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March 4, 1985
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Office of Nuclear Reactor Regulation
Attn: J. F. Stolz, Chief
Operating Reactors Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Stolz:

Three Mile Island Nuclear Station Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289
Damping Values for Conduit/Cable Tray Supports

Recently a study of the seismic performance capability of Class 1E cable tray and conduit raceway systems was performed for the Systematic Evaluation Program (SEP) Owners Group of which GPUN is a member. The results of this study were published in a document prepared by URS/John A. Blume and Associates, entitled "Seismic Evaluation of Electrical Raceway Systems". One of the highlights of the study was the investigation into the high damping effects of raceways, including their source and trends. Additionally, this report presented recommended damping levels to be used for analysis of raceway systems. Figure 2.15 of the attached paragraph 2.5 of the report indicates that a minimum 7% equipment damping is recommended for conduit and unloaded cable tray raceways with multiple supports.

Section 5.2.1.2.11 of the Updated FSAR currently indicates that for assemblies and structures which are bolted or riveted, the percent of critical damping is 2.5. For welded structures and assemblies the percent of critical damping is 1.0. In light of this recent report, Regulatory Guide 1.61 and IEEE Standard 344-1975 (both of which indicate OBE and SSE damping values of 2 and 4% for welded steel structures and 4 and 7% for bolted structures, respectively) the FSAR values appear to be needlessly conservative. Therefore, GPUN intends to apply floor response spectra curves for OBE and SSE values with 2 and 4% welded steel structure damping and 4 and 7% bolted steel structure damping respectively for conduit, conduit supports, cable trays and cable tray

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supports. Further, GPUN has performed a 10CFR50.59 evaluation of these damping values and determined that there are no unreviewed safety questions or Tech. Spec. changes required. GPUN plans to change the FSAR to indicate these values in the above referenced section for the 1986 update.

Sincerely,

H. D. Hukill
Director TMI-1

HDH/lr:1481f

cc: R. Conte
J. Van Vliet

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URS

ANALYTICAL TECHNIQUES, MODELS, AND SEISMIC EVALUATION OF ELECTRICAL RACEWAY SYSTEMS

prepared for

The SEP Owners Group
Under the Direction of
KMC, Incorporated
Washington, D.C.

prepared by

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plants' rod-hung raceways is 12 in. Allowing for the depth of the cross-member and the thickness of the connecting nuts, the typical intertier rod length is about 10 in. The lower dotted line in the figures corresponds to an L_i of 10 in. for the above parameter values. For raceways with no stiffness (no end restraints and $\hat{K}_B = 0$), the figures show (intersection of dotted line with solid line) that intertier displacement can be ignored for a two-tier system with L_1 greater than 19 in., for a three-tier system with L_1 greater than 26 in., and for a four-tier system with L_1 greater than 35 in. If the raceway system is braced ($\hat{K}_B > 0$), the region of applicability of the BOEF model expands. For example, for $\hat{K}_B = 1$, the minimum acceptable value of L_1 decreases to 18 in. for a two-tier system, 22 in. for a three-tier system, and 25 in. for a four-tier system. Also plotted in the figures is the line corresponding to $L_i = 20$ in. As can be seen, increasing L_i significantly reduces the region of applicability of the assumption.

From Figure 1.1 it can be seen that 75% of the hangers surveyed have a height of 2 ft or more ($L_1 \equiv 22$ in.). For a three-tier system (78% of the hangers have no more than three tiers) with a 50-ft-long end-restrained span with ladder trays ($GA = 20{,}000$ lb), $\hat{K}_B = 0.88$. Using Figure 2.10, the above parameter values, and the typical L_i value of 10 in., one will find that such systems can be adequately evaluated while ignoring the intertier displacement.

Although Figures 2.9 through 2.11 apply to a specific range of parameter values, they show that the assumption is appropriate for a significant amount of realistic raceway geometries, as characterized by the hanger statistics accumulated during the plant visits and summarized in Figure 1.1.

2.5 Damping of Raceway Systems

Raceways, particularly cabletray raceways, differ from typical structures in that the mass of the structure (cables) is not integral with the stiffness elements (hangers and trays). As a result, under dynamic loading there is a relative displacement between the cables and the tray and hangers. That relative displacement is not accounted for in the assumptions under which the equations for frequency and mode shape were derived. However, because these equations have yielded analytical frequencies and mode shapes that match the test results, the effect of that relative displacement can be accounted for by the damping value assumed for the dynamic model. The damping value wil both represent a "true" damping phenomenon and approximate the more complex dynamics implied by the relative displacement between cable and tray. This section discusses the damping behavior of raceway systems as developed from shaking-table testing of representative raceway systems.

The amount of apparent damping in the system is expected to be influenced by two factors: the relative motion between the cables and the tray, and the amount of cables in the tray (cable fill). The amount of relative motion is assumed to be a function of the level of lateral acceleration of the raceway system. That level of acceleration is quantified as the average peak response acceleration (A_B) of the raceway specimen as defined by Equation 2.20. As an example, consider shaking-table Test 46, presented in Reference 1. The test specimen was a two-tier, rod-hung tray system with cable fill of 50 lb/ft/tray and fixed at both ends. Analysis of the test results showed single-mode response with a frequency of 2.4 Hz, a sinusoidal mode shape, and a 1.7-in. peak displacement at the center of the span. When the mode shape is normalized to unit peak displacement, the average peak response acceleration is:

$$A_B = \frac{1}{L}\int_0^L \Delta_{max}\ \omega^2\phi(x)dx \qquad (2.20)$$

$$= \frac{\Delta_{max}\,\omega^2}{L}\int_0^L \sin\frac{\pi x}{L}\,dx = 0.64g$$

Rod-Supported Systems. The damping (d), as determined in Reference 1, is plotted against the average peak response acceleration (A_B) in Figure 2.12 for all rod-supported tray specimens tested, except those in Tests 38-40 of Phase I and Tests 85-89 and 95-108 of Phase II. The plotting symbols denote the amount of cable fill and whether the test specimen was restrained at its end.

Several facts are apparent from Figure 2.12. First, unrestrained specimens are less damped than restrained specimens responding at the same level of acceleration. This difference can be attributed to the tray deformation

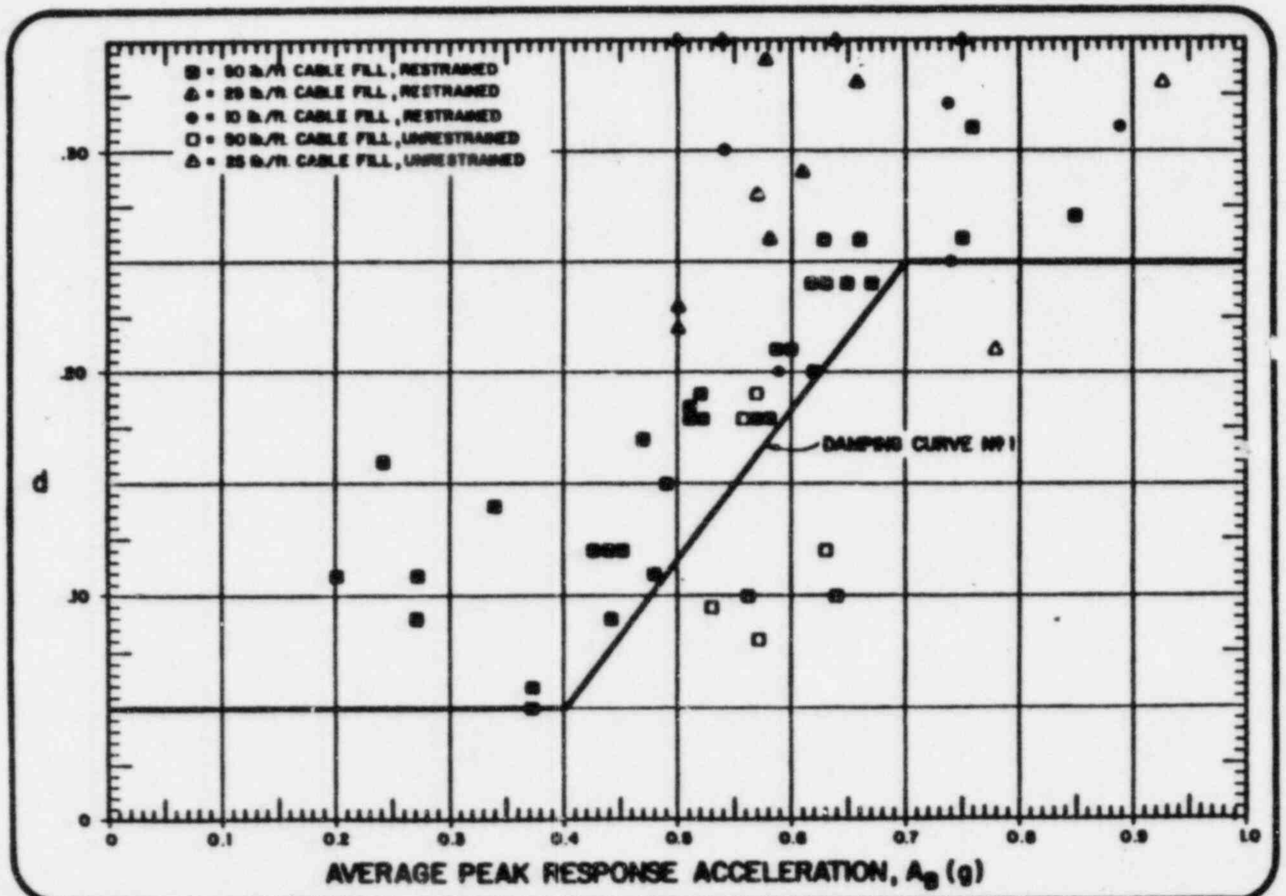


FIGURE 2.12 BEHAVIOR OF THE APPARENT SYSTEM DAMPING AS A FUNCTION OF THE AVERAGE PEAK RESPONSE ACCELERATION FOR ROD-SUPPORTED CABLETRAY SYSTEMS

induced by restraining the specimen, which results in higher apparent system damping. Figure 2.8 shows that for rod-hung raceways the distance between lateral supports has to exceed 75 ft before even a system with hangers as short as 2 ft approaches a true unrestrained response. Such long lengths of raceway without lateral restraint from wall brackets, tray risers, or wall penetrations do not commonly occur. Therefore, a damping curve developed from the restrained-specimen results (damping curve 1 in Figure 2.12) is more applicable to realistic systems than the lower-bound envelope of all the data points in the figure.

The second conclusion that can be drawn from Figure 2.12 is that the damping does indeed increase with increased A_B. This increase is particularly pronounced for restrained specimens. Note that A_B incorporates both the level of input motion and the dynamic properties of the raceway specimen. Therefore, a specimen with a frequency in a low-amplification region of the input spectrum subjected to a high-level input motion could have a lower A_B, and thus a lower level of damping, than a specimen subjected to a lower level of input motion but with a frequency in the peak amplification region of the input spectrum.

Finally, Figure 2.12 provides insight into the relationship between damping and the level of cable fill. The amount of cable fill affects the damping in two ways. An empty tray has a low level of damping. As the cable fill increases from zero, the damping level increases as the sliding of the cables within the tray and the cable collisions with both the tray and other cables dampen the dynamic response. After a certain point, increasing the cable fill will serve to restrict the motion of the cables already in the tray and the damping level will decrease. In the extreme case, a tray packed with cable to the point that sliding of the cable is impossible, a low damping level should result. These effects are reflected in the test data summarized in Figure 2.12. Those specimens tested with cable fill of 25 lb/ft showed higher damping than the 50-lb/ft specimens responding at the same acceleration level, thus indicating that when the cable fill was doubled, the decrease in damping due to increased restriction on the cables' movement dominated the increase in damping due to the increase in the amount of cable. A limited number of tests were conducted with a light fill of 10 lb/ft. The damping of these specimens fell between the levels for the 25-lb/ft specimens and the 50-lb/ft specimens responding at the same acceleration level. This indicates that in decreasing the fill from 25 lb/ft to 10 lb/ft, the decreasing effect on damping of decreasing the number of cables outweighs the increasing effect of the cables' greater freedom of movement. Damping curve 1 can thus be used for the evaluation of restrained, rod-supported cabletray raceways with cable fill of 10 lb/ft or more. A nominal damping level of 5% can be conservatively used for lightly loaded (less than 10 lb/ft) rod-supported cabletray raceways.

At some of the participating plants a number of cabletrays have been sprayed with a fire-retardant material. After curing, this material encases the cables, resulting in a solid mass inside the tray. As described in Reference 1, shaking-table tests were conducted to investigate the effect of the fire-retardant material on damping. The results are summarized in Figure 2.13. As would be expected from the discussion above, the fire retardant reduced the damping levels by significantly reducing the movement of the cables within the tray. As a result, damping curve 2 was developed for the evaluation of rod-supported cabletray raceways with sprayed-on fire retardant. Although only tests with cable fill of 25 lb/ft were conducted, it can be concluded that damping curve 2 is appropriate for the analysis of raceways with cable fill of 10 lb/ft or more and that a constant damping value of 5% is appropriate for lightly loaded systems sprayed with fire retardant. Shaking-table tests were also conducted using a rod-supported conduit raceway specimen. These tests indicated that rod-supported conduit raceways are lightly damped and that a constant damping value of 5% is adequate for realistic systems.

Strut-Supported Systems. The damping, d, is plotted against the average peak response acceleration, A_B, in Figure 2.14 for the strut-supported specimens tested in Phase III. Also shown in the figure is damping curve 1, which is based on the damping data for restrained rod-supported tray specimens.

Restraining the rod-supported tray specimens forced the trays to carry a significant part of the seismically induced lateral loads, thus causing the trays to deform. As discussed in the section on damping of rod-supported specimens, the deformation of the trays resulted in increased damping levels. The strut-supported tray specimens used to obtain the damping values represented in Figure 2.14 were supported only by their hangers, without any

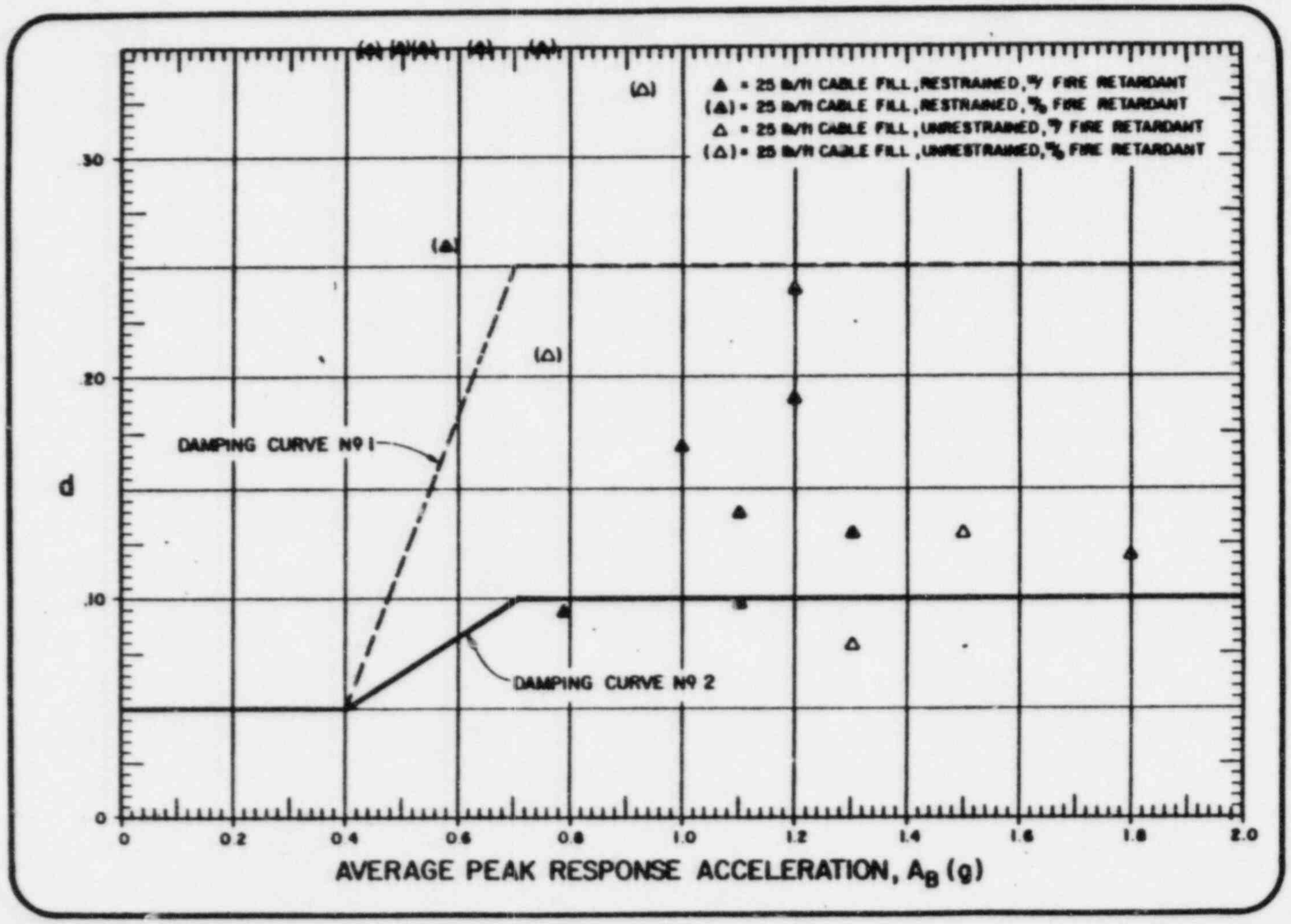


FIGURE 2.13 BEHAVIOR OF THE APPARENT SYSTEM DAMPING AS A FUNCTION OF THE AVERAGE PEAK RESPONSE ACCELERATION FOR ROD-SUPPORTED CABLETRAY SYSTEMS WITH SPRAYED-ON FIRE-RETARDANT MATERIAL

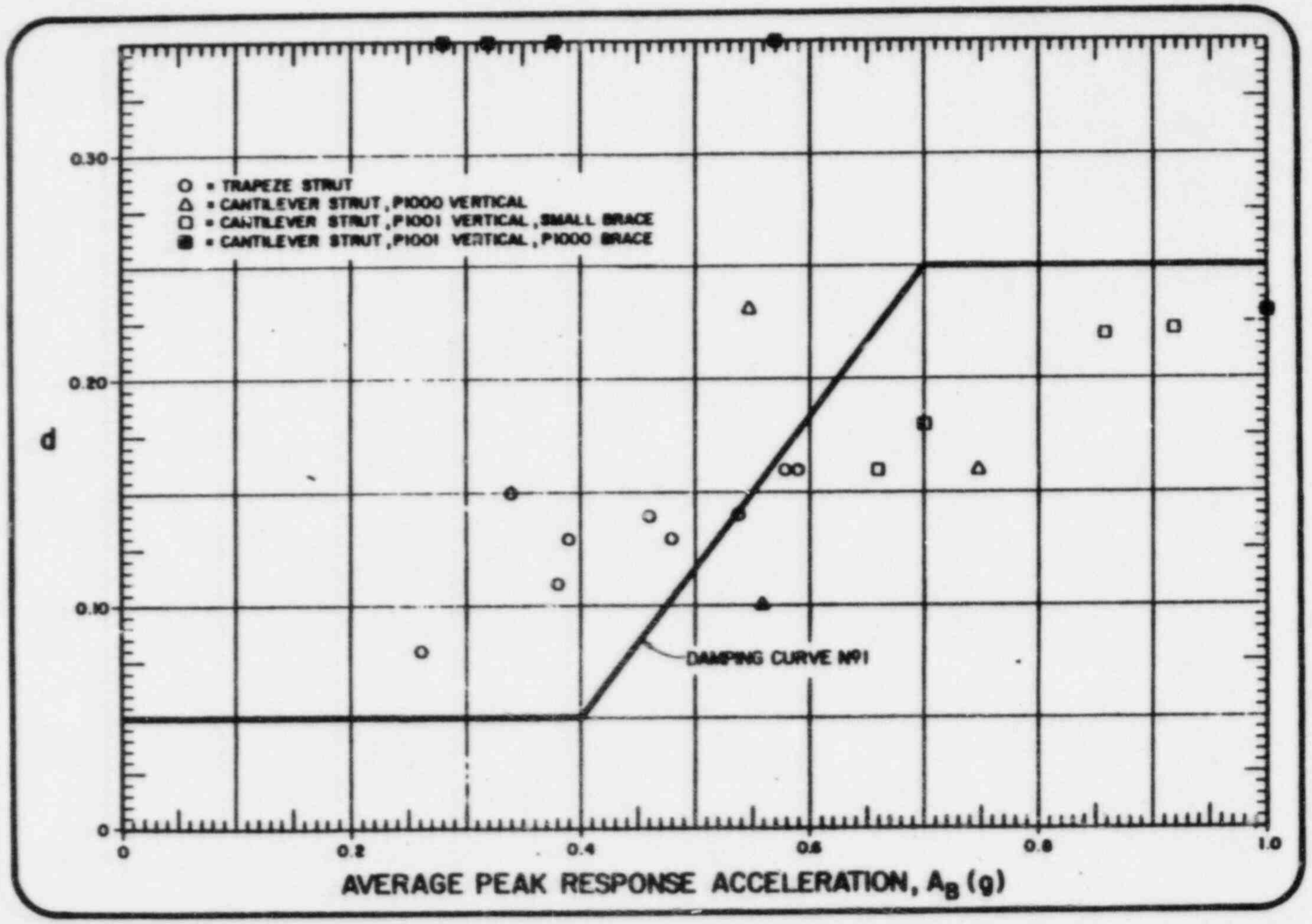


FIGURE 2.14 BEHAVIOR OF THE APPARENT SYSTEM DAMPING AS A FUNCTION OF THE AVERAGE PEAK RESPONSE ACCELERATION FOR STRUT-SUPPORTED CABLETRAY SYSTEMS

end restraints. No appreciable tray deformation occurred during the shaking-table tests of these unrestrained specimens.

As with rod systems, in actual field situations such unrestrained strut systems are virtually nonexistent. Lateral restraints are usually provided at penetration points through walls; by hangers braced directly to the floor, a wall, or a structural column; and sometimes by a change of direction of the raceway system itself. These lateral restraints would result in deformation of the tray. Damping levels similar to those observed for end-restrained rod-supported systems (damping curve 1) would then be expected. In effect, extensive damping data for systems supported by heavily braced strut hangers were developed by ANCO Engineers and Bechtel Power Corporation in their raceway testing program.[2] Because of the bracing, considerable tray deformation was observed in that testing program. After analysis of their test results,[3] Bechtel recommended the curve shown in Figure 2.15, which has been found to correlate well with damping curve 1.

The Bechtel curve relates damping to the zero period acceleration (ZPA) of the input spectrum rather than to the average peak response acceleration, A_B, of the raceway. The reason is that in the Bechtel program the test motion was tuned to the fundamental frequency of the particular specimen being tested. As a result, each test specimen's fundamental frequency fell within the peak-amplification region of the test spectrum. An approximate translation of the Bechtel curve from damping versus ZPA to damping versus A_B has been accomplished as described below.

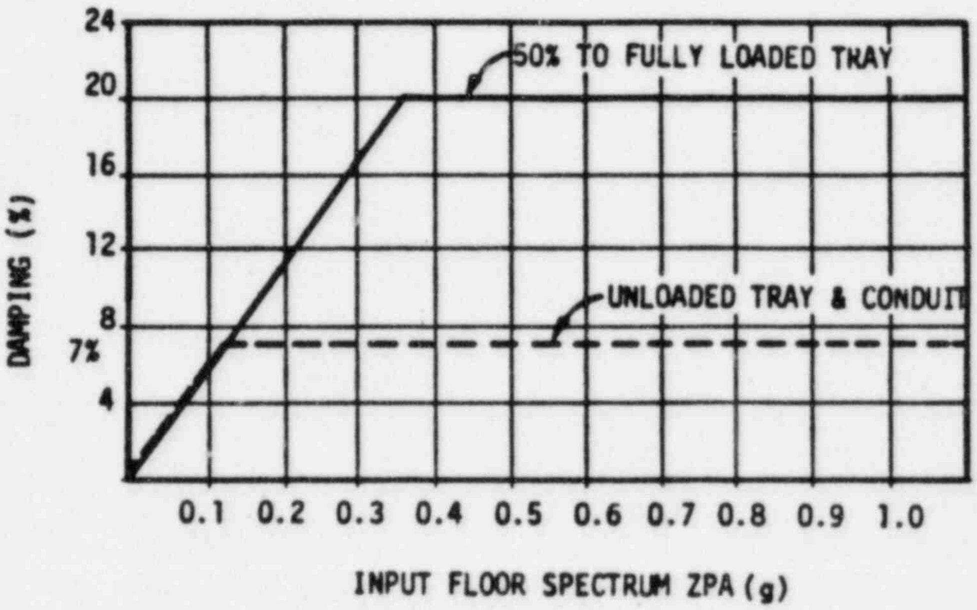
The Bechtel damping curve can be represented by:

$$d = \begin{cases} 0.56\,ZPA & ZPA < 0.36\text{g} \\ 0.20 & ZPA > 0.36\text{g} \end{cases} \qquad (2.21)$$

where:

d = fraction of critical damping

ZPA = zero-period acceleration (g)



Source: Reference 3.

FIGURE 2.15 RECOMMENDED DAMPING FOR THE DESIGN OF RACEWAY SYSTEMS

For purposes of this study, the ratio of the peak value of an acceleration response spectrum, S_p, to its ZPA for different damping values has been approximated by:

$$\frac{S_p}{ZPA} = \frac{1}{(2d)^y} \qquad (2.22)$$

where the exponent is a characteristic of the input motion's frequency content. If the input motion were a pure sine wave, y would be equal to 1. For a more broad-band excitation, such as seismic motion, y is a value less than 1. The test spectra achieved during the ANCO/Bechtel test program typically had a peak-to-ZPA ratio between 3.0 and 4.5 for a 5% damping value.[2] This indicates a value of y between 0.48 and 0.65.

The relationship between S_p and A_B is a function of the shape of the test specimen's fundamental mode of response (see Equation 2.20). Since ANCO's test motion was tuned to the fundamental frequency of the specimen, an approximation of this relationship that is both reasonable and uncomplicated is simply that the two parameters are equal:

$$S_p = A_B \qquad (2.23)$$

Combining Equations 2.21, 2.22, and 2.23 accomplishes the desired translation of the Bechtel damping curve:

$$d = \begin{cases} \left[0.56(2)^y A_B\right]^{\frac{1}{1-y}} & A_B \leq 0.36(0.4)^{-y} \\ 0.20 & A_B \geq 0.36(0.4)^{-y} \end{cases} \qquad (2.24)$$

Equation 2.24 is plotted in Figure 2.16 for y values of 0.48, 0.57, and 0.65 (peak-to-ZPA ratios of 3.0, 3.75, and 4.5 for a damping value of 5%). Also plotted is damping curve 1. As can be seen, damping curve 1 correlates well with Equation 2.24, especially for $y = 0.61$. Thus, the relationship between response acceleration and damping can be assumed to be the same for both end-restrained rod-supported and end-restrained strut-supported systems and all

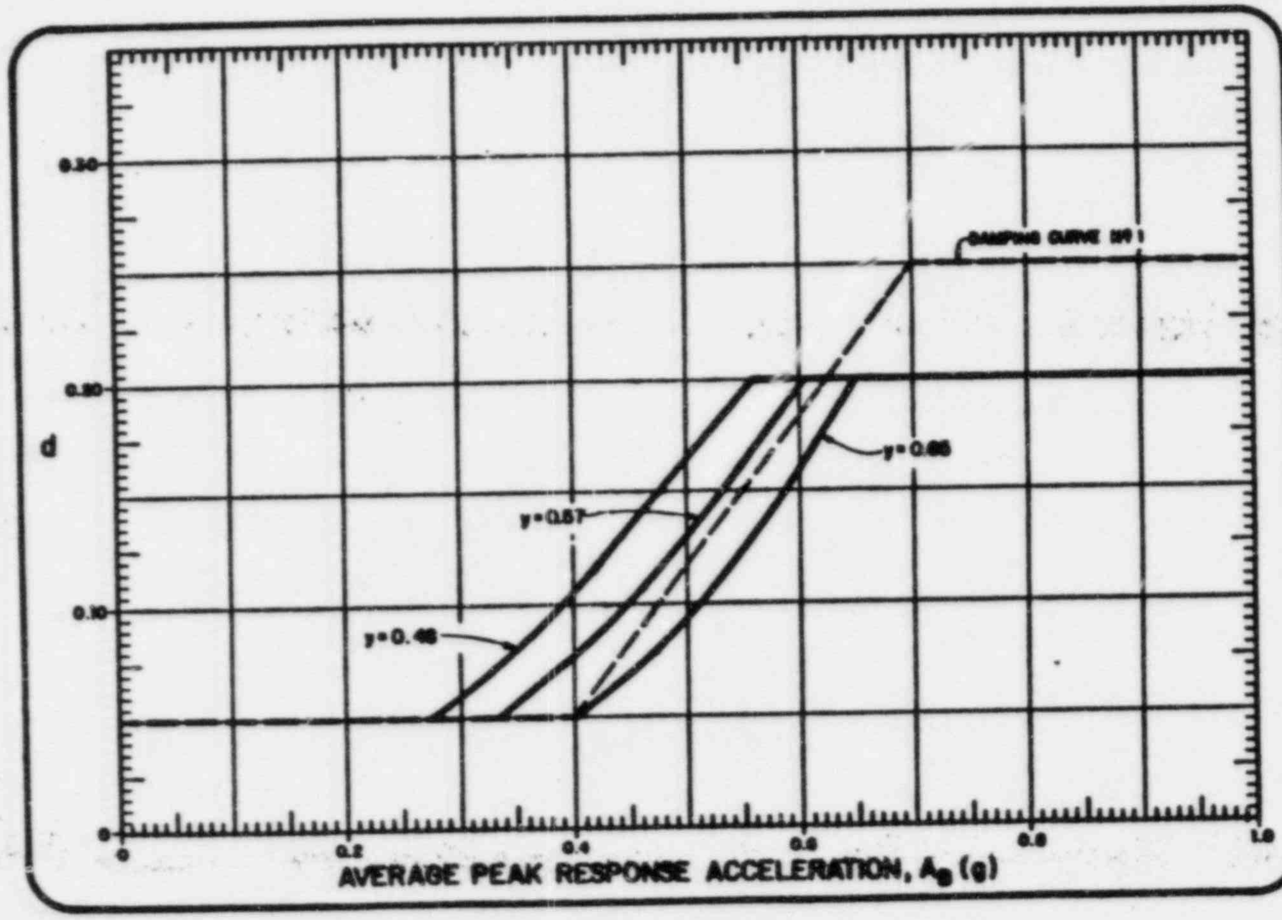


FIGURE 2.16 COMPARISON OF THE DAMPING CURVE FOR BRACED STRUT-SUPPORTED SYSTEMS WITH DAMPING CURVE 1

effects discussed for rod-supported systems are also applicable to strut-supported systems, including the cable fill and sprayed-on fire retardants. This is to be expected, since the sources of apparent system damping are not affected by the type of support used. The resulting damping curves for the seismic evaluation of raceway systems are summarized in Figure 2.17.

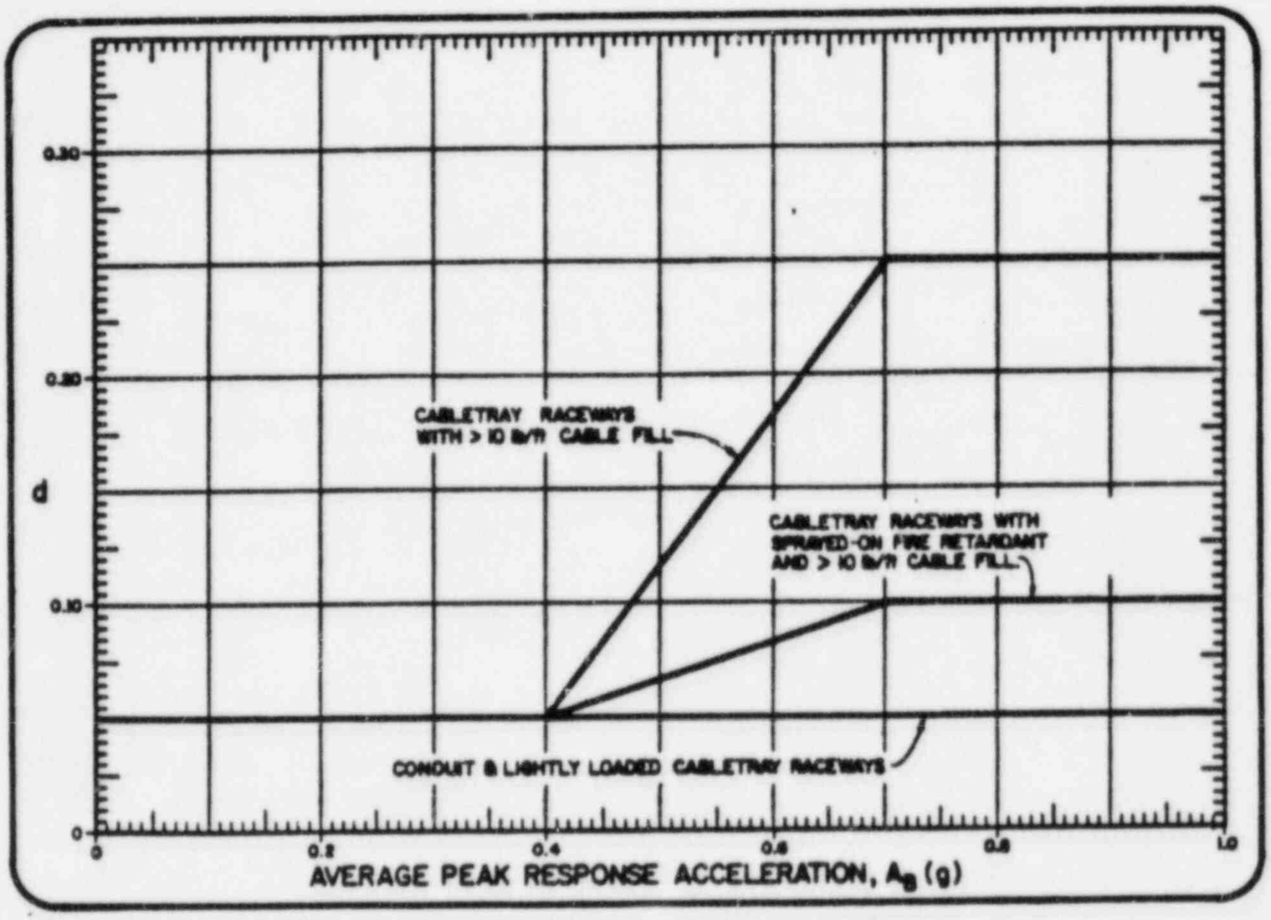


FIGURE 2.17 BEHAVIOR OF THE APPARENT RACEWAY SYSTEM DAMPING AS A FUNCTION OF THE AVERAGE PEAK RESPONSE ACCELERATION

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