Florida

Investigation of behavior of tailings dams for gypsum wastes including seepage and stability analyses and model tests. Recommendations for new embankment design.

Esso Libya, Libya

Analysis of thermal flow patterns for storage tanks for liquid natural gas and recommendations for design.

NATIONAL SCIENCE FOUNDATION, WASHINGTON, D.C. (Sept 1963-July 1966)

National Science Foundation Graduate Fellowship at Massachusetts Institute of Technology

Earned Doctor of Philosophy degree in Civil Engineering.

T. WILLIAM LAMBE & ASSOCIATES, CAMBRIDGE, MA (Sept 1964-July 1966)

Part-time Employment as Soils Engineer

Creole Petroleum Corporation, Caracus, Venezuela

Laboratory testing of soil for proposed earth dam for storage of fuel oil, including triaxial tests and fuel oil permeability tests. Also design studies for same dam.

Esso Libya, Libya

Thermal flow studies for storage tank for liquid natural gas.

CREOLE PETROLEUM CORPORATION, CARACAS, VENEZUELA (June 1964-Sep 1964)

Soils Engineer (Through T. William Lambe & Associates)

Field supervision of borings and soil exploration at Amuay, Venezuela, for proposed earth dam for storage of fuel oil.

Field investigation of failure of Siburua Dam.

Field investigation of failure of cooling and settling tank at Quiriquire, Venezuela.

U.S. AIR FORCE (Sept 1959-Sept 1963)

Second Lieutenant and First Lieutenant

Goodfellow Air Force Base, San Angelo, Texas

Assistant base civil engineer.

Headquarters, European Security Region, Frankfurt Am Main, Germany

Staff civil engineer in charge of maintenance and minor construction projects for region extending from Scotland to Pakistan, preparation of military construction programs and minor construction programs, coordination with U.S. Army and with German engineers on problems arising in Germany, and general staff supervision of civil engineering operations.

OTIS ELEVATOR COMPANY, NEW YORK, NY (Sept 1957-Jan 1958)

Design Draftsman

Designed elevator installations for international operations division.

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO, TORONTO, ONTARIO (June 1955-Sept 1955)

Surveyor on St. Lawrence Seaway Project.

BRAZILIAN TRACTION LIGHT AND POWER, SAO PAULO, BRAZIL (June 1954-Sept 1954)

Surveyor on Cubatao hydroelectric power project.

SARGENT & LUNDY | **Resume** **Ahmed E. Meligi**

Title

Head
Component Qualification Division

Education

Michigan Technological University - M.S. Engineering Mechanics - 1971
Cairo University, Egypt - B.S. Aeronautical Engineering - 1965

Registration

Professional Engineer - Illinois

Appointed Associate - 1984

Responsibilities

Mr. Meligi is responsible for developing and implementing comprehensive qualification programs for assuring the operability, functionability and structural integrity of power plant components and component supports during all loading and environmental postulated plant conditions. The components include equipment (mechanical, electrical, and HVAC), controls, instrumentation, HVAC ducts and penetration assemblies for all nuclear and fossil plants. He directs and reviews the activities related to optimal design/analysis methods for the reliability of components, special analysis of fluid mechanics, heat transfer, creep-fatigue, fracture mechanics, dynamics, vibration and material evaluations.

Experience

Mr. Meligi has extensive experience in component qualifications by testing and/or analysis for steam-electric generating stations. He has been involved in numerous projects, all nuclear- and some fossil-fueled, within Sargent & Lundy. He has written and supervised the writing of technical standards that established the oesign criteria and procedures for handling the divisional assignments. Mr. Meligi also is actively participating on various ASME and ANSI committees for the design and qualification of nuclear components and component supports.

Mr. Meligi has in-depth experience in dynamic and vibration analysis, fracture mechanics, stress analysis and material sciences. Prior to joining Sargent & Lundy in 1971, he taught engineering mechanics, perfor ed and reviewed stress analysis calculations for aircraft structures, and worked as an aeronautical engineer in the areas of flight testing, cycle calculations and thermal analysis. Mr. Meligi also has conducted project maintenance, surveillance, and spare parts procurement and replacement activities. These activities covered areas such as planning, scheduling, inventory control, shelf life, and storage conditions.

Memberships

American Society of Mechanical Engineers
ASME Section III, Working Group on Component Supports (Subsection NF)
ASME Section III, Special Working Group on Dynamic Analysis (Appendix N)
ANSI-N45 - Area IVX N551 "Project Pumps": Member of TF #1 (Pump) and TF #3 (Motor), Chairman of Operability - Qualification Group (Part of TF #1)
Institute of Environmental Sciences

Publications

Mr. Meligi has written and coauthored ten technical papers in the areas of equipment qualifications, dynamic testing and analysis, operability verifications, etc., that were presented and/or published in technical conferences and magazines of ASME, ASCE, SMIRT, IES, ASI and the Shock and Vibration Symposium.

January 1984

WIESEL, ROBERT C.

SENIOR STRUCTURAL ENGINEER
STRUCTURAL DIVISION

EDUCATION

Northeastern University - M.S. in Structural Engineering 1978
University of Massachusetts - B.S. in Civil Engineering 1972

LICENSES AND REGISTRATIONS

Professional Engineer - Massachusetts and New York

EXPERIENCE SUMMARY

Mr. Wiesel joined Stone & Webster Engineering Corporation (SWEC) as an Engineer in the Structural Division in June 1972. He has been assigned responsible positions on both fossil-fueled and nuclear-powered projects. His experience includes Project Engineering, Field Engineering, and Construction Coordination of power generating facilities. Mr. Wiesel is currently assigned to a nuclear power station as Lead Structural Engineer.

Mr. Wiesel has provided responsible leadership and has actively participated in both fossil-fueled and nuclear project site selection, engineering, design, and construction of power plant structures, offshore intake and discharge facilities, marine and waterfront structures, and major equipment rigging and installation.

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers

DETAILED EXPERIENCE RECORD
WIESEL, ROBERT C. 97046

STONE & WEBSTER ENGINEERING CORPORATION, BOSTON, MA (June 1972 to Present)

Appointments:

Senior Structural Engineer - Feb 1982
Structural Engineer - Aug 1978

Shoreham Nuclear Power Station, Long Island Lighting Company (Jan 1978 to Present)

Assigned as LEAD STRUCTURAL ENGINEER, responsible for all Structural Engineering and design activities on the project and within the site engineering office. Also responsible for the interface and coordination of construction activities in the structural area.

Oswego Unit 6, Niagara Mohawk Power Company (Feb 1977-Jan 1978)

Assigned as an ENGINEER, responsibilities included specification preparation, resolution of construction problems, and engineering and design coordination of plant structures, offshore intake structure, and concrete stack.

North Anna Units 3 and 4, Virginia Electric and Power Company (Sept 1976-Feb 1977)

Assigned as an ENGINEER, responsibilities included engineering and design coordination of the fuel building and intake tunnels, specification preparation, and resolution of construction problems.

Shoreham Nuclear Power Station, Long Island Lighting Company (Feb 1975-Sept 1976)

Assigned as HEAD OF THE SITE ENGINEERING OFFICE, responsibilities included the authority of the Project Engineer for all engineering and design work performed on the Shoreham Jobsite. Prior to the establishment of the site engineering office, was the project liaison between the construction site and the project group and functioned as the project engineer's representative in the field.

River Bend Station, Gulf States Utilities Company (Mar 1974-Feb 1975)

Assigned as an ENGINEER, was responsible for a range of project specifications and their associated contracts. Also, responsibilities included coordination of engineering and design efforts for the waterfront structures, cooling tower area, and site development preparations.

Career Development Program (June 1972-Mar 1974)

Assigned to the Structural Design Division for a period of 12 months. Gained structural design experience on both nuclear and fossil power facilities. Major areas of concentration were in the computer analysis and design of precipitator structural steel, seismic analysis of the service building for North Anna Unit 3, and finite element analysis of a stack liner.

Assigned to the Construction Department and to the North Anna Nuclear Power Station, Mineral, Virginia. While in the field was involved with the following activities: reactor vessel installation, concrete placement for the reactor containment and internal structures, concrete batch plant operations, and the installation of rock anchor bolts, structural steel, and cadwelded joints.

During an assignment to the Geotechnical Division, was a field inspector on both on-shore and off-shore drilling rigs. During this period, activities consisted of determining boring locations, and logging and classifying samples.