3/28/79

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of the Application of	)	
Public Service Company of Oklahoma,	)	
Associated Electric Cooperative, Inc.	)	Docket Nos. STN 50-556
and	)	STN 50-557
Western Farmers Electric Cooperative	)	
	)	
(Black Fox Station, Units 1 and 2)	)	

APPLICANTS' PROPOSED FINDINGS OF FACT
CONCERNING LOAD COMBINATION METHODOLOGY

1. In our Order ruling on the motions for summary disposition, we stated that we would hear evidence on the subject of load combination methods.[1/] The adequacy of structures and components at the Black Fox Station (BFS) to withstand various load combinations was considered in Paragraphs Q. and T. of Part III to our Partial Initial Decision. We address here only the controversy between the NRC Staff and the Applicants over the acceptability of certain methods for combining dynamic loads in the design of the Black Fox Station.[2/]

1/ "Order Ruling On Motions For Summary Disposition", dated September 8, 1978, pp. 18-19.

2/ It is more accurate to refer to the "combination of responses" rather than loads (Written Testimony of Edward D. Fuller following Tr. 8113, p. 1); however, it appears that the terms "combination of loads" or "load combinations" have become accepted euphemisms, and therefore, we will consider the terms "combination of responses" and "combination of loads" synonomous in the context of this issue.

2. The controversy revolves around the recommendation of the NRC Staff that the construction permits for BFS be conditioned to require the use of the Absolute Sums (AS) method for combining dynamic responses in the design of BFS. Under this condition, Applicants would be required to use AS exclusively except that the Square-Root-of-the-Sum-of-the-Squares (SRSS) method could be used for combining dynamic responses within the Reactor Pressure Vessel Boundary which result from the coincidence of an SSE and LOCA.[3/] The Applicants are unwilling to accept this condition. Instead, they are generally willing to commit to the use of AS for the design of structures and SRSS for the design of components and piping at BFS.[4/]

3. Before addressing the evidence submitted by the parties, the question of NRC regulations and regulatory requirements applicable to load combination methods should be considered. The parties have cited none, and we have found no NRC regulation that is relevant to the controversy between Applicants and the NRC Staff. The only related regulation, 10 CFR Part 50, Appendix A, General Design Criterion 2, requires that the combination of certain dynamic responses be reflected in design

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3/ Written testimony and supplemental testimony of Mr. Steven A. Varga following Tr. 8221, pp. 16-57a - 16-58 and 3 respectively.

4/ The nature of Applicants' commitment is stated here in a simplified form. The entire text of the commitment is set forth in the written testimony of Mr. Vaughn L. Conrad following Tr. 8113.

of nuclear power reactors. However, as conceded by the NRC Staff, the method for accomplishing the combination of dynamic responses is not prescribed in Criterion 2.[5/] Moreover, no guidance in the form of NRC Regulatory Guides or Branch Technical Positions exists on the use of AS as a load combination method.[6/] The guidance that does exist is Regulatory Guide 1.92 which is applicable to the seismic design of nuclear power reactors and that document specifically authorizes the use of the SRSS method.[7/] The NRC Staff apparently is relying solely on the views set forth in NUREG-0484 "Methodology for Combining Dynamic Responses" as its basis for its regulatory position.[8/] NUREG-0484 is a preliminary report on load combination methods,[9/] and the entire matter is still undergoing review by the Advisory Committee on Reactor Safeguards.[10/] Finally, a supplement to NUREG-0484 is under preparation which will likely approve a more extended use

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5/ Tr. 8228.

6/ Tr. 8227-28.

7/ Tr. 8227. Regulatory Guide 1.92, Revision is limited in its application to combining modal responses and spatial components in seismic response analyses for the design of nuclear power reactors.

8/ Tr. 8226-29.

9/ Tr. 8266-67, 8271.

10/ Tr. 8233-34.

of the SRSS method for combining dynamic responses.[11/] In these circumstances, NUREG-0484 is not enough standing alone to establish the validity of NRC Staff's position. It must be established through the testimony of expert witnesses.

4. Applicants presented four witnesses, viz., Drs. Robert P. Kennedy and Chittoor V. Subramanian and Messrs. Edward D. Fuller and Vaughn L. Conrad.[12/] Dr. Rohini K. Mattu[13/] and Mr. Steven A. Varga[14/] appeared on behalf of the NRC Staff. Mr. Dale G. Bridenbaugh appeared on behalf of Intervenors.[15/]

5. Designers of nuclear power reactors are required by 10 CFR Part 50, Appendix A, General Design Criterion 2. to reflect in designs the combined structural and mechanical responses due to various dynamic loads caused by postulated accidents, anticipated operating conditions and natural phenomena such as earthquakes. SRSS and AS are two methods for combining these dynamic responses. The SRSS method consists of squaring the peak value from each individual response, adding the squared values and taking the square root

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11/ Tr. 8234-39.

12/ The written testimony of all four witnesses follows Tr. 8113.

13/ Dr. Mattu sponsored NUREG-0484 "Methodology for Combining Dynamic Responses" into evidence as his testimony following Tr. 8221.

14/ Written testimony and supplemental testimony following Tr. 8221.

15/ Written testimony (pp. 13-14) following Tr. 7709.

of the sum.[16/] The AS method simply adds the peak dynamic responses together.[17/]

6. In deciding between the positions of the Applicants and the NRC Staff, we must carefully consider the weight to be accorded to the evidence submitted by the parties. The credentials of the Applicants' witnesses were particularly impressive, and we find they are qualified experts on the subject of load combination methodology and its application to the design of nuclear power reactors, and, in particular, Black Fox Station.[18/]

16/ Written testimony of Fuller, pp. 4-5.

17/ Id.

18/ Dr. Kennedy, a co-author with Dr. N. M. Newmark of the "Newmark-Kennedy Criteria" for the use of the SRSS method, has a Ph.D. in Structural Engineering from Stanford University. He has extensive experience in the structural design of nuclear and other facilities, particularly with respect to the treatment of load combinations in such designs. (Professional Qualifications, Attachment A to Dr. Kennedy's written testimony following Tr. 8113; 8148 and 8174-75). Mr. Fuller has a Masters Degree in Nuclear Engineering from Stanford University and he has had extensive experience in reactor design both while employed at the General Electric Company and as a consultant with S. Levy, Inc. (Professional Qualifications, Attachment I to Mr. Fuller's testimony on Contention 65 following Tr. 7112). Dr. Subramanian has a Ph.D. in Structural Engineering from the University of California, and he has had fourteen years of experience in structural and civil engineering, including seven years of experience in seismic and structural analysis and design for nuclear power plants. Dr. Subramanian is (i) a co-author with Dr. Kennedy of a report entitled "Technical Bases For The SRSS Method of Combining Dynamic Responses," (Attachment I to Mr. Fuller's testimony); and (ii) a co-author of a report, which determined the application of SRSS using the "Newmark-Kennedy Criteria," entitled "SRSS Application Criteria as Applied to Mark II Load Combination Cases," (Attachment II to Dr. Subramanian's testimony.)

Of the NRC Staff's two witnesses, only Dr. Mattu was qualified as an expert on the subject of load combination methodology. Mr. Varga candidly admitted that he was not such an expert.[19/] Further, Dr. Mattu's field of design experience and responsibility is in the area of reactor components and piping as opposed to reactor buildings and structures; and as a conquence his expertise on load combination methods is limited to combining dynamic loads as they affect components and piping.[20/] We find that Dr. Mattu's views and testimony on load combination methods as they apply to reactor component and piping design are entitled to weight as expert opinion. The NRC Staff offered no witness on the application of load combination methods to the design of reactor buildings and structures.

7. The origin of the SRSS method of response combination is found in the technical literature and it has been subject of study, investigation and analysis by structural engineers and designers for over twenty-five years,[21/] and a statistical basis has been established for the method.[22/] Since 1960, SRSS has been used extensively for earthquake design analyses for building structures.[23/] The SRSS method has

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19/ Tr. 8226.

20/ Professional Qualifications of Dr. Mattu following Tr. 8221; and Tr. 8242.

21/ Written testimony of Kennedy, pp. 4-6.

22/ Id. at Attachment B.

23/ Written testimony of Kennedy, pp.3-8.

been used in connection with the seismic design of nuclear power reactors since 1965;[24/] and that methodology has been accepted by the NRC Staff, and it is being used at the present time.[25/]

8. It is the extension of the SRSS method in reactor design to the combination of dynamic responses due to various dynamic loads caused by postulated accidents and anticipated operating conditions that presents the instant controversy. Applicants offer substantial justification for their position. Applicants testified that the response combination method should only preserve the conservatism incorporated in the course of other steps in the design process. Adding conservatism to the design process by using AS, we are told, is unreliable and upsets the concept of a balanced or optimum design. An optimum design is one where the need for strength in the facility to accommodate primary dynamic stresses from, for example, seismic loads is balanced against the need for flexibility to accommodate thermal expansion stresses under normal operating conditions.[26/] Despite extensive cross-examination, the conviction of Applicants' witnesses to these premises remained unshaken.[27/] Moreover, the NRC Staff's expert agreed with the concept of an optimum

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24/ Written testimony of Kennedy at 8.

25/ Regulatory Guide 1.92, Revision 1; Tr. 8226-27.

26/ Written testimony of Kennedy, pp. 12-14; and written testimony of Fuller, pp. 12-14 and Section A.6 of Attachment I.

27/ Tr. 8119-23, 8149, 8152-54, 8167-70, 8173-78, 8185-86 and 8208-10 (Kennedy); and 8124-28 and 8210-11 (Fuller).

design[28/] and he also agreed with Dr. Kennedy that the load combination method was not the proper point in the design process to add conservatism.[29/]

9. In answer to any suggestion that the additional conservatism which might be derived from the AS method was needed, Mr. Fuller testified that the dynamic reserve margin present in the design of nuclear plants assures that no adverse consequences in structural integrity results in the unlikely event[30/] the actual peak combined exceeds the SRSS value.[31/] He also testified that the dynamic loads of concern, i.e., loss of coolant accident loads, safety relief valve actuation loads and earthquake loads, are conservatively defined for BWR power plant design.[32/]

10. In response to the statements in NUREG-0484 concerning the need for additional information and a better understanding of the application of the SRSS method, Drs. Kennedy and Newmark developed a set of criteria in August, 1978, (hereinafter referred to as the "Criteria") for the

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28/ Applicants' Exhibit No. 42, introduced into evidence at Tr. 8255, and Tr. 8252-62, 8269-70, 8281-83.

29/ Tr. 8288.

30/ The basis for the low likelihood that the SRSS value will be exceeded is set forth in the written testimony of Fuller, pp. 10-11, and Section 4. and Appendix A of Attachment I.

31/ Id. at 7-10, Section 5. of Attachment I and Attachment II. The latter document was co-authored by Dr. Kennedy.

32/ Written testimony of Fuller, pp. 11-12. See also the written testimony of Sobon and Guyot following Tr. 7546 concerning the load definitions for the Black Fox Station.

use of SRSS.[33/] Neither the NRC Staff nor Intervenors offered any direct testimony that controverted these Criteria. Moreover, the validity of these Criteria was not impugned by hostile cross-examination. In these circumstances, we have reviewed the Criteria, and find they are founded on and are an extension of the earthquake engineering experience discussed supra in Paragraph 7.[34/]--experience that has been accepted and embraced by the NRC Staff. Under Criterion 1., a nuclear power plant designer would compare the important time history characteristics for earthquakes with those for other transient inputs (such as from a postulated loss-of-coolant accident). If the comparison showed sufficient similarity, the SRSS method could be used to combine the dynamic responses under consideration.[35/] Likewise under Criterion 2., earthquake engineering provides the basis for establishing conditions which, if met, warrants the use of the SRSS method for combining the dynamic responses under consideration.[36/] The methods are mutually exclusive and

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33/ Written testimony of Kennedy, pp. 8-9.

34/ Id. at 9-12.

35/ Id. at 14-17.

36/ Id. at 17-20.

the satisfaction of either warrants the use of SRSS.[37/] We find that the Criteria are logically a proper extension of earthquake engineering, and that they provide a valid tool for the application of the SRSS method.

11. Dr. Subramanian's testimony was not controverted by either the NRC Staff or Intervenors. Our review of his testimony discloses that he provides the vital link between the generic Criteria developed by Kennedy and Newmark and its application to the Black Fox Station. He first determined that the Criteria applied to so-called Mark II plants.[38/] Based on the Mark II study (Attachment II of his testimony), Dr. Subramanian concluded that the Criteria can be successfully applied to determine the acceptability of combining dynamic responses using SRSS methodology for the design of the Black Fox Station, a Mark III plant.[39/] His conclusion was based on (i) the similarity of the input loading phenomena[40/], and structural characteristics and responses[41/] between Mark II and Mark III plants, and (ii) the fact that illustrative examples of Mark III load cases were shown to meet the Criteria.[42/] We find that the Criteria have application to the Black Fox Station.

37/ Written testimony of Kennedy at p. 10.

38/ Written testimony of Subramanian, pp. 2-3, and Attachment II.

39/ Written testimony of Subramanian, p. 12.

40/ Id. at 4-8.

41/ Id. at 8-9.

42/ Id. at 10-12, including tables and figures.

12. Our understanding of the NRC Staff's position is that SRSS is acceptable for combining SSE and LOCA loads within the Reactor Coolant Pressure Boundary and its supports. The extension of SRSS to the balance of the plant for the SSE and LOCA combination and for other load combinations throughout the facility requires an appropriate basis yet to be developed. However, this position is preliminary and the NRC Staff is studying the matter further and it is likely that it soon will expand the application of SRSS.[43/]

13. During the course of cross-examination, Dr. Mattu candidly pointed out discrepancies in NUREG-0484, his adopted testimony. First, Dr. Mattu admitted there was no technical reason for not permitting the use of SRSS for combining SSE and LOCA for the design of components and piping throughout the reactor plant.[44/] In essence, the arbitrary cut-off at the Reactor Coolant Pressure Boundary was necessitated by a lack of time.[45/] We note that NUREG-0484 does not offer this explanation. Second, Dr. Mattu testified that for the design of components and piping, it may be appropriate, in his judgment, to combine OBE and SRV

43/ Written testimony of Mattu, pp. 11, 14-15; Tr. 8226-39.

44/ Tr. 8242.

45/ Tr. 8241-42.

by the SRSS method,[46/] and that the matter would be addressed in the Supplement to NUREG-0484.[47/] Finally, and of significance, is the fact that Dr. Mattu's views were ignored during the development of NUREG-0484. His specific and strong suggestion was that the report should be revised to state:

> "The use of ABS method may result in more rigid systems which is not beneficial when the design must consider thermal stresses."

and

> "SRSS represents a way of designing a less rigid system than ABS and thus permits a degree of design optimization when thermal stresses are present and rigidity is not desirable."[48/]

These recommendations were not included in NUREG-0484 and no explanation was offered for their conclusion. Dr. Mattu still holds to these views and he believes they should be included in the report at the present time.[49/] Moreover, as indicated supra in Paragraph 8., Dr. Mattu, the only expert witness offered by the NRC Staff, agrees and accepts Applicants' position on the use of SRSS to achieve an

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46/ Tr. 8250-52.

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47/ Tr. 8252.

48/ Applicants' Exhibit No. 42.

49/ Tr. 8253-54, 8269-70.

optimum design; and he also embraces Dr. Kennedy's view that the load combination method should preserve the conservatism included in the other design steps and not attempt to do so through the choice of method.[50/]

14. Based on our review of the hearing record, we are compelled by the weight of the evidence, to find in favor of the Applicants. Specifically, we find that (i) the Applicants have provided substantial bases for the use of SRSS to combine dynamic responses due to loads from postulated accidents, operating conditions and natural phenomena, (ii) the testimony of the expert witness for the NRC Staff supports the Applicants' position, and (iii) that the fact that the NRC Staff is considering the load combination method question generically does not excuse them from carrying their burden of going forward to substantiate their position in this case. We therefore reject the recommendation of the NRC Staff to condition the construction permits and, instead, accept the commitment of the Applicants as articulated in Mr. Conrad's testimony. This same commitment was included in the PSAR by Amendment 15,[51/] and, therefore, we see no need to include the commitment as an express condition of the construction permit documents.

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50/ See supra n. 28-29.

51/ Applicants' Exhibit No. 38.

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Western Farmers Electric Cooperative	)	
	)	
(Black Fox Station, Units 1 and 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing NOTICE OF FILING; and APPLICANTS' PROPOSED FINDINGS OF FACT CONCERNING LOAD COMBINATION METHODOLOGY has been served on each of the following persons by deposit in the United States mail, first class postage prepaid, this 28th day of March, 1979.

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