SEISMIC EVALUATION OF WOLF CREEK GENERATING STATION

STRUCTURES USING LIVERMORE SPECTRUM

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I. INTRODUCTION

At the request of the NRC Staff, an evaluation was made to determine the effect a new free field response spectrum has on the safety-related structures and structural components at the Wolf Creek Generating Station. The new spectrum was recently prepared by Lawrence Livermore Laboratories[1] (LLL) for the NRC. In their report, (LLL) suggests for the Safe Shutdown Earthquake (SSE) an 84 percentile spectrum , based on real records from 10 earthquakes of magnitude (M_L) 5.3$\pm$0.5 at rock sites measured within 20 Km of the epicenter. Figure 1 compares (at 5% critical damping) the (LLL) spectrum with the Wolf Creek spectra used for design. The design spectra is in accordance with NRC Reg. Guide 1.60 anchored at 0.12g ZPA (zero period acceleration) as reported in the FSAR. By linearly increasing the current design spectra g level upward to a ZPA of 0.15g the (LLL) spectrum is enveloped by a significant margin for periods greater than approximately 0.3 seconds and a good approximation is obtained for periods between approximately 0.04 and 0.3 seconds.

Current NRC licensing practice requires the Operating Basis Earthquake (OBE) to have a minimum return period in the order of 100 years. 1
The (LLL) report confirms that the design OBE spectra, which is also in accordance with Reg. Guide 1.60 but anchored at 0.06g,

satisfies this criteria. Therefore this evaluation is limited to the effects of the Livermore SSE spectrum as approximated by a Reg. Guide 1.60 Spectra anchored at 0.15g ZPA.

This evaluation is intended to identify additional margins inherent in the design of the affected structures as an aid to the NRC staff in expediting the licensing process. It should not be construed that this evaluation implies or in any way suggests that the response spectra as reported in the FSAR is either inadequate or unconservative.

II. DISCUSSION

Wolf Creek is part of the Standard Nuclear Unit Power Plant System (SNUPPS) which is designed for enveloping seismic loads obtained from several sites, all of which utilize Reg. Guide 1.60 response spectrum anchored at a minimum of 0.2g ZPA. Details of the design and the seismic analyses are reported in the SNUPPS FSAR. Therefore all standard plant safety-related structures, including the reactor building, auxiliary building, control building, diesel generator building, fuel building and safety-related tanks automatically envelope the suggested Livermore spectrum and need not be considered in this evaluation. Other structural components, such as buried safety-related duct banks and buried ESWS piping, although not part of the standard power plant, are also designed using envelope seismic loads. Consequently, the only safety-related structures requiring further consideration are limited to the following:

ESWS Pumphouse

Electrical Manholes

ESWS Valvehouse

Discharge Structure

Circulating and Warming Water 1
Pipe Incasements

A description of these structures, including their design basis, is provided in Section 3.8 of the Wolf Creek FSAR Site Addendum.

A. <u>Safety Related Manholes, ESWS Valvehouse, Discharge Structure and Circulating and Warming Water Pipe Incasements</u> 1

The design of the manholes, valvehouse, and discharge structure, as well as the circulating and warming water pipe incasements, is controlled by loading cases involving the OBE even when the 0.15g SSE is considered. The reason becomes apparent by examination of the load cases involving both the OBE and SSE as defined in table 3.8.2 of the Wolf Creek FSAR Site Addendum: 1 1

OBE Load Case $U=1.4D + 1.7L + 1.9E_{OBE}$

SSE Load Case $U=1.0D + 1.0L + 1.0E_{SSE} + (T_o + R_o)$

Where U=Required Section Strength

D=Dead Load

L=Live Load

E_{OBE}, E_{SSE}=Seismic Loads

(T_o & R_o) are thermal and pipe reaction loads which are either negligible or do not affect design for these structures)

Each of these structures have lateral static earth pressure (including surcharge effects) as their predominant loading. Since static earth pressure is treated as live load, the required increase in actual static earth pressure by 1.7 in the OBE load case completely overshadows the seismic effect in the SSE load case, particularly since the OBE load case also requires increasing the seismic loads by a factor of 1.9.

B. ESWS Pumphouse

The pumphouse is more complicated than the other structures and requires a detailed evaluation to determine its capability to resist increased SSE loads. The pumphouse is of heavy shear wall reinforced concrete construction. Figures 2 thru 4, reproduced from the Wolf Creek FSAR Site Addendum and included here for convenience, show the plan and sections of the building. Ground surface (grade) elevation has been added to Figure 4.

1. Seismic Analysis

The seismic analysis conducted for the design of the pumphouse, and as reported in the Wolf Creek FSAR Site Addendum consider a detailed finite element representation of the soil using the FLUSH Program. This method was selected in compliance with Standard Review Plan (SRP) criteria for deeply embedded structures. In the evaluation effort the same structural representation as used in the FLUSH analysis is employed, but in lieu of the finite element soil consideration the structure is attached to a fixed base. Otherwise the evaluation

analysis approach was similar to that of the original design. The fixed base representation would be expected to result in conservative but realistic results for horizontal input motion as compared with the FLUSH analysis for the following reasons:

a. The input time history motion described in BC-TOP4A is applied at the bottom of the base mat. This is conservative as compared to the Standard Review Plan FLUSH analysis approach.

b. No material or radiation damping of the soil (as included in the FLUSH analysis) is considered. This is conservative since these considerations absorb energy, effectively reducing response of the structure to input motion.

c. The presence of the soil surrounding the embedded portion of the structure is conservatively omitted. The presence of soil serves to reduce the effective height of the building as well as provide a mechanism allowing loads to be transferred laterally into the soil above the base mat, effectively reducing the building shears and moments.

To determine the adequacy of the fixed base model representation and validate the above statements a comparison of building shear and moment as well as key building response spectra are included in Figures 5 thru 11 for both the finite element (FLUSH) and fixed

base representation for the 0.12g earthquake. Building
shear and moments exhibit good correlation above El. 2000.
Below El. 2000 the lack of supporting soil in the fixed
base model yields conservative results. This con-
servatism may be somewhat excessive in the East-West
direction. Horizontal building response spectra also
exhibits good correlation between the two analyses. The
fixed base representation results in an upward shift
of the peaks by approximately 3 Hz in the North-South
(N-S) direction, and approximately 4-5 Hz in the East-
West (E-W) direction. This is believed to be caused 1
by the rigid foundation in the fixed base representation
combined with no consideration of soil mass surrounding
the structure below grade which may be mobilized with
the structure. Both of these considerations tend to
increase the first structural mode natural frequency.
With the exception of N-S direction at El. 2025 the fixed
base model produced somewhat higher peak response. This
is believed to be the result of not considering soil damp- 1
ing and dissipation effects. The exception at El. 2025
N-S where the peak of the fixed base model is somewhat
lower than that of the FLUSH analyses is reasonably
counteracted by the excesses of the fixed base repre-
sentation in the E-W direction.

Contrary to the conservative nature for horizontal
motion, the fixed base model is not necessarily

conservative when vertical seismic input motion is applied. The relative flexibility of the foundation creates a rocking phenomena which may couple with a vertical input, amplifying the vertical response above that predicted by the fixed base model. As shown in Figure 8 the fixed base representation fails to include the coupling effect. For this reason the results for vertical input motion into the fixed base representation will not be used for evaluation of vertical motion effects in the pumphouse evaluation. Rather the original FLUSH analysis, adjusted linearly upward by 25% (to reflect the rise from 0.12g to 0.15g) will be used for evaluation of vertical motion effects. This is conservative 1
since due to the strain dependent nature of the soil the actual increase is less than linear.

The seismic results used to evaluate the pumphouse are included in Figures 12 through 18. These results represent building moments, shear and response spectra developed in accordance with the fixed base representation previously discussed, excited in the E-W and N-S directions with the horizontal time history described in BC-TOP4A[2], representing the response spectra in accordance with Reg. Guide 1.60 anchored at 0.15g. The results for vertical input motion were obtained by conservatively increasing the FLUSH results obtained at 0.12g upward by 25% to represent the results of a 0.15g

analysis.

2. Structural Design

Design considerations associated with the increased SSE are limited to the portion of structure below Elev. 2000 for several reasons.

- The portion of structure above El. 2000 has much lower building shears and moments imposed (see Figure 12).
- The bulk of the structure above El. 2000 has a much greater cross-section resulting in a much greater capacity to accept seismic loads.
- The portion of structure above grade is designed to resist the effects of a tornado missile impact, which controls the wall thicknesses and reinforcing requirements, and provides excessive capability to resist applied seismic loads.

Structural considerations investigated included the following:

- Soil bearing pressure
- Base mat capability
- Capability of the walls to resist increased shear (including associated torsional effects) and flexure
- Building stability (i.e., overturning and sliding)
- Effects on HVAC and cable tray supports

Allowable stresses and margins of safety are consistent

with those imposed on the original design and as reported in the FSAR.

A refined analysis of building weight distribution and base mat configuration resulted in soil bearing pressures within that reported for the 0.12g seismic analysis. 1 Since no increase in soil bearing pressure was realized, the stresses in the base mat were not adversely affected. The most significant effect of the increased SSE in wall stresses is shear stresses caused by combined shear and torsions effects. However, these stresses remain within 90% of allowable for the SSE case. Similarly, electrical cable tray and HVAC supports were also found to be within original design allowable stresses without exception.

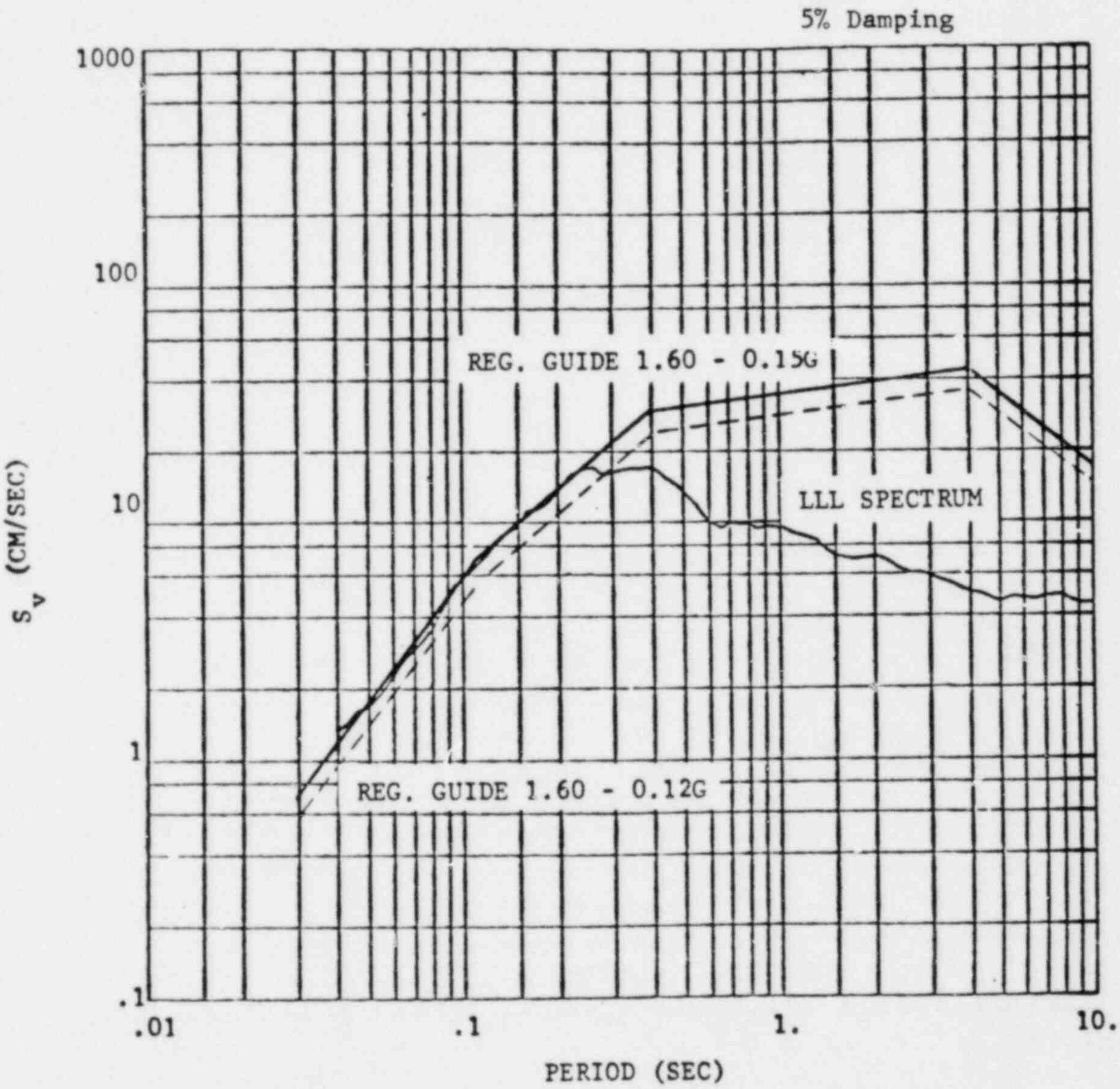
III. CONCLUSIONS

All aspects of the Wolf Creek structures and structural components have been reevaluated using a response spectra which conservatively approximates the (LLL) suggested response spectrum and have been found to remain within all allowable stress limits imposed in the original design.

Effects of the (LLL) spectrum on equipment, including piping systems will be addressed in a separate report.

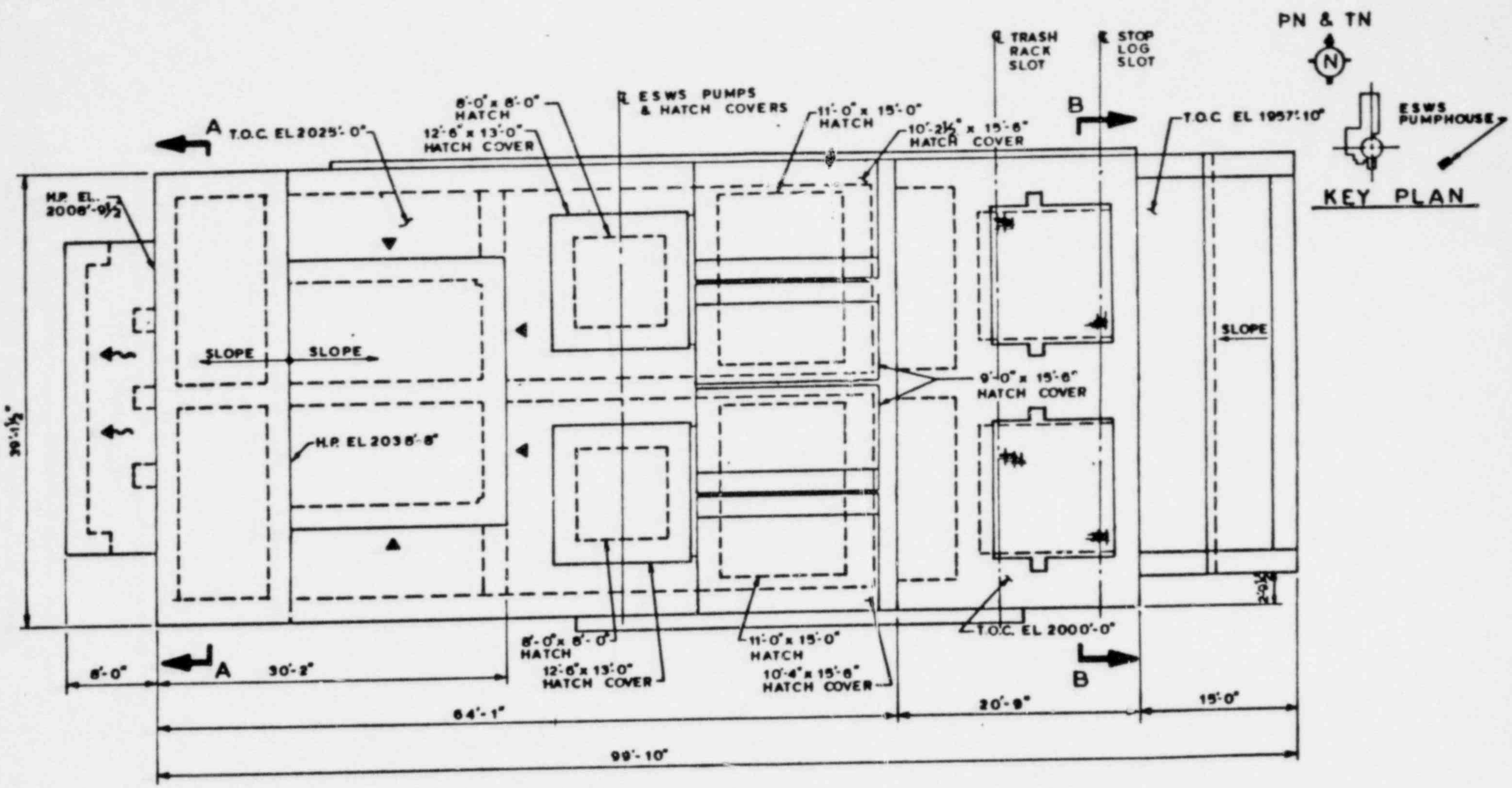
REFERENCES:

1. Lawrence Livermore Laboratories, "Seismic Hazard Analysis of the Wolf Creek Site" Draft, March 1, 1982.
2. Bechtel Power Corporation, "Topical Report-Seismic Analysis of Structures and Equipment for Nuclear Power Plants" BC-TOP-4A, Rev. 3, November 1974.



COMPARISON OF LAWRENCE LIVERMORE SPECTRUM
WITH WOLF CREEK DESIGN SPECTRA

Figure 1



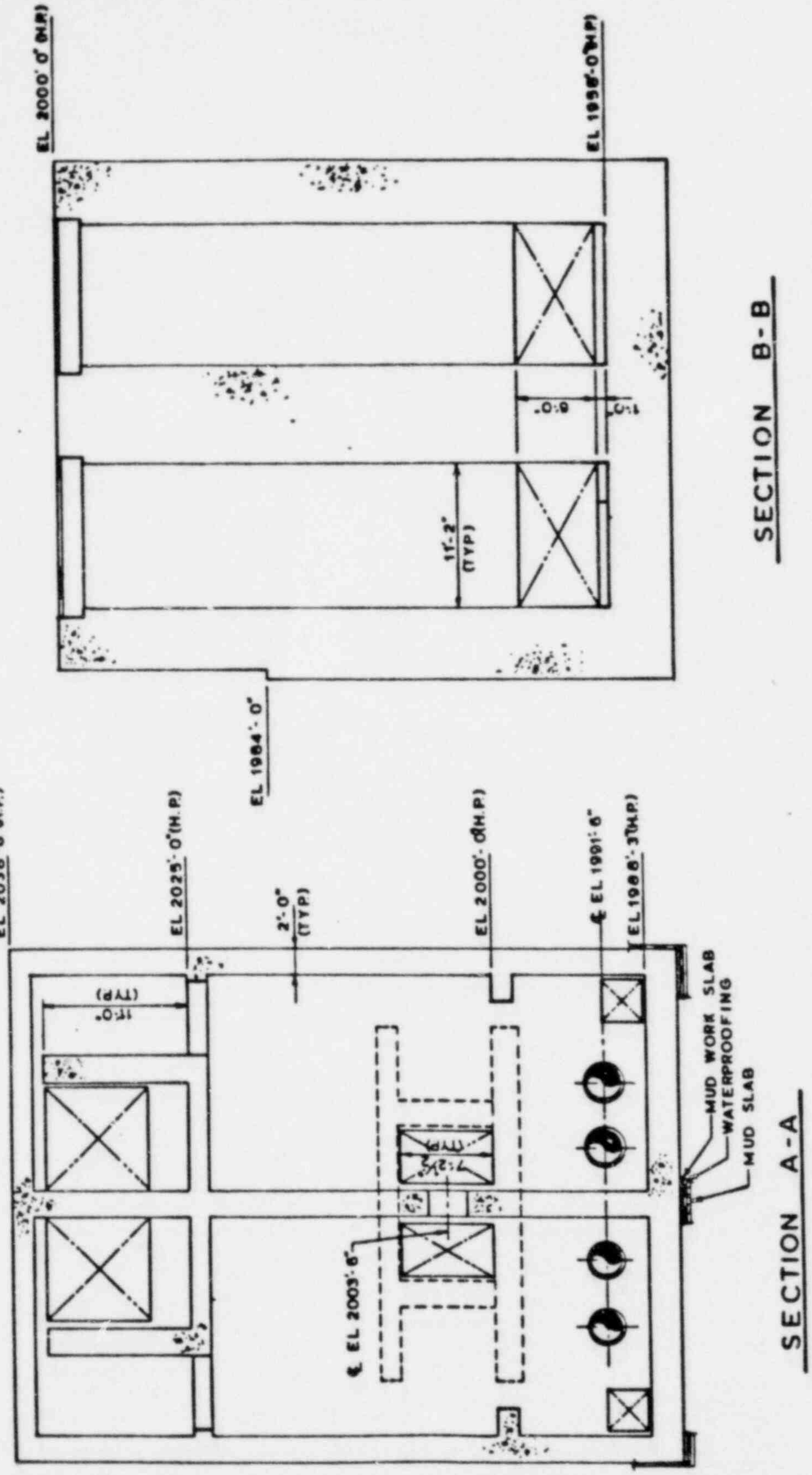
NOTE: ROOFS AND HATCHES AT EL 2038'-8", EL 2025'-0" AND EL 2008'-9½" HAVE f'c = 5000 psi MINIMUM AT 90 DAYS. ALL OTHER CONCRETE IS f'c=4000 psi MINIMUM AT 28 DAYS

▶ AIR INTAKE

~▶ AIR EXHAUST

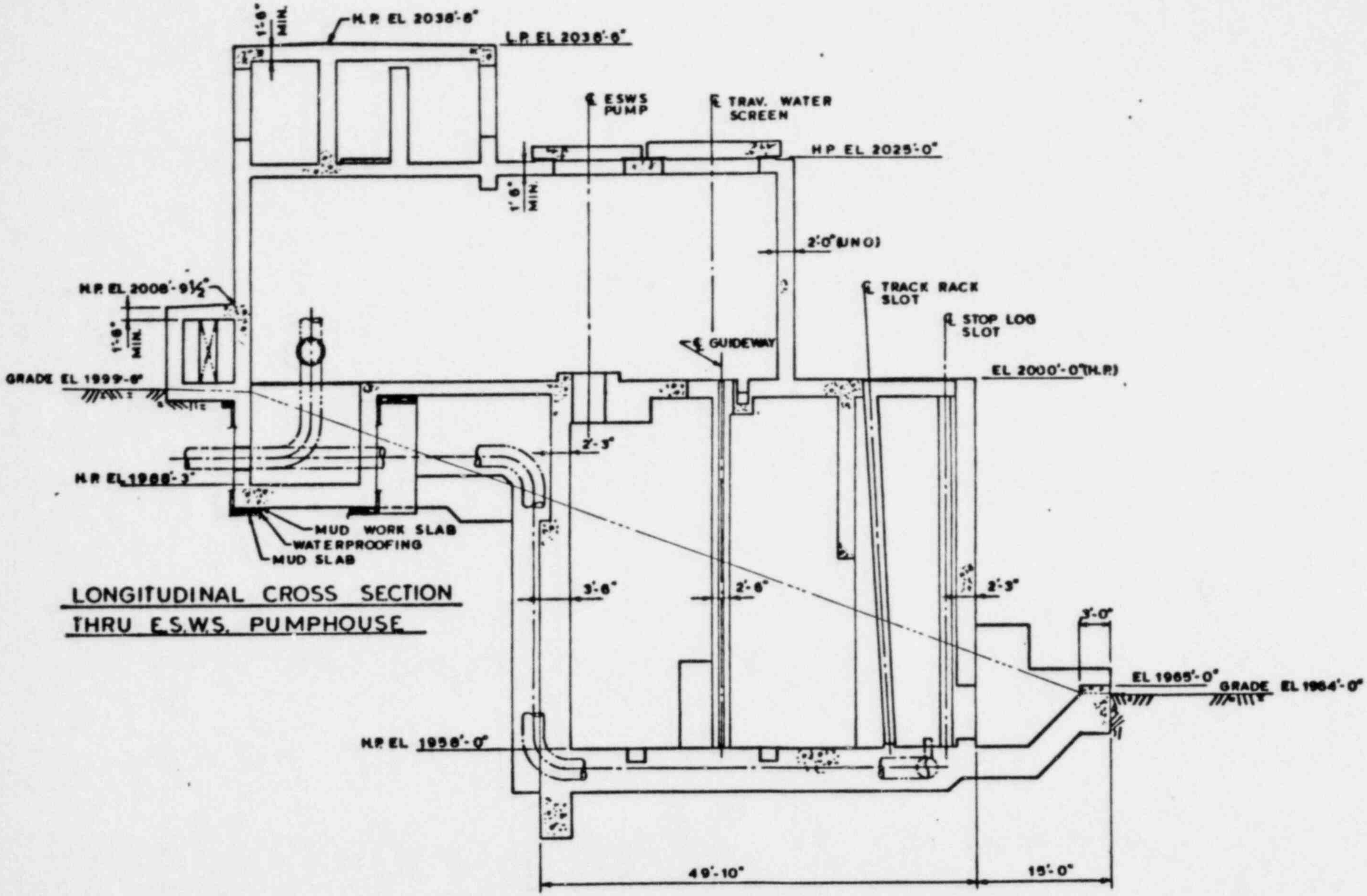
PLAN VIEW - E.S.W.S. PUMPHOUSE

Figure 2



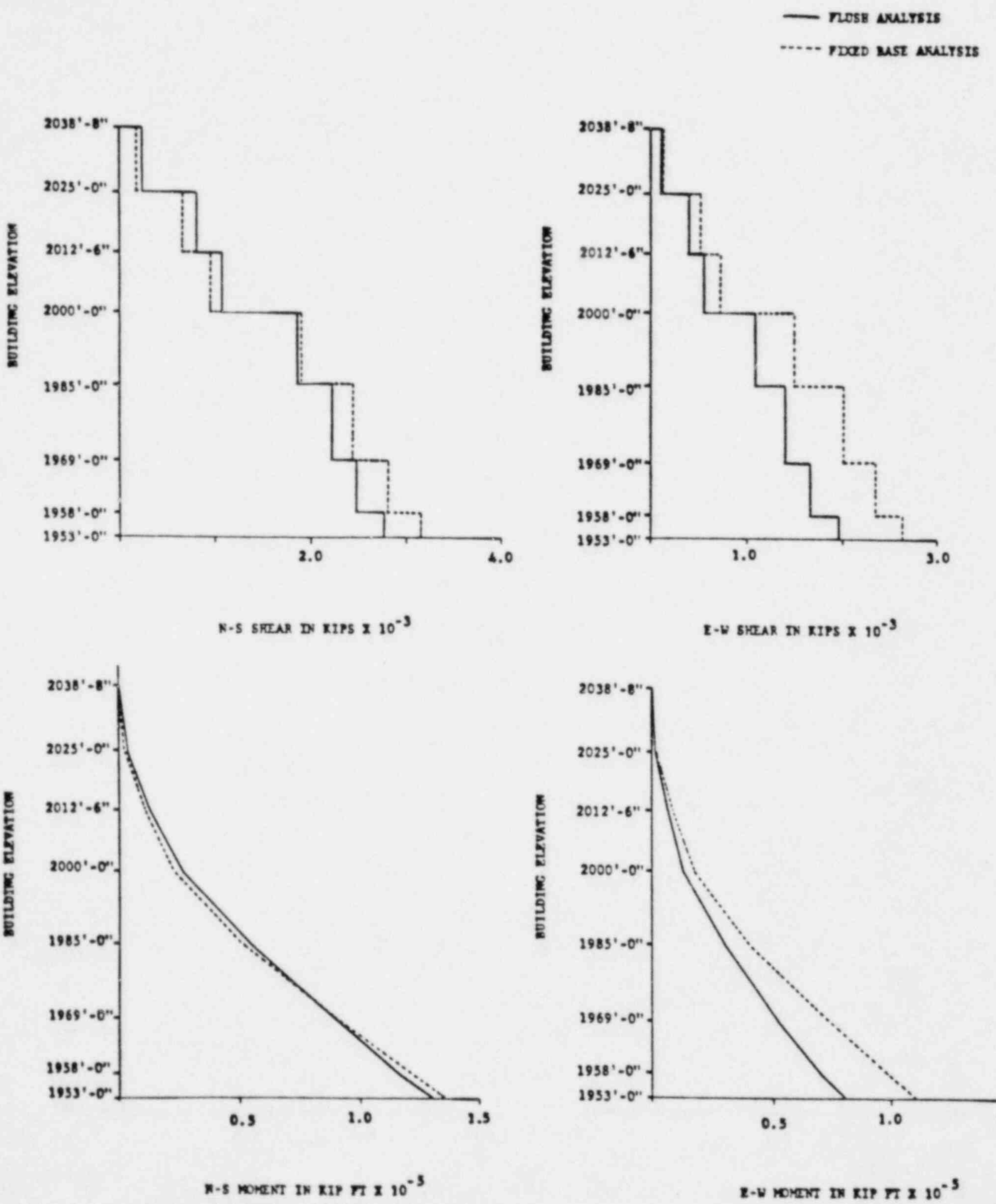
N-S SECTION - E.S.W.S. PUMPHOUSE

Figure 3



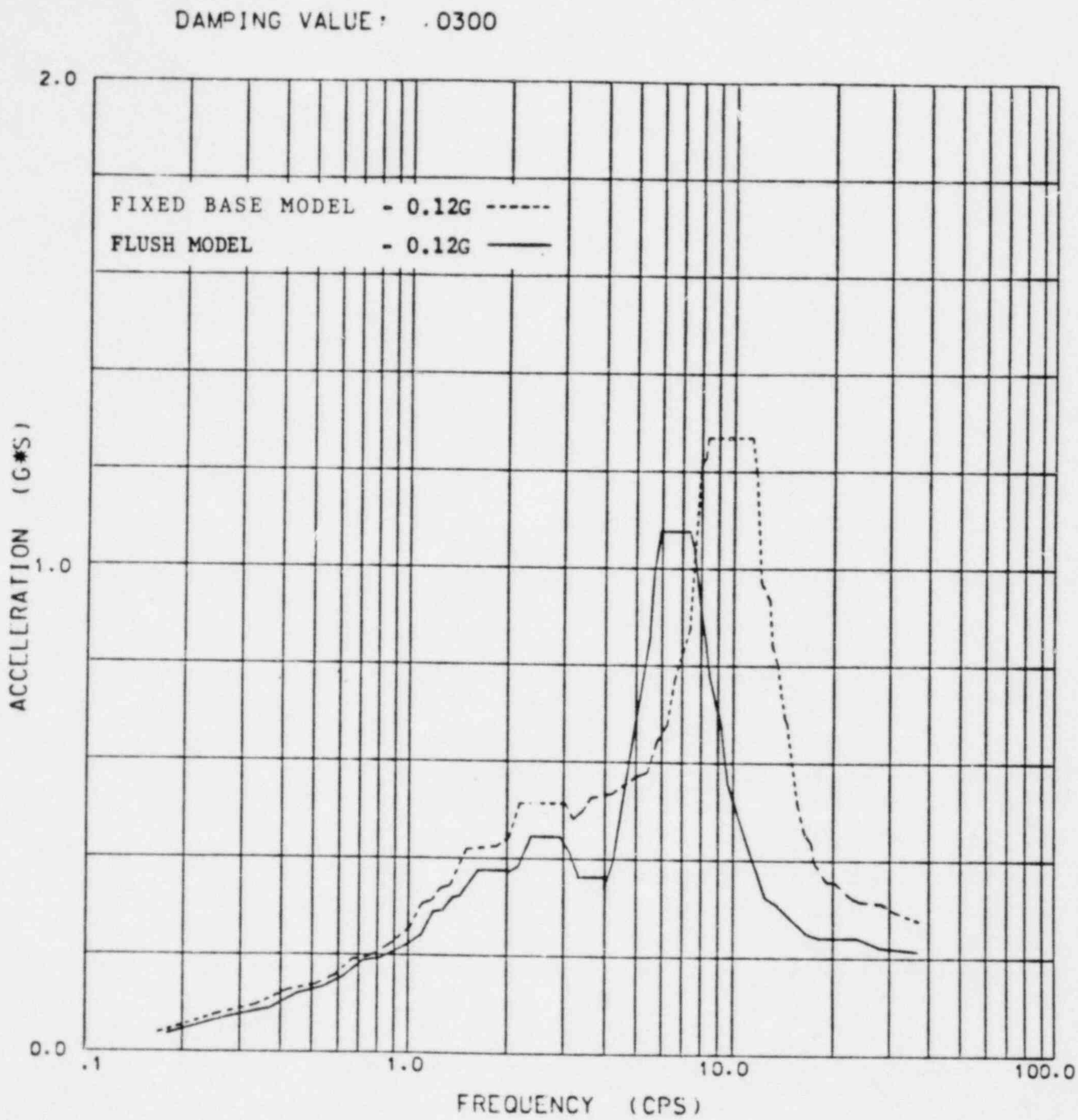
E-W SECTION - E.S.W.S. PUMPHOUSE

Figure 4



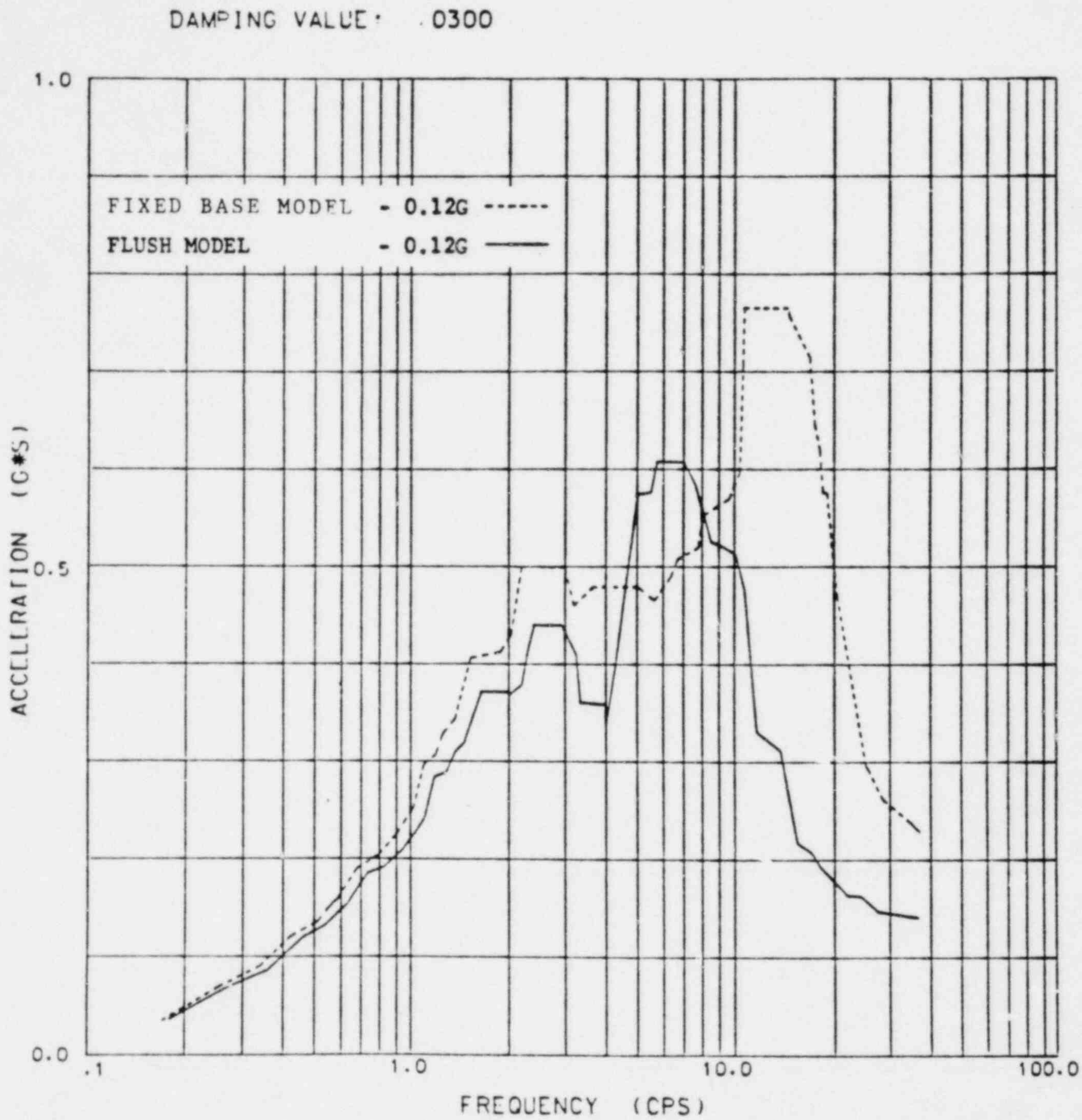
COMPARISON OF FLUSH AND FIXED BASE
ANALYSIS BUILDING SHEAR AND MOMENTS

Figure 5



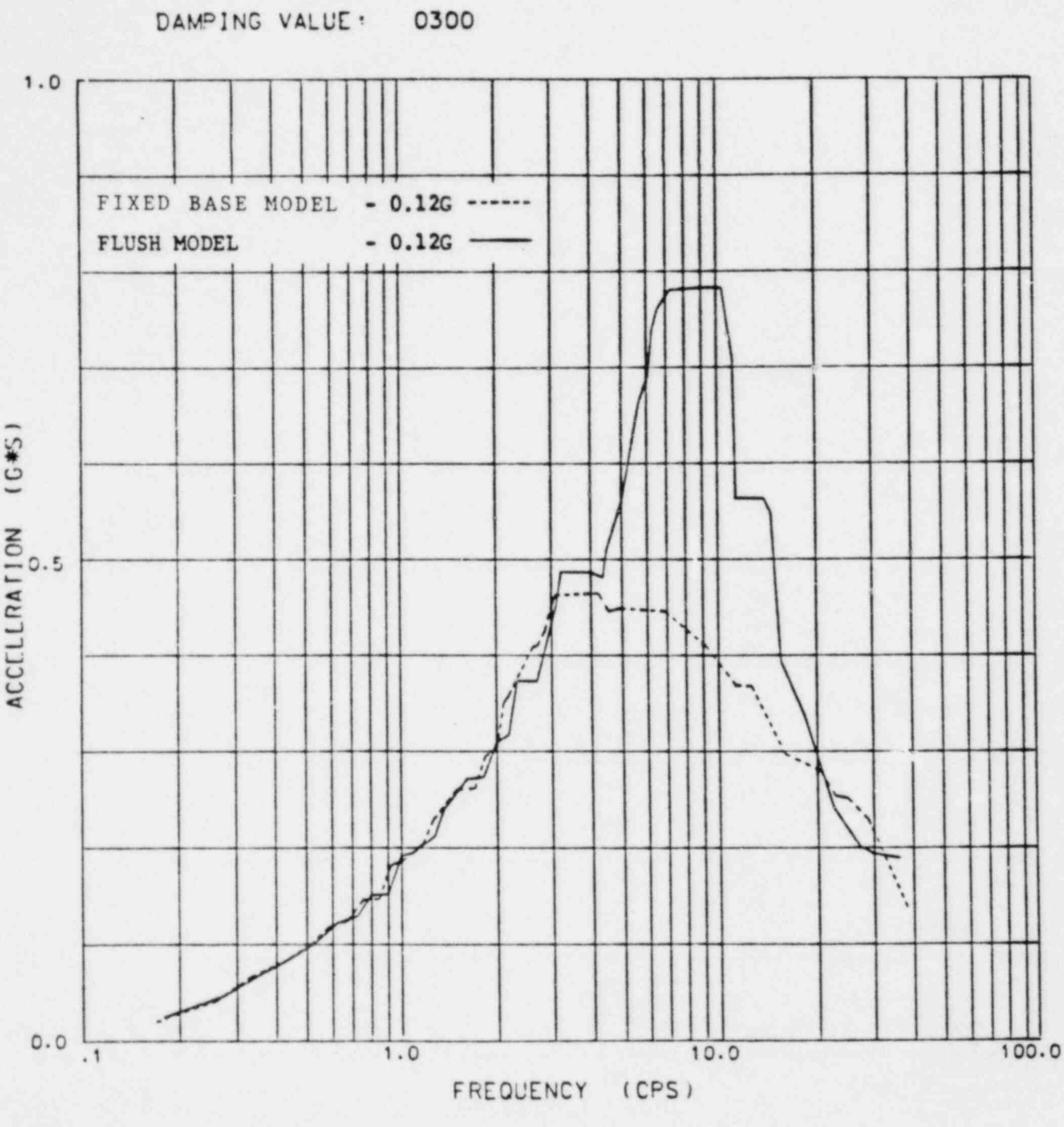
COMPARISON OF FLUSH AND FIXED BASE ANALYSIS PUMPHOUSE
N-S RESPONSE SPECTRUM AT EL. 2000, 3% DAMPING

Figure 6



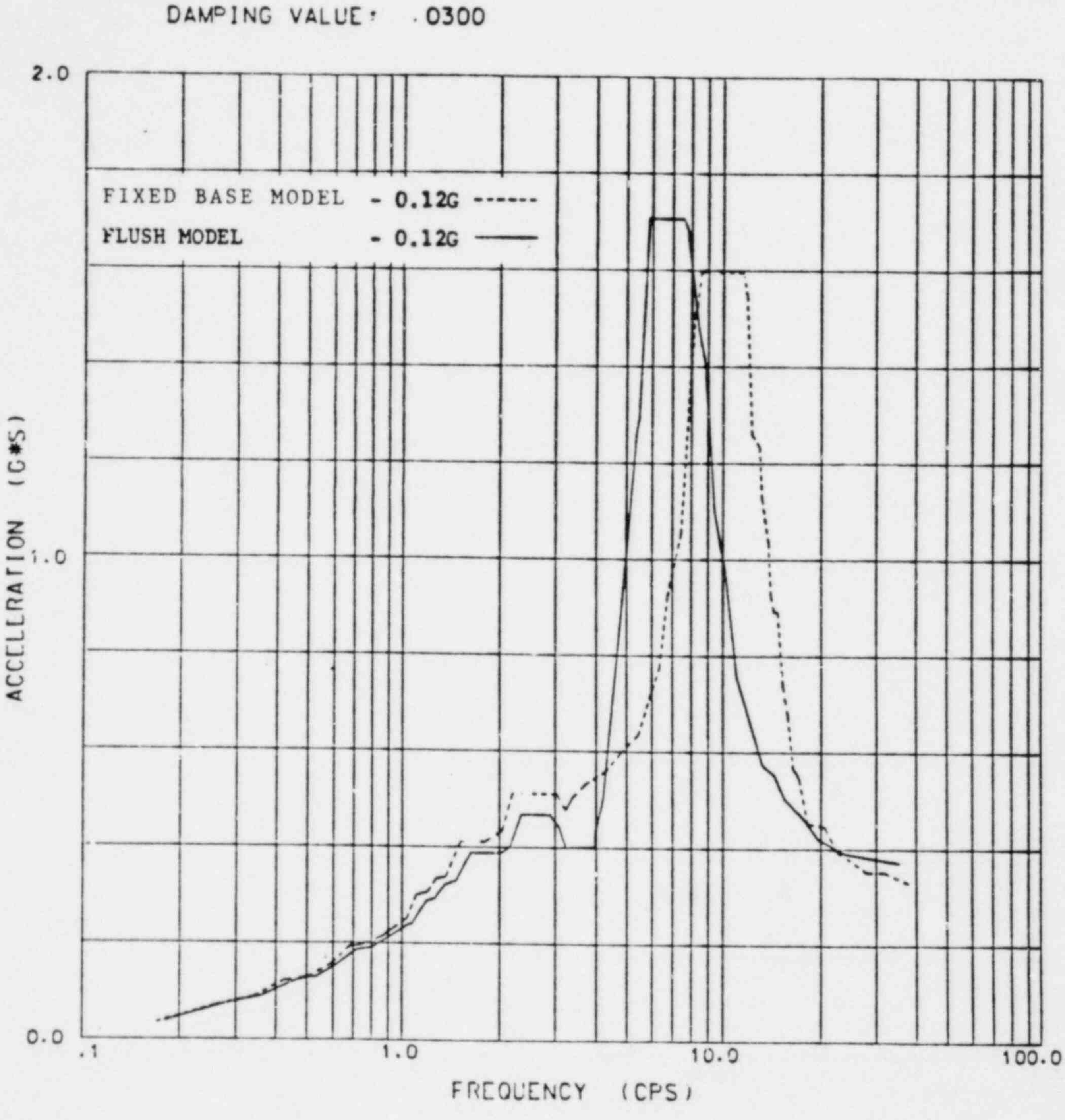
COMPARISON OF FLUSH AND FIXED BASE ANALYSIS PUMPHOUSE
E-W RESPONSE SPECTRUM AT EL. 2000, 3% DAMPING

Figure 7



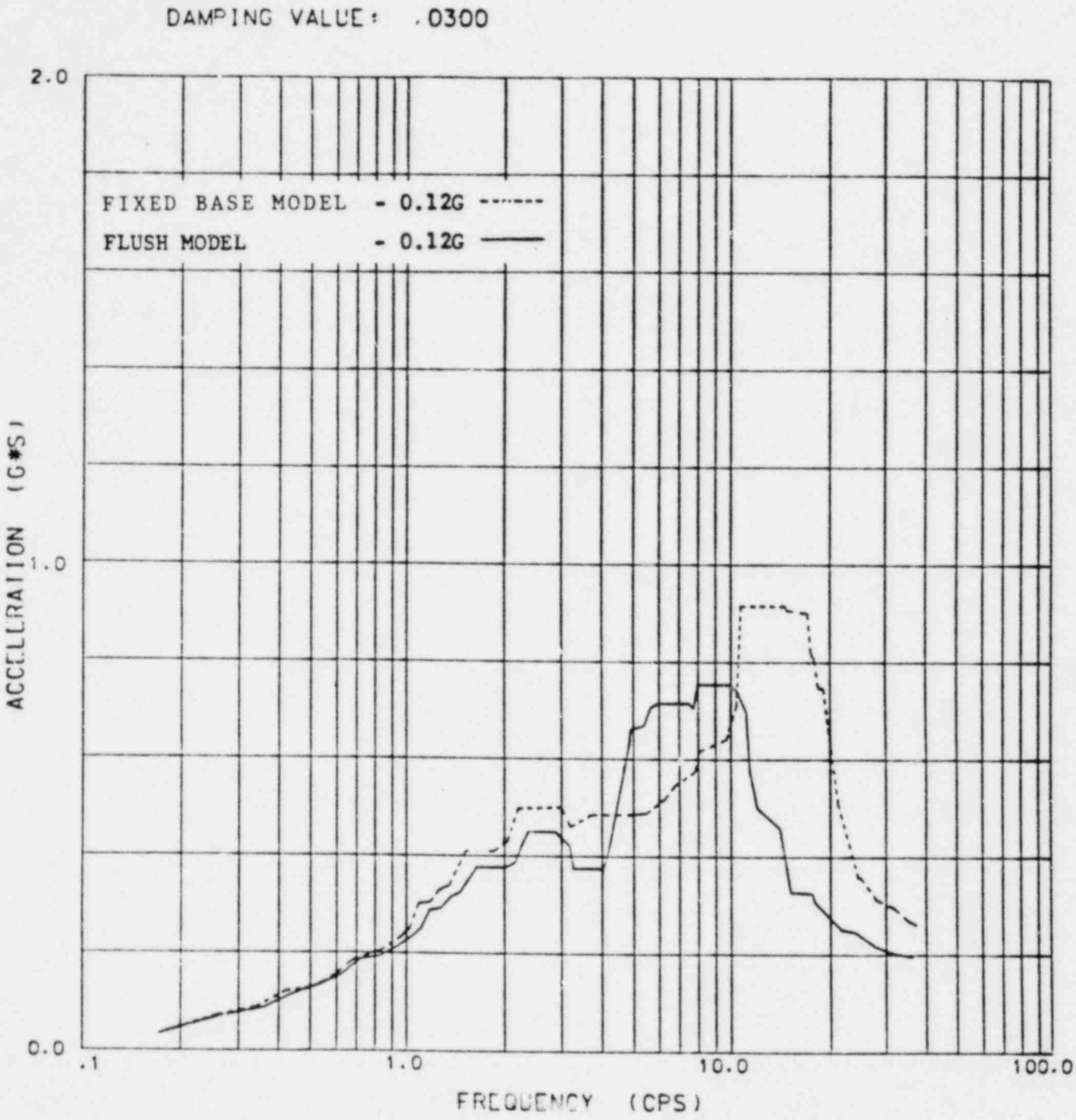
COMPARISON OF FLUSH AND FIXED BASE ANALYSIS PUMPHOUSE
VERTICAL RESPONSE SPECTRUM AT EL. 2000, 3% DAMPING

Figure 8



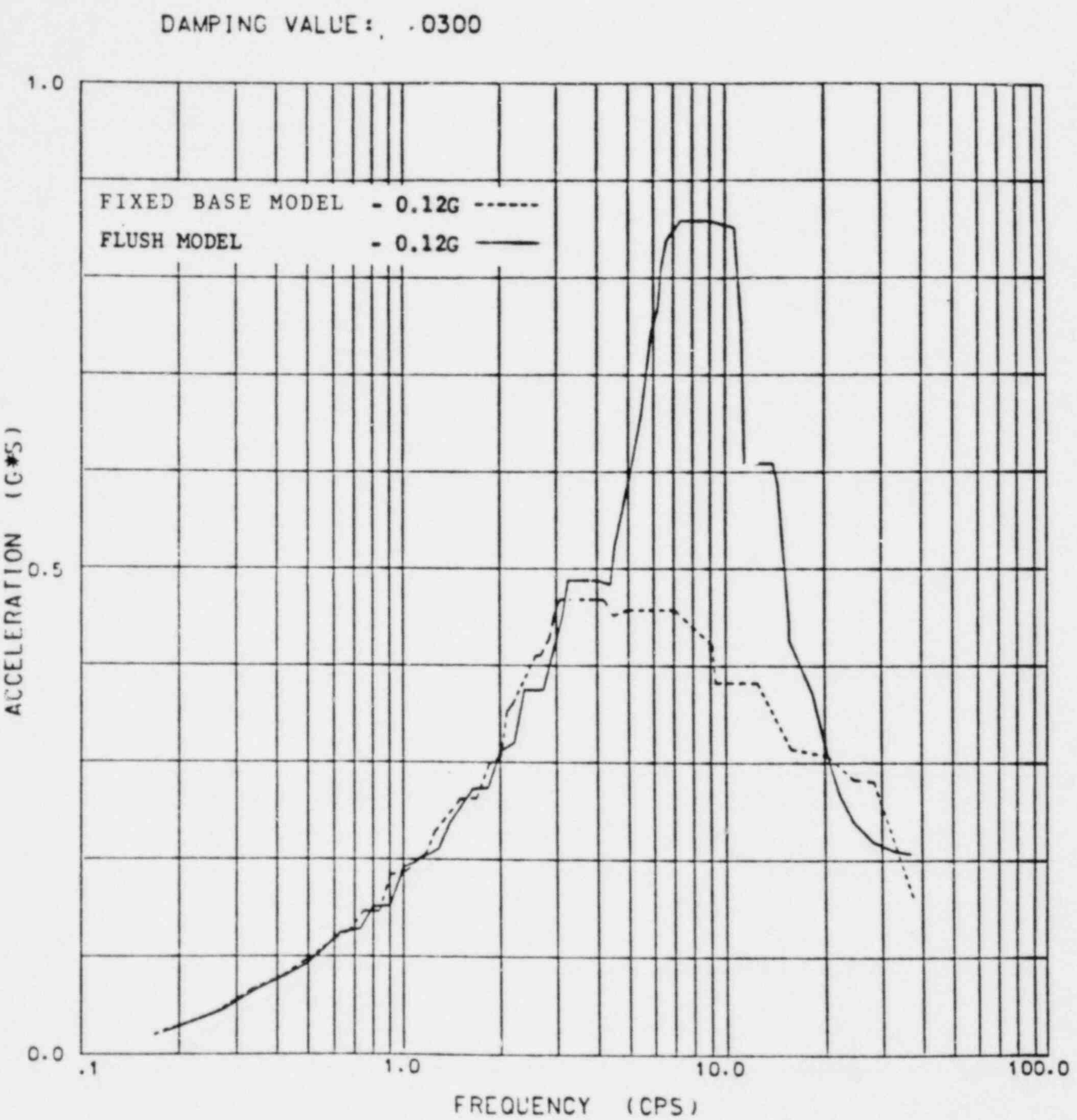
COMPARISON OF FLUSH AND FIXED BASE ANALYSIS PUMPHOUSE
N-S RESPONSE SPECTRUM AT EL. 2025, 3% DAMPING

Figure 9



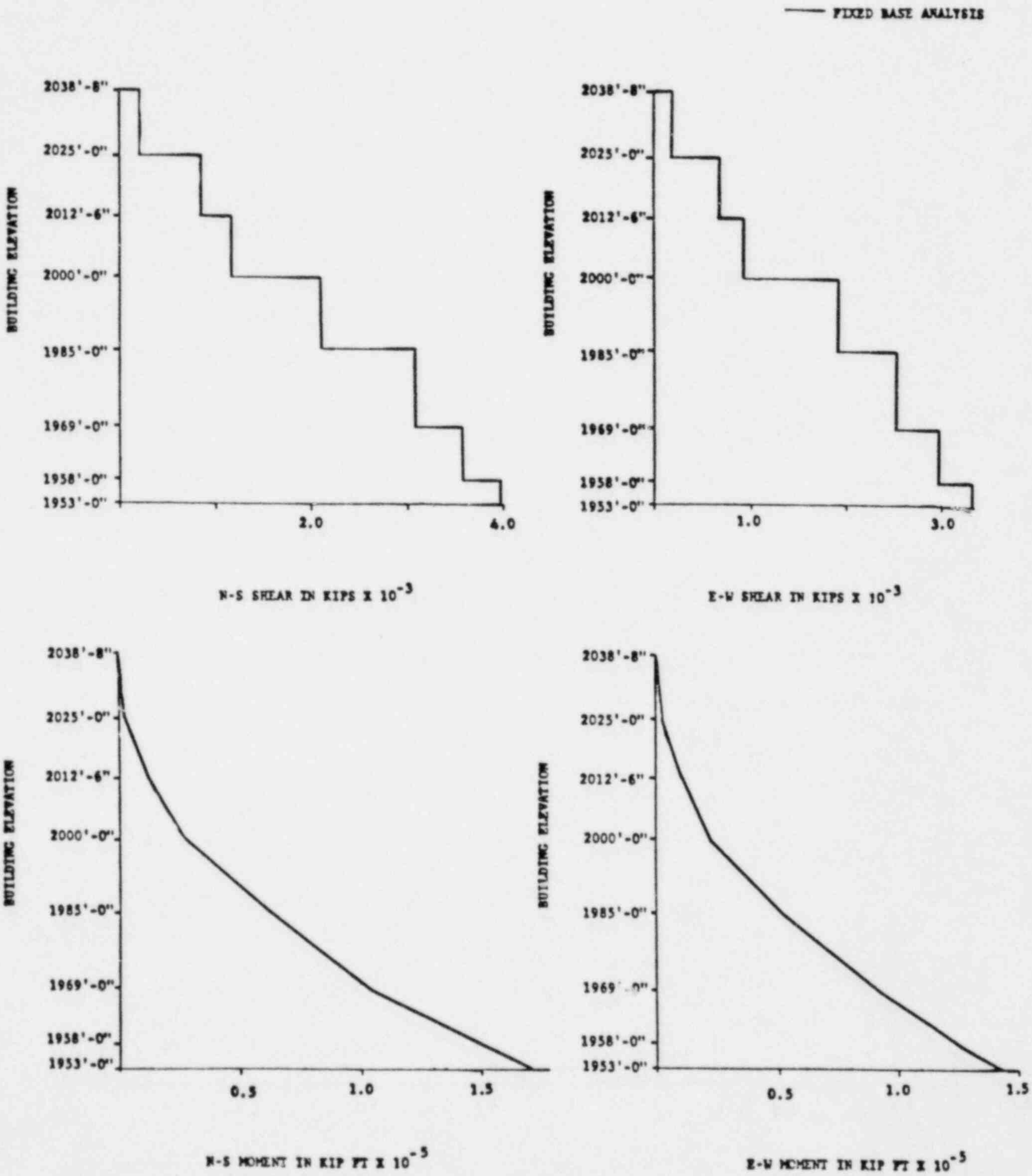
COMPARISON OF FLUSH AND FIXED BASE ANALYSIS PUMPHOUSE
E-W RESPONSE SPECTRUM OF EL. 2025, 3% DAMPING

Figure 10



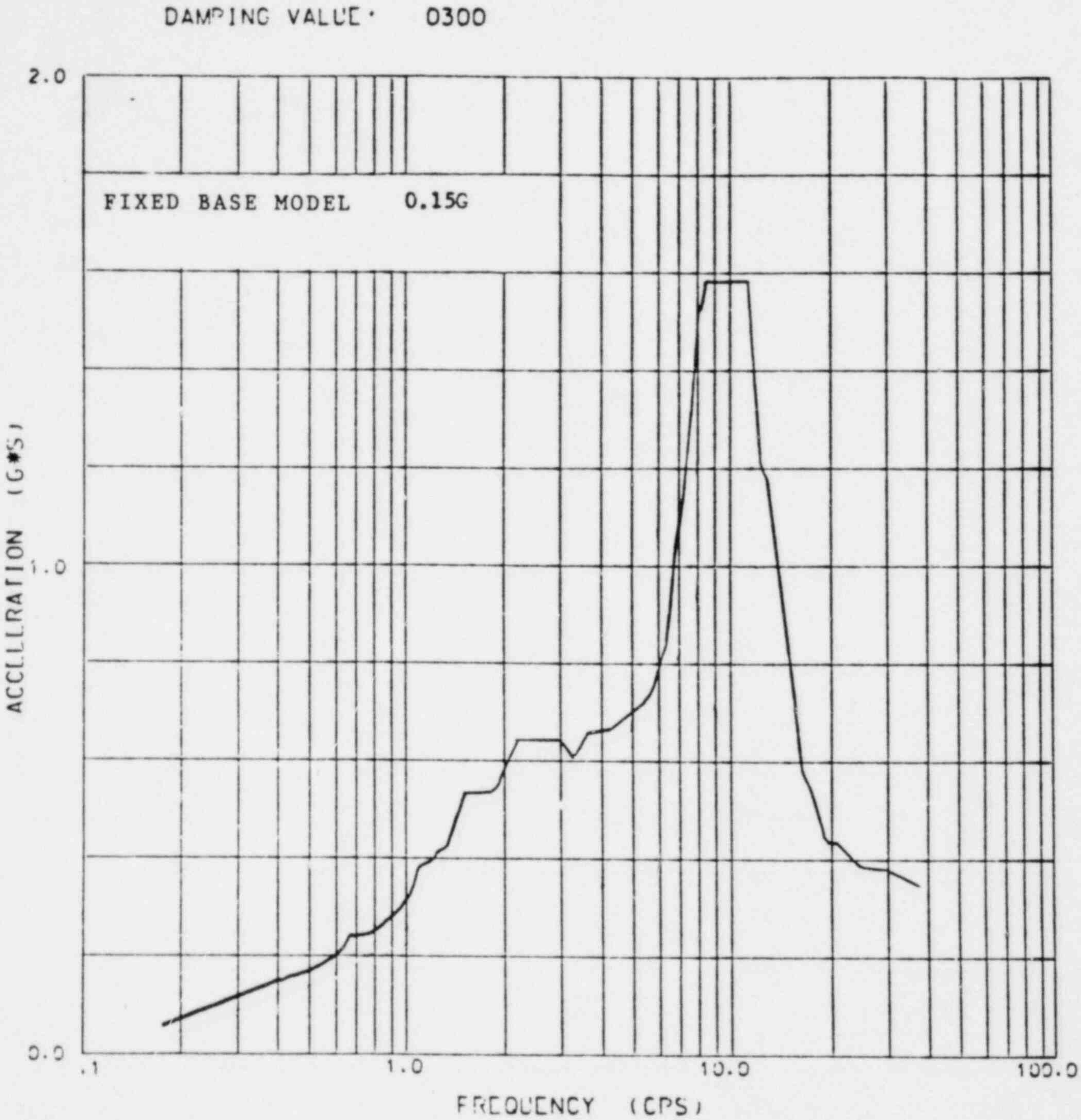
COMPARISON OF FLUSH AND FIXED BASE ANALYSIS PUMPHOUSE
VERTICAL RESPONSE SPECTRUM AT EL. 2025, 3% DAMPING

Figure 11



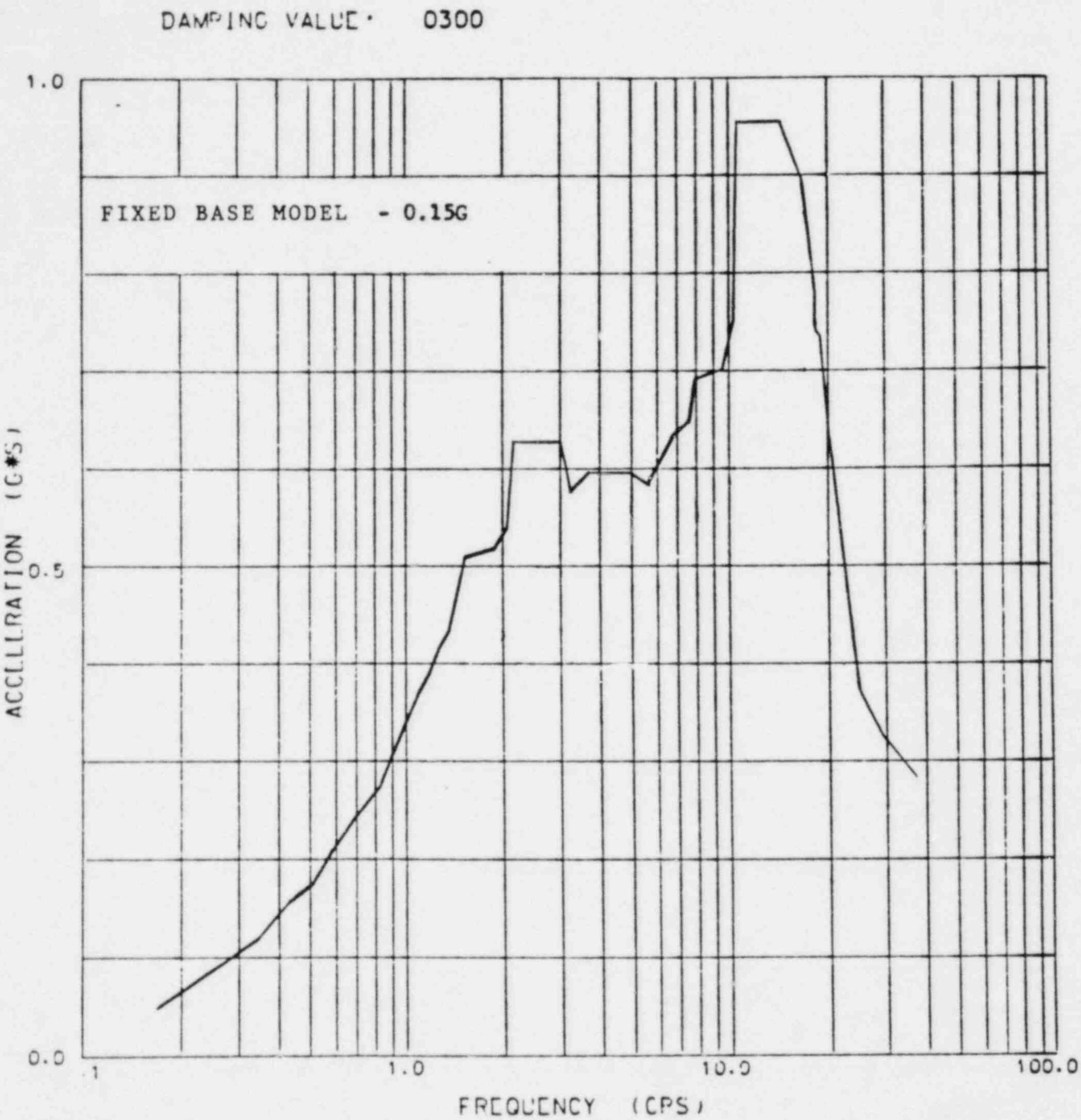
PUMPHOUSE SHEAR AND MOMENTS FOR 0.15g SSE

Figure 12



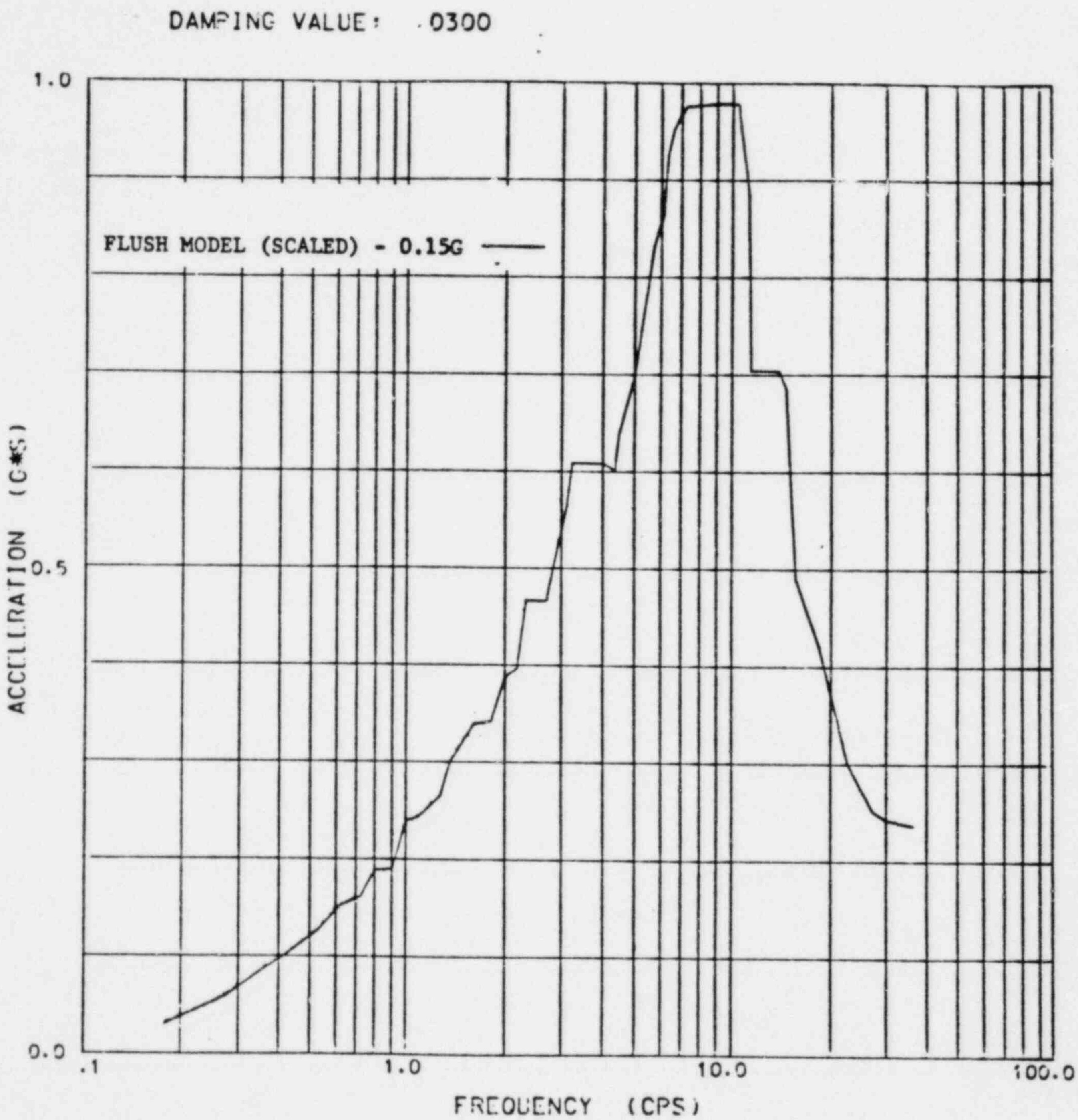
PUMPHOUSE RESPONSE SPECTRUM FOR 0.15g SSE
N-S DIRECTION AT EL. 2000, 3% DAMPING

Figure 13



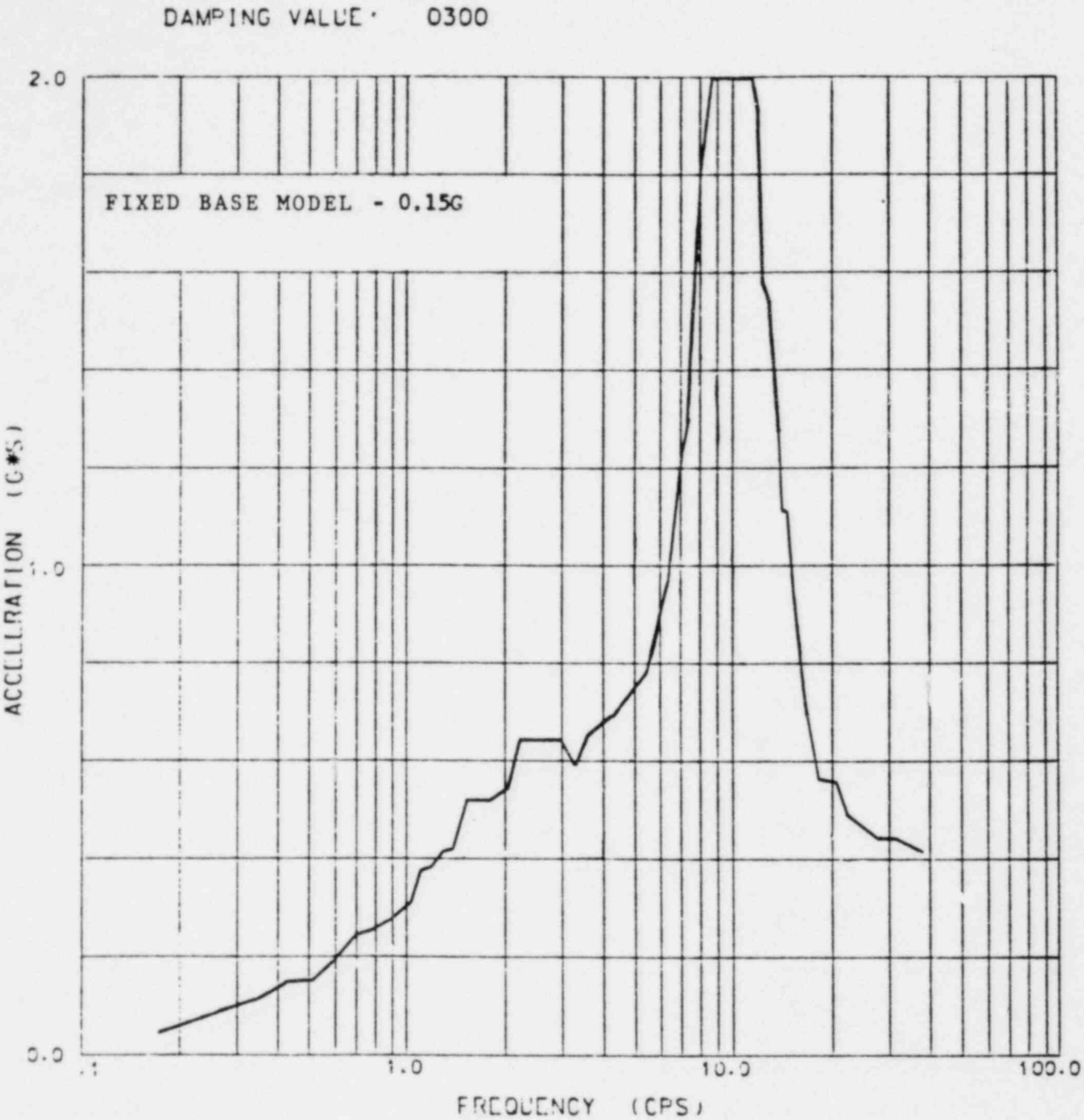
PUMPHOUSE RESPONSE SPECTRUM FOR 0.15g SSE
E-W DIRECTION AT EL. 2000, 3% DAMPING

Figure 14



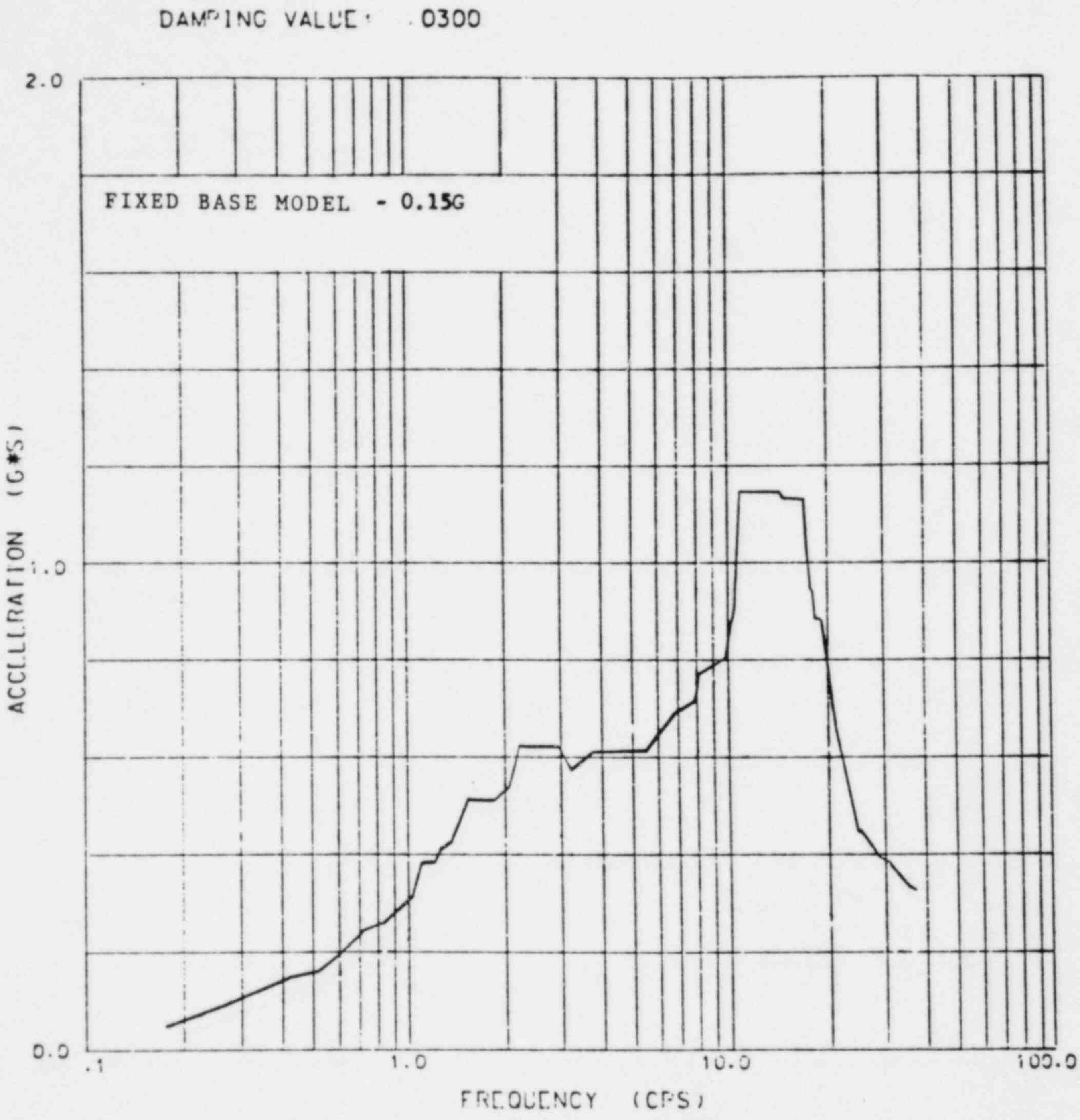
PUMPHOUSE RESPONSE SPECTRUM FOR 0.15g SSE
VERTICAL DIRECTION AT EL. 2000, 3% DAMPING

Figure 15



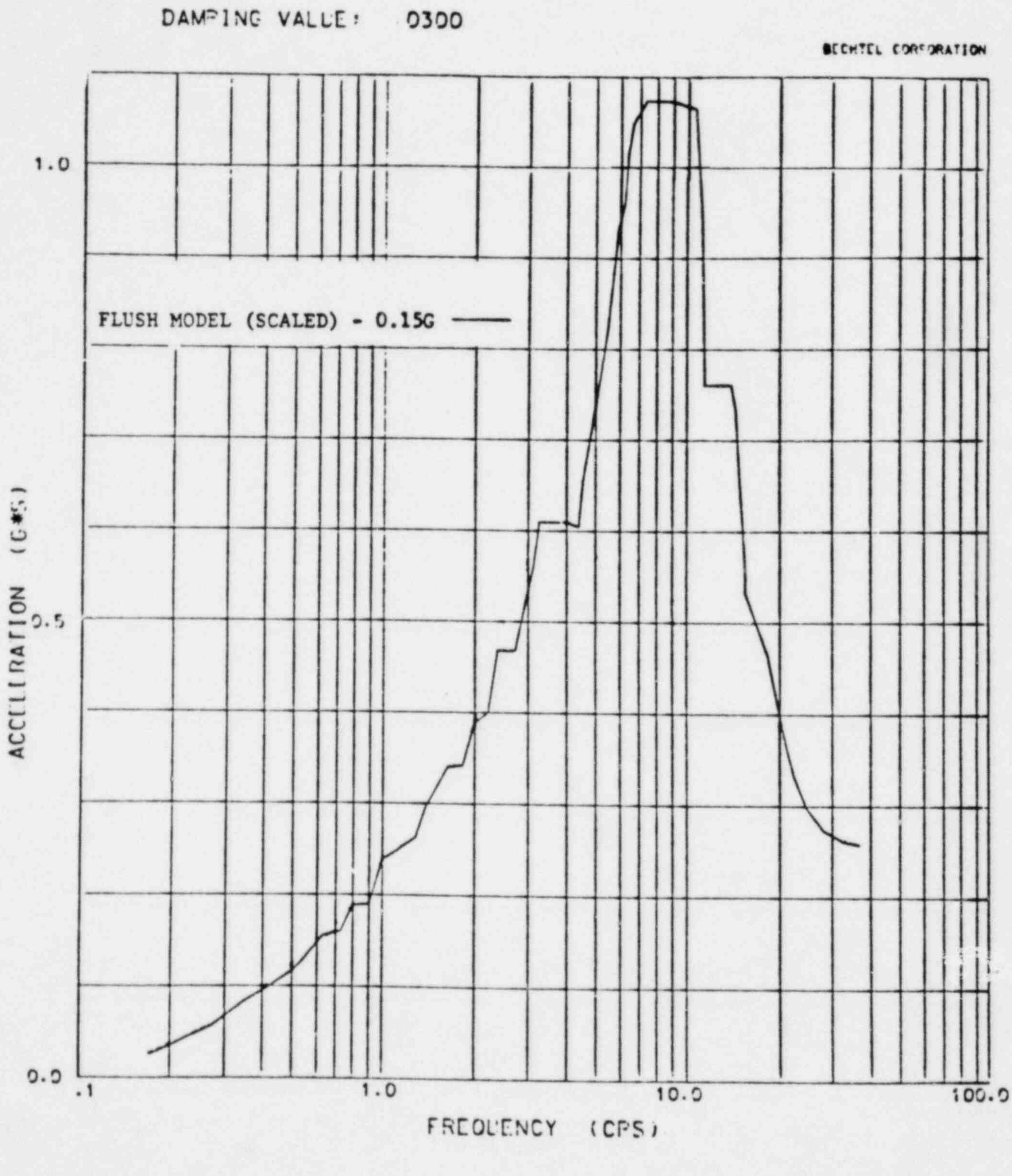
PUMPHOUSE RESPONSE SPECTRUM FOR 0.15g SSE
N-S DIRECTION AT EL. 2025, 3% DAMPING

Figure 16



PUMPHOUSE RESPONSE SPECTRUM FOR 0.15g SSE
E-W DIRECTION AT EL. 2025, 3% DAMPING

Figure 17



PUMPHOUSE RESPONSE SPECTRUM FOR 0.15g SSE
VERTICAL DIRECTION AT EL. 2025, 3% DAMPING

Figure 18