MONTICELLO

APPENDIX A

SEISMIC DESIGN CRITERIA

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SEISMIC DESIGN CRITERIA

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GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPARTMENT

MONTICELLO NUCLEAR GENERATION PLANT

RECOMMENDED EARTHQUAKE CRITERIA

JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

JOHN A. BLUME
J. P. NICOLETTI
H. J. SEXTON
R. L. SHARPE
D. M. TEIXEIRA

JOHN A. BLUME & ASSOCIATES, ENGINEERS
612 HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94105 • (415) 397-2525

July 15, 1966

General Electric Company
175 Curtner Street
San Jose, California

Attention: Mr. R. B. Gile

Subject: Earthquake Design Criteria for the Monticello Nuclear Generation Plant

Gentlemen:

Transmitted herewith is our recommended earthquake design criteria for the subject project.

Since not all field data have yet been made available it will be necessary that we review the findings presented herein. We do not however, expect drastic changes in these criteria.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

H. J. Sexton,
Vice President and Chief Engineer

JOHN A. BLUME
J. P. NICOLETTI
H. J. SEXTON
R. L. SHARPE
D. M. TEIXEIRA

JOHN A. BLUME & ASSOCIATES, ENGINEERS
HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94105 • (415) 397-2525

February 6, 1967

General Electric Company
Atomic Power Equipment Dept.
175 Curtner Street
San Jose, California 95103

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

SUBJECT: Monticello Nuclear Plant

Gentlemen:

The following telegram was sent to Northern States Power Company this date:

> MR. A. V. DIENHART
> NORTHERN STATES POWER CO.
> 414 NICOLLET AVENUE
> MINNEAPOLIS, MINNESOTA
>
> SUBJECT: MONTICELLO NUCLEAR PLANT
> REFERENCE OUR LETTER TO GENERAL ELECTRIC DATED SEPTEMBER 30, 1966. WHEN LETTER WAS WRITTEN WE WERE AWARE THAT THE CLAY LAYER WAS TO BE REMOVED AND REPLACED WITH A COMPACTED GRANULAR FILL. IT IS OUR OPINION THAT THE GROUND ACCELERATION AND RESPONSE SPECTRA DATA PRESENTED IN OUR REPORT OF JUly 15, 1966 ARE STILL VALID.

Reference is made to our letter of September 30, 1966. At the time of this letter we were aware that the clay layer assumed to underlie the reactor building foundation was to be removed and replaced with a compacted granular fill. Since this layer is assumed to be only about 15 feet in depth, it is our opinion that changing the clay layer to a granular fill layer will have no effect on the earthquake criteria.

Your attention is invited to the end of the first sentence of the above-referenced letter. The date of the dynamic response report was listed as July 17, 1966. This should be revised to July 7, 1966. For your information we are transmitting herewith two (2) copies of the Dynamic-Response Data Investigation.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

E. J. Keith

E. J. Keith
Assistant Vice President

EJK/hp
Enclosures

JOHN A. BLUME
J. P. NICOLETTI
H. J. SEXTON
R. L. SHARPE
D. M. TEIXEIRA

JOHN A. BLUME & ASSOCIATES, ENGINEERS
[illegible] HOWARD STREET • SAN FRANCISCO, CALIFORNIA 9410[illegible] • (415) 397-2525

September 30, 1966

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

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

SUBJECT: Earthquake Design Criteria for the
Monticello Nuclear Generation Plant

Gentlemen:

We have reviewed the Dames & Moore Report of Foundation Investigation, Proposed Nulcear Power Plant - Unit Number 1 for the Northern States Power Company dated July 27, 1966 and the report on the Dynamic Response Data Investigation, Proposed Nuclear Power Plant, Monticello, Minnesoto for Northern States Power Company dated July 17, 1966. The data provided therein have no effect on the results of the report to you dated July 15, 1966 and the findings therein are sound.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

H. J. Sexton

HJS/gr

PRELIMINARY EARTHQUAKE DESIGN CRITERIA

FOR THE

MONTICELLO NUCLEAR GENERATION PLANT

NEAR

MONTICELLO, MINNESOTA

This report is based on preliminary geologic and soil data furnished by Dames and Moore, foundation engineers, and the assumption that the reactor-building is founded in a 15-foot layer of stiff clay immediately above sandstone. When final earth science reports are available this report will be reviewed and revised if necessary.

The proposed site is located near the right bank of the Mississippi River in Wright County, Minnesota at about latitude 45° 20' North and Longitude 93° 50' West, approximately 30 miles northwest of Minneapolis.

GEOLOGY

Regional Geology - The basement rocks of Minnesota, some as old as Precambrian, generally are covered by Pleistocene glacial debris and younger alluvial deposits. Volcanic rocks occur in some areas. Sediments of these types rest on glacially-carved bedrock of sandstone and shale in turn underlain by weathered granite rocks. The bedrock surface slopes east to southeast.

The Minnesota area here discussed is part of a deep, southerly-trending trough in which were deposited sediments and volcanics during later Precambrian and Paleozoic time. Paleozoic rocks are exposed in the southern part of the trough and, in the Minneapolis-St. Paul area, form an artesian basin.

Regional Faulting - The results of regional geophysical surveys indicate that a major fault system of Precambrian age may be present in the region. Displacements of thousands of feet are believed to have occurred on the faults in Precambrian time and displacements of lesser magnitude in Paleozoic time. There is no evidence of faulting in the last few million years.

Two lobes of ice, both of the Wisconsin glacial stage, advanced across the region, the older from the Lake Superior area and the other from the southwest. Both left terminal moraines, the moraines of the older of the lobes being immediately south of the present-day Mississippi River.

The depths of stream channels cut in the area in pre-glaciation time not only may be greater than that of the Mississippi River, but they also bear no directional relationship to present-day channel. The locating of these old channels is hindered by lack of bore-hole information.

Site Geology - Decomposed igneous rocks of Precambrian age lie at a depth of about 70 feet at the site. These rocks are overlain by 10 to 15 feet of sandstone which, although in places weathered and friable, is in general moderately well cemented. The sandstone is in turn overlain by approximately 50 feet of glacial and alluvial debris consisting of sands and gravels. In the reactor-building area, the sandstone is overlain by clay of variable thickness. It is not presently known whether or not the building will be founded in this clay.

Borings and well information in the vicinity of Monticello - about 2-3/4 miles east of the site - indicate that that locality is underlain by 150 to 200 feet of unconsolidated alluvium and glacial drift which in turn

overlie sandstone and shale; granite at that locality lies at a depth greater than 500 feet. The indication is therefore, that the rock and soil units at the site slope eastward toward the sedimentary basin and its artesian ground-water aquifers

SEISMOLOGY

Seismic History - Table A numerically lists the earthquakes in the general region in and around Minnesota. Those more applicable to the site are plotted on Plate I. The earliest earthquake on record occurred in 1860 in central Minnesota, thus the record here is for only some ninety years. During that period the historical earthquakes have had little effect at the proposed site.

Faulting in Area - The nearest known or inferred fault - the Douglas Fault - is 23 miles southeast of the site (Plate 2). According to referenced geological information, there is no indication that faulting has affected the area of the site in the last few million years. The major fault system of Precambrian age, which is associated with the Precambrian structural trough, is also seen on Plate 2. Major movements of thousands of feet along this system appear to have been restricted to Precambrian time, with minor displacements having occurred during the Paleozoic. Faulting within recent geologic time is not in evidence.

Richter's Seismic Regionalization Map (Plate A, Appendix) shows the area of the site in a probable maximum intensity of VIII, Modified Mercalli. This intensity has been based on the area's relationship to the Canadian shield. Stable shields in other continents are usually fringed by belts of moderate seismicity, with occasionally large earthquakes. Historically, this area is too young to prove or disprove such seismic activity.

The Coast and Geodetic Survey's Seismic Probability Map of the United States (Plate B in Appendix) assigns the area to Zone 0 - no damage.

It is our opinion that neither the regionalization nor the probability map is satisfactory in determining a proper seismic factor if considered alone. Each, however, is based on judgment and fact which, when weighed with other data, become more meaningful. In the case at hand, the assignment of an VIII as the largest probable intensity for general area must be tempered by the fact that the intensity at or near the sandstone will be much less than that experienced in areas of less competent material, where invariably the maximum damage is sustained.

Earthquakes can and do occur in this region away from faults, and probably result from residual stresses due to recent glaciers. A quake similar to Nos. 12 and 24 was postulated near the site and using the dynamic response data obtained insitu, the Taft earthquake of July 21, 1952

North 69 West component with an applied factor of 0.33 was selected as best representative for the design earthquake. Plate 3 shows single-mass spectra when averaged. Recommended design criteria follow which utilize this earthquake record.

RECOMMENDED EARTHQUAKE DESIGN PROCEDURES

For purposes of design, structures (buildings or equipment) are divided into two classes:

Type I. Those structures whose failure may damage vital equipment and thus might cause a nuclear incident.

Type II. Those structures whose failure could cause no nuclear incident.

Recommended Procedures for Type I Structures and Equipment

1. For structures or equipment founded directly on soil, a structural design shall first be executed based on estimated seismic shears, moments, and displacements. The structures thus designed shall then be subjected to a dynamic analysis using the spectra on Plate 3 and damping values from Table 1. Sufficient modes shall be included to assure participation of all modes having a period greater than 0.08 second. A vertical ground acceleration of two-thirds the horizontal ground acceleration shall be applied to the structure and resulting stresses due to horizontal and vertical accelerations shall be considered to act simultaneously and shall be added directly. When combined with stresses from operating conditions, the resulting stresses shall comply with applicable codes without the usual fractional increase for short-term loading. The final design shall be reviewed for compliance with local requirements. If computerized methods of dynamic analysis are used, the mathematical model may be subjected to an excursion through the Taft earthquake of July 21, 1952 North 69 West component with an applied factor of 0.33. After this has been satisfied, the structure shall be examined under values of twice those given in Plate 3 or a dynamic excursion through the Taft earthquake of July 21, 1952 North 69 West component, with an applied factor of 0.66. As before, horizontal and vertical seismic components shall be considered with other appropriate loads, but in this case vertical ground accelerations shall be 0.08g. Under this loading condition there shall be no failure that could cause injury or prevent a safe shutdown during or after the earthquake.

2. Structures or equipment supported in or on other structures or equipment are placed into three categories based on their natural frequency and the predominant frequency of the supporting structure:

(1) Rigid category: $\frac{fm}{f} > 2.0$

(2) Resonance category: $0.7 \leq \frac{fm}{f} \leq 2.0$

(3) Flexible category: $\frac{fm}{f} < 0.7$

Where:

fm is the natural frequency of the mechanical structure or equipment, and f is a predominant frequency of supporting structure at the location of installation.

(1) For Rigid Category: Because of the high frequency, the design shall be based on an acceleration corresponding to the maximum acceleration experienced by the supporting structure at the location of equipment support.

(2) For Resonance Category: Elimination of resonance phenomena is one of the principles of the design. In order to eliminate resonance vibration some modification of the natural frequency of the supporting structure may be required. In case the resonance vibration cannot be avoided, prevention of large amplitudes by means of damping devices is requiredor dynamic design considering resonance vibration is required. In case the mass of the object is such as to produce an "Appendage" condition with large deflections and accelerations, a thorough dynamic study will be performed. Should the restriction of vibration be enough to make the object rigid, examination for rigid category is also required.

(3) For Flexible Category: Those items which are designated as flexible will be designed using induced accelerations corresponding with their frequencies. Careful examinations will be made concerning objects coming into contact because of excessive displacements.

3. For structures and equipment too complex for direct analytical procedures, vibration tests should be performed to establish the earthquake-resistant capabilities.

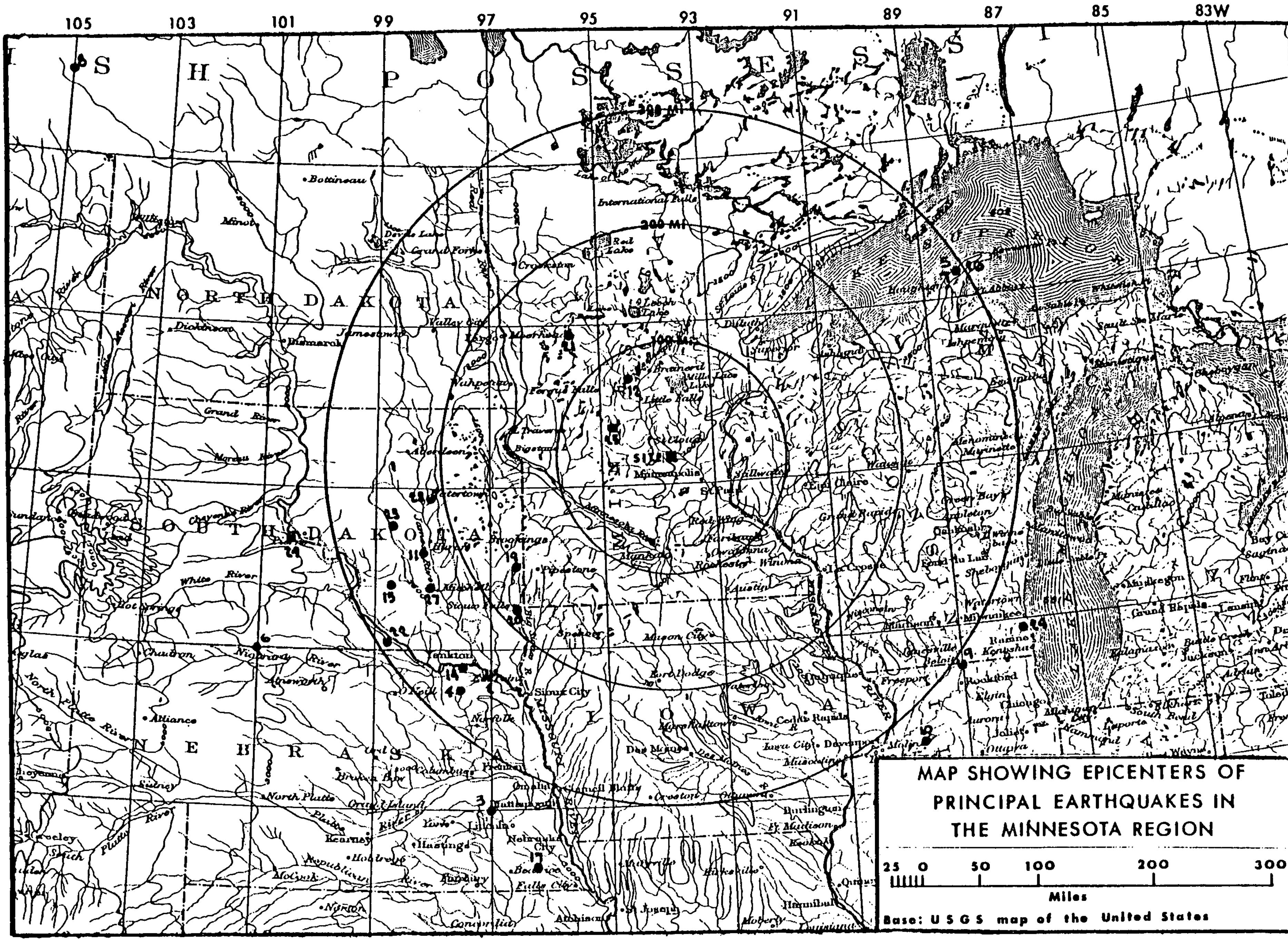
TABLE 1

RECOMMENDED DAMPING VALUES

Item	Percent Critical Damping
Reactor-building (massive construction with many cross walls and equipment and providing only secondary containment	5.0
Thin-shell and prestressed concrete structures	2.0
Steel structures	2.0
Vital piping systems	0.5
Ground rocking modes of vibration	10.0

Recommended Procedures For Type II Structures and Equipment

It is recommended that Type II structures and equipment be designed on basis of a minimum seismic horizontal coefficient of 0.10 with a one-third allowable increase in basic stress. Allowable increase in soil stresses if any, must be taken from recommendations of the Soils Engineer. All equipment should be so bolted or fastened that its displacement will not occur if friction is non existent.

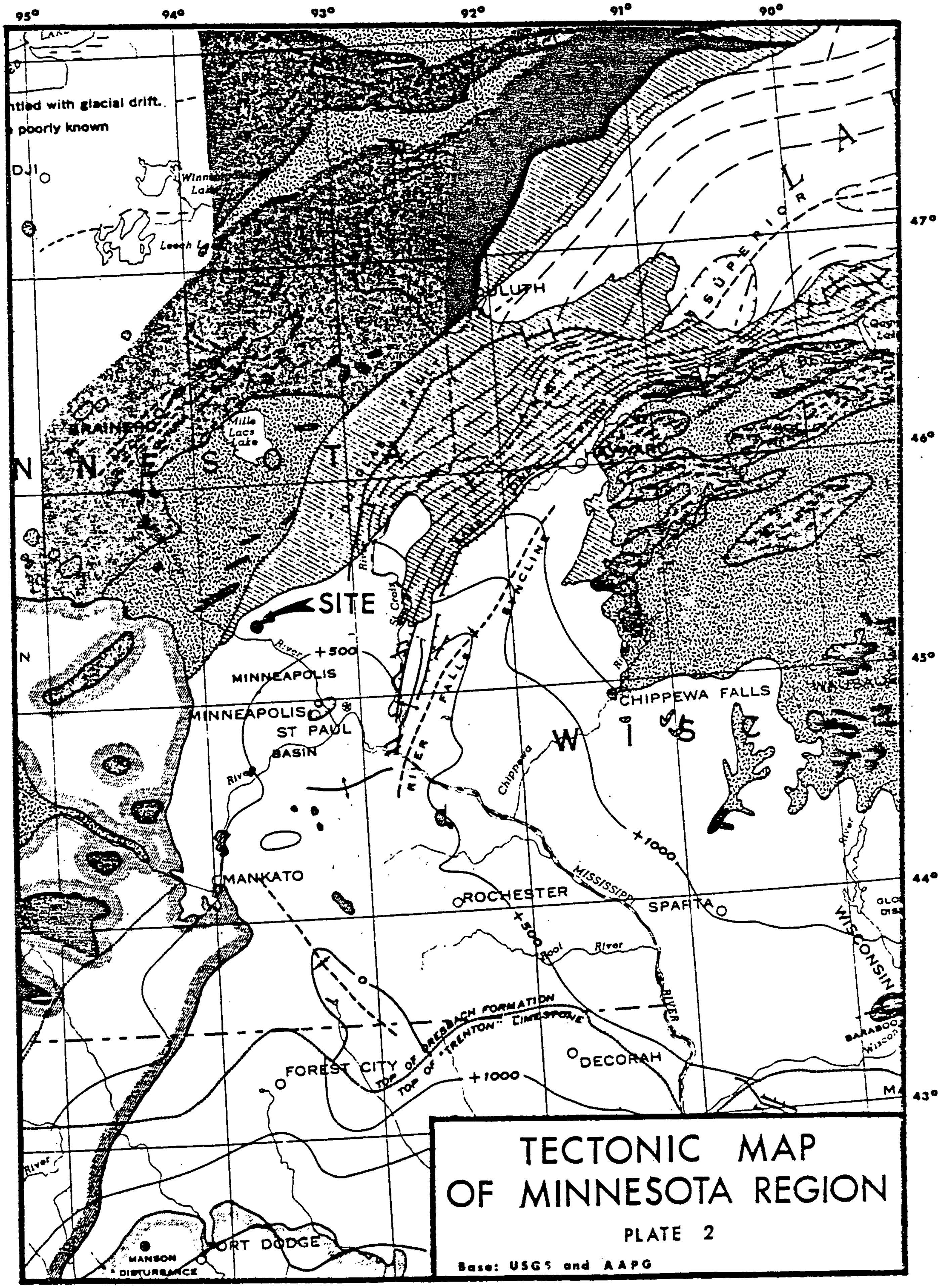


MAP SHOWING EPICENTERS OF PRINCIPAL EARTHQUAKES IN THE MINNESOTA REGION

Scale: 25 0 50 100 200 300 Miles

Base: U S G S map of the United States

PLATE 1



TECTONIC MAP OF MINNESOTA REGION

PLATE 2

Base: USGS and AAPG

JOHN A. BLUME & ASSOCIATES, ENGINEERS

RESPONSE ACCELERATION SPECTRA

FOR THE

MONTICELLO NUCLEAR GENERATION PLANT

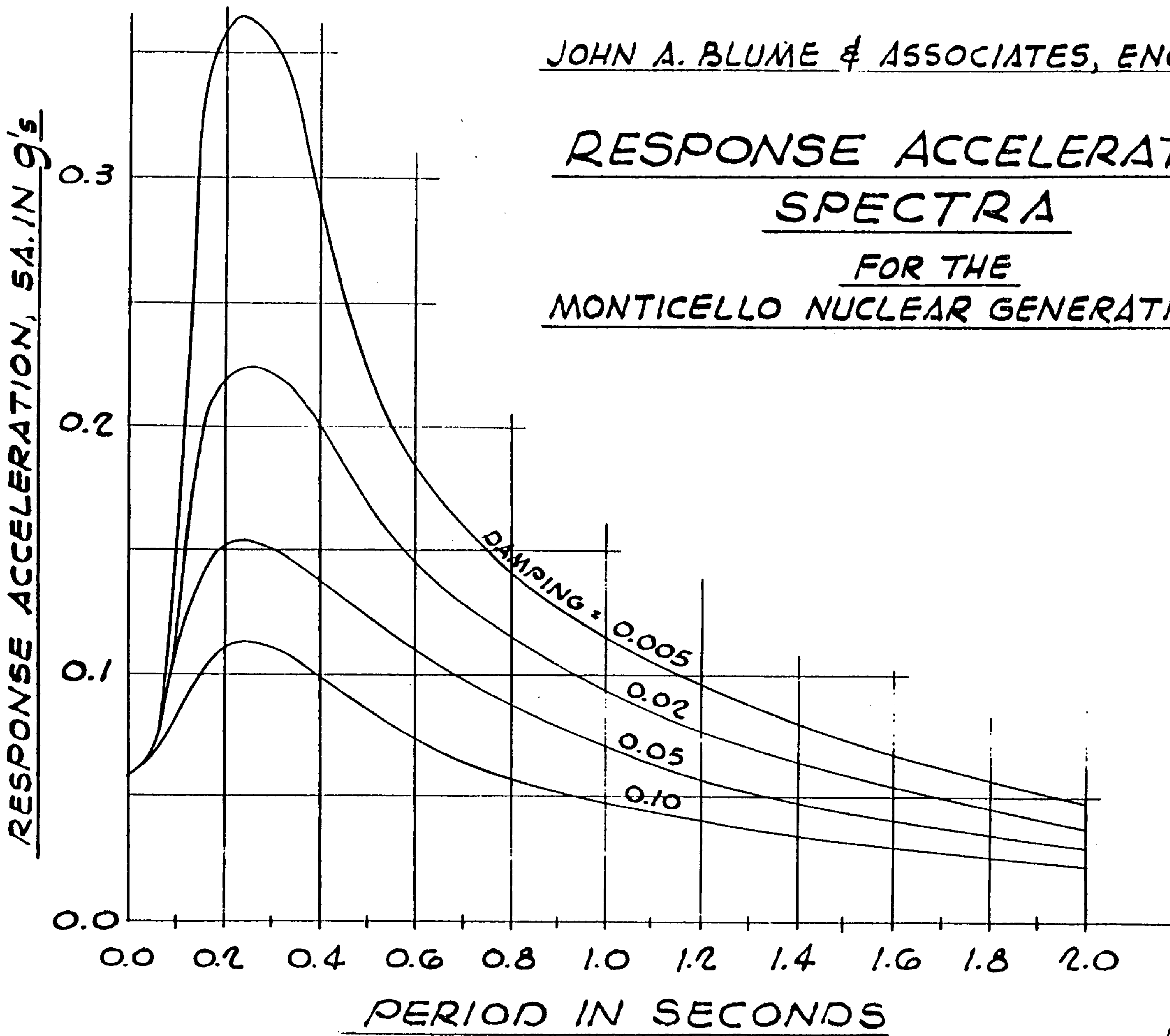


PLATE 3

REFERENCES

1. Dames and Moore, Preliminary Geological Report for the Proposed Nuclear Power Plant near Monticello, Minnesota, June 22, 1966.

2. Dames and Moore, Report - Dynamic Response Data Investigation Monticello, Proposed Nuclear Plant for the Northern States Power Company, July 7, 1966.

3. Monticello Soil Boring Data, Sheets 1, 2 & 3, Northern States Power Company, February 17, 1966.

4. Hough, Jack, L., Geology of the Great Lakes, University of Illinois, 1958.

5. Heck, N.H., Earthquake History of the United States, U.S.Coast and Geodetic Survey, 1956 revised.

6. Richter, C.F., Seismic Regionalization, Bulletin of the Seismological Society of America, Vol. 49, No. 2, April, 1959.

7. Building Design in Canada 1965 associate committee on the National Building Code, National Research, Council, Ottawa, Canada

8. Blume, John A., Earthquake Ground Motion and Engineering Procedures for Important Installation Near Active Faults, Third World Conference on Earthquake Engineering, 1965.

9. Wiggins, John H., Jr., Effect of Site Conditions on Earthquake Intensity, ASCE, Vol. 90 No. ST2, Part 1 (1964).

10. Hershberger, John, A Comparison of Earthquake Acceleration with Intensity Ratings, Bulletin of the Seismological Society of America, Vol. 46, 1956.

11. Seed, H.B., Soil Strength During Earthquakes, Second World Earthquake Conference, Tokyo, 1960.

APPENDIX

TABLE A

SEISMIC HISTORY OF THE REGION

No.	Date	Location: Place	Location: N.Lat	Location: W.Long	Intensity (M.M.)	Remarks
						* Indicates epicenter not plotted on map
*1	1860	Central Minn.	-	-	Unknown	
2	10/9/1872	Sioux City, Iowa	42.7	97.0	V	Felt over 3,000 square miles.
3	11/15/1877	East Neb.	41.0	97.0	VII	Felt over 140,000 square miles.
4	7/28/1902	East Neb.	42.5	97.5	V	Felt over 35,000 square miles.
5	7/26/1905	Calumet, Mich.	47.3	88.4	VII	Felt over 16,000 square miles.
6	5/9/1906	Washabaugh County, S. D.	43.0	101.0	VI	Felt over 8,000 square miles.
7	5/26/1906	Keewenaw Peninsula, Michigan	47.3	88.4	VIII	Felt over 1,000 square miles.
8	5/15/1909	Canada, felt to South	50.0	105.00	VIII	Felt over 500,000 square miles.
9	5/26/1909	Dixon, Ill.	42.5	89.0	VII	Felt over 40,000 square miles.
10	10/22/1909	Sterling, Ill.	41.6	89.8	IV-V	
11	6/2/1911	South Dak.	44.2	98.2	V	Felt over 40,000 square miles.
12	9/3/19/7	Minnesota	46.3	94.5	VI	Felt over 10,000 square miles.
*13	2/38/1925	Canada	48.2	70.8	VIII	Felt over 2,000,000 square miles.
14	10/6/1929	Yankton, S.D.	42.8	97.4	V (est.)	
15	1/17/1931	White Lake, S.D.	43.8	98.7	V (est.)	
*16	11/12/1934	Rock Island & Moline, Ill. Davenport, Iowa	41.4	90.5	V	
17	3/1/1935	Eastern Neb.	40.3	96.2	VI	Felt over 50,000 square miles.
*18	11/1/1935	Canada	46.8	79.1	IX & over	Felt over 1,000,000 square miles, felt in Minn.

No.	Date	Location			Intensity	Remarks
		Place	N.Lat	W.Long	(M.M.)	
19	11/1/1935	Egan, S.D.	44.0	96.6	V (est.)	
20	10/1/1938	Siox Falls, S.D.	43.5	96.6	V	Felt over 3,000 square miles.
21	1/28/1939	Detroit Lake, Minn.	46.9	95.5	V (est.)	
22	6/10/1939	Fairfax, S.D.	43.1	98.8	VI (est.)	
23	7/23/1946	Wessington, S.D.	44.5	98.7	VI (est.)	
24	5/6/1947	Milwaukee Area	42.9	87.9	VII	Felt Sheboygon to Kenosha.
25	2/15/1950	Alexandria, Minn.	45.7	94.8	V-VI(est.)	
26	1/6/1955	Hancock, Mich.	47.3	88.4	V	
27	12/3/1957	Mitchell, S.D.	43.8	98.0	V	
28	1/12/1959	Doland, S.D.	44.9	98.0	V	
29	12/31/1961	W.Pierre, S.D.	44.4	100.5	VI	

TABLE 2

MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed, walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

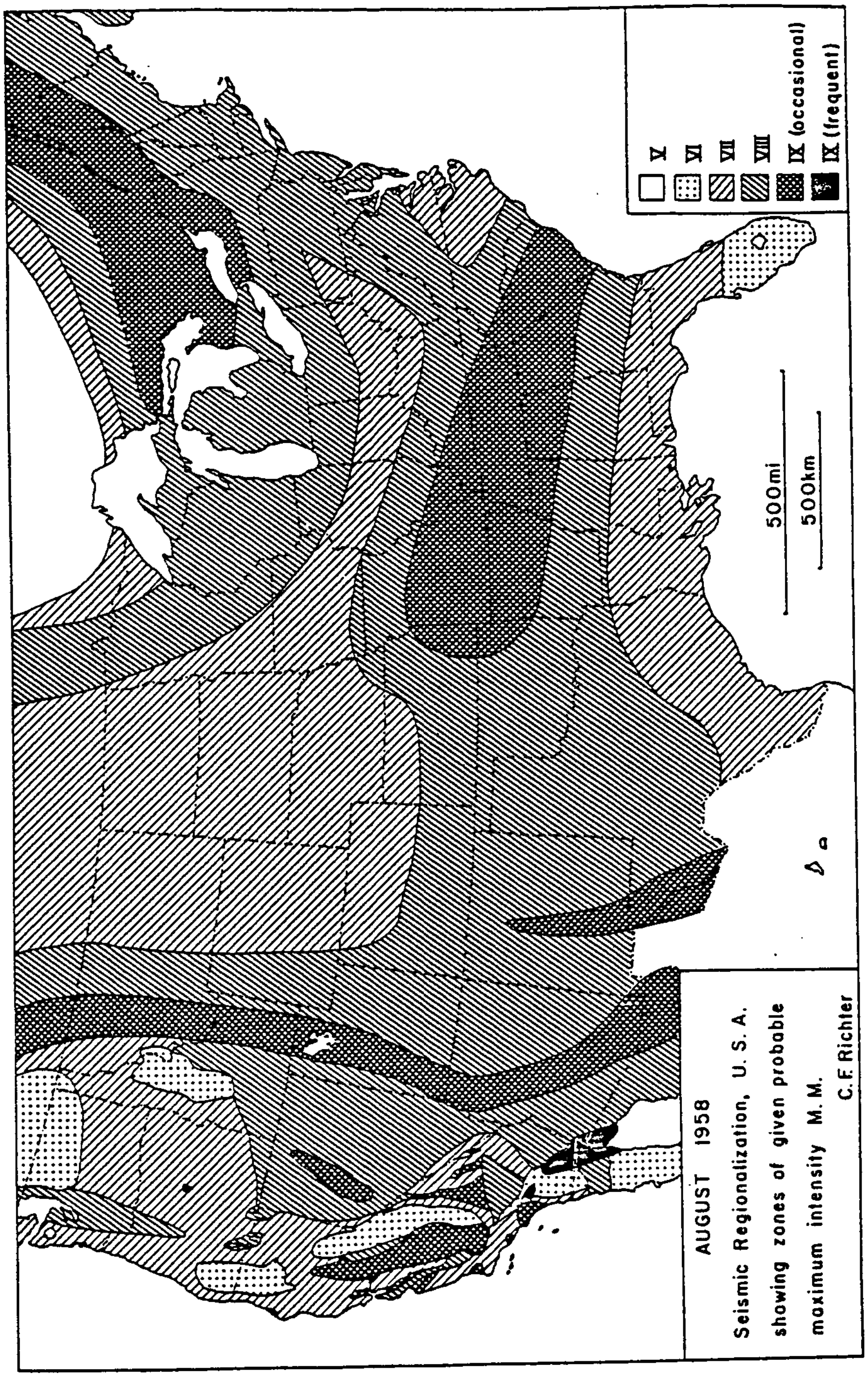
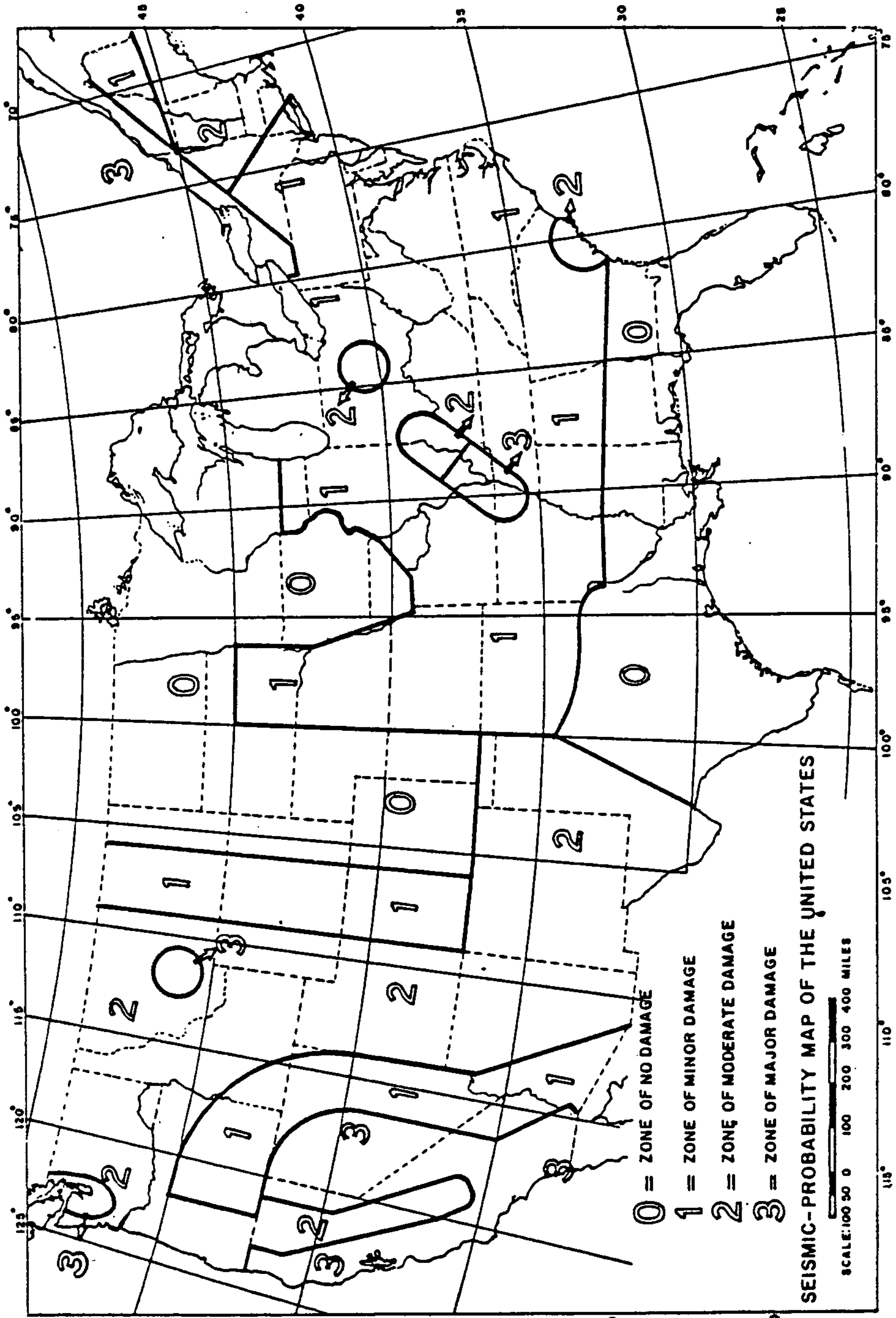

V
VI
VII
VIII
IX (occasional)
IX (frequent)
500mi
500km
AUGUST 1958
Seismic Regionalization, U. S. A.
showing zones of given probable
maximum intensity M. M.
C. F. Richter

PLATE A



From U.S. Coast and Geodetic Survey

PLATE B

GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPARTMENT

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS: REACTOR BUILDING

JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

JOHN A. BLUME & ASSOCIATES, ENGINEERS
612 HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94105 • (415) 397-2525

July 18, 1967

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

ATTENTION: Mr. R. B. Gile

SUBJECT: Monticello Nuclear Generation Plant
Earthquake Analysis of the
Reactor Building

Gentlemen:

Transmitted herein is the subject report based on the information furnished us by General Electric Company, and as listed in the references.

The analysis consists of an investigation of the coupled flexural dynamic response and the rocking dynamic response of the subject building including appendage, the results of which are presented in the report. This analysis is based upon the preliminary building drawings listed in the reference which were furnished to facilitate the preparation of the subject earthquake report. The results presented herein should be used in producing the final building design drawings, and these final drawings should then be reviewed to determine if any changes in the building's structural properties warrant a further earthquake analysis.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

E. J. Keith

E. J. Keith
Assistant Vice President

EJK/nb
Enclosure

GENERAL ELECTRIC COMPANY
Atomic Power Equipment Department

MONTICELLO NUCLEAR GENERATION PLANT

Report on the Earthquake Analysis of the Reactor Building

JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

MONTICELLO NUCLEAR GENERATION PLANT

REACTOR BUILDING

SEISMIC ANALYSIS

Page

TABLE OF CONTENTS

MONTICELLO NUCLEAR GENERATION PLANT

REACTOR BUILDING

SEISMIC ANALYSIS

INTRODUCTION

The purpose of this report is to summarize the results of the seismic investigation of the Monticello Nuclear Generation Plant Reactor Building. Based upon the recommended earthquake design criteria established for the Plant, design envelopes of maximum acceleration, displacement, shear, and overturning moment versus height of the building have been developed for both directions and are herein presented.

DESIGN CRITERIA

Based upon data developed by John A. Blume & Associates, Engineers (Reference 6), the design earthquake established for this analysis is the North 69° West Component of the 1952 Taft earthquake, normalized to a maximum ground acceleration of 0.06 gravity.

BUILDING DESCRIPTION

The reactor building is a reinforced concrete structure from its foundation at elevation 890'-3" to elevation 1027'-8". (See Sheets 10 through 15 & 18). At this level a steel framed top story has been placed.

The arrangement of the framing of this top story is indicated on Sheet SK-C41D of the Bechtel drawings. (See Reference 1 and also Sheets 16 through 18). The lateral bracing elements at the top story are as shown on Sheet 17.

The reactor building is founded on medium sand with some gravel at an elevation of 890'-3". The foundation of this building is of reinforced concrete having plan dimensions of 143'-6" by 140'-6". At elevation 935'-0", the building has plan dimensions of 137'-6" by 137'-6" with an appendage of 57'-0" by 28'-6". This configuration of concrete building is maintained to elevation 1001'-2" where the dimensions of the structure diminish to 137'-6" by 105'-3".

METHOD OF ANALYSIS

For the dynamic response analysis, the equivalent mass system shown on Sheet 1 was selected to approximate the reactor building. Masses were lumped at each floor level except that the top story steel frame was approximated by an equivalent two-mass system.

Each story level mass represents the mass of the concrete and equipment at each floor and the tributary mass of the concrete walls and equipment between adjacent floors. The top story masses are similarly developed but include the tributary mass of the walls, frame, bridge crane, and the mechanical equipment of the top story.

The average area and moment of inertia of the concrete walls between floors was used to determine the stiffness characteristics between masses. The steel framed top story, however, was investigated separately. For this story an equivalent frame stiffness was developed for each direction. A value of 3,000,000 psi was assigned as the Elastic Modulus of the concrete.

The natural frequencies and mode shapes and the dynamic response of the equivalent lumped mass system were determined with the aid of an IBM 7094 digital computer. Three modes were considered with the damping value assigned as 5 percent for all modes.

The ground motion utilized in determining the dynamic response of the reactor building has a maximum base acceleration of 0.06 gravity and corresponds to the response spectrum set forth in Reference 6.

ELASTIC SPRINGS
REPRESENTING SOIL CONDITION

References 2 and 12 present the data associated with the granular material which supports the reactor building. These values are as follows:

E_{dyn} = 78,500 pounds per square inch.

G = 29,500 pounds per square inch.

μ = 0.33 (dimensionless).

ρ = 135 pounds per cubic foot.

Using these given field determined values the rotational and lateral foundation spring supports were determined using the following equations (References 3 and 4):

$$K_s = \frac{E_{dyn}}{m\sqrt{A}\,(1-\mu^2)} = 90.58 \qquad \text{kips per cubic foot} \text{ -------- } (1)$$

$$K_{rot} = K_s\, I_B \qquad \text{-------- } (2)$$

For earthquake in N-S direction:

K_{rot} = 3,299,934,382 kip - feet per radian.

For earthquake in E-W direction:

K_{rot} = 4,234,677,410 kip - feet per radian.

$$K_G = \frac{mm'G\sqrt{A}}{1-\mu} = 1,581,549 \qquad \text{kips per foot} \text{ -------------- } (3)$$

where: A = Area of foundation base = 21,786.25 square feet

m = 0.95

mm'= 0.845 (Table I - 11 of Ref. 4)

ANALYTICAL PROCEDURE

Periods and Mode Shapes

The natural periods of vibration and mode shapes of the mathematical model are given by Equation (4).

$$\left[\underline{K} - W_n^2 \underline{M}\right] \underline{\Phi}_n = \underline{0} \qquad \text{------------------ (4)}$$

where:

$\underline{K}$ = Stiffness matrix (see Remarks on the Computer Program)

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.

Generalized Displacement Response

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

$$\underline{\ddot{Y}_n(t)} + 2W_n\lambda_n \underline{\dot{Y}_n(t)} + W^2 \underline{Y_n(t)} = \underline{M_n}^{-1} \underline{R_n(t)} \ddot{U}_g(t) \quad \text{----- (5)}$$

where:

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

$$= \frac{R_r}{\underline{M_n} W_n} \int_0^t \ddot{U}_g(\tau)\, e^{-\lambda_n W_n (t-\tau)} \operatorname{Sin}\left[W_n (t-\tau)\right] d\tau \quad \text{---- (6)}$$

$\underline{M_n}$ = 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 percent for all modes

$d\tau$ = Integration interval used in the step by step solution of the Duhamel Integral - 0.010 second. (Experience has shown that excellent accuracy is obtained if the integration interval is less than one tenth of the first mode period of vibration of the building).

From the Generalized Coordinate matrix the time history of displacements is found according to Equation (7).

$$\underline{v(t)} = \underline{\Phi}\ \underline{Y(t)} \qquad \text{-------------------- (7)}$$

where:

$$\underline{\Phi} = \begin{bmatrix} \Phi_1 & \Phi_2 & \text{--------} & \Phi_m \end{bmatrix}$$

m = Number of modes considered.

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

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

Inertia Forces

The time history of the inertia forces is then determined according to Equation (8).

$$\underline{Q(t)} = \underline{K} \; \underline{v(t)} \qquad \text{------------------ (8)}$$

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, the time histories of shears, moments, and accelerations are determined. These records are then enveloped to determine the maximum values which are then graphically presented in the report and used by the designer.

Remarks on the Computer Program

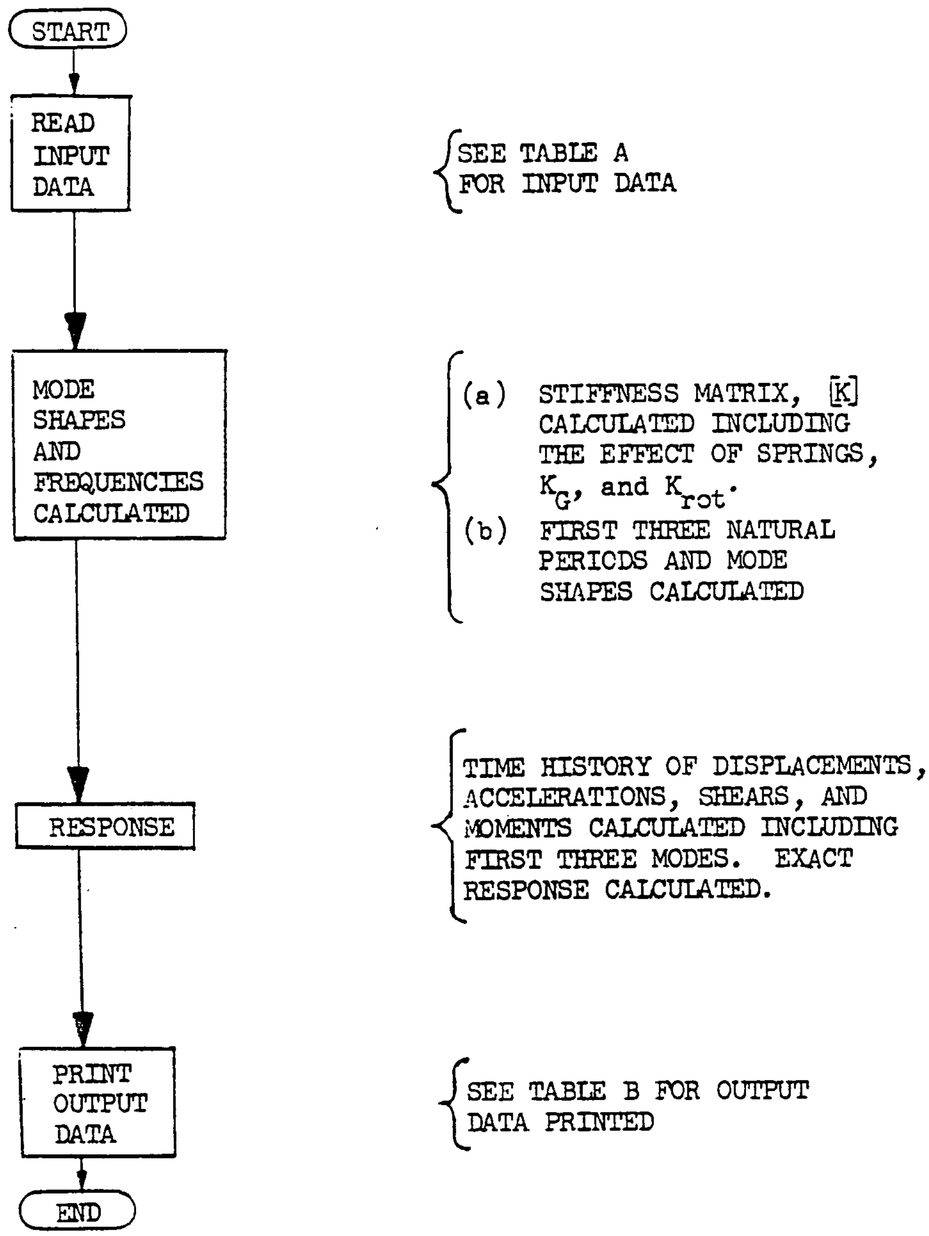
1) The computer program used in this analysis was specially designed to solve the dynamic response of structures subjected to arbitrary ground motions. Since the program was written to cover as many structural configurations as possible, the structural member input data for the program, except for the foundation springs, is in the form of member moments of inertias, areas, and effective shear areas. The effects of axial deformations and shear deformations are included in the calculation of the stiffness matrix.

2) 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 responses of each mass point for each mode at a particular instant of time. This results in an exact combination of mode participation without the necessity of using approximate methods such as the root-mean-square method.

3) Individual elements in the stiffness matrix are designated K_{ij} and are stored in the computer such that the i value designates the row number and the j value the column number. K_{ij} is determined by applying a unit displacement at the $\underline{j^{th}}$ point while restraining the other points against

displacement, and finding the corresponding reaction at the $\underline{i}^{th}$ point. In this manner the foundation spring constants are included in the stiffness matrix. This procedure couples the foundation springs and elastic springs of the structural system.

4) The general computer techniques used in this analysis are taken from References 7, 8, 9, 10 and 11. A simplified block diagram of the computer program, and the input and output data are shown on Plate A, and Tables A and B respectively.



<u>SIMPLIFIED BLOCK DIAGRAM</u>

<u>OF DYNAMIC COMPUTER PROGRAM</u>

PLATE A

TABLE A

INPUT DATA

1. Geometry of Model
   a) Vertical distances between mass points
   b) Mass point identification

      ie: Mass 1

      Mass 2

      Etc.
2. Cross Section Properties and Foundation Stiffnesses
   a) Moments of inertia of columns
   b) Areas of columns
   c) Shear areas of columns
   d) Foundation spring constants K_G, K_s
3. Weights and Masses
   a) Weight of each mass point
   b) Mass of each mass point
4. Input Earthquake Data
   a) Input earthquake - time in seconds and acceleration in gravity units.
   b) Time length of earthquake record used - 9.6 seconds of earthquake.
   c) Integration interval to be used in step by step solution of Duhamel Integral (0.010 second).

TABLE B

OUTPUT DATA

1. Maximum displacement of each mass point.
2. Maximum absolute accelerations of each mass point.
3. Maximum shears at each mass point.
4. Maximum overturning moments at each mass point.
5. Natural circular frequency of vibration of each mode calculated.

DISCUSSION OF RESULTS

Absolute Accelerations

The curves shown on Sheets 2 and 6 give an envelope of the maximum absolute accelerations with respect to height. These curves can be used for the seismic design of equipment elements rigidly attached to the reactor building, but since the curves given are for absolute accelerations the moment, shear and displacement curves presented should be used in the design of the building. Critical pieces of equipment which cannot be definitely assumed as rigid (period greater than 0.05 second) shall not be designed on the basis of the curves presented, but should be dynamically investigated, individually, to determine the effect of the interaction of the equipment and building.

Shears, Moments and Displacements

The maximum envelopes of building design shears, moments and displacements are presented graphically on Sheets 3, 4, 5, 7, 8 and 9. These curves should be used in the seismic design of the reactor building.

Periods of Vibration

Direction of Earthquake	First Mode (Seconds)	Second Mode (Seconds)	Third Mode (Seconds)
North-South	0.596	0.211	0.183
East-West	0.549	0.221	0.186

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 plant to safely shut down. In addition to the horizontal accelerations, a vertical building (and equipment) acceleration of 0.04 gravity, acting simultaneously with the horizontal accelerations is recommended for design.

MONTICELLO NUCLEAR GENERATION PLANT

REACTOR BUILDING

SEISMIC ANALYSIS

REFERENCES

1. Preliminary Design Drawings

   General Electric Drawings:

   5828-SK-C-15D, dated June 7, 1967
   5828-SK-C-41D, dated June 6, 1967
   NF-36166, dated April 3, 1967

2. Report of Foundation Investigation - Proposed Nuclear Power Plant - Unit Number 1, Monticello, Minnesota, by Dames and Moore, dated July 27, 1966 (including Supplements 1 through 5).

3. Theory of Elasticity, by Timoshenko and Goodier, Second Edition, McGraw Hill Company, 1951.

4. Dynamics of Bases and Foundations, by D. D. Barkan, McGraw Hill Company, 1962.

5. Nuclear Geoplosics, Stanford Research Institute, Defense Atomic Support Agency, Part Two, Mechanical Properties of Earth Materials, May 1962.

6. Recommended Earthquake Criteria, by John A. Blume and Associates, July 15, 1966.

7. Earthquake Analysis by Response Spectrum Superposition, by R.W. Clough, Bulletin of the Seismological Society of America Vol. 52, No. 3, July 1962.

8. 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.

9. 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.

REFERENCES (Con't.)

10. Dynamic Effects of Earthquakes, by R. W. Clough, Transactions of the American Society of Civil Engineers, Paper No. 3252.

11. Large Capacity Multistory Frame Analysis Programs, by R. W. Clough, Edward L. Wilson, and Ian P. King, Journal of the American Society of Civil Engineers, ST 4, August 1963.

12. Report - Dynamic Response Data Investigation - Proposed Nuclear Power Plant, Monticello, Minnesota, by Dames and Moore, dated July 7, 1966.

MONTICELLO NUCLEAR GENERATION PLANT

REACTOR BUILDING

SEISMIC ANALYSIS

LIST OF FIGURES

LIST OF PROPERTIES

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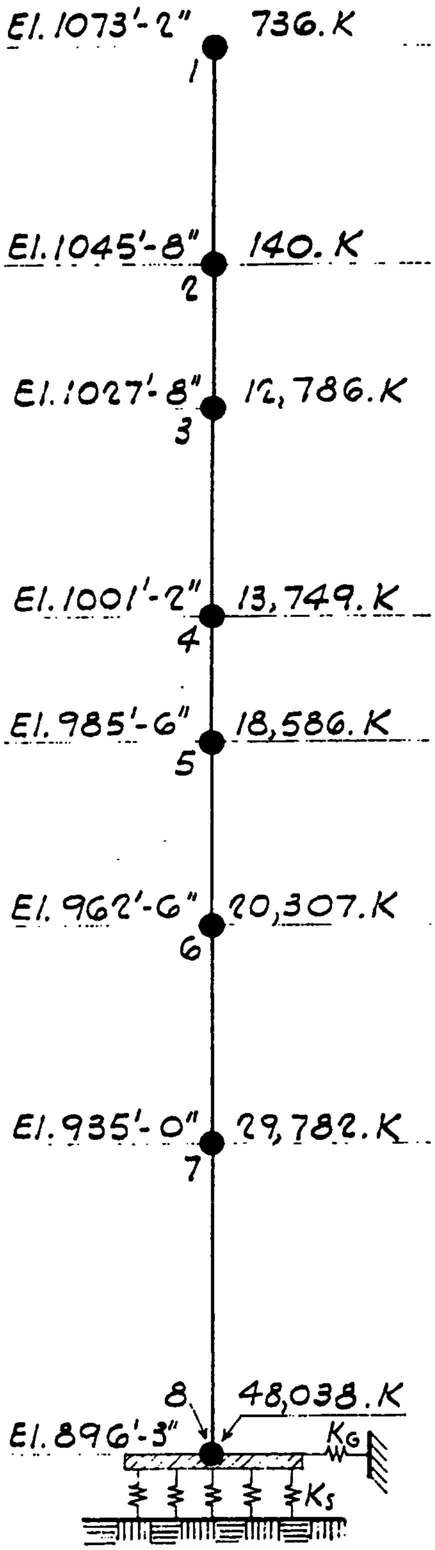
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS



Segment	I_c (ft^4) N-S AXIS	I_c (ft^4) E-W AXIS	A_c (ft^2)
1–3	BRACED AREA		
3–4	3,662,210.	1,805,790.	2,256.
4–5	5,202,269.	5,140,204.	3,365.
5–6	4,481,508.	4,460,485.	2,835.
6–7	4,052,402.	5,006,316.	2,784.
7–8	11,808,952.	9,693,452.	5,941.
Base	I_{BASE} = 46,750,688.8	I_{BASE} = 36,431,158.9	A_{BASE} = 21,786.25

MATHEMATICAL MODEL

SHEET NO. 1

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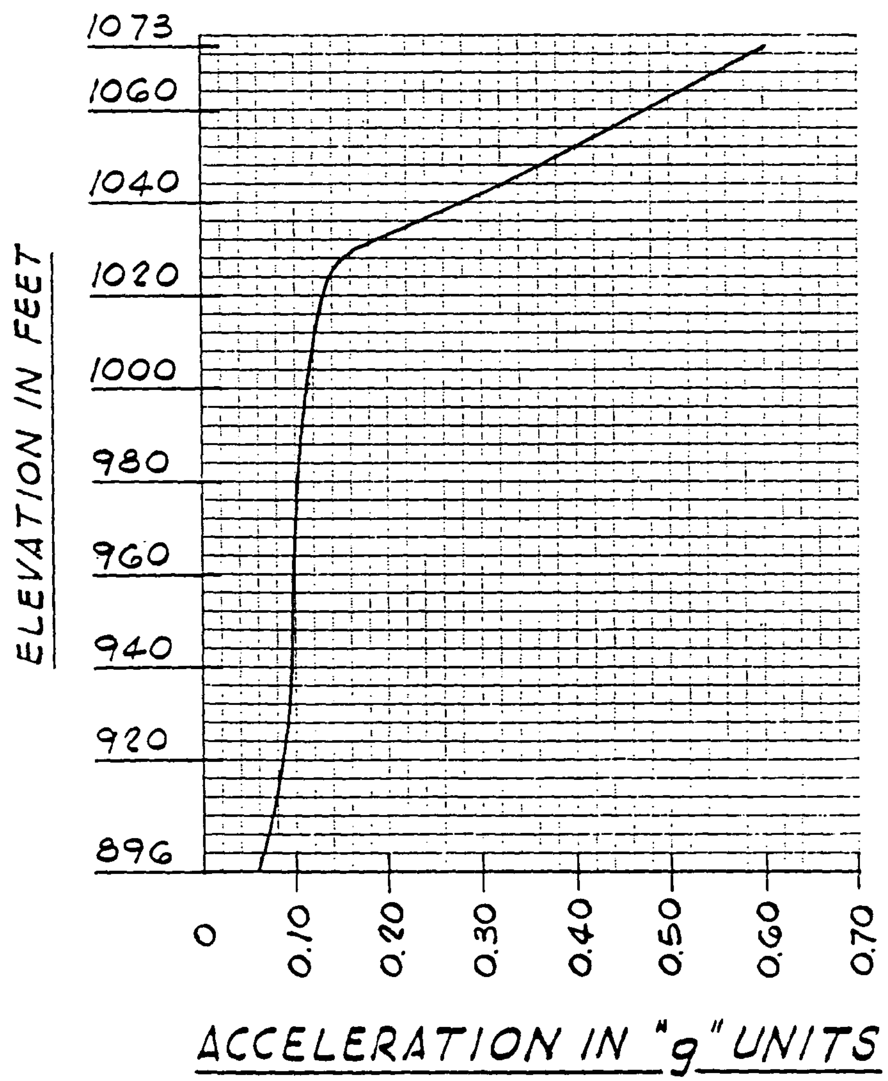
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
ACCELERATION DIAGRAM
UNDER SEISMIC LOADS
N-S DIRECTION



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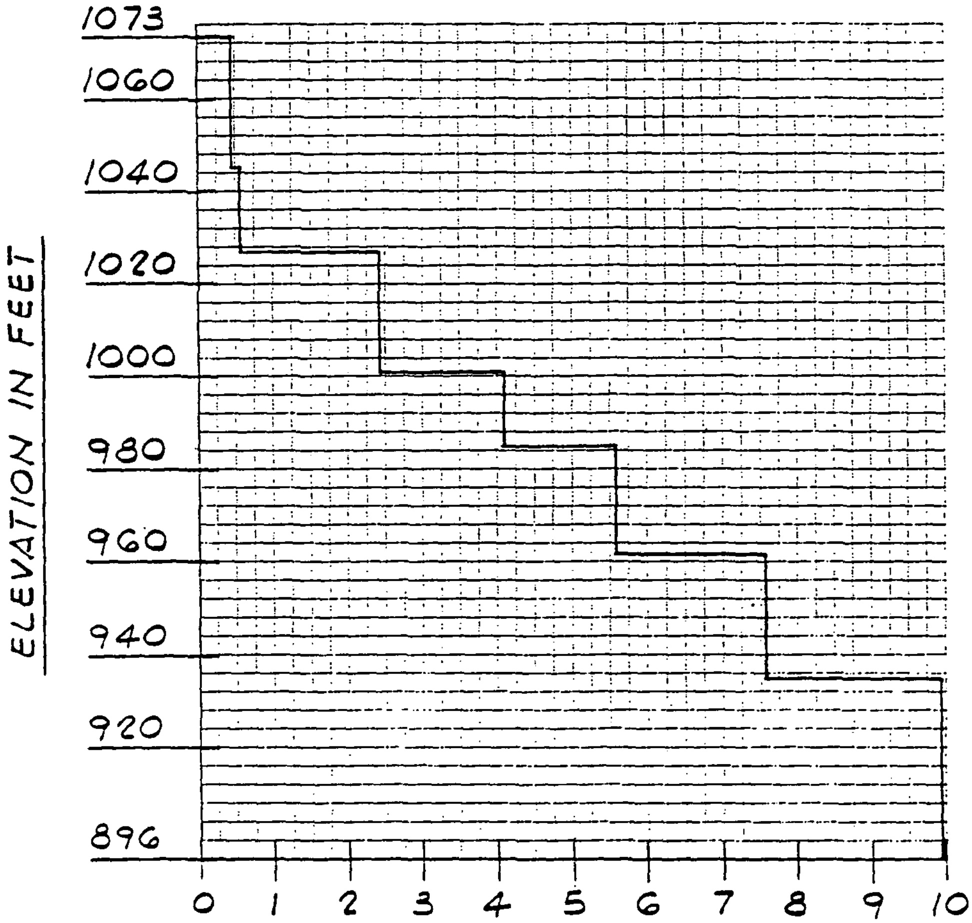
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
SHEAR DIAGRAM
UNDER SEISMIC LOADS
N-S DIRECTION



SHEAR IN KIPS × 10^3

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MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
MOMENT DIAGRAM
UNDER SEISMIC LOADS
N-S DIRECTION

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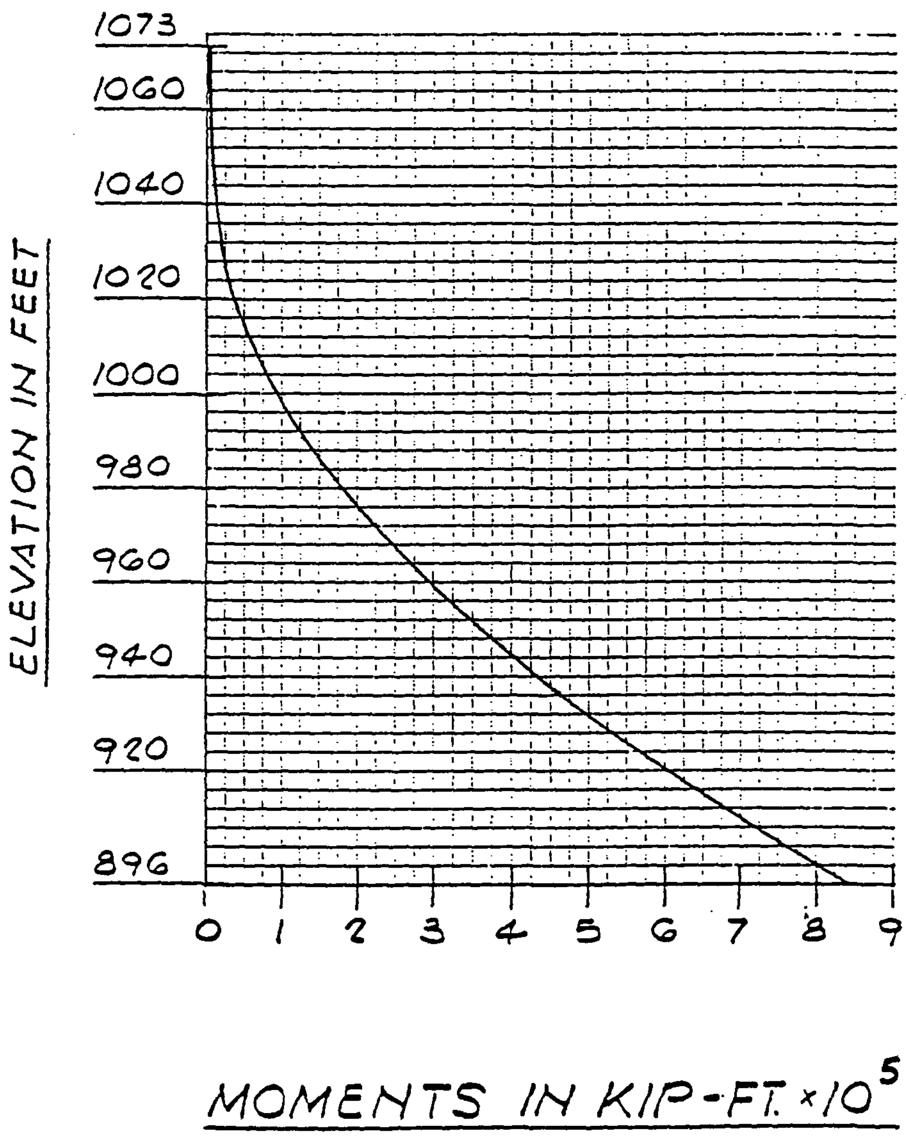

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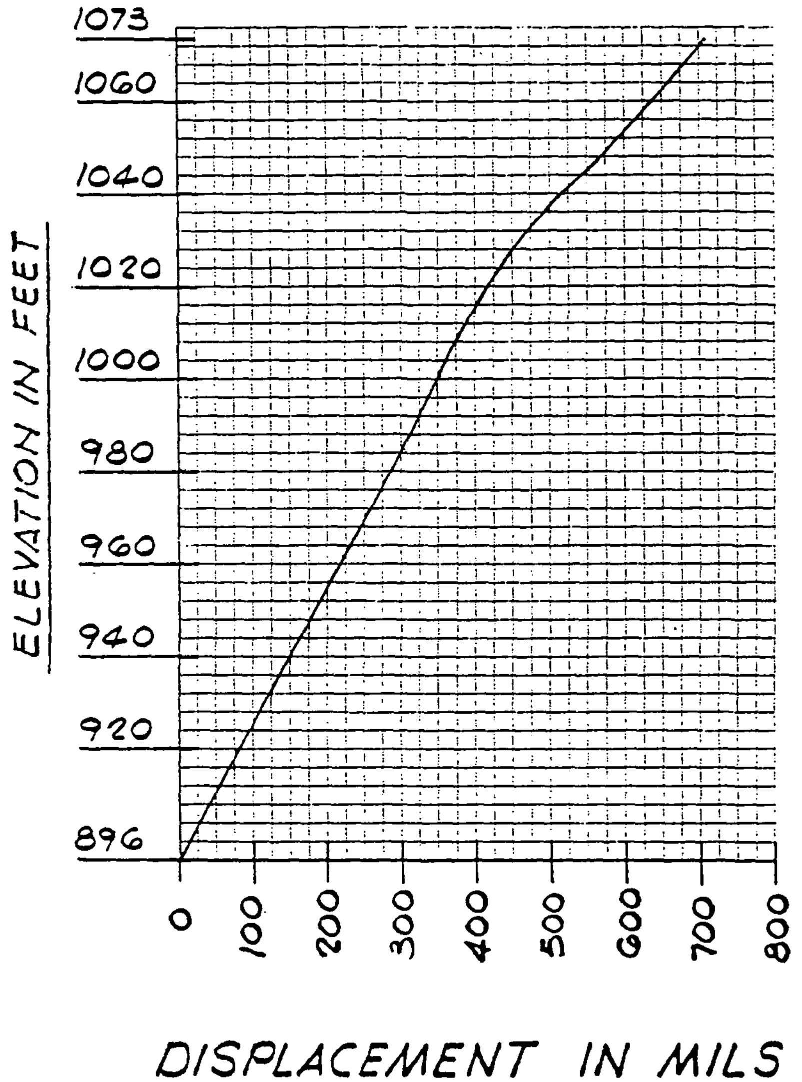
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
DISPLACEMENT DIAGRAM UNDER SEISMIC LOADS N-S DIRECTION



DISPLACEMENT IN MILS

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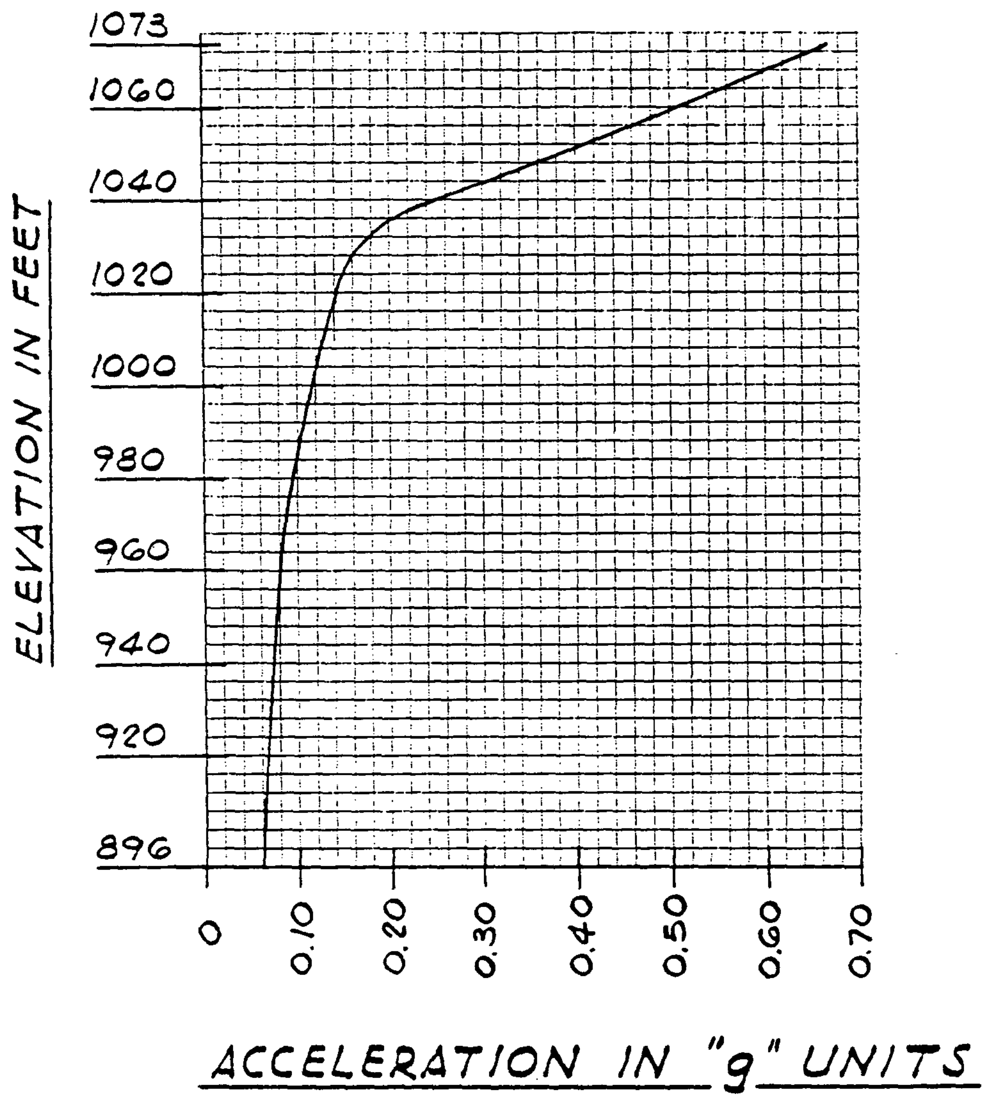
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
ACCELERATION DIAGRAM
UNDER SEISMIC LOADS
E-W DIRECTION



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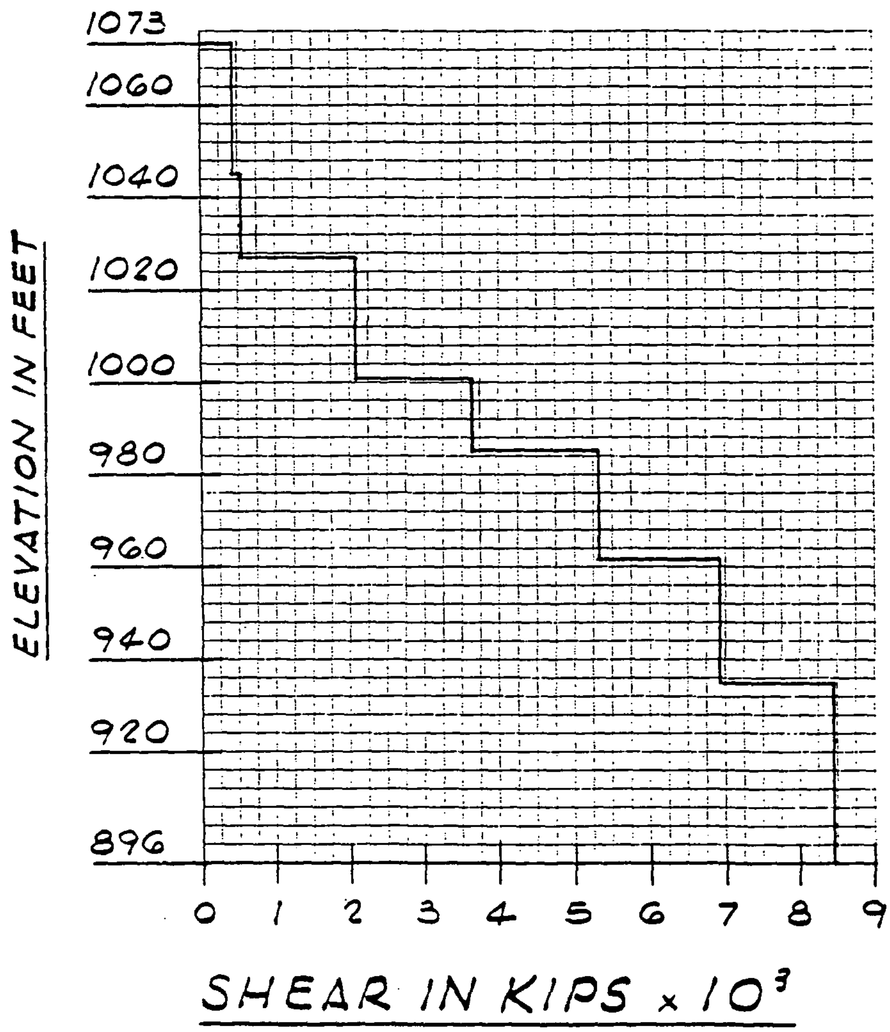
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
SHEAR DIAGRAM
UNDER SEISMIC LOADS
E-W DIRECTION



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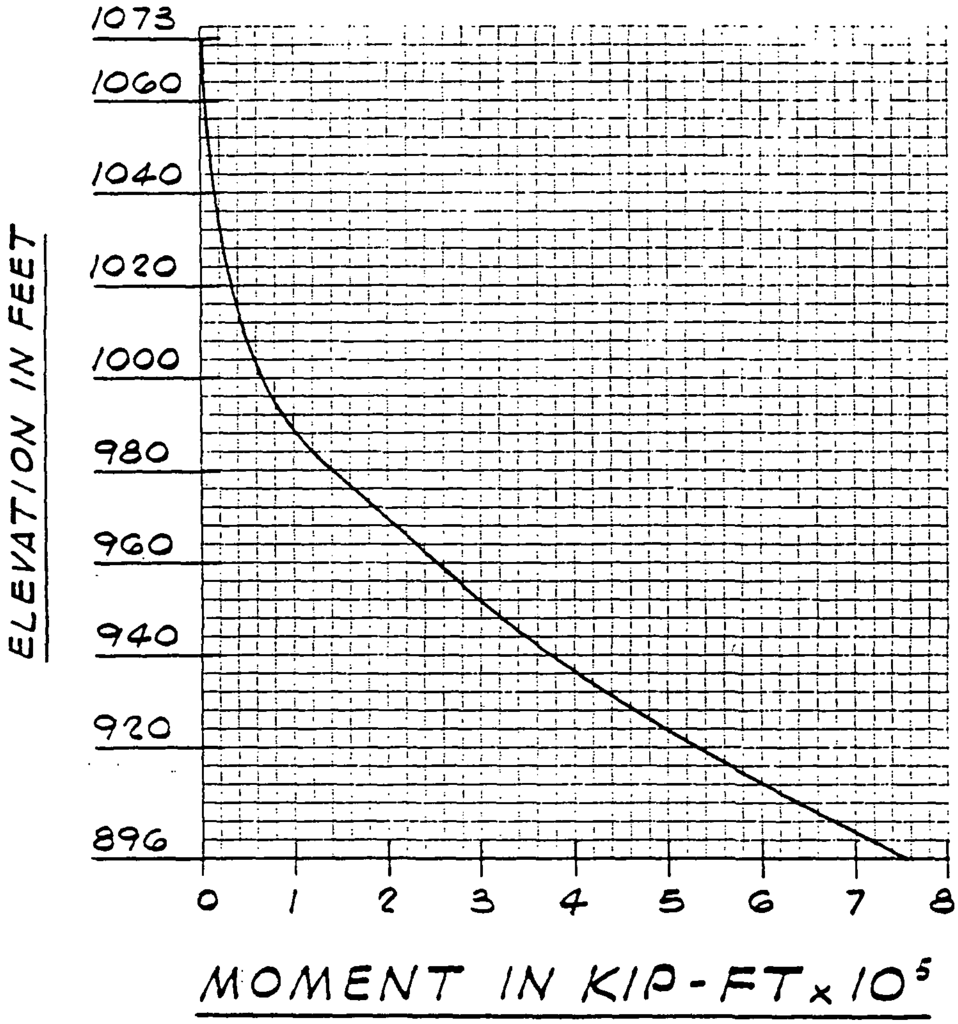
MONTICELLO REACTOR BUILDING SEISMIC ANALYSIS MOMENT DIAGRAM UNDER SEISMIC LOADS E-W DIRECTION



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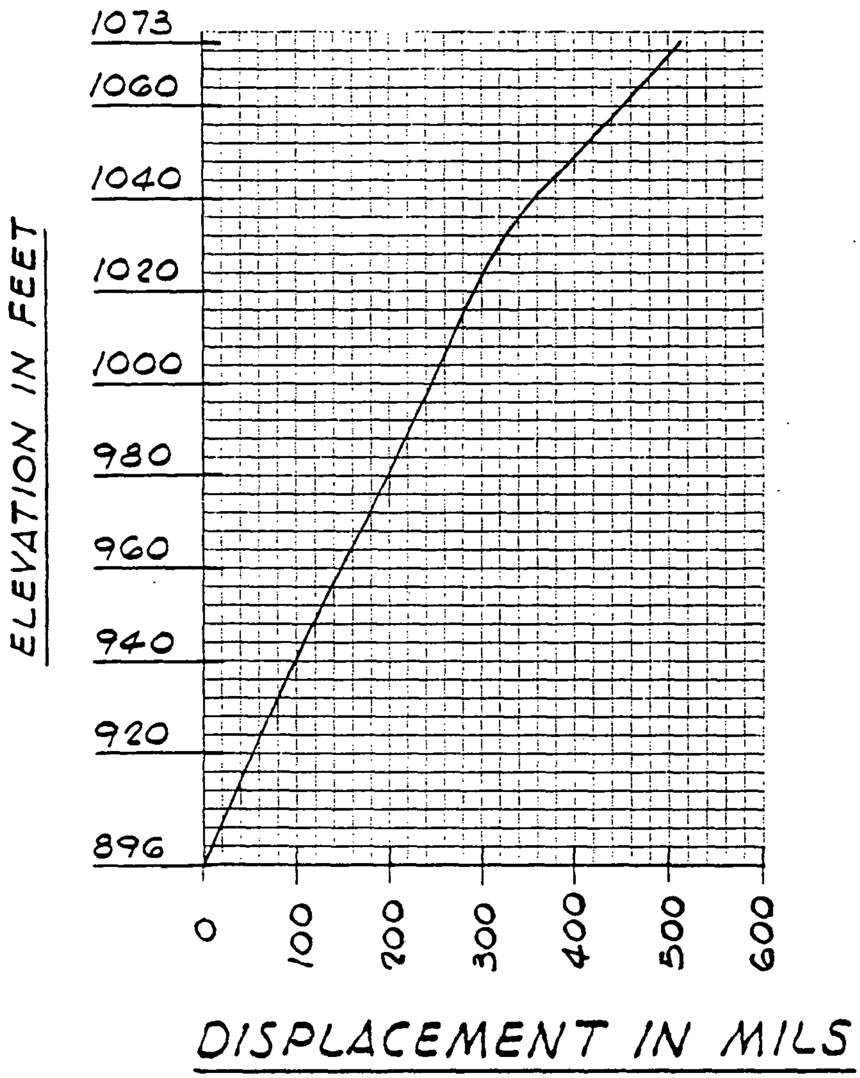
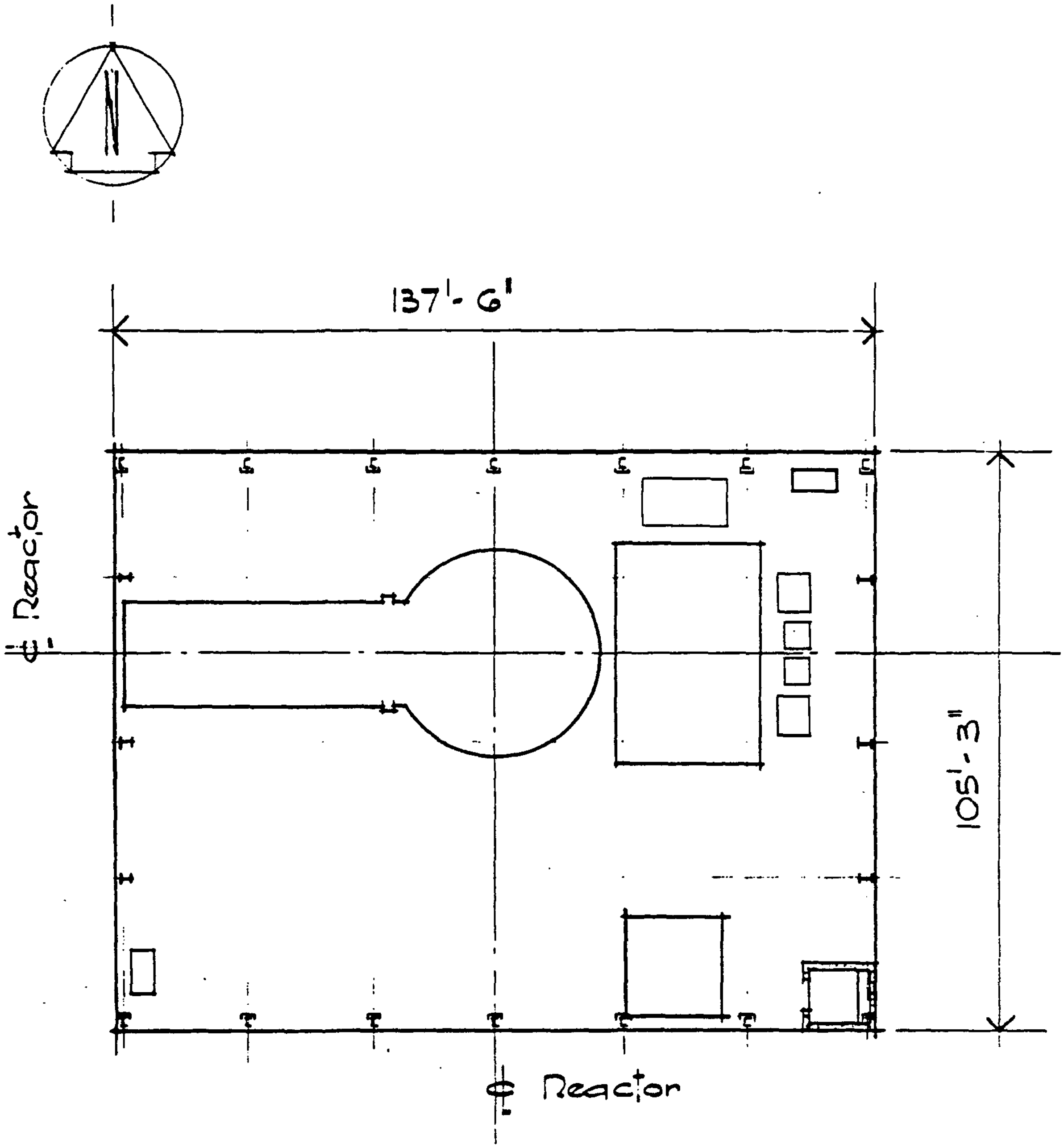
MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS
DISPLACEMENT DIAGRAM
UNDER SEISMIC LOADS
E-W DIRECTION





PLAN AT ELEV. 1027'-8"

SHEET 15

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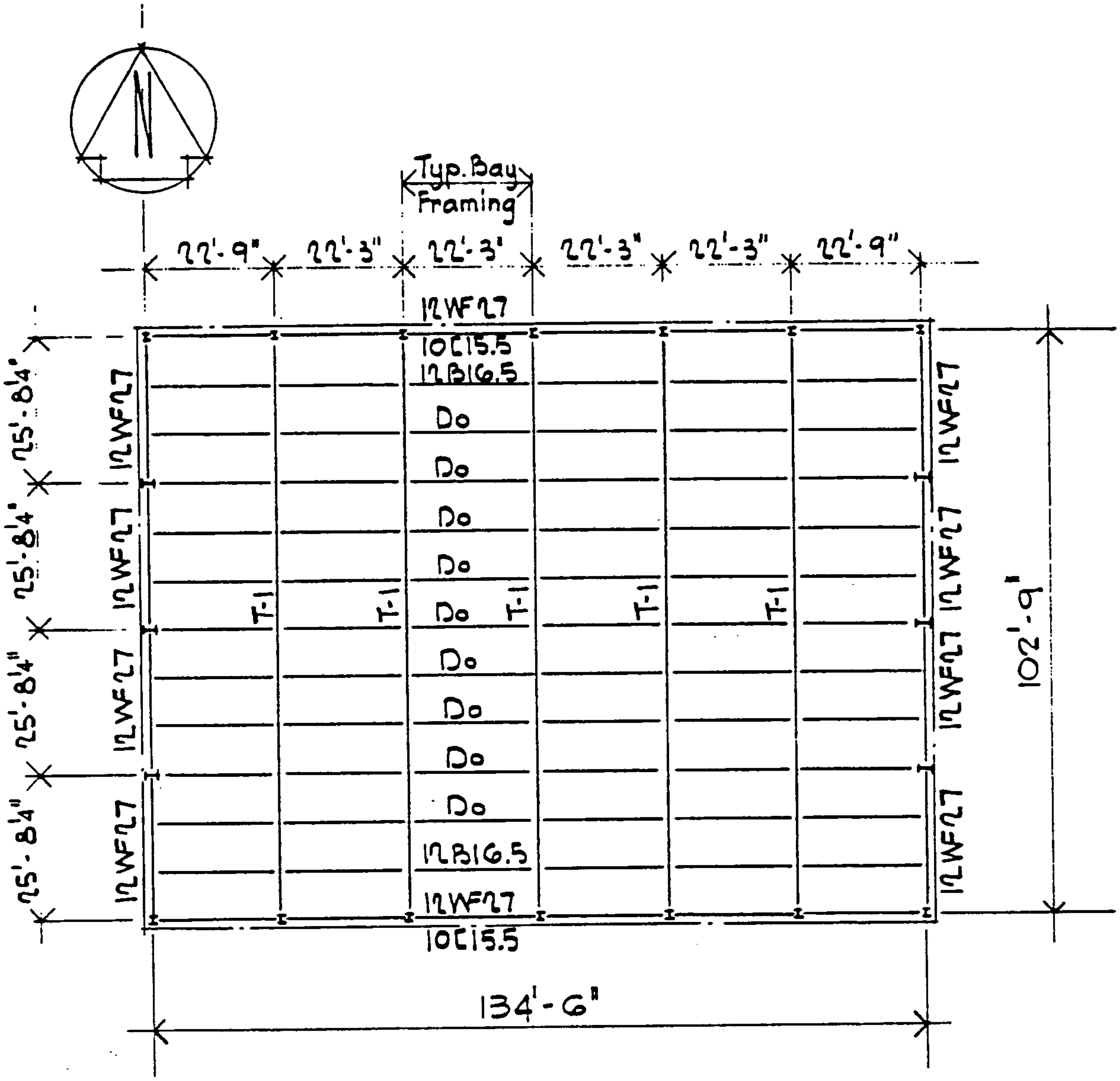
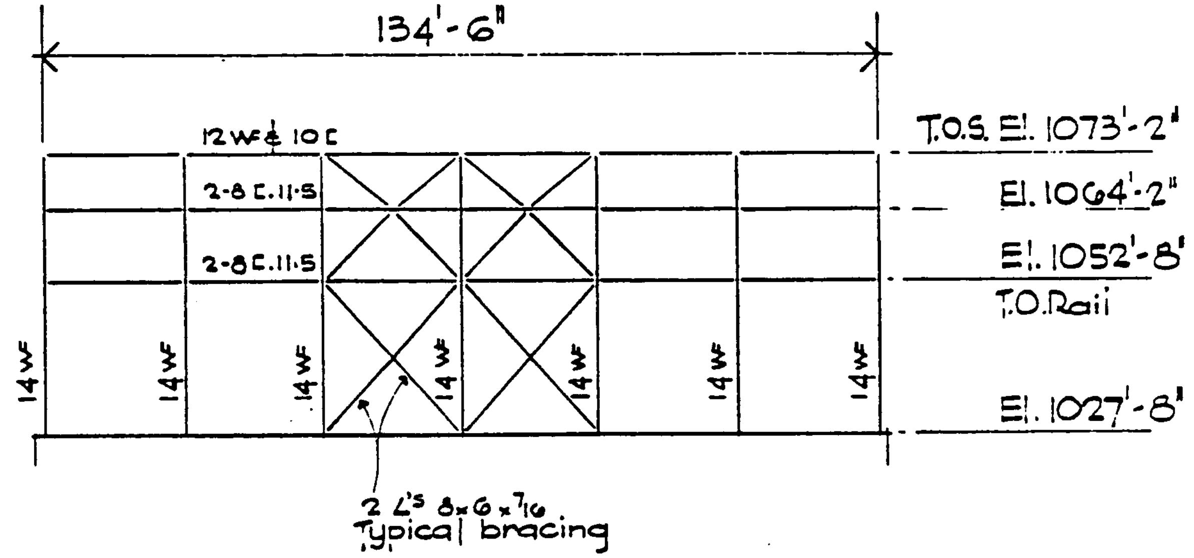
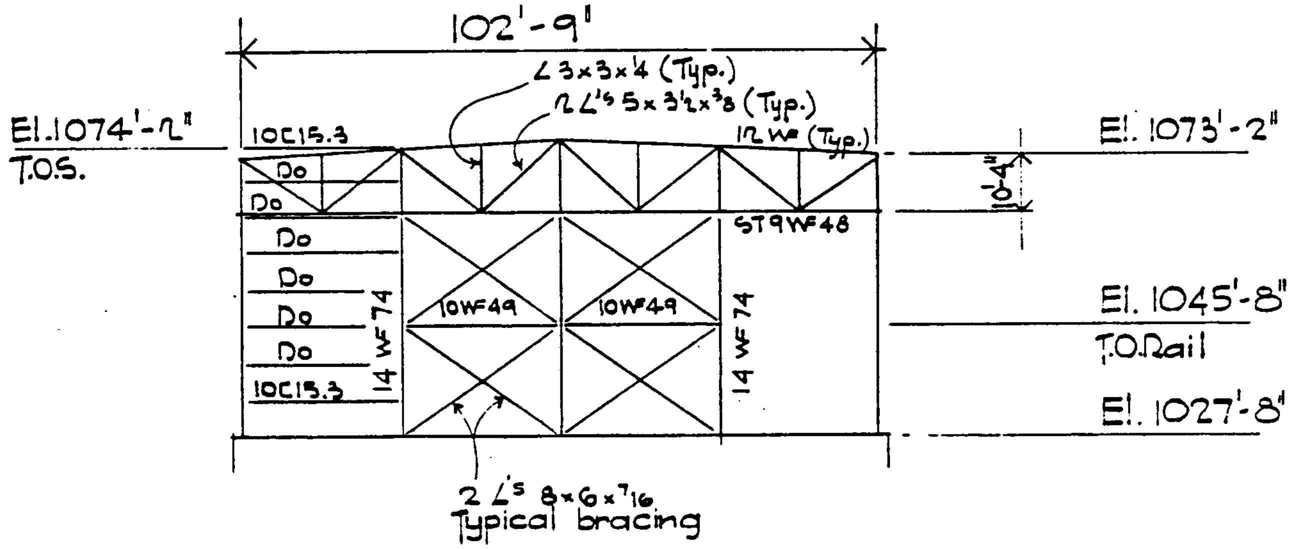


ROOF AT ELEV. 1073'-2"

SHEET 16

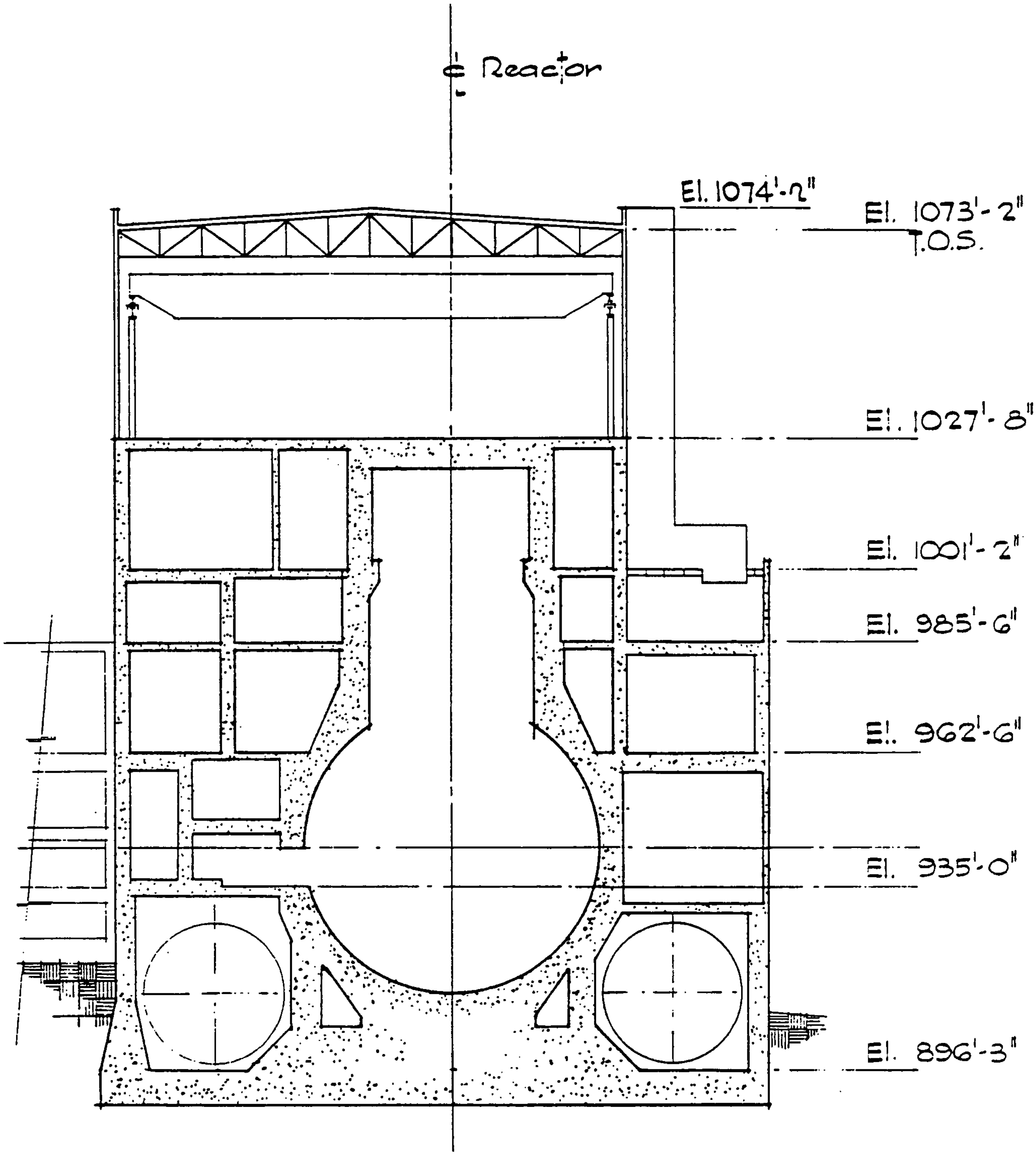


NORTH & SOUTH ELEVATIONS



EAST & WEST ELEVATIONS

SHEET NO. 17



TRANSVERSE SECTION

SHEET NO. 18

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MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

LUMPED WEIGHTS

WEIGHT 1 (@ EL. 1073'-2")

ROOF = 18 PSF

$= 0.018 \times 137.5 \times 105.3 \quad = 260.62\text{ K}$

WALLS = 12 PSF

$= 0.012 \times (137.5 + 105.3) \times 14.9 \times 2 \quad = 86.82$

$\frac{1}{2}$ BRIDGE CRANE $= \frac{1}{2} \times (200 + 57) \quad = 128.50$

$\frac{1}{2}$ CRANE RAIL $= \frac{1}{2} \times 134.5 \times 2 \times$

$\times \left(\frac{0.100}{3} + 0.194 + 0.058\right) \quad = 38.33$

SNOW LOAD = 15 PSF

$= 0.015 \times (137.5 \times 105.3) \quad = 217.13$

VENT STACK $= 13.75 \times \frac{24}{72} \quad = 4.58$

WEIGHT 1 = 735.98 K

WEIGHT 2 (@ EL. 1045'-8")

WALLS = 12 PSF

$= 0.012 \times (137.5 + 105.3) \times 22.75 \times 2 \quad = 132.56\text{ K}$

VENT STACK $= 22.75 \times \frac{24}{72} \quad = 7.58$

WEIGHT 2 = 140.14 K

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MONTICELLO REACTOR BUILDING SEISMIC ANALYSIS

WEIGHT 3 (@ EL. 1027'-8")

VOLUME OF CONCRETE:

WALLS & COLUMNS BELOW:

½ × 26.50 × 2,255.58	= 29,886.44 ft.³

SLABS @ EL. 1027'-8":

6.00 × 820.49	= 4,922.94
2.00 × 9,090.11	= 18,180.22

BEAMS:

3.00 × 6.00 × 256.75	= 4,621.50
3.00 × 7.00 × 114.00	= 2,394.00
3.00 × 5.00 × 90.75	= 1,361.25
2.00 × 4.00 × 10.00	= 800.00

SHIELD:

22.25 × 40.86	= 909.14
TOTAL VOLUME OF CONCRETE	= 63,075.49 ft.³

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MONTICELLO REACTOR BUILDING SEISMIC ANALYSIS

WEIGHT 3 (CONT.)

TOTAL WEIGHT OF CONCRETE = 0.15 x 63,075.49	=	9,461.32 K
WALLS ABOVE = 0.012 x (137.5 + 105.3) x 9 x 2	=	52.44
1/2 BRIDGE CRANE	=	128.50
1/2 CRANE RAIL	=	38.53
CRANE COLUMNS = 14 x 0.074 x 25.25	=	26.16
VENT STACK = 22.25 x $\frac{24}{72}$	=	7.42
1/10 DRYWELL	=	120.00
1/5 HOIST & SUPPORT STEEL (ASSUMED)	=	4.00
1/5 VENTILATION EQUIPMENT (ASSUMED)	=	20.00
LINER, POOLS & REACTOR WELL	=	135.00
1/10 ELEVATOR (ASSUMED)	=	42.00
1/5 MISC. ELECT. EQUIPMENT	=	50.00
1/5 MISC. PIPING	=	50.00
STUD TENSIONERS	=	16.00
JIB CRANE	=	3.00
MISC. LIFTING SLINGS	=	14.00
SHIELDING PLUG OVER VESSEL (6 PCS.)	=	940.00
REFUELING BRIDGE & SERV. PLATFORM	=	50.00
1/3 WATER IN FUEL STORAGE POOL	=	822.00
WATER-DRYER & SEPARATOR POOL	=	638.00
NEW FUEL STORAGE VAULT (1.5 x 6 x 7)	=	168.00

WEIGHT 3 = 12,786.17 K

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MONTICELLO REACTOR BUILDING SEISMIC ANALYSIS

WEIGHT 4 (@ EL. 1001'-2")

VOLUME OF CONCRETE:

WALLS & COLUMNS ABOVE:

½ x 26.50 x 2,255.58	= 29,886.44 ft³

WALLS & COLUMNS BELOW:

½ x 15.67 x 3,393.69	= 26,589.59

SLABS @ EL. 1001'-2":

4.00 x 198.00	= 792.00
2.50 x 220.00	= 550.00
2.00 x 840.00	= 1,680.00
1.00 x 8,071.19	= 8,071.19
2.00 x 210.00	= 420.00

BEAMS:

2.00 x 4.00 x 235.50	= 1,884.00

SHIELD:

21.08 x 40.86	= 861.33
TOTAL VOLUME OF CONCRETE	= 70,734.55 ft³

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MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

WEIGHT 4 (CONT.)

TOTAL WEIGHT OF CONCRETE = 0.15 x 70,734.55	=	10,610.18 K
VENT STACK = $13.25 \times \frac{24}{72}$	=	4.42
DECK ROOF = 0.005 x (32.25 x 113.50)	=	18.30
1/5 DRYWELL	=	240.00
1/5 HOIST & SUPPORT STEEL (ASSUMED)	=	4.00
1/5 VENTILATION EQUIPMENT (ASSUMED)	=	20.00
1/5 R.P.V. WATER & FUEL	=	600.00
1/5 ELEVATOR (ASSUMED)	=	84.00
1/5 MISC. ELECT. EQUIPMENT	=	50.00
1/5 MISC. PIPING	=	50.00
SKIMMER SURGE TANKS	=	24.00
STEAM DRYER	=	51.00
STEAM SEPARATOR	=	37.00
1/2 WATER IN FUEL STORAGE POOL	=	1,233.00
1/2 WATER-DRYER & SEPARATOR POOL	=	633.00
STAND-BY LIQUID CONTROL SYSTEM TANK	=	26.00
STAND-BY LIQUID CONTROL SYSTEM PUMPS	=	6.00
STAND-BY LIQUID CONTROL SYSTEM TEST TANK	=	2.00
HOLD UP PUMPS	=	1.00
WEIGHT 4	=	13,748.90 K

SHEET NO. C3

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

WEIGHT 5 (@ EL. 985'-6")

VOLUME OF CONCRETE :

WALLS & COLUMNS ABOVE :

1/2 × 15.67 × 3,365.19	= 26,365.26 ft³

WALLS & COLUMNS BELOW :

1/2 × 23.00 × 2,834.69	= 32,598.94

SLABS @ EL. 985'-6" :

4.00 × 598.00	= 2,392.00
3.00 × 880.00	= 2,640.00
2.00 × 635.50	= 1,307.00
1.50 × 2,109.42	= 3,164.13
5.50 × 1,040.00	= 5,720.00
1.00 × 9,665.19	= 9,665.19

BEAMS :

2.50 × 6.00 × 61.00	= 915.00
3.00 × 6.00 × 64.50	= 1,161.00
3.00 × 8.00 × 66.75	= 1,602.00
2.00 × 4.00 × 55.13	= 441.00
3.00 × 7.00 × 48.00	= 1,008.00

SHIELD :

19.33 × 40.86	= 789.82
TOTAL VOLUME OF CONCRETE	= 89,770.34 ft³

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MONTICELLO REACTOR BUILDING SEISMIC ANALYSIS

WEIGHT 5 (CONT.)

TOTAL WEIGHT OF CONCRETE = 0.15 x 89,770.34	=	13,465.55 K
MASONRY WALLS = 0.15 x 1,391.53	=	208.73
1/5 DRYWELL	=	240.00
1/5 HOIST & SUPPORT STEEL (ASSUMED)	=	4.00
1/5 VENTILATION EQUIPMENT	=	20.00
2/5 R.P.V. WATER & FUEL	=	1,200.00
1/5 ELEVATOR (ASSUMED)	=	84.00
1/5 MISC. ELECT. EQUIPMENT	=	50.00
1/5 MISC. PIPING	=	50.00
SHIPPING CASK	=	150.00
1/6 WATER IN FUEL STORAGE POOL	=	411.00
FUEL & EQUIPMENT IN POOL (4.4 x 40 x 26 - 2465)	=	2,115.00
FUEL POOL COOLING HEAT EXCH. & PUMPS	=	36.00
FILTERS	=	42.00
COOLING WATER HEAT EXCHANGER	=	120.00
COOLING WATER PUMPS	=	42.00
COOLING WATER SURGE TANK	=	26.00
COLLECTOR TANKS	=	282.00
CHEMICAL WASTE TANK	=	40.00
WEIGHT 5	=	**18,586.28 K**

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

WEIGHT 6 (@ EL. 962'-6")

VOLUME OF CONCRETE:

WALLS & COLUMNS ABOVE:

$\frac{1}{12} \times 3.14 \times 11.5 \times [8 \times (6 \times 46) + (44 \times 60) - (32 \times 48)]$ = 9,966.36 ft^3

$\frac{1}{2} \times 23.00 \times 2{,}050.63$ = 23,582.24

$9.50 \times 2.50 \times 18$ = 427.50

WALLS & COLUMNS BELOW:

$(\frac{1}{4} \times 3.14 \times 70^2 \times 13.75)$

$- \frac{1}{12} \times 3.14 \times 13.75 [48^2 + 60^2 + (48 \times 60)]$ = 21,285.27

$\frac{1}{2} \times 27.50 \times 1{,}741.27$ = 23,942.50

SLABS @ EL. 962'-6":

4.00×720.00 = 2,880.00

$2.00 \times 1{,}056.00$ = 2,112.00

$2.50 \times 1{,}877.00$ = 4,692.50

3.50×426.14 = 1,491.49

3.00×500.00 = 1,500.00

$1.00 \times 8{,}105.25$ = 8,105.25

SLAB @ EL. 972'-0":

2.50×101.50 = 253.75

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

WEIGHT 6 (CONT.)

BEAMS:

3.00 x 6.00 x 77.25	=	1,390.50 $ft.^3$
2.00 x 6.00 x 32.00	=	384.00
3.00 x 8.00 x 90.75	=	2,178.00
2.00 x 5.00 x 196.75	=	1,967.50
3.00 x 7.00 x 88.75	=	1,863.75
3.50 x 8.00 x 36.00	=	1,008.00
2.00 x 4.00 x 45.25	=	362.00
3.50 x 6.50 x 38.00	=	864.50
4.50 x 8.25 x 30.00	=	1,113.60
3.00 x 5.00 x 44.50	=	667.50
3.00 x 5.50 x 42.00	=	693.00

SHIELD:

25.25 x 40.86	=	1,031.72
TOTAL VOLUME OF CONCRETE	=	113,762.93 $ft.^3$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

WEIGHT 6 (CONT.)

TOTAL WEIGHT OF CONCRETE = 0.15 x 113,762.93	17,064.44 K
MASONRY WALLS = 0.15 x 1581.53	247.23
STEEL FLOOR FRAMING = 0.02 x 3216.00	64.32
1/4 DRYWELL	300.00
1/2 RECIRCULATION PIPING, WATER, VALVES & PUMPS	224.00
1/5 HOIST & SUPPORT STEEL (ASSUMED)	4.00
1/5 VENTILATION EQUIPMENT (ASSUMED)	20.00
2/5 R.P.V. WATER & FUEL	1,200.00
1/4 ELEVATOR (ASSUMED)	105.00
MOTOR GENERATORS	200.00
1/5 MISC. ELECT. EQUIPMENT	50.00
1/5 MISC. PIPING	50.00
SLUDGE STORAGE TANKS	140.00
DECANTE PIPES	1.00
WASTE SLUDGE TANK	92.00
CONDENSATE SLUDGE TANK	321.00
SLUDGE RECEIVER TANKS	60.00
NON-REGEN. HEAT EXCHANGER	57.00
REGEN. HEAT EXCHANGER	38.00
RECIRCULATION SURGE TANK	5.00
RECIRCULATION PUMPS	64.00
WEIGHT 6	20,306.99 K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

WEIGHT 7 (@ EL. 935'-0")

VOLUME OF CONCRETE:

WALLS & COLUMNS ABOVE:

$\frac{1}{2} \times 27.50 \times 1{,}532.55$ = 21,072.50 ft³

13.00×202.00 = 2,626.00

WALLS & COLUMNS BELOW:

$(\frac{1}{4} \times 3.14 \times 66^2 \times 19.37)$

$- [\frac{1}{3} \times 3.14 \times 19.37^2 \times (3 \times 31 - 19.37)]$

$+ (\frac{1}{4} \times 3.14 \times 40^2 \times 5)$

$- [\frac{1}{2}(3 \times 2) \times 3.14 \times 52]$ = 43,110.23

$(3 \times 7) \times 3.14 \times 68$ = 4,483.92

$19.37 \times (134.00 \times 3.5) \times 4$ = 36,338.12

$3.50 \times 17.38 \times [(2 \times 28) + 57]$ = 6,873.79

SLABS @ EL. 935'-0":

$2.50 \times 3{,}238.50$ = 8,096.25

$3.00 \times 6{,}020.24$ = 18,060.72

$2.00 \times 6{,}233.35$ = 12,466.70

SHIELD:

27.00×263.76 = 7,121.52

TOTAL VOLUME OF CONCRETE = 160,249.75 ft³

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING SEISMIC ANALYSIS

WEIGHT 7 (CONT.)

TOTAL WEIGHT OF CONCRETE = 0.15 x 160,249.75	=	24,037.46 K
MASONRY WALLS = 0.15 x 8,044.17	=	1,206.63
1/3 DRYWELL	=	400.00
1/2 SUPPRESSION CHAMBER & VENTS	=	850.00
1/2 WATER IN SUPPRESSION CHAMBER	=	2,367.00
1/2 RECIRCULATION PIPING, WATER, VALVE & PUMPS.	=	224.00
1/5 HOIST & SUPPORT STEEL (ASSUMED)	=	4.00
1/5 VENTILATION EQUIPMENT (ASSUMED)	=	20.00
ISOLATION VALVES	=	100.00
CORE SPRAY PUMPS	=	20.00
REACTOR EQUIP'T, DRAIN TANK & PUMP	=	47.00
FLUX MONITOR EQUIPMENT	=	10.00
GAMMA MONITORING	=	25.00
INSTRUMENTS & AIR LINES	=	25.00
1/4 ELEVATOR (ASSUMED)	=	105.00
SHUT-DOWN HEAT EXCHANGER	=	60.00
SHUT-DOWN PUMPS	=	60.00
1/5 MISC. ELECT. EQUIPMENT	=	50.00
1/5 MISC. PIPING	=	50.00
CONTROL ROD DRIVE EQUIPMENT	=	121.00
WEIGHT 7	=	29,782.09 K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

WEIGHT 8 (@ EL. 896'-3")

VOLUME OF CONCRETE:

$(\frac{1}{4} \times 3.14 \times 66^2 \times 10) - [(5.25 \times 8) + (8 \times 2)] \times (15 \times 8)$	=	27,603.55 ft³
$\frac{1}{12} \times 3.14 \times 9 [66^2 + 84^2 + (66 \times 84)] - (24 \times 9 \times 8)$	=	38,203.38
$8 \times [(140.5 \times 140.5) + (3 \times 83) + (24 \times 9)]$	=	161,642.00
$19.37 \times (134.00 \times 3.50) \times 4.00$	=	36,333.12
$[(25 \times 3) + (40 \times 3)] \times \frac{14}{3}$	=	910.00
$19.37 \times (52 \times 3) \times 4$	=	12,086.88
$19.37 \times 3.5 \times [(2 \times 28) + 57] + (8 \times 3.14 \times 57)$	=	22,024.84
TOTAL VOLUME OF CONCRETE	=	298,810.77 ft³

TOTAL WEIGHT OF CONCRETE = 0.15 x 298,810.77	=	44,821.62 K
½ SUPPRESSION CHAMBER & VENTS	=	850.00
½ WATER IN SUPPRESSION CHAMBER	=	2,367.00
WEIGHT 8	=	48,038.62 K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

SECTION PROPERTIES

a. EARTHQUAKE IN N-S DIRECTION (E-W AXIS)

EL. 1027'-0" TO EL. 1001'-2"

b ft.	d ft.	L ft.	A = bd ft.^{2}	$I_o = \frac{1}{12} A d^2$ ft.^{4}	AL^2 ft.^{4}
2×1.00	105.25	16.13	210.50	194,318.86	54,765.79
1.00	24.00	0.00	24.00	1,152.00	0
6.00	14.00	18.00	84.00	1,372.00	27,216.00
6.00	14.00	18.00	84.00	1,372.00	27,216.00
5.00	50.50	0.25	252.50	53,661.51	15.15
1.00	15.00	28.50	15.00	281.25	12,183.75
1.00	13.00	30.00	13.00	183.08	11,700.00
135.50	1.00	36.00	135.50	11.29	175,608.00
135.50	1.00	68.25	135.50	11.29	631,167.13
26.00	5.50	22.75	143.00	360.47	74,011.08
26.00	5.00	22.50	130.00	270.83	65,812.50
2×47.00	2.50	10.75	235.00	122.39	27,156.60
11.00	2.00	24.50	22.00	7.33	13,205.50
57.50	1.00	35.50	57.50	4.79	72,464.38
9.00	1.00	57.50	9.00	0.75	29,756.25
2×2.00	1.50	34.75	6.00	1.12	7,245.36
5×3.00	1.50	34.75	22.50	4.21	27,170.10
2×2.00	1.50	44.50	6.00	1.12	11,881.50
4×3.00	1.50	44.50	18.00	3.37	35,644.50
2×2.00	1.50	67.00	6.00	1.12	26,934.00
5×3.00	1.50	67.00	22.50	4.21	101,002.50
4.00	2.00	24.00	8.00	2.66	4,608.00
2×2.00	6.00	22.25	24.00	72.00	11,881.44
2.00	3.00	0.00	6.00	4.50	0
			1,669.50	253,224.15	1,448,644.93

CIRCULAR PART:

$$A = \pi \frac{D_o + D_i}{2} \cdot t = 3.14 \times \frac{42.33 + 32.33}{2} \cdot 5.00 = 586.08 \text{ ft.}^2$$

$$I = \frac{A}{16}(D_o^2 + D_i^2) = \frac{586.08}{16}(42.33^2 + 32.33^2) = 103,921.14 \text{ ft.}^4$$

$$\Sigma A = 1,669.50 + 586.08 = \underline{2,255.58 \text{ ft.}^2}$$

$$\Sigma I = 253,224.15 + 1,448,644.93 + 103,921.14 = \underline{1,805,790.22 \text{ ft.}^4}$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 1001'-2" TO EL. 985'-6"

b ft.	d ft.	L ft.	A=bd ft²	Ad²/12 ft⁴	AL² ft⁴
2×1.00	137.50	0.00	275.00	433,268.22	0
2.00	26.00	0.00	52.00	2,929.33	0
6.00	10.00	20.00	60.00	500.00	24,000.00
6.00	10.00	20.00	60.00	500.00	24.000.00
5.50	52.00	0.00	286.00	64,445.33	0
1.60	24.00	54.50	38.40	1,843.20	114,057.20
3+2+4	5.00	28.00	45.00	93.75	35,280.00
1.00	30.75	51.00	30.75	2,422.99	79,980.75
26.00	4.00	32.50	104.00	138.67	109,850.00
0.50	19.00	47.00	9.50	285.79	20,985.50
1.00	4.00	39.00	4.00	5.33	6,084.00
2.00	6.00	38.50	12.00	36.00	17,787.00
2.00	9.00	45.00	18.00	121.50	36,450.00
2×1.00	6.00	53.50	12.00	36.00	34,347.00
0.50	16.00	51.50	8.00	170.66	21,218.00
1+(3×1.5)	8.00	63.50	44.00	234.66	177,419.00
1.50+2.50	24.00	56.00	96.00	4,608.00	301,056.00
135.50	1.50	68.00	203.25	38.10	939,828.00
41.00	0.50	67.75	20.50	0.42	94,096.23
6+3+10	1.00	50.50	19.00	1.58	48,454.75
12.67	1.50	44.00	19.01	3.56	36,803.36
132.50	1.50	35.75	198.75	37.27	254,014.92
2×26.00	6.00	22.5	312.00	936.00	157,950.00
2×10.00	1.50	25.00	30.00	5.62	18,750.00
26.00	4.00	23.50	104.00	138.66	57,434.00
11.00	1.00	53.50	11.00	0.92	31,484.75
3.00	2.00	36.50	6.00	2.00	7,993.50
22.00	1.50	45.50	33.00	6.18	68,318.25
4.00	3.00	45.50	12.00	9.00	24,843.00
1.00	3.50	48.00	3.50	3.57	8,064.00
14.00	2.00	45.00	28.00	9.33	56,700.00
42.00	2.50	45.25	105.00	54.68	214,993.80
45.00	2.50	58.00	112.50	58.59	378,450.00

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

EL. 1001'-2" TO EL. 985'-6" (CONTINUED)

b ft.	d ft.	L ft.	A ft.^{2}	$Ad^2/12$ ft.^{4}	AL^2 ft.^{4}
45.50	1.00	67.25	45.50	3.79	205,776.48
42.00	0.50	67.50	21.00	0.43	95,681.25
135.50	1.00	68.00	135.50	11.29	626,552.00
9.00	1.00	58.00	9.00	0.75	30,276.00
2×2.00	1.00	34.75	4.00	0.33	4,830.24
5×3.00	1.00	34.75	15.00	1.25	18,113.40
2×3.00	3.00	10.75	18.00	13.50	2,080.08
3.00	2.50	35.00	7.50	3.90	9,187.50
3.00+2.00	2.50	44.50	12.50	6.51	24,753.13
3.00+2.00	1.50	67.00	7.50	1.40	33,667.50
2×2.00	5.00	22.25	20.00	41.66	9,901.20
2.00	2.50	0.00	5.00	2.60	0
1.00	4.00	56.00	4.00	5.33	12,544.00
7.00	1.50	39.50	10.50	1.97	16,382.63
1.50	3.00	37.00	4.50	3.38	6,160.50
			2,619.66	513,043.00	4,496,559.32

CIRCULAR PART:

$$A = 3.14 \times \frac{44.50+33.50}{2} \times 5.50 = 673.53 \text{ ft.}^2$$

$$I = \frac{673.53}{16} \times (44.50^2 + 33.50^2) = 130,601.67 \text{ ft.}^4$$

$$\Sigma A = 2,619.66 + 673.53 = \underline{3,365.19 \text{ ft.}^2}$$

$$\Sigma I = 513,043.00 + 4,496,559.32 + 130,601.67 = \underline{\underline{5,140,203.99 \text{ ft.}^4}}$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 985'-6" TO EL. 962'-6"

b ft.	d ft.	L ft.	A = bd ft.^{2}	Ad^2/12 ft.^{4}	AL^2 ft.^{4}
2x1.00	137.50	0.00	275.00	433,268.22	0
2.00	26.00	0.00	52.00	2,929.33	0
2x2.00	10.00	61.00	40.00	333.33	148,840.00
1.00	23.00	45.00	23.00	1,013.91	46,575.00
2.75	10.00	22.50	27.50	229.16	13,921.88
1.50	5.00	15.00	7.50	15.62	1,687.50
1.50	8.00	20.00	12.00	64.00	4,800.00
3.00x$\frac{15}{10}$	10.00	21.00	45.00	375.00	19,845.00
1.50x$\frac{9.0}{3.5}$	3.50	9.50	13.50	13.78	1,218.37
2.75	13.00	13.00	35.75	503.47	6,041.75
2.75x$\frac{8}{5}$	5.00	22.00	22.00	45.83	10,648.00
2.75x$\frac{12}{4}$	4.00	20.00	33.00	44.00	13,200.00
1.00	52.00	0.00	52.00	11,717.33	0
1.50	47.50	45.00	71.25	13,396.48	144,281.25
4.00x$\frac{6}{2}$	2.00	25.50	24.00	8.00	15,606.00
4.00	19.00	37.00	76.00	2,286.33	104,044.00
2.75+2.50	17.00	55.50	89.25	2,149.43	274,912.31
2x2.00	5.50	65.00	22.00	55.45	92,950.00
2.75	24.00	56.00	66.00	3,168.00	206,976.00
24.00	1.00	68.00	24.00	2.00	110,976.00
111.50	1.50	67.75	167.25	31.35	767,687.53
8.00	2.75	26.00	22.00	13.86	14,872.00
10.50	2.00	56.00	21.00	7.00	65,856.00
95.00	1.00	36.00	95.00	7.91	123,120.00
24.00	0.50	35.25	12.00	0.25	14,910.72
17+9+6+4	2.00	34.50	72.00	24.00	85,698.00
2.00+7.00	2.75	26.00	24.75	15.59	16,731.00
19.00	1.50	11.50	28.50	5.34	3,769.13
25.00	1.50	0.75	37.50	7.03	21.00
11.00	4.00	23.50	44.00	58.66	24,299.00
6.50	2.75	24.00	17.88	11.26	10,298.88
26.00	3.25	44.50	84.50	74.36	167,331.13
35.00	2.75	44.25	96.25	60.63	188,463.23

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

EL. 985'-6" TO EL. 962'-6" (CONTINUED)

b ft.	d ft.	L ft.	A=bd ft.^{2}	Ad^2/12 ft.^{4}	AL^2 ft.^{4}
2.75+1.50	6.50	3.00	27.63	97.26	248.63
26.00	2.50	67.50	65.00	33.85	296,156.25
54.00	1.50	68.00	81.00	15.18	374,544.00
48.00	1.00	68.25	48.00	4.00	223,586.88
9.00	1.00	58.00	9.00	0.75	30,276.00
2x11.00	1.00	26.00	22.00	1.83	14,872.00
2.00+3.00	3.00	35.25	15.00	12.00	18,638.40
2.00	2.00	22.25	4.00	1.33	1,980.24
2.00	3.00	35.00	6.00	4.50	7,350.00
3+3+2	3.00	44.50	24.00	18.00	47,526.00
2.5+3.0	1.50	68.00	8.25	1.54	38,148.00
3+3+2	2.00	68.25	16.00	5.33	74,528.96
2x2.50	5.00	22.25	25.00	52.08	12,376.50
2.50	2.50	0.00	6.25	3.25	0
			2,090.51	472,184.81	3,839,812.59

CIRCULAR PART:

$$A = 3.14 \times \frac{45.50 + 33.50}{2} \times 6.00 = 744.18 \text{ ft.}^2$$

$$I = \frac{744.18}{16} \times (45.50^2 + 33.50^2) = 148,487.16 \text{ ft.}^4$$

$$\Sigma A = 2,090.51 + 744.18 = \underline{\underline{2,834.69 \text{ ft.}^2}}$$

$$\Sigma I = 472,184.81 + 3,839,812.59 + 148,487.16 = \underline{\underline{4,460,484.56 \text{ ft.}^4}}$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 962'-6" TO EL. 935'-0"

b ft.	d ft.	L ft.	$A = bd$ ft.^{2}	$Ad^2/12$ ft.^{4}	AL^2 ft.^{4}
2×1.00	137.50	0.00	275.00	433,268.22	0
2.00	26.00	0.00	52.00	2,929.33	0
1.00	36.00	51.00	36.00	3,888.00	93,636.00
4.00	29.00	49.00	116.00	8,129.66	278,516.00
4.00	33.50	51.00	134.00	12,531.79	348,534.00
$3.00 \times \frac{11}{8}$	8.00	45.00	33.00	176.00	66,825.00
$2.50 \times \frac{30}{21}$	21.00	30.50	75.00	2,756.25	69,768.75
134.50	1.00	68.25	134.50	11.20	626,509.07
23.00	1.00	67.25	23.00	1.91	104,018.88
32+52	2.00	67.25	168.00	56.00	759,790.08
8.00	1.00	56.00	8.00	0.66	25,088.00
26.00	2.50	48.50	65.00	33.85	152,896.25
7.00	2.00	35.00	14.00	4.66	17,150.00
9.00	1.00	58.00	9.00	0.75	30,276.00
34.00	0.5	68.00	17.00	0.35	78,608.00
116.50	1.00	68.25	116.50	9.70	542,663.99
2×2.00	2.50	44.50	10.00	5.20	19,802.50
2×3.50	3.50	44.50	24.50	25.01	48,516.13
2×2.+3×3.	1.50	67.00	19.50	3.65	87,535.50
2×3.00	1.00	66.75	6.00	0.50	26,533.50
2×2.50	6.00	23.00	30.00	90.00	15,870.00
2.50	3.00	0.00	7.50	5.62	0
11.00	1.50	59.00	16.50	3.09	57,436.50
18.00	1.00	51.00	18.00	1.50	46,818.00
13.00	1.00	46.50	13.00	1.08	28,109.25
2×1.00	3.00	48.75	6.00	4.50	14,259.38
1.50	5.00	64.50	7.50	15.63	31,201.88
$1.50 \times \frac{13.50}{9.00}$	9.00	58.00	20.25	136.69	68,121.00
$1.50 \times \frac{3.50}{3.00}$	3.00	54.00	5.25	3.94	15,309.00
37.50	2.00	54.50	75.00	25.00	222,768.75
2.00	12.00	49.00	24.00	288.00	57,624.00
2.00	8.00	45.00	16.00	85.33	32,400.00
$2.00 \times \frac{12.00}{8.50}$	8.50	50.00	24.00	144.49	59,999.37
			1,559.00	464,637.56	4,026,584.78

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

EL. 962'-6" TO EL. 935'-0" (CONTINUED)

CIRCULAR PART:

$$A = 3.14 \times \frac{72.00+62.00}{2} \times 5.00 - 5.00 \times (9.00+10.00) =$$

$$= 1{,}051.90 - (45.00+50.00) = 956.90\ ft.^2$$

$$I = \frac{1{,}051.90}{16} \times (72.00^2+62.00^2) - 45.00 \times \left(\frac{5.00^2}{12}+33.5^2\right) - 50.00 \times \left(\frac{7.50^2}{12}+23.50^2\right) =$$

$$= 593{,}534.57 - (50{,}594.85 + 27{,}846.50) = 515{,}093.22\ ft.^4$$

SHIELD: $A = \frac{1}{2} \times 3.14 \times (25+17) \times 4 = 267.76\ ft.^2$

$$\Sigma A = 1559.00 + 956.90 + 267.76 = 2{,}783.66\ ft.^2$$

$$\Sigma I = 464{,}637.56 + 4{,}026{,}584.78 + 515{,}093.22 = 5{,}006{,}315.56\ ft.^4$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 935'-0" TO EL. 896'-3"

b ft.	d ft.	L ft.	$A=bd$ ft.^{2}	$Ad^2/12$ ft.^{4}	AL^2 ft.^{4}
3.50+3.50	137.50	0.00	962.50	1,516,438.80	0
3.00	25.00	0.00	75.00	3,906.25	0
$4[3.00\times\frac{35}{25}]$	25.00	47.00	420.00	21,875.00	927,780.00
4×5.00	7.50	32.00	150.00	703.12	153,600.00
2×130.00	3.50	67.00	910.00	92,895.83	4084990.00
40.00	3.00	70.25	120.00	90.00	592,207.20
5×4.00	1.00	65.00	20.00	1.66	84,500.00
2×1.00	4.00	9.50	8.00	10.66	722.00
4×7.50	5.00	62.00	150.00	312.50	576,600.00
$4[4.00\times\frac{8}{7}]$	7.00	21.00	128.00	522.66	56,488.00
$4[4.00\times\frac{8}{3}]$	3.00	9.00	128.00	96.00	10,368.00
28.00	3.50	67.00	98.00	100.04	439,922.00
28.00	3.50	13.50	98.00	100.04	17,860.50
3.50	57.00	40.25	199.50	54,014.63	323,202.37
			3,467.00	1,691,067.19	7,268,240.07

CIRCULAR PARTS:

$$A = 3.14 \times \frac{68.00+54.00}{2} \times 7.00 = 1,340.78 \text{ ft.}^2$$

$$I = \frac{1,340.78}{16} \times (68.00^2 + 54.00^2) = 631,842.57 \text{ ft.}^4$$

$$A = \frac{3.14}{4} \times 38^2 = 1,133.54 \text{ ft.}^2$$

$$I = \frac{1,133.54}{16} \times 38^2 = 102,301.98 \text{ ft.}^4$$

$$\Sigma A = 3,467.00 + 1,340.78 + 1,133.54 = \underline{5,941.32 \text{ ft.}^2}$$

$$\Sigma I = 1,691,067.19 + 7,268,240.07 + 631,842.57 + 102,301.98 = \underline{9,693,451.81 \text{ ft.}^4}$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

b. EARTHQUAKE IN E-W DIRECTION (N-S AXIS)
EL. 1027'-0" TO EL. 1001'-2"

b ft.	d ft.	L ft.	A=bd $ft.^2$	$Ad^2/12$ $ft.^4$	AL^2 $ft.^4$
2x105.25	1.00	68.25	210.50	17.54	980,522
24.00	1.00	67.25	24.00	2.00	108,541
14.00	6.00	17.50	84.00	252.00	25,725
14.00	6.00	17.50	84.00	252.00	25,725
50.50	5.00	49.50	252.50	526.04	618,686
15.00	1.00	0	15.00	1.25	0
13.00	1.00	58.00	13.00	1.08	43,732
1.00	135.50	0	135.50	207,317.82	0
1.00	135.50	0	135.50	207,317.82	0
5.50	26.00	34.00	143.00	8,055.67	165,308
5.00	26.00	34.00	130.00	7,323.33	150,280
2x2.50	47.00	45.00	235.00	43,259.58	475,875
2.00	11.00	61.00	22.00	221.83	81,862
1.00	57.50	29.00	57.50	15,842.45	48,358
1.00	9.00	64.00	9.00	60.75	36,864
2x1.50	2.00	67.25	6.00	2.00	27,135
4x1.50	3.00	34.00	18.00	12.00	20,808
2x1.50	2.00	67.25	6.00	2.00	27,135
4x1.50	3.00	34.00	18.00	12.00	20,808
2x1.50	2.00	67.25	6.00	2.00	27,135
4x1.50	3.00	34.00	18.00	12.00	20,808
2.00	4.00	60.00	8.00	10.67	28,800
2x6.00	2.00	66.75	24.00	8.00	106,933
3.00	2.00	66.75	6.00	2.00	26,733
				490,513.83	3,067,775

CIRCULAR PART:

$I = 103,921.14 \; ft.^4$

$\Sigma I = 103,921.14 + 490,513.83 + 3,067,775.00 = \underline{3,662,209.97 \; ft.^4}$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 1001'-2" TO EL. 985'-6"

b ft.	d ft.	L ft.	A=bd ft.^{2}	$Ad^2/12$ ft.^{4}	AL^2 ft.^{4}
2x137.50	1.00	68.25	275.00	22.91	1,280,967
26.00	2.00	66.75	52.00	17.33	231,689
10.00	6.00	17.50	60.00	180.00	18,375
10.00	6.00	17.50	60.00	180.00	18,375
52.00	5.50	49.00	282.00	710.87	677,082
24.00	1.60	44.50	38.40	8.19	76,042
5.00	3.00	67.50	15.00	11.25	68,344
5.00	2.00	56.00	10.00	3.33	31,360
30.75	1.00	26.50	30.75	2.56	21,594
5.00	4.00	43.00	20.00	26.67	36,980
4.00	26.00	54.00	104.00	5,858.67	303,264
1.00	6.00	46.00	6.00	18.00	12,696
19.00	0.50	67.50	9.50	0.19	43,284
4.00	1.00	56.00	4.00	0.33	12,544
6.00	2.00	37.50	12.00	4.00	16,375
9.00	2.00	42.00	18.00	6.00	31,752
6.00	1.00	51.50	6.00	0.50	15,914
6.00	1.00	59.00	6.00	0.50	20,886
16.00	0.50	23.50	8.00	0.16	4,418
8.00	1.00	67.25	8.00	0.67	36,180
8.00	1.50	56.00	12.00	2.25	37,632
8.00	1.50	45.00	12.00	2.25	24,300
8.00	1.50	34.00	12.00	2.25	13,872
24.00	4.00	22.00	96.00	128.00	46,464
1.50	135.50	0	203.25	310,976.73	0
0.50	41.00	47.50	20.50	2,871.70	46,253
1.00	3.00	38.50	3.00	2.25	4,447
1.50	12.67	38.00	19.01	254.19	27,450
1.50	135.50	0	203.25	310,976.73	0
2x6.00	26.00	34.00	312.00	17,576.00	8,925

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL.1001'-2" TO EL. 985'-6" (CONTINUED)

b ft.	d ft.	L ft.	A=bd $ft.^2$	$Ad^2/12$ $ft.^4$	AL^2 $ft.^4$
2x1.50	10.00	61.00	33.00	275.00	122,793
1.00	10.00	29.00	10.00	83.33	8,410
2.00	3.00	40.00	6.00	4.50	9,600
1.50	22.00	57.50	33.00	1,331.00	109,106
3.00	4.00	45.50	12.00	16.00	24,843
1.00	11.00	38.50	11.00	110.92	16,305
2.00	14.00	31.00	28.00	457.33	26,908
2.50	42.00	0	105.00	15,435.00	0
2.50	45.00	46.00	112.50	18,984.37	238,050
1.00	45.50	45.50	45.50	7,844.69	94,163
0.50	42.00	0	21.00	3,087.00	0
1.00	135.50	0	135.50	207,317.82	0
1.00	9.00	64.00	9.00	60.75	36,864
2x1.00	2.00	66.75	4.00	1.33	17,822
4x1.00	3.00	34.00	15.00	11.25	17,340
2x3.00	3.00	44.50	18.00	13.50	35,645
2.50	3.00	0	7.50	5.62	0
2.50+1.50	5.00	56.00	20.00	41.66	62,720
2x5.00	2.00	66.75	20.00	6.66	89,111
2.50	2.00	66.75	5.00	1.66	22,278
3.50	1.00	37.50	3.50	0.29	4,922
4.00	1.00	34.00	4.00	0.33	4,624
1.50	7.00	62.50	10.50	42.88	41,016
3.00	1.50	60.00	4.50	0.84	16,200
				904,983.21	4,166,684

CIRCULAR PART:

$I = 130{,}601.67\ ft.^4$

$\Sigma I = 130{,}601.67 + 904{,}983.21 + 4{,}166{,}684 = \underline{5{,}202{,}268.88\ ft.^4}$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 985'-6" TO EL. 962'-6"

b ft.	d ft.	L ft.	A=bd ft.²	Ad²/12 ft.⁴	AL² ft.⁴
2×137.50	1.00	68.25	275.00	22.91	1,280,967
26.00	2.00	66.75	52.00	17.33	231,684
10.00	2.00	41.00	20.00	66.67	33,620
10.00	2.00	28.50	20.00	66.67	16,245
23.00	1.00	28.00	23.00	1.91	18,032
10.00	2.75	45.00	27.50	200.65	55 688
5.00	1.50	34.00	7.50	1.40	8,670
8.00	1.50	29.50	12.00	2.25	10,443
$3\times\frac{15}{10}$	10.00	21.00	45.00	375.00	19,845
$1.5\times\frac{9}{8}$	8.00	24.00	13.50	72.00	7,776
13.00	2.75	45.50	35.75	22.52	74 011
$2.75\times\frac{8}{5}$	5.00	43.00	22.00	45.83	40 678
$2.75\times\frac{12}{4}$	4.00	20.00	33.00	44.00	13,200
52.00	1.00	54.50	52.00	4.33	154 455
47.50	1.50	67.00	71.25	13.35	319,841
$4\times\frac{6}{2}$	2.00	53.00	24.00	8.00	67 416
19.00	4.00	51.00	76.00	101.33	197,676
17.00	2.75	22.50	36.75	23.15	18,605
17.00	2.50	45.00	42.50	22.13	86,063
5.50	2.00	28.50	11.00	3.66	8,935
5.50	2.00	39.50	11.00	3.66	17,163
24.00	2.75	15.00	66.00	41.58	14.850
1.00	24.00	58.00	24.00	1,152.00	80.736
1.50	111.50	12.00	167.25	173,274.48	24.084
2.75	8.00	36.00	22.00	117.33	28,511
2.00	10.50	35.00	21.00	192.93	25,725
1.00	95.00	20.00	95.00	71,447.91	38,000
0.50	24.00	0	12.00	576.00	0
2.00	17.00	21.00	34.00	818.83	14,994
2.00	12.00	18.00	24.00	288.00	7,776

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING
SEISMIC ANALYSIS

EL. 985'-6" TO EL. 962'-6" (CONTINUED)

b ft.	d ft.	L ft.	$A=bd$ ft.^{2}	$Ad^2/12$ ft.^{4}	AL^2 ft.^{4}
2.00	3.00	44.50	6.00	4.50	11,882
2.00	2.00	66.75	4.00	1.33	17,822
2.75	9.00	30.00	24.75	167.06	22 275
1.50	19.00	38.00	28.50	857.37	41,154
1.50	25.00	34.50	37.50	1,953.12	44 634
4.00	11.00	61.00	44.00	443.66	163,724
2.75	6.50	28.00	17.88	62.95	14,018
3.25	26.00	36.50	84.50	4,760.16	112,575
2.75	35.00	4.00	96.25	9,825.52	1,540
6.50	1.50	34.00	9.75	1.83	11,270
2.50	26.00	53.50	65.00	3,661.66	186 046
1.50	54.00	12.00	81.00	19,683.00	11,664
1.00	48.00	45.00	48.00	9,216.00	97,200
1.00	9.00	64.00	9.00	60.75	36,864
2×1.00	11.00	60.50	22.00	221.83	80 526
3.00	3.00	44.50	9.00	6.75	17,822
3.00	2.00	66.75	6.00	2.00	26,733
2.00	2.00	22.25	4.00	1.33	1,980
3.00	2.00	0	6.00	2.00	0
5.00	8.00	44.50	40.00	213.33	79,210
1.50	2.50	0	8.25	4.29	0
2×5.00	2.50	66.50	25.00	13.02	110,556
2.50	2.50	66.50	6.25	3.25	27 634
				300,194.52	4,032,826

CIRCULAR PART:

$I = 148,487.16$ ft.^{4}

$$\Sigma I = 148,487.16 + 300,194.52 + 4,032,826.00 = 4,481,507.68 \text{ ft.}^4$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

EL. 962'-6" TO EL. 935'-0"

b ft.	d ft.	L ft.	A=bd $ft.^2$	$Ad^2/12$ $ft.^4$	AL^2 $ft.^4$
2x137.50	1.00	68.25	275.00	22.91	1,280,967
26.00	2.00	66.75	52.00	17.33	231,689
36.00	1.00	67.25	36.00	3.00	162,812
29.00	4.00	14.00	116.00	154.66	22,736
33.50	4.00	14.00	134.00	178.66	26,264
$3 \times \frac{11}{8}$	8.00	45.00	33.00	176.00	66,825
$2.5 \times \frac{30}{21}$	21.00	41.00	75.00	2,756.25	126,075
1.00	134.50	0	134.50	202,761.55	0
1.00	23.00	56.00	23.00	1,013.92	72,128
2.00	32.00	28.00	64.00	5,461.33	50,176
2.00	52.00	42.00	104.00	23,434.67	183,456
1.00	8.00	20.00	8.00	42.67	3,200
2.50	26.00	33.00	65.00	3,661.67	70,785
2.00	7.00	63.00	14.00	57.17	55,566
1.00	9.00	64.00	9.00	60.75	36,864
0.50	34.00	10.00	17.00	1,637.67	1,700
1.00	116.50	0	116.50	322,552.09	0
2x2.50	2.00	66.75	10.00	3.33	44,556
2x3.50	3.50	51.00	24.50	25.01	63,725
2x1.50	2.00	66.75	6.00	2.00	26,733
2x1.50	3.00	44.50	9.00	6.75	17,822
2x1.00	3.00	22.25	6.00	4.50	2,970
2x6.00	2.50	66.50	30.00	15.63	132,668
3.00	2.50	66.50	7.50	3.91	33,167
1.50	11.00	62.50	16.50	166.38	64,453
1.00	18.00	54.50	18.00	486.00	53,465
1.00	13.00	57.00	13.00	183.08	42,236
2.00	1.00	63.00	2.00	0.17	7,935
2.00	1.00	46.00	2.00	0.17	4,230
5.00	1.50	33.50	7.50	1.41	8,416
$1.50 \times \frac{13.50}{9.00}$	9.00	38.00	20.25	136.69	29,241
$1.50 \times \frac{3.50}{3.00}$	3.00	44.50	5.25	3.94	10,396
2.00	37.50	5.00	75.00	8,789.06	1,875
12.00	2.00	23.00	24.00	8.00	12,696
8.00	2.00	22.00	16.00	5.33	7,744
$2.00 \times \frac{12.00}{8.00}$	8.00	18.00	24.00	128.00	7,776
				573,961.66	2,963,347

CIRCULAR PART:

$I = 515{,}093.22\ ft.^4$

$\Sigma I = 515{,}093.22 + 573{,}961.66 + 2{,}963{,}347 = \underline{4{,}052{,}401.88\ ft.^4}$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR BUILDING

SEISMIC ANALYSIS

EL. 935'-0" TO EL. 896'-3"

b ft.	d ft.	L ft.	A=bd $ft.^2$	$Ad^2/12$ $ft.^4$	AL^2 ft^4
2x137.50	3.50	67.00	962.50	982.55	4,320,663
25.00	3.00	70.25	75.00	112.50	370,130
4[3x $\frac{35}{25}$]	25.00	47.00	420.00	21,875.00	927,780
4x7.50	5.00	62.50	150.00	312.50	585,938
2x3.50	130.00	0	910.00	1,281,583.33	0
3.00	40.00	0	120.00	16,000.00	0
4x1.00	5.00	13.00	20.00	41.67	3,380
2x4.00	1.00	64.75	8.00	.67	33,540
4x5.00	7.50	32.00	150.00	703.13	153,600
4[4x $\frac{8}{3}$]	3.00	9.00	128.00	96.00	10,368
4[4x $\frac{8}{7}$]	7.00	21.00	128.00	522.67	56,448
2x3.5	28.00	82.75	196.00	12,805.33	1,342,122
57.00	3.50	98.50	199.50	203.66	1,935,599
				1,335,239.01	9,739,568

CIRCULAR PARTS:

$I = 631,842.57 + 102,301.98 = 734,144.55\ ft^4$

$\Sigma I = 734,144.55 + 1,335,239.01 + 9,739,568.00 = \underline{\underline{11,808,951.56\ ft^4}}$

GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPARTMENT

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS: DRYWELL

JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

JOHN A. BLUME & ASSOCIATES, ENGINEERS
612 HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94105 • (415) 397-2525

December 27, 1967

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
Earthquake Analysis of
Drywell

Gentlemen:

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

This report summarizes the analytical procedures and results for the seismic analysis of Monticello Drywell for both empty and flooded conditions.

Very truly yours,
JOHN A. BLUME & ASSOCIATES, ENGINEERS

E. J. Keith

E. J. Keith
Assistant Vice President

MPJ/ps

GENERAL ELECTRIC COMPANY

Atomic Power Equipment Department

MONTICELLO NUCLEAR GENERATION PLANT

REPORT ON THE EARTHQUAKE ANALYSIS OF THE DRYWELL

JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS OF DRYWELL

TABLE OF CONTENTS

MONTICELLO NUCLEAR GENERATION PLANT
EARTHQUAKE ANALYSIS OF DRYWELL

INTRODUCTION

The purpose of this report is to summarize the analytical procedures and results of seismic investigation of the Monticello Drywell. Based on the design earthquake stated below, design envelopes of seismic-induced maximum absolute acceleration, relative displacement, moment and shear versus height of the drywell have been developed and are presented herein. The design earthquake acting in the north-south and east-west directions has been considered for both empty and flooded conditions of the drywell.

DESIGN CRITERIA

Earthquake design criteria are presented in detail in Reference 1. The design earthquake used in this analysis is the north 69° west component of Taft earthquake of 1952 normalized to a maximum ground acceleration of 0.06 gravity.

DESCRIPTION OF DRYWELL

The drywell is a bulb shaped steel shell of variable plate thickness. The spherical part has an inside radius of 32'.0" and is joined to the cylindrical part of the drywell by a knuckle of plate thickness 2.5 inches. The cylindrical part consists of three cylindrical shells 23'-8", 3'-0" & 6'-3" long, having inside radii of 16'-6", 13'-5-3/4", 13'-5-3/4", plate thickness of 0.635 inch, 1.5 and 1.25 inches respectively, joined by a 5'-3" high truncated cone of plate thickness 1.25 inches. The drywell is embedded in concrete at elevation 917'-11-3/16" and is laterally supported by the reactor building at elevation 992'-5-1/2". Location of personnel lock vent system and geometry of drywell is shown in Appendix Sheet 1.

MATHEMATICAL MODEL OF DRYWELL

The drywell is idealized as a lumped mass system supported on elastic columns. The drywell was mathematically modelled as an eighteen mass system and is shown in Appendix Sheet 3. However, to take into consideration

the interaction of the reactor building and drywell during an earthquake occurrence, the drywell model was coupled with the mathematical model of the reactor building (Reference 2) by an inextensible bar at elevation 992'-5-1/2" representing the shear lug, and by another such bar at elevation 917'-11-3/16" representing the embedment of drywell in the reactor building. This results in a twenty-six lumped mass coupled system which is shown in Appendix Sheet 2.

CALCULATED DATA

Calculated data used as input to the computer is given in Appendix Sheet 3. These calculations result from information or drawings supplied by General Electric (Reference 3).

Properties of the elastic column were determined by cutting a horizontal section between mass points and calculating the moment of inertia and effective shear area. The data presented in Reference 2 were suitably modified for use in this analysis. The mass of personnel lock and vent system was considered and appropriately lumped along with the drywell mass.

The following values were assigned as the elastic moduli:

1. Concrete 3.0×10^6 pounds per square inch
2. Drywell Steel 29.5×10^6 pounds per square inch
3. Structural Steel 30.0×10^6 pounds per square inch

ANALYTICAL PROCEDURE - Periods and Mode Shapes

The natural periods of vibration and mode shapes of the mathematical model are calculated by solving for the eigenvalues and eigenvectors of the n number of equations represented by Equation (1).

$$\underline{K}\,\underline{\phi_i} - \omega_i^2\,\underline{M}\,\underline{\phi_i} = \underline{0} \quad \text{---------------------------------------} \quad (1)$$

where:

$\underline{K}$ = Structure stiffness matrix

ϕ_i = Mode shape vector of the i^{th} mode of vibration

$\underline{\phi_i}$ = Mode shape matrix

ω_i = Natural circular frequency of the i^{th} mode

i = 1, 2, 3, ..., n

n = Number of degrees of freedom of the mathematical model

$\underline{M}$ = Mass matrix

$\underline{O}$ = Null matrix

ANALYTICAL PROCEDURE - Response

The generalized displacement response of the structure, once periods and mode shapes have been determined, is given by Equation (2).

$$\underline{\ddot{Y}_i(t)} + 2\,\omega_i\lambda\ \underline{\dot{Y}_i(t)} + \omega_i^2\ \underline{Y_i(t)} = \frac{\underline{Ri}}{\underline{M_i^*}}\ \ddot{U}_g(t) \quad \text{-------------(2)}$$

where:

$Y_i(t)$ = Generalized coordinate vector for the i^{th} mode

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

$\underline{\dot{Y}_i(t)}$ = Generalized velocity matrix

$\underline{\ddot{Y}_i(t)}$ = Generalized acceleration matrix

λ_i = Damping value for the i^{th} mode

$\underline{M_i^*}$ = Generalized mass matrix which is set equal to unity in eigenvalue solution

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

$\frac{\underline{Ri}}{\underline{M_i^*}}$ = Participation factor matrix

$\underline{R_i} = \underline{\phi_i}^T \cdot \underline{M}$

$\ddot{U}_g(t)$ = Ground motion

The generalized coordinate vector for the i^{th} mode is given as:

$$Yi(t) = \frac{Ri}{M_i^* \omega_i} \int_0^t \ddot{U}_g(t) e^{-\lambda_i \omega_i (t-\tau)} (\sin \omega_i (t-\tau) d\tau)$$

Where:

$d\tau$ = Integration interval

R_i = Participation factor for the i^{th} mode

M_i^* = Generalized mass for i^{th} mode

The integral in the above expression, called the Duhamel Integral is numerically integrated.

From the generalized coordinate matrix the time history of displacement, $\underline{V_{(t)}}$, is found from Equation (3).

$$\underline{V_{(t)}} = \underline{\phi_i} \cdot \underline{Y_i(t)} \quad \text{--(3)}$$

The solution for generalized acceleration response is identical to the above, except that Equation (2) is solved for acceleration, from which the relative acceleration-time history matrix is calculated. To this is added the ground acceleration, resulting in the absolute acceleration-time history.

Once displacement and acceleration-time histories have been established, the time histories of shears and moments are determined. These records are then enveloped to determine the maximum values which are then graphically presented in the report and are recommended for use by the designer.

ANALYTICAL PROCEDURE - Computer Program

The computer program used in this analysis was specially designed to solve the dynamic response of structures subjected to arbitrary ground motions. The effects of axial deformation and shear deformations are included in the calculation of the stiffness matrix. Individual elements in the stiffness matrix are designated K_{ij} and are stored in the computer such that the i^{th} value designates the row number and the j^{th} value the column number. K_{ij} is determined by applying a unit displacement at the j^{th} point while restraining the other points against distortion, and finding the corresponding reaction at the i^{th} point.

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 responses of each mass point for each mode at a particular instant of time. This results in an exact combination of mode participations without the necessity of using approximate methods such as the root-mean-square method.

The increment of time referred to above is used in the step-by-step integration of Duhamel's Integral and is selected by the computer such that it is always smaller than one-tenth of the period of vibration of the mode for which the response is calculated. The computer takes into account all peaks and valleys of the design ground motion.

The general computer techniques used in this analysis are taken from References 4, 5, 6, and 7. A simplified block diagram of the computer program is shown in Diagram I.

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS OF DRYWELL

COMPUTER PROCESS DIAGRAM

Geometry of Coupled System Read

Member Moments of Inertia, Cross-Sectional Areas, Effective Shear Areas and Elastic Moduli Read

Foundation Springs Stiffness Read

Design Earthquake Read

Coupled System Stiffness Matrix Generated

Coupled System Mode Shapes and Frequencies Calculated

Coupled System's Generalized Coordinates Calculated

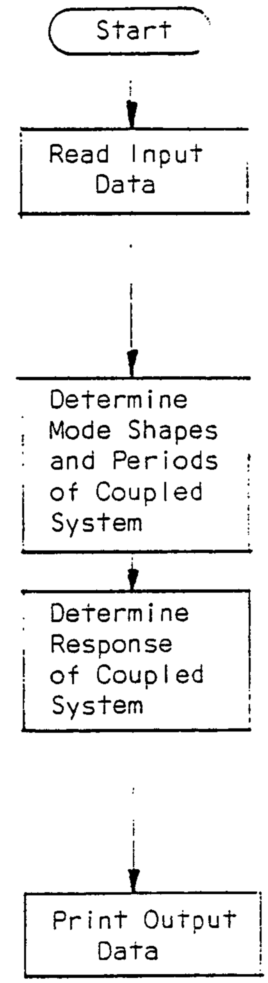
Coupled System's Displacements, Accelerations, Moments and Shears Calculated

Coupled System's Mode Shapes and Frequencies Printed

Coupled System's Displacements, Accelerations, Moments and Shears Printed

Force in Shear Lug Printed

Drywell Displacements Relative to Reactor Building Printed



RESULTS

The analysis was performed with the aid of an IBM 1130 digital computer. A damping value of three percent was assigned to all modes of the coupled system. The influence of seventh and higher modes of vibration was considered negligible and, therefore, ignored in the coupled system's response calculations.

Periods

The following table summarizes the natural periods of vibration for the coupled system in the east-west and the north-south directions for both empty and flooded conditions of drywell.

Periods of Vibration in Seconds

Mode of Vibration	East-West Direction		North-South Direction	
	Drywell Empty	Drywell Flooded	Drywell Empty	Drywell Flooded
First	0.542	0.556	0.590	0.597
Second	0.222	0.223	0.208	0.210
Third	0.185	0.187	0.180	0.181
Fourth	0.052*	0.103*	0.053*	0.103*
Fifth	0.045	0.052	0.041	0.053
Sixth	0.039	0.045	0.040	0.045

* Reflects fundamental period of the drywell

Response

The envelopes of maximum absolute accelerations, maximum shears, maximum moments and maximum displacements (relative to the base of the reactor building) induced by seismic loading in the east-west direction are presented in Appendix Sheets 4, 5, 6, and 7 respectively.

Similar results for seismic loading in the north-south direction are presented in Appendix Sheets 8 through 11.

Maximum displacements of empty drywell relative to the reactor building for earthquake acting in north-south direction are presented in Appendix Sheet 12.

Forces and Displacement at Shear Lug

The following table gives the maximum value of force, in drywell shear lug at elevation 992'-5-1/2", induced during the excursions of the design earthquake.

(Note: Maximum force includes effect of drywell only)

Case	East-West Direction	North-South Direction
Drywell Empty	81 Kips	111 Kips
Drywell Flooded	90 Kips	138 Kips

The maximum displacement of the empty drywell at shear lug elevation relative to its embedment point at elevation 917'-11-3/16" is 33 mils. This does not include displacement due to rotation or translation of the base of the reactor building.

Hydrodynamic Effect

Based upon experience with other drywell structures, the resulting effect of hydrodynamics is to reduce the total seismic forces. Because of this, the effects of the dynamic response of the fluid in the drywell are conservatively neglected in this seismic analysis.

RECOMMENDATIONS

The subject drywell should be designed on the basis of the results presented herein. The final design of the drywell should be reviewed for

twice the design parameters presented herein. In addition to the horizontal acceleration presented herein, a vertical acceleration of 0.04 gravity acting simultaneously with the horizontal acceleration is recommended for design, and twice this value is recommended in evaluating the ability of the plant to safely shut down.

Critical pieces of equipment which are not rigidly attached to the drywell should not be designed on the basis of the results presented herein, but should be investigated separately to determine the effect of the interaction of the equipment and drywell.

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS OF DRYWELL

REFERENCES

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

2. Monticello Nuclear Generation Plant Earthquake Analysis, Reactor Building, John A. Blume & Associates, Engineers, July 18, 1967.

3. Drawings

    a. G. E. Dwg. No. 719 E 147

    b. C.B.I.Calculation Sheets, dated 9-2-66.

4. 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.

5. 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.

6. Dynamic Effects of Earthquakes, by R. W. Clough, Transaction of the American Society of Civil Engineers, Paper No. 3252.

7. Large Capacity Multistory Frame Analysis Programs, by R. W. Clough, Edward L. Wilson and Ian P. King, Journal of the American Society of Civil Engineers, ST 4, August 1963.

APPENDIX

DATA AND DESIGN FIGURES

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS OF DRYWELL

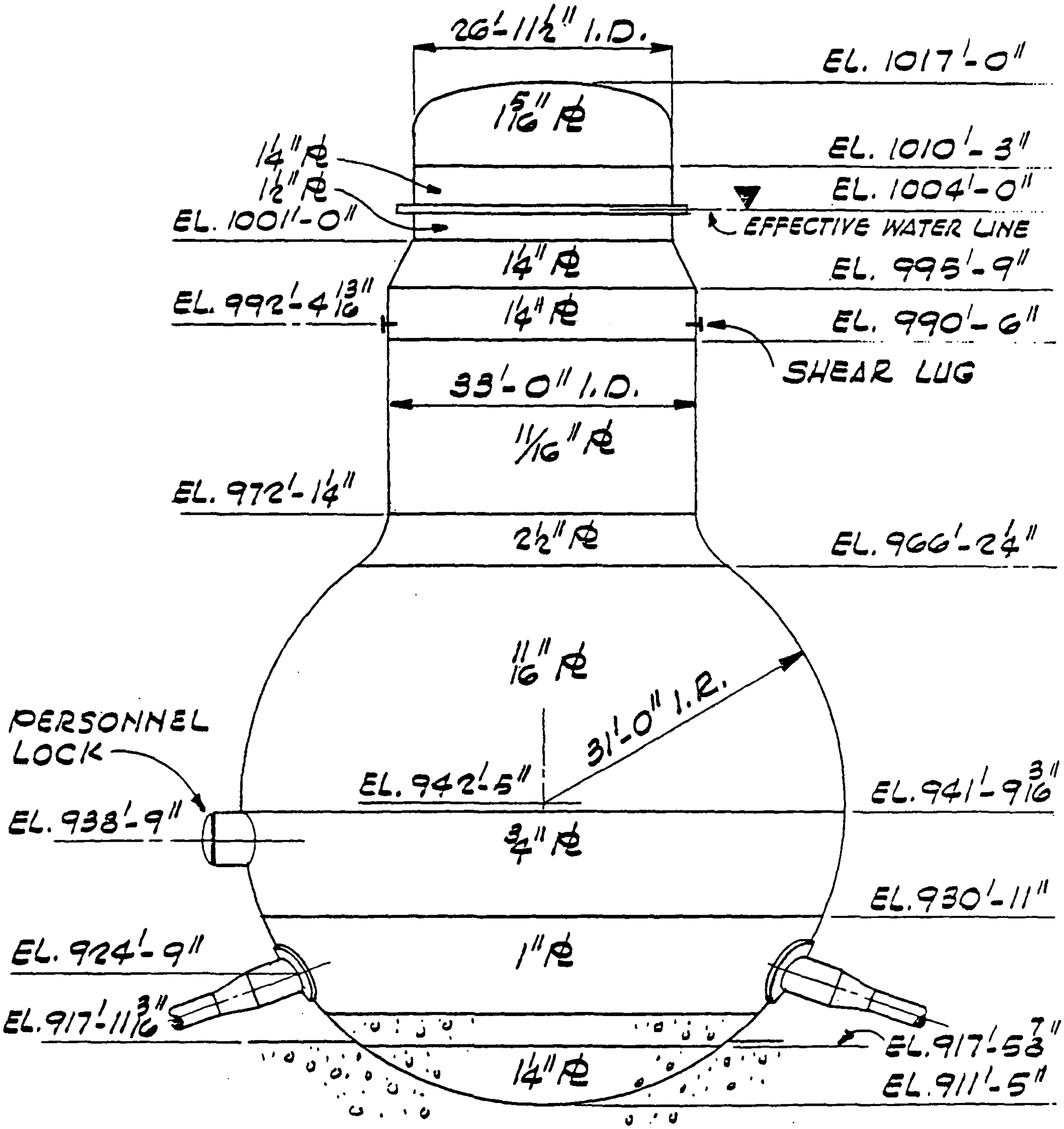
LIST OF FIGURES

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

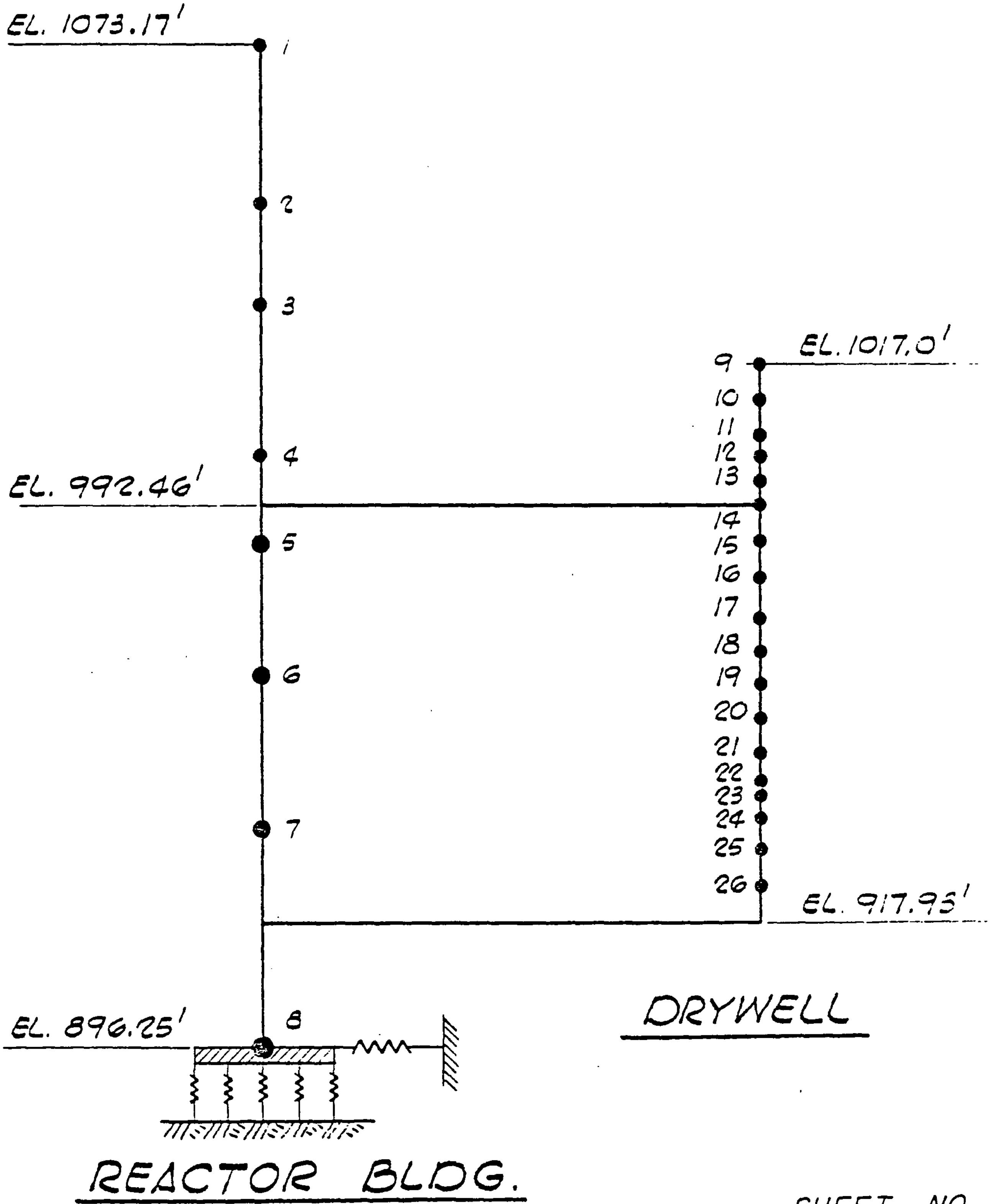
SEISMIC ANALYSIS

GEOMETRIC FIGURE



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL
SEISMIC ANALYSIS
MATHEMATICAL MODEL



SHEET NO. 2

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

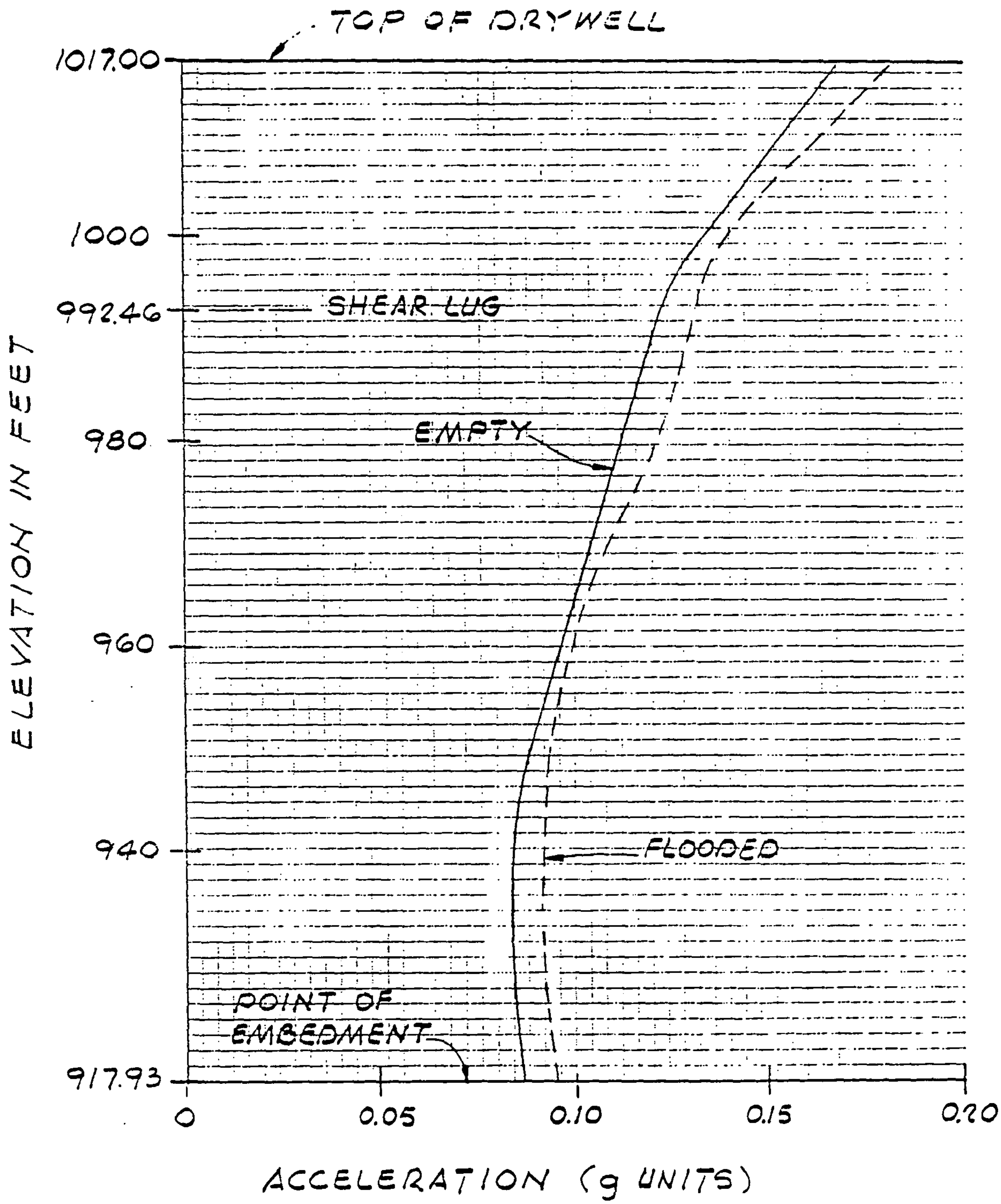
SEISMIC ANALYSIS

LUMPED MASSES & SECTION PROPERTIES

Elevation	Node	MASS (K-SEC.²/FT.) EMPTY CASE	MASS (K-SEC.²/FT.) FULL CASE	LENGTH (FT.)	I (FT.⁴)	A (FT.²)
ELEV. 1017.0'	9	0.92	0.92			
				6.75	851.8	9.29
	10	1.20	1.20			
				6.25	810.3	8.35
	11	2.42	2.67			
				3.00	974.6	10.63
	12	0.72	1.76			
				5.25	1113.1	9.34
	13	0.77	3.47			
				3.29	1483.3	10.35
ELEV. 992.46'	14	1.46	5.11			
				6.79	750.0	5.49
	15	0.60	5.50			
				6.79	750.0	5.49
	16	0.60	5.50			
				6.78	750.0	5.49
	17	1.63	6.03			
				5.91	4046.5	23.72
	18	2.02	10.60			
				5.94	2380.0	8.49
	19	1.06	18.66			
				5.94	3792.0	9.93
	20	1.40	25.39			
				5.94	4818.5	10.76
	21	1.66	29.62			
				5.95	5326.0	11.13
	22	0.59	16.76			
				0.65	5372.0	11.16
	23	0.58	15.44			
				5.43	5712.0	12.08
	24	1.20	26.54			
				5.42	5063.0	11.59
	25	1.51	25.92			
				6.49	5061.0	14.03
	26	1.68	24.41			
ELEV. 917.93'				6.50	2736.0	11.36

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL
SEISMIC ANALYSIS
ACCELERATION DIAGRAM
E-W DIRECTION



SHEET NO. 4

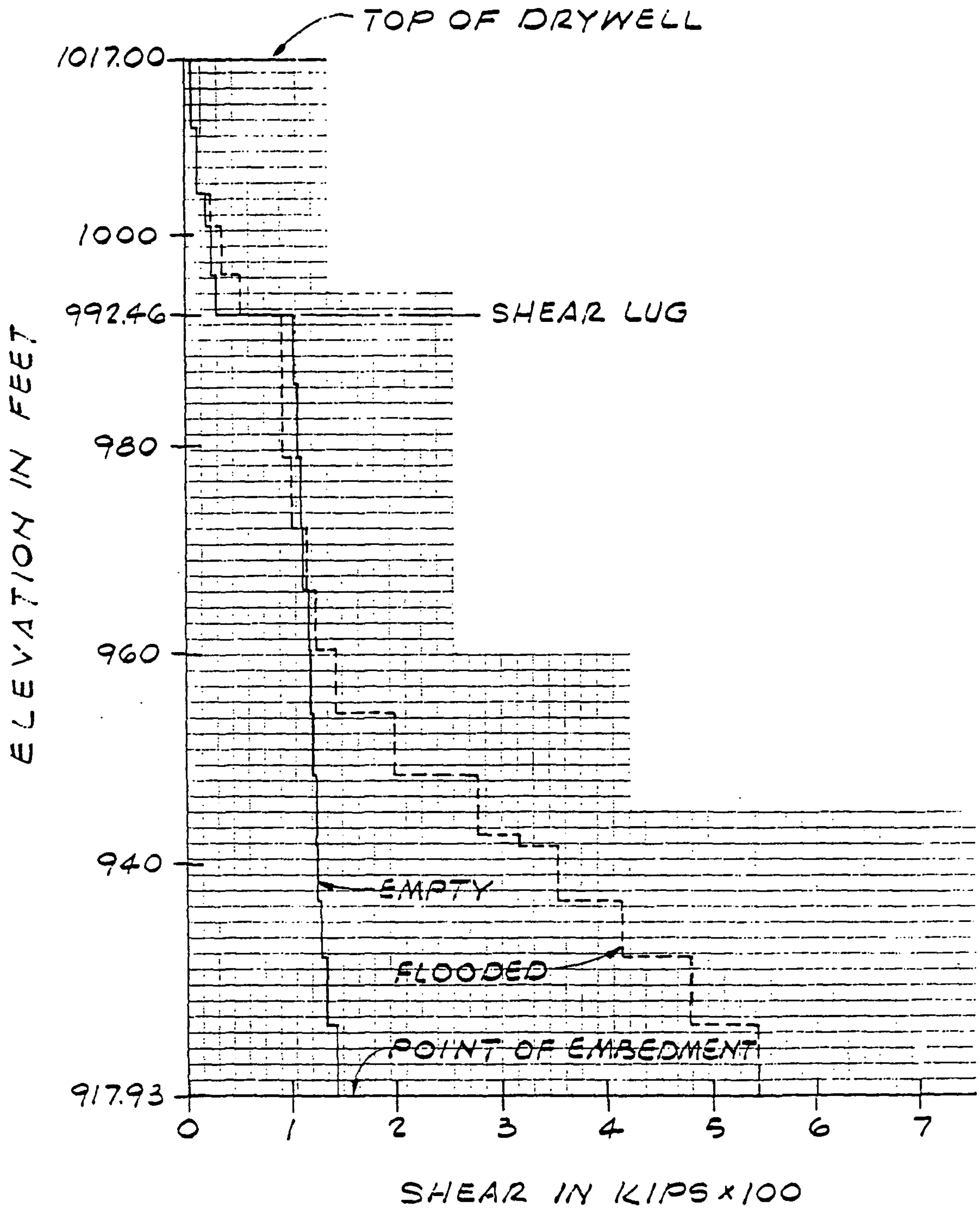
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

SEISMIC ANALYSIS

SHEAR DIAGRAM

E-W DIRECTION

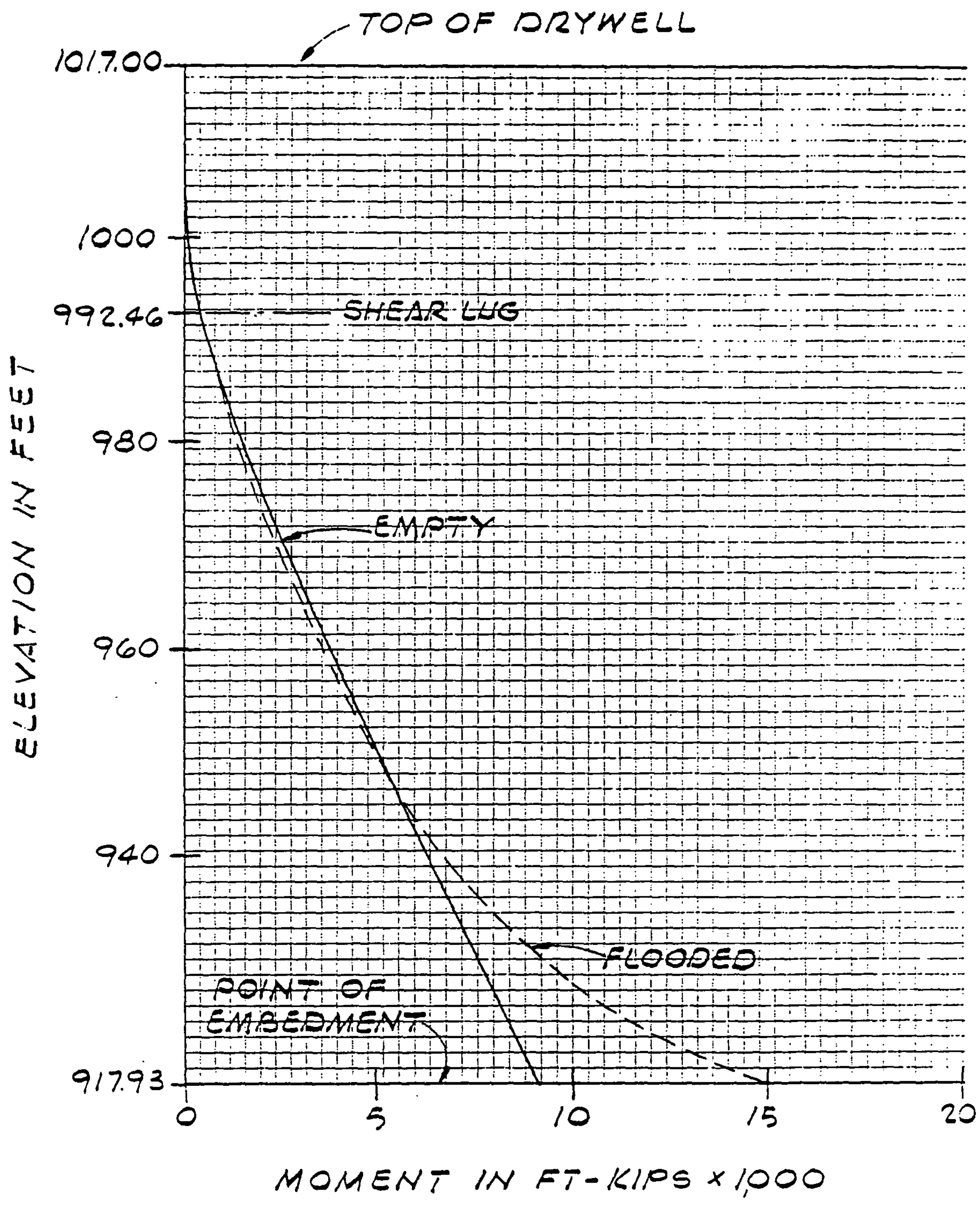


SHEET NO. 5

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL
SEISMIC ANALYSIS

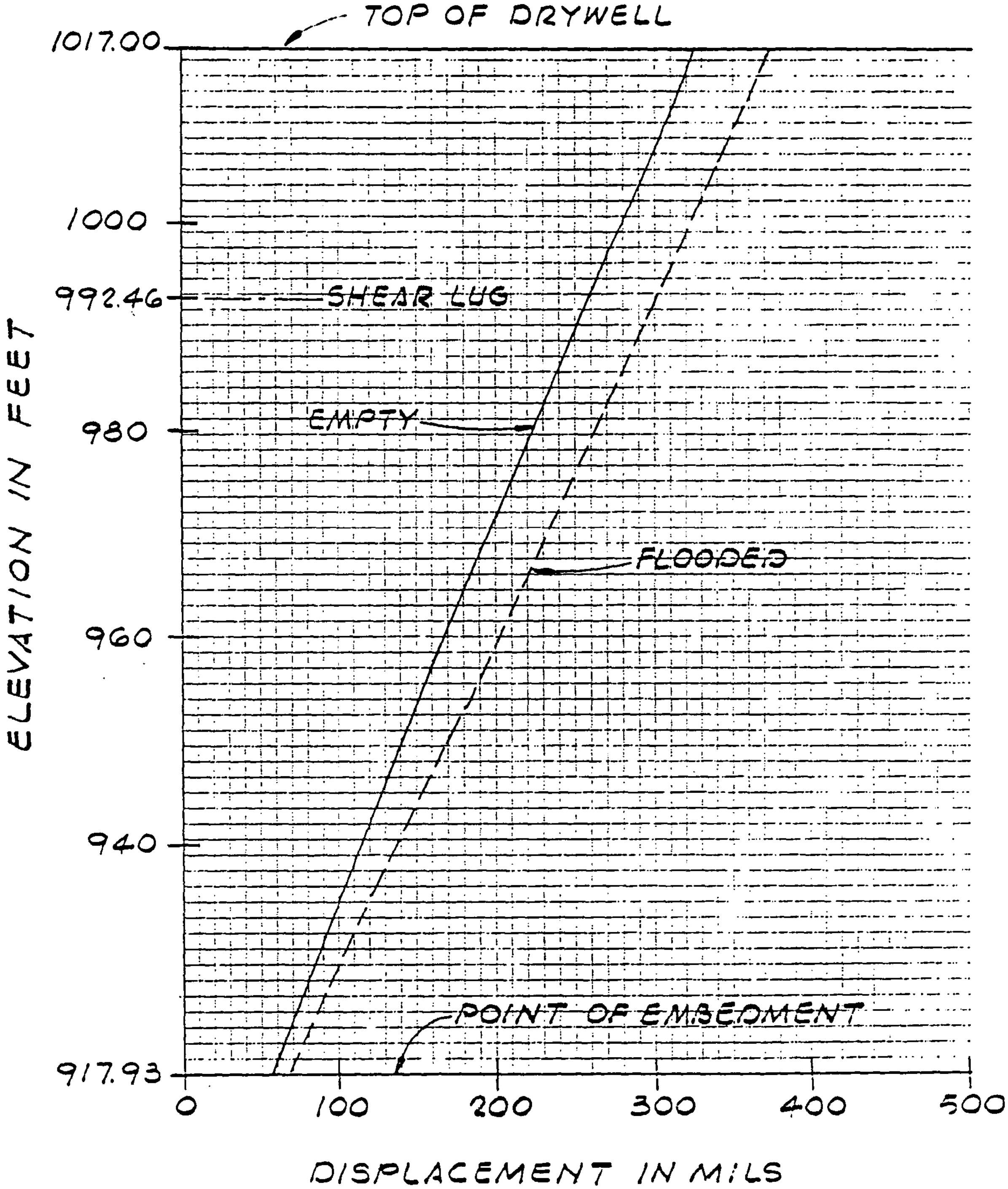
MOMENT DIAGRAM
E-W DIRECTION



SHEET NO. 6

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL
SEISMIC ANALYSIS
DISPLACEMENT DIAGRAM
E-W DIRECTION



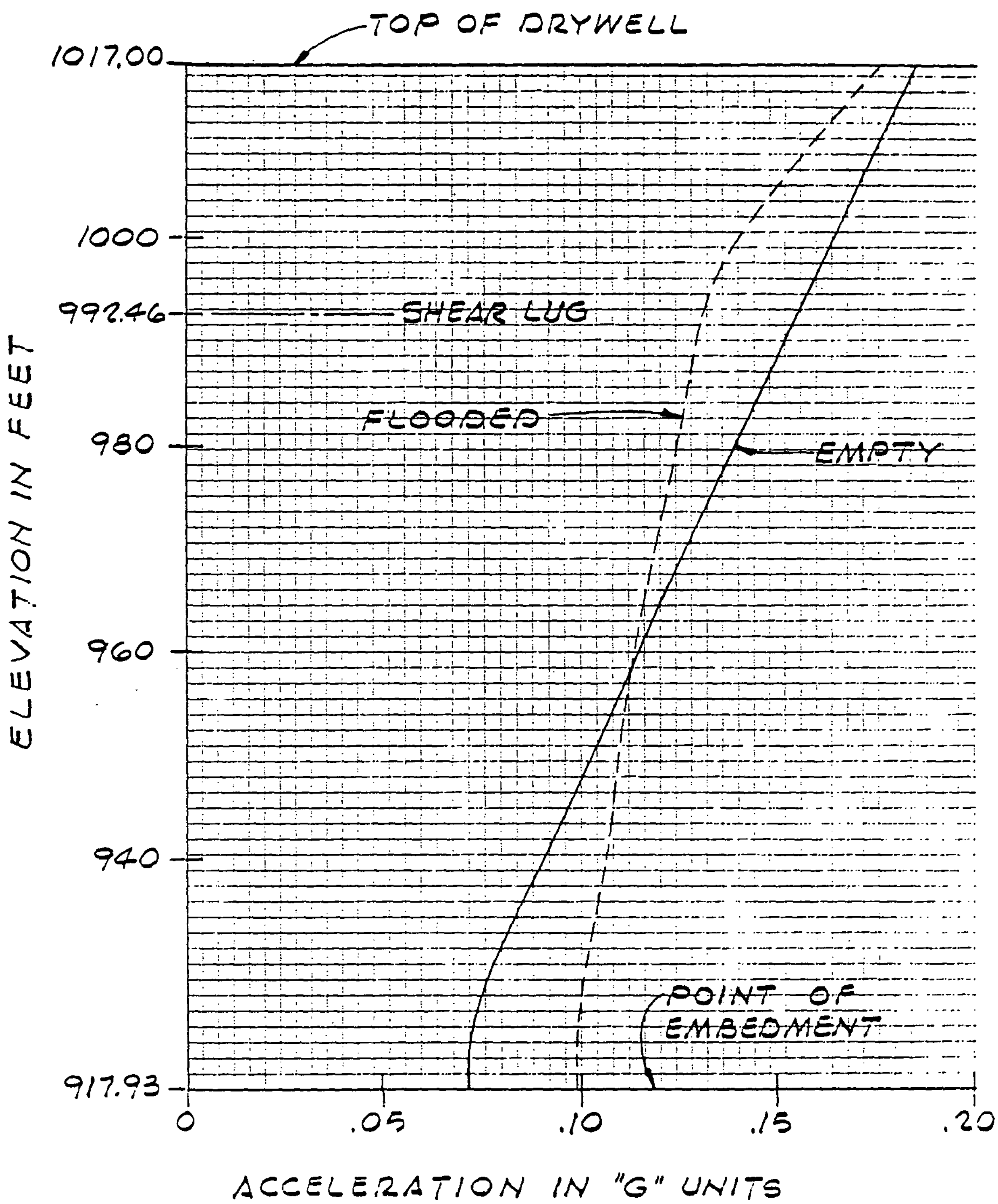
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

SEISMIC ANALYSIS

ACCELERATION DIAGRAM

N-S DIRECTION



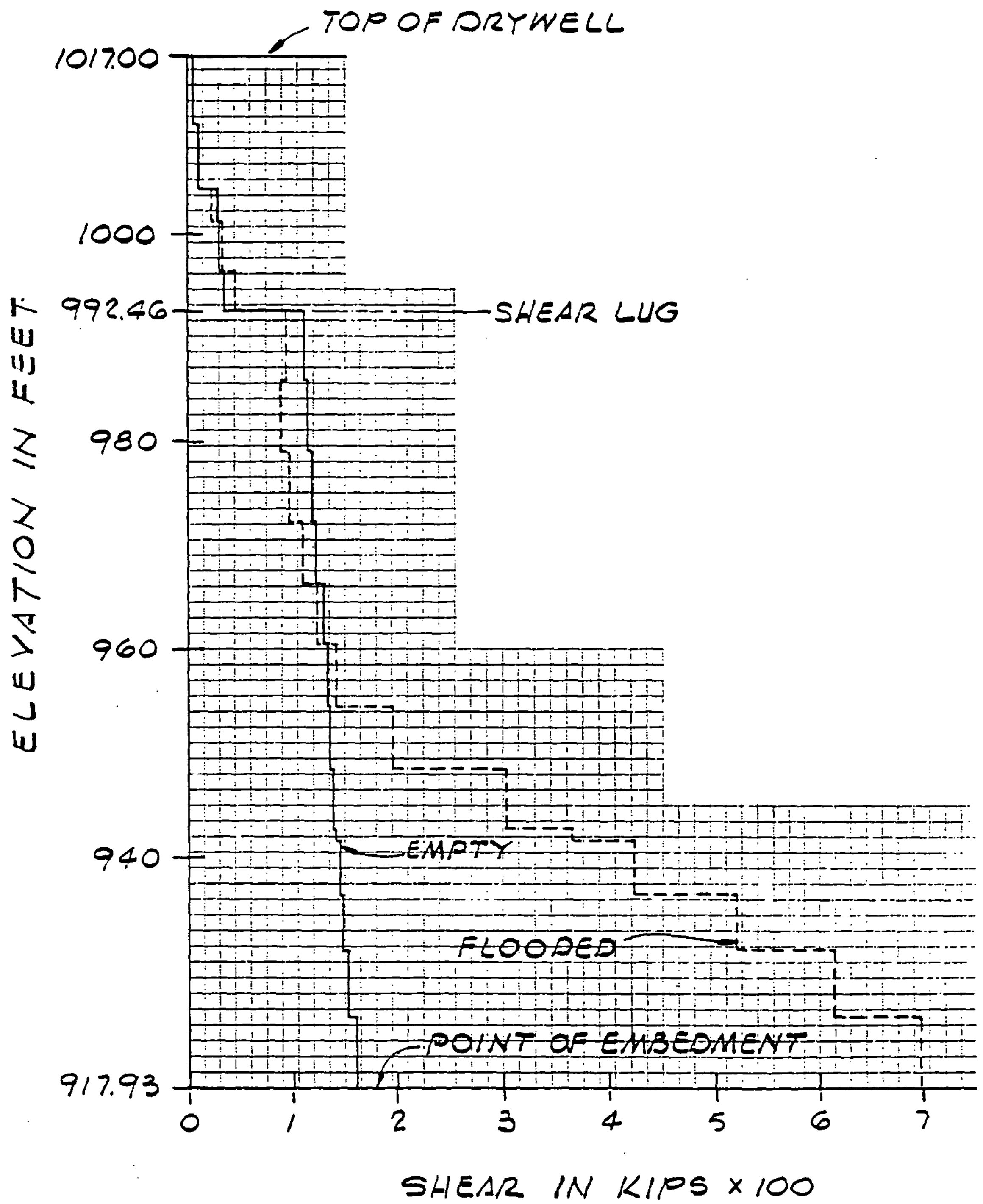
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

SEISMIC ANALYSIS

SHEAR DIAGRAM

N-S DIRECTION



SHEET NO. 9

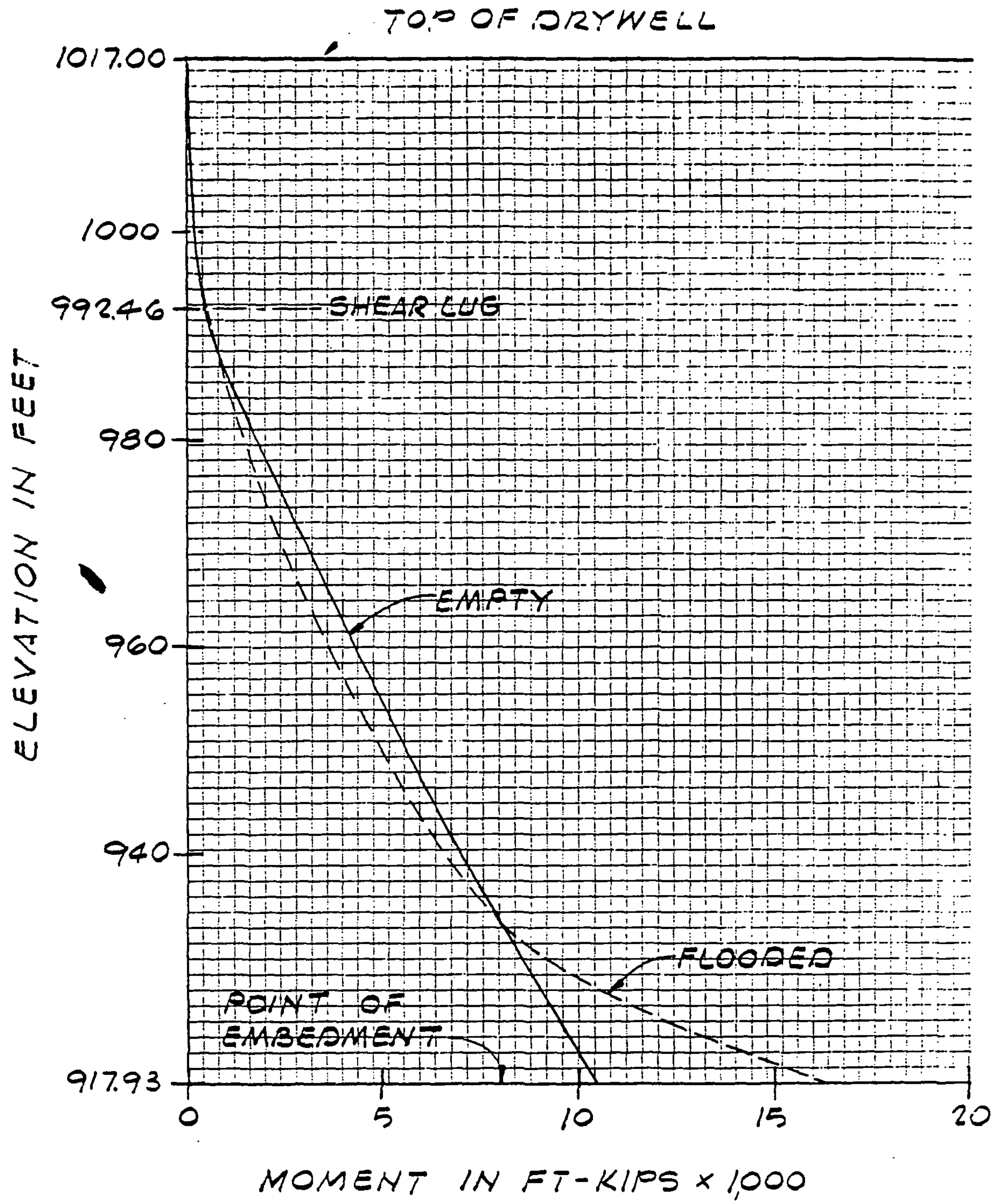
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

SEISMIC ANALYSIS

MOMENT DIAGRAM

N-S DIRECTION



SHEET NO. 10

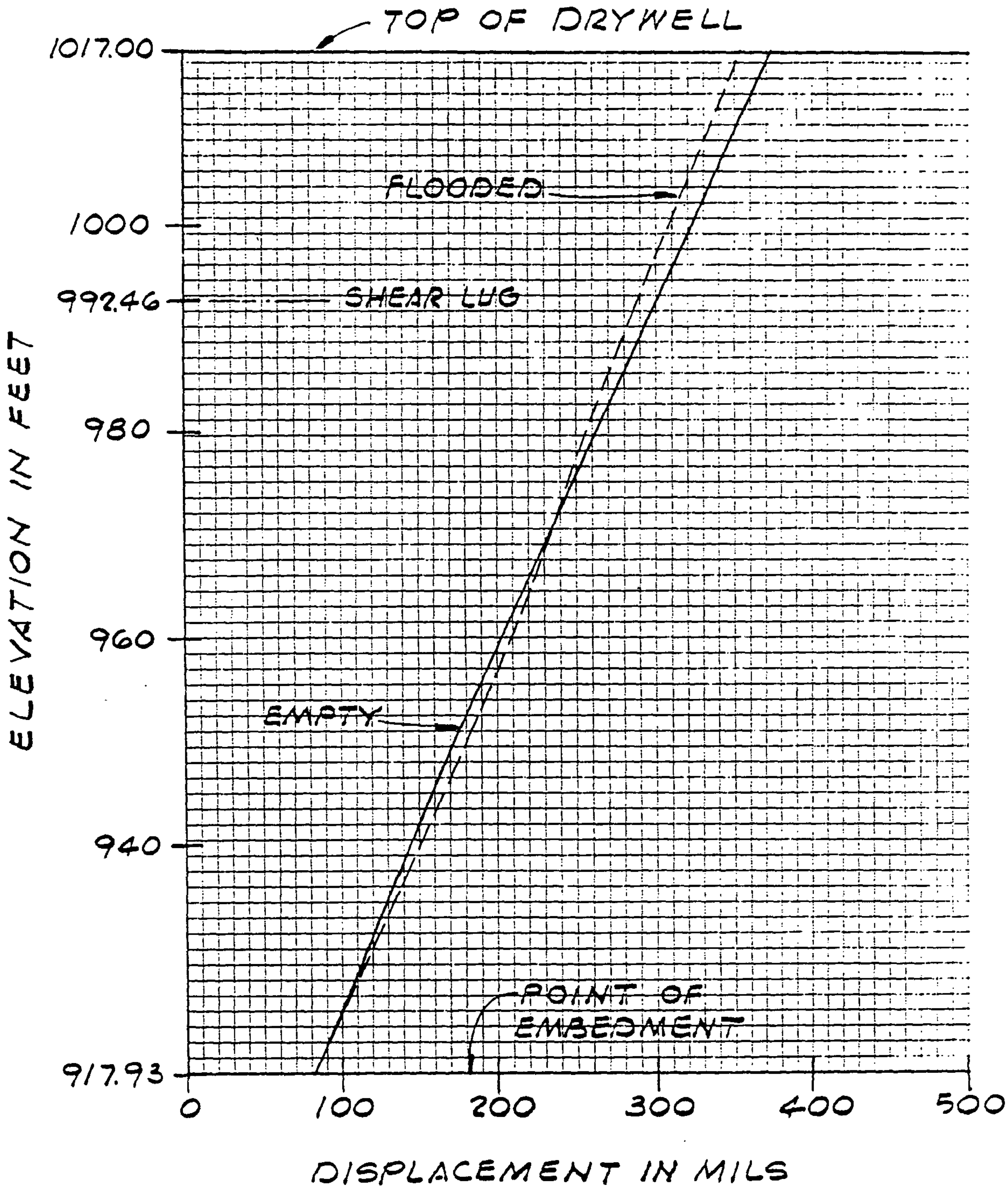
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL

SEISMIC ANALYSIS

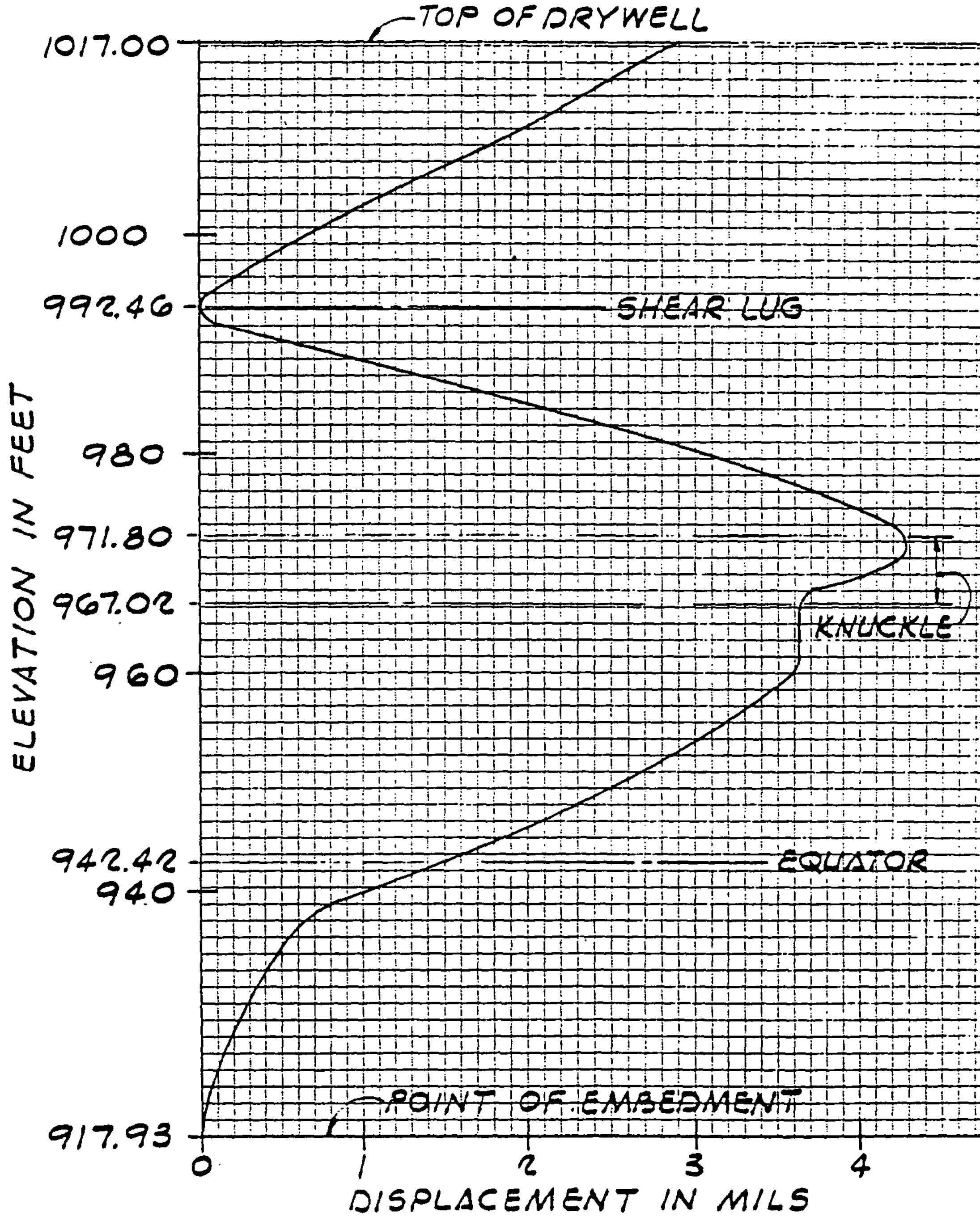
DISPLACEMENT DIAGRAM

N-S DIRECTION



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO DRYWELL
SEISMIC ANALYSIS
MAXIMUM DRYWELL DISPLACEMENTS RELATIVE TO REACTOR BUILDING DRYWELL EMPTY N-S DIRECTION

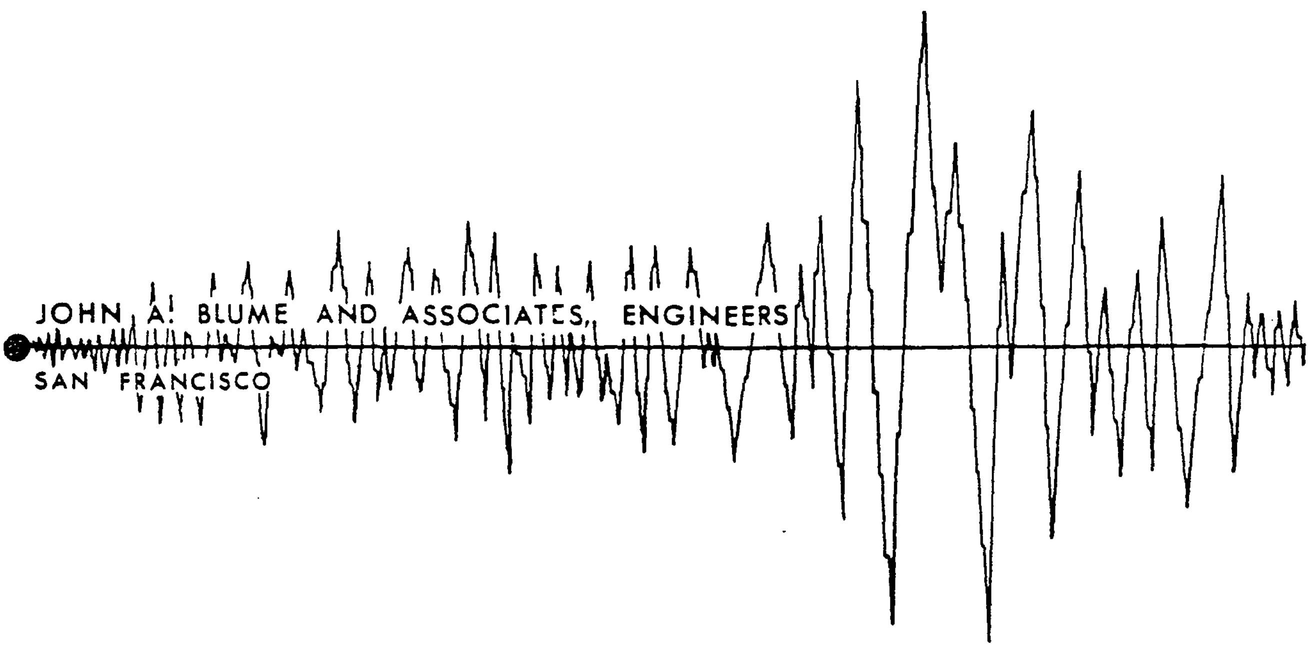


SHEET NO. 12

GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPARTMENT

MONTICELLO NUCLEAR GENERATION PLANT

EARTHQUAKE ANALYSIS: REACTOR PRESSURE VESSEL



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SAN FRANCISCO

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EDWARD J. KEITH
LLOYD A. LEE
RALPH T. YOKOYAMA

July 28, 1967

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
Report on Earthquake Analysis of
Reactor Pressure Vessel

Gentlemen:

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

The analysis assumes soil properties as described in the report on Earthquake Analysis of Reactor Building prepared by this office for the subject generation plant.

This report summarizes the analytical procedures and results for the seismic analysis of Monticello Reactor Pressure Vessel. The response of reactor pressure vessel to jet load reactions is also included.

The results presented herein should be used in review of the final designs' seismic adequacy and to determine whether any changes in soil or structural properties would warrant further earthquake analysis.

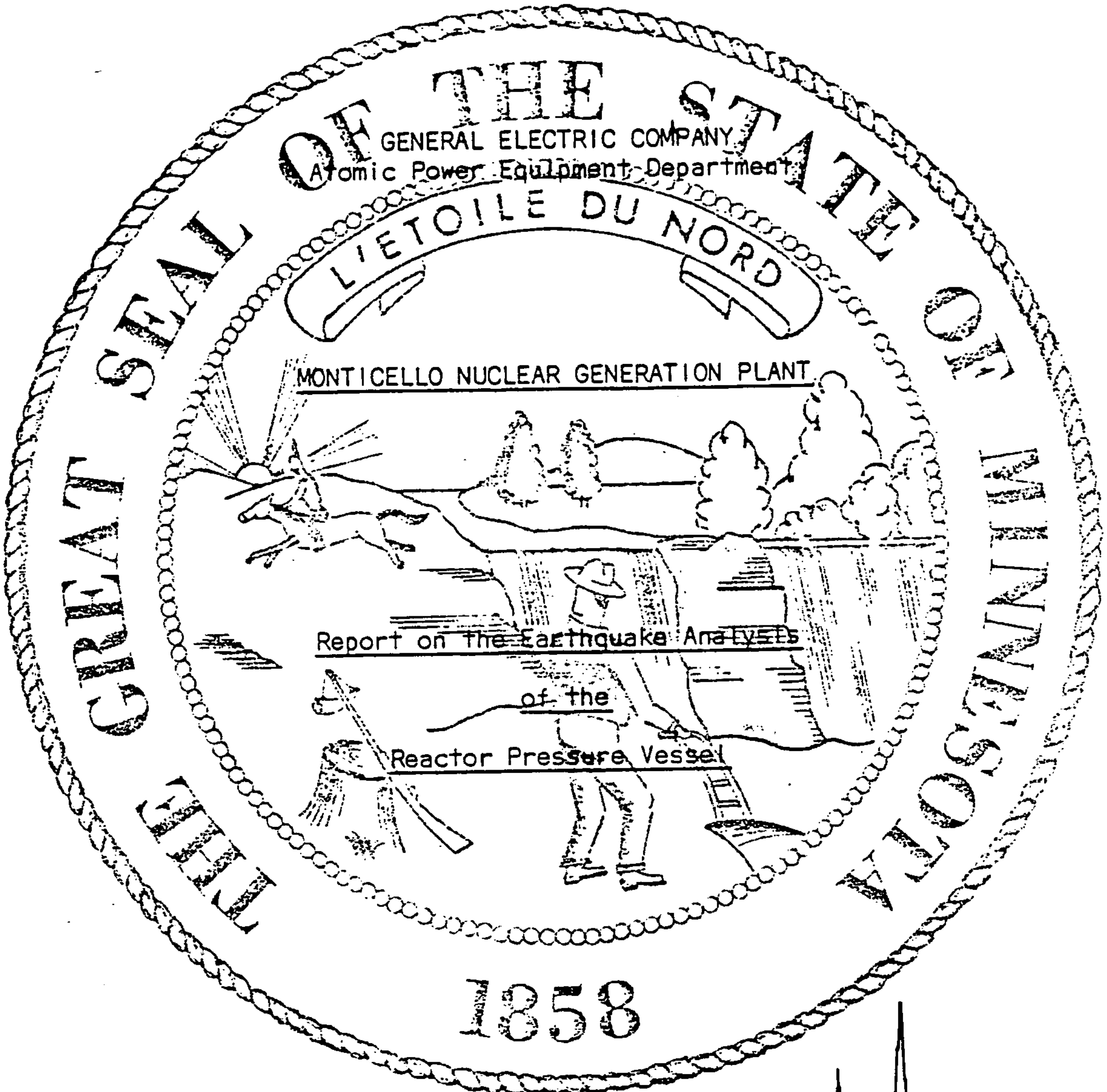
Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

E. J. Keith
Assistant Vice President

EJK/ss

GENERAL ELECTRIC COMPANY
Atomic Power Equipment Department



MONTICELLO NUCLEAR GENERATION PLANT

Report on the Earthquake Analysis of the Reactor Pressure Vessel

JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

MONTICELLO NUCLEAR GENERATION PLANT
REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS

TABLE OF CONTENTS — Page

MONTICELLO NUCLEAR GENERATION PLANT
REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS

INTRODUCTION

The purpose of this report is to summarize the results of the seismic investigation of the Monticello Nuclear Generation Plant Reactor Pressure Vessel. Based on the recommended earthquake design criteria 1, design envelopes of maximum acceleration, displacement, moment and shear have been developed and are presented herein. In addition, the response of the reactor pressure vessel to the jet load reactions has also been determined and is presented.

Some minor differences exist between the known RPV component weights as compared to those used in this analysis. The differences result in a net decrease in weight that is a small percentage of overall system mass. Therefore, Monticello recognizes this analysis as providing conservative results for the RPV seismic response. 01245382

DESCRIPTION OF REACTOR PRESSURE VESSEL

The reactor pressure vessel consists of a 63' - 2" long cylindrical shell having an inside diameter of 17' - 1". It is supported by concrete pedestal through steel skirt. Lateral support is provided by stabilizers between reactor pressure vessel and shield wall at El. 994' - 2". A truss consisting of 16' - 10" XXS pipes between shield wall and reactor building laterally support the shield wall at El. 992' - 5½". Geometric relation between reactor pressure vessel, shield wall, pedestal wall and reactor building is shown in Appendix A, Sheet 1.

MATHEMATICAL MODEL OF REACTOR PRESSURE VESSEL

The entire Monticello reactor structure (i.e., building, drywell, pressure vessel and shield) was mathematically modeled as a 27 mass coupled system. The system couples model described in previous report[2] with the shield wall, reactor pressure vessel and pedestal wall. The mathematical model is shown in Appendix A, Sheet 2.

ANALYTICAL PROCEDURES PERIODS AND MODE SHAPES

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

$$\left[\underline{K} - \omega_n^2 \underline{M}\right] \underline{\Phi_n} = \underline{0} \qquad (1)$$

Where $\underline{K}$ = Stiffness matrix of coupled system.

$\underline{\Phi_n}$ = Mode shape of the n^{th} mode.

ω_n = Natural circular frequency of the n^{th} mode.

$\underline{M}$ = Mass matrix.

$\underline{0}$ = Null matrix.

ANALYTICAL PROCEDURES - RESPONSE

With mode shapes and frequencies calculated, the generalized coordinate response can be calculated by solution of Equation (2).

$$\underline{\ddot{Y}_n(t)} + 2\omega_n\lambda_n \underline{\dot{Y}_n(t)} + \omega_n^2 \underline{Y_n(t)} = \frac{R_n}{M_n^*} \underline{\ddot{U}_g(t)} \qquad (2)$$

Where $\underline{Y_n(t)}$ = Generalized coordinate vector for the n^{th} mode.

$$= \frac{R_n}{M_n^* \omega_n} \int_0^t \ddot{U}_g(\tau)\, e^{-\lambda_n \omega_n (t-\tau)} \sin\omega_n(t-\tau)\, d\tau$$

λ_n = Damping value for the n^{th} mode, selected as 0.03 for all modes.

R_n = Participation factor of the n^{th} mode.

M_n^* = Generalized mass of the n^{th} mode.

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

$\underline{\ddot{U}_g(t)}$ = Design earthquake.

$d\tau$ = Integration interval, selected as 0.01 seconds; the Duhamel Integral is numerically integrated.

The general acceleration vector may be obtained from Equation (3).

$$\underline{\ddot{Y}_n(t)} = \underline{D_2}\ \underline{Y_n(t)} \qquad (3)$$

Where $\ddot{\underline{Y}}_n(t)$ = Generalized acceleration vector for the n^{th} mode.

$\underline{D_2}$ = Second order differentiating matrix.

The acceleration time history of the i^{th} point of the coupled system can be obtained with Equation (4).

$$\ddot{\underline{U}}_i(t) = \Phi_{in} \ddot{\underline{Y}}_n(t) \quad \text{--(4)}$$

Where $\ddot{\underline{U}}_i(t)$ = Acceleration time history of the i^{th} point of the coupled system.

Φ_{in} = Modal displacement of the i^{th} point of the coupled system for the n^{th} mode.

$$\underline{V(t)} = \underline{\Phi_n}\, \underline{Y_n(t)} \quad \text{--(5)}$$

Where $\underline{V(t)}$ = Displacement time history of the coupled system considering n modes.

The time history of inertia forces can then be determined with Equation (6).

$$\underline{Q(t)} = \underline{K}\, \underline{V(t)} \quad \text{--(6)}$$

Where $\underline{Q(t)}$ = Inertia force time history of coupled system.

Once the displacement and inertia force time histories have been established, time histories for shears and moments are easily determined. These records are scanned for maximum values to be 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.[6,7,8] Member input data for the program, except for foundation springs and lateral supports of the reactor pressure vessel and shield, are in the form of moments of inertia, areas and effective shear areas. The effects of axial and shear deformations are included in the formation of the stiffness matrices.

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 algebraic sum of each mass point's modal contribution at that particular instant of time. This results in a precise combination of mode participations.

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

MONTICELLO REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS
COMPUTER PROCESS DIAGRAM

Geometry of Coupled System Read
Member Moments of Inertia, Cross-Sectional Areas and Elastic Moduli Read
Spring Constants Read
Design Earthquake Read
Jet Load Reactions Read

Coupled System Stiffness Matrix Generated
Coupled System Mode Shapes and Frequencies Calculated

Coupled System's Generalized Coordinates Calculated
Coupled System's Displacements, Accelerations, Moments and Shears Calculated

Coupled System's Mode Shapes and Frequencies Printed
Coupled System's Displacements, Accelerations, Moments and Shears Printed
Coupled System's Displacements, Moments, Shears due to Jet Load Reactions Printed

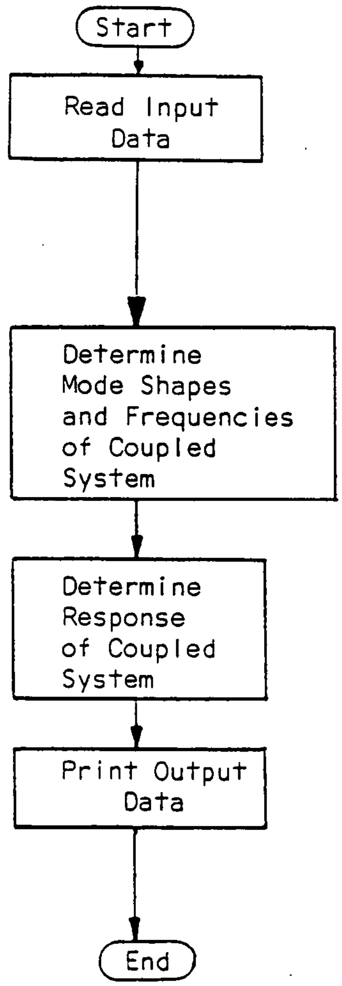


DIAGRAM I

CALCULATED DATA

Calculated data used as input to the computers is given in Appendix B. Values of the foundation springs were taken from a previous report.[2]

The following assumptions were made in calculating the spring constant between shield wall and reactor building.

(1) Compared to the truss members, the ring which consists of the concrete reactor shield is very rigid.

(2) All end reactions are tangential to the supporting ring.

(3) Young's modulus of elasticity is 4.32×10^6 K/Ft^2.

The remaining calculations result from information or drawings supplied by General Electric.[3,4]

RESULTS

The results of the seismic analysis in the form of design moment, design shear, maximum absolute acceleration and relative displacement envelopes are presented in Appendix A, Sheets 3 through 6.

Summary of spring forces is presented on Sheet 16.

Displacements, shears and moments induced in the structure due to jet reaction at steam outlet and recirculation outlet are presented in Appendix A, Sheets 7, 8, 9 and 10, 11, 12, respectively.

Forces in truss members are presented in Appendix A, Sheets 13, 14 and 15.

The previously described calculations were performed with the aid of an IBM 7094/II digital computer. The influence of 7^{th} and higher modes of vibration were considered negligible and, therefore, ignored in the coupled system's response calculations. The first 6 natural periods of vibration for the coupled system are as below:

First Mode	0.535 Seconds	Fourth Mode	0.102 Seconds
Second Mode	0.215 Seconds	Fifth Mode	0.065 Seconds
Third Mode	0.140 Seconds	Sixth Mode	0.048 Seconds

A damping value of three percent was assigned to the coupled system.

RECOMMENDATIONS

It is recommended that the subject structural elements be designed to resist the seismic shears and moments presented herein without the usual increase in stress for short term loadings. In addition, these elements should be reviewed to assure that they can resist twice the seismic shears and moments presented here without hindering the ability of the reactor plant to safely shut down. A vertical acceleration of 0.04g acting simultaneously with the horizontal accelerations included herein, is recommended for design.

MONTICELLO NUCLEAR GENERATION PLANT

REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

REFERENCES

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

2. Monticello Nuclear Generation Plant Earthquake Analysis: Reactor Building, John A. Blume & Associates, Engineers, July 18, 1967.

3. Drawings:

   General Electric

   719E110, 719E401, 719E489

   718E944, Sheet 1 through 3

   886D482, Sheet 1 and 7

   C. B. & I. Company

   VPF-1811-36-1

   VPF-1811-78-1

   VPF-1811-75-3

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7. Structural Analysis of Multistory Buildings, R. W. Clough, I. P. King and E. L. Wilson, Journal of the Structural Division of the American Society of Civil Engineers, ST3, June 1964.

8. Dynamic Effects of Earthquakes, R. W. Clough, Transactions of the American Society of Civil Engineers, Paper No. 3252.

APPENDIX A

DATA AND DESIGN FIGURES

MONTICELLO NUCLEAR GENERATION PLANT
REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS

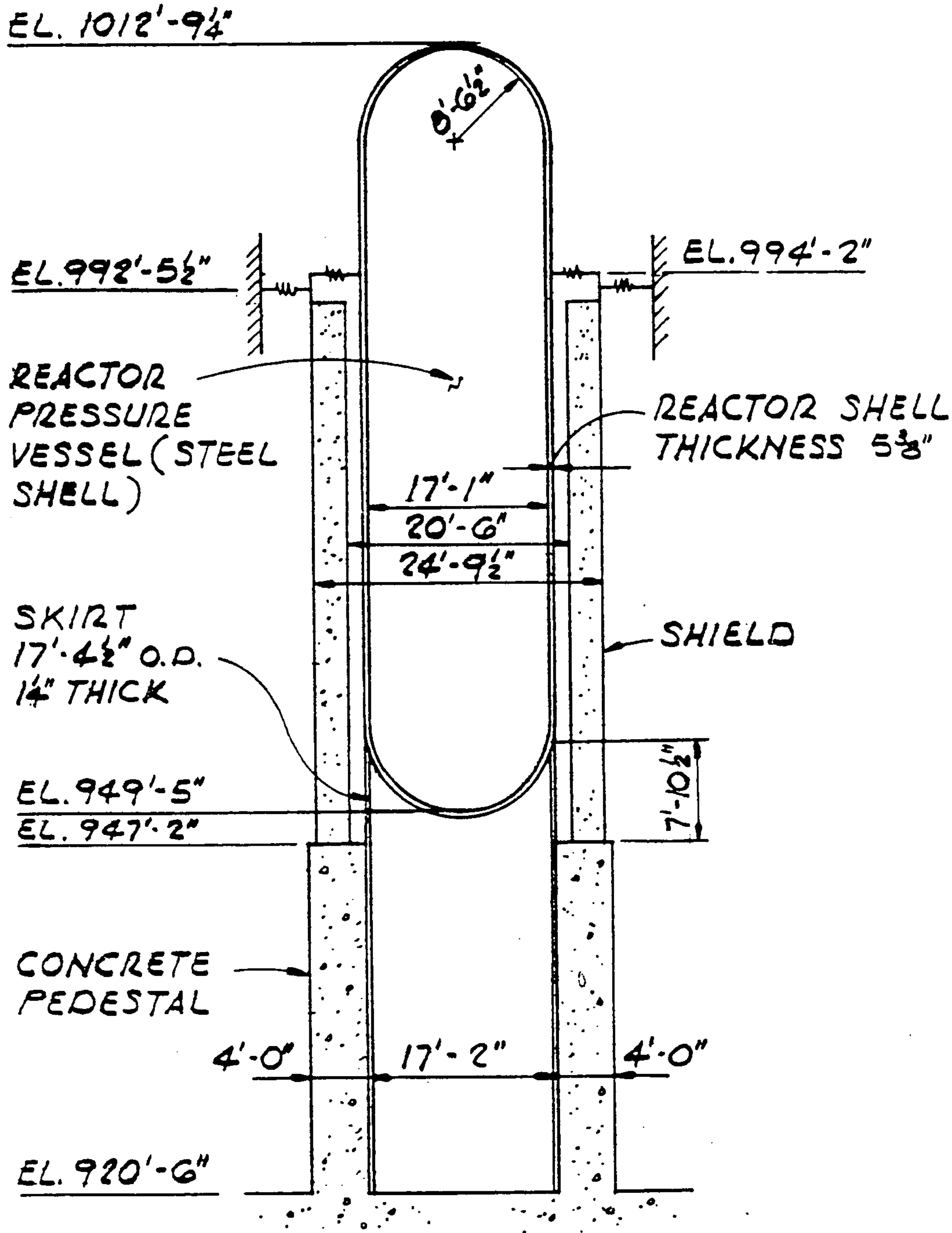
LIST OF FIGURES

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

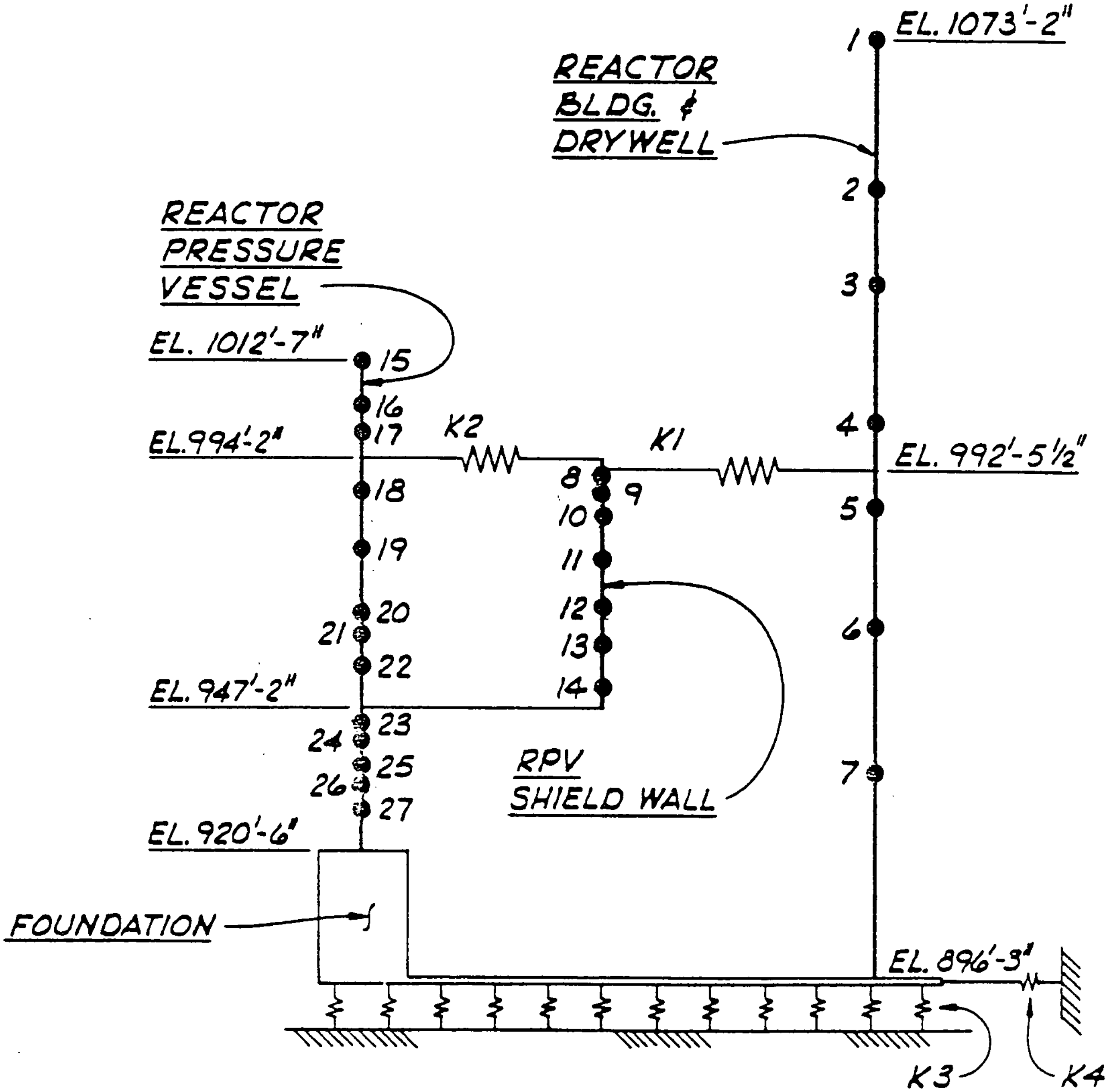
GEOMETRIC FIGURE



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

MATHEMATICAL MODEL COUPLED REACTOR BLDG. & REACTOR PRESSURE VESSEL

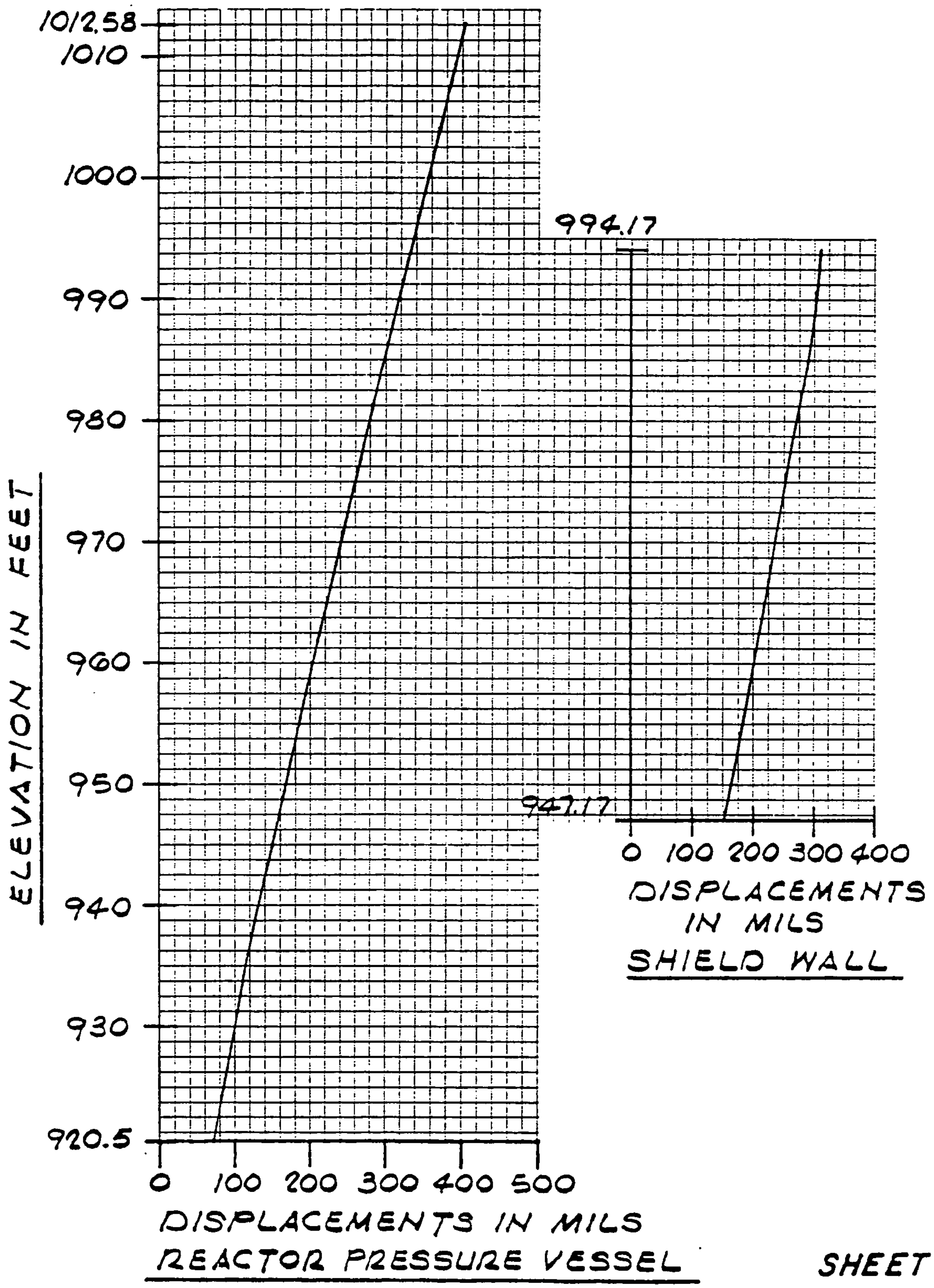


SHEET NO. 2

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

DISPLACEMENT DIAGRAM



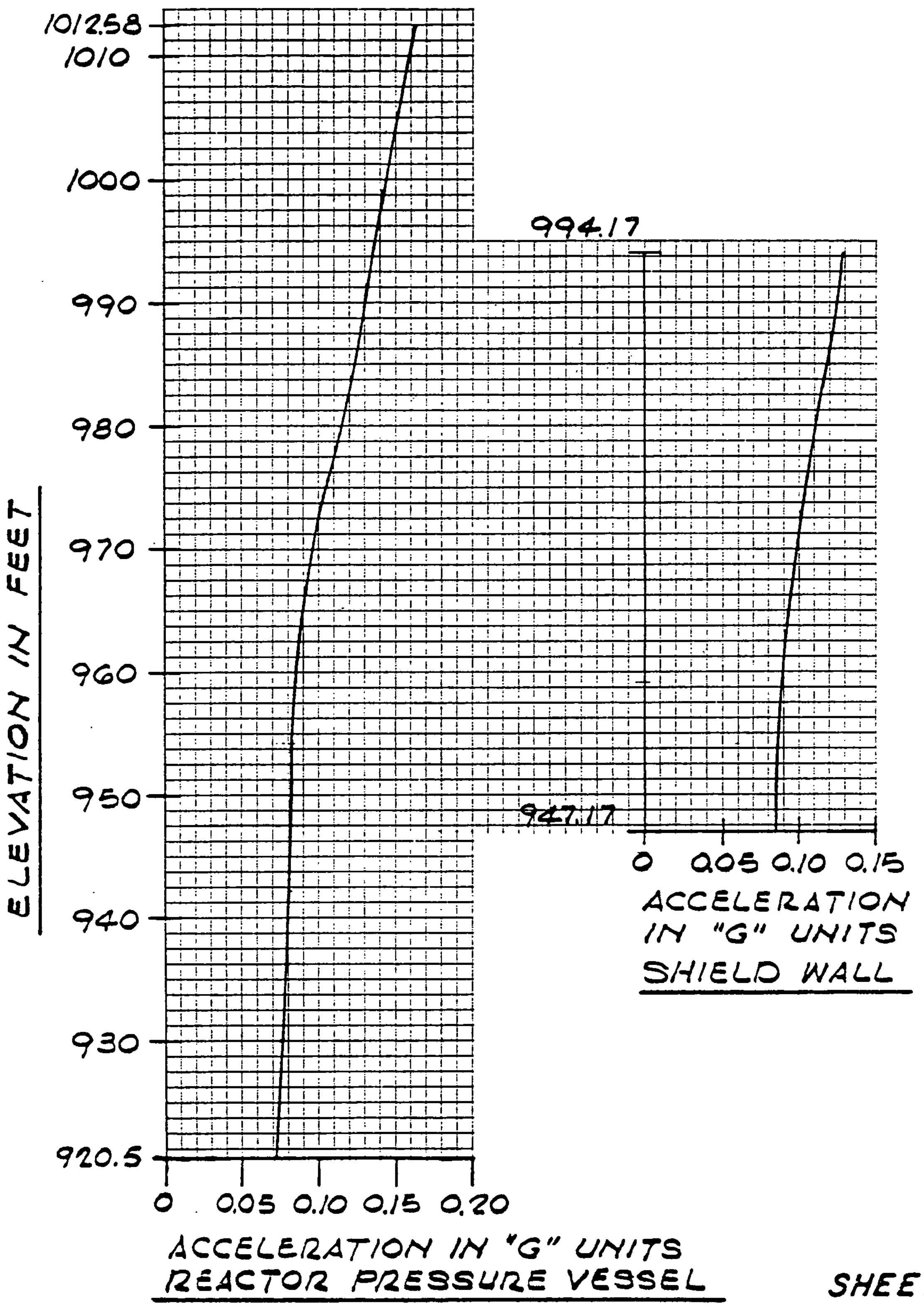
SHEET NO. 3

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

ACCELERATION DIAGRAM



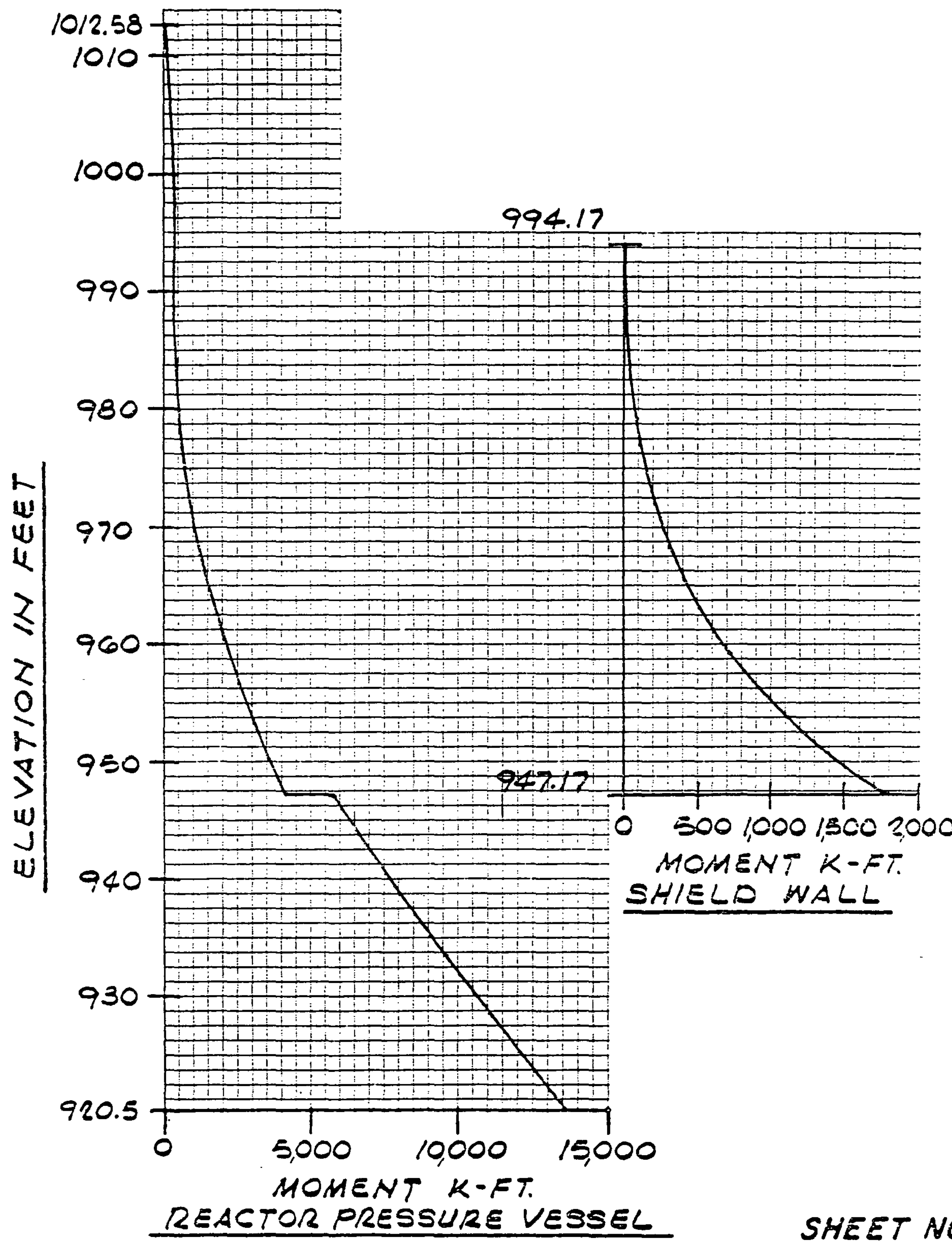
SHEET NO. 4

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

MOMENT DIAGRAM

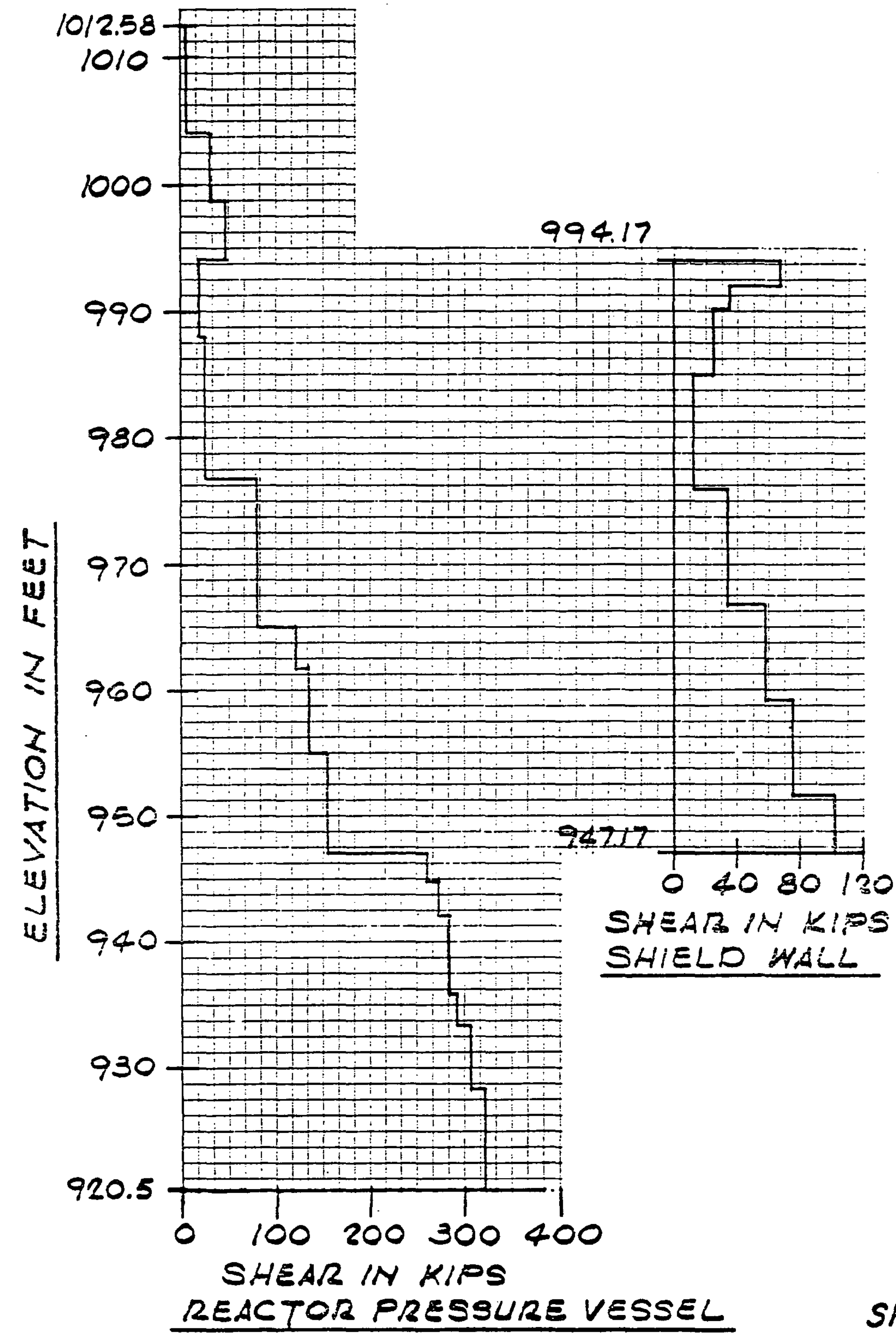


JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

SHEAR DIAGRAM



SHEET NO. 6

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

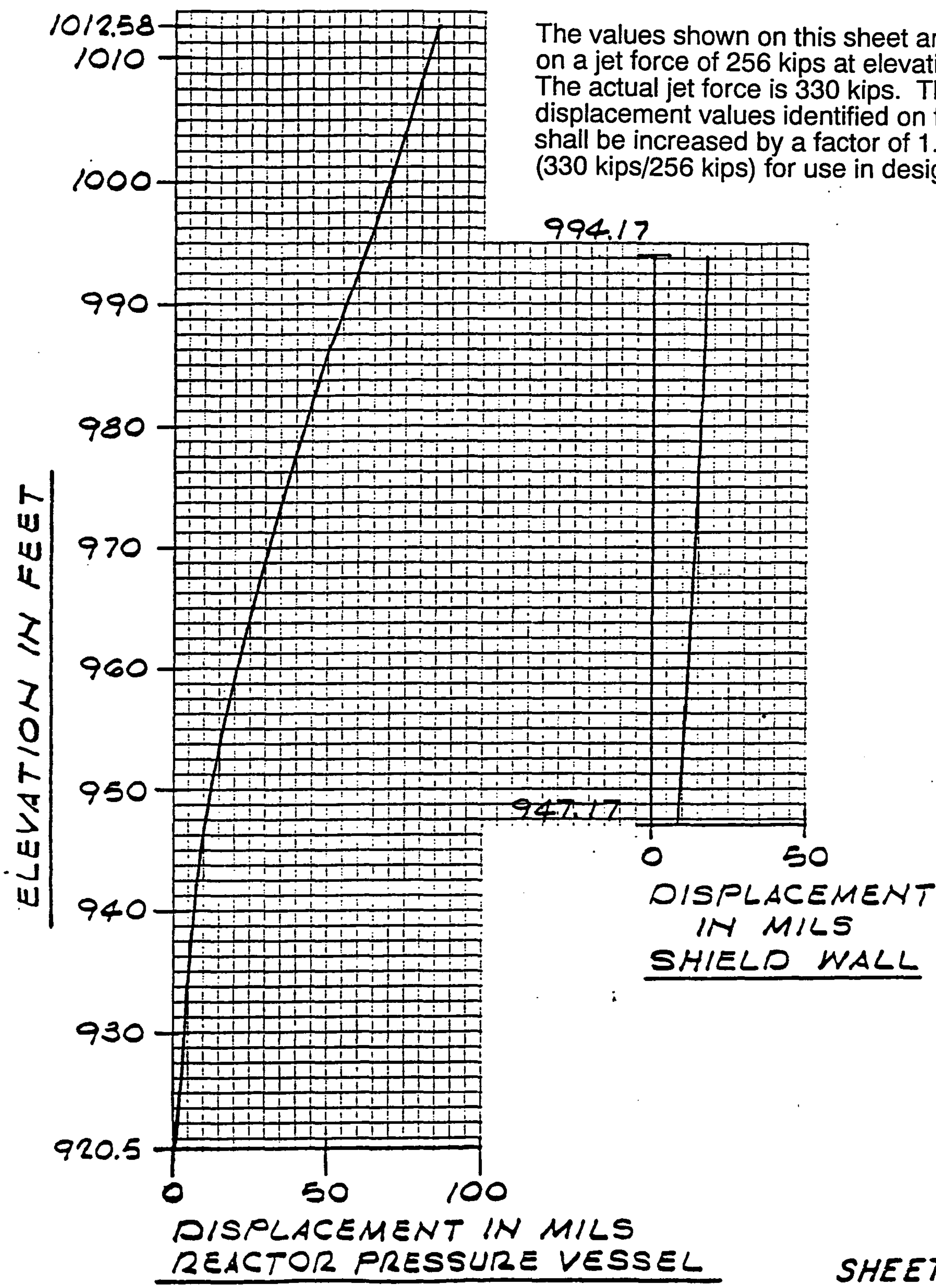
MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

DISPLACEMENT DIAGRAM

(JET LOAD 256^K @ ELEV. 999'-0" - CASE 1)

The values shown on this sheet are based on a jet force of 256 kips at elevation 999'-0". The actual jet force is 330 kips. The displacement values identified on this sheet shall be increased by a factor of 1.29 (330 kips/256 kips) for use in design.

00-206



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

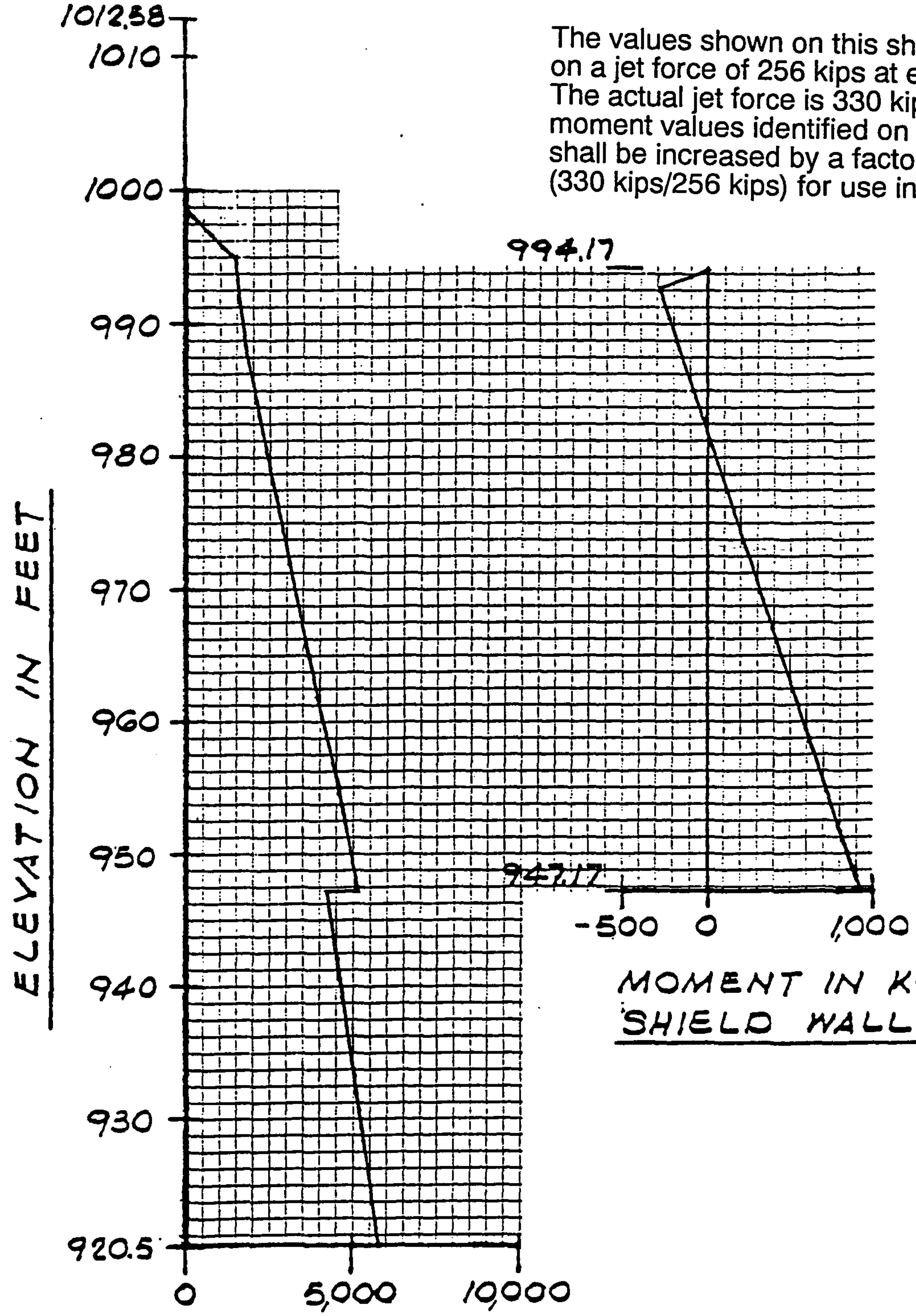
SEISMIC ANALYSIS

MOMENT DIAGRAM

(JET LOAD 256ᴷ @ ELEV. 999'-0"-CASE 1)

The values shown on this sheet are based on a jet force of 256 kips at elevation 999'-0". The actual jet force is 330 kips. The moment values identified on this sheet shall be increased by a factor of 1.29 (330 kips/256 kips) for use in design.

00-206



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

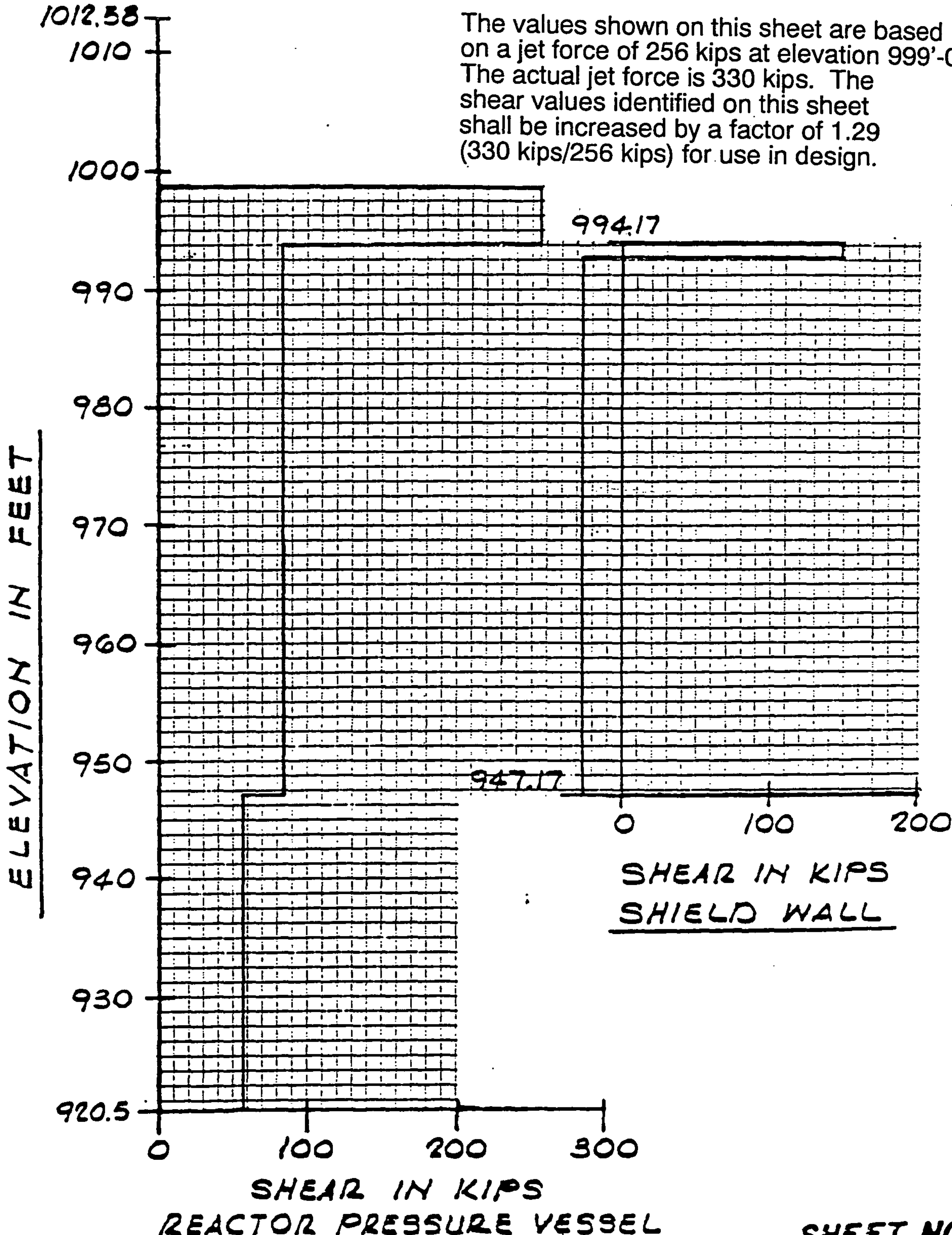
MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

SHEAR DIAGRAM

(JET LOAD 256ᴷ @ ELEV. 999'-0" - CASE 1)

The values shown on this sheet are based on a jet force of 256 kips at elevation 999'-0". The actual jet force is 330 kips. The shear values identified on this sheet shall be increased by a factor of 1.29 (330 kips/256 kips) for use in design.

00-206

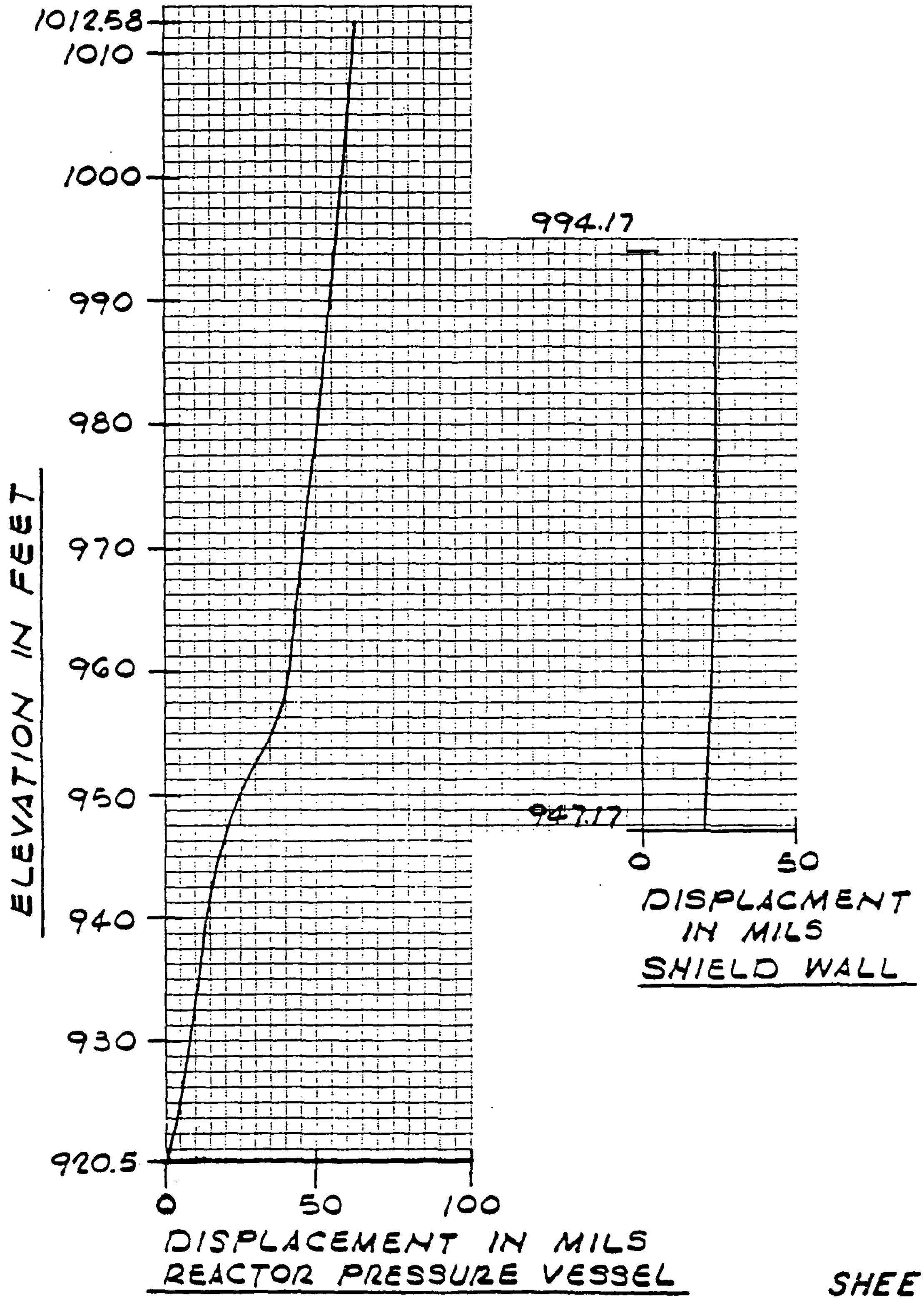


JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

DISPLACEMENT DIAGRAM

(JET LOAD 664^K @ ELEV. 961'-11" - CASE 2)



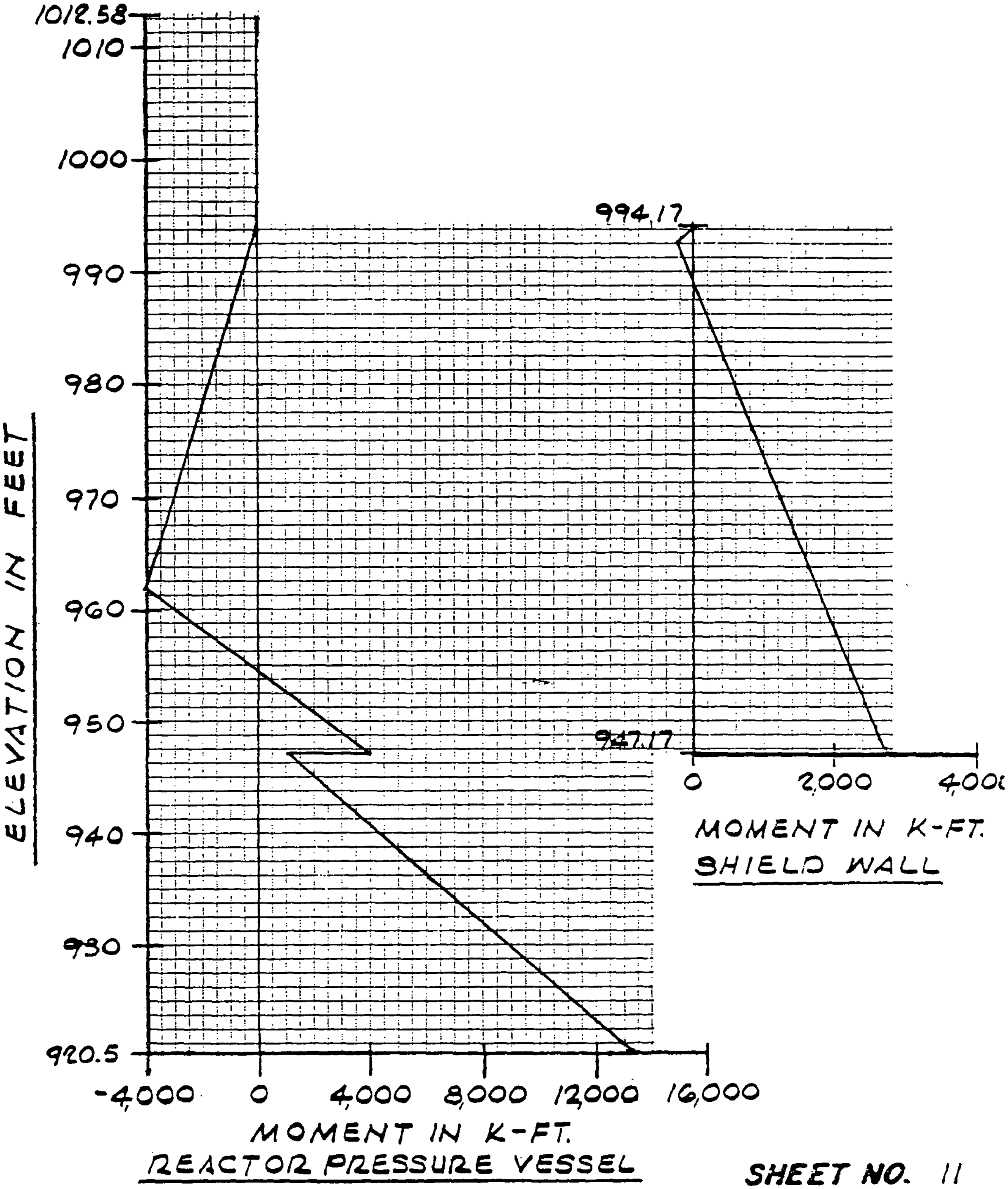
SHEET NO. 10

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

MOMENT DIAGRAM

(JET LOAD 664K @ ELEV. 961'-11" - CASE 2)

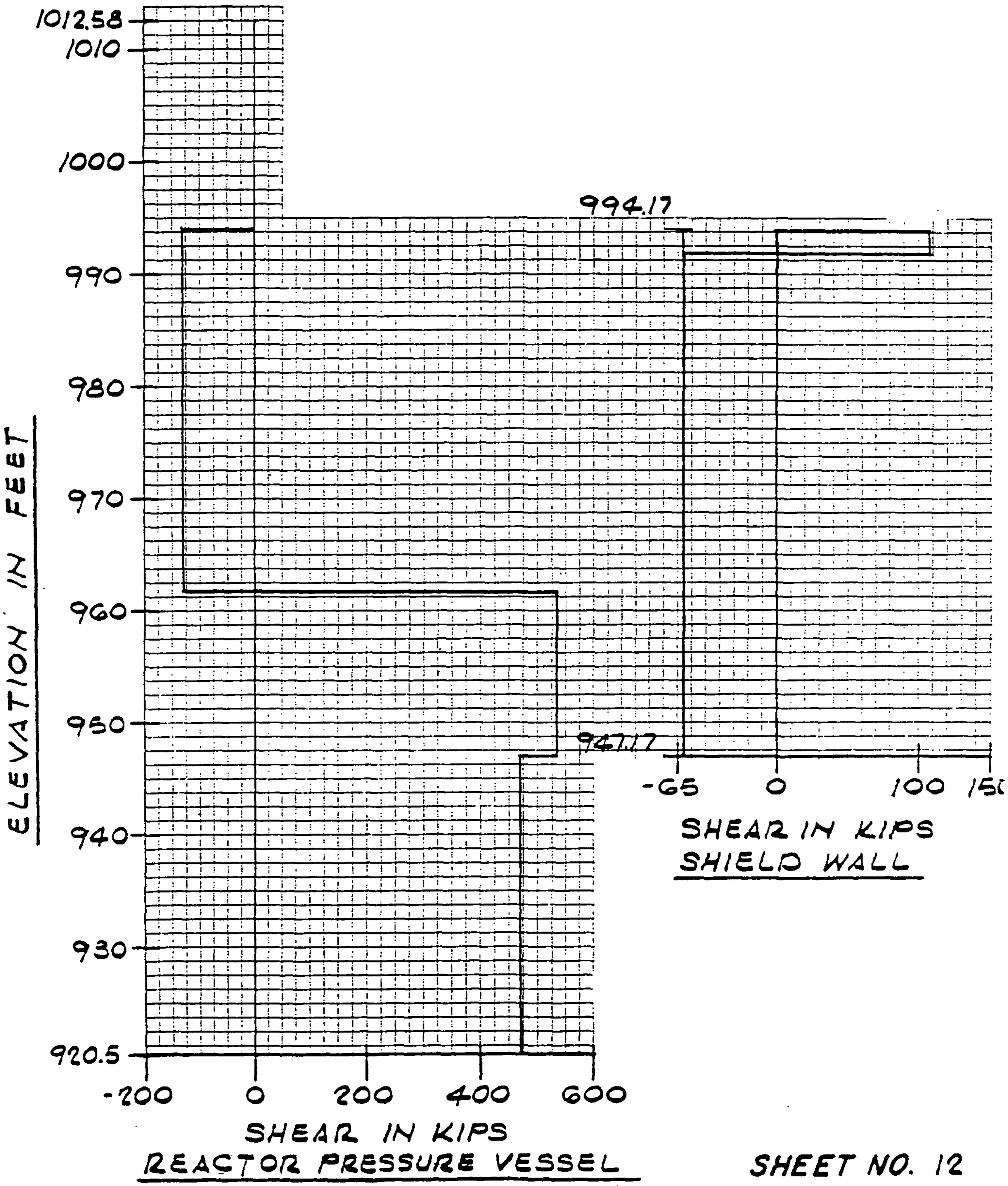


SHEET NO. 11

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS
SHEAR DIAGRAM

(JET LOAD 664^K @ ELEV. 961'-11" - CASE 2)



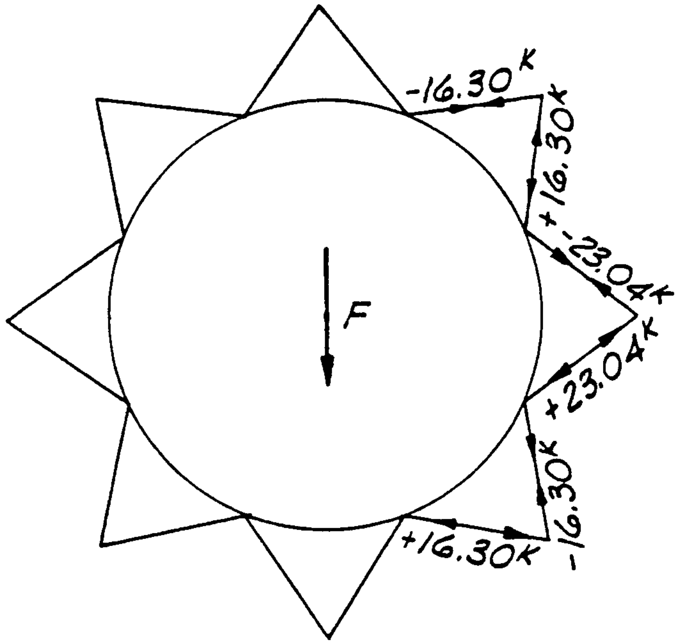
SHEET NO. 12

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

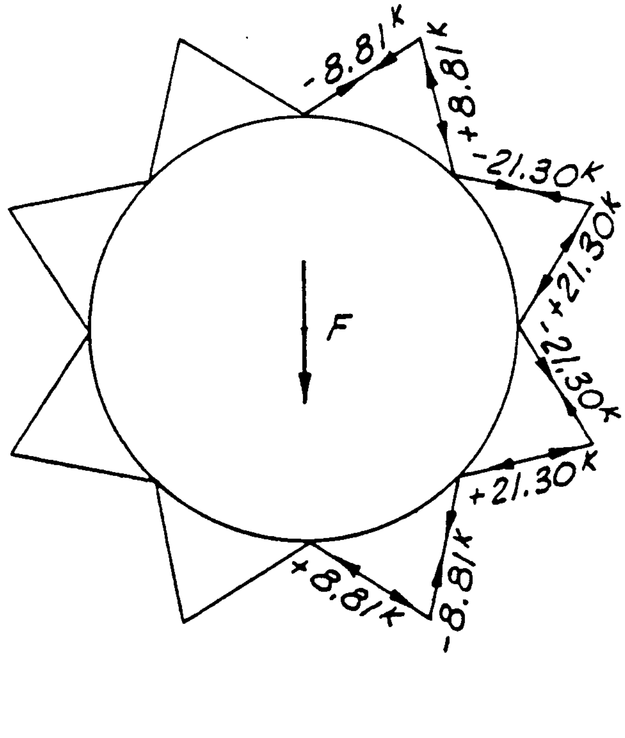
MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

SHIELD SUPPORT ANALYSIS
TRUSS FORCES UNDER SEISMIC LOAD

SPRING FORCE $F = 106.1^K$



CASE I



CASE II

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

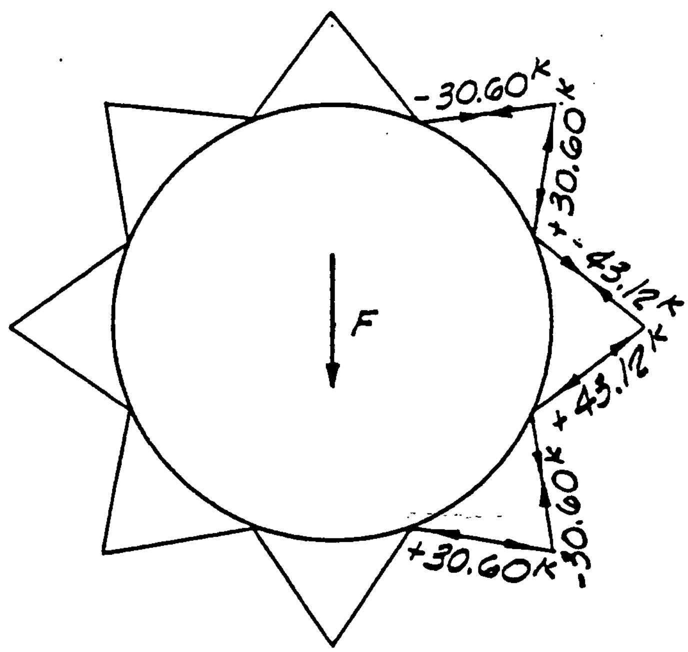
MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

SHIELD SUPPORT ANALYSIS (CONT'D)

TRUSS FORCES UNDER JET LOAD (CASE I, 256.0^{k} @ EL. 999'-0")

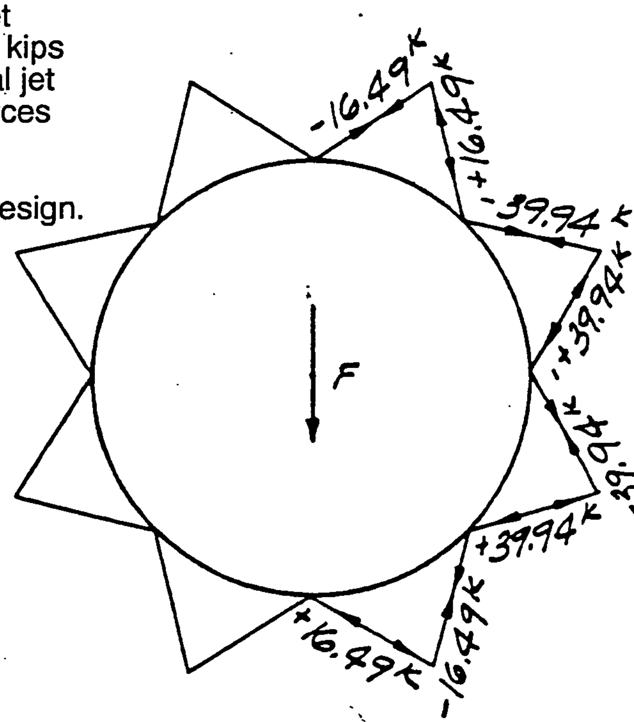
SPRING FORCE $F = 198.7^{k}$



CASE I

The values shown on this sheet are based on a jet force of 256 kips at elevation 999'-0". The actual jet force is 330 kips. The truss forces identified on this sheet shall be increased by a factor of 1.29 (330 kips/256 kips) for use in design.

00-206



CASE II

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

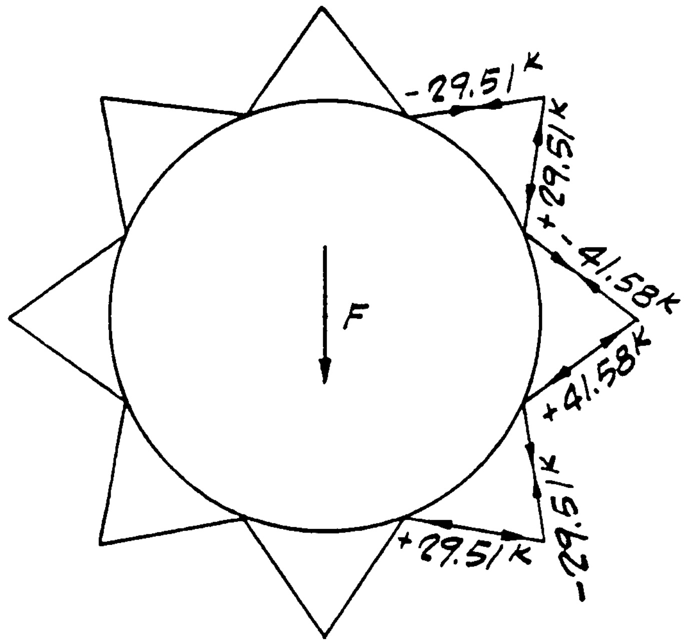
MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

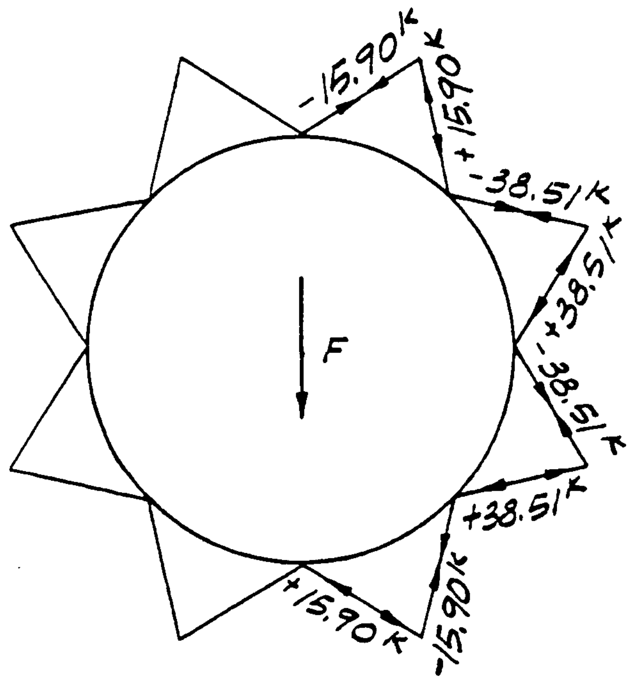
SHIELD SUPPORT ANALYSIS (CONT'D)

TRUSS FORCES UNDER JET LOAD (CASE 2 664^K @ EL. 961'-11")

SPRING FORCE F = 191.6^K



CASE I



CASE II

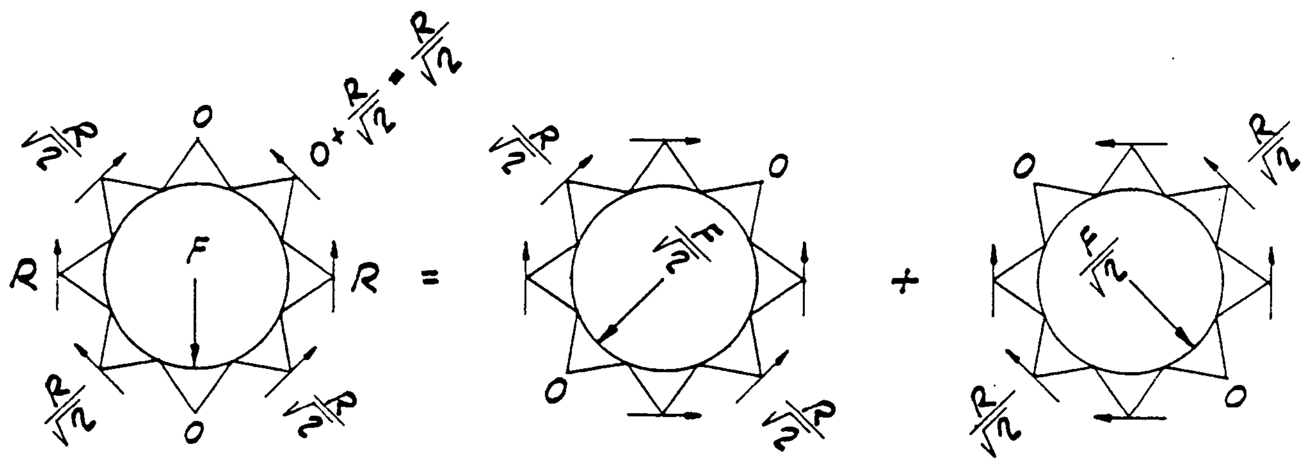
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

SPRING CONSTANT

CASE I (ARBITRARY FORCE F)

A. TANGENTIAL REACTIONS



NATURE OF SYMMETRY AND ANTISYMMETRY REDUCE THE STRUCTURE TO STATICALLY DETERMINATE.

$F = 4R$

$R = F/4$

APPENDIX B

CALCULATED DATA SHEETS

MONTICELLO NUCLEAR GENERATION PLANT
REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS

LIST OF SHEETS

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS
LUMPED WEIGHTS

LOCATION & STATION NO.		ELEVATION	WEIGHT	LOCATION & STATION NO.		ELEVATION	WEIGHT
REACTOR BUILDING	1	1073'-2"	736 K	REACTOR PRESSURE VESSEL	15	1012'-7"	29.46 K
	2	1045'-8"	140		16	1004'-0"	172.78
	3	1027'-8"	12,786		17	999'-0"	124.89
	4	1001'-2"	13,149		18	988'-3"	316.23
	5	985'-6"	17,386		19	977'-0"	538.43
	6	962'-6"	19,232		20	964'-11"	324.11
	7	935'-0"	22,840		21	961'-11"	237.94
SHEILD WALL	8	992'-5½"	42.92		22	955'-0½"	278.15
	9	990'-3½"	113.10	PEDESTAL WALL	23	944'-11"	142.9
	10	984'-11½"	187.43		24	942'-2"	178.5
	11	975'-11½"	281.59		25	936'-0"	182.9
	12	966'-11½"	270.40		26	933'-6"	314.3
	13	959'-3"	202.35		27	928'-6"	269.5
	14	951'-6"	454.66				

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS
LUMPED WEIGHTS
I. REACTOR BUILDING & DRYWELL

WEIGHT 1 @ EL. 1073'-2"	*736^K
WEIGHT 2 @ EL. 1045'-8"	*140^K
WEIGHT 3 @ EL. 1027'-8"	*12,786^K
WEIGHT 4 @ EL. 1001'-2"	13,749^K
LESS 1/5 R.P.V, WATER & FUEL	- 600
	13,149^K
WEIGHT 5 @ EL. 985'-6"	18,586^K
LESS 2/5 R.P.V, WATER & FUEL	1,200
	17,386^K
WEIGHT 6 @ EL. 962'-6"	20,432^K
LESS 2/5 R.P.V, WATER & FUEL	1,200
	19,232^K
WEIGHT 7 @ EL. 935'-0"	29,782^K
LESS CONTROL ROD DRIVE EQUIPMENT	121
LESS CENTRAL POLYGON 1/2 2347×38.75×.15	6821
	22,840^K

* = WEIGHT AS PER REFERENCE No. 2

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

LUMPED WEIGHTS (CONT'D.)

II SHIELD WALL

WEIGHT 8 @ EL. 993'-7"	
CONCRETE	37.54 K
STEEL (12-27WF177)	3.48
STEEL (¼" PL)	1.90
	42.92 K
WEIGHT 9 @ EL. 990'-3½"	
CONCRETE	98.90 K
STEEL (12-27WF177)	9.18
STEEL (¼" PL)	5.02
	113.10 K
WEIGHT 10 @ EL. 984'-11½"	
CONCRETE	163.91 K
STEEL (12-27WF177)	15.21
STEEL (¼" PL)	8.31
	187.43 K
WEIGHT 11 @ EL. 975'-11½"	
CONCRETE	206.04 K
STEEL (12-27WF177)	19.12
STEEL (¼" PL)	10.45
STEEL (1½" PL)	45.98
	281.59 K
WEIGHT 12 @ EL. 966'-11½"	
CONCRETE	191.38 K
STEEL (12-27WF177)	17.76
STEEL (¼" PL)	9.71
STEEL (1½" PL)	51.55
	270.40 K
WEIGHT 13 @ EL. 959'-3"	
CONCRETE	176.96 K
STEEL (12-27WF177)	16.42
STEEL (¼" PL)	8.97
	202.35 K
WEIGHT 14 @ EL. 951'-6"	
CONCRETE	187.72 K
STEEL (12-27WF177)	17.42
STEEL (¼" PL)	9.52
BEAM REACTION	240.00
	454.66 K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

LUMPED WEIGHTS

III REACTOR PRESSURE VESSEL

WEIGHT 15 @ EL. 1012'-7"

TOP HEAD PLATES	= 28.36^K
NOZZLE N-6	= 0.87
NOZZLE N-7	= 0.23
	29.46^K

WEIGHT 16 @ EL. 1004'-0"

TOP HEAD PLATES	= 12.94^K
TOP HEAD FLANGE	= 57.31
SHELL PLATES	= 4.06
SHELL FLANGE	= 47.59
STUDS	= 17.80
NUTS	= 12.16
WASHERS	= 1.09
GUIDE RODS	= 0.10
½ STEAM DRYER PANELS	= 7.81
½ HOUSING	= 11.92
	172.78^K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

LUMPED WEIGHTS (CONT'D.)

REACTOR PRESSURE VESSEL

WEIGHT 17 @ EL. 999'-0"

SHELL PLATES	= 90.28^K
NOZZLES N-3	= 10.69
NOZZLES N-11	= 0.46
½ STEAM DRYER PANELS	= 7.81
SUPPORT RING	= 3.23
GUIDE RODS	= 0.50
½ HOUSING	= 11.92
	124.89^K

WEIGHT 18 @ EL. 988'-3"

SHELL PLATES	= 126.11^K
NOZZLES N-4	= 6.82
NOZZLES N-5	= 3.71
NOZZLES N-9	= 0.52
NOZZLES N-12	= 0.46
WATER SEAL SKIRT	= 4.72
GUIDE RODS	= 0.50
HOLD DOWN BOLTS	= 15.12
LIFT RODS	= 1.40
STEAM SEPARATORS	= 38.05
BOLT RINGS	= 4.01
STAND PIPES	= 14.10
½ SHROUD HD. DOME	= 4.22
½ SHROUD HD. FLANGE	= 2.42
FLUID WEIGHT	= 87.21
FLUID AROUND PERIPHERY	= 6.86
	316.23^K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

LUMPED WEIGHTS (CONT'D.)

REACTOR PRESSURE VESSEL

WEIGHT 19 @ EL. 977'-0"

SHELL PLATES	=133.75 K
½ SHROUD HD. DOME	= 4.22
½ SHROUD HD. FLANGE	= 2.42
SHROUD	= 32.81
UPPER CORE GRID	= 10.19
CORE SPRAY SPARGERS & NOZZLES	= 1.34
½ FUEL SUPPORT CASTINGS	= 1.82
½ FUEL ASSEMBLIES	= 224.38
CONTROL RODS FULL IN	= 21.23
TEMPORARY CONTROL CURTAINS	= 4.37
INCORE ASSEMBLIES	= 3.37
SLEEVES	= 5.67
FLUID WEIGHT	= 54.76
FLUID AROUND PERIPHERY	= 38.10
	538.43 K

WEIGHT 20 @ EL. 964'-11"

SHELL PLATES	= 86.46 K
NOZZLES N-2	= 25.41
SHROUD	= 21.39
FUEL SUPPORT CASTING	= 1.82
FUEL ASSEMBLIES	= 108.13
CONTROL RODS (FULL IN)	= 10.23
TEMPORARY CONTROL CURTAINS	= 2.11
IN-CORE ASSEMBLIES	= 1.63
SLEEVES	= 2.73
FLUID WEIGHT	= 39.57
FLUID AROUND PERIPHERY	= 24.63
	324.11 K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

LUMPED WEIGHTS (CONT'D.)

REACTOR PRESSURE VESSEL

WEIGHT 21 @ EL. 961'-11"

SHELL PLATES	= 62.09 K
NOZZLE N-1	= 18.43
NOZZLE N-8	= 0.91
SHROUD	= 14.18
CORE PLATE ASSEMBLIES	= 15.29
JET PUMP ASSEMBLIES	= 20.00
½ GUIDE TUBES	= 16.94
½ CONTROL ROD DRIVES & THERMAL SLEEVES	= 33.76
FLUID WEIGHT	= 40.01
FLUID AROUND PERIPHERY	= 16.33
	237.94 K

WEIGHT 22 @ EL. 955'-0½"

BOTTOM HEAD	= 104.75 K
SKIRT KNUCKLE	= 15.10
SHROUD	= 12.84
½ CONTROL ROD DRIVES & THERMAL SLEEVES	= 33.76
½ GUIDE TUBES	= 16.94
NOZZLE N-10	= 0.23
INTERNAL SHROUD SUPPORT	= 8.95
SKIRT EXTENSION WEIGHT	= 24.60
FLUID WEIGHT	= 59.35
FLUID AROUND PERIPHERY	= 1.63
	278.15 K

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

LUMPED WEIGHTS (CONT'D.)

IV PEDESTAL WALL

WEIGHT 23 @ EL. 944'-11"

CONCRETE $0.785(25.167^2-17.167^2)(2.25+\frac{2.75}{2})\times 0.15$

$-\frac{2.75}{2}\times 2(3.75+3.25)4\times 0.15$ $= 132.9^K$

STEEL $0.785(17.375^2-17.167^2)(2.25+\frac{2.75}{2})\times 0.49 = 10.0$

142.9^K

WEIGHT 24 @ EL. 942'-2"

CONCRETE $0.785(25.167^2-17.167^2)(\frac{2.75}{2}+\frac{6.167}{2})\times 0.15$

$-\frac{2.75}{2}\times 2(3.75+3.25)4\times 0.15$ $= 166.2^K$

STEEL $0.785(17.375^2-17.167^2)(\frac{2.75}{2}+\frac{6.167}{2})\times 0.49 = 12.3$

178.5^K

WEIGHT 25 @ EL. 936'-0"

CONCRETE $0.785(25.167^2-17.167^2)(\frac{6.167}{2}+\frac{2.5}{2})\times 0.15$

$-\frac{2.5}{2}\times 2.5\times 4.0\times 0.15$ $= 170.9^K$

STEEL $0.785(17.375^2-17.167^2)(\frac{6.167}{2}+\frac{2.5}{2})\times 0.49 = 12.0$

182.9^K

WEIGHT 26 @ EL. 933'-6"

CONCRETE $0.785(25.167^2-17.167^2)(\frac{2.5}{2}+\frac{5.0}{2})\times 0.15$

$-2.5\times(\frac{2.5}{2}+\frac{5.0}{2})4.0\times 0.15$ $= 143.9^K$

DEAD LOAD ON BEAMS $= 160.0$

STEEL $0.785(17.375^2-17.167^2)(\frac{2.5}{2}+\frac{5.0}{2})\times 0.49$ $= 10.4$

314.3^K

WEIGHT 27 @ EL. 928'-6"

CONCRETE $0.785(25.167^2-17.167^2)(\frac{5.0}{2}+\frac{8}{2})\times 0.15$

$-2.5\times 1.5\times 4.0\times 0.15$

$-3.0\times 3.0\times 4.0\times 0.15$ $= 251.5^K$

STEEL $0.785(17.375^2-17.167^2)(\frac{5.0}{2}+\frac{8}{2})\times 0.49$ $= 18.0$

269.5^K

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MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

MEMBER PROPERTIES

	STATION NO.	A (Ft^2)	I (Ft^4)
REACTOR BUILDING	1	BRACED AREA	
	2		
	3		
		2,256	1,805,790
	4		
		3,365	5,140,204
	5		
		2,835	4,460,485
	6		
		2,784	5,006,316
	7		
		5,941	9,693,452
SHIELD WALL	8		
		6.70	434.40
	9		
		4.89	304.46
	10		
		6.70	434.40
	11		
		6.70	434.40
	12		
		5.62	358.85
	13		
		6.31	380.87
	14		
		6.70	434.40

	STATION NO.	A (Ft^2)	I (Ft^4)
REACTOR PRESSURE VESSEL	15		
		10.62	299.2
	16		
		24.66	946.8
	17		
		24.66	946.8
	18		
		24.66	946.8
	19		
		24.66	946.8
	20		
		24.66	946.8
	21		
		23.52	821.3
	22		
		5.64	210.0
PEDESTAL WALL		317.26	17321.
	23		
		261.26	10991.
	24		
		317.26	17321.
	25		
		307.26	16196.
	26		
		307.26	16196.
	27		
		307.26	16196.

$K_1 =$ 325,723 K/Ft.

$K_2 =$ 48,000 K/Ft.

$K_3 = I_b K_s =$ 3,299,934,382 K/Ft. RAD

$K_4 =$ 1,581,549 K/Ft.

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MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

CROSS SECTIONAL AREA & MOMENT OF INERTIA

I REACTOR BUILDING*

STATION NO.	A_c (Ft.^{2})	I_c (Ft.^{4})
1	BRACED AREA	
2		
3		
	2,256	1,805,790
4		
	3,365	5,140,204
5		
	2,835	4,460,485
6		
	2,784	5,006,316
7		
	5,941	9,693,452

$K_3 = I_b K_5 = 3{,}299{,}934{,}382$ K-Ft./RAD

$K_4 = 1{,}581{,}549$ K/Ft.

* AS PER REFERENCE NO. 2

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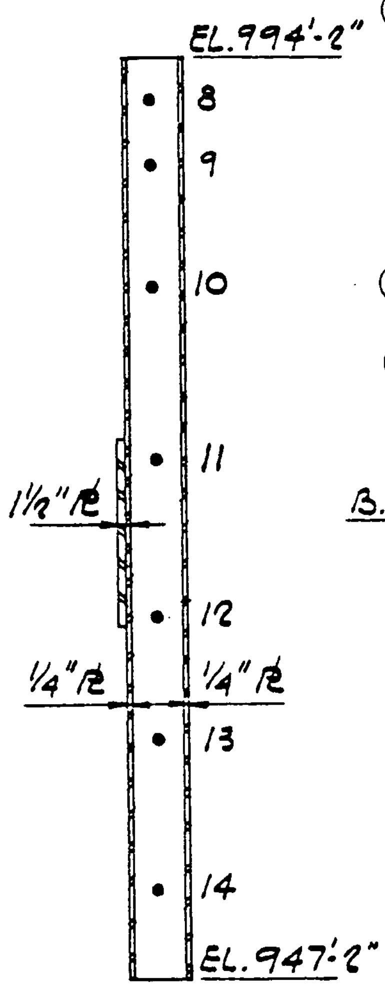
MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

CROSS SECTIONAL AREA & MOMENT OF INERTIA (CONT.)

II SHIELD WALL (ASSUME CONCRETE HAS NO STRENGTH)



A. SECTIONS (NO OPENINGS)

AREA

① 27WF177 $\quad 12 \times \frac{52.1}{144} = 4.33\ ft.^2$

② 1/4" PL $\quad \frac{288}{360} \times 3.14(24.8 + 20.5) \times \frac{1}{4} \times \frac{1}{12} = 2.37$

$= 6.70\ ft.^2$

MOMENT OF INERTIA

① 27WF177 $\quad \frac{52.1}{144} \times 4 \times (11.32)^2 \{\sin^2 15° + \sin^2 45° + \sin^2 75°\} = 278.18\ ft.^4$

② 1/4" PL $\quad \frac{288}{360} \times 3.14 \times \frac{1}{48}(12.4^3 + 10.25^3) = 156.22$

$= 434.40\ ft.^4$

B. SECTION (7 OPENINGS)

AREA

① 27WF177 $\quad 8 \times \frac{52.1}{144} = 2.89\ ft.^2$

② 1/4" PL $\quad \left[\frac{312}{360} \times 3.14(24.8 + 20.5) - (14 \times 4.1) + (14 \times 2.15)\right]\frac{1}{48} = 2.00$

$= 4.89\ ft.^2$

MOMENT OF INERTIA

① 27WF177 $\quad \frac{52.1}{144} \times 4 \times (11.32)^2 \{\sin^2 15° + \sin^2 75°\} = 185.45\ ft.^4$

② 1/4" PL $\quad \frac{312}{360} \times 3.14 \times \frac{1}{48}(12.4^3 + 10.25^3)$

$- 2 \times 4.1 \times \frac{1}{48}\left[4\sin^2 45° + 2\sin^2 90° + \sin^2 65°\right](11.32)^2$

$+ 2 \times 2.15 \times \frac{1}{48}\left[4\sin^2 45° + 2\sin^2 90° + \sin^2 65°\right](11.32)^2 = 119.01$

$= 304.46\ ft.^4$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

CROSS SECTIONAL AREA & MOMENT OF INERTIA (CONT.)

C. SECTION (10 x 4'-1" x 4'-1" + 2 x 5'-4" x 5'-4" OPENINGS)

AREA

① 27WF177 $12 \times \frac{52.1}{144} = 4.33\ ft^2$

② 1/4" PL $\left[\frac{288}{360} \times 3.14(24.8 + 20.5) - (20 \times 4.1) - (4 \times 5.33) + (24 \times 2.15)\right]\frac{1}{4} \times \frac{1}{12} = 1.29\ ft^2$

$5.62\ ft^2$

MOMENT OF INERTIA

① 27WF177 $\frac{52.1}{144} \times 4 \times (11.32)^2\{\sin^2 15° + \sin^2 45° \times \sin^2 75°\} = 278.18\ ft^4$

② 1/4" PL $\left[\frac{288}{360} \times 3.14 \times (12.4^3 + 10.25^3) - 2 \times 4.1 \times (11.32)^2(4\sin^2 30° + 4\sin^2 60°) - 2 \times 5.33 \times (11.32)^2(2\sin^2 90°) + 2 \times 2.15 \times (11.32)^2(4\sin^2 30° + 4\sin^2 60° + 2\sin^2 90°)\right]\frac{1}{48} = 80.67$

$358.85\ ft^4$

D. SECTION (1 x 4'-1" x 4'-1" OPENING)

AREA

① 27WF177 $11 \times \frac{52.1}{144} = 3.97\ ft^2$

② 1/4" PL $\left[\frac{294}{360} \times 3.14(24.8 + 20.5) - (2 \times 4.1) + (2 \times 2.15)\right]\frac{1}{48} = 2.34$

$6.31\ ft^2$

MOMENT OF INERTIA

① 27WF177 $\frac{52.1}{144} \times (11.32)^2[4\sin^2 30° + 4\sin^2 60° + \sin^2 90°] = 231.81\ ft^4$

② 1/4" PL $\left[\frac{294}{360} \times 3.14(12.4^3 + 10.25^3) - (2 \times 4.1)(11.32^2) + (2 \times 2.15)(11.32^2)\right]\frac{1}{48} = 149.06$

$380.87\ ft^4$

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MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

CROSS SECTIONAL AREAS & MOMENT OF INERTIA (CONT.)

III REACTOR PRESSURE VESSEL

A. TOP HEAD SECTION

$A = 0.785\,(15.25^2 - 14.80^2) = 10.62\ ft.^2$

$I = 0.049\,(15.25^4 - 14.80^4) = 299.2\ ft.^4$

B. CYLINDRICAL SECTION

$A = 0.785\,(17.979^2 - 17.083^2) = 24.66\ ft.^2$

$I = 0.049\,(17.979^4 - 17.083^4) = 946.8\ ft.^4$

C. SKIRT SECTION

$A = 0.785\,(17.375^2 - 17.167^2) = 5.64\ ft.^2$

$I = 0.049\,(17.375^4 - 17.167^4) = 210.0\ ft.^4$

D. BOTTOM HEAD

$A = 0.785\,(17.167^2 - 16.271^2) = 23.52\ ft.^2$

$I = 0.049\,(17.167^4 - 16.271^4) = 821.3\ ft.^4$

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MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

CROSS SECTIONAL AREAS & MOMENT OF INERTIA (CONT.)

IV PEDESTAL WALL

A. SECTIONS (NO OPENINGS)

$$A = 0.785(25.167^2 - 17.167^2) + 0.785(17.375^2 - 17.167^2) \times \frac{3945600}{432000} = 317.26 \ ft.^2$$

$$I = 0.049(25.167^4 - 17.167^4) + 0.049(17.375^4 - 17.167^4) \times 9.14 = 17{,}321. \ ft.^4$$

B. SECTIONS (OPENINGS FOR PIPES)

$$A = 0.785(25.167^2 - 17.167^2) - 2 \times 4.0(3.75 + 3.25) + 0.785(17.375^2 - 17.167^2) \times 9.14 = 261.26 \ ft.^2$$

$$I = 0.049(25.167^4 - 17.167^4) - \frac{2 \times 4.0}{12}(3.75^3 + 3.25^3) - 2 \times 4.0(3.75 + 3.25)\left(\frac{21.167}{2}\right)^2 + 0.049(17.375^4 - 17.167^4) \times 9.14 = 10{,}991. \ ft.^4$$

C. SECTIONS (OPENINGS FOR PERSONNEL)

$$A = 0.785(25.167^2 - 17.167^2) - 4.0 \times 2.5 + 0.785(17.375^2 - 17.167^2) \times 9.14 = 307.26 \ ft.^2$$

$$I = 0.049(25.167^4 - 17.167^4) - 4\frac{(2.5)^3}{12} - 4.0 \times 2.5\left(\frac{21.167}{2}\right)^2 + 0.049(17.375^4 - 17.167^4) \times 9.14 = 16{,}196. \ ft.^4$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

MODULI OF ELASTICITY

A. REACTOR PRESSURE VESSEL

$E = 26.0 \times 10^6$ psi @ 550°F $= 37.44 \times 10^5$ K/ft.^{2}

$\nu = 0.26 \sim 0.27$

USE $\nu = 0.265$

$G = \frac{E}{2(1+\nu)} = 0.395E = 14.789 \times 10^5$ K/ft.^{2}

B. SKIRT

$E = 27.4 \times 10^6$ psi @ 300°F $= 39.456 \times 10^5$ K/ft.^{2}

$G = 0.395E = 15.585 \times 10^5$ K/ft.^{2}

C. STRUCTURAL STEEL

$E = 30 \times 10^6$ psi $= 43.20 \times 10^5$ K/ft.^{2}

$G = 0.4E = 17.28 \times 10^5$ K/ft.^{2}

D. CONCRETE

$E = 3 \times 10^6$ psi $= 4.32 \times 10^5$ K/ft.^{2}

$G = 0.4E = 1.728 \times 10^5$ K/ft.^{2}

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MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

SUMMARY OF SPRING FORCES

FORCE \ LOADING CONDITION	SEISMIC	JET LOAD 256.0^K @ EL.999'-0"	JET LOAD 664.0^K @ EL.961'-11"
BETWEEN RPV AND SHIELD STABILIZER	67.0^K	172.0^K	126.9^K
BETWEEN SHIELD AND BUILDING	106.1^K	198.7^K	191.6^K

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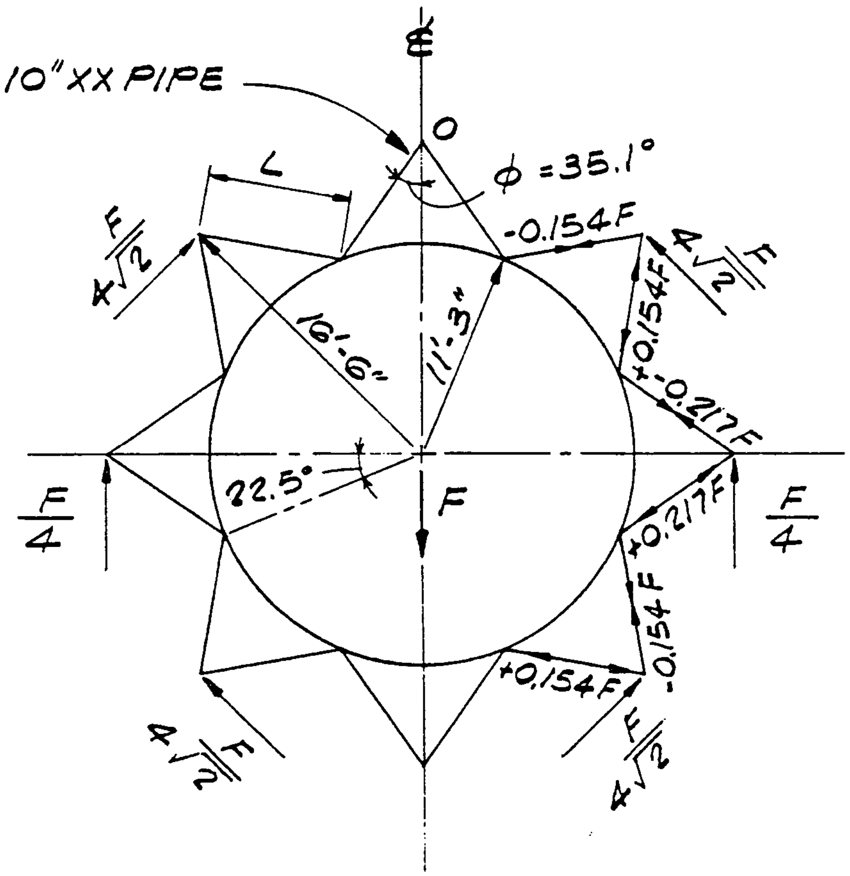
MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

SPRING CONSTANT (CONT'D)

B. TRUSS LOADS



+ DENOTES TENSION

- DENOTES COMPRESSION

$L = (16.5^2 + 11.25^2 - 2 \times 16.5 \times 11.25 \cos 22.5°)^{1/2} = 7.483$ FT.

$\sin\phi = \frac{11.25}{7.483} \sin 22.5° = 0.5753, \quad \phi = 35.1°$

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MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

SPRING CONSTANT (CONT'D)

$$\delta = \frac{FL}{AE} \Sigma u^2$$

$$F = 1^K$$

$$L = 7.483 \text{ FT}$$

$$E = 30 \times 10^6 \text{ LB/IN}^2 = 4{,}320{,}000 \text{ K/FT}^2$$

$$\text{A OF 10'' XXS PIPE} = 0.2127 \text{ FT}^2$$

$$\Sigma u^2 = 4(\bar{0}^2 + 0.2172^2 + 2 \times 0.1536^2) = 0.3774$$

DISPLACEMENT $\delta = \frac{1 \times 7.483 \times 0.3774}{4{,}320{,}000 \times 0.2127} = 3.074 \times 10^{-6} \text{ FT}$

SPRING CONSTANT

$$F = K\delta$$

$$1 = K\delta$$

$$K = \frac{1}{\delta} = 325{,}330 \text{ K/FT}$$

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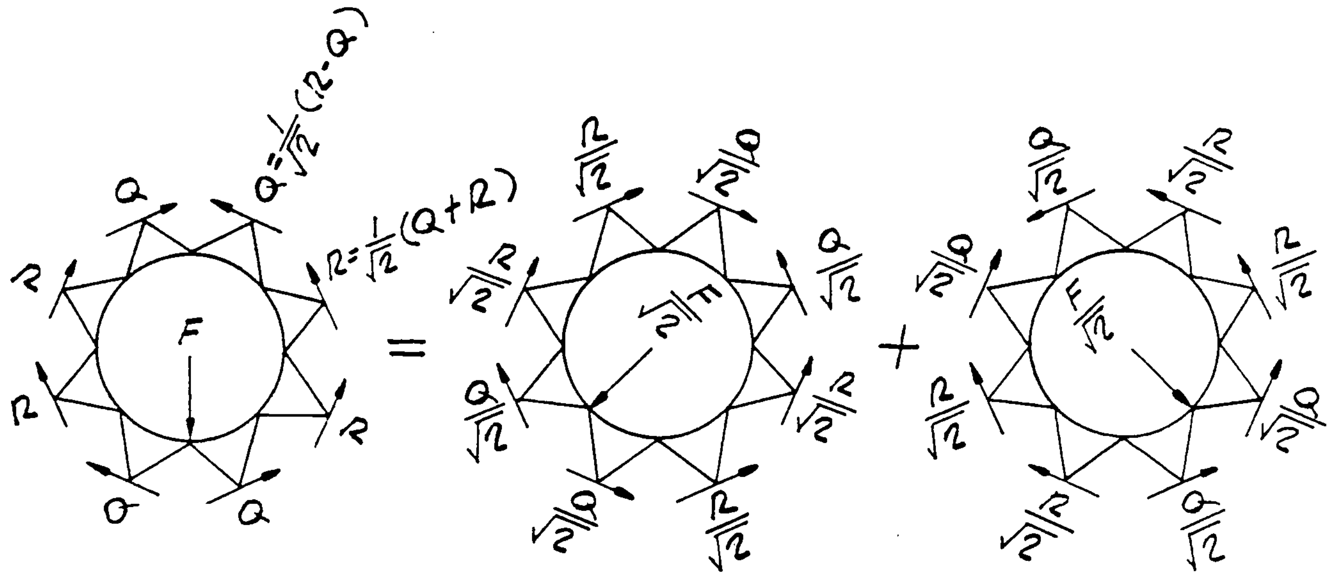
MONTICELLO REACTOR PRESSURE VESSEL SEISMIC ANALYSIS

SPRING CONSTANT (CONT'D)

CASE II (ARBITRARY FORCE F)

A. TANGENTIAL REACTIONS



NOTE: THE NATURE OF SYMMETRY & ANTISYMMETRY

$$\begin{cases} \Sigma F = F_1 + F_2 \\ R = \frac{1}{\sqrt{2}}(Q+R) \\ \Sigma V = 0, \text{ GIVES} \\ F = 4(R \cos \pi/8 + Q \sin \pi/8) \end{cases}$$

SOLUTION : $\begin{cases} Q = 0.0955\ F \\ R = 0.231\ F \end{cases}$

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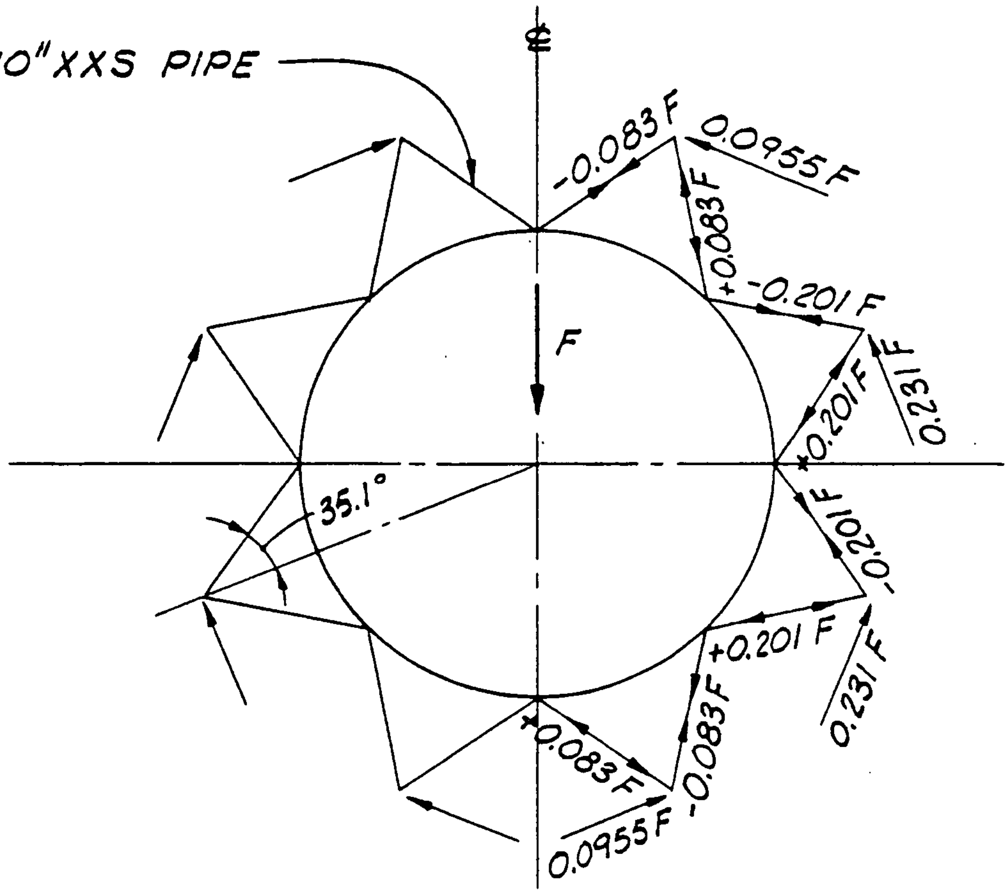
MONTICELLO REACTOR PRESSURE VESSEL

SEISMIC ANALYSIS

SPRING CONSTANT (CONT'D)

B. TRUSS LOADS



\+ DENOTES TENSION

\- DENOTES COMPRESSION

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO REACTOR PRESSURE VESSEL
SEISMIC ANALYSIS

SPRING CONSTANT (CONT'D)

$$\delta = \frac{FL}{AE} \Sigma u^2$$

$$L = 7.483 \text{ FT}$$

$$F = 1^K$$

$$A = 0.2127 \text{ FT}^2$$

$$E = 30 \times 10^6 \text{ LBS/IN}^2 = 4{,}320{,}000 \text{ K/FT}^2$$

$$\Sigma u^2 = 8(\overline{0.083}^2 + \overline{0.201}^2) = 0.3777$$

DISPLACEMENT $\delta = \frac{1 \times 7.483 \times 0.3777}{4320000 \times 0.2127} = 3.0757 \times 10^{-6} \text{ FT}$

SPRING CONSTANT $K = \frac{1}{\delta} = 325{,}129 \text{ K/FT}$

GENERAL ELECTRIC COMPANY
Atomic Power Equipment Department

MONTICELLO NUCLEAR GENERATION PLANT

Report on the Earthquake Analysis of the Control Room

JOHN A. BLUME & ASSOCIATES, ENGINEERS
SAN FRANCISCO

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

November 22, 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
Control Room Earthquake Analysis

Gentlemen:

Transmitted herewith is the subject report based on the information furnished us by Bechtel Corporation, General Electric Company, and as listed in the References.

The analysis consists of an investigation of the coupled flexural dynamic response and the rocking dynamic response of the subject building. The results of the analysis are presented in this report, and are based on the building drawings listed in the References. These drawings should be reviewed to determine if any substantial changes in the building's structural properties have been made to warrant a further earthquake analysis.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

R. T. Yokoyama
Assistant Vice President

RTY/vdr

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1

CONTROL ROOM

EARTHQUAKE ANALYSIS

CONTENTS

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1
CONTROL ROOM
EARTHQUAKE ANALYSIS

INTRODUCTION

The purpose of this report is to summarize the results of the seismic investigation of the Monticello Nuclear Generation Plant Control Room. Based upon the recommended earthquake design criteria established for the Plant, design envelopes of maximum acceleration, displacement, shear and overturning moment versus height of the building have been developed for both directions and are herein presented.

DESIGN CRITERIA

Based upon data developed by John A. Blume & Associates, Engineers (Reference 2), 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.

BUILDING DESCRIPTION

The control room is a separate, multistory structure located on the south side of the turbine building and adjacent to the east side of the reactor building. Both concrete block and reinforced concrete are used in wall construction throughout the structure. The reinforced concrete walls resist both vertical and lateral loads. Walls of concrete block resist lateral loading, and resistance to vertical loading in these areas is provided by use of steel columns and framing.

METHOD OF ANALYSIS

For the dynamic response analysis, the equivalent mass system shown on Sheet No. 1 was selected to approximate the building. Masses were lumped at the floor levels indicated, and each represents the mass of concrete and steel at these floor levels and the tributary mass of the concrete and steel between them.

The average area and moment of inertia of the concrete and concrete block walls between floors were used to determine the stiffness characteristics.

References 7, 10, and 11 present the data associated with the granular material which supports the reactor building. These values are as follows:

E_{dyn} = 78,500 pounds per square inch.

G = 29,500 pounds per square inch.

μ = 0.33 (dimensionless).

ρ = 135 pounds per cubic foot.

Using these given field determined values the following rotational and lateral foundation spring supports were determined using Equation (212) from Reference 3 and Equation (1-4-5) from Reference 9:

For earthquake in N-S direction:

K_{rot} = 285,000,000 kip - feet per radian.

For earthquake in E-W direction:

K_{rot} = 165,000,000 kip - feet per radian.

For earthquake in N-S & E-W directions

K_G = 628,000 kips per foot

The natural periods and mode shapes and the dynamic response of the equivalent lumped mass system were determined with the aid of an IBM 1130 digital computer. The first three modes were considered, with the damping value assigned as 5 percent for each mode.

ANALYTICAL PROCEDURE

Periods and Mode Shapes

The natural periods of vibration and mode shapes of the mathematical

model are given by Equation (1).

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

where:

$\underline{K}$ = Stiffness matrix (see Remarks on the Computer Program)

W_n = Natural circular frequency 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.

Generalized Acceleration and Displacement Response

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

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

where:

$\underline{Y_n(t)}$ = Generalized displacement response for the n^{th} mode

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

M_n = Generalized mass for the n^{th} mode

$$= \underline{\Phi}_n^T \cdot \underline{M} \cdot \underline{\Phi}_n$$

$\underline{\ddot{U}_g(t)}$ = Earthquake ground acceleration

λ_n = Damping for the n^{th} mode - taken as 5 percent for all modes

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

From the Generalized displacement response the time-history of displacements is found according to Equation (4).

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

where:

$$\underline{\Phi} = \left[\underline{\Phi}_1 \; \underline{\Phi}_2 \; \text{--------} \; \underline{\Phi}_m\right], \; m = \text{Number of modes considered}$$

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

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

The solution for generalized acceleration response is identical to the above, except that Equation (2) is solved for acceleration, from which the relative acceleration - time-history matrix is calculated. To this is added the ground acceleration, resulting in the absolute acceleration - time-history.

Once displacement and acceleration - time-histories have been established, the time-histories of shears and moments are determined. These records are then enveloped to determine the maximum values which are then graphically presented in the report and used by the designer.

Remarks on the Computer Program

1) The computer program used in this analysis was specially designed to solve the dynamic response of structures subjected to

arbitrary ground motions. Since the program was written to cover as many structural configurations as possible, the structural member input data for the program, except for the foundation spring, is in the form of member moments of inertia, areas, and effective shear areas. The effects of axial deformations and shear deformations are included in the calculation of the stiffness matrix.

2) 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 responses of each mass point for each mode at a particular instant of time. This results in an exact combination of mode participation without the necessity of using approximate methods such as the root-mean-square method.

3) Individual elements in the stiffness matrix are designated K_{ij} and are stored in the computer such that the i value designates the row number and the j value the column number. K_{ij} is determined by applying a unit displacement at the j^{th} point while restraining the other points against displacement, and finding the corresponding reaction at the i^{th} point. In this manner the foundation spring is included in the stiffness matrix. This procedure couples the foundation spring and elastic springs of the structural system.

4) The general computer techniques used in this analysis are taken from References 5, 6, and 8. However, the referenced techniques have been extensively modified and expanded by John A. Blume & Associates, Engineers to increase their versatility and capability. A simplified block diagram of the computer program is shown on Plate A, and the input and output are indicated in Tables A and B respectively.

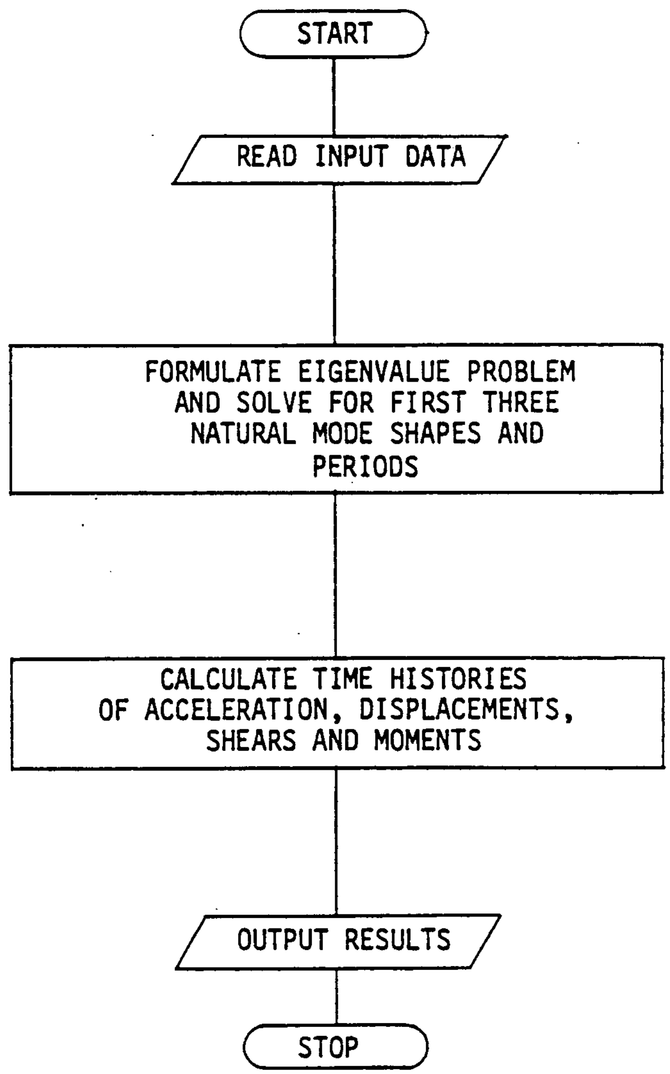


PLATE A

FLOW DIAGRAM OF COMPUTER PROGRAM

TABLE A

INPUT DATA

1. Geometry of Model
   a) Vertical distances between mass points
   b) Mass point identification
      ie: Mass 1
          Mass 2
          Etc.

2. Section and Foundation Properties
   a) Moments of inertia of columns
   b) Areas of columns
   c) Shear areas of columns
   d) Foundation spring constants, K_g, K_s

3. Weights and Masses
   a) Weight of each mass point
   b) Mass of each mass point

4. Input Earthquake Data
   a) Input earthquake - time in seconds and acceleration in gravity units.
   b) Time length of earthquake record used - 10.0 seconds.

TABLE B

OUTPUT RESULTS

1. Maximum displacement of each mass point.
2. Maximum absolute accelerations of each mass point.
3. Maximum shears at each mass point.
4. Maximum overturning moments at each mass point.
5. Period of vibration of each mode calculated.

DISCUSSION OF RESULTS

Absolute Acceleration

The curves shown on Sheets 2 and 6 give an envelope of the maximum absolute accelerations with respect to height. These curves can be used for the seismic design of equipment elements rigidly attached to the subject building, but the moment, shear, and displacement curves presented should be used in the design of the building.

Shears, Moments, and Displacements

The maximum envelopes of building design shears, moments, and displacements are presented graphically on Sheets 3, 4, 5, 7, 8, and 9. The displacement values plotted are relative to the base. These curves should be used in the seismic design of the building.

Periods of Vibration

Direction of Earthquake	First Mode (Seconds)	Second Mode (Seconds)	Third Mode (Seconds)
North-South	0.21	0.085	0.026
East-West	0.244	0.090	0.031

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 plant to safely shut down. In addition to the horizontal accelerations, a vertical building (and equipment) acceleration of 0.04 gravity, acting simultaneously with the horizontal accelerations is recommended for design.

MONTICELLO NUCLEAR GENERATION PLANT

CONTROL ROOM

EARTHQUAKE ANALYSIS

REFERENCES

1. Design Drawings

   BECHTEL Drawings

   C-19, Rev. 1, dated June 14, 1968
   C-460, Rev. 2; C-461, Rev. 3; C-462, Rev. 1, dated July 17, 1968
   C-463, Rev. 2; C-466, Rev. 2; C-468, Rev. 1, dated July 17, 1968
   C-465, Rev. 1; C-467, Rev. 1, dated April 18, 1968
   C-470, Rev. 2, dated May 10, 1968
   C-471, Rev. 2, dated July 25, 1968
   C-472, Rev. 2, dated July 25, 1968

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

3. Theory of Elasticity, Timoshenko and Goodier, Second Edition, McGraw Hill Company, 1951.

4. Nuclear Geoplosics, Stanford Research Institute, Defense Atomic Support Agency, Part Two, Mechanical Properties of Earth Materials, May 1962.

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

6. Structural Analysis of Multistory Buildings, 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.

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

8. Dynamic Effects of Earthquakes, R. W. Clough, Transactions of the American Society of Civil Engineers, Paper No. 3252.

9. Dynamics of Bases and Foundations, D. D. Barkan, McGraw Hill Company, 1962.

10. Report of Foundation Investigation - Proposed Nuclear Power Plant-Unit Number 1, Monticello, Minnesota, by Dames & Moore, dated July 27, 1966 (including Supplements 1 through 5)

REFERENCES (cont'd)

11. Report-Dynamic Response Data Investigation - Proposed Nuclear Power Plant, Monticello, Minnesota, by Dames & Moore, dated July 7, 1966.

MONTICELLO NUCLEAR GENERATION PLANT-UNIT 1

CONTROL ROOM

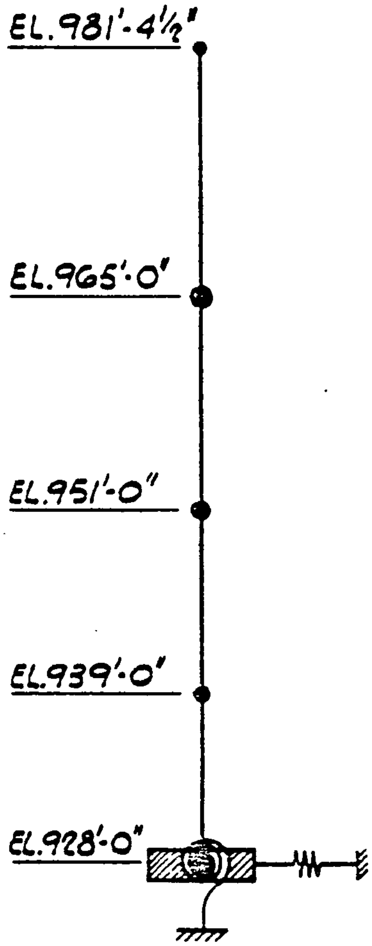
EARTHQUAKE ANALYSIS

LIST OF FIGURES — SHEET NO.

LIST OF PROPERTIES

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
MATHEMATICAL MODEL



	EARTHQUAKE IN N-S DIRECTION		EARTHQUAKE IN E-W DIRECTION	
WEIGHT(K)	$\bar{A}$ (FT^2)	I (FT^4)	$\bar{A}$ (FT^2)	I (FT^4)
734.8				
	187	33,566	95	24,971
1848.8				
	142	78,682	137	71,575
1502.0				
	133	77,050	137	65,950
1220.0				
	217	110,643	134	66,139
3970.6	$A_{BASE} = 3340$	$I_{BASE} = 1,235,000$	$A_{BASE} = 3340$	$I_{BASE} = 710,000$

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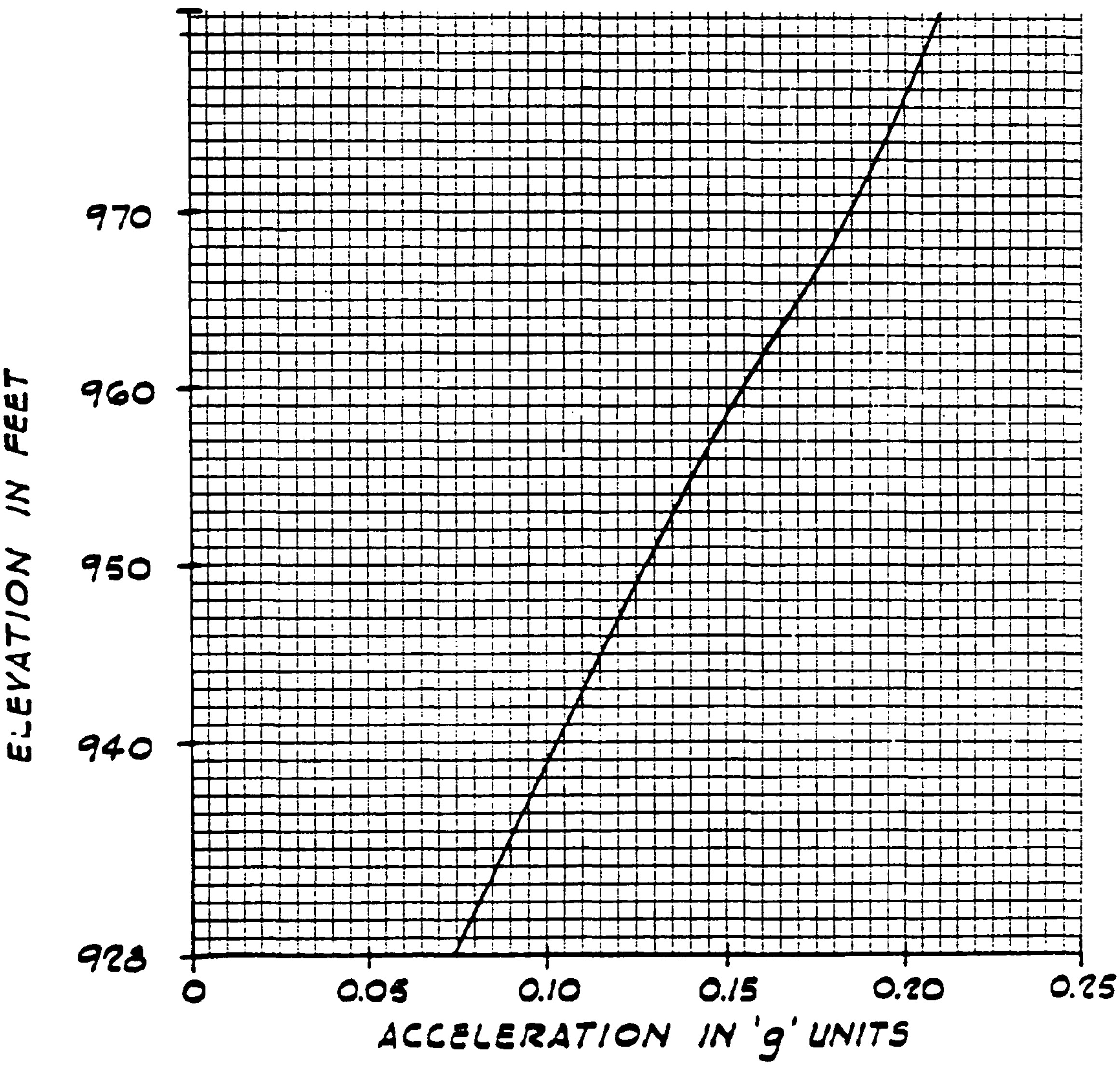
MONTICELLO CONTROL ROOM SEISMIC ANALYSIS

ACCELERATION DIAGRAM NORTH - SOUTH DIRECTION



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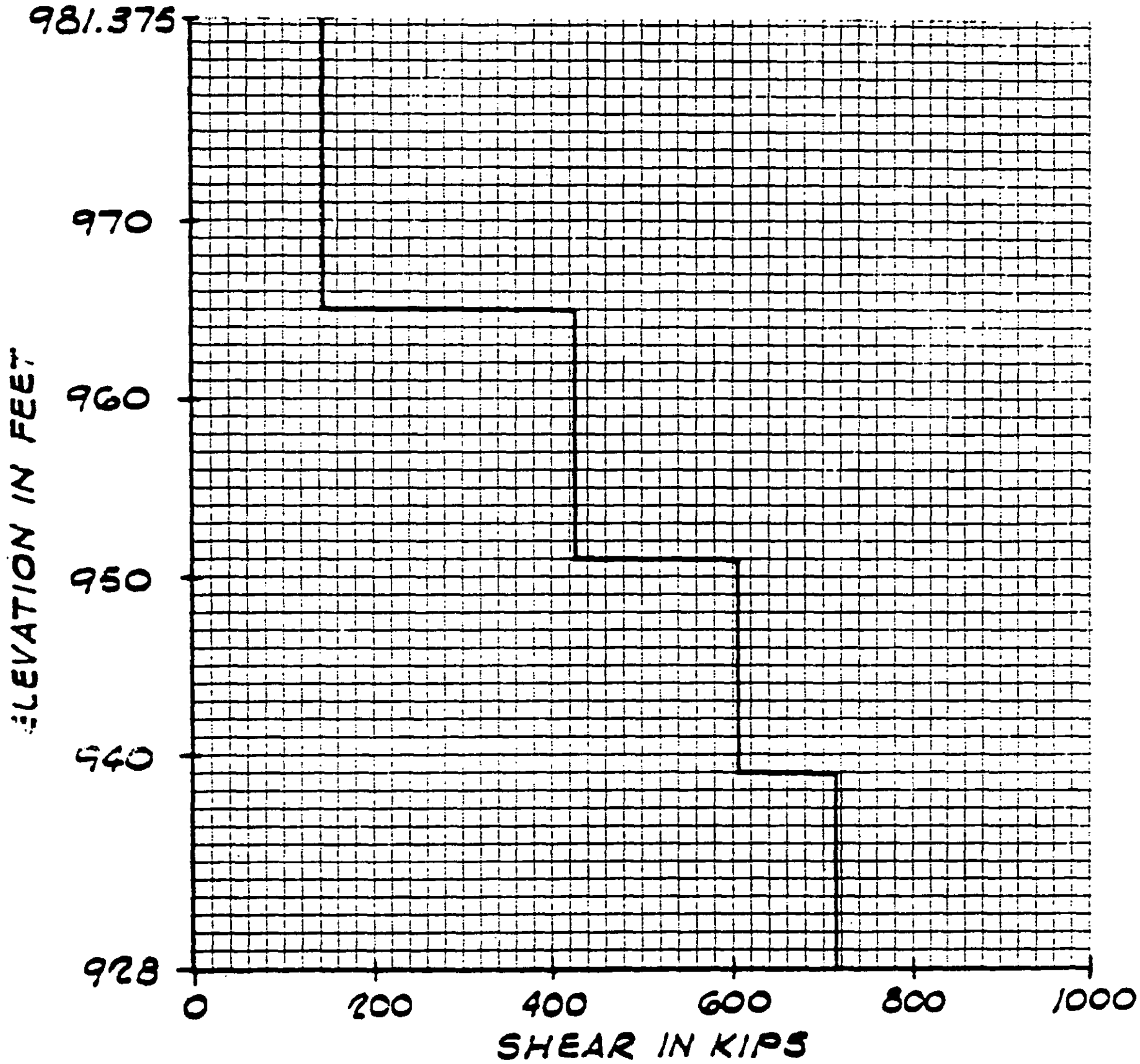
MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

SHEAR DIAGRAM

NORTH-SOUTH DIRECTION



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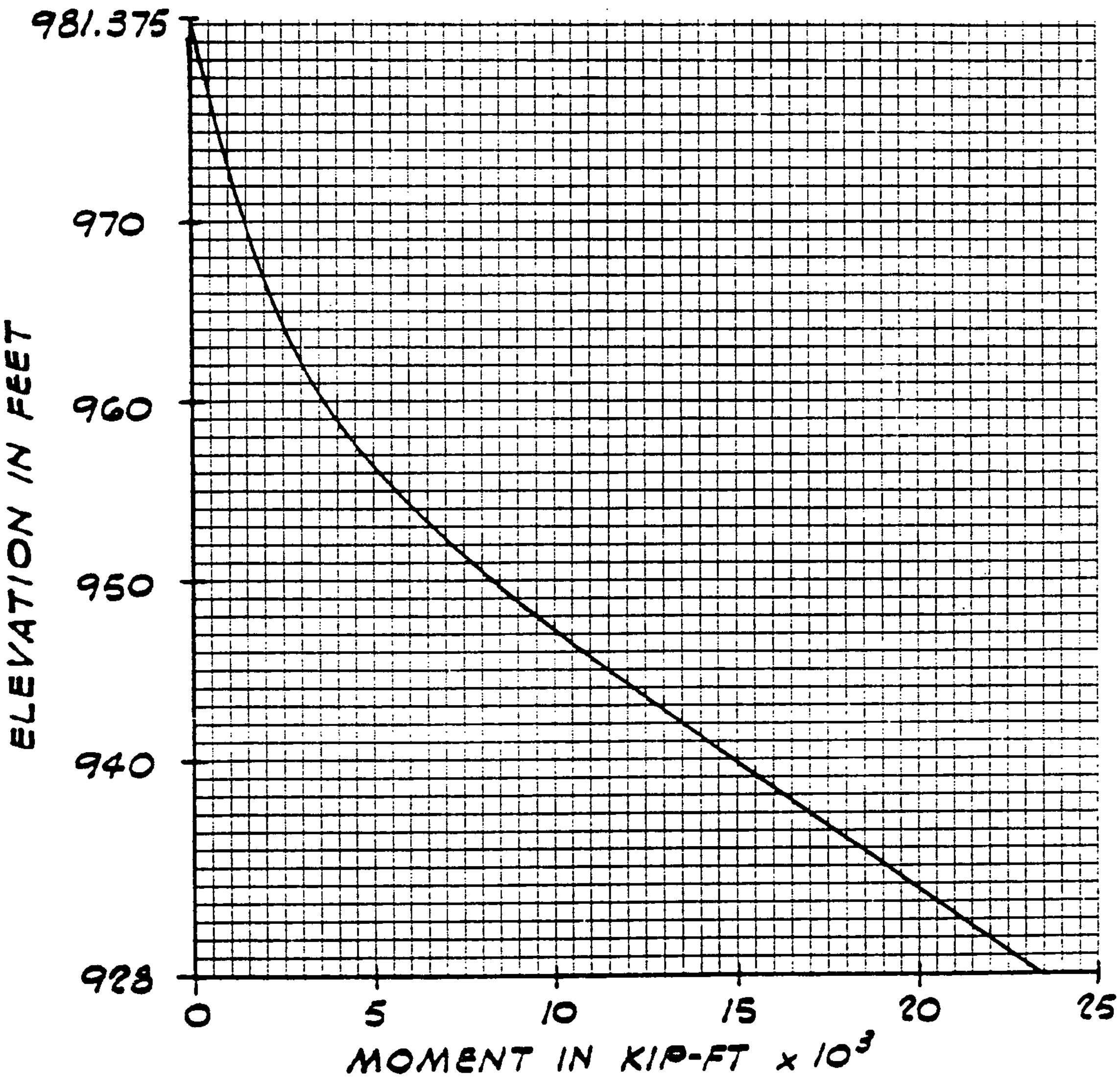
MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
MOMENT DIAGRAM
NORTH-SOUTH DIRECTION



SHEET NO. 4

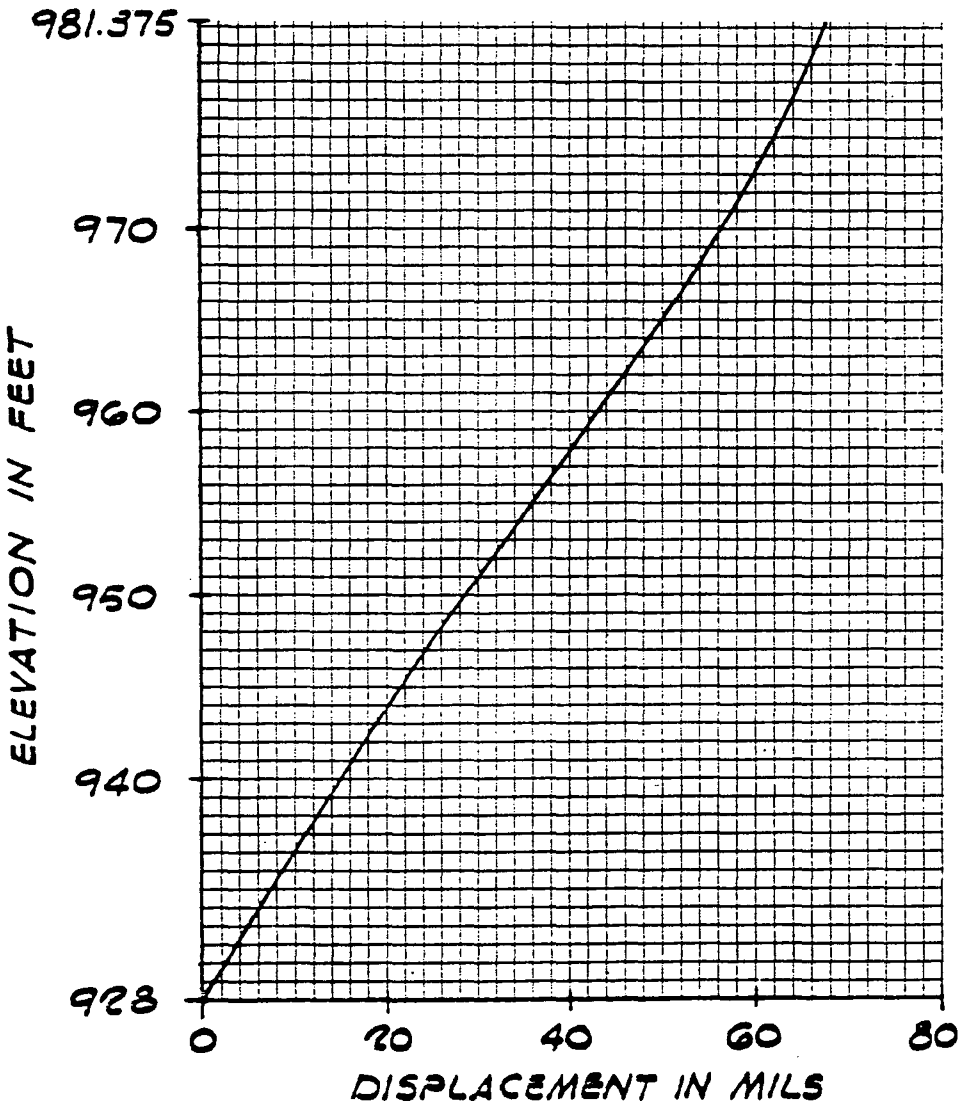
JOHN A. BLUME AND ASSCCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

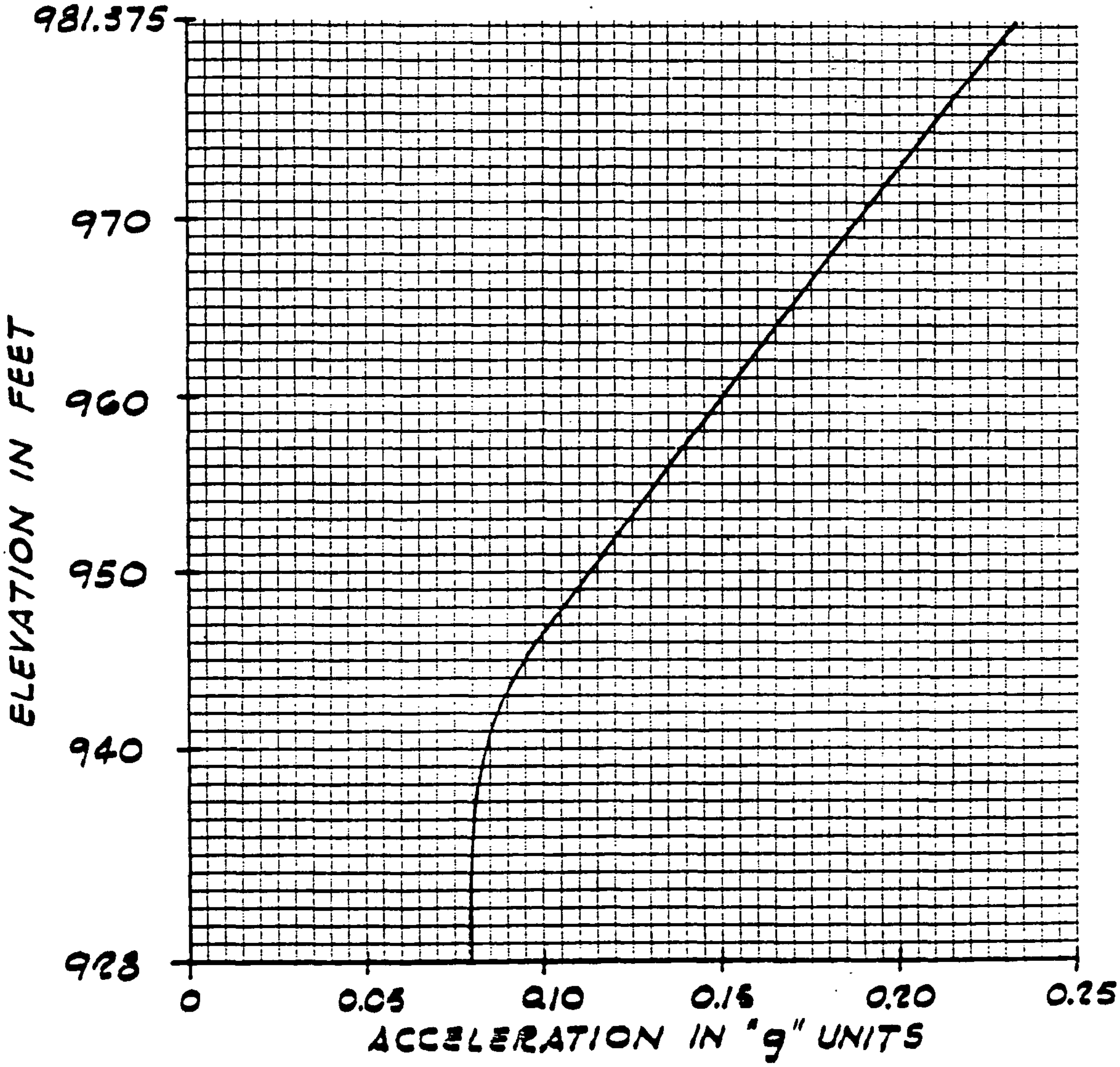
DISPLACEMENT DIAGRAM

NORTH-SOUTH DIRECTION



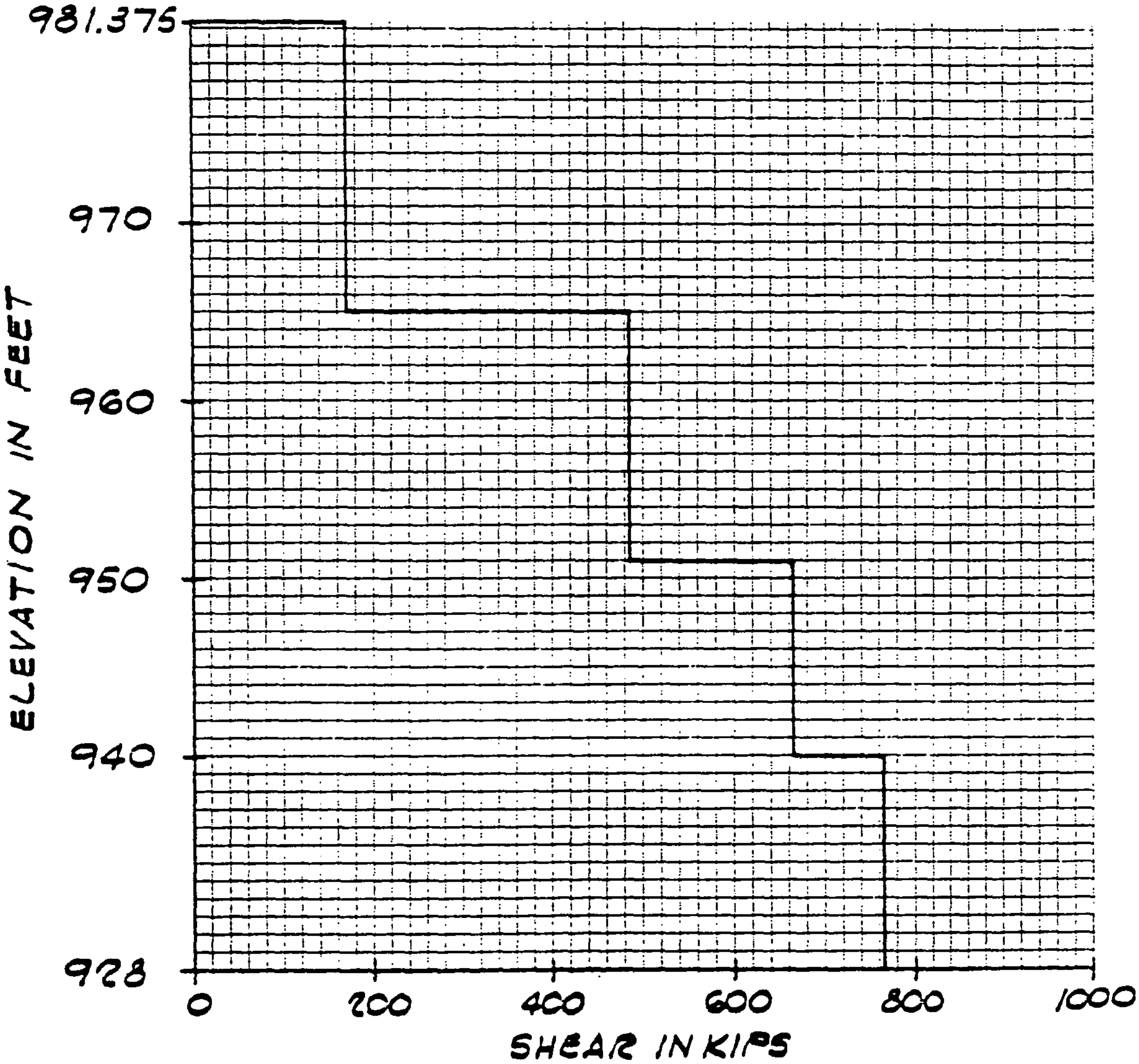
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
ACCELERATION DIAGRAM
EAST-WEST DIRECTION



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
SHEAR DIAGRAM
EAST-WEST DIRECTION



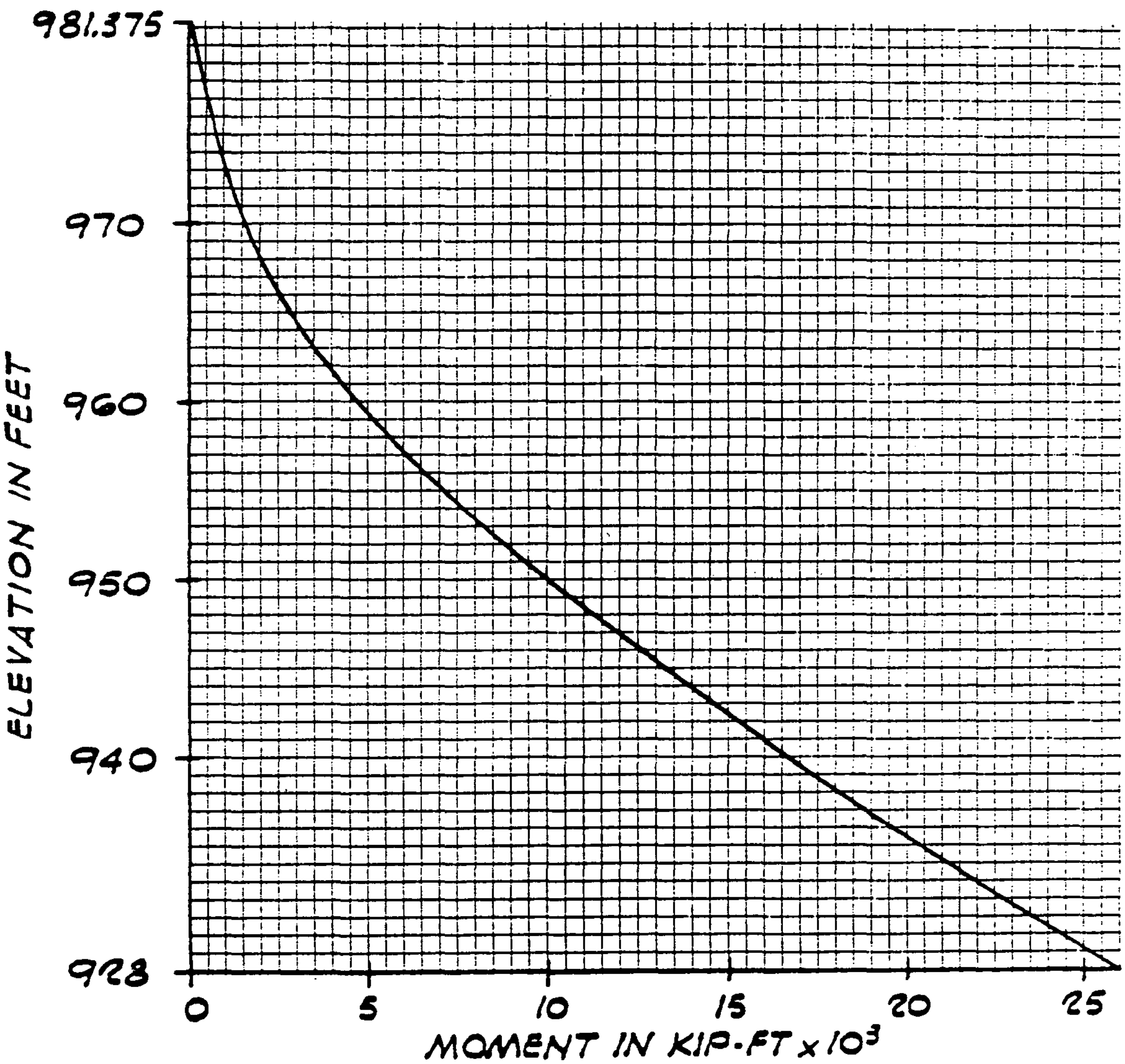
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

MOMENT DIAGRAM

EAST-WEST DIRECTION



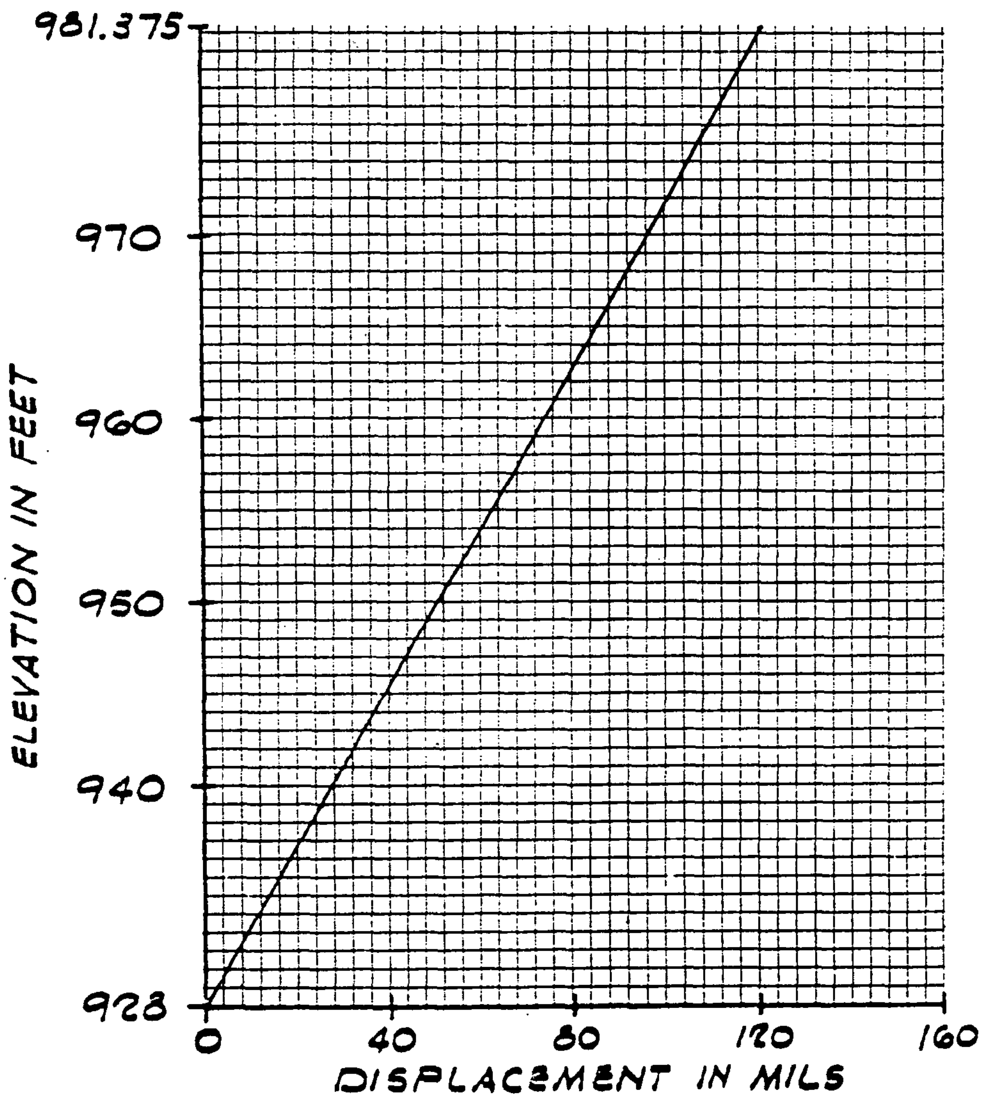
JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

DISPLACEMENT DIAGRAM

EAST-WEST DIRECTION

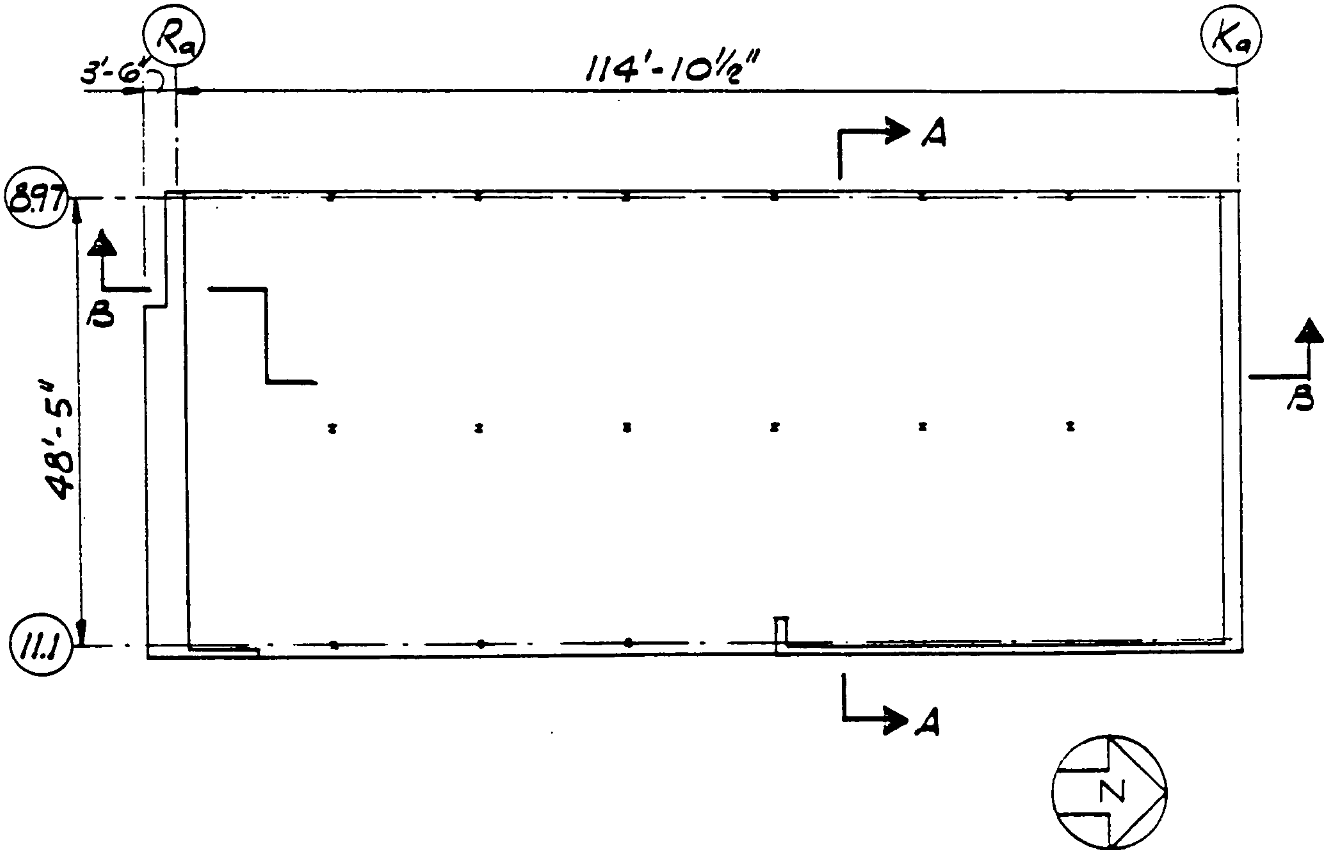


JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

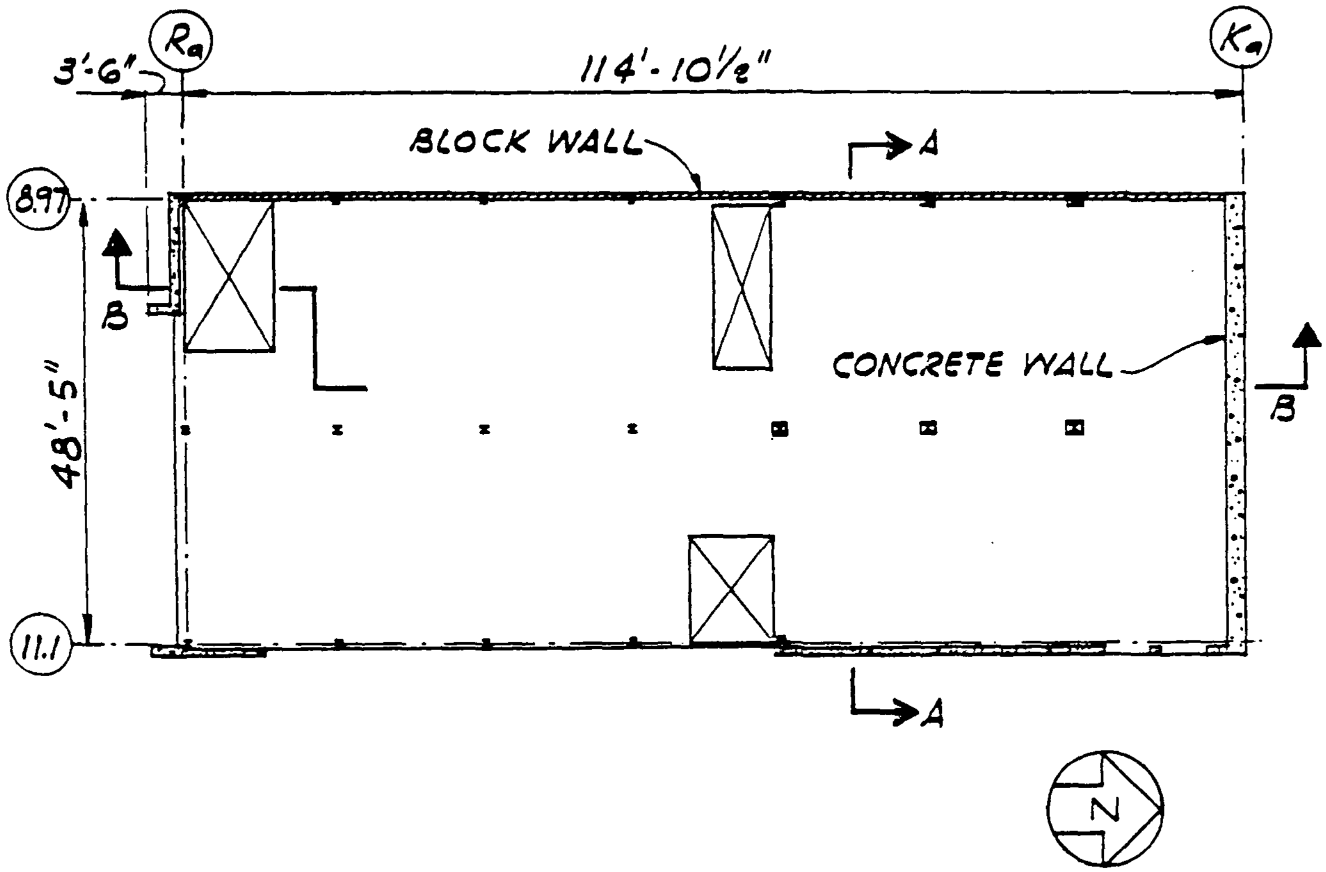
SEISMIC ANALYSIS

ROOF PLAN @ EL. 981'-4½"



JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
FLOOR PLAN @ EL. 965'-0"

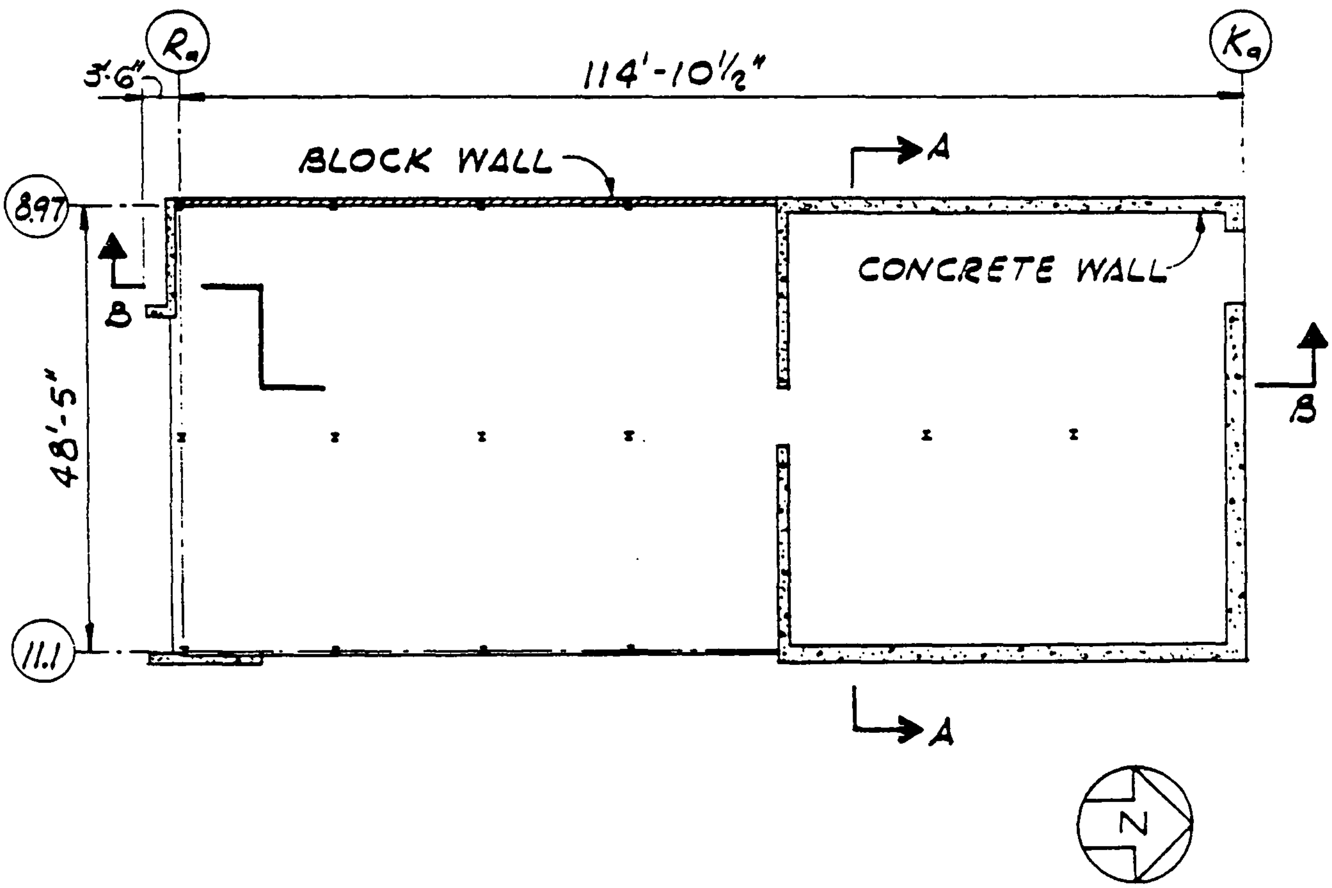


JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

FLOOR PLAN @ EL. 951'-0"

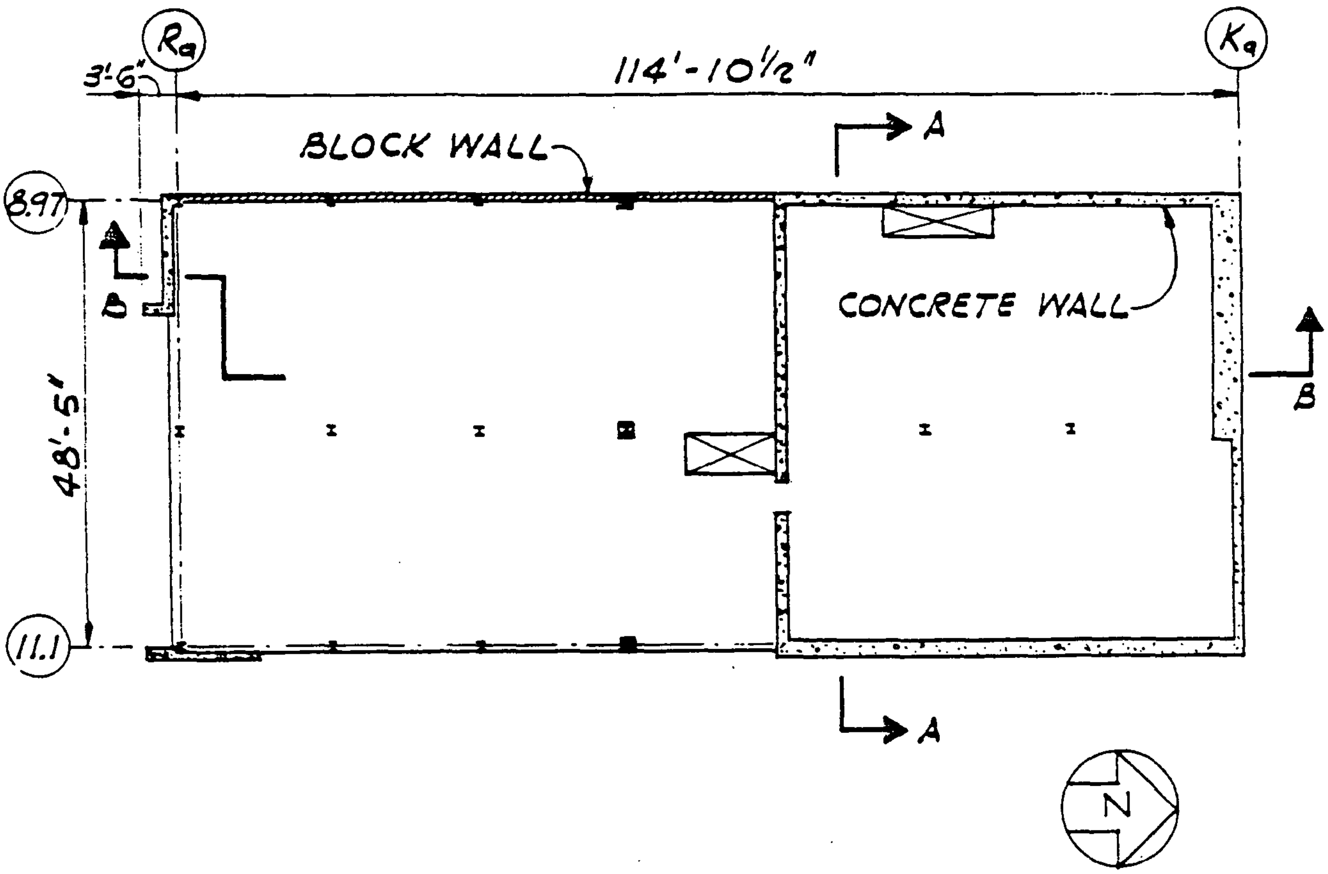


JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

FLOOR PLAN @ EL. 939'-0"



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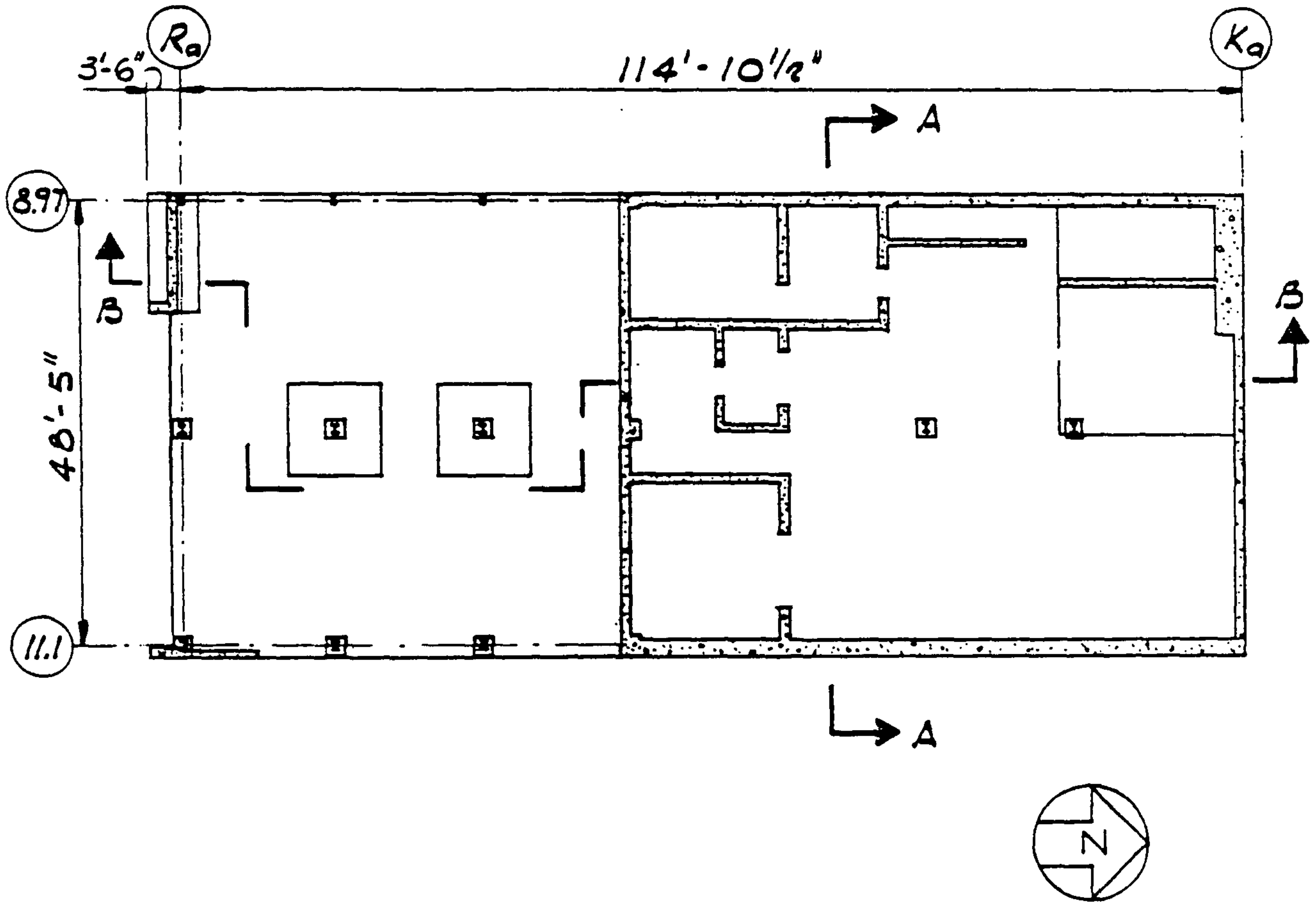
MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

FLOOR PLAN @ EL. 928'-0"



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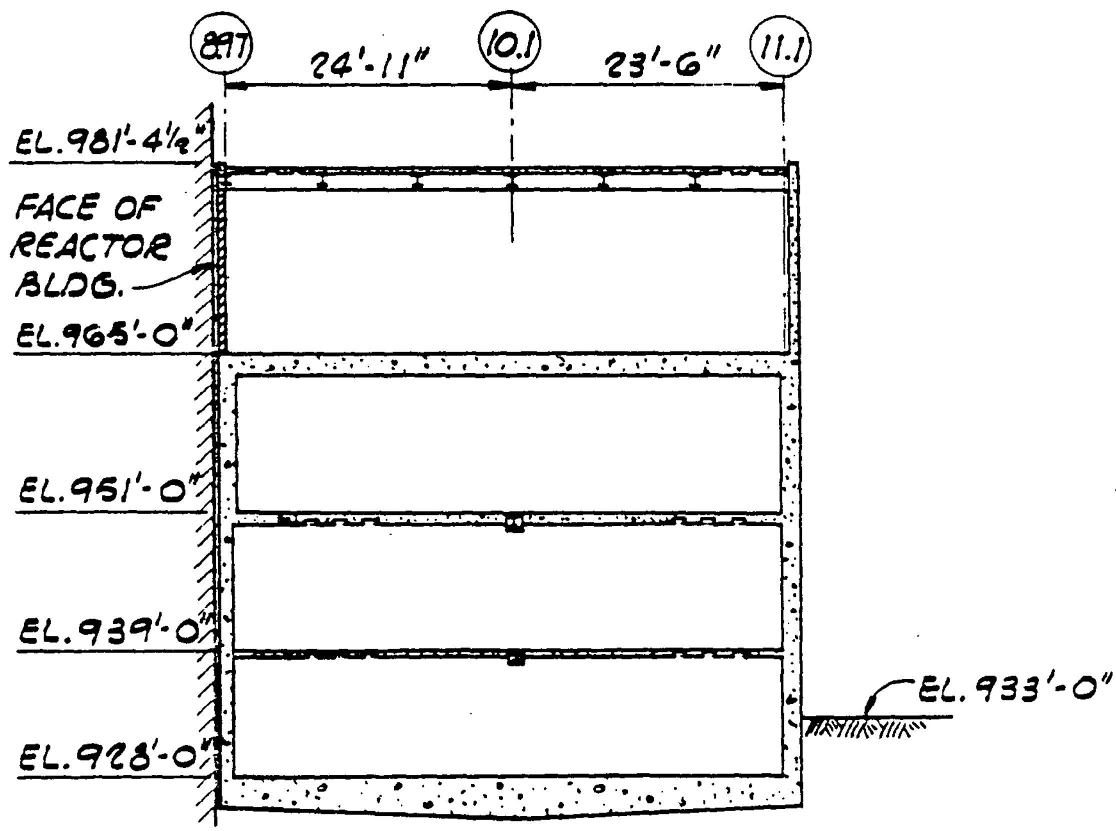
MONTICELLO CONTROL ROOM

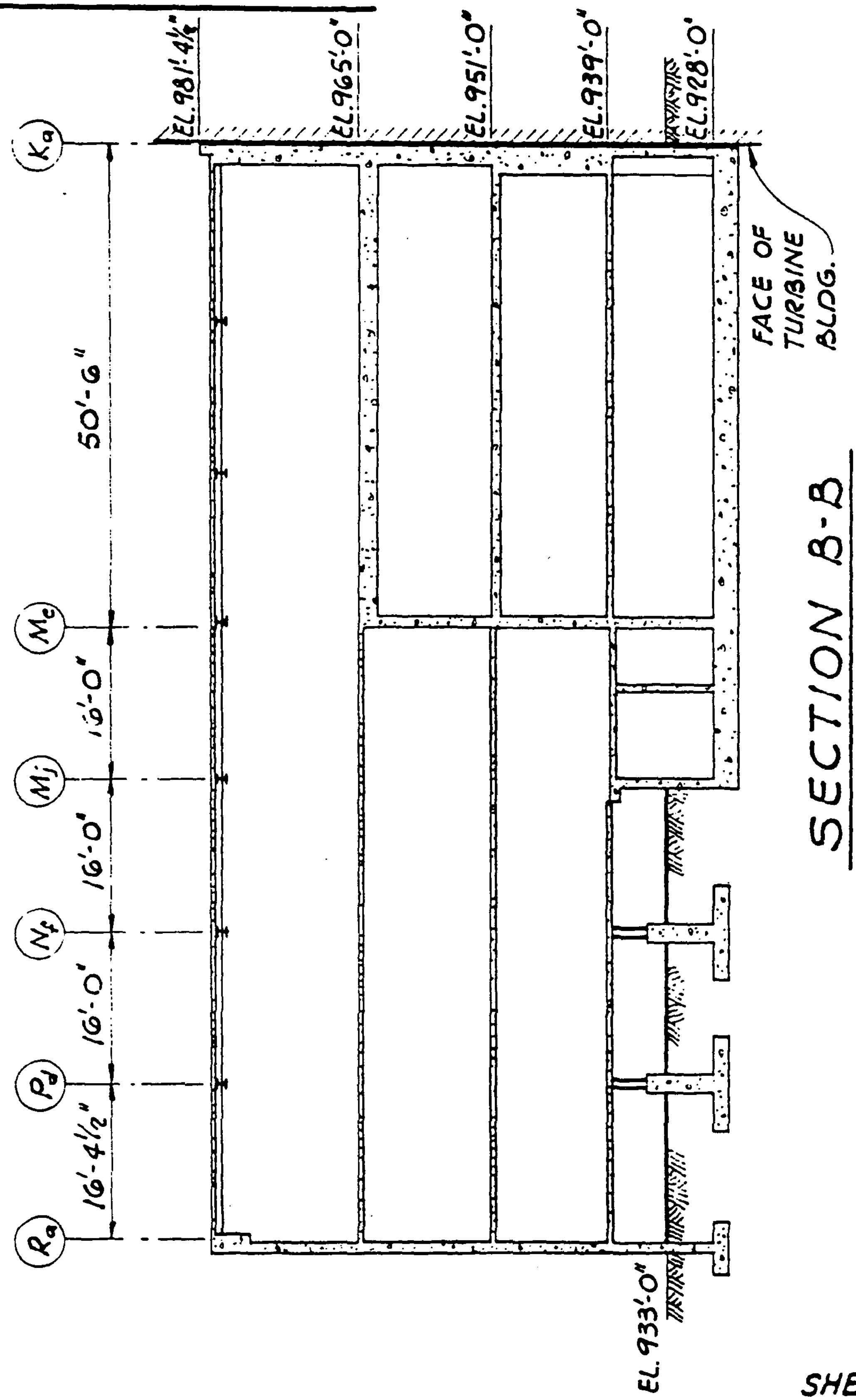
SEISMIC ANALYSIS



SECTION A-A

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS



SHEET NO. 16

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
LUMPED WEIGHTS

WEIGHT 1 @ EL. 981'-4½"

SNOW LOAD: 0.015 x 50.3 x 114.88	=	87.0^K
METAL ROOF + BEAMS + PURLINS: 0.010 x 50.3 x 114.88	=	57.8
CONCRETE DECK: 0.15 x 0.3 x 50.3 x 114.88	=	260.4
½ WALLS BELOW: 0.15 x 8.19 x (2 x 50.3 + 1 x 15.1 + 0.833 x 48.5 + 1 x 11.75 + 0.833 x 11.75) + 0.15 x (1.25 x 38.4 x 3 + 0.875 x 11.5 x 4 + 0.67 x 2.25 x 112.38) + 0.065 x 5.94 x 112.38 + 0.02 x 8.19 x (36.25 + 56)	=	330.0
DEDUCT OPENINGS: 0.15 x 0.833 x 40	=	-5.0
½ COLS. BELOW: 8.19 x (.039 x 6 + .045 x 3 + .033 x 6)	=	4.6
		734.8

WEIGHT 2 @ EL. 965'-0"

CONCRETE SLAB: 0.15 x 2 x 47.5 x 48.4	=	689.0^K
METAL DECK W/CONCRETE SLAB: 0.048 (64.5 x 48.4 - 10 x 16.3 - 6 x 18.2 - 9.1 x 11.63)	=	131.9
½ WALLS ABOVE & BELOW: 0.15 x 15.19 x (2 x 50.3 + 1 x 15.1 + 0.833 x 49.5 + 0.833 x 11.75) + 0.15 (1.5 x 48.6 x 8 + 0.75 x 49.5 x 7 + 1.5 x 8 x 5.5 + 1 x 7 x 47.4) + 0.065 x (112.88 x 15.19 + 64.75 x 8) + 0.02 x (36.25 x 15.19 + 56 x 15.19) + 0.043 x 26 x 11.5	=	752.0
½ COLS. ABOVE & BELOW: 15.19 x (0.036 x 6 + 0.039 x 3)	=	5.1
STEEL FLOOR FRAMING: 0.0086 x 64.4 x 50.3	=	27.8
EQUIPMENT: 0.06 x 47.5 x 48.4 + 0.04 (64.5 x 48.4 - 10 x 16.3 - 6 x 18.2 - 9.1 x 11.63)	=	248.0
DEDUCT FOR OPENINGS IN WALLS: 0.15 x 0.833 x 40	=	-5.0
		1848.8

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MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
LUMPED WEIGHTS CONT'D.

WEIGHT 3 @ EL. 951'-0"

CONCRETE SLAB : 0.15 x 1 x 47.5 x 48.4	= 344.5 K
METAL DECK W/ CONCRETE SLAB : 0.048 (64.5 x 48.4 -10 x 16.3 - 6 x 18.2 - 9.1 x 11.63)	= 131.9
1/2 WALLS ABOVE & BELOW : 0.15 (2 x 50.3 x 7 + 1 x 23.88 x 6 + 3 x 26.6 x 6 + 1 x 47.4 x 13 + 1 x 15.1 x 13 + 0.833 x 16 x 4 + 0.875 x 15.75 x 10 + 1 x 50.5 x 6 + 1.75 x 50.5 x 7 + 1.625 x 49.5 x 13 + 1 x 11.75 x 13) + 0.02 x (36.25 x 7 + 20.5 x 6 + 56 x 3) + 0.065 x (64.38 x 13) + 0.043 x (26 x 14)	= 745.4
1/2 COLS. ABOVE & BELOW : 13 x (.078 + .045) x 4	= 6.9
STEEL FLOOR FRAMING : 0.0085 x 50.3 x 114.88	= 49.0
EQUIPMENT : 0.060 x 47.5 x 48.4 + 0.040 (64.5 x 48.4 - 10 x 16.3 - 6 x 18.2 - 9.1 x 11.63)	= 248.0
DEDUCT FOR OPENINGS IN WALLS : 0.15 x (2 x 7 x 8 + 1 x 6.38 x 7)	= -23.7
	1502.0

WEIGHT 4 @ EL. 939'-0"

CONCRETE SLAB: 0.15 x (1 x 9 x 17 + 0.75 x 13 x 11 + 0.67 x 6 x 4)	= 41.5 K
METAL DECK W/ CONCRETE SLAB : 0.048 x (48 x 47.5 - 320 - 56) + 0.043 x 48.83 x 48.38 + 0.07 x 14 x 17 + 0.061 x (33 x 16 - 40)	= 258.8
1/2 EXTERIOR WALLS ABOVE & BELOW : 0.15 x [(1 x 20.3 + 3 x 26.6 + 1 x 47.5 + 1.625 x 49.5) x 6 + (1 x 35.13 + 3 x 14.17 + 0.833 x 49.2 + 1 x 64.5) x 5.5 + 0.833 x 55 x 4 + 1 x 15.1 x 13 + 1 x 11.75 x 11.5 + 0.833 x 17 x 1.625] + 0.02 x (36.25 x 7 + 20.5 x 6) + 0.065 x (64.38 x 6 + 56 x 4.17)	= 482.5
1/2 INTERIOR WALLS BELOW : 0.15 x 1 x 177.5 x 5 + 0.15 x 0.67 x 45 x 5	= 154.0
LANDING : 0.15 x (0.67 x 9 x 15.75 + 0.54 x 11.75 x 7)	20.9
1/2 COLS. ABOVE & BELOW : 10.16 x (0.039 x 6 + 0.045 x 3)	= 3.8
STEEL FLOOR FRAMING : 0.0078 x 50.3 x 114.8	= 45.0
EQUIPMENT : 0.04 x (47.5 x 48.4 + 64.5 x 48.4 - 3.5 x 11.5 - 4.5 x 9.5)	= 213.5
	1220.0

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MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

LUMPED WEIGHTS CONT'D.

WEIGHT 5 @ EL. 928'-0"

CONCRETE MAT: $0.15 \times \left(\frac{2.5+3.5}{2}\right) \times 50.3 \times 67.5$	= 1530.0
CONCRETE SLAB @ EL. 933'-0": $0.15 \times 1/6 \times 47.38 \times 48$	= 56.8
FOOTINGS: $0.15 \times (1.5 \times 42.54 \times 5.42 + 1.5 \times 50.88 \times 5 + 1.5 \times 50.88 \times 4.83 + 1.5 \times 10 \times 10 \times 2)$	= 209.4
1/2 EXTERIOR WALLS ABOVE & BELOW: $0.15 \times 5.5 \times (1 \times 99.6 + 0.833 \times 100.18 + 1.5 \times 47.38 + 1.625 \times 66.5 + 2 \times 2 \times 5.5 + 3 \times 15.1)$	= 339.4
1/2 INTERIOR WALLS ABOVE:	= 154.0
1/2 CONCRETE COLS. ABOVE: $0.15 \times 2 \times 1 \times 5.5 \times 3$	= 5.0
EARTH FILL: $48 \times 47.38 \times 4.8 \times 0.135$	= 1472.0
EQUIPMENT: $0.060 \times 50.3 \times 67.5$	= 204.0
	3970.6

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MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
SECTION PROPERTIES
ELEV. 981'-4½" TO ELEV. 965'-0"

EQ IN N-S DIR.

$$I_{E-W} = \frac{0.833(50.5)^3}{12} + 8(2)(2)(24.25)^2 + \frac{1}{6}\frac{(8)(18.0)^3}{12}$$

$$+ 8(2)(2)(8.25)^2 + \frac{1}{6}\frac{(8)(15)^3}{12} \times 6 + 8(1)(1)(8.8)^2 + \frac{0.833(11.75)^3}{12}$$

$$= 33{,}566.1 \text{ FT}^4$$

$$\bar{A} = \frac{5}{6}(0.833 \times 50.5 + 0.833 \times 11.75) + \frac{1}{6}(8 \times 18 + 8 \times 15 \times 6)$$

$$= 187.2 \text{ FT}^2$$

EQ IN E-W DIR.

$$I_{N-S} = \frac{2(50.3)^3}{12} + 8(0.67 \times 0.67 \times \frac{1}{6}) \times 25.2^2 + 8(0.833$$

$$\times 0.833) \times 24.0^2 + \frac{1(13)^3}{12}$$

$$= 24{,}971.2 \text{ FT}^4$$

$$\bar{A} = \frac{5}{6}[2(50.3) + 1(13)]$$

$$= 94.7 \text{ FT}^2$$

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MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

SECTION PROPERTIES

ELEV. 965'-0" TO ELEV. 951'-0"

EQ IN N-S DIR.

$$I_{E-W} = \frac{1.625(50.5)^3}{12} + 8 \times 1 \times 1 \times (24.75)^2 + 8 \times 2 \times 2 \times (24.25)^2$$

$$+ \frac{1.25(50.5)^3}{12} + 8 \times 1 \times 1 \times (24.75)^2 + 8 \times 2 \times 2 \times (24.5)^2$$

$$= 78{,}682.4 \text{ FT}^4$$

$$\bar{A} = \frac{5}{6}(1.625 \times 50.5 + 1.25 \times 50.5 + 0.833 \times 11.75)$$

$$+ \frac{1}{6}\left(8 \times 16 \times \frac{1}{6} \times 4\right)$$

$$= 141.7 \text{ FT}^2$$

EQ IN E-W DIR.

$$I_{N-S} = \frac{2(50.3)^3}{12} + 8 \times 1.625 \times 1.625 \times (23.9)^2 + 8 \times 1.25$$

$$\times 1.25 \times (25.0)^2 + \frac{1(50.3)^3}{12} + 8 \times 1.625 \times 1.625$$

$$\times (23.9)^2 + 8 \times 1.25 \times 1.25 \times (25.0)^2$$

$$= 71{,}574.5 \text{ FT}^4$$

$$\bar{A} = \frac{5}{6}(2 \times 50.3 + 1 \times 50.3 + 1 \times 13)$$

$$= 136.6 \text{ FT}^2$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM

SEISMIC ANALYSIS

SECTION PROPERTIES

ELEV. 951'-0" TO ELEV. 939'-0"

EQ IN N-S DIR.

$$I_{E\text{-}W} = \frac{1.625(50.5)^3}{12} + 8\times2\times2\times(24.75)^2 + 8\times1\times1\times(24.75)^2$$

$$+ \frac{1(50.5)^3}{12} + 8\times2\times2\times(24.75)^2 + 8\times1\times1\times(24.75)^2$$

$$= 77{,}050.3 \text{ FT}^4$$

$$\bar{A} = \frac{5}{6}(1.625\times50.5 + 1\times50.5 + 0.833\times12)$$

$$+ \frac{1}{6}\left(8\times16\times\frac{1}{6}\times4\right)$$

$$= 133.0 \text{ FT}^2$$

EQ IN E-W DIR.

$$I_{N\text{-}S} = \frac{2(50.3)^3}{12} + 8\times1.625\times1.625\times(23.9)^2 + 8\times1\times1\times(25)^2$$

$$+ \frac{1(50.3)^3}{12} + 8\times1.625\times1.625\times(23.9)^2 + 8\times1\times1\times(25)^2$$

$$= 65{,}949.5 \text{ FT}^4$$

$$\bar{A} = \frac{5}{6}(2\times50.3 + 1\times50.3 + 1\times13)$$

$$= 136.6 \text{ FT}^2$$

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO CONTROL ROOM
SEISMIC ANALYSIS
SECTION PROPERTIES
ELEV. 939'-0" TO ELEV. 928'-0"

EQ IN N-S DIR.

$$I_{E\text{-}W} = \frac{1.625(66.5)^3}{12} + 8\times1.5\times1.5\times(32.5)^2 + 8\times1.17\times1.17\times(32.5)^2$$

$$+ \frac{1.17\times(66.5)^3}{12} + 8\times1.5\times1.5\times(32.5)^2 + 8\times1.17\times1.17\times(32.5)^2$$

$$= 110{,}643.0\ FT^4$$

$$\bar{A} = \frac{5}{6}(1.625\times66.5 + 1.17\times66.5 + 1\times17 + 0.67\times16 + 1\times29 + 1\times18)$$

$$= 217.15\ FT^2$$

EQ IN E-W DIR.

$$I_{N\text{-}S} = \frac{1.5(50.3)^3}{12} + 8\times1.17\times1.17\times(25.0)^2 + 8\times1.625\times1.625\times(23.9)^2$$

$$+ \frac{1.17(50.3)^3}{12} + 8\times1.17\times1.17\times(25.0)^2 + 8\times1.625\times1.625\times(23.9)^2$$

$$= 66{,}138.8\ FT^4$$

$$\bar{A} = \frac{5}{6}(1.5\times50.3 + 1.17\times50.3 + 1\times27)$$

$$= 134.4\ FT^2$$

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

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

May 27, 1968

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

ATTENTION: Mr. Ralph B. Gile

SUBJECT: Monticello Nuclear Generation
Plant-Earthquake Analysis
20 Inch Suction Header

Gentlemen:

Transmitted herewith is our report on the subject analysis. In accordance with your instructions, we have performed this analysis to determine the forces, moments and stresses produced by the design earthquake for the subject facility.

Very truly yours,

H. J. Sexton & Associates, Engineers

E. J. Keith

E. J. Keith
Associate

EJK/pb
Encl.

REPORT ON THE
DYNAMIC EARTHQUAKE ANALYSIS
OF THE
20 INCH SUCTION HEADER
FOR THE
MONTICELLO NUCLEAR GENERATION PLANT

This report, prepared for the General Electric Company, presents the results of a dynamic earthquake analysis of the 20 Inch Suction Header for the Monticello Nuclear Generation Plant. A typical segment of this pipe was analysed for the two directions of horizontal earthquake motion parallel to the primary axes of the reactor building. The results are presented for each case including coordinates, forces, moments, support reactions and stresses at all critical points along the pipe. Displacements are not presented since the results indicate that these displacements are negligibly small, being less than three mils maximum.

DESCRIPTION OF 20 INCH HEADER

The 20 inch suction header consists of a 20 inch outside diameter steel pipe having a wall thickness of 3/8-inch. The header is a 16-segmented closed loop connected to the pressure suppression chamber by four 20 inch tees and 24 pairs of one-half inch by two and one-half inch pin-connected struts. The entire closed loop lies in a horizontal plane at Elevation 902'-3" and is centered about the vertical centerline of the pressure suppression chamber. Figures 1 and 2 show the plan and details of the header and its connections to the suppression chamber. Page 6 summarizes the pertinent properties of the header.

ANALYTICAL CRITERIA

The analysis was based on the following data included in the Plant's Design and Analysis Report:

1. Design Earthquake

   North 69° West component of the 1952 Taft, California Earthquake normalized to 0.06 gravity. Safe shutdown is at twice the design earthquake.

2. Damping Factors

   Critical Piping------------------------0.5%

Only the results for the Design Earthquake are presented herein. To obtain the results for the safe shutdown, multiply the results presented by a factor of 2.0.

METHOD OF ANALYSIS

A typical representative segment of pipe was idealized as a mathematical model consisting of lumped masses separated by elastic members. Lumped masses were located at critical points as required to adequately represent the typical segment of pipe. Using elastic properties of the pipe between successive mass points the flexibility matrix of the modeled three-dimensional pipe system was determined. The flexibility calculations included the effects of torsional, bending, shear and axial deformations. Comments on the adequacy of the model's boundry conditions and resonance effects are presented later in this report. 2

After the flexibility and mass matricies of the mathematical model were obtained, the frequencies and mode shapes for the first three modes of vibration were determined. Normally, after the frequency has been determined for each mode, the spectral acceleration is read from the appropriate support point response spectra and the response displacement is calculated. In this case, however, the period of vibration of the first mode of the header is only 0.03 seconds and is so small the header may be treated as a rigid system supported on a rigid suppression chamber. (The first mode period of the pressure suppression chamber is 0.04 seconds). Therefore, the header was analysed as if it were loaded with a uniform equivalent static coefficient equal to the response acceleration of the suppression chamber times a factor of 1.33 to account for the effects of higher modes in the header and the minor magnification that could be

produced from interaction between the suppression chamber and the header. The resulting uniform static coefficient of 0.20 was used in the horizontal direction and was assumed to act simultaneously with a uniform static coefficient of 0.05 in the vertical direction. Since the stresses resulting from this loading are very small, no further refinement of analysis was deemed justified.

COMPUTATION OF STRESSES

The values of forces and moments given in this report are for both member coordinate and global coordinate systems and the particular system used is so noted on the sheets containing the results. Using the results given for the member coordinate system, the pipe stresses are determined in accordance with Reference 2.

DESCRIPTION OF COMPUTER PROGRAM

All of the calculations were performed with the aid of an IBM 360/65 digital computer. The computer program employed was written specifically for the analysis of three dimensional piping systems.

The input data for this program consists of the coordinates of all joints, pipe diameter, pipe wall thickness, pipe weight per foot, modulus of elasticity and boundary conditions. The computer calculates the pipe stiffness matrix, force transformation matrix, mode shapes, frequencies, inertia forces, internal forces, displacements and support reactions.

DISCUSSION OF RESULTS

The results presented herein are in the form of coordinates, internal 3
forces and moments in global and member coordinates, support reactions and stresses. These results are given for two different horizontal directions of earthquake acting simultaneously with the vertical direction of earthquake.

The following table summarizes the maxima of certain selected parameters:

Maximum stress	329 psi (at tee)
Maximum deflection	3 mils
Maximum moments acting at end of tee section in member coordinate system:	
Bending	4.86 kip-feet
Torsion	4.86 kip-feet

Maximum forces acting at
end of tee section in member
coordinate system:
Shear -------------------------- 2.44 kips
Axial -------------------------- 2.44 kips
Maximum stresses acting
on tee at connection to
suppression chamber ----------------- 820 psi
Maximum force in
horizontal strut ----------------------0.415 kips
Maximum stress in
horizontal strut ---------------------- 330 psi
Allowable stress in
horizontal strut ---------------------11,260 psi
Allowable bolt force in
horizontal strut --------------------- 8.84 kips

It should be pointed out that the above results are for seismic conditions alone. Dead load and thermal conditions have not been considered. In order to check the vertical strut it was necessary to find the force in the strut due to dead load. This was found to be 2.54 kips. The strut force due to seismic effects was found to be 0.12 kips. Thus, the total vertical strut force is 2.66 kips which produces a maximum stress of 3.15 ksi. This is less than the allowable tensile stress of 20 ksi. The strut support system and connecting bolts are therefore adequate for the seismic plus dead load condition.

COMMENTS ON ASSUMPTIONS

This analysis is based on the assumption that the header segments may 4
be considered rigid at their connection to the 20-inch tee sections. While this assumption is not strictly true, it leads to the conclusion that the period of vibration of the header is extremely short and the earthquake induced stresses are very small compared to the allowable stresses. Even if the tee sections provided only partial restraint they would not increase the period of vibration of the header by more than about fifty per-cent, thus producing a period of vibration of the header of only 0.045 seconds, still very small. Furthermore, even if the period was 0.045 seconds and the header was subjected to magnification factors greater than those assumed in this analysis, the current calculated stresses are so low that there is ample margin for such magnifications. Therefore, it is our opinion that the results presented herein are adequate and should be used for the design of the 20-inch suction header and its supports.

LIST OF FIGURES

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Weights and Properties

1. Outside diameter of pipe	20.0 inches
2. Wall thickness of pipe	3/8 inches
3. Weight of pipe per foot	78.6 lbs.
4. Weight of contents per foot	126 lbs.
5. Modulus of elasticity	4,032,000 ksf.

H. J. [illegible]XTON & ASSOCIATES, ENGINEERS
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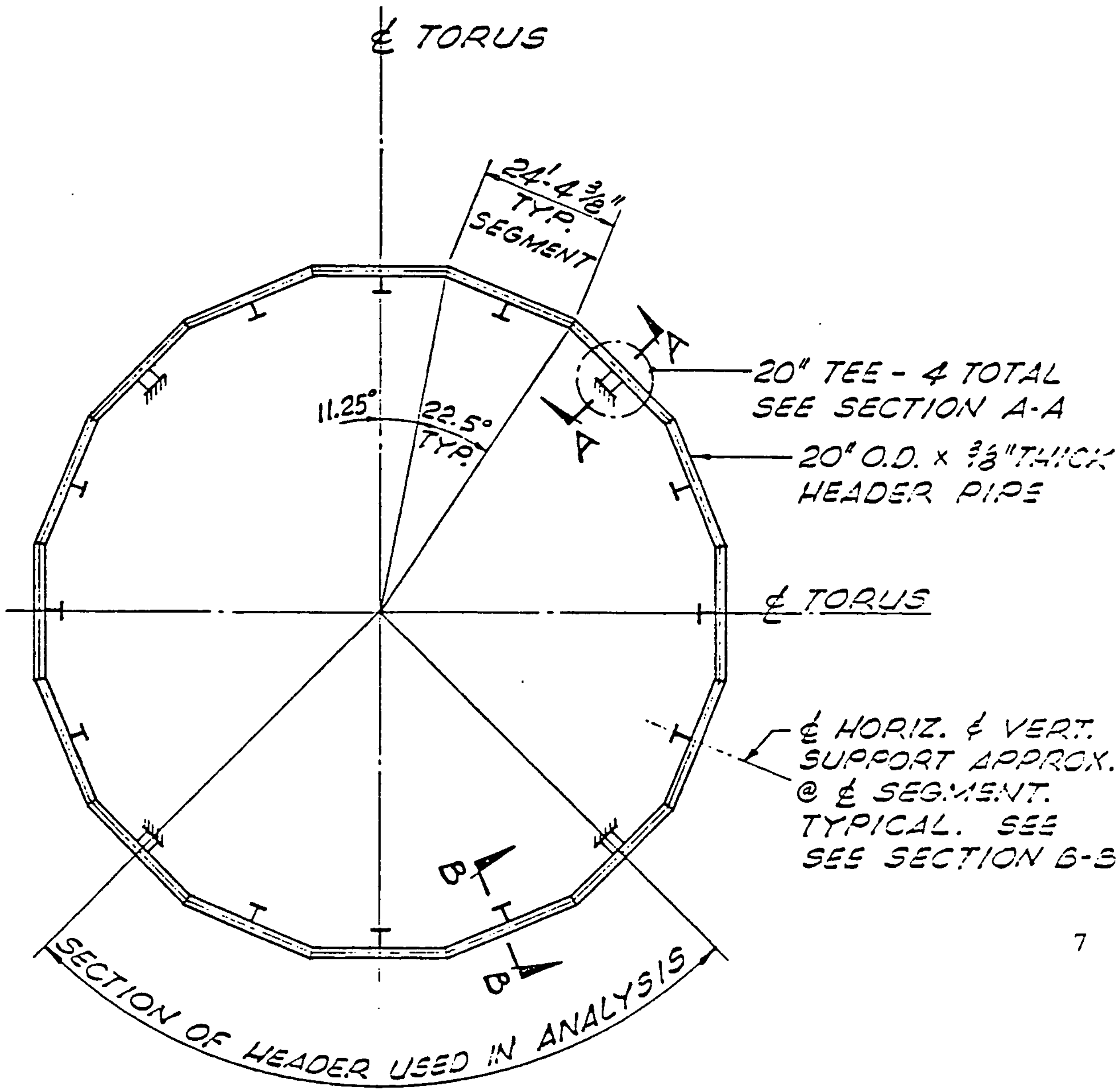
MONTICELLO NUCLEAR GENERATION PLANT



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PLAN OF 20 INCH HEADER

FIGURE 1

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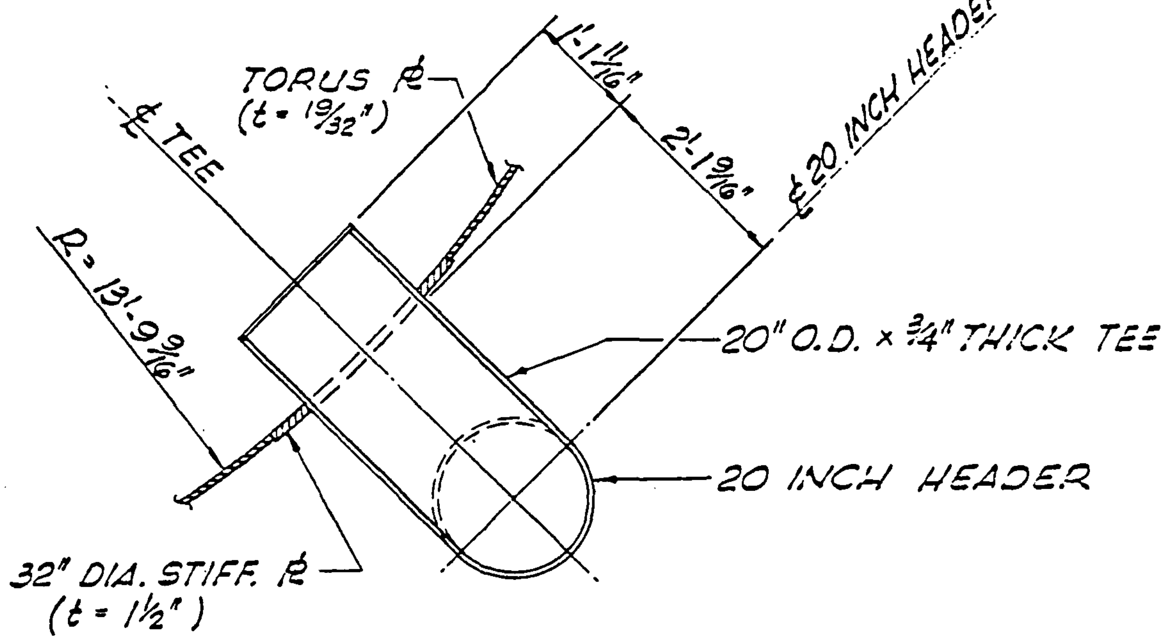
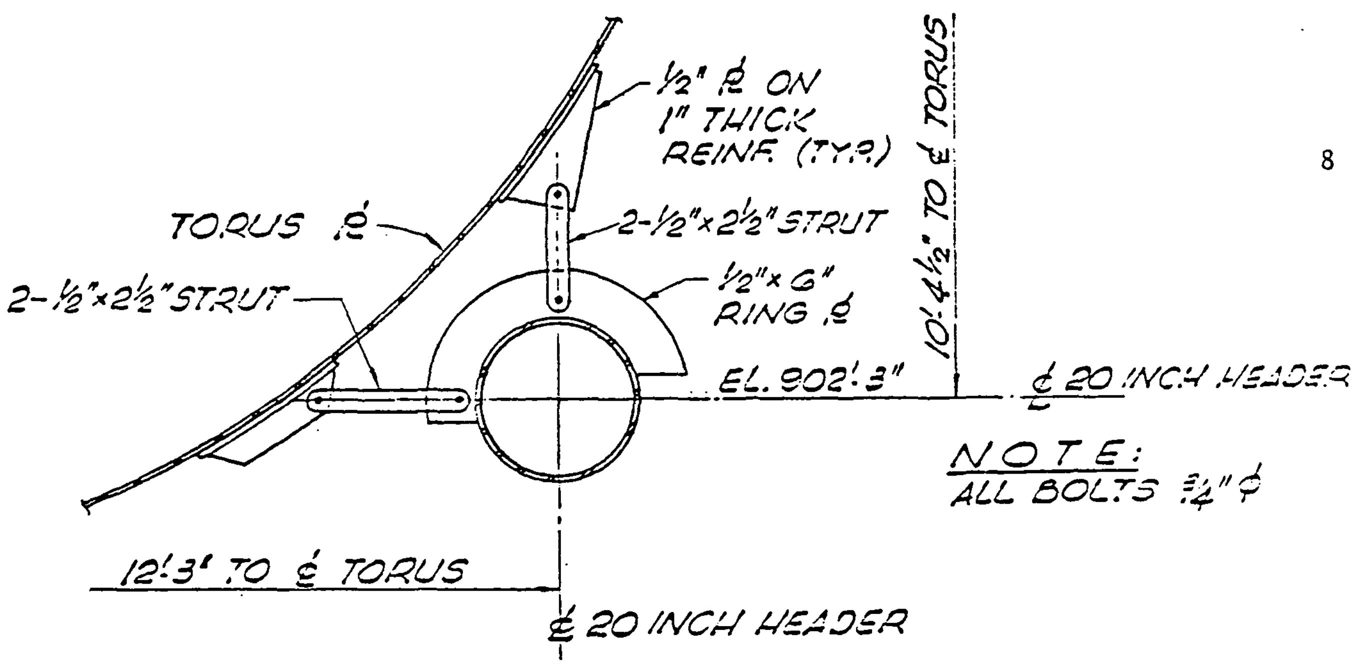


SECTION A-A



SECTION B-B

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FIGURE 2

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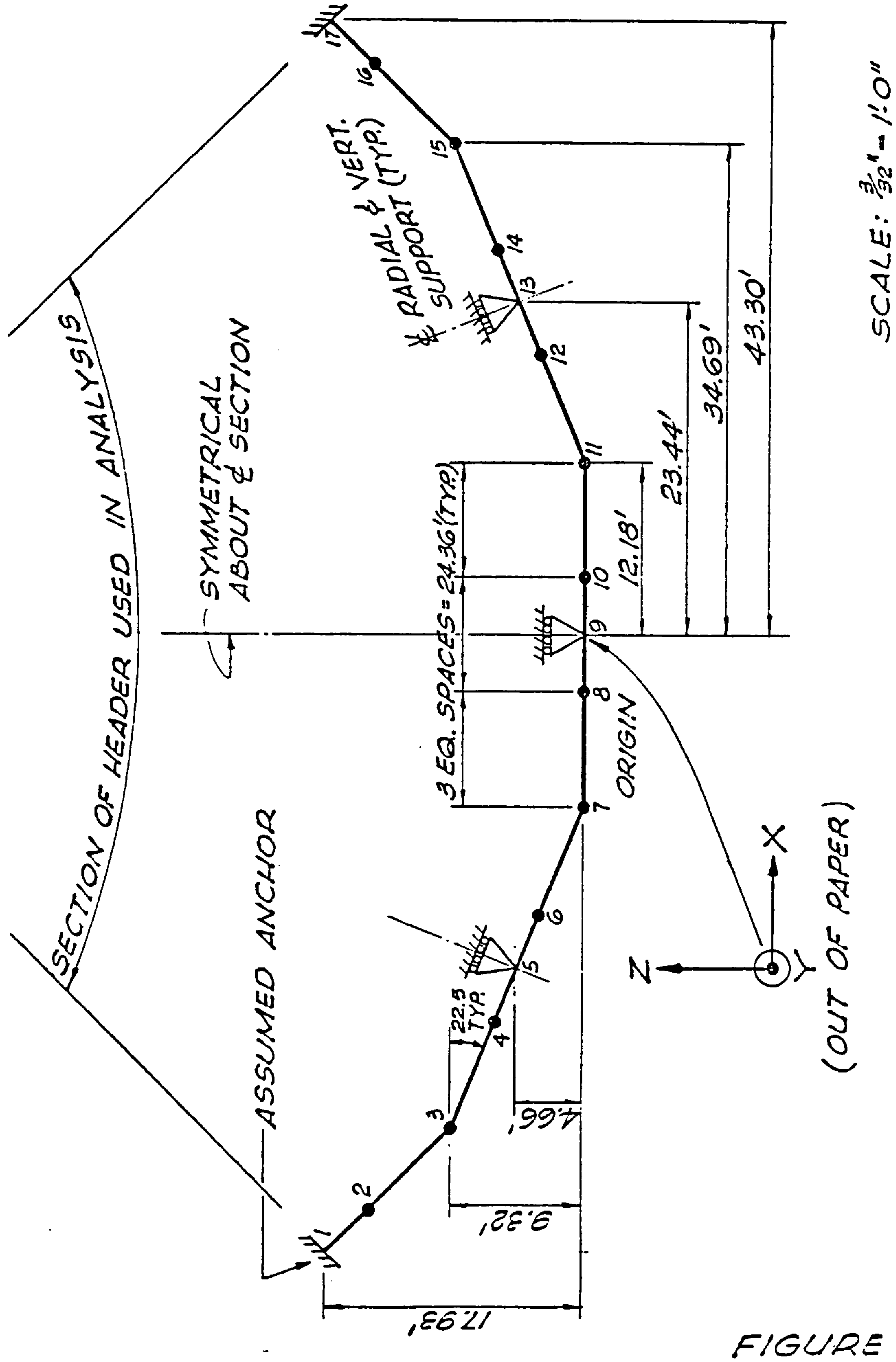

MATHEMATICAL MODEL

FIGURE 3

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Coordinates of Joints

Joint	X Feet	Y Feet	Z Feet
1	-43.30	0.00	17.93
2	-40.43	0.00	15.06
3	-34.69	0.00	9.32
4	-27.19	0.00	6.21
5	-23.44	0.00	4.66
6	-19.68	0.00	3.11
7	-12.18	0.00	0.00
8	-4.16	0.00	0.00
9	0.00	0.00	0.00
10	4.16	0.00	0.00
11	12.18	0.00	0.00
12	19.68	0.00	3.11
13	23.44	0.00	4.66
14	27.19	0.00	6.21
15	34.69	0.00	9.32
16	40.43	0.00	15.06
17	43.30	0.00	17.93

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MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined X and Y Direction Earthquake

Forces at Joints (Global Coordinates)

Joint	X Direction Kips	Y Direction Kips	Z Direction Kips
1	1.52	0.08	0.78
2	1.52	0.08	0.78
3	1.36	0.05	0.78
4	1.02	0.13	0.79
5	0.99	0.13	0.79
6	0.99	0.12	0.07
7	0.67	0.05	0.07
8	0.33	0.13	0.07
9	0.00	0.13	0.07
10	0.33	0.13	0.07
11	0.67	0.05	0.07
12	0.99	0.12	0.07
13	0.99	0.13	0.79
14	1.02	0.13	0.79
15	1.36	0.05	0.78
16	1.52	0.08	0.78
17	1.52	0.08	0.78

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined X 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	2.99	0.18
2	0.20	0.86	0.05
3	0.02	2.46	0.29
4	0.11	0.20	0.04
5	0.31	2.06	0.49
6	0.12	0.77	0.05
7	0.00	0.81	0.23
8	0.00	0.27	0.12
9	0.00	0.00	0.65
10	0.00	0.27	0.12
11	0.00	0.81	0.23
12	0.12	0.77	0.05
13	0.39	2.06	0.49
14	0.11	0.20	0.04
15	0.02	2.46	0.29
16	0.20	0.86	0.05
17	0.44	2.99	0.18

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MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined X and Y Direction Earthquake

Forces at Joints (Member Coordinates)

Joint	Axial Kips	Shear Y Kips	Shear Z Kips
1	1.64	0.08	0.53
2	1.64	0.08	0.53
3	1.52	0.05	0.42
4	1.25	0.13	0.46
5	0.94	0.13	0.46
6	0.94	0.12	0.32
7	0.64	0.05	0.20
8	0.33	0.13	0.07
9	0.00	0.13	0.07
10	0.33	0.13	0.07
11	0.64	0.05	0.20
12	0.94	0.12	0.32
13	0.94	0.13	0.46
14	1.25	0.13	0.46
15	1.52	0.05	0.42
16	1.64	0.08	0.53
17	1.64	0.08	0.53

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined X and Y Direction Earthquake

Moments at Joints (Member Coordinates)

Joint	Torsional Kip-Feet	Bending Y Kip-Feet	Bending Z Kip-Feet
1	0.19	3.00	0.44
2	0.19	0.85	0.11
3	0.19	2.46	0.27
4	0.09	0.21	0.08
5	0.09	2.06	0.60
6	0.09	0.77	0.10
7	0.09	0.80	0.23
8	0.00	0.27	0.12
9	0.00	0.00	0.65
10	0.00	0.27	0.12
11	0.09	0.80	0.23
12	0.09	0.77	0.10
13	0.09	2.06	0.60
14	0.09	0.21	0.08
15	0.19	2.46	0.27
16	0.19	0.85	0.11
17	0.19	3.00	0.44

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined X and Y Direction Earthquake

Pipe Support Reactions (Global Coordinates)

Forces at Points 5 and 13

X Direction	0.29 kips
Y Direction	0.25 kips
Z Direction	0.72 kips

Forces at Point 9

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

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined X and Y Direction Earthquake

Stresses at Joints

Joint	Stress Kips/Sq. In
1	0.329
2	0.095
3	0.269
4	0.026
5	0.232
6	0.090
7	0.091
8	0.033
9	0.070
10	0.033
11	0.091
12	0.090
13	0.232
14	0.026
15	0.269
16	0.095
17	0.329

MONTICELLO NUCLEAR GENERATION PLANT

20 Inch Header

Combined Z and Y Direction Earthquake

Forces at Joints (Global Coordinates)

Joint	X Direction Kips	Y Direction Kips	Z Direction Kips
1	0.74	0.08	0.83
2	0.74	0.08	0.83
3	0.74	0.05	0.67
4	0.74	0.13	0.34
5	0.74	0.13	0.58
6	0.53	0.12	0.58
7	0.50	0.05	0.25
8	0.50	0.13	0.41
9	0.50	0.13	0.41
10	0.50	0.13	0.41
11	0.50	0.05	0.25
12	0.53	0.12	0.58
13	0.74	0.13	0.58
14	0.74	0.13	0.34
15	0.74	0.05	0.67
16	0.74	0.08	0.83
17	0.74	0.08	0.83

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

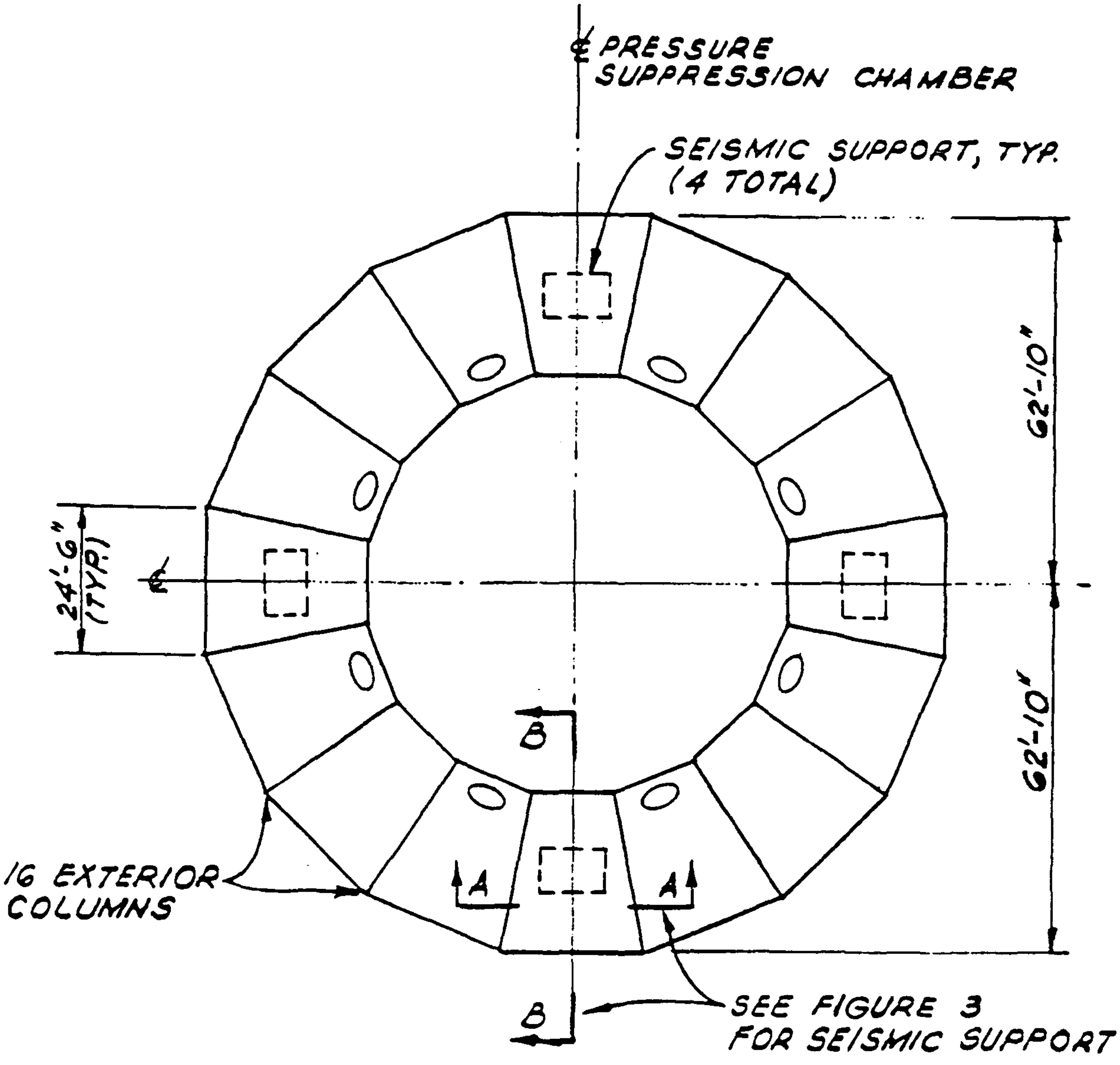
The torus is idealized as a single degree of freedom system. Its spring constant is determined from the calculated shear deformations of the pins and bottom plates of the four seismic supports. By comparison the upper plates are rigid in shear, and all plates and pins are considered rigid in bending. 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

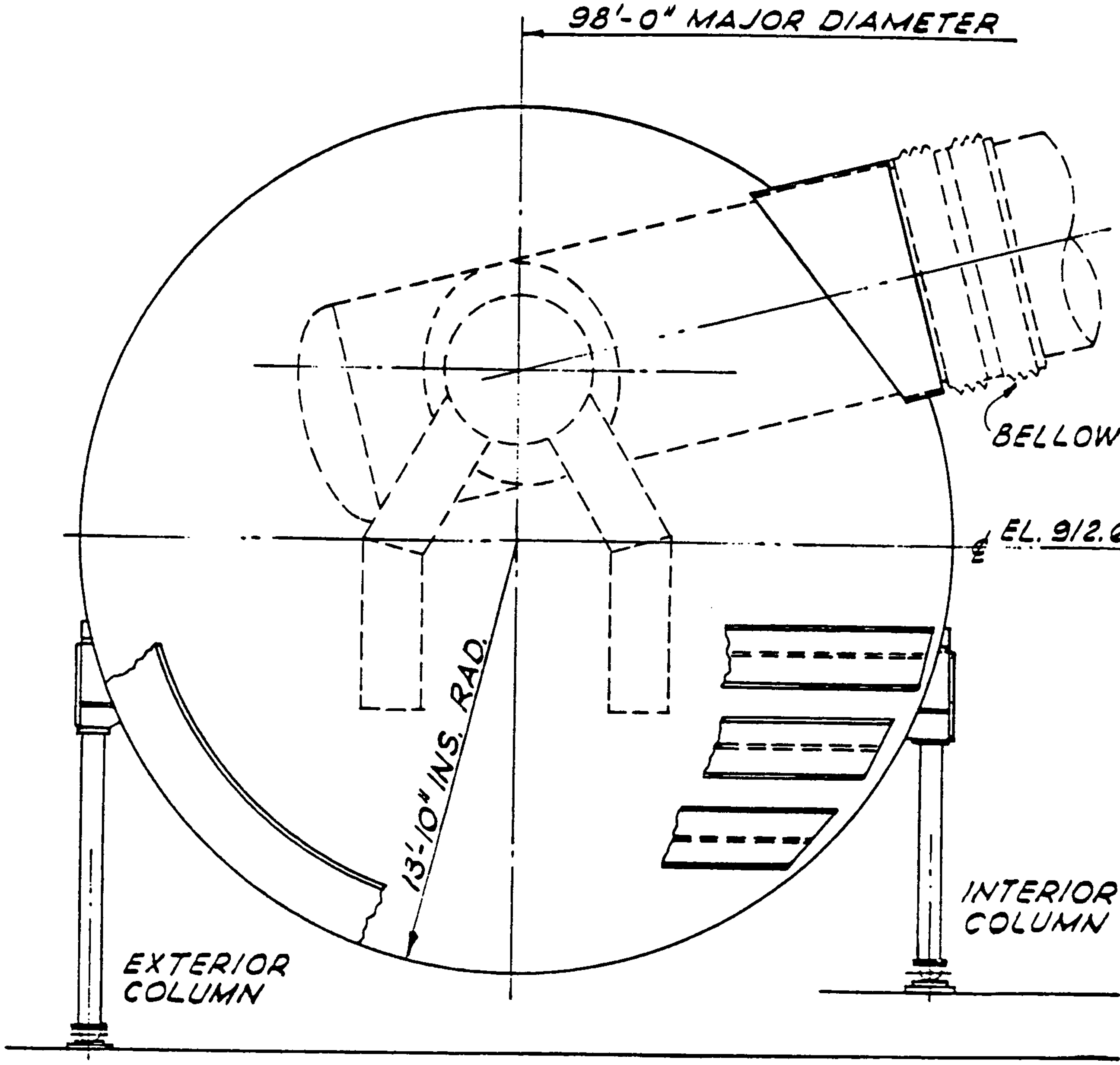
LIST OF FIGURES



PLAN

PRESSURE SUPPRESSION CHAMBER

FIGURE 1



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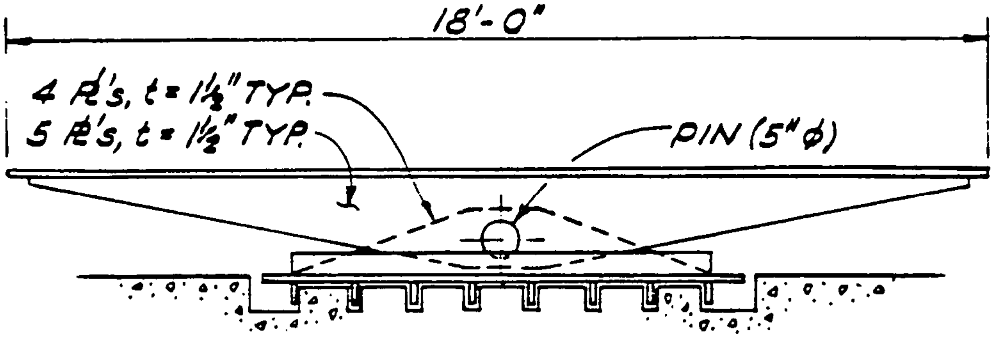
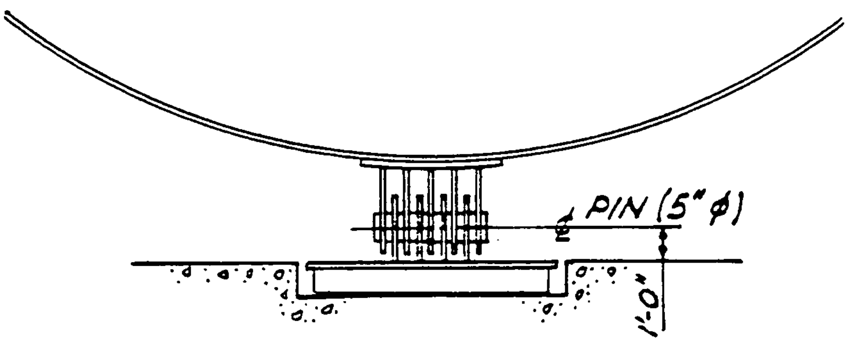
TYPICAL SECTION
PRESSURE SUPPRESSION CHAMBER

FIGURE 2



SECTION A-A



SECTION B-B

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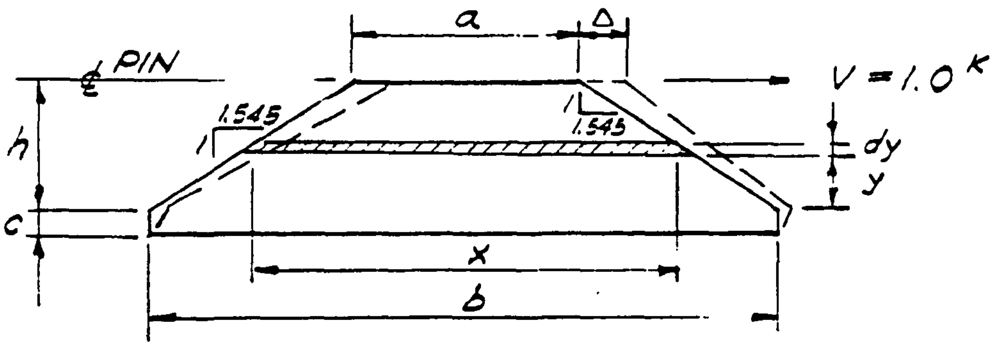
FIGURE 3

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

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

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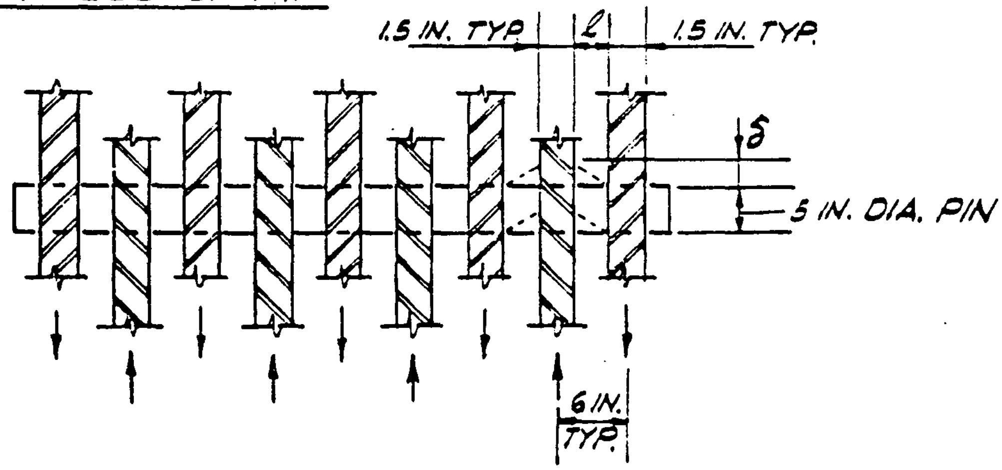
b. STIFFNESS OF PIN



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.

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

c. STIFFNESS OF EACH CHAMBER SUPPORT

$$\frac{1}{K_S} = \frac{1}{K_{\not{R}}} + \frac{1}{K_{PIN}} = \frac{1}{2.63 \times 10^5} + \frac{1}{1.41 \times 10^5} = 1.09 \times 10^{-5}$$

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

2. TORUS STIFFNESS K_T 9

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

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

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

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

b. FLOODED CONDITION

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

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

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.)

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.

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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

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

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

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

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

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 1 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-SS1A	T	HYDRO TEST	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	NORMAL	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	SCRAM	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	SHUTDOWN 1	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	SHUTDOWN 2	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	SHUTDOWN 3	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	LOSS OF FW PUMP 1	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	LOSS OF FW PUMP 2	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	LOSS OF FW PUMP 3	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	RPV OVERPRES 1	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	T	RPV OVERPRES 2	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	W	WEIGHT	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	S	SEISMIC Y	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	S	SEISMIC X	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	S	SEISMIC Z	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	S	SEISOB	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1A	S	SEISOB	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040-SS1B	T	HYDRO TEST	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SS1B	T	NORMAL	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SS1B	T	SCRAM	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SS1B	T	SHUTDOWN 1	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SS1B	T	SHUTDOWN 2	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040-SS1B	T	SHUTDOWN 3	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II

*T - THERMAL, W - WEIGHT, S - SEISMIC, S.A.M. - SEISMIC ANCHOR MOVEMENT, TT - THERMAL TRANSIENT

PIPING STRESS CALCULATION INDEX

REV. NO. 2

PROJECT MONTICELLO 1 NO. 10040 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 -SS1B	T	LOSS OF FW PUMP 1	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	T	LOSS OF FW PUMP 2	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	T	LOSS OF FW PUMP 3	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	T	RPV OVERPRES 1	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	T	RPV OVERPRES 2	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	W	WEIGHT	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	S	SEISMIC Y	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	S	SEISMIC X	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	S	SEISMIC Z	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	S	SEISOB	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1B	S	SEISDB	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II
SR-10040 -SS1C	TT		HWH	1-23-85	RECIRCULATION/RHR			APPENDIX F, VOL. III-V
SR-10040 -SS1D	SECT III CLASS I		HWH	1-23-85	RECIRCULATION/RHR - LOOP A			APPENDIX E, VOL. I
SR-10040 -SS1E	SECT III CLASS I		HWH	1-23-85	RECIRCULATION/RHR - LOOP B			APPENDIX E, VOL. II
SR-10040 -SS1A	T	SHUTDOWN 4	ANDREWS	12-17-84	RECIRCULATION/RHR - LOOP A			APPENDIX F, VOL. I
SR-10040 -SS1B	T	SHUTDOWN 4	ANDREWS	12-19-84	RECIRCULATION/RHR - LOOP B			APPENDIX F, VOL. II

*T = THERMAL, W = WEIGHT, S = SEISMIC, S A M = 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
61? 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 ?. 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 7^{th} 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).

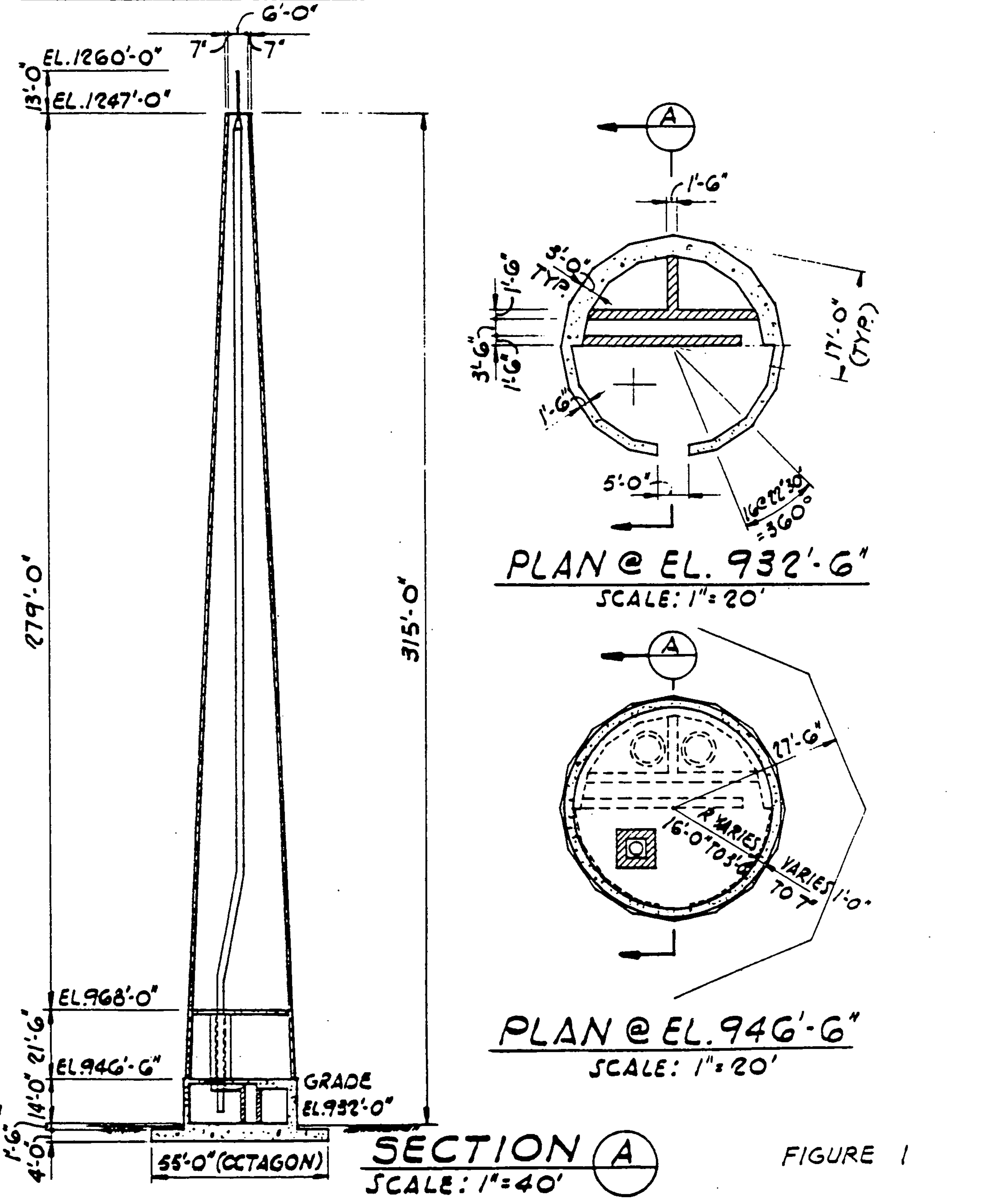
5. "Dynamic Response Data Investigation - Proposed Nuclear Power Plant, Monticello, Minnesota," Dames & Moore, July 7, 1966.

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



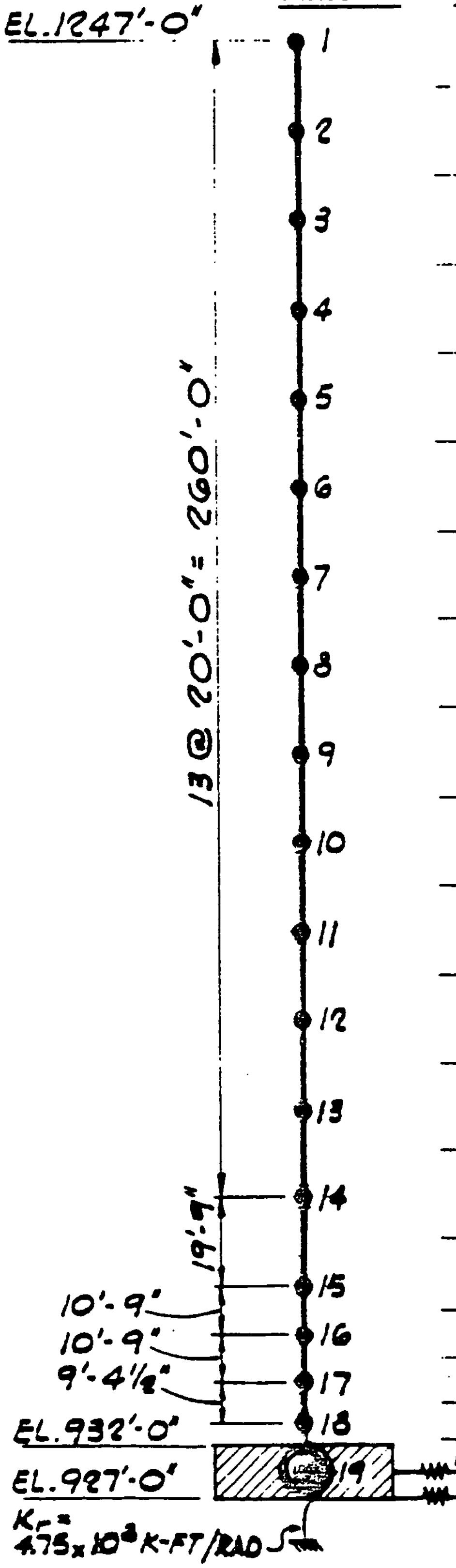
A-124

FIGURE 1

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

MONTICELLO NUCLEAR GENERATION PLANT

OFF-GAS STACK



MASS NO.	WEIGHT (KIPS)	AREA (FT^2)	I (FT^4)
1	19.911		
		13.988	97.982
2	48.125		
		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

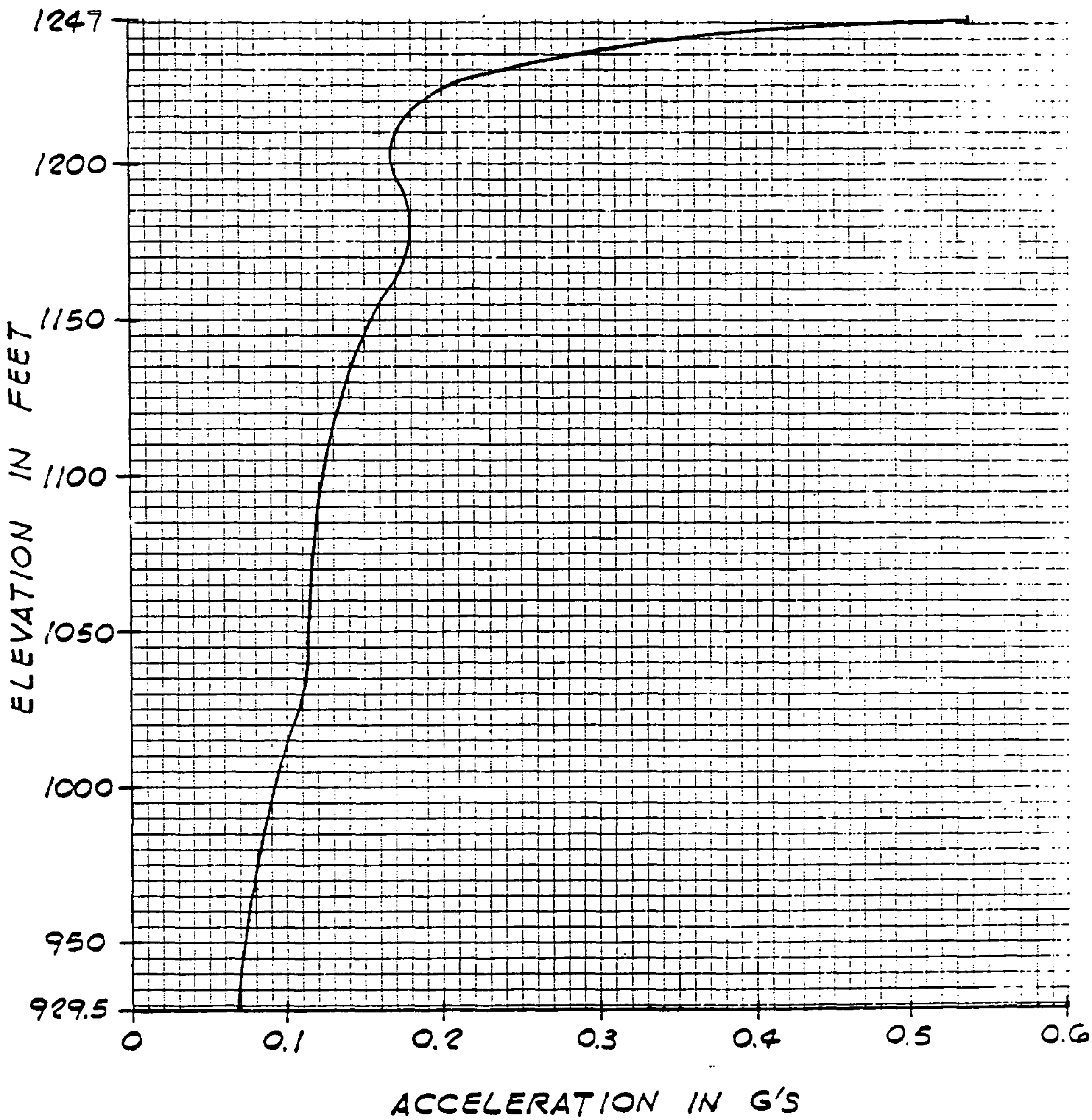


FIGURE 3

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

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

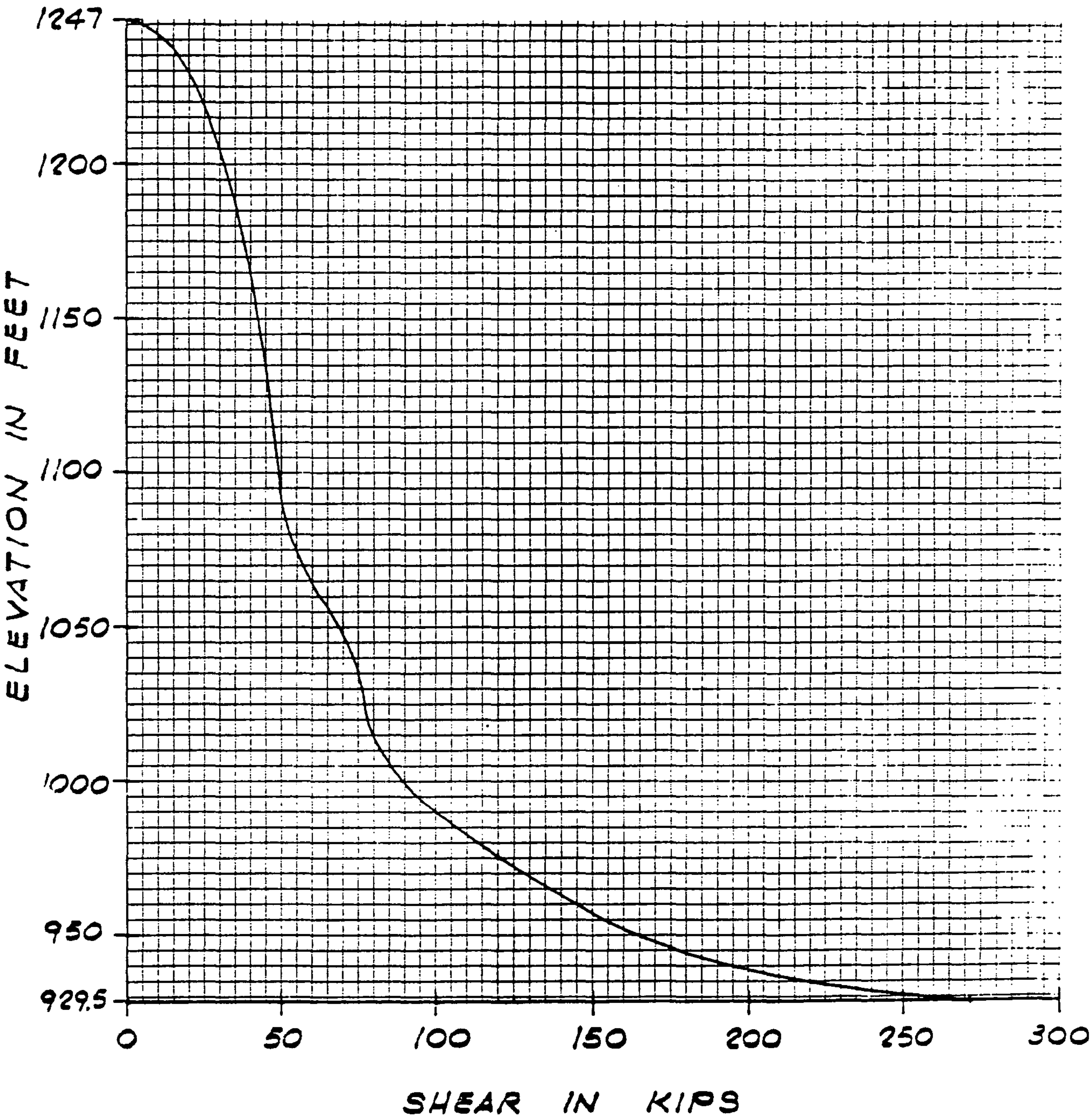


FIGURE 4

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

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

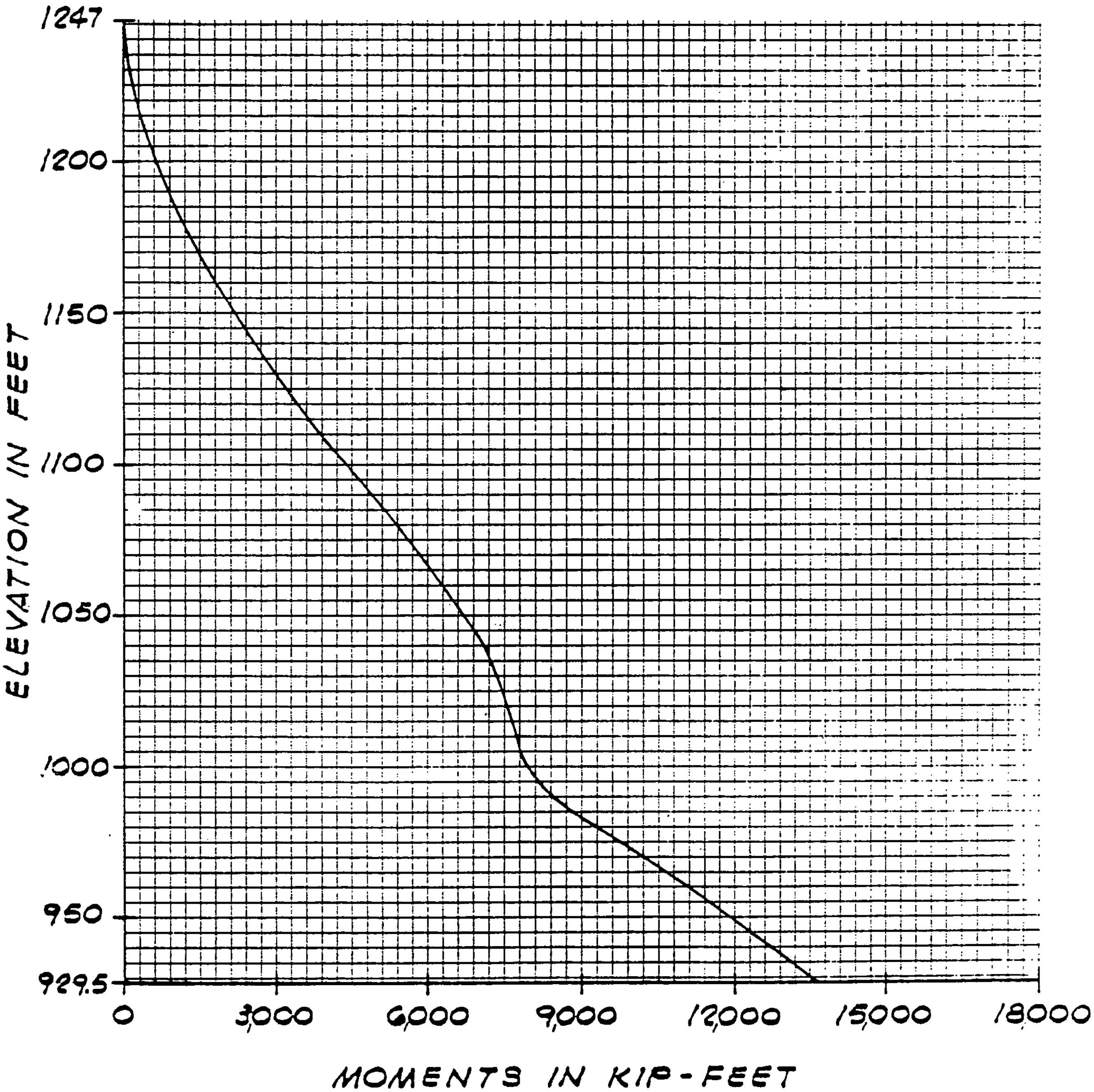


FIGURE 5

JOHN A. BLUME AND ASSOCIATES, ENGINEERS

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

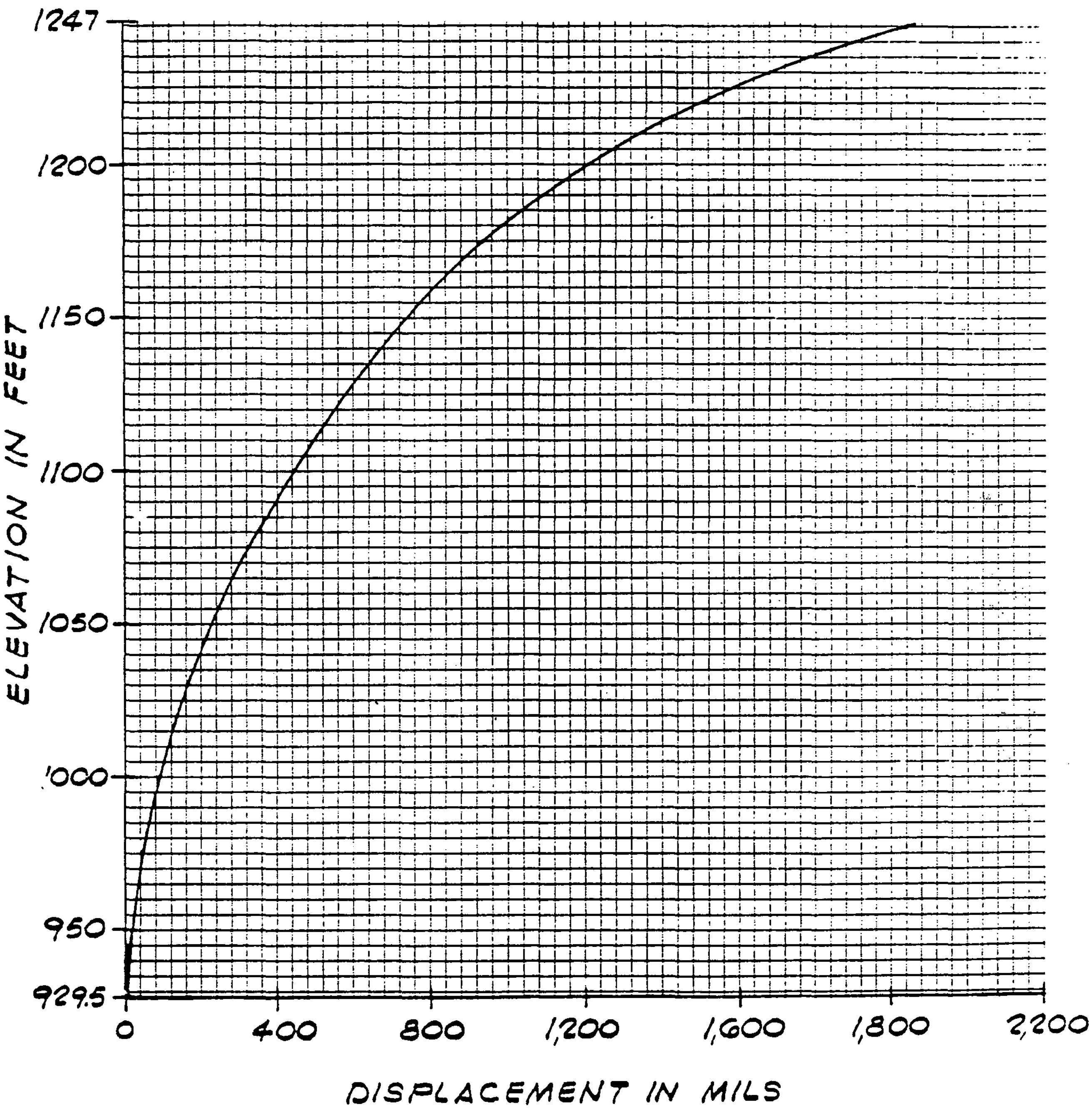


FIGURE 6