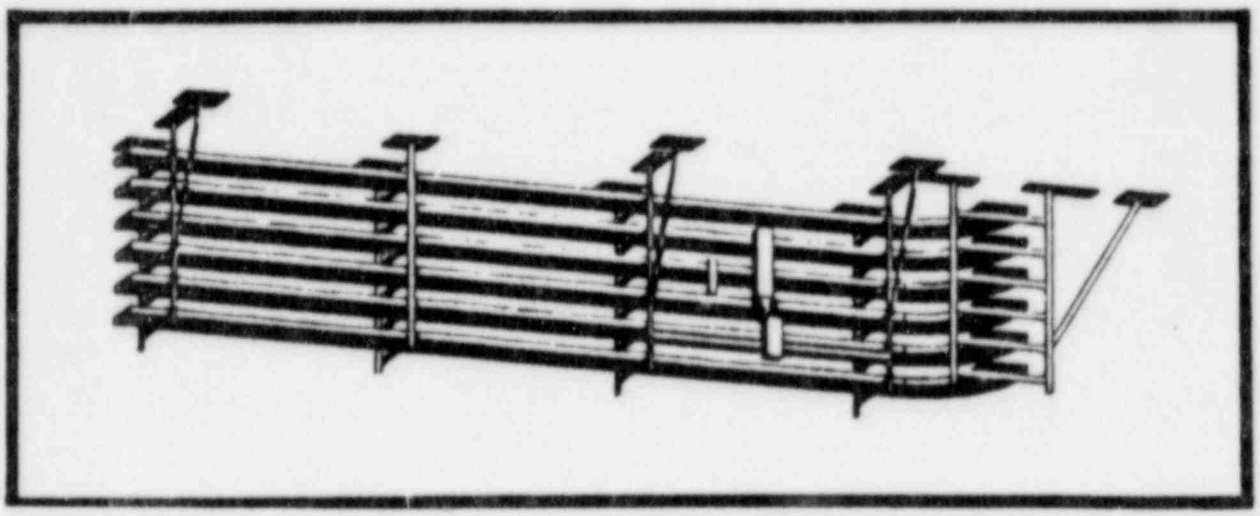
ATTACHMENT 2

Seabrook Station
New Hampshire Yankee

Cable Tray Support Qualification Program



MARCH 31, 1986

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1.0 EXECUTIVE SUMMARY

Dynamic test programs conducted throughout the industry have demonstrated that Cable Tray Support Systems exhibit significant seismic capacity. These dynamic studies have enabled the Seabrook Project to pursue a test based qualification program. The program is based upon plant-specific tests to justify the seismic qualification of the existing Seabrook cable tray support configurations in their present state of completion. In the absence of this test based qualification program, a substantial amount of seismic bracing, and hardware improvements would be necessary to complete the original design concept.

Cable tray support performance and behavior for typical Seabrook systems details and materials were evaluated in the laboratory during the initial phase of this program. This included full scale dynamic testing on representative support and tray configurations at high levels of seismic input. These proof and fragility tests were fundamental to the development of a revised analytical approach for the Seabrook cable tray support qualification.

The testing program demonstrates that the typical Cable Tray Systems exhibit substantial seismic capacity. The testing results have shown: (1) existing connections exhibit substantial rotational resistance and (2) the Cable Tray Systems exhibit highly damped response. The test data has been used to develop an analytical approach based upon actual and predictable system behavior.

The final phase of the program couples this technology with the Seabrook installation by performing an individual support seismic evaluation and component interaction review. This phase of the program provides the final documentation for the cable tray support qualification.

It is concluded, therefore, that implementation of this program fulfills project commitments for the qualification of the existing Seabrook cable tray support installation.

2.0 PROGRAM OBJECTIVES AND SCOPE

2.1 Background

Seismic qualification of cable tray supports in certain Seismic Category I buildings is to be completed by utilizing dynamic testing and analytical methods to refine the existing project analytical methods. The decision to redirect the Seabrook cable tray qualification was influenced by the following factors:

- o Past shake table testing of Cable Tray Support Systems have shown that Cable Tray Systems exhibit inherent seismic capacity with varying amounts of seismic bracing.
- o Existing project analysis modeling methods of Cable Tray Systems could be refined to be more reflective of actual system behavior.
- o Dynamic testing is an accepted seismic qualification method by the USNRC Standard Review Plan (Section 3.10).

2.2 Objective

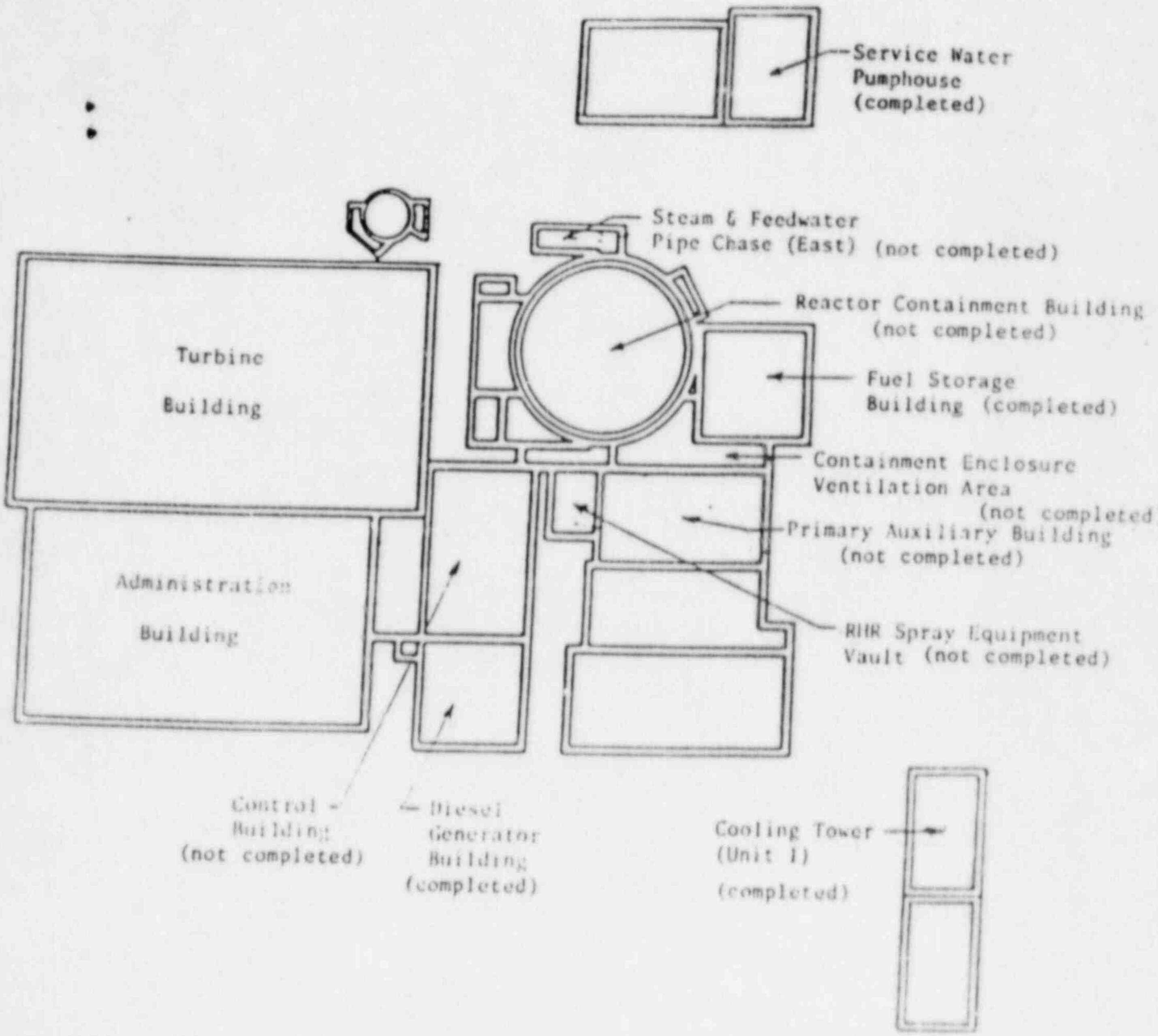
The objective of the refined qualification program is to produce and implement a methodology which will optimize the project's use of available resources while meeting appropriate acceptance criteria and margins.

2.3 Scope

Seismic qualification of cable tray supports by dynamic testing/analytical methods will pertain to supports located in seven of a total of eleven Seismic Category I buildings which still require final documentation of their qualification. In the remaining four Seismic Category I buildings, the design, installation and final documentation of cable tray supports based on the original design concept is complete. Figure 2.1 and the lists below identify the buildings with applicable seismic qualification programs.

Seismic Qualification Building Status

Buildings Utilizing Refined Program	Completed Buildings
Control Building	Service Water Pumphouse
Reactor Containment Building	Cooling Tower (Unit 1 Side)
Primary Auxiliary Building	Diesel Generator Building
Containment Enclosure Ventilation Area	Fuel Storage Building
RHR Spray Equipment Vault	
Steam and Feedwater Pipe Chase (East)	
Electrical Tunnels Trains A and B	



STATUS OF CABLE TRAY SUPPORT QUALIFICATION

FIGURE 2-1

3.0 QUALIFICATION PROGRAM

Implementation of the qualification program will be performed on an individual support basis. A review of all supports is planned using as-constructed drawings and walkdown results. Individual support qualification will be accomplished by implementation of one of the following three (3) methods: (a) testing, (b) analysis or (c) combination test plus analysis. Support qualification by testing will be utilized when the support geometry/hardware mass and seismic environment, etc., are bounded by a specific test case. Supports not directly bounded by the geometry of the test cases but whose behavior is consistent with the behavior of the test cases, will be qualified by a combination of test and analysis. Supports not represented by test models will be qualified by a unique analysis.

An overall description of the qualification program is presented below. Detailed descriptions of the qualification methods are presented in Section 4. Table 3-1 summarizes the implementation phase of the qualification program.

3.1 Testing Program

The qualification test data base was developed by shake table testing of four representative support configurations which are predominant throughout the seven Seismic Category 1 buildings. The system behavior of each of the configurations was obtained by testing full scale systems. Figures 3-1 through 3-4 show standard construction details of the supports simulated by test. Figures 3-5 through 3-12 show typical cable tray layouts which are conservatively enveloped by the test configuration.

The test program data provides the necessary data to extract an understanding of system performance. The data is then used as an effective link to the analytical applications program as follows:

1. Connection test data is used to: (a) establish appropriate spring rates to be inserted into support finite element models and to (b) establish appropriate connection rotational and stress limits.

2. Finite element models of the test case samples derived in Item 1, are then compared to the system test data. Correlation of these analyses with the test results in terms of dynamic properties and response levels serves to verify the modeling approach.

3. The connection performance data developed in Item 1 is then reviewed versus the system data. Utilizing these connection performance data will result in responses that are limited to less than those observed during system testing. This will ensure that supports qualified analytically and in conformance with the acceptance criteria will be within the response levels generated during system tests. Joint rotation, for example will always be limited to values less than those observed during system testing.

Supplemental analytical evaluations are used to illustrate the severity of the test conditions and their resulting broad applicability. This is because the input margins included in the test programs resulted in bounding response data. In plant applications, the connection moments and forces, connection rotations, etc., are limited to values which are less than those recorded during the tests. Therefore, although the test samples do not geometrically envelope 100% of the plant, they were subjected to responses which, by the implementation of our qualification criteria, will envelope the actual support system responses at Seabrook. A support-by-support review will verify that indeed the tested supports envelope the response conditions of the vast majority of the existing support installations. This confidence is due to our parametric surveys which have yielded the following data:

- o The Test Response Spectra (TRS) exceeds the horizontal ARS of all elevations in the Control Building by a minimum of 60% at all frequencies above 1 Hz.

- o Fifty percent (50%) of all trays in the Control Building are loaded to 20% or less fill by area (note: 40% fill was used in the test program).

- o Seventy percent (70%) of all supports are spaced at intervals of 8 feet or less (note: 10 feet was used in the testing program).

- o 95% of all supports have more bracing than the unbraced test configurations.

3.2 Cable Tray Support Qualification

Each support will be qualified and documented by one of the following methods. Detailed descriptions of these methods are presented in Sections 5.0 and 6.0.

3.2.1 Testing

Critical elements of supports are enveloped by tested conditions.

Critical Parameters

- o ARS
- o Configuration
- o Hardware
- o Cable loading

Examples are shown in Figures 3-13 and 3-14.

3.2.2 Combination Test and Analysis

To evaluate configurations similar, but not identical, to the test configurations, supplementary analysis is performed. Analysis is directed toward key support items that ensure integrity. Examples of such configurations are shown in Figures 3-15 and 3-16.

3.2.3 Unique Analysis

Any support not qualified by test or combination test and analysis will require a unique analysis.

This analysis ranges from a complete analysis of the support of concern to an analysis which addresses any minor deviations between the support and a previously qualified configuration.

Analytical refinements, derived as a result of the test program, are incorporated where possible, for example:

1. Experimentally determined connection spring rates are used.

2. The analytical acceptance criteria is expanded to incorporate the connection rotational and capacity limits provided by the testing program.

3. Damping values up to a maximum of 20% will be utilized. (Note: The justification to use increased damping at Seabrook was submitted to the NRC in Reference 1. The Seabrook testing program serves to confirm the applicability of these damping values.)

Analytical criteria is presented in detail in Section 5.0 of this report.

Each support qualification will be documented in accordance with the guidelines and checklists contained in Section 6.0 of this report.

3.3 Other Issues

The seismic qualification program will also address the following open NRC issues:

1. 10CFR50.55(e) Report Electrical Cable Tray Support strut-nuts hardware. The test configurations included bolting hardware which exhibit slippage capacities less than published allowed loads.

2. All cable tray supports at Seabrook have been as-built to the level of detail shown on Figure 3-13. The personnel conducting the as-built are qualified in accordance with applicable ANSI standards.

3.4 Past Performance of Cable Trays in Seismic Events

To further document the inherent seismic capacity of cable tray supports, Seabrook cable tray support details are compared to cable tray supports that have experienced strong motion earthquakes. This comparison is made by EQE, Inc., an engineering consulting firm that deals primarily with the historical performance of various equipment that have survived past earthquakes. EQE, Inc., has accumulated an extensive data base that includes Cable Tray Systems similar to Seabrook including tray without axial bracing. Historically, Cable Tray Systems have performed very well during and after major earthquakes, with ground motion in excess of the Seabrook safe shutdown earthquake. This data supports the conclusions of the Seabrook dynamic test program and is provided in Appendix A.

CABLE TRAY SUPPORT
QUALIFICATION PROGRAM
IMPLEMENTATION

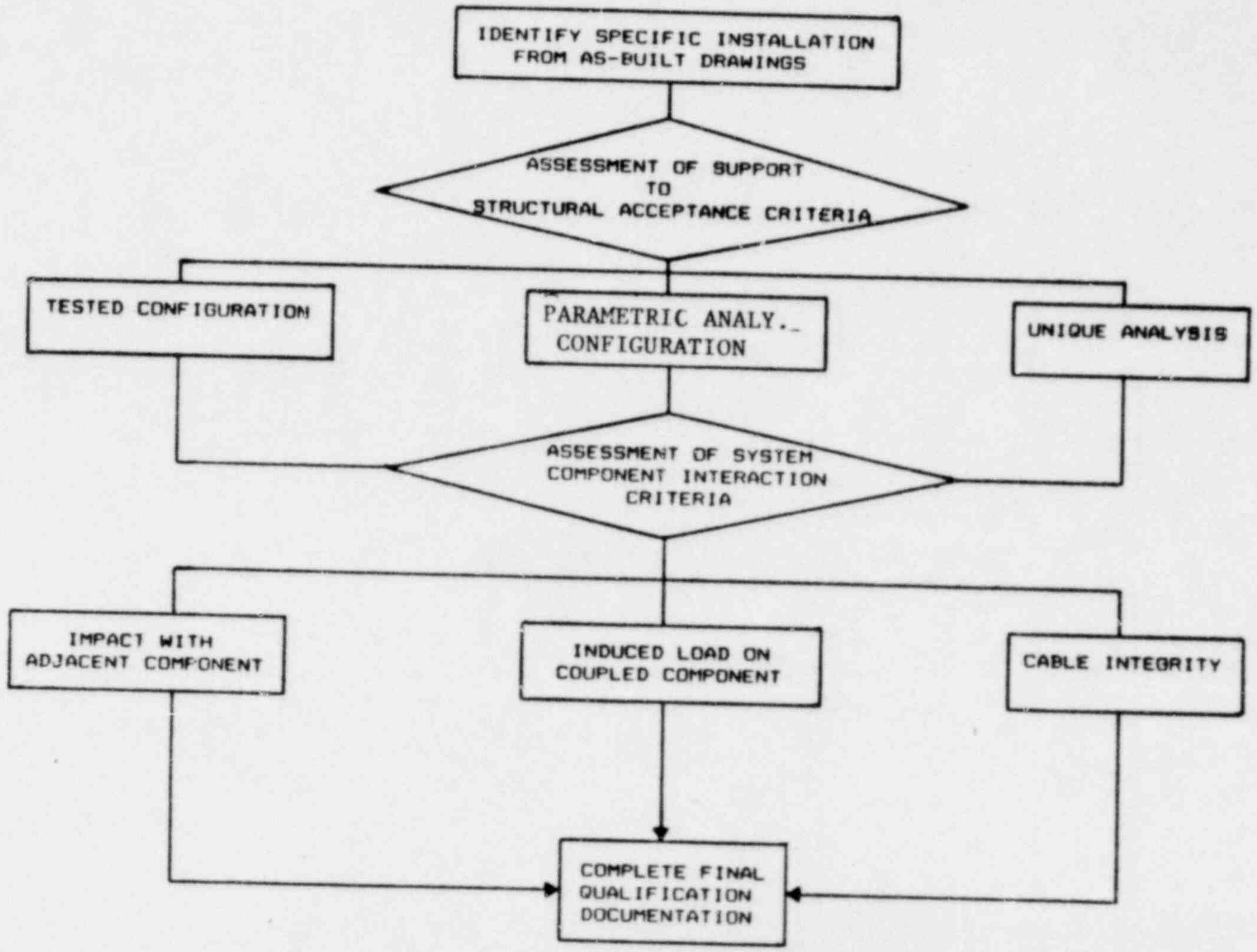
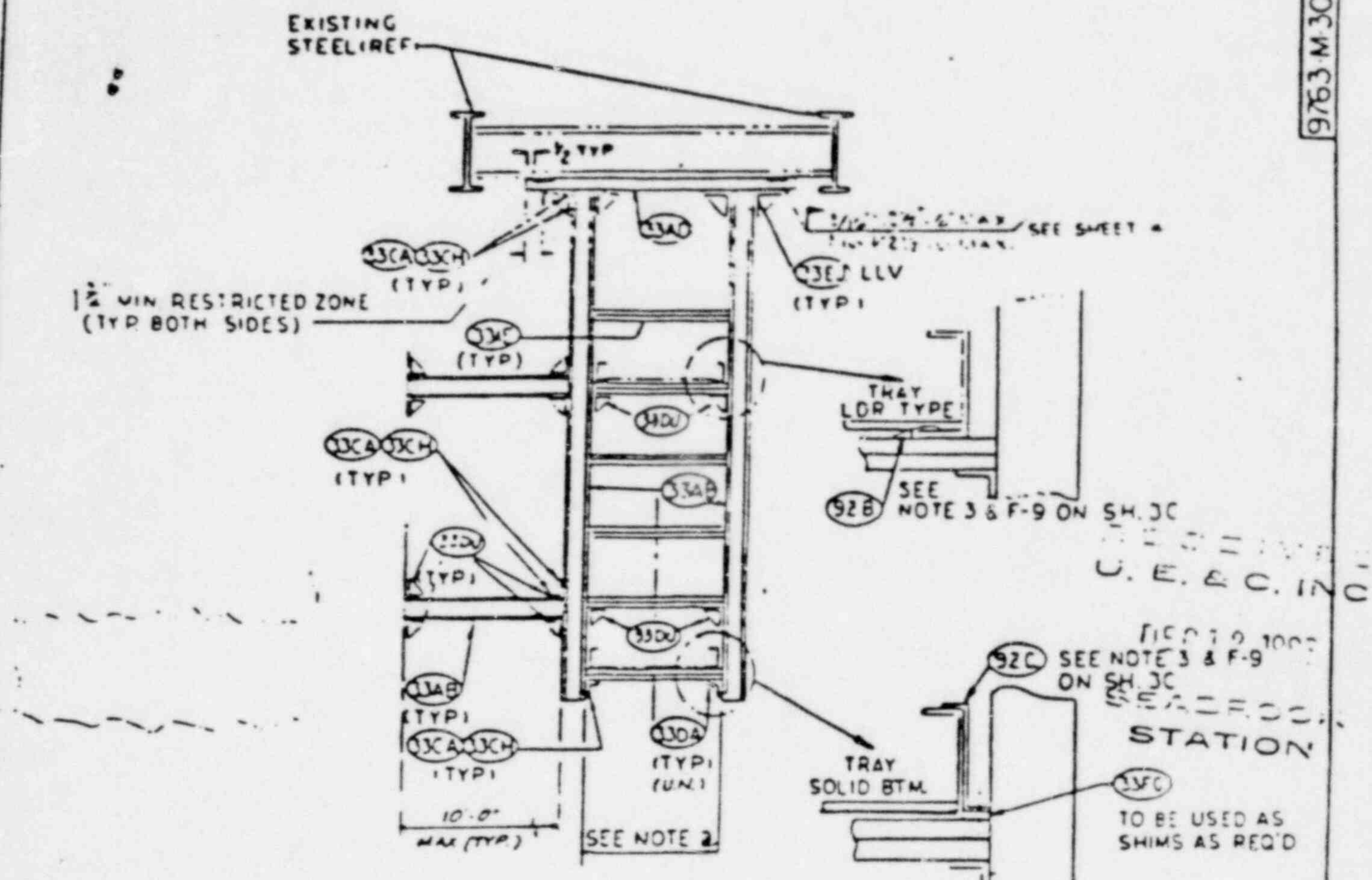


TABLE 3-1



CABLE TRAY SUPPORT SUSPENDED FROM CEILING
HORIZONTAL BRACING ONLY

NOTES:

1. NUMBER OF TRAYS PER SUPPORT MAY VARY. THE SEISMIC QUALIFICATION FOR THIS SUPPORT IS BASED ON MAXIMUM NUMBER OF TRAYS AND SPANS AS SHOWN ON DRAWINGS.
2. MAXIMUM DISTANCE BETWEEN VERTICAL SUPPORT MEMBERS (33XH) IS NOT TO EXCEED 54".
3. HOLD DOWN CLAMPS TYPICAL BOTH SIDES OF TRAY SUPPORTS.
4. SEE SHEETS T47 SERIES, T107 SERIES AND T111 FOR APPLICABLE ALTERNATE ATTACHMENTS.
5. FOR BRACING REQUIREMENTS AND TOLERANCES, REFER TO GENERAL NOTE A7.

NUCLEAR SAFETY RELATED

10		REVISED AS NOTED		
9		REV. AS NOTED		
8		REV PER ECA		
7		REV. AS NOTED		
6		[illegible]		

FIGURE 3-1

CABLE TRAY SYSTEMS
NOTES AND TYPICAL DETAILS

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SEABROOK STATION

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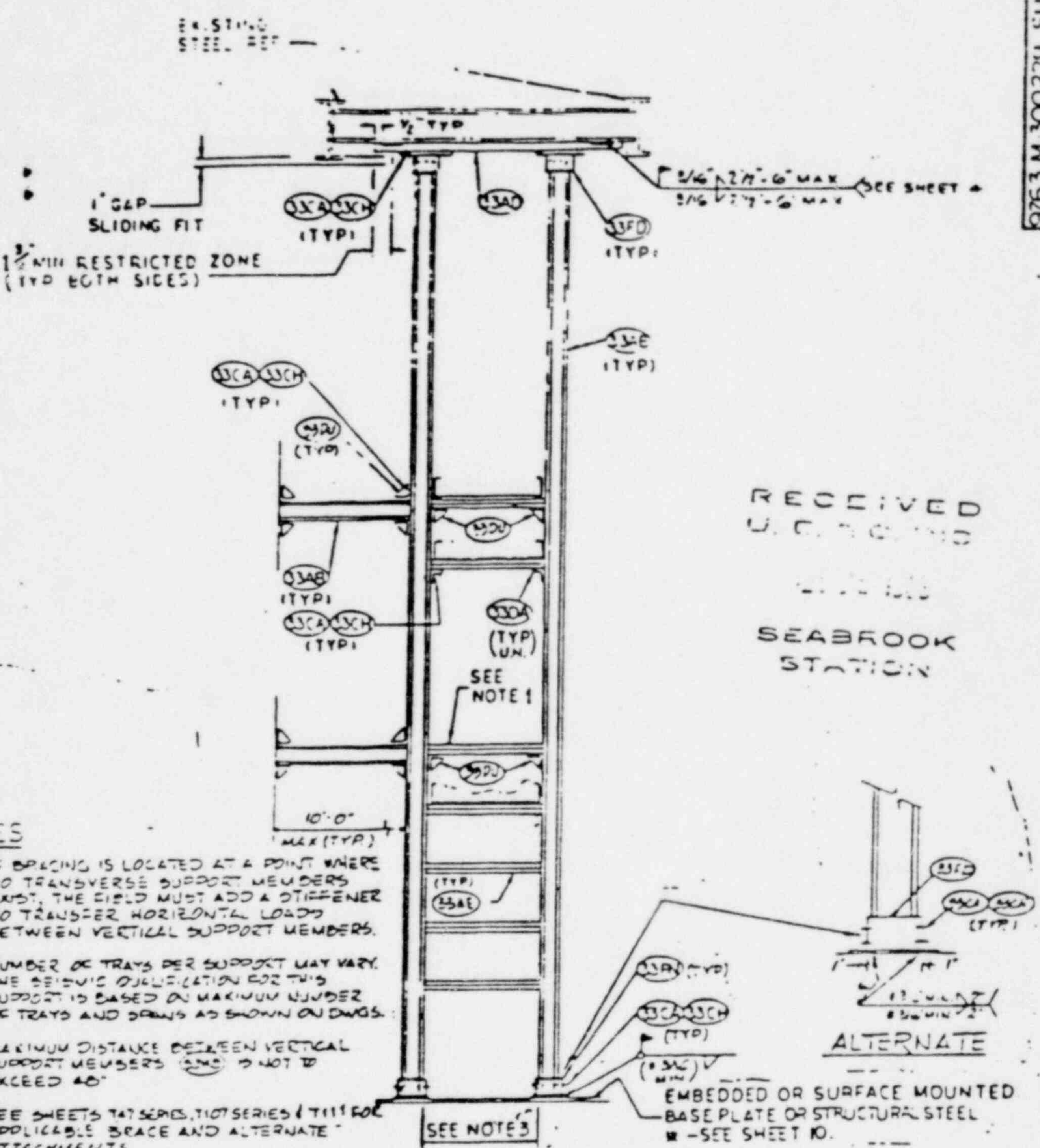

NOTES

1. IF BRACING IS LOCATED AT A POINT WHERE NO TRANSVERSE SUPPORT MEMBERS EXIST, THE FIELD MUST ADD A STIFFENER TO TRANSFER HORIZONTAL LOADS BETWEEN VERTICAL SUPPORT MEMBERS.
2. NUMBER OF TRAYS PER SUPPORT MAY VARY. THE SEISMIC QUALIFICATION FOR THIS SUPPORT IS BASED ON MAXIMUM NUMBER OF TRAYS AND SPANS AS SHOWN ON DWGS.
3. MAXIMUM DISTANCE BETWEEN VERTICAL SUPPORT MEMBERS (33HG) IS NOT TO EXCEED 48"
4. SEE SHEETS T47 SERIES, T107 SERIES & T111 FOR APPLICABLE BRACE AND ALTERNATE ATTACHMENTS
5. FOR BRACING REQUIREMENTS AND TOLERANCES, REFER TO GENERAL NOTE A7.

CABLE TRAY SUPPORT FROM FLOOR TO CEILING

HORIZONTAL BRACING ONLY

NUCLEAR SAFETY RELATED

FIGURE 3.2

CABLE TRAY SYSTEMS

NOTES AND TYPICAL DETAILS

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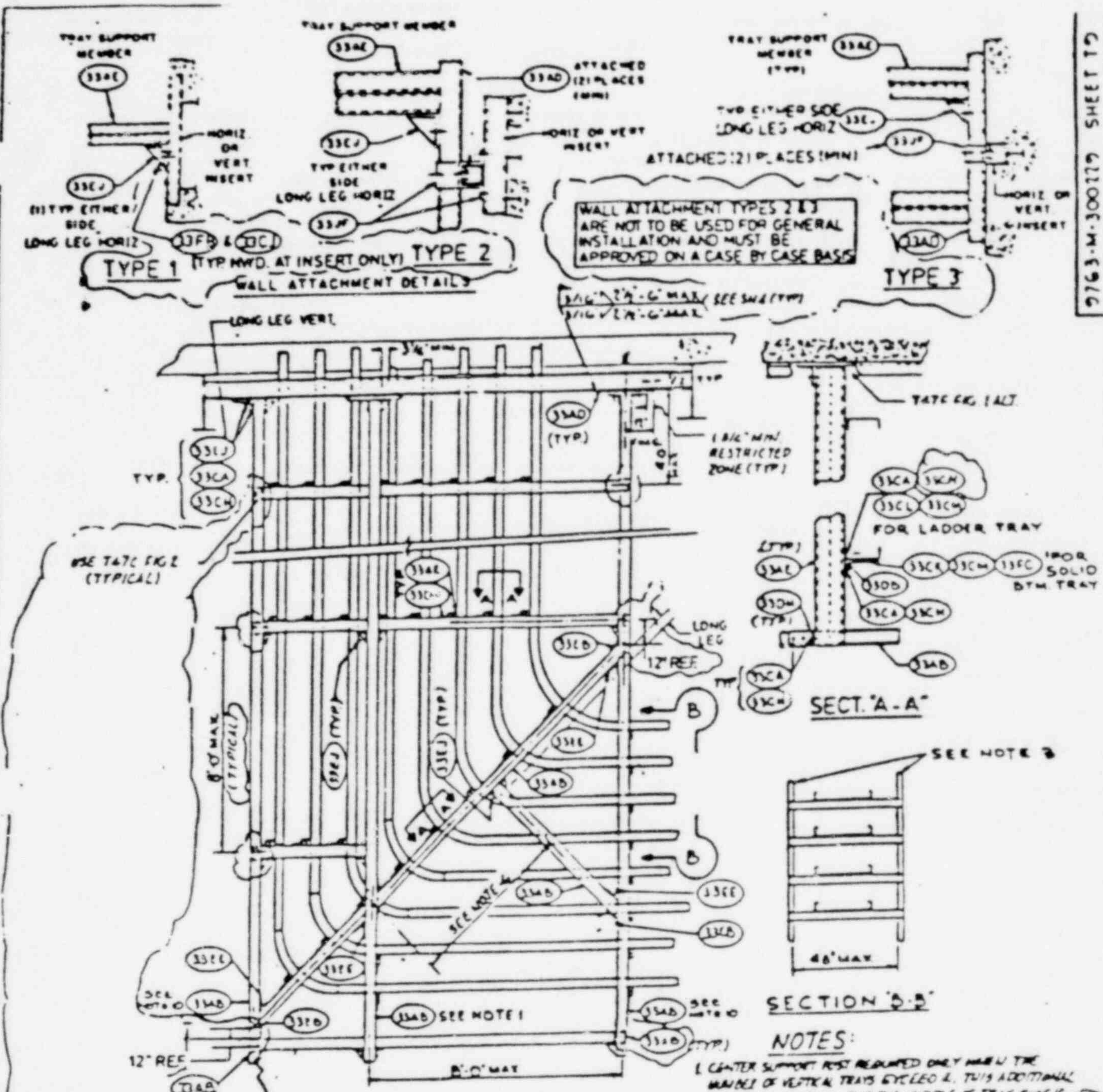
9 REVISED AS NOTED

8 REVISED AS SHOWN

7 REVISED PER ECA



NOTES:

1. CENTER SUPPORT POST REQUIRED ONLY WHEN THE NUMBER OF VERTICAL TRAYS EXCEED 4. THIS ADDITIONAL MEMBER SHOULD BE NEAR THE MIDDLE OF TRAY RISER. SEISMIC QUALIFICATION FOR THIS SUPPORT MUST BE ON A CASE BY CASE BASIS.
2. ALL FASTENING HARDWARE TO BE ... CA ...
3. 33AB VERTICAL MEMBER MAY BE SUBSTITUTED ... CONCRETE INSERT WHEN RISER IS ADJACENT TO A WALL.
4.
5. SEE SHEETS ... FOR APPLICABLE ALTERNATE ATTACHMENTS.
6. LOCATE STRUT APPROXIMATELY AT CENTER SPAN OF DIAGONAL.
7. HORIZONTAL MEMBERS 33AE FOR TYPICAL SUPPORTING TRAYS MAY BE RELOCATED TO THE OPPOSITE SIDE OF CROSS MEMBER 33AB TO AVOID INTERFERENCES.
8. —
9. WHEN VERTICAL TRAYS EXTEND BEYOND THE VERTICAL SUPPORT LEGS, ITEM 33AM MAY BE SUBSTITUTED FOR ITEM 33AB ALLOWING THE TRAYS TO BE SUPPORTED OUTSIDE THE VERTICAL 33AB LEGS.
10. FOR CONNECTIONS OF DIAGONAL AND HORIZONTAL STRUTS TO VERTICAL SUPPORT LEGS TURNED 90° SEE SHT. TATC FIG 1 & 2.

SEABROOK STATION
VERT. CABLE TRAY SUPPORT WITH 90° TURN (TYPE I)

NUCLEAR SAFETY RELATED

CABLE TRAY SYSTEMS
NOTES AND TYPICAL DETAILS

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SEABROOK STATION

United Engineers

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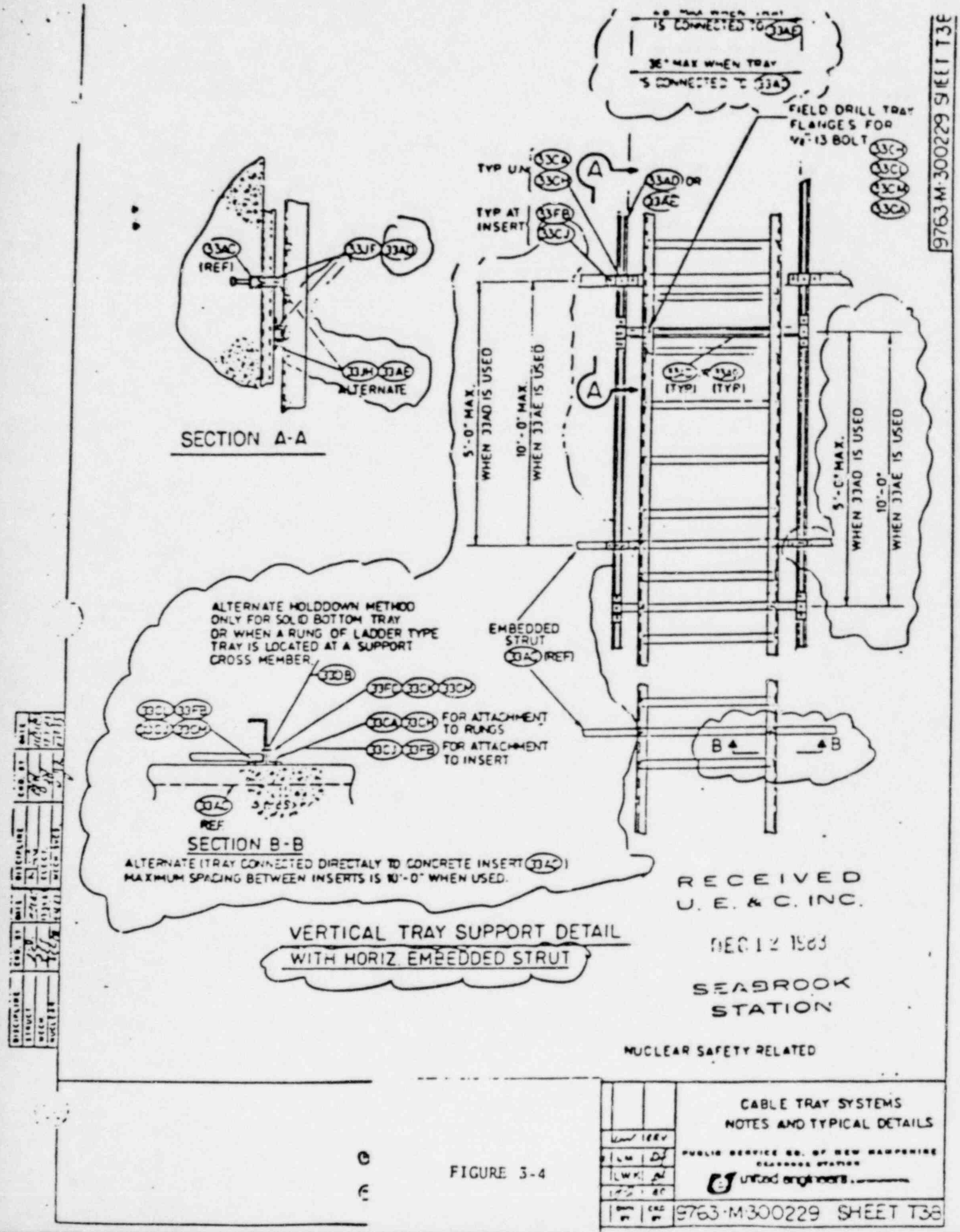
FIGURE 3-6



IS CONNECTED TO 33AD
36" MAX WHEN TRAY
IS CONNECTED TO 33AE
FIELD DRILL TRAY FLANGES FOR 1/2"-13 BOLT
TYP UN
TYP AT INSERT
33AD OR 33AE
ALTERNATE
SECTION A-A
5'-0" MAX. WHEN 33AD IS USED
10'-0" MAX. WHEN 33AE IS USED
(TYP) (TYP)
5'-0" MAX. WHEN 33AD IS USED
10'-0" WHEN 33AE IS USED
ALTERNATE HOLDDOWN METHOD ONLY FOR SOLID BOTTOM TRAY OR WHEN A RUNG OF LADDER TYPE TRAY IS LOCATED AT A SUPPORT CROSS MEMBER
EMBEDDED STRUT
(REF)
FOR ATTACHMENT TO RUNGS
FOR ATTACHMENT TO INSERT
REF
SECTION B-B
ALTERNATE (TRAY CONNECTED DIRECTLY TO CONCRETE INSERT)
MAXIMUM SPACING BETWEEN INSERTS IS 10'-0" WHEN USED.
VERTICAL TRAY SUPPORT DETAIL
WITH HORIZ. EMBEDDED STRUT
RECEIVED
U. E. & C. INC.
DEC 12 1983
SEABROOK STATION
NUCLEAR SAFETY RELATED
CABLE TRAY SYSTEMS
NOTES AND TYPICAL DETAILS
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FIGURE 3-4

Control Building - Switchgear Room, Elevation 21'6"

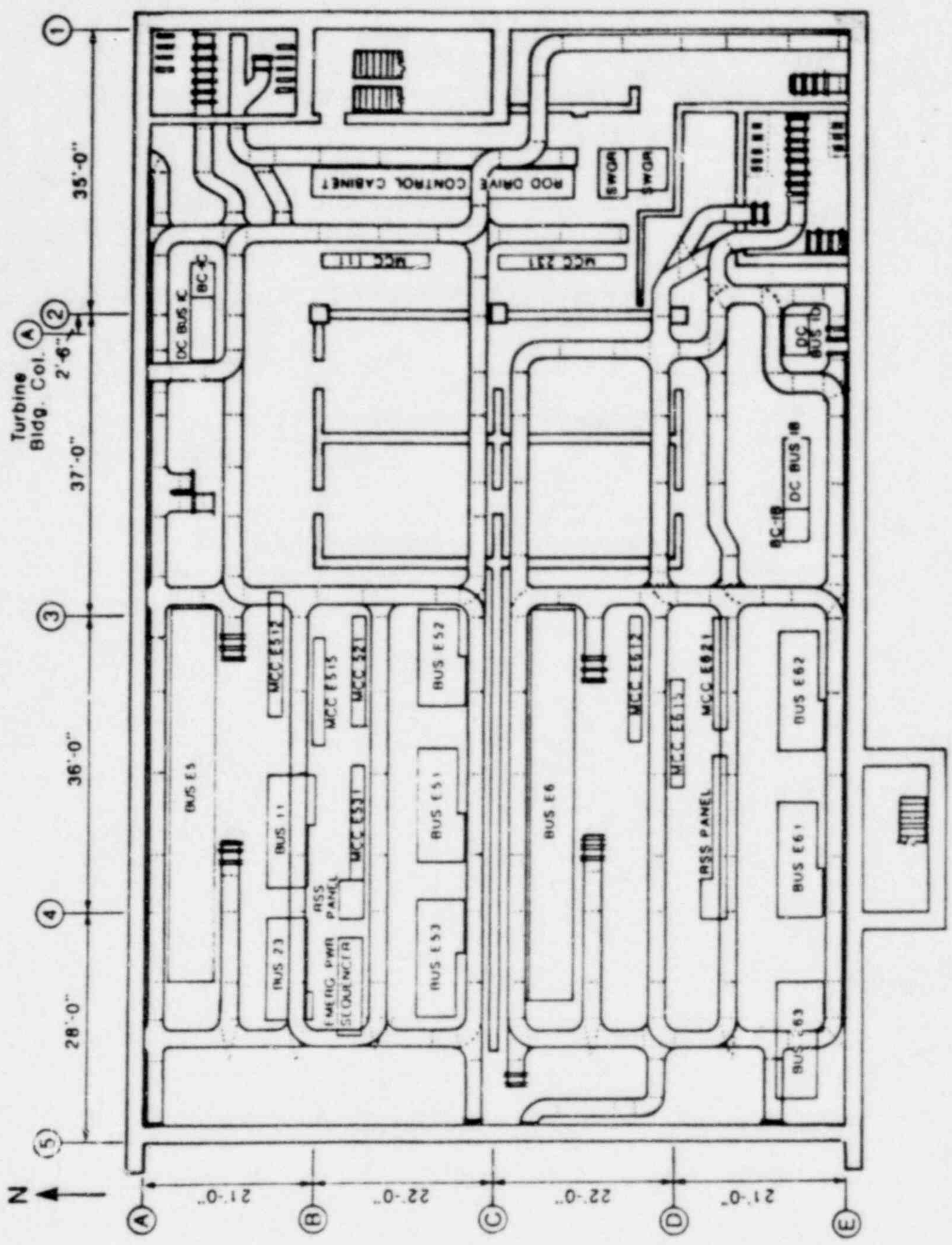


Figure 3.5 The typical configuration of cable trays in this area is a double trapeze with up to 8 tiers. The trapezes are connected to the ceiling using the standard connection "boot" either bolted or welded to overhead structural steel wide-flange beams. On multiple-tiered trays, at least every fourth tier is braced in the transverse direction. Bracing details include triangular gussets at major connections and clip angles at other connections. The cable trays are connected to the trapeze supports with either internal clips or "Z"-clips. Cable is routed from the tray into electrical busses through wireways and flexible conduit.

Control Building - Cable Spreading Room, Elevation 50'0"

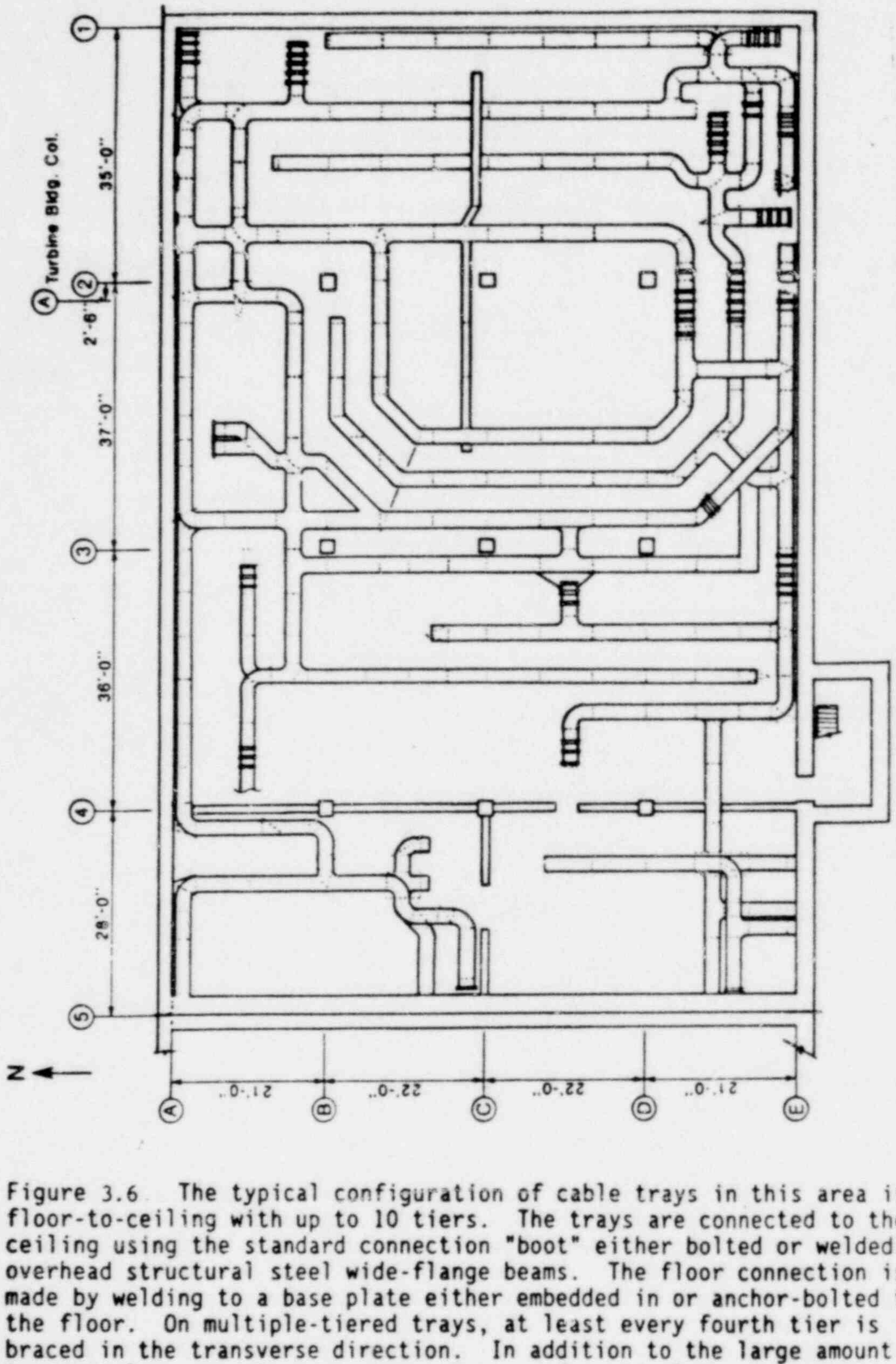


Figure 3.6 The typical configuration of cable trays in this area is floor-to-ceiling with up to 10 tiers. The trays are connected to the ceiling using the standard connection "boot" either bolted or welded to overhead structural steel wide-flange beams. The floor connection is made by welding to a base plate either embedded in or anchor-bolted to the floor. On multiple-tiered trays, at least every fourth tier is braced in the transverse direction. In addition to the large amount of horizontal trays, there are several runs of vertical trays connecting the switchgear area (elevation 21'6") with the control room (elevation 75'0").

Control Building - A Train Electrical Tunnel and Penetration Area, Elevation 0'0"

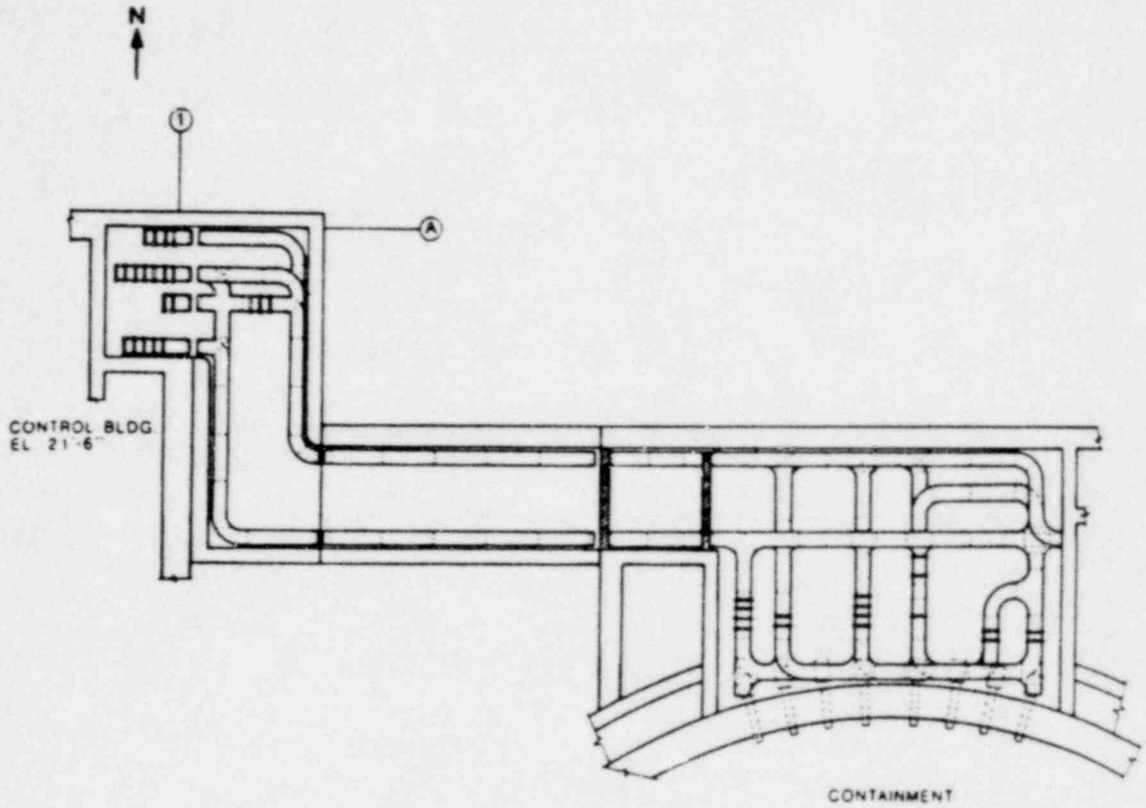


Figure 3.7 The typical cable tray configuration in the tunnel area is floor-to-ceiling, with up to 10 tiers. One side of the tray is supported using a floor-to-ceiling column. The other side of the tray is braced with struts attached to embedded steel channel in the concrete wall. The trays are connected to the ceiling using the standard connection detail either bolted or welded to overhead structural steel wide-flange beams. The floor connection is made by welding to a base plate either embedded or bolted to the floor. Cable tray loading in this area does not exceed 40 plf. Seismic gaps are evident here.

The penetration area contains a high density of cable trays. The configurations of these trays are trapeze, floor-to-ceiling, and various combinations of trapeze and floor-to-ceiling supports. In addition to the cable trays, this area contains ducts, electrical cabinets and penetration assemblies.

Control Building - B Train Electrical Tunnel and Penetration Area, Elevation -20'0"

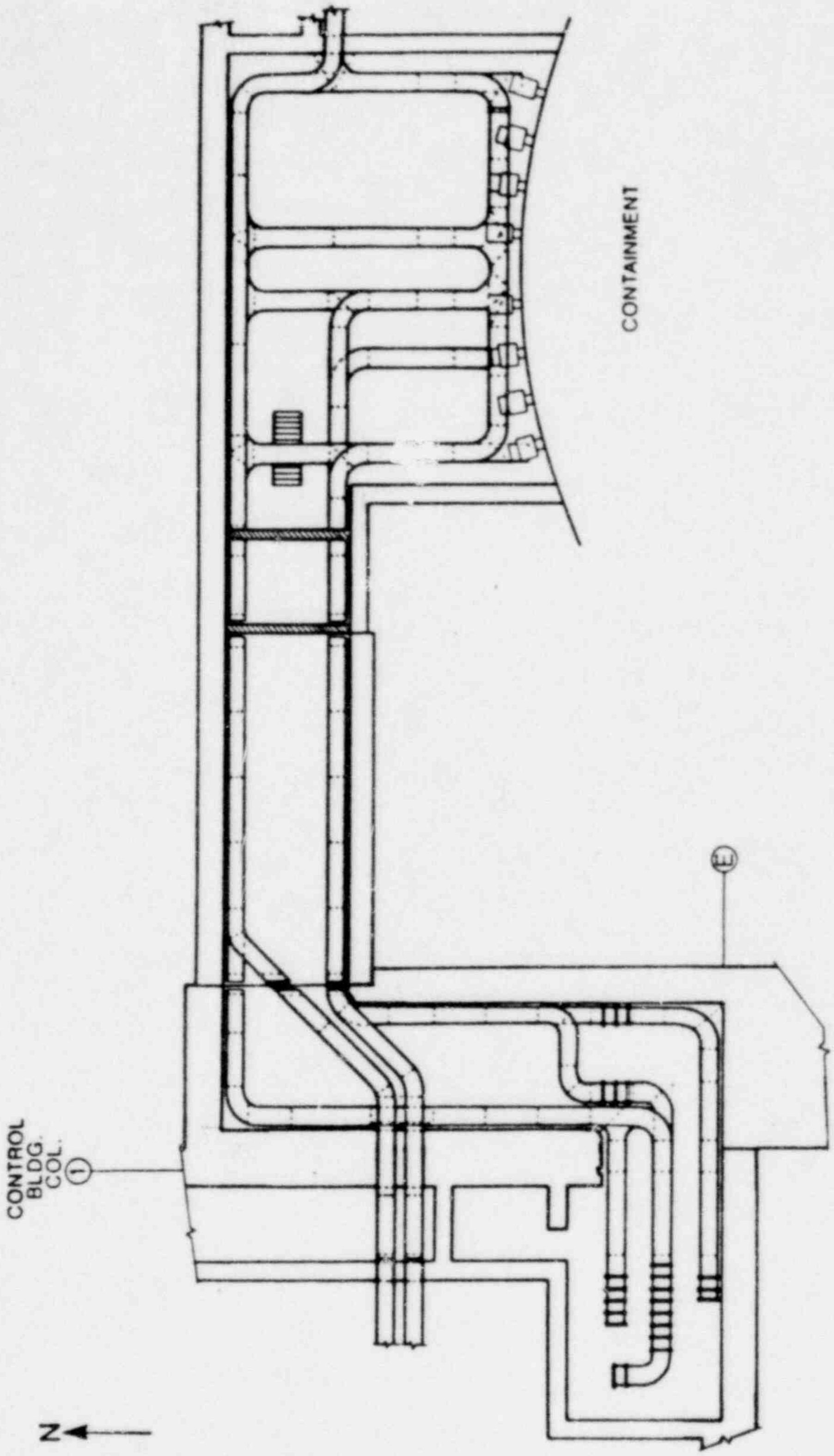


Figure 3.8 The cable trays found here are similar to those found in the A Train Elec'rical Tunnel and Penetration Area.

Reactor Containment Building - Elevation -26'0"

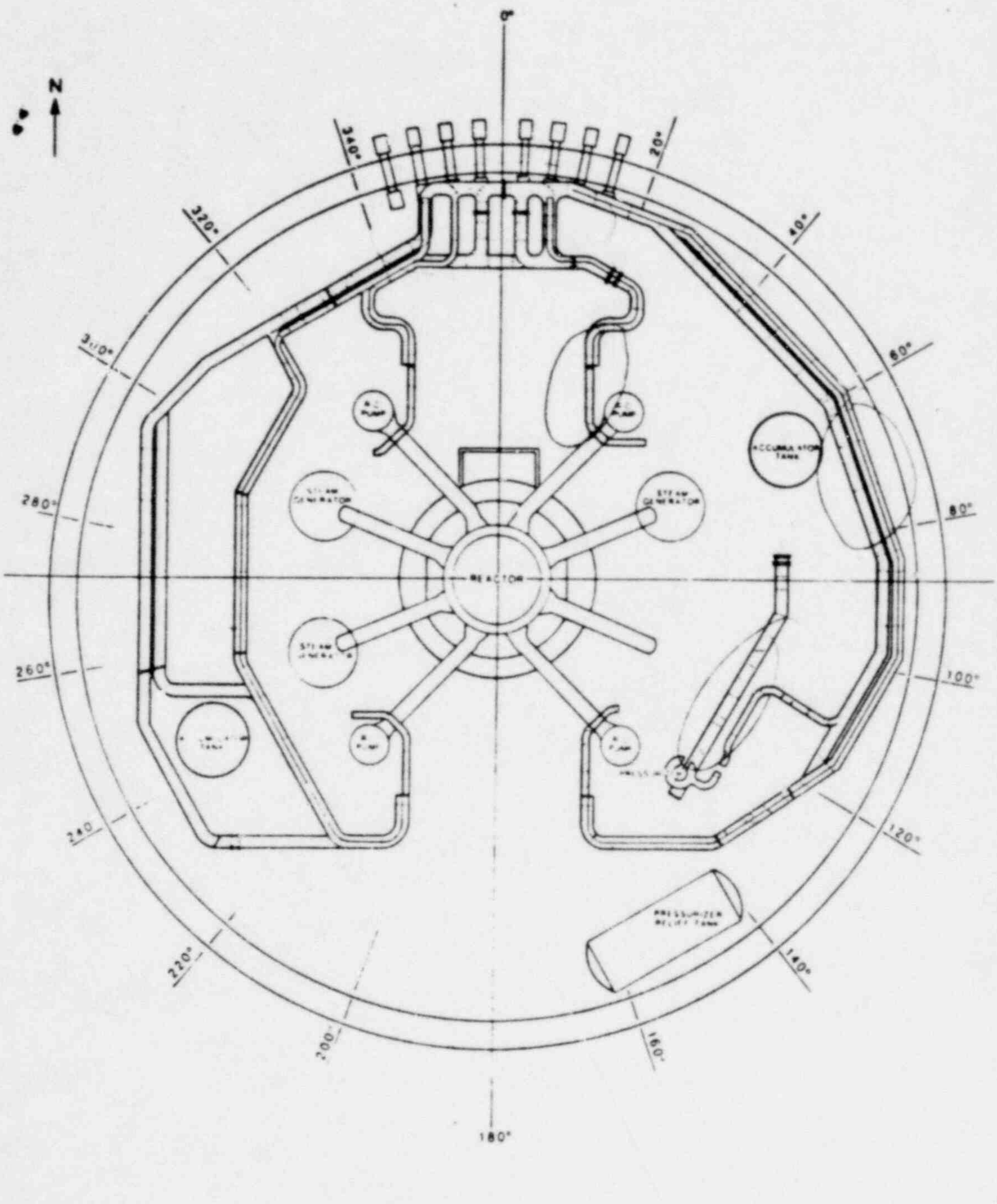


Figure 3.9 The typical cable tray configurations in this area are double trapeze and floor-to-ceiling supports. Most of the trapeze supports have 3 or 4 tiers. Cable tray loading in this area does not exceed 40 plf. The cable trays and penetration assemblies found here are similar to those found at Elevation 0'0".

Primary Auxiliary Building - Elevation 53'0"

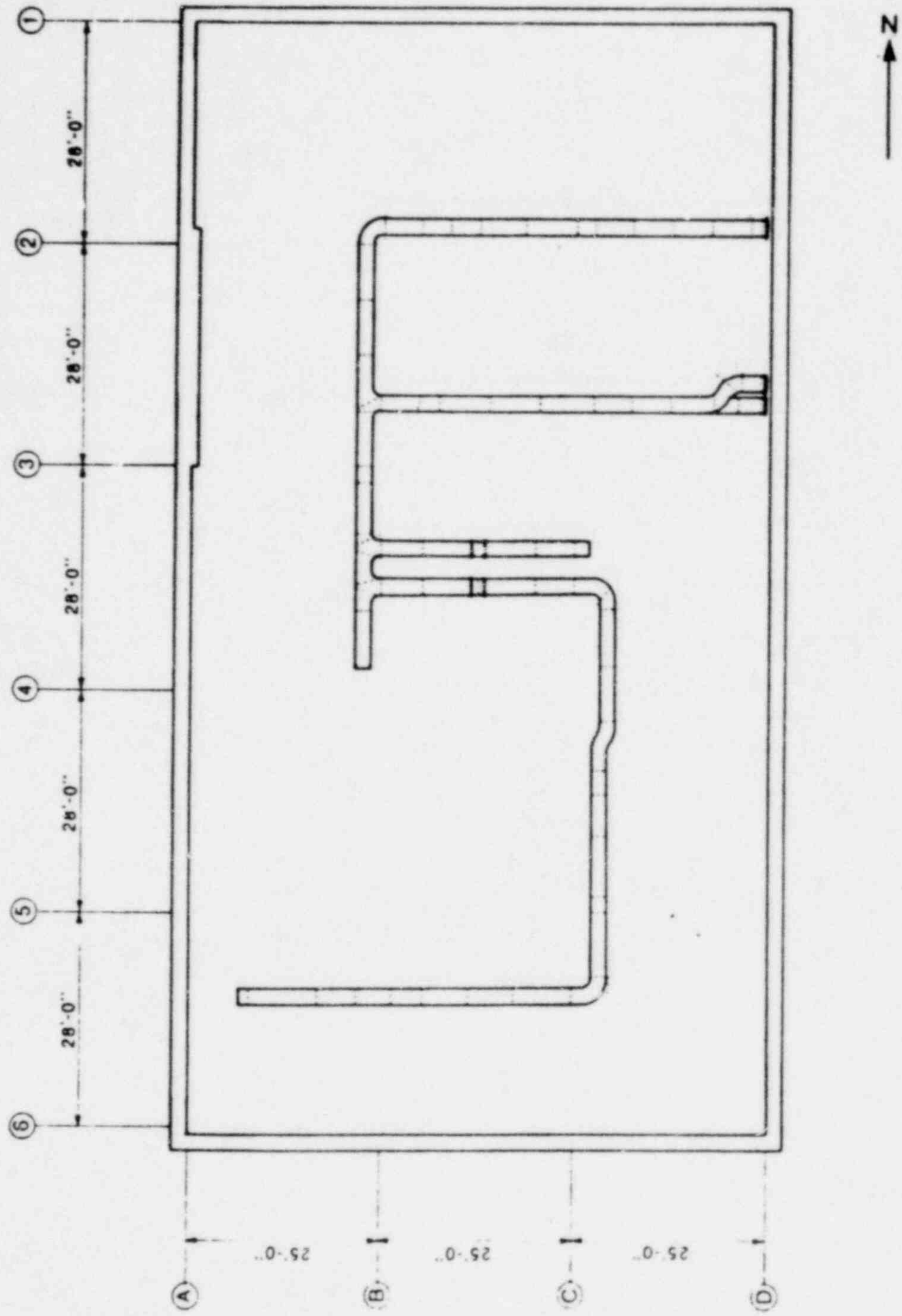


Figure 3-10 In this area, cable trays are mounted around the perimeter of the building in a 3-tier trapeze configuration. The supports are welded to the overhead structural steel wide-flange beams of the ceiling. In addition to the trapeze supports, some of the cable trays are supported on pedestals.

Primary Auxiliary Building - Elevation 25'0"

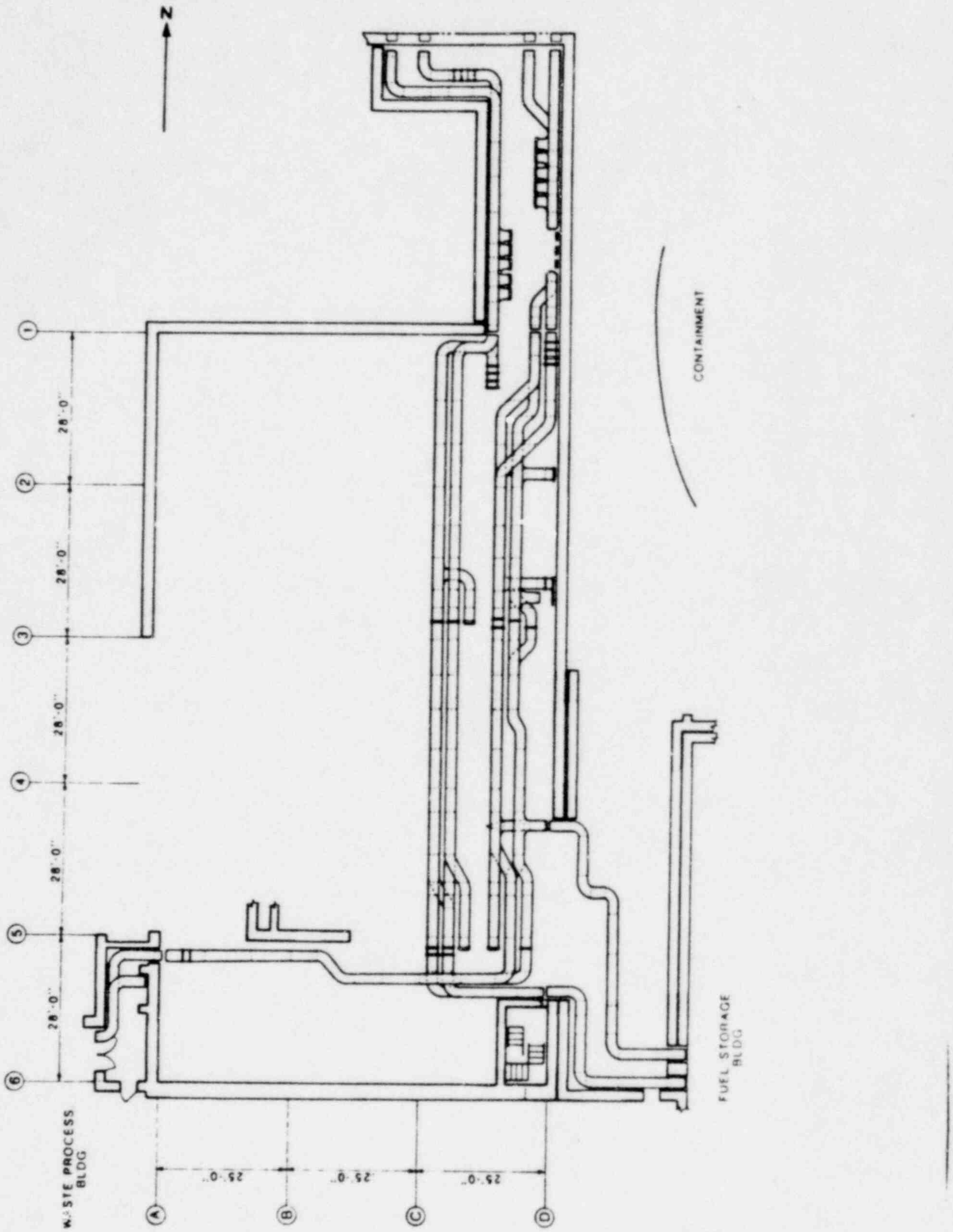


Figure 3-11 The typical configurations of cable trays in this area are double trapeze and floor-to-ceiling with up to 4 tiers.

Steam and Feedwater Pipe Chase (East) - Elevations 2'0" and 12'0"

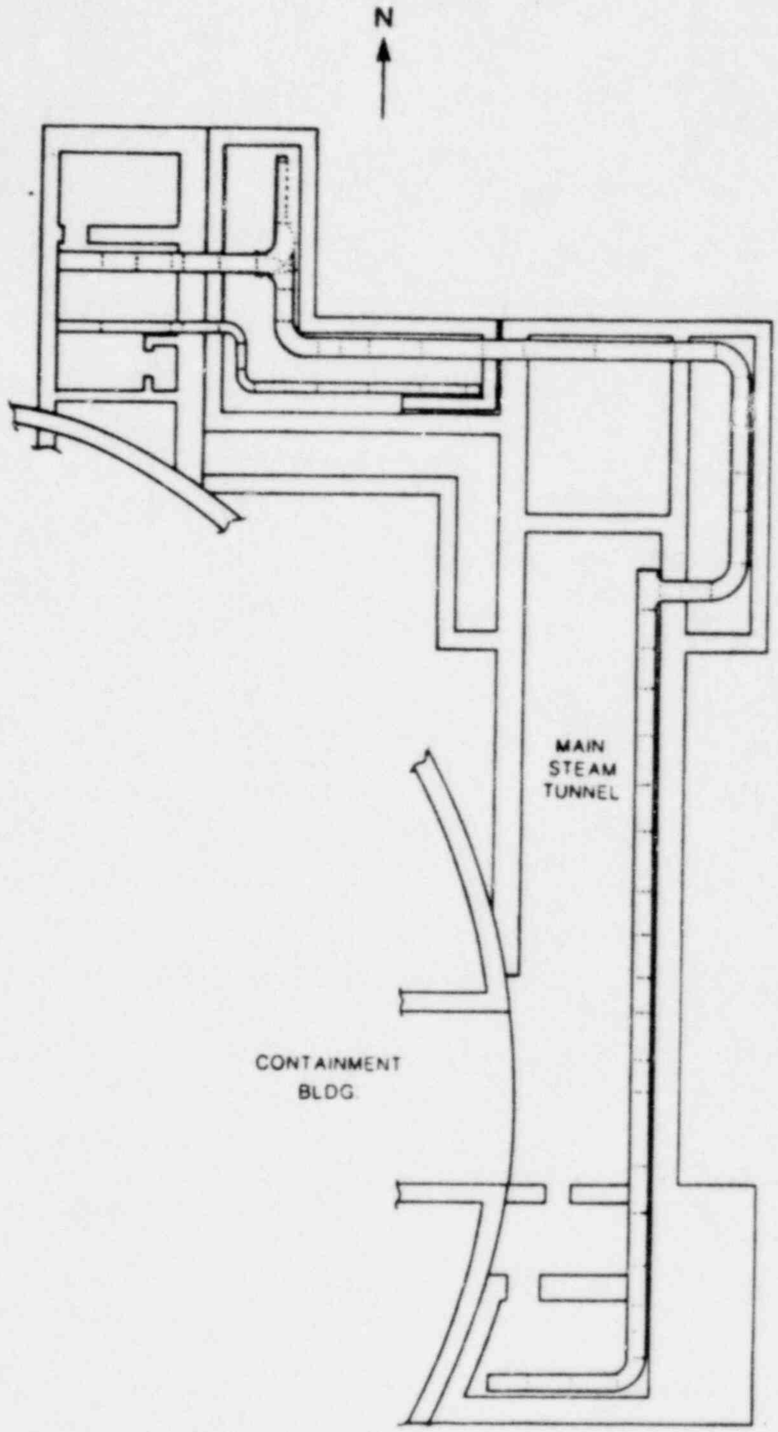
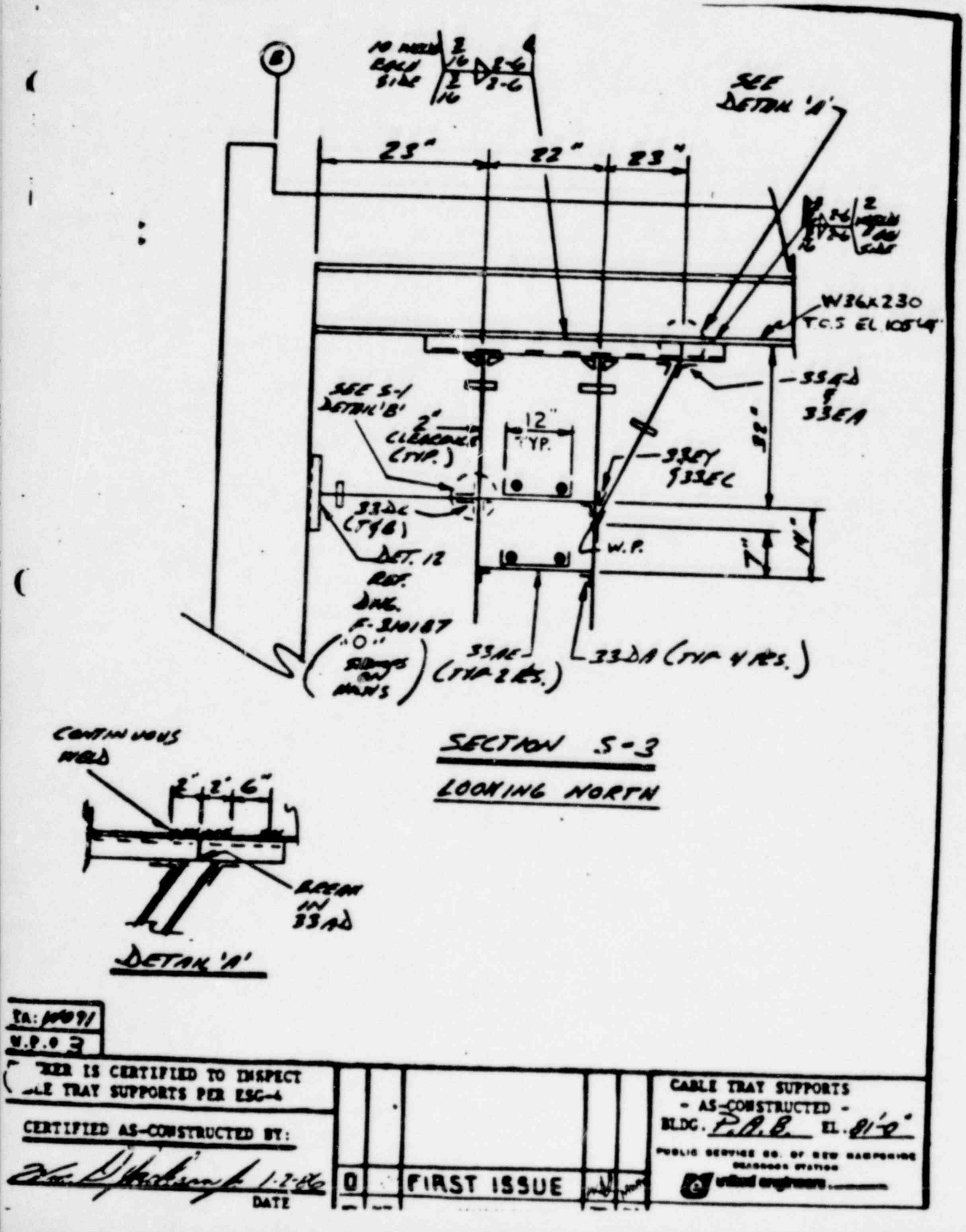


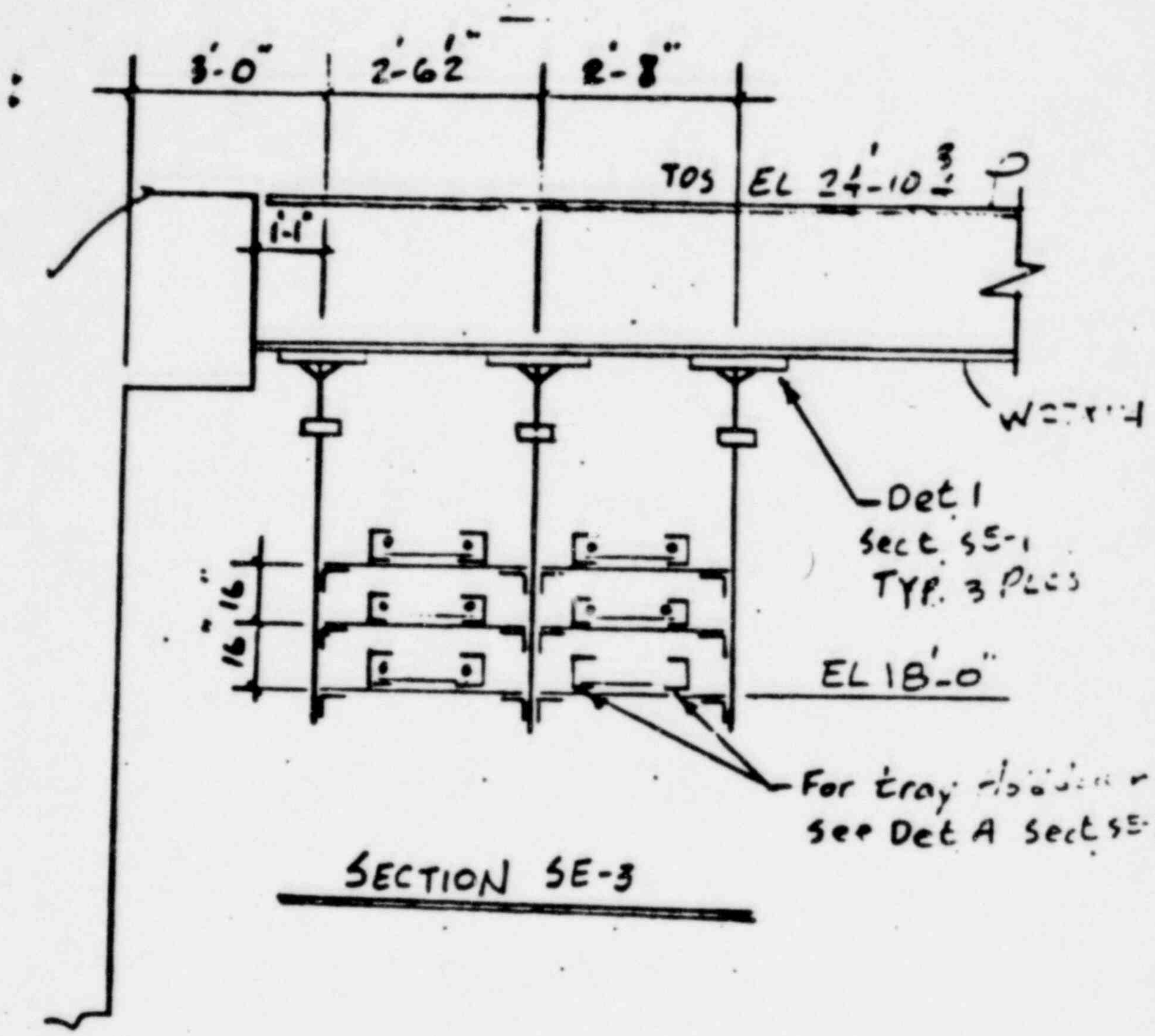
Figure 3-12 The typical cable tray configurations in this area are trapeze, cantilevered and pedestal supports. The cantilevered cable trays are two tiered, with each tier braced to embedded steel channel in the concrete wall. The pedestal supports are also braced to the wall at each tier.

FIGURE 3-13



SEE DETAIL 'A'
W36x230
T.O.S EL 105'4"
23"
22"
23"
33ED & 33EA
SEE S-1 DETAIL 'B'
2" CLEARANCE (TYP.)
12" TYP.
33EY & 33EC
33DC (TYP 8)
W.P.
DET. 12 REF. DWG. F-310187
33AE (TYP 2 PCS.)
33DA (TYP 4 PCS.)
SECTION S-3
LOOKING NORTH
CONTINUOUS WELD
2" 2" 6"
33AD
DETAIL 'A'
IS CERTIFIED TO INSPECT
TRAY SUPPORTS PER ESG-6
CERTIFIED AS-CONSTRUCTED BY:
1-2-86
DATE
0
FIRST ISSUE
CABLE TRAY SUPPORTS
- AS-CONSTRUCTED -
BLDG. P.A.B. EL. 81'0"
PUBLIC SERVICE CO. OF NEW HAMPSHIRE
SEABROOK STATION
united engineers

FIGURE 3-14



W100	
CHECKER IS CERTIFIED TO INSPECT TRAY SUPPORTS PER ESC-4	
CERTIFIED AS-CONSTRUCTED BY:	
1/10/86	DATE

0		FIRST ISSUE		

CABLE TRAY SUPPORTS
- AS-CONSTRUCTED -
BLDG. CNTMT EL.

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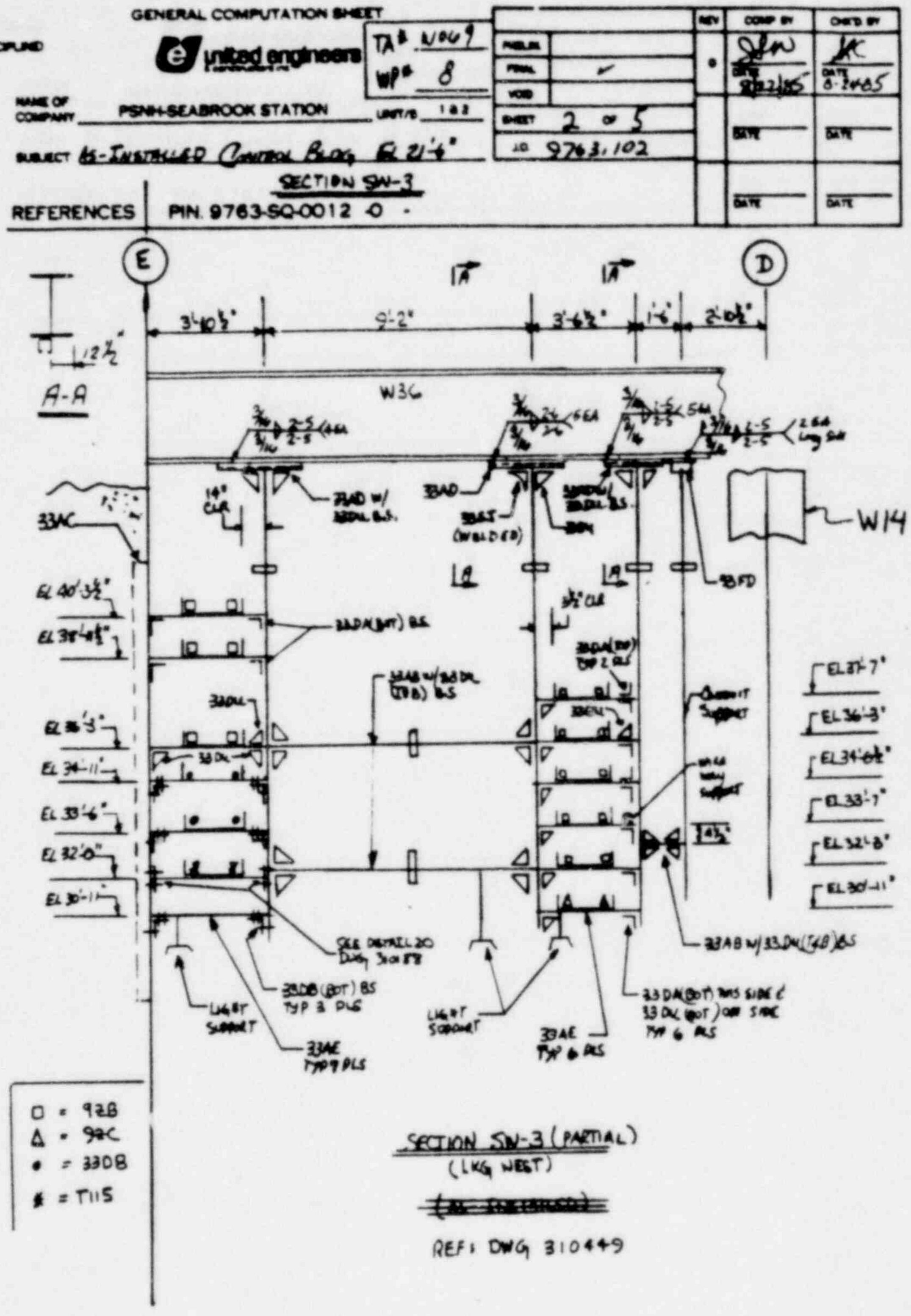
9763-L-370141 SH. 7A

FIGURE 3-15



TA: W069

W.P.# 8

'ECKER IS CERTIFIED TO INSPECT CABLE TRAY SUPPORTS PER ESG-4

CERTIFIED AS-CONSTRUCTED BY:

Steven R Callahan 12-7-85

0	12/30/85	FIRST ISSUE	SRC	

CABLE TRAY SUPPORTS
- AS-CONSTRUCTED -
BLDG. CONTROL EL. 21'-6"

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SEABROOK STATION
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FIGURE 3-16

GENERAL COMPUTATION SHEET

(DISCIPLINE) united engineers & constructors inc.

TA# W069
WP# 8

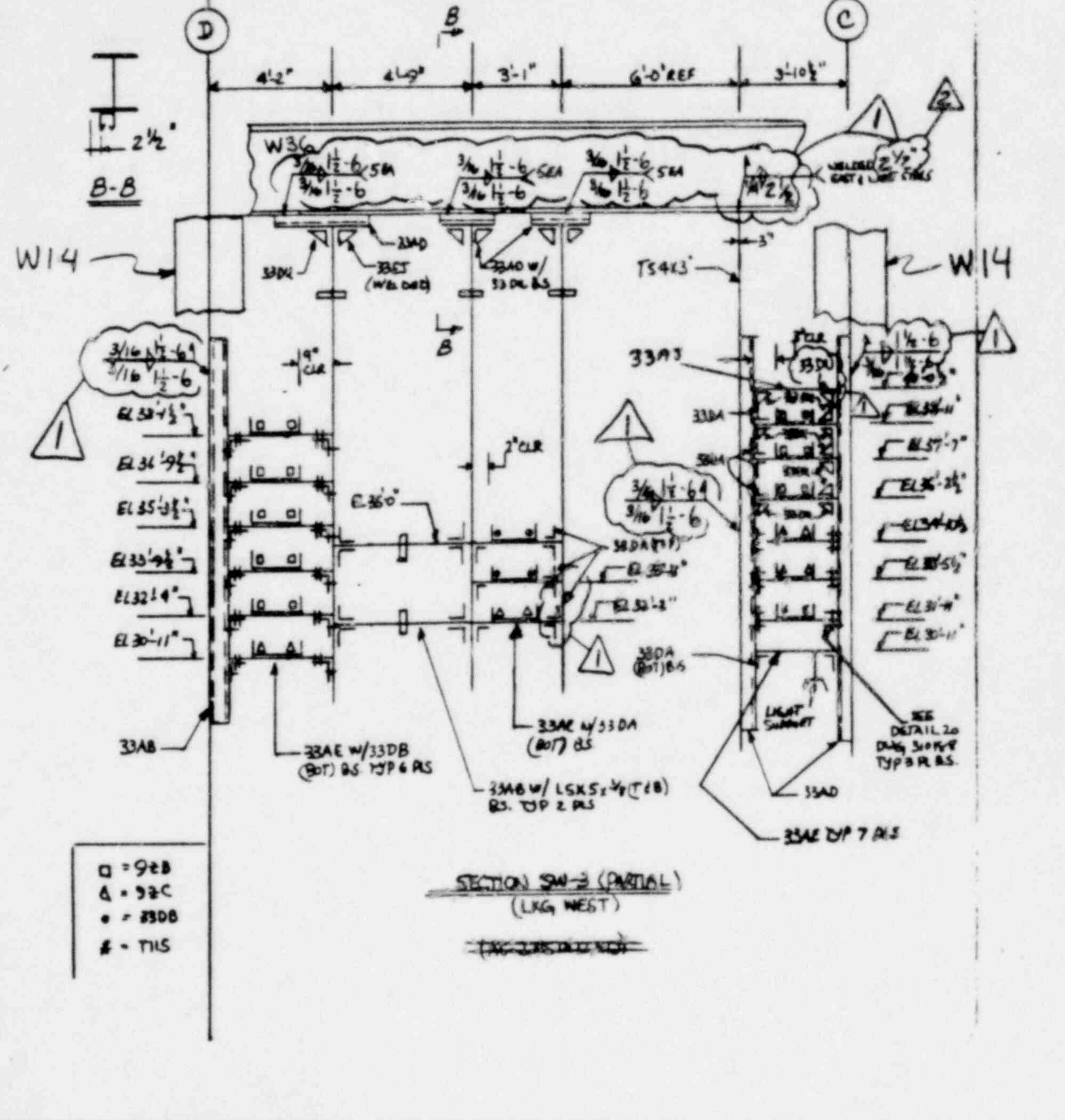
NAME OF COMPANY PSNH-SEABROOK STATION UNIT/S 1&2

SUBJECT AS-INSTALLED CONTROL BLDG EL 21'-6"

SECTION SW-3

REFERENCES PIN. 9763-SQ-0012 -0 -

		REV	COMP BY	CHKD BY
PRELIM		0	JPM DATE 8/22/85	SRC DATE 8-24-85
FINAL	✓			
VOID			DATE	DATE
SHEET 3 OF 5				
JO 9763.102			DATE	DATE



TA: W069	REV. 1 CERTIFIED TO ESG-4
W.P.# 8	J. M. Hunt 1-30-86

REV. 2 CERTIFIED TO ESG-4
Bruce E. Rhodes 2/10/86

CHECKER IS CERTIFIED TO INSPECT CABLE TRAY SUPPORTS PER ESG-4

CERTIFIED AS-CONSTRUCTED BY:
Steven R. Callahan 2-7-85

2	2/4/86	REVISED AS NOTED	BEZ	JMH
1	2/4/86	REVISED AS NOTED AND PER CD16 & 18	JMH	BEZ
0	12/10/85	FIRST ISSUE	SRC	JPM

CABLE TRAY SUPPORTS
- AS-CONSTRUCTED -
BLDG. CONTROL EL. 21'-6"

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SEABROOK STATION

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4.0 TEST PROGRAM DEVELOPMENT

4.1 Test Program

The Cable Tray System qualification program includes the development of the items identified in Section 3; specifically, dynamic testing of full scale system models, connection tests and analytical applications program. In addition, the program data base was enlarged by the utilization of an existing Bechtel Raceway Test Program. The detailed development of these programs and a summary of ensuing results is included in the following sections.

4.1.1 Dynamic Test Program

The primary objective of the Seabrook specific tests was to study the seismic resistance and response of typical multi-tier Cable Tray Systems, constructed using representative site-specific details and hardware subjected to various levels of postulated seismic loadings.

Other objectives include the collection and analysis of data to determine trends in resonant frequencies, damping ratios, response shapes and support loads. This information is later coordinated with an analytical applications program to qualify the support system as described in Section 4.2.3.

The test effort investigated the performance of the typical Cable Tray Systems using three different load sequences and input levels. They are identified as follows: (Reference 10, Vol. 1.)

SSE Test

Each test configuration was subjected to one SSE Test Response Spectra (TRS). To study system response, the test configuration was also subjected to fractional SSE events.

Fatigue Test

Each test configuration was subjected to five OBE TRS followed by one SSE TRS.

Fragility Test

Each test configuration was subjected to incremental TRS, using the SSE TRS shape, until the table limit was reached. This resulted in an application of spectra ranging from 1.2 to 1.5 of the SSE TRS.

Each test sample was subjected to a specific sequence of test inputs to optimize data and performance evaluations. All the test cases include low level random testing, fractional SSE testing, SSE testing, fatigue testing and bracing studies. Details of the test sequence for each test can be found in Tables 4.1 through 4.3. Test plans for each test are found in References 2 and 3.

4.1.2 Development of the Dynamic Test Configurations

Site walkdowns, performed to support the Bechtel damping study of the Seabrook cable tray supports (Reference 5), were used as the basis for the proposal of the two test sample geometries (Case A and B). A description of these two cases are provided in Figures 4-1 and 4-2. These two configurations were judged to be the most representative of site conditions. Two test cases were selected initially, as it was felt that additional test cases could be added as warranted.

The main Seabrook typical supports are represented by the trapeze support T26 (representative of T4, T8, T26, T27 and T29) and by the typical support T5 (floor to ceiling support). A sketch of typical supports, T26 and T5 is provided in Figures 4-3 and 4-4. These two types were selected for dimensional, quantity and behavioral reasons. These initial configurations consisted of reduced transverse and no longitudinal bracing, which is consistent with the program objectives.

After the completion of Test Case A, it was decided to establish a third configuration, Test Case C. This test case is illustrated in Figures 4-5 and 4-6, and incorporates two major types of supports (change in direction supports, T9, T10) and supports for vertical tray, T38). The third case, by enlarging the data base, serves the joint purpose of illustrating the seismic resistance of two different distinct types of support conditions, while providing additional data to aid in the analytical applications studies. A sketch of typical support, T9, is provided in Figure 4-7.

Testing was performed almost exclusively with site supplied hardware. Due to shortages of necessary details, locally supplied hardware was used, however, only site representative vendors were utilized. All the test samples incorporated various representative in situ details which were determined to be particularly sensitive to the increased motions of unbraced systems. Table 4.4 provides a list of typical features simulated. Typical connections, anchors and tray fasteners tested are shown in Figures 4.8 a, b and c. Further, in addition to these representative in situ simulations, several items were maximized for conservatism and margin. In addition to the reduced bracing previously mentioned, the primary features were: a) the use of all trays at a forty percent fill (by area), and b) the use of a maximum cable tray support spacing (10 feet in lieu of typical 8 feet or less).

All testing was performed using an envelope spectra. Thus, the Test Response Spectra (TRS) generated to envelope the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) envelope all applicable site conditions. This is extremely conservative and it must be remembered that at certain elevations, locations and directions in the plant, the local Amplified Response Spectra (ARS) is a fraction of the plant envelope TRS. In most cases, the applicable design ARS is only one-third to one-half of the TRS. Testing to the TRS, then, provides significant margin. (Figure 4-13)

The use of envelope conditions (maximum cable load, maximum support spacing and envelope spectra) were selected to give the testing program the most flexibility and broadest applicability possible. The program objective is to envelope the behavior of as many supports as possible. The comparison of typical conditions (vs. envelope conditions) is identified in Section 3.

4.1.3 Connection Tests

In addition to full scale dynamic tests (Reference 10, Vol. 5), load deflection stiffness tests and cyclic fatigue connection tests of key representative connections have been performed as an integral part of the qualification program. The connection tests were developed to study the performance of typical cable tray support connections and to provide data to refine modeling techniques, and establish appropriate connection stress and rotation limits. The connection test plan is found in Reference 4. Past Bechtel Raceway Testing (Reference 6) established that the behavior of the primary connections is a key parameter in determining the system behavior of Cable Tray Support Systems. As discussed earlier in Section 3, the data collected is used as input to the cable tray support analytical models. Specifically, spring rates are developed to model these connections in various finite element models. Three test types were performed:

- o Moment resistance as a function of angular rotation (M versus θ).

- o Load resistance as a function of deflection (P versus Δ).

The connections tested are shown in Figure 4-9. These connections are representative of the anchor connections found in the field and simulated during the shake table testing.

The test setup is shown in Figure 4-10. The connection test system consists of a rigid vertical surface to which sacrificial plate and strut assemblies can be attached horizontally (as shown) or vertically, permitting testing of each anchor detail in its principal axes. The following equipment is required:

- o A double acting hydraulic cylinder.

- o A stiff member (6 inch x 6 inch x 1/2 inch) to limit strut deflection.

- o A load cell to sense load.

- o A linear potentiometer to sense deflection.

- o A mechanical force gauge to sense applied axial load and a group of tension springs to apply that load.

4.1.4 Coordination With Bechtel Raceway Support Program

New Hampshire Yankee is also a member of the Bechtel Joint Owner's Group and therefore the data from Raceway Support Program (Reference 6) is coordinated with the Seabrook testing. Bechtel (Reference 5) previously reviewed the proposed Seabrook design and evaluated the design for applicability of the test data. Because of the generic nature of the data, it was determined that the Seabrook design was bounded, and the data was applicable. This data has been presented to the NRC and their initial concurrence received in May 1985 (Reference 7).

The design damping curve for the Seabrook Project (Figure 4.11) was developed from the results of the Bechtel sponsored, "Cable Tray and Conduit Raceway Test Program" performed by ANCO Engineers, Inc. To date, in excess of 2,000 dynamic tests have been performed as part of the Bechtel Cable Tray Testing Program. Numerous tray support systems have been tested and the effects of a broad range of parameters have been investigated. Flexible as well as rigid support systems have been tested. Results of these tests have demonstrated that the Cable Tray Support System damping is greatly influenced by the amount of motion of cables in the trays.

For linear dynamic structural analysis, the effects of the various mechanisms which tend to dissipate the energy of a system are typically lumped together in a single factor known as the effective viscous damping. This velocity dependent parameter is commonly quantified by means of dynamic testing, and can include the effects of many energy dissipating mechanisms, such as friction and rotation in bolted connections, hysteresis, radiation of energy away from foundations, and others.

The predominant energy dissipating mechanism observed during the Cable Tray Test Program was the vibration of the cables. A significant amount of

energy was absorbed as a result of friction between adjacent moving cables and between cables and trays. An equivalent viscous damping was calculated for each tested system, based upon the recorded dynamic input and response. A detailed discussion of the damping computations can be found in the test report (Reference 6).

The individual damping values clearly demonstrated that the tested cable tray supports comprise a dynamic system with high equivalent viscous damping. Results from tests of many support types and configurations are included in the data, but in the interest of providing a generic design damping curve, the conservative bound of the accumulated test data, represented as a bilinear curve, was utilized.

Variations in support rigidity did not significantly impact the system damping, that is, damping data in excess of Figure 4-11 was still realized. The effect of the cables on damping is heightened with increased input acceleration levels. When cable trays are lightly loaded, or when the system is subjected to low input acceleration levels, the measured damping approaches the values in NRC Regulatory Guide 1.61 for bolted structures.

The tested support systems were constructed using standard cold-formed struts and standard bolted fittings from a variety of manufacturers. Cable trays and fittings for the tests were provided by several manufacturers, including Metal Products Corporation, which is the sole supplier of cable trays for Seabrook. Tests included trapeze supports of varying height and with various transverse and longitudinal bracing configurations and rigid supports. Cable loading ranged from 0 to 50 pounds per foot.

The fundamental frequencies of the tested support configurations were found to be in two ranges: the more flexible support systems had fundamental frequencies of 2 to 6 cycles per second (CPS); the more rigid support systems had a range of 9 to 25 CPS. The latter frequency range results primarily from tray variations, as the supports themselves were comparatively rigid.

The wide variety of the tray types and support configurations included in the test program simulated actual field installed conditions. A large number of variables were investigated, including:

- Types and manufacturers of trays
- Type and size of tray supports
- Location of tray splices
- Number of tray tiers
- Configuration of support systems
- Type and spacing of transverse and longitudinal bracing
- Weight of cables
- Cable ties

Extensive dynamic testing of the effects of these and other variables has produced voluminous raw data, which has been summarized in the test report.

In view of the scope of the test program, it has been concluded that the tests simulate actual field conditions, and that the results are applicable to the design of comparable tray support systems.

The testing program clearly demonstrated that a significant portion of the support system damping was a product of cable motion and the resulting friction between cables and between cables and trays. Therefore, in order to assess the compatibility of the Seabrook system and the tested system, the frequency and general characteristics of the Seabrook system have been studied to determine whether they fall within the bounds of the test program, thereby providing assurance that the cable motion necessary to produce the predicted damping will occur.

As a result of the Bechtel Application Study, the generic results of Raceway Test Program have been applied to the Seabrook Station. The more important conclusions are tabulated below:

a. Cable Tray Raceway Systems have damping that ranges from 15 to 50 percent for trays with cable loading from 20 to 50 #/ft. Below 20 #/ft, a reduction in damping is observed. The lowest damping was for unloaded trays which have damping more closely approximating the 7 percent permitted for bolted steel structures by USNRC Regulatory Guide 1.61. Input motions (both vertical and horizontal) excite cables within the loaded trays and cause them to move relative to the tray. This movement is either a bouncing or sliding of the cable within the tray. The motion of the cables appears to be one of the energy absorbing mechanisms that contributes significantly to the high damping valves.

b. Damping tends to increase with increasing input. At response levels anticipated during strong earthquakes (0.2g and greater SSE), raceways are so highly damped that they respond to a broad band energy input rather than to a narrow frequency band energy characteristic of a resonance condition.

c. Anchor point flexibility, as determined by the connection details, can be more important than the flexural stiffness of the struts in determining lateral frequency of systems. This indicates that the tested connection details result in a partially-fixed condition at the anchorages.

d. Typically, cables do not appear to influence overall system stiffness and consequently only the mass of the cables need be considered in computing system dynamic responses.

The recent shake table testing of the Seabrook support systems reinforces the inclusion of the Seabrook system. Using site supplied hardware and site-specific configurations, similar system conclusions and damping data (see Section 4.2) were obtained. Therefore, the entire Bechtel data base, in

addition to the Seabrook test data can be applied to system evaluations at Seabrook. The actual damping values to be used at Seabrook as presented to the NRC this past May (Figure 4-11) remains the same. These conclusions are confirmed by ANCO. See Reference 10, Vol. 1.

4.2 Program Results

4.2.1 Dynamic Test Results

The seismic simulation tests (Cases A, B and C) have been completed. One item to note prior to any discussion of the results is a discussion of the Test Response Spectra (TRS) and it's relative magnitude in comparison to the Required Response Spectra (RRS). The RRS envelops the floor response spectrum of the seven seismic Category I buildings within the scope of this qualification program. Figure 4-12 represents a typical TRS versus RRS comparison plot. The TRS is very broad and contains greater energy than the RRS. In addition, although not a complete site envelope spectra, the TRS possesses significant margin when compared to specific site locations. For example, Figure 4-13 depicts an SSE TRS versus the control building floor response spectra (E-W, elevation 21'6" to 50'). The test enveloping is very conservative. The above building floor response spectra may also be subdivided into area local ARS which further increases the conservatism of the test envelope.

The primary results of the seismic simulation tests is as follows:

1. Seabrook specific testing results were in agreement with the results of the Bechtel Raceway Support Program (Reference 6).

2. With increasing levels of input, some minor damage was observed. Table 4.5 illustrates representative damage as a function of percent SSE input for the "non fatigue" earthquake testing. Recall, however, the conservativeness of the SSE envelope RRS and the TRS enveloping.

3. All primary connections survived all testing, thus ensuring overall system integrity.

4. The measured damping for all the earthquake testing was in excess of 20% critical. Tables 4.6 and 4.7 provide a summary of a portion of the available data.

5. The tested cable did not exhibit any physical wear or damage. No loss of continuity was observed when monitored.

6. Overall integrity was demonstrated for the three test samples in both braced and unbraced configurations.

7. Table 4.8 provides a summary of the maximum support displacements (relative to the test table) due to "SSE" testing for Cases A and B. Case C, although not shown, was less than Case A or B. For illustrative purposes, representative displacements are also provided for Case A. These are displacements due to the TRS input shown in Figure 4-13.

8. Horizontal brace loads were more effective in resisting seismic loads than the diagonal braces. Table 4.9 illustrates the degradation of the braces during fatigue testing. The degradation stems primarily from the geometry of the connections for diagonal braces and the fact they are two-bolt clips. It should be noted that (1) diagonal braces were effective when used with horizontal braces (Cases B and C) and (2) the TRS conservatively enveloped the SSE envelope RRS.

9. Fatigue testing (at the envelope OBE) did soften the system and effect load distribution. The qualification program will consider the load distribution observed from the testing program.

10. Maximum stresses (peak) recorded in both the brace and post during each test were typically less than 5 KSI, which is well below allowable stress values. (See Table 4-12.)

4.2.2 Connection Test Results

As introduced in Section 4.1.3, representative connections were tested to obtain rotational and translational stiffness data, and cyclic fatigue data. The data was required to a) assist in the development of finite element models of the shake table test samples and the Seabrook installations and to b) to establish performance requirements.

A sample moment-rotation curve for the 4-bolt gusseted angles (Detail 33DU, Figure 4-8a) is provided in Figure 4-14. This data is typical of the connection tests in that it demonstrates: (a) ductile behavior and (b) a significant connection moment capacity. These results are very similar tc the results of various past connection tests performed by Bechtel (Reference 6). The fatigue tests document the large number of cycles these connections can undergo. This, also, was demonstrated in earlier Bechtel testing. The Seabrook data enlarges the data base and results in conservative predictions of connection fatigue performance for Seabrook. The typical shape of a fatigue plot is shown in Figure 4-17. The number of cycles to failure (N) is depicted as a function of a constantly applied rotation (θ).

4.2.3 Correlation Analysis of Test Samples

4.2.3.1 Analysis of Test Samples

The analytical modeling of the four test cases is an integral step in the qualification of the in situ cable tray supports at the Seabrook Station. The shake table test data will be combined with the connection test data and used to demonstrate that the refined analytical models will enable realistic system evaluation.

As discussed in Section 4.2.1, the shake table test program demonstrated two distinct features associated with the Cable Tray System dynamics which must be addressed: joint flexibility and amplitude dependent frictional losses due to cable vibration, etc. Analytically, the treatment of

amplitude dependent frictional losses will be approximated by the use of realistic damping values and joint flexibility based on moment-rotation test data.

Linear finite element models have been developed for test Cases A, B and C. Preliminary spring rates have been developed for the connections and have been inserted into the finite element models to simulate joint behavior. Tables 4.10 and 4.11 demonstrate the ability of the analytical models to closely correlate with test results. All the models represented in these two tables utilized identical spring rates and damping, therefore, demonstrating the consistency of the techniques involved. Other than incorporating these two effects in the finite element models, the modeling techniques are unchanged with relation to existing project techniques. Preliminary analysis has demonstrated that the use of the previously described springs and damping valves result in a system which correlates well with the test results. The analytical results indicate that Cable Tray Support Systems are effective because they resist lateral loads by framing action.

The correlation of the test and analysis illustrates the effectiveness of the refined modeling techniques to predict the dynamic properties of these representative models. The correlation of analysis and test results for the test sample effectively serves as a program link which combines the connection tests and shake table tests. The correlation demonstrates the importance of the connection behavior, validates the refined analysis modeling and provides the data required to establish a connection performance criteria.

4.2.3.2 Application of Connection Test Program

The Seabrook dynamic tests (Section 4.2.1) clearly demonstrated the inherent seismic capacity and energy absorption capabilities of the tested Cable Tray Support Systems. As stated earlier, these three samples were selected for dimensional, behavioral and quantity reasons. All the system geometries that are installed in the plant, however, may not be bounded by the three tested samples. This necessitates an analytical program, wherein the support systems not already geometrically bounded can be evaluated.

The shake table tests presented a bounding condition within the limits of the test facility. The tested geometries were subjected to seismic inputs in excess of plant envelope conditions, braced and unbraced conditions, maximum cable loadings, maximum support spans, maximum support widths, hardware variations, etc. These severe conditions and the ensuing performance are indicative of the available margins exhibited by the test samples. It is felt that the test samples were subjected to response levels (stresses, strains, displacements, etc.), which will envelope the large majority of site conditions. Thus, the primary purpose of the analytical phase of the qualification program is to evaluate the plant conditions to assure that the acceptable response levels demonstrated experimentally will not be exceeded. As discussed in Section 3, the existing plant evaluation methodology must be slightly amended to accomplish this task. The details of the amendments necessary to evaluate the connections is described in the following paragraphs.

As the existing project criteria does not address certain joint flexibilities, a criteria is added to document the flexibility of the key connections of the support systems. The use of connection springs in raceway-modeling has been implemented previously by Bechtel in conjunction with the Bechtel Raceway Test Program (Reference 6) and has been reviewed and accepted by the NRC staff. The NRC staff has considered Bechtel submittals of design guides, sample calculations, sample computer models, etc., in their past reviews. References 8 and 9 document past NRC programmatical acceptance in the form of plant Safety Evaluation Reports (SER). Because the connection springs represent a new feature in the Seabrook analysis program, an acceptance criteria consistent with the existing criteria is required. The nature of the connection's behavior and cyclic loading requires an evaluation of not only the allowable load and displacement, but also an evaluation of the connection's fatigue capabilities. This is, again, in conformance with past methodologies utilized by the Bechtel Power Corporation. Detailed methodologies have been submitted on several occasions; and therefore, only a brief summary is provided here.

A sample behavior of a typical cable tray support connection is illustrated in Figure 4-14. As presented, there is typically very ductile behavior and substantial reserve capacity. The criteria proposed for the

analytical program would conservatively neglect these attributes since connection rotations are limited. The connection spring stiffness, , is a conservative application, as it underestimates joint strain energy capacity and the response is conservative until the rotational acceptance criteria is exceeded.

4.2.4 Analytical Configurations

Analytical models developed to evaluate the cable tray supports at the Seabrook Station will utilize the criteria identified in Sections 3 and 4.2.3.2. Because of the similarity reflected in many of the supports, parametric models are generated. As discussed earlier, the qualification program for individual supports entails a review using test and parametric analysis results. Supports not qualified in this fashion will utilize individual evaluation.

The analytical models discussed above have been generated from the results of a site walkdown and review of as-built drawings. The site walkdown and as-built review were performed by a team of engineers from YNSD and Bechtel, who were familiar with both the testing program and the Seabrook cable tray layout. The purpose of the walkdown and as-built review was to identify support configurations which were not geometrically enveloped by the tested configurations. The following parameters were considered:

- o Width of the support.
- o Support spacing.
- o Cable fill.
- o Type of connection used at the building attachment.
- o Other considerations (custom configuration, miscellaneous attachments and close proximity items).

As a result of the as-built review, several configurations were identified for parametric analysis. These configurations are representative of the support types, size and loading in the buildings under consideration. Each of these configurations will be analyzed using data obtained from the test to determine system response and load path distributions to primary support and bracing members. Figures 4-15 and 4-16 depicts typical wall-mounted configurations to be modeled for the analytical program.

TABLE 4-1

TEST SEQUENCE - CASE A

- o Preliminary testing, low level random input to determine frequencies, mode shapes and damping ratios
- o Earthquake testing of configuration A at (3) fractional SSE input levels and (1) full level SSE.
- o Fatigue testing of configuration A; five OBE level events followed by a single SSE level event
- o Remove all bracing from test configuration.
- o Preliminary testing, low level random input to determine frequencies, mode shapes and damping ratios
- o Earthquake testing at SSE level and at levels exceeding SSE level.

TABLE 4-2

TEST SEQUENCE - CASE B

- Preliminary testing, low level random input to determine frequencies, mode shapes and damping ratios
- Earthquake testing of configuration B at (2) fractional SSE levels and (1) full level SSE.
- Fatigue testing of configuration B; five OBE level events followed by a single SSE level event
- Earthquake testing of configuration B at a level exceeding the SSE level
- Remove all bracing from test configuration. Preliminary testing, low level random input to determine frequencies, mode shapes and damping ratios.
- Earthquake testing of unbraced configuration at SSE level.
- Disconnect bottom connections at 'floor to floor' supports. Preliminary testing, low level random input to determine frequencies, mode shapes, and damping ratios.
- Earthquake testing of unbraced configuration at SSE level

TABLE 4-3

TEST SEQUENCE - CASE C

- Preliminary testing, low level random input to determine frequencies, mode shapes and damping ratios

- Earthquake testing of configuration C at (2) fractional SSE levels and (1) full level SSE

- Fatigue testing of configuration C: five OBE level events followed by a single SSE level event

- Earthquake testing of configuration C at a level exceeding the SSE level

- Remove all bracing with strut connection hardware. Install longitudinal braces between S3 & S4. Install transverse brace at S3 with welded connections. Earthquaking testing at SSE level.

- Remove all bracing. Earthquake testing at SSE level.

TABLE 4-4

SIMULATION OF VARIOUS IN-SITU CONDITIONS

- o Site supplied materials (strut, hardware, cable ties, etc.)
- o Typical wireway attachments
- o Alternate tray hold down hardware
- o Mixing of tray hold down hardware
- o Eccentric connections
- o Vendor variation of connection fittings
- o Standard primary connections
- o Tray type variation
- o Cable ties
- o Cable tray voltage levels
- o Vendor variation of strut nuts
- o Typical cable tray splice and cover details
- o Variation of horizontal brace connection details
- o Cable tray elevation transitions
- o Cable tray direction transitions
- o Conduit to cable tray interface details
- o Forty percent cable tray fill (by area)
- o Bolt torque values

TABLE 4-5

OBSERVED PERFORMANCE (REPRESENTATIVE)

- Approximately 40% SSE Input Level
  - No visible deformation of connection hardware
  - Isolated bolts lose some torque
- Approximately 60 to 70% SSE input level
  - No visible deformation of connection hardware
  - A few bolts lose some torque
  - Isolated bolts (typically diagonal braces) become loose
- Approximately 90% SSE input level
  - Isolated 'Z-clip' deformation
  - Slightly more bolt loosening than previous category (a few bolts become loose)
- Approximately SSE input level
  - Cable tie breakage
  - Multiple 'Z-clips" deform
  - Acute brace clip angle deformation or fracture
  - 1" Ø conduit clamp movement
  - Tray slippage (w/mix of bent and 'Z' clip usage)
- Approximately 100% to 130% SSE input level
  - Many cable ties break
  - Overhead gusseted angle weld fracture
  - Overhead P1000 deformation
  - Vertical slippage of horizontal member
  - Minor horizontal member rotation
  - Isolated internal connection visibly deformed
  - Diagonal brace and overhead connection bolts lose some torque

TABLE 4-6

DAMPING - CASE A

TEST	LONGITUDINAL	TRANSVERSE
7.3.1.2.6 - PARTIAL SSE W/BRACING	22%	36%
7.3.3 - OBE W/BRACING	22%	25%
7.3.7 - SSE AFTER (5) OBE W/BRACING	23%	27%

TABLE 4-7

DAMPING - CASE B

TEST	LONGITUDINAL	TRANSVERSE
7.6.0.1 - PARTIAL SSE W/BRACING	30%	27%
7.6.2 - OBE W/BRACING	32%	28%
7.6.7 - SSE AFTER (5) OBE W/BRACING	33%	32%

TABLE 4-8

MAXIMUM DISPLACEMENTS

		BRACED	UNBRACED	BRACED (FATIGUE)
CASE A	LONGITUDINAL	4.3"	5.2"	4.6"
	TRANSVERSE	2.6"	5.2"	3.8"
CASE B	LONGITUDINAL	1.6"	4.0"	2.0"
	TRANSVERSE	2.7"	4.6"	3.8"

REPRESENTATIVE DISPLACEMENTS

CASE-A (BRACED)

TEST - 7.3.1.2.7 (70% SSE)

LONGITUDINAL	TRANSVERSE
1.92"	0.96"

TABLE 4-9

HORIZONTAL BRACE VS. DIAGONAL BRACES

SUPPORT #1
CASE A - DIAGONAL BRACE
CASE B - HORIZONTAL BRACE

TEST	CASE A	CASE B
OBE #1	3800#	4000#
OBE #2	3000#	3300#
OBE #3	1000#	3000#
OBE #4	500#	3000#
OBE #5	500#	3000#
SSE	750#	4500#

TABLE 4-10

FUNDAMENTAL MODE COMPARISONS
(w/o Bracing)

TEST	DIRECTION	FREQUENCY	
		ANALYSIS	TEST
CASE A	Longitudinal	2.0	1.8
	Transverse	2.5	2.6
CASE B	Longitudinal	3.4	2.9
	Transverse	4.2	4.3

TABLE 4-11

FUNDAMENTAL MODE COMPARISONS
(w/ Bracing)

TEST	DIRECTION	FREQUENCY	
		ANALYSIS	TEST
CASE A	Longitudinal	3.6	3.3
	Transverse	5.4	5.7
CASE B	Longitudinal	3.5	3.6
	Transverse	5.2	6.0
CASE C	Longitudinal	5.1	5.8
	Transverse	5.1	5.6

MAXIMUM TEST STRESSES

SSE (with bracing)

CASE A	BRACE / POST (TOP)	3.3 / 2.7	(KSI)
CASE B	BRACE / POST (TOP)	3.6 / 3.9	(KSI)

ALLOWABLE STRESS = 0.9Sy = 40 KSI

TABLE 4-12

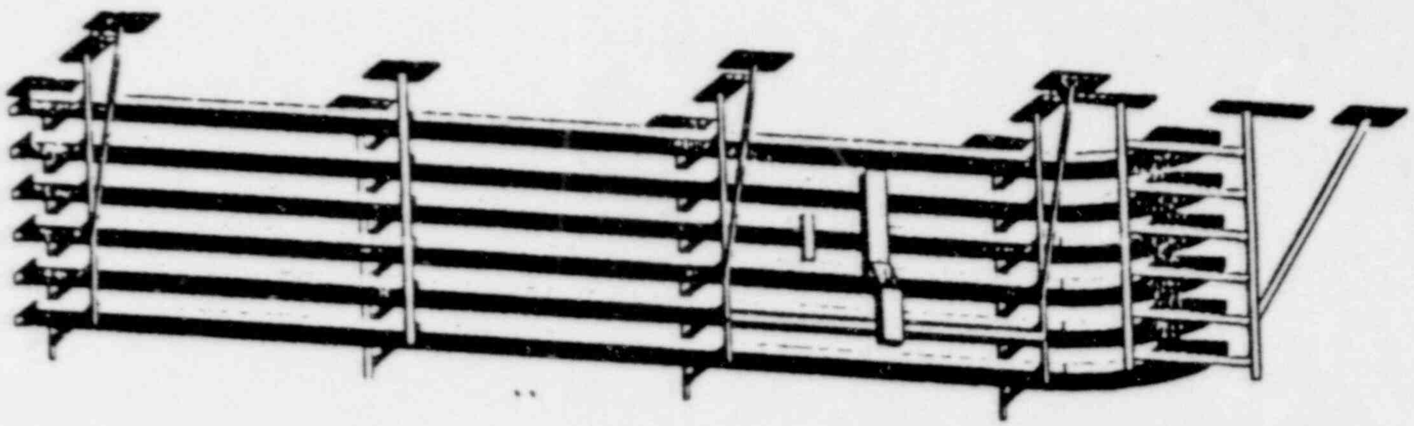


FIGURE 4-1 TEST CONFIGURATION (CASE A)

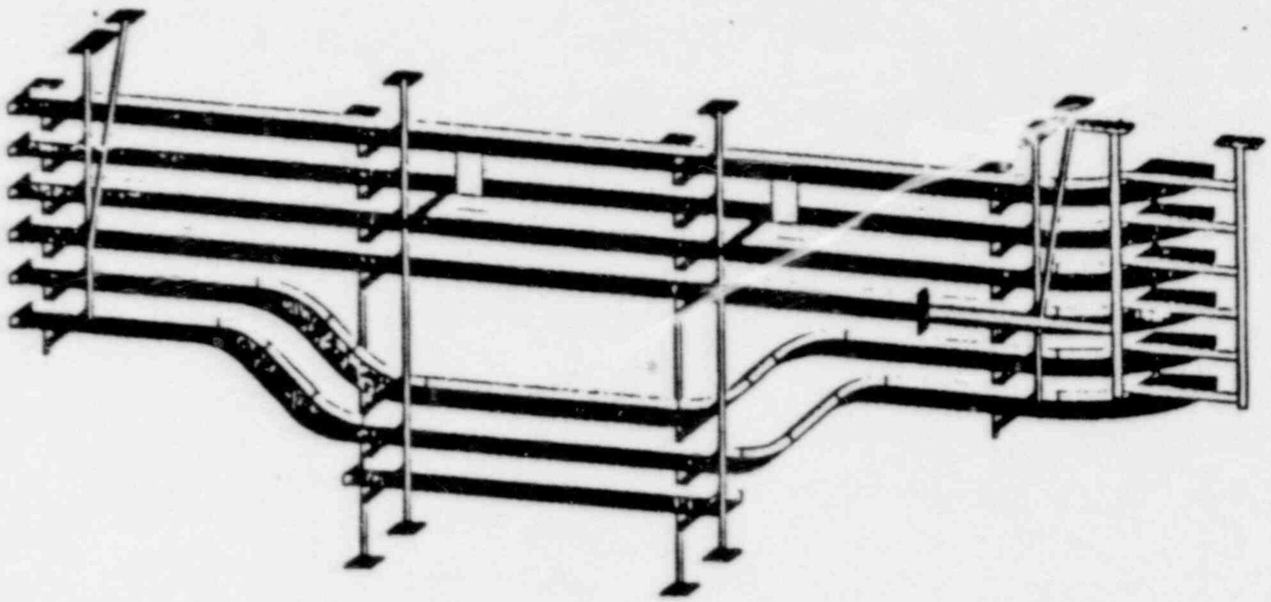


FIGURE 4-2 TEST CONFIGURATION (CASE B)

SEABROOK CABLE TRAY SUPPORT TYPES

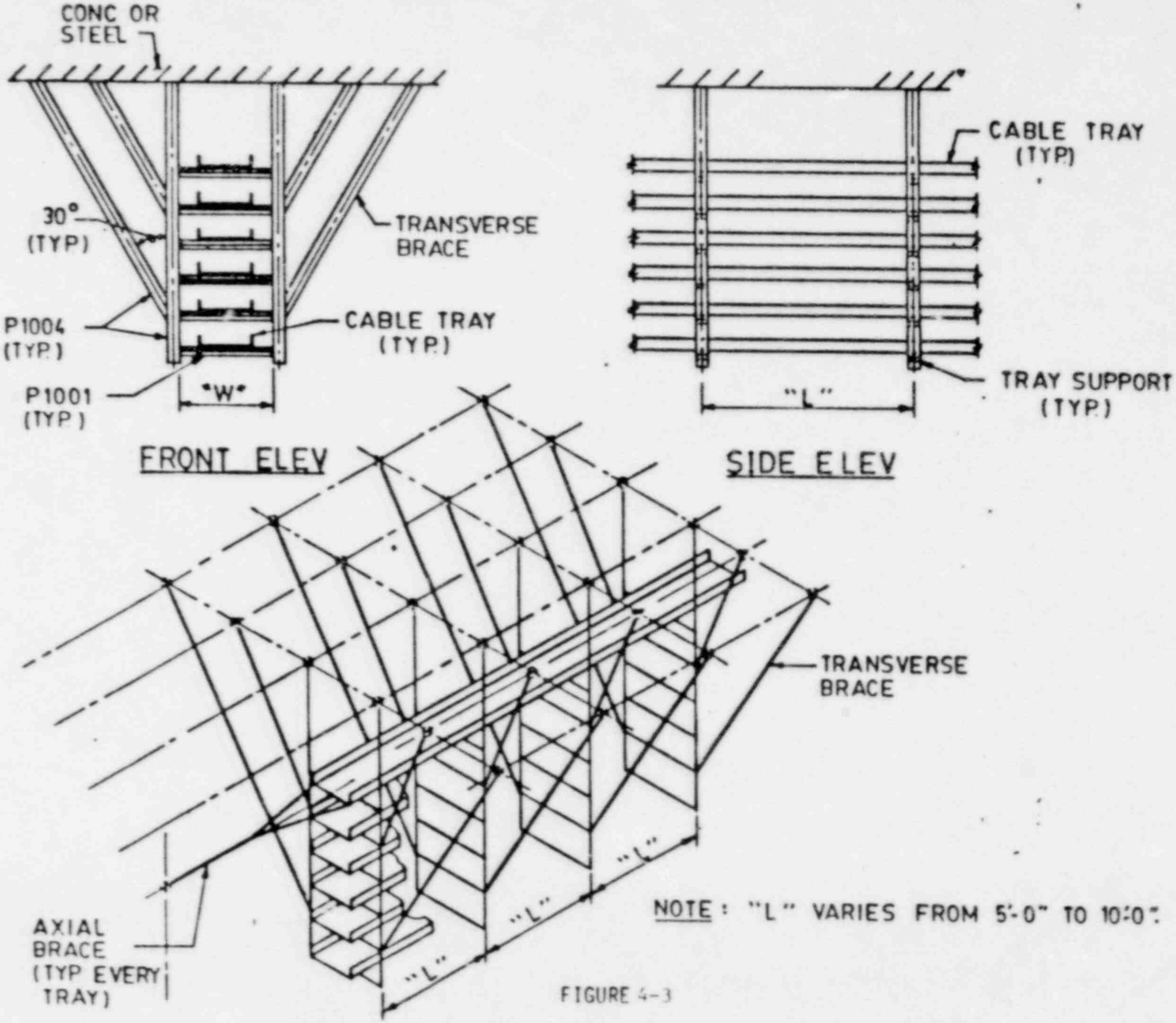


FIGURE 4-3

TYPICAL TRAPEZE-TYPE TRAY SUPPORT TYPE 26

SEABROOK CABLE TRAY SUPPORT TYPES

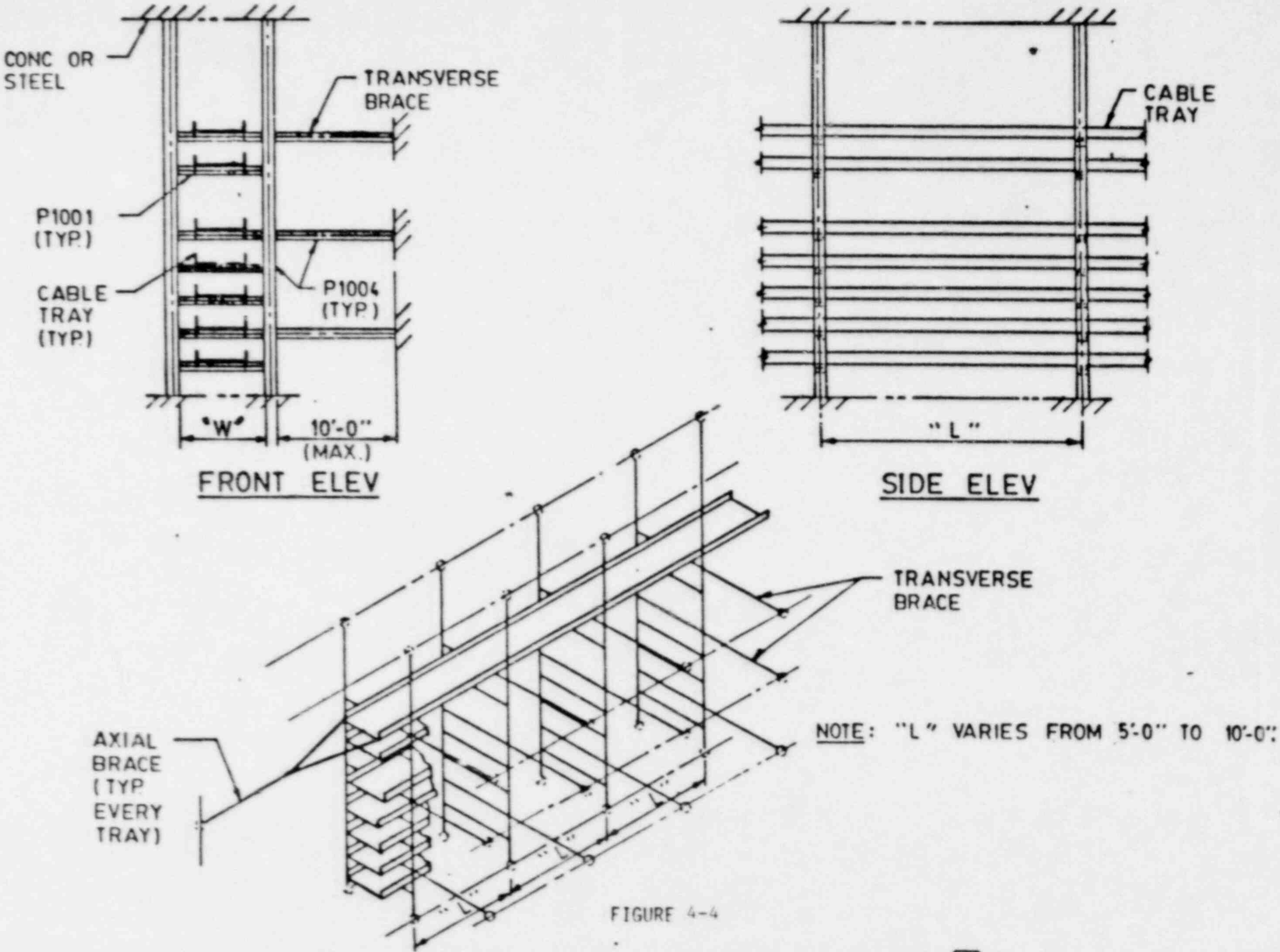


FIGURE 4-4

TYPICAL FLOOR TO CEILING TYPE TRAY SUPPORT TYPE ⟨5⟩

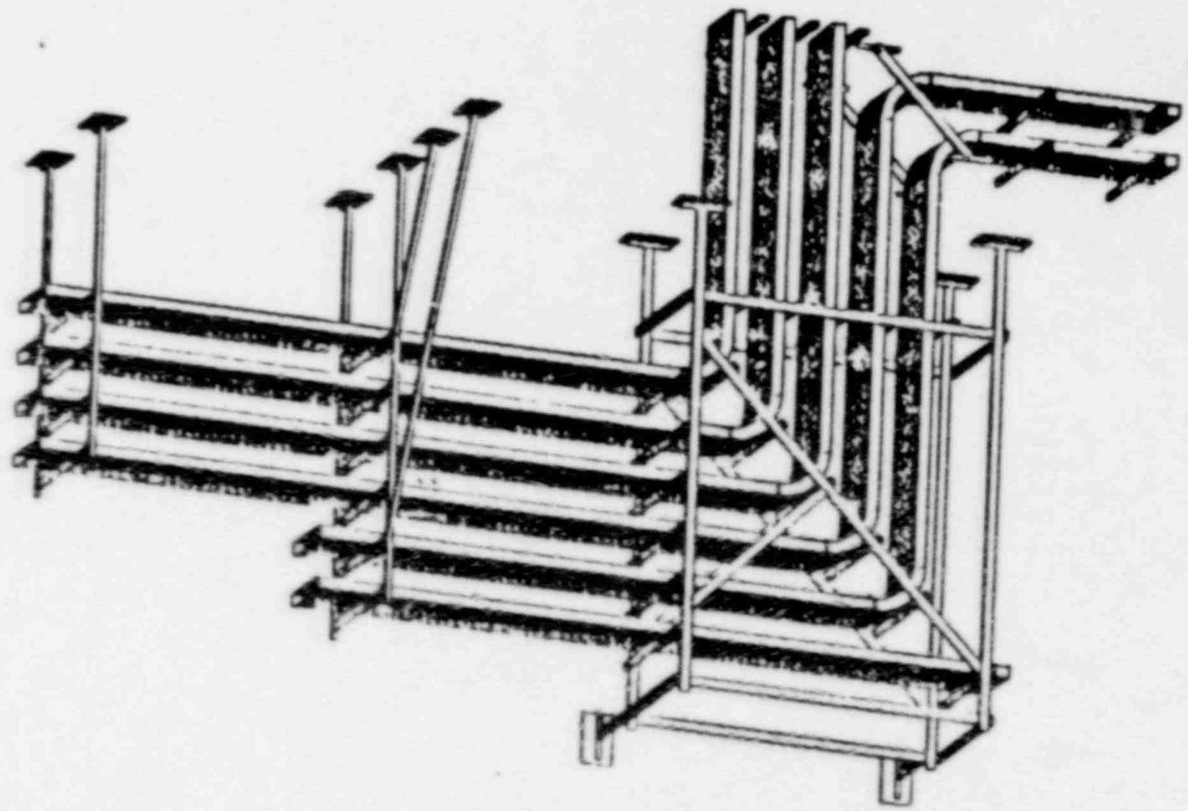


FIGURE 4-5 TEST CONFIGURATION (CASE C)

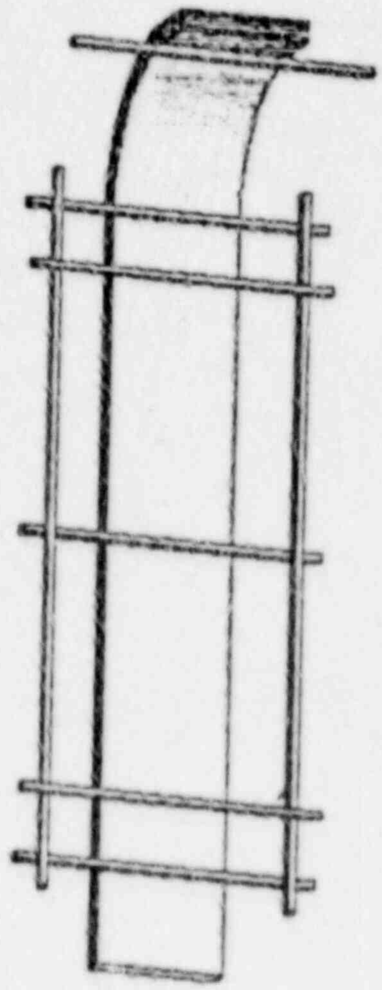
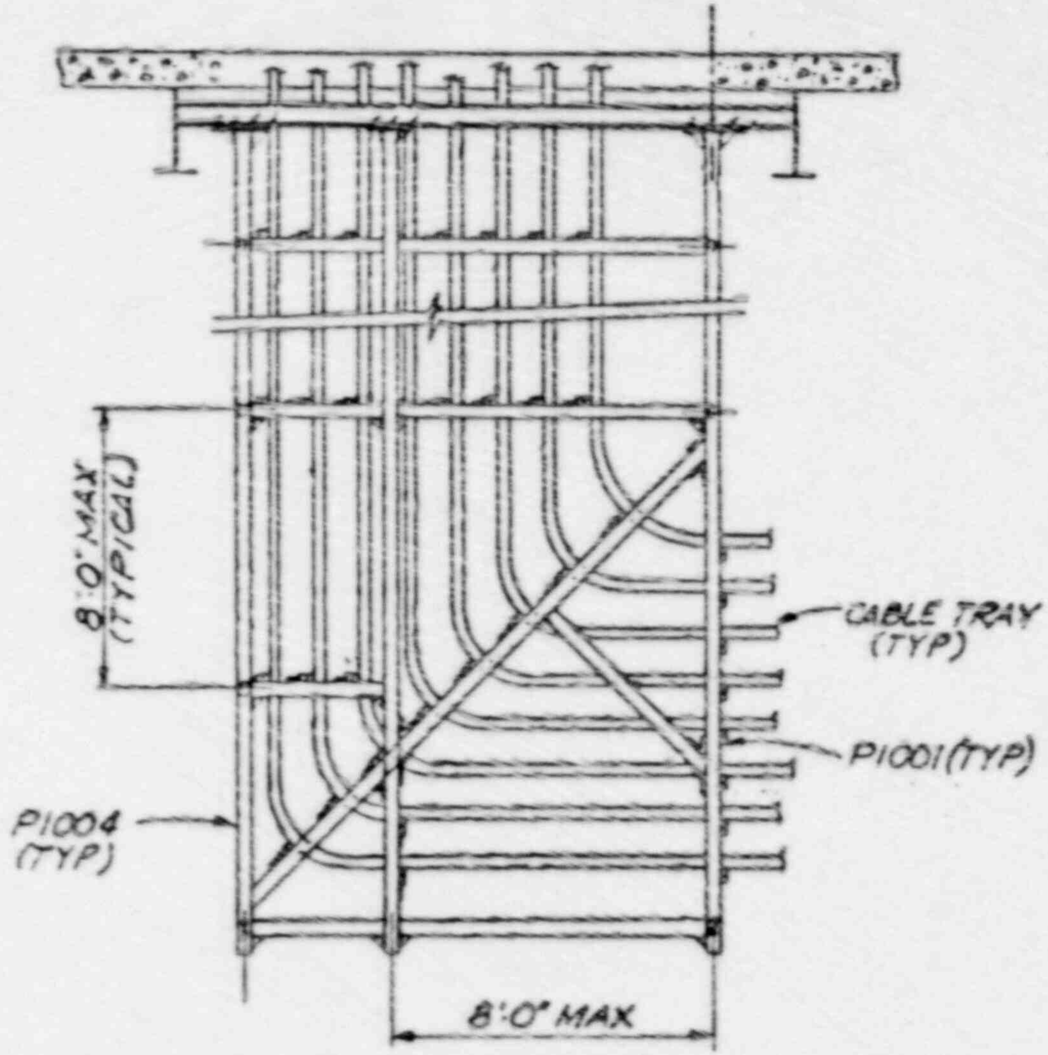


FIGURE 4-6 TEST CONFIGURATION (CASE C')

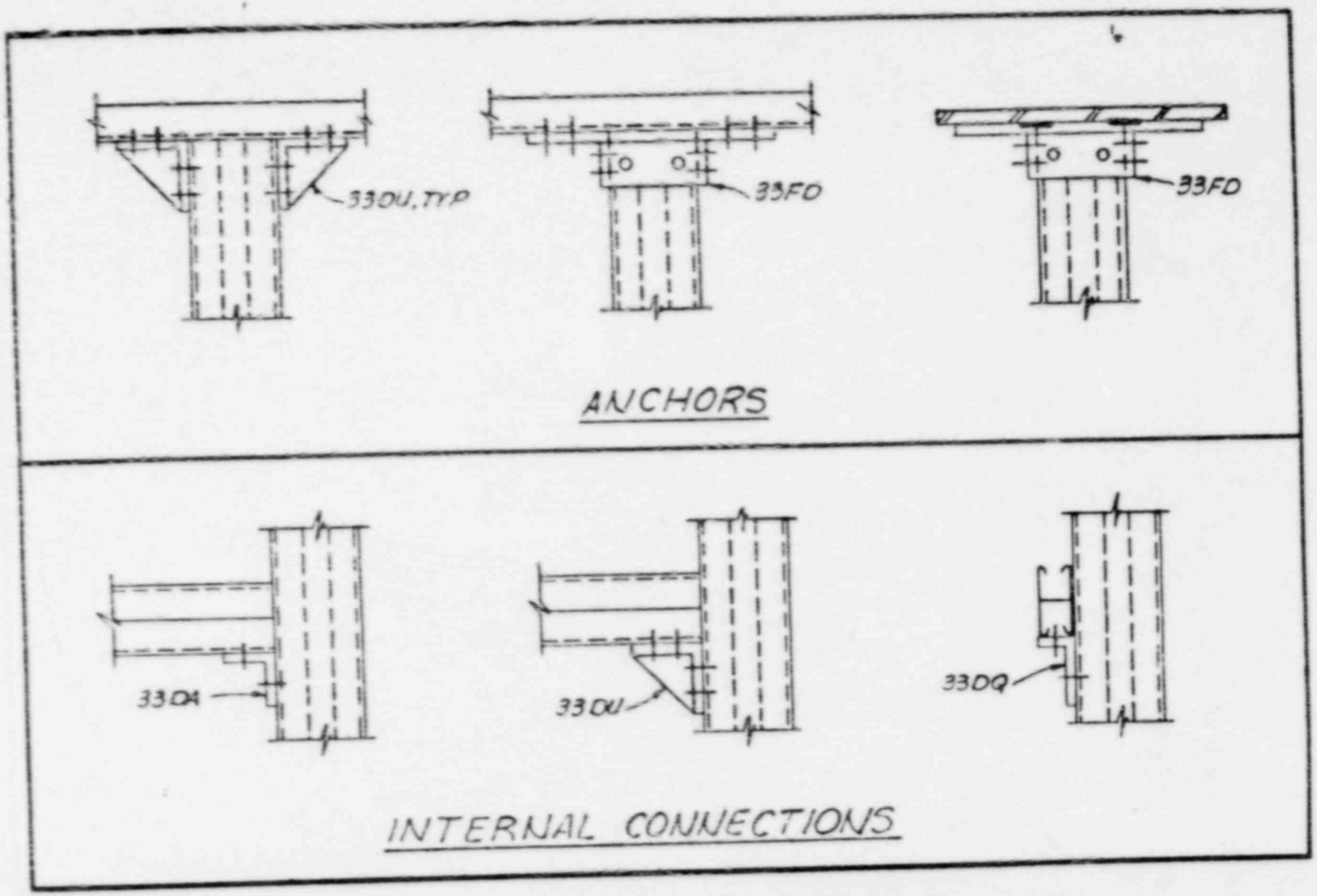
SEABROOK CABLE TRAY SUPPORT TYPES



SIDE ELEVATION

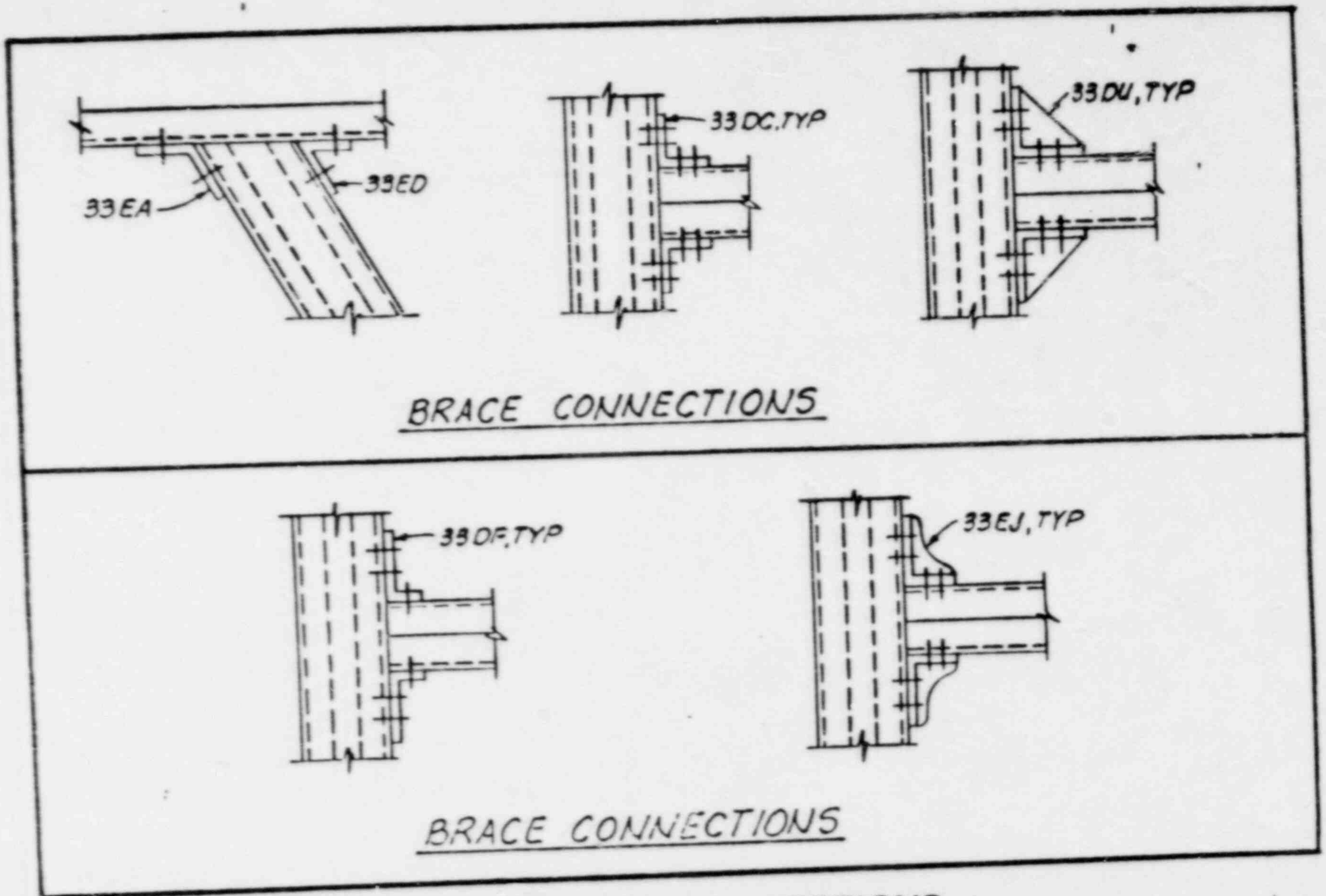
TYPICAL TRANSITIONAL TYPE TRAY SUPPOPT TYPE ⟨9⟩

FIGURE 4-7



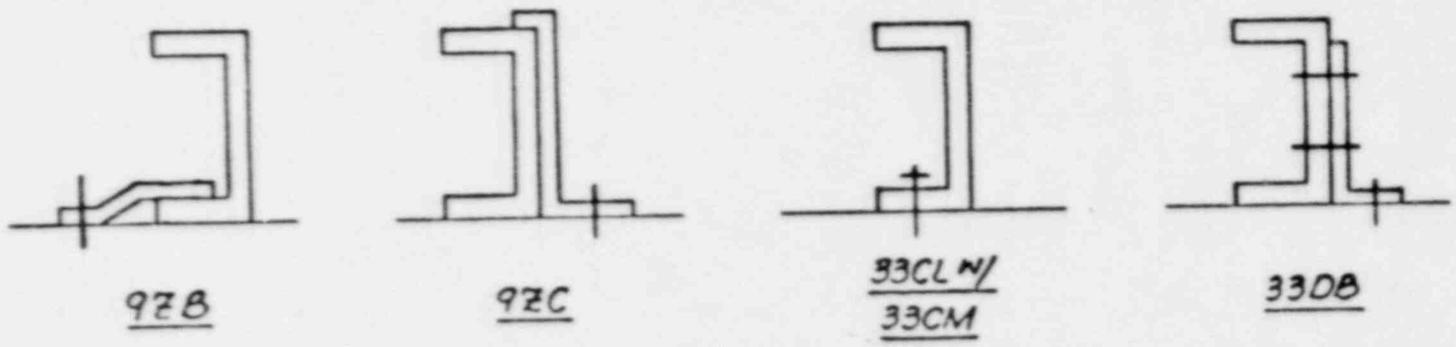
TRAY SUPPORT CONNECTIONS

FIGURE 4-8a



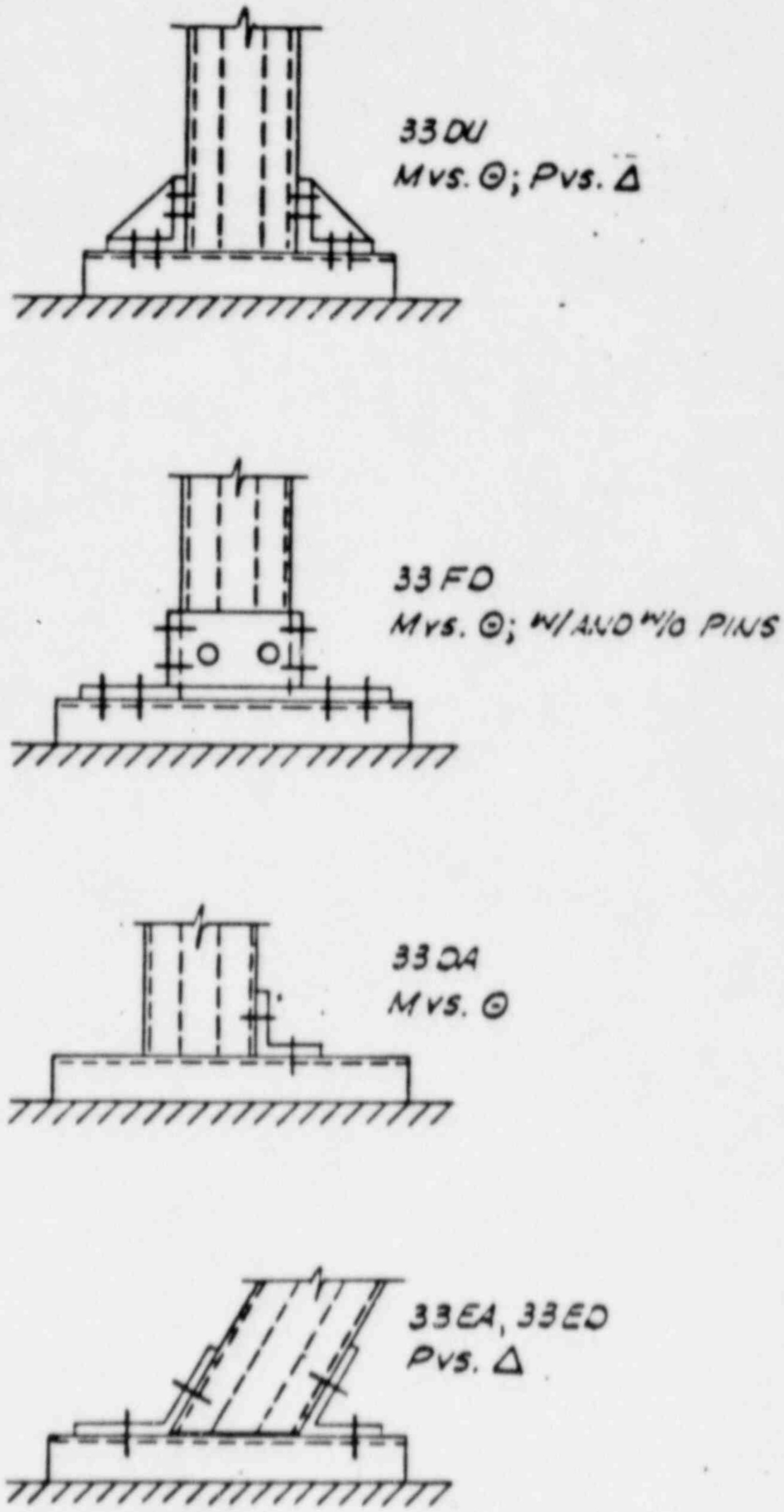
TRAY SUPPORT CONNECTIONS

FIGURE 4-8b



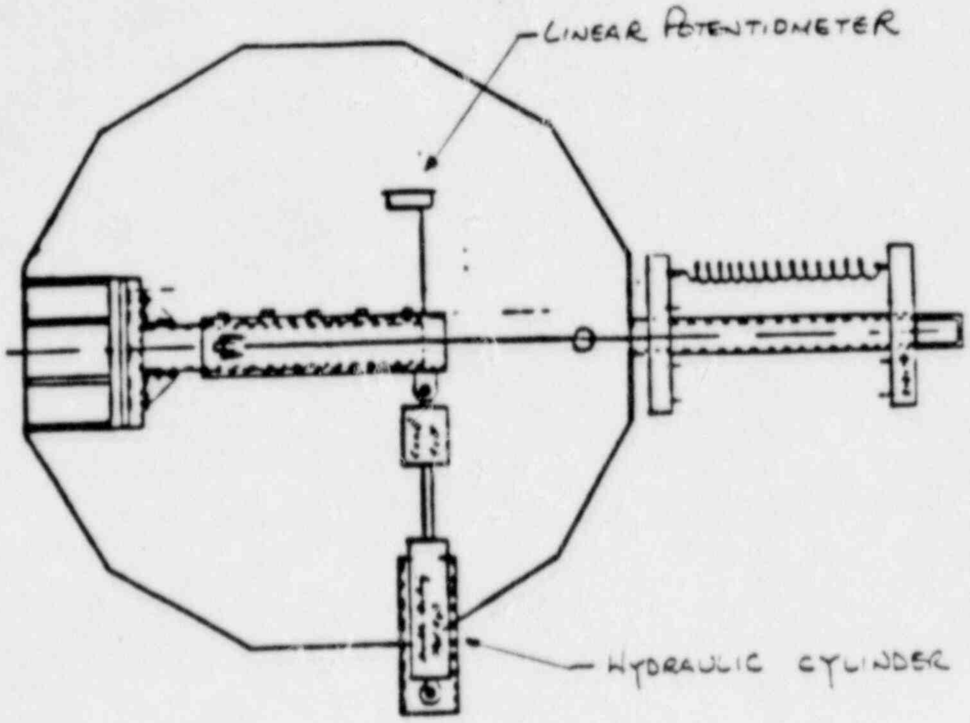
TRAY FASTENING HARDWARE

FIGURE 4-8c



- CONNECTION TESTS

FIGURE 4-9



CONNECTION TEST
SET-UP

Figure 4-10

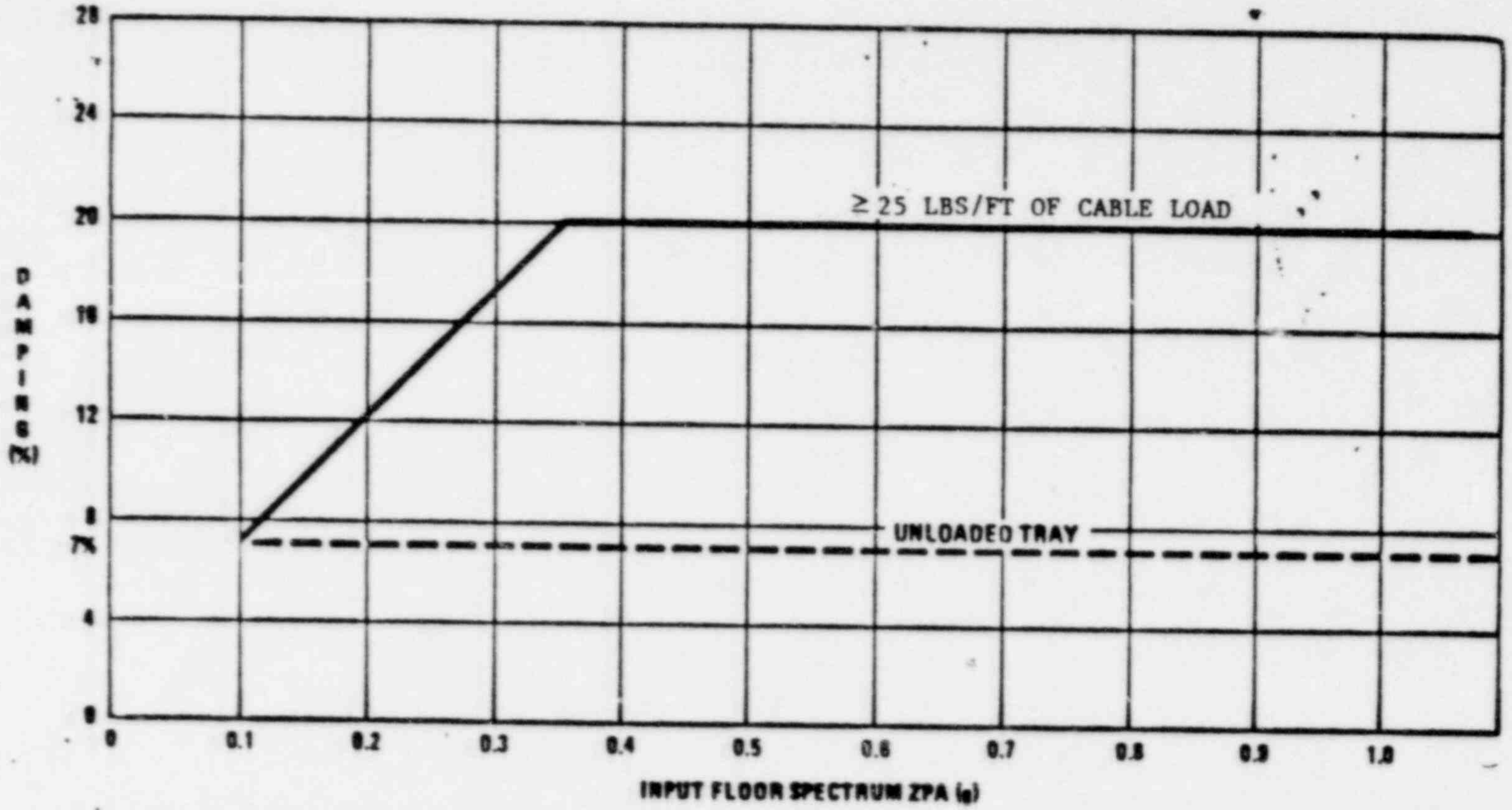


Figure 4.11 – **DAMPING AS A FUNCTION OF INPUT ZPA** (Lower Bound)

FIGURE 4-12 REPRESENTATIVE TRS vs. ENVELOPE RRS COMPARISON (7% DAMPING)

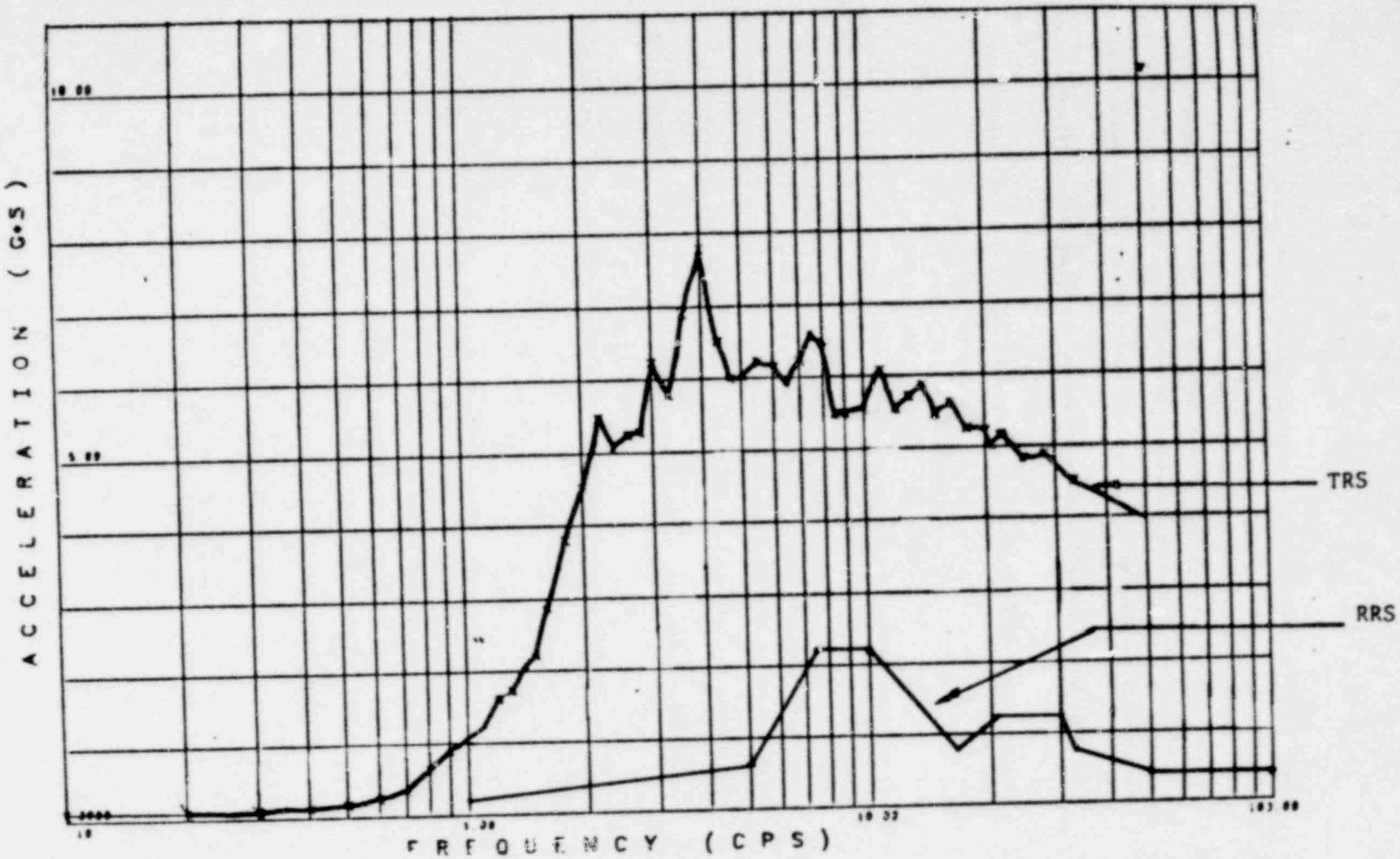


FIGURE 4-13 TRS vs. RRS @ 7% DAMPING
RRS - CONTROL BLDG. EL 21'-6"-30'
E-W SSE

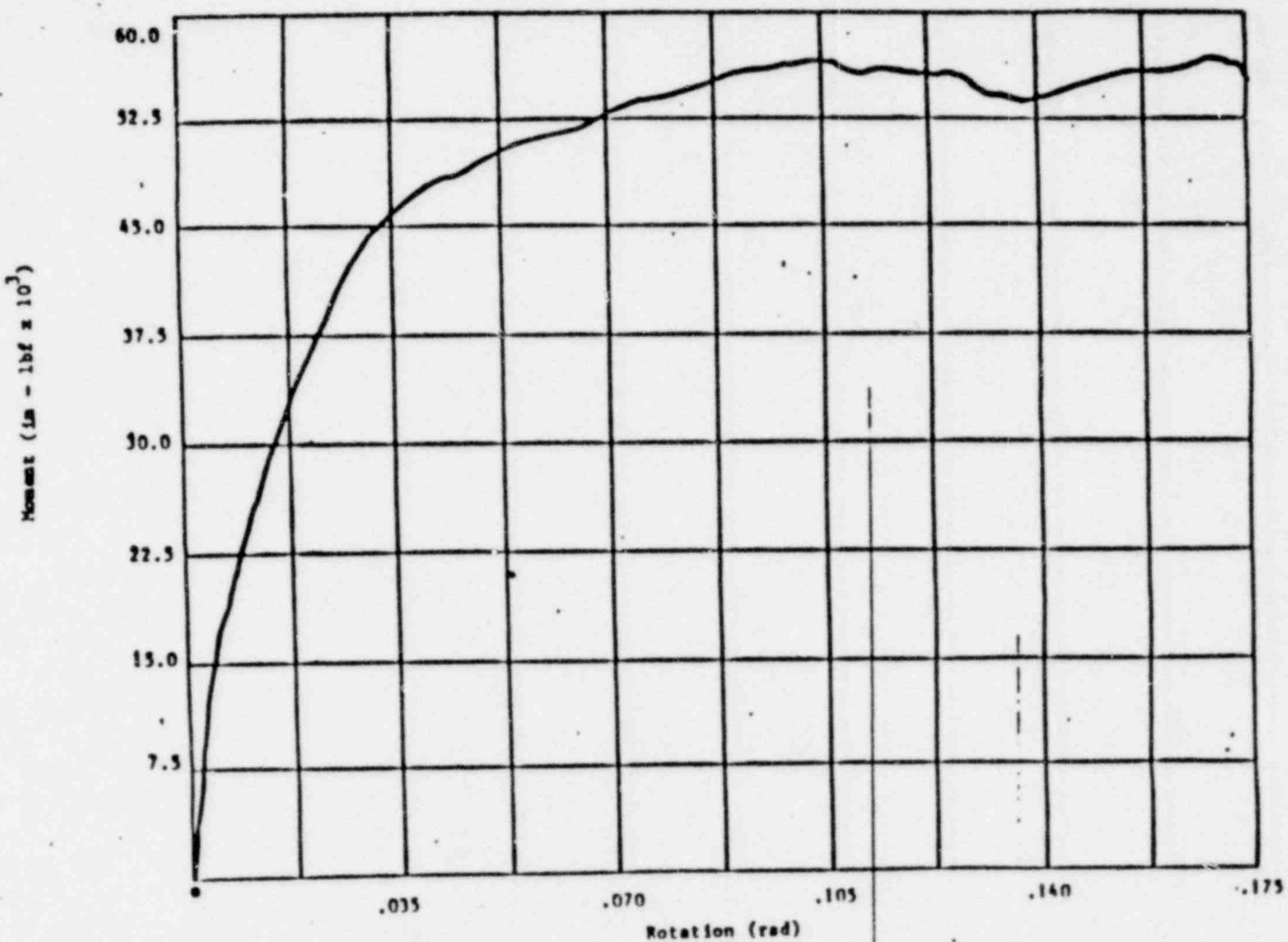


FIGURE 4-14 - REPRESENTATIVE CONNECTION TEST M vs. Θ PLOT (33DU)

ANCO

ANCO ENGINEERS, INC., 9937 JEFFERSON BLVD., CULVER C[illegible]Y, CA 90230-6881

ANALYSIS

TEST	RUN	TEST OBJECT		ACCEL	LOCATION	mV/g
7.4.1.1	1	Case II Strong Direction	A	X	Celsco	1"/volt
DATE 10/26/85		COMMENTS	B	Y	MTS Load Cell	2000#/Volt
TIME 1615	BY JCS					

DATE 10/26/85 RMS/PEAK

BY JCS AVG ---

WTG --- FREQ ---

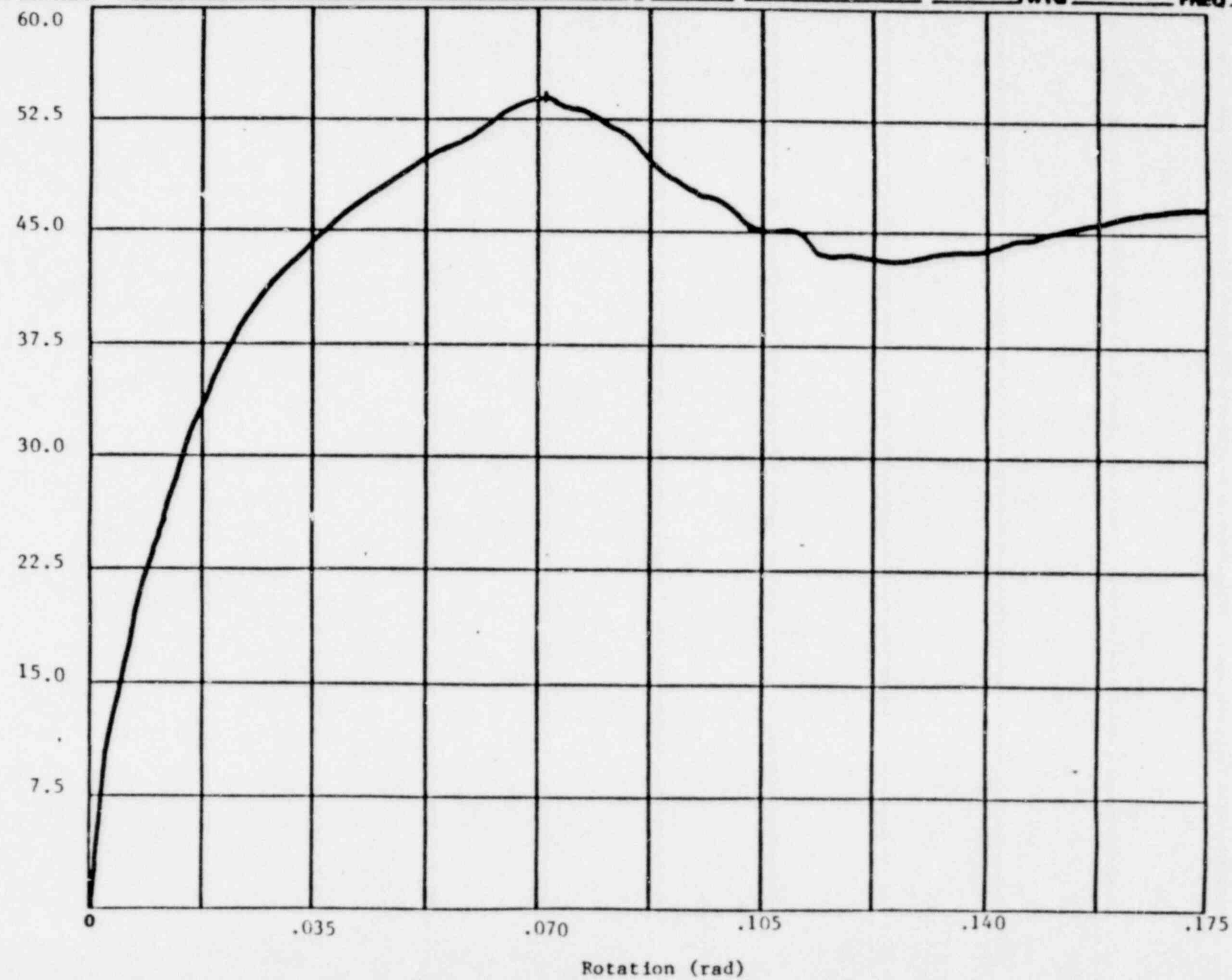


Figure 4-14a

ANCO DOCUMENT# A-000161 PAGE# F-23

ANCO

ANCO ENGINEERS, INC., 9937 JEFFERSON BLVD., CULVER [illegible], CA 90230-[illegible]

TEST 7.4.1.1 RUN 2 TEST OBJECT Case II Strong Direction	ACCEL	LOCATION	mV/g	ANALYSIS
DATE 10/26/85 COMMENTS	A X	Celsco	1"/volt	DATE 10/26/85 RMS/PEAK
TIME 1645 BY JCS	B Y	MTS Load Cell	2000#/Vo	BY JCS AVG ---
				WTG --- FREQ ---

Moment (in - lbf x 10^3)

Figure 4-14b

ANCO DOCUMENT# A-000161 PAGE# F-24

ANCO

ANCO ENGINEERS, INC., 9937 JEFFERSON BLVD., CULVER CITY, CA 90230-3591

TEST 7.4.1.1	RUN 3	TEST OBJECT Case II Strong Direction	
DATE 10/28/85		COMMENTS	
TIME 1035	BY JCS		

ACCEL	LOCATION	mV/g
A X	Celesco	1"/volt
B Y	MTS Load Cell	2000#/vol

ANALYSIS

DATE 10/28/85 RMS/PEAK

BY JCS AVG ---

WTG --- FREQ ---

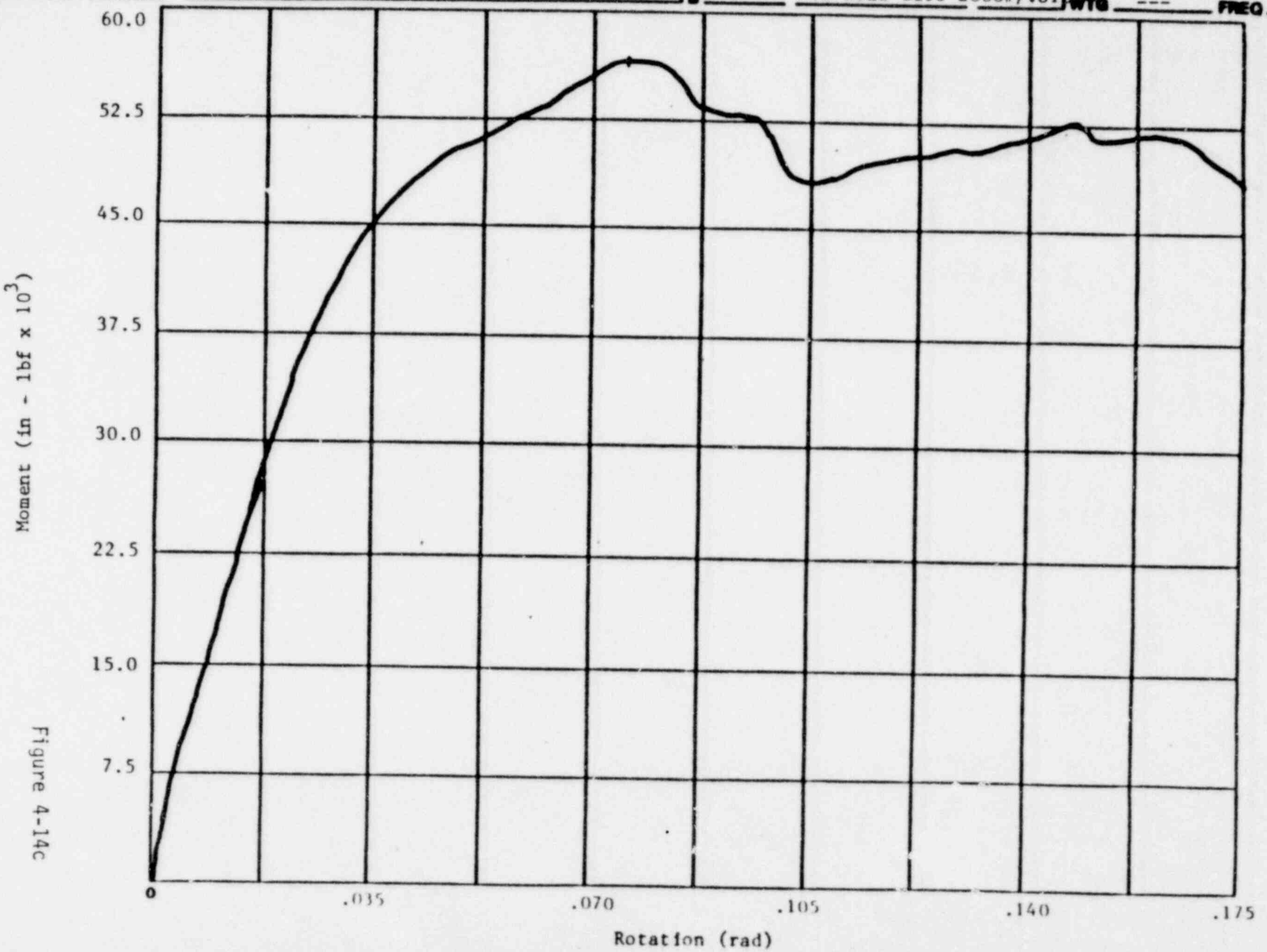
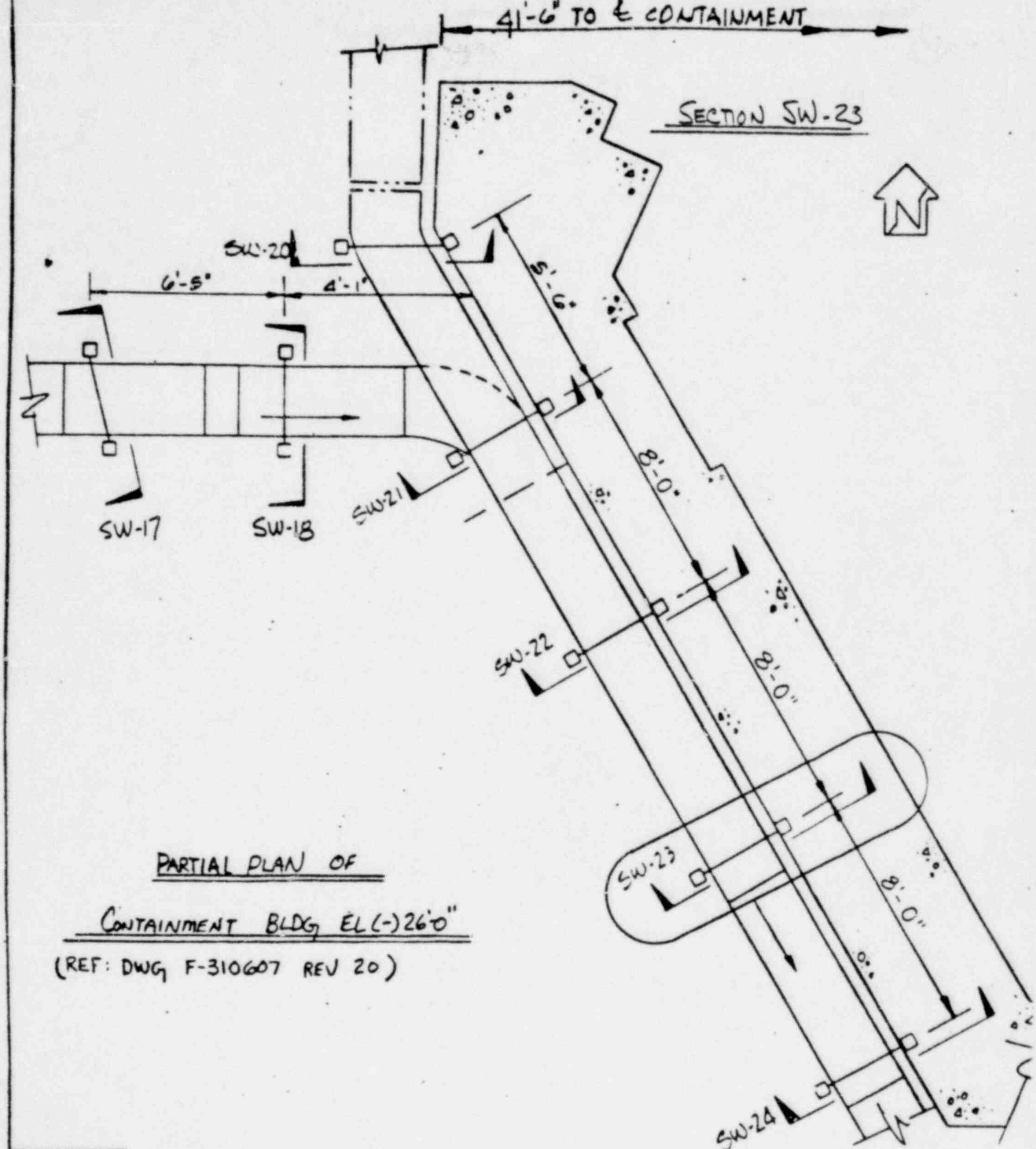


Figure 4-14c

ANCO DOCUMENT# A-000161 PAGE# F-25



TA: W096
W.P.# 8

FIGURE 4-15

CHECKER IS CERTIFIED TO INSPECT CABLE TRAY SUPPORTS PER ESG-4

CERTIFIED AS-CONSTRUCTED BY:

John F Moran 1/11/86

DATE

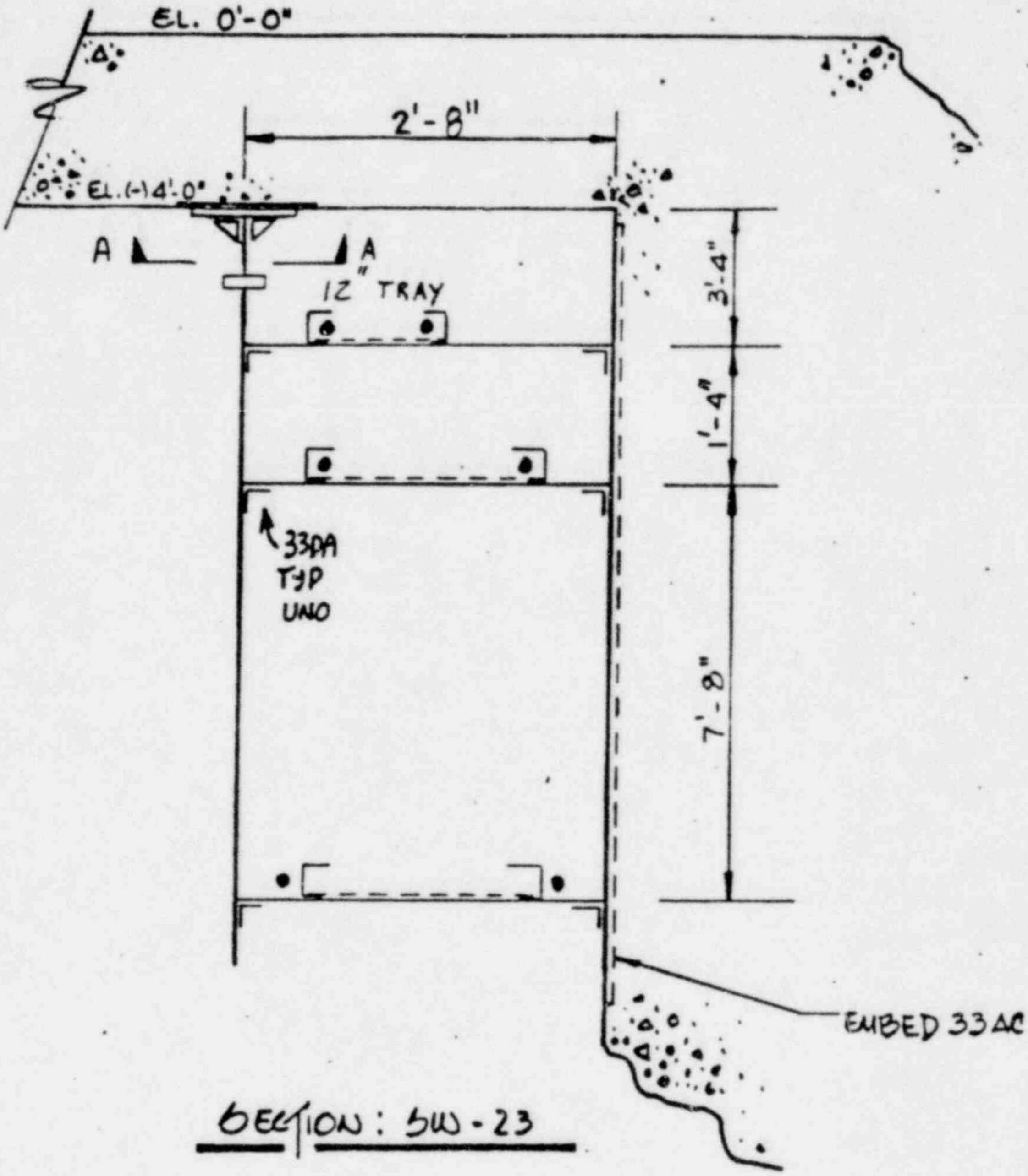
REV	DATE	DESCRIPTION	DWN BY	CHD BY
0	2-5-86	FIRST ISSUE	JSW	R.H.

CABLE TRAY SUPPORTS
- AS-CONSTRUCTED -
BLDG. CONTAINMENT EL. (-)26

PUBLIC SERVICE CO. OF NEW HAMPSHIRE
SEABROOK STATION

united engineers

9763-L-370/37 SH. 3



TA: W096

W.P.# 8

FIGURE 4-16

CHECKER IS CERTIFIED TO INSPECT CABLE TRAY SUPPORTS PER ESG-4

CERTIFIED AS-CONSTRUCTED BY:

John E. Noran 1/13/86

DATE

0	1st	FIRST ISSUE	JBN	R.W.

CABLE TRAY SUPPORTS
- AS-CONSTRUCTED -
BLDG Containment EL (-)26'-

PUBLIC SERVICE CO. OF NEW HAMPSH
SEABROOK STATION

united engineers

9763-L-370/37 SH. 33

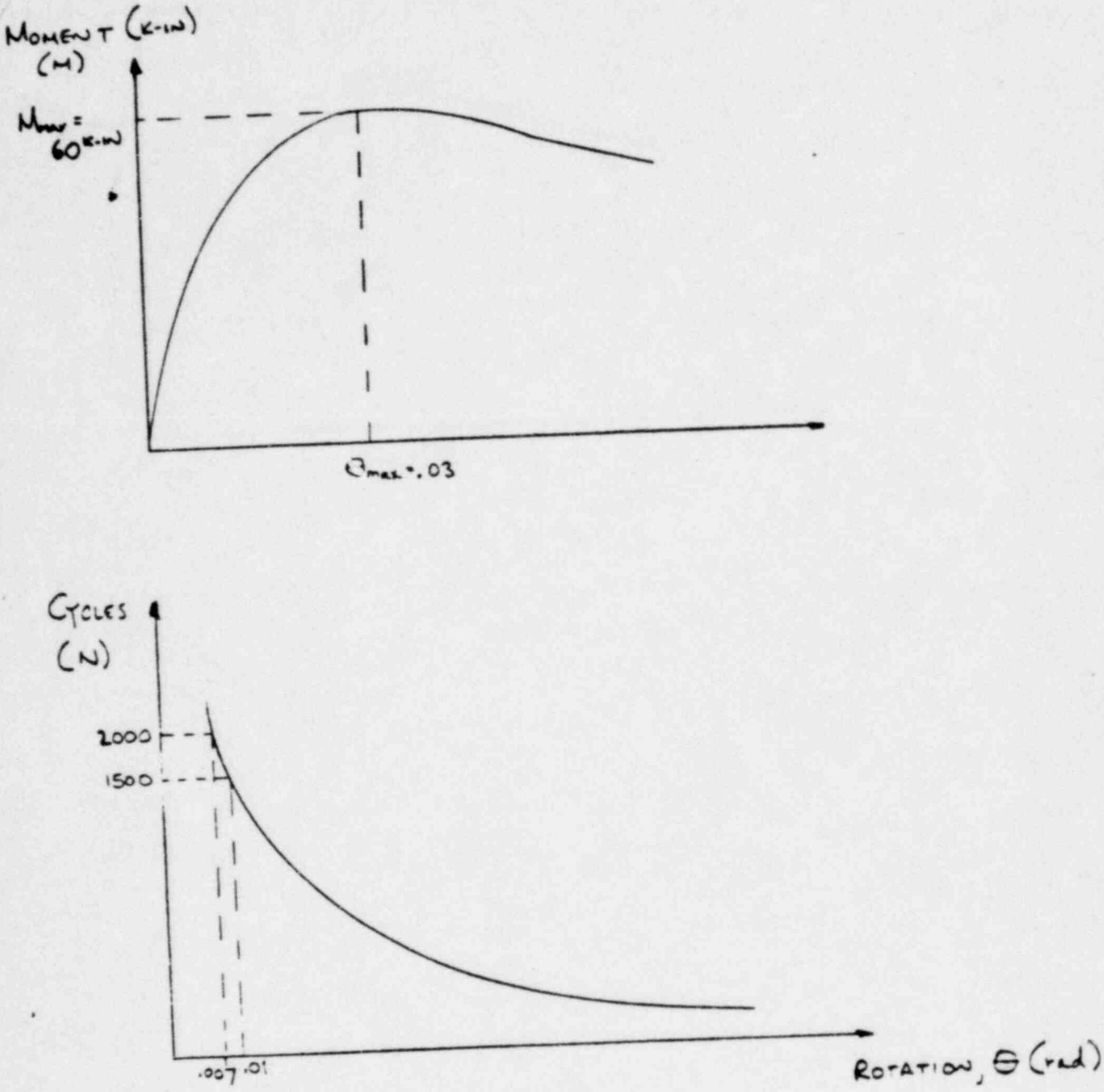


FIGURE 4-17 - TYPICAL CONNECTION BEHAVIOR

5.0 SUPPORT QUALIFICATION CRITERIA

5.1 Criteria Summary

The purpose of this evaluation criteria is to provide the means by which to document the ability of cable tray supports to maintain their structural integrity during postulated seismic loadings. Representative full-scale support testing (Reference 10) has demonstrated that adequate primary connection integrity ensures the cable's functionality and the support's ability to carry the cable load during and after a seismic event. Support behavior consistent with the full-scale tests is considered acceptable performance.

The criteria is applied to supports and support features which are compatible with the full scale tests results. Specifically, the full-scale Seabrook tests (Reference 10) and the Bechtel Generic Raceway tests (Reference 6) have demonstrated that typical cable tray support systems behavior is essentially controlled by the behavior of the primary overhead (vertical load) carrying connections and the brace connections. Supports of compatible geometry and hardware with the full scale tests, then, can be qualified utilizing this criteria.

Implementation of this criteria, consistent with the test results, will ensure acceptable performance of the cable tray supports consistent with the full scale test results (Reference 10). Primary load path stresses will be limited to levels identified in Section 5.4.

Figure 2(b) serves to define support primary stresses and test compatibility. Case I is completely test compatible, based on its similarity to the Case A test presented in Reference 1. The vertical strut and primary connection create the primary load path, and require evaluation. The brace and its connections are not primary, and are more fully discussed in Section 5.4. Full scale testing has demonstrated the brace is secondary in terms of support integrity and functionality. Figure 2(b), Case II, is compatible with the test program, however, its geometry creates additional primary load paths (and stresses). Cable load is carried both horizontally

and vertically. Figure 2(b), Case III, is also compatible with the test program.

Supports and/or support features not compatible with the test (i.e., welded steel frame support) will require a unique support evaluation. These supports will be qualified in accordance with Reference 11. Pertinent test data (e.g., connection test results) can be used to enhance the structural modeling and evaluation of cable tray supports, as applicable.

A flow chart depicting the various evaluation alternatives is presented in Figure 1.

5.2 Scope

The scope of this evaluation criteria can be applied to the cable tray support system as follows. The cable tray evaluation is limited to members, connections, etc., whose sole purpose is to support the cable tray. Figure 2(a) presents a typical cable tray support which serves to clarify the scope of evaluations performed per this criteria. Specifically, the limits of this criteria are as follows:

Supplemental Steel	-	Reference 11 provides the technical guidelines for this evaluation.
Support Anchorages (including braces)	-	System anchorages (embedded plates, inserts and channels; surface plates and channels, welded channels) are within the scope of the evaluations performed per this criteria. Specific anchorage evaluations should be performed in accordance with Reference 11.
Primary Connection, etc.	-	The support proper (i.e., primary connections, brace connections, etc.) are to be evaluated utilizing this criteria, as outlined in Section 5.1.

5.3 Evaluation by Test

Support evaluation by test is limited to configurations where critical elements of the support under consideration are enveloped by the tested conditions. The four major test configurations are depicted in Figures 3 through 6; however, test details are provided in Reference 10. The cable tray support can be qualified directly utilizing the system test data with proper consideration of the following parameters:

- o Support Width
- o Support Height
- o Support Boundary Conditions
- o Cable Mass
- o Hardware Compatibility
- o Bracing
- o Span
- o Response Spectra

Planar (i.e., transverse and vertical) enveloping is assured if, individually, all the above parameters are enveloped by a tested support. Further, planar enveloping can be demonstrated for any configuration where the critical primary elements (e.g., the primary load paths) of the support under consideration are enveloped by the tested conditions.

In addition to enveloping the "in-plane" geometry, consideration must be given to the "out of plane" (longitudinal) dimension effects, that is, the routing of the overall cable tray system. Case A and B, as shown in Figures 3 and 4 have a general shape (in plan) of the letter "J". This "J"

configuration was chosen to investigate the load distribution of the global "X" direction (longitudinal). The one support "around the corner" (i.e., the support perpendicular to the other four supports) served to stiffen the longitudinal system direction, and typically must be considered in any "out of plane" evaluation.

For qualification purpose, then, the system restraint in the longitudinal direction requires evaluation. Longitudinal restraint can be provided by a combination of support framing, system restraint, and/or brace resistance. To carry the longitudinal load, direct longitudinal support of the system can be provided, supports perpendicular to the longitudinal direction may be used, or adjacent supports can be braced together as a means of accepting the lateral load. The "J" configuration used in the test survived both braced and unbraced conditions; therefore, various in situ conditions (and brace patterns) can be qualified by direct comparison to the test program. Routing configurations which provide additional support to the tray system can be accepted by test. The overall eccentricity of the system should be considered. The tested "J" sample was subjected to overall eccentricity (Figures 3 and 4). Geometries with greater eccentricity (due primarily to larger unbraced lengths) must be considered.

5.4 Evaluation by Combination Test and Analysis

It has been demonstrated by the dynamic system tests (Reference 10) and the capacity and fatigue connection tests (References 10 and 12) that the critical elements for support and system integrity are the primary overhead connections.

Correspondingly, the analyses of test compatible supports will be directed towards the investigation of the above key parameters. Supports qualified by test/analysis will require the primary load paths to be verified for integrity. This will be demonstrated by the following:

Primary Connections - These connections must be demonstrated to adequately carry the vertical load during and after the seismic event. Primary connections subject to joint rotations due to seismic loads must be evaluated to verify the connection's ability to carry the primary loads per Section 5.4.1.

Brace Connections - These connections must be demonstrated to maintain integrity during and after the seismic event. These connections must be evaluated per Section 5.4.2.

Displacements - Support displacements may require limitation due to their immediate proximity to other plant hardware. The local proximity must be evaluated for available clearances. In these situations the support displacement must be limited by existing hardware, or the support will be modified to strengthen its lateral support and/or longitudinal restraint.

5.4.1 Primary Connections

A sample trapeze type support is pictured in Figure 7. Support flexibility is controlled by the rotational stiffness of the primary connections and the translational stiffness of the brace hardware. These key features are then modeled in any support mathematical evaluation. A typical test moment-rotation diagram for a primary connection is provided in Figure 8. Mathematically, this behavior can best be represented by bilinear elastic-plastic behavior. The connection, although possessing some initial stiffness, will essentially rotate at a constant moment at higher loading conditions. To ensure structural integrity, primary connection rotation will be limited to its ultimate value derived by connection testing and divided by a factor of ___ (to be established after completion of testing). Conversely,

the connection may be conservatively modeled as a simple pin and the joint rotation must meet the acceptance criteria.

Primary connections must be evaluated against the allowance derived per Reference 11 in the load carrying direction. Connection tests (still in progress) will be utilized to develop these interaction curves.

5.4.2 Brace Connections

Brace connections must also maintain their integrity. They differ from the overhead primary connections, however, as they may or may not function as primary connections. Their role as a primary connection is dependent upon their application.

Brace connections will be considered a primary connection if they are utilized in the following applications: (1) Serves as a wall support - the connections must carry vertical and horizontal loads (refer to Figure 2(b)); (2) serves to limit the rotation of primary overhead connections to within acceptable limits; and (3) serves to limit support displacements to prevent impact on other plant hardware. For these applications, the brace connection will be limited to its allowable load.

Brace connections which are not considered primary connections do not need to offer resistance. Integrity of the brace will be maintained if the brace is limited to 70 percent of its ultimate displacement derived by test. A typical load deflection curve for brace connection is presented in Figure 9.

5.4.3 Modeling Methodology/Evaluation

Analytical modeling will utilize classical structural modeling techniques, similar to those in Reference 11, with a few notable exceptions.

Connection stiffness, based on test program data, can be inserted into the mathematical models in the form of translational and rotational springs. The dynamic system tests demonstrated the importance of the connections in

determining system dynamic properties (frequencies, mode shapes, etc.) and system fragilities. The actual spring rates to be modeled will be based on the connection test data performed at ANCO (Reference 10) and the data summarized in Reference 12.

The evaluation of these key connections is summarized in Sections 5 4.1 and 5.4.2. Modeling/analysis will essentially fall into one of two categories - system analysis and supplemental analysis.

A system analysis consists of the creation of a complete analytical model for a single cable tray support or a group of supports and cable tray. The model must be large enough to reflect the load transfer of the support system. The response levels extracted from the system analysis are then used to evaluate the primary stresses required by this criteria.

Supplemental analysis can be performed without a system analysis or finite element model development. Supplemental analysis is used to evaluate minor deviation between in situ and tested support systems. Typically, this would encompass evaluation of a unique connection, etc.

System analysis, in general, requires the use of either static or dynamic analysis techniques. These procedures are described in Sections 5.4.3.1 and 5.4.3.2.

5.4.3.1 Static System Analysis

A static system analysis can be performed to qualify a cable tray support system meeting the general requirements of Section 5.1. If the static approach is used, the analysis must conform with the requirements of Reference 11 with the following exceptions:

a. Modeling (and analysis) is not limited to the use of the STARDYNE computer code. Other verified finite element computer codes may be utilized.

b. Damping values utilized must be consistent with Section 5.5 of this criteria.

c. Consistent with Section 5.5 of this criteria, all analysis will be performed using the SSE condition seismic loads.

d. The evaluation requires an assessment of the primary connections as established in Section 5.1.

5.4.3.2 <u>Dynamic Analysis Method</u>

The dynamic analysis can be performed using a modified approach to the step by step procedure outlined in Section 6.2.2 of Reference 11. The initial six steps in Section 6.2.2 relate to specifics of the STARDYNE approach and, therefore, would be modified to utilize any alternate computer program. Step 7 would utilize Steps 11 through 19 of the static load approach. Rather than tie the dynamic analysis approach specifically to a computer code, the following guidelines are provided to develop the analytical model. Acceptable alternates may be utilized provided that adequate justification is presented.

a. Model size - The model must be sufficient in size to accurately account for system load transfer.

b. Cable tray ends (at the midspan between supports) are assumed to be free in translation and fixed in rotation to simulate system continuity, when applicable.

c. Significant mass which has been distributed by the computer code to nodes which have not been assigned dynamic degrees of freedom is lumped from such nodes to the nearest node which has been assigned a dynamic degree of freedom.

d. The support system must be evaluated to support the mass of the cable, cable tray, support members, miscellaneous hardware, and attachments (wireway, etc.). A contingency for future cable additions is normally included.

e. Modal combinations (using the response spectra techniques) should be by the SRSS technique; however, all modes within 10 percent of each other will be combined by absolute sum, in accordance with Regulatory Guide 1.92. Unless justified, a minimum of 85 percent of the model mass must be retrieved in all three directions at frequencies up to 33 Hz. If this mass retrieved in any direction is less than 85 percent, then the effect of the balance of the mass (i.e., the "rigid" mass) can be added as a static inertial load by using the floor ZPA. Cutoff frequencies less than 33 Hz may be utilized, when appropriate.

f. Directional combinations (of the two horizontal and one vertical direction response) should utilize the SRSS technique for response spectra solutions.

g. Time history analysis should be in accordance with the guidelines of Regulatory Guide 1.92.

h. Items 4.3.1(i) through 4.3.1(iv) apply to all dynamic analyses as well as the static analyses.

5.5 Required Review Data

5.5.1 Loads

Loads should include weights of the following, whichever is applicable.

a. Cable

b. Cable Tray and Tray Covers

c. Support Members

The load for any support should be derived for all tray levels in a consistent fashion. That is, the maximum loads in Reference 11 can be used unless the loads are selected to more closely bound the in situ conditions.

However, the system under evaluation must utilize either entirely full design loads or in situ loads, exclusively.

5.5.2 Damping

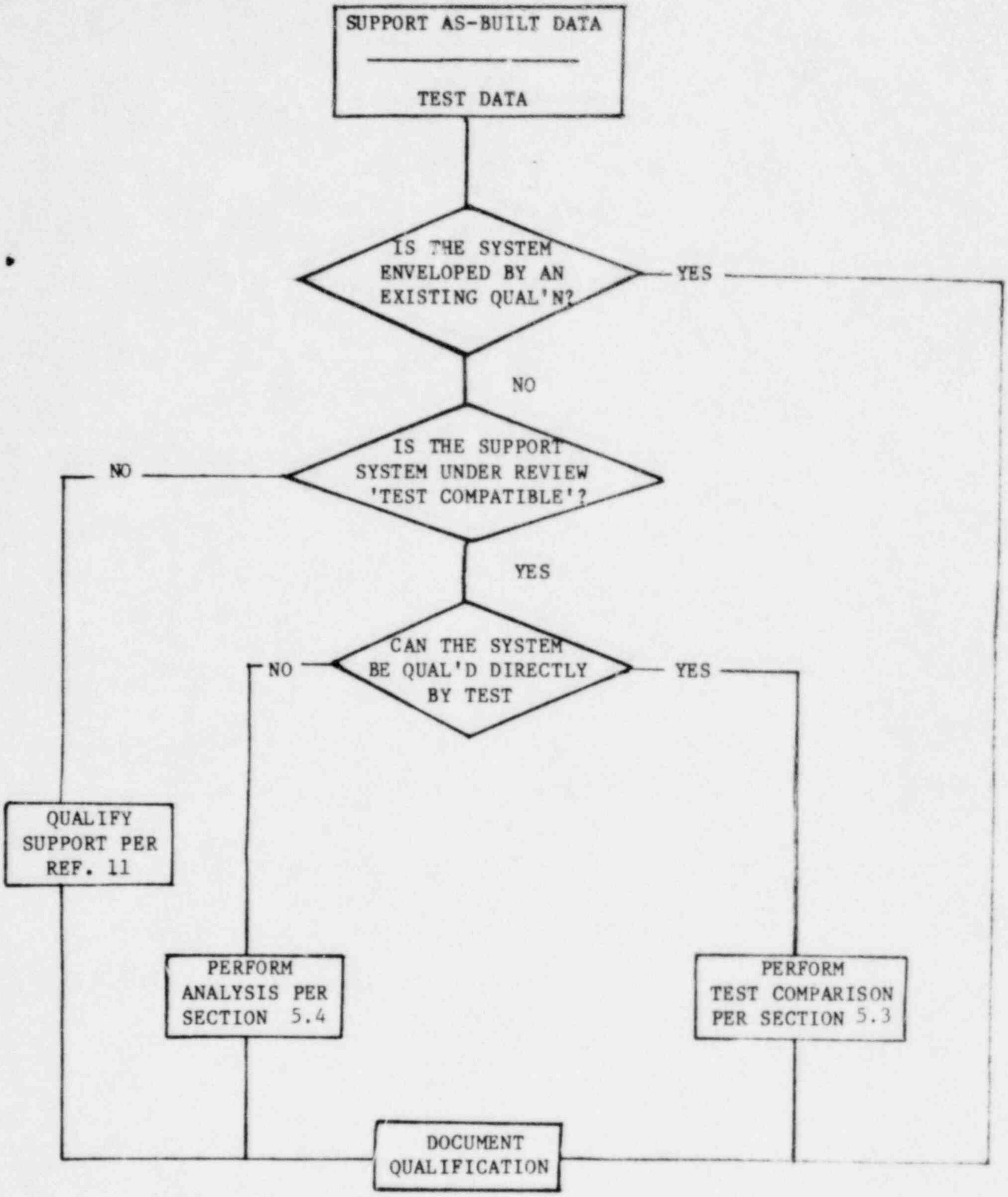
Damping valves will be in compliance with Figure 10.

As shown in Figure 10, the design damping for Seabrook cable tray supports is dependent upon:

a. Cable Load

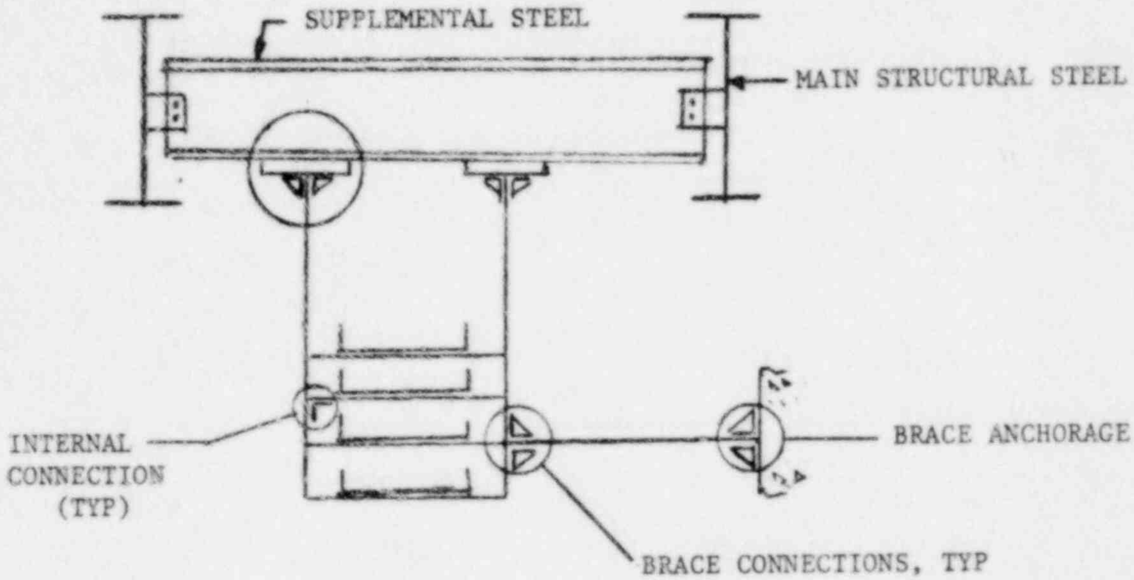
b. Input Floor Response Spectrum ZPA

For trays loaded with between 25 lb/ft and 35 lb/ft of cable load (i.e., total cable plus tray load of between 30 lb/ft and 40 lb/ft), the appropriate damping values range from 7 percent and 20 percent, depending upon the input floor response spectrum ZPA. For trays without cables, damping values consistent with USNRC Regulatory Guide 1.61 are applicable. For cable loading less than 25 lb/ft, linear interpolation is used to determine the applicable damping value.



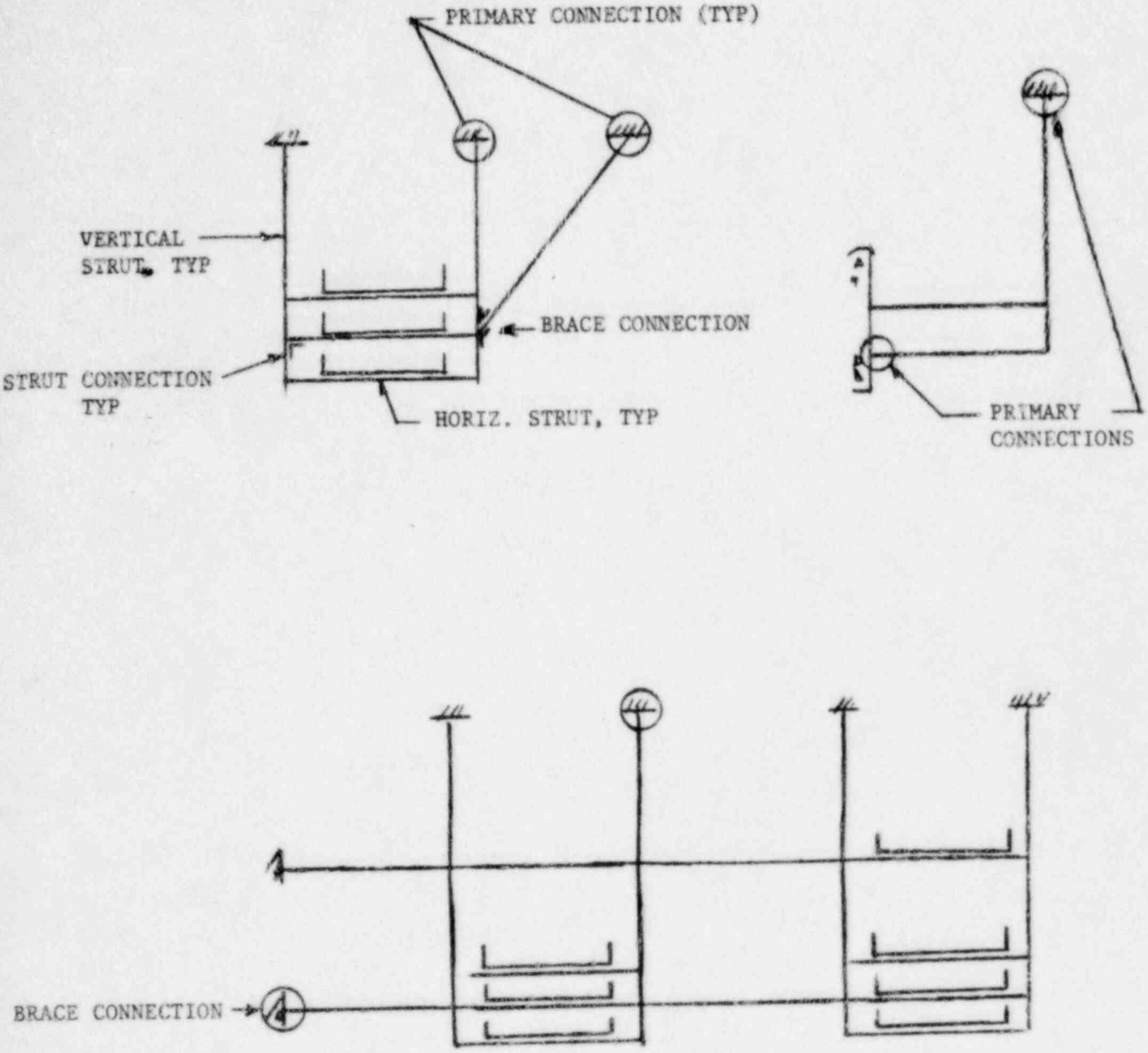
SYSTEM QUALIFICATION FLOWCHART

FIGURE 1



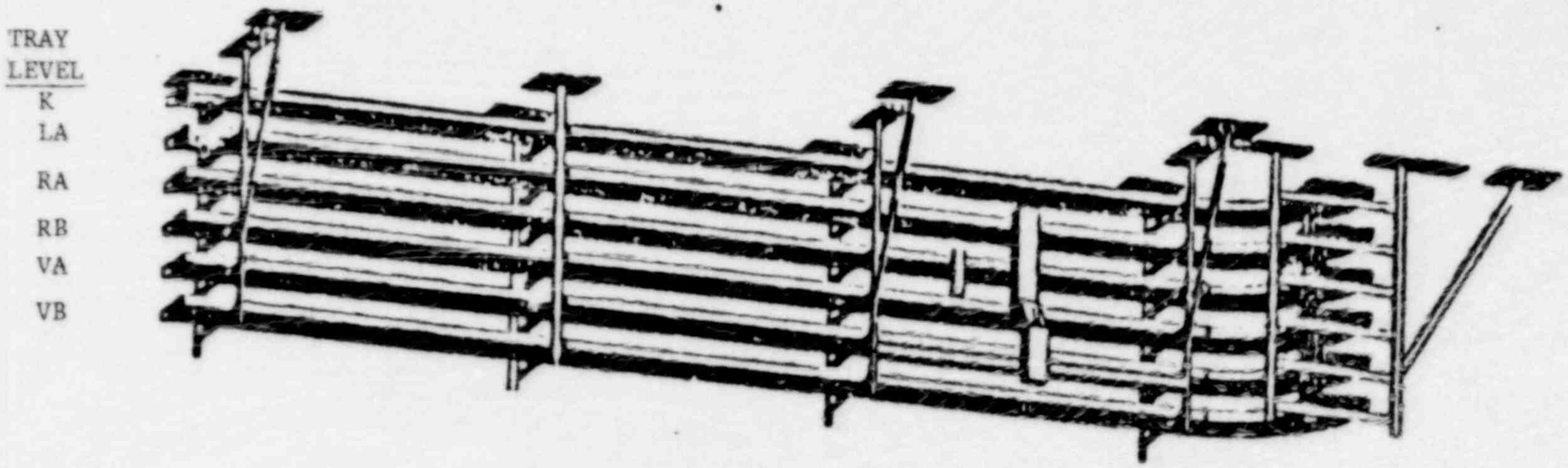
TYPICAL CABLE TRAY SUPPORT

FIGURE 2 (a)



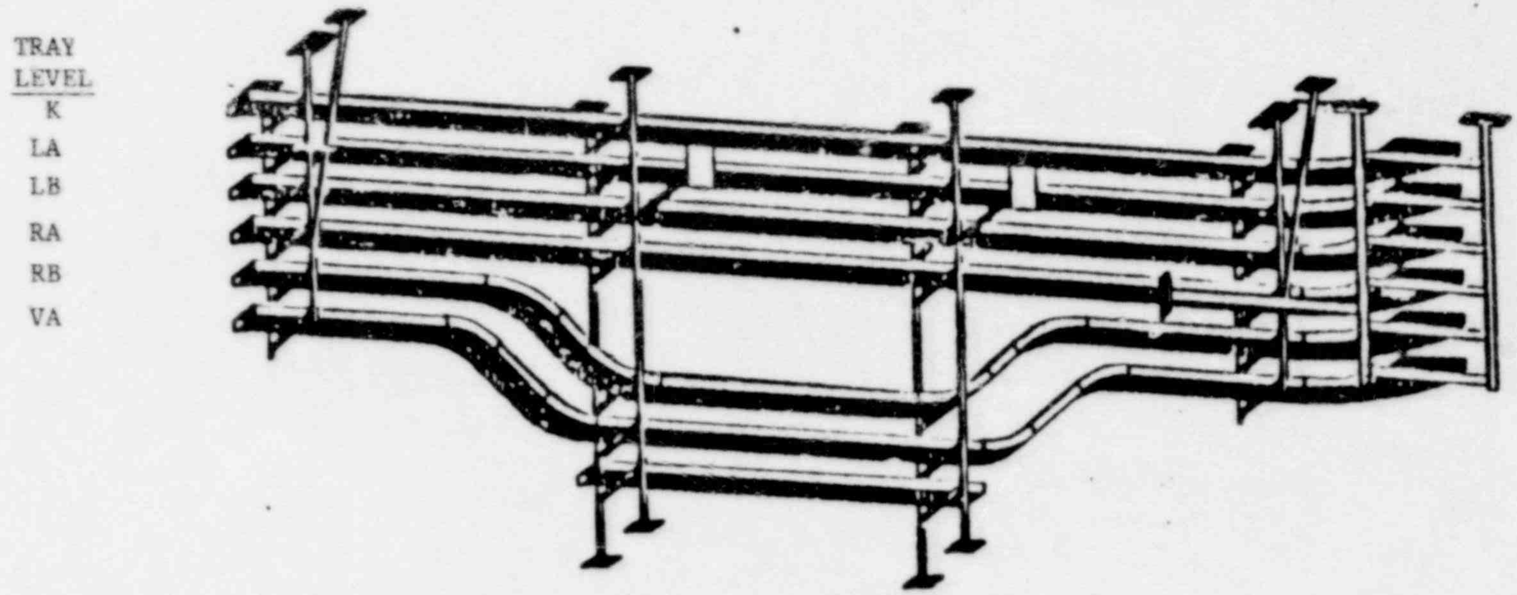
TYPICAL CABLE TRAY SUPPORT CONFIGURATIONS

FIGURE 2 (b)



CASE A

FIGURE 3

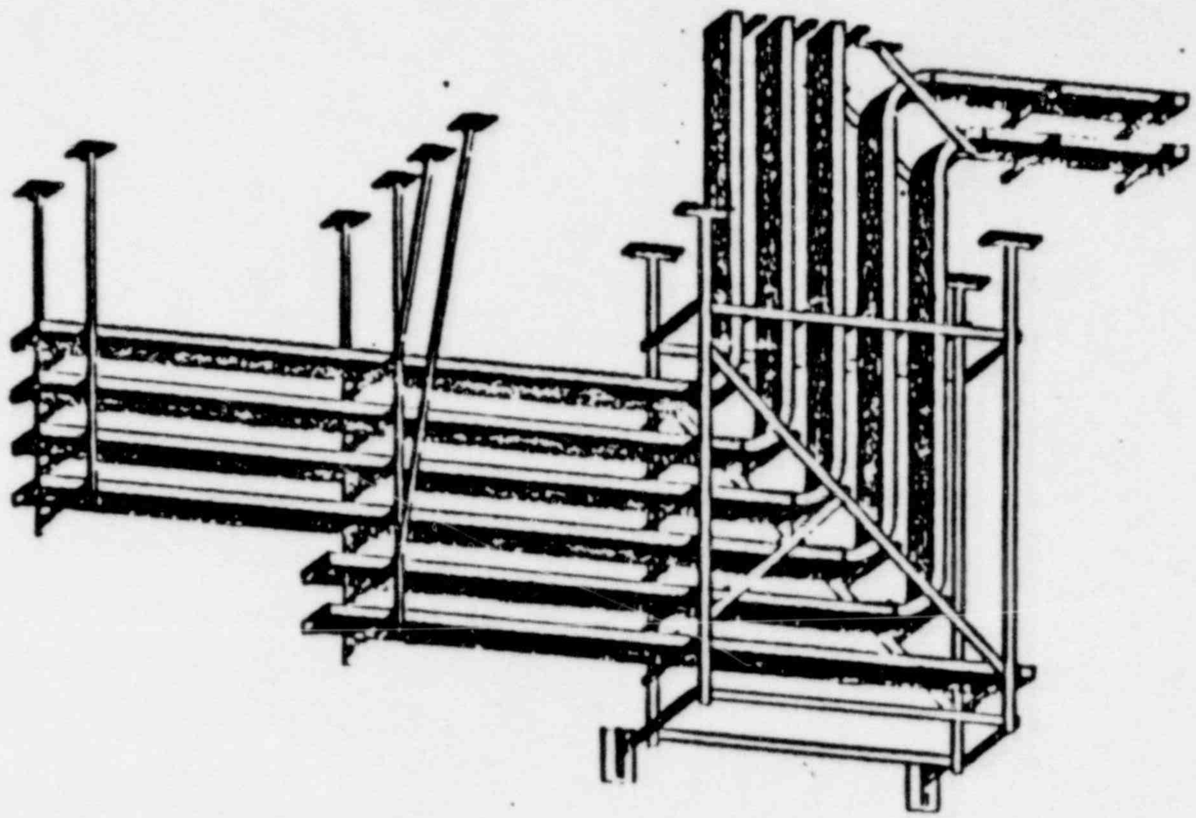


CASE B

FIGURE 4

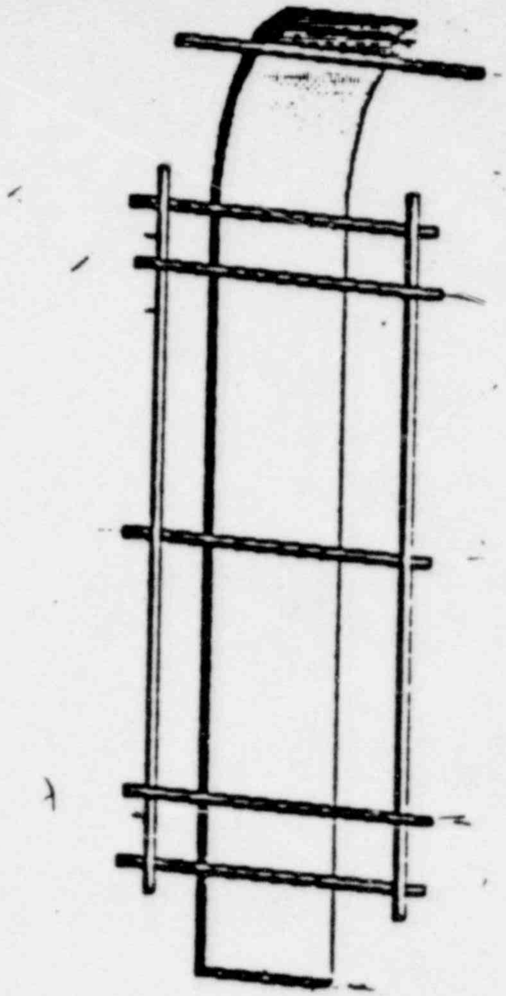
TRAY
LEVEL

LA
LB
RA
RB
VA
VB



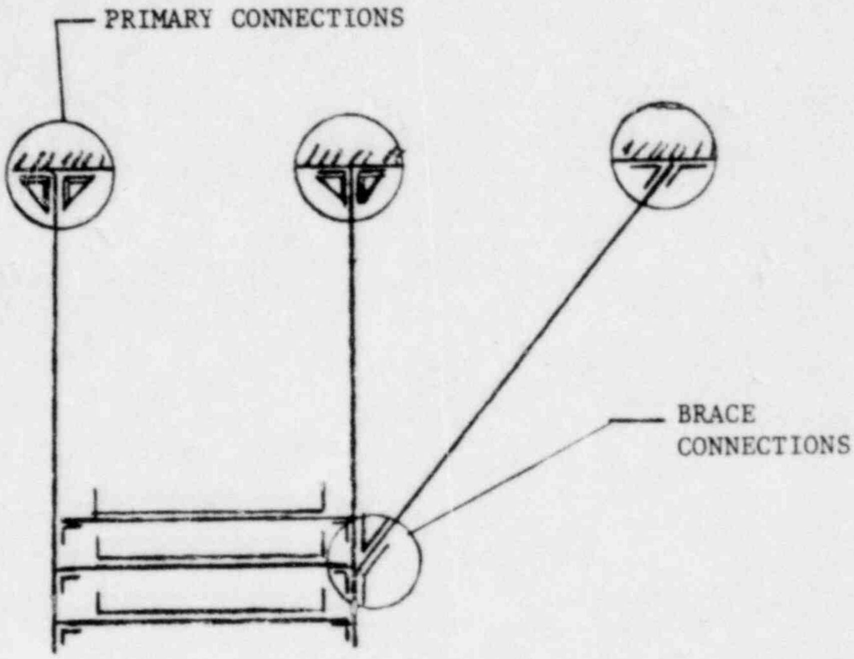
CASE C

FIGURE 5



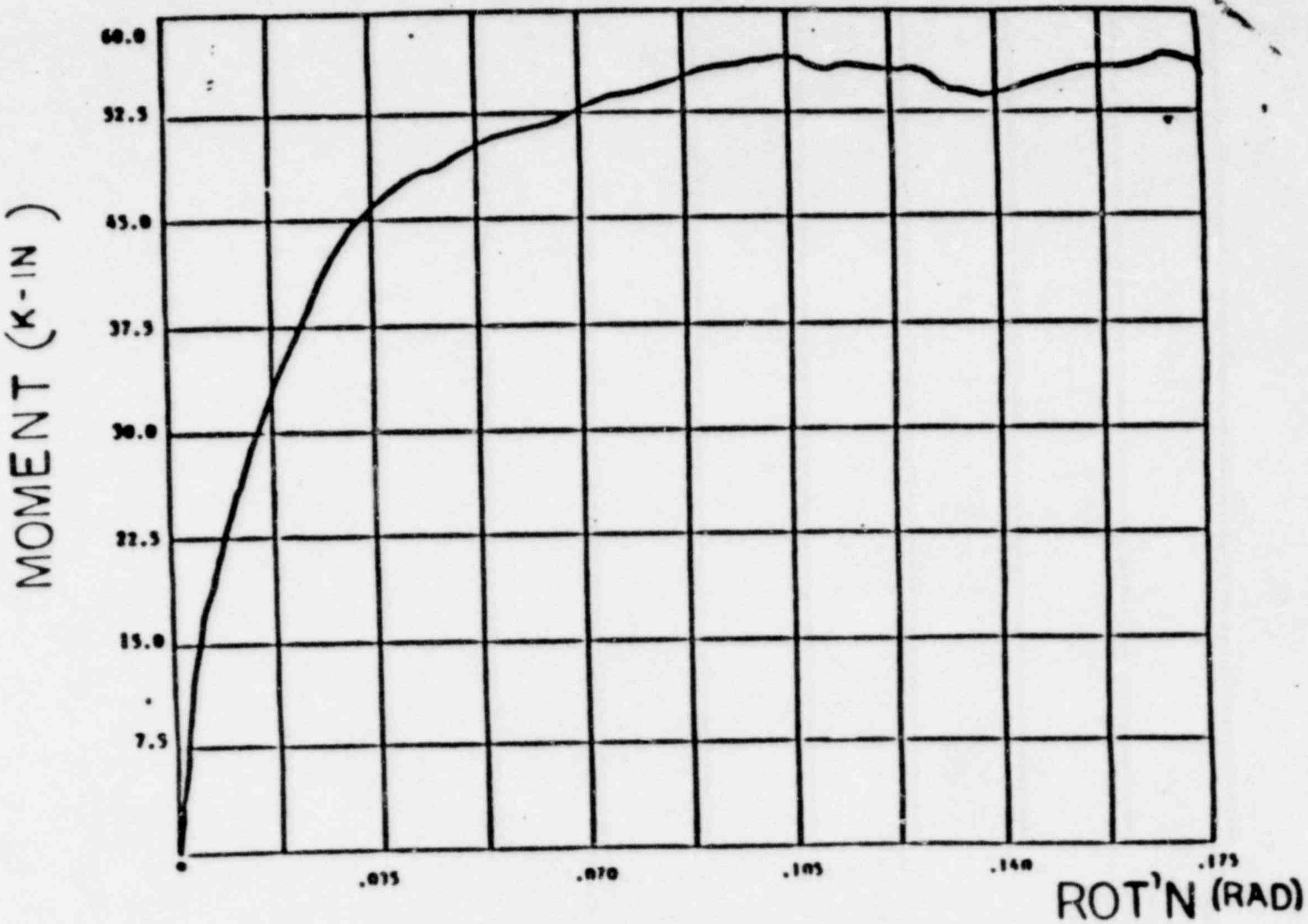
CASE C′

FIGURE 6



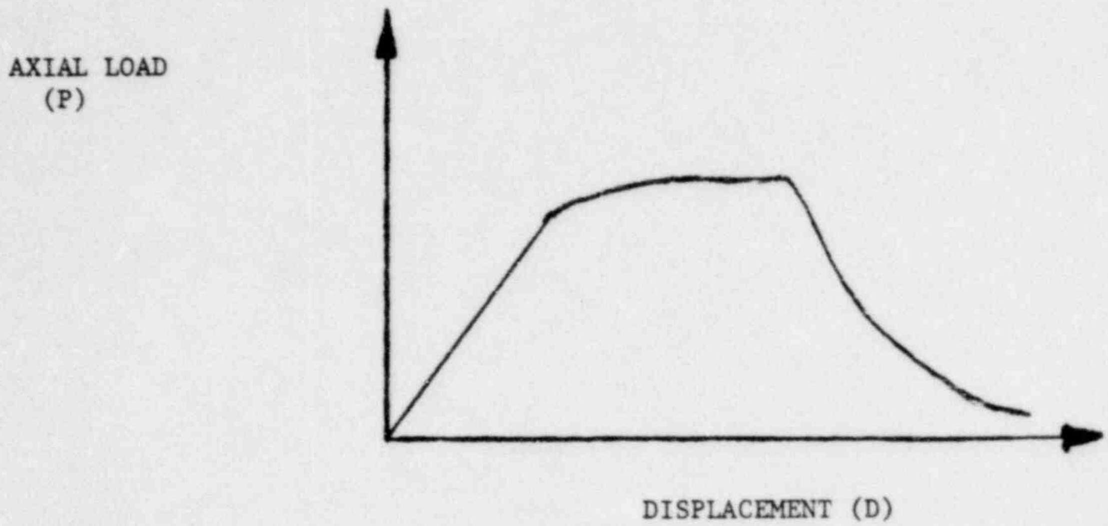
TYPICAL CABLE TRAY SUPPORT

FIGURE 7



TYPICAL M vs Θ
33DU

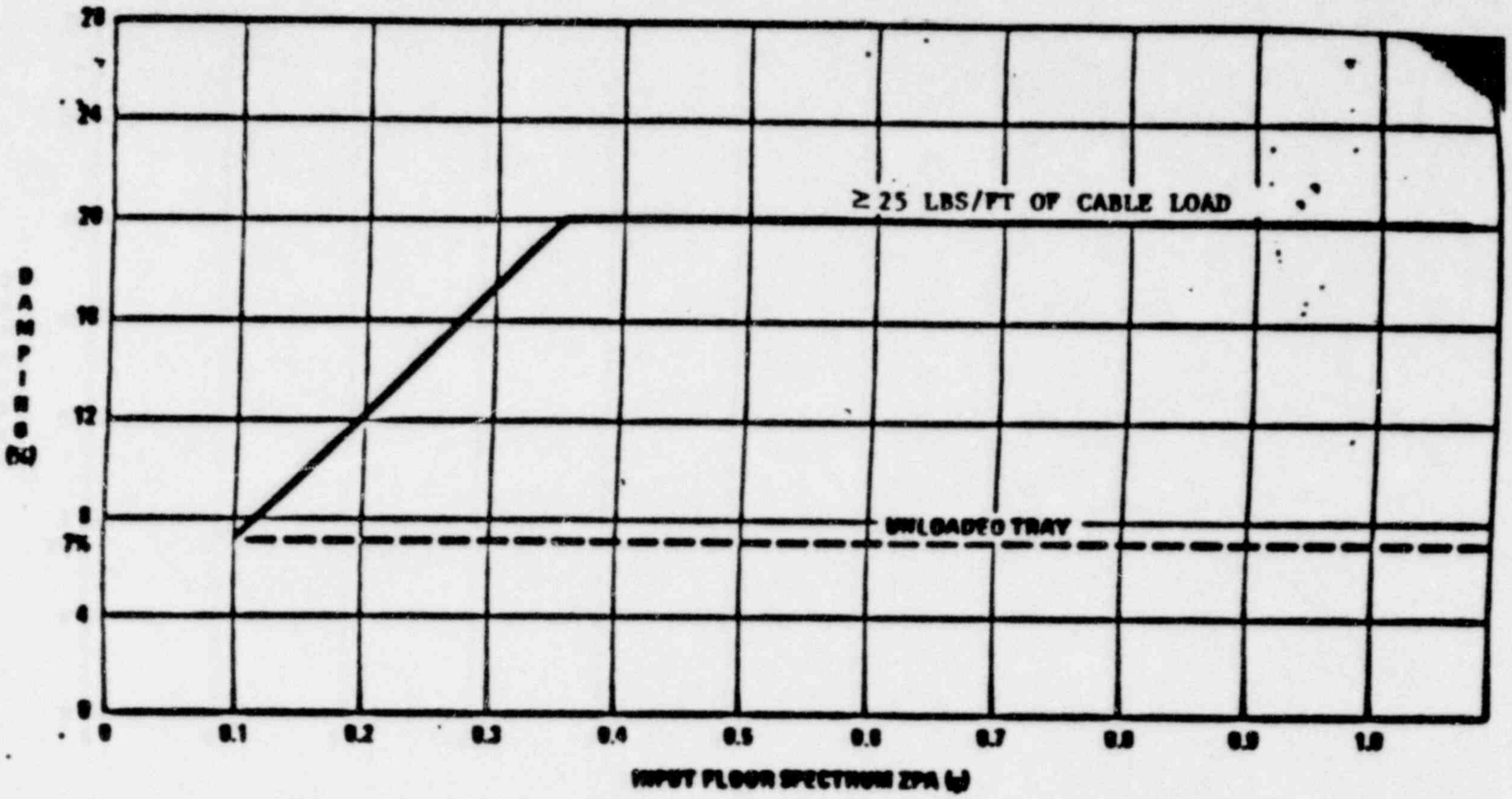
FIGURE 8



TYPICAL LOAD DEFLECTION CURVE FOR

BRACE CONNECTION

FIGURE 9



Lower Bound Damping as a Function of Input ZPA

Note: For tray loaded less than 25#/ft (cable), linear interpolation is used to determine the associated design damping value.

FIGURE 10

6.0 SEABROOK CABLE TRAY SUPPORT EVALUATION PROCEDURE

This procedure summarizes the acceptance criteria for cable tray supports at Seabrook. A number of full scale tests of cable trays and supports were conducted. These tests demonstrated the outstanding integrity of the existing cable tray and support configuration and provide the basis for the criteria. The detailed test procedure and results are provided in Reference 10. The following criteria is to be utilized in the categorization, evaluation and acceptance of cable tray supports and is based on the Evaluation Criteria defined in Section 5.0 of this report.

6.1 APPLICATION

In the process of categorizing, evaluating and accepting cable tray supports the use of check lists is required. Rather than allow the user to interpret the Evaluation Criteria on an item by item basis, this document provides the detailed acceptance criteria and presents the background and technical justification for each step in the process. For each support the check list will require reference to the appropriate sections of this report which are used in the categorization, evaluation and acceptance process. See Figure 6.5 for a sample check list.

6.2 Categorization

In order to determine the type of evaluation to be performed on a specific support the check list user must first determine the categorization status of that support. Two categories are provided as follows:

6.2.1 **Test Configuration**

Figure 6.1 provides support geometry details that are qualified by the dynamic tests. In addition to assuring that the support under consideration complies with one of the details in Figure 6.1, the evaluator must assure that the cable tray section containing the support satisfies the displacement criteria of Section 6.4.

The support under consideration is acceptable if the dimensions and loads are equal to or less than those provided by Figure 6.1 and the cable tray geometry complies with Figures 6.2(a), 6.2(b), 6.2(c) and 6.2(f).

6.2.2 **Analyzed Configuration**

It is anticipated that individual supports may exist which are not covered by the Test Configuration (6.2.1). For such cases an evaluation in accordance with Section 5.4 is required.

In order to reduce the number of individual support calculations required a number of generic analyses have been performed. These analyses include consideration of the cable tray system as well as an evaluation of individual supports.

The support under consideration is acceptable if the dimensions and loads are equal to or less than those provided by Figure 6.3, if the support exists in a cable tray geometry in compliance with Figure 6.2 and the support is typical of an analyzed model, e.g. Figure 6-2(d) or Figure 6.2(e).

6.3 ACCEPTANCE CRITERIA

In the process of categorizing supports, the evaluator automatically adopts an acceptance criteria when the specific support falls into the Test Configuration (6.2.1) or the Analytical Configuration (6.2.2). In order to provide technical background and justification for that acceptance the following discussion of each category is provided.

6.3.1 Test Configuration

Supports which fall into the Test Configuration category are acceptable because they are represented by the supports subjected to dynamic testing which satisfied the following limits (Reference 10).

6.3.1.1 Loading

The section of 24" wide cable tray, including support, which was tested had the following loading:

Tray Fill	40% (25-50 lbs/ft)
No. of Trays	6
Max. Support Spacing	10 feet
TRS Peak (SSE)	
max	7.8G
@ 10Hz	5.5G
Fatigue	5 OBE + 1 SSE
Max TRS Peak	9.3G to 11.7G

6.3.1.2 Resultant Stresses

The maximum peak strains measured in the support members results in the following stresses for the case with braces present.

TRS Peak (SSE)	2.7 KSI
Max TRS Peak	3.9 KSI

The tests were rerun with all bracing removed and the TRS (SSE) was applied. The maximum member stress was 3.6 KSI.

6.3.1.3 Cable Tray Displacements

The displacements of the cable trays during testing is as follows:

Case A (SSE)		
Braced		
Longitudinal	4.29 Inches	
Lateral	3.81 Inches	
Unbraced		
Longitudinal	5.12 Inches	1.2 SSE
Lateral	5.12 Inches	1.2 SSE
Case B (SSE)		
Braced		
Longitudinal	1.19 Inches	
Lateral	3.85 Inches	
Unbraced		
Longitudinal	1.96 Inches	
Lateral	4.63 Inches	

Unbraced Trapeze (Floor Connections Removed)

Longitudinal	3.35 Inches
Lateral	5.62 Inches

Case C (SSE)

Braced

Longitudinal	0.79 Inches
Lateral	1.30 Inches

Unbraced

Longitudinal	1.46 Inches
Lateral	2.82 Inches

6.3.1.4 Summary

The loadings applied to actual cable tray supports which are represented by the Test Configuration are less than those applied in the test since the actual fill is equal to or less than 40% for all trays, the support spacing is normally less than 10 feet and the maximum peak acceleration from any amplified floor response spectrum that is applicable to cable trays is 6. Using a static equivalence approach the load per support can be determined as follows:

Test

F = 10 ft. (40 lbs/ft) 7.8G = 3120 lbs.

As-built (typical)

F = 8 ft. (20 lbs/ft) 6.0G = 960 lbs.

Generally, then, the as-built support is approximately 36% that of the test support load.

Based on the above, any support satisfying the requirements of Section 6.2.1 will have lower loads and stresses than the tested support and is acceptable.

6.3.2 Analysis Configuration

Supports which fall into the Analysis Configuration category are acceptable because they are represented by an analysis of a cable tray and support geometry that is similar in load and acceptance criteria. A set of generic analyses have been performed. These analyses represent cable tray routing and support geometries exemplified in Figures 6.2(d), 6.2(e), 6.2(g), 6.2(h) and 6.2(i). The analyses considered actual cable tray loading, envelope amplified floor response spectra, appropriate damping and connection stiffness. The resulting displacements (including connection rotations) and primary member stresses satisfied the requirements of Section 5.0. Displacements were evaluated with respect to cable terminations and adjacent components or structures.

It is anticipated that a significant number of supports at Seabrook will fall into this category since general support geometries are quite similar. Major differences are related to cable tray routing, number of trays, cable fill per tray and allowable displacement.

6.3.3 CONNECTION DETAILS

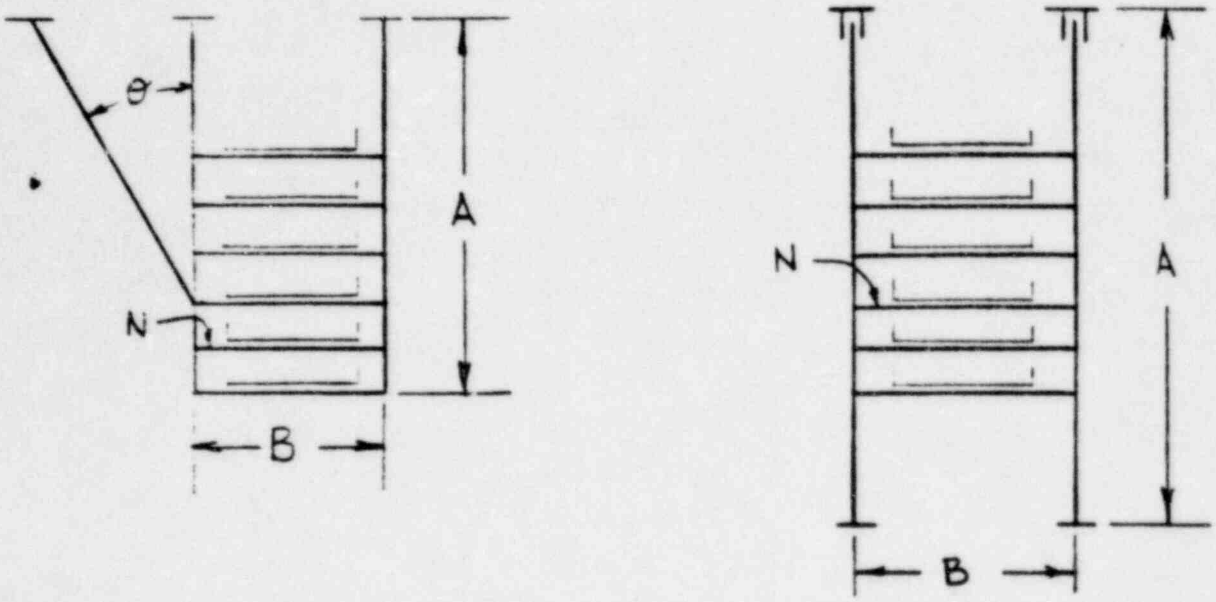
An integral part of the acceptance of a support is the connection details. Primary connections, which are those connecting the support to building structure, and Secondary connections, which are those connecting members of the support together, have been qualified by testing. However, the evaluator of the support must determine that the connections are acceptable. This is accomplished by assuring that all connections are in compliance with Figure 6.4 which indicates acceptable details along with allowable loads. The allowable loads on the connections have been determined from testing and include load cycling effects. It is important to recognize that cycling effects are not a requirement for design of cable tray supports, however, the allowable loads of Figure 6.4 include this effect. The cyclic effect is included since Seabrook test indicated degradation of 33EY, EC, EA and ED brace connections which results in higher loads on primary members and tray displacements larger than those which would be determined assuming full capacity of those connections.

6.4 DISPLACEMENT CRITERIA

6.4.1 Analysis Configuration

Supports which fall into the Analysis Configuration category are acceptable because they are represented by an analysis of a cable tray and support geometry that is similar in load and acceptance criteria. A set of generic analyses have been performed. These analyses represent cable tray routing and support geometries shown in Figure 6.2(d),

6.2(e), 6.2(g), 6.2(h) and 6.2(i). The analyses considers actual cable tray loading, envelope amplified floor response spectra, appropriate damping and connection stiffness. The resulting displacements (including connection rotations) and primary member stresses satisfied the requirements of Section 5.0. Displacements were evaluated with respect to cable terminations and adjacent components or structures.



Figure[2]	A	B	N[3]	Q[1]	DEAD LOAD
1a					
1b					

NOTES:

1. A brace is not required for acceptance.
2. Displacement criteria of section must be satisfied.
3. N - number of trays.

FIGURE 6.1

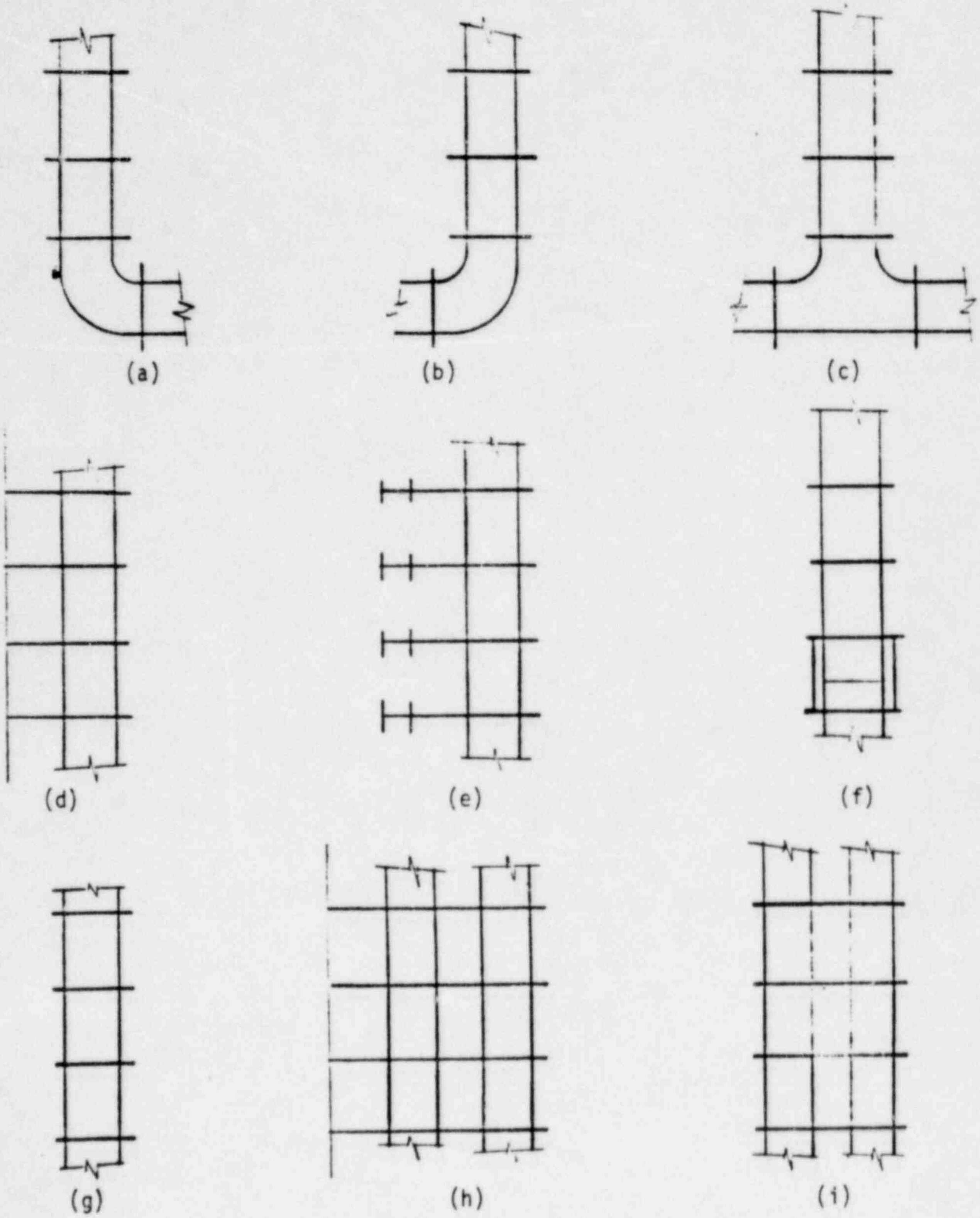


FIGURE 6.2

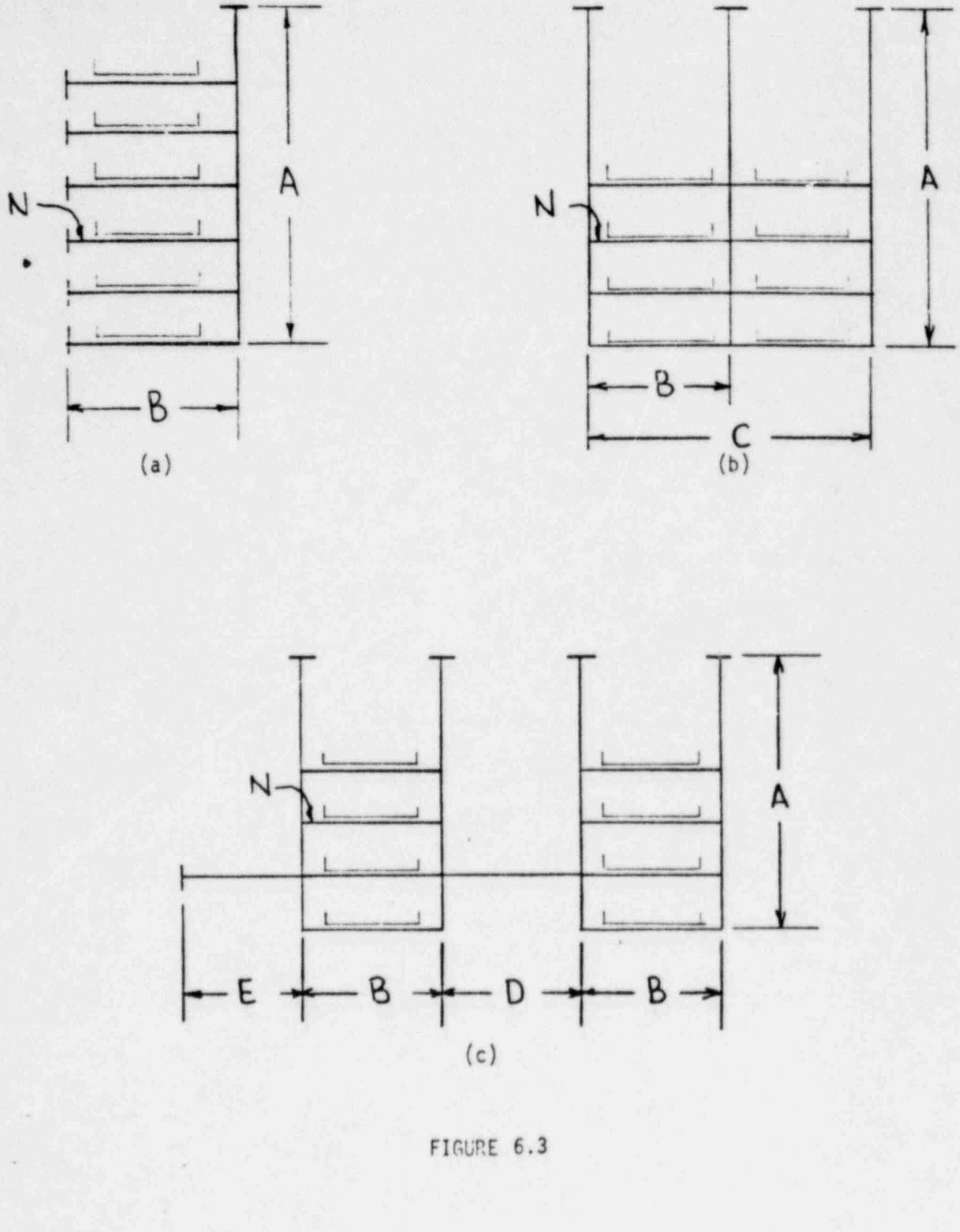


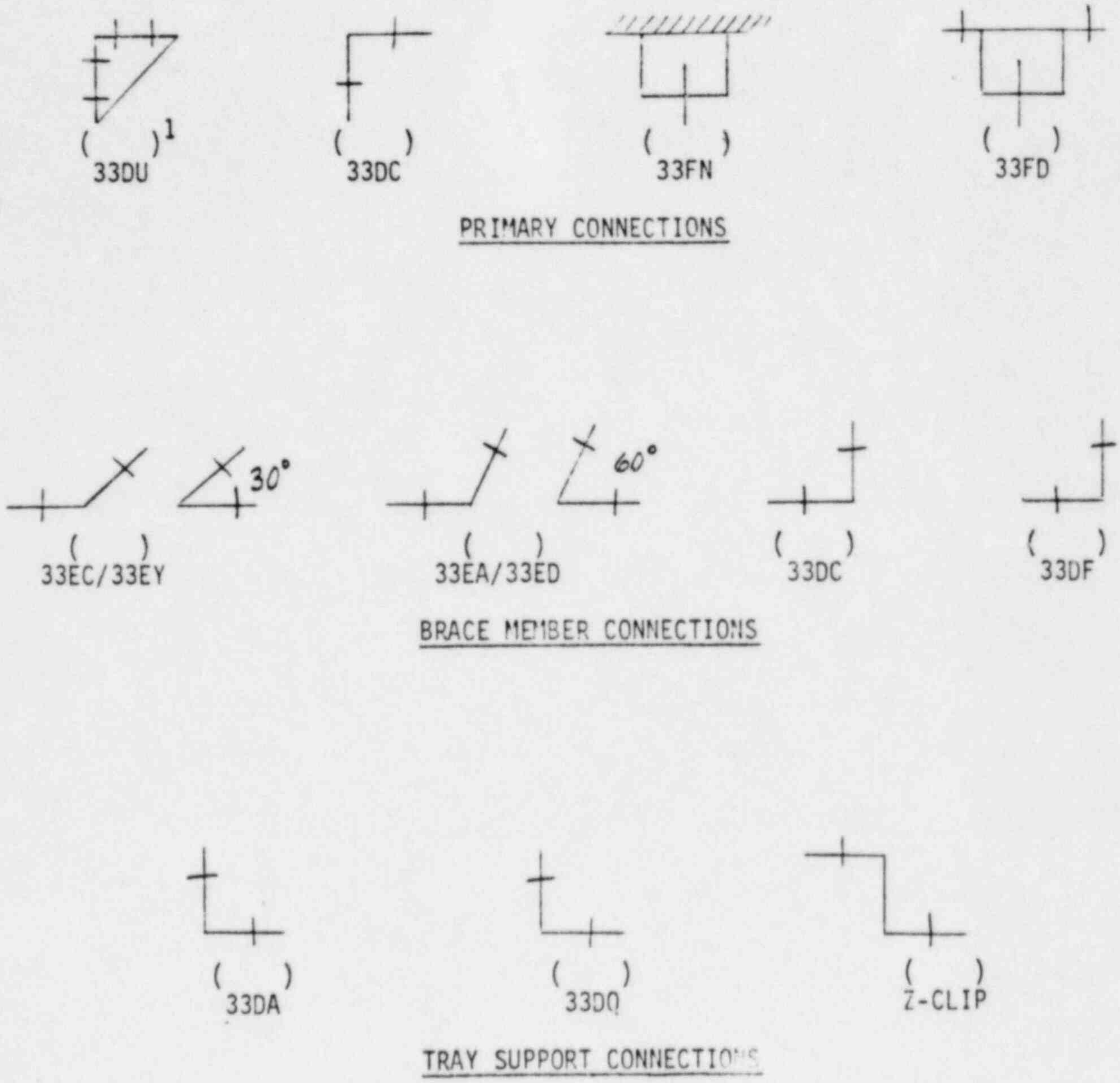
FIGURE 6.3

FIGURE 6.3
(continued)

Figure	A	B	C	D	E	N[3]	θ[1]	DEAD LOAD
3a			NA[2]	NA	NA			
3b			NA	NA	NA			
3c			NA	NA	NA		NA	
3d							NA	
3e							NA	

NOTES:

1. A brace is not required for acceptance of Figures 6.3(a) and 6.3(b).
2. NA = Not applicable.
3. N = Number of trays.



NOTE:
1. (   ) Allowable connection load.

FIGURE 6.4

SEABROOK CABLE TRAY SUPPORT QUALIFICATION

CHECK SHEET

Support I. D. Number: ______________________________

SUPPORT CONFIGURATION PARAMETERS (fill-in)

a. Support height, A = ____

b. Support width, B = ____

c. Support brace angle, O = ____

d. Number of trays, N = ____

e. $\frac{Kl}{r}$ (max) = ____

	Qualified By Section
I. SUPPORT CATEGORIZATION (check one)	
1. Test Configuration ____	________
2. Analyzed Configuration ____	________
3. Analysis Required Configuration ____	________
II. SUPPORT LOADING PARAMETERS (fill-in)	
a. Number of trays: ____	________
b. Max. width f trays: ____ in.	________
c. Max. % tray fill volume: ____ %	________
d. Ave. support spacing to adjacent supports: ____ ft.	________
e. Peak floor response spectra acceleration: Horiz. ____ G's	________
Vert. ____ G's	________
III. SUPPORT BRACING PARAMETERS (check one)	
a. Lateral bracing None: ___ Horiz: ___ Diagonal: ___	________
b. Longitudinal bracing None: ___ Horiz: ___ Diagonal: ___	________
IV. SUPPORT CONNECTION PARAMETERS (identify)	
a. Primary connectiors ________	________
________	________
b. Brace member connections ________	________
________	________
c. Tray support connections ________	________
________	________
V. SUPPORT DISPLACEMENT PARAMETERS (identify)	
a. Distance to cable termination point: ____ in.	________
b. Distance to adjacent components: ____ in.	________

BY: ______________ DATE: ________

CHK'D BY: ______________ DATE: ________

FIGURE 6.5

7.0 REFERENCES

1. Letter from J. DeVincentis (PSNH) to G. W. Knighton (NRC), "Cable Raceway System Damping," dated June 3, 1985.

2. "Test Plan - Performance Testing of a Typical Cable Tray Configuration: Seabrook Station - Test Cases A & B," ANCO Engineers, Inc., Document A-000146, Prepared for Bechtel Power Corp., August 1985, Revision 1.

3. "Test Plan - Performance Testing of a Typical Cable Tray Configuration, Seabrook Station - Test Case C," ANCO Engineers, Inc., Document A-000151, Prepared for Bechtel Power Corp., September 1985, Revision 0.

4. "Test Plan - Performance Testing of Typical Cable Tray Support Connections - Seabrook Station," ANCO Engineers, Inc., Document A-000147, Prepared for Bechtel Power Corp., September 1985, Revision 0.

5. "Summary Report - Cable Tray Support Damping at Seabrook Station," Bechtel Power Corp., June 1985.

6. "Cable Tray and Conduit Raceway Seismic Test Program - Release 4 (Final)," Test Report No. 1053-21.1-4, Volumes 1 and 2, December 15, 1978, Volume 3, May 1980; Volume 4, March 1981, ANCO Engineers, Inc.

7. Meeting Summary, Prepared by V. Nerses, USNRC, Applicant - PSNH, Facility - Seabrook Station, Units 1 and 2, dated June 25, 1985.

8. Safety Evaluation Report, NUREG-0881, Docket STN 50-482, USNRC, PP. 3-11, dated December 1981.

9. Safety Evaluation Report, NUREG-0831, Supplement No. 1, Docket Nos. 50-416 and 50.417, USNRC, Section 3.7.3, December 1981.

10. "Performance Testing of Typical Cable Tray Configurations and Strength Testing of Selected Connection Details, Seabrook Station Test Cases A, B, C," Test Report No. 1053.43B, Document No. A-000161, ANCO Engineers, Inc.

11. "Technical Guide for the Design and Analysis of Seismic Category I Cable Tray Support Systems," PSNH, Seabrook Station, Revision 2, March 6, 1984, PIN No. 9763-SQ-00121, 82025.

12. "Strut Nut Connection Test Report - Phase II, PSNH Seabrook Station, Units 1 and 2," Report No. 9763-SQ-00121-3Z014, June 9, 1983.

APPENDIX A

4.D A COMPARISON OF CABLE TRAYS AT THE SEABROOK NUCLEAR STATION WITH THE SEISMIC EXPERIENCE DATA BASE

The seismic capacity of cable tray systems at Seabrook Station is assessed through a study of comparable cable tray systems that have experienced strong motion earthquakes. The excellent performance of cable tray systems that have experienced seismic motion in excess of the Seabrook design-basis safe shutdown earthquake (SSE) provided the basis for this study.

The experience of cable tray systems in past earthquakes is extracted from the data base of earthquake effects to power and industrial facilities, compiled by EQE Inc., under the sponsorship of the Seismic Qualification Utilities Group (SQUG). This experience data base, encompassing approximately 20 facilities and a total of eight major earthquakes, includes a diversity of cable tray systems. The total data base inventory includes on the order of 10 miles of cable trays which experienced strong motion earthquakes. This inventory of data base cable trays covers a wide range of structural types, support configurations, cable tray system layout, locations within buildings, and seismic input loads. Most of the sites surveyed in compiling the data base experienced ground motion comparable to or in excess of the Seabrook Station safe shutdown earthquake. Within the experience data base there is only one instance of seismic damage to a cable tray structure. This single instance of seismic damage was to an exceptionally weak, atypical cable tray support structure subjected to high seismic load.

Normal industry practice in the construction of cable tray systems does not include a specific design for seismic loads. Cable tray support structures (outside of nuclear plants) are normally designed to accommodate gravity load only. In spite of this fact, the performance record of cable trays in past earthquakes is excellent. Cable tray systems display a large margin for the absorption of seismic loads without damage. This inherent seismic margin in cable trays does not appear to be sensitive to variations in cable tray construction, layout, or seismic input.

The purpose of this comparison of cable tray systems in Seabrook Station with cable trays in the seismic experience data base is to illustrate the following points:

- The seismic experience data base includes all parameters associated with the ability of cable trays to resist seismic loads.

- The parameters associated with the seismic capacity of data base cable trays envelop the parameters of Seabrook Station cable trays, i.e., data base cable trays range from similar to weaker when compared to Seabrook cable trays.

- In most cases data base cable trays have experienced seismic loads comparable to or in excess of the design basis seismic loads for Seabrook cable trays.

- Cable tray systems constructed according to normal industry practice, even without specific provisions for seismic loads, are sufficient to withstand earthquakes in excess of the seismic design basis for Seabrook Station.

- The diversity of critical parameters encompassed by the cable tray data base demonstrates that the capacity to survive earthquakes is not sensitive to minor variations in the details of cable tray construction or layout. For this reason cable trays are generically adequate to sustain moderate seismic loads (such as the design basis for Seabrook Station), as long as their construction conforms to or exceeds normal industry practice.

4.D-1 The Seismic Experience Data Base

Details of the performance of power and industrial facilities in past earthquakes have been compiled into a seismic experience data base by EQE. The primary sponsor for the compilation of this data base has been the Seismic Qualification Utilities Group (SQUG). The SQUG was organized in 1981 by a group of electric power utilities with operating

nuclear plants. The primary purpose for the organization of the SQUG was to develop a program to address Unresolved Safety Issue A-46, the potential seismic hazard to critical equipment in operating nuclear plants.

- The basis for the SQUG program was to determine the realistic seismic hazard to the equipment installations of nuclear power plants, based on the experience of facilities with comparable installations in past earthquakes. Very few components of critical nuclear plant systems are specific to nuclear facilities. Critical nuclear plant systems include electrical switchgear, control panels, motor-operated valves, pumps, piping, ducts, conduit, cable trays, etc., all common components of conventional power plants and large industrial facilities.

  Strong motion earthquakes frequently occur in California and Latin American Countries, where power plants or industrial facilities are included in the affected areas. By studying the performance of these earthquake-affected (or data base) facilities, a large inventory of various types of equipment can be compiled that have experienced substantial seismic motion. The ground acceleration experienced at most data base sites, measured by nearby ground motion records, is comparable to or in excess of the seismic design basis for most eastern United States nuclear plant sites.

  The primary purposes of the seismic experience data base are summarized as follows:

  - To determine the most common sources of seismic damage, or adverse effects, on facilities that contain installations representative of critical nuclear plant systems.

  - To determine the thresholds of seismic motion corresponding to various types of seismic damage.

  - To determine the types of installations that are normally undamaged by earthquakes, regardless of the levels of seismic motion.

- To determine minimum standards in equipment installations, based on past experience, to assure the ability to withstand anticipated seismic loads.

To summarize, the primary assumption is that the actual seismic hazard to nuclear power plant installations is best demonstrated by the performance of similar installations in past earthquakes.

4.D-2 Facilities Surveyed in Compiling the Data Base

The seismic experience data base is founded on studies of over 60 facilities located in the strong motion areas of 10 earthquakes that have occurred in California and Latin American countries since 1971. The data base was compiled through surveys of the following types of facilities:

- Fossil-fueled power plants
- Hydroelectric power plants
- Electrical distribution substations
- Oil processing and refining facilities
- Water treatment and pumping stations
- Natural gas processing and pumping stations
- Manufacturing facilities
- Large commercial facilities (focusing on their HVAC plants).

In general, data collection efforts focused on facilities located in the areas of strongest ground motion for each earthquake investigated. Facilities were sought that contained substantial inventories of mechanical, or electrical equipment, or control and instrumentation systems. Because of the number of earthquake-affected areas and types of facilities investigated, there is a wide diversity in the types of installations included in the data base. For the equipment

installations of focus in the investigations, this means a wide diversity in age, size, configuration, application, operating conditions, manufacturer, type of building, location within building, local soil conditions, quality of maintanence, and quality of construction.

The data base includes a total of ten earthquakes, with several different sites investigated in each earthquake-affected area. The earthquakes investigated range in Richter magnitude from 5.7 to 8.1. Measured or estimated ground accelerations for data base sites range from 0.15g to 0.70g. The duration of strong motion (on the order of 0.10g or greater) ranges from 5 seconds to over 40 seconds. Local soil conditions range from deep alluvium to rock. The buildings housing the equipment installations of interest have a wide range in size, and type of construction. As a result, the data base covers a wide diversity of seismic input to equipment installations, in terms of seismic motion amplitude, duration, and frequency content.

4.D-3 Type of Data Collected

Information on each data base facility, its performance during the earthquake, and any damage or adverse effects caused by the earthquake were collected through the following sources:

- Interviews with the facility management and operating personnel usually provide the most reliable and detailed information on the effects of the earthquake on each facility. At most facilities several individuals were consulted to confirm or enhance details. In most cases interviews are recorded on audio tape.

- The facility operating logs provide a written record of the conditions of the operating systems, before and after the earthquake. Operating logs list problems in system operation associated with the earthquake, and usually tabulate earthquake damage to the facility. Operating logs are useful in determining the amount of time the facility

may have been out of operation following the earthquake, and any problems encountered in restarting the facility.

- The facility management often produces a report summarizing the effects of the earthquake following detailed inspections. These reports normally desribe causes of any system malfunctions or damage, and typically include any incipient or long term effects of the earthquake.

- If the facility can be surveyed immediately following the earthquake, as has been the case in four of the ten earthquakes included in the data base, earthquake damage can often be inspected prior to repairs.

Standard procedures used in surveying data base facilities focus on collecting all information on damage or adverse effects of any kind caused by the earthquake. For a large majority of the facilities surveyed in the data base, this is not a lengthy task. Except for sites that experienced very high seismic motion (in excess of 0.50 g peak ground acceleration), seismic damage to well-engineered facilities is normally limited to only a few items.

4.D-4 The Data Base for Cable Trays

Within the experience data base, approximately 20 facilities, encompassing eight earthquakes, include good examples of cable tray systems. Table 4.D-1 lists these facilities with a brief description of the type of cable trays found at each site. In general the data base offers a wide diversity of cable tray designs, configurations, locations within building structures and conditions of seismic loading.

Figures 4.D-1 through 4.D-3 include illustrations of the primary parameters that affect the seismic loads on cable trays for several data base sites. These figures include a plot of the response spectrum representing ground acceleration at the data base site. This response spectrum is based on the nearest or most applicable ground motion records for the site. The response spectrum shown is the average of the response spectra for the two horizontal components of motion measured at

the nearest record. This spectrum then does not represent the highest horizontal motion at the site, but rather the average horizontal motion.

For comparison, each plot also includes the horizontal ground motion spectrum from USNRC Regulatory Guide 1.60, normalized to a peak ground acceleration of 0.25 g, the design basis for the Seabrook Station. All response spectra correspond to 5% damping.

Each figure includes a schematic elevation view of the data base building structure, illustrating the height and construction of the building, and showing the primary locations of the cable trays with respect to grade elevation.

The figures also include sketches of the typical cable tray construction at the site, including the typical number of tiers, support configuration, and attachment to walls, floor, or ceiling.

4.D-5 Cable Tray Parameters at Seabrook and in the Experience Data Base

In order to verify the seismic adequacy of the Seabrook cable tray systems using experience from past earthquakes, relevant parameters must be chosen which make comparisons between cable trays in the data base and at Seabrook meaningful. Cable tray parameters were defined based on their effect on system mass, stiffness, strength, and response to seismic loading. The following critical parameters are the basis of the comparison of cable trays at Seabrook Station with those in the seismic experience data base:

- Cable tray dimension (width, depth)
- Cable tray loading
- Number of tiers
- Cable tray type (ladder, trough, solid bottom)
- Support construction (trapeze, cantilever bracket, rod, Unistrut)
- Cable tray span (length between supports)

- Connection details (e.g., tray-to-support connection)
- Additional cable tray support loading (conduit, piping)
- Cable tray interfaces (with electrical cabinets, with conduit)
- Cable tray layout
- Location of trays
- Type of building
- Seismic ground motion

Each of the above cable tray parameters at Seabrook is compared to the seismic experience data base. Data for the parameter comparison were taken from the following sites, which provided the most cable tray details:

- Sylmar Converter Station (PGA = 0.50g)
- Valley Steam Plant (PGA = 0.30)
- Humboldt Bay Power Plant (PGA = 0.25g, 0.30g)
- El Centro Steam Plant (PGA = 0.42g)
- Drop IV Hydroelectric Plant (PGA = 0.40g).
- Las Ventanas Power Plant (PGA = 0.30g)
- La Villita Hydroelectric Plant (PGA = 0.15g)
- El Infiernillo Hydroelectric Plant (PGA = 0.15g)

Each of the critical cable tray parameters listed above is addressed in the paragraphs that follow.

Cable Tray Dimensions. Cable tray dimensions contribute to the system mass and stiffness which, in turn, partially determine the system response to seismic loading. Cable tray dimensions refer to cable tray

width and depth. The NEMA standard addressing cable tray systems gives standard cable tray widths of 6, 12, 18, 24, 30, and 36 inches. Cable trays in the data base range from 6 to 24 inches in width. Seabrook trays range from 12 to 24 inches in width.

- The NEMA-specified inside depth of cable trays ranges from 3 to 6 inches. Cable trays in the experience data base range from 3 to 4 inches deep. Seabrook cable trays have an inside depth of 3-1/16 inches.

<u>Cable Tray Loading</u>. Cable tray loading is the primary contributor to the mass of the system. Of secondary importance is the effect of cable loading on system damping. For a nominal 3 inch deep tray, there is roughly a direct correlation between percent fill and weight/ft (i.e., 40% full is roughly 40 pounds per linear foot, plf). Examples of varying data base cable tray loading are shown in the photographs in Figure 4.D-4. Cable trays at Seabrook vary from 20% to 40% full; cable loading never exceeds 40 plf. The data base contains cable trays which are more heavily loaded than 40 plf, thereby enveloping Seabrook for gravity load. In addition, the data base trays range from empty to over 100% full (i.e., from 0 to over 100 plf), thereby enveloping any system damping effects.

<u>Number of Tiers</u>. The number of tiers, specifically the number of tiers without transverse bracing, contributes to the overall mass and stiffness of a cable tray system. The number of tiers refers to the number of horizontal spans suspended from a vertical support. In addition to vertical supports, transverse supports are significant to system seismic response. Cable trays at Seabr[illegible]ation include transverse bracing at nearly every support. D[illegible]e trays rarely have transverse supports. Although Seabrook tray [illegible]ems include up to 12 tiers, the number of tiers between transverse supports is typically far less than in the data base.

<u>Cable Tray Type</u>. Cable tray type contributes to the stiffness of the system. There are three primary types of cable trays described in the NEMA standard on cable tray systems:

- Ladder
- Trough
- Solid-bottom

A ladder type tray consists of two longitudinal rails connected by individual transverse members (rungs). A trough type tray is a metal structure with a ventilated bottom contained within longitudinal side rails. A solid-bottom type tray consists of a continuous sheet with no openings, contained within longitudinal side rails. Table 4.D-1 lists the data base cable tray types by site. Seabrook cable trays are either ladder or solid-bottom type.

Support Construction. Cable tray support construction contributes significantly to the system's resistance to seismic loads. Support construction refers to the structure of cable tray supports and the members from which a support is made. The NEMA standard on cable tray systems defines three types of supports:

- Trapeze
- Cantilever bracket
- Individual rod suspension

Cable trays supported by individual rod suspension are relatively uncommon, and are not representative of cable tray supports at Seabrook.

Trapeze supports consist of two vertical members, typically bolted or welded to the ceiling, connected by a horizontal member, upon which the cable tray rests. The structural members of data base trapeze supports are constructed from rod, strut, or steel angles.

Cantilever bracket supports refer to a large variety of structures in which the tray is cantilevered from a vertical member anchored to a wall, a floor, or a ceiling. Data base cantilever brackets include "L"-supports and "T"-supports (Figure 4.D-5). In addition, at some data base sites, cable trays are supported from cantilevers on floor-to-

ceiling columns (Figure 4.D-5). Data base cantilever bracket supports are especially susceptible to seismic loads because of the dead load moment inherent in their asymmetric design.

Table 4.D-1 lists the data base support types by site. Most of the data base sites have trapeze supports or various forms of cantilever bracket supports. In general, cable tray supports in the data base do not consider seismic loads in their design. Seismic design is not required in the NEMA standard for cable tray construction.

Seabrook cable tray supports are of two basic types:

- Trapeze
- Floor-to-ceiling box frame

All Seabrook supports are made of cold-formed steel strut. Each Seabrook trapeze support is transversely braced, making it significantly sturdier than data base trapeze supports. In addition to trapeze supports, many Seabrook cable trays are supported on floor-to-ceiling box frames. These supports consist of two vertical members, supported at both the ceiling and floor, with cross members to which the cable trays are bolted. Seabrook floor-to-ceiling supports are symmetric, which mediates dead load moment.

Cable Tray Span. Cable tray span is a significant contributor to the system stiffness. A span refers to the horizontal distance between vertical supports. Cable trays at Seabrook Station are supported vertically at least every ten feet. In most cases and for most configurations, Seabrook trays are supported every five feet. The spacing of vertical supports of data base trays range from four to ten feet.

Most Seabrook cable tray supports include transverse bracing. In many cases, data base trays have no transverse bracing; lateral support is provided only by the geometry of the system (i.e., transverse support of a cable tray run is provided by an intersecting branch run). At some data base sites, transverse bracing forms part of the vertical support.

Data base sites, normally have no specific provision for longitudinal bracing. Instead, longitudinal load resistance is provided by inherent features of the cable tray system, such as:

- Geometry (e.g., cable tray intersections with branch runs)
- Vertical supports
- Interfaces with the building (e.g., walls)
- Electrical cabinet connections

<u>Cable Tray/Support Connection Details</u>. Cable tray and support connection details contribute significantly to the strength and stiffness of the system. The connection details considered here include:

- Tray-to-support connection
- Tray-to-tray connection
- Anchor-point connection (e.g., wall, ceiling, or floor connections)
- Cable-to-tray connection
- Support internal connections (e.g., connections between vertical and horizontal trapeze members)

A comparison of connection details between Seabrook and data base cable tray supports is shown in Figures 4.D-7 through 4.D-9.

Tray-to-support connection refers to the method by which the cable tray is attached to its support. Data base cable trays are typically attached to their supports either with two small screws (i.e., 1/8 inch) or using gravity alone (i.e., in some cases, there is no positive connection between tray and support). Cable trays at Seabrook Station are attached to supports using either internal clips or "Z" clips.

Tray-to-tray connection refers to the attachment between cable trays. At Seabrook Station, tray-to-tray connections are made with eight 3/8 inch bolts. Connection details between cable trays in the data base are typically made using a similar configuration to Seabrook, however data base tray connections have fewer bolts.

Anchor-point connections refer to the connection details at the interface of cable tray supports with ceilings, floors, and walls. At Seabrook Station, a special "boot" connection detail has been designed to connect cable tray supports to anchor points. Seabrook cable tray supports are bolted into the boot, which is welded to a steel base plate. At other anchor points, Seabrook supports are welded or bolted to embedded steel channels in the concrete wall. Data base trays have anchorage connection details which are not only weaker than Seabrook's, but which have fewer anchorages per length of tray. Data base cable tray supports are generally bolted to the ceiling with expansion anchors (i.e., 1/2 inch bolts). At two data base sites, ceiling anchorage consists of friction clips attaching the support to overhead wide flange beams. Figures 4.D-7 through 4.D-8 are photographic comparisons of anchor-point connection details at Seabrook and at sites in the experience data base.

Cable-to-tray connection refers to the attachment of cables to trays. Typically, cables are individually attached to trays using plastic ties. At Seabrook Station, cables are tied to ladder type trays at every tenth rung (maximum 90 inches) for horizontal trays, and at every fourth rung (maximum 36 inches) for vertical trays. Data base cable trays typically do not have ties for horizontal runs and have ties at every fourth cable tray rung on vertical runs.

Support internal connections refer to the connection details within the cable tray support structure. Examples include the connection of the vertical and horizontal members of a trapeze, or the connection of diagonal bracing to a support. Cable tray supports at both Seabrook and at data base sites have standard connection details (as specified, for example, in a Unistrut catalog). In addition to standard connections, Seabrook cable tray supports are strengthened with clip angles and

triangular gussets at critical locations. Most data base cable tray supports have little or no additional reinforcement. Figure 4.D-9 shows support internal connection details at Seabrook and at a typical data base site.

- Additional Cable Tray Loading. In addition to cable trays, conduit is sometimes mounted on cable tray supports. Additional cable tray loading can contribute significantly to the mass of the system. At Seabrook and at data base sites, conduit is occasionally mounted on or cantilevered from cable tray supports.

Cable Tray Interfaces. Cable tray interface refers to the means of routing cable between cable trays and electrical cabinets. Cable tray interfaces affect the system seismic response by:

- Providing a source of reaction to seismic loads
- Providing a source of seismic interaction (impact) between the cabinet and the cable tray

At Seabrook Station cable is routed between cable trays and cabinets through conduit or wireways. The conduit/wireways are bolted to the tray, and connected to the cabinet through a flexible coupling designed to accommodate minor differential displacements between tray and cabinet. This type of interface connection is intended to minimize any potential interaction hazards in the following ways:

- The flexible connection allows relative displacements between the cable tray and the cabinet, without imposing significant seismic loads on either.
- The continuous connection provided by the conduit/wireway that routes the cable from tray to cabinet prevents impact between the tray or the cabinet and the conduit/wireway.

By comparison, many data base cable trays interface with electrical cabinets by routing a small section of tray directly into the cabinet. This interfacing tray section is often bolted to both the cabinet and the main section of cable tray, imposing seismic reaction loads from the

cable tray system onto the cabinet. Alternately, some data base cable trays interface with cabinets by abutting the cabinet, or conduit attached to the cabinet, without positive connection. This creates the potential for pounding between the cable tray and cabinet structures.

- Interaction between cable trays and electrical cabinets has never caused damage in past earthquakes, in spite of the general lack of design provisions to accommodate seismic interaction.

Cable Tray Layout. The effect on seismic response of cable tray layout can be illustrated using experience data. Multi-directional cable tray systems are difficult to analyze accurately or to mount on a shake table. Cable tray systems in the experience data base are comparable to Seabrook Station's cable tray system for cable tray layout. Cable tray layout is a general parameter that includes the following components:

- The extent of cable trays within the building (i.e. the typical length and directions of cable tray runs)

- The relative configuration of intersecting sections of the cable tray system

The extent of cable tray runs affects the stiffness of the cable tray structural system, which in turn affects the response frequencies (within the range of seismic excitation), and the mode shapes of the tray system. A secondary effect of cable tray extent relates to the seismic input imparted to continuous cable runs by different sections of the building. Short runs of cable tray typically receive a uniform seismic input from local sections of the building. Extended runs of cable trays receive seismic inputs that vary in amplitude and phase, according to the seismic response of different sections of the building.

The relative configurations of intersecting sections of the cable tray system affect the stiffness of the cable tray system, and the seismic reaction loads imposed by one cable tray section on another. Cable tray configuration parameters include:

- Spacing of intersections

- Angles of intersection

- Relative mass and stiffness of intersecting sections

- Details of attachment at intersections

This in turn affects the response frequencies and mode shapes of the tray system.

The parametric components of cable tray extent and configuration might be generalized as the complexity of cable tray layout. The experience data base offers complexity in the layout of typical cable tray systems that is comparable to the complexity of layout at Seabrook Station. In other words, data base cable tray systems are typically of comparable (or greater) extent than the Seabrook systems. Data base cable trays include tray sections intersecting from a variety of directions and angles. Data base systems include atypical cable tray details such as offsets in cable tray run, which create potential weaknesses in longitudinal load resistance. Data base cable tray systems include a variety of interfaces with electrical cabinets, conduit systems, structural supports, building walls, and floors.

The complexity of cable tray layout also includes the potential for interaction with adjacent fixtures. Data base cable tray systems are frequently routed in congested areas that include other fixtures such as piping, conduit, catwalks, or structural steel. Since the support of data base fixtures is flexible compared to typical nuclear plant installations, there exists the potential for substantial sway and seismic interaction between cable trays and adjacent fixtures. In spite of the high seismic interaction potential in data base facilities, there are no instances of interaction damage to cable trays in past earthquakes.

The various components included in cable tray layout, as well as typical examples of the complexity of data base cable tray systems, are illustrated in Figures 4.D-10 through 4.D-12.

Cable Tray Location. Cable tray location within a building structure affects that level of motion experienced by the system. Of particular interest is the elevation of the cable tray system above grade elevation. The amplification of seismic ground motion generally increases within a building with height above grade.

The location of cable trays at the Seabrook Station ranges in elevation from 47 feet below grade, to 60 feet above grade. The building elevation of data base cable tray systems ranges from basement locations to locations in steel boiler structures, over 100 feet above grade.

Type of Building. The type of building affects the amplification and filtering of seismic ground motion into the supports of a cable tray system. The parameter of building type also includes soil conditions at the site (i.e., rock, deep alluvium, etc). The various types of structures found at the power stations and industrial facilities surveyed in compiling the experience data base offer a wide diversity of building size, and flexibility. This in turn suggests a wide diversity in the amplification, distortion, and filtration of the ground motion experienced at the various sites.

Data base buildings that house cable trays range from flexible structures to structures comparable in stiffness to the buildings at Seabrook Station.

One extreme is the tall, open steel-frame boiler support structures typical of fossil power plants. Steel-frame boiler structures are typically five or more stories high, and contain the massive furnace-boiler system, usually supported as a pendulum from the top of the structure. The boiler system is usually free to swing within the steel-frame structure. As an example of the flexibility of boiler structures, a response motion record taken near the top of the 169 foot tall open steel-framed boiler structure of the Las Ventanas Power Plant recorded a primary response frequency of approximately 1 Hz during the March 1985 Chile earthquake. The record measured a peak acceleration of 0.80g, with a duration of strong motion of about 60 seconds. The boiler

structure contains a system of cable trays which was undamaged in the earthquake.

The bulk of the cable tray systems included in the data base are contained in two- to three-story steel frame or concrete shear wall buildings, such as the turbine buildings of power plants. This type of structure is generally similar to the Seabrook Station structures (other than the reactor containment). Typical fundamental response frequencies for this type of building range from 1 to 5 Hz, which corresponds to the frequency range of maximum energy content for most earthquake ground motion. Table 4.D-2 summarizes the types of buildings and the site soil conditions for various data base sites.

The Seabrook Station building structures are somewhat stiffer in comparison. Based on building response analyses, fundamental frequencies for the Control Building, Primary Auxiliary Building, and the Containment range from 5 to 10 Hz. This frequency range is slightly above the range of maximum energy content for typical seismic ground motion.

Seismic Ground Motion. The level of anticipated seismic ground motion forms the basis for the seismic design of cable trays. Seismic ground motion is defined in terms of three components:

- Peak ground acceleration
- Duration of strong motion (typically defined as > 0.10g)
- Frequency content of ground motion

These three components are characterized either directly or indirectly by a ground motion response spectrum. The basis for the seismic design of cable trays at Seabrook Station is represented by the ground motion spectra of USNRC Regulatory Guide 1.60, normalized to a 0.25 g peak ground acceleration. This response spectrum is compared to a range of data base site response spectra from various earthquakes in Figure 4.D-14 (plotted with 5% damping). As shown in the figure, most

data base ground response spectra are either comparable to or in excess of the Seabrook design-basis spectrum.

4.D-6 Conclusions

The comparison of cable tray systems at Seabrook Station with cable trays in the seismic experience data base has demonstrated the following points:

- All parameters associated with the seismic capacity of Seabrook cable trays are enveloped by data base cable trays, i.e., data base cable trays are similar or weaker in all aspects related to seismic capacity, compared to Seabrook cable trays.

- Most data base cable tray systems have experienced seismic loads comparable to or greater than the seismic design-basis loads for Seabrook cable tray systems.

- Cable tray systems constructed according to normal industry practice have more than sufficient margin to absorb the seismic loads anticipated from moderate earthquakes (such as the Seabrook seismic design basis), even without specific seismic design provisions.

- The capacity of cable trays to survive seismic loads is not sensitive to details of cable tray construction or layout.

By a comparison with cable tray systems that have survived past strong motion earthquakes, it is apparent that the cable tray systems at Seabrook Station have more than adequate capacity to survive their design-basis safe shutdown earthquake.

Table 4.D-1

CABLE TRAYS IN THE SEISMIC EXPERIENCE DATA BASE

EARTHQUAKE	SITE	PEAK GROUND* ACCELERATION	CABLE TRAY TYPE	SUPPORT TYPE	CONFIGURATION
San Fernando Earthquake 1971	Sylmar Converter Station	0.50g	Ladder & Trough	Unistrut	Trapeze
	Valley Steam Plant	0.30g	Trough	Unistrut	Trapeze & Cantilever
	Burbank Power Plant	0.32g	Trough	Rod	Trapeze
	Glendale Power Plant	0.27g	Trough	Rod	Trapeze
	Pasadena Power Plant	0.18g	Solid-Bottom	Steel Angle	Floor-to-Ceiling Cantilever
	Saugus Substation	0.35g	Ladder	Unistrut	Floor-to-Ceiling Cantilever
Point Mugu Earthquake 1973	Ormond Beach Power Plant	0.20g	Trough	Unistrut	Trapeze
Ferndale/ Humboldt Earthquakes 1975/1980	Humboldt Bay Power Plant	0.30g 0.25g	Trough	Unistrut	Trapeze
Imperial Valley Earthquake 1979	El Centro Steam Plant	0.42g	Ladder & Trough	Unistrut	Trapeze
	Drop IV Hydro.Plant	0.30g	Solid-Bottom	Steel Angle	Trapeze
Coalinga Earthquake 1983	Union Oil Butane Plant	0.60g	Ladder	Rod	Trapeze

* Average of Two Horizontal Components of Ground Motion

Table 4.D-1 (continued)

EARTHQUAKE	SITE	PEAK GROUND* ACCELERATION	CABLE TRAY TYPE	SUPPORT TYPE	CONFIGURATION
Morgan Hill Earthquake 1984	United Tech. Chem. Plant	0.50g	Ladder	Unistrut	Trapeze & Floor-to-Ceiling Cantilever
Santiago, Chile Earthquake 1985	Renca Power Plant	0.35g	Ladder	Rod	Trapeze
	Rapel Hydro.Plant	0.31g	Ladder	Steel Angle	Floor-to-Ceiling Cantilever
	Laguna Verde Power Plant	0.30g	Ladder & Trough	Steel Angle	Trapeze
	Las Contes Hospital	0.25g	Ladder	Rod	Trapeze
	Las Ventanas Copper Refine.	0.30g	Ladder	Unistrut	Trapeze & Cantilever
	Las Ventanas Power Plant	0.18g	Ladder	Unistrut Rod	Trapeze & Cantilever
Mexico Earthquake 1985	Infiernillo Dam	0.15-0.20g	Trough	Unistrut	Floor-to-Ceiling Cantilever
	La Villita Power Plant	0.15g	Ladder	Unistrut	Trapeze Cantilever
	SICARTSA Steel Mill	0.15g	Ladder	Steel Pedestals	Mounted on Pipe Gallery

* Average of Two Horizontal Components of Ground Motion

Table 4.D-2

BUILDING/SOIL TYPES

EARTHQUAKE	SITE	ESTIMATED PGA**	BUILDING TYPE	SOIL TYPE
•	Seabrook Station	0.25g*	Reinforced concrete shear wall structures	Rock.
San Fernando Earthquake 1971	Sylmar Converter Station	0.50g	2-story steel frame structures with penthouses and reinforced concrete structure.	Sand, silt & clay. 50 ft. to bedrock.
	Valley Steam Plant	0.30g	2- and 8- story braced frame structures; first 2 stories with reinforced frame and shear walls.	Deep alluvium to 500 ft.
	Burbank Power Plant	0.32g	Five-story braced steel frame structures; first story with reinforced concrete frame and shear walls.	Brown, sandy loam to 25 ft., dense sand below.
	Glendale Power Plant	0.27g	4-sto[illegible]rtially braced steel frame structures; with reinforced concrete first floor and basement with 2 lower stories.	intermediate alluvium.
	Pasadena Power Plant	0.18g	4-story steel braced frame structure with concrete walls.	Intermediate alluvium.
	Saugus Substation	0.35g	1-story reinforced concrete structure.	Alluvium.
Point Mugu Earthquake 1973	Ormond Beach Power Plant	0.20g	2-story steel frame structure with reinforced concrete walls.	Alluvium.

*Design Basis Earthquake

** Average of Two Horizontal Components of Ground Motion

Table 4.D-2 (continued)

EARTHQUAKE	SITE	ESTIMATED PGA**	BUILDING TYPE	SOIL TYPE
Ferndale/ Humboldt Earthquakes 1975/1980	Humboldt Bay Power Plant	0.30g 0.25g	2- and 5- story steel frame structures and 2-story reinforced concrete frame structures.	Deep alluvium to 400 ft.
Imperial Valley Earthquake 1979	El Centro Steam Plant	0.42g	2- to 6-story steel frame high bay and braced steel frame structures.	Deep alluvium.
	Drop IV Hydro.Plant	0.30g	High bay reinforced concrete shear wall structure with partial reinforced concrete basement	Rock.
Coalinga Earthquake 1983	Union Oil Butane Plant	0.60g	Cable trays are supported on steel racks running through the facility yard.	Shallow alluvium.
Morgan Hill Earthquake 1984	United Tech. Chem. Plant	0.50g	1-story tilt-up concrete structure.	Shallow alluvium.
Santiago, Chile Earthquake 1985	Renca Power Plant	0.35g	3-story braced steel frame.	Deep alluvium.
	Rapel Hydro.Plant	0.31g	High bay reinforced concrete structure with a 4-story reinforced concrete frame mezzanine, adjacent to concrete dam wall.	Marine sediments.
	Laguna Verde Power Plant	0.30g	4-story high bay steel frame structure, partially braced, with reinforced concrete shear wall first story	Rock.

** Average of Two Horizontal Components of Ground Motion

Table 4.D-2 (continued)

EARTHQUAKE	SITE	ESTIMATED PGA**	BUILDING TYPE	SOIL TYPE
	Las Ventanas Copper Refine.	0.30g	High bay steel frame structures with bracing	Compact fluvial sand to 165 ft.
	Las Ventanas Power Plant	0.30g	5-story braced steel frame structure. Boiler structure is a 169 ft. steel frame.	Compact fluvial sand to 165 ft.
Mexico Earthquake	Infiernillo Dam	0.15-0.20g	High bay reinforced concrete frame and shear wall structure, with 2-story steel frame mezzanine, completely underground.	Rock.
1985	La Villita Power Plant	0.15g	High bay steel frame structure with 5-story steel frame mezzanine.	Rock.

** Average of Two Horizontal Components of Ground Motion

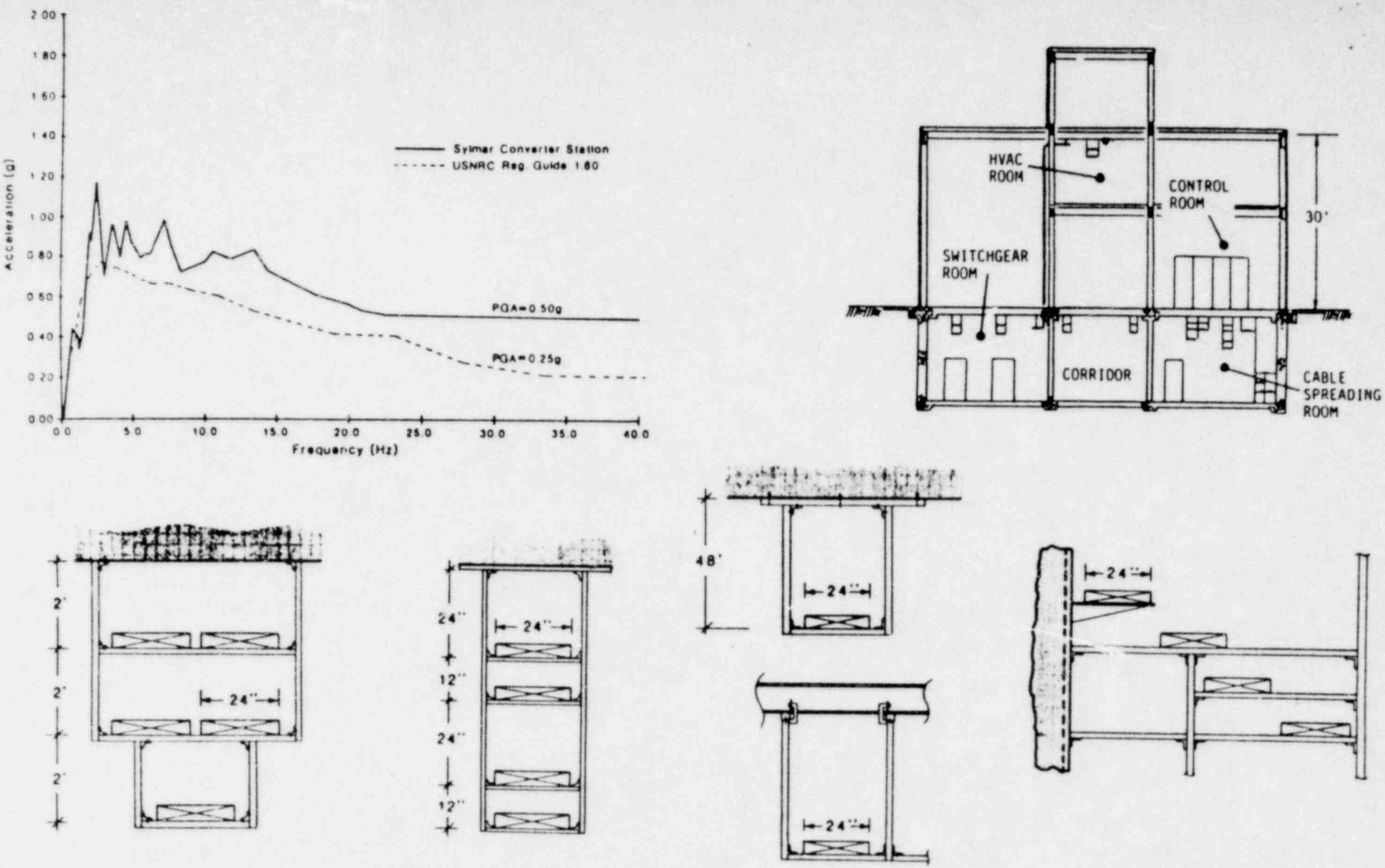


Figure 4.D-1: The Sylmar Converter Station, affected by the 1971 San Fernando Earthquake. Average horizontal peak ground acceleration is estimated at 0.50g. The response spectrum is represented by the nearest ground motion record taken at Pacioma Dam. The cable trays are located in the basement and suspended from the ceiling of the second floor of a 2-story steel frame building. Typical cable tray supports are Unistrut frames in trapeze configurations. Some supports are framed directly into adjacent concrete walls.

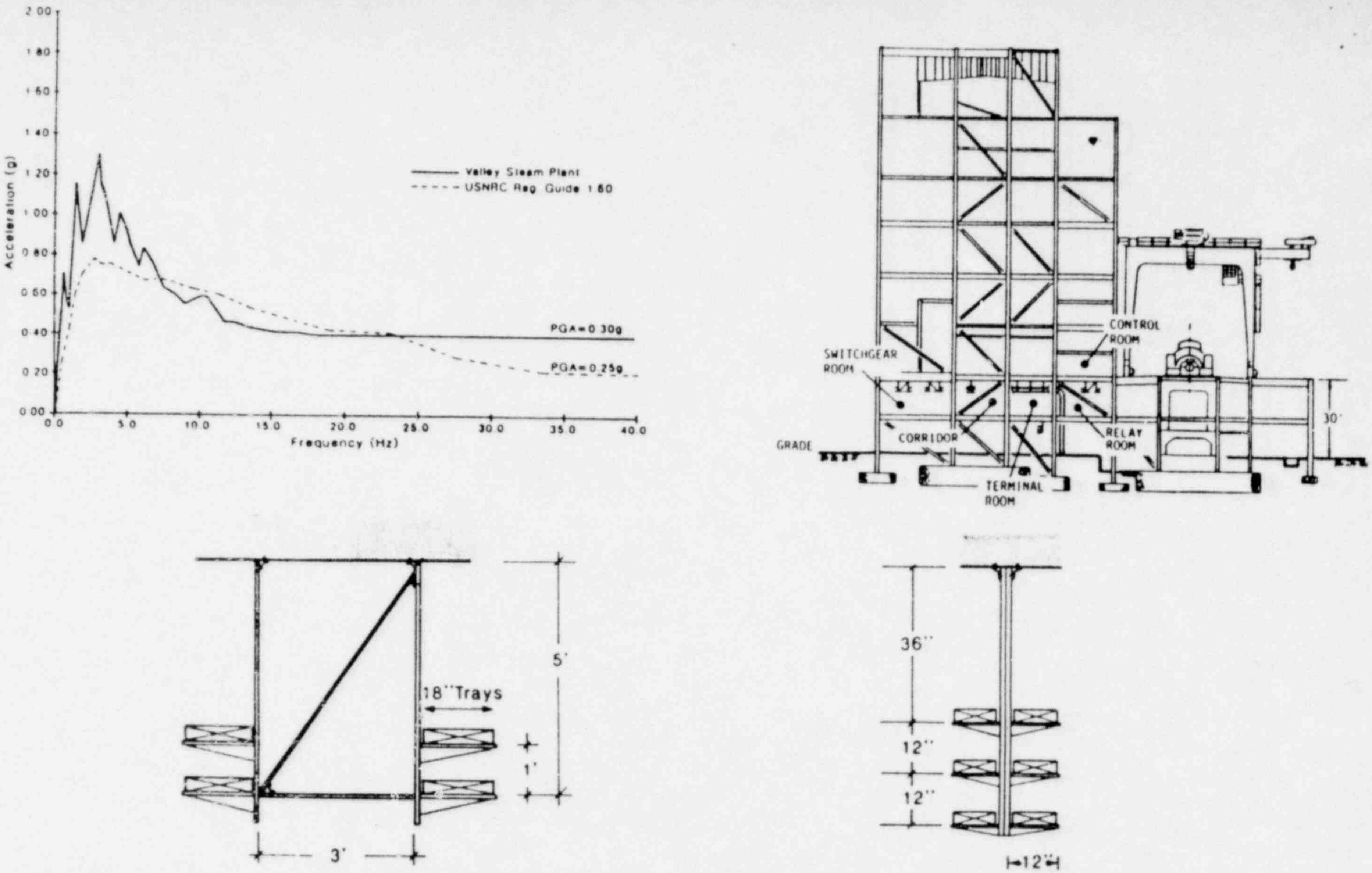


Figure 4.D-2: The Valley Steam Plant, affected by the 1971 San Fernando Earthquake. Average horizontal peak ground acceleration is estimated at 0.30g. The response spectrum is represented by the nearest ground motion record taken at 8224 Orion Blvd. The cable trays are suspended from the ceilings of the first and second floors of an 8-story braced steel frame structure. The cable tray supports consist of light gauge steel members in framed and braced trapeze configurations.

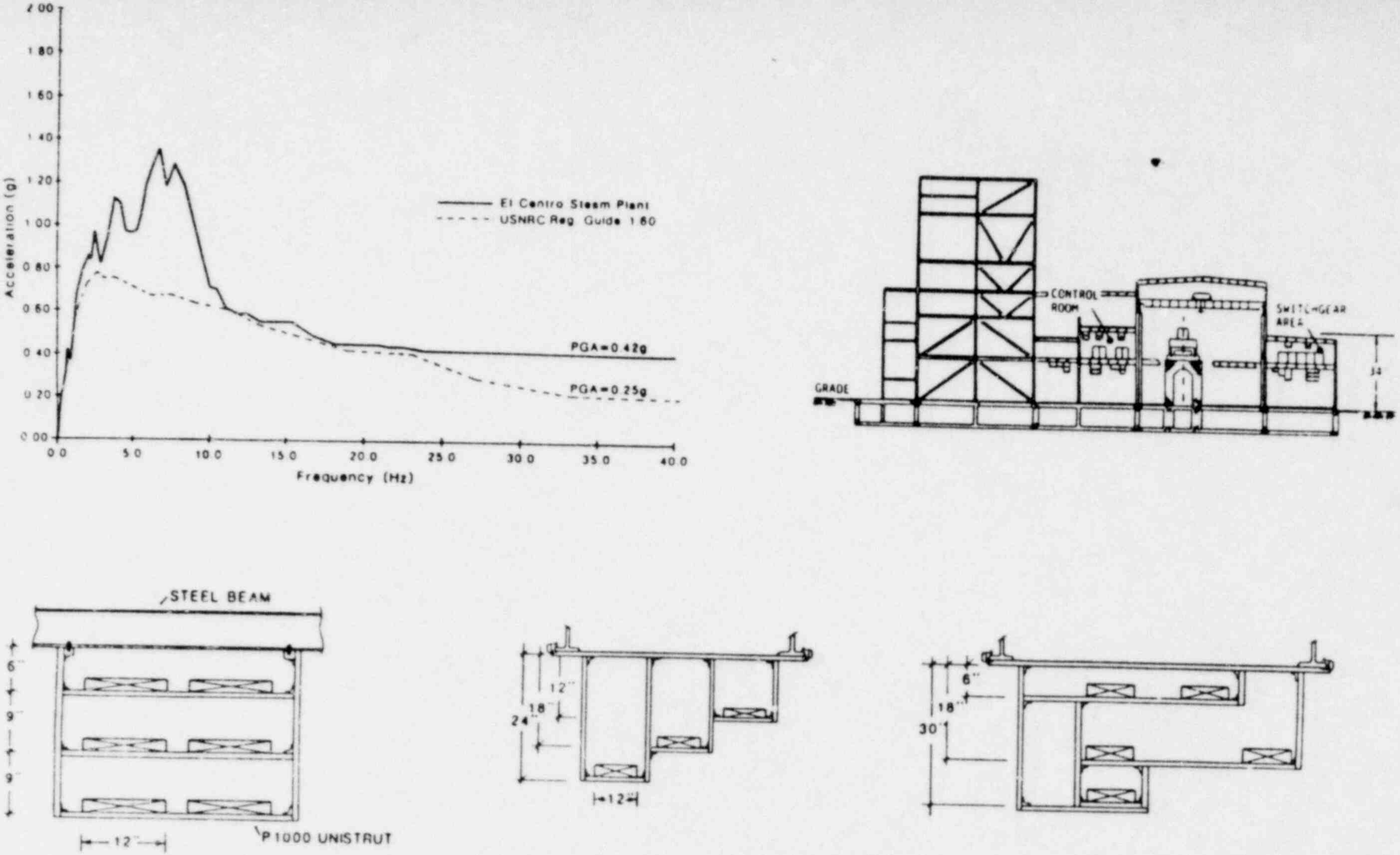


Figure 4.D-3 The El Centro Steam Plant, affected by the 1979 Imperial Valley Earthquake. Average horizontal peak ground acceleration (measured at the site) is 0.42g. The cable trays are suspended from the ceilings of the first and second floors of 2-story steel frame buildings adjacent to the turbine building and boiler structure. The cable tray supports are Unistrut frame trapeze configurations.

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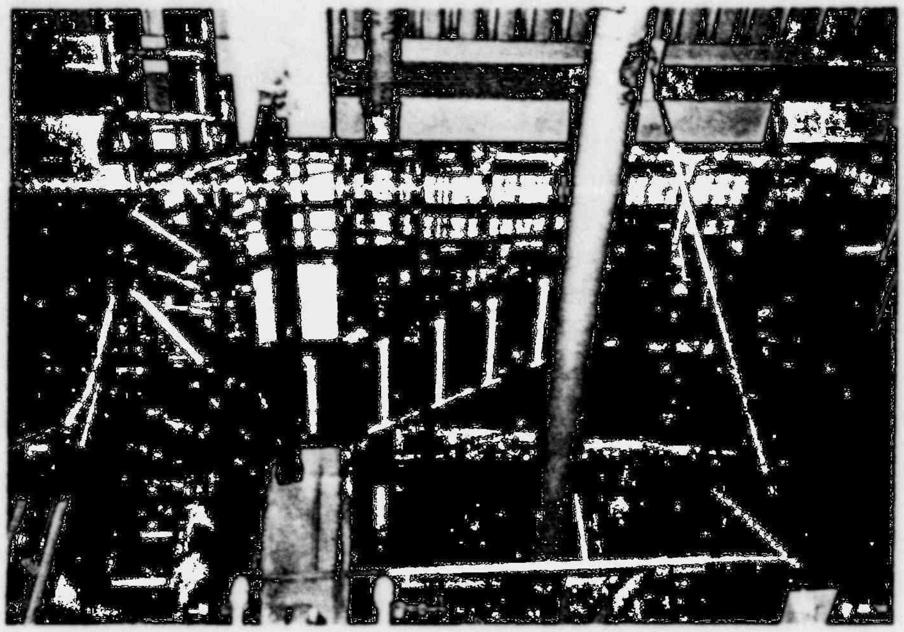


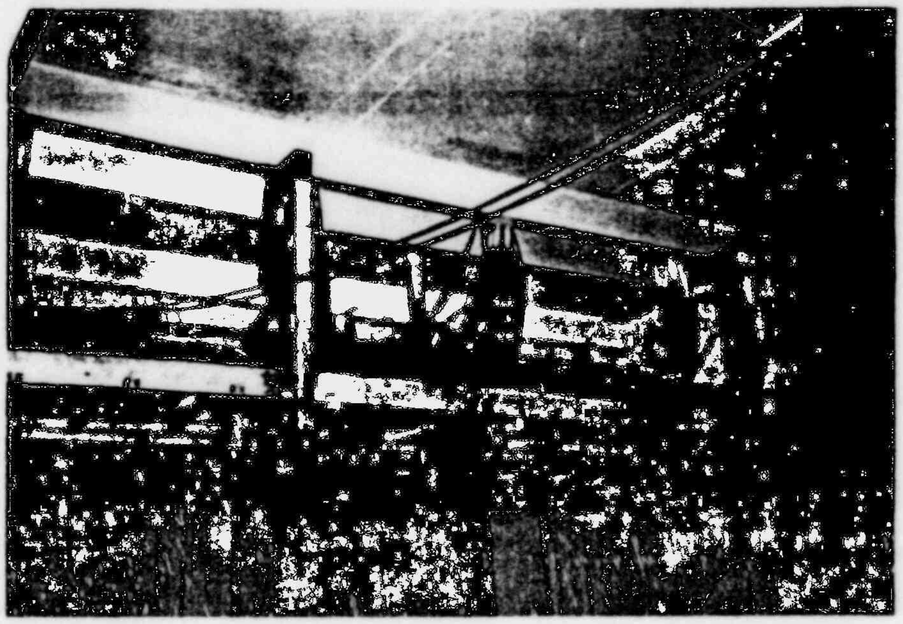


Figure 4.D-4: Data base cable trays range from almost empty to over 100% full, as shown by El Centro Steam Plant (upper photo) and La Villita Hydroelectric Plant (lower photo).

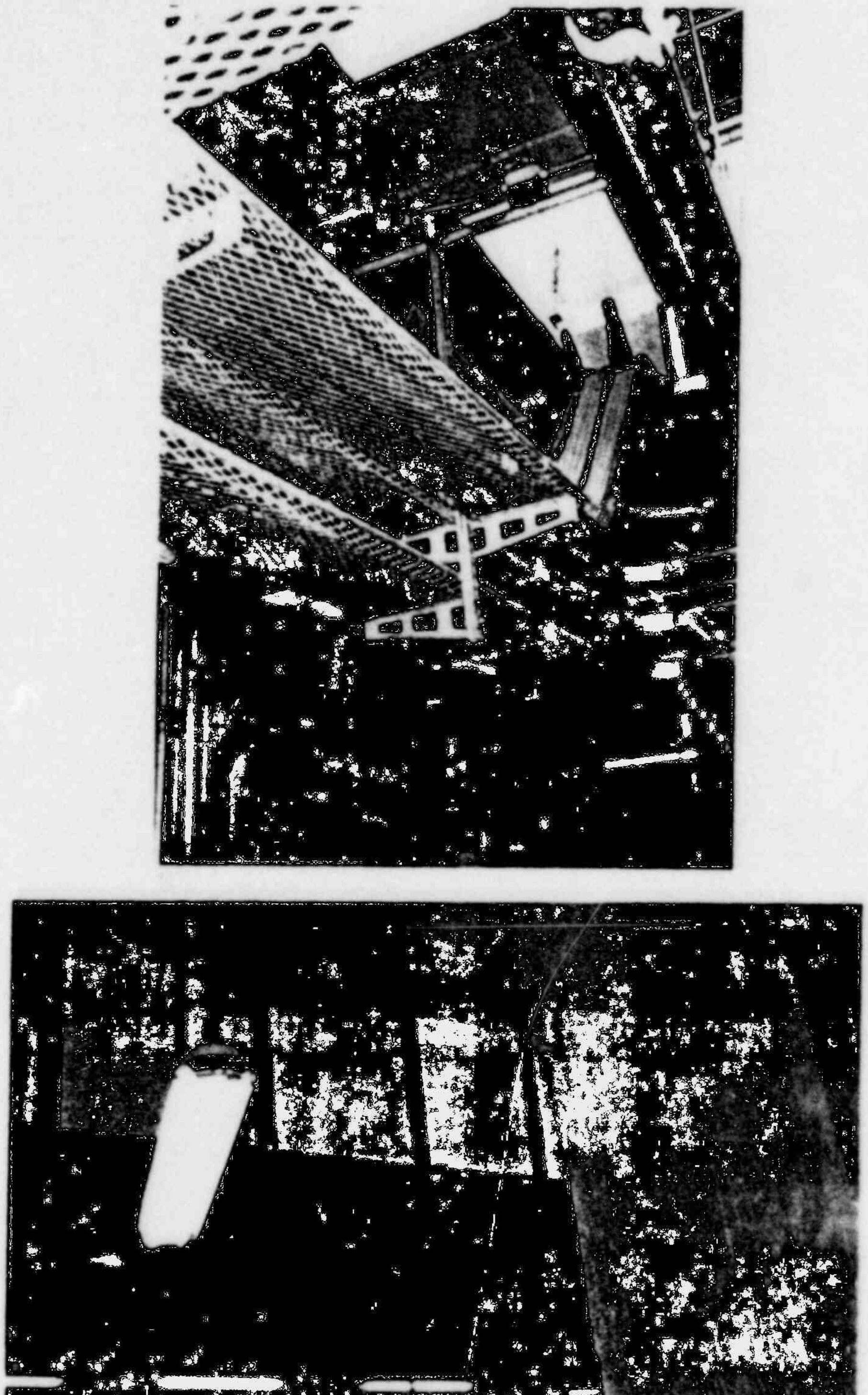


Figure 4.D-5: The experience data base contains examples of both T-configuration (Valley Steam Plant-upper photo) and L-configuration (Rapel Hydroelectric Plant-lower photo) cantilever bracket, cable tray supports.

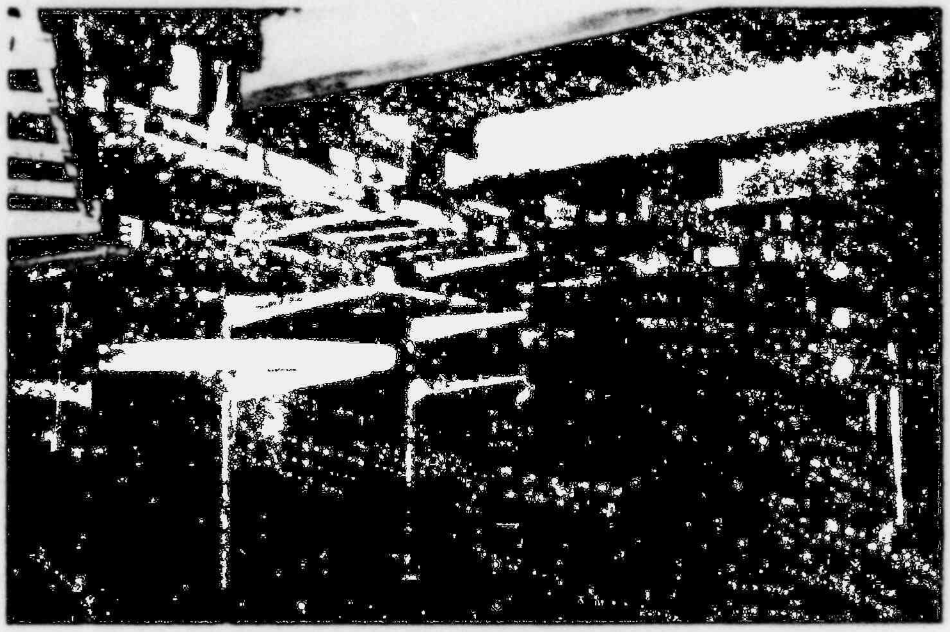


Figure 4.D-6: Typical floor-to-ceiling, cantilevered cable tray supports at the Saugus Substation (upper photo) and El Infiernillo Dam (lower photo).

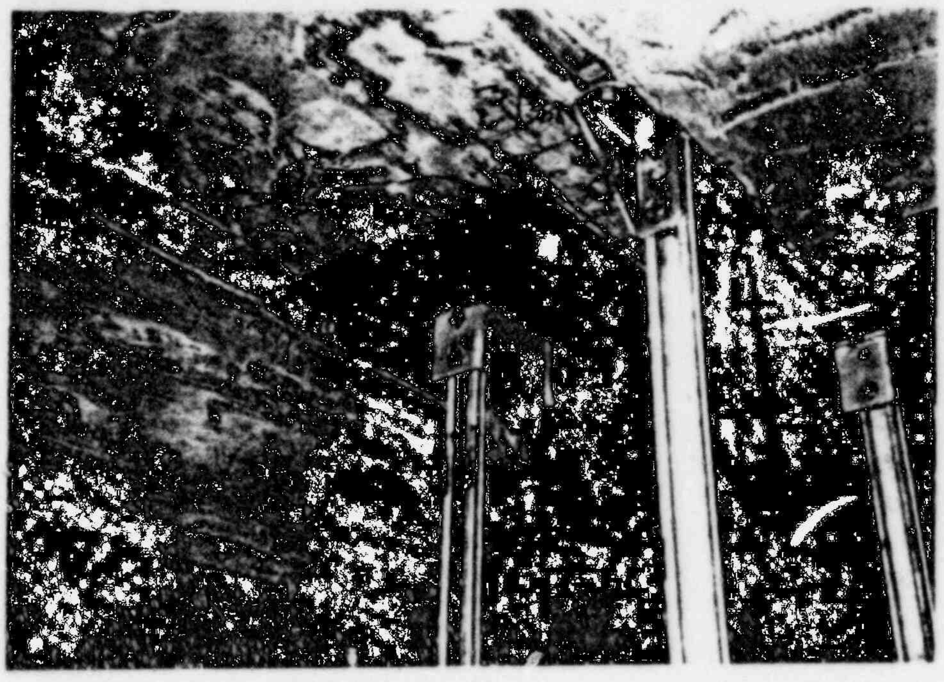
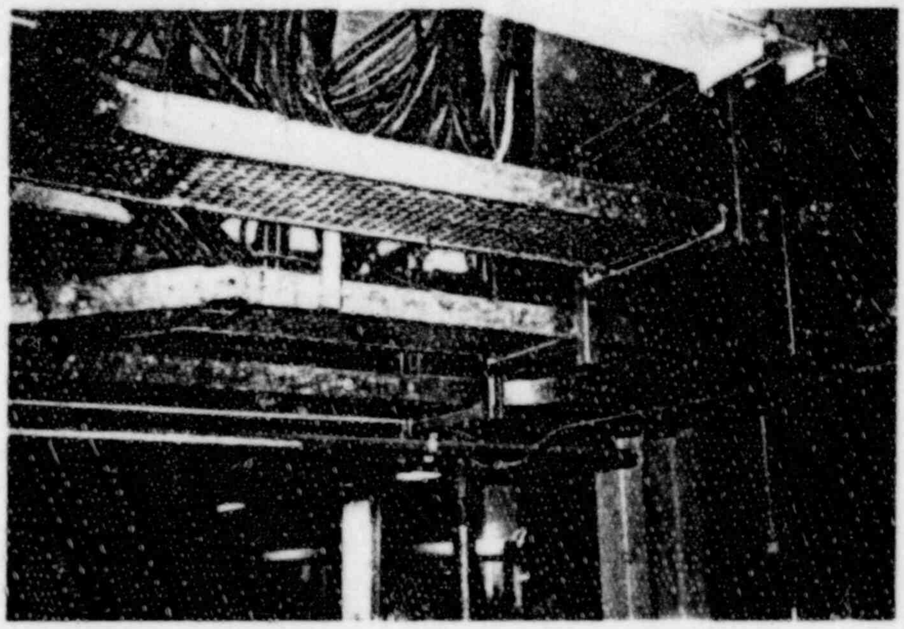


Figure 4.D-7: At data base sites, such as the Drop IV Hydroelectric Plant (upper photo), cable tray supports are typically anchored to concrete ceilings using expansion anchors. At Seabrook Station, supports are typically anchored through a "boot" connection or bolted to embedded steel channel in the concrete ceiling (lower photo).



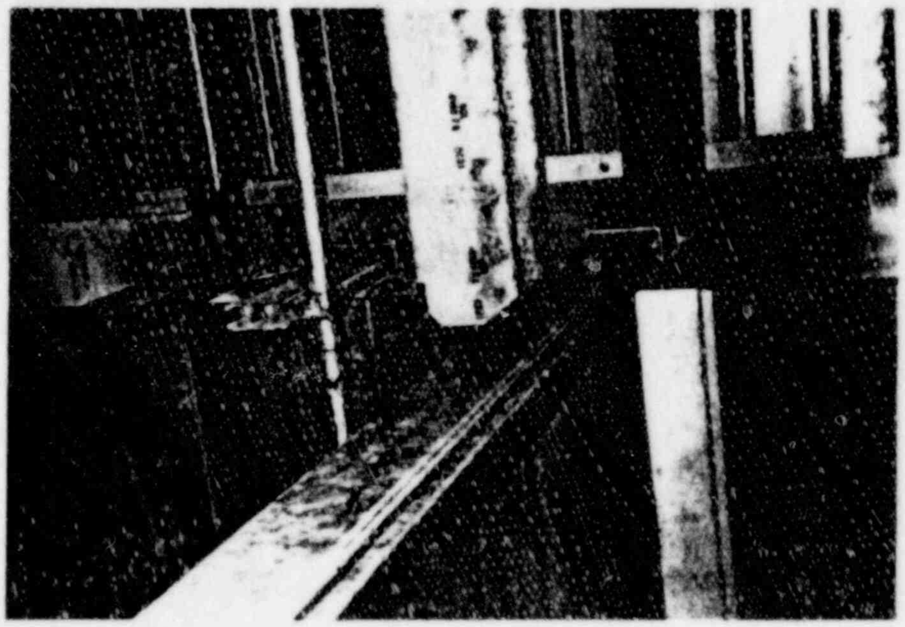


Figure 4.D-8: At data base sites, such as El Centro Steam Plant (upper photo), cable tray supports are typically attached to overhead wide-flange beams using friction clips. At Seabrook Station, supports are typically anchored to overhead beams by welded connections or with a "boot" connection (lower photo).

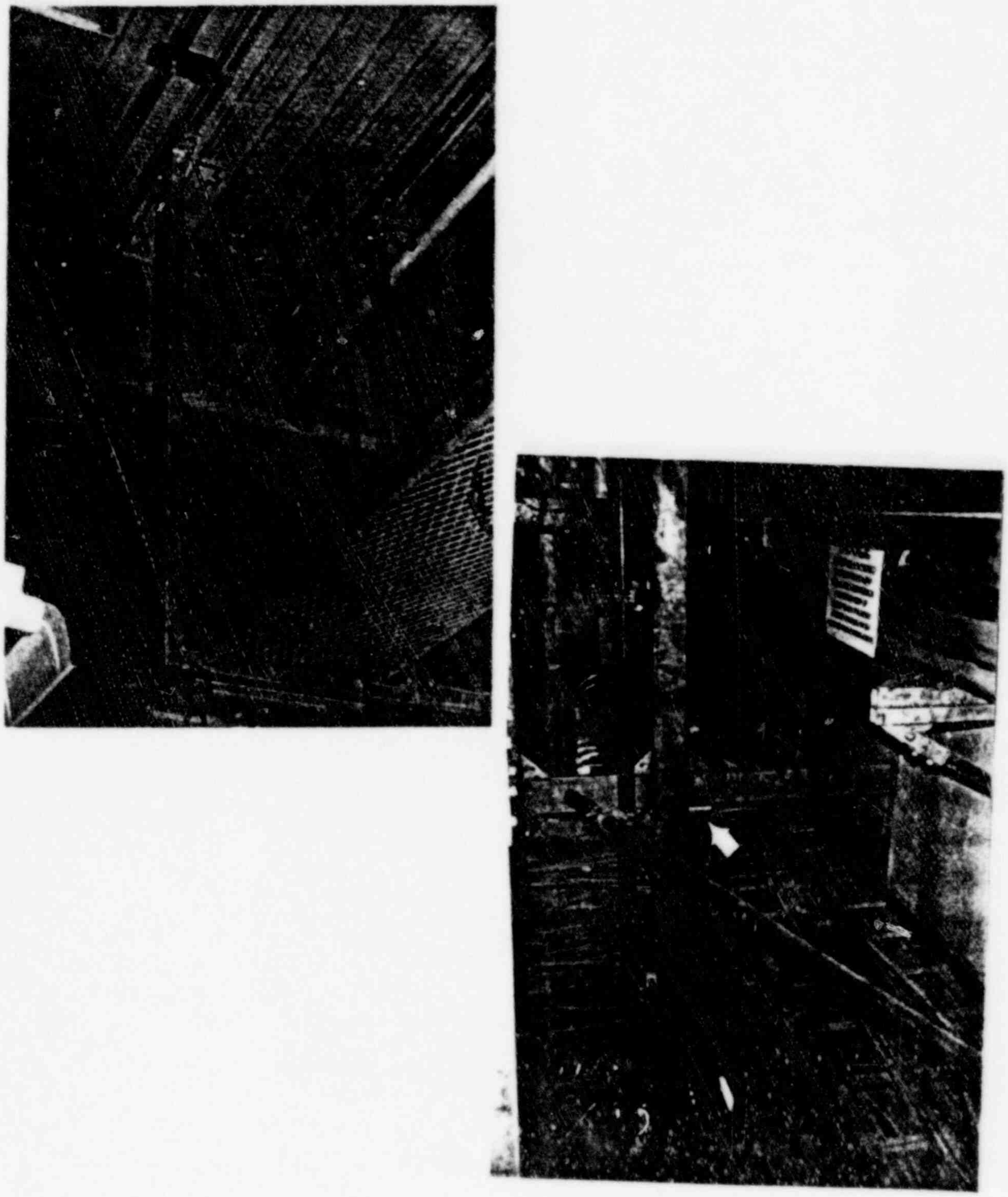
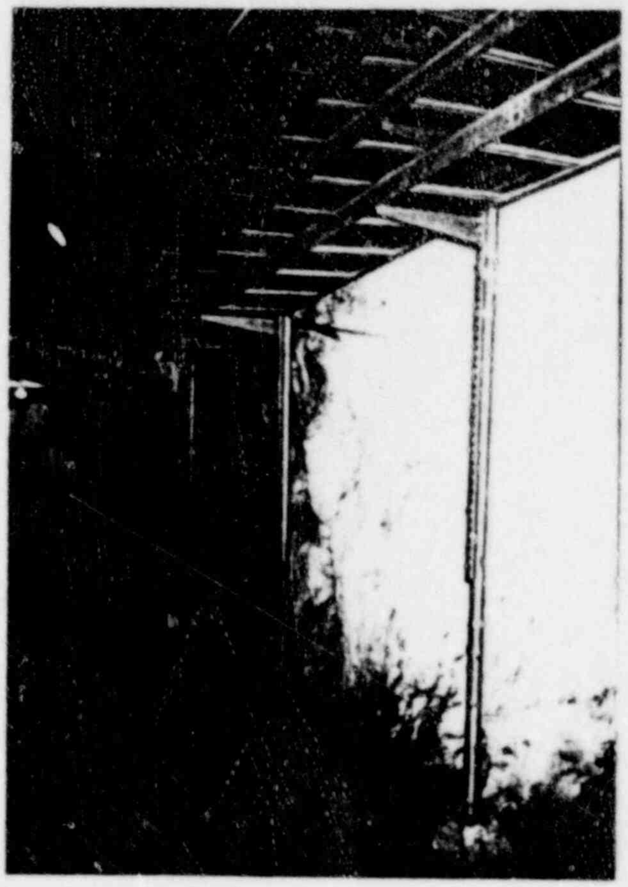


Figure 4.D-9: Typical support internal connections at the Sylmar Converter Station (upper photo) and at Seabrook Station (lower photo).



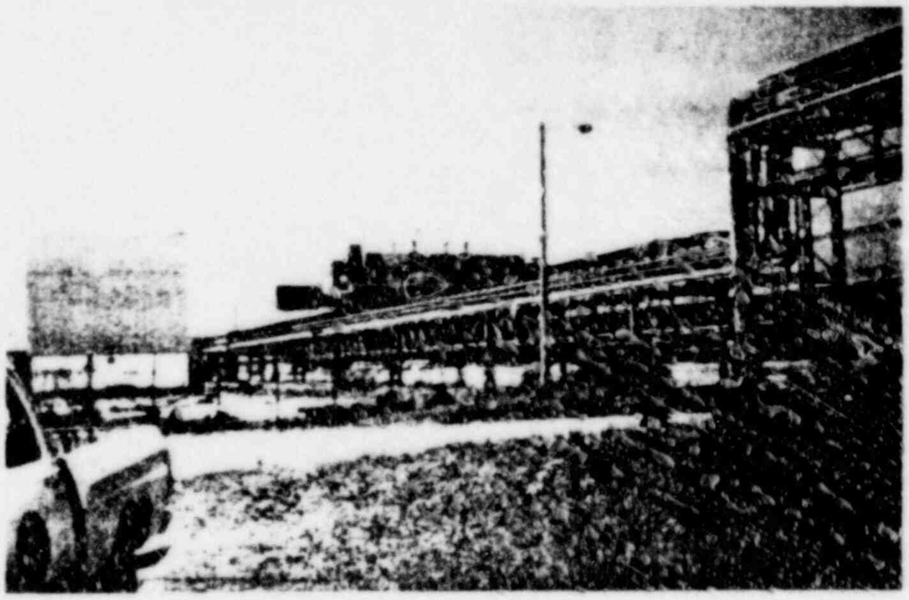
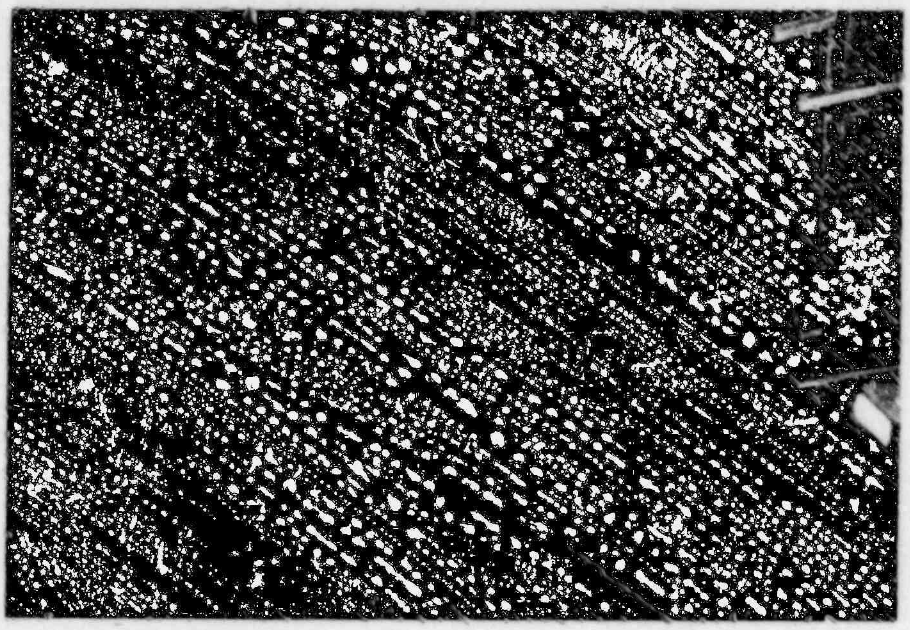


Figure 4.D-10: The extent of continuous runs of cable trays affects the stiffness of the system, and subsequently its response frequencies and mode shapes. Examples of extensive runs include the pole-mounted cable trays routed for over 300 feet through the power house access tunnel at the Infiernillo Hydroelectric Plant, (upper photo). More extreme examples are found at the neighboring SICARTSA Steel Mill (lower photo), where continuous runs of cable trays and piping, supported on racks extend up to a mile between different sections of the plant.



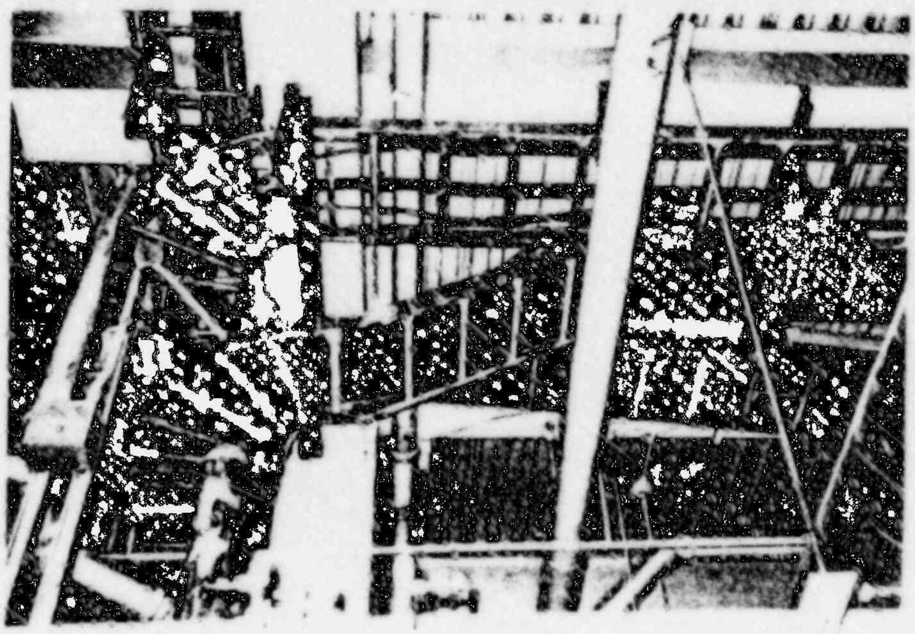
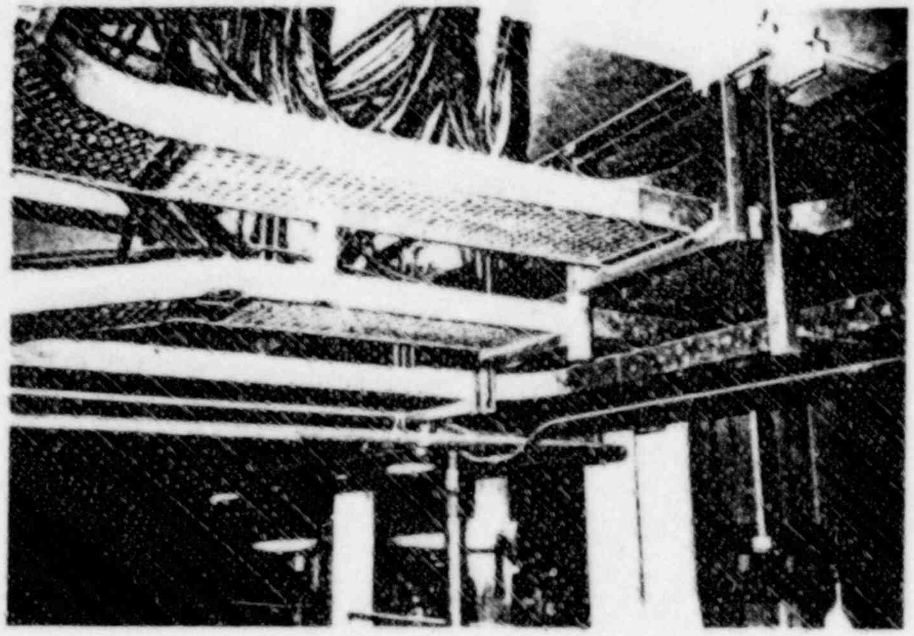


Figure 4.D-11: The relative configuration of adjoining sections of cable trays affects the stiffness, and subsequently the response frequencies and mode shapes of the system. The angles of intersection of adjoining trays and the details of their connections affect the magnitude and direction of the loads imposed by one tray section on another. Examples of diversity in adjoining tray intersections are shown at Las Ventanas Copper Refinery (upper photo), and the El Centro Steam plant (lower photo).



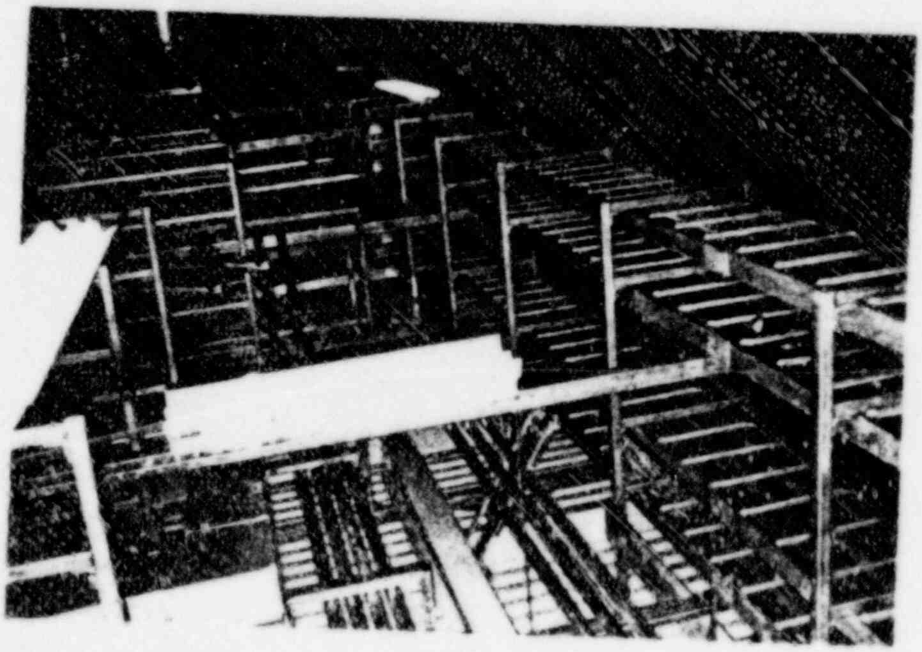
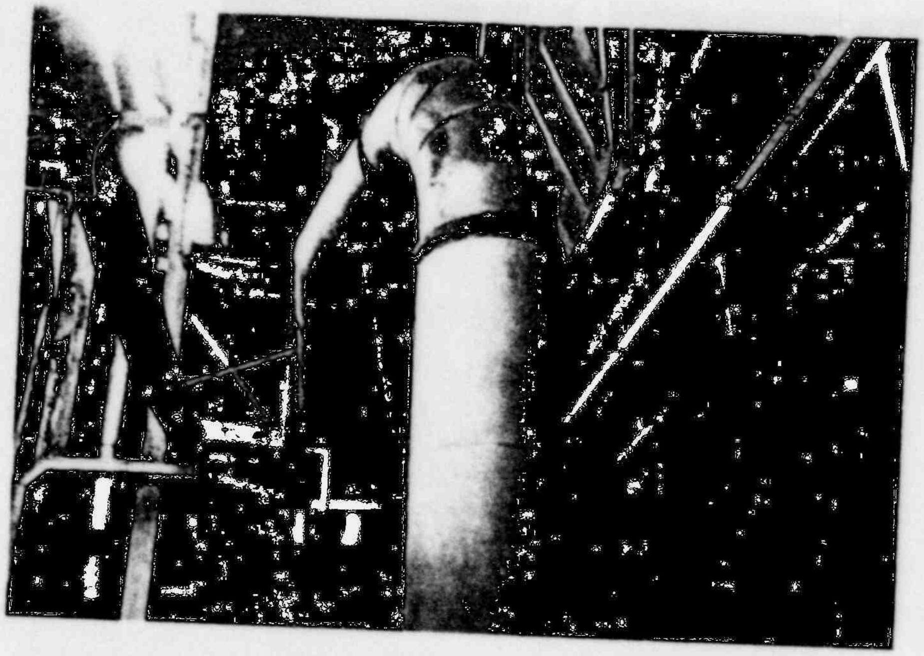


Figure 4.D-12: The complexity of typical data base cable tray configurations is illustrated at the El Centro Steam Plant (upper photo), and the Sylmar Converter Station (lower photo).



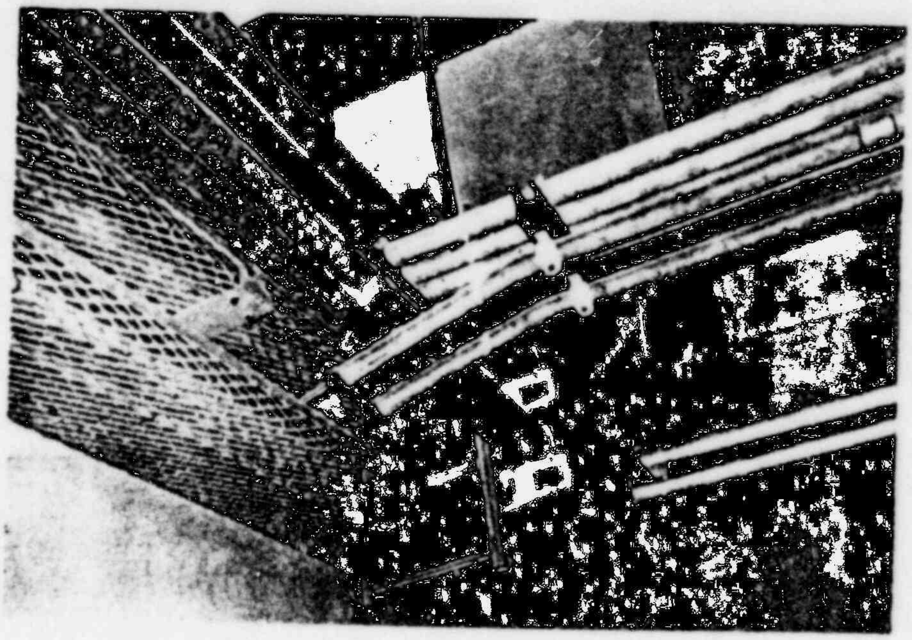


Figure 4.D-13: Data base cable tray configurations typically offer the potential for seismic interaction (impact) with adjacent fixtures, such as piping, at Las Ventanas Copper Refinery (upper photo), and conduit, at the Valley Steam Plant (lower photo). Seismic interaction has never been a source of damage to cable trays in spite of dense configurations and flexible supports of piping, conduit, ducts, and cable trays in data base facilities.

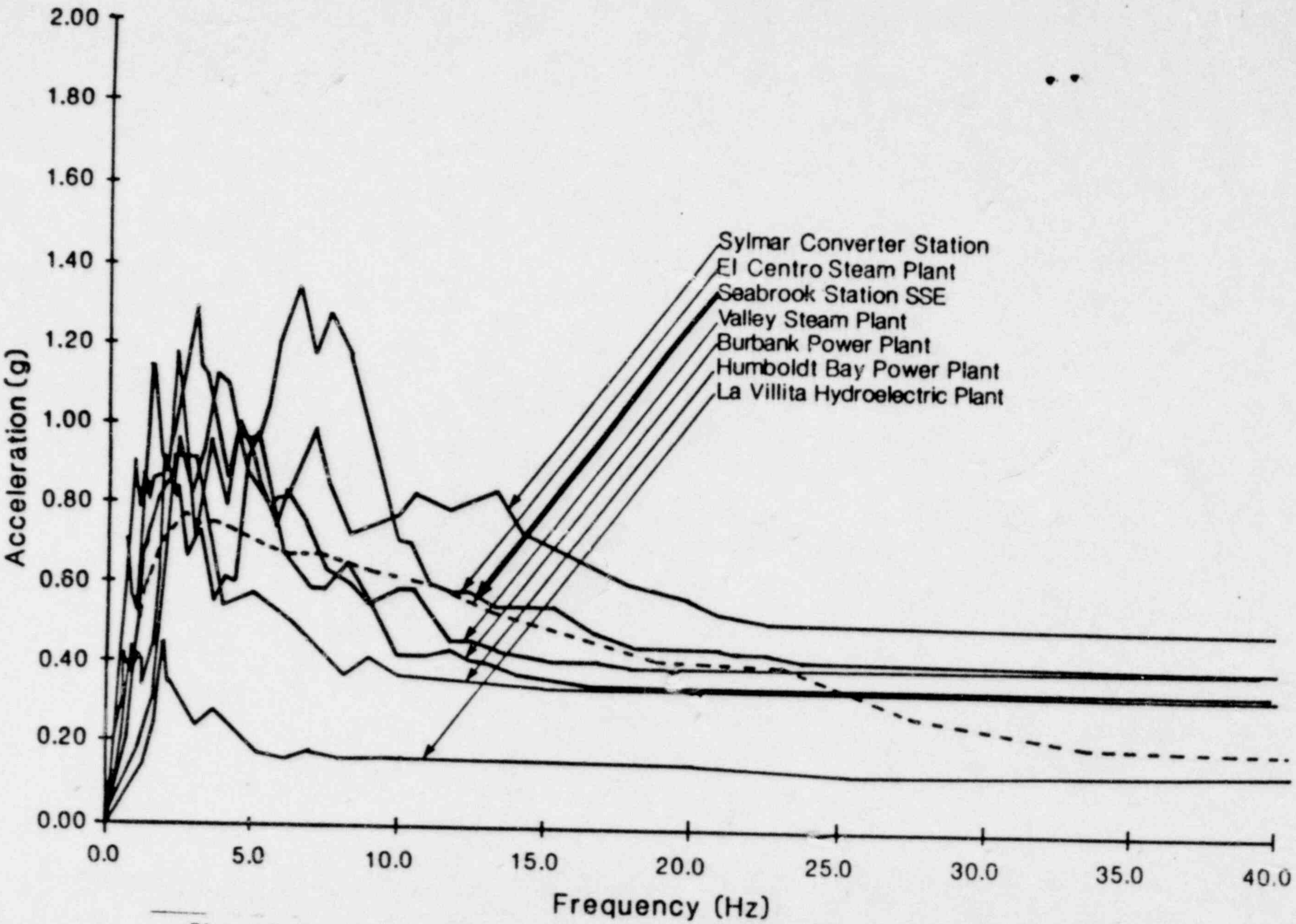


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Figure 4.D-14: Range of data base seismic ground motion response spectra superimposed upon the Seabrook Station SSE (USNRC Regulatory Guide 1.60 Spectrum with PGA=0.25g).