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September 23, 1981

NUCLEAR PRODUCTION DEPARTMENT

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Attention: Mr. Harold R. Denton, Director

Dear Mr. Denton:

SUBJECT: Grand Gulf Nuclear Station
Units 1 and 2
Docket Nos. 50-416 and 50-417
File 0260/L-334.0/L-350.0
Response to Structural Engineering Branch Request for Additional Information; Damping Value for Cable Tray Design, SER 1.9(1)
AECM-81/357

A meeting was held August 17, 1981, between Mississippi Power & Light Company, Bechtel, and staff members from the Structural Engineering Branch which generated a request for additional information pertaining to cable tray tests.

Attached are six responses to informal questions on cable tray testing. The responses reference sections, figures, etc., in the test report entitled, "Cable Tray and Conduit Raceway Seismic Test Program," 1053-21.4. This program was first presented in a meeting between Bechtel Power Corporation and the NRC held on January 8, 1980. To followup Bechtel's presentation on the cable tray and conduit raceway test program, Bechtel submitted, under separate cover, four volumes of the test report prepared by ANCO Engineers as documented in letter from R. J. Kosiba to Dr. F. Schauer dated January 21, 1980, and again, under separate cover, Volume 3 of the report was submitted as documented in letter from R. J. Kosiba to Dr. F. Schauer dated July 25, 1980. The information presented herein is in direct response to the Grand Gulf Safety Evaluation Report (NUREG-0831, September 1981) item 1.9(1).

The concerns pertaining to the cable tray and conduit raceway test program were directed to MP&L informally by the Structural Engineering Branch (SEB). These responses are provided for information only and will not be incorporated into the Grand Gulf Final Safety Analysis Report (FSAR).

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If you have any questions or require further assistance, please contact this office.

Yours truly,

L. F. Dale
Manager of Nuclear Services

RFP/JGC/JDR:lm
Attachments

cc: Mr. N. L. Stampley
Mr. G. B. Taylor
Mr. R. B. McGehee
Mr. T. B. Conner

Mr. Victor Stello, Jr., Director
Office of Inspection & Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

AE3I2

QUESTION:

1. Provide a discussion on how major cable tray test results were used in arriving at the 20% modal damping. The discussion sculd assure consistency of observed data and calculations used.

RESPONSE:

In a linear dynamic analysis, velocity dependent forces (i.e., viscous damping) are introduced to account for various mechanisms of energy dissipation. These mechanisms include such things as; friction and slip in bolted connections, hysteresis, radiation of energy away from a foundation, the effects of fluids, and other mechanisms as well. Since these various mechanisms cannot be accounted for explicitly in a linear analysis, their effect is lumped in a single viscous damping. Dynamic testing is used to determine an effective viscous damping, appropriate for seismic response. This procedure is common to all structural dynamic analysis.

During the cable tray and conduit raceway test program, the random vibration of cables was identified as one of the significant energy dissipating mechanisms. This occurred because the cables represent most of the mass of the system, are able to move relative to each other, and were not rigidly attached to the supporting tray. During the tests, this phenomennon manifested itself as a noticable relative movement and impact of the cables within the tray. As is the case with other energy dissipating mechanisms, this effect was quantified in terms of an equivalent viscous damping based upon the relationship between the recorded response and the applied input to each test specimen. The test report entitled, "Cable Tray and Conduit Raceway Seismic Test Program," provides a detailed discussion of the methods used to compute an equivalent viscous damping from the recorded results of the dynamic tests. This discussion can be found in Section 5 with supplementary information in Appendices G, H, and I.

The computed damping values from the various tests are tabulated in Appendix K of the test report. Data was taken from these tables and plotted as shown in Figure 39-1 (Attached). On this figure, the data points of computed equivalent viscous damping are plotted as function of input acceleration (floor spectrum ZPA) for over 100 tests of various braced strut hanger tray systems. These results represent all the data from simulated earthquake inputs. Low level sinusoidal and snap back test data are not included since they are not directly applicable. Since these tests represented a wide variety of tray type, connection details, struts, and cable configuration, there is a broad scatter in the data. These data, however, do clearly show that the recorded responses of the tested tray systems is best described by a dynamic system with an equivalent viscous damping. It should be noted that the data realistically can be utilized with accepted curve fitting techniques to obtain a "best-fit" curve which reflects the statistical average of the test data. Such an approach would result in a maximum damping value far in excess of the conservative 20% value. However, in the interest of conservatism, a bilinear curve, which effectively bounds the lower end of nearly all the points, was utilized. This curve, given in Figure 39-1, represents the recommended design values of equivalent viscous damping.

In addition to the determination of equivalent viscous damping, as described in the test report, linear analysis was performed on finite element models of several of the tray system test setups. These analyses confirmed that a very high viscous damping was required in order to predict responses similar to those recorded during the dynamic testing. These analyses confirmed that the application of the damping values recommended for design in a linear analysis was consistent with the results of the test program and, therefore, would result in a conservative design of support systems.

QUESTION:

2. Why was cable tray test input loading applied at a 45° angle instead of simultaneous horizontal and vertical load input? What are the implications of this testing method upon the validity of the recommended 20% sampling (e.g., with respect to statistical independency requirements of different directional inputs)?

RESPONSE:

The cable tray and conduit raceway test input loading was applied at 45° (vector biaxial) because the shake table used was limited to vector biaxial motion. In choosing the 45° relationship (i.e., horizontal equals vertical), the floor response spectra of many containments and auxiliary buildings were reviewed and this equality of horizontal and vertical motion was deemed most appropriate.

IEEE-344 and NRC regulatory guides recommend, but do not require, independent biaxial input. In the case of raceways, the modes of vibration are symmetrical and are dominantly either horizontal or vertical and so would be adequately excited by vector biaxial motion. As the different modes of a given raceway generally have quite distinct resonant frequencies, there is no problem introduced by the zero phase between horizontal and vertical loading (i.e., vertical and horizontal responses will be randomly varying in and out of phase even though the vertical and horizontal inputs are in phase). Independent biaxial input is preferred in non-symmetrical cases and in the possible but unusual case of testing a structure with a mode whose axis if sensitivity would be at 90° to the vector biaxial input, and hence not excited. The raceways are simple structure systems with distinct vertical, transverse, and longitudinal modes; this was confirmed during testing. Therefore, the test results are not affected by the use of vector biaxial input.

As described above, widely spaced modes of vibration with little cross coupling were observed during the testing. For example, longitudinal swaying modes were quite low (1.8 Hz), transverse modes followed (3.2 Hz) with tray modes following at 6.1 and 15 Hz for a typical 4'6" single tier unbraced raceway. This data is illustrated in Figures 7.8 and 7.13 of Volume 1 for a 100% cable loaded raceway of 0.10 g peak response. Similar frequency ratios for longer strut hung raceways are illustrated in relevant data.

The purpose of the able tray test program was essentially to verify the mathematical model used in the analysis, not to seismically qualify the raceway systems by testing only.

QUESTION:

3. Will sprayed-on fireproofing affect cable friction and thus the damping ratios?

RESPONSE:

Yes. However, Grand Gulf does not use sprayed on fireproofing.

QUESTION:

4. The cable tray test conditions do not reflect the actual physical site situation. Provide the rationale for extending the test results to the actual design which is different from the test configuration.

RESPONSE:

The test fixture used to test cable trays was specifically designed for this test program. Its inverted pendulum design permitted siesmic input to suspended tray support systems. Additionally, the fixture was designed to accommodate a 40 foot long tray system segment of up to 5 tiers and a hanger of up to 13 feet in length. Sufficient width was provided in the test bay to accommodate two parallel runs, including cross connections and attached conduit. This facility allowed for testing of long multitiered tray systems with various bracing arrangements.

The test program included tests of a large number of varied tray types and support types in various configurations. These test configurations were used during the testing program in order to simulate the actual field installed conditions. Supports with or without bracing and with multitier cable trays were tested. In addition, a combined system configuration comprised of various tray fittings such as tees, elbow, vertical bend, and multitiers of straight cable tray runs was tested. In view of the scope of the testing and the various test setups, it was concluded that these tests do actually simulate conditions encountered in the field and, therefore, the results of the testing would be applicable to the design of cable trays at Grand Gulf.

QUESTION:

5. Specify different conditions under which different modal damping ratios ranging from 7-20% are used. (cable tray)

RESPONSE:

Damping of the cable tray system is dependent on the amount of cable in the trays and the input amplitude of vibration. Figure 43-1 presents the lower bound values of equivalent viscous damping as a function of input floor response spectrum ZPA and the amount of cable in the tray. To be able to use the maximum value of damping, 20%, the instructure response spectra must have a ZPA value of at least 0.35g and the tray must be at least 50% full, by weight, of cable.

QUESTION:

6. It appears that the scope of the cable tray test and the number of test.. ?ay not support direct extension to the Grand Gulf cable tray design. Justify that the scope of test conducted is adequate for direct design application.

RESPONSE:

The scope of the cable tray and conduit raceway test program included the evaluation of a large number of variables in the design of cable trays. Included in the test report are discussions of the following variables:

- Type of tray
- Type and length of hanger
- Location of splices
- Number of tiers
- Trapeze and cantilever support
- Connection details such as
  - single clip angle
  - double clip angle
  - gusseted clip
  - tray to strut type hanger
- Type and location of bracing
- Amount of cable fill
- Size and distribution of cables
- Cable ties
- Combined conduit and tray systems
- Sprayed fire protection material

In order to evaluate the effects of these and other variables, over 2000 individual dynamic vibration tests were performed over a period of 11 months of testing. As a result of these tests, over 50 volumes of raw data were generated and evaluated. The results of the evaluation of these data form the basis for the conclusion contained in the test report and the design recommendations implemented in the Grand Gulf design.

In addition to the wide range of variables that were evaluated, tests were performed on tray and strut systems similar to the Grand Gulf design.

As a result of the evaluation of the variables described above and the testing of hardware and support configurations similar to the Grand Gulf design, a set of design recommendations were formulated. These recommendations were developed to be generally applicable to a wide variety of hardware and specifically applicable to the support configurations used by this project and the other test program participants. For example, the recommended damping from the data of over 100 dynamic tests on this type of system. Figure 39-1 shows the recommended damping as a function of floor acceleration in the form of a bilinear curve. As can be seen from this curve, the recommended damping for the most part, represents a lower bound of all the data obtained from the test program. Similar conservative recommendations were formulated from the results of the test program for other aspects of design. Consequently, it is concluded that the design recommendations formulated as a result of the cable tray and conduit raceway test program are broadly applicable to the design of strut supported raceway systems and were conservatively applied in the design of the Grand Gulf raceway supports.

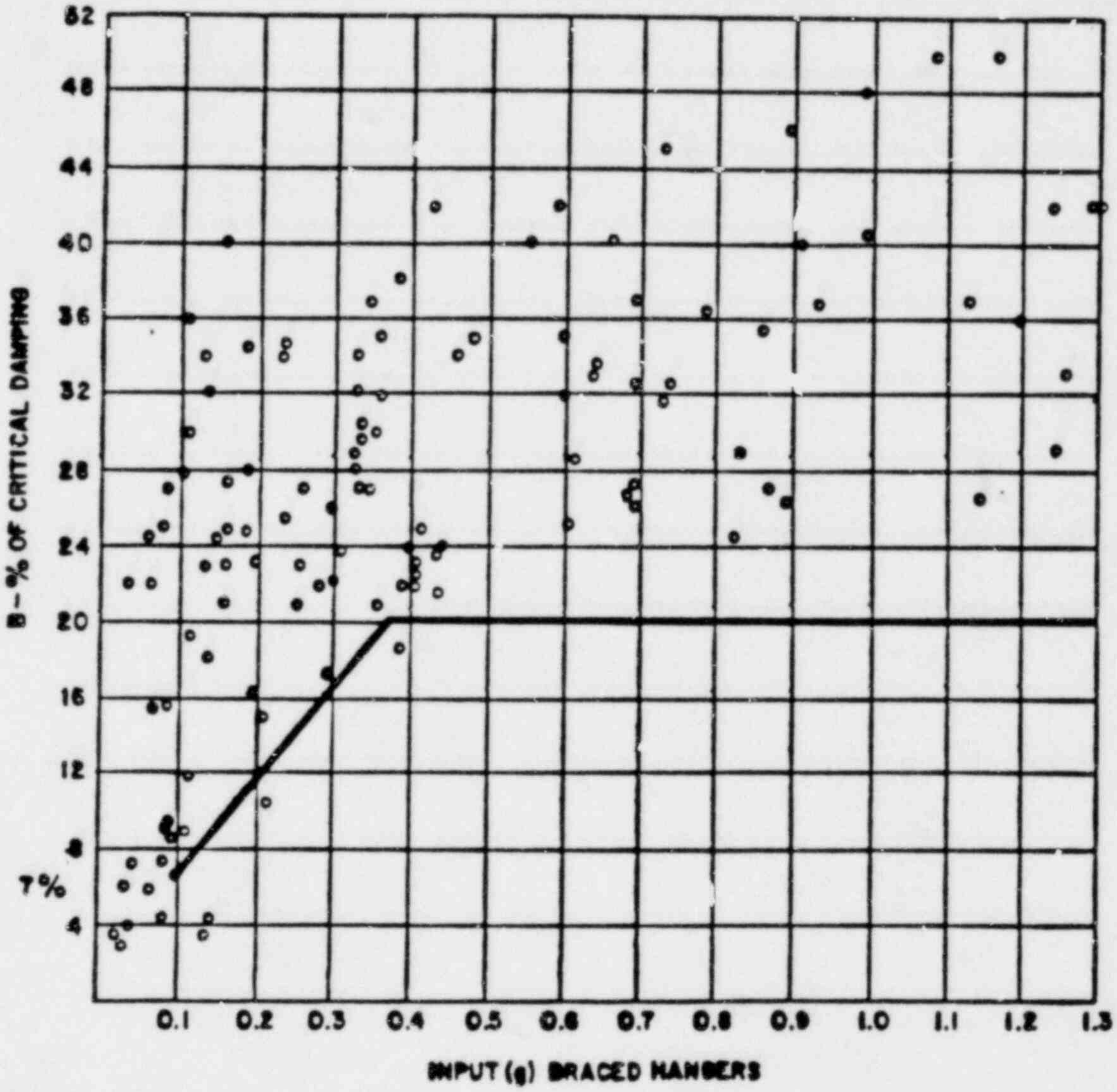

FIGURE 39-1 DAMPING VS. INPUT LEVEL FOR BRACED HANGER SYSTEMS

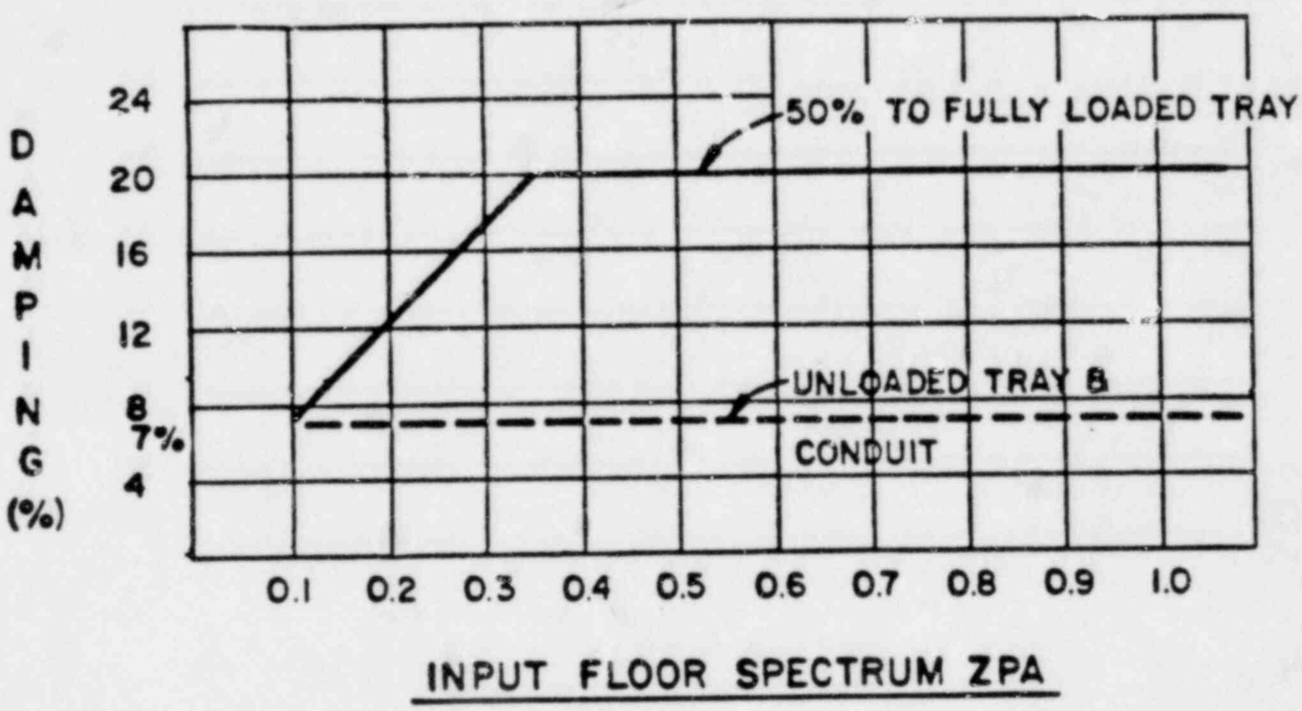

FIGURE 43-1 LOWER BOUND DAMPING AS A FUNCTION OF INPUT ZPA