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SEISMIC AND STRUCTURAL ANALYSIS OF LACBWR AND GENOA 3 STACKS

Prepared Under NES Project 5101 for

DAIRYLAND POWER COOPERATIVE

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1. SUMMARY

This report, prepared for Dairyland Power Cooperative (DPC), presents the results of the seismic and structural analysis performed by Nuclear Energy Services, Inc. to evaluate the structural adequacy of the LACBWR and GENOA 3 stacks to withstand a seismic event.

Linear seismic analysis, using the response spectrum, modal superposition techniques, have been performed to determine the response of the stacks to the Safe Shutdown Earthquake. Soil structure interaction effects are included by providing appropriate foundation springs. The seismic response of the stacks in terms of overturning moments and shear forces at various elevations of the stacks are calculated and compared against the overturning moment and shear load-carrying capacities of the stacks at the corresponding elevations. It has been concluded that the existing structural designs of the LACBWR and GENOA 3 stacks are adequate to withstand the loadings associated with the Safe Shutdown Earthquake.

2. INTRODUCTION

In response to the AEC/DL's request to determine the effects of an earthquake event on the LaCrosse Boiling Water Reactor, Dairyland Power Cooperative (DPC) requested Gulf United Nuclear Fuels Corporation to evaluate the adequacy of the major LACBWR plant structures and equipment to withstand seismic loadings. The seismic study performed by Gulf United Nuclear Fuels Corporation (Reference 1) included a seismic analysis of the LACBWR and GENOA 3 stacks which showed that the overturning moments due to the Safe Shutdown Earthquake (SSE) are greater than the moment load-carrying capacities of the chimney cross-sections. Gulf United concluded that both stacks could collapse with possible penetration of the Waste Disposal Building, the Turbine Building and/or the Reactor Containment Building.

The Gulf United analysis, however, made several simplifying but extremely conservative assumptions with regard to the input seismic motions, soil structure interaction effects and the moment load-carrying capacities of the stack cross-sections. In light of these assumptions NES has redone the seismic analysis of the LACBWR and GENOA 3 stacks using response spectrum, modal superposition methods of analysis incorporating soil-structure interaction effects. To account for the variation in the soil properties and to evaluate the effect of changing the foundation spring stiffness on the seismic response results of the stack, the foundation spring constants were increased and reduced by a factor of 1.5 and 0.4 respectively.

Section 3. of this report describes the overall dimensions and the foundation design of the LACBWR and GENOA 3 stacks. Applicable codes, standards and various loads and loading combinations are given in Sections 4 and 5 respectively. The analytical procedures and structural acceptance criteria are summarized in Sections 6 and 7. The results and conclusions of the analysis are presented in Section 8 of the report. The detail analytical input data and the structural calculations are given in Appendices A and B for the LACBWR and GENOA 3 stacks respectively.

3. DESCRIPTION OF STACKS

3.1 LACBWR Stack

As shown in Figure 3.1, the LACBWR stack is a 350 foot high, tapered, reinforced concrete structure with an outside diameter of 7.19 feet at the top and 24.719 feet at the base. The 4 foot thick foundation mat of the LACBWR stack rests on a pile cluster composed of 78 piles. Each pile is 80 feet long with a nominal capacity of 50 tons. The drawings of Reference 3 show the diameter, thickness and the arrangement of the reinforcing steel at various heights of the stack.

3.2 GENOA 3 Stack

As shown in Figure 3.2, the GENOA 3 stack is a 500 foot high, tapered, reinforced concrete structure with an outside diameter of 17.42 feet at the top and 38.198 feet at the base. The tapered octagonal shaped foundation mat of the GENOA 3 stack rests directly on the foundation soil. The drawings of Reference 4 give the diameter, thickness and the arrangement of the reinforcing steel at various heights of the stack.

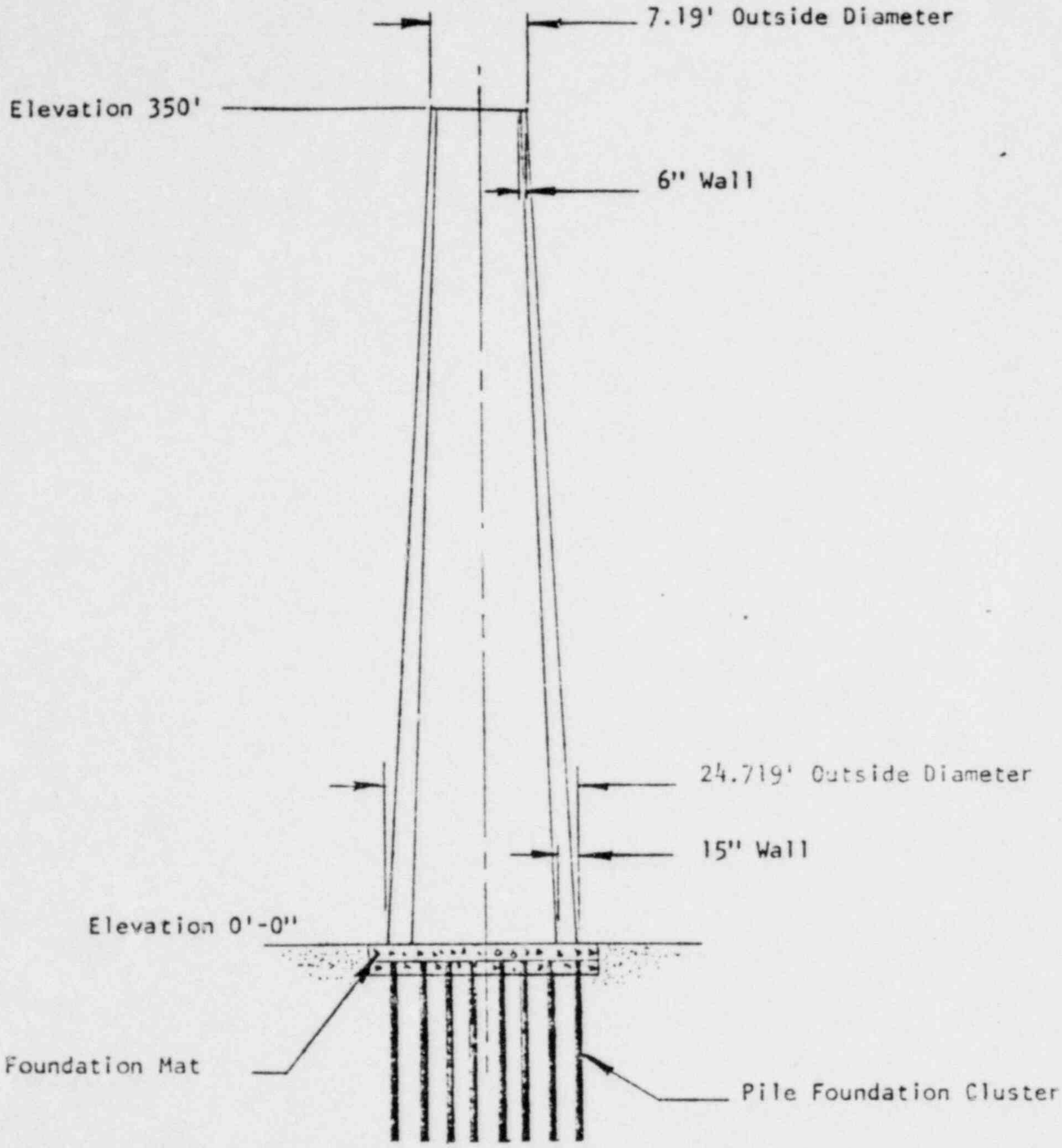


FIGURE 3.1 SCHEMATIC SKETCH OF LACBWR STACK

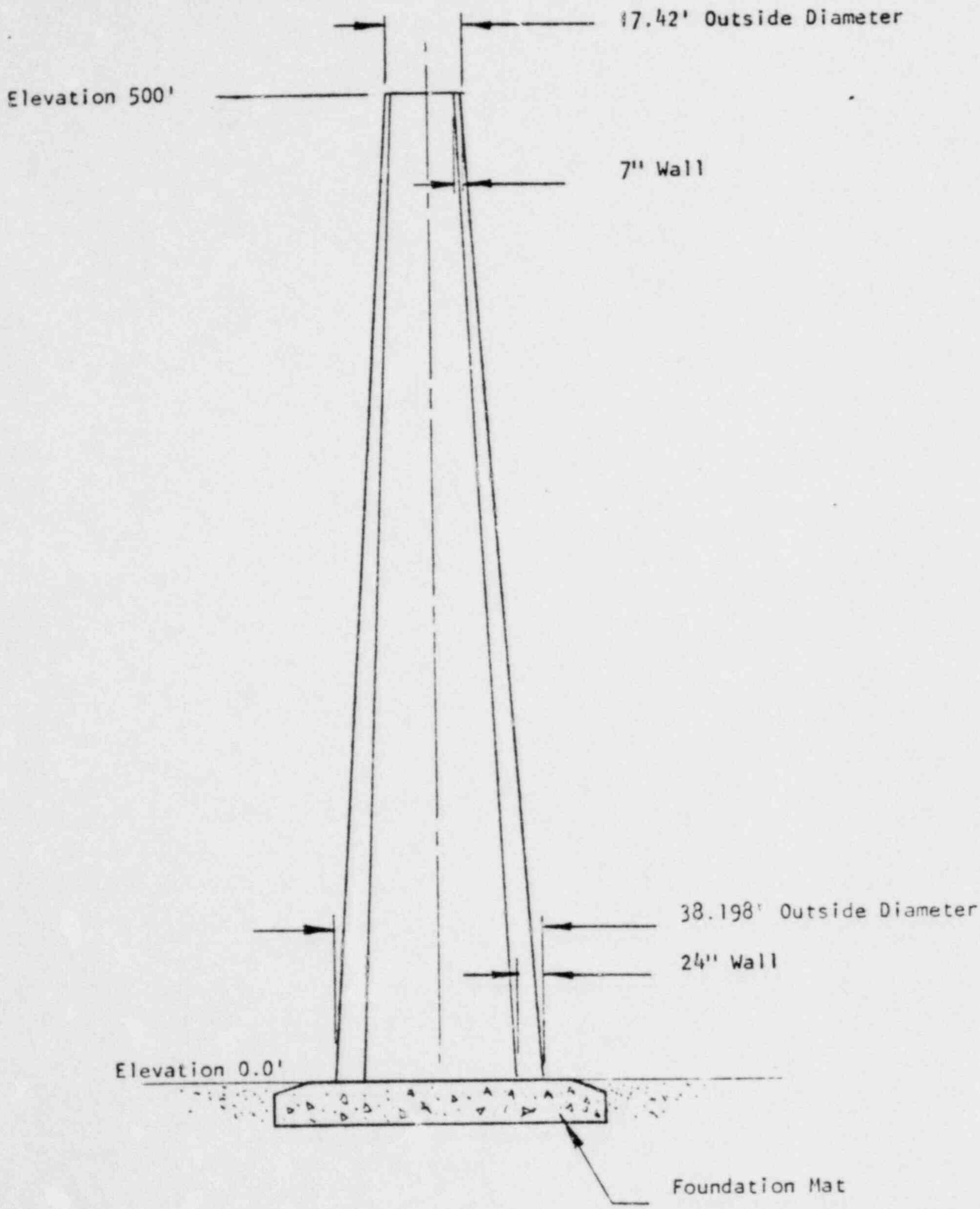


FIGURE 3.2 SCHEMATIC SKETCH OF GENOA 3 STACK

4. APPLICABLE CODES, STANDARDS AND SPECIFICATIONS

The following codes of practice, regulatory guides and references have been used in the seismic and structural analysis of the LACBWR and GENOA 3 stacks.

1. ACI 318-71 "Building Code Requirements for Reinforced Concrete" American Concrete Institute.

2. Uniform Building Code, 1973 Edition.

3. AEC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October 1973.

4. AEC Document (B), "Structural Design Criteria for Evaluating the Effects of High Energy Pipe Breaks on Category 1 Structures Outside the Containment;" Structural Engineering Branch; Directorate of Licensing, June 1973.

5. George Winter et. al. - "Design of Concrete Structures," McGraw Hill Book Company, 1964.

6. Robert V. Whitman, "Soil Structure Interactions," Seminar on Seismic Design for Nuclear Power Plant; Massachusetts Institute of Technology, April, 1969.

5. LOADS AND LOADING COMBINATIONS

The seismic lateral inertia loading on the coupled model of the stacks and its foundations is in the form of the ground acceleration response spectrum given in Reference 1. The free field ground response spectrum (Fig. 5.1) for the Safe Shutdown Earthquake for 7 percent structural damping (Reference 8) has been used in the seismic analysis.

In addition to the seismic inertia loading the dead loads and their resulting moments have also been included in the analysis. The following load combination equation (Reference 7) was used in evaluating the adequacy of the stacks to withstand a seismic event.

$$U = D + 1.0\,E$$

where:

D = Dead loads and their resulting moments

E = Loads and moments generated by the Safe Shutdown Earthquake

U = Section strength required to resist design loads and based on ultimate strength design methods described in ACI 318-71 Code.

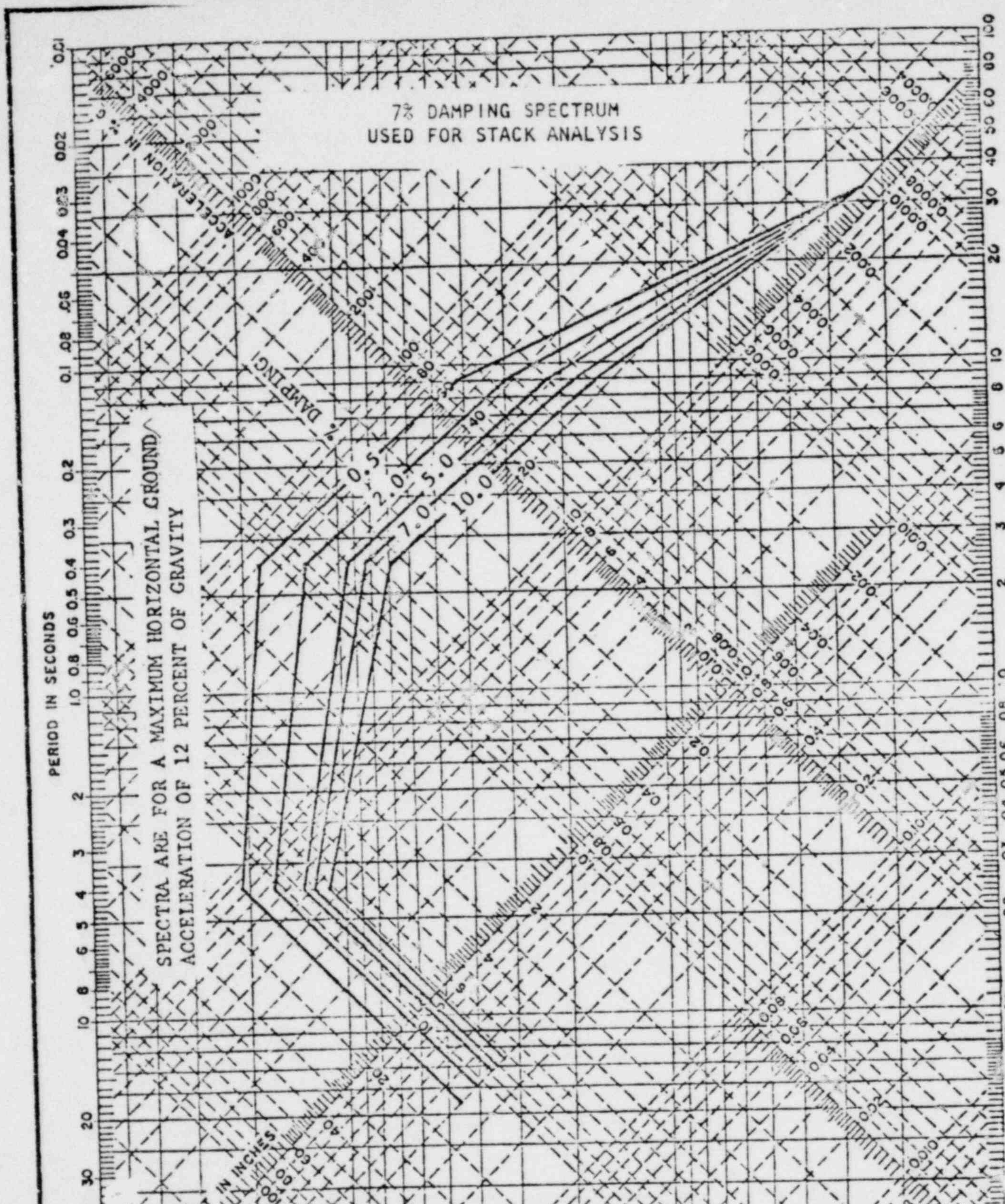


FIGURE 5.1
LACBWR RESPONSE SPECTRA

6. ANALYTICAL PROCEDURES

6.1 Seismic Analysis

6.1.1 Mathematical Model

In order to perform the seismic analysis, each stack is mathematically modeled as an assembly of elastic-structural elements inter-connected at discrete nodal points. The three dimensional, multidegree-of freedom models of the stacks are attached to the ground by means of foundation springs, representing the deformations of the soil under the stack foundations. A lateral spring is provided in the LACBWR stack mathematical model to account for the shear deformation of the soil under the foundation. Due to the presence of a pile cluster under the LACBWR stack foundation, there will not be any vertical deformation of the soil, consequently no rocking foundation spring has been provided in the LACBWR stack mathematical model (Figure 6.1). Lateral as well as rocking springs have been provided under the GENOA 3 stack mathematical model (Figure 6.2) to account for the shear and vertical deformation of the soil under the GENOA 3 stack foundation. To account for the variation in the soil properties and to evaluate the effect of changing the foundation spring constants on the seismic response of the stacks, the foundation springs have been increased and reduced by a factor of 1.5 and 0.4 respectively.

The distributed mass of the stack is lumped at the system nodal points. Each mass represents the tributory weight of the stack walls above and below the nodal point. Masses are lumped so that the lumped mass, multi-degree-of-freedom model represents the dynamic characteristics of the stack. In order to reduce the number of dynamic degrees-of-freedom, only translational degrees-of-freedom are considered at each mass point. (The masses associated with the rotational degrees-of-freedom are set to zero.)

6.1.2 Foundation Spring Stiffness

The stiffness of the lateral and rocking springs representing the shear and vertical deformation of the soil beneath the foundation mat are obtained using the following equations. These equations are taken from Reference 9.

1. <u>Rectangular Base (LACBWR Stack)</u>:

Horizontal spring stiffness, $K_x = 2(1+\mu)\, G\beta_x \sqrt{BL}$ (1)

where μ = Poisson's Ratio of Soil

G = Shear Modulus of Soil

β_x = Co-efficient from Figure 4. Reference 9

B = Width of Foundation Mat

L = Length of Foundation Mat

2. <u>Circular Base (GENOA 3 Stack)</u>:

Horizontal spring stiffness, $K_x = \frac{32(1-\mu)}{7-8\mu}$ (2)

Rocking spring stiffness, $K_\phi = \frac{8 G r^3}{3(1-\mu)}$ (3)

where r = Effective Radius of Foundation Mat

6.1.3 Eigenvalue Analysis

The eigenvalues (natural frequencies) and the eigenvectors (mode shapes) for each of the natural modes of vibration are calculated by solving the following frequency equation:

$$\left[K - \omega_n^2 M\right] \{\phi_n\} = \{0\} \quad (4)$$

where:

K = System stiffness matrix

ω_n = Natural angular frequency for the n^{th} mode

M = System mass matrix

$\{\phi_n\}$ = Mode shape vector for the n^{th} mode

$\{0\}$ = Null vector

The eigenvalue/eigenvector extraction is performed using the Householder QR technique.

6.1.4 Dynamic (Seismic) Load Analysis

Considering only translational degrees of freedom and assuming viscous (velocity proportional) form of damping, the equation of motion in matrix form can be expressed as follows:

$$M(\ddot{U}_t + \ddot{U}_{gt}) + C\dot{U}_t + KU_t = 0 \qquad (5)$$

where:

$\ddot{U}_t$ = Relative acceleration time history vector

$\ddot{U}_{gt}$ = Ground acceleration time history vector

C = Damping matrix

$\dot{U}_t$ = Velocity time history vector

U_t = Relative displacement time history vector

Rearranging equation (5)

$$M\ddot{U}_t + C\dot{U}_t + KU_t = -M\ddot{U}_{gt} = P_{eff} \qquad (6)$$

To uncouple equation (6), assume

$$U = \phi Y_t$$

where:

ϕ = Characteristic free vibration mode shapes matrix

Y_t = Generalized coordinate displacement time history vector.

Pre- and post-multiplying equation (6) by the transpose of ϕ and by ϕ respectively and using orthogonality conditions, the following uncoupled equations of motion are obtained:

$$\ddot{Y}_{nt} + 2\omega_n \lambda_n \dot{Y}_{nt} + \omega_n^2 Y_{nt} = M_n^{*-1} R_n \ddot{U}_{gt} \qquad (7)$$

where:

Y_{nt} = Generalized displacement coordinate time history for n^{th} mode

λ_n = Damping ratio for the n^{th} mode expressed as percent of critical damping

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

$= \phi_n^T M \phi_n = \sum M_i \phi_{in}^2$

The mode shape ϕ_n is normalized such that $M_n^* = 1$

R_n = Participation factor for the n^{th} mode

$= \phi_n^T MI = \sum M_i \phi_{in}$

1 = Column vector whose elements are generally unity

The solution for the differential equation (7) is given by the Duhamel Integral

$$Y_{nt} = \frac{R_n}{M_n^* \omega_n} \int^t \ddot{U}_{gt} \, e^{-\lambda_n \omega_n (t-\tau)} \sin \omega_n (t-\tau) \, d\tau$$

Using the response spectrum method of analysis, the maximum values of the generalized response for each mode is given by:

$$\ddot{Y}_n \max = \frac{R_n S_{an}}{M_n^*} \quad (8)$$

where:

$\ddot{Y}_n \max$ = Maximum generalized coordinate acceleration response for the n^{th} mode.

S_{an} = Spectral acceleration value for the n^{th} mode (from the applicable response spectrum curve)

From the maximum generalized coordinate response, the maximum acceleration ($\ddot{U}_n$max) and maximum inertia forces (F_n max) at each mass point are given by:

$$\ddot{U}_n \max = \ddot{Y}_n \max \phi_{in}$$

$$F_n \max = M_n \ddot{U}_n \max$$

The inertial forces (F_n max) for each of the system natural modes are applied as external static forces, and the system response (displacements, member internal forces and stresses) are calculated. Total system response is then obtained by combining the individual modal response values by the square-root of the sum of the squares method; lower modes having large contribution to the response (all modes having natural frequency under 30 cycles per second) are considered and higher modes with negligible participation are neglected.

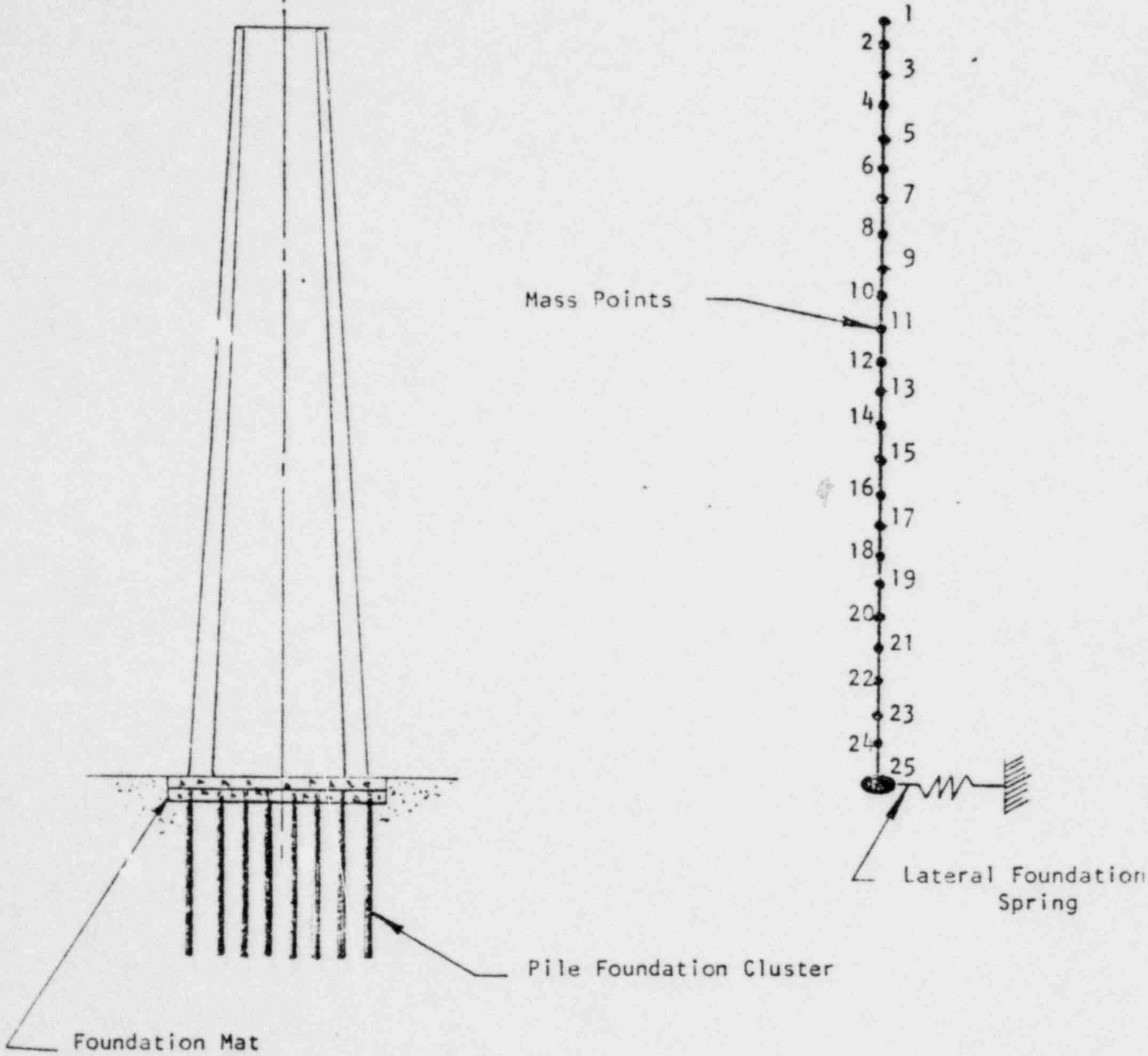


FIGURE 6.1 MATHEMATICAL MODEL LACBWR STACK

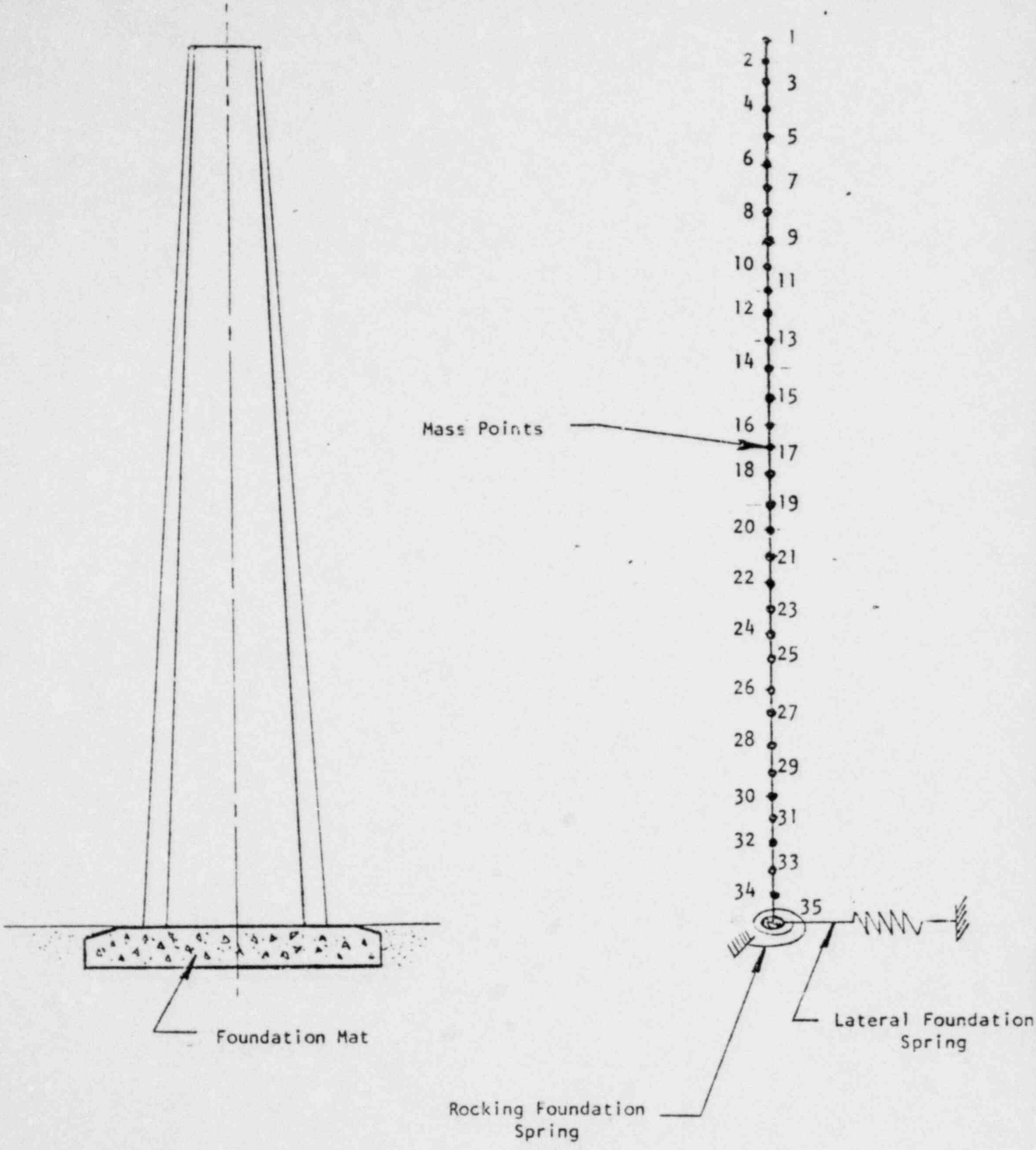
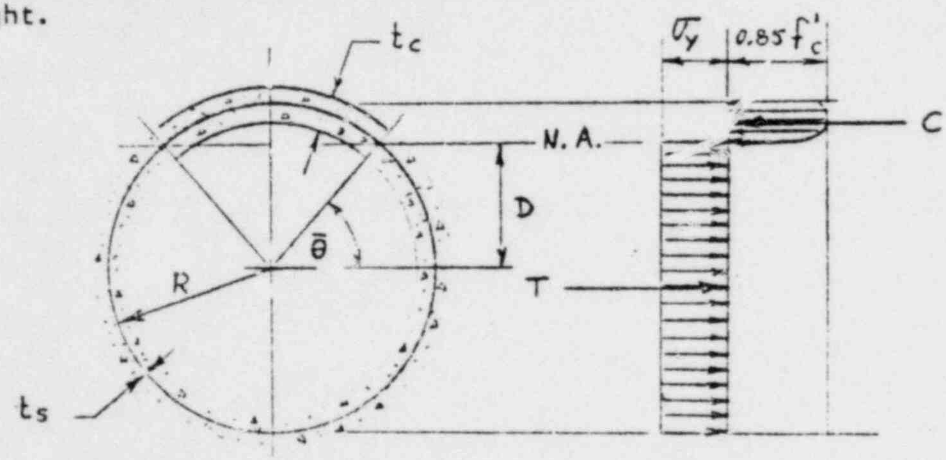


FIGURE 6.2 MATHEMATICAL MODEL GENOA 3 STACK

6.2 Structural Analysis

The moment load carrying capacities of the reinforced concrete stack cross-sections can be calculated using the ultimate strength design methods as given in ACI 318-71, "Building Code Requirements for Reinforced Concrete," American Concrete Institute. As indicated below, the neutral axis for the stack cross-section is first established by equating the compressive and tensile forces. The moment about the neutral axis due to the compressive, tensile forces and the dead weight are then estimated. The moment load-carrying capacity of the stack cross-section is equal to the summation of moments about the neutral axis due to the compressive, tensile forces and the dead weight.



Cross section of stack   Stress Distribution

where:

tc = Thickness of concrete stack wall

ts = Equivalent thickness of steel representing reinforcing bars

f'c = Minimum compressive strength of concrete at 28 days

σ_y = 1.15 times the minimum yield strength of reinforcement

C = Total compressive force

T = Total tensile force

Assumptions: 1) plane section remain plane after bending
2) concrete does not carry any tension force

$$C = 2 \times .85 \times .85 f'c \int_{\bar{\theta}}^{\pi/2} t_c R d\theta$$

$$C = 1.445 f'c\, t_c\, R \left[\frac{\pi}{2} - \bar{\theta}\right] \quad (9)$$

$$T = 2 \times \sigma y \int_0^{\pi/2} ts\, Rd\theta + 2\, \sigma y \int_0^{\bar{\theta}} ts\, Rd\theta$$

$$= 2\, \sigma y\, ts\, R \left[\frac{\pi}{2} + \bar{\theta}\right] \quad (10)$$

Since T = C for equilibrium

$$2\, \sigma y\, t_s R \left[\frac{\pi}{2} + \bar{\theta}\right] = 1.445 f'c\, t_c R \left[\frac{\pi}{2} - \bar{\theta}\right] \quad (11)$$

Taking moments about neutral axis NA.

Moment Mc due to compressive force:

$$Mc = 2 \times (.85)^2 f'c \int_0^{90-\bar{\theta}} (R \cos\theta - D)\, tcRd\theta$$

$$= 1.445 f'c\, tcR \int_0^{90-\bar{\theta}} (R \cos\theta - R \sin\bar{\theta})\, d\theta$$

$$= 1.445 f'c\, tc\, R^2 \left[\sin\theta - \theta \sin\bar{\theta}\right]$$

$$Mc = 1.445 f'c\, tc\, R^2 \left[\sin (90 - \bar{\theta}) - \frac{(90 - \bar{\theta})}{180} \pi \sin\bar{\theta}\right] \quad (12)$$

Mome.. . due to tensile force:

$$Mt = 2\, \sigma y \int_0^{90+\bar{\theta}} tsR(R\cos\theta + R\sin\theta)\, d\theta$$

$$= 2\, \sigma y\, ts\, R \int_0^{90+\bar{\theta}} (R \cos\theta + R \sin\bar{\theta})\, d\theta$$

$$= 2\, \sigma y\, ts\, R^2 \;\; \sin\theta + \theta \sin\bar{\theta}$$

$$Mt = 2\, \sigma y\, ts\, R^2 \;\; \sin (90 + \bar{\theta}) + \frac{(90 + \bar{\theta})}{180} \sin\bar{\theta} \quad (13)$$

Moment M_{DW} due to deadweight W

$$M_{DW} = WR \sin\bar{\theta} \quad (14)$$

Total Moment Carrying capacity M of the section for stresses in the reinforcement up to yield limit is:

$$M = Mc = Mt + M_{DW} \quad (15)$$

Procedure for calculating the ultimate moment carrying capacity up to yielding in reinforcement is:

1. knowing the dimensions of the section (R, ts, tc) and material properties (ty, f'c) calculate $\bar{\theta}$ using equation 11.

2. calculate Mc, Mt, M_{DW} and M using equation 12, 13, & 14 and 14 respectively.

7. ACCEPTANCE CRITERIA

The ultimate moment and shear load-carrying capacities of the stack cross-sections have been calculated using the acceptable maximum stress values as given in USAEC Document (B) (Reference 7) and the ACI 318-71 Design Code (Reference 5).

The specific acceptable stress values used in this analysis are given below:

Maximum compressive stress = $0.85 f'_c$

Maximum shear stress = $4 \phi \sqrt{f'_c}$

Maximum stress in reinforcing steel $\sigma_Y = f_Y \times 1.15$

where:

f'_c = compressive strength of concrete at 28 days

= 3,000 psi. for LACBWR stack

= 4,000 psi. for GENOA 3 stack

ϕ = 0.85

f_Y = Yield stress value for reinforcing steel

= 40.0 ksi. for LACBWR stack

= 40.0 ksi. for GENOA 3 stack

The maximum yield stress in reinforcing steel has been increased by 15 percent to account for the increase in stress values that is permitted under dynamic loading conditions (Reference 7). It should be noted that the actual yield stress value of reinforcing steel is generally 15 to 20% higher than the minimum specified yield stress value (40 ksi.). Additionally Reference 9, which has been accepted by USNRC, also specifies a dynamic increase factor of 1.20 for reinforcing steel with 40 ksi. yield strength. Therefore for evaluating the seismic capability of an existing structure, the use of 15% increase in the minimum specified yield stress of reinforcing steel is justified.

8. RESULTS OF ANALYSIS AND CONCLUSIONS

8.1 LACBWR Stack

Appendix A presents the detail calculations for the three foundation spring stiffness models: standard, softer (0.4 times standard) and stiffer (1.5 times standard) foundation spring values. The overturning moment load-carrying capacities of the stack cross-sections and the detail response results of the seismic analysis are also presented in Appendix A. The results of the analysis are summarized in Tables 8.1(a) through 8.1(c) and shown graphically in Figures 8.1(a) through 8.1(c).

From Table 8.1(a), which summarizes the natural frequencies for the first 10 modes of vibration of the LACBWR stack, it can be seen that the LACBWR stack is a fairly flexible (low frequency) system and that the lower modes of vibration are not very sensitive to the changes in the foundation spring stiffness. Since the frequencies of vibration of the higher modes were only slightly different for the three spring models, it was decided to verify the results of the initial analysis by using a different approach to represent the foundation spring model. In this second approach, the softer foundation spring was replaced by an equivalent additional member of 0.1 inch length at the base of the stack which was then fixed to the ground. The member properties (shear area and moment of inertia) were chosen to give a stiffness value equal to that of the softer foundation spring stiffness. The frequency and seismic response results for this approach were almost identical to those of the LACBWR stack with softer foundation springs thereby verifying the results of the initial analytical method.

Figure 8.1(a) shows the displacement response of the LACBWR stack. From Figure 8.1(a) it can be noted that the maximum lateral displacement at the top of the stack is in the order of 8 inches and that this displacement is essentially due to uniform flexural deformations throughout the height of the stack. For a 350 foot high stack, a maximum displacement of 8 inches due to a Safe Shutdown Earthquake is reasonable. The displacements at the base of the stack are negligible. From Figure 8.1(a) it can also be noted that the displacements for the softer foundation spring (Model 2) are slightly greater than those for the standard foundation spring (Model 1) and the displacements for the stiffer foundation spring (Model 3) are slightly smaller than those for the standard foundation spring.

Figure 8.1(b) shows the maximum acceleration response of the LACBWR stack. The maximum horizontal accelerations at the top of the stack are of the order of 0.9 G to 1.04 G . The acceleration values up to an elevation of 320 feet are less than 0.5 G with only the upper 20 to 30 feet of the stack having acceleration values in the range of 1G. This indicates that a fair amount of energy will be absorbed in this region during an earthquake event.

Figure 8.1(c) shows the variation of maximum seismic overturning moments throughout the height of the LACBWR stack. It can be seen that the overturning moment diagram is continuous throughout the height of the stack. The maximum seismic overturning moments for the three models of the LACBWR stack are also summarized and compared with the allowable overturning moment values in Table 8.1(b). From Table 8.1(b) it can be seen that the seismic overturning moments in all members of each model are within the allowable overturning moment values. In fact, the seismic overturning moment values in all members but members 5 and 6 are less than the allowable overturning moment values as calculated without the 15% increase in the yield stress value of reinforcing steel permitted in Reference 7 for dynamic loading conditions.

The maximum seismic shear stress values in all the members of the LACBWR stack are summarized in Table 8.1(c). The maximum shear stress value of 39.18 psi. is well within the allowable shear stress value of 201.1 psi. for an adequately reinforced (vertical as well as circumferential reinforcement) concrete stack.

In summary, the results of the subject analysis, which considers a wide variation in the foundation soil properties of the LACBWR stack indicates that the lateral displacements, maximum overturning moment and maximum shear stress values due to a Safe Shutdown Earthquake are within their acceptable values. Therefore, it can be concluded that the existing structural design of the LACBWR stack is adequate to withstand a Safe Shutdown Earthquake event.

TABLE 8.1 (a)

NATURAL FREQUENCIES OF VIBRATION - LACBWR STACK

MODE NO.	MODEL 1 STANDARD FOUNDATION SPRING (FREQUENCY CPS)	MODEL 2 SOFTER FOUNDATION SPRING (FREQUENCY CPS)	MODEL 3 STIFFER FOUNDATION SPRING (FREQUENCY CPS)
1	0.481	0.481	0.481
2	1.557	1.557	1.558
3	3.635	3.587	3.645
4	6.484	6.083	6.538
5	9.700	7.976	10.012
6	12.304	10.946	13.466
7	15.576	15.166	16.327
8	20.122	19.949	20.315
9	25.300	25.103	30.621
10	30.554	30.492	36.042

TABLE 8.1 (b)

MAXIMUM SEISMIC MOMENTS - LACBWR STACK

MAXIMUM SEISMIC OVERTURNING MOMENT (IN LBS)

MEMBER NO.	MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING	ALLOWABLE OVERTURNING MOMENT (IN LBS)
1	2.2588E+05	2.4283E+05	2.1640E+05	8.1705E+06*
2	3.1759E+06	3.4803E+06	3.0255E+06	9.6173E+06*
3	7.4878E+06	8.4666E+06	7.0971E+06	1.1542E+07*
4	1.1937E+07	1.3620E+07	1.1440E+07	1.4545E+07*
5	1.6287E+07	1.8144E+07	1.5919E+07	1.9645E+07
6	2.0717E+07	2.2107E+07	2.0493E+07	2.3151E+07
7	2.5202E+07	2.6044E+07	2.4959E+07	3.6046E+07*
8	2.9560E+07	3.0319E+07	2.9256E+07	6.4069E+07*
9	3.3776E+07	3.4855E+07	3.3508E+07	6.9482E+07*
10	3.8019E+07	3.9379E+07	3.7813E+07	8.9431E+07*
11	4.2453E+07	4.3788E+07	4.2204E+07	1.0870E+08*
12	4.7128E+07	4.8271E+07	4.6762E+07	1.3088E+08*
13	5.2074E+07	5.3183E+07	5.1652E+07	1.5914E+08*
14	5.7435E+07	5.8810E+07	5.7056E+07	1.8585E+08*
15	6.3523E+07	6.5283E+07	6.3184E+07	2.1398E+08*
16	7.0708E+07	7.2675E+07	7.0333E+07	2.4134E+08*

MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING	ALLOWABLE OVERTURNING MOMENT (IN LBS.)
7.9270E+07	8.1132E+07	7.8832E+07	2.7072E+08*
8.9386E+07	9.0953E+07	8.8943E+07	3.0876E+08*
1.0120E 08	1.0255E+08	1.0080E+08	3.3999E+08*
1.1482E+08	1.1629E+08	1.1445E+08	3.7346E+08*
1.3034E+08	1.3240E+08	1.2986E+08	4.0038E+08*
1.4768E+08	1.5087E+08	1.4694E+08	4.2551E+08*
1.6677E+08	1.7169E+08	1.6557E+08	4.5206E+08*
1.8758E+08	1.9499E+08	1.8569E+08	4.9763E+08*

* Allowable overturning moment values without 15 percent increase in yield stress value of the steel reinforcement permitted under dynamic loading conditions.

TABLE 8.1 (c)

MAXIMUM SEISMIC SHEAR STRESS - LACBWR STACK

MEMBER NO.	Maximum Seismic Shear Stress (Psi.) MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING
1	5.00	5.37	4.79
2	20.98	23.02	19.98
3	29.52	33.78	28.07
4	31.09	34.38	30.72
5	32.79	32.64	32.85
6	34.50	34.17	33.33
7	34.32	37.48	32.63
8	33.60	39.18	32.92
9	32.95	37.21	32.71
10	32.15	33.76	31.13
11	31.13	31.97	29.69
12	29.35	31.28	28.47
13	27.72	30.68	27.41
14	26.18	28.92	25.80
15	26.50	28.30	25.79
16	28.10	29.10	27.35
17	29.38	30.20	28.89
18	30.49	31.74	30.18
19	31.40	33.34	30.99
20	32.22	34.81	31.55

TABLE 8.1 (c) continued

MAXIMUM SEISMIC SHEAR STRESS LACBWR STACK

MEMBER NO.	Maximum Seismic Shear Stress (Psi.) MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING
21	33.10	36.23	32.17
22	33.22	36.79	32.11
23	26.26	29.56	25.22
24	23.62	27.26	22.42

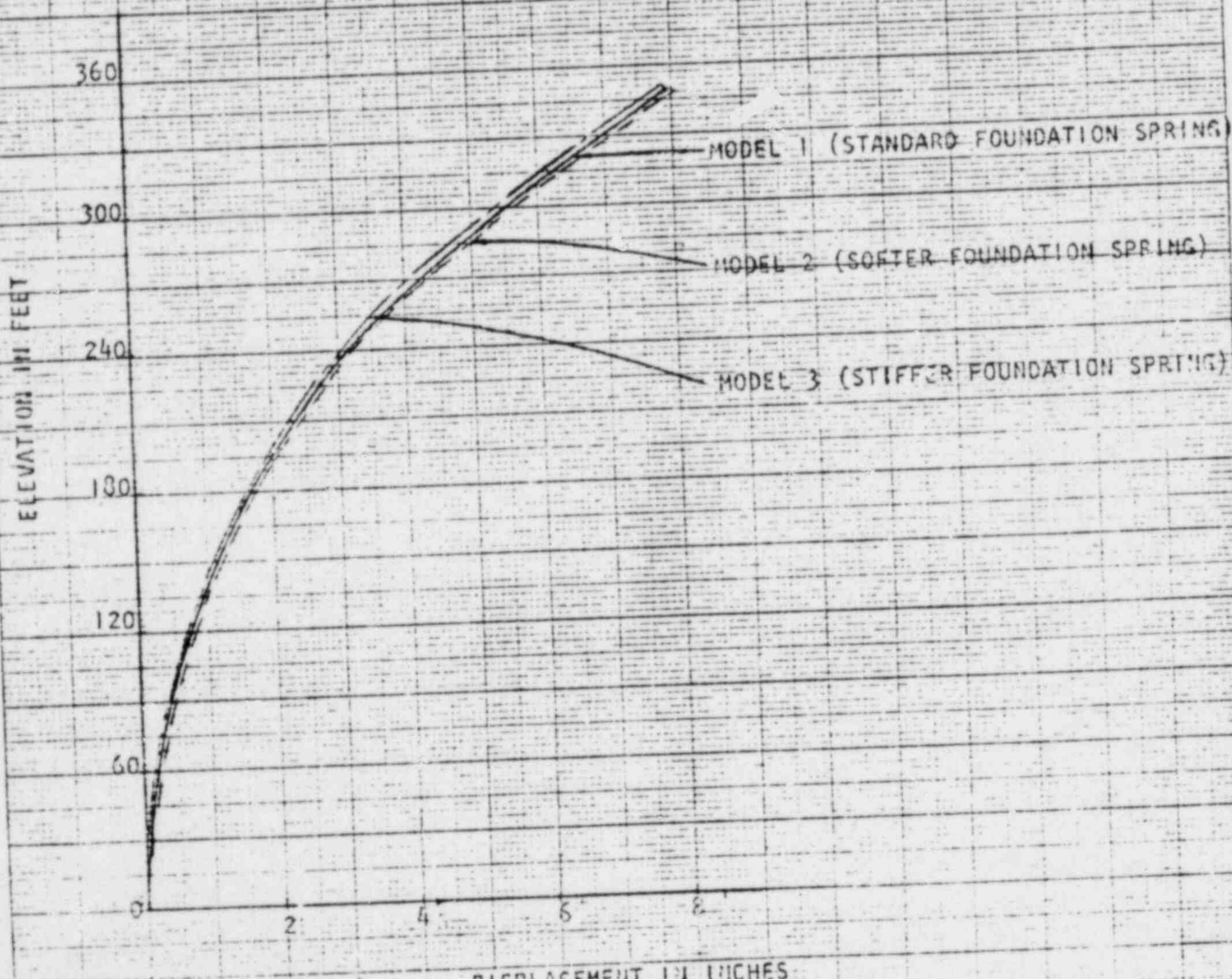


FIGURE 8.1 (a) MAXIMUM SEISMIC DISPLACMENT - LACBWR STACK

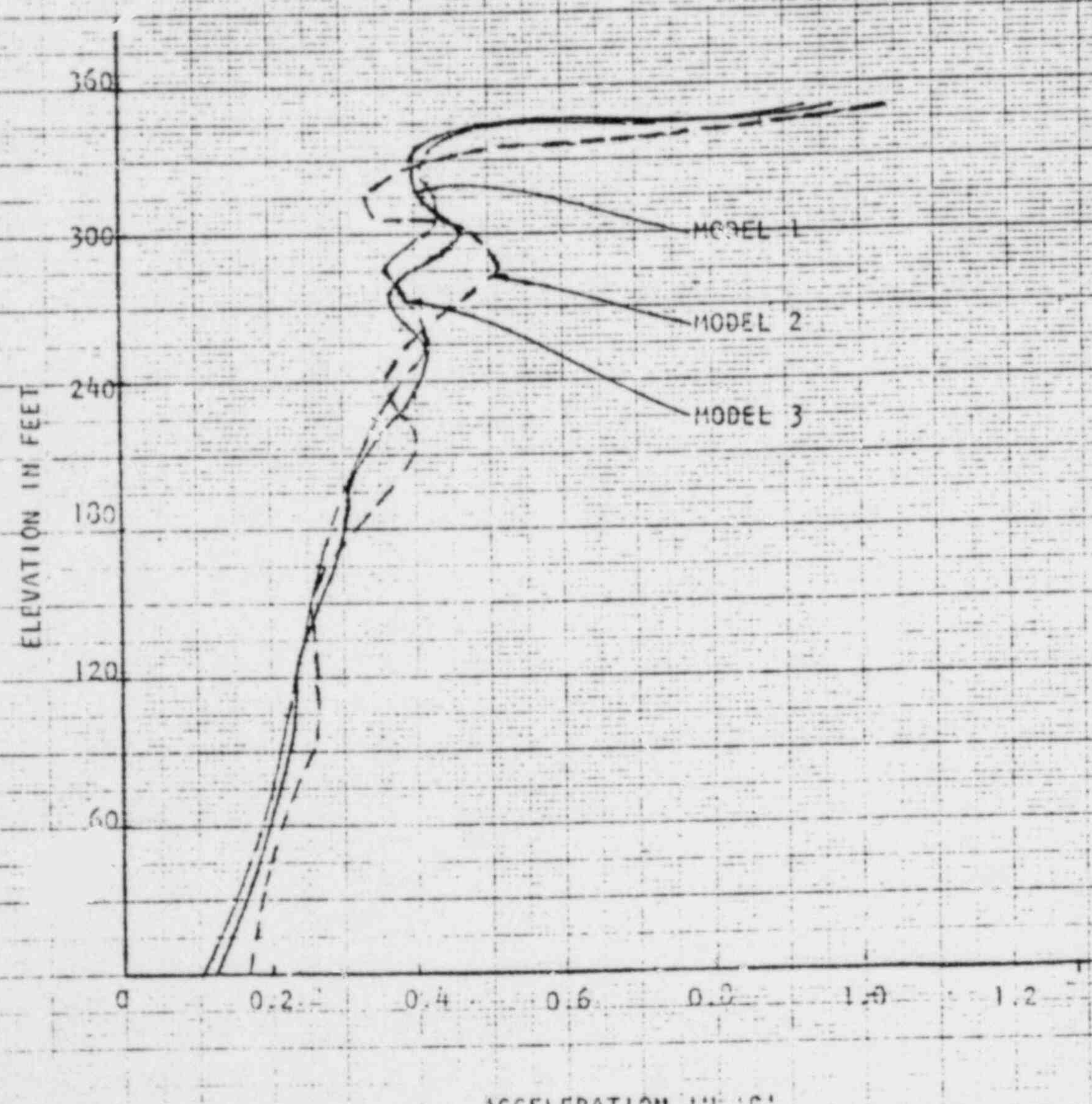


FIGURE 8.1 (b) MAXIMUM SEISMIC ACCELERATION - LACBWR STACK

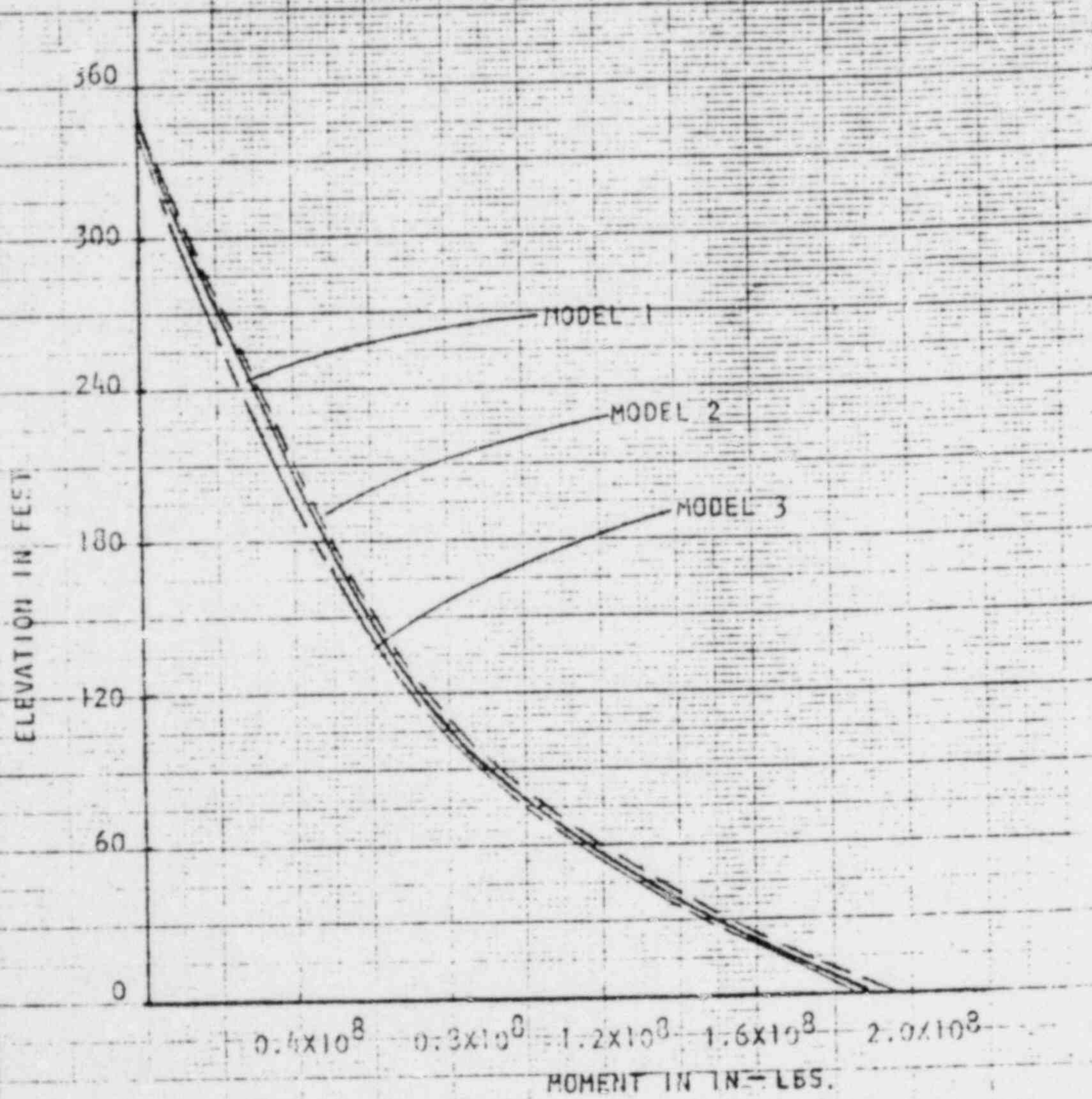


FIGURE 8.1 (c) MAXIMUM SEISMIC OVERTURNING MOMENT - LAC...

8.2 GENOA 3 Stack

Appendix B presents the detail calculations for the foundation spring stiffnesses of the three models: standard, softer (0.4 times standard), and stiffer (1.5 times standard) foundation spring values. The overturning moment load carrying capacities of the stack cross-sections and the detail response results of the seismic analysis are also given in Appendix B. The results of the analysis are summarized in Tables 8.2(a) through 8.2(c) and shown graphically in Figures 8.2(a) through 8.2(c).

From Table 8.2(a). which summarizes the natural frequencies for the first 11 modes of vibration of the GENOA 3 stack, it can be seen that the stack is a fairly flexible (low frequency) system and that the lower modes of vibration are not very sensitive to the changes in the foundation spring stiffnesses.

Figure 8.2(a) shows the displacement response of the GENOA 3 stack. From Figure 8.2(a) it can be noted that the maximum lateral seismic displacement at the top of the stack is in the order of 9.8 inches. For a 500 foot high stack, a maximum displacement of 9.8 inches due to a Safe Shutdown Earthquake is reasonable. The displacements at the base of the stack are negligible. From Figure 8.2(a) it can also be noted that the displacements for the softer foundation spring (Model 2) are greater than those for the standard foundation spring (Model 1) and the displacements for the stiffer foundation spring (Model 3) are slightly smaller than those for the standard foundation spring.

Figure 8.2(b) shows the variation of maximum acceleration response of the GENOA 3 stack through its height. The maximum lateral accelerations at the top of the stack are in the order of 0.85 G to 0.9 G. The acceleration values up to an elevation of 420 feet are about 0.4 G with only the upper 30 feet of the stack having a high acceleration response. This indicates that a fair amount of energy will be absorbed in this region during an earthquake event.

Figure 8.2(c) shows the variation of maximum seismic overturning moments throughout the height of GENOA 3 stack. It can be seen that the variation of the overturning moments diagram is continuous through the height of the stack. The maximum seismic overturning moments for the three models of the GENOA 3 stack are summarized and compared with the allowable overturning moment in Table 8.2(b). From Table 8.2(b) it can be seen that the seismic overturning moments in all members of each model are within the allowable overturning moment values. In fact, the seismic overturning moment values in all members but members 8 and 9 are less than the allowable overturning moment values as calculated without the 15% increase in the yield stress value of steel reinforcement permitted in Reference 7 for dynamic loading conditions.

The maximum seismic shear stress values in all the members of the GENOA 3 stack are summarized in Table 8.2(c). The maximum shear stress value of 55.17 psi. is well within the allowable shear stress value of 269 psi. for an adequately reinforced (vertical as well as circumferential reinforcement) concrete stack

In summary, the results of the subject analysis which considers a wide variation in the foundation soil properties of the Genoa 3 stack indicate that the lateral displacements, maximum overturning moment and maximum shear stress values due to a Safe Shutdown Earthquake are within their acceptable values. Therefore, it can be concluded that the existing structural design of the Genoa 3 stack is adequate to withstand a Safe Shutdown Earthquake event.

TABLE 8.2 (a)

NATURAL FREQUENCIES OF VIBRATION - GENOA 3 STACK

MODE NO.	FREQUENCY (CPS) MODEL 1 STANDARD FOUNDATION SPRINGS	MODEL 2 SOFTER FOUNDATION SPRINGS	MODEL 3 STIFFER FOUNDATION SPRINGS
1	0.375	0.357	0.379
2	1.464	1.353	1.495
3	3.305	3.045	3.384
4	5.726	4.909	5.906
5	8.065	6.487	8.671
6	10.190	9.357	11.050
7	13.480	13.003	13.785
8	17.269	17.028	17.442
9	21.521	21.358	21.624
10	25.838	25.720	25.907
11	30.312	30.226	30.361

TABLE 8.2 (b)

MAXIMUM SEISMIC MOMEMTS - GENOA 3 STACK

MAXIMUM SEISMIC OVERTURNING MOMENT (IN LBS)

MEMBER NO.	MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING	ALLOWABLE OVERTURNING MOMENT (IN LBS)
1	7.3980E+05	7.3170E+05	7.2104E+05	5.0222E+07*
2	9.8249E+06	9.8473E+06	9.5282E+06	5.9467E+07*
3	2.5639E+07	2.6412E+07	2.4607E+07	6.9326E+07*
4	4.4850E+07	4.7568E+07	4.2624E+07	8.0760E+07*
5	6.4693E+07	7.0642E+07	6.1029E+07	9.2273E+07*
6	8.3324E+07	9.3374E+07	7.8399E+07	1.0410E+08*
7	9.9968E+07	1.1411E+08	9.4393E+07	1.1776E+08*
8	1.1476E+08	1.3190E+08	1.0934E+08	1.4646E+08
9	1.2835E+08	1.4658E+08	1.2367E+08	1.5234E+08
10	1.4131E+08	1.5854E+08	1.3746E+08	1.6179E+08*
11	1.5396E+08	1.6871E+08	1.5054E+08	1.7516E+08*
12	1.6630E+08	1.7827E+08	1.6276E+08	1.9541E+08*
13	1.7811E+08	1.8815E+08	1.7411E+08	2.3970E+08*
14	1.8930E+08	1.9891E+08	1.8487E+08	2.8347E+08*
15	2.0008E+08	2.1070E+08	1.9552E+08	3.3360E+08*
16	2.1090E+08	2.2339E+08	2.0654E+08	3.8834E+08*
17	2.2231E+08	2.3677E+08	2.1826E+08	4.6641E+08*

TABLE 8.2 (b), continued

MEMBER NO.	MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING	ALLOWABLE OVERTURNING MOMENT (IN LBS)
18	2.3474E+08	2.5070E+08	2.3084E+08	5.5474E+08*
19	2.482[illegible]	2.6498E+08	2.4422E+08	6.4935E+08*
20	2.6292E+08	2.7971E+08	2.5845E+08	7.3926E+08*
21	2.7880E+08	2.9528E+08	2.7389E+08	8.3359E+08*
22	2.9602E+08	3.1200E+08	2.9089E+08	9.5946E+08*
23	3.1485E+08	3.3017E+08	3.0992E+08	1.0596E+09*
24	3.3576E+08	3.5007E+08	3.3145E+08	1.1455E+09*
25	3.5935E+08	3.7196E+08	3.5598E+08	1.2412E+09*
26	3.8630E+08	3.9620E+08	3.8400E+08	1.3325E+09*
27	4.1720E+08	4.2325E+08	4.1594E+08	1.4203E+09*
28	4.5252E+08	4.5363E+08	4.5221E+08	1.5524E+09*
29	4.9270E+08	4.8[illegible]01E+08	4.9324E+08	1.6889E+09*
30	5.3827E+08	5.2733E+08	5.3954E+08	1.8472E+09*
31	5.9004E+08	5.7294E+08	5.9190E+08	1.9839E+09*
32	6.4908E+08	6.2680E+08	6.5111E+08	2.1231E+09*
33	7.1612E+08	6.9062E+08	7.1754E+08	2.2480E+09*
34	7.9128E+08	7.6531E+08	7.9092E+08	2.4098E+09*

* Allowable overturning moment values without 15 percent increase in yield stress value of the steel reinforcement permitted under dynamic loading conditions.

TABLE 8.2 (c)

MAXIMUM SEISMIC SHEAR STRESS - GENOA 3 STACK

MEMBER NO.	Maximum Seismic Shear Stress (Psi.) MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING
1	5.52	5.46	5.38
2	22.16	22.23	21.48
3	37.56	39.29	35.84
4	44.67	48.93	42.07
5	45.85	52.29	43.14
6	44.27	51.08	42.54
7	43.02	47.49	42.78
8	43.64	43.96	44.06
9	45.50	42.56	45.17
10	45.39	42.35	43.55
11	47.74	47.33	44.49
12	47.31	50.88	43.82
13	46.58	53.53	43.98
14	46.47	54.58	45.11
15	47.44	55.17	46.76
16	49.16	54.87	48.25
17	50.97	54.50	49.29

TABLE 8.2 (c) continued

MAXIMUM SEISMIC SHEAR STRESS - GENOA 3 STACK

MEMBER NO.	Maximum Seismic Shear Stress (Psi.) MODEL 1 STANDARD FOUNDATION SPRING	MODEL 2 SOFTER FOUNDATION SPRING	MODEL 3 STIFFER FOUNDATION SPRING
18	52.41	54.47	49.99
19	46.99	48.38	44.64
20	47.95	49.66	45.94
21	47.62	49.80	46.31
22	45.18	47.42	44.55
23	44.80	46.67	44.49
24	43.80	44.90	43.50
25	44.15	44.39	43.66
26	44.60	44.16	43.93
27	45.06	44.26	44.28
28	43.06	42.29	42.30
29	39.69	39.27	38.99
30	34.66	34.74	34.01
31	29.34	29.94	28.66
32	31.86	33.15	30.87
33	34.10	36.17	32.70
34	35.97	38.90	34.08

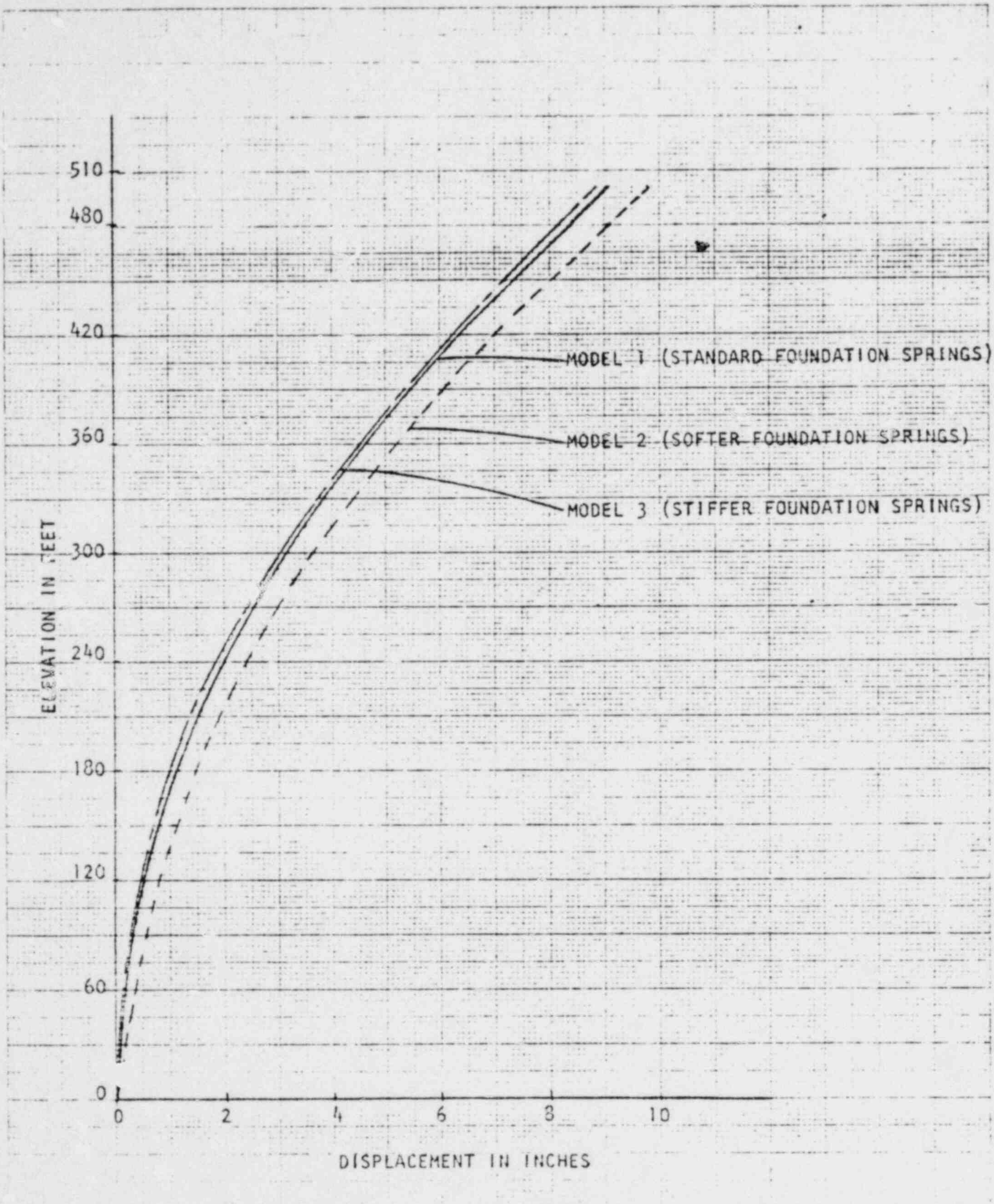


FIGURE 8.2 (a) MAXIMUM SEISMIC DISPLACEMENT - GENOA 3 STACK

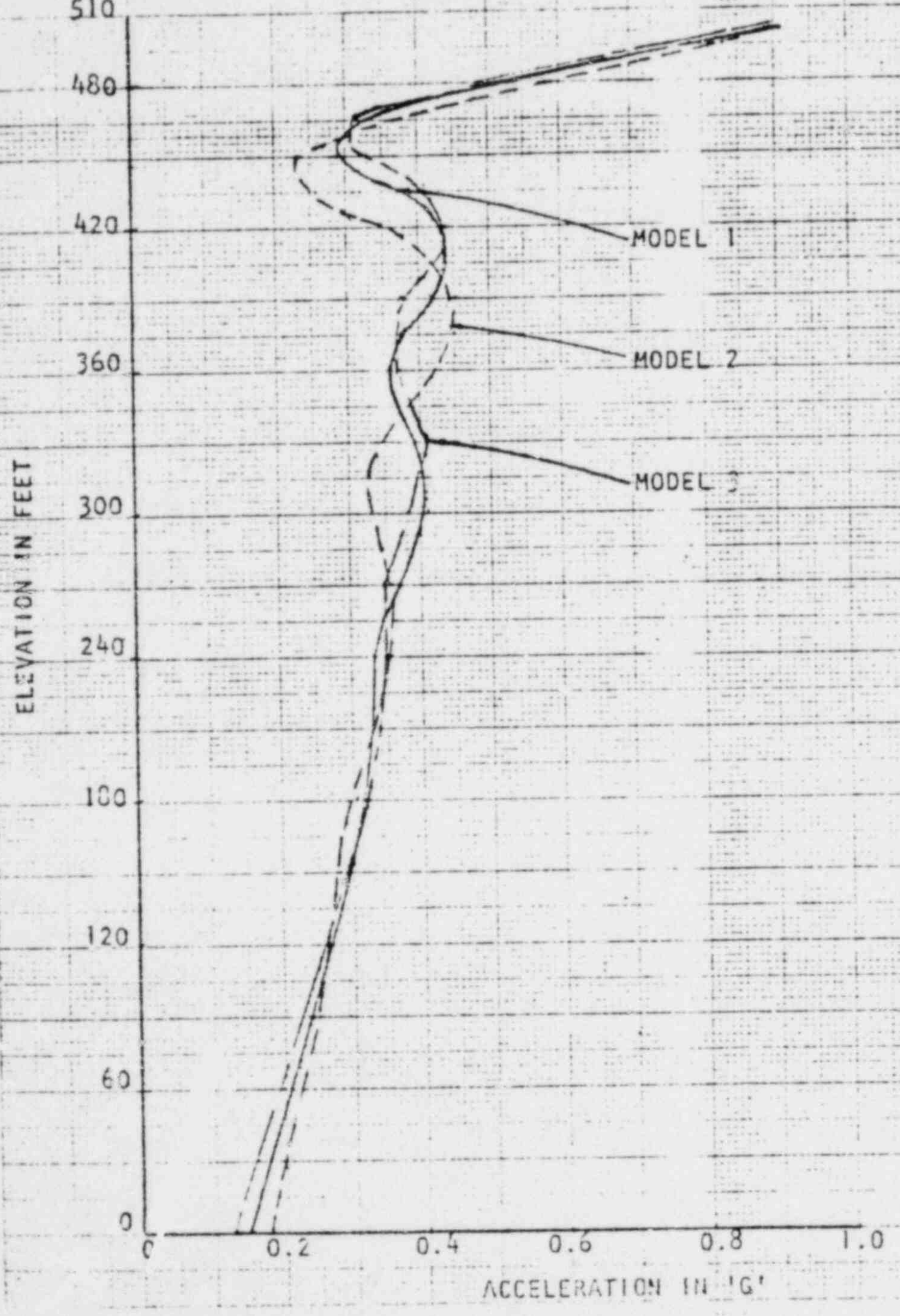


FIGURE 8.2 (b) MAXIMUM SEISMIC ACCELERATION - GENOA 3 STACK

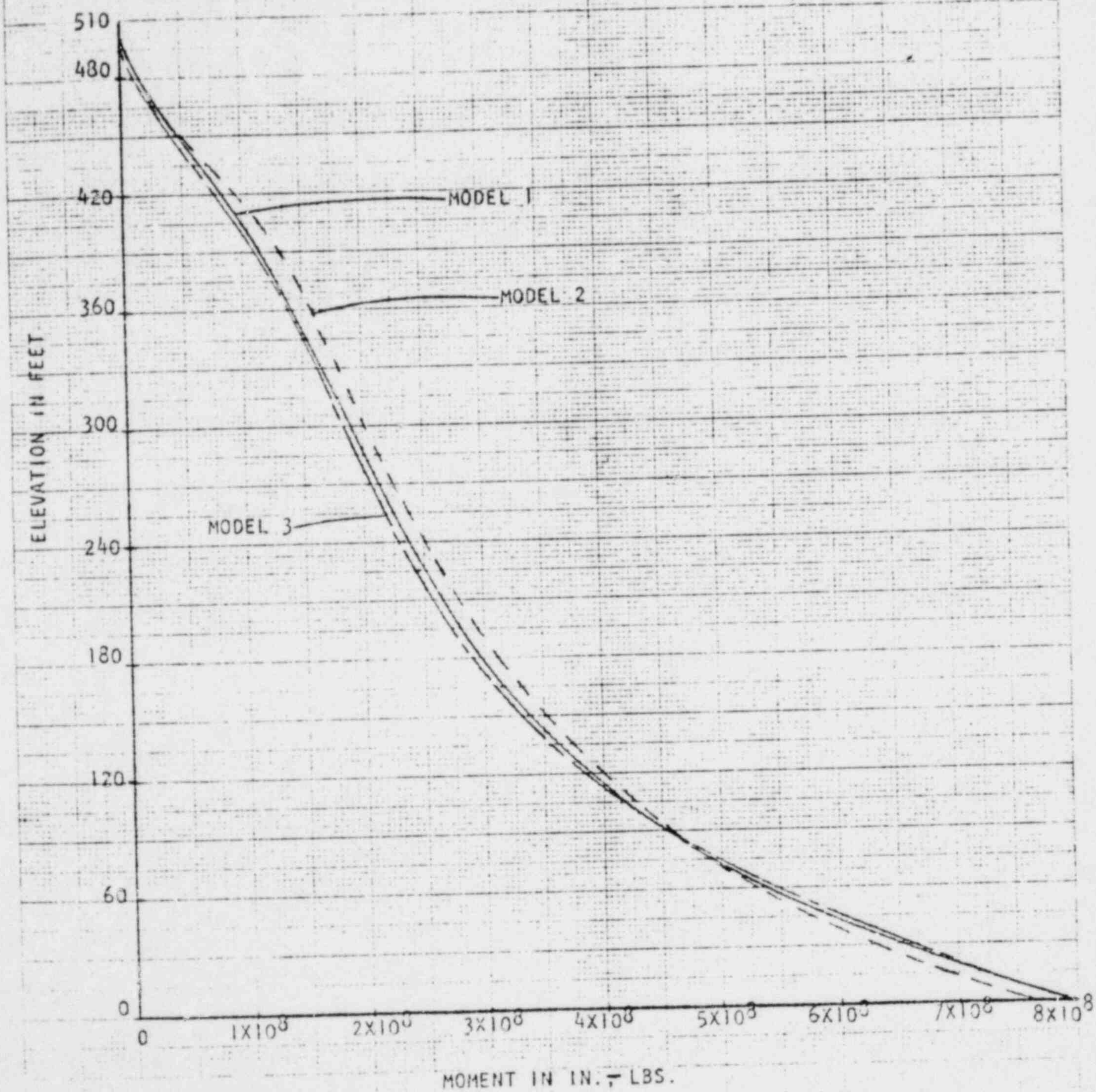


FIGURE B.2 (c) MAXIMUM SEISMIC OVERTURNING MOMENT GENOA 3 STACK

9. REFERENCES

1. Gulf United Services Report No. SS-1162 "Seismic Evaluation of the LaCrosse Boiling Water Reactor" dated January 11, 1974.

2. LACBWR Application for full term operating authorization, LAC-2783 of October 9, 1974.

3. LACBWR Stack Drawings, Sargent and Lundy Engineers, LACBWR Drawings Nos. 41-503434, 41-503435.

4. GENOA 3 Stack Drawings, The M. W. Kellogg Company, GENOA 3 Drawings Nos. 6152-1, 2, 3, 4, 5, 6, 13 and 16 ED.

5. ACI 318-71 - "Building Code Requirements for Reinforced Concrete," American Concrete Institute.

6. George Winter et. al. - "Design of Concrete Structures," McGraw Hill Book Company, 1964.

7. AEC Document (B) "Structural Design Criteria for Evaluating the Effects of High Energy Pipe Breaks on Category 1 Structures Outside the Containment," Structural Engineering Branch, Directorate of Licensing, June, 1975.

8. AEC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October, 1973.

9. Robert W. Whitman, "Soil Structure Interaction," Seminar on Seismic Design of Nuclear Power Plant, Massachusetts Institute of Technology, April, 1969.

10. BC-TOP-9A Rev. 2, September, 1974, "Topical Report Design of Structures for Missile Impact," Bechtel Power Corporation, San Francisco, California.

APPENDIX A

LACBWR STACK - INPUT DATA, RESPONSE RESULTS AND STRUCTURAL CALCULATIONS

A-1 - INPUT DATA

LACBWR STACK FOUNDATION SPRING STIFFNESS

The foundation mat for the LACBWR stack is almost square in shape as shown on Sargent and Lundy Drawing No. 41-503434, 41-503435 (Reference 3) and it rests on a cluster of piles. Since these piles are fairly stiff, the LACBWR stack will not be able to rotate at its base; however, it could have lateral displacement due to the shear deformation of the soil. Therefore, soil structure interaction effects have been accounted for by providing a horizontal spring at the base of the LACBWR stack mathematical model. The soil properties used for the standard foundation spring are those obtained from boring number 3.

Using equation 1 given in Section 6.1.2

Horizontal Spring Stiffness $K_x = 2(1+\mu)\, G \beta_x \sqrt{BL}$

where:

μ = Poisson's Ratio for soil = 0.24

G = Shear Modulus of Soil = 2.4×10^6 lbs/ft.^{2}
(Boring number 3, Table 3.1, Reference 1)

$B = L$ = Length and Width of the Foundation Mat
= 39.75 feet

β_x = Coefficient from Figure 4 of Reference 9
= 1.0

$$K_x = 2(1+0.24)\, 2.4 \times 10^6 (1) \sqrt{(39.75)(39.75)}$$
$$= 2.37 \times 10^8 \text{ lbs/ft.}$$
$$= 19.72 \times 10^6 \text{ lbs/in.}$$

For Standard Foundation Spring (Model 1)

$$K_x = 19.72 \times 10^6 \text{ lbs/in.}$$

For Softer Foundation Spring (Model 2)

$$G = 1.0 \times 10^6 \text{ lbs/ft.}^2$$

$$K_x = \frac{1.0}{2.4} \times 19.72 \times 10^6 = 8.217 \times 10^6 \text{ lbs/in.}$$

AI - INPUT DATA

LACBWR STACK LUMPED WEIGHTS

NODE NO.	LUMPED WEIGHT (LBS)
1	.39083E+04
2	.16075E+05
3	.25033E+05
4	.26432E+05
5	.27863E+05
6	.29340E+05
7	.30813E+05
8	.32285E+05
9	.34474E+05
10	.39183E+05
11	.42936E+05
12	.42573E+05
13	.55554E+05
14	.64677E+05
15	.73993E+05
16	.80234E+05
17	.84873E+05
18	.89953E+05
19	.95744E+05
20	.10226E+06
21	.10849E+06
22	.11564E+06
23	.14053E+06
24	.17752E+06
25	.10447E+07
SUMMATION	.25903E+07

AI - INPUT DATA

LACBWR STACK MEMBER PROPERTIES

MEMBER NO.	JOINT NO.		OUTSIDE DIAMETER (IN)	THICKNESS (IN)	LENGTH (IN)	AREA (IN)^2	POLAR MOMENT OF INERTIA (IN)^4	MOMENT OF INERTIA (IN)^4
1	1	2	8.563E+01	6.000E+00	6.000E+01	1.501E+03	2.392E+06	1.196E+06
2	2	3	8.862E+01	6.000E+00	1.800E+02	1.557E+03	2.672E+06	1.336E+06
3	3	4	9.337E+01	6.000E+00	1.800E+02	1.647E+03	3.158E+06	1.579E+06
4	4	5	9.813E+01	6.000E+00	1.800E+02	1.737E+03	3.700E+06	1.850E+06
5	5	6	1.031E+02	6.000E+00	1.800E+02	1.831E+03	4.334E+06	2.167E+06
6	6	7	1.081E+02	6.000E+00	1.800E+02	1.925E+03	5.037E+06	2.518E+06
7	7	8	1.131E+02	6.000E+00	1.800E+02	2.019E+03	5.811E+06	2.906E+06
8	8	9	1.191E+02	6.000E+00	1.800E+02	2.114E+03	6.662E+06	3.331E+06
9	9	10	1.256E+02	6.125E+00	1.800E+02	2.299E+03	8.231E+06	4.115E+06
10	10	11	1.356E+02	6.375E+00	1.800E+02	2.589E+03	1.084E+07	5.419E+06
11	11	12	1.456E+02	6.660E+00	1.800E+02	2.908E+03	1.407E+07	7.035E+06
12	12	13	1.556E+02	7.094E+00	1.800E+02	3.310E+03	1.830E+07	9.149E+06
13	13	14	1.656E+02	7.660E+00	1.800E+02	3.801E+03	2.377E+07	1.188E+07
14	14	15	1.756E+02	8.530E+00	1.800E+02	4.476E+03	3.134E+07	1.567E+07
15	15	16	1.856E+02	9.000E+00	1.800E+02	4.994E+03	3.905E+07	1.952E+07
16	16	17	1.956E+02	9.000E+00	1.800E+02	5.277E+03	4.605E+07	2.303E+07
17	17	18	2.066E+02	9.000E+00	1.800E+02	5.588E+03	5.467E+07	2.734E+07
18	18	19	2.186E+02	9.000E+00	1.800E+02	5.927E+03	6.523E+07	3.262E+07
19	19	20	2.306E+02	9.094E+00	1.800E+02	6.329E+03	7.778E+07	3.889E+07
20	20	21	2.426E+02	9.220E+00	1.800E+02	6.761E+03	9.222E+07	4.611E+07
21	21	22	2.546E+02	9.280E+00	1.800E+02	7.153E+03	1.078E+08	5.390E+07
22	22	23	2.666E+02	9.470E+00	1.800E+02	7.651E+03	1.267E+08	6.333E+07
23	23	24	2.786E+02	1.237E+01	1.800E+02	1.035E+04	1.838E+08	9.192E+07
24	24	25	2.906E+02	1.425E+01	1.800E+02	1.237E+04	2.369E+08	1.184E+08

For Stiffer Foundation Spring (Model 3)

$$G = 1.5 \times 2.4 \times 10^6 \text{ lbs/ft.}^2$$

$$K_x = 1.5 \times 19.72 \times 10^6$$

$$= 29.58 \times 10^6 \text{ lbs/in.}$$

A1 - INPUT DATA

LACBWR STACK - RESPONSE SPECTRUM

1	FREQ =	.050000,	SPECTRA =	.772800
2	FREQ =	.100000,	SPECTRA =	3.091200
3	FREQ =	.150000,	SPECTRA =	6.955200
4	FREQ =	.250000,	SPECTRA =	19.320000
5	FREQ =	.400000,	SPECTRA =	29.207200
6	FREQ =	.600000,	SPECTRA =	44.436000
7	FREQ =	.800000,	SPECTRA =	50.232000
8	FREQ =	1.000000,	SPECTRA =	59.892000
9	FREQ =	1.500000,	SPECTRA =	86.440000
10	FREQ =	2.000000,	SPECTRA =	108.192000
11	FREQ =	2.500000,	SPECTRA =	127.512000
12	FREQ =	3.000000,	SPECTRA =	123.648000
13	FREQ =	4.000000,	SPECTRA =	115.920000
14	FREQ =	5.000000,	SPECTRA =	113.988000
15	FREQ =	6.000000,	SPECTRA =	112.056000
16	FREQ =	8.000000,	SPECTRA =	106.260000
17	FREQ =	10.000000,	SPECTRA =	96.600000
18	FREQ =	15.000000,	SPECTRA =	77.280000
19	FREQ =	20.000000,	SPECTRA =	65.688000
20	FREQ =	25.000000,	SPECTRA =	56.028000
21	FREQ =	33.000000,	SPECTRA =	46.368000
22	FREQ =	50.000000,	SPECTRA =	46.364000

A-11 - SEISMIC RESPONSE RESULTS

LACBWR STACK SEISMIC ACCELERATION RESPONSE

MODEL 1 STANDARD FOUNDATION SPRING		MODEL 2 SOFTER FOUNDATION SPRING		MODEL 3 STIFFER FOUNDATION SPRING	
NODE NO.	ACCELERATION (IN/SEC^2)	NODE NO.	ACCELERATION (IN/SEC^2)	NODE NO.	ACCELERATION (IN/SEC^2)
1	3.72100352E+02	1	4.00161471E+02	1	3.56740589E+02
2	3.03877050E+02	2	3.35243051E+02	2	2.89943525E+02
3	1.51444000E+02	3	1.65915093E+02	3	1.52570849E+02
4	1.60361207E+02	4	1.30020709E+02	4	1.65270044E+02
5	1.79104095E+02	5	1.83628525E+02	5	1.61955551E+02
6	1.53744514E+02	6	1.09143450E+02	6	1.39167580E+02
7	1.41094440E+02	7	1.72512797E+02	7	1.52121565E+02
8	1.58430227E+02	8	1.42586079E+02	8	1.60251507E+02
9	1.61697583E+02	9	1.39378324E+02	9	1.44816629E+02
10	1.43769630E+02	10	1.50565484E+02	10	1.31157596E+02
11	1.25395075E+02	11	1.52366516E+02	11	1.28312734E+02
12	1.19441207E+02	12	1.40133740E+02	12	1.23238698E+02
13	1.17767674E+02	13	1.21010871E+02	13	1.11557531E+02
14	1.11525177E+02	14	1.05312339E+02	14	1.02234736E+02
15	1.01830783E+02	15	9.33211773E+01	15	9.94724540E+01
16	9.40673625E+01	16	1.00860117E+02	16	9.56292289E+01
17	9.07950114E+01	17	1.03457913E+02	17	9.04804053E+01
18	8.92535580E+01	18	1.02652367E+02	18	8.44813420E+01
19	8.77509511E+01	19	9.76887424E+01	19	8.06360456E+01
20	8.28797993E+01	20	9.01103177E+01	20	7.76011728E+01
21	7.58213874E+01	21	8.22543097E+01	21	7.26966049E+01
22	6.91274317E+01	22	7.57520066E+01	22	6.51916830E+01
23	6.09539715E+01	23	7.07821093E+01	23	5.62343073E+01
24	5.49731139E+01	24	6.63620453E+01	24	4.22651223E+01
25	4.96258221E+01	25	6.29904765E+01	25	4.06020249E+01

A-11 - SEISMIC RESPONSE RESULTS

LACBWR STACK
MODEL 1 - (STANDARD FOUNDATION SPRING)
SEISMIC SHEAR FORCE AND MOMENT RESPONSE

MEMBER NO.	NODE NOS.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)
1	1	3.7646E+03	2.4933E-05
	2	3.7646E+03	2.2598E+05
2	2	1.6302E+04	2.2598E+05
	3	1.6302E+04	3.1759E+06
3	3	2.4327E+04	3.1759E+06
	4	2.4327E+04	7.4878E+06
4	4	2.7075E+04	7.4878E+06
	5	2.7075E+04	1.1937E+07
5	5	3.0094E+04	1.1937E+07
	6	3.0094E+04	1.6297E+07
6	6	3.3293E+04	1.6297E+07
	7	3.3293E+04	2.0717E+07
7	7	3.4726E+04	2.0717E+07
	8	3.4726E+04	2.5202E+07
8	8	3.5530E+04	2.5202E+07
	9	3.5530E+04	2.9560E+07
9	9	3.7052E+04	2.9550E+07
	10	3.7052E+04	3.3776E+07
10	10	4.1691E+04	3.3776E+07
	11	4.1691E+04	3.8019E+07
11	11	4.5328E+04	3.8019E+07
	12	4.5328E+04	4.2453E+07
12	12	4.8647E+04	4.2453E+07
	13	4.8647E+04	4.7128E+07
13	13	5.2763E+04	4.7128E+07
	14	5.2763E+04	5.2074E+07
14	14	5.8723E+04	5.2074E+07
	15	5.8723E+04	5.7435E+07
15	15	6.6280E+04	5.7435E+07
	16	6.6280E+04	6.3523E+07
16	16	7.4262E+04	6.3523E+07
	17	7.4262E+04	7.0708E+07
17	17	8.2203E+04	7.0708E+07
	18	8.2203E+04	7.9270E+07
18	18	9.0492E+04	7.9270E+07
	19	9.0492E+04	8.9386E+07
19	19	9.9473E+04	8.9386E+07
	20	9.9473E+04	1.0120E+08
20	20	1.0904E+05	1.0120E+08
	21	1.0904E+05	1.1492E+08
21	21	1.1851E+05	1.1492E+08
	22	1.1851E+05	1.3034E+08
22	22	1.2720E+05	1.3034E+08
	23	1.2720E+05	1.4768E+08
23	23	1.3609E+05	1.4768E+08
	24	1.3609E+05	1.6677E+08
24	24	1.4640E+05	1.6677E+08
	25	1.4640E+05	1.8758E+08

A-11 - SEISMIC RESPONSE RESULTS

LACBWR STACK
MODEL 2 - (SOFTER FOUNDATION SPRING)
SEISMIC SHEAR FORCE AND MOMENT RESPONSE

MEMBER NO.	NODE NO.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)
1	1	4.0475E+03	8.5249E-06
	2	4.0475E+03	2.4285E+05
2	2	1.7987E+04	2.4285E+05
	3	1.7987E+04	3.4803E+06
3	3	2.7905E+04	3.4803E+06
	4	2.7905E+04	8.4666E+06
4	4	2.9933E+04	8.4666E+06
	5	2.9933E+04	1.3620E+07
5	5	2.9953E+04	1.3620E+07
	6	2.9953E+04	1.8144E+07
6	6	3.2966E+04	1.8144E+07
	7	3.2966E+04	2.2107E+07
7	7	3.7920E+04	2.2107E+07
	8	3.7920E+04	2.6044E+07
8	8	4.1482E+04	2.6044E+07
	9	4.1482E+04	3.0319E+07
9	9	4.2860E+04	3.0319E+07
	10	4.2860E+04	3.4855E+07
10	10	4.3772E+04	3.4855E+07
	11	4.3772E+04	3.9379E+07
11	11	4.6550E+04	3.9379E+07
	12	4.6550E+04	4.3788E+07
12	12	5.1853E+04	4.3788E+07
	13	5.1853E+04	4.8271E+07
13	13	5.8412E+04	4.8271E+07
	14	5.8412E+04	5.3183E+07
14	14	6.4853E+04	5.3183E+07
	15	6.4853E+04	5.8810E+07
15	15	7.0776E+04	5.8810E+07
	16	7.0776E+04	6.5283E+07
16	16	7.6900E+04	6.5283E+07
	17	7.6900E+04	7.2675E+07
17	17	8.4479E+04	7.2675E+07
	18	8.4479E+04	8.1132E+07
18	18	9.4183E+04	8.1132E+07
	19	9.4183E+04	9.0953E+07
19	19	1.0563E+05	9.0953E+07
	20	1.0563E+05	1.0255E+08
20	20	1.1781E+05	1.0255E+08
	21	1.1781E+05	1.1629E+08
21	21	1.2971E+05	1.1629E+08
	22	1.2971E+05	1.3240E+08
22	22	1.4097E+05	1.3240E+08
	23	1.4097E+05	1.5087E+08
23	23	1.5320E+05	1.5087E+08
	24	1.5320E+05	1.7169E+08
24	24	1.6893E+05	1.7169E+08
	25	1.6893E+05	1.9499E+08

A-11 - SEISMIC RESPONSE RESULTS

LACBWR STACK
MODEL 3 - (STIFFER FOUNDATION SPRING)
SEISMIC SHEAR FORCE AND MOMENT RESPONSE

MEMBER NO.	NODE NO.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)	MEMBER NO.	NODE NO.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)
1	1	3.6093E+03	2.5255E-05	13	13	5.2179E+04	4.6762E+07
	2	3.6093E+03	2.1650E+05		14	5.2179E+04	5.1652E+07
2	2	1.5610E+04	2.1650E+05	14	14	5.7869E+04	5.1652E+07
	3	1.5610E+04	3.0255E+06		15	5.7869E+04	5.7056E+07
3	3	2.3187E+04	3.0255E+06	15	15	6.4501E+04	5.7056E+07
	4	2.3187E+04	7.0971E+06		16	6.4501E+04	6.3184E+07
4	4	2.6749E+04	7.0971E+06	16	16	7.2277E+04	6.3184E+07
	5	2.6749E+04	1.1440E+07		17	7.2277E+04	7.0333E+07
5	5	3.0146E+04	1.1440E+07	17	17	8.0825E+04	7.0333E+07
	6	3.0146E+04	1.5919E+07		18	8.0825E+04	7.7832E+07
6	6	3.2154E+04	1.5919E+07	18	18	8.9559E+04	7.7832E+07
	7	3.2154E+04	2.0493E+07		19	8.9559E+04	8.6943E+07
7	7	3.3016E+04	2.0493E+07	19	19	9.8126E+04	8.6943E+07
	8	3.3016E+04	2.4959E+07		20	9.8126E+04	1.0080E+08
8	8	3.4957E+04	2.4959E+07	20	20	1.0676E+05	1.0080E+08
	9	3.4957E+04	2.9256E+07		21	1.0676E+05	1.1445E+08
9	9	3.7669E+04	2.9256E+07	21	21	1.1516E+05	1.1445E+08
	10	3.7669E+04	3.3508E+07		22	1.1516E+05	1.2986E+08
10	10	4.0358E+04	3.3508E+07	22	22	1.2295E+05	1.2986E+08
	11	4.0358E+04	3.7813E+07		23	1.2295E+05	1.4694E+08
11	11	4.3234E+04	3.7813E+07	23	23	1.3070E+05	1.4694E+08
	12	4.3234E+04	4.2204E+07		24	1.3070E+05	1.6557E+08
12	12	4.7132E+04	4.2204E+07	24	24	1.3896E+05	1.6557E+08
	13	4.7132E+04	4.6762E+07		25	1.3896E+05	1.6569E+08

A III - STRUCTURAL CALCULATIONS

LACBWR STACK - ALLOWABLE OVERTURNING MOMENT

The allowable overturning moment carrying capacity of various crossections of the LACBWR stack are calculated using the equations and procedures described in Section 6.2.1. The results of the structural calculations are summarized in Table A III. A typical structural calculation is shown below:

Member No. 5, Node No. 6:
(Refer to section 6.2.1 for nomenclature)

Outside diameter = 105.6 in,; Wall Thickness, t_c = 6 in.

Reinforcement = 30 #4; A_s = 6.0 in.^{2}; 2R = 101,6 in.

t_s = 0.0188 in.^{2}; f'c = 3.5 ksi.

σ_y = 1.15 x 40 ksi (15 percent increase for dynamic loading)

Using Equation 11

$$\left(\frac{\pi}{2} + \overline{\theta}\right) = \frac{1.44 \times 3.5 \times 6.0}{2 \times 1.15 \times 40 \times 0.0188} \left(\frac{\pi}{2} - \overline{\theta}\right) = X \left(\frac{\pi}{2} - \overline{\theta}\right)$$

$$X = 1\ 75445$$

$$\therefore \overline{\theta} = \frac{\pi}{2} \frac{(x-1)}{(x+1)} \text{ radians} = 90 \frac{(x-1)}{(x+1)} = 80.294^{\circ}$$

Using Equations 12, 13, 14 and 15

$$M_c = \frac{1.445 \times 3.5 \times (101.6)^2}{4} \times 6 \ \{\text{Sin}\ (90 - 80.294) - \frac{(90 - 8.294)}{180} \pi \ \text{Sin}\ 80.294\} = \underline{127.06 \text{ k-in.}}$$

$$M_t = 2 \times 1.15 \times 40 \times \frac{(101.6)^2}{4} \times 0.0188 \ \{\text{Sin}(30 + 80.294) + \frac{(90 + 80.294)}{180} \pi \ \text{Sin}\ 80.294\} = \underline{13,828.9 \text{ k-in.}}$$

$$M_{D.W.} = WR \ \text{Sin}\ \overline{\theta} = 113.61 \times \frac{101.6}{2} \ \text{Sin}\ 80.294 = \underline{5,688.8 \text{ K-in.}}$$

$\therefore$ Allowable Overturning Moment M

$$M = 127.06 + 13,828.9 + 5688.8 = \underline{19644.8 \text{ k-in.}}$$

TABLE A III - LACBWR STACK ALLOWABLE OVERTURNING MOMENT

NODE NO.	O.D. (IN)	tc (IN)	REIN-FORCE-MENT	As (IN²)	2R (IN)	ts (IN)	X	$\overline{\theta}$ (DEG)	Mc (K-IN)	Mt (K-IN)	Mc + Mt (K-IN)	DEAD WT KIPS	$M_{D.W.}$ (K-IN)	M (K-IN)
1	85.6	6.0	24#4	4.8	81.6	0.0187	20.284	81.54	54.09	7741.05	7795.1	0	0	7795.1
2	86.25	6.0	24#4	4.8	82.25	0.0186	20.393	81.59	53.99	7823.77	7877.8	7.82	292.69	8170.5
3	91.0	6.0	24#4	4.8	87.0	0.0176	21.552	82.02	51.62	8291.45	8343.1	32.15	1274.2	9617.3
4	95.75	6.0	25#4	5.0	91.75	0.0173	21.926	82.15	54.67	9067.11	9121.8	57.88	2419.9	11541.7
5	100.6	6.0	28#4	5.6	96.6	0.0185	20.503	81.63	72.97	10734.96	10807.9	85.01	3737.3	114545.0
6	105.6	6.0	30#4	6.0	101.6	0.0188	20.176 (17.544)	81.50 (80.294)	85.05 (127.06)	12063.69 (13828.9)	12148.7 (113955.9)	113.61	5251.4 (5688.8)	17400.1 (19644.8)
7	110.6	6.0	32#4	6.4	106.6	0.0191	19.859 (17.269)	81.37 (80.147)	97.93 (145.69)	13487.81 (15459.9)	13585.7 (15605.59)	143.69	6966.21 (7545.71)	20551.9 (23151.4)
8	115.6	6.0	40#5	12.4	111.6	0.0354	10.715	74.64	602.72	26768.72	27371.4	175.24	8674.8	36046.2
9	120.6	6.0	40#6	[illegible]	[illegible]	[illegible]	7.902	[illegible]	1492.35	38665.12	53587.5	208.26	10481.8	64069.3
10	130.6	6.25	52#6	[illegible]	[illegible]	[illegible]	6.872	[illegible]	2642.46	53737.42	56379.9	244.19	13102.7	69482.6
11	140.6	6.50	46#7	[illegible]	[illegible]	[illegible]	6.391	[illegible]	3853.36	69283.25	73136.6	284.63	16294.0	89430.6
12	150.6	6.875	52#7	[illegible]	[illegible]	[illegible]	6.420	[illegible]	4643.06	84068.96	88412.0	330.06	20292.3	108704.3
13	160.6	7.25	44#8	[illegible]	[illegible]	[illegible]	6.493	[illegible]	5445.00	100321.70	105766.7	381.78	25114.5	130881.2
14	170.6	8.125	50#8	[illegible]	[illegible]	[illegible]	6.803	[illegible]	5104.56	122034.47	128039.0	441.17	31105.6	159144.6
15	180.6	9.0	54#8	[illegible]	[illegible]	[illegible]	7.399	[illegible]	6103.60	141096.24	147199.8	[illegible]	38651.5	185851.3
16	190.6	9.0	58#8	[illegible]	[illegible]	[illegible]	7.276	[illegible]	7121.49	159883.18	167004.7	589.16	46971.0	213975.7
17	200.6	9.0	61#8	45.15	[illegible]	[illegible]	7.294	[illegible]	7851.13	177079.17	184930.3	671.6	56412.9	[illegible]
18	212.6	9.0	63#8	[illegible]	[illegible]	[illegible]	7.496	[illegible]	8235.84	194583.10	202818.9	758.9	67897.6	270716.3
19	224.6	9.0	67#8	52.93	220.6	0.0764	7.447	[illegible]	9366.54	218891.75	228258.3	851.5	80499.0	308757.3
20	236.6	9.125	68#8	53.72	232.6	0.0735	7.849	[illegible]	9192.18	235446.13	244638.3	950.39	95347.3	339985.6
21	248.6	9.25	69#8	54.51	244.6	0.0709	8.245	[illegible]	9033.62	252395.70	261429.3	1055.99	112028.3	373457.6
22	260.6	9.375	89#7	53.4	256.6	0.0662	8.953	[illegible]	8093.65	261255.14	269348.8	1167.79	131035.2	400384.0
23	272.6	9.5	86#7	51.6	268.6	0.0611	9.829	[illegible]	6991.41	266110.16	273101.6	1287.29	152407.6	425509.2
24	284.6	14.0	80#7	48.0	280.6	0.0545	16.240	[illegible]	2801.32	265328.39	268129.7	1448.99	183933.6	452063.3
25	296.6	15.0	80#7	48.0	292.6	0.0522	18.166	[illegible]	2376.11	277169.42	279545.5	1642.32	218087.8	497633.3

* Number in parenthesis represents calculated values with 15 percent increase in yield stress value of reinforcing steel for dynamic earthquake loads.

APPENDIX B

GENOA 3 STACK - INPUT DATA, RESPONSE RESULTS AND STRUCTURAL CALCULATIONS

B-I INPUT DATA

- Lumped Weight
- Member Properties
- Foundation Spring Constants
- Response Spectrum

B-II SEISMIC RESPONSE RESULTS

- Displacement Response
- Acceleration Response
- Moment and Shear Force Response

B-III STRUCTURAL CALCULATIONS

- Allowable Overturning Moment

B-1 - INPUT DATA

GENOA 3 STACK LUMPED WEIGHT

NODE NO.	LUMPED WEIGHT (LBS)
1	.13625E+05
2	.47186E+05
3	.72154E+05
4	.74215E+05
5	.76277E+05
6	.78338E+05
7	.80400E+05
8	.82462E+05
9	.84523E+05
10	.88303E+05
11	.90364E+05
12	.90708E+05
13	.92898E+05
14	.95346E+05
15	.97923E+05
16	.10050E+06
17	.10309E+06
18	.10565E+06
19	.11586E+06
20	.12624E+06
21	.13113E+06
22	.14226E+06
23	.15566E+06
24	.16968E+06
25	.18450E+06
26	.19787E+06
27	.21166E+06
28	.23276E+06
29	.26843E+06
30	.32633E+06
31	.41863E+06
32	.47996E+06
33	.49050E+06
34	.50110E+06
35	.42532E+07
SUMMATION	.98797E+07

B-1 - INPUT DATA

GENOA 3 STACK MEMBER PROPERTIES

MEMBER NO	JOINT NS		OUTSIDE DIAMETER (IN)	THICKNESS (IN)	LENGTH (IN)	AREA (IN^4)	POLAR MOMENT OF INERTIA ($IN.^4$)	MOMENT OF INERTIA ($IN.^4$)
1	1	2	2.100E+02	7.000E+00	6.000E+01	4.464E+03	4.605E+07	2.302E+07
2	2	3	2.140E+02	7.000E+00	1.800E+02	4.552E+03	4.882E+07	2.441E+07
3	3	4	2.200E+02	7.000E+00	1.800E+02	4.684E+03	5.319E+07	2.659E+07
4	4	5	2.260E+02	7.000E+00	1.800E+02	4.816E+03	5.780E+07	2.890E+0
5	5	6	2.320E+02	7.000E+00	1.800E+02	4.948E+03	6.268E+07	3.134E+0
6	6	7	2.380E+02	7.000E+00	1.800E+02	5.080E+03	6.783E+07	3.392E+0
7	7	8	2.440E+02	7.000E+00	1.800E+02	5.212E+03	7.325E+07	3.663E+0
8	8	9	2.500E+02	7.000E+00	1.800E+02	5.344E+03	7.895E+07	3.948E+0
9	9	10	2.560E+02	7.000E+00	1.800E+02	5.476E+03	8.494E+07	4.247E+0
10	10	11	2.720E+02	7.000E+00	1.800E+02	5.828E+03	1.024E+08	5.119E+0
11	11	12	2.680E+02	7.000E+00	1.800E+02	5.740E+03	9.782E+07	4.891E+0
12	12	13	2.740E+02	7.000E+00	1.800E+02	5.872E+03	1.047E+08	5.236E+0
13	13	14	2.807E+02	7.000E+00	1.800E+02	6.020E+03	1.129E+08	5.643E+0
14	14	15	2.882E+02	7.000E+00	1.800E+02	6.185E+03	1.224E+08	6.119E+0
15	15	16	2.957E+02	7.000E+00	1.800E+02	6.350E+03	1.324E+08	6.622E+0
16	16	17	3.032E+02	7.000E+00	1.800E+02	6.515E+03	1.430E+08	7.151E+0
17	17	18	3.107E+02	7.000E+00	1.800E+02	6.680E+03	1.542E+08	7.708E+0
18	18	19	3.182E+02	7.000E+00	1.800E+02	6.845E+03	1.659E+08	8.293E+0
19	19	20	3.257E+02	8.000E+00	1.800E+02	7.986E+03	2.017E+08	1.009E+0
20	20	21	3.332E+02	8.000E+00	1.800E+02	8.174E+03	2.163E+08	1.082E+0
21	21	22	3.407E+02	8.250E+00	1.800E+02	8.618E+03	2.383E+08	1.192E+0
22	22	23	3.482E+02	9.000E+00	1.800E+02	9.592E+03	2.762E+08	1.381E+0
23	23	24	3.557E+02	9.500E+00	1.800E+02	1.033E+04	3.100E+08	1.550E+0
24	24	25	3.639E+02	1.025E+01	1.800E+02	1.139E+04	3.563E+08	1.781E+0
25	25	26	3.729E+02	1.075E+01	1.800E+02	1.223E+04	4.013E+08	2.006E+0
26	26	27	3.819E+02	1.125E+01	1.800E+02	1.310E+04	4.502E+08	2.251E+0
27	27	28	3.909E+02	1.175E+01	1.800E+02	1.399E+04	5.034E+08	2.517E+0
28	28	29	3.999E+02	1.300E+01	1.800E+02	1.590E+04	5.919E+08	2.959E+0
29	29	30	4.089E+02	1.500E+01	1.800E+02	1.856E+04	7.209E+08	3.605E+0
30	30	31	4.179E+02	1.850E+01	1.800E+02	2.321E+04	9.275E+08	4.638E+0
31	31	32	4.269E+02	2.400E+01	1.800E+02	3.038E+04	1.237E+09	6.185E+0
32	32	33	4.359E+02	2.400E+01	1.800E+02	3.105E+04	1.322E+09	6.608E+
33	33	34	4.449E+02	2.400E+01	1.800E+02	3.173E+04	1.410E+09	7.049E+
34	34	35	4.539E+02	2.400E+01	1.800E+02	3.241E+04	1.502E+09	7.510E+

GENOA 3 STACK - FOUNDATION SPRING STIFFNESS

The foundation mat of the GENOA 3 stack is octagonal in shape, as shown on the M. W. Kellogg Company Drawing No. 6152-ED, and it rests directly on the soil. For the purpose of calculating the stiffness of the foundation springs, the GENOA 3 stack foundation mat is assumed to be equivalent to a circular base of 75 feet diameter. The soil properties are taken from Reference 1. For the standard foundation spring, the soil properties correspond to averaged values for boring number 5 and 6 and a shear strain of 0.005 percent (Table 3.1)

Using equations 2 and 3 given in Section 6.1.2

Horizontal Spring Stiffness $K_x = \frac{32(1-\mu)\,G}{7-8\,\mu}$

Rocking Spring Stiffness $K_\theta = \frac{8\,G\,\gamma^3}{3\,(1-\mu)}$

where:

G = Shear Modulus of Soil = 2.51×10^6 lbs/ft.^{2} (Tables 3.1 and 2.2 of Reference 1)

μ = Poisson's Ratio = 0.4 (Calculated from data given in Table 3.1)

γ = Effective Radius of Foundation Mat = 37.5 feet

$$K_x = \frac{32\,(1-0.4)\,2.51 \times 10^6 \times 37.5}{7 - 8 \times 0.4}$$

$$K_x = 475.6 \times 10^6 \text{ lbs/ft.} = 39.63 \times 10^6 \text{ lbs/in.}$$

$$K_\theta = \frac{8 \times 2.51 \times 10^6\,(37.5)^3}{3\,(1 - 0.4)}$$

$$K_\theta = 588.28 \times 10^9 \text{ lbs.ft./radian}$$

$$K_\theta = 7059.38 \times 10^9 \text{ lbs.in./radian}$$

For Standard Foundation Springs (Model 1):

$$K_x = 39.63 \times 10^6 \text{ lbs/in.}$$

$$K_\theta = 7059.38 \times 10^9 \text{ lbs.in./radian}$$

For Softer Foundation Springs (Model 2):

$$G = 1.0 \times 10^6 \text{ lbs/ft.}^2$$

$$K_x = \frac{1.0}{2.51} \times 39.63 \times 10^6$$

$$K_x = 1.5789 \times 10^7 \text{ lbs/in.}$$

$$K_\theta = \frac{1.0}{2.51} \times 7059.38 \times 10^9$$

$$K_\theta = 2.8125 \times 10^{12} \text{ lbs.in./radian}$$

For Stiffer Foundation Springs (Model 3):

$$G = 3.765 \times 10^6 \text{ lbs/ft.}^2$$

$$K_x = 1.5 \times 39.63 \times 10^6$$

$$K_x = 5.9445 \times 10^7 \text{ lbs./in.}$$

$$K_\theta = 1.5 \times 7059.38 \times 10^9$$

$$K_\theta = 1.0589 \times 10^{13} \text{ lbs.in./radian}$$

B-1 - INPUT DATA

GENOA 3 STACK - RESPONSE SPECTRUM

1	FREQ =	.050000,	SPECTRA =	.772800
2	FREQ =	.100000,	SPECTRA =	3.091200
3	FREQ =	.150000,	SPECTRA =	6.955200
4	FREQ =	.250000,	SPECTRA =	19.320000
5	FREQ =	.400000,	SPECTRA =	28.207200
6	FREQ =	.600000,	SPECTRA =	44.436000
7	FREQ =	.800000,	SPECTRA =	50.232000
8	FREQ =	1.000000,	SPECTRA =	59.392000
9	FREQ =	1.500000,	SPECTRA =	86.940000
10	FREQ =	2.000000,	SPECTRA =	108.192000
11	FREQ =	2.500000,	SPECTRA =	127.512000
12	FREQ =	3.000000,	SPECTRA =	123.648000
13	FREQ =	4.000000,	SPECTRA =	115.920000
14	FREQ =	5.000000,	SPECTRA =	113.988000
15	FREQ =	6.000000,	SPECTRA =	112.056000
16	FREQ =	8.000000,	SPECTRA =	106.260000
17	FREQ =	10.000000,	SPECTRA =	96.600000
18	FREQ =	15.000000,	SPECTRA =	77.280000
19	FREQ =	20.000000,	SPECTRA =	65.688000
20	FREQ =	25.000000,	SPECTRA =	56.028000
21	FREQ =	33.000000,	SPECTRA =	46.368000
22	FREQ =	50.000000,	SPECTRA =	46.368000

B-11 - SEISMIC RESPONSE RESULTS

GENOA 3 STACK - SEISMIC DISPLACEMENT RESPONSE

Maximum Displacement (IN)

NODE NO.	MODEL 1 STANDARD FOUNDATION SPRINGS	MODEL 2 SOFTER FOUNDATION SPRINGS	MODEL 3 STIFFER FOUNDATION SPRINGS
1	9.02056579E+00	9.70624976E+00	8.84073924E+00
2	8.84967728E+00	9.66306189E+00	8.67235458E+00
3	8.33930050E+00	9.06830230E+00	8.16948582E+00
4	7.83423314E+00	8.53504233E+00	7.67155243E+00
5	7.33671990E+00	8.01052292E+00	7.19078025E+00
6	6.94908497E+00	7.49728052E+00	6.60347483E+00
7	6.27345957E+00	6.99742983E+00	6.22978085E+00
8	5.91165700E+00	6.51267152E+00	5.77357575E+00
9	5.46510195E+00	6.04422115E+00	5.33243712E+00
10	5.03520441E+00	5.59301172E+00	4.90764153E+00
11	4.62250644E+00	5.15935922E+00	4.40974135E+00
12	4.22745407E+00	4.74375936E+00	4.10335929E+00
13	3.95143532E+00	4.34746655E+00	3.73770733E+00
14	3.49476573E+00	3.97087467E+00	3.38530367E+00
15	3.15754271E+00	3.61419401E+00	3.05223437E+00
16	2.83974807E+00	3.27747032E+00	2.77843971E+00
17	2.54134710E+00	2.96068293E+00	2.44404773E+00
18	2.26230066E+00	2.66365754E+00	2.16391819E+00
19	2.00256208E+00	2.38617207E+00	1.91303386E+00
20	1.76153674E+00	2.12773218E+00	1.67623093E+00
21	1.53867093E+00	1.88672179E+00	1.45656354E+00
22	1.33300748E+00	1.66301210E+00	1.25531267E+00
23	1.14462712E+00	1.45611633E+00	1.07100056E+00
24	9.72620578E-01	1.26507003E+00	9.03312095E-01
25	8.16505617E-01	1.05936642E+00	7.51702885E-01
26	6.75894512E-01	9.29261982E-01	6.15972366E-01
27	5.50257810E-01	7.81300315E-01	4.05209211E-01
28	4.30400929E-01	6.48475330E-01	3.99830188E-01
29	3.43437605E-01	5.29339182E-01	2.99453847E-01
30	2.61304393E-01	4.23297047E-01	2.23177086E-01
31	1.91972630E-01	3.29486984E-01	1.59842599E-01
32	1.33030709E-01	2.46903241E-01	1.07840524E-01
33	8.57560719E-02	1.74874082E-01	6.56271249E-02
34	4.97029697E-02	1.16142504E-01	3.40577520E-02
35	2.60202417E-02	7.75326233E-02	1.57522223E-02

GENOA 3 STACK - SEISMIC ACCELERATION RESPONSE

MODEL 1 STANDARD FOUNDATION SPRINGS		MODEL 2 SOFTER FOUNDATION SPRINGS		MODEL 3 STIFFER FOUNDATION SPRINGS	
NODE NO.	ACCELERATION (IN/SEC²)	NODE NO.	ACCELERATION (IN/SEC²)	NODE NO.	ACCELERATION (IN/SEC²)
1	3.40677486E+02	1	3.45951079E+02	1	3.40812609E+02
2	3.12421662E+02	2	3.14870638E+02	2	3.22358922E+02
3	2.04022513E+02	3	2.23177569E+02	3	1.92069741E+02
4	1.22813614E+02	4	1.41394025E+02	4	1.20196488E+02
5	1.11344509E+02	5	9.13031946E+01	5	1.24395246E+02
6	1.45222207E+02	6	9.95969402E+01	6	1.55303609E+02
7	1.70604165E+02	7	1.33940769E+02	7	1.68353343E+02
8	1.74537454E+02	8	1.61567464E+02	8	1.60365788E+02
9	1.61879069E+02	9	1.74841904E+02	9	1.44157792E+02
10	1.44607871E+02	10	1.73840257E+02	10	1.36094274E+02
11	1.36411366E+02	11	1.63170939E+02	11	1.42350756E+02
12	1.41535742E+02	12	1.48174947E+02	12	1.53870493E+02
13	1.52106750E+02	13	1.34537472E+02	13	1.59509726E+02
14	1.59116381E+02	14	1.27323330E+02	14	1.56159966E+02
15	1.58572022E+02	15	1.27746931E+02	15	1.47050055E+02
16	1.51373730E+02	16	1.32764426E+02	16	1.37982927E+02
17	1.41379149E+02	17	1.38028674E+02	17	1.33553933E+02
18	1.33074443E+02	18	1.40411772E+02	18	1.33677896E+02
19	1.28960369E+02	19	1.39618924E+02	19	1.34954641E+02
20	1.28307002E+02	20	1.33340521E+02	20	1.33963254E+02
21	1.28566247E+02	21	1.26077184E+02	21	1.30277837E+02
22	1.27264630E+02	22	1.18513293E+02	22	1.24362662E+02
23	1.23572453E+02	23	1.12270934E+02	23	1.18070317E+02
24	1.19062418E+02	24	1.08113474E+02	24	1.12571275E+02
25	1.11977069E+02	25	1.05236863E+02	25	1.09296833E+02
26	1.06385467E+02	26	1.04526843E+02	26	1.04727635E+02
27	1.01649450E+02	27	1.03052144E+02	27	1.01179009E+02
28	9.73101422E+01	28	1.00521354E+02	28	9.66327170E+01
29	9.25791580E+01	29	9.65614085E+01	29	9.07157725E+01
30	8.69511180E+01	30	9.13945773E+01	30	8.35396409E+01
31	8.05863874E+01	31	8.56800523E+01	31	7.57642918E+01
32	7.41094486E+01	32	8.02819117E+01	32	6.93328794E+01
33	6.79535772E+01	33	7.54902475E+01	33	6.14080654E+01
34	6.23121623E+01	34	7.16444494E+01	34	5.53923139E+01
35	5.73744457E+01	35	6.20420316E+01	35	5.00523831E+01

B-11 - SEISMIC RESPONSE RESULTS

GENOA 3 STACK - SEISMIC SHEAR FORCE AND MOMENT RESPONSE

MODEL 1 - STANDARD FOUNDATION SPRINGS

MEMBER NO.	NODES NOS.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)
1	1	1.2330E+04	1.2431E-04
	2	1.2330E+04	7.3980E+05
2	2	5.0475E+04	7.3980E+05
	3	5.0475E+04	9.6240E+06
3	3	8.8022E+04	9.6240E+06
	4	8.8022E+04	2.5639E+07
4	4	1.0764E+05	2.5639E+07
	5	1.0764E+05	4.4850E+07
5	5	1.1351E+05	4.4850E+07
	6	1.1351E+05	6.4693E+07
6	6	1.1251E+05	6.4693E+07
	7	1.1251E+05	8.3324E+07
7	7	1.1217E+05	8.3324E+07
	8	1.1217E+05	9.9948E+07
8	8	1.1666E+05	9.9948E+07
	9	1.1666E+05	1.1476E+08
9	9	1.2463E+05	1.1476E+08
	10	1.2463E+05	1.2825E+08
10	10	1.3233E+05	1.2825E+08
	11	1.3233E+05	1.4131E+08
11	11	1.3708E+05	1.4131E+08
	12	1.3708E+05	1.5396E+08
12	12	1.3805E+05	1.5396E+08
	13	1.3805E+05	1.6630E+08
13	13	1.4027E+05	1.6630E+08
	14	1.4027E+05	1.7811E+08
14	14	1.4376E+05	1.7811E+08
	15	1.4376E+05	1.8930E+08
15	15	1.5048E+05	1.8930E+08
	16	1.5048E+05	2.0008E+08
16	16	1.6013E+05	2.0008E+08
	17	1.6013E+05	2.1090E+08
17	17	1.7031E+05	2.1090E+08
	18	1.7031E+05	2.2231E+08
18	18	1.7943E+05	2.2231E+08
	19	1.7943E+05	2.3474E+08
19	19	1.8771E+05	2.3474E+08
	20	1.8771E+05	2.4928E+08
20	20	1.9608E+05	2.4928E+08
	21	1.9608E+05	2.6292E+08
21	21	2.0528E+05	2.6292E+08
	22	2.0528E+05	2.7830E+08
22	22	2.1681E+05	2.7830E+08
	23	2.1681E+05	2.9602E+08
23	23	2.3158E+05	2.9602E+08
	24	2.3158E+05	3.1495E+08
24	24	2.4955E+05	3.1495E+08
	25	2.4955E+05	3.3576E+08
25	25	2.7011E+05	3.3576E+08
	26	2.7011E+05	3.5935E+08
26	26	2.9229E+05	3.5935E+08
	27	2.9229E+05	3.8630E+08
27	27	3.1553E+05	3.8630E+08
	28	3.1553E+05	4.1720E+08
28	28	3.4043E+05	4.1720E+08
	29	3.4043E+05	4.5252E+08
29	29	3.6848E+05	4.5252E+08
	30	3.6848E+05	4.9270E+08
30	30	4.0233E+05	4.9270E+08
	31	4.0233E+05	5.3827E+08
31	31	4.4662E+05	5.3827E+08
	32	4.4662E+05	5.9004E+08
32	32	4.9579E+05	5.9004E+08
	33	4.9579E+05	6.4908E+08
33	33	5.4229E+05	6.4908E+08
	34	5.4229E+05	7.1612E+08
34	34	5.8422E+05	7.1612E+08
	35	5.8422E+05	7.8126E+08

GENOA 3 STACK - SEISMIC SHEAR FORCE AND MOMENT RESPONSE

MODEL 2 - STANDARD FOUNDATION SPRINGS

MEMBER NO.	NODES NOS.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)	MEMBER NO.	NODE NOS.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)
1	1	1.2105E+04	9.4299E-05	19	19	1.9328E+05	2.[illegible]070E+08
	2	1.2105E+04	7.3170E+05		20	1.9328E+05	2.6498E+08
2	2	5.0643E+04	7.3170E+05	20	20	2.0306E+05	2.6498E+08
	3	5.0643E+04	9.9473E+06		21	2.0306E+05	2.7971E+08
3	3	9.2098E+04	9.9473E+06	21	21	2.1465E+05	2.7971E+08
	4	9.2098E+04	2.6412E+07		22	2.1465E+05	2.9528E+08
4	4	1.1790E+05	2.6412E+07	22	22	2.2752E+05	2.9528E+08
	5	1.1790E+05	4.7568E+07		23	2.2752E+05	3.1200E+08
5	5	1.2945E+05	4.7568E+07	23	23	2.4126E+05	3.1200E+08
	6	1.2945E+05	7.0642E+07		24	2.4126E+05	3.3017E+08
6	6	1.2993E+05	7.0642E+07	24	24	2.5579E+05	3.3017E+08
	7	1.2993E+05	9.3374E+07		25	2.5579E+05	3.5007E+08
7	7	1.2383E+05	9.3374E+07	25	25	2.7161E+05	3.5007E+08
	8	1.2383E+05	1.1411E+08		26	2.7161E+05	3.7196E+08
8	8	1.1733E+05	1.1411E+08	26	26	2.8938E+05	3.7196E+08
	9	1.1733E+05	1.3190E+08		27	2.8938E+05	3.9620E+08
9	9	1.1659E+05	1.3190E+08	[illegible]	27	3.0989E+05	3.9620E+08
	10	1.1659E+05	1.4558E+08		28	3.0989E+05	4.2325E+08
10	10	1.2365E+05	1.4558E+08	28	28	3.3436E+05	4.2325E+08
	11	1.2365E+05	1.5954E+08		29	3.3436E+05	4.5363E+08
11	11	1.3500E+05	1.5954E+08	29	29	3.6474E+05	4.5363E+08
	12	1.3500E+05	1.6871E+08		30	3.6474E+05	4.8801E+08
12	12	1.4946E+05	1.6871E+08	30	30	4.0379E+05	4.8801E+08
	13	1.4946E+05	1.7827E+08		31	4.0379E+05	5.2733E+08
13	13	1.6120E+05	1.7827E+08	31	31	4.5574E+05	5.2733E+08
	14	1.6120E+05	1.8815E+08		32	4.5[illegible]E+05	5.7294E+08
14	14	1.6975E+05	1.8815E+08	32	32	5.1527E+05	5.7294E+08
	15	1.6975E+05	1.9891E+08		33	5.1527E+05	6.2620E+08
15	15	1.7523E+05	1.9891E+08	33	33	5.7503E+05	6.2690E+08
	16	1.7523E+05	2.1070E+08		34	5.7503E+05	6.9062E+08
16	16	1.79[illegible]1E+05	2.1070E+08	34	34	6.3175E+05	6.9062E+08
	17	1.79[illegible]1E+05	2.[illegible]30E+08		35	6.3175E+05	7.[illegible]571E+08
17	17	1.8[illegible]E+05	2.[illegible]30E+08				
	18	1.8[illegible]E+05	2.[illegible]477E+08				
18	18	1.[illegible]	2.[illegible]477E+08				
	19	1.[illegible]	[illegible]				

B-11 - SEISMIC RESPONSE RESULTS

GENOA 3 STACK - SEISMIC SHEAR FORCE AND MOMENT RESPONSE

MODEL 3 - STANDARD FOUNDATION SPRINGS

MEMBER NO.	NODES NOS.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)	MEMBER NO.	NODE NOS.	MAXIMUM SHEAR FORCE (LBS)	MAXIMUM MOMENT (IN LBS)
1	1	1.2017E+04	9.4994E-05	19	19	1.7832E+05	2.3084E+08
	2	1.2017E+04	7.2104E+05		20	1.7832E+05	2.4422E+08
2	2	4.8831E+04	7.2104E+05	20	20	1.8783E+05	2.4422E+08
	3	4.8831E+04	9.5282E+06		21	1.8783E+05	2.5845E+08
3	3	8.4005E+04	9.5282E+06	21	21	1.9962E+05	2.5845E+08
	4	8.4005E+04	2.4607E+07		22	1.9962E+05	2.7399E+08
4	4	1.0139E+05	2.4607E+07	22	22	2.1377E+05	2.7399E+08
	5	1.0139E+05	4.2624E+07		23	2.1377E+05	2.9089E+08
5	5	1.0679E+05	4.2624E+07	23	23	2.2998E+05	2.9099E+08
	6	1.0679E+05	6.1029E+07		24	2.2998E+05	3.0992E+08
6	6	1.0813E+05	6.1029E+07	24	24	2.4721E+05	3.0992E+08
	7	1.0813E+05	7.8399E+07		25	2.4721E+05	3.3145E+08
7	7	1.1155E+05	7.8399E+07	25	25	2.6715E+05	3.3145E+08
	8	1.1155E+05	9.4393E+07		26	2.6715E+05	3.5598E+08
8	8	1.1780E+05	9.4393E+07	26	26	2.8748E+05	3.5598E+08
	9	1.1780E+05	1.0934E+08		27	2.8748E+05	3.8400E+08
9	9	1.2374E+05	1.0934E+08	27	27	3.1097E+05	3.8400E+08
	10	1.2374E+05	1.2367E+08		28	3.1097E+05	4.1594E+08
10	10	1.2695E+05	1.2367E+08	28	28	3.3441E+05	4.1594E+08
	11	1.2695E+05	1.3746E+08		29	3.3441E+05	4.5221E+08
11	11	1.2775E+05	1.3746E+08	29	29	3.6222E+05	4.5221E+08
	12	1.2775E+05	1.5054E+08		30	3.6222E+05	4.9324E+08
12	12	1.2870E+05	1.5054E+08	30	30	3.9534E+05	4.9324E+08
	13	1.2870E+05	1.6276E+08		31	3.9534E+05	5.3954E+08
13	13	1.3244E+05	1.6276E+08	31	31	4.3637E+05	5.3954E+08
	14	1.3244E+05	1.7411E+08		32	4.3637E+05	5.9190E+08
14	14	1.3957E+05	1.7411E+08	32	32	4.8046E+05	5.9190E+08
	15	1.3957E+05	1.8487E+08		33	4.8046E+05	6.5111E+08
15	15	1.4851E+05	1.8497E+08	33	33	5.1998E+05	6.5111E+08
	16	1.4851E+05	1.9552E+08		34	5.1998E+05	7.1754E+08
16	16	1.5722E+05	1.9552E+08	34	34	5.5340E+05	7.1754E+08
	17	1.5722E+05	2.0654E+08		35	5.5340E+05	[illegible]
17	17	[illegible]	[illegible]				
	18	1.6442E+05	2.1936E+08				
18	18	[illegible]	[illegible]				

B-III - STRUCTURAL CALCULATIONS

GENOA 3 STACK - ALLOWABLE OVERTURNING MOMENT

The allowable overturning moment carrying capacity of various cross-sections of GENOA 3 stack are calculated using the equations and procedure described in Section 2.1. The results of the structural calculations are summarized in Table B-III. A typical structural calculation is shown below:

Member No. 8, Node No. 9:

(Refer to Section 6.2.1 for nomenclature)

Outside diameter = 253.0 in.; wall thickness t_c = 6.0 in.; 2R = 249.0 in.

Reinforcement 67 - #4; A_s = 13.4 in.^{2}; t_s = 0.0171 in.^{2}

$f'c$ = 4.0 ksi.; σ_Y = 1.15 x 40.0 ksi. (15% increase for dynamic loading)

Using equation 11

$$\left(\frac{\pi}{2} + \theta\right) = \frac{1.445 \times 4.0 \times 7.0}{2 \times 1.15 \times 40 \times 0.0171}\left(\frac{\pi}{2} - \theta\right) = X\left(\frac{\pi}{2} - \theta\right)$$

$$X = 25.718$$

$$\theta = \frac{\pi}{2}\,\frac{(X-1)}{(x+1)} \text{ radians} = 90\,\frac{(X-1)}{(X+1)} = 83.263^\circ$$

Using equation 12, 13, 14 and 15

$$Mc = 1.445 \times 4.0 \times \frac{(249.0)^2}{4} \times 7\left[\sin(90 - 80.263) - \frac{(90-80.263)}{180}\pi \sin 80.263\right]$$

$$= 339.36 \text{ K.in.}$$

$$M_t = 2 \times 1.15 \times 40 \frac{(249.0)^2}{4} \times 0.0171 \left[\sin(90+80.263) + \frac{(90+80.263)}{180} \pi \sin 80.263 \right]$$

$$= 76091.95 \text{ K.in.}$$

$$M_{D.W} = 566.4 \times \frac{249}{2} \sin 80.263 = 70029.89 \text{ K.in.}$$

Allowable overturning moment $M = 339.36 + 7,6091.95 + 70029.89$

$= 14,6461.2$ K.in.

TABLE B III - GENOA 3 STACK ALLOWABLE OVERTURNING MOMENT

NODE NO.	O.D. (IN)	tc (IN)	REIN-FORCE-MENT	As (IN^2)	2R (IN)	ts (IN)	X	$\overline{\theta}$ (DEG)	Mc (K-IN)	Mt (K-IN)	Mc + Mt (K-IN)	DEAD WT KIPS	$M_{D.W.}$ (K-IN)	$\overline{M}$ (K-IN)
1														
2	211.0	7	58#4	11.6	207	0.0178	28.413	83.88	175.86	47655.69	47831.6	25.25	2391.6	5022[illegible].2
3	217.0	7	59#4	11.8	213	0.017[illegible]	28.736	83.95	179.89	49897.71	50077.6	96.37	9389.7	59467.3
4	223.0	7	60#4	12.0	219	0.0174	29.0661	84.01	184.57	52154.59	52339.2	169.55	16987.2	69326.[illegible]
5	229.0	7	62#4	12.4	225	0.0175	28.9	83.98	197.77	55364.96	55562.7	244.8	25197.1	80759.8
6	235.0	7	63#4	12.6	231	0.0174	29.0661	84.01	205.35	58026.75	58232.1	322.11	34040.6	92272.7
7	241.0	7	64#4	12.8	237	0.0172	29.404	83.72	249.075	60346.49	60595.6	401.48	43506.7	104102.[illegible]
8	247.0	7	66#4	[illegible]	243	0.0173	29.234	84.05	222.73	63847.0	64070.3	482.91	53688.9	117759.2
9	253.0	[illegible]	67#4	[illegible]	24[illegible]	0.0171	29.5[illegible] (25.7[illegible])	[illegible].11 ([illegible].263)	226.86 (339.36)	66271.39 (76091.95)	66498.3 (76431.31)	566.4	64532.9 (70029.89)	131031.2 (146461.2)
10	259.0	7	69#4	[illegible]	255	0.0172	29.4[illegible] (25.5[illegible])	[illegible].72 ([illegible].225)	288.35 (361.45)	69861.14 (80263.84)	70149.5 (80625.79)	651.95	76014.8 (71711.7)	146164.3 (152337.5)
11	265.0	7	70#4	[illegible]	26[illegible]	[illegible]	29.[illegible]	[illegible].11	249.26	72812.92	73062.2	743.0	88733.6	[illegible]1795.8
12	271.0	7	72#4	[illegible]	[illegible]	0.0172	29.[illegible]	[illegible].72	316.13	73187.40	73503.5	832.68	101656.1	175159.6
13	277.0	7	74#4	14.[illegible]	273	0.0171	29.5[illegible]	[illegible].11	272.69	79662.28	79935.0	924.42	115475.8	195410.8
14	284.5	7	98#4	19.6	280.5	0.0222	22.[illegible]	[illegible].43	610.76	108818.8	109429.6	1018.48	130269.2	239[illegible]98.8
15	292.0	7	120#4	24.0	288	0.0265	19.0[illegible]	[illegible].04	1066.90	136476.06	137543.0	1115.11	145927.1	28[illegible]470.1
16	299.5	7	94#5	[illegible]	295.5	0.0314	16.1[illegible]	[illegible]	1816.24	169492.90	171309.1	1214.32	162288.0	333597.1
17	307.0	7	112#5	[illegible]	303.0	0.0365	13.[illegible]	[illegible]	2916.93	206068.66	208985.6	1316.12	179351.9	388339.5
18	314.5	7	100#6	44.0	310.5	0.0451	11.[illegible]	[illegible].56	5498.13	264698.73	270196.9	1420.52	196215.7	466412.6
19	322	7.5	124#6	[illegible]	317.0	[illegible].0548	[illegible]		8644.86	332576.6	341221.4	1527.42	213523.2	554744.6
20	329.5	8.0	108#7	[illegible]	324.5	[illegible].0637	9.[illegible]	[illegible].13	12153.5	402463.2	414616.7	1652.22	234728.4	649345.1

TABLE B III - GENOA 3 STACK ALLOWABLE OVERTURNING MOMENT (continued)

NODE NO.	O.D. (IN)	tc (IN)	REIN-FORCE-MENT	As (IN^2)	2R (IN)	ts (IN)	X	$\overline{\theta}$ (DEG)	Mc (K-IN)	Mt (K-IN)	Mc + Mt * (K-IN)	DEAD WT KIPS	$M_{D.W.}$ (K-IN)	M (K-IN)
21	337.0	8.0	94#8	74.26	332.0	0.0712	8.118	70.26	17164.16	466238.4	483402.6	1778.92	255855.3	739257.9
22	344.5	8.5	108#8	85.32	339.5	0.0780	7.8734	69.71	20695.08	532454.7	553149.8	1914.52	280438.1	833587.9
23	352.0	9.25	96#9	96.0	347.0	0.088[illegible]	7.586	69.036	25928.00	625820.2	651748.2	2064.42	307710.1	959458.3
24	359.375	10.0	104#9	104.[illegible]	354.0	0.0935	7.737	69.374	27796.60	692610.1	720406.7	2225.92	339234.5	1059641.2
25	368.375	10.5	108#9	108.0	363.0	0.0947	8.011	70.024	27900.9	740360.0	768260.[illegible]	2403.82	377240.6	1145501.5
26	377.375	11.0	112#9	112.0	372.0	0.0958	9.296	72.517	20637.45	796983.0	817620.5	2594.92	423530.7	1241151.2
27	386.375	11.5	116#9	[illegible]	[illegible]	0.0969	8.575	71.20	28100.0	839925.1	868025.1	2799.62	464484.3	1332509.4
28	395.375	12.0	118#9	[illegible]	[illegible]	[illegible]	9.00[illegible]	72.01	26946.05	878311.9	905257.9	3018.32	510513.6	1420271.5
29	404.375	14.0	124#9	[illegible]	[illegible]	[illegible]	10.22[illegible]	73.97	23326.51	953100.8	976427.3	3265.22	575996.1	1552423.4
30	413.375	16.0	130#9	[illegible]	[illegible]	[illegible]	11.4[illegible]	[illegible]5.48	20745.65	1028512.5	1049258.2	3555.22	639700.2	1688958.4
31	422.375	21.0	134#9	[illegible]	[illegible]	[illegible].1023	14.83[illegible]	[illegible].63	13691.16	1096693.7	1110384.9	3917.92	736786.2	1847171.1
32	431.375	24.0	134#9	[illegible]	[illegible]	[illegible]	17.[illegible]	[illegible].176	10543.79	1125259.5	1135803.3	4392.52	848136.5	[illegible]83939.8
33	440.375	24.0	134#9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].362	10382.45	1150470.6	1160853.0	4877.72	962255.3	2123108.3
34	449.375	24.0	133#9	[illegible]	[illegible]	[illegible]	18.19[illegible]	[illegible].622	9966.04	1165197.0	1175163.0	5373.52	1082819.6	2248016.6
35	458.375	24.0	133#9	133.0	453.0	0.0935	18.54[illegible]	[illegible].79	9827.49	1190545.7	1200373.2	5879.92	1209462.0	2409[illegible]35.2

* Number in parenthesis represents [illegible] values with 15 percent increase in yield stress value of reinforcing steel [illegible] dynamic earthquake loadings.