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SEISMIC EFFECTS ON A PROPOSED UNDERGROUND REACTOR FACILITY

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SUBJECT SEISMIC EFFECTS ON A PROPOSED UNDERGROUND REACTOR FACILITY		NAME F.Tokarz/R. Murray	
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INTRODUCTION

A study was conducted to determine the seismic effects on the containment structure of a proposed underground reactor facility. Simplified and often inadequate building code equivalent static design procedures frequently used for conventional reactor systems are not adequate for partially buried or fully buried reactor systems. A sophisticated dynamic analysis which can consider soil-structure interaction effects resulting from both seismic displacements and forces must be employed. One such approach would be to use the finite element method*. This note gives the results of using such an approach to consider both the static overburden and dynamic earthquake effects on the containment structure of the proposed underground reactor facility.

The first step in the seismic analysis and evaluation of a reactor facility is the postulation of possible earthquake ground motions at the site. Once the reactor site has been selected an investigation of the seismicity and geology of the area permits estimates of both potential earthquake magnitudes and their potential epicenter locations. These estimates coupled with knowledge of site soil conditions permits estimates of peak ground motions and frequency distributions of ground motion for the site.

Two approaches are usually used to predict the ground accelerations resulting from any given earthquake. One approach uses recorded surface motions from past earthquakes to extrapolate directly motions at some epicentral distance. The other estimates the bedrock motion underlying the site and then uses detailed site properties to compute both surface and subsurface motion above the bedrock level. For this analysis the latter approach is assumed.

Since no specific site is being considered here the prediction of earthquake motions for use in the analysis was quite arbitrary. Similarly the choice of detail site properties required to define the media surrounding the containment structure was quite arbitrary. However, the earthquake motions used here are representative of the magnitude and frequency content of previous recorded earthquake ground motions measured in bedrock. In addition, the material properties used for the geological media are considered to be reasonable estimates.

ANALYSIS

Figure 1 defines the containment structure and the extent of the surrounding media considered. The containment structure consists of a steel liner surrounded by 5 ft of concrete. The steel liner consists of a 90 ft diameter cylinder closed on top by a spherical dome. The steel liner is 1.8 in. thick. Both the steel liner and the concrete are integral with a 10 ft thick foundation which is located 340 ft below the surface. Extending from the top of the spherical dome to the surface is a 10 ft diameter (1.25 in. thick) steel pipe used for access to the contained area.

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*The finite element method is a technique for determining the displacements, strains and stresses in continuous bodies (structures). The basic concept assumes that the entire structure may be considered as an assemblage of substructures or elements. The structure is divided into a finite number of such elements which are interconnected at nodal points. All of the elements are then assembled and analyzed by the displacement method of structure analysis. The finite element method is readily applicable to treatment of non-homogenous structures with complex shapes and loading. Non-linear effects may be included if desireable.

The model extends 500 ft below the surface where bedrock is assumed. The horizontal boundaries are located at 500 ft from the axis of the symmetry. Various different geologial media are considered as shown in Figure 1.

Two types of loading are considered - an overburden loading and a horizontal earthquake loading*. Analyses were conducted separately and then superimposed. As indicated earlier the earthquake loading is applied at the assumed bedrock level. The 1971 San Fernando (Pacoima Dam) acceleration record normalized at 0.2 g maximum acceleration was used.

RESULTS

All of the calculations were made using the finite element computer programs called DTVIS2 and GHOSH. Both codes can treat axisymmetric structures subjected to dynamic loads. In addition, GHOSH can consider non-axisymmetric loading and DTVIS2 can treat thermal problems if desired. For more information regarding these programs see ENW-72-13 and the DTVIS2 User's Manual.

The results are summarized in Figures 2 through 7. The dynamic analysis considered the lowest five fundamental modes of vibration. Five percent critical viscous damping was used in all modes and all materials. Figure 2 gives the first and second mode shapes (magnified considerably), the first five natural periods, and percent participation factors of the combined containment structure and surrounding media. As indicated by the 68 percent participation factor, the combined containment structure and media is responding primarily in the first mode.

Figure 3 gives some of the results obtained from the static overburden analysis. Given are the deformed shape (magnified 500 times) and stress contours of maximum and minimum principal stresses and maximum shear stress. Such information would prove helpful when determining excavation cuts and the selection of backfill material. By excluding the containment structure, backfill material and sand an analysis could be made to evaluate the stability of excavation slopes.

Figures 4 through 7 give plots of maximum axial and hoop stresses versus depth in the steel liner and concrete for both static overburden loading and earthquake loading.

For the static overburden loading maximum stresses in the steel and concrete are:

	Axial Stress (psi)	Hoop Stress (psi)
Steel pipe	- 30,000	- 5,000
Steel pipe/dome	- 42,000	- 48,000
Steel dome	- 17,000	- 12,000
Steel cylinder	- 22,000	- 11,000
Concrete dome	- 425	- 600
Concrete cylinder	- 600	- 250

*For this analysis the reactor site is assumed to be sufficiently removed from possible fault rupture (e.g. greater than 1/4 mile as per USAEC 10CFR, Appendix A).

The maximum steel stresses resulting from the earthquake loading are as follows:

	Axial Stress (psi)	Hoop Stress (psi)
Steel pipe	± 8,000	± 15,000
Steel pipe/dome	± 43,000	± 32,000
Steel dome	± 7,500	± 8,000
Steel cylinder	± 3,300	± 5,000

In the concrete the maximum axial stress is approximately ± 120 psi with a maximum hoop stress of ± 380 psi near the top of the dome.

CONCLUSIONS

As expected the results show that, except in the area of the pipe/dome junction, the static overburden loading produces stresses which are generally much greater than those produced by the earthquake loading. In the pipe/dome area more detail analysis is required to establish more precise values for the stresses. Special design considerations are needed in this area.

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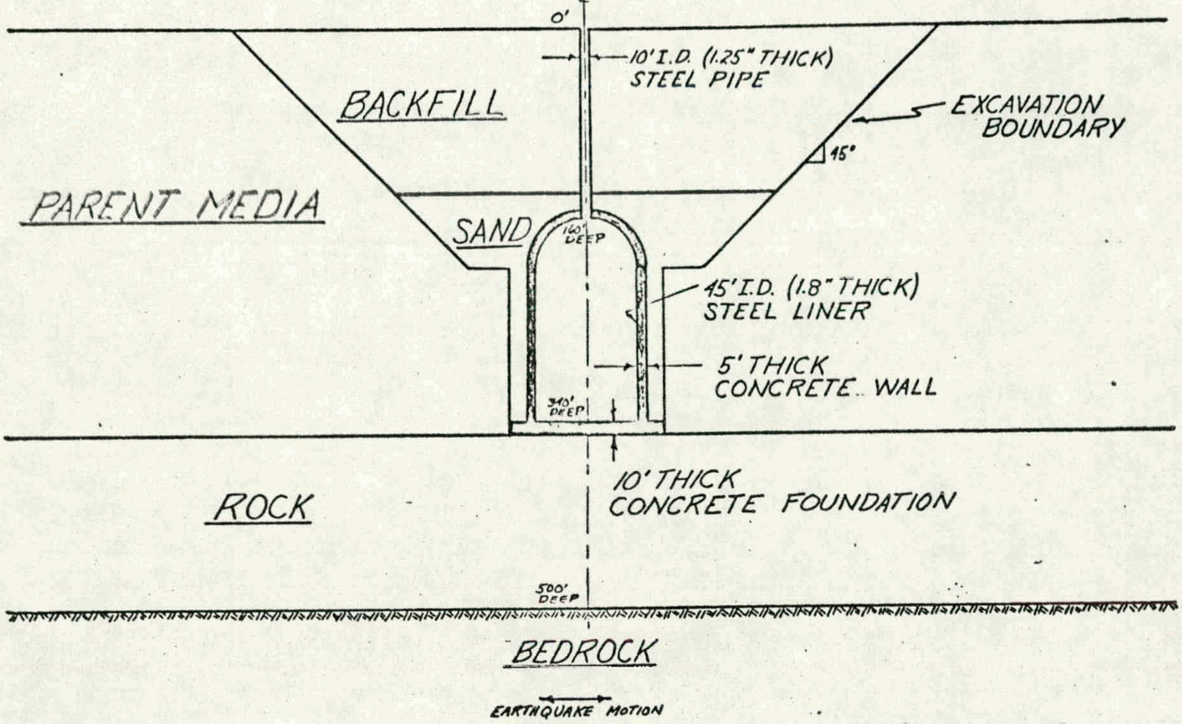
MODEL



MATERIAL PROPERTIES

MATERIAL	E (KSI)	υ	γ (lbs/ft³)
SAND	50	0.40	100
BACKFILL	100	0.33	120
PARENT MEDIA	500	0.33	130
ROCK	1000	0.33	160
CONCRETE	1000	0.17	150
STEEL	30000	0.33	490

EARTHQUAKE RECORD

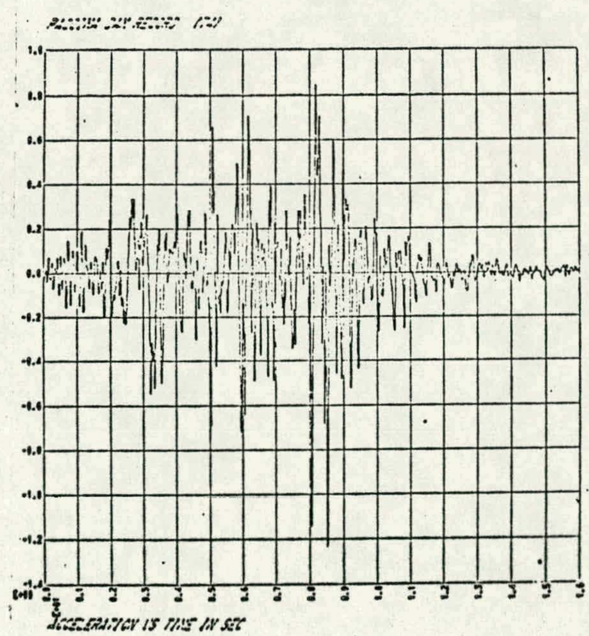
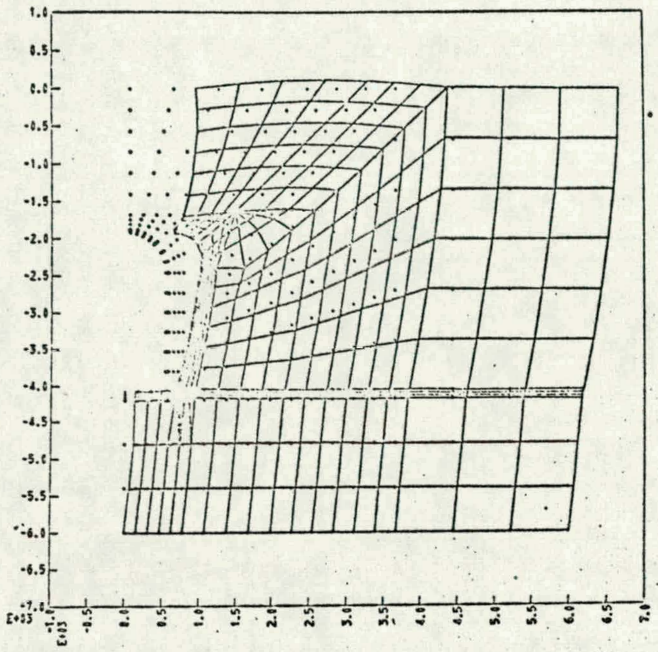
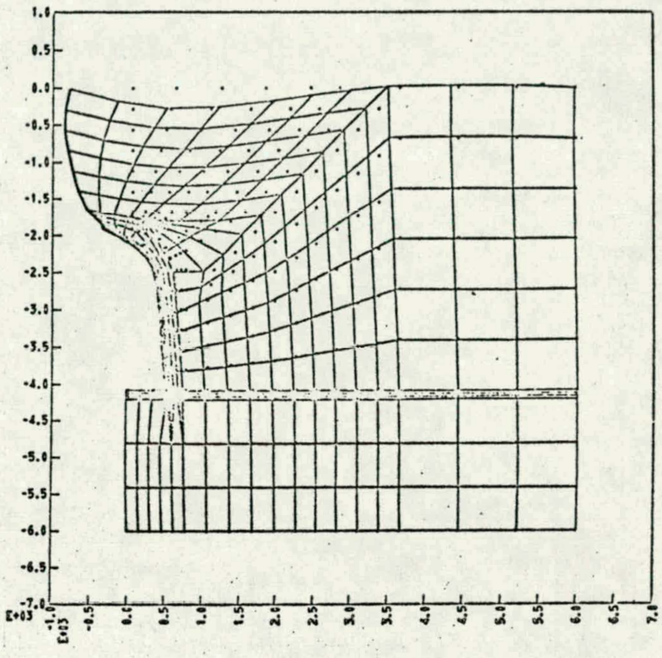


FIG. 1

1ST MODE SHAPE



2ND MODE SHAPE



MODE	PERIOD (SEC.)	PARTICIPATION FACTOR (%)
1	0.67	68.0
2	0.40	7.0
3	0.34	7.0
4	0.30	8.0
5	0.26	10.0

FIG. 2

STATIC OVERBURDEN RESULTS

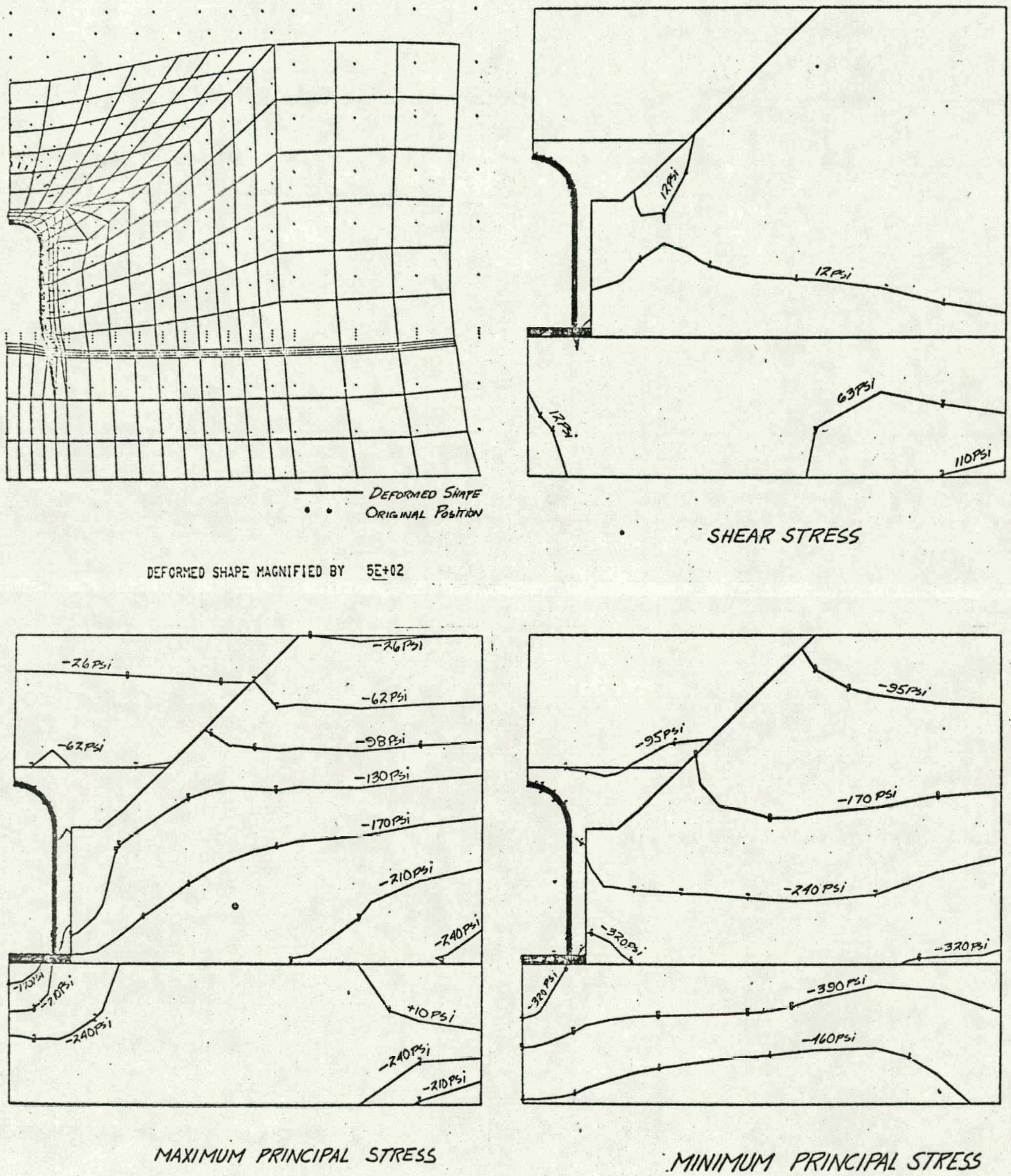


FIG. 3

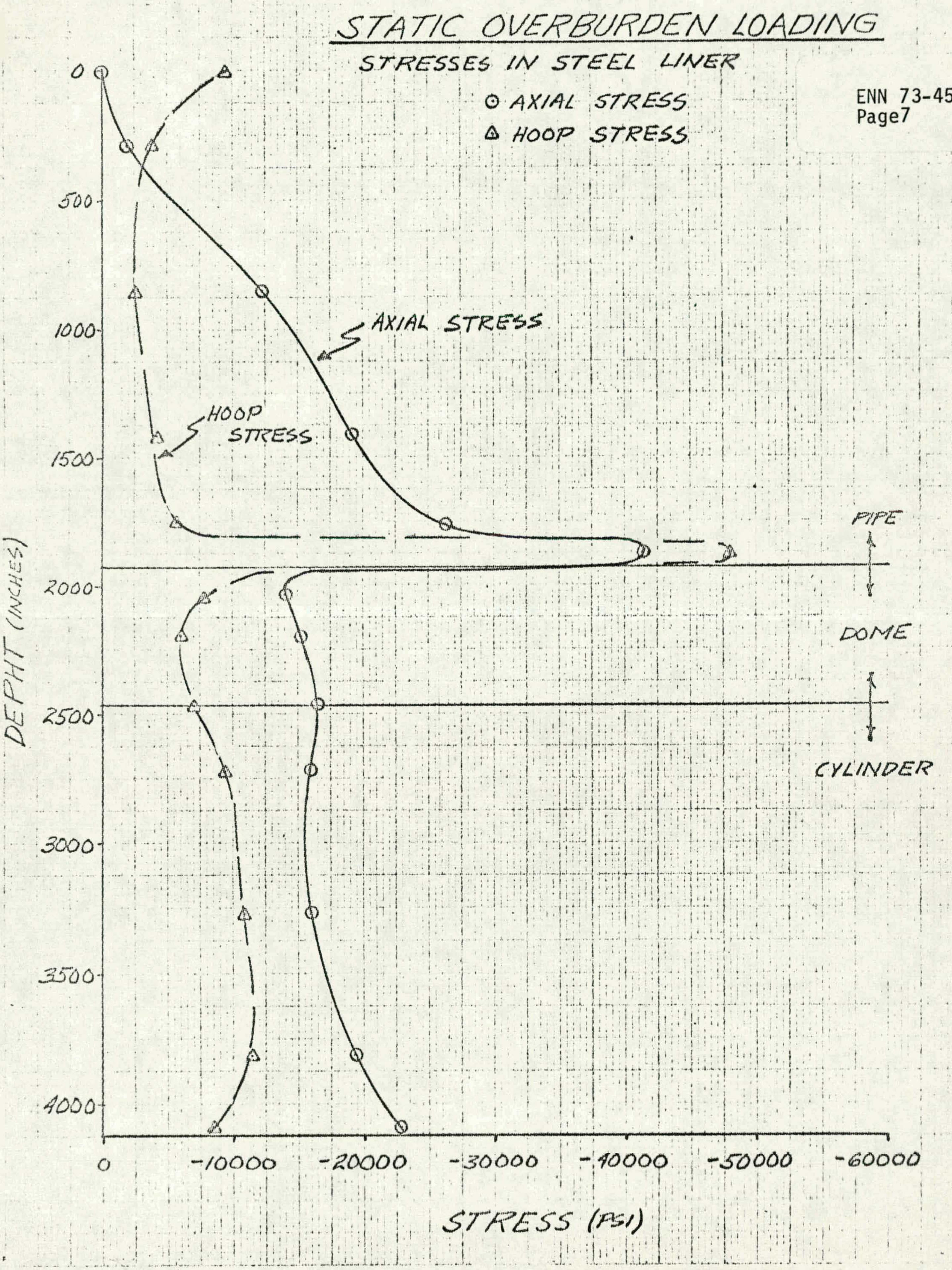

STATIC OVERBURDEN LOADING
STRESSES IN STEEL LINER
AXIAL STRESS
HOOP STRESS
AXIAL STRESS
HOOP STRESS
PIPE
DOME
CYLINDER
DEPHT (INCHES)
0
500
1000
1500
2000
2500
3000
3500
4000
0
-10000
-20000
-30000
-40000
-50000
-60000
STRESS (PSI)

FIG 4

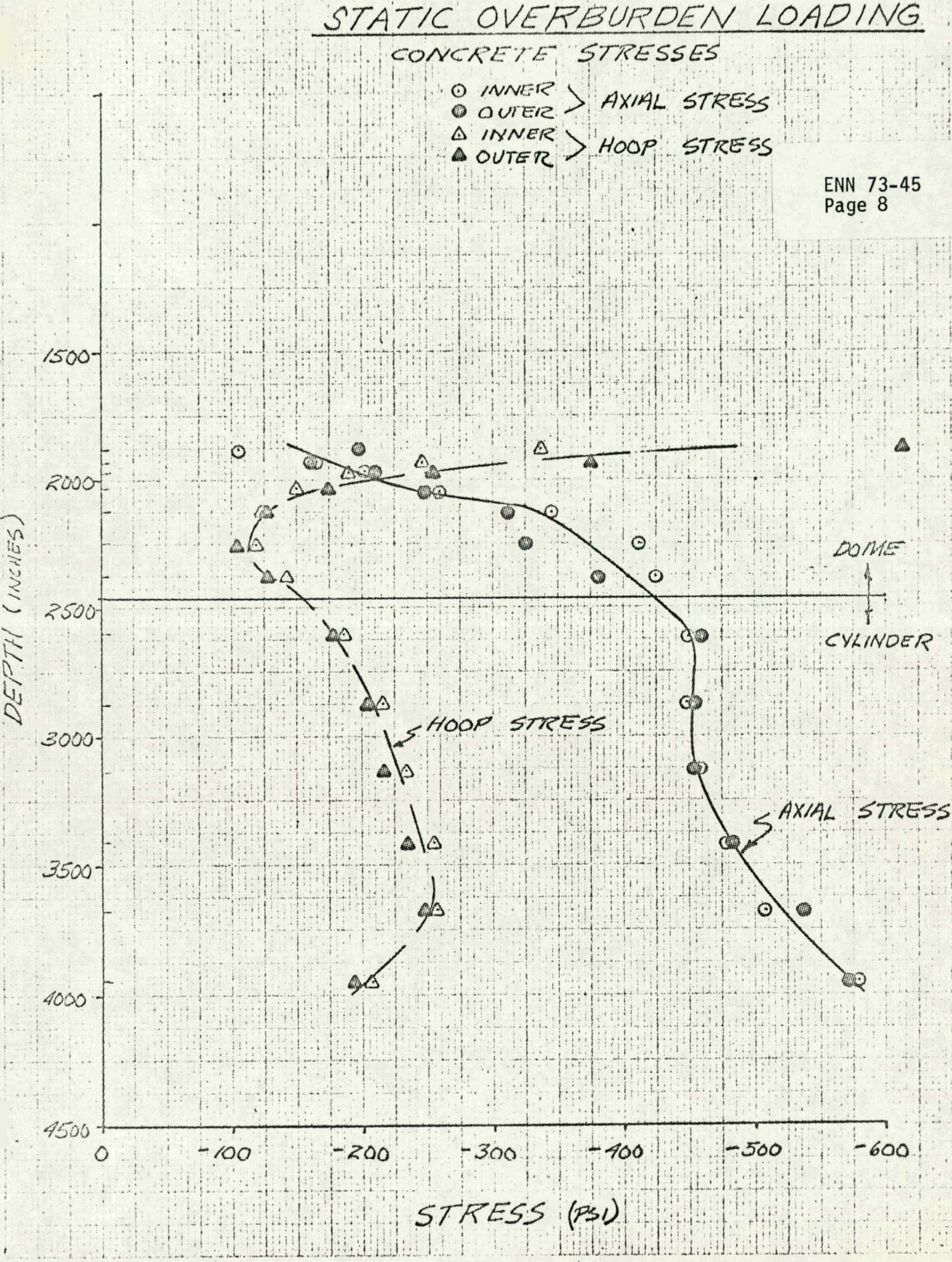

STATIC OVERBURDEN LOADING
CONCRETE STRESSES
INNER
OUTER
AXIAL STRESS
INNER
OUTER
HOOP STRESS
DEPTH (INCHES)
1500
2000
2500
3000
3500
4000
4500
DOME
CYLINDER
HOOP STRESS
AXIAL STRESS
0
-100
-200
-300
-400
-500
-600
STRESS (PSI)

FIG. 5

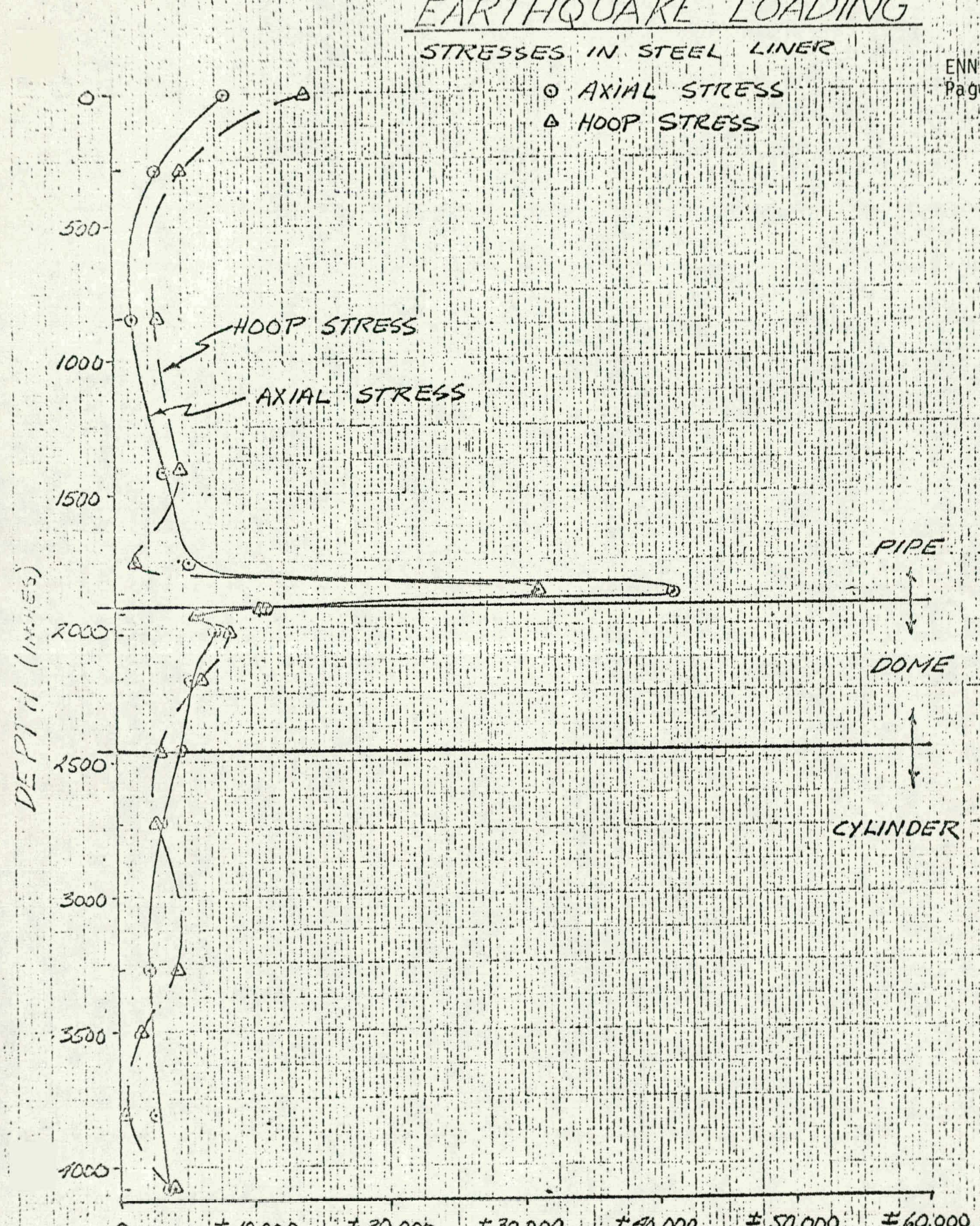

EARTHQUAKE LOADING
STRESSES IN STEEL LINER
⊙ AXIAL STRESS
△ HOOP STRESS
HOOP STRESS
AXIAL STRESS
PIPE
DOME
CYLINDER
DEPTH (INCHES)
0
500
1000
1500
2000
2500
3000
3500
4000
0
±10,000
±20,000
±30,000
±40,000
±50,000
±60,000
STRESS (PSI)

FIG. 6

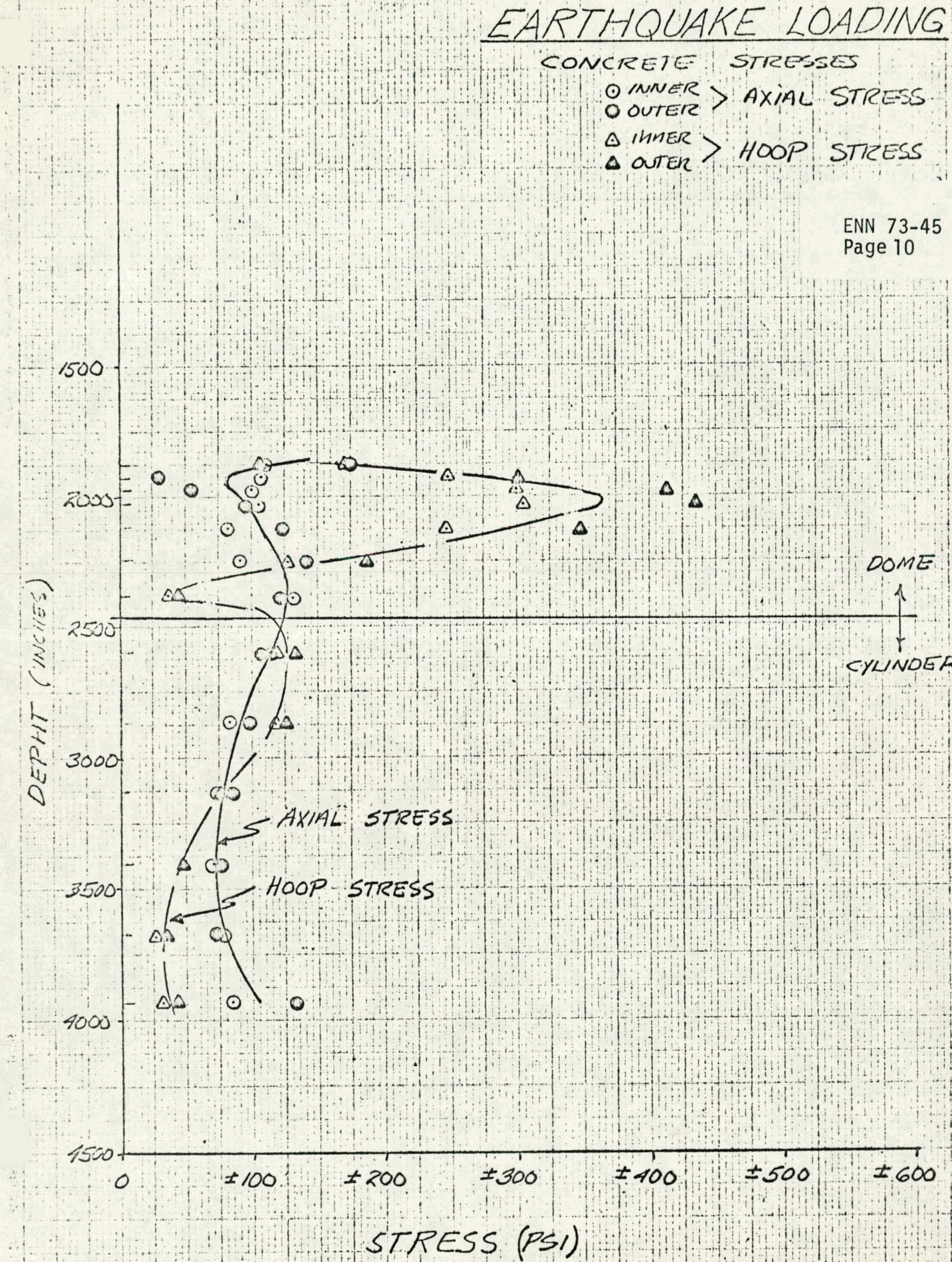

EARTHQUAKE LOADING
CONCRETE STRESSES
INNER
OUTER
AXIAL STRESS
INNER
OUTER
HOOP STRESS
1500
2000
2500
3000
3500
4000
4500
DEPHT (INCHES)
DOME
CYLINDER
AXIAL STRESS
HOOP STRESS
0
±100
±200
±300
±400
±500
±600
STRESS (PSI)

FIG. 7

SUBJECT SEISMIC EFFECTS ON A PROPOSED UNDERGROUND REACTOR FACILITY

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