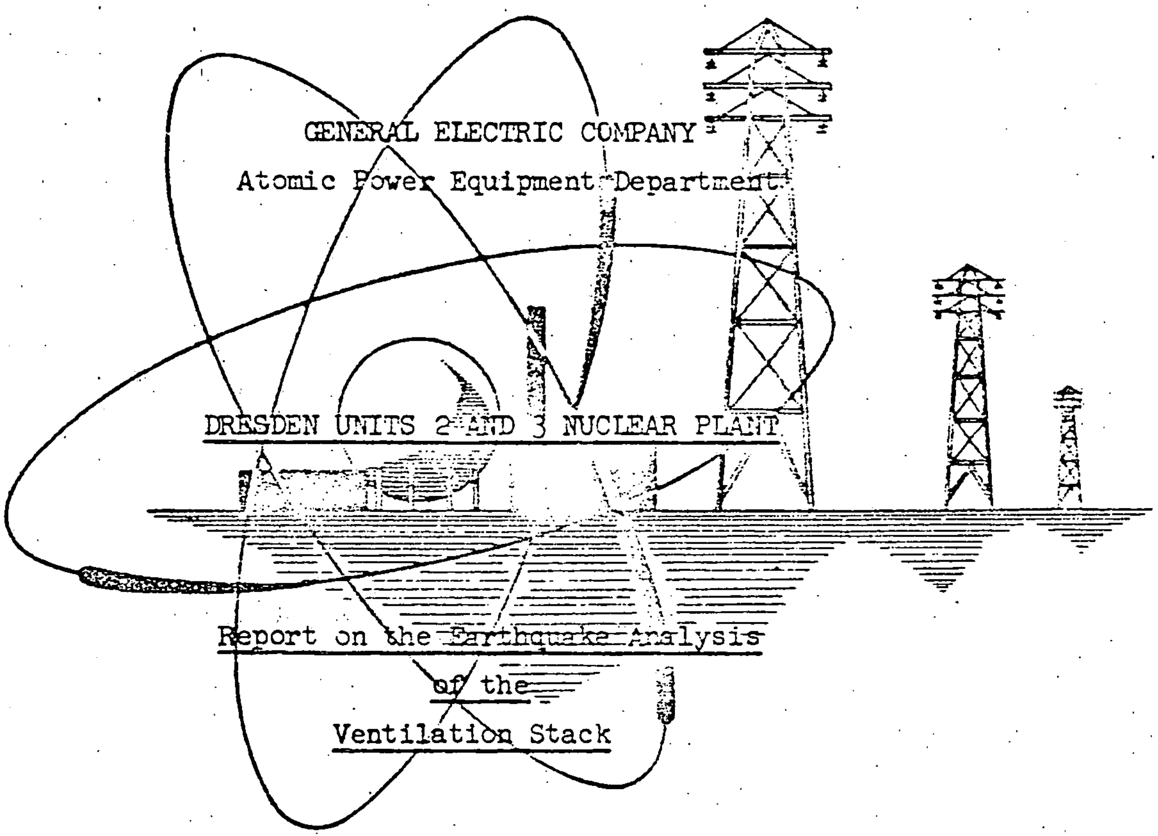

GENERAL ELECTRIC COMPANY

Atomic Power Equipment Department

DRESDEN UNITS 2 AND 3 NUCLEAR PLANT

Report on the Earthquake Analysis of the Ventilation Stack

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SAN FRANCISCO

DRESDEN UNITS 2 & 3 NUCLEAR PLANT

VENTILATION STACK

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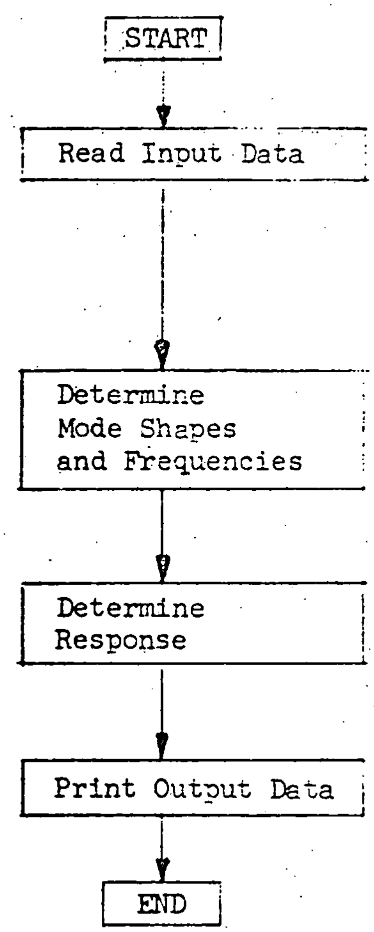

DIAGRAM 1

DRESDEN UNITS 2 & 3 NUCLEAR PLANT
VENTILATION STACK
SEISMIC ANALYSIS

INTRODUCTION

The purpose of this report is to summarize the results of the seismic investigation of ventilation stack for the Dresden Units 2 & 3 Nuclear Plant. Based on the recommended earthquake design criteria, design envelopes of maximum displacements, shears and overturning moments versus height have been developed and are presented herein. The earthquake criteria used as the basis for this analysis are set forth in Reference 1.

DESCRIPTION OF STACK

The ventilation stack is a 310 feet high tappered reinforced concrete structure, having an internal diameter of 11'-0 at top and 22'-7$\frac{1}{2}$" at base. The thickness of the ventilation stack is 7" for the top 100' and 18" for the bottom 30'-0.

Information on geometry of the stack is shown in Appendix Figure 1.

MATHEMATICAL MODEL OF VENTILATION STACK

The ventilation stack was treated as a flexible cantilever system with base fixed at the top of foundation. Thirty three mass points were considered to be supported by weightless elastic columns. The mathematical model is shown in Appendix Figure 2.

ANALYTICAL PROCEDURES - PERIODS AND MODE SHAPES

Subsequent to the formation of mass and stiffness matrices for the cantilever system, the periods and mode shapes are calculated by solving for eigenvalues and eigenvectors of equation (1).

$$\left[\underline{K} = W_n^2 \underline{M}\right] \underline{\Phi}_n = \underline{0} \qquad \text{----------------} \quad (1)$$

where:

$\underline{K}$ = Stiffness matrix

W_n = Natural circular frequencies for the n^{th} mode

$\underline{M}$ = Mass matrix

$\underline{\Phi}_n$ = Mode shape matrix for the n^{th} mode

$\underline{0}$ = Zero matrix

By use of a computer program the W_n value and the $\underline{\Phi}_n$ matrix for the n^{th} mode are obtained.

ANALYTICAL PROCEDURES - RESPONSE

The generalized displacement response of the structure, once the period and mode shapes have been determined, is given by the following equation:

$$\underline{\ddot{Y}_n(t)} + 2W_n \lambda_n \underline{\dot{Y}_n(t)} + W_n^2 \underline{Y_n(t)} = \underline{M_n}^{-1} \underline{R_n(t)} \ddot{U}_g(t) \quad \text{-----} \quad (2)$$

where:

$\underline{Y_n(t)}$ = Generalized coordinate matrix

$$= \frac{R_n}{M_n W_n} \int_0^t \ddot{U}_g(\tau)\, e^{-\lambda_n W_n (t-\tau)} \left(\sin W_n (t-\tau)\, d\tau\right) \quad \text{----} \quad (3)$$

$\underline{M_n}$ = Generalized mass matrix

$$= \underline{\Phi_n}^T \cdot \underline{M} \cdot \underline{\Phi_n}$$

$\underline{M_n}^{-1}$ = Inverse of the Generalized mass matrix

$\ddot{U}_g(t)$ = Earthquake input ground motion

λ_n = Damping for each mode - taken as 5 per cent for all modes

$d\tau$ = Integration interval used in the step by step solution of the Duhamel Integral - 0.010 second.

From the Generalized Coordinate matrix, the time history of displacements is found according to Equation (4).

$$\underline{v(t)} = \underline{\Phi}\ \underline{Y(t)} \qquad \text{------------------} \quad (4)$$

where:

$$\underline{\Phi} = \left[\phi_1 \vdots \phi_2 \vdots \cdots \vdots \phi_m \right]$$

m = Number of modes considered.

$$\underline{Y(t)} = \begin{bmatrix} Y_1\ (t) \\ \cdots\cdots \\ Y_2\ (t) \\ \cdots\cdots \\ Y_m\ (t) \end{bmatrix}$$

$\underline{v(t)}$ = Displacement - time history matrix

The time history of the inertia forces are then determined according to Equation (5).

$$\underline{Q(t)} = \underline{K}\ \underline{v(t)} \qquad \text{------------------} \quad (5)$$

where:

$\underline{Q(t)}$ = Matrix of inertia forces for each time increment for each mass

Once displacement and inertia force - time histories have been established, a time history of shears, moments, displacements, and accelerations is determined. These records are then scanned to determine the maximum values which are then graphically presented in the report and used by the designer.

ANALYTICAL PROCEDURES - COMPUTER PROGRAMMING

The computer program used in this analysis was specially designed to solve the dynamic response of structures subject to arbitrary ground motions [3, 4, 5]. Member input data for the program are in the form of moments of inertia, areas and effective shear areas. The effects of axial and shear deformation are included in the formation of stiffness matrix.

The response of each mass for each mode considered at each increment of time is retained in the computations and total response for each increment of time is obtained through the algebric sum of each mass points model contribution at that particular instant of time. This results in a precise combination of mode participation.

The process logic of the computer aided solution is summarized in Diagram 1.

CALCULATED DATA

Calculated data used as input to the computer is given in Appendix Figure 2.

These calculations are based on the information contained in Reference 2.

RESULTS

The results of the seismic analysis in the form of design shears, design moments and relative displacement envelopes are presented in Appendix Figures 3 through 5.

The previously described calculations were performed with the aid of an IBM 7094/II digital computer. The influence of 8th and higher modes of vibration was considered negligible and, therefore, ignored in the response calculations. A damping value of five percent was assigned to all modes.

The first seven natural periods of vibration are listed below:

First Mode ...... 1.381 Seconds
Second Mode ...... 0.372 Seconds
Third Mode ...... 0.158 Seconds
Fourth Mode ...... 0.089 Seconds
Fifth Mode ...... 0.058 Seconds
Sixth Mode ...... 0.042 Seconds
Seventh Mode ...... 0.033 Seconds

RECOMMENDATIONS

It is recommended that the subject structure be designed to resist the seismic shears and moments presented herein without the usual increase in stress for short term loadings. In addition, the structure should be reviewed to assure that it can resist twice the seismic shears and moments presented herein without hindering the ability of the plan to safely shut down, and without collapse or failure which could cause damage to other structures or components whose integrity is necessary to assure a safe shut down of the plant.

REFERENCES

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2. Rust Engineering Co., Drawing No. C-67053 dated 4-20-67 Computation Sheet No. C-67053

3. Use of Modern Computers in Structural Analysis, by R. W. Clough Journal of the Structural Division of the American Society of Civil Engineers, ST 3, May, 1958.

4. Structural Analysis of Multistory Buildings, by R. W. Clough, Ian P. King, and Edward L. Wilson, Journal of the Structural Division of the American Society of Civil Engineers, ST 3, June, 1964.

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VENTILATION STACK

SEISMIC ANALYSIS

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APPENDIX

DESIGN AND DATA FIGURES

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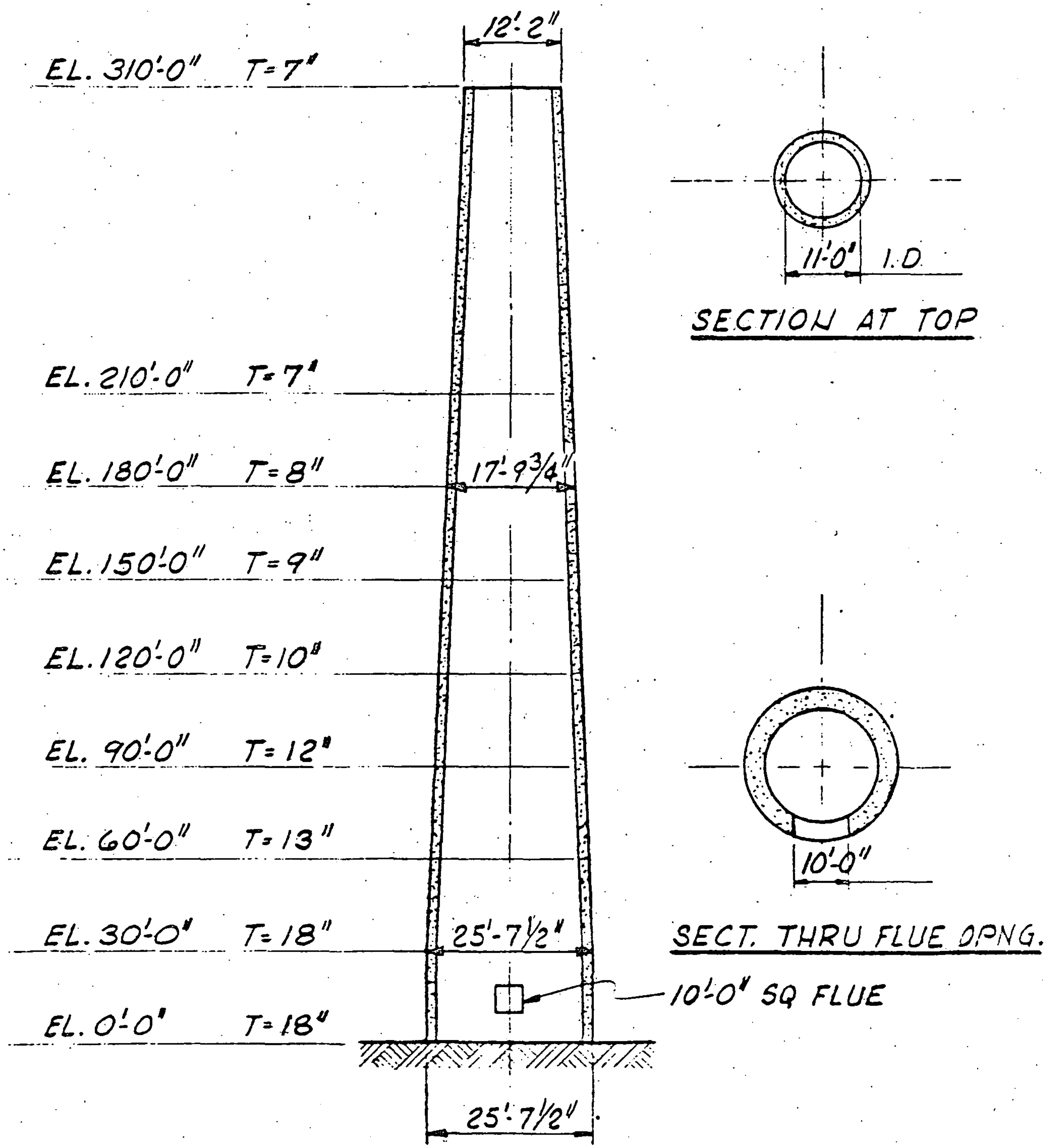
DRESDEN UNITS 2 & 3 VENTILATION STACK GEOMETRY



* NO SCALE

FIGURE 1

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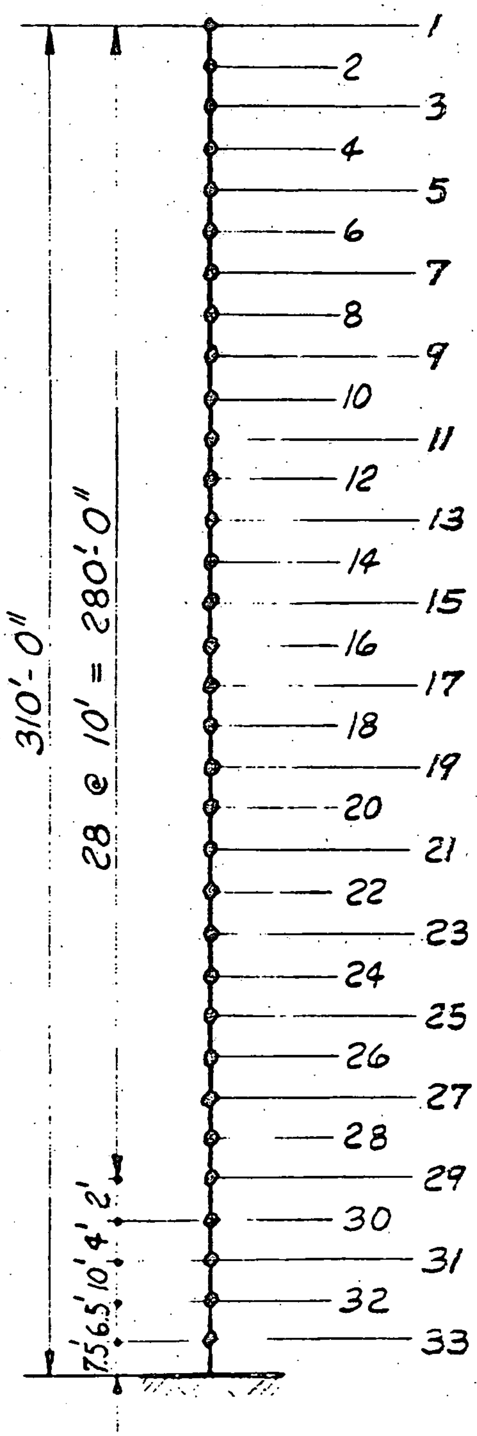
DRESDEN UNITS 2 & 3
VENTILATION STACK
MATHEMATICAL MODEL



MASS	WEIGHT KIPS	MEMBER	A (ft^2)	I (ft^4)
1	16.4	1 - 2	22.7	435
2	34.6	2 - 3	23.5	483
3	35.8	3 - 4	24.3	533
4	37.0	4 - 5	25.1	587
5	39.2	5 - 6	25.8	645
6	39.4	6 - 7	26.6	706
7	40.6	7 - 8	27.4	771
8	41.8	8 - 9	28.2	840
9	42.9	9 - 10	29.0	913
10	44.1	10 - 11	29.8	990
11	45.9	11 - 12	31.3	1097
12	48.8	12 - 13	33.7	1239
13	52.3	13 - 14	36.1	1395
14	56.0	14 - 15	38.6	1575
15	60.0	15 - 16	41.3	1786
16	64.1	16 - 17	44.2	2019
17	68.5	17 - 18	47.1	2267
18	72.9	18 - 19	50.1	2545
19	77.7	19 - 20	53.5	2863
20	83.1	20 - 21	57.3	3218
21	87.7	21 - 22	59.7	3518
22	95.7	22 - 23	67.9	4195
23	105.3	23 - 24	72.5	4692
24	111.4	24 - 25	76.2	5159
25	117.9	25 - 26	81.1	5911
26	127.5	26 - 27	88.9	6707
27	140.3	27 - 28	98.1	7668
28	152.8	28 - 29	105.5	7276
29	95.8	29 - 30	111.3	7761
30	50.1	30 - 31	111.3	7761
31	121.8	31 - 32	96.3	5669
32	142.7	32 - 33	111.3	7761
33	111.3	33 - BASE	111.3	7761

FIGURE - 2

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DRESDEN UNITS 2 & 3
VENTILATION STACK
MAXIMUM SHEAR DIAGRAM
UNDER SEISMIC LOADS

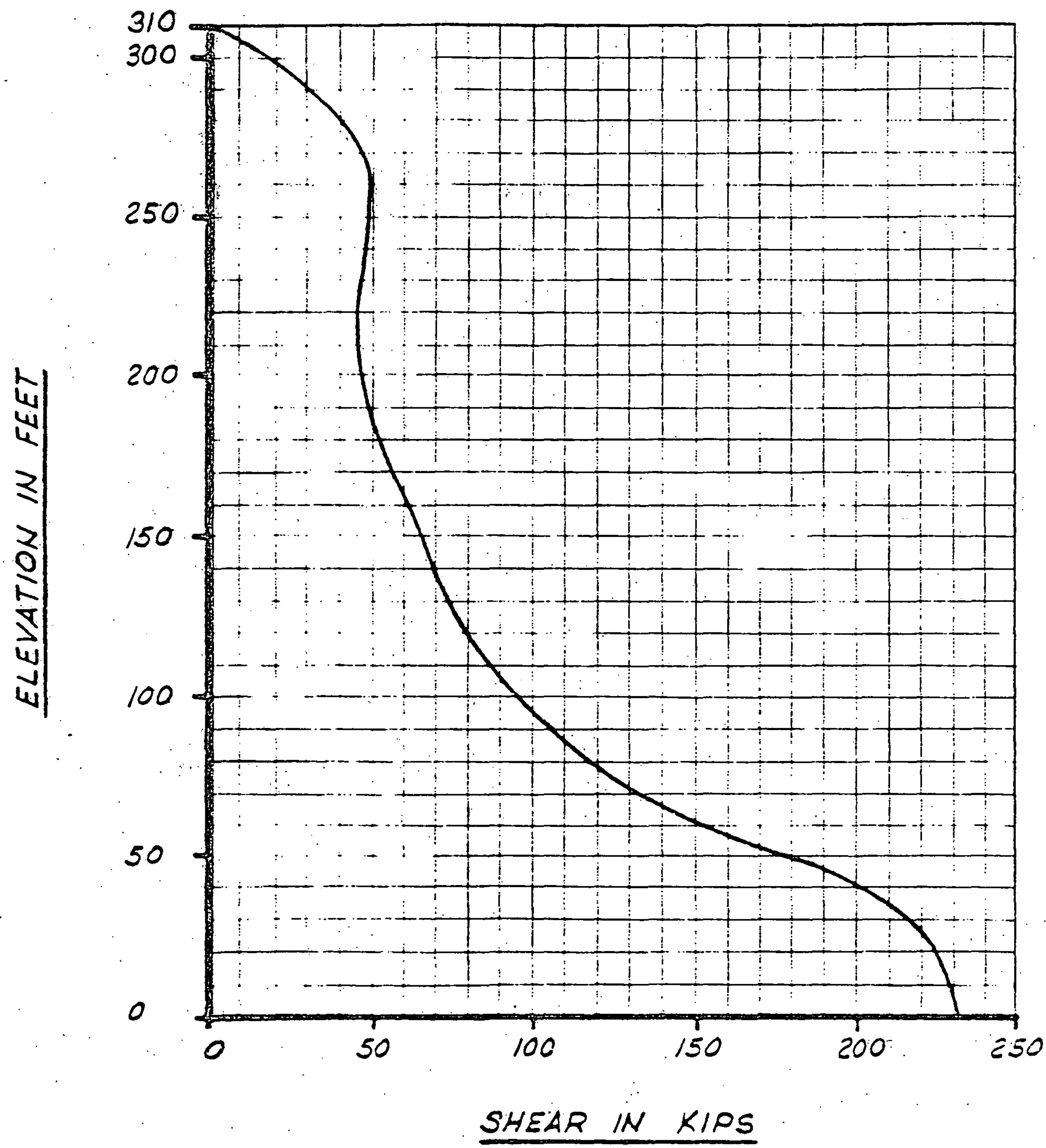

FIGURE -3

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DRESDEN UNITS 2 & 3
VENTILATION STACK
MAXIMUM MOMENT DIAGRAM
UNDER SEISMIC LOADS

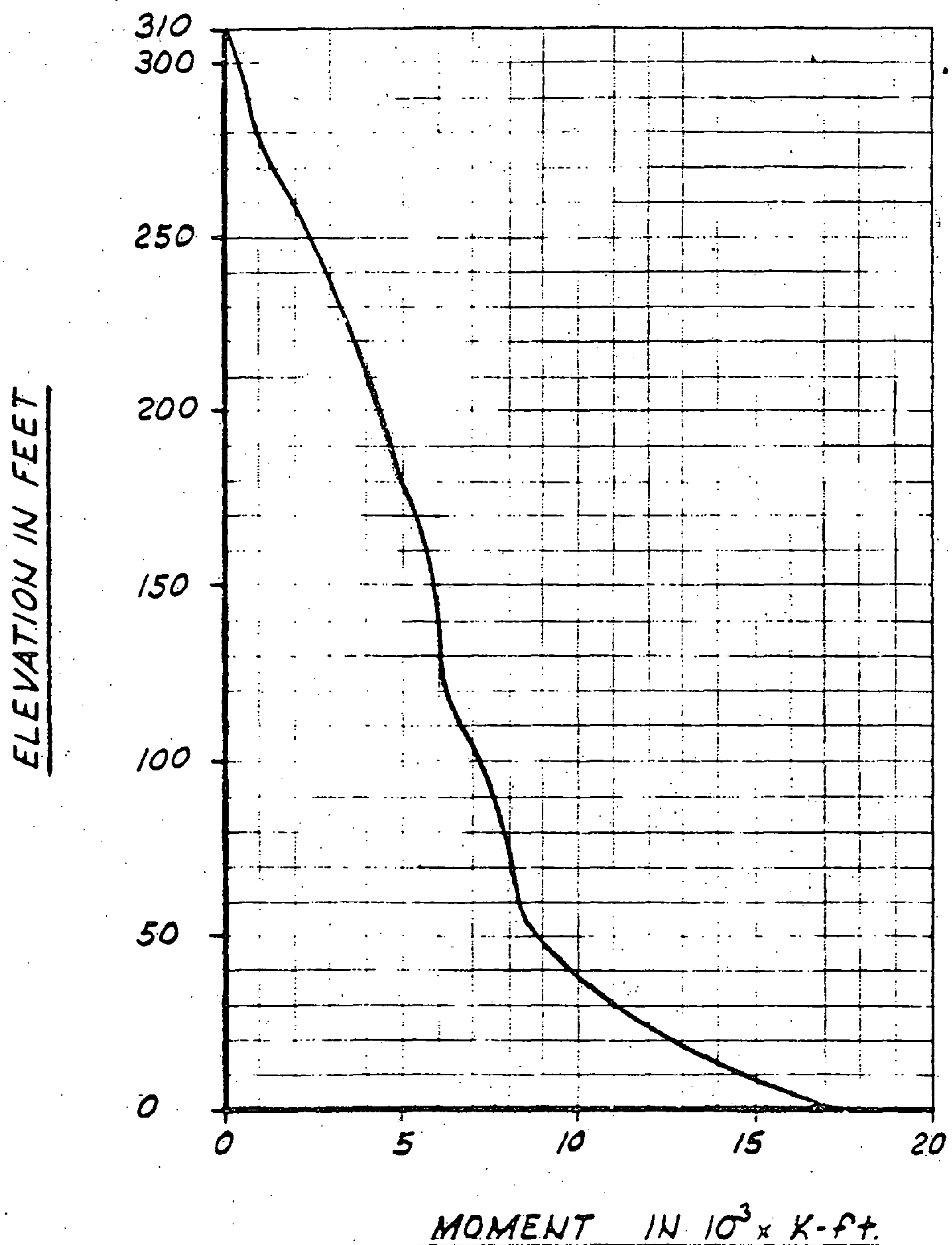

FIGURE - 4

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DRESDEN UNITS 2 & 3

VENTILATION STACK

MAXIMUM DISPLACEMENT DIAGRAM

UNDER SEISMIC LOADS

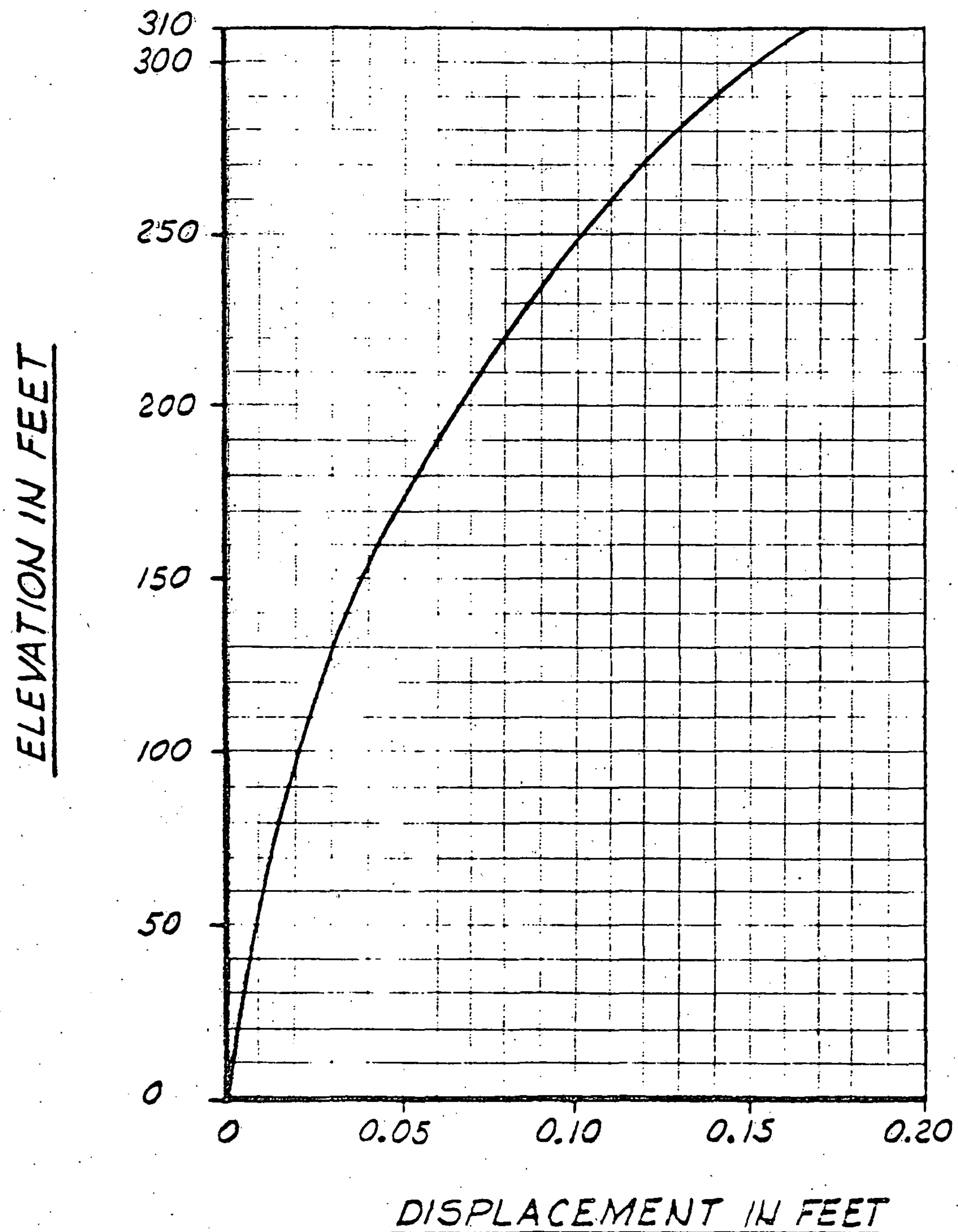

FIGURE - 5