TOPICAL REPORT EVALUATION

REPORT TITLE: Technical Basis for the Use of the Square Root of the Sum of Squares (SRSS) Method for Combining Dynamic Loads for Mark II Plants

ORIGINATING: The General Electric Company (GE)

REPORT NO.: NEDE-24010-P, July 1977
NEDO-24010-1, Supplement 1, October 1978
NEDO-24010-2, Supplement 2, December 1978
NEDO-24010-3, Supplement 3, August 1979

REVIEWED BY: Mechanical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
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SUMMARY OF TOPICAL REPORT:

Plants may be subjected to the results of dynamic events which are postulated to occur simultaneously such as earthquakes, loss of coolant accident, and loads resulting from the hydrodynamic effects of discharges to a suppression pool. The response of the load resulting from each event is computed separately. The peaks of these responses must subsequently be combined in a rational manner, so that a safe and yet not overly conservative design is achieved.

The subject topical report was prepared by the General Electric Company for the Mark II Owners. The purpose of the report is to justify the use of the Square Root of the Sum of Squares (SRSS) method for combining Mark II dynamic responses. Statistical studies were conducted. Numerical examples using actual Mark II dynamic responses were investigated. In addition, two generic criteria for judging the applicability of the SRSS method, the so-called "Kennedy Newmark Criteria" were developed.

GE Topical Report NEDE-24010-P concludes that the SRSS method is applicable to Mark II plants on the following bases:

1. The probability of having the maximum combined response exceeding the SRSS value is generally low.

2. The probability of having a simultaneous occurrence of several dynamic events is very low.

3. The use of the SRSS method instead of the absolute sum method has negligible effects on structural reliability, and may even be beneficial for piping systems if flexibility is required.

SUMMARY OF REGULATORY EVALUATION:

A. Introduction:

Due to the lack of rigorous mathematical proof of the SRSS method, the potential generic applicability for all plants in addition to the intended application of the SRSS method for Mark II plants, the review conducted by the staff of Mechanical Engineering Branch (MEB) emphasized the following aspects:

1. Can SRSS be justified as a generic rule for combining any dynamic responses?

2. If not, can there be generic criteria adopted or developed to provide guidance for its application?

3. To what extent may the SRSS method be used for Mark II mechanical systems?

The Mechanical Engineering Branch contracted with the Brookhaven National Laboratory (BNL) to perform specific portions of the review.

Since the information required to reach a quantitative conclusion on the subjects of event probability and reliability, included in GE Topical

Report NEDE 24010-P, was insufficient in that topical report, the staff review was limited to the non-exceedance of the response level of SRSS combinations. The scope of MEB evaluation concentrated on the applicability of the SRSS methodology to mechanical systems and components and does not include its applicability to structures.

B. BNL was requested to perform the following review:

1. Generic review:

(a) Perform a parametric study of dynamic response combination characteristics, using Monte Carlo simulations and Cumulative Distribution Functions (CDF).

(b) Investigate and develop methods and criteria needed for appropriate combination of dynamic responses.

2. Mark II Specific review:

(a) Study the validity, adequacy, limitations and applicability of the "Kennedy Newmark Criteria", the two criteria proposed by the Mark II Owners which appear in NEDO-24010-2.

(b) Verify the acceptability of using the SRSS method for Mark II mechanical systems by generating CDFs from the digitized Mark II response functions supplied by the Mark II Owners.

C. BNL and NRC staff Evaluation and Conclusions:

BNL has completed its contractual studies and the results of its review is presented in NUREG/CR-1330, "Review of Methods and Criteria for Dynamic Combination in Piping Systems" issued in March 1980. The staff evaluation of NUREG/CR-1330 concludes the following:

1. As a result of the BNL parametric studies, the probability of not having the maximum combined response more than the SRSS value, (i.e. - the non-exceedance probability (NEP) of the SRSS value) was found to vary from case to case and is effected by several parameters including frequency content, frequency ratio and amplitude duration . This indicates that the SRSS method should not be accepted as a universal rule for combining dynamic responses without investigating the nature of the response functions. However, we also observed that cases with low NEP are generally extreme, and are not typical of the usual practical application.

2. Kennedy Newmark Criterion No. 1 proposes that SRSS may be used if either the load or the response functions are earthquake like, which means they have zero mean, are uncorrelated, are of short duration and have less than a specified number of peaks exceeding certain levels.

   The BNL studies demonstrate that Criterion No. 1 cannot be applied generically, since the nature of response functions may be drastically different from the loading function. Functions with wider peaks, even less in number, may significantly influence and cause a lower NEP than a function with narrow peaks. Response functions to certain dynamic loads may have non-zero means. Guidance to deal with such circumstances was not provided in Criterion No. 1. The requirement for uncorrelated functions specified in Criterion No. 1 appears to be irrelevant with respect to NEP if the random time lag of the response functions is considered. BNL utilized simulated numerical examples in its review, which resulted in NEP's far below 50% even though Criterion #1 is met.

   The staff concurs with the BNL conclusions and believes that Criterion #1 in its originally presented form is unacceptable for generic application.

3. Kennedy Newmark Criterion No. 2 proposes that SRSS may be used if the NEP of the combined response at the SRSS level and the slope of CDF curve in the critical range meet specified requirements.

   The BNL work on the response functions evaluated, demonstrated agreement with criterion No. 2 via their independent numerical results, although they feel that the number of examples verified were somewhat limited, and they believe the method of CDF curve construction requires additional guidance. The BNL conclusion was that 84% or greater was an acceptable value for the NEP of the combined response at the SRSS level, and that this value is approximately equivalent to the mean plus one standard deviation.

   The staff evaluation of the General Electric and BNL studies has concluded that Criterion No. 2 is acceptable for generic application. This is based on the BNL numerical results, and the General Electric work supplemented by the additional justification in the report "An Analytical Method for Determining the Probability Distribution of the Maximum of Combined Response", by MIT Professor C. A. Cornell dated December 1979. We have reviewed the BNL recommendations for constructing the CDF curves and their conclusions on the 84% acceptable NEP level, and find both are acceptable.

4. The GE topical report NEDE-24010-P investigated the SRSS applicability for combining representative response functions of Mark II structures and components under specific dynamic loads of Mark II plants. The results indicate that an average NEP of 86% is achieved.

   BNL made an independent assessment of the GE results based on digitized response functions of Mark II mechanical systems. BNL results verify that the use of SRSS does represent a high level of NEP in the Mark II cases.

Based on the above confirmation, the staff evaluation concludes that the use of the SRSS method for combining responses is acceptable without additional justification for the mechanical systems in the Mark II plants under the dynamic loads specified in NEDE-24010-P. Since the applicability of the SRSS method may vary if either the plant structure or the nature of dynamic loads varies from the specified conditions in NEDE 24010-P, Mark II or other users of the SRSS methodology should demonstrate the appropriateness of such methodology for combining their mechanical system responses wherever their loads or structures are different from those investigated.

5. The BNL studies also indicate that for cases combining more than two dynamic responses, the use of SRSS method causes a very high level of NEP. The staff evaluation concludes that the use of SRSS method is acceptable for combining more than two dynamic responses.

REGULATORY POSITION:

The Regulatory Staff, based on findings of the BNL studies delineated in NUREG/CR-1330, has evaluated the acceptability of GE topical report NEDE-24010-P and its three supplements. The following are the NRC positions regarding acceptable methods for combining dynamic responses in mechanical systems and components.

A. The structural integrity of systems and components subjected to a combination of various events should be evaluated by considering a combination of the response of the systems and components rather than a combination of the loading events.

B. To consider a combination method other than absolute sum, all response functions to be combined should have the following characteristics:

1. Function is rapidly varying with time.

2. Duration of the strong motion portion is short.

3. Phasing relationship due to time lag among functions is random.

4. Response is calculated on a linear elastic basis.

C. The SRSS method may be used for combining the dynamic responses to LOCA and SSE within the reactor coolant pressure boundary and its supports and all ASME Class 1, 2, and 3 piping systems within the constraints of the latest revision of NUREG-0484.[1/]

D. The SRSS method may be used for combining more than two dynamic responses.

E. (1) For Mark II plants, the SRSS method may be used for combining responses to those loads identified in NEDE-24010-P without additional justification.

(2) For Mark II plants either having a higher seismic loading level or using a different containment structure than those evaluated in NEDE-24010-P, additional justification is required to verify the applicability of NEDE-24010-P.

F. For combining responses to dynamic loads other than those specified in C, D, and E above, the SRSS method may be used provided justification is furnished to the staff demonstrating that a NEP of 84% or higher is achieved for the combined SRSS response.

One acceptable approach to demonstrate that a value for the NEP of the combined SRSS response equal to or greater than 84% has been achieved is to meet all the following conditions:

[1/] Currently NUREG 0484 Rev. 1

(a) Define loads at approximately the 84 percentile or 1.15 times the median, whichever is greater.

(b) The SRSS value of the response combination, assuming only time lag randomness, has a NEP $\geq$ 50% from the CDF curve.

(c) 1.2 times the SRSS value of the response combination, assuming only time lag randomness, has a NEP $\geq$ 85% from the CDF curve.

In constructing the CDF curves, the recommendations of BNL presented in NUREG/CR-1330 should be used. Those Mark II plants referencing NEDE-24010-P need not reconstruct their CDF curves, since the conclusions of the BNL studies for the response involved indicated no change in the final result. In future submissions for other plant applications, the method for constructing CDF curves presented in NUREG/CR 1330 is the method which should be used.

G. For any case not meeting any of the criteria stated in C, D, E, and F, responses shall be combined by absolute sum.