MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined Z and Y Direction Earthquake

Moments at Joints (Global Coordinates)

Joint	X Direction Kip-Feet	Y Direction Kip-Feet	Z Direction Kip-Feet
1	0.44	0.08	0.17
2	0.21	0.20	0.05
3	0.20	0.18	0.28
4	0.11	0.06	0.04
5	0.31	1.06	0.51
6	0.12	0.35	0.05
7	0.00	0.69	0.23
8	0.00	0.03	0.12
9	0.00	1.69	0.65
10	0.00	0.03	0.12
11	0.00	0.69	0.23
12	0.12	0.35	0.05
13	0.31	1.06	0.51
14	0.11	0.06	0.04
15	0.20	0.18	0.28
16	0.21	0.20	0.05
17	0.44	0.08	0.17

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined Z and Y Direction Earthquake

Forces at Joints (Member Coordinates)

Joint	Axial Kips	Shear Y Kips	Shear Z Kips
1	1.11	0.08	0.07
2	1.11	0.08	0.07
3	0.99	0.05	0.05
4	0.81	0.12	0.28
5	0.68	0.12	0.35
6	0.68	0.12	0.35
7	0.56	0.05	0.08
8	0.50	0.13	0.41
9	0.50	0.13	0.41
10	0.50	0.13	0.41
11	0.56	0.05	0.08
12	0.68	0.12	0.35
13	0.68	0.12	0.35
14	0.81	0.12	0.28
15	0.99	0.05	0.05
16	1.11	0.08	0.07
17	1.11	0.08	0.07

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined Z and Y Direction Earthquake

Moment at Joints (Member Coordinates)

Joint	Torsional Kip-Feet	Bending Y Kip-Feet	Bending Z Kip-Feet
1	0.19	0.08	0.44
2	0.19	0.20	0.11
3	0.19	0.18	0.27
4	0.09	0.06	0.08
5	0.09	1.10	0.60
6	0.09	0.36	0.10
7	0.09	0.69	0.23
8	0.00	0.03	0.12
9	0.00	1.68	0.65
10	0.00	0.03	0.12
11	0.09	0.69	0.23
12	0.09	0.36	0.10
13	0.09	1.10	0.60
14	0.09	0.06	0.08
15	0.19	0.18	0.27
16	0.19	0.20	0.11
17	0.19	0.08	0.44

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined Z and Y Direction Earthquake

Pipe Support Reactions (Global Coordinates)

Forces at Points 5 and 13

X Direction	0.24 kips
Y Direction	0.25 kips
Z Direction	0.58 kips

Forces at Point 9

X Direction	0.00 kips
Y Direction	0.26 kips
Z Direction	0.83 kips

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined Z and Y Direction Earthquake

Stresses at Joints

Joint	Stress Kips/Sq.In
1	0.053
2	0.033
3	0.037
4	0.016
5	0.135
6	0.041
7	0.078
8	0.013
9	0.196
10	0.013
11	0.078
12	0.041
13	0.135
14	0.016
15	0.037
16	0.033
17	0.053

REFERENCES

1. Chicago Bridge and Iron Company

   20 Inch Header for Suppression Chamber
   Drawing 215 Rev. 5

   Support Ass'y for 20 " Header
   Drawing 216 Rev.0

2. Design of Piping Systems, The M.W. Kellogg Company, Revised Second Edition, John Wiley & Sons, Inc.

H. J. SEXTON & ASSOCIATES, ENGINEERS
SAN FRANCISCO • MENLO PARK, CALIFORNIA

IN REPLY REFER TO:
552 MISSION STREET
SAN FRANCISCO, 94105
(415) 781-8914

December 24, 1968

General Electric Company
Atomic Power Equipment Department
175 Curtner Avenue
San Jose, California 95125

ATTENTION: Mr. Ralph B. Gile

SUBJECT: Monticello Nuclear Power Station
Pressure Suppression Chamber
Dynamic Earthquake Analysis

Gentlemen:

Transmitted herewith is our report on the subject analysis. All pertinent information, calculations, and references are included.

Very truly yours,

H. J. Sexton and Associates, Engineers

Edward J. Keith
Associate

REPORT ON THE DYNAMIC EARTHQUAKE ANALYSIS OF THE PRESSURE SUPPRESSION CHAMBER OF THE MONTICELLO NUCLEAR POWER STATION

This report, prepared for the General Electric Company, presents the results of the seismic analysis of the Pressure Suppression Chamber for the Monticello Nuclear Power Station.

DESCRIPTION OF SUPPRESSION CHAMBER

The suppression chamber (Torus) is a torus-shaped steel vessel having an
inside diameter of 27 feet 8 inches and a major diameter of 98 feet. It is supported
vertically by 32 columns, 16 inner and 16 outer. Lateral stability is provided by four
pinned, embedded anchorage assemblies, identified as seismic supports, which 1
transmit seismic loads from the soffit of the torus to the concrete foundation.
Dynamically the torus is a complete system in itself; the vents, headers, and
downcommers are separated from the torus by means of bellows which provide no
support.

METHOD OF ANALYSIS

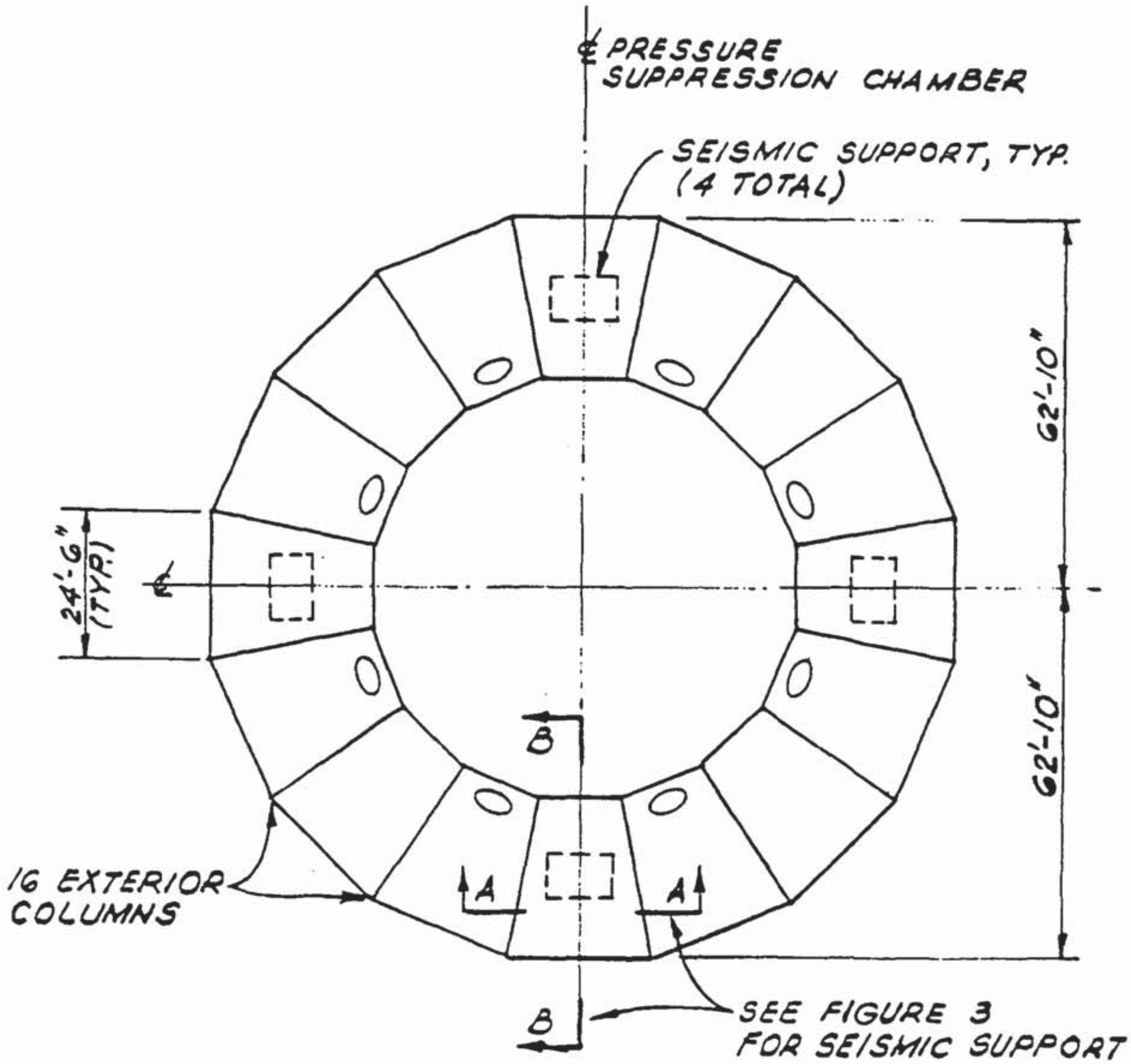
The torus is idealized as a single degree of freedom system. Its spring constant is determined from the calculated shear deformations of the pins and bottom plates of the four seismic supports. By comparison the upper plates are rigid in shear, and all plates and pins are considered rigid in bending. The columns contribute a negligible amount of resistance compared to the stiffness of the seismic supports. The anaylsis is presented for the operating and flooded conditions.

Using the calculated stiffness and mass, the fundamental period of vibration of the torus is determined for the two cases considered. The seismic coefficient is read from the response spectrum for 1.0% damping.

MONTICELLO NUCLEAR POWER STATION

PRESSURE SUPPRESSION CHAMBER

LIST OF FIGURES

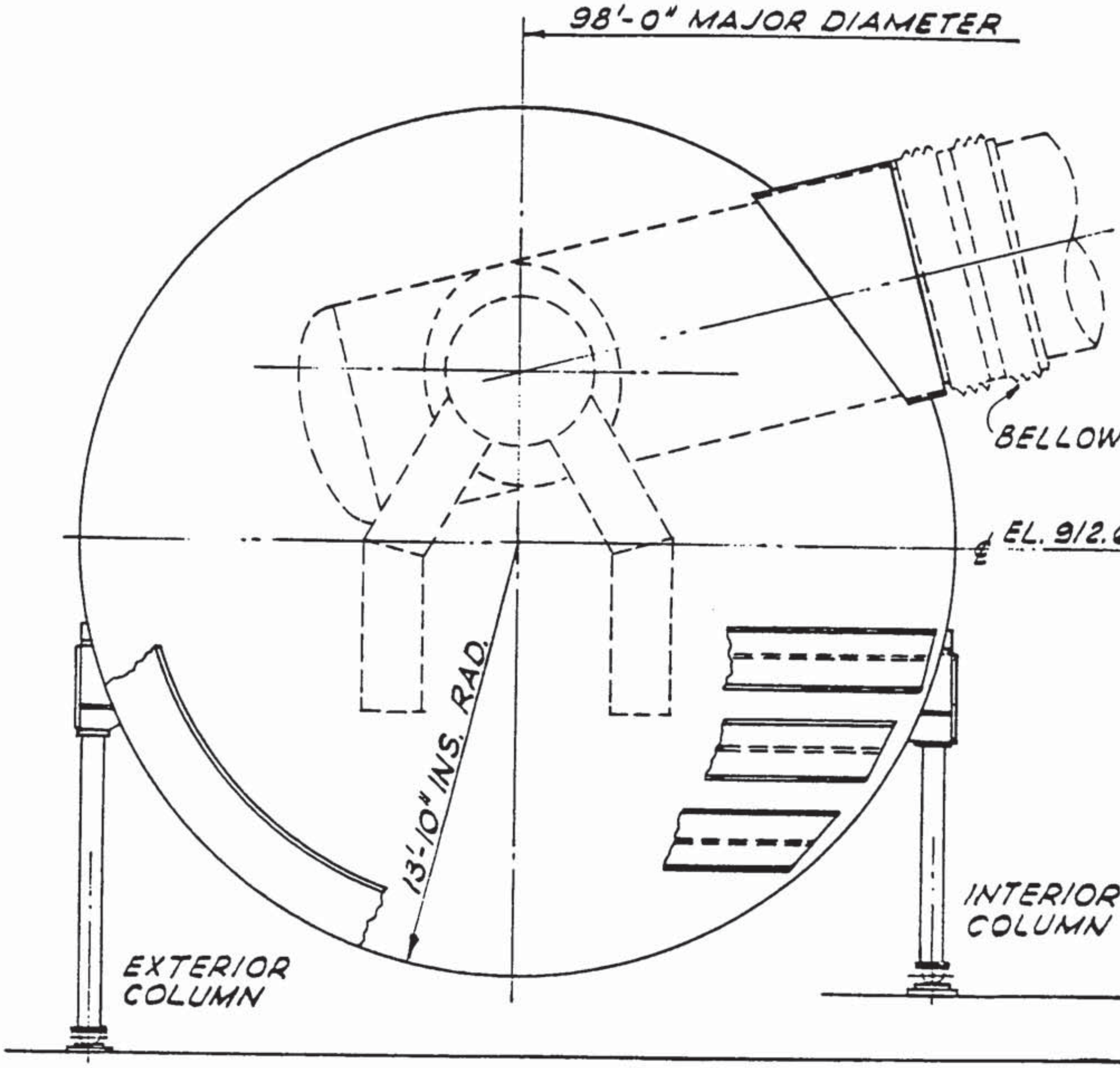


4

PLAN

PRESSURE SUPPRESSION CHAMBER

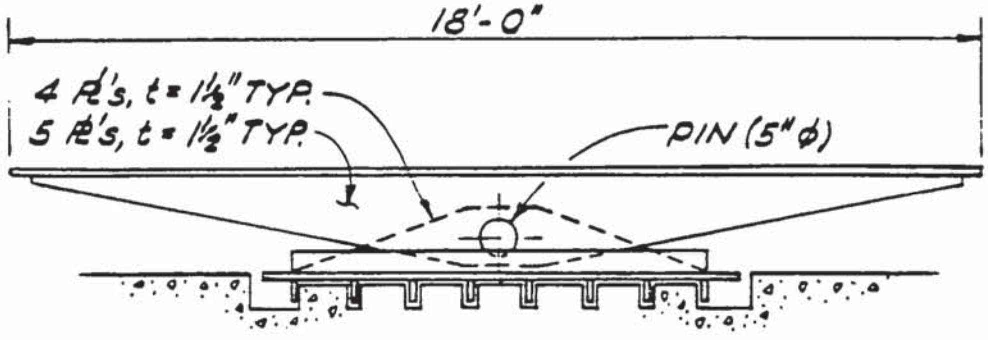
FIGURE 1



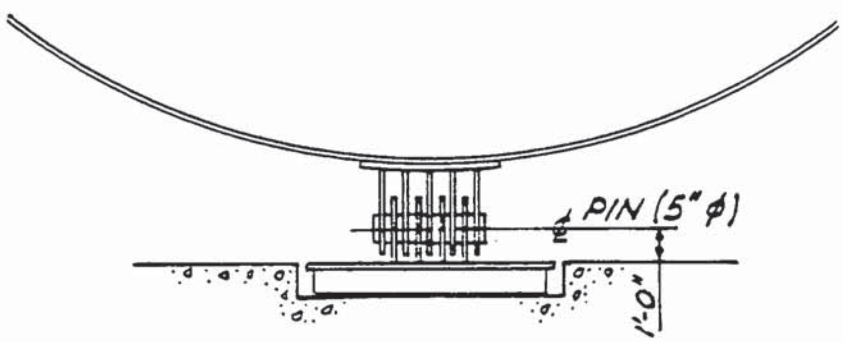
5

TYPICAL SECTION
PRESSURE SUPPRESSION CHAMBER

FIGURE 2



SECTION A-A



SECTION B-B

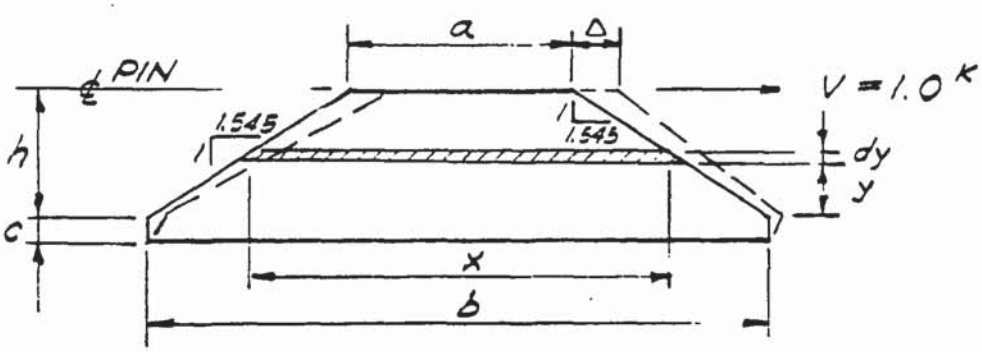
6

FIGURE 3

1. STIFFNESS OF CHAMBER SUPPORT

THE STIFFNESS OF EACH CHAMBER SUPPORT IS PROVIDED BY A SET OF FIVE STIFFENER PLATES AND PIN. ONLY SHEAR DEFORMATIONS OF PLATE AND PIN ARE CONSIDERED SINCE BENDING DEFORMATIONS ARE NEGLIGIBLE. ONLY THE LOWER PLATES ARE CONSIDERED SINCE THE UPPER PLATES ARE STIFF COMPARED TO THE LOWER PLATES.

a. STIFFNESS OF LOWER PLATES



ELEVATION

t = PLATE THICKNESS

$x = b - 2(1.545)y = b - 3.09y$

$A(y) = tx = t(b - 3.09y)$

$$\Delta = k\frac{Vc}{GA} + k\int_0^h \frac{V\,dy}{GA(y)} = \frac{kV}{G}\left[\frac{c}{A} + \int_0^h \frac{dy}{A(y)}\right]$$

$$\int_0^h \frac{dy}{A(y)} = \int_0^h \frac{dy}{t(b-3.09y)} = \frac{1}{3.09t}\,\ln\left(\frac{b}{b-3.09h}\right)$$

$$\Delta = \frac{kV}{Gt}\left[\frac{c}{b} + \frac{1}{3.09}\ln\left(\frac{b}{b-3.09h}\right)\right]$$

STIFFNESS OF CHAMBER SUPPORT (CONT'D.)

INNER PLATES

FOR $G = 12 \times 10^3$ KIP/IN^2; $t = 2(1.5) = 3$ IN.

$K = 6/5$; $b = 67$ IN.; $h = 9.875$ IN.; $C = 2.125$ IN.

$$\Delta = \frac{1.2(1)}{12 \times 10^3 \times 3}\left[\frac{2.125}{67.0} + \frac{1}{3.09}\ln\frac{67}{67-30.5}\right] = .765 \times 10^{-5} \text{ IN/KIP}$$

$$K = \frac{1}{\Delta} = \frac{1}{.765 \times 10^{-5}} = 1.31 \times 10^5 \text{ KIP/IN.}$$

OUTER PLATES

FOR $G = 12 \times 10^3$ KIP/IN^2; $t = 2(1.5) = 3$ IN.

$K = 6/5$; $b = 72$ IN; $h = 11.5$ IN.; $C = 0.5$ IN.

$$\Delta = \frac{(1.2)(1)}{(12 \times 10^3)(3)}\left[\frac{0.5}{72} + \frac{1}{3.09}\ln\frac{72}{72-35.5}\right] = 0.755 \times 10^{-5} \text{ IN/KIP}$$

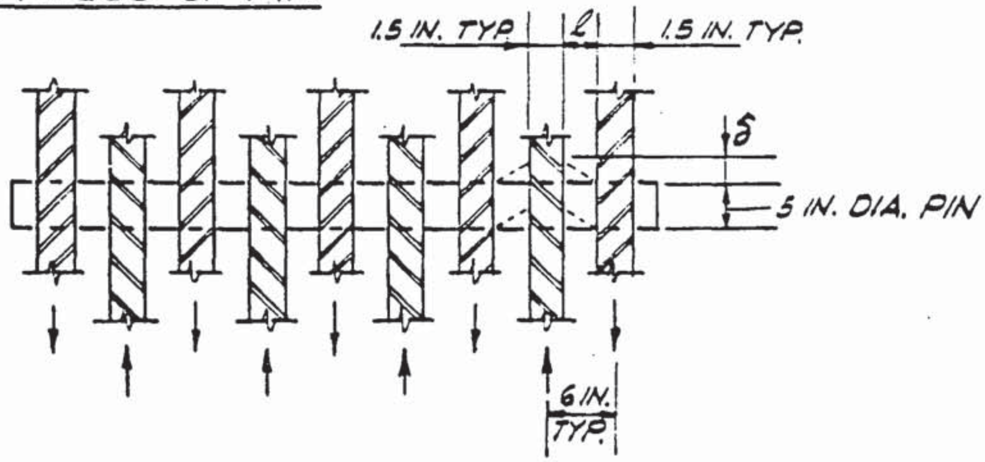
$$K = \frac{1}{\Delta} = 1.32 \times 10^5 \text{ KIP/IN.}$$

SUM

$$K_{\text{PL TOTAL}} = \Sigma K_{\text{PL}} = \underline{2.63 \times 10^5 \text{ KIP/IN.}}$$

8

b. STIFFNESS OF PIN



PLAN

STIFFNESS OF CHAMBER SUPPORT (CONT'D.)

$$\delta = \frac{KV\ell}{AG} \qquad K_{PIN} = \frac{V}{\delta} = \frac{AG}{K\ell}$$

FOR $A = 25 \times \pi/4 = 19.6\ IN^2$
$G = 12 \times 10^3\ KIP/IN.$
$K = 10/9 = 1.11$
$\ell = 1.5\ IN.$

$$K_{PIN} = \frac{(1.96)(12 \times 10^3)}{(1.11)(1.5)} = \underline{1.41 \times 10^5\ KIP/IN.}$$

c. STIFFNESS OF EACH CHAMBER SUPPORT

$$\frac{1}{K_S} = \frac{1}{K_{PL}} + \frac{1}{K_{PIN}} = \frac{1}{2.63 \times 10^5} + \frac{1}{1.41 \times 10^5} = 1.09 \times 10^{-5}$$

$$K_S = \frac{1}{1.09 \times 10^{-5}} = \underline{0.92 \times 10^5\ KIP/IN.}$$

2. TORUS STIFFNESS K_T

$$K_T = 2K_S = \underline{1.84 \times 10^5\ KIP/IN.}$$

3. MASS

a. WATER WEIGHT

OPERATING CONDITION	5,223. KIPS
FLOODED CONDITION	11,704. KIPS

b. STRUCTURE & EQUIPMENT

1,710. KIPS

4. TORUS PERIOD & RESPONSE

ITEM	UNIT	OPERATING CONDITION	FLOODED CONDITION
WATER WEIGHT	KIPS	5,223.0	11,704.0
STRUCTURE & EQUIP. WEIGHT	"	1,710.0	1,710.0
TOTAL WEIGHT, W	"	6,933.0	13,414.0
TORUS STIFFNESS, K_T	K/IN.	1.84×10^5	1.84×10^5
PERIOD $T = 2\pi\sqrt{\frac{W}{g K_T}}$	SEC.	0.062	0.087
Sa^{*} $\lambda = 1\%$	g	0.07	0.15
SEISMIC FORCE $F = \frac{W}{g} \times Sa$	KIPS	485.	2,010.0
TORUS DEFLECTION $\Delta_T = \frac{F}{K_T}$	IN.	0.00264	0.0109

*Sa FROM RESPONSE SPECTRUM CURVE.

5. MAX. SEISMIC FORCE AT EACH CHAMBER SUPPORT

$F_{MAX} = K_S \Delta_T$ 10

a OPERATING CONDITION

$F_{MAX} = (.92 \times 10^5 \text{ K/IN.})(.00264 \text{ IN.})$

$= \underline{\underline{243 \text{ KIPS}}}$

b. FLOODED CONDITION

$F_{MAX} = (.92 \times 10^5 \text{ K/IN.})(.0109 \text{ IN.})$

$= \underline{\underline{1,000 \text{ KIPS}}}$

REFERENCES

1. Chicago Bridge & Iron Company

General Plan, dated 9-5-67 VPF No. 1812-67-4 (General Electric Co.)
EP No. 16-11 (General Electric Co.)

2. Chicago Bridge & Iron Company

Earthquake Ties, dated 4-7-67 VPF No. 1812-12-7 (General Electric Co.)
EP No. 16-V (General Electric Co.)

3. Chicago Bridge & Iron Company

Suppression Chamber, General Plan and Field Assembly, dated 6-16-67
VPF No. 1812-68-5 (General Electric Co.)
EP No. 16-11 (General Electric Co.) 11

MONTICELLO

RECIRCULATION LINES

METHODS OF ANALYSIS

(Code Requirement Section III, Appendix C-1320)

The following is a description of the computer programs used in the subject stress analysis and a brief description of their assumptions and theory. All programs conform to the design and control measures required by Appendix B of 10 CFR Part 50.

PROGRAM THEORY AND ASSUMPTIONS

ME-101

PURPOSE

The stresses and loads in piping systems due to restrained expansion, dead weight, seismic movement and earthquake are calculated using the ME-101 computer program.

METHOD OF ANALYSIS

ME-101 is a finite element computer program which performs linear elastic analysis of piping systems using standard beam theory techniques. ME-101 may be used for static and seismic load analysis of piping systems and also performs effective weight calculations.

Static analysis considers one or more of the following: thermal expansion, dead weight, uniformly distributed loads, and externally applied forces, moments, displacements and rotations, or individual force loads.

Seismic analysis is based on standard normal mode techniques and uses response spectrum data. Three methods of eigenvalue solution are available. Both Determinant Search and Subspace Iteration consider all data points as mass points. Kinematic Reduction considers masses only at specified data points in designated directions. Differential seismic anchor movement analysis and static seismic analysis are also provided.

REFERENCES

1. K. Bathe, E. Wilson, F. Peterson, "SAP IV – Structural Analysis Program for Static and Dynamic Response of Linear Systems," U. of California, Berkeley, Report No. EERC73-11, June 1973.

2. J. Gere, W. Weaver, "Analysis of Framed Structures," New York, D. Van Nostrand, 1965.

3. BSAP Theoretical Manual, Vol. 1.

4. R. Roark, "Formulas for Stress and Strain," New York, McGraw-Hill, 1965.

5. J. Gere, "Moment Distribution," Princeton, N.J., D. Van Nostrand, 1963.

6. K. Bathe, E. Wilson, "Numerical Methods in Finite Element Analysis," Englewood Cliffs, N.J., Prentice Hall, 1976.

7. G. Stewart, "Error Bounds for Approximate Invariant Subspaces of Closed Linear Operators," SIAM J. of Numerical Analysis, Vol. 8, No. 4, December 1971.

8. G. Stewart, "Error and Perturbation Bounds for Subspaces Associated with Certain Eigenvalue Problems," SIAM J. of Numerical Analysis, Vol. 15, No. 4, October 1973.

9. G. Stewart, U. of Maryland Department of Computer Science, letter to R. Blum, November 22, 1977 (Attachment 1).

ME-101 STATIC ANALYSIS

For gravity, thermal and seismic movement analyses, the static load and displacement matrices are formed in addition to the stiffness matrix of the mathematical model. These matrices include the applied end forces and displacements, the distributed loading on the mathematical model, and the thermal forces developed in the members of the model, whichever is applicable. Once these matrices are formed, the system equilibrium equation is solved for $\underline{U}$ using the SESOL linear equation solver (see Ref. 6).

$$\bar{R} = \bar{K}\,\bar{U} - \bar{F}$$

in which:

$\bar{R}$ = End force matrix

$\bar{K}$ = Stiffness matrix of piping

$\bar{U}$ = End displacement matrix

$\bar{F}$ = Fixed end force matrix

After the end displacements are determined, the individual member forces are obtained by using the member stiffness properties, and finally, the support reactions are calculated.

DYNAMIC ANALYSIS

The dynamic analysis of flexible piping systems is performed using the response spectrum method. A flexible piping system is idealized as a mathematical model consisting of lumped masses connected by massless elastic members. The lumped masses are carefully located so as to adequately represent the dynamic and classic properties of the piping system. The three-dimensional stiffness matrix of the mathematical model is determined by the direct stiffness method. Axial, shear, flexural and torsional deformations of each member are included. For curved members, a decreased stiffness is used in accordance with the Code. The mass matrix is also calculated.

After the stiffness and mass matrix of the mathematical model are calculated, the natural frequencies of piping system and corresponding mode shapes are determined using the following equation:

$$\overline{M}\,\ddot{U}_\xi + \overline{K}\,U_\xi = -a_\xi\,\overline{M}\quad I_\xi \quad,\ \xi = X, Y \text{ or } Z$$

where,

$\overline{K}$ = stiffness matrix

$U_\xi\ \ddot{U}_\xi$ = displacement and accelerations due to the ground acceleration a_ξ, ξ = X, Y, or Z

$\overline{M}$ = mass matrix

I_X = vector with I's in positions corresponding to δ_X displacements, O's elsewhere

I_Y , I_Z = same as I_X except I's are in positions corresponding to δ_Y and δ_Z directions respectively

a_X, a_Y, a_Z = ground accelerations in X, Y and Z directions

The equation of motion is solved via modal analysis, i.e.

$$U_\xi = \sum_{\text{modes}} \eta_i\,\Phi_i\ ;$$

where, Φ_i = i^{th} mode shapes

η_i = generalized displacement of the i^{th} mode shape

Substituting the modal formulation of U_ξ into the equation of motion and pre-multiplying by Φ_j^T and enforcing orthogonality, i.e.

$$\Phi_i^T\,\overline{M}\,\Phi_j = \Phi_i^T\,\overline{K}\,\Phi_j = 0 \qquad i \neq j$$

yields the modal equation of motion

$$\ddot{\eta} + \omega_j^2\,\eta_j = \Gamma_j\,a_\xi$$

$$\text{where, } \omega_j^2 = \frac{\Phi_i^T\,\overline{M}\,\Phi_i}{\Phi_j^T\,\overline{M}\,\Phi_j} = \text{eigenvalue}$$

$$= (2\pi\ .\ \text{frequency})^2$$

$$\Gamma_j = \frac{-\Phi_j^T\,\overline{M}\left\{I_\xi\right\}}{\Phi_j^T\,\overline{M}\,\Phi_j} = \text{participation factor}$$

The maximum generalized accelerations, $\ddot{\eta}_{j\ max}$; and displacements, $\eta_{j\ max} = \ddot{\eta}_{j\ max}/\omega^2$, are determined by a response spectra curve for the input ground motion.

The responses of the piping system with frequencies greater than $\omega_{cut\text{-}off}$ are neglected.

The modal displacements and element end forces are:

displacement: $U_j = \eta_j \ \Phi_j$

end forces: $R_j = K\,U_j$

Two options are available for modal summation. They are square root of the sum of the squares (SRSS) and summation of closely spaced modes, via Regulatory Guide 1.92 Eqn. 4 (CS4).

VERIFICATION

The program has been verified by comparing its output with the ASME Benchmark Problem No. 1 as described in "Pressure Vessel and Piping 1972 Computer Programs Verification". The results were acceptable. Additional test problems are given in "Verification Report on ME-101, Linear Elastic Analysis of Piping Systems" Revision 1, February 1977, Bechtel Power Corporation.

PIPING STRESS CALCULATION INDEX

PROJECT MONTICELLO I NO. 10040

REV. NO. 2

SHEET 1 OF 2

CALC. NO.	CALC. TYPE *	LOADING CONDITION	BY	DATE	TITLE, SERVICE OR SYSTEM DESCRIPTION	SUPERCEDES CALC. NO.	SUPERCEDED BY CALC. NO.	STATUS/REMARKS
SR-10040-SSIA	T	HYDRO TEST	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	NORMAL	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	SCRAM	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	SHUTDOWN 1	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	SHUTDOWN 2	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	SHUTDOWN 3	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	LOSS OF FW PUMP 1	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	LOSS OF FW PUMP 2	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	LOSS OF FW PUMP 3	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	RPV OVERPRES 1	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	T	RPV OVERPRES 2	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	W	WEIGHT	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	S	SEISMIC Y	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	S	SEISMIC X	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	S	SEISMIC Z	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	S	SEISOB	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIA	S	SEISOB	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIB	T	HYDRO TEST	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	NORMAL	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	SCRAM	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	SHUTDOWN 1	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	SHUTDOWN 2	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	SHUTDOWN 3	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II

*T = THERMAL, W = WEIGHT, S = SEISMIC, SAM = SEISMIC ANCHOR MOVEMENT, TT = THERMAL TRANSIENT

PIPING STRESS CALCULATION INDEX

PROJECT MONTICELLO I NO. 10040

REV. NO. 2

SHEET 2 OF 2

CALC. NO.	CALC. TYPE *	LOADING CONDITION	BY	DATE	TITLE, SERVICE OR SYSTEM DESCRIPTION	SUPER-CEDES CALC. NO.	SUPER-CEDED BY CALC. NO.	STATUS/REMARKS
SR-10040-SSIB	T	LOSS OF FW PUMP 1	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	LOSS OF FW PUMP 2	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	LOSS OF FW PUMP 3	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	RPV OVERPRES 1	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	T	RPV OVERPRES 2	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	W	WEIGHT	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	S	SEISMIC Y	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	S	SEISMIC X	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	S	SEISMIC Z	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	S	SEISOB	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIB	S	SEISDB	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SSIC	TT		HWH	1-23-85	RECIRCULATION/RHR			APPENDIX F, VOL. III-V
SR-10040-SSID	SECT III CLASS I		HWH	1-23-85	RECIRCULATION/RHR - LOOP A			APPENDIX E, VOL. I
SR-10040-SSIE	SECT III CLASS I		HWH	1-23-85	RECIRCULATION/RHR - LOOP B			APPENDIX E, VOL. II
SR-10040-SSIA	T	SHUTDOWN 4	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SSIB	T	SHUTDOWN 4	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II

*T = THERMAL, W = WEIGHT, S = SEISMIC, SAM = SEISMIC ANCHOR MOVEMENT, TT = THERMAL TRANSIENT

GENERAL ELECTRIC COMPANY

Atomic Power Equipment Department

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1

Earthquake Analysis:

Off-Gas Stack

JOHN A. BLUME & ASSOCIATES, ENGINEERS
SAN FRANCISCO

JOHN A. BLUME & ASSOCIATES ENGINEERS
612 HOWARD STREET • SAN FRANCISCO, CALIF.

December 10, 1968

General Electric Company
Atomic Power Equipment Department
175 Curtner Avenue
San Jose, California 95125

ATTENTION: Mr. R. B. Gile
MC - 750

SUBJECT: MONTICELLO Nuclear Generation Plant - Unit 1
Earthquake Analysis:
Off-Gas Stack

Gentlemen:

Transmitted herewith is the subject report based on the information furnished by General Electric Company.

The results and recommendations presented herein are intended to be used in conjunction with the normal service loads in the final design calculations.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

Ralph T. Yokoyama
Assistant Vice President

RSV:jl

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1

EARTHQUAKE ANALYSIS:

OFF-GAS STACK

CONTENTS

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1

EARTHQUAKE ANALYSIS:

OFF-GAS STACK

INTRODUCTION

This report presents the results of our investigations of the design earthquake response of the off-gas stack for the Monticello Nuclear Generation Plant-Unit 1. Based upon the recommended earthquake design criteria established for the plant, design envelopes of the maximum accelerations, displacements, shears, and overturning moments versus the height of the stack have been developed and are presented herein.

DESIGN CRITERIA

Based upon data developed by John A. Blume & Associates, Engineers, the design earthquake used in this analysis is the North 69° West component of the July, 1952 Taft earthquake, normalized to a maximum ground acceleration of 0.06 gravity. The earthquake design criteria for the Monticello Nuclear Generation Plant is contained in Reference 1.

DESCRIPTION OF STACK

The off-gas stack is a 320-foot-high reinforced concrete structure, having an internal diameter of 6.0 feet at the top and 32.0 feet at the base, with a 4.0-foot-thick octagonal foundation. The thickness of the concrete shell of the stack varies from 12 inches at the base to 7 inches at the top. The physical characteristics of the subject stack are described in Reference 2, and are schematically shown in Figure 1.

METHOD OF ANALYSIS

The off-gas stack was treated as a flexible cantilever and was idealized as a mathematical model consisting of nineteen lumped

masses connected by weightless elastic columns. The soil-structure interaction has been considered through the application of base translational and rotational springs. The complete mathematical model (Figure 2) shows the location and magnitude of the lumped masses, area and moment of inertia of the connecting columns, and the values of the base springs. The values for the base springs are based on the subsurface geotechnical properties of the material supporting the stack, and are listed in References 3, 4, and 5.

The elastic properties of the columns and the coupled action of the base springs were used to determine the flexibility matrix for the mathematical model. The flexibility calculations included the effects of flexural and shear deformations. Periods and mode shapes were determined using the flexibility matrix and the mass matrix.

The model was then subjected to the design acceleration time-history at the base to obtain time-histories for accelerations, displacements, shear forces, and overturning moments at the various mass point elevations. These records were then scanned to determine the maximum values, which are graphically presented in Figures 3 through 6.

DESCRIPTION OF COMPUTER PROGRAM

The computer program used in this analysis was developed specifically to solve for dynamic response of structures subjected to arbitrary ground motions. Forms of input data used for the program include moments of inertia, effective shear area for the members, values of the base springs, weights of the lumped masses, and the input acceleration time-history.

The computer retains the response of each mass for each individual mode at each increment of time, and the total response for each increment of time is obtained by adding together the response of each mass point for each mode at a particular instant of time.

The result is an exact combination of mode participation which does not require approximate methods such as the root-mean-square method.

DISCUSSION OF RESULTS

The envelopes of maximum accelerations, shears, moments, and displacements are presented in Figures 3 through 6.

The calculations previously described were performed with the aid of a digital computer. The influence of 7th and higher modes of vibration was considered negligible, and therefore ignored in the response calculations. A damping value of 5% was assigned to all modes.

The first six natural periods of vibration are listed below:

First Mode........................1.131 seconds
Second Mode.......................0.360 seconds
Third Mode........................0.171 seconds
Fourth Mode.......................0.108 seconds
Fifth Mode........................0.081 seconds
Sixth Mode........................0.061 seconds

RECOMMENDATIONS

It is recommended that the off-gas stack be designed to resist the seismic shears and moments presented herein. The stack should be stable against an overturning moment of 14,312 kip-ft. In addition, the structure should be reviewed for safe shutdown requirements.

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1

EARTHQUAKE ANALYSIS:

OFF-GAS STACK

REFERENCES

1. "Monticello Nuclear Generation Plant, Recommended Earthquake Criteria," John A. Blume & Associates, Engineers, July 15, 1966.

2. Bechtel Drawing:
   No. SK-C-120, Revision A, November 1, 1968.

3. "Monticello Nuclear Generation Plant, Earthquake Analysis of the Reactor Building," John A. Blume & Associates, Engineers, July 18, 1967.

4. "Foundation Investigation - Proposed Nuclear Power Plant - Unit Number 1, Monticello, Minnesota," Dames & Moore, July 27, 1966 (includes Supplements 1 through 5).

5. "Dynamic Response Data Investigation - Proposed Nuclear Power Plant, Monticello, Minnesota," Dames & Moore, July 7, 1966.

Design Reconciliation

A design basis review of the Offgas Stack identified several differences between the designed configuration of the Offgas Stack and the analyzed configuration presented within this report. An engineering review of these differences concluded that the dynamic results presented herin are sufficiently accurate for design purposes.

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT

OFF-GAS STACK

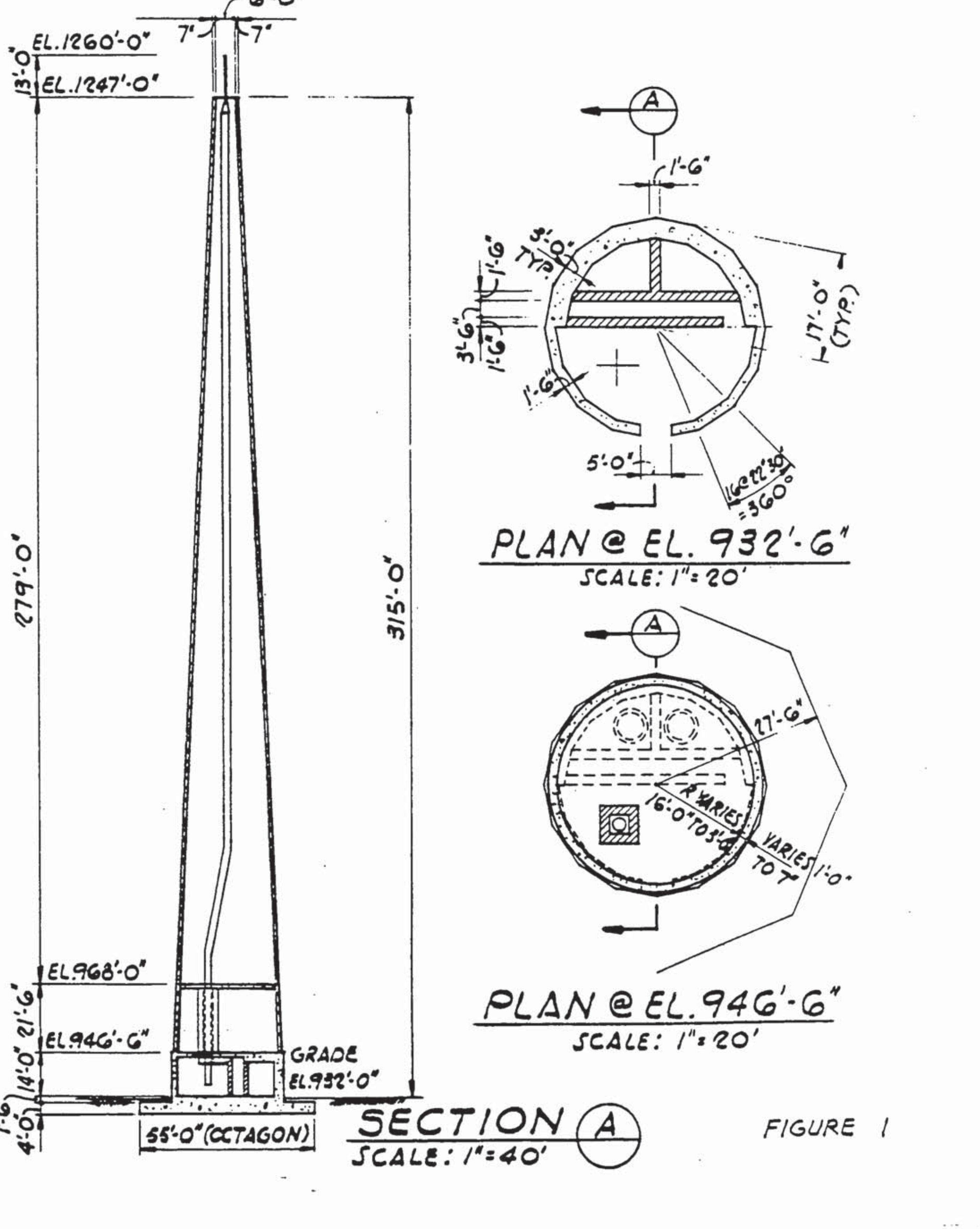


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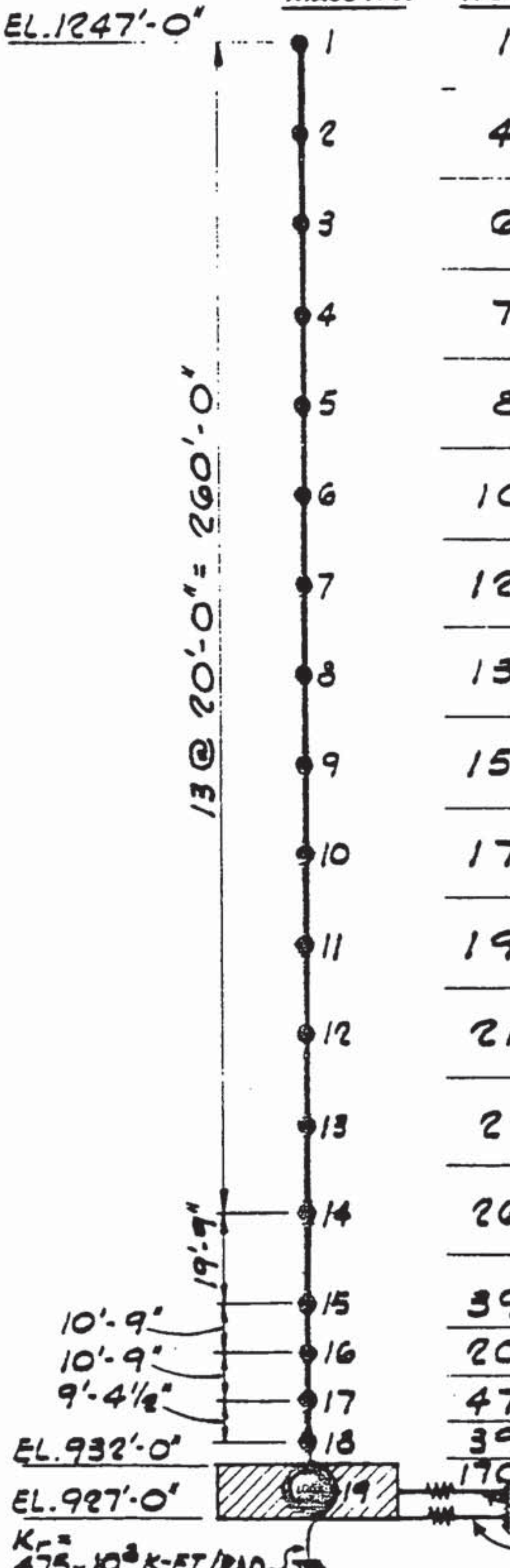
FIGURE 1

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT
OFF-GAS STACK



MASS NO.	WEIGHT (KIPS)	AREA (FT²)	I (FT⁴)
1	19.911		
		13.988	97.982
2	48.123		
		18.094	193.153
3	60.905		
		22.509	340.294
4	74.615		
		27.234	553.763
5	89.252		
		32.267	849.353
6	104.816		
		37.601	1244.283
7	120.424		
		42.673	1731.281
8	137.844		
		49.223	2408.237
9	157.074		
		55.493	3218.873
10	176.348		
		62.072	4212.079
11	196.548		
		68.960	5412.255
12	217.677		
		76.158	6845.217
13	239.733		
		83.664	8538.223
14	262.545		
		91.366	10502.770
15	390.450		
		97.481	12214.680
16	204.400		
		101.926	13545.563
17	475.000		
		225.666	28084.000
18	393.000		
		225.666	28084.000
19	1706.000		

FIGURE 2

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT
OFF-GAS STACK
ACCELERATION DIAGRAM
UNDER SEISMIC LOADS

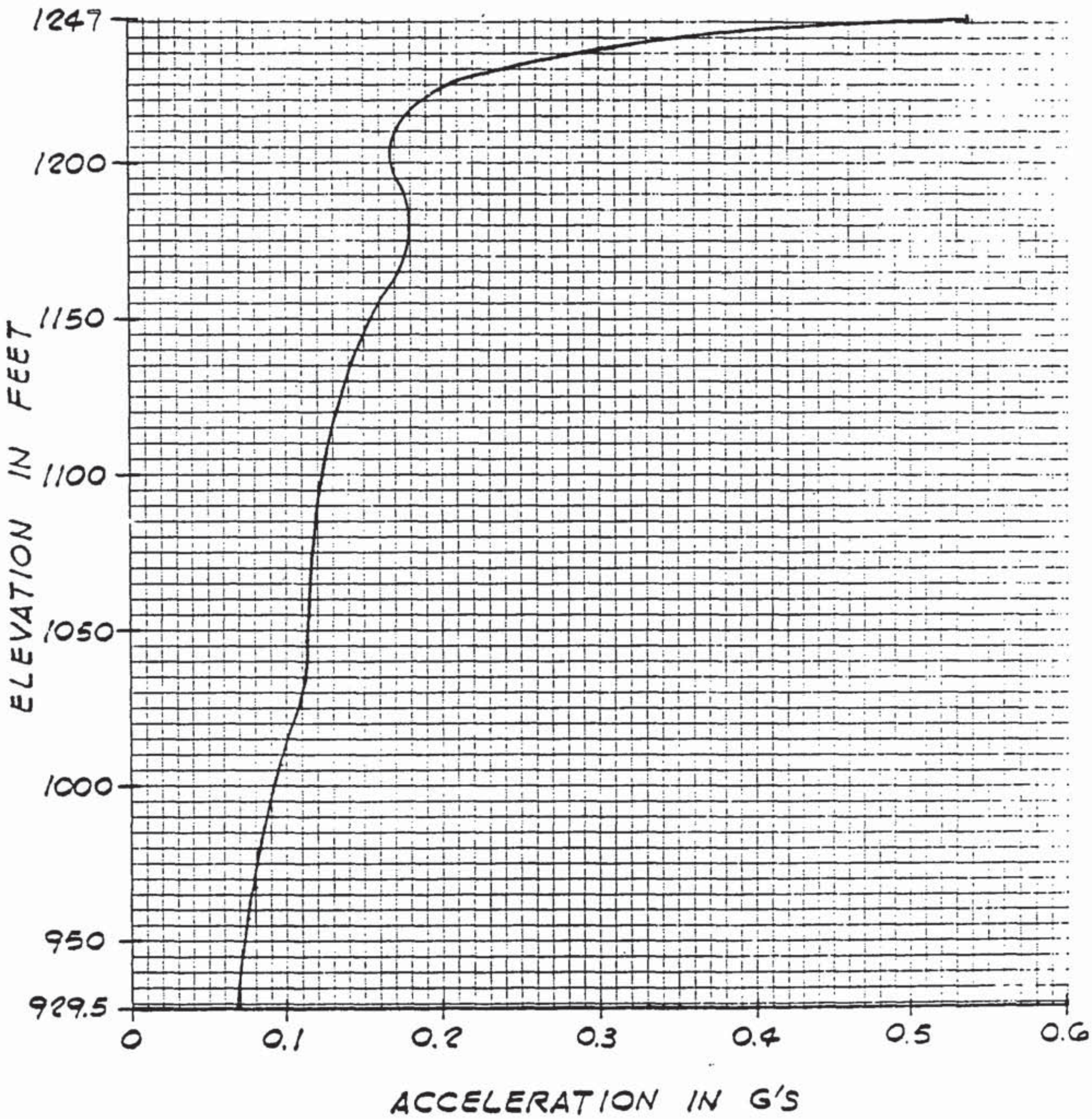


FIGURE 3

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT
OFF-GAS STACK
DESIGN SHEAR DIAGRAM
UNDER SEISMIC LOADS

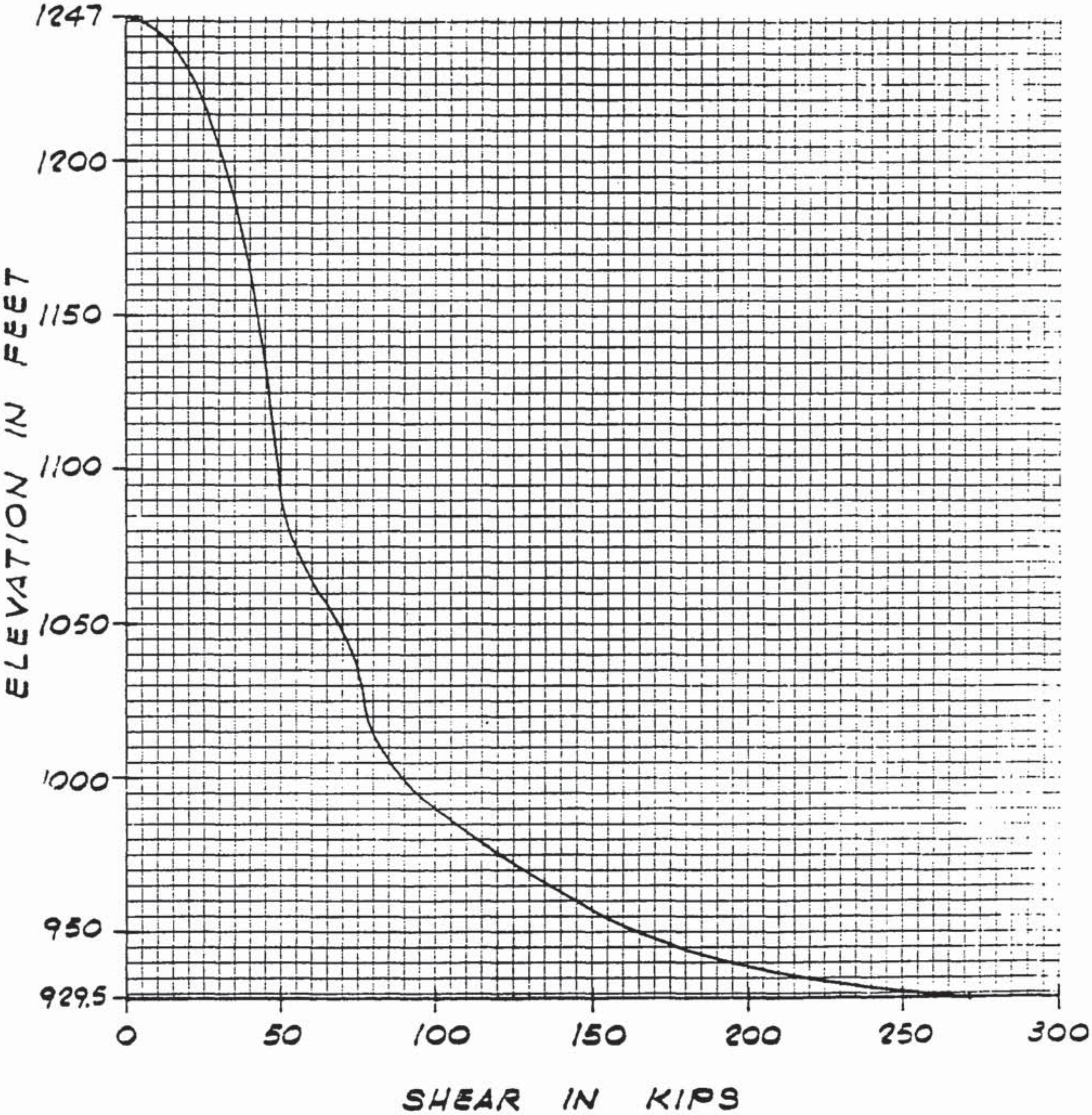


FIGURE 4

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT
OFF-GAS STACK
DESIGN MOMENT DIAGRAM
UNDER SEISMIC LOADS

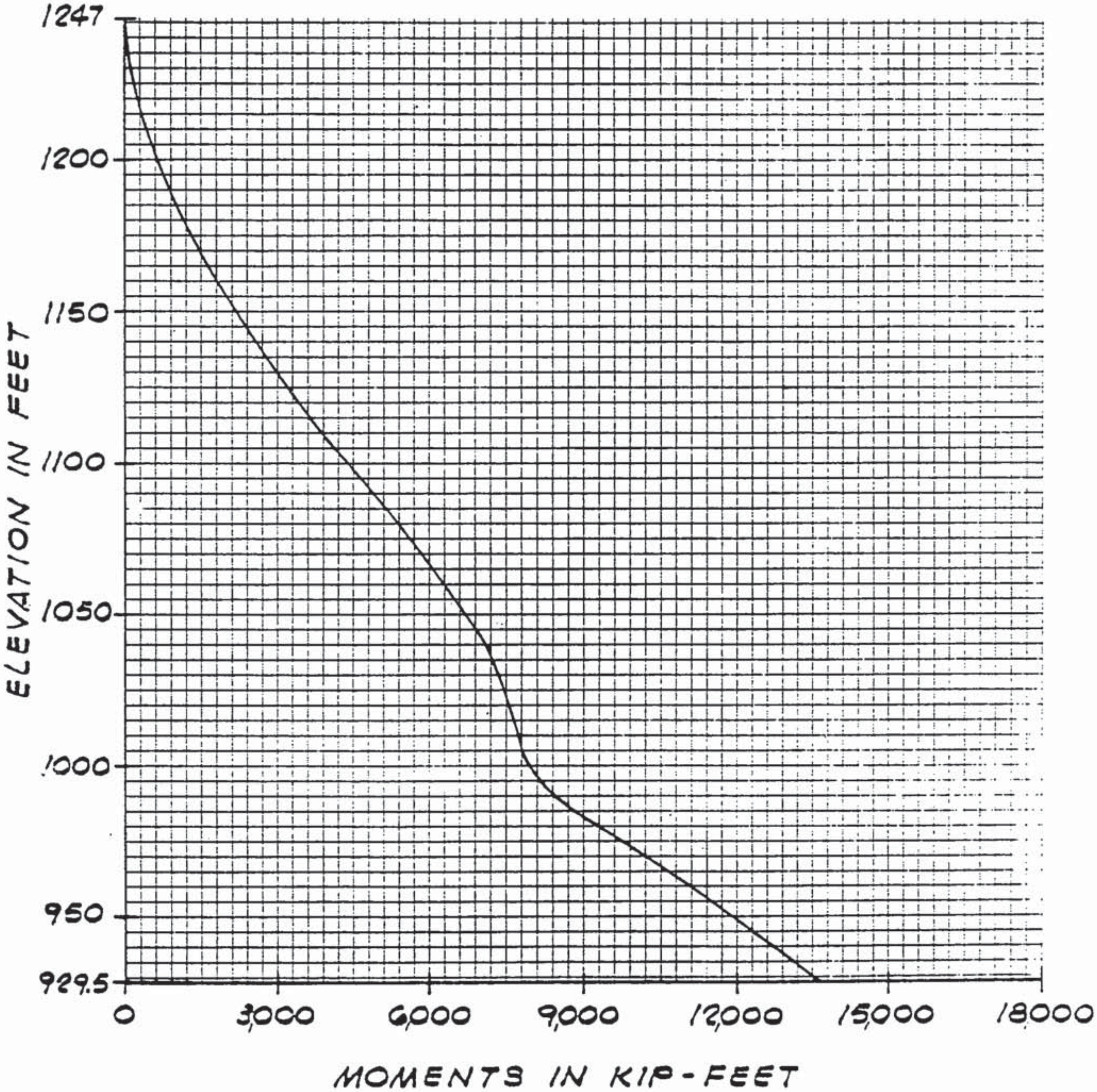


FIGURE 5

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT
OFF-GAS STACK
DISPLACEMENT DIAGRAM
UNDER SEISMIC LOADS

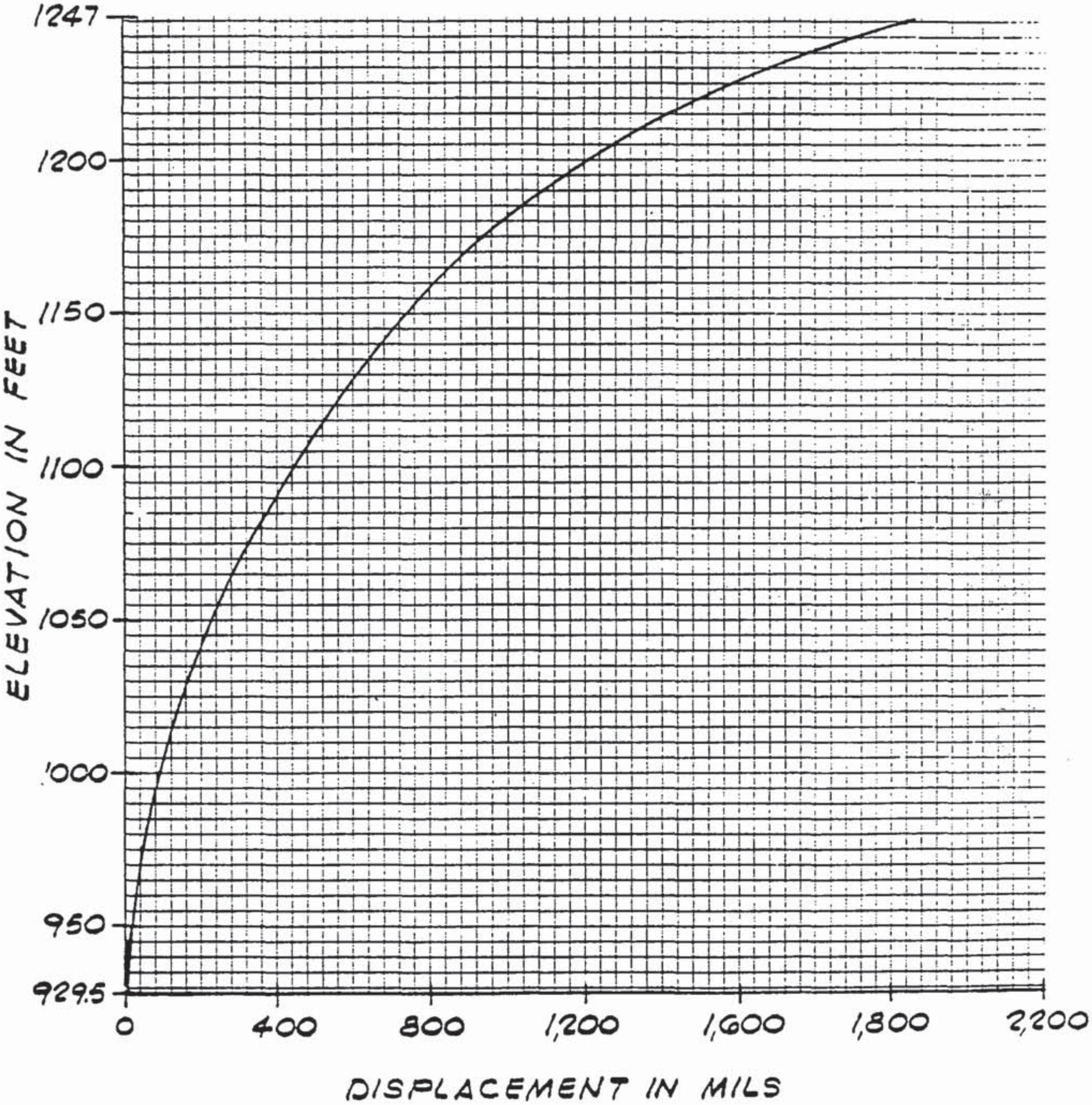


FIGURE 6