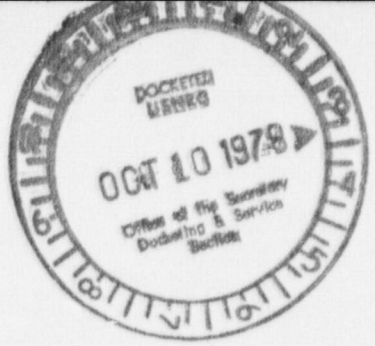

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of PORTLAND GENERAL ELECTRIC COMPANY, et al, (Trojan Nuclear Plant)	)))	Docket No. 50-344 (Control Building)

DIRECT TESTIMONY OF HAROLD I. LAURSEN

Q: Please state your name, address and occupation for the record.

A: My name is Harold I. Laursen. My address is 1520 N.W. 13th, Corvallis, Oregon 97330. I am a Professor of Structural Engineering at Oregon State University.

Q: What has been the nature and extent of your education and experience in the field of engineering?

A: With respect to my formal education, I hold a Bachelor of Science in Engineering from Oregon State University, 1958, and received a Master of Science in Engineering from Oregon State University in 1960. I was awarded a Ph.D. in Engineering from the University of California at Berkeley in 1964. In 1963, I was appointed an Assistant Professor in Engineering at Oregon State University. In 1965, I became an Associate Professor and, in 1969, a full professor.

My non-academic experience is listed below:

1. U.S. Army Corps of Engineers, summers, 1956, 1957, 1969, 1970 (Inspector and Structural Engineer);

2. U.S. Forest Service, summer, 1958 (Forest Road Study);

3. Boeing Airplane Company, 1959 to 1960 (Research Engineer on Missile Base facilities);

4. U.S. Navy Civil Engineering Laboratory, summer, 1965 (study of modeling concrete structures);

5. National Bureau of Standards, Center for Building Technology, 1972-1973 (visiting researcher, primarily on wind research programs. I set up the computer modeling of the Bailey's Cross-Roads building failure in 1973);

6. Bonneville Power Administration - (I undertook with BPA a two-year study on Response of Transmission Towers to Wind);

7. Organizing committee member for the Pacific Northwest Seismic Seminar for Structural Engineers;

8. Universities' Council for Earthquake Engineering Research;

9. Private consulting for various clients, including:

   a. Technical Advisory Service for Attorneys, Fort Washington, PA.

   b. National Bureau of Standards, Center for Building Technology.

   c. Accident and Failure Investigations, Inc.

   d. Kaiser Steel Building Co.

Q: Are you a member of any professional societies?

A: I am a registered Engineer with the State of Oregon and a member of the American Society of Civil Engineers.

Q: Have you received any professional awards or recognitions?

A: I am a member of Phi Kappi Phi, scholastic honorary; Pi Mu Epsilon, mathematics honorary; Tau Beta Pi and Sigma Tau, engineering honoraries; Sigma Xi, graduate scholastic and research honorary; Who's Who in the West; and I received the Carter Award in 1968 from the Oregon State School of Engineering as the outstanding instructor of the year.

Q: What are your fields of specialization?

A: My fields of specialization are: Structural Mechanics, Structural Engineering and Computer Applications (of large structural analysis programs).

Q: Do you have any professional publications to your credit?

A: My major relevant publications include:

Books:

"Matrix Analysis of Structures," (Textbook), McGraw-Hill Book Co., June, 1966;

"Structural Analysis," (Textbook), McGraw-Hill Book Co., January, 1969;

"Structural Analysis," 2nd Edition (Textbook), McGraw-Hill Book Co., January, 1978;

Conference Proceedings:

"Dynamic Matrix Analysis of Framed Structures," (with R.W. Clough and R.P. Shubinski), Proceedings of the 4th U.S. Congress of Applied Mechanics, June, 1962;

"Towards a General Program for the Numerical Solution of Ordinary Differential Equations," (with E. Close, R. DeVogelaere and N. Snoeck), published by the Department of Mathematics at University of California, under auspices of Office of Naval Research, September, 1962;

"Electro-Optical Deflection Measuring Device," (with R.A. Crist and R.D. Marshall), National Bureau of Standards Technical Note 873;

"Dynamic Response of Transmission Line Towers to Wind Loading," (NSF Grant No. ENG 74-12799), Final Report, January, 1978.

Q: Dr. Laursen, in your field of engineering, are you familiar with problems of seismic loading?

A: Yes.

Q: In connection with this case, were you asked by the Oregon State Department of Energy to make any study or evaluation?

A: Yes. I was asked to evaluate the ability of the Trojan Nuclear Plant Control Building shear walls to resist seismic loading.

Q: Would you describe your assignment?

A: I was to review and evaluate the purported design errors which were brought to the Nuclear Regulatory Commission's attention by Portland General Electric Co., namely, the discontinuous core reinforcement and the miscalculations of the allowable strength values for the shear wall concrete, and any PGE conclusions with respect to whether the existing shear walls could withstand the specified earthquake loading.

Q: Please outline briefly the parameters of your evaluation?

A: I first obtained the data which was in substance included in the Licensee Event Report No. 78-13 and Reportable Occurrence of May 5, 1978, together with the supplement of May 24, 1978. In addition, I received design drawings for the control building and had numerous conversations with employes of Portland General Electric Co. (PGE), the Bechtel Power Corporation (Bechtel), and the Nuclear Regulatory Commission (NRC) staff, to gather additional material about construction of the project.

My review included the subjects of:

1. The definition of appropriate design response spectra for both an operating basis earthquake (OBE) and a safe shutdown earthquake (SSE), (that is, representation of possible earthquake loading);
2. The technique used for the dynamic modeling of the combined control, auxiliary and fuel buildings (that is, the analysis of the structure under dynamic behavior);
3. The general features of the design and construction sequence (the sequence affects the performance of the structure);
4. The structural characteristics of the as-built structure; and

5. The nature and seriousness of the design errors.

I also reviewed Bechtel's 1974 design guide, Seismic Analyses of Structure and Equipment for Nuclear Power Plants.

Q: Did you examine in detail the computer program used by Bechtel?

A: No. However, I am familiar with the types of programs used for this kind of analysis. They are similar to the one we use at Oregon State University, the one used by the Oregon State Department of Transportation, Highway Division, and the one which I applied to the computer of the United States Bureau of Standards in 1972-1973. These latter programs were developed at the University of California at Berkeley, Earthquake Engineering Research Center. Bechtel's programs are somewhat more detailed than the program used at Oregon State University.

Q: Did you evaluate the various assumptions that were used in the re-analysis of the building?

A: Yes. In this connection, I wish to make clear that my attention was directed primarily to theory and application of sound engineering principles. I necessarily used data from Bechtel, such as as-built weights, and actual strength of reinforcing steel and concrete used.

Q: How did you utilize this information?

A: In conducting my review, I would verify, for example, that the use of the SRSS technique, rather than the absolute sum of the modal responses, was appropriate for determining the expected earthquake force on the building, or that the use of $2\sqrt{f'_c}$ was proper for determining the strength of concrete.

I did not reconstruct the mathematical computer model of the building from the engineering drawings. That would be a practical impossibility, but I was able to determine that the results provided by Bechtel are reasonable. For example, the plotted vibration mode shapes and association frequencies (e.g., Figure A-3, Appendix A, Licensee Event Report of May 5, 1978) are comparable to what is known to exist in similar buildings.

Q: Did you also review the modes used in the design of the project?

A: Yes, I did.

Q: What were your findings as your review progressed?

A: As far as the dynamic analysis is concerned, I was satisfied that the significant modes of vibration were properly considered. However, I was not satisfied with the first re-evaluation of the shear walls in which credit was given to the concrete core of the shear walls plus one-half the thickness of the grouted masonry block. The

discontinuity of some of the core reinforcing steel raised doubt in my mind about the integrity of the wall during the life of an earthquake and possible aftershocks. I was concerned that the project at least should conform to two widely used design references: Uniform Building Code, 1973 Edition, International Conference of Building Officials, and Recommended Lateral Force Requirements and Commentary, Seismology Committee of the Structural Engineers Association of California, 1966 version. As I later discovered, in fact the FSAR requirements for earthquake loading are more stringent than those of the above-stated references.

Q: Did you subsequently modify your initial conclusions?

A: Yes. Based upon detailed information later provided by Bechtel, I became convinced that dowel action of the reinforcing steel and the steel columns would provide additional strength to the walls.

This resistive mechanism, dowel action, is a commonly used and accepted technique in bridge and building composite girder design. In essence, it has the effect of tying the walls of the control building together should any of them become weakened during an earthquake. It provides the desired ductility and a large amount of damping.

Q: What effect did this supplemental information have on your evaluation of the capacity of the shear walls in the control building?

A: Based upon the information I have described, and giving proper credit to the dowel action, I was able to make my statement with reasonable assurance that was inclued in my June 14, 1978 report to the Oregon Department of Energy, namely, that the shear walls of the control building, as built, can ultimately withstand a .25g safe shutdown earthquake.

Q: Since your report of June 14, 1978 to the Oregon Department of Energy, have you made further evaluation of these shear walls?

A: Yes. In September, 1978, I received the results of the last control building shear wall analysis utilizing the STARDYNE model. My review included:

1. "Trojan Control Building Supplemental Structural Evaluation," dated September 19, 1978;
2. "Response to Questions from the Nuclear Regulatory Commission," dated September 20, 1978; and
3. The Holley and Bressler Report, dated September 20, 1978, entitled "Response of Trojan Nuclear Power Plant Control Building to Specified SSE Event."

Q: What is the significance of the STARDYNE model?

A: STARDYNE is a finite element model which can determine accurately the forces generated in various parts of a building complex during an earthquake. The model is much more sophisticated than those ordinarily used in building construction. Since the stresses can be predicted accurately, we need not rely upon the conservatism inherent in most building codes. Unless you can know with reasonable certainty what forces will be generated in various parts of a building during an earthquake, you must accept the use of conservative allowable stresses for design purposes. Codes in general stipulate conservative allowable stresses for design purposes because, in the ordinary case, no comprehensive finite element analysis will be performed.

Q: After the STARDYNE analysis, were recent wall tests used to determine the stress capacities of the shear walls?

A: Yes, These tests are referred to in the Trojan Control Building Supplemental Structural Evaluation, dated September 19, 1978, as (1) Schneider's tests; (2) University of California (Berkeley) tests; and (3) PCA tests. They are used by Bechtel to develop the criteria for capacities of the Trojan walls. The capacities of the walls are assessed by recognizing the basic composition of the walls, that is, the amount and strength of concrete, the concrete blocks, the grout and reinforcing steel.

Q: Did you review those tests?

A: Yes, I did. In my review, I took note of various factors which are pertinent in defining the capacity of the control building walls, such as:

1. The level of stress in the PCA concrete wall tests at which shear cracks first formed;
2. The effects of cyclical leading on the test results; and
3. The wall height-to-width ratios.

Q: Are you satisfied from the material you reviewed that the tests used to assess wall capacities were appropropriate for the shear wall capacity criteria stated in Section 4 and developed in Appendix B of the "Trojan Control Building Supplemental Structural Evaluation Report"?

A: Yes. Of particular importance to me is that the capacity criteria limit the acceptable level of stress in the concrete core to values that are in general less than those of first shear cracking in the PCA tests and to a value much less when the presence of reinforcing steel is questionable. This provides me with assurance that the integrity of the concrete core will be maintained during an earthquake. Evidence indicates that adequate reinforcing steel is present in the concrete blocks of the control building walls to permit stresses above the level of first

cracking in the blocks. With respect to the use of wall height-to-width ratios, expressing capacity criteria in this manner is appropriate and has become accepted practice. One can appreciate readily that the effects of lateral force applied to a tall wall are different from the same force applied to a short wall of equal thickness.

Q: How has the STARDYNE analysis affected your earlier conclusions relating to the capacity of the shear walls in the control building?

A: Based upon the STARDYNE analysis and the related material I have reviewed, again I can state with reasonable assurance that the shear walls of the control building can withstand a .25g safe shutdown earthquake. Because of the comprehensive comparison of wall capacities and predicted stresses, the resistive mechanism of the dowel action, upon which I previously relied, is no longer necessary to support my conclusion. However, that mechanism is still present, and therefore adds to the reliability of these findings.

Q: Does this complete your testimony?

A: Yes, it does.

CERTIFICATE OF SERVICE

I hereby certify that on the 6th day of October, 1978, I served a copy of the foregoing Prepared Testimony of Harold I. Laursen upon the persons listed below, by then depositing in the United States Post Office at Salem, Oregon, full, true and correct copies thereof, in sealed envelopes with postage pre-paid, addressed to the said persons listed below, which are their regular office addresses:

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