# SAN ONOFRE NUCLEAR GENERATING STATION

UNIT 1

## ELECTRICAL RACEWAY SUPPORTS

## SEISMIC REEVALUATION CRITERIA

August 13, 1982

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## 1.0 INTRODUCTION AND PROGRAM DESCRIPTION

### 1.1 Introduction

This report presents the scope, methodology and acceptance criteria used in the Seismic Reevaluation Program for the San Onofre Nuclear Generating Station, Unit 1 Electrical Raceway Supports. The electrical raceway reevaluation is being conducted as a part of the Systematic Evaluation Program (SEP).

### 1.2 Scope and Reevaluation Approach

The scope of the Electrical Raceway Supports Seismic Reevaluation Program includes all raceway supports which are safety related. The Design Basis Earthquake (DBE) as described in subsection 3.7.1 and Figure 3.7-1 of the document entitled "Balance of Plant Structures (BOPS) Seismic Reevaluation Criteria," (Reference 1) is employed in this evaluation. The design response spectra for horizontal ground motion correspond to the Housner spectra, as described in subsection 9.2 of the San Onofre Unit 1 FSA, normalized to 0.67g. The design response spectra for vertical ground motion are normalized to 2/3 of the horizontal spectra.

The floor response spectra employed in this program are included in Reference 2. A description of the methodology which is used to develop the floor response spectra is also included therein.

The reevaluation considers the ability of the raceway systems to structurally withstand the effects of the occurrence of a DBE in combination with normal plant operating loads.

Compliance with stress criteria based upon current code requirements along with consideration of original design codes and quality requirements (as defined in sections 3.0 and 4.0) will represent adequate reevaluation without further analysis. If the computed stress results do not comply with the specified stress criteria, alternate stress criteria based upon further consideration of the original design codes, original quality requirements, and failure probabilities and consequences may be utilized.

## 2.2 Conduit Supports

The rigid conduit support systems utilized at San Onofre Unit 1 consist of variations of three basic types of supports. The basic types of supports are as follows:

Type 4: Surface Mounted - This type of support is shown in Figure 4. The surface mounted support consists of a length of strut attached along the surface of the main structure with the conduit attached directly to the strut. Approximately 45% of all the rigid conduit supports are of the surface mounted type.

Type 5: Cantilever - The cantilever conduit support is shown in Figure 5. This type of support consists of a member extending outward from the structure with the conduit attached directly to it. This type of support accounts for about 40% of the conduit supports.

Type 6: Trapeze - This type of support is shown in Figure 6. It consists of two vertical members extending downward which are connected by a horizontal member that directly supports the conduit. The support is then laterally braced for transverse loads. This type of support accounts for about 15% of the conduit supports.

Variations in the three basic types of supports consist of configuration differences with respect to the following parameters:

a) The number of conduits being supported.
b) The orientation and elevation of conduits being supported.
c) The size of the conduits.
d) The location of a brace in relation to the conduit support.
e) The angle of the brace.
f) Whether the support is laterally braced or not.
g) Whether the support has a longitudinal brace.
h) The distance the support spans from the structure to the conduit location.
i) The size and type of strut used to construct the support.
j) The orientation of the support in relation to the conduit.
k) The interconnecting of supports.
l) The details of the connections between the members making up the support.
m) The anchorage details of the support to the main structure.

## 3.0 REEVALUATION CRITERIA

The criteria for reevaluation of the raceway support systems are consistent with the criteria utilized for the reevaluation of the Balance of Plant Structures (See reference 1). The practices employed during the original construction of the raceway are essentially the same as those used today for safety related raceway support systems. These practices include welding procedures, methods of fabrication, material properties, member sizes and other construction techniques. For this reason, the present day codes and allowables have been selected as the guideline acceptance criteria for the raceway support systems.

A list of the applicable codes., standards and the test program which the reevaluation allowables are based upon are the following:

A. A.I.S.C. Manual of Steel Construction, 8th Edition, 1980

B. A.I.S.I. Specification for the Design of Cold-Formed Steel Structural Members, 1980 Edition

C. A.W.S. Structural Welding Code, D1.1, 1980

D. Cable Tray and Conduit Raceway Seismic Test Program, 1053-21.1-4 Volumes I through IV prepared for and in collaboration with: Bechtel Power Corporation, Los Angeles Power Division, Norwalk, California, 1978

The damping values that are used in the raceway support reevaluation are listed in Table 1. The damping values for cable tray and conduit systems are based upon the results of the testing described in Reference 3.

The supports are evaluated for the DBE generated loads (three component motion) in conjunction with existing dead loads. The load combination and the corresponding allowables are given in Table 2.

The allowable tension and shear loads of concrete expansion anchors are given in Table 3. The allowable tension and shear loads of expansion anchors in grouted masonry walls and of through bolts in masonry walls are determined as follows:

a) The allowable shear is 1/4 of the allowable shear values specified in Table 3.

b) The allowable tension is 3/4 of the allowable tension values specified in Table 3.

For these cases no interaction equation was used. The allowable stress for the strut bolted connections is as shown in Table 4.

## 4.0 METHODS OF EVALUATION

The seismic reevaluation of the electrical raceway supports is accomplished by utilizing the methods described in this section. The supports are first examined, and information necessary for reevaluation is obtained using the procedures given in subsections 4.1 and 4.2. The final step is to evaluate the support using the appropriate method from subsection 4.3 and to ascertain the governing stress condition.

### 4.1 Cable Tray Supports Evaluation Procedures

Where design documents are available the cable tray supports are evaluated using method D of subsection 4.3. Cable tray supports, where no previous design documents are available, are visually inspected and the following information is recorded on an electrical raceway support evaluation summary form (See Figure 7).

- Assignment of a support number
- Location of support
- Number of trays, conduits, size and raceway I.D. number for each
- Actual weight of cable and tray per foot
- Tributary length of tray being supported
- Sketch of configuration, noting member types, sizes, connections and dimensions
- Comments (i.e., missing bolts, etc.)

After the above information is obtained, the appropriate evaluation method from subsection 4.3 is utilized to determine the adequacy of the support.

### 4.2 Conduit Supports Evaluation Procedures

Where design documents are available, the conduit supports are evaluated using method D of section 4.3. Otherwise the conduit supports are evaluated by first performing an inspection of the plant by area and recording information similar to that described in subsection 4.1, on an electrical raceway support evaluation summary form (See Figure 7).

Then, the conduit supports are subdivided by type of support (See Figures 4 through 6). Each support group is further subdivided by existing loading conditions (number and size of conduits, etc.) and the most critical support is determined in the subset by evaluating the loading, member span length, connection details, etc. The method of evaluation is selected in accordance with subsection 4.3. The other supports in the subset are evaluated based on the calculated results for the "critical" support.

## 4.3 Support Evaluation Methods

The electrical raceway supports are evaluated by using one of the five basic methods as described below. For each support evaluation, the most appropriate method is chosen.

Method A This method consists of calculating the stress conditions associated with the support for the loads and load combinations in Table 3.2 and comparing the actual stress to the allowable stresses as stated in Section 3.

The seismic forces are calculated using the equivalent static method of analysis. In this procedure the seismic forces applied to a particular support in a given direction are obtained by multiplying the tributary mass by a seismic coefficient. Structural systems which can be adequately characterized as a single-degree-of-freedom system are considered to have a seismic coefficient equal to the instructure spectra acceleration at the system frequency. If the acceleration is in the amplified region of the curve, the peak acceleration is used. Alternatively, the coefficients are established as follows:

a. Supports on Masonry Walls: No frequency calculations are made. For the cable tray supports the horizontal and vertical seismic coefficients are 1.5 times the peak spectral accelerations of the corresponding instructure response spectra at the top elevation of the wall. For the conduit supports the horizontal and vertical seismic coefficients are the peak spectral accelerations of the corresponding instructure response spectra at the top elevation of the wall. This is conservative since the conduit frequencies are in the unamplified region of the instructure response spectra.

b. Other Supports: The first step in computing the seismic coefficient is to determine the frequencies of the support system being evaluated. The configuration of the system, its mass distribution, member stiffnesses and connection flexibilities are all accounted for in determining the frequencies of the system. The seismic coefficients are then obtained by using the computed fundamental frequencies and obtaining the corresponding response accelerations from the appropriate instructure response spectra. For the vertical direction, the seismic coefficient is taken as 1.5 times the peak spectral acceleration of the applicable instructure spectrum. If no frequency calculations are made the horizontal and vertical seismic coefficients are 1.5 times the peak spectral acceleration of the applicable instructure response spectra.

The seismic loads from the three orthogonal directions are considered to occur simultaneously and these results are combined by the square-root-of-the-sum-of-the-squares method.

For those supports without a longitudinal brace, the seismic force in the longitudinal direction is assumed to be resisted by the closest support with a brace in that direction.

The seismic stresses are then combined with the dead load stresses and the resulting stresses are compared with the allowable values of Section 3 to determine the adequacy of the support.

Method B This method is for supports with configurations that compare favorably with previously tested supports (Reference 3). Particularly, conduit raceway supports rigidly attached to the walls, with typical support spacing of 8'(See Figure 4). For these cases the seismic acceleration levels are obtained from the appropriate instructure response spectrum. For those supports with acceleration levels equal to or less than 7.5g's the conduit supports are considered adequate based on the results of the testing in Reference 3. If the acceleration values are greater, the clamps holding the conduits to the supports are evaluated by Method A.

Method C This method is utilized for supports which are essentially the same as other supports previously evaluated by methods A or B. It consists of comparing the support with previously evaluated supports and based upon similarity making a judgment as to the adequacy of the support. In utilizing this method each factor which contributes to the structural behavior of the support (e.g. loading, member size and configuration, connection details, etc.) is compared with the previously evaluated support to ensure that a valid comparison exists.

Method D This method is utilized for supports which were recently engineered and installed. This method consists of reviewing the design calculations to ensure that all the requirements of the seismic reevaluation criteria are met. This includes, but is not limited to, floor response spectra acceleration values, stress allowables, combined effects of three component seismic loading and connection details.

Method E This method is utilized to evaluate the raceway support system within the 4160V switchgear room. The support system in this area is somewhat different from the supports throughout the rest of the plant. The main differences pertain to the extent of inter-connectivity between the supports and the use of structural steel members (wide flange shapes) for attaching the raceway support at the mezzanine level of the room. Because of the extensive inter-connecting of supports, the system resembles and therefore reacts to seismic loads in a manner similar to a space frame. Due to this situation, dynamic models of the typical support configurations are made. Then the seismic forces are computed by response spectrum method using the BSAP computer program.

The seismic stresses are then combined with the dead load stresses and the resulting stresses are compared with the allowable values of Section 3 to determine the adequacy of the support.

## 5.0 COMPARISON OF TEST RESULTS WITH REEVALUATION CRITERIA

In 1978 Bechtel sponsored the "Cable tray and Conduit Raceway Test Program", where full scale seismic tests were performed on various support configurations by ANCO Engineers, Incorporated (Reference 3). During this program some 2000 dynamic tests were performed on several hundred varied cable tray and conduit support systems. The effects of numerous parameters which could possibly influence system dynamics were investigated. Also, several different types of tray, conduit, and supports from various manufacturers were tested. As a result of this extensive test program and related activities, a design basis for Category I cable tray and conduit systems has been developed.

This section discusses the results of those tests in relation to the seismic reevaluation criteria presented herein.

### 5.1 Damping

The damping values utilized for the reevaluation of the cable tray support system are based upon the results of the testing program performed by ANCO Engineers, Incorporated (See Reference 3). The damping measurements that were documented in Reference 3 were conducted on trapeze-type supports although cantilever type supports were also tested. The conclusions of the testing program concerning damping, apply to cable tray support systems in general. This is due to the fact that the major energy absorbing source within the system is the motion of the cables within the trays themselves. As the level of input increases, the amount of cable movement (sliding back and forth and bouncing up and down) also increases. The motion of the cable and the internal friction generated absorb much of the input energy, resulting in a high level of equivalent damping. It was concluded that the largest portion of the system damping was the result of the amount of energy absorbed 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.) were insignificant in determining the overall system damping.

The cable tray damping data obtained from the ANCO testing was 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. Statistical analyses were also performed. Various combinations of systems braced in the same direction were combined and the mean curves and the 15% non-exceedence probability curves (corresponding approximately to mean minus one sigma) were computed. This information is presented in Reference 4.

Table 5 provides the critical damping values tabulated from Reference 4 and corresponding to an input acceleration of 0.67g, the lowest acceleration level at the SONGS 1 plant for the DBE.

There were a limited number of tests performed on cantilever raceway support systems namely, tests I1-11B, 11C, and 11D. The configuration tested consisted of a five support, three tier cantilever system where the trays were supported every 8' with Unistrut brackets (Catalogue No. P2545) similar to those used at SONGS 1. 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 5 are appropriate for SONGS 1. However, for conservatism a critical damping value of 15% was used in the reevaluation of the cable tray raceway systems.

## 5.2 Calculation Procedures

For comparison purposes, calculations were performed following the procedures described in subsection 4.3 for a tested tray system similar to systems existing at SONGS 1. The configuration is a five support, three-tier cantilever system. The depth from the upper anchors to the bottom of the first tier was 5'. Spacing between tiers is 16". The tray (MPC ladder type H09P-24-120T) was supported every 8' on Unistrut brackets (Catalogue No. P-2545). Each support is laterally braced at the second tier elevation by double-channel strut. The cable loading was 50 lb/ft.

Calculations show that the dead load bending stress at the connection of the first tier with the vertical support would be about 25KSI. The comparison of the dead load stress with the allowable bending stress used in the evaluation criteria (0.9 x 33 KSI) indicates that the remaining capacity in the member is on the order of 4.7 KSI. Assuming the acceleration level due to the vertical earthquake is one half of the horizontal earthquake (consistent with the test input) then a horizontal acceleration larger than 0.3g would cause the total bending stress to exceed the reevaluation criteria limits.

The reduction of the test results as presented in table 6 shows that a peak horizontal acceleration level of 1.44g was observed during the successful testing of the support system. Comparing the test data with the calculation results shows that the cable tray raceway supports have substantial reserve margins and that their resistance capacity to earthquake-type motions as predicted by calculations are conservative. The differences between the calculations and the test data would be due to:

a. Inelastic action of the support system.
b. Actual versus design values for material properties.
c. Actual damping within the system.
d. Internal load distribution within the tray support system which was not considered in the reevaluation process.

## 6.0 REFERENCES


1. "Balance of Plant Structures Seismic Reevaluation Criteria" San Onofre Nuclear Generating Station, Unit 1, February 17, 1981.

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

3. "Cable Tray and Conduit Raceway Seismic Test Program," 1053-21.1-4 Volumes I through IV, prepared for and in collaboration with Bechtel Power Corporation, Los Angeles Power Division, Norwalk, Ca., 1978.

4. "Report on Cable Tray Support System Damping Values Vogtle Electric Generating Plant, March 3, 1982", enclosure to letter from D. Dutton to D. G. Eisenhut (NRC) dated March 5, 1982.

TABLE 1

DAMPING VALUES FOR SEISMIC REEVALUATION

| Item | Damping (Percent of Critical) |
|---|---|
| Conduit Supports | 7 |
| Cable Tray Supports | 15 |
| Combined Conduit and Cable Tray Supports (Same support) | 15 |
| Welded Steel Structures | 4 |
| Bolted and/or Riveted Steel Structures | 7 |
| Reinforced Concrete Structures | 7 |

TABLE 2

LOADS AND LOAD COMBINATIONS

| Loading Combinations | Allowables* |
|---|---|
| D & E' | $1.5F_s$ or $0.9F_y$ |

Definitions:

D = Dead load of equipment including weight of all permanent attachments

E' = Loads generated by the DBE

$F_s$ = Allowable stresses: from item B of section 3.

$F_y$ = Minimum yield stress of material: 33 KSI

*$1.5F_s$ is used for axial loads and local or lateral stability (buckling) requirements; $0.9\ F_y$ is used for bending or tensile stresses.

TABLE 3

CONCRETE EXPANSION ANCHOR ALLOWABLES

| Anchor Diameter (In') | Allowable Shear $V_A$ (lbs) | Allowable Tension $T_A$ (lbs) |
|---|---|---|
| 1/4 | 1066 | 365 |
| 3/8 | 1100 | 575 |
| 1/2 | 1970 | 1260 |
| 5/8 | 2840 | 1500 |
| 3/4 | 3790 | 2290 |
| 1 | 6750 | 3750 |

a. The above values (allowable) are for wedge type expansion anchors installed in 4000 psi concrete.

b. All allowable loads above are 1/4 of the manufacturer's recommended ultimate loads.

c. For evaluation of simultaneous tension and shear loading of concrete expansion anchors, the loads are combined by the following interaction formula:

$$\left(\frac{t}{T_A}\right)^2 + \left(\frac{v}{V_A}\right)^2 \leq 1.5$$

where t and v are the calculated tension and shear loads, respectively.

d. The interaction formula is based on the test results of drilled-in expansion bolts under static and alternating loads, Report no. BR-5853-C-4 by Bechtel Power Corporation., January 1975.

TABLE 4

STRUT BOLTED CONNECTIONS

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**The allowable stress for strut bolted connections is obtained as defined by the following equation.**

$$F_{st} = 0.9\ (2xF)$$

Where:

$F_{st}$ = Allowable stress

$F$ = The unistrut bolted connection allowable as defined in the Unistrut General Engineering Catalog No. 9 which provides a factor of safety of 3.

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TABLE 5

PERCENT CRITICAL DAMPING VALUES

BASED ON CABLE TRAY TESTS

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

TABLE 6

**Test:** II-11D **Run:** XZe,f,g,h **Direction:** Transverse + Vertical

**Description:** Sinusoidal and Earthquake Input, Lowest Transverse Mode Response. Three-tier Cantilever Raceway, 100% Cable Loading.

Sinusoidal Input

| Input (g) | $f_o$ (Hz) | $B_o$ (%) | (R/I) | Peak g at Ch 3 | Peak g at Ch 4 | Peak Displacement at ____ |
|---|---|---|---|---|---|---|
| - | 3.88 | 14.4 | | 0.48 | ~1.0 | |
| 0.41 | 3.88 | 19.1 | 2.9 | 1.18 | ~2.77 | |

Earthquake Input

| Input (g) | $f_o$ (Hz) | $B_o$ (%) | (R/I) | Peak g at Ch 3 | Peak g at Ch 4 | Peak Displacement at ____ |
|---|---|---|---|---|---|---|
| 0.06 | 3.9 | 7.0 | 5.12 | 0.31 | ~0.74 | |
| 0.15 | 3.84 | 14.0 | 3.62 | ~0.5 | 0.96 | |
| 0.17 | 3.85 | 14.5 | 3.50 | 0.60 | ~1.40 | |
| 0.30 | 3.85 | 21.5 | 2.67 | ~0.80 | | |
| 0.60 | 3.7 | 25.5 | 2.15 | 1.28 | | |
| 0.68 | 3.6 | ~25.7 | 2.13 | 1.44 | | |

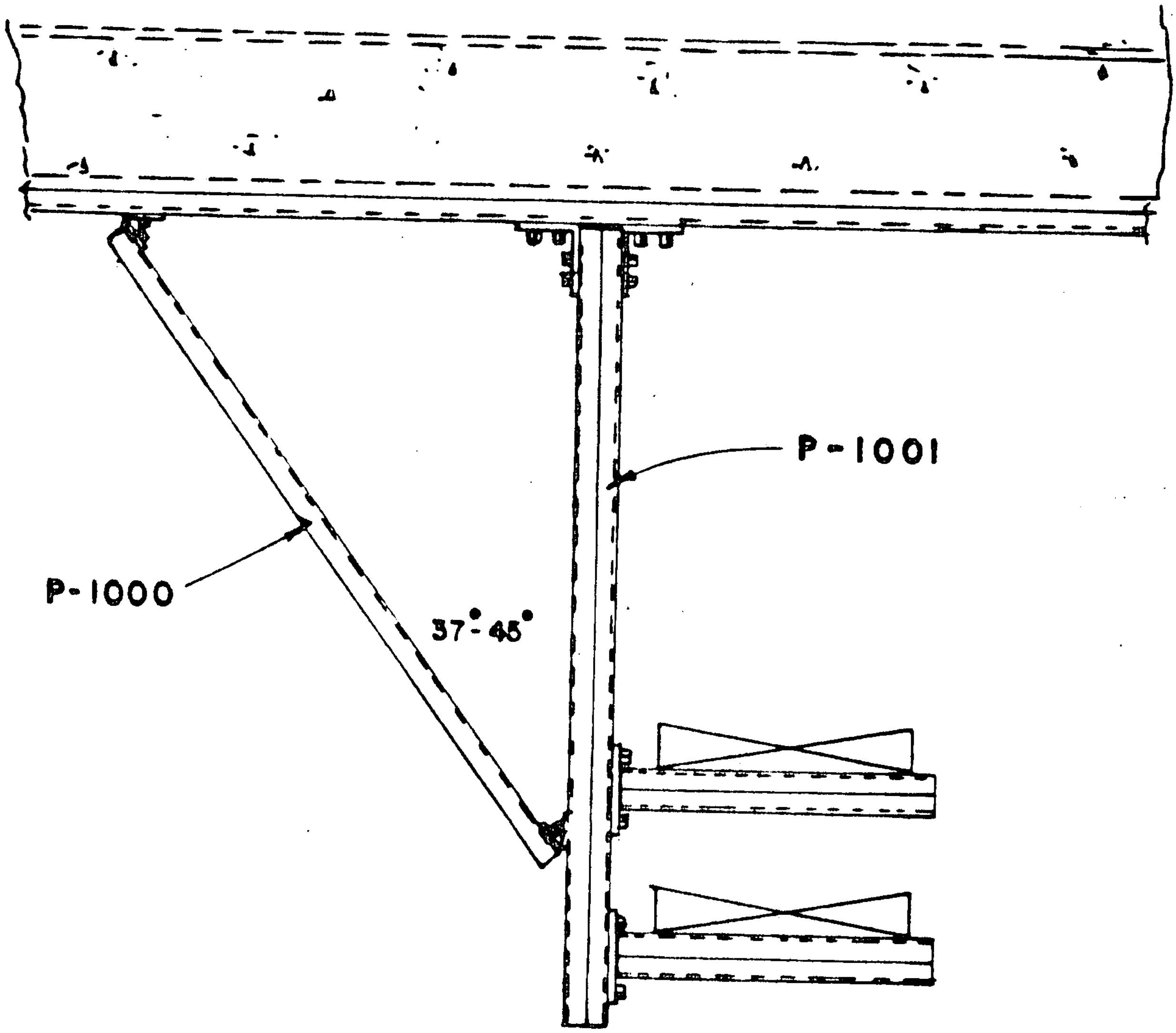


FIGURE 1

(braced cantilever)

GENERAL AS BUILT INSTALLATION NOTES FOR CABLE TRAY AND CONDUIT SUPPORTS

1. ALL MEMBERS AND CONNECTION BRACKETS ARE UNISTRUT ITEMS.
2. ALL BOLTED CONNECTIONS ARE 1/2" DIAMETER.
3. CONCRETE CONNECTIONS ARE EITHER EMBEDDED STRUT OR EXPANSION ANCHORED STRUT.
4. ATTACHMENTS TO STRUCTURAL STEEL ARE WELDED.
5. THE NUMBER OF TRAYS / CONDUITS AND MEMBER LENGTHS VARY.
6. FIGURES SHOWN ARE BASIC CONFIGURATIONS AND MAY VARY.

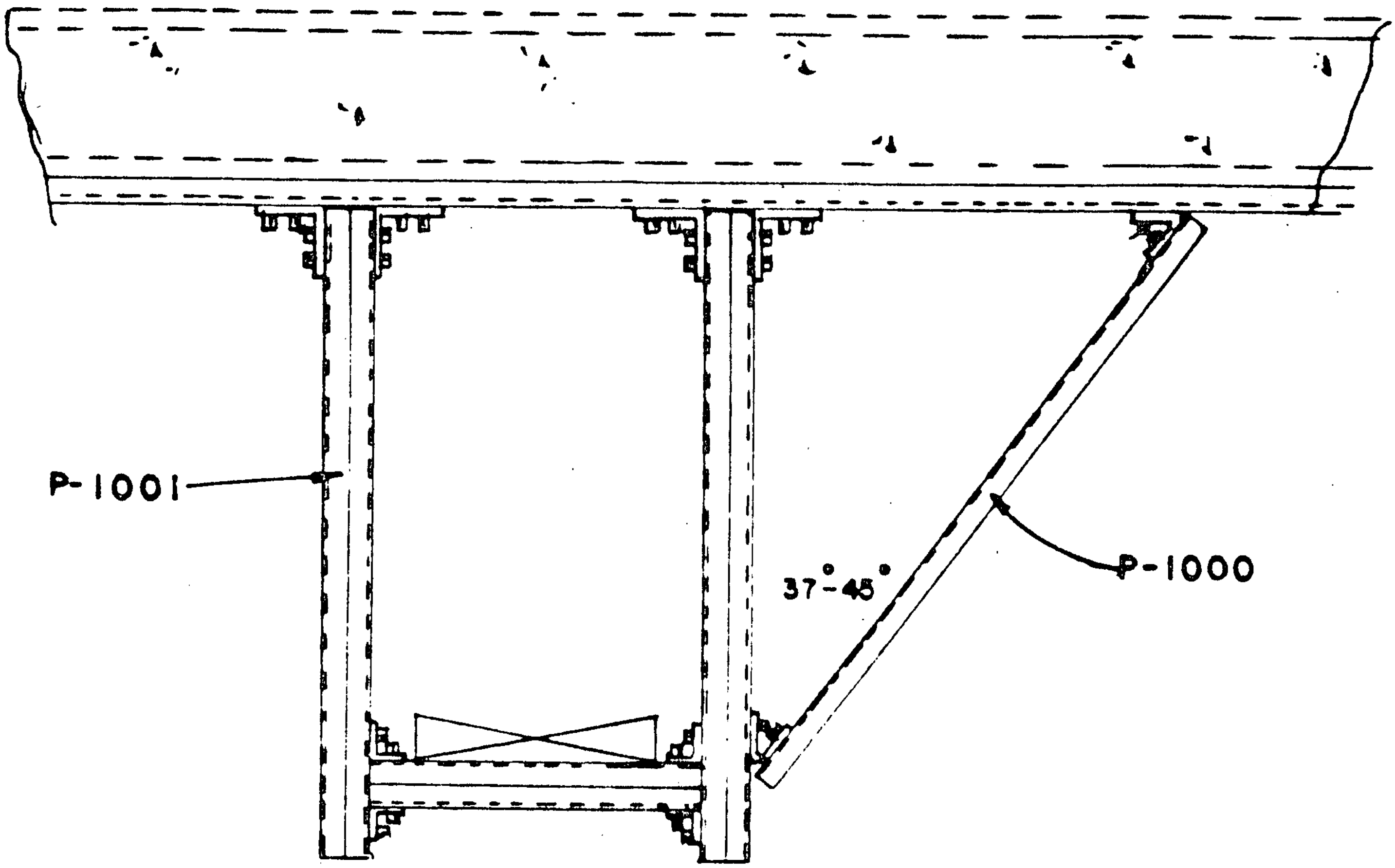


FIGURE 2
(trapeze)

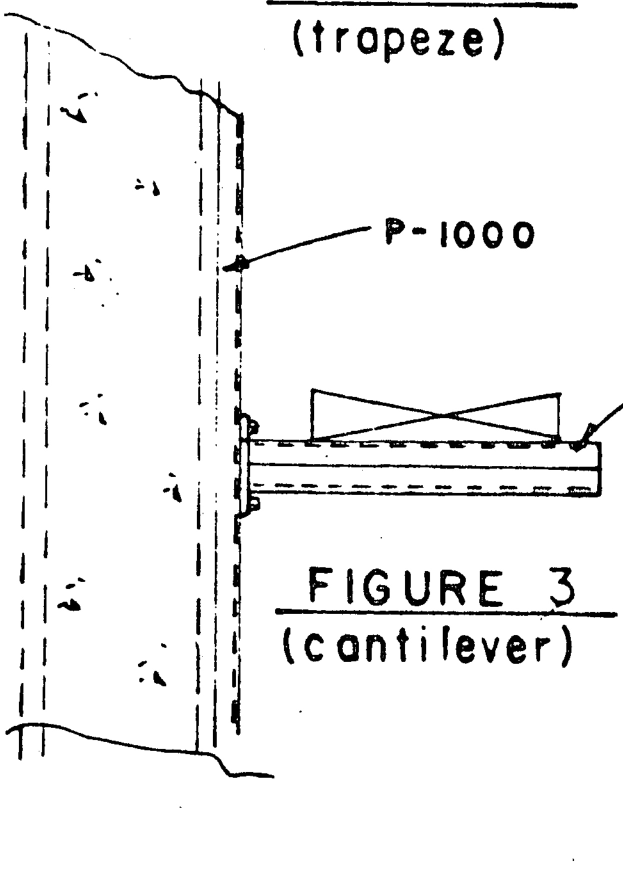


FIGURE 3
(cantilever)

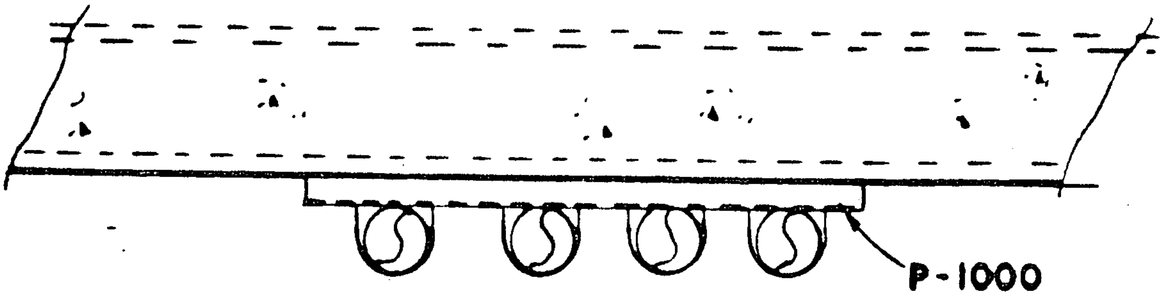


FIGURE 4
(surface mounted)

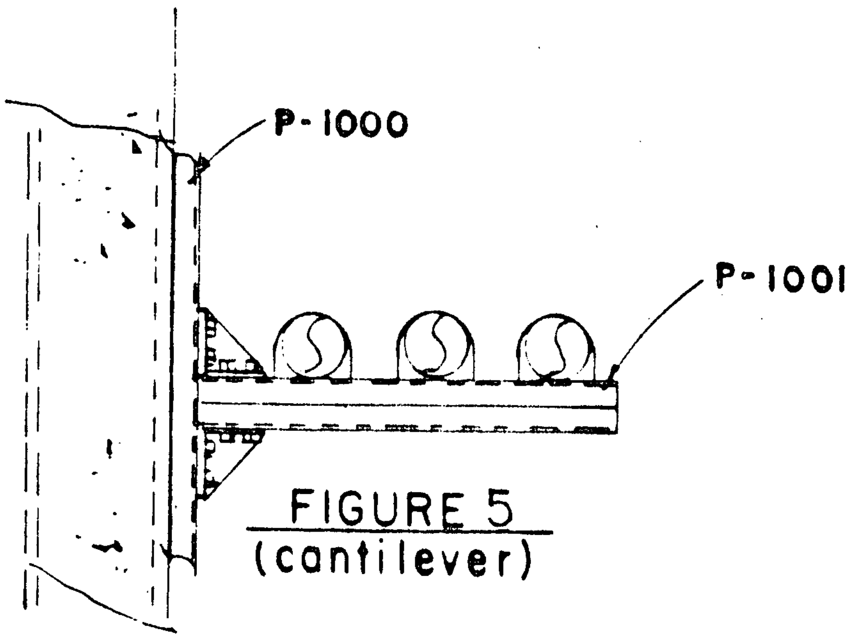


FIGURE 5
(cantilever)

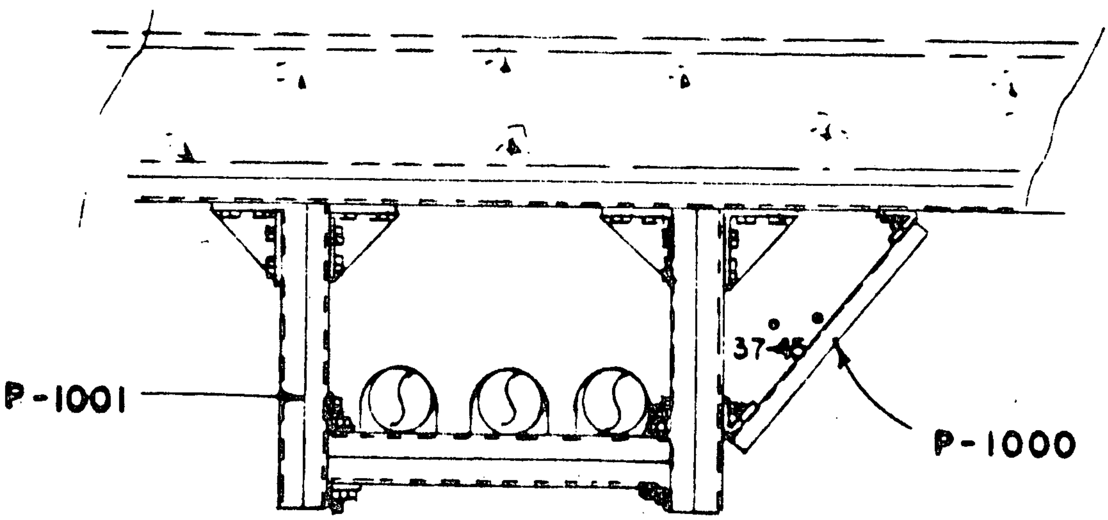


FIGURE 6
(trapeze)

SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1
# SAFETY RELATED ELECTRICAL RACEWAY SUPPORT EVALUATION SUMMARY
JOB 14000

CALC. NO. ____________

SIGNATURE ______________________ DATE ____________ CHECKED ____________ DATE ____________

PROJECT ______________________ JOB NO. ____________

SUBJECT ______________________ SHEET ______ OF ______ SHEETS

| | |
|---|---|
| AREA NO. ____________ | SUPPORT TYPE: ____________ |
| SUPPORT NO. ____________ | SUPPORT SPACING: ____________ |
| NO. OF TRAYS ____________ | BRACING: |
| NO. OF CONDUITS ____________ | LATERAL: ____________ |
| SIZE: ____________ | LONGITUDINAL: ____________ |
| ____________ | ANCHORAGE: |
| ____________ | BOLTED: ____________ |
| TRAY OR CONDUIT REFERENCE NO.: | WELDED: ____________ |
| ____________ | ELEVATION: ____________ |
| ____________ | BRACKET TYPE: ____________ |
| ____________ | COMMENTS: ____________ |
| ____________ | ____________ |
| ESTIMATED WT./FT. ____________ | ____________ |

CONFIGURATION

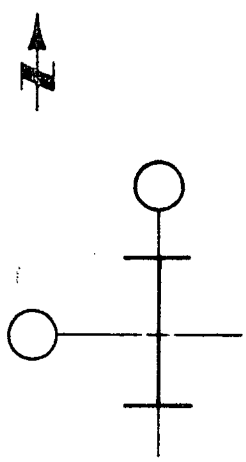


FIGURE 7

PF-5848 (14000) 10/81