MPR ASSOCIATES, INC.

OYSTER CREEK NUCLEAR GENERATING STATION

SEISMIC ANALYSIS OF 4160 VOLT SWITCHGEAR AND 460 VOLT UNIT SUBSTATION CABINETS

MPR-794

Prepared for:

GPU Nuclear
Parsippany, New Jersey

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1050 CONNECTICUT AVENUE, N.W. WASHINGTON, D.C. 20036 202-659-2320

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1. INTRODUCTION

1.1 PURPOSE

This report presents the results of a seismic analysis of two types of safety-related electrical equipment at the Oyster Creek Nuclear Generating Station: 4160 Volt Switchgear and 460 Volt Unit Substation cabinets. The seismic analysis of this equipment was performed in response to Section 4.11(3) of NUREG-0822 (Integrated Plant Safety Assessment - Seismic Evaluation Program - Oyster Creek Nuclear Generating Station) which requested, in part, that the licensee (GPU Nuclear/JCP&L) perform seismic analysis of the 4160 Volt Switchgear to demonstrate the adequacy of the anchorage. In addition, Section 4.11(3) of NUREG-0822 requested that the licensee perform a seismic load path evaluation for at least two typical electrical cabinets to demonstrate the structural integrity of internally mounted components.

In accordance with the requests of NUREG-0822, this report presents results of anchor adequacy and internal load path evaluations for both the 4160 Volt Switchgear and the 460 Volt Unit Substation cabinets.

1.2 SCOPE

The specific electrical equipment analyzed in this report includes four cabinet units of the 4160 Volt Switchgear (Units 1A, 1B, 1C, and 1D), located in the turbine building at elevation 23'-6", and two cabinet units of the 460 Volt Unit Substation (Units 1A2 and 1B2), located in the reactor

building at elevation 23'-6". Each 4160 Volt Switchgear consists of 9 to 12 individual breaker cabinets mounted side by side and connected mechanically and electrically to form a unit of switchgear equipment. Each 460 Volt Substation consists of seven individual breaker cabinets which are mounted side by side and are connected mechanically and electrically similar to the 4160 Volt cabinets.

The anchor adequacy and load path evaluations described in this report considered the effects of earthquake and dead-weight loads. The seismic input used to evaluate the effects of earthquake loads was based on floor response spectra generated by Lawrence Livermore National Laboratory (revised Appendix B of NUREG/CR-1981), scaled to the zero period acceleration of 0.165 g's recommended by the NRC for use in SEP evaluations.

The anchor adequacy analysis was performed for each of the 4160 volt and 460 volt cabinets described above because of weight and anchor variations between the individual cabinets. The load path evaluations, however, were only performed for single individual 4160 volt and 460 volt cabinets selected based on field examination to be representative of the most limiting configurations.

2. SUMMARY AND CONCLUSIONS

2.1 SUMMARY

Results of the anchor adequacy analyses for the 4160 Volt Switchgear and the 460 Volt Unit Substation cabinets are presented in Table 2-1. This table presents calculated pullout loads (P) and shear loads (V) on the anchors during the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE). The seismic loading consists of the combined effects of two horizontal and one vertical earthquake loads together with deadweight load. The adequacy of the anchors under combined pullout and shear loads was determined from the following linear interaction formula.

$$\frac{P}{P_{max}} + \frac{V}{V_{max}} = \frac{1}{\text{Factor of Safety}}$$

The objective of the analyses was to show that the minimum factor of safety for the combined pullout/shear loading exceed 4.0. The limiting pullout and shear values (P_{max} and V_{max}, respectively) were taken at the mean failure strengths of anchors based on tests performed by Teledyne Engineering Services (Reference a). The limiting pullout and shear values used in this analysis are given in Table 2-1. The limiting values used for anchors in the 460 volt cabinets were based on test data of actual anchors and embedment lengths used in the 460 volt cabinets (1/2" Hilti Kwick-Bolt with 2-1/4" embedment). The limiting values used for anchors in the 4160 volt cabinets were based on the lower bound of the mean failure strengths for seven different 1/2-inch anchors with embedments greater than 2 inches. A lower bound of the test data was used since the anchors in

the 4160 volt cabinets are of unknown type and embedment. (A discussion of embedment length assumptions and test data is presented in Section 3 of this report.)

As shown in Table 2-1, for OBE loads, the calculated pullout/shear load combinations for the 4160 volt and 460 volt cabinets result in minimum factors of safety on anchor failure of 11.15 and 7.35, respectively. For SSE loads, the calculated pullout/shear load combinations for the 4160 volt and 460 volt cabinets result in minimum factors of safety of 4.39 and 3.45, respectively. Although the 460 volt cabinets do not explicitly meet the original objective of a factor of safety of 4.0, because of the conservatisms in the analytical approach used, a factor of 3.45 is considered sufficient margin to assure no anchorage failure during a safe shutdown earthquake. For example, the analysis assumed that the horizontal earthquake acceleration is the peak of the response spectra rather than the actual acceleration associated with each cabinets natural frequency.

Results of the load path evaluations for the 4160 Volt Switchgear and the 460 Volt Unit Substation cabinets are presented in Table 2-2. This table presents calculated stresses in the limiting structural and support members of the typical 4160 volt and 460 volt electrical cabinets. The limiting members were determined from visual inspections of each cabinet type. As shown in Table 2-2, all calculated stresses are well within allowable values (less than 50% of the allowables).

2.2 CONCLUSIONS

Based on analyses presented in this report and summarized in Tables 2-1 and 2-2, the 4160 Volt Switchgear and 460 Volt Unit Substation cabinets are adequately anchored to withstand the effects of the OBE and SSE. In addition, the internal components of these cabinets are adequately mounted such that their structural integrity will be maintained. This satisfies the requirements of Section 4.11(3) of NUREG-0822.

Table 2-1

ANCHOR ADEQUACY RESULTS

OBE LOADS

Equipment	Pullout Load 'P' (lbs)	Shear Load 'V' (lbs)	$P/P_{max} + V/V_{max}$ (Note 1)	Factor of Safety
4160 Volt Switchgear Units:				
1A	(Note 2)	515.5	0.090	11.15
1B	(Note 2)	461.8	0.080	12.45
1C	(Note 2)	368.7	0.064	15.59
1D	(Note 2)	368.7	0.064	15.59
460 Volt Unit Substation Units:				
1A2	314.2	431.5	0.136	7.35
1B2	333.7	384.6	0.135	7.39

SSE LOADS

Equipment	Pullout Load 'P' (lbs)	Shear Load 'V' (lbs)	$P/P_{max} + V/V_{max}$ (Note 1)	Factor of Safety
4160 Volt Switchgear Units:				
1A	272.9	895.7	0.228	4.39
1B	270.6	802.4	0.211	4.75
1C	327.5	640.7	0.198	5.06
1D	275.4	640.7	0.184	5.44
460 Volt Unit Substation Units:				
1A2	763.1	718.2	0.290	3.45
1B2	761.6	640.1	0.279	3.58

NOTES:

1. For anchors on the 4160 volt cabinets, P_{max} = 3,804 lbs and V_{max} = 5,748 lbs (lower bound values for seven different 1/2" anchors with embedment greater than 2"). For anchors on the 460 volt cabinets, P_{max} = 3,804 lbs and V_{max} = 8,076 lbs (1/2" Hilti Kwick-Bolt with 2-1/4" embedment).

2. For OBE, the seismic load was less than the deadweight load. Therefore, there is no net pullout (tensile) load on the anchor bolts.

TABLE 2-2

STRESS ANALYSIS RESULTS FOR INTERNALLY MOUNTED COMPONENTS

OBE LOADS

Equipment	Component (Note 1)	Type of Stress	OBE Load (lbs)	Stress Area (in^2)	Stress (psi)	Allowable Stress (Note 2)
4160 Volt Switchgear	1/8-Inch Welds on Support Angles	Shear	3,920	2.245	1,746	24,360
	1/4 x 2/3-Inch Support Grooves	Shear	1,562	0.330	4,733	19,150
	1/2-Inch Support Rods	Shear	1,562	0.393	3,975	19,150
	Support Angles	Bending	2,503	--	4,378	31,600
460 Volt Unit Substation	1/2-Inch Breaker Pins	Shear	1,188	0.785	1,513	19,150
	1/8 x 3/8-Inch Keys	Shear	586	0.094	6,245	19,150
	1/4-Inch Rivets	Shear	1,188	0.393	3,026	19,150

SSE LOADS

Equipment	Component (Note 1)	Type of Stress	SSE Load (lbs)	Stress Area (in^2)	Stress (psi)	Allowable Stress (Note 2)
4160 Volt Switchgear	1/8-Inch Welds on Support Angles	Shear	4,729	2.245	2,107	24,360
	1/4 x 2/3-Inch Support Grooves	Shear	2,360	0.330	7,150	24,360
	1/2-Inch Support Rods	Shear	2,360	0.393	6,004	24,360
	Support Angles	Bending	2,656	--	4,645	40,600
460 Volt Unit Substation	1/2-Inch Breaker Pins	Shear	1,498	0.785	1,908	24,360
	1/8 x 3/8-Inch Keys	Shear	891	0.094	9,503	24,360
	1/4-Inch Rivets	Shear	1,498	0.393	3,815	24,360

Notes:

1. Locations of each component are shown on Figures 3-3 and 3-4.
2. Structural materials are assumed to have properties similar to ASTM A-36 steel. Allowable stress values are given in Section 3.2.2 of this report.

3. DESCRIPTION OF ANALYSES

This section of the report describes the analyses that were performed for the 4160 Volt Switchgear and the 460 Volt Unit Substation cabinets.

3.1 ANCHORAGE EVALUATION

A typical electrical cabinet and anchorage details are shown in Figure 3-1. The tensile pullout loads and shear loads on the anchors were calculated by taking into account seismic and deadweight loads. Detailed calculations of the anchorage loads are given in Appendix A.

3.1.1 Seismic Loads

In accordance with the methodology described in USNRC Regulatory Guide 1.92, the tensile pullout loads and shear loads due to seismic events were obtained by taking the square root of the sum of the squares (SRSS) of the anchor bolt load directional responses due to three components of earthquake motion (two horizontal and one vertical). Each earthquake loading was considered to act independently of the others. The seismic loads evaluated consist of the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE). Seismic loads are defined by horizontal and vertical response spectra generated by Lawrence Livermore Laboratories (LLL) in the revised Appendix B of NUREG/CR-1981 (Reference b).

Peak horizontal accelerations and the zero period vertical accelerations were taken from the LLL spectra to calculate

anchor bolt loads. The zero period vertical acceleration values were choosen due to the high natural frequencies of the cabinets in the vertical direction resulting from the large vertical stiffnesses of the cabinets. Calculations of cabinet vertical natural frequencies are given in Appendix A. Peak horizontal accelerations were used since the natural frequencies of the cabinets in the horizontal direction are expected to be in the 5-10 Hz range which includes the peak horizontal accelerations. No explicit horizontal natural frequency calculations were performed.

The accelerations were based on damping values of 4% for OBE and 7% for SSE for bolted steel structures in accordance with USNRC Regulatory Guide 1.61. The horizontal and vertical accelerations for the OBE and SSE conditions were multiplied by 0.165/0.22, based on a ZPA at ground of 0.165g's for Oyster Creek versus the ZPA at ground of 0.22g's used in NUREG/CR-1981. The acceleration values used in this analysis are summarized below.

Equipment	Location	OBE - 4% Damping		SSE - 7% Damping	
		Vertical (g's)	Horizontal (g's)	Vertical (g's)	Horizontal (g's)
4160 Volt Switchgear (Units-1A, 1B, 1C, 1D)	Turbine Building El. 23'-6"	0.065	0.47	0.13	0.71
4160 Volt Unit Substation (Units-1A2, 1B2)	Reactor Building El. 23'-6"	0.095	0.69	0.19	1.05

3.1.2 <u>Tensile Pullout Loads</u>

The net anchor bolt pullout loads (P) were calculated by subtracting the average effective deadweight anchor bolt

loads (compressive) from the SRSS seismic anchor bolt loads (tensile).

$$P = \sqrt{P_h(N\text{-}S)^2 + P_h(E\text{-}W)^2 + P_v^2} - P_d$$

P	-	Anchor bolt pullout load
$P_h(N\text{-}S)$	-	Anchor pullout load due to a horizontal earthquake acting in the north-south direction
$P_h(E\text{-}W)$	-	Anchor pullout load due to a horizontal earthquake acting in the east-west direction
P_v	-	Anchor pullout load due to a vertical earthquake
P_d	-	Effective downward load on the anchor due to deadweight

As indicated above, a local horizontal orientation system was defined in this analysis to differentiate between the two horizontal earthquakes (north-south and east-west). The direction reference is shown in Figure 3-1.

Pullout loads due to vertical earthquake motion were calculated by taking the weight of the cabinet times the vertical acceleration divided by the total number of anchor bolts. Pullout loads due to horizontal earthquake motion were calculated based on the assumption that the force reacting the overturning moment in bolt row 'i' is proportional to the distance from the tipping axis and the number of bolts in the row. A derivation of the pullout loads due to horizontal earthquake motion is presented in Figure 3-2. The formulas used to calculate pullout loads from individual earthquake motions are derived in Appendix A and are summarized below.

$$P_v = \frac{W \cdot g_v}{N_t}$$

$$P_h(N\text{-}S) = \frac{W \cdot g_h \cdot H_{cg} \cdot X_i}{\sum_{i=1}^{n} X_i^2 \, N_i}$$

$$P_h(E\text{-}W) = \frac{W \cdot g_h \cdot H_{cg} \cdot X_i}{\sum_{i=1}^{m} X_i^2 \, N_i}$$

Where:

W = Cabinet weight (lb)

g_h = Peak horizontal acceleration (g's)

g_v = ZPA vertical acceleration (g's)

H_{cg} = Distance from floor to cabinet center of gravity (ft)

X_i = Distance measured from the tipping edge to bolt row 'i' (ft)

N_i = Number of bolts in row 'i'

N_t = Total number of anchor bolts in cabinet

The effective anchor deadweight load is

$$P_D = \frac{W}{N_t}$$

which is the total cabinet weight divided by the total number of anchor bolts.

3.1.3 Shear Loads

Shear loads on the anchor bolts are caused by two horizontal earthquake motions. It was assumed in this analysis that the total horizontal seismic load is reacted by: 1) shear across the face of the anchor bolts and 2) friction between

the cabinets and the concrete floor. The formula used to calculate shear (V) on the anchors is derived in Appendix A and given below.

$$V = \frac{W}{N}\left[\underbrace{\sqrt{g_h^2 + g_h^2}}_{\text{Horizontal Seismic Load due to two components of horizontal earthquake motion}} - \underbrace{\mu(1 - g_v)}_{\text{Horizontal Load taken by friction between the cabinet and the and the floor}}\right]$$

The coefficient of friction (μ) between the concrete floor and the cabinet was conservatively assumed to be 0.20.

The calculated pullout and shear values for the 4160 volt and 460 volt cabinets are presented in Table 2-1 in Section 2 of this report.

3.1.4 Acceptance Criteria

A combination of the effects of pullout and shear loads were used in the criteria to evaluate cabinet anchor adequacy. The criteria were based on actual test data compiled by Teledyne Engineering Services for JCP&L and other utilities. Teledyne tested the combined pullout (P) and shear (V) behavior of a large number of anchor bolts of many sizes and types. Based on the lower bound of this test data, a linear interaction model was developed as follows:

$$\frac{P}{P_{max}} + \frac{V}{V_{max}} = \frac{1}{\text{F. of S.}}$$

Where:

P_{max} - mean failure pullout strengths
V_{max} - mean failure shear strengths
F. of S. - Factor of Safety

The objective was that the anchorages meet a minimum factor of safety of 4.0 for the SSE loading combination.

The use of the mean failure value for a test rather than the minimum failure value of any one bolt within a test in the interaction formula is considered appropriate in evaluating the anchor bolt strength of the 4160 volt and 460 volt cabinets since the cabinets are held down by a fairly large number of anchor bolts (i.e., a minimum of 39 for the 4160 volt cabinets and a minimum of 28 for the 460 volt cabinets). Thus, the overall strength of the anchorage for the 4160 volt cabinets and 460 volt cabinets would be governed by the mean failure strength of all the anchor bolts; not the minimum failure strength of any one anchor bolt.

5. Values of P_{max} and V_{max}

The pullout and shear failure values, P_{max} and V_{max}, used in the analysis are summarized below.

Equipment	Anchor Description	P_{max} (lb)	V_{max} (lb)
4160 Volt Switchgear	Size - 1/2-inch Type - ? Embedment - ?	3,804	5,748
460 Volt Unit Substation	Size - 1/2-inch Type - Hilti Kwick-Bolt Embedment - 2-1/4-inches	3,804	8,076

The type of anchor used in the 460 volt cabinets, the anchor size, and the anchor embedment are the same as one of the anchor bolt conditions tested by Teledyne. The values of

P_{max} and V_{max} were therefore taken as the mean failure strengths reported by Teledyne in Reference a.

The type and embedment length of the 1/2-inch anchor bolts used in the 4160 volt cabinets are unknown. In order to select conservative mean failure strengths for these anchors, actual Teledyne test data were reviewed in an attempt to set limits at the lower bound of the mean failure strengths representing many anchor types for reasonable conditions of embedment. Review of the Teledyne data indicated that, especially for 1/2-inch anchors, embedment is the dominant factor influencing pullout strength. Anchors embedded greater than 2 inches showed considerably higher pullout resistance than anchors embedded 2 inches or less. Based on JCP&L/GPUN installation specifications and vendor literature, it was concluded that for the original plant construction, as well as for the newly installed 1/2-inch anchors, the anchor embedment was probably greater than 2 inches. The values of P_{max} and V_{max} were therefore based on the lower bound test data for all the 1/2-inch anchors tested with embedments greater than 2 inches (Teledyne tested nine 1/2-inch anchor types, seven of which were embedded greater than 2 inches.)

Using the P_{max} and V_{max} values discussed above, the results of anchor adequacy analyses using the linear interaction model are calculated and presented in Table 2-1 in Section 2 of this report.

3.2 LOAD PATH EVALUATION

Typical breaker cabinets and the breaker internal support structures for the 4160 Volt Switchgear and the 460 Volt Unit Substation cabinets are shown on Figures 3-3 and 3-4,

respectively. Visual inspections of the cabinets were made to determine the load paths and limiting components in each structure. Calculations of the stresses in the limiting components for the 4160 Volt Switchgear cabinets are presented in Appendix B. Calculations of the stresses in the limiting components for the 460 Volt Unit Substation cabinets are presented in Appendix C.

3.2.1 Description of Load Paths

4160 Volt Switchgear

The 4160 Volt Switchgear consists of 9 to 12 individual cabinets which are mounted side by side and connected mechanically and electrically to form a unit of switchgear equipment. As shown in Figure 3-3, the main component of each cabinet is a 1000 amp or 3000 amp breaker. The breaker is mounted in a steel frame on wheels to allow easy removal, maintenance, and replacement. During installation, the breaker is rolled into a cabinet until the support angles on both sides of the breaker frame are aligned with the support boxes in the cabinet. The support boxes are mounted on mechanically driven power screws. Once the breaker is properly aligned, the power screws are used to raise the breaker by means of the support boxes until the receptacles on the top of the breaker engage with the cabinet. The breaker is held horizontally by means of two 0.25x2.83-inch lugs on the support angles which are fixed in grooves provided in the support boxes.

Vertical seismic and deadweight loads are transmitted from the breaker to the cabinet wall panels through a) 0.125-inch fillet welds between the breaker frame and support angle, b)

support angles, and c) support boxes. Horizontal seismic loads are transimtted from the breaker to the cabinet wall panels through a) 0.125-inch fillet welds between the breaker frame and support angle, b) support angle lugs, c) support box grooves, d) support boxes, and e) support rods.

Stresses were evaluated in the following limiting components:

- Shear on the 0.125-inch welds connecting the support angles to the breaker frame.
- Bending of the support angles.
- Shear across the 0.25 x 0.66-inch tip of the support box grooves.
- Shear on the 0.500-inch diameter support rods.

Since the support structures for the 1000 amp and 3000 amp breakers are identical, the stress analysis for the limiting components was performed for the heavier 3000 amp breaker.

<u>460 Volt Unit Substation</u>

The 460 Volt Unit Substation cabinets, consist of seven cabinets mounted side by side and connected mechanically and electrically to form a single unit of equipment, similar to the 4160 Volt Switchgear. Each cabinet contains three breakers mounted individually one atop the other. As shown in Figure 3-4, each breaker has four 0.500-inch pins mounted two on each side. The support mechanism inside the cabinet consists of two sliding rails, one on each side of the cabinet, with slots provided for the 0.500-inch breaker pins. The sliding rails move on fixed rails which are mounted to the sides of the cabinet by eight rivets (four on each side).

During installation of the breaker, the sliding rails are extended out of the cabinet. The breaker is placed in the slots provided in the sliding rails and slid into the cabinet until the receptacles in the back of the breaker engage with the back of the cabinet. Once the breaker is engaged, two keys, attached to the sliding rails, insert into the fixed rails to lock the breaker in the cabinet.

Vertical seismic and deadweight loads are transmitted from the breaker to the cabinet wall panels through a) breaker pins, b) sliding rails, c) fixed rails, and d) rivets. Horizontal seismic loads are transmitted from the breaker to the cabinet wall panels through a) breaker pins, b) sliding rails, c) keys, d) fixed rails, and e) rivets.

Stresses were evaluated in the following limiting components:

- Shear on the four 0.500-inch breaker pins.
- Shear on the two 0.125 x 0.375 inch keys.
- Shear on the eight 0.250-inch rivets.

3.2.2 Loads

The loads used in the evaluation of the internally mounted components of the electrical cabinets consisted of seismic and deadweight loads. The seismic loads consist of the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE). The OBE and SSE accelerations used for each cabinet were discussed in Section 3.1. The deadweight loads of the individual breakers are listed below.

Equipment	Weight (lb)
Breaker for 4160 Volt Switchgear (3000 AMP)	2350
Breaker for 460 Volt Unit Substation	600

The seismic accelerations given in Section 3.1 were used with the breaker weights to develop loads on the internal components of the cabinets. The various load combinations that are transmitted through the limiting components of the cabinets are described below.

Load Combination	Description	Resulting Loads
Vertical Loads	Vertical Seismic + Deadweight	$W\ (g_v + 1)$
Horizontal Loads	Horizontal Seismic (Two Components of Horizontal Earthquake)	$W \sqrt{{g_h}^2+{g_h}^2}$
Horizontal + Vertical Loads	Horizontal Seismic + Vertical Seismic + Deadweight	$W\left(\sqrt{{g_h}^2+{g_h}^2+{g_v}^2}\ +1\right)$

The limiting load components for each cabinet, the type of load transmitted, and the resulting loads are summarized on Table 3-1.

The calculated stresses and allowable values are presented in Table 2-2 in Section 2 of this report. The structural material in each cabinet was assumed to have properties

similar to ASTM A-36 carbon steel. The minimum yield and ultimate tensile values of A-36 and the allowable stresses in shear and bending are summarized below.

Material	Minimum Yield 'Sy'	Minimum Ultimate 'Su'
A-36 Carbon Steel	36,000 psi	58,000 psi

Loads	Service Levels	Stress Limit		Allowable Value (psi)
OBE (Note 1)	Level B	Shear	1.33 (0.4 Sy) or 0.42 Su	19,150
		Bending	1.33 (0.66 Sy)	31,600
		Weld Shear	1.33 (21,000) or .42 Su	24,360
SSE (Note 1)	Level D	Shear	2.0 (0.4 Sy) or 0.42 Su	24,360
		Bending	2.0 (0.66 Sy) or 0.7 Su	40,600
		Weld Shear	2.0 (21,000) or .42 Su	24,360

NOTES:

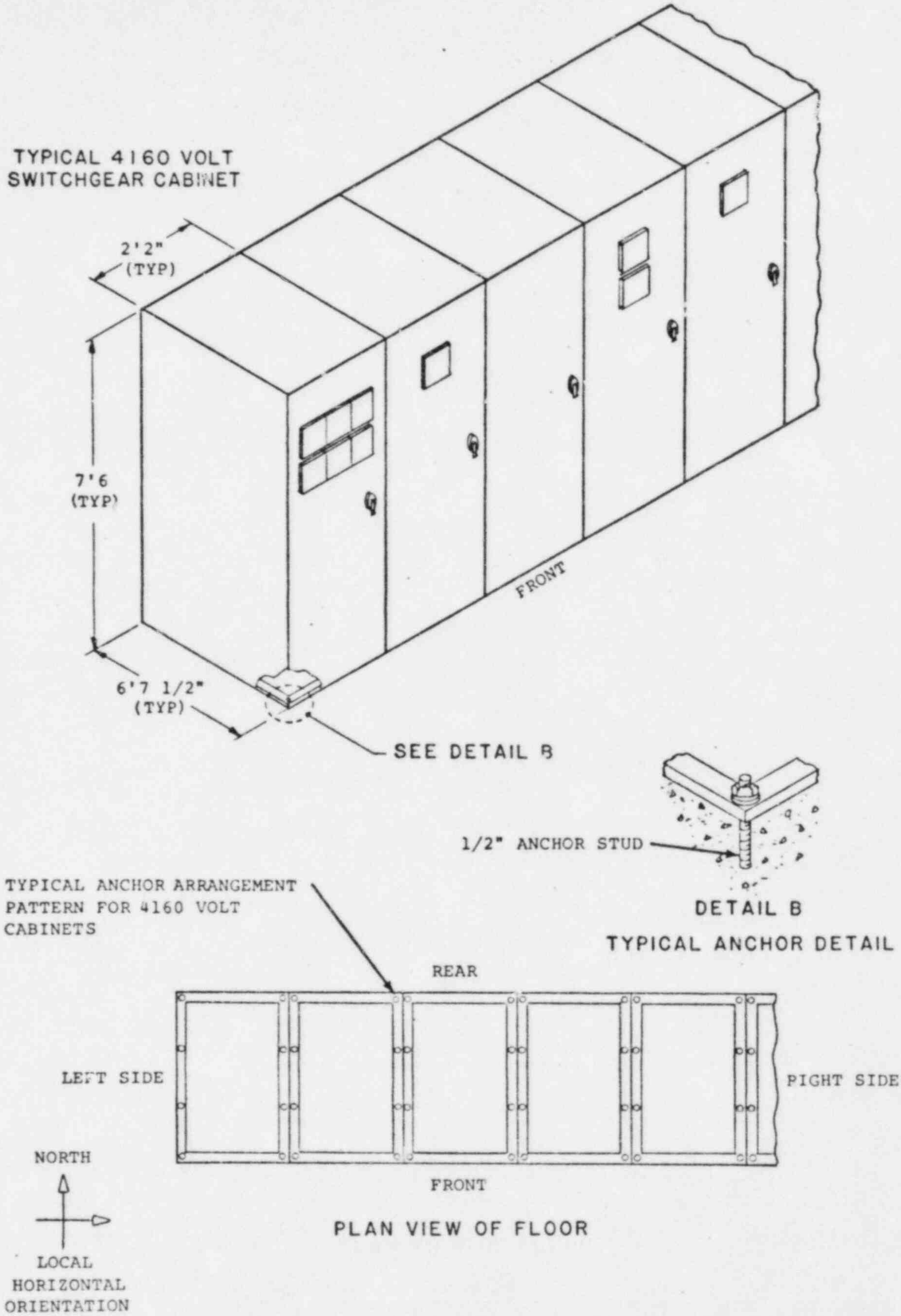
1. The allowable stress value is taken as the lesser of the two stress limits.

Allowable values of stress are taken from the ASME Boiler and Pressure Vessel Code, Section III, Subsection NF, "Component Supports," 1983 Edition. Allowable values of stress for component supports are taken from NF-3320. Allowable values of stress in welds are taken from NF-3324.5.

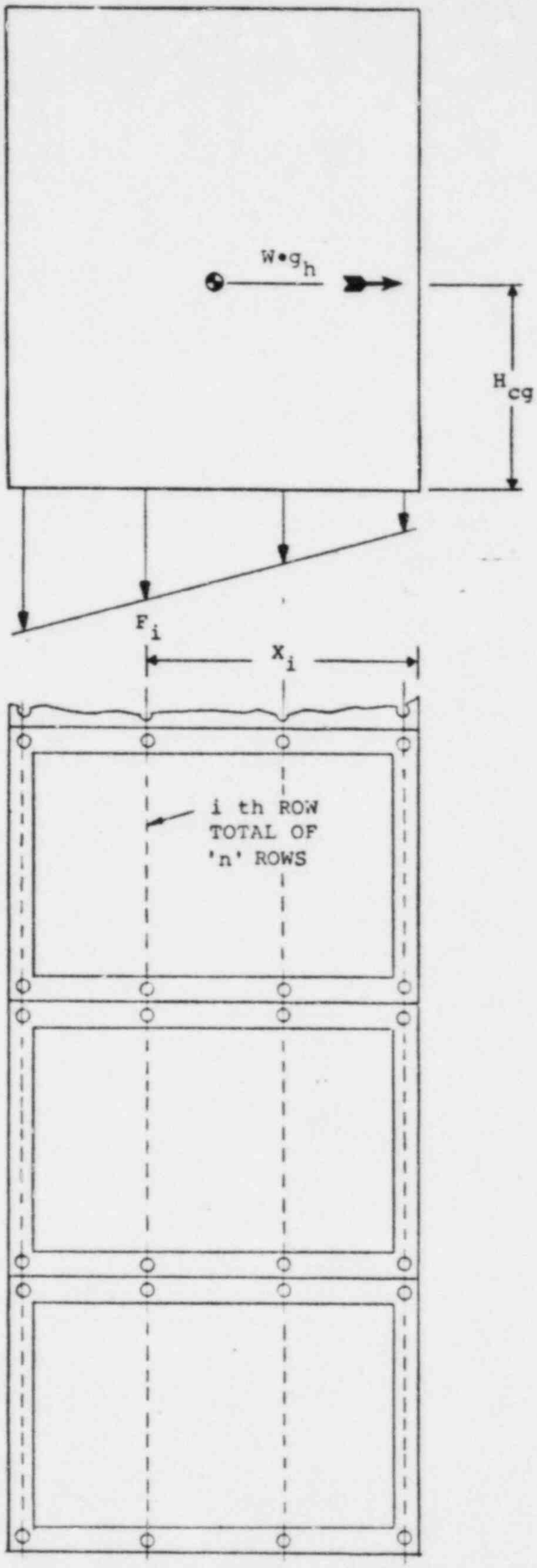
TABLE 3-1

LIMITING LOAD COMPONENTS AND
TYPE OF LOAD TRANSMITTED THROUGH EACH

Equipment	Component	Type of Load Transmitted	Resulting Loads	
			OBE (lbs)	SSE (lbs)
4160 Volt Switchgear	Shear on 0.125-Inch Welds	Horizontal + Vertical	3920	4729
	Shear on 0.25 x 0.67-Inch Support Grooves	Horizontal	1562	2360
	Shear on 0.500-Inch Support Rods	Horizontal	1562	2360
	Bending on Support Angles	Vertical	2503	2656
460 Volt Unit Substation	Shear on 0.500-Inch Breaker Pins	Horizontal + Vertical	1188	1498
	Shear on 0.125 x 0.375-Inch Keys	Horizontal	586	891
	Shear on 0.250-Inch Rivets	Horizontal + Vertical	1188	1498



TYPICAL
ELECTRICAL CABINET LAYOUT AND ANCHOR DETAILS
FIGURE 3-1



M_e = OVERTURNING MOMENT :

$$W \bullet g_h \bullet H_{cg}$$

M_r = REACTING MOMENT :

$$\sum_{i=1}^{n} F_i \bullet X_i$$

BY ASSUMING THE FORCE IN ROW 'i' IS PROPORTIONAL TO THE DISTANCE FROM THE TIPPING AXIS AND THE NUMBER OF BOLTS IN THE ROW (N_i):

$$F_i \propto X_i \bullet N_i$$

$$F_i = K \bullet X_i \bullet N_i \qquad (1)$$

WHERE 'K' IS SOME CONSTANT :

$$M_r = K \bullet \sum_{i=1}^{n} X_i^{\,2} \bullet N_i$$

SETTING :

$$M_r = M_e$$

$$W \bullet g_h \bullet H_{cg} = K \bullet \sum_{i=1}^{n} X_i^{\,2} \bullet N_i \qquad (2)$$

FROM EQUATION (1) ABOVE:

$$K = (F_i / N_i)\ (1/X_i)$$

AND

F_i / N_i = INDIVIDUAL ANCHOR PULLOUT LOAD 'P'

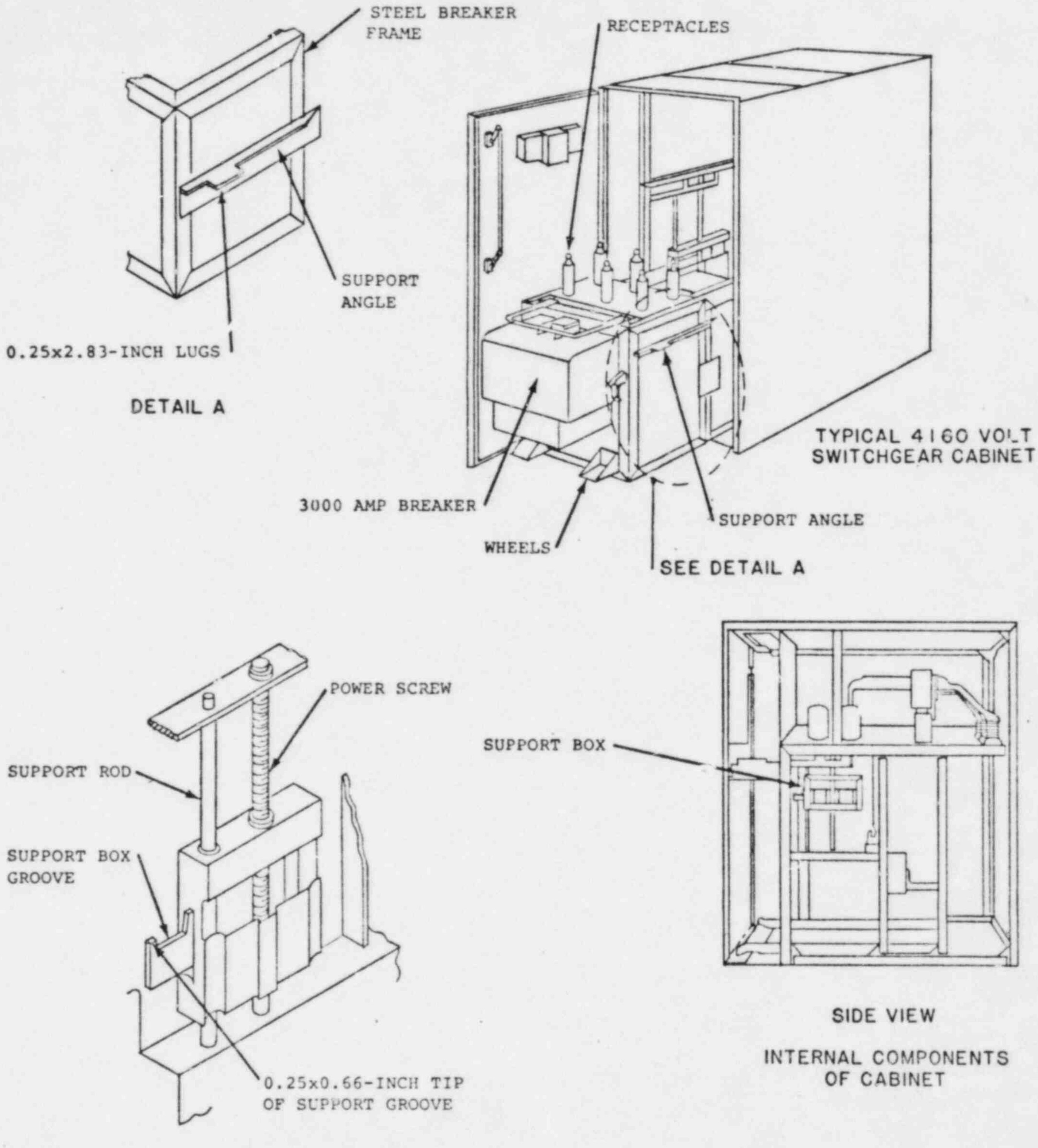
$$K = P \bullet (1/X_i)$$

SUBTITUTING IN TO EQUATION (2) GIVES

$$P = \frac{W \bullet g_h \bullet H_{cg} \bullet X_i}{\sum_{i=1}^{n} X_i^{\,2} \bullet N_i}$$

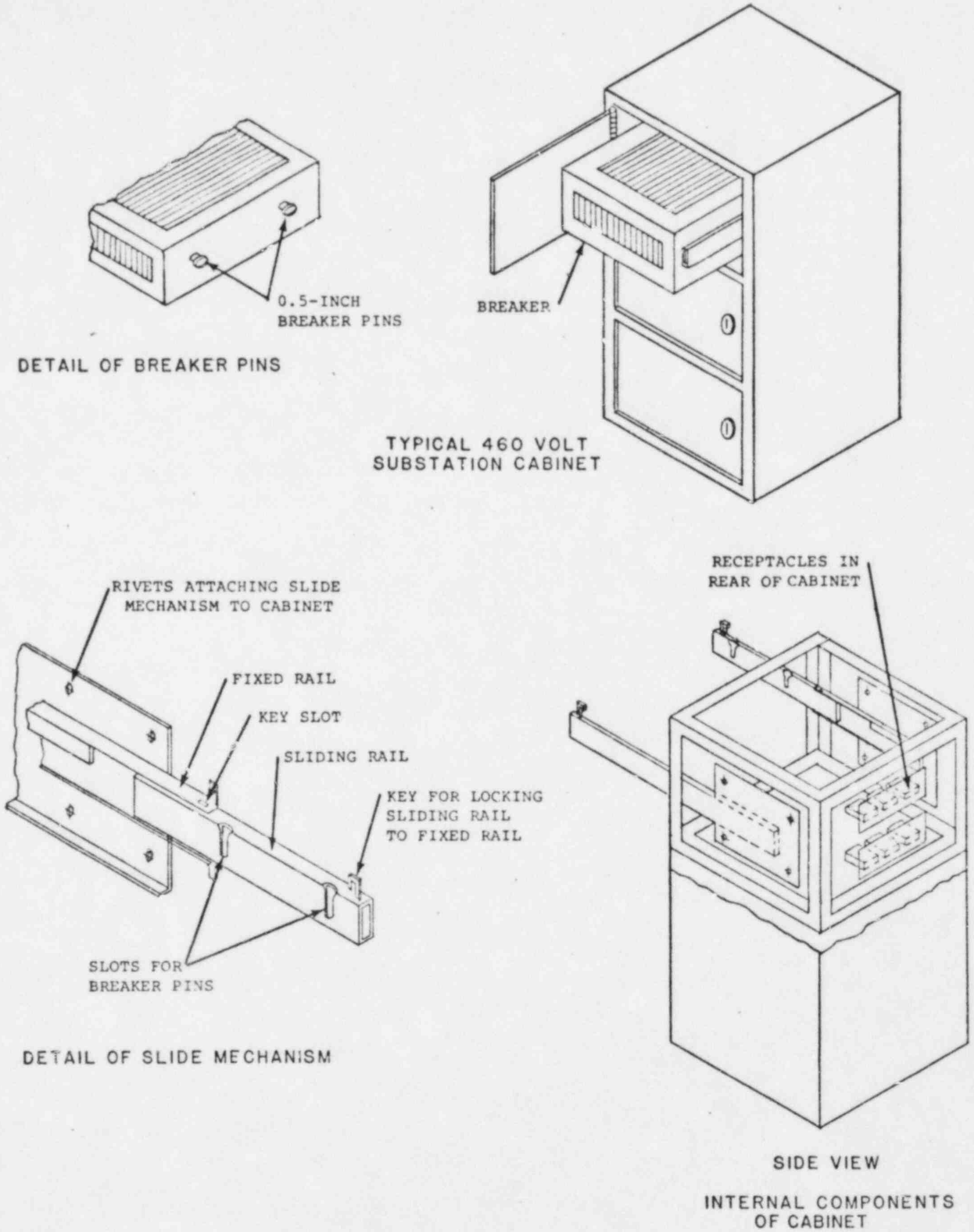
DERIVATION OF PULLOUT LOAD 'P'
DUE TO HORIZONTAL EARTHQUAKE MOTION

FIGURE 3-2



4160 VOLT SWITCHGEAR CABINET

FIGURE 3-3



460 VOLT UNIT SUBSTATION CABINET

FIGURE 3-4

4. REFERENCES

a. Teledyne Summary Report, TR-3501-2, "Generic Response to USNRC I&E Bulletin Number 79-02 Base Plate/Concrete Expansion Anchor Bolts," August 30, 1979.

b. NUREG/CR-1981, UCRL-53018, "Seismic Review of the Oyster Creek Nuclear Power Plant as Part of the Systematic Evaluation Program," April 1981. (Revised Appendix B. Received June 25, 1981, from LLL letter to MPR (W. Schmidt) dated June 23, 1981, Letter # SM-81-159.)

5. APPENDICES

APPENDIX A

EVALUATION OF CABINET ANCHORAGE

APPENDIX A

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

Title: EVALUATION OF CABINET ANCHORAGE	Calculated by: R. J. Lloyd	Date: 9-9-83
	Checked by: [illegible]	Date: 9/13/83
	Reviewed by: [illegible]	Date: 9/14/83

Project: OC SEP 83-03

PURPOSE

THE FOLLOWING CALCULATION IS USED TO VERIFY THE ADEQUACY OF THE ANCHORAGE OF THE 4160 VOLT AND 460 VOLT ELECTRICAL CABINETS AT THE OYSTER CREEK STATION.

RESULTS

RESULTS OF ANALYSES, PRESENTED IN TABLE 1, INDICATE THAT THE EQUIPMENT DESCRIBED ABOVE ARE SUITABLY ANCHORED TO WITHSTAND A OPERATING BASIS EARTHQUAKE (OBE) WITH A PULL OUT /SHEAR SAFETY FACTOR BETWEEN 7.35 AND 15.59. THE PULL OUT / SHEAR SAFETY FACTOR FOR A SAFE SHUTDOWN EARTHQUAKE (SSE) RANGES FROM 3.45 TO 5.44.

RESULTS

VERIFICATION OF ANCHOR ADEQUACY WAS BASED ON THE PULL OUT / SHEAR INTERACTION ACCEPTANCE CRITERIA SHOWN BELOW:

$$\frac{P}{P_{MAX}} + \frac{V}{V_{MAX}} = \frac{1}{\text{FACTOR OF SAFETY}}$$

RESULTS FROM THE ABOVE CRITERIA ARE:

EQUIPMENT	FACTOR OF SAFETY	
	OBE	SSE
4160 VOLT - UNIT 1A	11.15	4.39
4160 VOLT - UNIT 1B	12.45	4.75
4160 VOLT - UNIT 1C	15.59	5.06
4160 VOLT - UNIT 1D	15.59	5.44
460 VOLT - UNIT 1A2	7.35	3.45
460 VOLT - UNIT 1B2	7.39	3.58

THE OBJECTIVE WAS TO SHOW THAT MINIMUM FACTORS OF SAFETY EXCEED 4.0.

RESULTS (CONT)

THE ANCHOR ADEQUACY WAS BASED ON THE ASSUMPTION THAT THE MINIMUM EMBEDMENT FOR ANCHORS ON THE 4160 CABINETS IS GREATER THAN 2.0 INCHES. BASED ON THE LOWER BOUND OF PULL OUT AND SHEAR DATA FOR VARIOUS DIFFERENT ANCHOR TYPES WITH EMBEDMENT GREATER THAN 2.0 INCHES, THE PULL OUT AND SHEAR VALUES USED FOR ANCHORS ON THE 4160 CABINETS WAS 3,804 lbs AND 5,748 lb RESPECTIVELY. PULL OUT AND SHEAR VALUES FOR THE 460 CABINETS ARE BASED ON TEST DATA FOR THE ACTUAL 1/2 ANCHOR (HILTI KWICK-BOLT) EMBEDED 2 1/4 INCHES, AND ARE 3,804 lbs AND 8,076 lbs, RESPECTIVELY.

APPROACH

PER METHODOLOGY DESCRIBED IN NUCLEAR REGULATORY COMMISION, REGULATORY GUIDE 1.92 (REFERENCE 1), THE TENSILE PULL OUT LOADS (P) AND SHEAR LOADS (V) DUE TO SEISMIC LOADING WILL BE FOUND BY TAKING THE SQUARE ROOT OF THE SUM OF THE SQUARES OF THE BOLT LOAD CODIRECTIONAL RESPONSES DUE TO THREE COMPONENTS OF EARTHQUAKE MOTION (2 HORIZONTAL AND 1 VERTICAL).

$$P_S = \sqrt{(P_{N-S})^2 + (P_{E-W})^2 + (P_Y)^2}$$

P_S = TOTAL SEISMIC TENSILE PULL OUT LOAD

P_{N-S} = PULL OUT LOAD DUE TO NORTH-SOUTH HORIZONTAL EARTHQUAKE

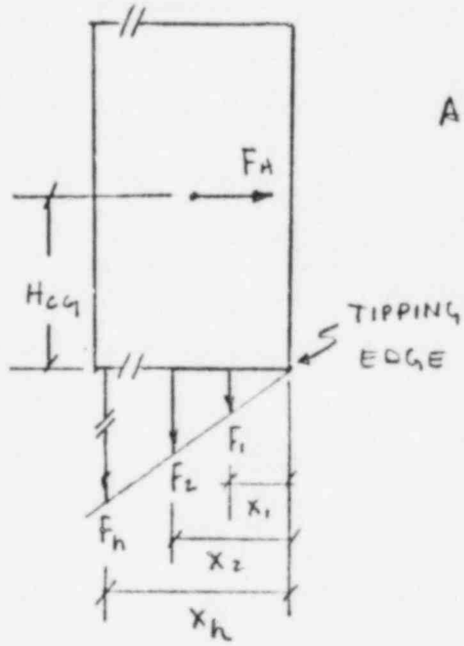
P_{E-W} = PULL OUT LOAD DUE TO EAST-WEST HORIZONTAL EARTHQUAKE

P_V = PULL OUT LOAD DUE TO VERTICAL EARTHQUAKE.

EACH EARTHQUAKE IS CONSIDERED TO ACT INDEPENDENTLY OF THE OTHERS.

PULL OUT LOADS DUE TO HORIZONTAL EARTHQUAKE

IT IS ASSUMED THAT THERE ARE N_i BOLTS IN EACH ROW OF THE CABINETS AT A DISTANCE X_i FROM THE TIPPING EDGE. THERE ARE A TOTAL OF n ROWS.



APPLIED MOMENT (M_A)

$$M_A = F_H \cdot H_{CG}$$

$$= W \cdot g_H \cdot H_{CG}$$

W = CABINET WEIGHT (lbs)

g_H = HORIZONTAL ACCELERATION (g's)

H_{CG} = DISTANCE FROM TIPPING EDGE TO CENTER OF GRAVITY (ft)

REACTING MOMENT (M_R)

$$M_R = F_1 x_1 + F_2 x_2 + \ldots F_n x_n$$

ASSUME BOLT LOAD IS PROPORTIONAL TO THE DISTANCE FROM THE TIPPING EDGE AND THE NUMBER OF BOLTS IN EACH ROW.

$$F_i \propto x_i N_i \Rightarrow F_i = K x_i N_i$$

$$M_R = K x_1^2 N_1 + K x_2^2 N_2 + \ldots K x_n^2 N_n$$

THEREFORE:

$$M_R = K \sum_{i=1}^{n} x_i^2 N_i$$

EQUATING THE MOMENTS:

$$M_R = M_A$$

$$K \sum_{i=1}^{n} x_i^2 N_i = W \cdot g_H \cdot H_{CG}$$

$$K = \frac{W \cdot g_H \cdot H_{CG}}{\sum_{i=1}^{n} x_i^2 N_i}$$

P_i = LOAD PER BOLT IN ROW i = $\frac{F_i \text{ (TOTAL LOAD IN ROW)}}{N_i \text{ (NO. OF BOLTS IN ROW)}}$

$$P_i = \frac{K x_i \cancel{N_i}}{\cancel{N_i}} = \frac{W \cdot g_H \cdot H_{CG} \cdot x_i}{\sum_{i=1}^{n} x_i^2 N_i}$$

$$P_i = \frac{W \cdot g_H \cdot H_{CG} \cdot x_i}{\sum_{i=1}^{n} x_i^2 N_i}$$

PULL OUT LOAD DUE TO VERTICAL EARTHQUAKE

$$P_V = \frac{W \cdot g_v}{N}$$

WHERE:

P_V = VERTICAL PULL OUT LOAD PER BOLT

W = CABINET WEIGHT (lbs)

g_V = VERTICAL ACCELERATION (g's)

N = TOTAL NUMBER OF ANCHORS IN CABINET

SHEAR LOAD (V)

IT IS ASSUMED THAT SHEAR LOADS CAUSED HORIZONTAL EARTHQUAKE LOADS ARE TAKEN BY:

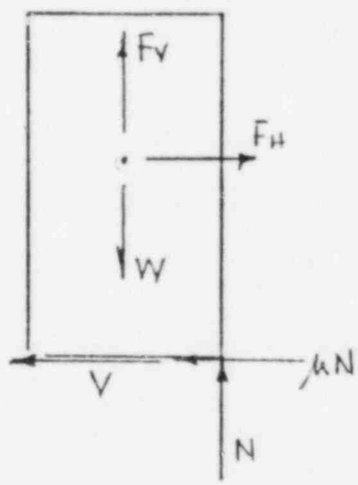
1) SHEAR ACROSS THE ANCHOR BOLTS AND

2) FRICTION BETWEEN THE CABINETS AND THE CONCRETE FLOOR.

A CONSERVATIVE FRICTION COEFFICIENT BETWEEN THE FLOOR

AND THE CABINET WAS ASSUMED AS:

$\mu = 0.20$



N' = NORMAL LOAD ON CABINET

$N' = W - F_V = W - W \cdot g_V$

$N' = W(1 - g_V)$

V = TOTAL SHEAR LOAD ON ALL ANCHORS IN CABINET $= F_H - \mu N'$

F_H = HORIZONTAL SEISMIC LOAD DUE TO 2 COMPONENTS OF HORIZONTAL ACCELERATION

$$= W\sqrt{g_H^2 + g_H^2}$$

$$V = W\left[\sqrt{g_H^2 + g_H^2} - \mu(1 - g_V)\right]$$

THE SHEAR LOAD PER BOLT IS:

$$V = W\left[\sqrt{g_H^2 + g_H^2} - \mu(1 - g_V)\right] \Big/ N$$

N = No. OF ANCHORS IN CABINET

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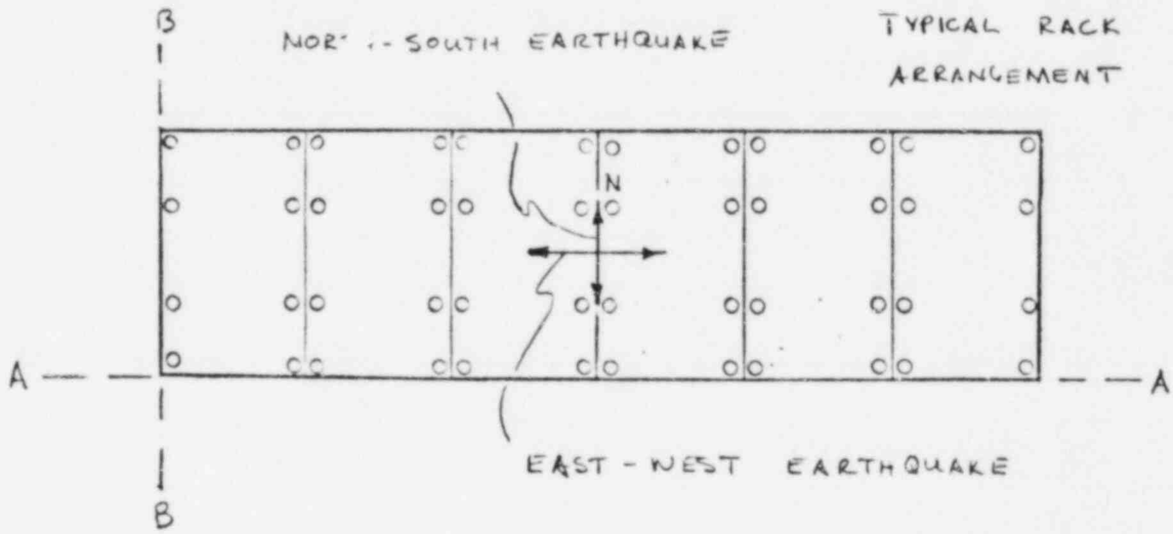
	Reviewed by: JJ	Date: 9-14-83

Project: 83-03

SUMMARY OF LOADS



$$P_{N-S} = \frac{M_A x_i}{\sum_i x_i^2 N_i} = W \cdot g_H \cdot H_{cg} \cdot \left(\frac{x_i}{\sum_i x_i^2 N_i} \right)_{A\text{-}A\ AXIS}$$

$$P_{E-W} = \frac{M_A x_i}{\sum_i x_i^2 N_i} = W \cdot g_H \cdot H_{cg} \cdot \left(\frac{x_i}{\sum_i x_i^2 N_i} \right)_{B\text{-}B\ AXIS}$$

$$P_V = W \cdot g_V / N$$

THE MAXIMUM SHEAR LOAD IS GIVEN BY

$$V = W\left[\sqrt{g_H^2 + g_H^2} - \mu(1 - g_V)\right] / N$$

SEISMIC LOADS

SEISMIC ANALYSIS IS BASED ON USING THE PEAK HORIZONTAL ACCELERATION AND ZERO PERIOD VERTICAL ACCELERATION FROM LAWRENCE LIVERMORE LABORATORY RESPONSE SPECTRA GIVEN IN REVISED APPENDIX B OF NUREG/CR-1981 (REFERENCE 2). JUSTIFICATION FOR USING THE ZPA IN THE VERICAL DIRECTION IS BASED ON THE ASSUMPTION THAT THE VERTICAL STIFFNESS IS LIMITED BY THE ANCHOR BOLTS.*

* ATTACHMENT A, AT THE END OF THIS CALCULATION, CONTAINS A CALCULATION TO JUSTIFY THE USE OF THE ZPA IN THE VERTICAL DIRECTION.

SEISMIC LOADS - TURBINE BUILDING (EL 23'-6")

	OBE (NOTE 1)	SSE (NOTE 2)
HORIZONTAL (g_H) - g's	0.47	0.71
VERTICAL (g_V) - g's	0.065	0.13

SEISMIC LOADS - REACTOR BUILDING (EL 23'-6")

	OBE (NOTE 1)	SSE (NOTE 2)
HORIZONTAL (g_H) - g's	0.69	1.05
VERTICAL (g_V) - g's	0.095	0.19

NOTES:

1. DEVELOPED FROM REFERENCE 2 CURVES x (.165/.22) x 0.5 (FOR OBE) @ 4% DAMPING - HORIZONTAL TAKEN AT PEAK VALUE - VERTICAL TAKEN AT ZPA. 4% DAMPING FOR BOLTED STEEL STRUCTURES IN REG GUIDE 1.61 (REF 3).
2. DEVELOPED FROM REFERENCE 2 CURVES x (.165/.22) @ 7% DAMPING - HORIZONTAL TAKEN AT PEAK VALUE - VERTICAL TAKEN AT ZPA. 7% DAMPING FOR BOLTED STEEL STRUCTURES IN REG GUIDE 1.61 (REF. 3).

ACCEPTANCE CRITERIA.

THE ACCEPTANCE CRITERIA USED TO VERIFY ANCHOR ADEQUACY IS BASED ON THE LINEAR PULL OUT / SHEAR INTERACTION EQUATION BELOW:

$$P/P_{MAX} + V/V_{MAX} \cdot 1/\text{FACTOR OF SAFETY}$$

WHERE:

$$P = P_S - D\,(\text{DEADWEIGHT})$$
$$= P_S - W/N$$

THE P_{MAX} AND V_{MAX} NUMBERS USED IN THIS ANALYSIS ARE MEAN FAILURE STRENGTH NUMBERS FROM TELEDYNE ENGINEERING TESTS TAKEN FROM TELEDYNE SUMMARY REPORT, TR-3501-2, (REFERENCE 5). THE VALUES CHOSEN FOR THE 1/2 INCH BOLTS OF THE 4160

VOLT CABINETS ARE BASED ON MINIMUM TEST VALUES FOR VARIOUS TYPES OF ANCHORS HAVING EMBEDMENTS GREATER THAN 2.0 INCHES. VALUES CHOSEN FOR THE 1/2 INCH BOLTS OF THE 460 VOLT CABINETS ARE BASED ON VALUES FOR 1/2 INCH HILTI KWICK LOCK BOLTS, EMBEDED 2 1/4 INCHES (REFERENCE 4).

ON THESE BASES:

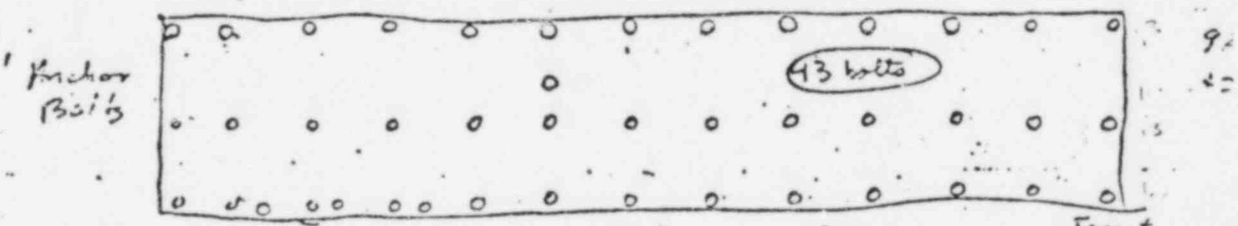
	4160 VOLT CABINET 1/2 IN. ANCHOR >2.0 IN. EMBEDMENT	460 VOLT CABINET 1/2 IN. ANCHOR 2 1/4 IN EMBEDMENT
P_{MAX}	3,804 lbs	3,804 lbs
V_{MAX}	5,748 lbs	8,076 lbs

VALUES OF P_{MAX} AND V_{MAX} ARE GIVEN IN REFERENCE 5.

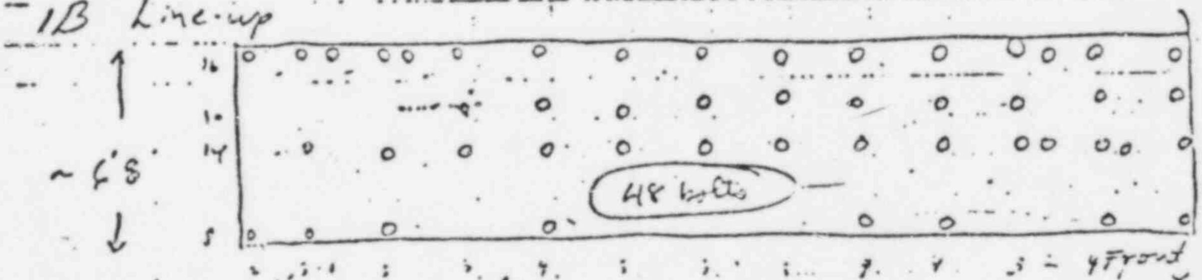
CALCULATIONS

THE AS-INSTALLED BOLT PATTERNS FOR 1460 SWITCH GEAR (1A, 1B, 1C, & 1D) ARE SHOWN BELOW.
- Pg 12 REFERENCE 5 - ATTACHMENT B.

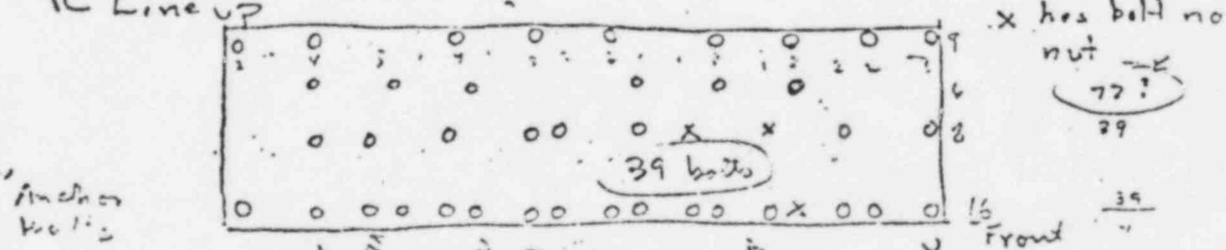
1A Lineup



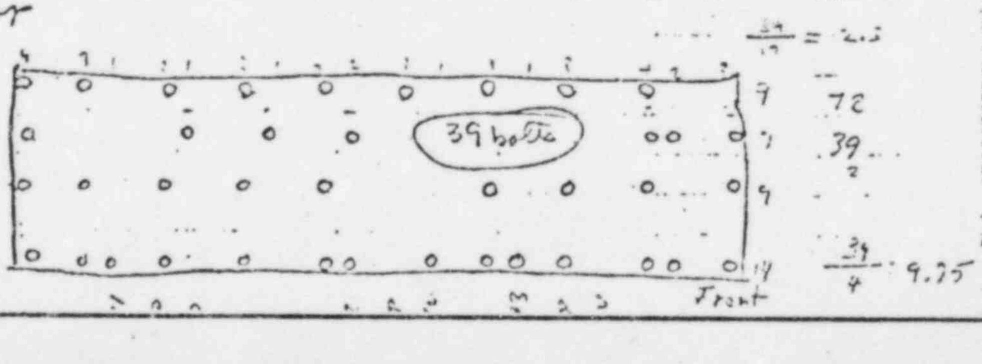
1B Line-up



1C Line up



1D Line up



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Calculated by: BT Date: 9-9-83
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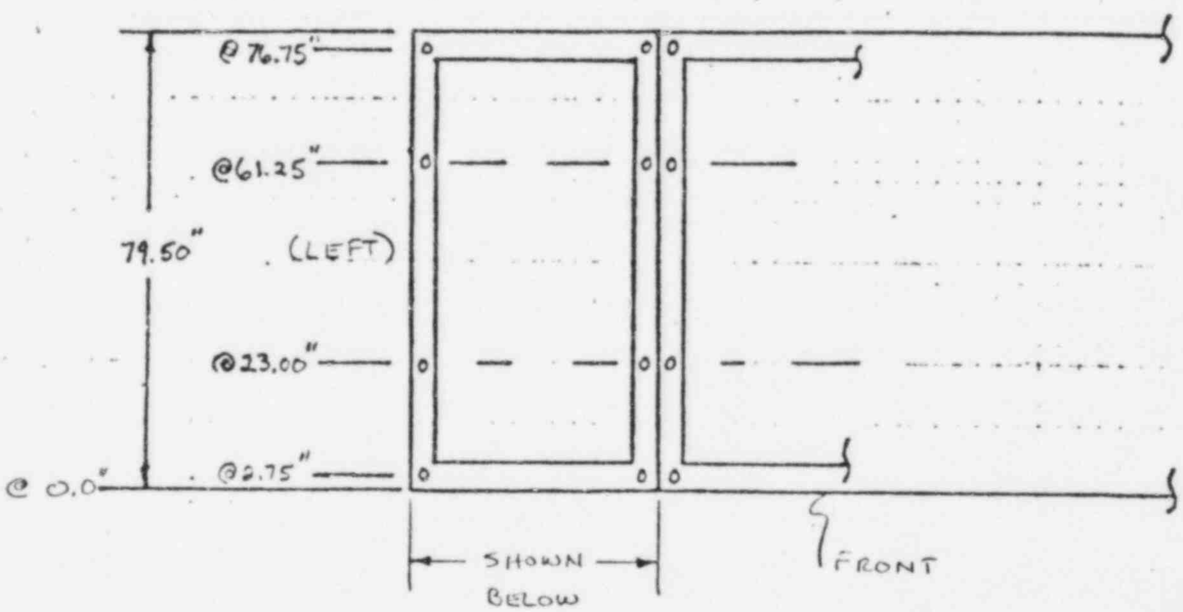
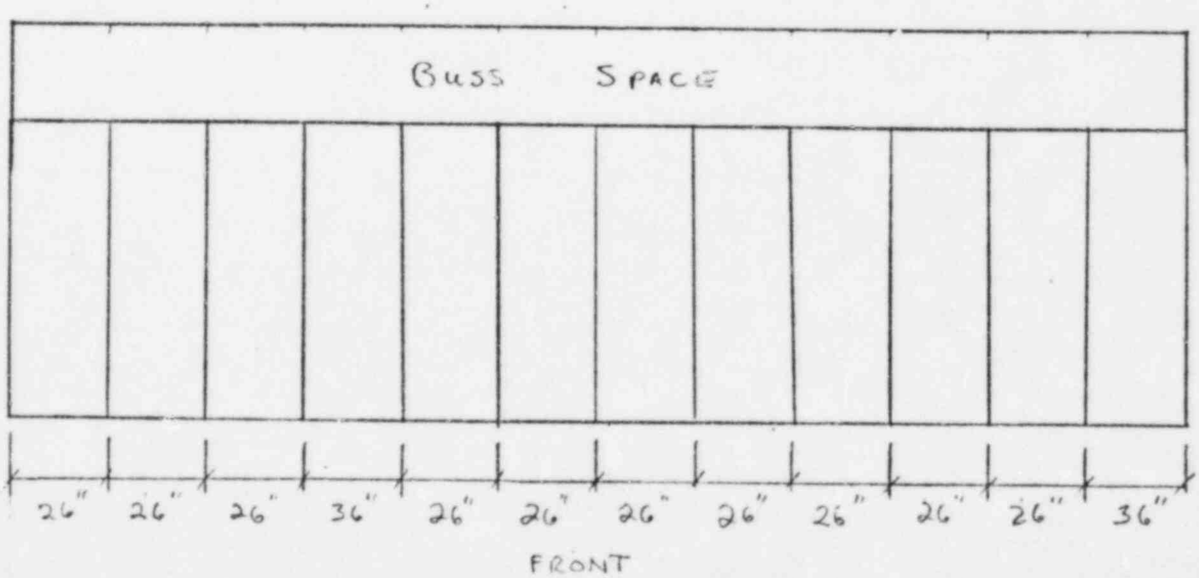
4160 V. SWITCHGEAR - UNITS 1A/1B

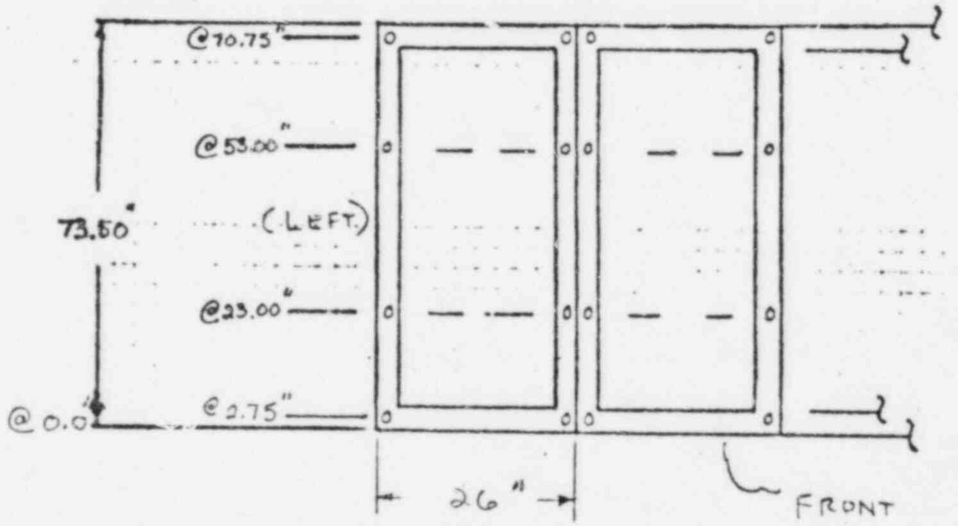
DETAILS OF THE BOLT PATTERNS ARE GIVEN ON GE DRWG 10206157 :





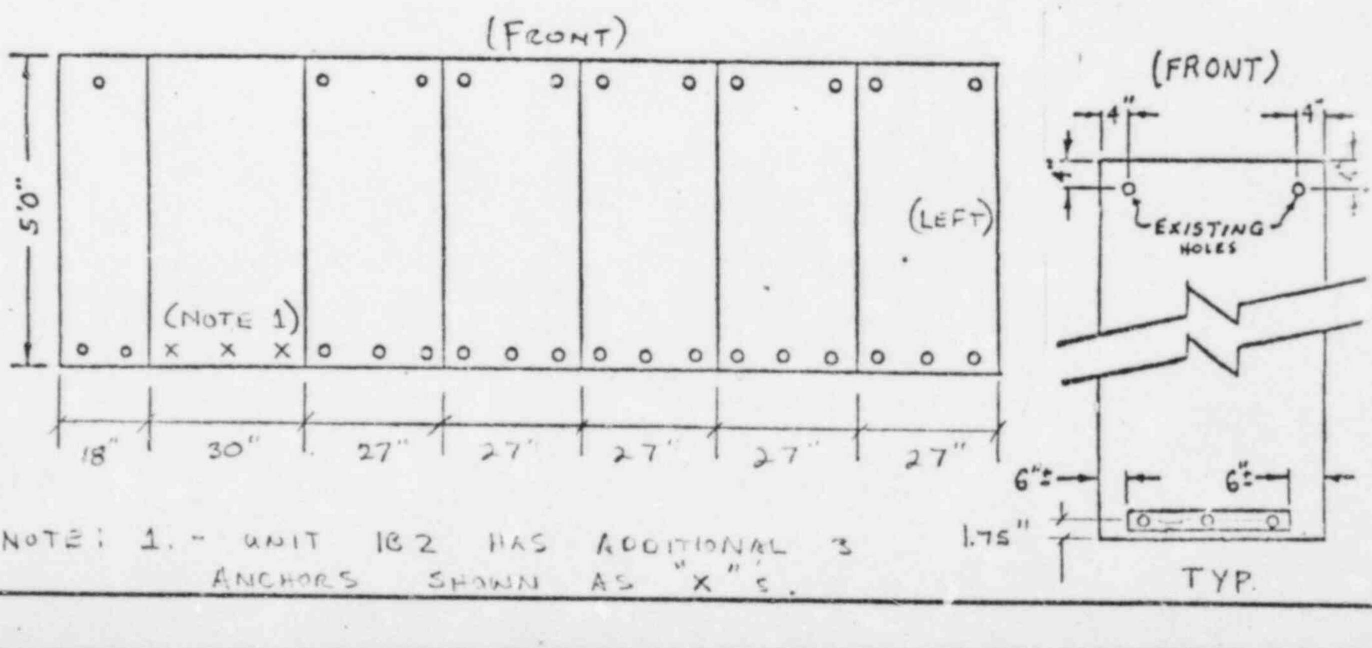
4160 V. SWITCHGEAR - UNITS 1C/1D

DETAILS OF THE BOLT PATTERNS ARE GIVEN ON GE DRWG 10206157:



460 V UNIT SUBSTATION 1A2/1B2

DETAILS OF BOLT PATTERNS GIVEN IN REFERENCE 8.



NOTE: 1. - UNIT 1B2 HAS ADDITIONAL 3 ANCHORS SHOWN AS "X"'s.

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4160 V SWITCHGEAR - UNITS 1A/1B

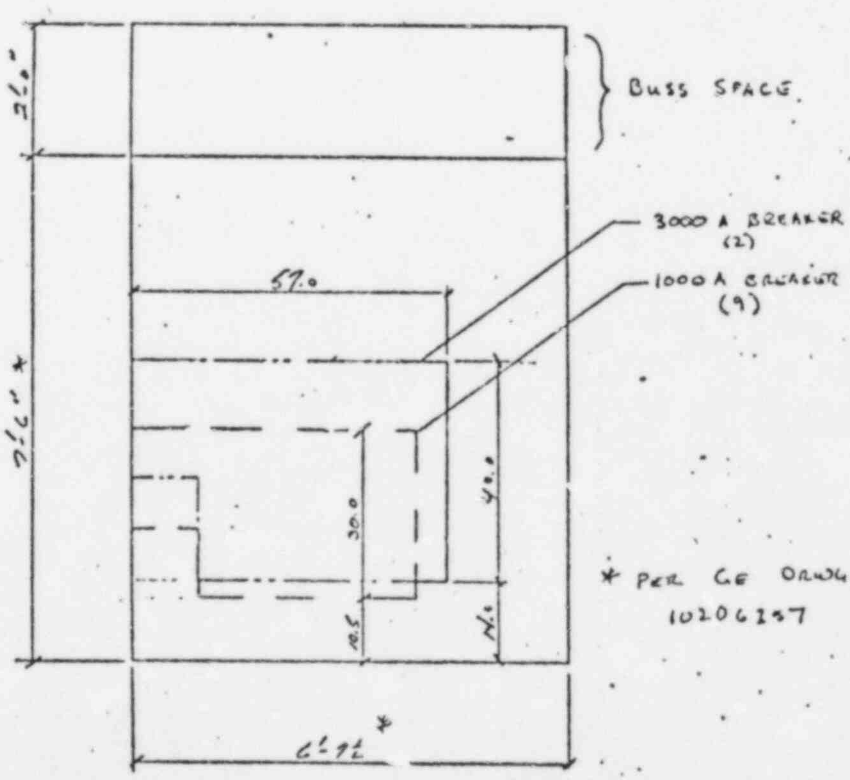
LOCATION: TURBINE BUILDING

ELEVATION: 23'-6"

WEIGHT: 46,400 # PER GE DRWG 10206157

CONTENTS: 2 - 3000 AMP CABINETS
9 - 1000 AMP CABINETS
1 - EMPTY (NO BREAKER)

H_{cg} = 1/2 · 7'6" = 3.75' - CONSERVATIVELY HIGH SINCE BREAKERS ARE HEAVIEST PIECE OF GEAR AND ARE ALMOST ENTIRERLY BELOW THIS HEIGHT



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4160 V SWITCHGEAR - UNITS 1C/1D

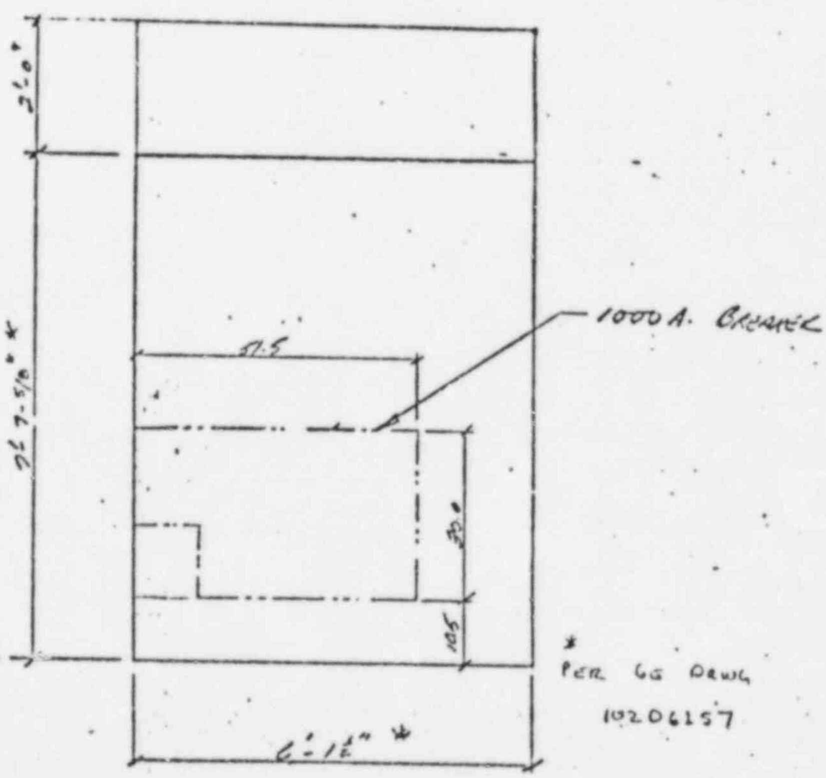
LOCATION : TURBINE BUILDING

ELEVATION : 23'- 6"

WEIGHT : 30,100# PER GE DRWG 10206157

CONTENTS : 9 - 1000 AMP CABINETS

H_{cg} = 1/2 · 7'-7 5/8" = 3.82' - CONSERVATIVELY HIGH SINCE BREAKERS ARE HEAVIEST PIECE OF GEAR AND ARE ENTIRERLY BELOW THIS HEIGHT.



460 V UNIT SUBSTATIONS 1A2 / 1B2

LOCATION: REACTOR BUILDING

ELEVATION: 23'-6"

WEIGHT: 15,200 # (1A2) 15,000 # (1B2)
PER GE DRWGS 169R0922 169R0921

CONTENTS: 3 BREAKERS POSITIONED UNIFORMLY IN EACH CABINET

HEIGHT = 7'-7 3/4" (REFERENCE 4)

H_{CG} = 1/2 HEIGHT = 3.82 ft.

$\sum_i x_i^2 N_i$

EQUIPMENT	ROTATION ABOUT (NOTE 1)			
	FRONT EDGE (ft^2)	REAR EDGE (ft^2)	LEFT SIDE (ft^2)	RIGHT SIDE (ft^2)
4160V - UNIT 1A	606.4	945.7	10291.0	12402.9
4160V - UNIT 1B	966.9	661.6	13941.2	11478.9
4160V - UNIT 1C	460.1	715.8	4976.1	4933.9
4160V - UNIT 1D	483.2	666.9	5182.7	5309.4
460V - UNIT 1A2	400.6	239.6	1685.2	2581.1
460V - UNIT 1B2	471.3	239.6	2155.1	2604.9

LOWER LIMITING VALUE USED TO FIND BOLT LOADS FOR NORTH-SOUTH EARTHQUAKES (front edge / rear edge)

LOWER LIMITING VALUE USED TO FIND BOLT LOADS FOR EAST-WEST EARTHQUAKES (left side / right side)

NOTES:

1. ATTACHMENT B, AT THE BACK OF THIS CALCULATION, CONTAINS A DETAILED CALCULATION FOR OBTAINING THE $\sum_i x_i^2 N_i$ VALUES IN THIS TABLE.

MAXIMUM VALUE OF xi

EQUIPMENT	xi N-S (ft)	xi E-W (ft)
4160 - UNITS 1A/1B	6.396	27.667
4160 - UNITS 1C/1D	5.896	19.500
460 - UNITS 1A2/1B2	4.667 *	14.750 **

* - OVERTURNING ON REAR EDGE
** - OVERTURNING ON LEFT SIDE

Ps

EQUIPMENT	WEIGHT (lb)	H_{cg} (ft)	P_{N-S} OBE/SSE (lb)	P_{E-W} OBE/SSE (lb)	P_V OBE/SSE (lb)	P_S OBE/SSE (lb)
4160 V - UNIT 1A	46,400.	3.75	862.6/1303.0	219.9/332.1	70.1/140.3	892.9/1352.0
4160 V - UNIT 1B	46,400.	3.75	790.6/1194.3	197.1/297.8	62.8/125.7	817.2/1237.3
4160 V - UNIT 1C	30,100.	3.82	692.5/1046.1	213.6/322.7	50.2/100.3	726.4/1099.3
4160 V - UNIT 1D	30,100.	3.82	659.4/996.1	203.3/307.2	50.2/100.3	691.9/1047.2
460 V - UNIT 1A2	15,200.	3.82	780.4/1187.5	350.7/533.6	51.6/103.1	857.1/1306.0
460 V - UNIT 1B2	15,000.	3.82	770.1/1171.9	270.6/411.8	46.0/91.9	817.6/1245.5

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ACCEPTANCE CRITERIA SUMMARY

EQUIPMENT	P_s OBE/SSE (lb)	V OBE/SSE (lb)	D DEADWEIGHT (lb)	P OBE/SSE (lb)	$P/P_{MAX} + V/V_{MAX}$ OBE/SSE	FACTOR OF SAFETY
4160 - UNIT 1A	892.9 / 1352.0	515.5 / 895.7	1079.1	N/A* / 272.9	0.090 / 0.228	11.15 / 4.39
4160 - UNIT 1B	817.2 / 1237.3	461.8 / 802.4	966.7	N/A* / 270.6	0.080 / 0.211	12.45 / 4.75
4160 - UNIT 1C	726.4 / 1099.3	368.7 / 640.7	771.8	N/A* / 327.5	0.064 / 0.198	15.59 / 5.06
4160 - UNIT 1D	691.9 / 1047.2	368.7 / 640.7	771.8	N/A* / 275.4	0.064 / 0.184	15.59 / 5.44
460 - UNIT 1A2	857.1 / 1306.0	431.5 / 718.2	542.9	314.2 / 763.1	0.136 / 0.290	7.35 / 3.45
460 - UNIT 1B2	817.6 / 1245.5	384.6 / 640.1	483.9	323.7 / 761.6	0.135 / 0.279	7.39 / 3.58

* BOLT DOES NOT GO INTO TENSION

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REFERENCES

1. NUCLEAR REGULATORY COMMISSION, REGULATORY GUIDE 1.92, "COMBINING MODAL RESPONSES AND SPATIAL COMPONENTS IN SEISMIC RESPONSE ANALYSIS", REVISION 1, FEBRUARY 1976.

2. REVISED APPENDIX B OF NUREG/CR-1981 (REVISED APPENDIX B WAS RECEIVED 6-25-81, FROM LLL LETTER TO MPR (B. SCHMIDT) DATED 6-23-81, LETTER # SM-81-159.)

3. NUCLEAR REGULATORY COMMISION, REGULATORY GUIDE 1.61, "DAMPING VALUES FOR SEISMIC DESIGN OF NUCLEAR POWER PLANTS", OCTOBER 1973.

4. GPU NUCLEAR, INSTALLATION SPECIFICATION 402-79-008, CLASS IE ELECTRICAL EQUIPMENT.

5. TELEDYNE SUMMARY REPORT, TR-3501-2, "GENERIC RESPONSE TO USNRC I&E BULLETIN NUMBER 79-02 BASE PLATE/CONCRETE EXPANSION ANCHOR BOLTS," AUGUST 30, 1979.

ATTACHMENT A

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Title: VERTICAL NATURAL FREQUENCY
Calculated by: B Tiplonel Date: 9-9-83
Checked by: [illegible] Date: 9/13/83
Reviewed by: J Johnson Date: 9-14-83

Project: OC SEP 83-03

ATTACHMENT A - NATURAL FREQUENCY CALCULATION

THE VERTICAL NATURAL FREQUENCY IS ASSUMED TO BE LIMITED BY THE STIFFNESS OF THE ANCHOR BOLTS.

$$\Delta = \frac{PL}{AE}$$

$$K = \frac{P}{\Delta}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}} = \frac{1}{2\pi}\sqrt{\frac{g\,AE}{W\,L}}$$

$E = 29.0 \times 10^6$ psi $g = 386.4$ in/sec^2

WHERE:

Δ = DISPLACEMENT OF CABINET IN VERTICAL DIRECTION
L = EFFECTIVE LENGTH OF ANCHOR BOLT (in)
A = TOTAL STRESS AREA (in^2)
E = MODULUS OF ELASTICITY (psi)
K = STIFFNESS OF ANCHOR BOLTS
f_n = NATURAL VERTICAL FREQUENCY
W = CABINET WEIGHT
g = GRAVITATIONAL CONSTANT

ANCHORS ARE 1/2 BOLTS

STRESS AREA = 0.1416 in^2/BOLT

EQUIPMENT	WEIGHT OF CABINET (lbs)	No. OF ANCHOR BOLTS	TOTAL STRESS AREA (IN^2)	$\frac{gAE}{W}$ (IN/sec^2)
4160 V- 1A/1B*	46,400.0	43	6.089	1.470×10^6
4160 V- 1C/1D	30,100.0	39	5.522	2.056×10^6
460 V- 1A2/1B2**	15,200.0	28	3.965	2.923×10^6

EFFECTIVE LENGTH (IN)	NATURAL FREQUENCY (HZ)		
	1A/1B	1C/1D	1A2/1B2
0.5	273	323	385
1.0	193	↓	↓
2.0	136	↓	↓
3.0	111	↓	↓
4.0	96	↓	↓
5.0	86	102	122

* LIMITING CABINET IS 1A
** LIMITING CABINET IS 1A2

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	Checked by: [illegible]	Date: 9/13/83
	Reviewed by: JJ	Date: 9-14-83

Project: 83-03

CONCLUSION

BASED ON THE ASSUMPTION THAT STIFFNESS IS LIMITED BY THE ANCHOR BOLTS, THE VERTICAL NATURAL FREQUENCIES ARE WELL ABOVE 35 HZ. THEREFORE, USE OF ZPA VALUE IS JUSTIFIED IN CABINET HOLD DOWN EVALUATION.

ATTACHMENT B

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

Title: $\Sigma x_i^2 N_i$ CALCULATIONS	Calculated by: [signature]	Date: 9-9-83
	Checked by: [signature]	Date: 9/14/83
	Reviewed by: [signature]	Date: 9-14-83

Project: OC SEP 83-03

ATTACHMENT B - $\sum_i x_i^2 N_i$ CALCULATIONS

4160 VOLT - UNIT 1A

OVERTURNING ON FRONT EDGE:

$$\sum_i x_i^2 N_i = 16(2.75)^2 + 13(23.0)^2 + 1(61.25)^2 + 13(76.75)^2$$
$$= 8.733 \times 10^4 \text{ IN}^2$$
$$= 606.4 \text{ ft}^2$$

OVERTURNING ON REAR EDGE:

$$\sum_i x_i^2 N_i = 13(2.75)^2 + 1(18.25)^2 + 13(56.50)^2 + 16(76.75)^2$$
$$= 1.362 \times 10^5 \text{ IN}^2$$
$$= 945.7 \text{ ft}^2$$

OVERTURNING ON LEFT SIDE:

$$\sum_i x_i^2 N_i = 4(26)^2 + 4(52)^2 + 4(78)^2 + 3(114)^2 + 4(140)^2 + 3(166)^2 + 3(192)^2 + 3(218)^2 + 3(244)^2 + 3(270)^2 + 3(296)^2 + 3(332)^2$$
$$= 1.482 \times 10^6 \text{ IN}^2$$
$$= 10291.0 \text{ ft}^2$$

OVERTURNING ON RIGHT SIDE:

$$\sum_i x_i^2 N_i = 3(36)^2 + 3(62)^2 + 3(88)^2 + 3(114)^2 + 3(140)^2 + 3(166)^2 + 4(192)^2 + 3(218)^2 + 4(254)^2 + 4(280)^2 + 4(306)^2 + 3(332)^2$$
$$= 1.786 \times 10^6 \text{ IN}^2$$
$$= 12402.9 \text{ ft}^2$$

Title:	$\Sigma x_i^2 N_i$ CALCULATIONS	Calculated by:	SY	Date:	9-9-83
		Checked by:	[illegible]	Date:	9/13/83
		Reviewed by:	JH	Date:	9-14-83

Project: 83-03

4160 VOLT – UNIT 1B

OVERTURNING ON FRONT EDGE:

$$\sum_i x_i^2 N_i = 8(2.75)^2 + 14(23.0)^2 + 10(61.25)^2 + 16(76.75)^2$$
$$= 1.392 \times 10^5 \text{ IN}^2$$
$$= 966.9 \text{ ft}^2$$

OVERTURNING ON REAR EDGE:

$$\sum_i x_i^2 N_i = 16(2.75)^2 + 10(18.25)^2 + 14(56.50)^2 + 8(76.75)^2$$
$$= 9.527 \times 10^4 \text{ IN}^2$$
$$= 661.6 \text{ ft}^2$$

OVERTURNING ON LEFT SIDE:

$$\sum_i x_i^2 N_i = 4(26)^2 + 4(52)^2 + 3(78)^2 + 4(114)^2 + 3(140)^2$$
$$+ 3(166)^2 + 3(192)^2 + 4(218)^2 + 4(244)^2$$
$$+ 5(270)^2 + 5(296)^2 + 4(332)^2$$
$$= 2.008 \times 10^6 \text{ IN}^2$$
$$= 13\,941.2 \text{ ft}^2$$

OVERTURNING ON RIGHT SIDE:

$$\sum_i x_i^2 N_i = 5(36)^2 + 5(62)^2 + 4(88)^2 + 4(114)^2 + 3(140)^2$$
$$+ 3(166)^2 + 3(192)^2 + 4(218)^2 + 3(254)^2 + 4(280)^2$$
$$+ 4(306)^2 + 2(332)^2$$
$$= 1.653 \times 10^6 \text{ IN}^2$$
$$= 11\,478.9 \text{ ft}^2$$

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: $\Sigma x_i^2 N_i$ CALCULATIONS	Calculated by: BJ	Date: 9-9-83
	Checked by: MJK	Date: 9/13/83
	Reviewed by: JJ	Date: 9-14-83

Project: 83-03

4160 VOLT – UNIT 1C

OVERTURNING ON FRONT EDGE:

$$\sum_i x_i^2 N_i = 16(2.75)^2 + 8(23.0)^2 + 6(53.0)^2 + 9(70.75)^2$$
$$= 6.626 \times 10^4 \text{ IN}^2$$
$$= 460.1 \text{ ft}^2$$

OVERTURNING ON REAR EDGE:

$$\sum_i x_i^2 N_i = 9(2.75)^2 + 6(20.50)^2 + 8(50.5)^2 + 16(70.75)^2$$
$$= 1.031 \times 10^5 \text{ IN}^2$$
$$= 715.8 \text{ ft}^2$$

OVERTURNING ON LEFT SIDE:

$$\sum_i x_i^2 N_i = 4(26)^2 + 4(52)^2 + 5(78)^2 + 5(104)^2 + 5(130)^2 + 4(156)^2 + 3(182)^2 + 4(208)^2 + 3(234)^2$$
$$= 7.166 \times 10^5 \text{ IN}^2$$
$$= 4976.1 \text{ ft}^2$$

OVERTURNING ON RIGHT SIDE:

$$\sum_i y_i^2 N_i = 4(26)^2 + 3(52)^2 + 4(78)^2 + 5(104)^2 + 5(130)^2 + 5(156)^2 + 4(182)^2 + 4(208)^2 + 2(234)^2$$
$$= 7.105 \times 10^5 \text{ IN}^2$$
$$= 4933.9 \text{ ft}^2$$

4160 VOLT - UNIT 1D

OVERTURNING ON FRONT EDGE:

$$\sum_i x_i^2 N_i = 14(2.75)^2 + 9(23.0)^2 + 7(53.0)^2 + 9(70.75)^2$$
$$= 6.958 \times 10^4 \text{ IN}^2$$
$$= 483.2 \text{ ft}^2$$

OVERTURNING ON REAR EDGE:

$$\sum_i x_i^2 N_i = 9(2.75)^2 + 7(20.50)^2 + 9(50.5)^2 + 14(70.75)^2$$
$$= 9.604 \times 10^4 \text{ IN}^2$$
$$= 666.9 \text{ ft}^2$$

OVERTURNING ON LEFT SIDE:

$$\sum_i x_i^2 N_i = 4(26)^2 + 4(52)^2 + 4(78)^2 + 5(104)^2 + 2(130)^2 + 4(156)^2 + 3(182)^2 + 6(208)^2 + 3(234)^2$$
$$= 7.463 \times 10^5 \text{ IN}^2$$
$$= 5182.7 \text{ ft}^2$$

OVERTURNING ON RIGHT SIDE:

$$\sum_i x_i^2 N_i = 6(26)^2 + 3(52)^2 + 4(78)^2 + 2(104)^2 + 5(130)^2 + 4(156)^2 + 4(182)^2 + 4(208)^2 + 4(234)^2$$
$$= 7.646 \times 10^5 \text{ IN}^2$$
$$= 5309.4 \text{ ft}^2$$

MPR ASSOCIATES, INC.
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Title: $\Sigma x_i^2 N_i$ CALCULATIONS	Calculated by: BJ	Date: 9-9-83
	Checked by: [illegible]	Date: 9/13/83
	Reviewed by: [illegible]	Date: 9-15-83

Project: 83-03

460 VOLT - UNIT 1A2

OVERTURNING ON FRONT EDGE:

$$\sum_i x_i^2 N_i = 17(58.25)^2 = 5.768 \times 10^4 \text{ IN}^2$$
$$= 400.6 \text{ ft}^2$$

OVERTURNING ON REAR EDGE:

$$\sum_i x_i^2 N_i = 11(56.0)^2 = 3.450 \times 10^4 \text{ IN}^2$$
$$= 239.6 \text{ ft}^2$$

OVERTURNING ON LEFT SIDE:

$$\sum_i x_i^2 N_i = 6^2 + 13.5^2 + 21^2 + 33^2 + 40.5^2 + 48^2 + 60^2$$
$$+ 67.5^2 + 75^2 + 87^2 + 94.5^2 + 102^2 + 114^2 + 121.5^2$$
$$+ 129^2 + 171^2 + 177^2 + 4^2 + 23^2 + 31^2 + 50^2 + 58^2$$
$$+ 77^2 + 85^2 + 104^2 + 112^2 + 131^2 + 174^2$$
$$= 2.427 \times 10^5 \text{ IN}^2$$
$$= 1685.2 \text{ ft}^2$$

OVERTURNING ON RIGHT SIDE:

$$\sum_i x_i^2 N_i = 6^2 + 12^2 + 54^2 + 61.5^2 + 69^2 + 81^2 + 88.5^2 + 96^2$$
$$+ 108^2 + 115.5^2 + 123^2 + 135^2 + 142.5^2 + 150^2$$
$$+ 162^2 + 169.5^2 + 177^2 + 9^2 + 52^2 + 71^2 + 79^2$$
$$+ 98^2 + 106^2 + 125^2 + 133^2 + 152^2 + 160^2 + 179^2$$
$$= 3.717 \times 10^5 \text{ IN}^2$$
$$= 2581.1 \text{ ft}^2$$

460 VOLT - UNIT 1&2

OVERTURNING ON FRONT EDGE:

$$\sum_i x_i^2 N_i = 20(58.25)^2 = 6.786 \times 10^4 \text{ IN}^2$$
$$= 471.3 \text{ ft}^2$$

OVERTURNING ON REAR EDGE:

$$\sum_i x_i^2 N_i = 11(56.0)^2 = 3.450 \times 10^4 \text{ IN}^2$$
$$= 239.6 \text{ ft}^2$$

OVERTURNING ON LEFT SIDE:

$$\sum_i x_i^2 N_i = 6^2 + 13.5^2 + 21^2 + 33^2 + 40.5^2 + 48^2 + 60^2 + 67.5^2 + 75^2 + 87^2 + 94.5^2 + 102^2 + 114^2 + 121.5^2 + 129^2 + 141^2 + 150^2 + 159^2 + 171^2 + 177^2 + 4^2 + 23^2 + 31^2 + 50^2 + 58^2 + 77^2 + 85^2 + 104^2 + 112^2 + 131^2 + 174^2$$
$$= 3.103 \times 10^5 \text{ IN}^2$$
$$= 2155.1 \text{ ft}^2$$

OVERTURNING ON RIGHT SIDE:

$$\sum_i x_i^2 N_i = 6^2 + 12^2 + 24^2 + 33^2 + 42^2 + 54^2 + 61.5^2 + 69^2 + 81^2 + 88.5^2 + 96^2 + 108^2 + 115.5^2 + 123^2 + 135^2 + 142.5^2 + 150^2 + 162^2 + 169.5^2 + 177^2 + 9^2 + 52^2 + 71^2 + 79^2 + 98^2 + 106^2 + 125^2 + 133^2 + 152^2 + 160^2 + 179^2$$
$$= 3.751 \times 10^5 \text{ IN}^2$$
$$= 2604.9 \text{ ft}^2$$

APPENDIX B

LOAD PATH ANALYSIS FOR
4160 VOLT SWITCHGEAR

APPENDIX B

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

Title: LOAD PATH ANALYSIS FOR 4160 VOLT SWITCHGEAR	Calculated by: B. [illegible]	Date: 9-13-83
	Checked by: [illegible]	Date: 9/19/83
	Reviewed by: [illegible]	Date: 10-11-83
Project: OC SEP 83-03		Page 1 of 13

PURPOSE

THE FOLLOWING CALCULATES THE STRESSES IN THE LIMITING LOAD CARRYING COMPONENTS OF THE 4160 VOLT ELECTRICAL CABINETS, UNITS 1A, 1B, 1C, & 1D, AT THE OYSTER CREEK STATION.

APPROACH AND DESCRIPTION

A VISUAL EXAMINATION OF THE 4160 VOLT CABINETS WAS MADE TO DETERMINE THE LIMITING LOAD PATHS. TWO BREAKERS, 1000 AMP & 3000 AMP, ARE USED IN THE 4160 V CABINETS. SINCE SUPPORT PARTS FOR BOTH BREAKERS ARE IDENTICAL, CALCULATED STRESSES WILL BE BASED ON THE HEAVIER, 3000 AMP BREAKER. A TYPICAL BREAKER AND SUPPORT COMPONENTS ARE SHOWN ON FIGURES 1 & 2.

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

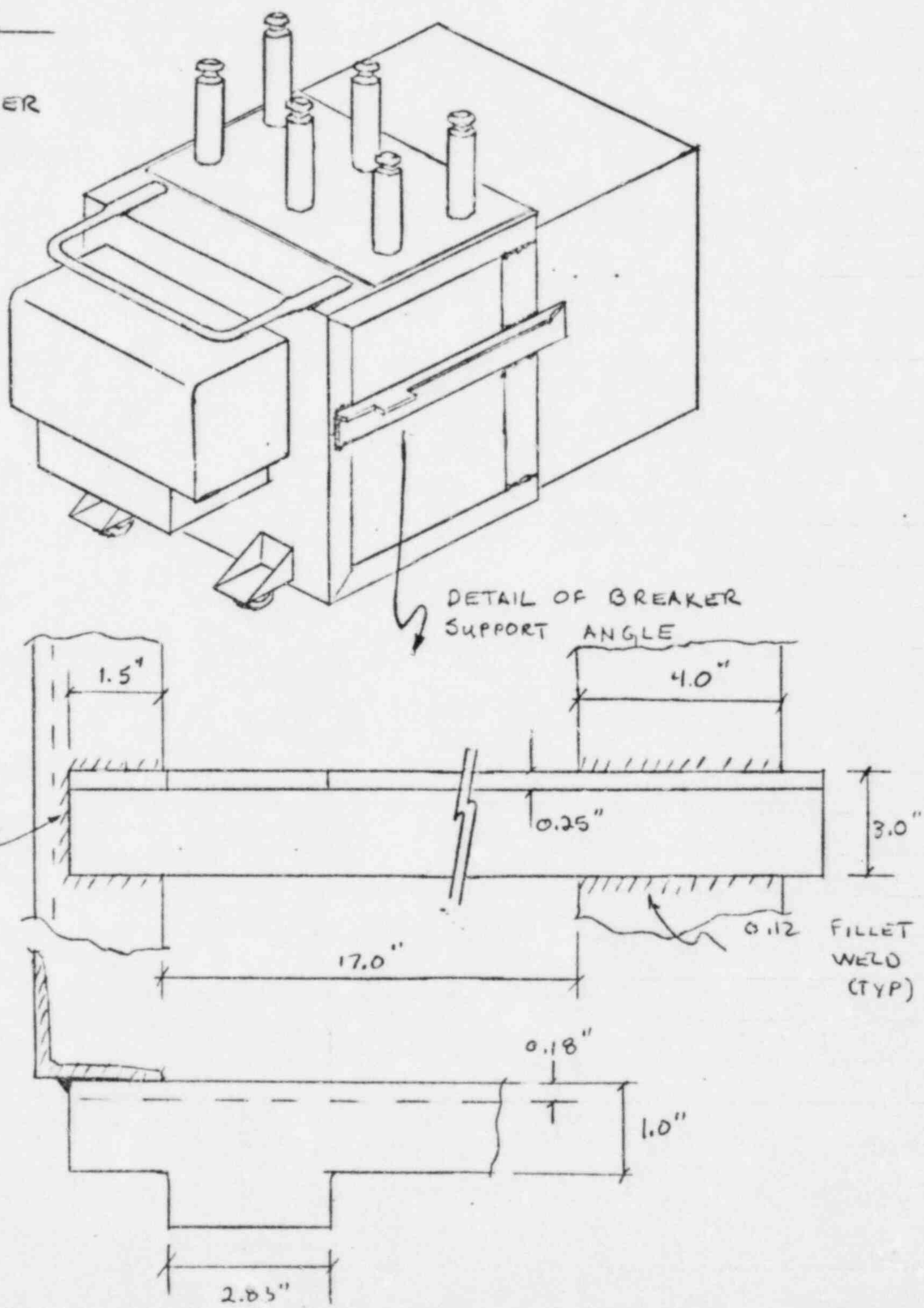
Title: LOAD PATH ANALYSIS FOR 4160 VOLT SWITCHGEAR
Calculated by: BJ Date: 9-13-83
Checked by: [illegible] Date: 9/8/83
Reviewed by: JJ Date: 10-11-83

Project: 83-03

FIGURE 1.

4160 BREAKER
3000 AMP

BREAKER
WEIGHT
2350 lbf

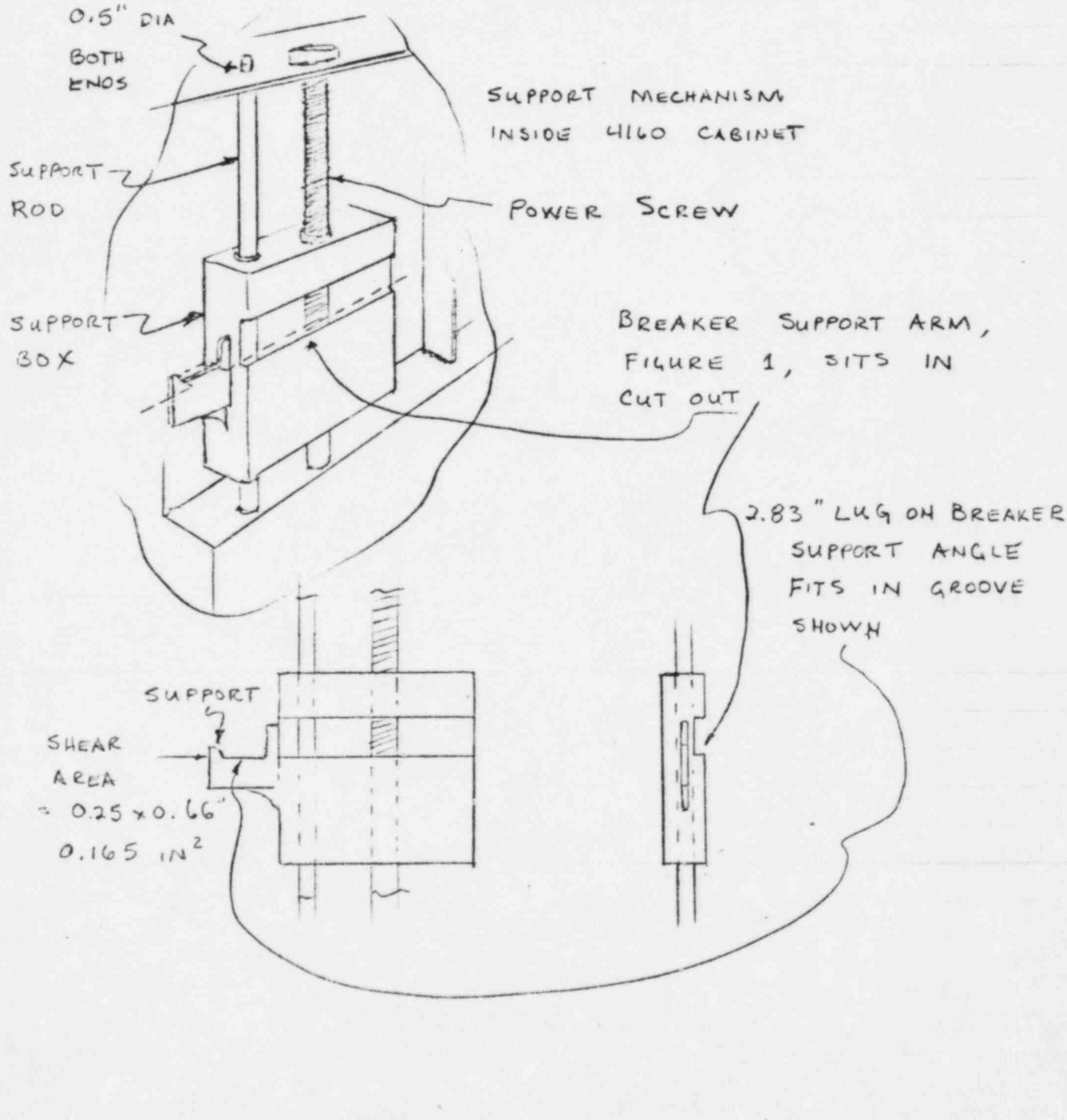


MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: LOAD PATH ANALYSIS FOR 4160 VOLT SWITCHGEAR
Calculated by: BJ — Date: 9-13-83
Checked by: MJK — Date: 9/19/83
Reviewed by: JT — Date: 10-11-83

Project: 83-03

FIGURE 2



TWO SUPPORT BOXES, ONE ON EACH SIDE OF A CABINET, ARE USED TO RAISE AND LOWER THE BREAKER UNIT. THE BOXES, SHOWN IN FIGURE 2, ARE CONTROLLED BY A POWER SCREW. DURING INSTALLATION OF THE BREAKER; THE SUPPORT BOXES IN THE CABINET ARE LOWERED; THE BREAKER IS ROLLED IN THE CABINET; AND SUPPORT BOXES ARE RAISED WITH THE SUPPORT ANGLES OF THE BREAKER RESTING IN THE SUPPORT BOX CUT OUTS. TO HOLD THE BREAKER HORIZONTALLY, 2.83 INCH LUGS ON THE BREAKER SUPPORT ANGLES REST IN THE SUPPORT GROOVES ON THE SUPPORT BOXES. SEISMIC LOADS INITIATE AT THE BREAKER AND ARE TRANSMITTED TO THE BREAKER SUPPORT ANGLES BY 1/8 INCH WELDS. THE HORIZONTAL

PORTION OF THIS SEISMIC LOAD THEN TRAVELS FROM THE BREAKER SUPPORT ANGLE TO THE SUPPORT ON THE CABINET BOX SUPPORTS. FROM THE SUPPORTS THE LOAD TRAVELS THROUGH SUPPORT RODS AND INTO THE CABINET. VERTICAL SEISMIC LOADS (INCLUDING DEADWEIGHT LOADS), AFTER PASSING FROM THE BREAKER TO THE SUPPORT ANGLES BY MEANS OF 1/8 INCH WELDS, ARE TRANSMITTED DIRECTLY TO THE SUPPORT BOXES AND FINALLY TO THE CABINET.

LOADS

SEISMIC LOADS ARE TAKEN FROM REVISED APPENDIX B OF NUREG/CR-1981 (REF. 1.) AND MODIFIED FOR SITE SPECIFIC ACCORDING TO PG 12 OF REFERENCE 2. THE 4160 V. CABINETS ARE ON THE TURBINE BUILDING FLOOR (EL 23'-6").

	g_H HORIZONTAL (g's)	g_V VERTICAL (g's)
OBE	0.47	0.065
SSE	0.71	0.13

HORIZONTAL LOAD : (F_H)

$$F_H = \sqrt{g_H^2 + g_H^2} \cdot W = \sqrt{2} \cdot g_H \cdot W$$

$$= 3323.4 \cdot g_H$$

ACCOUNTS FOR TWO HORIZONTAL SEISMIC MOTIONS.

VERTICAL LOAD: (F_v)

SINCE THE VERTICAL UPWARD LOAD DUE TO SEISMIC MOTION IS NEVER GREATER THAN THE DEADWEIGHT, THE BREAKER WILL NOT LIFT OFF THE SUPPORT BOXES IN THE CABINET.

VERTICAL LOADS ARE THE COMBINATION OF:

$F_{VERTICAL}$ = DEADWEIGHT + VERTICAL SEISMIC

2350 lb $\quad g_v$ (2350)

LOAD SUMMARY

	HORIZONTAL	VERTICAL	
	SEISMIC (lbs)	SEISMIC (lbs)	DEADWEIGHT (lbs)
OBE	1562.0	152.8	2350.0
SSE	2359.6	305.5	2350.0

SHEAR ON 1/8 INCH WELDS

$$AREA = \frac{\sqrt{2}}{2} \cdot \left(\frac{1}{8}\right) \cdot \left[2\left(1.7 + 2(1.5) + 2(4.0)\right)\right]$$

$$= 2.245 \text{ IN}^2$$

$$LOAD = \sqrt{\binom{\text{HORIZONTAL}}{\text{SEISMIC}}^2 + \binom{\text{VERTICAL}}{\text{SEISMIC}}^2} + \text{DEADWEIGHT}$$

	OBE	SSE
LOAD (lbs)	3919.5	4729.0
SHEAR (psi)	1746	2107

SHEAR ON SUPPORT FROM HORIZONTAL LOAD

$$AREA = 2(0.25 \cdot 0.66) = 0.330 \text{ IN}^2$$

	OBE	SSE
HORIZONTAL LOAD (lbs)	1562.0	2359.6
SHEAR (psi)	4733	7150

SHEAR ON 0.5 INCH DIA. SUPPORT RODS FROM HORIZONTAL LOAD

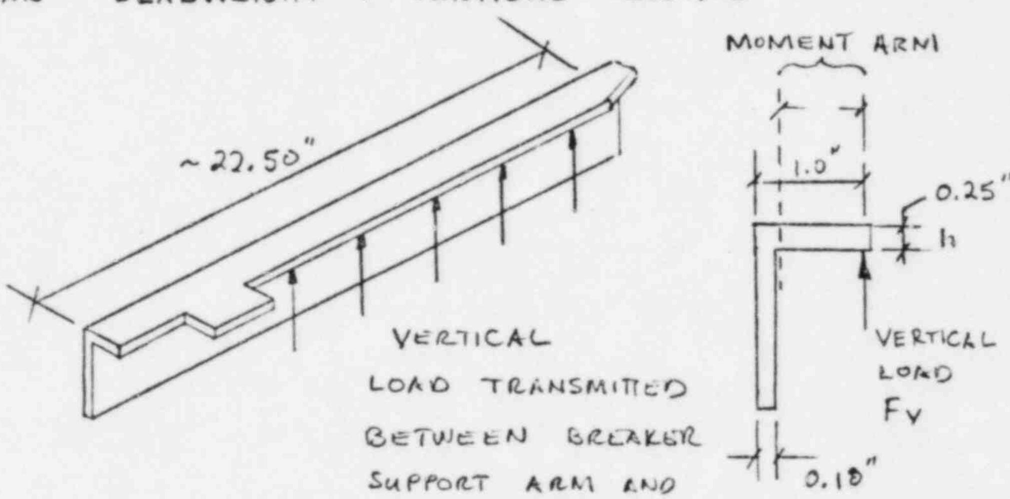
ASSUMING THE BREAKER IS ENGAGED (i.e., THE SUPPORT BOXES HAVE BEEN RAISED NEAR THE TOP OF THE SUPPORT MECHANISMS) THE HORIZONTAL LOAD TRANSMITTED FROM THE SUPPORT OF THE SUPPORT BOX WILL BE TAKEN ALMOST ENTIRERLY IN SHEAR ACROSS THE TOP OF THE SUPPORT RODS.

$$AREA = 2\,(\pi/4)\,(0.5)^2 = 0.393\ IN^2$$

	OBE	SSE
HORIZONTAL LOAD (lbs)	1562.0	2359.6
SHEAR (psi)	3975	6004

BENDING ON SUPPORT ANGLE FROM VERTICAL LOAD

VERTICAL LOAD = DEADWEIGHT + VERTICAL SEISMIC



$$\sigma_{BENDING} = \frac{Mc}{I} = \frac{M(h/2)}{1/12\, b h^3} = \frac{6M}{b h^2}$$

$M = F_V(1.0 - 0.18) = F_V \cdot 0.82$

$b = 22.5" \times 2 = 45.0$ IN

$h = 0.25$ IN

	OBE	SSE
VERTICAL LOAD (lbs)	2502.8	2655.5
BENDING STRESS (psi)	4378	4645

ALLOWABLE STRESS

MATERIAL = A36* (ASSUMED)
MINIMUM YIELD = 36.0 KSI (S_Y)
MINIMUM ULT. = 58.0 KSI (S_u)
TABLE I-7.1 – REF. 3.

* ASSUMED PROPERTIES EQUIVALENT TO A36

LOADS	SERVICE LEVEL	STRESS LIMIT		ALLOWABLE (psi)
OBE (NOTE 1)	LEVEL B	SHEAR	$1.33(0.4 S_y)$ OR $0.42 S_u$	19,150
		BENDING	$1.33(0.66 S_y)$	31,600
		WELD SHEAR	$1.33(21{,}000)$ OR $0.42 S_u$	24,360
SSE (NOTE 1)	LEVEL D	SHEAR	$2.0(0.4 S_y)$ OR $0.42 S_u$	24,360
		BENDING	$2.0(0.66 S_y)$ OR $0.7 S_u$	40,600
		WELD SHEAR	$2.0(21{,}000)$ OR $0.42 S_u$	24,360

NOTES:

1. THE ALLOWABLE STRESS VALUE IS TAKEN AS THE LESSER OF THE TWO STRESS LIMITS.

Title: LOAD PATH ANALYSIS FOR 4160 VOLT SWITCHGEAR
Calculated by: [illegible] Date: 9-13-83
Checked by: [illegible] Date: 9/19/83
Reviewed by: [illegible] Date: 10-11-83

Project: 83-03

SUMMARY OF RESULTS

LOAD COMPONENT	TYPE OF STRESS	STRESS OBE (psi)	STRESS SSE (psi)	ALLOWABLES OBE / SSE
1/8 INCH WELDS	SHEAR	1746	2107	24,360 / 24,360
SUPPORT	SHEAR	4733	7150	19,150 / 24,360
0.5" DIA PINS	SHEAR	3975	6004	19,150 / 24,360
SUPPORT ARMS	BENDING	4378	4645	31,600 / 40,600

CONCLUSIONS

ALL CALCULATED STRESSES ARE UNDER THE ALLOWABLE VALUES

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

Title:	LOAD PATH ANALYSIS FOR 4160 VOLT SWITCHGEAR	Calculated by:	Date: 9-13-83
		Checked by:	Date: 9/19/83
		Reviewed by:	Date: 10-11-83

Project: 83-03

REFERENCES

1. REVISED APPENDIX B OF NUREG/CR-1981 (REVISED APPENDIX B WAS RECIEVED 6-25-81, FROM LLL LETTER TO MPR (W. SCHMIDT) DATED 6-23-81, LETTER # SM-81-159.)

2. MPR CALCULATION BY B. LIPFORD, "VERIFICATION OF ANCHOR ADEQUACY FOR 4160 VOLT AND 460 VOLT ELECTRICAL CABINETS", DATED 9-9-83.

3. ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, APPENDICES, 1980 EDITION, UP TO AND INCLUDING WINTER 1982 ADDENDA.

APPENDIX C

LOAD PATH ANALYSIS FOR 460 VOLT UNIT SUBSTATION

Title: LOAD PATH ANALYSIS FOR 460 VOLT UNIT SUBSTATION
Calculated by: R. Gifford Date: 9-9-83
Checked by: [illegible] Date: 9/13/83
Reviewed by: [illegible] Date: 10-11-83

Project: OC SEP 83-03

PURPOSE

THE FOLLOWING CALCULATES THE STRESSES IN THE LIMITING LOAD CARRYING COMPONENTS OF THE 460 VOLT ELECTRICAL CABINETS, SUBSTATIONS 1A2 & 1B2, AT THE OYSTER CREEK STATION.

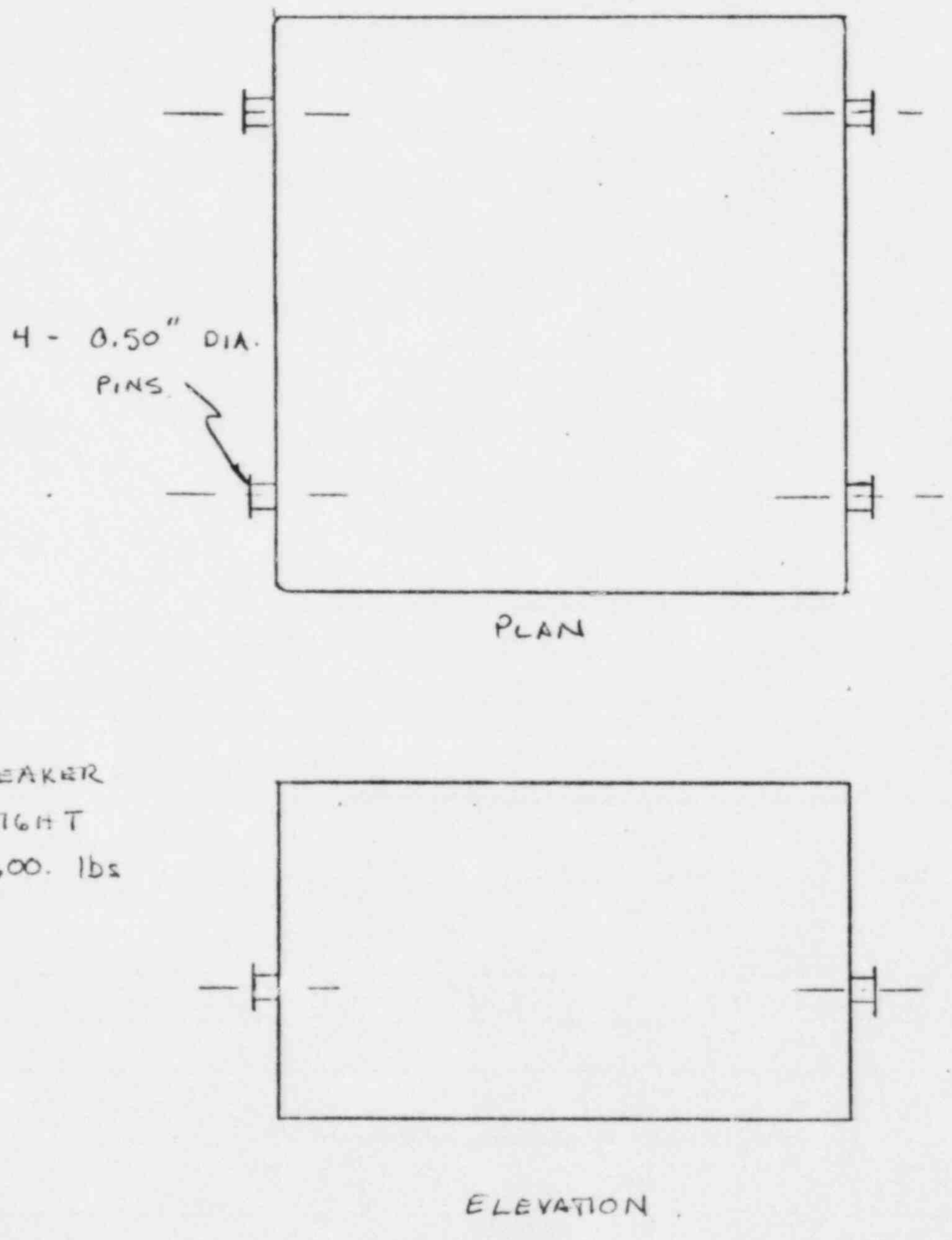
APPROACH AND DESCRIPTION

A VISUAL EXAMINATION OF THE 460 VOLT CABINETS WAS MADE TO DETERMINE THE LIMITING LOAD PATHS. A TYPICAL 460 VOLT BREAKER AND SUPPORT PARTS ARE SHOWN ON FIGURES 1 & 2.

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: LOAD PATH ANALYSIS FOR 460 VOLT UNIT SUBSTATION	Calculated by: BJ	Date: 9-9-83
	Checked by: [illegible]	Date: 9/13/83
	Reviewed by: [illegible]	Date: 10-11-83
Project: 83-03		Page 2 of 10

TYPICAL 460 V BREAKER



BREAKER WEIGHT 600. lbs

FIGURE 1

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

Title: LOAD PATH ANALYSIS FOR 460 VOLT UNIT SUBSTATION	Calculated by: BJ	Date: 9-9-83
	Checked by: [illegible]	Date: 9/12/83
	Reviewed by: [illegible]	Date: 10-11-83

Project: 83-03

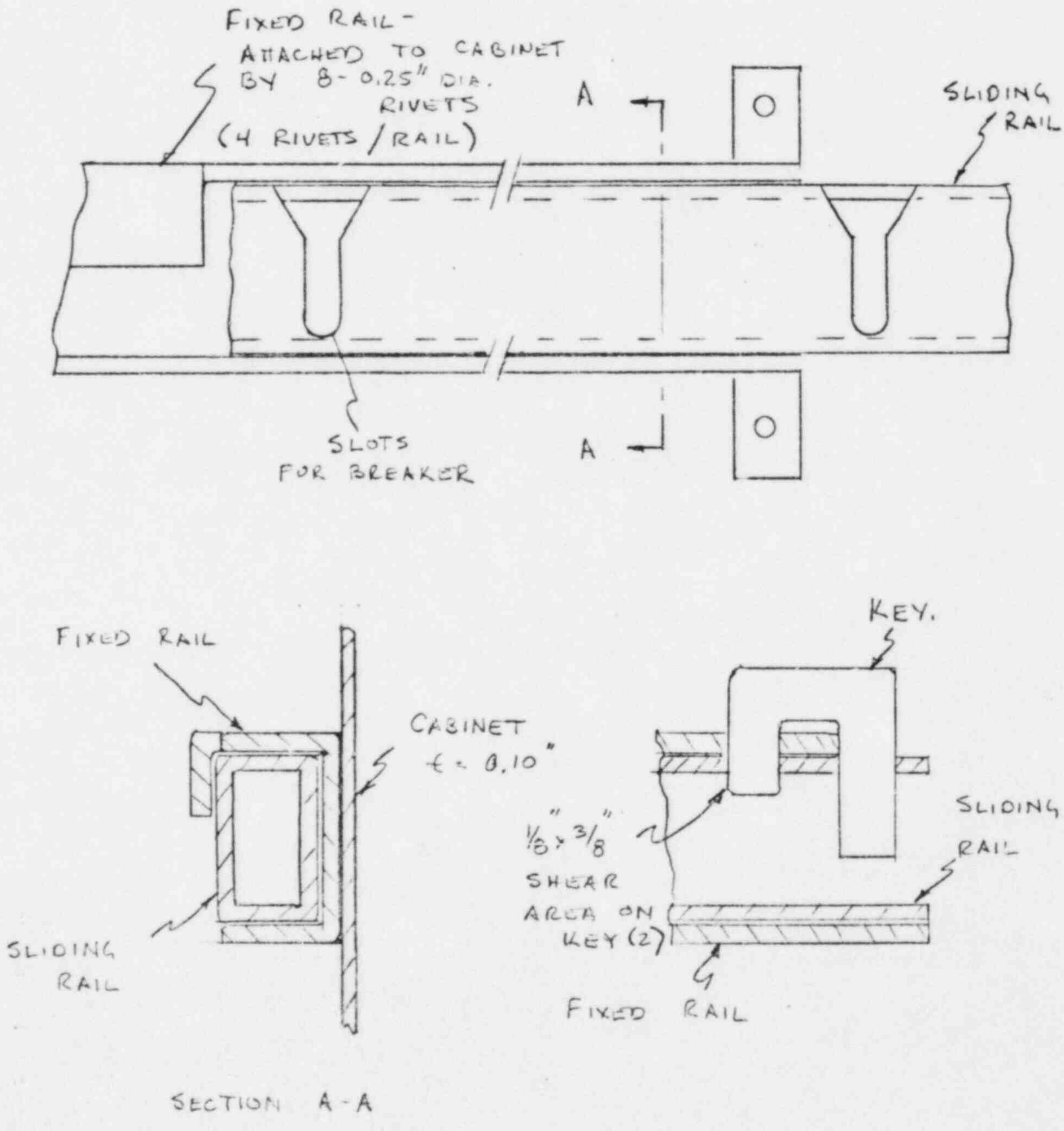


FIGURE 2

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

Title: LOAD PATH ANALYSIS FOR 460 VOLT UNIT SUBSTATION
Calculated by: BJ Date: 9-9-83
Checked by: MJK Date: 9/13/83
Reviewed by: JT Date: 12-11-83

Project: 83-03

THE SUPPORT MOUNT IN FIGURE 2 CONSISTS OF TWO SLIDING RAILS WITH 4 SLOTS FOR BREAKER PINS. THE RAILS EXTEND TO REMOVE BREAKER AND SLIDE BACK TO ENGAGE BREAKER WITH RECEPTACLES IN REAR OF CABINET. FIXED RAILS, ATTACHED TO CABINET BY 8-0.25 INCH RIVETS, ARE USED TO SUPPORT SLIDING RAILS. ONCE BREAKER IS ENGAGED TWO KEYS, ATTACHED TO THE SLIDING RAILS, HOOK ONTO THE FIXED RAILS TO KEEP BREAKER AND SLIDING RAILS FROM MOVING.

SEISMIC LOADS, INITIATING AT BREAKER, TRAVEL FROM 4-0.5 INCH PINS ON BREAKER TO SLIDING RAILS. HORIZONTAL LOADS CONTINUE THROUGH THE SLIDING RAILS TO THE KEYS. FROM THE KEYS THE LOAD GOES THROUGH THE FIXED RAILS TO THE 8-0.25 INCH RIVETS. VERTICAL LOADS TRAVEL FROM THE BREAKER PINS, THROUGH THE SLIDE RAILS, THROUGH THE FIXED RAILS, TO THE 8-0.25 INCH RIVETS.

LOADS

SEISMIC LOADS ARE TAKEN FROM REVISED APPENDIX B OF NUREG/CR-1981 (REF 1.) AND MODIFIED FOR SITE SPECIFIC ACCORDING TO pg 12 OF REFERENCE 2. THE 460 V CABINETS ARE ON THE REACTOR BUILDING FLOOR (EL 23'-6")

	g_H HORIZONTAL (g's)	g_V VERTICAL (g's)
OBE	0.69	0.095
SSE	1.05	0.19

HORIZONTAL LOAD: (F_H)

$$F_H = \sqrt{g_H^2 + g_H^2} \cdot W \approx 1.414\, g_H\, W$$

$$F_H = 848.4 \cdot g_H \text{ lbs}$$

ACCOUNTS FOR TWO HORIZONTAL SEISMIC MOTIONS.

VERTICAL LOAD : (F_Y)

SINCE THE VERTICAL UPWARD LOAD DUE TO SEISMIC MOTION IS NEVER GREATER THAN THE DEADWEIGHT, THE BREAKER WILL NOT LIFT OUT OF THE SLOTS IN THE SLIDING RAIL.

VERTICAL LOADS ARE THE COMBINATION OF:

$F_{VERTICAL}$ = DEADWEIGHT + VERTICAL SEISMIC

600 lbs g_V (600)

	HORIZONTAL SEISMIC (lbs)	VERTICAL SEISMIC (lbs)	VERTICAL DEADWEIGHT (lbs)
OBE	585.5	57.0	600.0
SSE	890.9	114.0	600.0

SHEAR ON 4 - 0.5" DIA BREAKER PINS

$$AREA = 4 \cdot (\pi/4) \cdot (0.5)^2 = 0.7854 \text{ in}^2$$

$$LOAD = \sqrt{(\text{HORIZONTAL SEISMIC})^2 + (\text{VERTICAL SEISMIC})^2} + \text{DEADWEIGHT}$$

	OBE	SSE
LOAD (lbs)	1188.3	1498.2
SHEAR (psi)	1513	1908

SHEAR ON KEYS FROM HORIZONTAL LOAD

$$AREA = 2 \times (1/8 \cdot 3/8) = 0.09375 \text{ IN}^2$$

	OBE	SSE
HORIZONTAL LOAD (lbs)	585.5	890.9
SHEAR (psi)	6,245	9,503

SHEAR ON 8 · 0.25" DIA RIVETS

$$AREA = 8\,(\pi/4)\,(0.25)^2 = 0.3927\ IN^2$$

HORIZONTAL AND VERTICAL LOADS ARE TRANSMITTED TO RIVETS.

	OBE	SSE
LOAD (lbs)	1188.3	1498.2
SHEAR (psi)	3026	3815

ALLOWABLE STRESS

ALLOWABLE SHEAR FOR OBE AND SSE (S_v)

MATERIAL: *A 36 (ASSUMED) MINIMUM YIELD = 36.0 ksi (S_y)
MINIMUM ULT = 58.0 ksi (S_u)

* ASSUMED PROPERTIES EQUIVALENT TO A-36

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW – Washington, DC 20036

Title: LOAD PATH ANALYSIS FOR 460 VOLT UNIT SUBSTATION	Calculated by: BJ	Date: 9-9-83
	Checked by: MJK	Date: 9/13/83
	Reviewed by: JJ	Date: 10-11-83

Project: 83-03

ALLOWABLE STRESS

LOAD	SERVICE LEVEL	STRESS LIMIT		ALLOWABLE (psi)
OBE (NOTE 1)	LEVEL B	SHEAR	1.33 (0.4 S_y) OR 0.42 S_u	19,150
SSE (NOTE 1)	LEVEL D	SHEAR	2.0 (0.4 S_y) OR 0.42 S_u	24,360

SUMMARY OF RESULTS

LOAD COMPONENT	SHEAR STRESS OBE (psi)	SHEAR STRESS SSE (psi)	ALLOWABLES OBE / SSE
4 - 0.5" PINS ON BREAKER	1513	1908	19,150 / 24,360
2 - 1/8 x 3/8 KEYS	6245	9503	19,150 / 24,360
8 - 0.25" RIVETS	3026	3815	19,150 / 24,360

CALCULATED STRESSES IN LIMITING LOAD COMPONENTS ARE WITHIN ALLOWABLE VALUES.

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Calculated by: BY Date: 9-9-83

Checked by: [illegible] Date: 9/13/83

Reviewed by: [illegible] Date: 10-1-83

Project: 83-03

REFERENCES

1. REVISED APPENDIX B OF NUREG/CR-1981 (REVISED APPENDIX B WAS RECIEVED 6-25-81, FROM LLL LETTER TO MPR (W. SCHMIDT) DATED 6-23-81, LETTER # SM-81-159.)

2. MPR CALCULATION BY B. LIPFORD, "VERIFICATION OF ANCHOR ADEQUACY FOR 4160 VOLT AND 460 VOLT ELECTRICAL CABINETS", DATED 9-9-83.

3. ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, APPENDICES, 1980 EDITION, UP TO AND INCLUDING WINTER 1982 ADDENDA.