ELECTRICAL RACEWAY SUPPORT
IMPLEMENTATION PLAN FOR
RETURN TO SERVICE

San Onofre Nuclear Generating Station

Unit 1

September 1984

TABLE OF CONTENTS

Section		Page
1.	Introduction	1
2.	Scope of Raceway Support Modifications for Return-to-Service	1
3.	Justification for Return-to-Service	2
4.	Conclusion	7
5.	References	9
6.	Tables	10

1. INTRODUCTION

The purpose of this report is to describe the electrical raceway support implementation plan for return-to-service. Justification for the plan is also presented.

2. SCOPE OF RACEWAY SUPPORT MODIFICATIONS FOR RETURN-TO-SERVICE

Re-evaluation of the electrical raceway supports is complete. The criteria which was employed for evaluations is stated in Reference 1. The final design of all supports requiring upgrade is substantially complete and most of the supports which did not meet the re-evaluation criteria have been upgraded in the past two years to withstand the 0.67g Housner DBE.

The raceway support modifications have been subgrouped into the following categories:

a. Cable tray support modifications

b. Cable tray tie-down modifications

c. Conduit support modifications

d. Replacement of masonry wall expansion anchors in ungrouted cells with through bolts.

The cable tray support modifications include the addition of longitudinal and/or transverse supports, upgrading of support members and connections, etc. (exclusive of tie-down modifications).

Table 2.1 identifies the approximate number of raceway support modifications which will be implemented prior to return-to-service (RTS) for each of these categories. Table 2.1 also provides a comparison of this RTS scope with the total number of support modifications which have been identified as not meeting the reevaluation criteria.

As shown in Table 2.1, the support modifications which will be installed prior to return-to-service include:

a. A significant portion (over 80 %) of the total tray and conduit support modifications which have been identified as not meeting the re-evaluation criteria.

b. A significant portion (over 80 %) of the tray tie-down modifications, including all tray tie-down modifications for cantilever supports.

c. All masonry wall expansion anchor replacement modifications.

Table 2.2 shows the locations of required modifications. As shown in this table the RTS scope for tray and conduit modifications are distributed throughout the plant.

Table 2.2 includes both new supports (which were added to reduce the existing support spacings and provide additional longitudinal brace points) and the modifications of existing supports. As shown in Table 2.3, relatively few new supports were identified as being necessary to meet the re-evaluation criteria compared with the number of existing supports installed at San Onofre Unit 1 (approximately 1,200 cable tray supports and 7,300 conduit supports.) Additionally, as shown in Table 2.3, most of the new supports which were identified to meet the re-evaluation criteria are included in the return-to-service scope.

These tables show that a very significant portion of the raceway supports will be modified prior to return-to-service. Because of this upgrade, the raceway systems will have a significant increase in margins even though there is a technical basis, as discussed in the following sections, for not upgrading the raceway support systems.

3. JUSTIFICATION FOR RETURN-TO-SERVICE

Justification for the return-to-service scope identified in Section 2 consists of:

a. Conservatisms associated with the evaluation and final design process.

b. The evidence of high seismic capacity of raceway systems as observed in the extensive testing programs described in References 2 and 3.

3.1 Conservatisms Associated with the Evaluation and Final Design Process

The evaluation and final design process employed for SONGS Unit 1 utilized conservative parameters for seismic input and damping as well as a conservative methodology. Each of these considerations is addressed in the following discussions.

Seismic Input . The basic seismic input (instructure response spectra) used in the re-evaluation and the design of the modifications of the support systems was described in Reference 4. Subsequently, in November 1982, in response to a request expressed by the NRC staff, the conservative nature of instructure spectra was demonstrated. A summary of the conservatisms is provided in Table 3.1.

Damping . The damping values utilized for the re-evaluation of the cable tray support system are conservatively based upon the results of the testing program performed by ANCO Engineers, Incorporated (See Reference 2).

The damping measurements that were documented in Reference 2 were conducted on trapeze and braced cantilever type supports. The cable tray damping data obtained from the ANCO testing were grouped into sets according to the direction of input, the type of tray support, the spacing of bracing and the amount of cable loading. The trend of the data suggests that in most cases a bilinear relationship exists between the damping ratio and the acceleration level. A typical acceleration vs. damping relationship is shown in Figure 1.

Extensive evaluation of the test data as presented in Reference 2 was also performed as discussed in Reference 7. Various combinations of systems braced in the same direction were combined and the mean curves and the 15% non-exceedance probability curves (corresponding approximately to mean minus one sigma) were computed utilizing statistical procedures. Table 3.2 provides the critical damping values from the curves in Reference 7 corresponding to 0.67g, which is the ground level acceleration (lowest acceleration level) for evaluation and design in the SONGS 1 seismic reevaluation program. Using the aceleration vs. damping relationships presented in Reference 7, it is noted that the damping will be higher at acceleration levels above 0.67g.

The conclusions of the testing program concerning damping apply to cable tray support systems in general, as the largest portion of the system damping was the result of the amount of energy dissipated between the adjacent moving cables and through friction between cables. The type of tray and the type of tray support system being utilized (trapeze, cantilever, etc.) was not a significant factor in determining the overall system damping. Three tests (II-11B, 11C, and 11D) were performed on cantilever raceway support systems. The configuration tested consisted of a five support, three tier cantilever system with trays supported every 8 feet. A review of the test data indicated that the magnitude of damping observed was somewhat higher than the comparable trapeze system and the resonant frequency was about equal.

Therefore, damping values corresponding to those in Table 3.2 are appropriate for SONGS 1 cable tray support systems. However, to be conservative, a critical damping value of 15% was selected. Table 3.3 shows the damping values used in the re-evaluation and final design of the raceway systems.

Methodology . The basic concept used in the re-evaluation process is an equivalent static analysis with consideration given to the dynamic character of the seismic loadings. The methodology uses manual calculations and engineering judgement to predict the behavior of a continuous complex system by simplified models, and no credit is taken for load sharing between adjacent supports or the continuous nature of the raceway systems. This process does not reflect the following considerations which are attributable to the actual behavior of raceway support systems as observed in the test programs:

a. Inelastic action of the support system

b. Actual damping within the system

c. Internal load redistribution of a continuous system

d. Actual material strength versus the allowable design values used for material properties

e. High level of reserve capacity inherent in steel structures due to material ductility.

Because the evaluation and design process does not reflect the above considerations, the results are considered to be conservative estimates of the stress levels. This, in turn, leads to a conservative amount of modifications necessary to restore design margins. This is illustrated in Table 3.4, which shows the comparison between the test and re-evaluation results for a cable tray support system which was successfully tested in the Reference 2 test program. As described in Table 3.4, the application of the re-evaluation criteria and methodology to the actual test specimen configuration concluded that modification of the tested support system would be necessary in order to meet the re-evaluation criteria. It should be emphasized that the acceleration values recorded during the testing were greater than the values used in the calculations, and even at the higher test values no damage was observed.

It is concluded that the overall methodology, criteria and procedures used in the evaluation and design process are conservative and that the number of modifications identified would have been significantly reduced if more sophisticated methods which account for the factors a. through e. above had been utilized.

3.2 High Seismic Capacity of Tested Raceway Support Systems

Over the past two decades, many earthquakes have occurred within the United States. Of these, several were of sufficient magnitude to cause structural damage to industrial facilities. Following such strong earthquakes, inspection of power generation and distribution facilities has offered valuable information as to the overall performance of engineered structures. The 1971 San Fernando earthquake has been of particular interest in this regard. It was one of the most severe earthquakes Southern California has experienced in recent history. A survey of structural damage to the Sylmar Converter Station, located within a few miles of the epicenter, provided data relative to the behavior of electrical distribution equipment and electrical raceway systems when excited by strong ground motion. Of special interest was the fact that simple unbraced raceway hanger systems were able to survive the earthquake without major structural damage. Another finding was that even at locations where a minor amount of structural distressing occurred, the cables within the tray systems did not lose their functional integrity. The fact that the converter station's unbraced support system survived the San Fernando earthquake generated interest regarding the practicality of using similar systems in nuclear power plants.

In the years following the San Fernando earthquake, an increasing effort has been put into the design of earthquake resistant structures. Included in the list of structures are nuclear power plants. As early as October 1971, design guidelines were developed by Bechtel that outlined methodologies for the engineering of raceway supports. In March 1974, Bechtel issued a design standard by which most seismic raceway supports have been designed. This standard closely followed the guidelines set forth in USNRC regulatory guides and standard review plans, which were also being developed during the same period of time. Designs based upon these criteria have tended to require substantial amounts of bracing. By contrast, the Sylmar Station support systems were essentially unbraced. Consequently, it appeared that either the design methods or the design criteria, or possibly both, were unnecessarily conservative.

In 1976, a plan was initiated to test electrical raceway systems. The goal of the testing was to establish the best possible approach to create an economical, yet adequate, support system for electrical cabling within nuclear plants. By the first part of 1977, a clearly defined program that outlined the types and sizes of raceway systems that would be tested was established. In the last months of 1977, testing was begun by Anco Engineers, Incorporated. Full scale installations of both cable tray and conduit raceway systems were tested. By the end of 1978, over 2000 individual dynamic tests had been performed, generating over 50 volumes of raw data.

The details of each phase of each task will not be explained in this report. This information is detailed at length in Reference 2. Instead, the overall philosophy is discussed. In addition, some specific examples are included.

In general, testing was performed by starting with the simplest test setup as possible. Initally, this involved testing of cable tray or conduit on rigid supports independent of their trapeze type hangers. These tests provided information that was useful in the next set of tests in which the cable tray or conduit was mounted on trapeze hangers that were totally unbraced.

This step allowed the collection of meaningful data related to a flexible hanger system. Next, bracing was added to the hangers to restrict certain modes of vibration and attempt to begin the simulation of an in-situ seismic restraint. Again the data developed in previous tests was valuable in understanding the behavior of the more complex system.

To augment the dynamic testing performed on the shake table, several static and quasi-dynamic tests were performed. The static tests were performed on cable trays. There were five types of cable tray used in the test program. It was the goal of this test sequence to develop a better understanding of tray section properties and to establish an upper limit as to static load carrying capacities of the trays. The quasi-dynamic tests were performed to establish low-cycle fatigue characteristics of standard strut type connections. The data collected from both types of testing was used to establish the design criteria for the tray and connection components.

The trays and conduit were loaded with miscellaneous sizes of electrical cable. The design load for the 24-inch wide tray was 50 lb/ft. Tests were run with cable weight varying from 0 to 50 lb/ft. Conduit loadings were also varied depending upon the size of conduit. Most of the conduit testing was performed using maximum cable loads. Conduit not filled to the maximum was loaded only to 50% of the maximum weight. All cable used as fill was typical power plant material.

The earthquake time history used to formulate the majority of shake table input motions was the Bechtel Horizontal Synthetic Time History - H1. This record was selected due to its conformance with USNRC Regulatory Guide 1.60. In addition, a select group of four historical earthquake records was used during a limited group of tests. However, the actual input motion to the shake table was not the input motion corresponding to any one of the records mentioned. Rather, a modification to each record was made to account for effects of building amplification for the purpose of creating a "worst case" shake table input motion.

The strut supported systems that were tested survived all testing without loss of function. The type of damage that was observed in a few cases consisted mostly of fracturing of strut type angle fittings. This damage was due to low cycle fatigue resulting from significant ductile-plastic deformation that occurs at connections during large amplitude loading. Of the four angle fittings that are used to attach the hanger to the overhead steel (i.e., two fittings per vertical element, two vertical elements per hanger), never did more than one fitting of the four fracture during any one specific large amplitude test. Most of the systems were tested at input levels corresponding to 1.0 to 3.0g's maximum acceleration. These input levels were demonstrated to be equivalent to ground motion levels of 0.25 to 0.75g free-field acceleration. Never in the course of some 2000 dynamic tests did a total structural collapse of a strut-supported raceway occur. Nor was there any loss of function in the electrical circuits that were monitored.

The test results indicate that for conduit and tray supports similar to those in SONGS 1, seismic acceleration levels about the same or higher than expected for SONGS 1 can be achieved without impairment of the structural integrity of the raceway support systems.

The test results on combined tray and conduit support systems similar to those at SONGS 1 indicate that no loss of circuit continuity is expected when these support systems undergo maximum displacements of about 3-4 inches. The effects of seismic induced displacements on the structural integrity of the raceway support systems were evaluated based on the results of these tests. For cases where raceway systems would be subjected to differential displacements greater than 3-4 inches, the elements of structures were modified to assure that the resulting differential displacements would be less than 3-4 inches.

The seismic capacity of the raceway systems was also observed in more recent seismic testing (Reference 3). Although the design input levels for these tests were less than the SONGS 1 input levels, Reference 3 concluded that the seismic capacity of the raceway systems is attributable mainly to the high level of damping and the high level of reserve capacity inherent in steel structures due to material ductility.

The results of some of the specific tests conducted in the Reference 2 test program which are applicable to the type and configuration of raceway supports at San Onofre Unit 1 are discussed in the following sections.

Testing of Rigidly Supported Conduit. For these tests conduits were attached by clamps to a strut mounted rigidly to the vertical testing surface. The test setup simulated conduits attached directly to a structural wall (Fig. 3a). The testing was conducted to determine the ultimate capacity of the conduit clamps. The supports were spaced at eight foot intervals, typical at SONGS 1, with 3/4" and 2" diameter rigid steel conduits attached. The conduit clamps utilized in the test program are equivalent (similar in design characteristics) to those used at San Onofre Unit 1.

Several tests were run on each setup. These tests included both uniaxial and biaxial dynamic loading. A sinusolidal input motion was used. In the biaxial tests, the input motion in the vertical direction was one half the input motion in the horizontal direction which was directed parallel to the conduit axis. Vertical slippage of the clamps was considered to have occurred when a displacement of 0.1" or greater occurred at the clamp locations.

For the 3/4" diameter conduits, the fragility levels were in excess of the shake table capacity of 13 to 15 g's. For the 2" diameter conduits, Table 3.5 shows the maximum input acceleration levels obtained during testing. These tests were conducted with sinusoidal input motions, and input frequency to conduit frequency ratios of 0.83 to 0.90. The average acceleration input achieved with no slippage in these tests (excluding the two nonrepresentative tests results shown in Table 3.5) was 11.40g's.

The 2" diameter rigid steel conduits were also tested with various clamp types for sixteen feet support spacing. For the B-2013 clamps (equivalent to the P1117 clamp used in SONGS 1), vertical slippage was observed at a 1.10g sinusoidal input at the conduit resonance frequency.

Rigid steel 4" diameter conduits were also tested with various clamp types for twenty feet support spacings. For the B-2013 clamps, vertical slippage was observed at a 1.14g sinusoidal input at the conduit resonance frequency.

Testing of Flexible Supported Conduits. For these tests conduits were attached to a horizontal strut which was connected to two vertical struts which in turn was attached to the testing facility (Figure 3b). These tests simulated conduits supported by trapeze or cantilever hangers. The tests were conducted to determine the adequacy of the clamps attaching the conduit to its support.

Rigid steel 2" diameter conduits with supports at 8 foot intervals were tested with the B-2013 clamp type. Table 3.6 gives the input acceleration levels obtained during the biaxial sinusoidal tests. For these cases, clamp slippage did not occur. The acceleration amplitudes listed represent the limits of the shake table, therefore, the fragility input levels for these specimens are in excess of the amplitude given.

Both 2" and 4" diameter rigid steel conduits on trapeze type supports were also tested for ten feet support spacing. Tests were conducted with and without lateral bracing at the middle support. The objective of the testing was to determine the dynamic characerisics of conduit runs supported by standard trapeze raceways. Peak accelerations as high as 3.4 g's were recorded at the hangers during the test. Slippage of the conduit hold down devices were not detected and there were no failures associated with the conduit or its coupling devices.

Testing of Combined Tray and Conduit Support System. This test was conducted to determine whether fracturing of conduit fitting, pullout of a conduit from a panel, or a large deformation of the cable tray side rails could induce an interruption of electrical signals or jeopardize the quality of interlocking materials. Both 2" and 4" diameter conduits were assembled as shown in Figure 4 and tested.

Table 3.7 shows the results of the testing. It should be noted that large horizontal and vertical displacements were achieved between the base attachment point and the cable tray attachment points. During the testing there was no loss of circuit continuity nor was there any change in the integrity of the insulation. No failure of the conduit fittings or electrical boxes occurred other than the loosening of conduit fittings. Minor loosening of the conduit to tray clamp occurred at approximately 80% of the input acceleration values given in Table 3.7. Large distortions of the cable tray side rail occurred at maximum input, however, the tray was still able to adequately support the installed cables. After retightening the clamp, the input acceleration was advanced to the capacity of the shake table and no further evidence of clamp loosening was observed.

4. CONCLUSION

It is concluded that this implementation plan for return-to-service will provide for a seismic withstand capability of 0.67g without impairment of the overall integrity of electrical raceway support systems, and without impairment of the plant capability to achieve a hot standby condition (Mode 3). This conclusion is based upon:

a. Due consideration to the scope of raceway modifications to be installed for return-to-service as addressed in Section 2.

b. Recognition of the conservatisms associated with the evaluation and final design processes which were utilized in the identification of raceway support modifications, as discussed in Section 3.

c. The observed high seismic capacity of raceway support systems which are similar to the San Onofre Unit 1 support systems, as discussed in Section 3.

d. Consideration that the tray and conduit raceway support systems are redundantly supported.

5. REFERENCES

1. Enclosure to letter from K. P. Baskin (SCE) to D. M. Crutchfield (NRC), dated August 17, 1982; enclosure entitled "Electrical Raceway Supports, Seismic Reevaluation Criteria" dated August 12, 1982.

2. "Cable tray and Conduit Raceway Seismic Test Program," 1053-21.1-4 Volumes I through IV, prepared for and in collaboration with Bechtel Power Corporaton, Los Angeles Power Division, Norwalk, California, 1978.

3. "Shaking Table Testing for Seismic Evaluation of Electrical Raceway Systems". The SEP Owners Group Under the Direction of KMC, Incorporated by URS/John A. Blume and Associates, Engineers, April 1983.

4. Enclosure to letter from K. P. Baskin (SCE) to D. M. Crutchfield (NRC), dated July 9, 1982.

5. "Final Progress Report for the San Onofre Nuclear Generating Station Unit 1, Auxiliary Feedwater System Project" Draft for Comments, Seismic Safety Margins Research Program, June 18, 1982.

6. "Soil Backfill Conditions, San Onofre Nuclear Generating Station Unit 1", August 12, 1982, and its revisions and addenda dated April 18, 1983, September 1, 1983, September 20, 1983, and November 28, 1983.

7. "Report on Cable Tray Support System Damping Values" Vogtle Electric Generating Plant, March 3, 1983. Enclosure to letter from D. Hutton to D. G. Eisenhut, dated March 5, 1982.

TABLE 2.1

SCOPE OF RACEWAY SUPPORT MODIFICATIONS FOR RETURN-TO-SERVICE (RTS)

	Approx. Number of Support Modifications in RTS Scope	Number of Support Modifications Necessary to Meet Evaluation Criteria	Percent of Support Modifications in RTS Scope
Cable tray support modifications	459	617	75%
Cable tray tie-down modifications	871	1,020	84%
Conduit Support Modifications	1,316	1,596	83%
Replacement of masonry wall expansion anchors	231	231	100%

TABLE 2.2

LOCATIONS OF SUPPORT MODIFICATIONS

TO BE INSTALLED PRIOR TO RTS

SUPPORT AREA	BUILDING/LOCATION	APPROX. NUMBER OF MODIFICATIONS IN RTS SCOPE		
		Tray	Conduit	Tray Tie-Downs
1	Containment	25	329	117
2	North Turbine Extension	43	49	60
3	480V Switchgear Room	53	121	109
5	East Turbine Extension	68	126	80
6	West Turbine Extension	60	106	86
7	South Turbine Extension	16	69	61
8	Auxiliary/Radwaste building	27	79	58
9	Intake Structure	--	19	--
10	Control Building	36	157	92
10	4160V Switchgear Room	87	158	154
11	Transformer Yard	--	--	4
12	Tank Area	4	1	4
14	Outside Area	36	22	42
16	Diesel Generator Building	1	43	1
17	Diesel Generator Building	3	37	3
	Totals	459	1316	871

TABLE 2.3

NEW SUPPORT LOCATIONS

AREA	BUILDING/LOCATION	APPROX. NUMBER OF NEW SUPPORTS: TO BE INSTALLED PRIOR TO RTS		APPROX. NUMBER OF NEW SUPPORTS: NECESSARY TO MEET RE-EVALUATION CRITERIA	
		Tray	Conduit	Tray	Conduit
1	Containment	1	30	1	45
2	North Turbine Extension	13	9	25	12
3	480V Switchgear Room	6	19	9	19
5	East Turbine Extension	11	73	17	85
6	West Turbine Extension	3	4	3	7
7	South Turbine Extension	4	9	9	18
8	Auxiliary/Radwaste Bldg.	--	17	2	21
9	Intake Structure	--	12	--	12
10	Control Building	3	16	3	25
10	4160V Switchgear Room	3	67	9	82
11	Transformer Yard	--	--	--	--
12	Tank Area	--	--	--	--
14	Outside Area	5	6	6	7
16	Diesel Generator Bldg.	--	6	--	7
17	Diesel Generator Bldg.	--	9	--	9
	Totals	49	273	84	349

TABLE 3.1

SUMMARY OF INSTRUCTURE

RESPONSE SPECTRA CONSERVATISMS

Structures	Conclusions
Containment Sphere, and Reactor Building	The spectra are based on soil-structure inter-action damping values limited to 10% in the horizontal directions and 17% in the vertical direction which is conservative, and the seismic input motion is applied at the foundation level without reduction in amplitude due to embedment effects. In addition, it has been shown that the spectra currently used in SONGS 1 for evaluation and design, envelope by a considerable margin the spectra in Reference 5.
Diesel Generator Building, and Sphere Enclosure Building	The spectra are based on time-histories that envelope the San Onofre Unit 2 and 3 ground design spectra which is more conservative than the Housner ground design spectra (the applicable seismic input for the seismic re-evaluation program).
Control and Administration Building	The spectra at each elevation is an envelope of the responses of different locations at that elevation and thus are a conservative representation of the response levels expected.
Circulating Water Intake Structure, and the Reactor Auxiliary Building	The spectra used are conservatively taken as the ground design response spectra without any reduction in amplitude due to embedment effects and without change in frequency content.
Fuel Storage Building, Ventilation Equipment Building, and the Turbine Building	The spectra are an envelope of responses due to soil stiffness parameters corresponding to 95 percent compacted native backfill conditions and backfill as characterized in Reference 6.

TABLE 3.2

PERCENT CRITICAL DAMPING VALUES BASED ON CABLE TRAY TESTS

Type of Bracing	Direction of Input Motion	% Damping Mean	% Damping Mean minus one Sigma
8', 16', 32' Transverse	Transverse and Vertical	35	28
One or Two Longitudinal	Longitudinal and Vertical	28	21

TABLE 3.3

DAMPING VALUES FOR SEISMIC RE-EVALUATION

Item	Damping Percent of Critical
Conduit Supports	7
Cable Tray Supports	15
Combined Conduit and Cable Tray Supports (same support)	15

TABLE 3.4

COMPARISON OF TEST AND EVALUATION RESULTS

The single-tier trapeze tray support system shown in Figure 2 was used and consisted of five supports spaced eight feet apart. The depth for the upper anchors to the bottom of the tier was 4'6". Unistrut P1001 was used for the vertical and horizontal members. The cable loading was 50 lb/ft.

Case*	Test Result: Test Table ZPA	Test Result: Peak Recorded Response	Test Result: Observation	Evaluation Result
1 (No transverse bracing)	3.2g	1.94g (at middle support)	No damage was observed when tested with combined horizontal and vertical earthquake input.	Both configurations were evaluated using the re-evaluation criteria and methodology in Reference 1. Calculations were performed for 1g horizontal and 1g vertical seismic accelerations. The equivalent static method with a 1.5 factor was used for the seismic load computations. Neither case satisfied the re-evaluation criteria and it was determined that the necessary modifications would include the addition of at least two transverse braces.
2 (With a transverse brace at the middle support)	2.8g	2.19g (at end support)	No damage was observed when tested with combined horizontal and vertical earthquake input.	

*Cases 1 and 2 represented amplified input motions which corresponded to equivalent free-field ground accelerations of 0.54g and 0.60g, respectively.

TABLE 3.5

MAXIMUM INPUTS FOR

2" CONDUIT, 8' SUPPORT SPACING BIAXIAL TESTING, RIGIDLY SUPPORTED

Ratio of input frequency to conduit frequency	Maximum input achieved with no slippage (g's)
0.90	6.36*
0.85	12.39
0.90	4.95*
0.90	8.13
0.90	12.03
0.83	12.03
0.83	13.09

* These test series were conducted with coarse step size increases in acceleration input. Therefore these values, while conservative, are not representative of the test fragility levels.

TABLE 3.6

MAXIMUM INPUTS FOR

2" CONDUIT, 8' SUPPORT SPACING BIAXIAL TESTING, FLEXIBLY SUPPORTED

Ratio of input frequency to conduit frequency	Maximum input achieved with no slippage (g's)
1.19	12.75*
1.00	10.97*

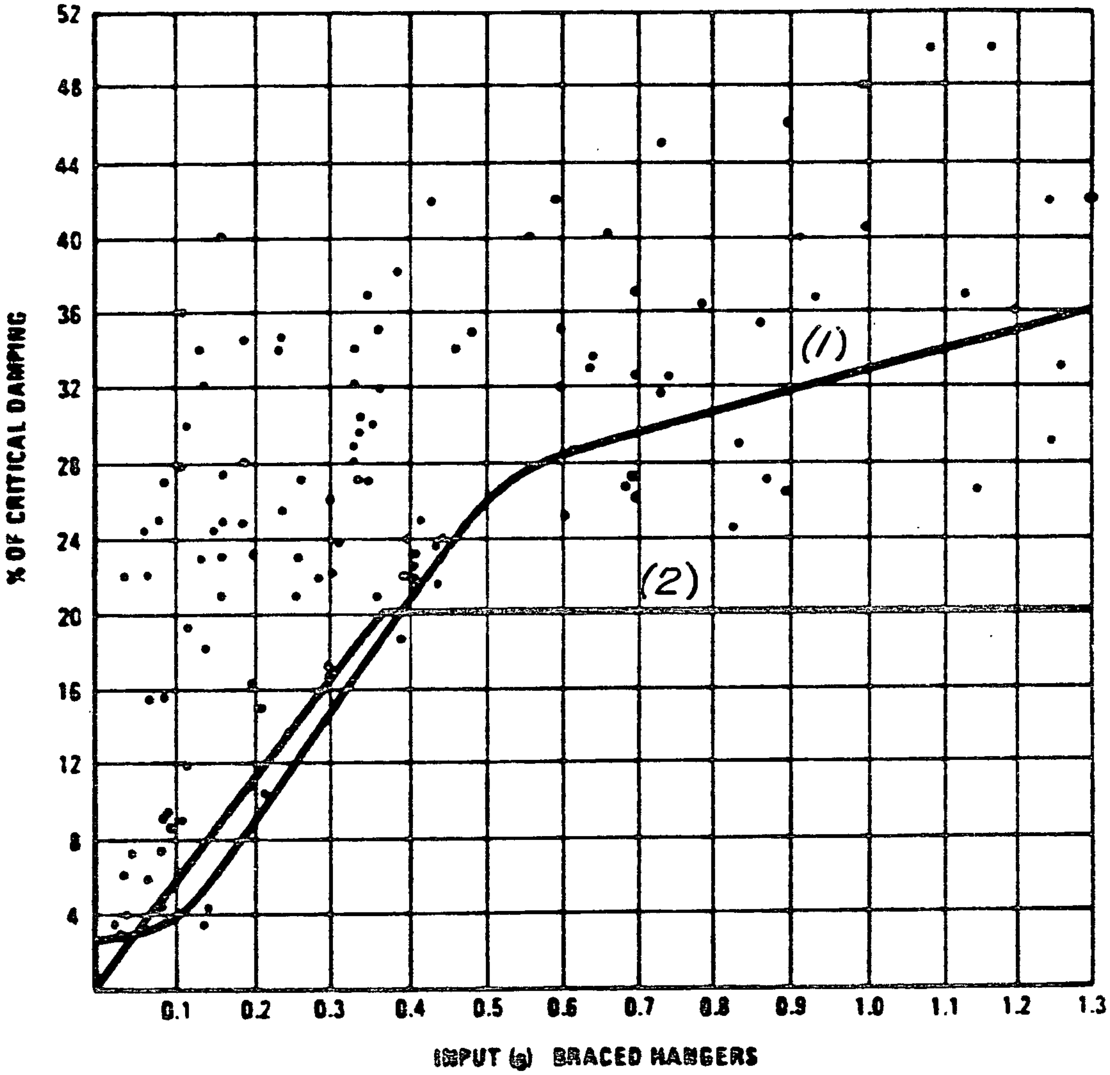
*The input level was limited by the shake table capacity.

TABLE 3.7

COMBINED TRAY AND CONDUIT TESTING RESULTS

Direction	Acceleration at Conduit Attachment Point		Relative Displacement Between Conduit Attachment Point and Support Point	Gross Displacement Between Conduit Attachment Point and Ground
	Top Tier	Second Tier		
a) 2" Rigid Steel Conduit				
H	1.25	1.50	2.10"	4.22"
V	-	0.50	-	2.53"
b) 4" Rigid Steel Conduit				
H	1.11	1.44	1.75"	3.87"
V	-	0.42	-	2.34"

MKnarr:0249D



(1) 10% EXCEEDANCE CURVE
(2) A LOWER BOUND DESIGN CURVE

FIGURE I

TYPICAL DAMPING TRENDS FOR CABLE TRAY TESTS

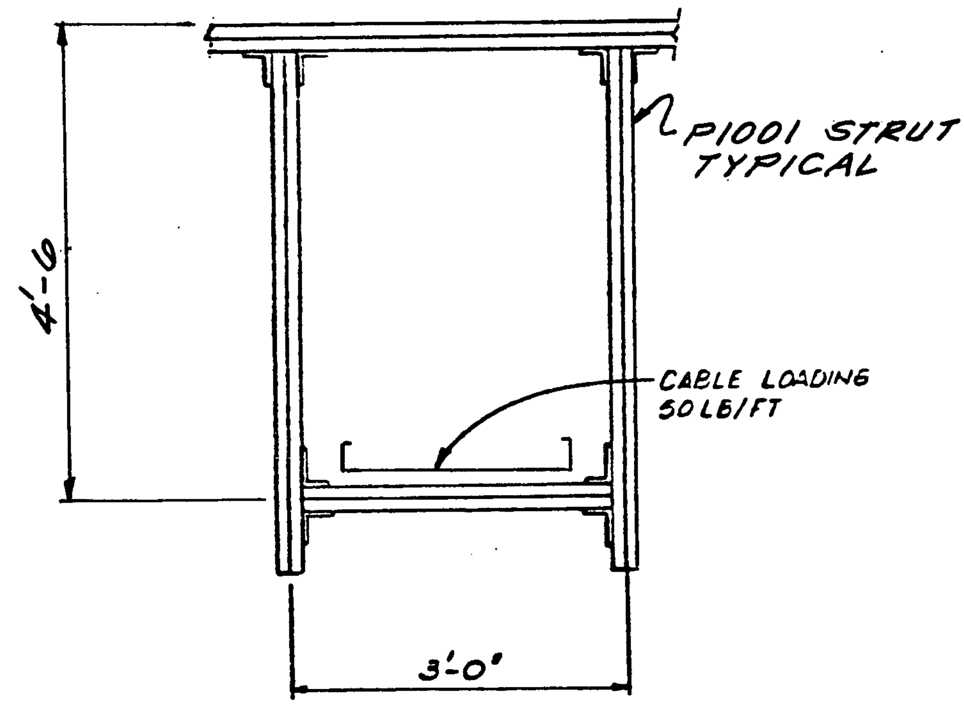


FIGURE 2. TRAY CONFIGURATION TESTED

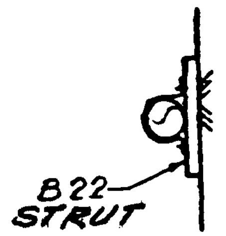


FIGURE 3A. RIGIDLY SUPPORTED CONDUITS

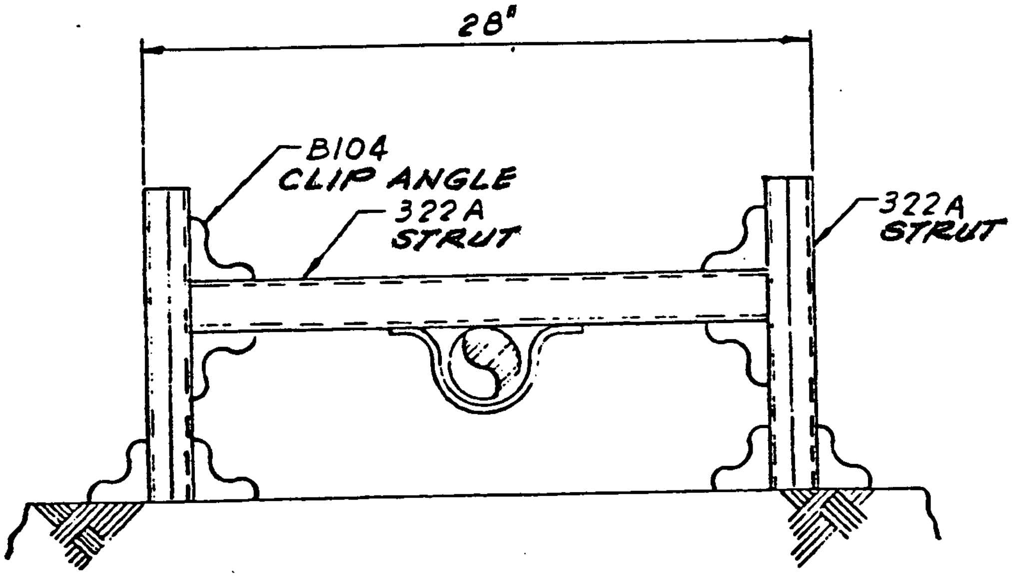
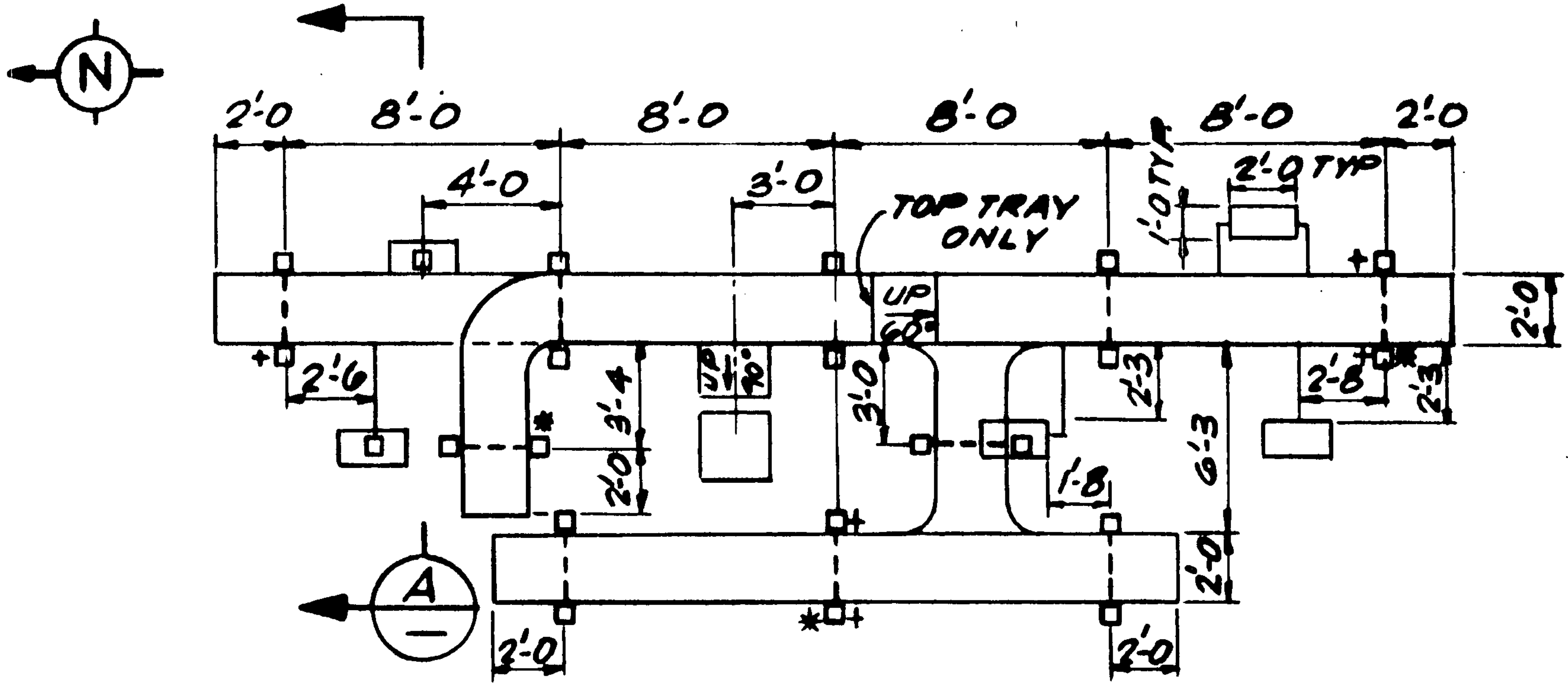
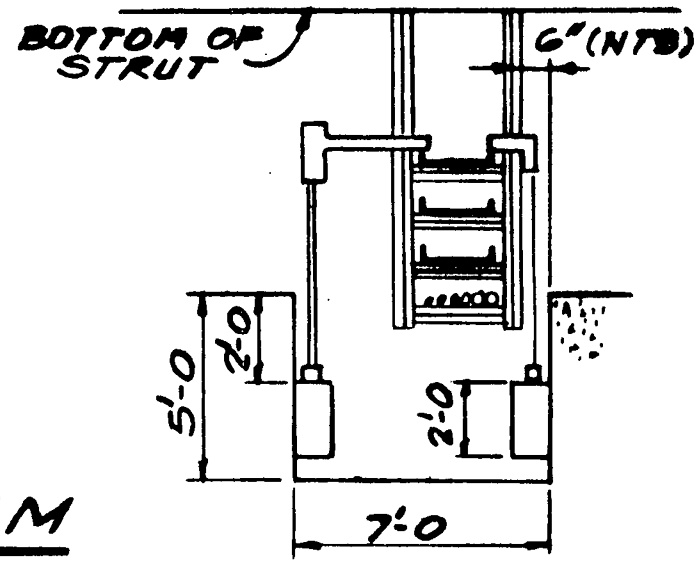


FIGURE 3B. FLEXIBLY SUPPORTED CONDUITS



COMPOSITE RACEWAY SYSTEM



SECTION (A)

✱ LOCATION OF TRANSVERSE BRACE

+ LOCATION OF LONGITUDINAL BRACE

FIGURE 4. COMBINED SYSTEM