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STATE OF MAINE
PUBLIC UTILITIES COMMISSION
242 State Street
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December 3, 1979

William Russell
Office of Nuclear Radar Regulation
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Russell:

We have reviewed the preliminary transcript of your October 25, 1979 deposition, however, we will not be in a position to determine whether or not your presence at a hearing will be requested until we review any revisions or corrections that you may make. If further participation by you is necessary written testimony would be required by [redacted] I expect that such testimony would be similar to the statements made during the deposition. The parties would have the opportunity to cross examine you at a hearing presently scheduled for [redacted] We would appreciate your efforts to keep these dates open.

In addition, I have enclosed a copy of testimony which has already been submitted by one of the parties. The testimony is of a technical nature and addresses the same matters we discussed in Augusta. I would appreciate it if you or your staff could review this testimony and inform me of any areas of agreement or disagreement.

Thank you for your cooperation and assistance in this matter.

Sincerely,

David Moskovitz
Attorney

DM/nl
Enclosure

12-3-79
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TESTIMONY OF RONALD W. HAUPT

ON BEHALF OF

MAINE COMMITTEE FOR UTILITY RATE REFORM

TESTIMONY OF RONALD W. HAUPT

CONCERNING PIPING SEISMIC ANALYSIS,

ALGEBRAIC INTRAMODAL COMBINATION METHOD

Q. Please state your name and business address.

A. Ronald W. Haupt, FMC Associates, Consulting Engineers, 545 Mission Street, San Francisco, California.

Q. What is your educational background?

A. I received a Bachelor of Science degree in Civil Engineering from Stanford University in 1958 and a Master of Science degree in Civil Engineering from the Massachusetts Institute of Technology in 1966. I am a registered Civil Engineer and Mechanical Engineer in the State of California. I am a member of the ANSI/ASME (American National Standards Institute/American Society of Mechanical Engineers) B31.1 Committee on Power Piping. Between 1971 and 1977 I was a member of the BPVC (Boiler and Pressure Vessel Code) Section III Nuclear Power Plant Components Working Group on Piping Design and Working Group on Component Supports.

Q. Please describe your work experience.

A. Since 1966 I have been involved in the design and analysis of nuclear and non-nuclear power plant structures and equipment. From 1966 to 1969, I was employed by John A. Blume and Associates, Engineers, San Francisco. As a structural dynamicist, I have developed criteria, analyzed, and wrote computer programs to analyze nuclear power plant structures and equipment, including piping, for seismic loadings. From 1969 to 1977, I was employed by EDS Nuclear, San Francisco.

As Data Processing Manager, Project Engineer, and later Section Manager, I wrote computer programs and was responsible for the entire analysis process of nuclear piping systems. My duties included training EDS and client personnel in seismic analysis, developing and reviewing of project seismic criteria, and writing and modifying computer programs to perform seismic analysis of piping systems. Since 1977, I have been employed by FMC Associates, San Francisco. As a principal engineer, I have been involved in the design and analysis of non-nuclear power plant structures and equipment. My duties have included developing plant seismic criteria, preparation and review of plant equipment seismic design specifications, and seismic analysis and design of non-nuclear piping systems.

Q. In the matter before this Commission, have you read the U.S. Nuclear Regulatory Commission (NRC) Show Cause Order (Reference 1) regarding alleged piping seismic analysis discrepancies?

A. Yes, I have.

Q. Do you have an opinion regarding the piping seismic analysis methods that were used?

[redacted]*/

Q. On what do you base your opinion?

A. I have found nowhere in the literature a technical justification of the algebraic summation method in the context of modal superposition earthquake analysis techniques. Algebraic summations

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*/Intramodal and other seismic modal superposition terminology is summarized in Appendix A.

have been justified when the time phasing of different responses are known when performing time history analysis (Para. N-1720, Reference 4). Algebraic summations have also been justified for modal superposition techniques for shock loadings.*/ However, for earthquake-like excitations more conservative methods of modal combinations are preferable (Reference 6).

[redacted]*/ I think it is important to note that no other modal superposition method described in the literature yields inconsistent results according to the coordinate system selected for an analysis. After my own examination of the effects of changing the global coordinate system, I agree with Lin's conclusion.

In addition, Stone and Webster, in reference to the algebraic summation method, stated that:

> This technique could either overestimate or underestimate earthquake loads on a piping system. In the limit, it might indicate essentially zero earthquake loading; i.e.,

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*/It is of some interest, although any inference is by no means certain, that the questioned computer program containing the algebraic summation technique is named SHOCK I. (Reference 2).

**/The proof of this statement is as simple as running two piping seismic analyses, one right hand problem and the other the same but opposite hand (mirror image), and comparing the results. Using this intramodal algebraic summation method will lead to two different sets of results.

equivalent to omitting earthquake from the design conditions. (Reference 7)

In my opinion the statement made by Stone and Webster is correct and concern about the extent the technique will yield results that approach the zero limit is a legitimate one. In conclusion, as a result of my review of the technical literature, specifically that of C.W. Lin and Stone and Webster, and as a result of my own analysis, I can only reiterate that there neither was, nor is any apparent technical justification for the algebraic summation method questioned by the NRC and used by Stone and Webster in the analysis of piping systems at Maine Yankee.

Q. As the result of responses to NRC IE Bulletin No. 79-07 regarding seismic stress analysis of safety-related piping (Reference 3) it seems as though the algebraic summation method was used by others performing piping seismic analysis. Could you comment?

A. It appears as though at least 24 nuclear power plants had some safety-related piping analyzed using this method. At least 11 domestic architect/engineers or pipe fabricators may have used this method. There is no question that the method was widely used and its use documented. [redacted]

(Reference 12)

A 1973 report by Nathan M. Newmark, Consultant Engineering

Services (Reference 13), reviewing the Salem FSAR stated that the seismic analysis of piping appeared to be in line with current practice. [redacted] Dr. Newmark is specifically mentioned here because of his significant and very credible knowledge of earthquake engineering. He is a consultant to the NRC, has been active in the field of earthquake engineering for more than 25 years, and has co-authored a seminal paper on a statistical basis for the modal combination of seismic effects (Reference 5). His approval, either explicit or tacit, could virtually imply correctness.

STAFF HAS NO OPINION. LIKELY THAT 5.37 WAS NOT Reviewed by Newmark

The same implication may also arise in the context of Newmark's review of Maine Yankee. [redacted]eference 8). His subsequent report to the AEC regulatory staff (Reference 9) stated the belief that the design outline for Class I structures and equipment can provide an adequate margin of safety for seismic resistance, although the algebraic summation method was not specifically commented upon. As noted, and once again, it might be inferred that in 1968 Dr. Newmark considered the algebraic intramodal combination methodology for piping to be correct.

see opposite page

Q. What is your opinion concerning the possible inferences from the above quoted Newmark reviews?

A. In my opinion the algebraic summation method was not appropriate in either 1968 or 1973.

Q. Upon what do you base your opinion, Mr. Haupt?

A. In addition to the reasons mentioned in answers to previous questions concerning the C.W. Lin Paper, the Stone and Webster statement and my own investigations, [redacted] (Reference 10). [redacted] along a (see facing page.) given coordinate axis. The reason is that the article further states that these earthquake effects should be combined "directly and linearly" with effects from other sources such as dead load, live load, thermal and pressure effects. There is no question that modal superposition earthquake effects should be combined with other source effects by absolute summation.

Thus, one must compare any inferences to be drawn from the Newmark reviews of the Salem FSAR and the Maine Yankee PSAR with explicit statements made by him in the referenced

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*/An absolute summation is a summation of the magnitude of values without regard to sign, i.e. the absolute sum of +3 and -4 equals 7.

1969 article. In my opinion, as noted in other answers, there was and is no technical justification for the algebraic summation technique.

Q. Are alternative summation techniques more computationally complex or expensive than the algebraic intramodal summation technique?

A. No. An alternative summation technique would require a change to less than 25 computer program statements (out of many thousands for a reasonably comprehensive piping analysis computer program) and no appreciable increase in computer computational time.

Q. Stone and Webster has stated that they concur that a single aspect of their piping seismic analysis method does not give uniformly conservative results. (Reference 14). Aren't there adequate offsetting conservative assumptions inherent in the total piping analysis to balance the non-conservatisms in the algebraic intramodal combination method?

A. There are numerous assumptions made in any engineering analysis; and most are conservative. When an assumption is consistent, quantitatively or qualitatively, it can be balanced against one or more offsetting consistent assumptions (within a rational factor of safety).*/ However, many assumptions are not easy to verify as being consistent, quantitatively or

*/A quantitatively consistent assumption would be one which yielded, say, consistently positive answers. The positive answers could be offset (assuming comparable magnitudes) against an assumption which yielded consistently negative results.

qualitatively. In such cases a conservative assumption is necessary.

Inherent in piping analysis in general, and in the Maine Yankee piping analyses in particular, are several identified conservatisms. In the verification of the SHOCK I computer program, for example, (Reference 2) the method of intermodal response combination is noted to be a modified square root of the sum of the squares (SRSS) method. This modified approach is stated to be always more conservative than the simple SRSS method which is one of the most widely used and accepted (and technically justified in Reference 5) method of seismic modal superposition. (For example, see Para. N-1223, Reference 4).

There are other conservatisms as well. Examples include elastic analysis methods using low damping values, and analyzing three directions of earthquake. In addition, pressure-temperature considerations provide an inherent seismic resistance capability in the piping systems; and piping code compliance assures a reasonable factor of safety against unintended and uncertain loads.

On the other hand, the method used to combine the modal inertia forces and to apply the resultant forces as a set of static forces to determine the remaining seismic effects (i.e., displacements and rotations, forces and moments, and stresses) is not conservative because significant high frequency modal effects may be reduced. The intramodal algebraic combination method yields no consistent results (results may either overestimate or underestimate earthquake loads (Reference

7)) and thus cannot be rationally offset by any other consistent assumption. It should be noted that the Stone and Webster SHOCK I verification (Reference 2) seems to indicate that some relationship <u>may</u> exist that would correlate the algebraic combination method with some consistent quantitative seismic response. However, it is not explained or technically justified. Until such an explanation or justification is put forth, use of the algebraic intramodal combination method is questionable.

REFERENCES

1. U.S. Nuclear Regulatory Commission, Maine Yankee Atomic Power Company, Docket No. 50-309, Order to Show Cause, 13 March 1979, Washington, D.C.
2. Stone & Webster Engineering Corporation, "Verification of Shock I Program for Maine Yankee Atomic Power Station," 19 April 1979, Boston, MA.
3. U.S. Nuclear Regulatory Commission, IE Bulletin No. 79-07, Seismic Stress Analysis of Safety-Related Piping, 14 April 1979, Washington, D.C.
4. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III Nuclear Power Plant Components, Appendix N, Winter 1978 Addenda, 31 December 1978.
5. L.E. Goodman, E. Rosenblueth, and N.M. Newmark, "Aseismic Design of Firmly Founded Elastic Structures," American Society of Civil Engineers, Proceedings-Separate No. 349, November 1953 (also ASCE Transactions, Vol. 120, pp. 782-802, 1955)
6. Y.C. Fung and M.V. Barton, "Some Shock Spectra Characteristics and Uses," Journal of Applied Mechanics, Vol. 25, P. 365, 1958.
7. Stone & Webster Engineering Corporation, "Report on the Reanalysis of Safety-Related Piping Systems, Surry Power Station, Unit 1, 5 June 1979, Boston, MA.
8. Nathan M. Newmark, Consulting Engineering Services, Letter to Dr. P.A. Morris, U.S. Atomic Energy Commission regarding Maine Yankee Atomic Power Station Preliminary Safety

Analysis Report, 20 March 1968, Urbana IL.

9. Nathan M. Newmark, Consulting Engineering Services, "Report to AEC Regulatory Staff, Adequacy of the Structural Criteria for the Maine Yankee Atomic Power Station," 28 June 1968, Urbana, IL.

10. N.M. Newmark and W.J. Hall, "Seismic Design Criteria for Nuclear Reactor Facilities," Proceedings-Fourth World Conference on Earthquake Engineering, 1969, Santiago, Chile.

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12. Public Service Electric & Gas Company, Answer to Question 5.37, "Amendment 13 to Final Safety Analysis Report, Salem Nuclear Generating Station," Docket 50-272, 7 August 1972.

13. Nathan M. Newmark, Consulting Engineering Services, "Commentary on Structural Adequacy of Salem Nuclear Generating Station Units 1 and 2, Public Service Electric and Gas Company," Dockets 50-272 and 50-311, 20 March 1973, Urbana, IL.

14. W.F. Allen, Jr., Chairman and Chief Executive Officer of Stone & Webster Engineering Corporation, Statement before the Subcommittee on Energy and the Environment, Committee on Interior and Insular Affairs, U.S. House of Representatives, 19 March 1979, Washington D.C.

APPENDIX A

SUMMARY OF SEISMIC MODAL SUPERPOSITION TERMINOLOGY

In piping seismic modal superposition methods the piping is represented as an idealized assemblage of masses and elastic springs from which the vibratory characteristics of the piping can be computed. These characteristics are a set of mode shapes and frequencies. A mode shape is a characteristic shape that the idealized piping will assume as it vibrates. Modal effects, i.e. displacements, rotations, forces, moments, and stresses are a function of the mode shape. Each mode shape vibrates at its own characteristic frequency. A mode shape will be excited by being shaken at its characteristic frequency. An earthquake can be represented as as assemblage of various shaking frequencies. Thus, an earthquake can excite the certain modes, usually defined as the significant modes. The modal superposition method assumes that the maximum earthquake response of the piping is a function of some combination of the individually excited significant modal effects. A set of modal effects can be computed for each of three earthquake directions, two horizontal and one vertical, and for each mode excited by the earthquakes. Combination of modal effects by earthquake direction is defined as intramodal; combination of modal effects by mode is defined as intermodal.