NOV 28 1979

Docket Nos. 50-272 50-309
50-280 50-324
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The Honorable Morris K. Udall, Chairman
Subcommittee on Energy and the Environment
Committee on Interior and Insular Affairs
United States House of Representatives
Washington, DC 20515

Dear Congressman Udall:

Mr. Henry Myers of your staff discussed with me his request for clarification of earlier testimony, which occurred on March 19, 1979, concerning the shutdown by NRC of five nuclear power plants designed in part by the Stone and Webster Engineering Corporation. The five plants were ordered to be shut down because of the use of a particular calculational technique in a computer code used by Stone and Webster for the design of piping systems for seismic events. The computer code involved is called SHOCK II. This code uses a technique of spectral analysis and combines the individual responses (i.e., displacements and forces) that occur in a colinear direction by an algebraic summation technique. The algebraic summation technique is acceptable for a time history analysis and is not acceptable for a spectral analysis when multiple independent earthquake inputs are involved.

As a result of the reanalyses that were required by the March 13, 1979, NRC show-cause orders, some general observations concerning the use of algebraic techniques can be made. In particular, the magnitude of the design deficiency resulting from the use of these techniques varied significantly from plant to plant. In the case of Maine Yankee, the original design conservatism was such that reanalysis did not require the modification of hardware in the facility. The reanalysis effort on Maine Yankee was completed in approximately two months.

In the case of Beaver Valley, only a few systems required hardware changes due to use of the algebraic summation technique as a result of the reanalysis effort. The results are significantly different from those perceived in early March 1979 when the plants were ordered to be shut down. Following the meeting on March 8, 1979, at which Duquesne Light Company reported the use of the algebraic summation technique in the design of piping at the Beaver Valley Plant, the licensee was requested to perform additional analyses to determine the significance of the algebraic summation for piping design. NRC personnel were sent to Stone and Webster offices over the weekend of March 10, 1979, to observe the reanalysis effort. The results of the reanalyses that weekend indicated that piping systems could be overstressed by as much as 300 percent, and that a significant number of pipe supports were beyond their design values.

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In some cases, the seismic portion of the stress increased by as much as six times its original value. Reanalyses performed during that weekend were preliminary due to time constraints and were not subject to quality assurance checks by Stone and Webster Engineering. It was later determined that the piping configurations that were reanalyzed were not representative of actual piping systems in the plant. Rather, they were preliminary design analyses based on preconstruction drawings and analyses of designs that were subsequently modified and thus had no significance with respect to the safety of the plant.

Of the 10 calculations that were provided that weekend to the NRC staff and brought back to Washington for further review, only one calculation was representative of the actual piping in the power plant. These facts concerning the calculations performed that weekend were not available until late April 1979 at which time the licensee had identified several modifications that were necessary for the Beaver Valley plant. Therefore, the shutdown order for Beaver Valley and the other four facilities was left in effect and the licensee was required to complete the analysis effort required by the order.

In the case of the Surry Unit 1 and FitzPatrick plants, more extensive modifications than those on Beaver Valley were required as a result of the reanalysis. The reanalysis effort on Surry Unit 2 is not yet complete as a result of a decision by the licensee to defer the reanalysis effort and place priority on the completion of Surry Unit 1. Surry Unit 2 has been shut down for steam generator replacement and is not expected to restart until after January 1980. The seismic reanalysis effort will be completed prior to restart following the steam generator replacement effort.

Based on the four plants reanalyzed to date, approximately 2 percent of the piping systems required modifications as a result of having used the algebraic summation technique. The attached table (Enclosure 1) provides the results of the reanalysis of all piping systems and those supports at the time the plant was permitted to restart operation. In this table, the reasons for modifications are broken into two categories: modifications due to the algebraic summation technique, and modifications as a result of the original plant construction not being in accordance with the design (as-built problems). The second category, which is unrelated to the calculational technique used, has required a larger number of modifications to the facility and has resulted in the issuance by the Office of Inspection and Enforcement of Bulletin 79-14 to all operating plants. A copy of IE Bulletin 79-14 is attached as Enclosure 2.

In the course of the reanalysis effort on Stone and Webster designed plants, the NRC staff became aware that other facilities were designed by other firms using algebraic summation techniques. As a result, the Office of Inspection and Enforcement issued Bulletin 79-07 on April 14, 1979 (Enclosure 3). The responses by licensees to that bulletin indicated that a total of 29 facilities (including the five facilities that were shut down) used the algebraic summation technique. Four of those facilities are still under construction and 25 are operating reactors.

Five different computer codes were involved in the algebraic summation technique. The codes are SHOCK II by Stone and Webster Engineering Corporation, WESTDYN by Westinghouse Electric Corporation, ADLPIPE by Arthur D. Little Company, DAPS by General Electric Company, and PIPEDYN II by Franklin Institute. The extent of the use of the these codes on the 25 operating reactors varied from the design of a few piping systems to the design of all safety-related piping in the facility. In addition to the five plants that were shut down by the show-cause order, four other facilities had made extensive use of algebraic summation: Brunswick Units 1 and 2, Indian Point Unit 3, and Salem Unit 1. Salem Unit 1 was shut down for refueling at the time and remained shut down until the reanalysis for algebraic summation had been completed. In the case of Brunswick Units 1 and 2 and Indian Point Unit 3, the NRC staff met with the licensees and determined that there were sufficient conservatisms in the original designs such that it was unlikely that modifications would be required. Therefore, these units were allowed to continue operation during the seismic reanalysis effort.

For the majority of the other 16 operating reactors, the seismic reanalysis effort had already been completed by the time the staff was notified that the algebraic summation technique had been used. Modifications to these facilities were not required as a result of the use of algebraic summation. Attached is a listing of all the facilities that used the algebraic summation technique (Enclosure 4) including a description of the extent of the problem, whether the facility was required to be shut down, and the results of the staff evaluation. It should be noted that Pilgrim Unit 1 and Brunswick Units 1 and 2 were required to be shut down during the seismic reanalysis effort because it was discovered that there were differences between the as-built plant and the design specifications for the facility.

The following comments pertain to the question of whether the algebraic summation technique was an error.

a. The staff position on acceptable methods for combining modal responses for seismic design was not articulated until December 1974 with the issuance of Regulatory Guide 1.92 and the NRC staff required reanalysis as described in Enclosure 4. The staff did not review the methods used prior to that time to determine if unacceptable methods had been used.

b. A total of 29 facilities whose seismic design commenced prior to December 1974 used seismic design methods that involved the algebraic summation of modal responses (see Enclosure 4). Five firms involved in seismic design knowingly used the method of algebraic summation in developing their code. One firm, the Arthur D. Little Company, provided the bases for the use of algebraic summation in their code ADLPIPE (see Enclosure 5). This code was developed to handle one-dimensional earthquakes. This earthquake was separated into component parts, north-south and east-west directions, for ease of calculations. The resultant forces were then recombined using algebraic summation for the combination of the colinear modal responses. In this instance, the relationship between the north-south earthquake component and the east-west earthquake component is known and the components are statistically dependent on each other, and the use of

algebraic summation is acceptable. However, the staff has required that independent earthquakes be input orthogonally to each other (90° apart). Therefore, the use of the ADLPIPE code for statistically independent earthquakes is today believed incorrect and the NRC staff required reanalysis as described in Enclosure 4. The problem is one of application of the code in a method different from that for which it was developed.

c. It can be shown that the algebraic summation technique for combining colinear responses for multiple-dimensional earthquake inputs is technically incorrect because in some situations the forces or displacements can incorrectly cancel out each other. In other situations, the method can produce acceptable results.

d. During the development of dynamic analysis techniques for earthquakes, the staff requirements were progressing from one-dimensional to two-dimensional and finally to three-dimensional earthquakes that are used today. In parallel, computer codes were already being developed to perform the dynamic analysis. It was not until December 1974 that the staff provided specific guidance on acceptable methods for combining colinear responses. Prior to that time, the staff generally accepted the absolute summation technique for two-dimensional earthquake responses.

In summary, the algebraic summation technique was used in a variety of computer codes used in the early 1970's prior to the existence of definitive NRC guidance on the appropriate methods for combining modal responses. The applicable NRC guidance (Regulatory Guide 1.92 issued in December 1974) does not find the algebraic summation technique acceptable unless a time history approach is used. However, in most instances in which the algebraic summation technique was used, the original design included sufficient conservatism so that the algebraic summation analysis technique did not result in a requirement for facility design change.

We have concluded that the significance of the use of the algebraic summation technique in the dynamic analysis of piping systems for earthquakes is not as great as first perceived. The majority of the piping systems that were reanalyzed using acceptable techniques indicated that the original designs were adequate. In a few cases (approximately 2 percent), facility design changes were required to be implemented to restore original design margins. In addition, most of the necessary modifications were minor in nature (i.e., redesign of piping supports). In nearly all cases, the reanalysis results indicated a factor of safety of at least two between recalculated loading and the point at which failure would be expected (i.e., the ultimate strength of the component under static loading). The design changes that were implemented

in the facility were therefore required to restore the safety margin to that originally required at the time the facility was licensed.

Sincerely yours,

Original Signed by
H. R. Denton

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

cc: Rep. Steven Symms

Enclosures:

1. Piping System Reanalysis
2. IE Bulletin 79-14, Revision 1
3. IE Bulletin 79-07
4. Status Algebraic Summation of Modal Responses
5. Arthur D. Little Company letter to Vincent S. Noonan, April 19, 1979

Distribution:

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* by phone

	Safety-related piping reanalyses to perform	Reanalyzed & Acceptable	Reanalyzed & Acceptable with Modification	Modification for Algebraic Summation	Modification for "As Built"	New or Modified Supports as a Result of Pipe Reanalysis	Total Original Supports	Reanalyzed & Acceptable	Reanalyzed & Acceptable with Modification	Modification for Algebraic Summation	Modification for "As Built"	Supports to be Analyzed as of Date of Order	Supports Which Would Not Meet Factor of Safety of 2
Maine Yankee	19	19	0	0	0	0	?	?	2	0	2	0	0
Beaver Valley	116	114*	2	2	0	3	1060	1052	8	0	8	0	0
Fitzpatrick	96	91	05	1	4	9	335/654	315/287	20/14	12/3	8/11	0/353	1
Surry 1	63	44	19	4	15	64	492/528	441/156	51/14	12/0	39/14	0/358	4 (10?)
Total	294	268	26	7	19	76	3069	2251	107	27	80	711	5 to 15

FOUR PLANT TOTALS — THREE PLANT TOTALS

*includes 4 problems previously analyzed for DBE & Waterhammer against 2.4 Sh vice 1.8 Sh and 1 river water branch line as discussed in SER.

Note:

Inside Containment

Outside Containment

Enclosure 1