SEISMIC AND STRUCTURAL ANALYSIS
FOR THE
LACBWR CONTAINMENT BUILDING

Prepared For

DAIRYLAND POWER COOPERATIVE

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1. SUMMARY

This report, prepared for Dairyland Power Cooperative (DPC), presents the results of the seismic/structural analysis of the LACBWR containment building using the NRC site-specific ground response spectra for the Safe Shutdown Earthquake event (SSE).

Linear seismic analysis, using the site specific spectra and modal superposition methods, was performed to determine the response of the LACBWR containment building for the SSE event. Soil structure interaction effects were included using the information provided by Dames & Moore. The foundation springs reflect the updated information from the most recent boring program. The combination of deadload and seismic stress of the containment building is compared to the allowable stress. From the results of the analysis, it has been concluded that the containment building is capable of withstanding the specified Safe Shutdown Earthquake. Forces, moments and stresses in all structural elements of the building were determined. All member stresses were found to be less than their allowable values.

2. DESCRIPTION OF THE BUILDING

The Containment Building is a multiple story 30 feet radius structure. It consists of a basement floor (El. 621'), ground floor (El. 642.75'), intermediate floor (El. 667'), and main floor (El. 701.0'). In addition to those floors, an overhead crane is at (El. 726.5') and a water storage tank is located at the top of the building (El. 756.5'). The structure, with a total height of 135.5 ft. is supported by 228 concrete filled pipe piles with a design load capacity of 100k/pile.

For the purpose of analysis the Containment Building can be sub-divided into four component parts: the containment shell, the outer shield building, the inner shield building and the reactor vessel. All other dead and live loads are calculated and are lumped in the appropriate nodes of the model.

The Containment Shell: This is the outer steel shell and represents the pressure retaining component of the Containment Building.

It is made of ASTM A201, Grade B steel with a thickness of 1.16", a height of 144 feet and an inside radius of 30 feet. The hemispherical dome of the containment shell is constructed of 0.60 inch steel and contains an elliptical water storage tank with a capacity of 42,500 gallons.

Outer Shield Building: The containment shell is lined on the inside by the outer shield building which consists of 9" of reinforced concrete. This structure has a 30 foot radius, 105.5 foot height (from basement floor to crane level), and supports a crane with capacity of 50 Tons/5 Tons at El. 726.5'.

Inner Shield Building: The inner shield structure consists of an octagonal shaped reinforced concrete wall around the reactor. The inner and outer shield structures are connected to each other by reinforced concrete floors at four elevations.

Reactor Vessel: The reactor vessel generates steam for the turbine generator and is located inside the inner shield building core. It is made of ASTM A302 Grade B steel, with 4.125 feet inside radius, 4 inch thickness, and 37 feet height (from ground floor to El. 684.75 feet). The vessel is seated on a skirt support which is anchored to the inner shield building at the ground floor. Also at El. 680.77 feet, the vessel is supported by the inner shield building via an expansion joint (bellows). The Reactor Vessel is included in the mathematical model of the Containment Building to evaluate the effect of its mass on the other components.

3. APPLICABLE CODES, STANDARDS AND SPECIFICATIONS

The following codes of practice and regulatory guides were used in the analysis of the LACBWR Containment Building.

1. USNRC Regulatory Guide 1.92, "Combination of Modes and Spatial Components in Seismic Reponse Analysis", Revision 1, February, 1976.

2. USNRC Standard Review Plan Section 3.7.2.

3. USNRC Reg. Guide 1.61, "Damping Values For Seismic Design of Nuclear Power Plants", October, 1973.

4. Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-76), American Concrete Institute, Detroit, MI., 1978.

5. USNRC Standard Review Plan Section 3.8.2.

6. USNRC Standard Review Plan Section 3.8.3.

7. Building Code Requirements for Reinforced Concrete, (ACI 318-77), American Concrete Institute, Detroit, MI., 1977.

8. ASME Boiler and Pressure Vessel Code, Section VIII, DIV.2, Alternate Rules, 1977 Edition.

4. LOADS AND LOADING COMBINATIONS

The lateral seismic inertia loading on the coupled model of the containment building and its foundation is in the form of the ground acceleration response spectrum (Figure 4.1) given in Reference 1. The free field ground response spectrum for the Safe Shutdown Earthquake for 5 percent structural damping was modified to the appropriate percent of combined damping (output of LANCZOS run) and used in the seismic analysis. (See USNRC Reg. Guide 1.61).

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 equations from SRP 3.8.2 and 3.8.3 were used in evaluating the adequacy of the containment building to withstand a seismic event.

Containment Shell

1. $D + L + E' + P_a$

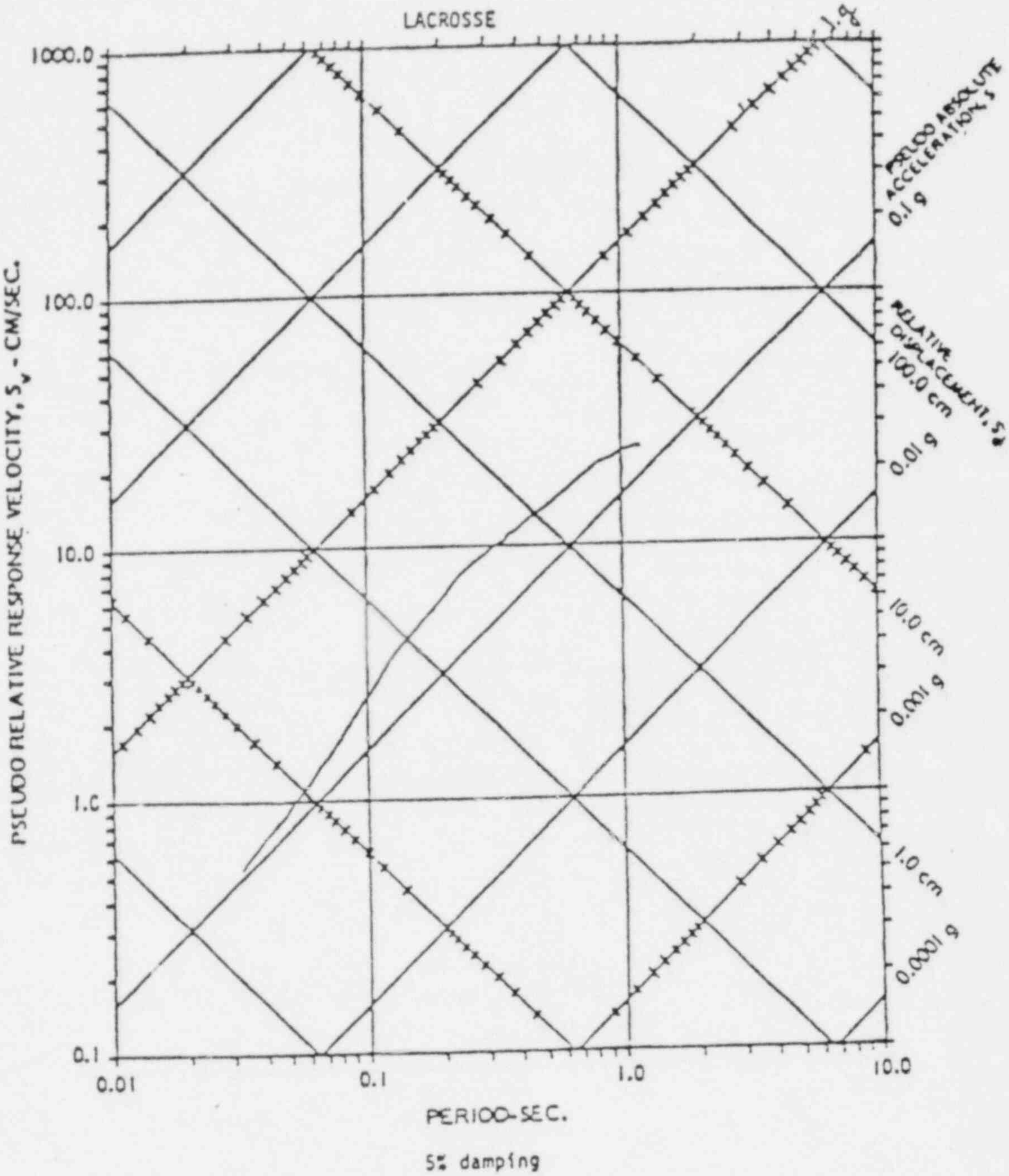


FIGURE 4.1

LACBWR SITE-SPECIFIC RESPONSE SPECTRA

Reinforced Concrete Shield Structure

2. D + L + E'

Where:

D = Dead loads and their resulting moments

L = Live loads

E = Loads and moments generated by the Operating Basis Earthquake

E' = Loads and moments generated by the Safe Shutdown Earthquake

P_a = Pressure load generated by loss-of-coolant acccident (LOCA)

For the reinforced concrete shield structure the load combination containing the OBE earthquake, 1.4D + 1.7L + E, was determined not be critical compared to the combination containing the SSE earthquake. The load factors applied to the dead and live loads increase the axial compression in the concrete shield structure. When this compressive stress is combined with the OBE induced bending stress, the resulting concrete tension stress is less than the tension stress developed by the SSE earthquake load combination.

5. STRUCTURAL ACCEPTANCE CRITERIA

The following allowable limits constitute the structural acceptance criteria for each of the loading combinations presented in Section 4.

Containment Shell

Stresses in the containment shell shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Div. 2., 1977 Edition.

Stress Intensity	Limit
P_m	KS_m
$P_m + P_b$	$1.5K\ S_m$

Where P_m = General Primary Membrane Stress

P_b = Primary Bending Stress

S_m = Design Stress Intensity

K = Factors given in Table AD-150.0

Reinforced Concrete

Load Combinations	Limit
D + L + E'	U

Where U is required section strength based on the ultimate strength design method defined in the ACI. 318-77 code

6. ANALYTICAL PROCEDURES

6.1 SEISMIC ANALYSIS:

The seismic analysis of the Containment Building was performed using NRC site-specific ground response spectra. Damping values of 4% and 7% were used for steel and reinforced concrete respectively. (See NRC Reg Guide 1.61). The vertical response spectra was taken as 2/3 of the horizontal response spectra for the whole range of frequency, as stated in Reference 9.

6.1.1 Mathematical Model

In order to perform the seismic analysis, the containment building is mathematically modeled as an assembly of elastic structural elements interconnected at discrete nodal points. The three dimensional, multidegree of freedom model of the containment building is attached to the ground by means of foundation springs, representing the deformations of the soil under the containment building foundation. Lateral, as well as rocking springs, have been provided in the LACBWR Containment Building mathematical model (Figure 6.1) to account for the shear and vertical deformation of the soil under the LACBWR Containment Building foundation. To account for the variation in the soil properties and to evaluate the effect of the foundation spring constants on the seismic response of the Containment Building, the foundation springs were varied using information supplied by Dames and Moore. The frequencies found using this data are shown in Table 6.2. The effect of the variation on deflections, accelerations, moments and shears can be seen in Figure 6.2.a - 6.2.h .

The distributed mass of the Containment Building is lumped at the system nodal points. Each mass represents the tributory weight of the Containment Building walls above and below the nodal point. Masses are lumped so that the lumped mass, multidegree of freedom model represents the dynamic characteristics of the Containment Building. 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 equations shown in Table 6.1 and Figure 6.3. These equations are taken from Reference 4.

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:

$$(K - \omega_n^2 M) \{\phi_n\} = \{0\} \qquad (1)$$

Where:

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

M = System mass matrix

ϕ_n = Mode shape vector for the n^{th} mode

0 = Null vector

The eigenvalue/eigenvector extraction was performed using the the Lanczos Modal Extraction Method.

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:

$$M(\ddot{U}_t + \ddot{U}_{gt}) + C\dot{U}_t + KU_t = 0 \qquad (2)$$

Where:

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

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

C = Damping matrix

$\dot{U}_t$ = Relative velocity time history vector

U_t = Relative displacement time history vector

Rearranging equation (2):

$$M\ddot{U}_t + C\dot{U}_t + KU_t = -M\ddot{U}_{gt} = P_{eff} \qquad (3)$$

To uncouple equation (3), 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 (3) by the transpose of ϕ and ϕ respectively and using orthogonality conditions, the following uncoupled equations of motion are obtained:

$$\ddot{Y}_{nt} + 2\,\omega_n\lambda_n\,\dot{Y}_{nt} + \omega_n^2\,Y_{nt} = M_n^{*-1}\,R_n\,\ddot{U}_{gt} \qquad (4)$$

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.

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

I = Column vector whose elements are generally unity

The solution for the differential equation (4) is given by the Duhamel Integral:

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

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

$$\ddot{Y}_{n\,max} = \frac{R_n S_{an}}{M_n^*} \qquad (5)$$

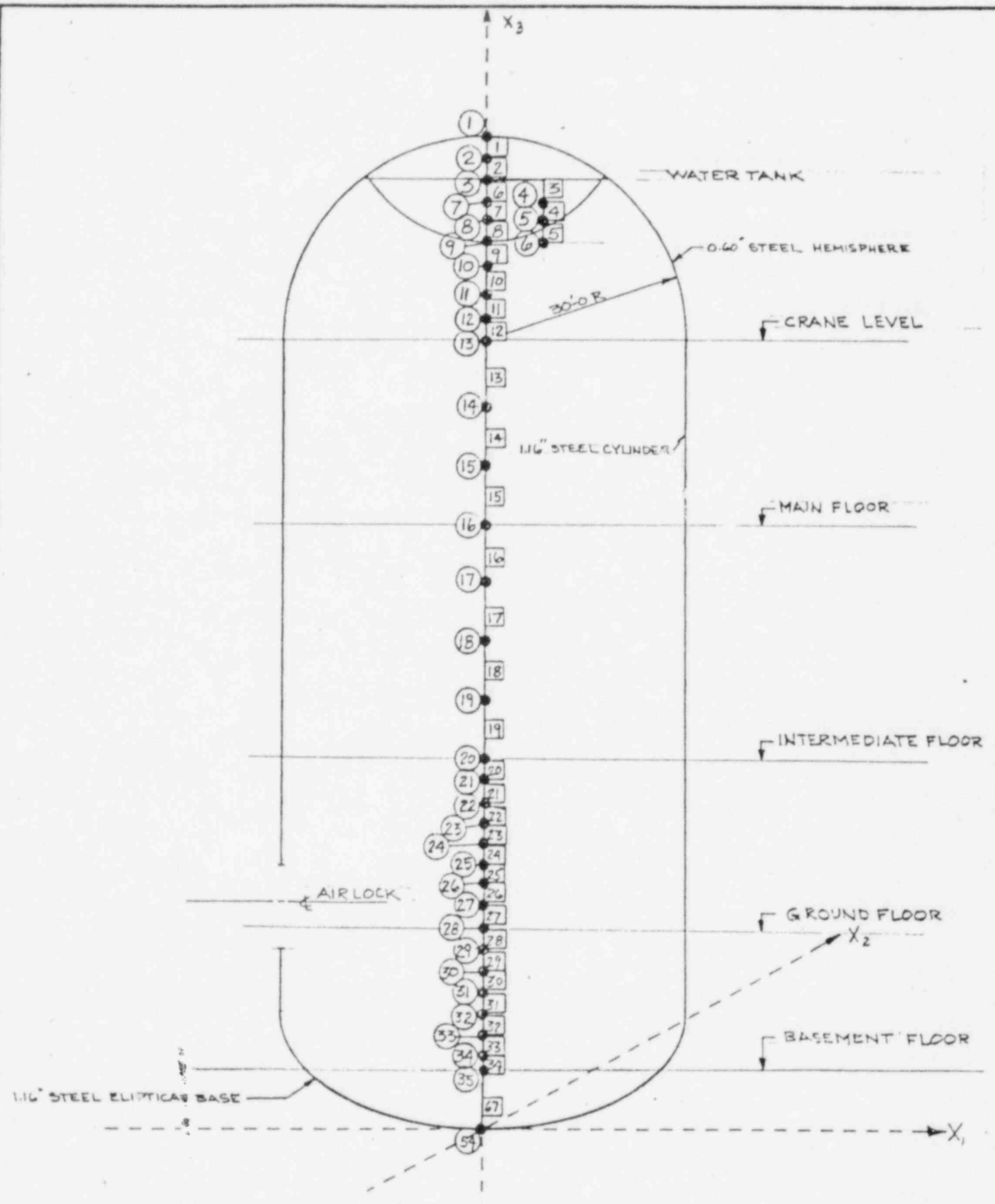


FIGURE 6.1a
MATHEMATICAL MODEL OF STEEL CONTAINMENT

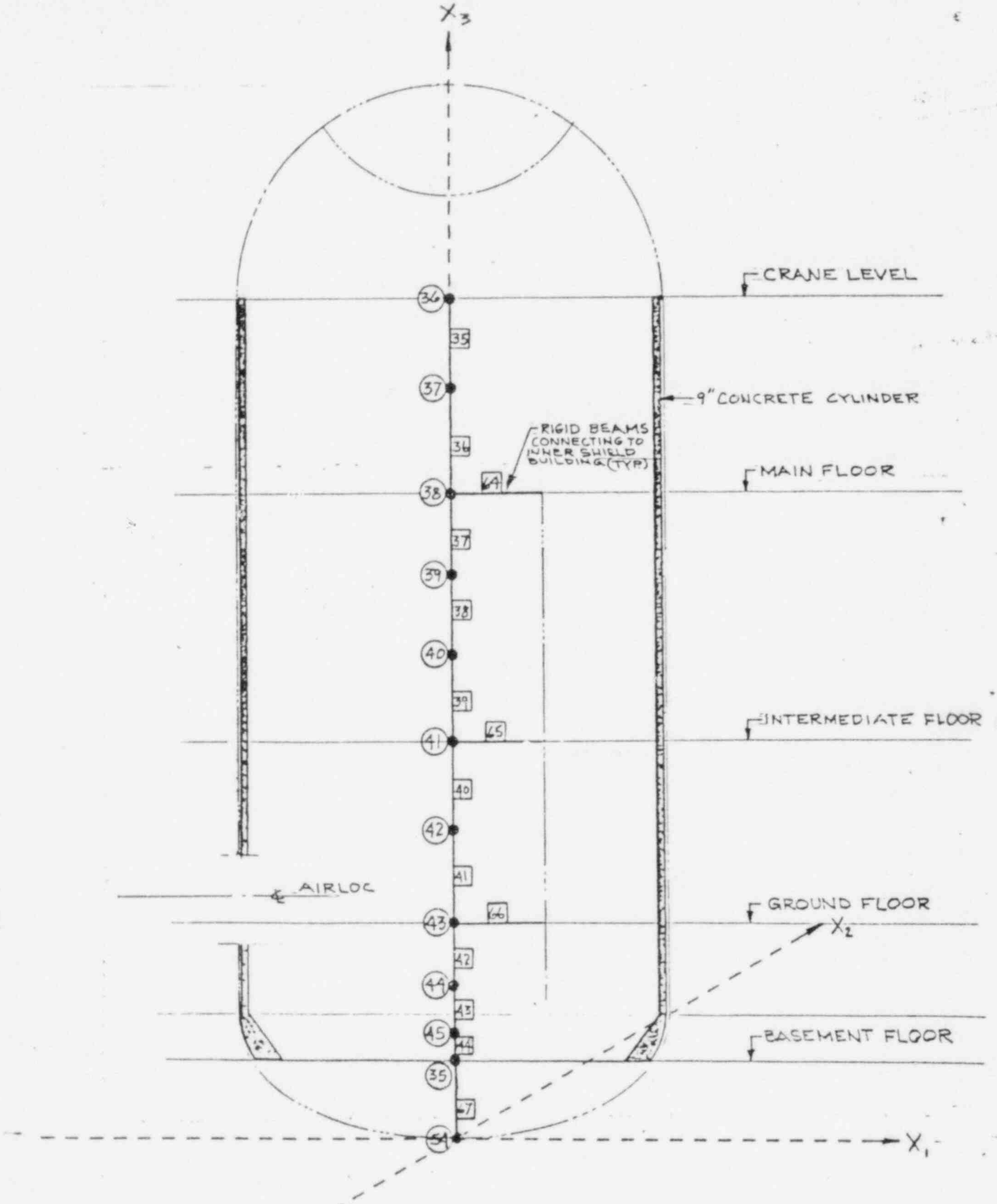


FIGURE 6.1b
MATHEMATICAL MODEL OF OUTER SHIELD BUILDING

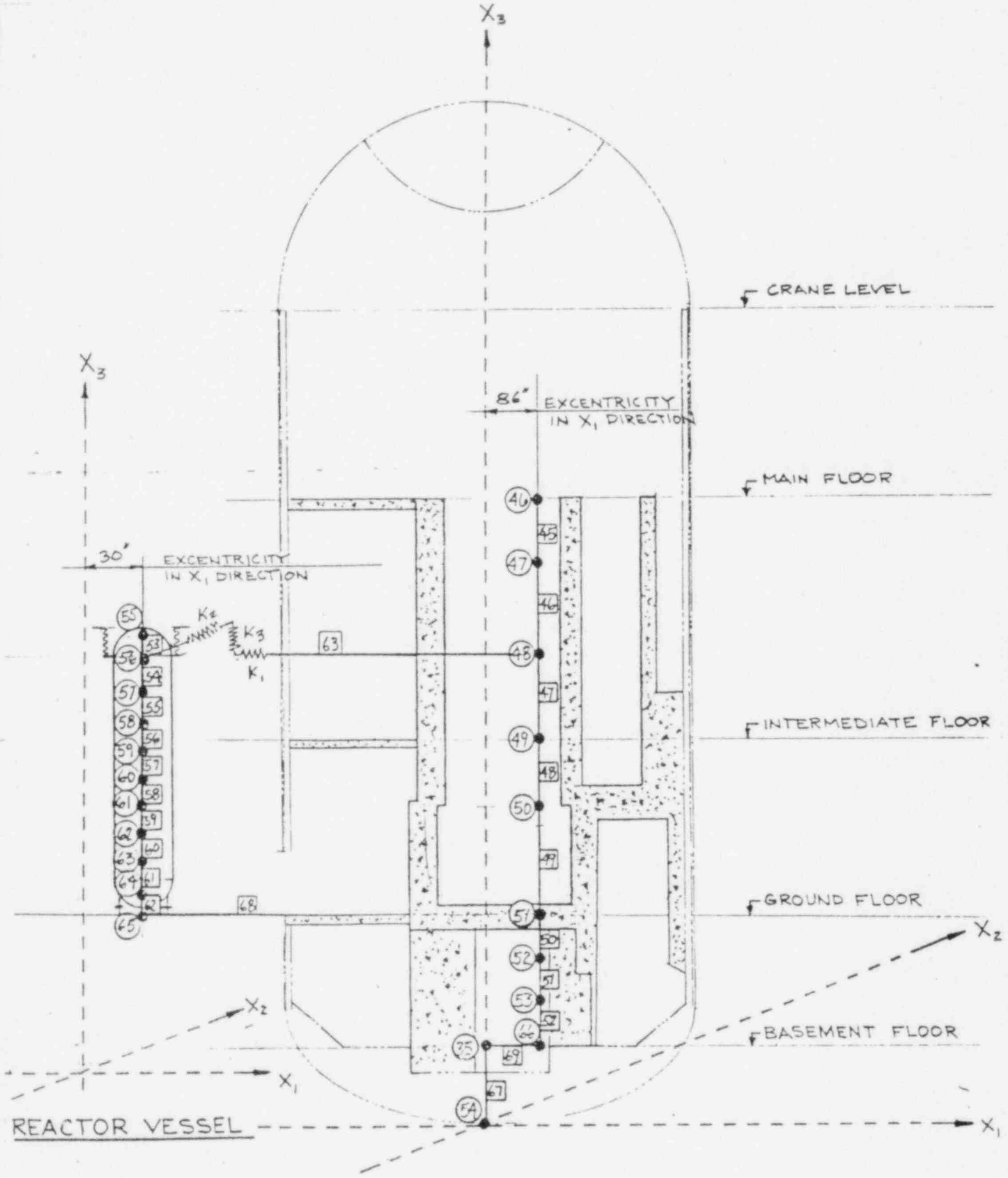


FIGURE 6.1c
MATHEMATICAL MODEL OF INNER SHIELD BUILDING
AND REACTOR VESSEL

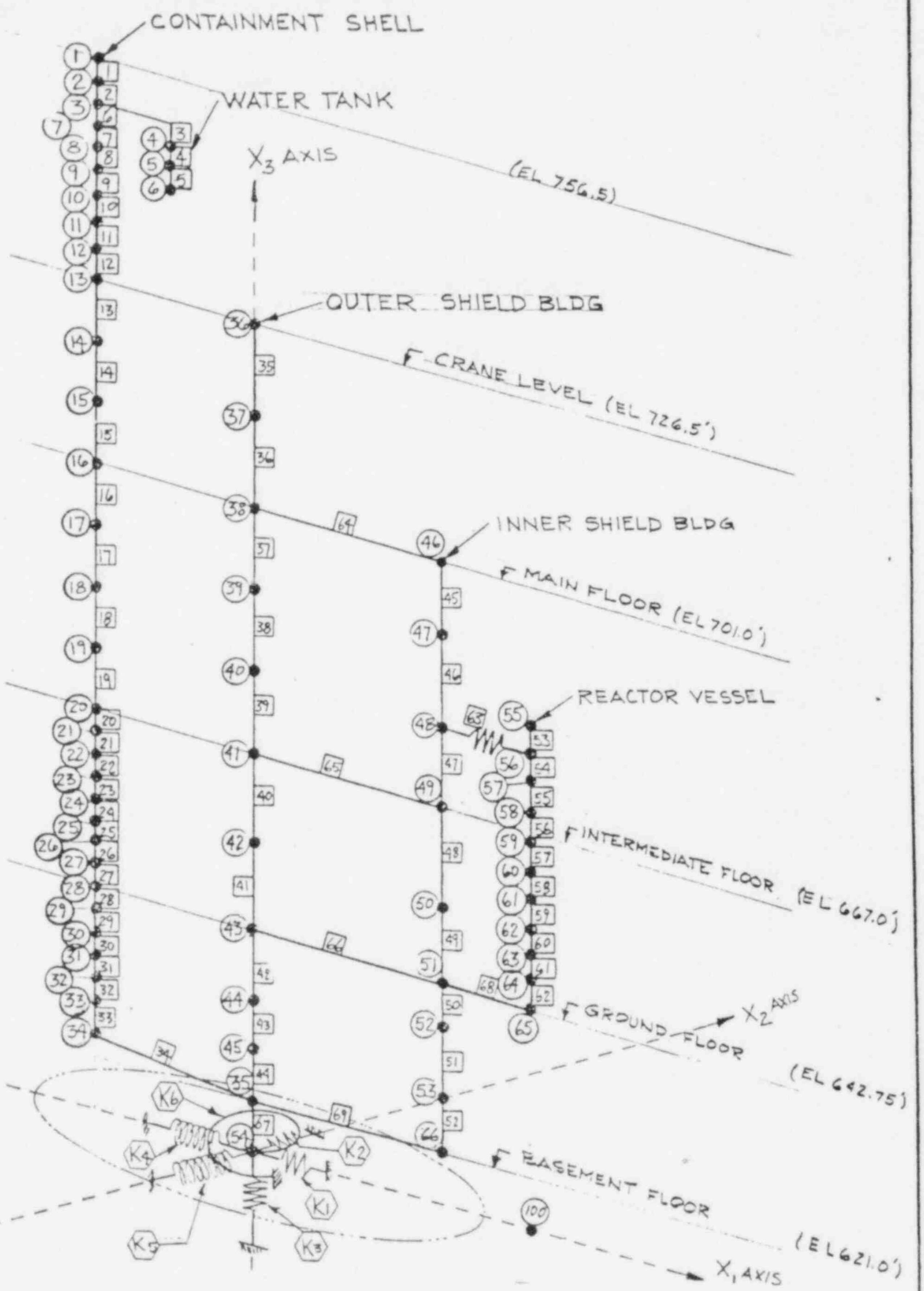


FIGURE 6.1d - MATHEMATICAL MODEL OF LACBWR CONTAINMENT BUILDING

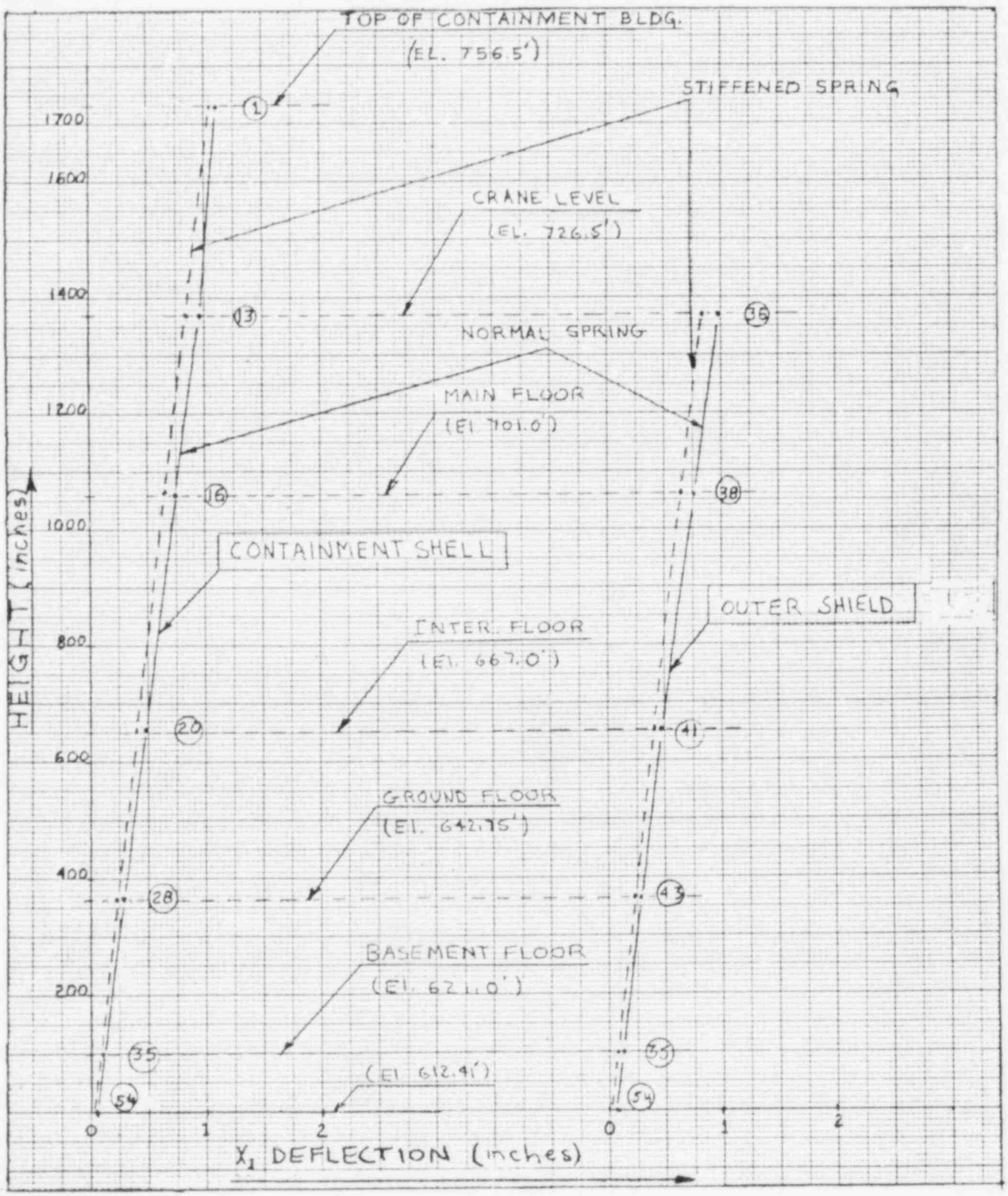


FIGURE 6.2a - EFFECT OF VARIATION OF SOIL PROPERTIES ON DEFLECTION RESPONSE

(Containment Shell & Outer Shield Bldg.)

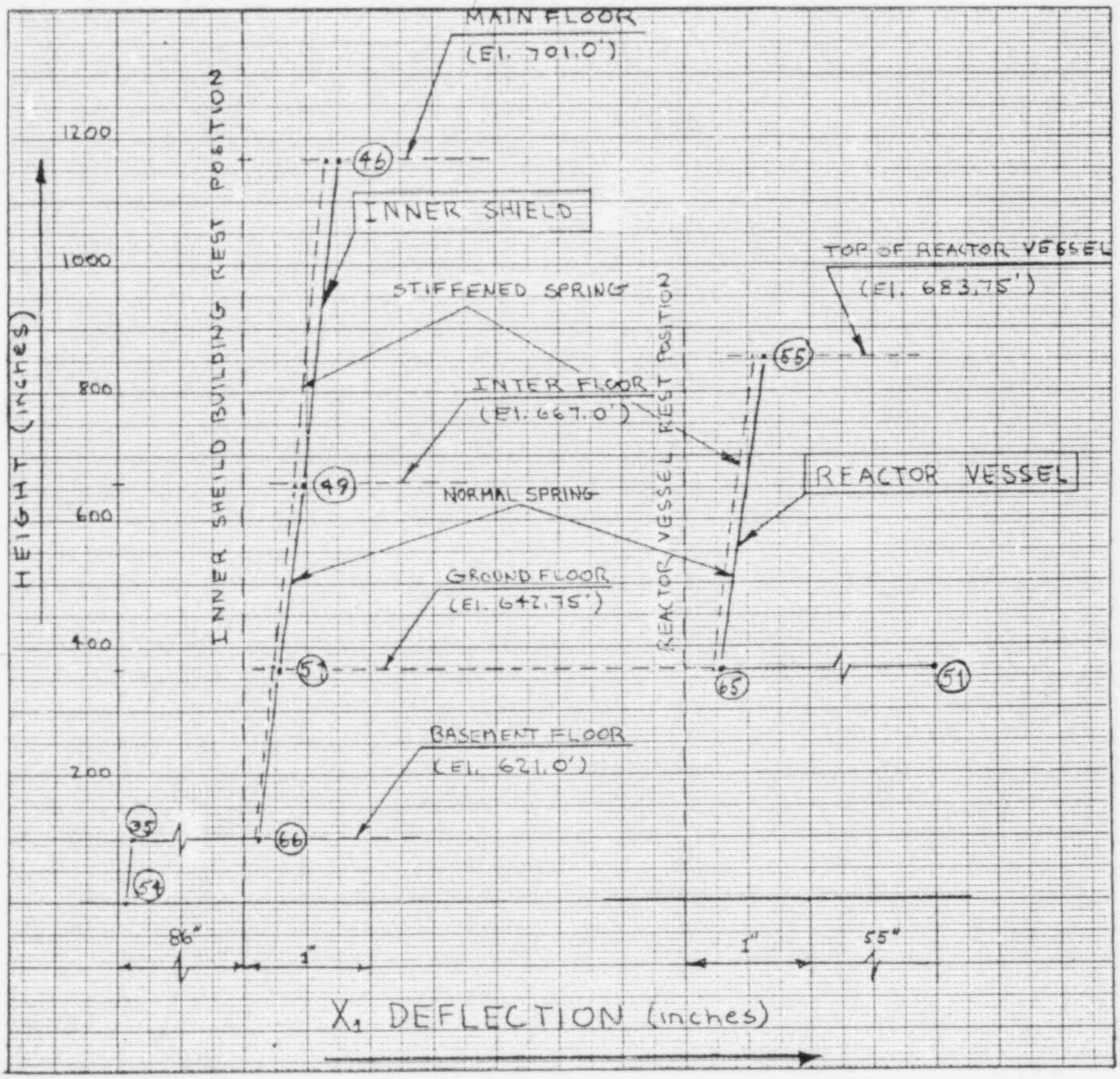


FIGURE 6.2b - EFFECT OF VARIATION OF SOIL PROPERTIES ON DEFLECTION RESPONSE

(Inner Shield Bldg. & Reactor Vessel)

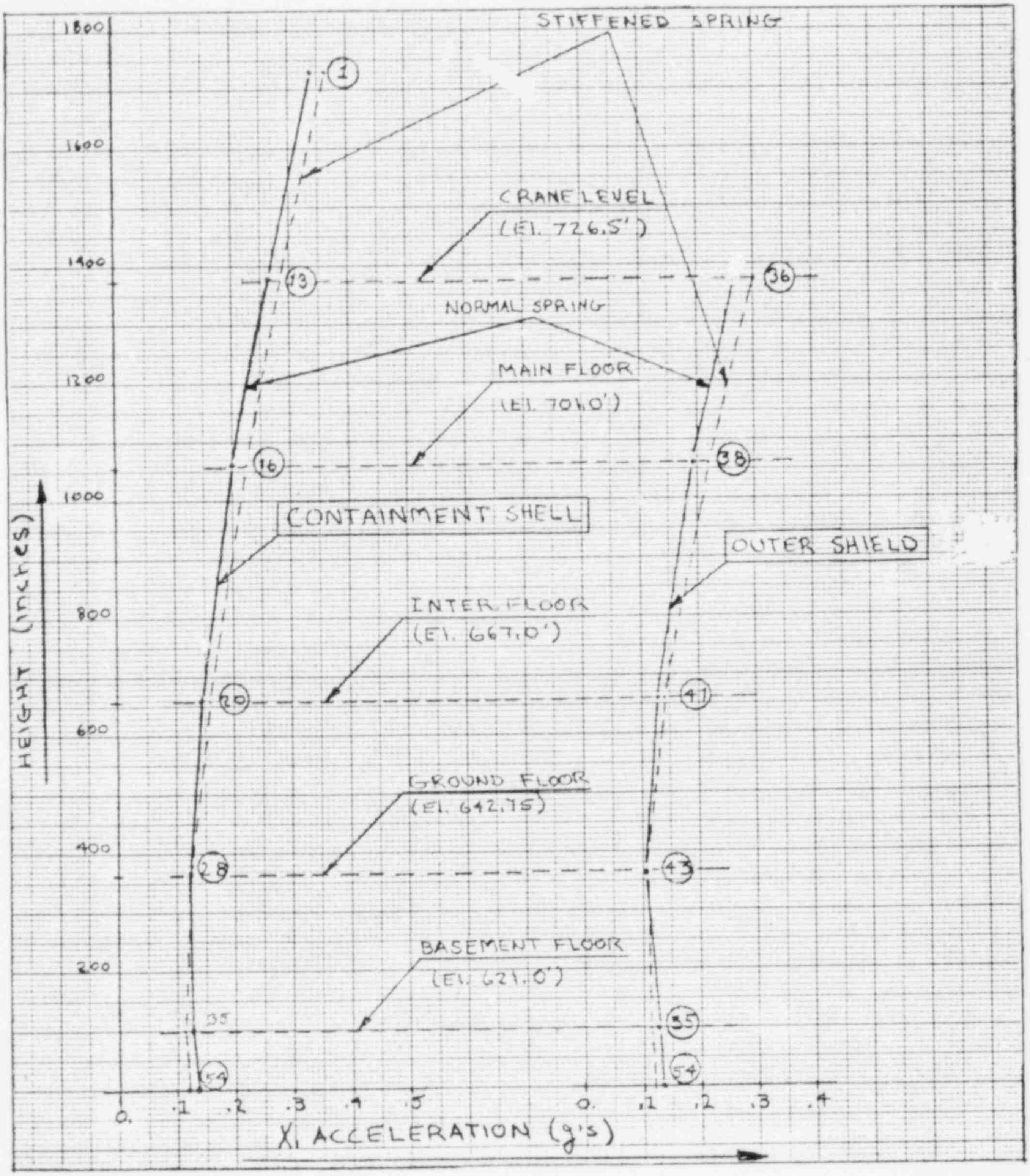


FIGURE 6.2c - EFFECT ON VARIATION OF SOIL PROPERTIES ON ACCELERATION RESPONSE

(Containment Shell & Outer Shield Bldg.)

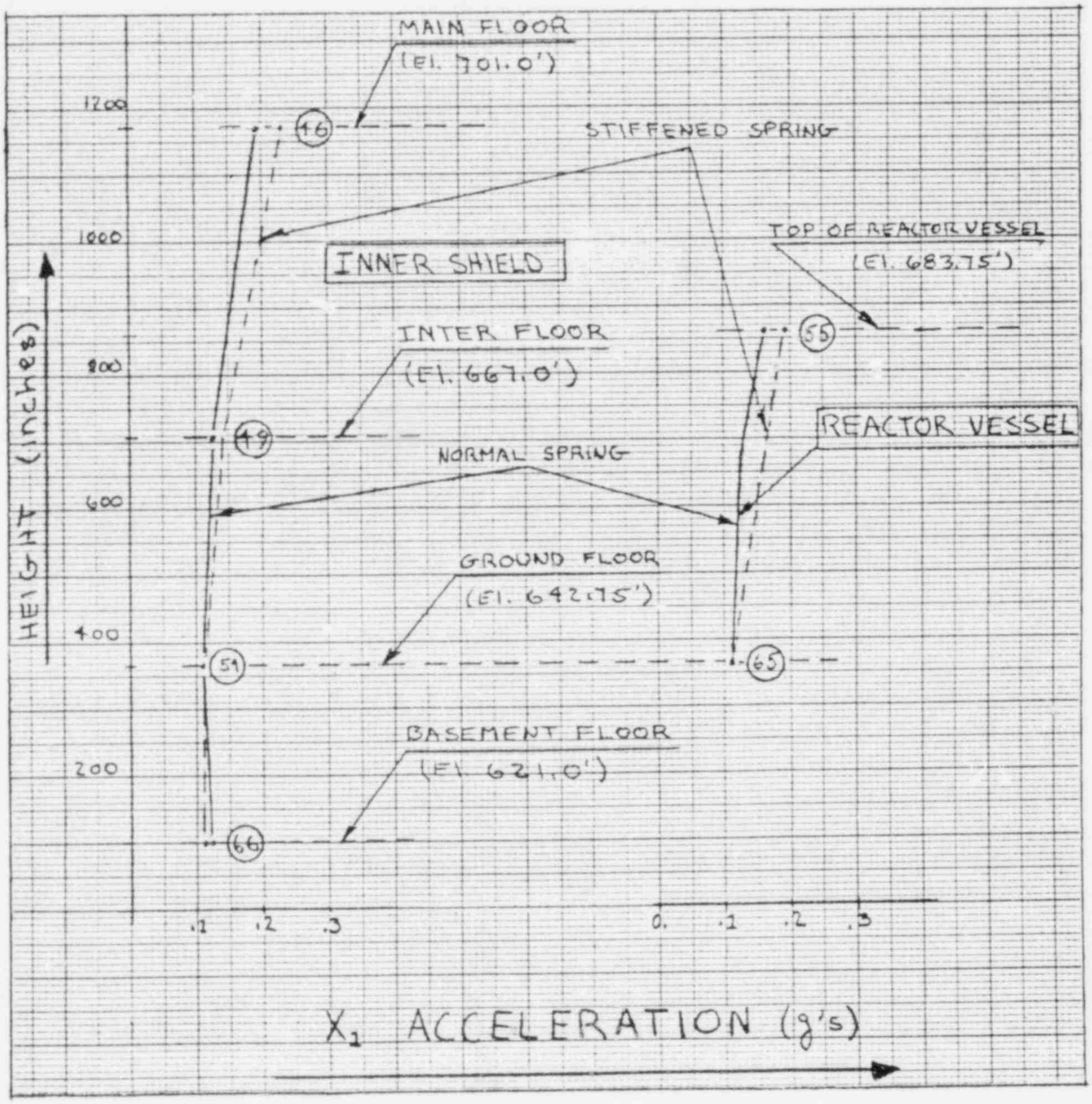


FIGURE 6.2d - EFFECT OF VARIATION OF SOIL PROPERTIES ON ACCELERATION RESPONSE

(Inner Shield Bldg. & Reactor Vessel)

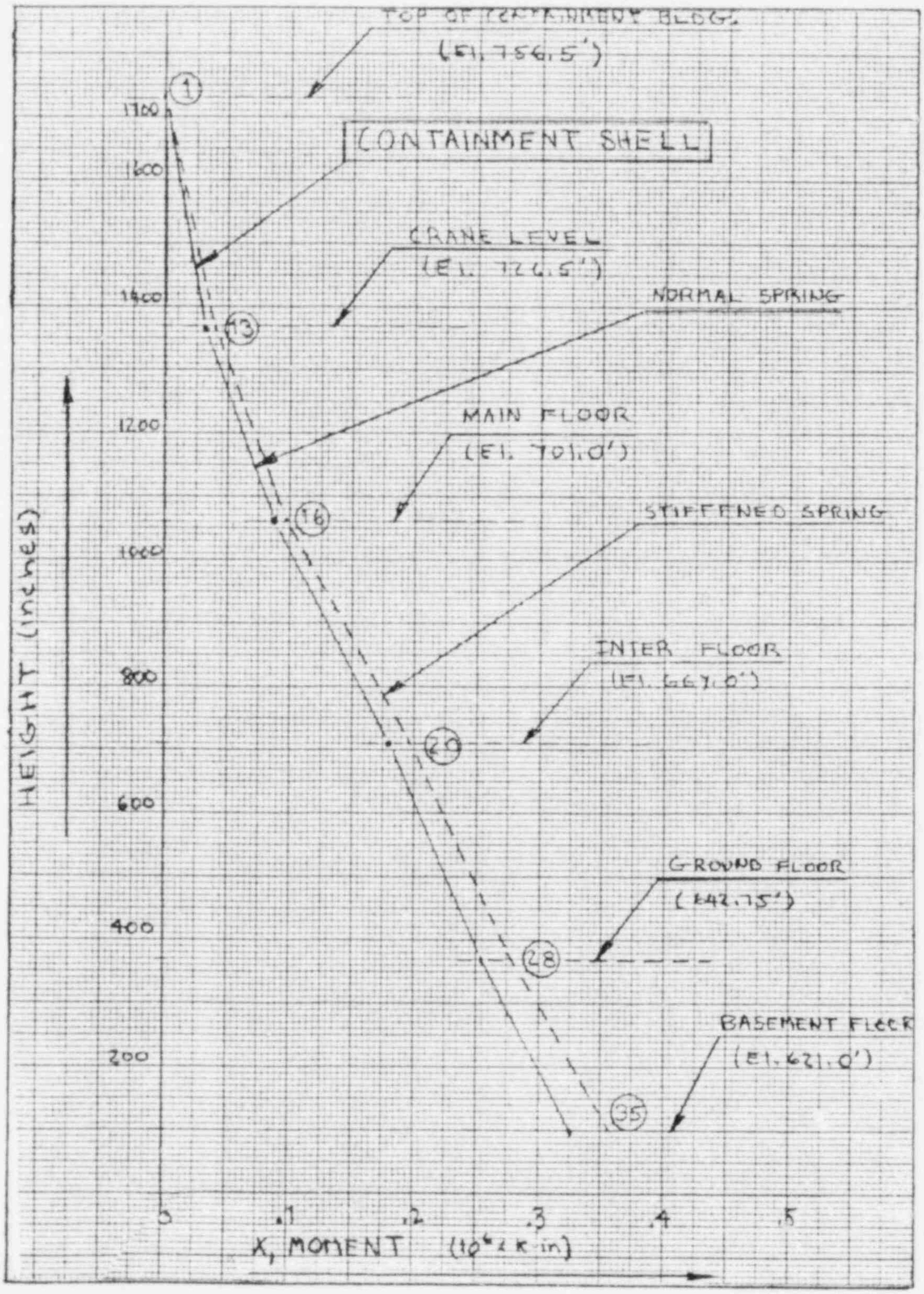


FIGURE 6.2e - EFFECT OF VARIATION OF SOIL PROPERTIES ON MOMENT RESPONSE (Containment Shell)

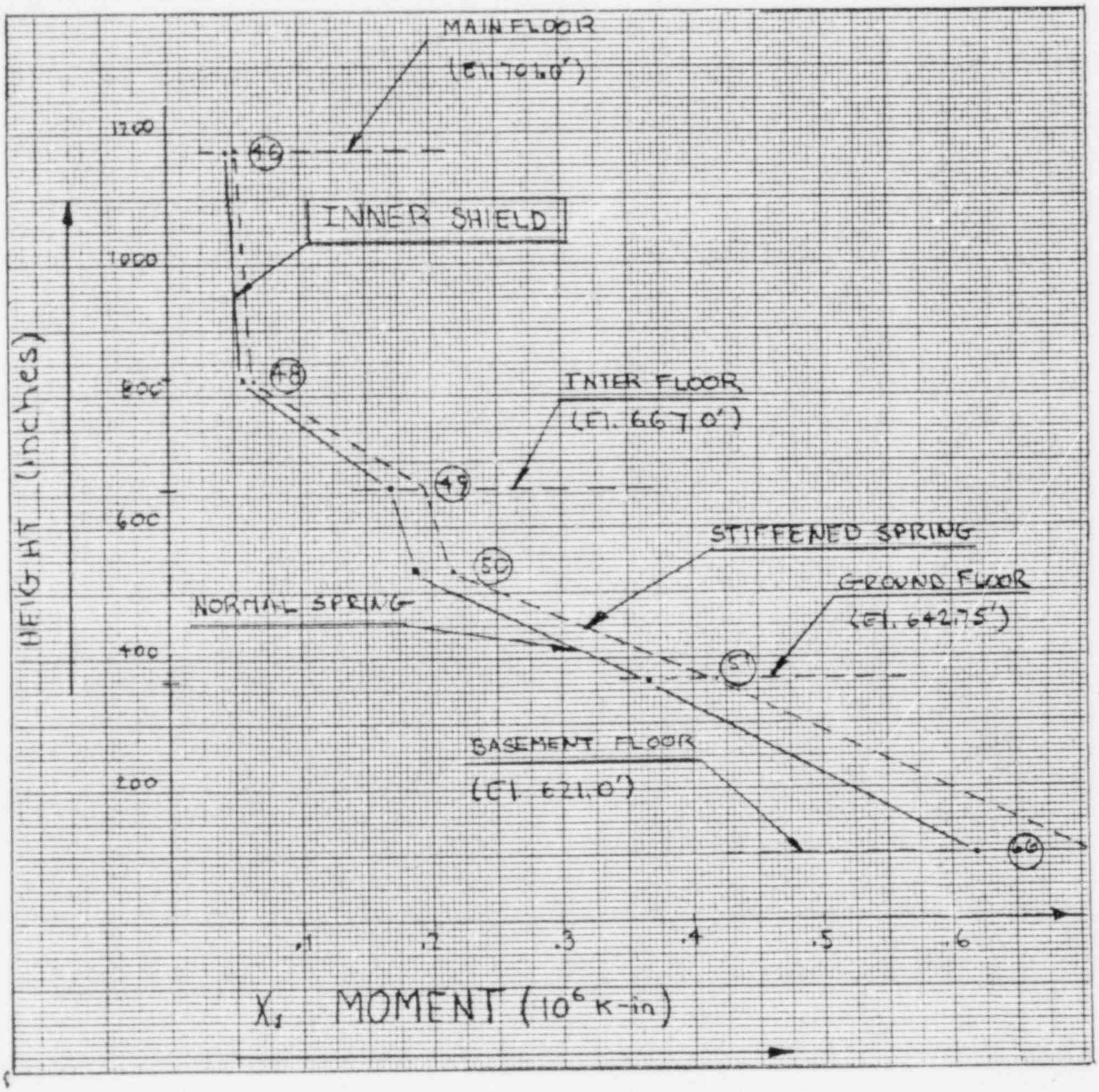


FIGURE 6.2f - EFFECT OF VARIATION OF SOIL PROPERTIES ON MOMENT RESPONSE

(Inner Shield Bldg.)

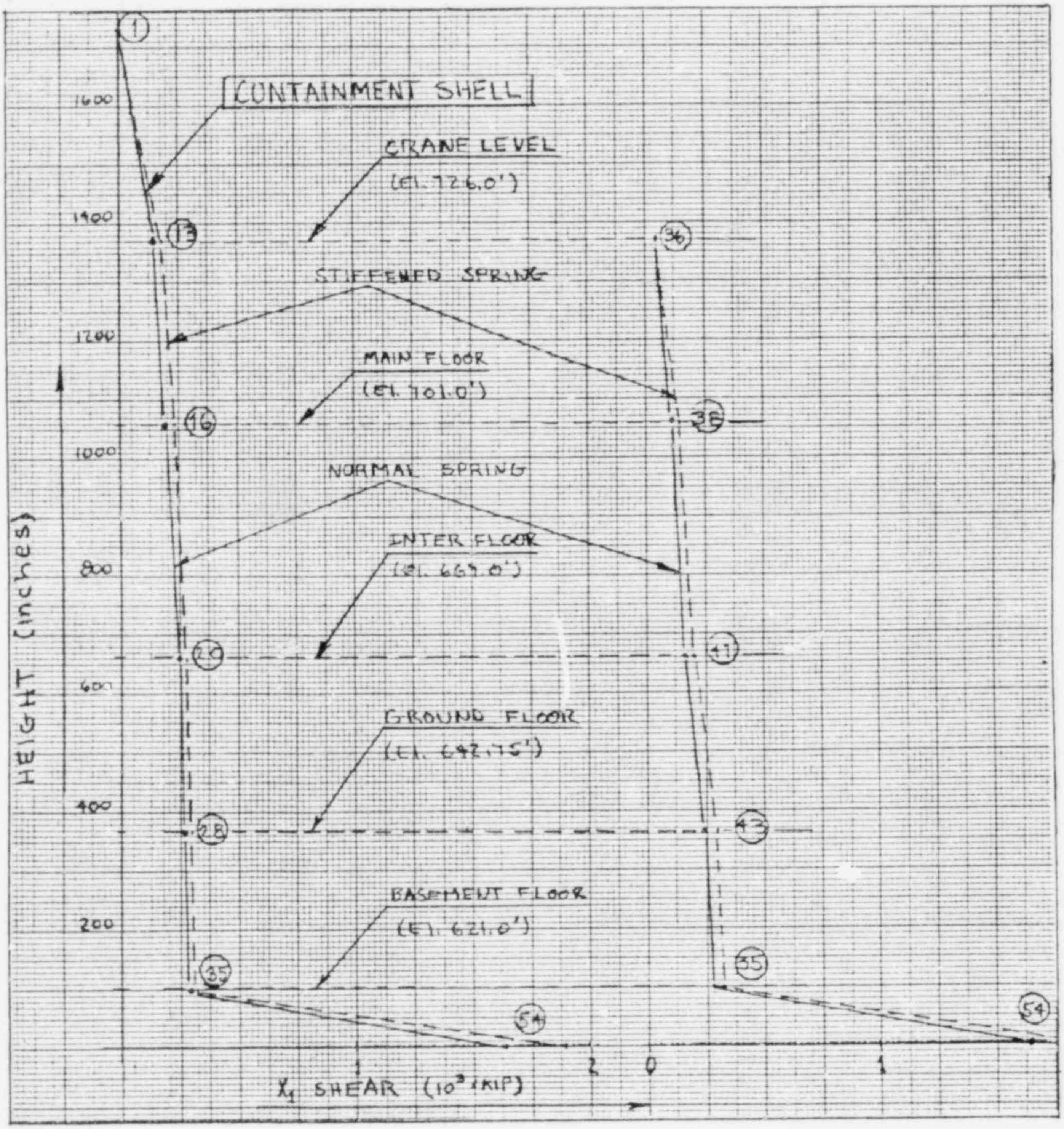


FIGURE 6.2g - EFFECT OF VARIATION OF SOIL PROPERTIES ON SHEAR RESPONSE
(Containment Shell & Outer Shield Bldg.)

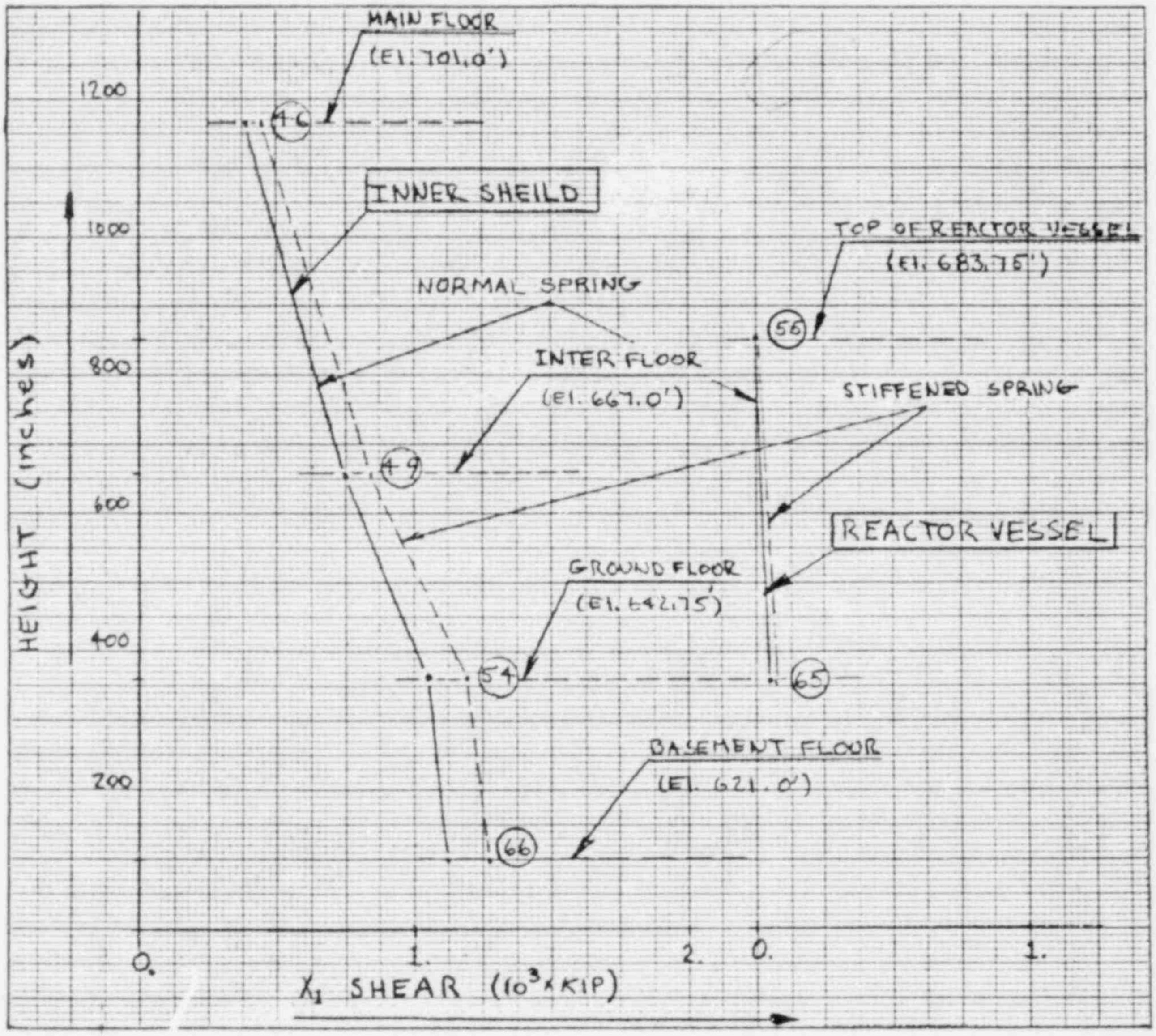


FIGURE 6.2h - EFFECT OF VARIATION OF SOIL PROPERTIES ON SHEAR RESPONSE

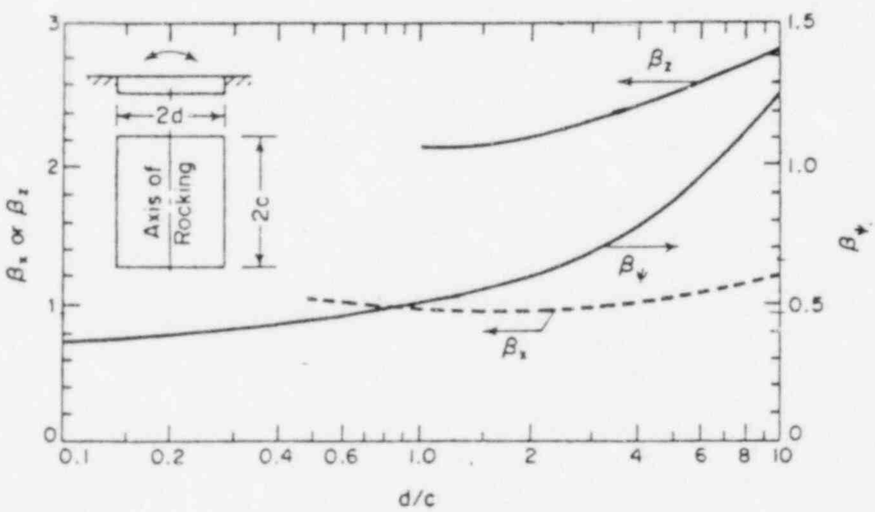
(Inner Shield & Reactor Vessel)

TABLE 6.1
FOUNDATION SPRING CONSTANTS

Spring Constants for Rigid Rectangular Footing Resting on Elastic Half-Space

Motion	Spring Constant	Reference
Vertical	$k_z = \frac{G}{1-\nu}\beta_z\sqrt{4cd}$	Barkan (1962)
Horizontal	$k_x = 4(1+\nu)G\beta_x\sqrt{cd}$	Barkan (1962)
Rocking	$k_\psi = \frac{G}{1-\nu}\beta_\psi 8cd^2$	Gorbunov-Possadov (1961)

(*Note:* values for β_z, β_x, and β_ψ are given in Fig. 6.3 for various values of d/c)



Coefficients β_z, β_x, and β_ψ for rectangular footings (*after Whitman and Richart, 1967*).

FIGURE 6.3 - FOUNDATION SPRING STIFFNESS

TABLE 6.2

NATURAL FREQUENCIES OF VIBRATION - LACBWR CONTAINMENT BLDG.

	Model 1 G=1600ksf (softer)		Model 2 G=3600ksf (stiffened)	
Mode No.	Frequency (Hz)	Modal Direction	Frequency (Hz)	Modal Direction
1	1.550	X_2	2.244	X_2
2	1.552	X_1	2.253	X_1
3	4.085	X_3	6.033	X_3
4	6 290	X_2	6.507	X_2
5	6.327	X_1	6.552	X_1
6	8.379	X_2	11.591	X_2
7	8.494	X_1	11.807	X_1
8	16.467	X_1	16.540	X_1
9	21.434	X_2	21.601	X_2
10	23.693	X_2	23.849	X_3
11	23.814	X_3	24.295	X_2
12	24.528	X_1	24.577	X_1
13	24.812	X_2	25.991	X_2
14	28.774	X_1	28.849	X_1
15	32.410	X_1	32.431	X_1

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 inertia forces ($F_{n\,max}$) for each of the systems' natural modes were applied as external static forces, and system response (displacements, member internal forces and stresses) were calculated. Total system response was than 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 35 cycles per second) were included and higher modes with negligible participation were neglected.

7. RESULTS OF ANALYSIS AND CONCLUSIONS

The results of the seismic analysis of the LACBWR Containment building performed with the STARDYNE computer code are contained in Reference 5. Appendix A contains the assumptions used in the analysis. Detailed calculations are included in Appendix B.

The natural frequencies of vibration of the LACBWR containment building are given in Table 6.2. From this table, it can be seen that the containment building is a low frequency system (fundamental frequency of 1.550 Hz and 2.244 Hz in accordance with soil constant G=1600Ksf and G=3600Ksf), and the variation in the fundamental

Frequencies is 45% (1.550 HZ to 2.244 Hz) as compared to the 125% variation in the foundation soil constants (1600 ksi to 3600 ksi). Through Figure 6.2c to Figure 6.2h, we can see that acceleration induced, moment induced, shear induced are greater for stiffened foundation soil constant (G = 3600 ksi). Hence the results for the analysis for softer foundation soil constant (G = 1600 ksi) are not reported since the analysis of normal foundation soil constant (G = 2400 ksi) and stiffened foundation soil constant (G=3600 ksi) are more conservative. The results of the seismic and structural analysis, which are taken as the more conservative results of either the normal or stiffened cases, are summarized in Table 7.1 thru Table 7.3 and discussed below.

Steel Containment Shell:

The maximum shear, compressive and tensile bending stresses in the steel containment shell are significantly lower than the allowable values. The maximum hoop and longitudinal tensile stresses in the containment shell resulting from LOCA event (52 psi, maximum internal pressure) are 16.1 ksi and 15.6 ksi respectively.

Concrete Outer Shield Building:

The maximum shear and compressive stresses in the outer shield building and the maximum tensile stresses in the reinforcing bar are within the allowable values.

Concrete Inner Shield Building:

The maximum shear and compressive stresses in the inner shield building and the maximum tensile stresses in the reinforcing bar are within the allowable values.

Foundation Mat:

The maximum shear and compressive stress in the foundation mat are lower than the allowable values. There is no reinforcement in the foundation mat to carry any tensile load, however, the foundation mat will not rupture because the modulus of rupture for the concrete (0.377 ksi) is much greater than the maximum tensile stress (.00360 ksi)

Pile Foundation:

The maximum compressive load on a pile is 191.55k, greater than its rated capacity of 100k and lower than the ultimate load capacity of 400k Ref. (10). The maximum tensile load on a pile is 41.75k. No pull out load tests have been performed, however,the skin frictional resistance load of 74.8k calculated from pile driving data, is more than adequate to resist the calculated pull out force.

TABLE 7.1

SUMMARY OF SEISMIC/STRUCTURAL EVALUATION (NORMAL STRESS)

			Allowable normal stress		Calculated normal stress	
Node	Component	Elevation	Tension	Compression	Tension	Compression
35 (For 36 thru 45 & 35)	Outer Shield Bldg.	621.0'	.230 ksi	2.975 ksi	0.069 ksi	.369 ksi
47	Inner Shield Bldg.	690.875'	-	2.975 ksi	-	.038 ksi
49	Inner Shield Bldg.	667'	.0515 ksi	2.975 ksi	.030 ksi	.144 ksi
51	Inner Shield Bldg.	642.75'	.118 ksi	2.975 ksi	.054 ksi	.223 ksi
66	Inner Shield Bldg.	621.0'	.118	2.975 ksi	.076 ksi	.430 ksi
54	Pile	Under 621.0'	*	*	41.75k/pile	191.55k/pile

* See Pile Foundation Section.

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TABLE 7.2

SUMMARY OF SEISMIC/STRUCTURAL EVALUATION (SHEAR STRESS).

Node	Component	Elevation	Allowable Shear Stress (ksi)	Calculated Shear Stress (ksi)
35 (For 36 thru 45 & 35)	Outer Shield Bldg.	621.0'	.118 ksi	.042 ksi
66 (For 46 thru 53 & 66)	Inner Shield Bldg.	621.0'	.100 ksi	.044 ksi

TABLE 7.3

Containment Shell Seismic/Structural Evaluation

At Node 35 (For 1 thru 35) Elevation 621.0'

Load Combination	P_m	Limit	P_b	$P_m + P_b$	Limit
$D + L + P_a$	16.828 ksi	(1.0)(18.9)= 18.9 ksi	0	16.828	(1.5)(1.0)(18.9)= 28.35 ksi
$D + L + P_a + E'$	16.828 ksi	18.9 ksi	2.602	19.43	28.35 ksi

K=1.0 for both load combinations

Plate material A515, A516

S_m=18.9 ksi @ 300°F for A515, Grade 60

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8. ASCE, "Journal of the Geotechnical Engineering" Volume 102 No. GT3 March 1976

9. NUREG/CR-0098 N.M. Newmark, W.J. Hall, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants", May 1978.

10. Specification A-4109, "Foundation Piles, LaCross Boiling Water Reactor Project Dairyland Power Cooperative Association", Sargent and Lundy Engineers, Chicago, IL, January 1975.

APENDIX A

Containment Building Analysis

Assumptions:

1. The assumptions used for ultimate strength design and compatibility of strains are the same as those given in ACI Building Code (318-77).

2. Maximum steel stress at ultimate capacity is assumed as "fy".

3. Compressive reinforcement is not considered.

4. Inner shield building and reactor vessel are eccentric with Outer Shield building by their calculated centroid.

APPENDIX B

DETAILED
CALCULATIONS

TABLE OF CONTENTS FOR APPENDIX B

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Mathematical Model	B-3
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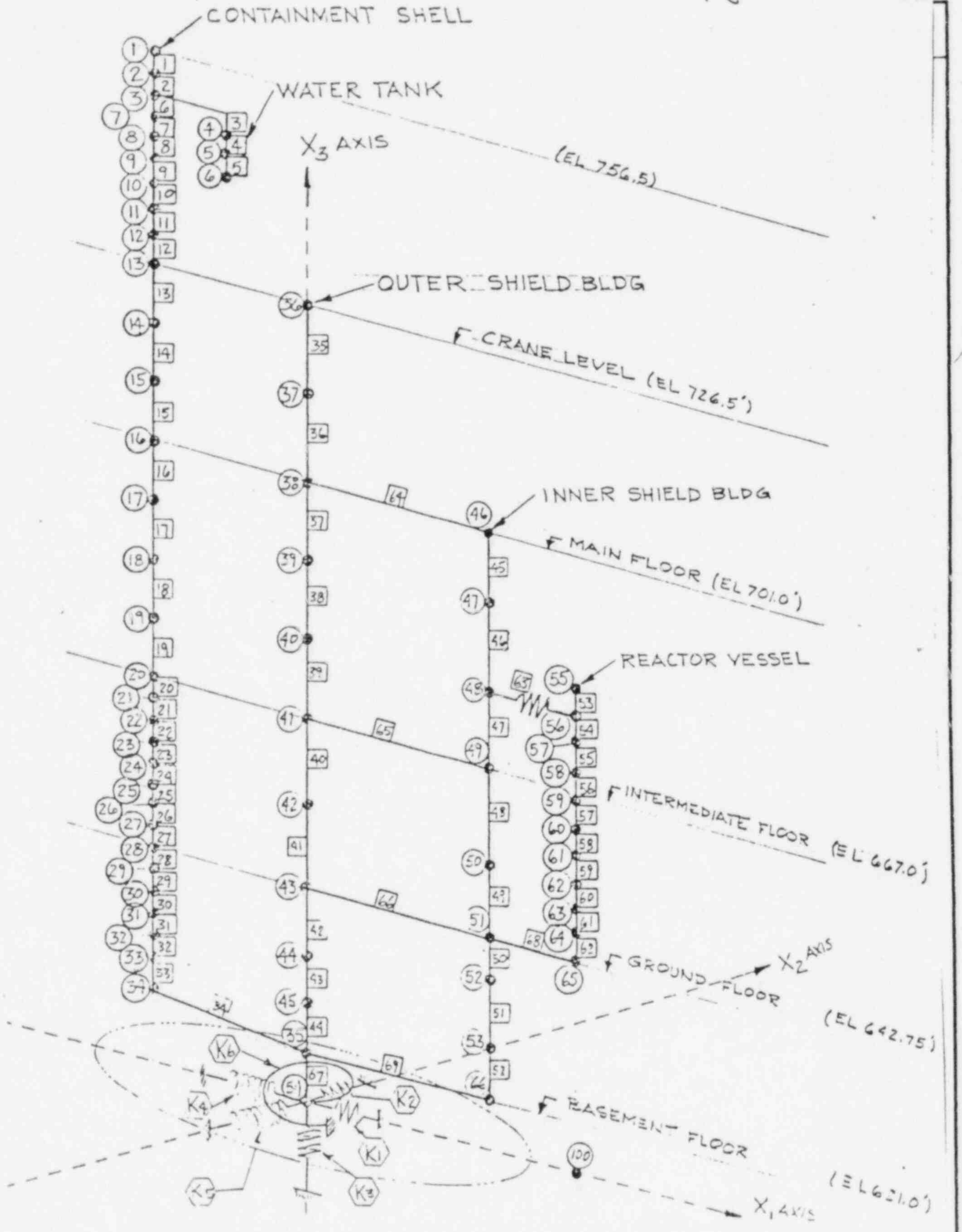
INTRODUCTION | REF.

THE CONTAINMENT BUILDING ANALYSIS WAS ACCOMPLISHED THROUGH THE USE OF A 66 NODE FINITE ELEMENT LUMPED MASS MODEL. THE BUILDING WAS BROKE UP INTO FIVE MAJOR PARTS: THE CONTAINMENT SHELL, THE OUTER SHIELD BLDG, THE INNER SHIELD BUILDING, REACTOR VESSEL; AND THE FOUNDATION.

THE CONTAINMENT SHELL WAS MODELED USING 34 MASSES. PROPERTIES AND WEIGHTS WERE CALCULATED IN SECTION 2 OF THIS NOTEBOOK. THE OUTER SHIELD BUILDING WAS MODELED USING 11 NODES. PROPERTIES AND WEIGHTS WERE CALCULATED AND PRESENTED IN SECTION 3 OF THIS NOTEBOOK. THE INNER SHIELD BUILDING WAS MODELED USING 9 NODES. PROPERTIES AND WEIGHTS WERE CALCULATED AND PRESENTED IN SECTION 4 OF THIS NOTEBOOK. THE REACTOR VESSEL ITSELF WAS MODELED USING 11 NODES. PROPERTIES AND WEIGHTS WERE CALCULATED AND ARE PRESENTED IN SECTION 5 OF THIS NOTEBOOK. FOUNDATION WEIGHTS AND SOIL SPRING STIFFNESS WERE CALCULATED AND PRESENTED IN SECTION 6 OF THIS NOTEBOOK.

NUCLEAR ENERGY SERVICES

BY R.R DATE 6-23-81 PROJ. 5101 TASK 026
CHKD. NC DATE 1/29/82 PAGE ____ OF ____
LACBWR CONTAINMENT BLDG.



3-D MODEL USED IN DYNAMIC ANALYSIS

NUCLEAR ENERGY SERVICES

CONTAINMENT BUILDING - COMPUTER DATA

Ref: BOB RULIF Note book Calculation

CONTAINMENT BUILDING - BEAM PROPERTIES TABLE

PROPERTY N°	H_2(in)	H_3(in)	A(in²)	J(in⁴)	I_2(in⁴)	I_3(in⁴)	CTORS	SF2	SF3	SSF2	SSF3
1	227.84	227.84	428.33	.0553E8	.0277E8	.0277E8	113.92	.53	.53	2.	2.
2	317.01	317.01	596.43	.1493E8	.07464E8	.07464E8	158.51	.53	.53	2.	2.
3	436.38	436.38	821.43	.39E8	.195E8	.195E8	218.19	.53	.53	2.	2.
4	408.49	408.49	768.86	.3198E8	.1599E8	.1599E8	204.25	.53	.53	2.	2.
5	323.19	323.19	608.07	.1582E8	.0791E8	.0791E8	161.6	.53	.53	2.	2.
6	240.	240.	451.25	.0647E8	.0323E8	.0323E8	120.	.53	.53	2.	2.
7	517.52	517.52	973.87	.65E8	.325E8	.325E8	258.76	.53	.53	2.	2.
8	578.28	578.28	1088.9	.9084E8	.4542E8	.4542E8	289.14	.53	.53	2.	2.
9	625.29	625.29	1177.52	1.1488E8	.5744E8	.5744E8	312.65	.53	.53	2.	2.
10	668.95	668.95	1259.81	1.4068E8	.7034E8	.7034E8	334.48	.53	.53	2.	2.
11	698.46	698.46	1315.44	1.6016E8	.8008E8	.8008E8	349.23	.53	.53	2.	2.
12	715.58	715.58	1347.71	1.7224E8	.8612E8	.8612E8	357.79	.53	.53	2.	2.
13	722.32	722.32	1355.66	1.753E8	.8765E8	.8765E8	361.16	.53	.53	2.	2.
14	722.32	722.32	2627.63	3.4164E8	1.7082E8	1.7082E8	361.16	.53	.53	2.	2.
15	722.32	722.32	2465.26	3.1925E8	1.6949E8	1.4976E8	361.16	.53	.53	2.	2.
16	718.1	718.1	2627.63	3.416E8	1.708E8	1.708E8	359.05	.53	.53	2.	2.
17	705.42	705.42	2562.08	3.1768E8	1.5884E8	1.5884E8	352.71	.53	.53	2.	2.
18	720	720	20075	25.033E8	12.6517E8	12.6517E8	360	.53	.53		
19	720	720	18852	25.266E8	12.133E8	12.633E8	360	.53	.53		
20	552	301.7	73028	5.9768E8	5.3114E8	11.7458E8	150	.527	.706		

NUCLEAR ENERGY SERVICES

REF.

CONTAINMENT BUILDING - BEAM PROPERTIES TABLE (CONTINUE)

PROPERTY N°	H_2(in)	H_3(in)	A(in²)	J(in⁴)	I_2(in⁴)	I_3(in⁴)	CTORS	SF2	SF3	SSF2	SSF3
21				SAME	20						
22				SAME	20						
23	539 ✓	301.7 ✓	89232 ✓	6.9977E8	6.4939E8	15.9625E8	150. ✓	.52 ✓	.635		
24	470 ✓	564 ✓	87983 ✓	11.0547E8	11.5807E8	14.8361E8	171.4 ✓	.433 ✓	.477 ✓		
25	904.8 ✓	564 ✓	70205 ✓	3.0733E8	16.8304E8	19.7665E8	171.4 ✓	.786 ✓	.703 ✓		
26	641.5 ✓	564 ✓	70205 ✓	3.0733E8	16.8304E8	19.7665E8	42. ✓	.786 ✓	.703 ✓		
27	641.5 ✓	564 ✓	54972 ✓	.2726E8	12.4805E8	14.0501E8	42 ✓	.764 ✓	.759 ✓		
28	76.2 ✓	76.2 ✓	1237.36	1.6046E06	.8023E6	.8023E6	38.1 ✓	.53	.53	2.	2.
29	106.92	106.92	1280.88	3.3996E6	1.6998E6	1.6998E6	53.46	.53 ✓	.53	2.	2.
30				SAME 29							
31	115.	115.	368.44	.976E6	.4881E6	.4881E6	57.5	.53	.53	2.	2.
32			14.093 ✓	13314. ✓	13300. ✓	13.756					
33				Rigid beam							
34	798	798	50.01E4	398.12E8	199.06E8	199.06E8	399	.89	.89		

CONTAINMENT BUILDING - COMPUTER DATA

	REF.
CONTAINMENT SHELL AND WATER TANK	

NUCLEAR ENERGY SERVICES INC.
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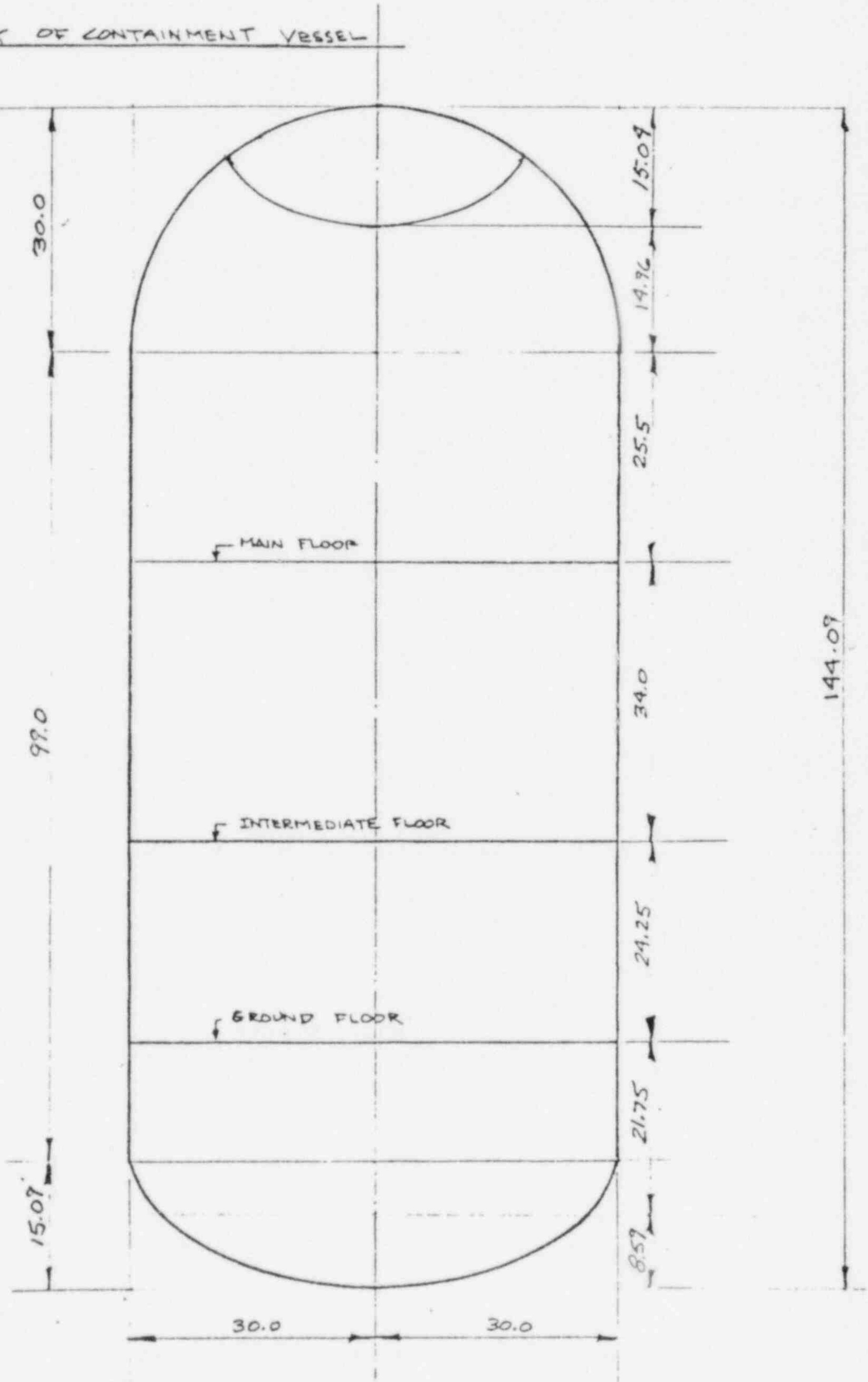
REF.

SCALE 1:20

GEOMETRY OF CONTAINMENT VESSEL



NES 105 (2/74)

	REF.
MATERAL PROPERTIES	
$f_c' = 3500$ PSI — REFERENCE: ALLIS-CHALMERS SPECIFACTION 41-551, S&L No W1735	
REINFORCING BARS — STANDARD SPECIFICATION FOR REINFORCED CONCRETE WORK (FORM 1715P)	
DESIGNATION A15 (INTERMEDIATE GRADE BARS, DEFORMED)	
$f_y = 40{,}000$ PSI	
$E_c = 57{,}000\sqrt{f_c'}$ ✓ 1.	ACI 318-77 SEC 8.5 Pg 26
$E_c = 57{,}000\sqrt{3500} = 3372$ KSI	
$E_s = 29{,}000$ KSI (30,000) ✓ FOR STEEL	ACI 318-77 SEC 8.5 Pg 26
POISSON'S RATIO $\nu = .17$ FOR CONCRETE — REF DESIGN OF CONCRETE STRUCTURES By G. WINTER, A. NILSON 8TH ED	
$\nu = .3$ FOR STEEL 2.	AISC 7TH ED Pg IX

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BY R.R. DATE 3-19-79 PROJ. 5101 TASK 026
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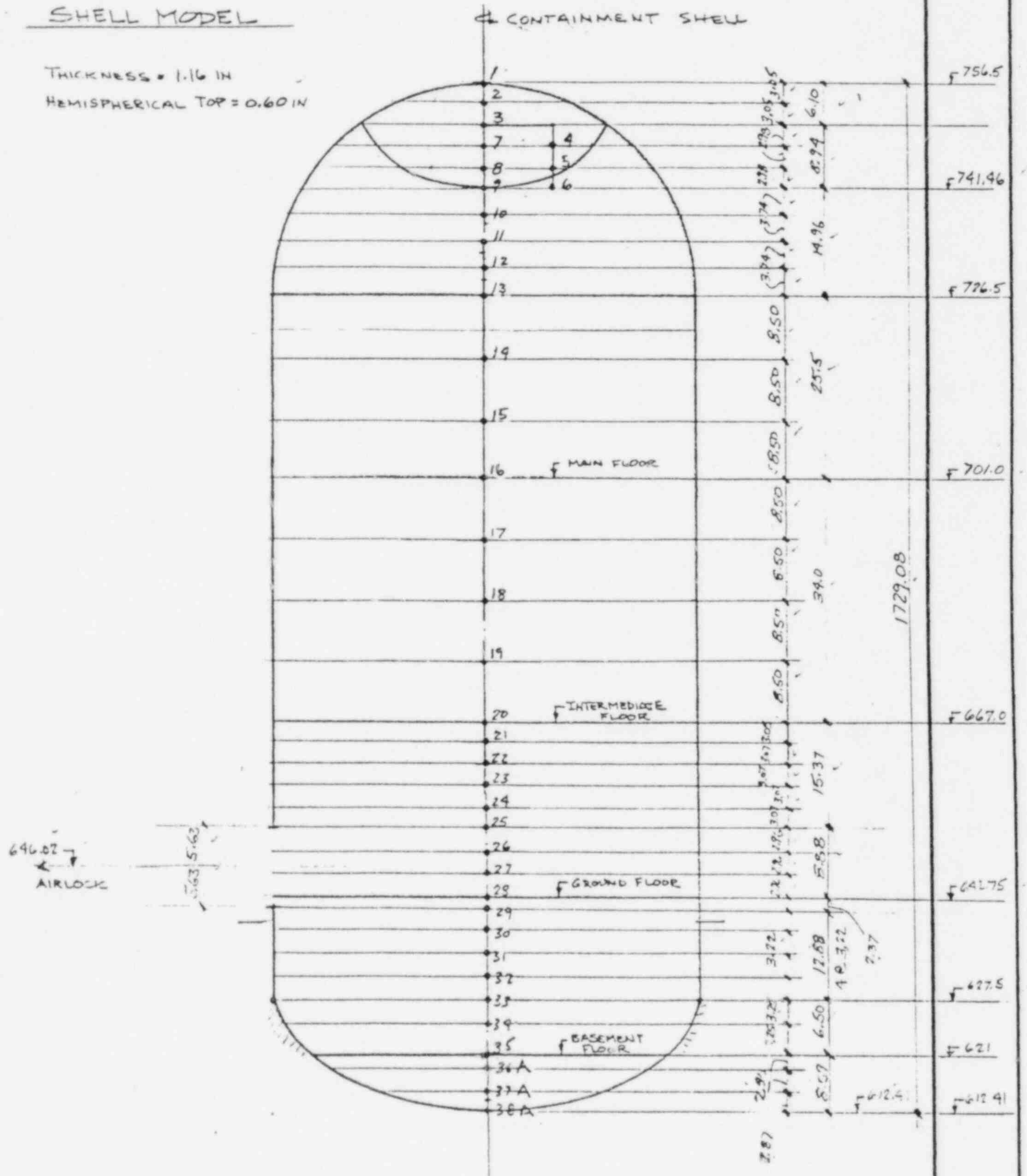
REF.

SCALE 1:20

SHELL MODEL

THICKNESS = 1.16 IN
HEMISPHERICAL TOP = 0.60 IN



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CONTAINMENT BLDG | REF.

PROPERTIES

NODE NO	AREA	I_{x2}	I_{x3}	DEAD WEIGHT	WATER
38A	7.7711	638.2853		5.46k	
37A	10.7011	1666.6662		15.00k	65.12k ADD TO FNON @ NODE 35
36A	14.2970	47.0629		20.04k	
35	16.4451	6098.7157		24.62k	
34	17.7922	7660.2866		28.33k	
33	18.1133	8082.5704		28.83k	
32	18.2474	8236.8458		28.79k	
31	18.2474	8236.8458		28.79k	
30	18.2474	8236.8458		28.79k	
29	17.1200	8173.8600	7222.39	23.02k	
28	↓	↓	↓	22.36k	
27				29.83k	
26				29.83k	
25	17.1200	8173.8600	7222.39	26.14k	
24	18.2474	8237.8458		27.45k	
23	↓	↓		27.45k	
22				27.45k	
21				27.36k	
20				51.64k	
19				76.00k	
18				76.00k	
17				76.00k	
16				76.00k	
15				76.00k	
14	18.2474	8237.8458		76.00k	
13	9.4143	4227.0299		46.00k	
12	9.3591	4153.1125		15.91k	
11	9.1350	3861.8270		15.53k	
10	8.7487	3392.3118		19.88k	
9	8.1772	2770.0236		13.30k	
8	7.5618	2190.4951		11.04k	
7	6.7630	1567.0966		9.86k	
3	5.7044	940.3590		6.42k	93.91k
2	4.1419	359.9645		6.20	
1	1.487	133.3300		1.12k	
4	5.3393	771.1298		7.80	163.29k
5	4.2227	381.4658		6.17	95.00k
6	3.1337	155.5996		1.14	10.56k

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OUTER CONTAINMENT SHELL

NODE No.	WEIGHT (water ✓)	AREA $\times 10^2$ in^2	$I_{x2} \times 10^8$ in^4	$I_{x3} \times 10^8$ in^4	$K \times 10^8$ in^4	$H_2 = H_3 \times 10^2$
1	1.12	4.2833	0.0277	0.02765	0.0553	2.2784
2	6.20	5.9643	0.07464	0.07464	0.1493	3.1701
3	8.43 / 93.91 > 101.34	8.2143	0.1950	0.1950	0.3900	4.3638
4	7.80 / 163.29 > 171.09	7.6886	0.1599	0.1599	0.3198	4.0849
5	6.17 / 95.00 > 101.17	6.0807	0.0791	0.0791	0.1582	3.2319
6	1.14 / 10.56 > 11.7	4.5125	0.03233	0.03233	0.0647	2.4000
7	9.36	9.7387	0.3250	0.3250	0.6500	5.1752
8	11.04	10.8890	0.4542	0.4542	0.9084	5.7828
9	13.30	11.7752	0.5744	0.5744	1.1488	6.2529
10	19.88	12.5981	0.7034	0.7034	1.4069	6.6895
11	15.53	13.1544	0.8008	0.8008	1.6016	6.9846
12	15.71	13.4771	0.8612	0.8612	1.7224	7.1558
13	46.00	13.5566	0.8765	0.8765	1.7530	7.2232
14	76.00	26.2763	1.7082	1.7082	3.4164	7.2232
15	76.00	26.2763	1.7082	1.7082	3.4164	7.2232
16	76.00	26.2763	1.7082	1.7082	3.4164	7.2232
17	76.00	26.2763	1.7082	1.7082	3.4164	7.2232
18	76.00	26.2763	1.7082	1.7082	3.4164	7.2232
19	76.00	26.2763	1.7082	1.7082	3.4164	7.2232
20	51.64	26.2763	1.7082	1.7082	3.4164	7.2232
21	27.45	26.2763	1.7082	1.7082	3.4164	7.2232

REF.

NES 105 (2/74)

NES 105 (2/74)

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OUTER CONTAINMENT SHELL

NODE No	WEIGHT	AREA $\times 10^2$ IN^2	$I_{Y2} \times 10^5$ IN^4	$I_{X3} \times 10^5$ IN^4	K $\times 10^2$ IN^4	$H2 = H3$
22	27.45 k	26.2763	1.7082	1.7082	3.4164	7.2232
23	27.45 k	26.2763	1.7082	1.7082	3.4164	7.2232
24	27.45 k	26.2763	1.7082	1.7082	3.4164	7.2232
25	26.14 k	24.6528	1.6949	1.4976	3.1925	7.2232
26	24.83 k	24.6528	1.6949	1.4976	3.1925	7.2232
27	24.83 k	24.6528	1.6949	1.4976	3.1925	7.2232
28	22.36 k	24.6528	1.6949	1.4976	3.1925	7.2232
29	23.02 k	24.6528	1.6949	1.4976	3.1925	7.2232
30	28.79 k	26.2763	1.7080	1.7080	3.4160	7.2232
31	28.79 k	26.2763	1.7080	1.7080	3.4160	7.2232
32	28.79 k	26.2763	1.7080	1.7080	3.4160	7.2232
33	28.53 k	26.2763	1.7080	1.7080	3.4160	7.181
34	28.23 k	25.6208	1.5834	1.6884	3.1768	7.0592
35	24.62 k + 15.00 + 5.46 = 45.08 k	23.6809	1.2543	1.2543	2.5085	7.5209

REF.

NES 105 (2/74)

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OUTER SHIELD BLDG

NODE	WEIGHT	AREA $\times 10^4$ IN^2	I_{x2} $\times 10^8$ IN^4	I_{x3} $\times 10^8$ IN^4	K $\times 10^8$ IN^4	SF2 = SF3 =
36	133.31	2.0075	12.6517	12.6517	25.3033	0.53
37	266.62	2.0075	12.6517	12.6517	25.3033	
38	251.77	2.0075	12.6517	12.6517	25.3033	
39	236.93	2.0075	12.6517	12.6517	25.3033	
40	237.03	2.0075	12.6517	12.6517	25.3033	
41	245.40	2.0075	12.6517	12.6517	25.3033	
42	248.51	1.8852	12.6330	12.6330	25.2660	
43	206.99	1.8852	12.6330	12.6330	25.2660	
44	159.45	2.0075	12.6517	12.6517	25.3033	
45	209.50	2.0075	12.6517	12.6517	25.3033	

REF.

PROPERTIES OF HEMISPHERICAL TOP & ELLIPTICAL WATER TANK | REF.

HEMISPHERICAL TOP

AT NODE 12 — y = 3.74′, W = 3.74

d_1 = 59.5319′
d = 59.6319′ → 7.1558×10² IN
A = 9.3591 FT²
I = 4153.1125 FT⁴
M = 17.15 K

AT NODE 11 — y = 7.48′, W = 3.74

d_1 = 58.1051′
d = 58.2051′ — W = 32.335 — 6.9846×10² IN
A = 9.1350 FT²
I = 3861.8270 FT⁴
M = 16.74 K

AT NODE 10 — y = 11.22′, W = 3.74

d_1 = 55.6957′
d = 55.7457′ — W = 30.969 — 6.6895×10² IN
A = 8.7487 FT²
I = 3392.3118
M = 16.03 K

AT NODE 9 — y = 14.96, W = 3.36

d_1 = 52.0076′
d = 52.1076′ = 6.2529×10² IN
A = 8.1772 FT²
I = 2770.0236 FT⁴
M = 13.46 K

AT NODE 8 — y = 17.94′, W = 2.98

d_1 = 48.0898′
d = 48.1898′ = 5.7828×10² IN
A = 7.5618 FT²
I = 2190.4951 FT⁴
M = 11.04 K

AT NODE 7 — y = 20.92′, W = 2.98

d_1 = 43.0048′
d = 43.1048′ 5.1726×10² IN
A = 6.7630 FT²
I = 1567.0966 FT⁴
M = 9.88 K

AT NODE 3 — y = 23.90′, W = 3.015

d_1 = 36.2651′
d = 36.3651 = 4.3638×10² IN
A = 5.7094 FT²
I = 990.3590 FT⁴
M = 8.43 K

AT NODE 2 — y = 26.95′, W = 3.05

d_1 = 26.3539
d = 26.4539 = 3.1701×10² IN
A = 4.1419
I = 359.9695 FT⁴
M = 6.19 K

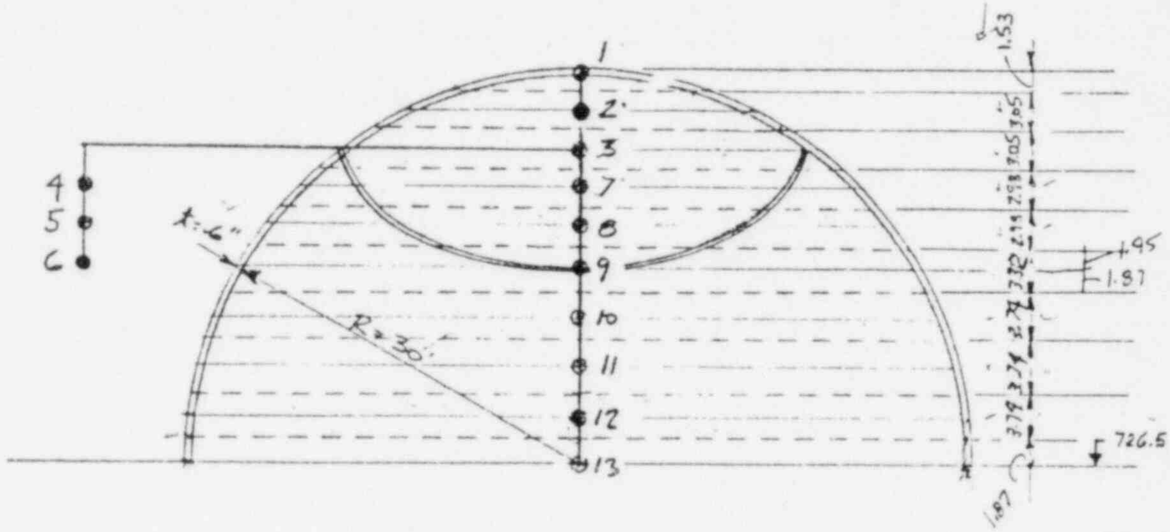
HALF WAY BETWEEN 2 & 1 — y = 28.475, W = 1.525

d_1 = 18.8864
d = 18.9864 = 2.2784×10² IN²
A = 2.9745 FT²
I = 133.3300 FT⁴
M = 1.11 K

HALF WAY BETWEEN 13 & 12 — y = 1.87, W = 1.87

d_1 = 59.8833
d = 59.9833
A = 9.4143 FT²
I = 4227.0294 FT⁴
M = 8.6263

MASS CALCULATION FOR CONTAINMENT VESSEL | REF.



NODE 1.

$A_1 = 0$

$A_2 = 2.9745\ FT^2$

AVERAGE = 1.487 FT² = 2.14130 × 10² IN²

VOLUME = (1.4875)(1.53) = 2.2759 FT³

WEIGHT = (.490)(2.2759) = 1.12^K

NODE 2

✓A = 4.1419 FT²

✓V = 12.6328 FT³

✓W = 6.1901^K → (use) 6.20^K

NODE 3 (+ WATER TANK)

✓A = 5.7044 FT²

✓V = 17.3984 FT³

W = 8.43^K + 93.91^K* = 101.34^K

*SEE WATER TANK

NODE 7

A = 6.7630 FT²

V = 20.1537 FT³

W = 9.86^K

NODE 8

A = 7.5618 FT²

V = 22.5341 FT³

W = 11.04 K

NODE 9

A = 8.1772 FT²

✓V = 27.1483 FT³

W = 13.30

NODE 10

A = 8.7487 FT²

V = 30.3580 FT³

W = 14.88 K

NODE 11

A = 9.1350 FT²

V = 31.6935 FT³

W = 15.53 K

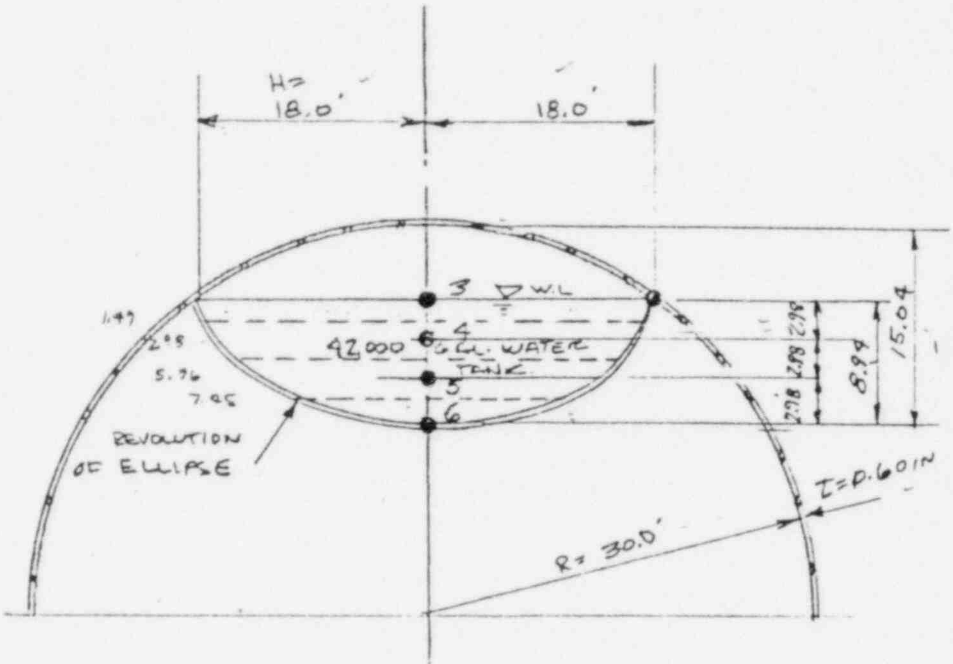
NODE 12

A = 9.3591 FT²

V = 32.4761 FT³

W = 15.91 K

PROPERTIES OF HEMISPHERICAL TOP & ELLIPTICAL WATER TANK | REF.



PROPERTIES OF WATER TANK ELLIPSE

$y = 1.49'$
d_1 35.4965'
d = 35.5965' = 4.2716x10²
A = 5.5836 FT²
I = 881.9073 FT²

$y = 7.45'$
d_1 = 19.8997'
d = 19.9997' = 2.400x10²
A = 3.1337 FT²
I = 155.8996 FT⁴

TI

y STO 1
B = 8.94 STO 2
H = 18.0 STO 3
2t = .1 STO 6

At NODE 4 $y = 2.98'$
d_1 = 33.9411'
d = 34.0411' = 4.0849x10² in
A = 5.3393 FT²
I = 771.1298 FT⁴

$y = 0$
d_1 = 36'
d = 36.1'
A = 5.6627 FT²
I = 919.9125

NODE 5 $y = 5.96'$
d_1 = 26.8328'
d = 26.9328 = 3.2319x10² in
A = 4.2227 FT²
I = 381.4658 FT⁴

PROPERTIES OF OUTER CYLINDRICAL STEEL CONTAINMENT SHELL | REF.

PROPERTIES OF ELEMENTS OF SIDES

FROM NODE 14 TO 24

AREA

$$A = \frac{\pi (d^2 - d_1^2)}{4} = \frac{\pi (60.1933^2 - 60^2)}{4}$$

$A = 18.2474\ FT^2$

MOMENT OF INERTIA

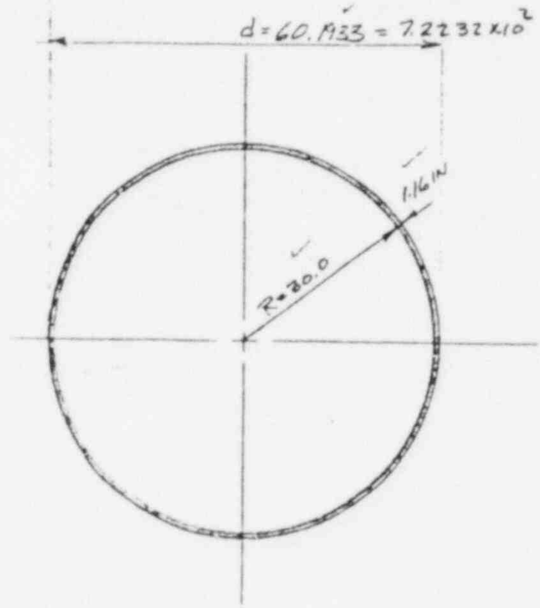
$$I = \frac{\pi (d^4 - d_1^4)}{64} = 8237.8458\ FT^4$$

TORSIONAL CONSTANT

$K = \frac{1}{2}\pi (r_1^4 - r_0^4)$ $r_0 = 30'$

$K = \frac{1}{2}\pi (30.0967^4 - 30.0^4)$ $r_1 = 30.0967$

$K = 16484.2562\ FT^4$



FROM NODE 25 TO 29

$$A = \left[2 \times 2 \times \frac{79.193}{360} 2\pi) + 2 \times \frac{10.81}{360}(2\pi)\right] 30 \frac{1.16}{12}$$

(A₁ term, A₂ term)

$A = 17.12\ FT^2$ ← AREA

$A_1 = 8.015\ FT^2$

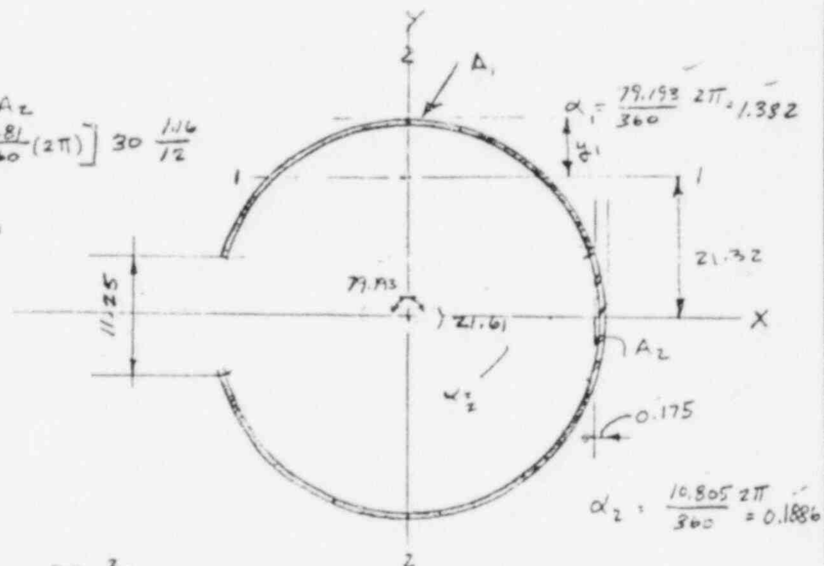
$A_2 = 1.09\ FT^2$

FOR A_1

$y_1 = R\left(1 - \frac{\sin\alpha}{\alpha}\right)$

$y_1 = 30\left(1 - \frac{0.9823}{1.382}\right)$

$y_1 = 8.68\ FT$



$I_1 = R^3 t\left(\alpha + \sin\alpha\cos\alpha - \frac{2\sin^2\alpha}{\alpha}\right)$

$I_1 = 30^3 \frac{1.16}{12}\left(1.382 + \sin 79.193 \cos 79.193 - \frac{2\sin^2 79.193}{1.382}\right) = 438\ FT^4$

$I_2 = R^3 t(\alpha - \sin\alpha\cos\alpha)$

$I_2 = 30^3 \frac{1.16}{12}(1.382 - \sin 79.193 \cos 79.193) = 3126.32\ FT^4$

FOR A_2

$I_1 = R^3 t(\alpha - \sin\alpha\cos\alpha)$

$I_1 = 30^3 \frac{1.16}{12}(0.1886 - \sin 10.807 \cos 10.807) = 11.55\ FT^4$

$y_2 = 30\left(1 - \frac{\sin 10.807}{.1886}\right) = 0.175\ FT$

PROPERTIES OF OUTER CYLINDRICAL STEEL CONTAINMENT SHELL | REF.

$I_z = R^3 t\left(\alpha + \sin\alpha\cos\alpha - \frac{2\sin^2\alpha}{\alpha}\right)$ ✓

$I_z = 30^3 \frac{1.16}{12}\left(0.1886 + \sin 10.805 \cos 10.805 - \frac{2\sin^2 10.805}{0.1886}\right) = .16$ ✓
3
2

$I_{xx} = 2(438) + 2(8.015)\times 21.32^2 + 11.55 = 8173.86\ FT^4$ ✓

ASSUME ℄ AT CENTROID

$I_{yy} = 2\times 3126.32 + .16 + 1.09\times 29.825^2 = 7222.39\ FT^4$ ✓

MASS CALCULATION FOR WATER TANK | REF.

BY USING AN APPROXIMATE VOLUME CALCULATION

$\rho_{H_2O} = 62.4$

NODE 3.

WEIGHT H_2O

$d_1 = 36.0$	$y = 0$	$\Delta = .5$		$A_1 = 5.6627$
$d_1 = 35.9436$	$y = .5$	$\Delta = .5$	31.66	$A_2 = 5.5836$
$d_1 = 35.7741$	$y = 1.0$	$\Delta = .5$	31.36	$A_{AV} = 5.6232$ FT^2
$d_1 = 35.4965$	$y = 1.49$	$\Delta = .5$	30.89	$V = 8.3785$ FT^3
			93.91^k H_2O	$W = 4.11^k$ STEEL

98.02^k TOTAL

NODE 4

WEIGHT H_2O

		$\Delta = .5$		
$d_1 = 35.0876$	$y = 2.00$	$\Delta = .5$	30.16	$A_1 = 5.3393$ FT^2
$d_1 = 34.5638$	$y = 2.50$	$\Delta = .5$	29.27	$V = 15.9111$ FT^3
$d_1 = 33.9125$	$y = 3.0$	$\Delta = .5$	28.18	$W = 7.80^k$ STEEL
$d_1 = 33.1264$	$y = 3.5$	$\Delta = .5$	26.89	
$d_1 = 32.1955$	$y = 4.0$	$\Delta = .47$	25.40	
$d_1 = 31.1769$	$y = 4.47$		23.39	
			163.29^k H_2O	

171.09^k TOTAL

NODE 5.

WEIGHT H_2O

$d_1 = 29.8431$	$y = 5.0$	$\Delta = .53$	21.82	
d_1 28.3810	$y = 5.5$	$\Delta = .5$	19.74	$A = 4.2227$
d_1 26.6879	$y = 6.0$	$\Delta = .5$	17.45	$V = 12.5836$
d_1 24.7163	$y = 6.5$	$\Delta = .5$	14.97	$W = 6.17^k$ STEEL
d_1 22.3929	$y = 7.0$	$\Delta = .5$	12.29	
d_1 19.8997	$y = 7.45$	$\Delta = .45$	8.73	
			95.00 K H_2O	

101.17^k TOTAL

NODE 6

WEIGHT H_2O

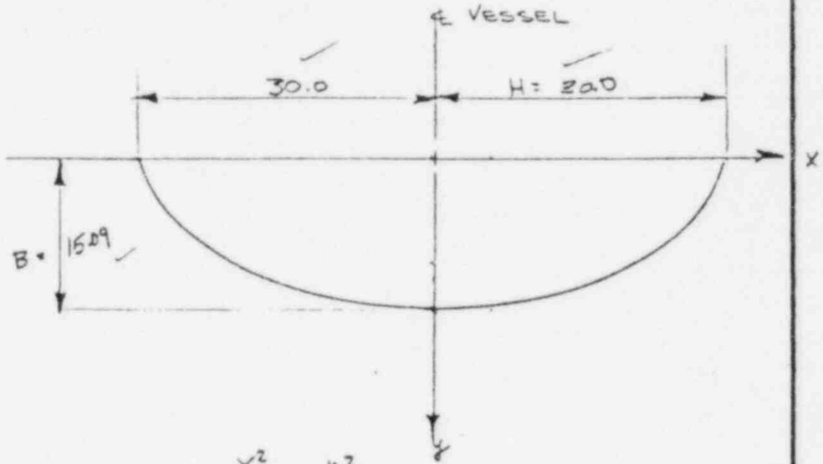
				$A = 0$
$d_1 = 16.0689$	$y = 8.0$	$\Delta = .55$	6.33	$A = 3.1337$ FT^2
$d_1 = 11.1549$	$y = 8.5$	$\Delta = .5$	3.05	$V = 2.33$ FT^3
$d_1 = 7.38$	$y = 8.75$	$\Delta = .44$	1.18	$W = 1.14^k$ STEEL
			10.56^k H_2O	

11.7^k TOTAL

33276

PROPERTIES OF OUTER ELIPTICAL STEEL CONTAINMENT SHELL BOTTOM | REF.

ELIPTICAL BOTTOM SHELL



H = 30'

B = 15.09'

$2t = \frac{2(1.16)}{12} = .193$ FT

$$\frac{x^2}{H^2} + \frac{y^2}{B^2} = 1$$

$$x^2 = \left[1 - \frac{y^2}{B^2}\right] H^2$$

$$x = \sqrt{\left[1 - \frac{y^2}{B^2}\right]} H$$

½ BETWEEN NODE 34 & 33 y = 1.625
d₁ = 59.6511 INSIDE DIAMETER
d = 59.8441 INSIDE DIAMETER = 7.181×10^2 IN
A = 18.1133
I = 8082.5704

NODE 34
d_1 = 58.5919 y = 3.25
d : 58.7849 7.0542×10^2 in
A : 17.7922 FT^2
I : 7660.2866 FT^4

NODE 35
d_1 : 54.1983 y = 6.50
d : 54.3413 7.5209×10^2
A : 16.4451 FT^2
I : 6048.7157 FT^4

NODE 36A y ~ 9.36
d_1 47.0629
d 47.2559
A 14.2970 FT^2
I 470629 FT^4

NODE 37A y = 12.22
d_1 = 35.2017
d = 35.3947
A = 10.7011 FT^2
I = 1666.6662 FT^4

½ WAY BETWEEN NODE 38A & 37A y = 13.655
d_1 = 25.5370
d = 25.7300
A = 7.7711 FT^2
I = 638.2853 FT^4

	REF.

WEIGHTS

NODE 38A
7.7711 FT² (2.87) ½ (.490) = 5.46ᵏ ✓

NODE 37A
10.7011 FT² (2.86)(.490) = 15.00ᵏ ✓

NODE 36A
14.5197 FT² (2.86)(.490) = 20.35ᵏ ✓

NODE 35
16.4451 FT² ((2.86+3.25)/2)(.490) = 24.62ᵏ

NODE 34
17.7922 FT² (3.25)(.490) = 28.33ᵏ

NODE 33
18.1133 FT² (3.25/2)(.490) = 14.43ᵏ
18.2474 FT² (3.22/2)(.490) = 14.40ᵏ
> 28.83ᵏ

NODE 32
18.2474 FT² (3.22)(.490) = 28.79ᵏ

NODE 31
18.2474 FT² (3.22)(.490) = 28.79ᵏ

NODE 30
18.2474 FT² (3.22)(.490) = 28.79ᵏ

NODE 29
18.2474 FT² (2.37/2)(.490) = 10.60ᵏ
17.12 FT² (2.96/2)(.490) = 12.42ᵏ
> 23.02

NODE 28
17.12 FT² ((2.37+2.96)/2)(.490) = 22.36ᵏ

NODE 27
17.12 FT² (2.96)(.490) = 24.83ᵏ

NODE 26
17.12 FT² (2.96)(.490) = 24.83ᵏ

NODE 25
17.12 FT² (2.96/2)(.490) = 12.42ᵏ
18.2474 FT² (3.07/2)(.490) = 13.72ᵏ
> 26.14

NODE 24
18.2474 FT² (3.07)(.490) = 27.45ᵏ

357.28ᵏ

	REF.

WEIGHTS (CON'T)

NODE 23
18.2474 FT² (3.07)(.490) = 27.45^k ✓

NODE 22
18.2474 FT² (3.07)(.490) = 27.45^k ✓

NODE 21
18.2474 FT² ((3.07+3.09)/2)(.490) = 27.54^k ✓

NODE 20
18.2474 FT² ((3.09+8.5)/2)(.490) = 51.81^k ✓

NODE 19
18.2474 FT² (8.50)(.490) = 76.00^k ✓

NODE 18
18.2474 FT² (8.50)(.490) = 76.00^k ✓

NODE 17
18.2474 FT² (8.50)(.490) = 76.00^k

NODE 16
18.2474 FT² (8.50)(.490) = 76.00^k ✓

NODE 15
18.2474 FT² (8.50)(.490) = 76.00^k ✓

NODE 14
18.2474 FT² (8.50)(.490) = 76.00^k ✓

NODE 13
18.2474 FT² (8.50/2)(.490) = 38.00^k ✓
9.4143 FT² (3.47/2)(.490) = 8.00
} 46.00 ✓

NODE 12
9.3591 FT² (3.47)(.490) = 15.91^k ✓

NODE 11
9.1350 FT² (3.47)(.490) = 15.53^k ✓

NODE 10
8.7487 FT² (3.47)(.490) = 14.88^k ✓

NODE 9
8.1772 FT² (3.32)(.490) = 13.30^k

NODE 8
7.5618 FT² (2.98)(.490) = 11.04^k ✓

706.56^k

	REF.

WEIGHTS (CON'T)

NODE 7
6.7630 FT² (2.98)(.490) = 9.86^k

	Steel	Water
NODE 3	= 12.64^k ✓	93.91^k USE (conservative) → 106.56
NODE 2	= 6.60^k ✓	
NODE 1	= 1.12^k ✓	
NODE 4	= 7.80^k ✓	163.29^k → 171.09
NODE 5	= 6.17^k ✓	95.00^k
NODE 6	= 1.14^k ✓	10.56^k
	45.33^k	362.78^k

TOTAL WEIGHT CONTAINMENT SHELL
AND WATER TANK

45.33^k   362.78^k H2O
706.56
357.28
1109.17 STEEL

	REF.
BIOLOGICAL SHIELD BUILDING	

NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY R.R DATE 3-29-79 PROJ. 5101 TASK 026
CHKD. aB DATE 6-8-81 PAGE 2 OF
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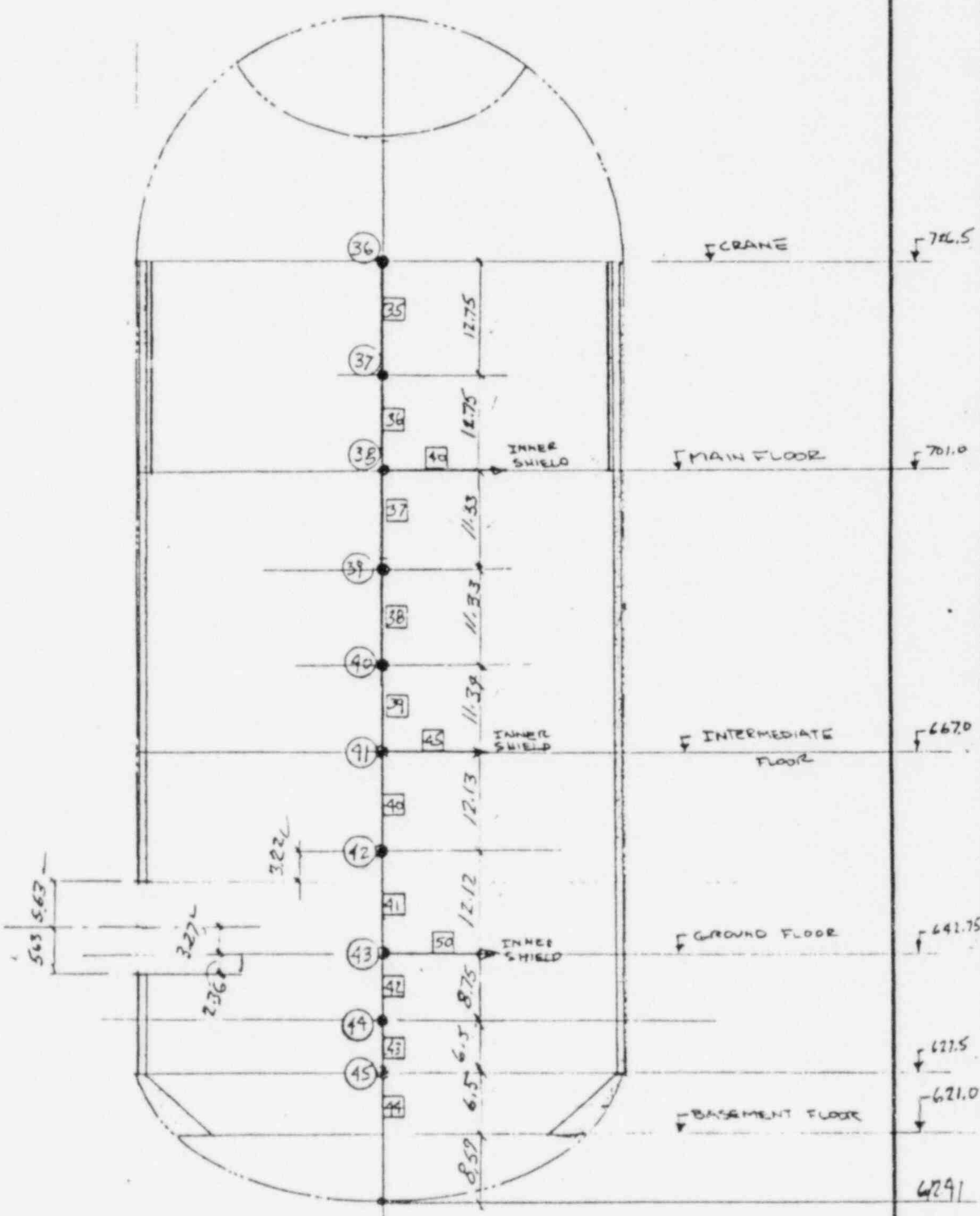
OUTER SHIELD BLDG. | REF.



OUTER SHIELD BLDG. | REF.

NODE NO	AREA	I_{x2}	I_{x3}	DEAD WEIGHT k
36	139.41 Ft^2	61013.08	6101308	133.31 (93k CRANE) 226.31
37	139.41	61013.08	61013.08	266.62
38	139.41	61013.08	61013.08	251.77
39	139.41	61013.08	61013.08	236.93
40	139.41	61013.08	61013.08	237.03
41	139.41	61013.08	61013.08	245.40
42	130.92	60923.06	53483.03	248.51 ✓
43	130.92	60923.06	53483.03	206.99
44	139.41	61013.08	61013.08	159.45
45	139.41	61013.08	61013.08	209.50
				2195.51 k

$J = I_2 + I_3 =$

$H_2 = 60'$; $H_3 = 60'$

$C = 30'$

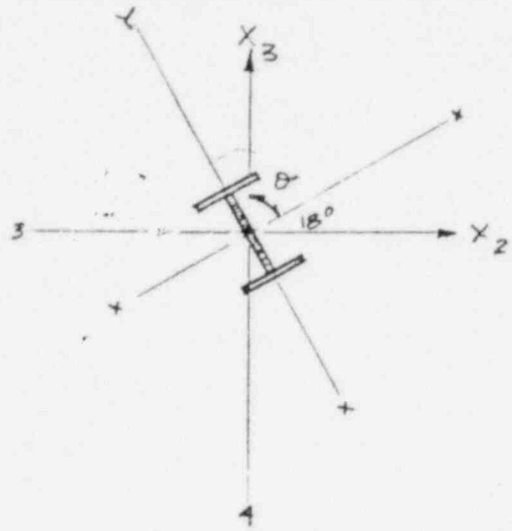
$SF2 =$

Change Ft^2 to in^2

Node No	Area (in^2)	I_{x2} (in^4)	I_{x3} (in^4)	K $\times 10^8$ in^4
36	2.0075×10^4	12.6517×10^8	12.6517×10^8	25.3033
37	↓	↓	↓	↓
38				
39				
40				
41	↓	↓	↓	↓
42	1.8852×10^4	12.633×10^8	11.0902×10^8	23.723
43	1.8852×10^4	12.633×10^8	11.0902×10^8	23.723
44	2.0075×10^4	12.6517×10^8	12.6517×10^8	25.303
45	2.0075×10^4	12.6517×10^8	12.6517×10^8	25.303

OUTER SHIELD BLDG. | REF.

PROPERTIES OF CRANE COLUMNS



PROPERTIES FOR WF14x43

$A = 12.6 \, in^2$

$I_{xx} = 429.0 \, in^4$ $r = 1.89 \, in$

$I_{yy} = 45.1 \, in^4$

$S_{xx} = 62.97 \, in^3$

$S_{yy} = 11.3 \, in^3$

PROPERTIES FOR C15x33.9

$A = 9.96 \, in^2$ $r = 5.62 \, in.$

$I_{xx} = 315 \, in^4$

$I_{yy} = 8.13 \, in^4$

$S_{xx} = 42.0 \, in^3$

$S_{yy} = 3.11 \, in^3$

$$I_3 = I_x \sin^2\theta + I_Y \cos^2\theta$$

$$I_4 = I_x \cos^2\theta + I_Y \sin^2\theta$$

OUTER SHIELD BLDG | REF.

CALCULATE CONTRIBUTION OF CRANE COLUMNS.

WF COLUMN DEGREE OF CENTER	I_{x_2}	I_{x_3}	$4\ I_{x_2}$	$4\ I_{x_3}$
18°	0.08192	0.003943	0.7568	.01577
36°	0.01429	0.008571	0.05717	0.03429
54°	0.008571	0.01429	0.03429	0.05712
72°	0.003943	0.08192	0.01577	0.07568
90°	0.002175	0.02069	0.00870	0.08275
0°	0.020689	0.00217	0.08275	0.00870
			0.27436 ft^4	0.27436 ft^4

$n = \frac{E_s}{E_c}$, $E_c = 57{,}000\sqrt{f'_c}$ $f'_c = 3000^*$ ACI-71 SEC 8.3

$E_c = 3122$ KSI

$E_s = 29{,}000$ KSI *ASSUMED

$n = \frac{29000}{3122} = 9.29$

USING A RELATIVE STIFFNESS FACTOR OF 9.29 THE nI FACTOR OF THE COLUMNS = 2.55 FT^4 WHICH IS VERY SMALL AS COMPARED TO THAT OF THE CONCRETE CYLINDER.

TORSIONAL STIFFNESS CONSTANT

$K = 1.05\ in^4$ FOR W14x43

$\frac{(9.29)\,20\,K}{12^4} = 0.9383$ NEGLECT

OUTER SHIELD BLDG	REF.

PROPERTIES OF CONCRETE CYLINDER @ EL 726'-6"

$A = \frac{\pi}{4}(d^2 - d_1^2)$ WHERE $d = 59.9167$ FT
$d_1 = 58.4167$ FT

$A = \frac{\pi}{4}(59.9167^2 - 58.4167^2)$

$A = 139.4082$ FT^2

$I = \frac{\pi}{64}(d^4 - d_1^4)$

$I = \frac{\pi}{64}(59.9167^4 - 58.4167^4)$

$I_c = 61013.0828$ FT^4

WEIGHT 99' @ 139.4082 x .15 = 2070.21^k

CONCRETE CYLINDER 9"

AREA = 139.4082

MOMENT INERTIA = 61013.0828 FT^4

WEIGHT = 2070.21^k

OUTER SHIELD BLDG | REF.

WEIGHT CALC

NODE 36

$WEIGHT = \frac{(12.75)}{2}(139.41)(.150) = 133.31^{k}$ ✓

NODE 37

$WEIGHT = (12.75)(139.41)(.150) = 266.62^{k}$ ✓

NODE 38

$WEIGHT = \left(\frac{12.75+11.33}{2}\right)(139.41)(.150) = 251.77^{k}$ ✓

NODE 39

$WEIGHT = (11.33)(139.41)(.150) = 236.93^{k}$ ✓

NODE 40

$WEIGHT = \left(\frac{11.33+11.34}{2}\right)(139.41)(.150) = 237.03^{k}$ ✓

NODE 41

$WEIGHT = \left(\frac{11.34+12.13}{2}\right)(139.41)(.150) = 245.40^{k}$ ✓

NODE 42

$WEIGHT = \left[(3.88)(130.92) + \left[\frac{12.13}{2} + \left(\frac{12.12}{2} - 3.88\right)\right](139.41)\right].15 = 248.51^{k}$ ✓

NODE 43

$WEIGHT = \left[\left(\frac{12.12}{2} + 2.75\right)(130.92) + \left(\frac{8.75}{2} - 2.75\right)(139.41)\right].15 = 206.99^{k}$ ✓

NODE 44

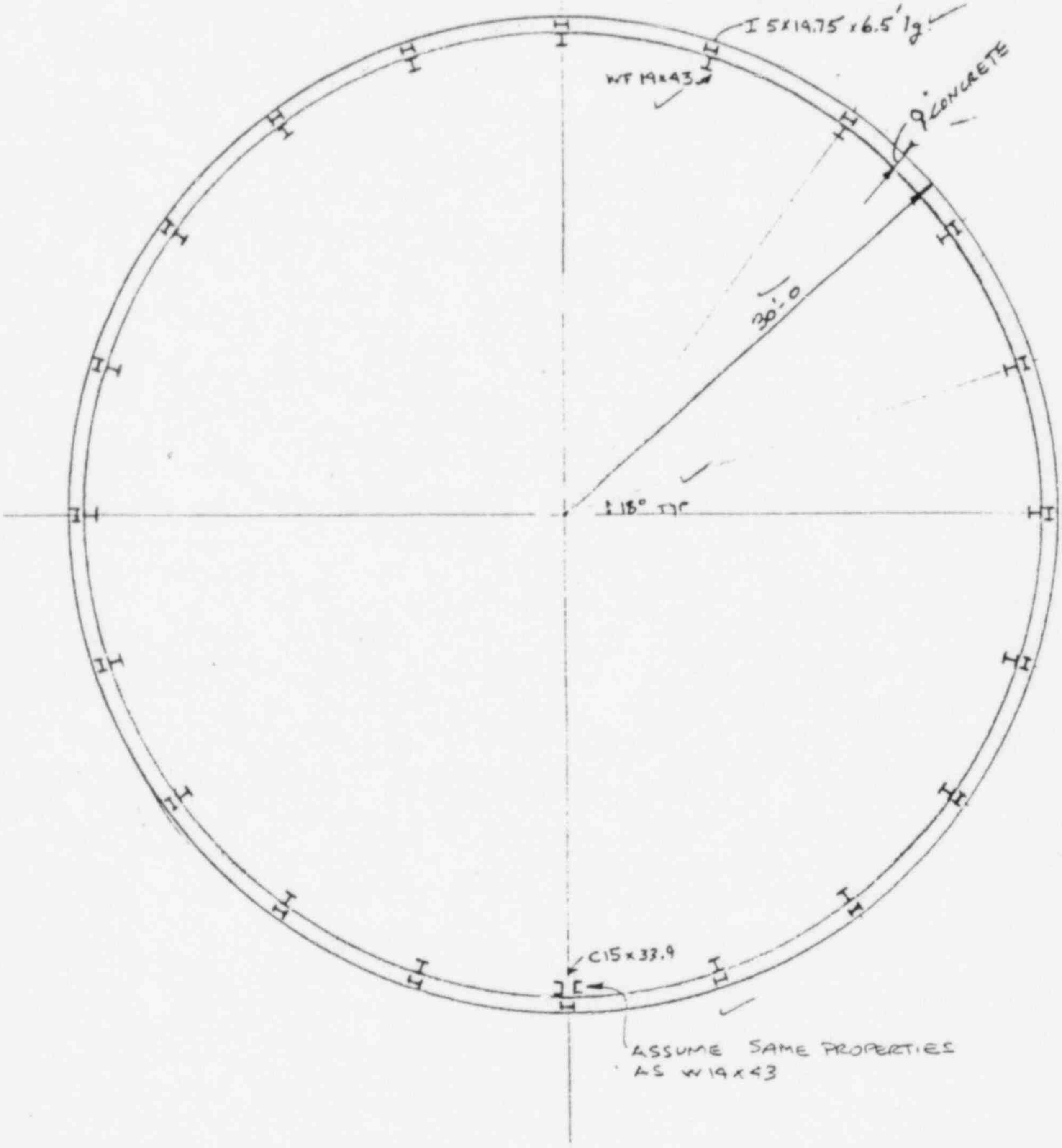
$WEIGHT = \left(\frac{8.75+6.5}{2}\right)(139.41)(.150) = 159.45^{k}$ ✓

NODE 45

$WEIGHT = \left(\frac{6.5}{2}\right)(139.41)(.15) + 141.54^{k} = 209.50^{k}$ ✓

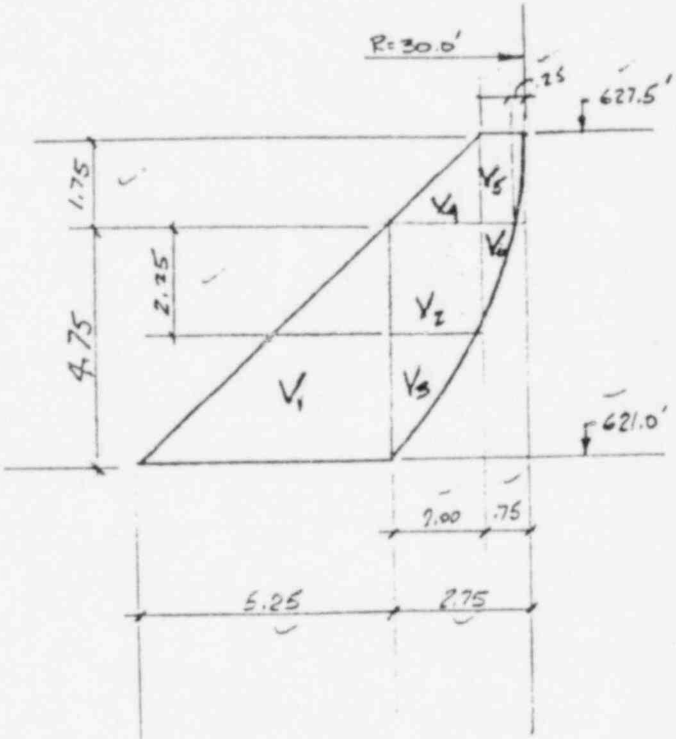
2195.51^{k} = TOTAL WEIGHT ✓

OUTER SHIELD BLDG.	REF.
PROPERTIES OF CONCRETE SHELL & CRANE COLUMNS	DWG 41-503950



PLAN @ ELEV. 726'-6"

REF.



VOLUME V_1

$A_{BOT} = \pi \frac{d_o^2 - d_i^2}{4} = \frac{\pi}{4}(27.25^2 - 22.00^2) = 203.07 \text{ FT}^2$

$V_1 = \frac{1}{2}(4.75)(203.07) = 482.29 \text{ FT}^3$

WEIGHT = 72.34 K

VOLUME V_2

$A = \frac{\pi}{4}(d_o^2 - d_i^2) = \frac{\pi}{4}(29.25^2 - 27.25^2) = 88.75 \text{ FT}^2$

$V_2 = 2.25(88.75) = 199.69 \text{ FT}^3$

WEIGHT = 29.95 K

VOLUME V_3

$A = \frac{\pi}{4}(29.25^2 - 27.25^2) = 88.75 \text{ FT}^2$

$V_2 = \frac{1}{2}(2.5)(88.75) = 110.94 \text{ FT}^3$

WEIGHT = 16.64 K

VOLUME V_4

$A = 88.75 \text{ FT}^2$

$V_1 = \frac{1}{2}(1.75)(88.75) = 77.66 \text{ FT}^3$

WEIGHT = 11.65 K

VOLUME V_5

$A = \frac{\pi}{4}(30^2 - 29.25^2) = 34.90 \text{ FT}^2$

$V_5 = 1.75(34.90) = 61.08 \text{ FT}^3$

WEIGHT = 9.16 K

VOLUME V_6

$A = \frac{\pi}{4}(29.75^2 - 29.25^2) = 23.17 \text{ FT}^2$

$V_6 = \frac{1}{2}(2.25)(23.17) = 26.07 \text{ FT}^3$

WEIGHT = 3.91 K

TOTAL WEIGHT = 143.65 K

OUTTER SHIELD BLDG. | REF.

FOR AREA A_2

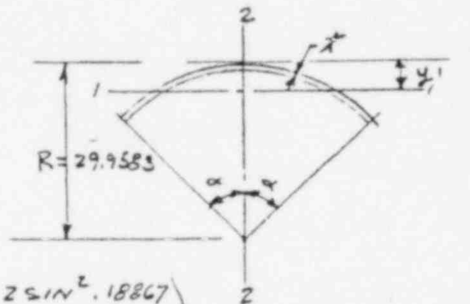
$\alpha = 0.18867$ RAD
$2\alpha = 0.37734$ RAD.

$A_2 = 2\alpha R t$

$A_2 = 2\frac{(10.81)}{360}(2\pi)(30)(.75) = 8.49 FT^2$

$y_1 = R(1 - \frac{\sin\alpha}{\alpha})$

$y_1 = 30(1 - \frac{\sin .18867}{.18867}) = 0.1777$



$I_1 = R^3 t(\alpha + \sin\alpha\cos\alpha - \frac{2\sin^2\alpha}{\alpha})$

$I_1 = 30^3(.75)(.18867 + \sin .18867 \cos .18867 - \frac{2\sin^2 .18867}{.18867})$

$I_1 = 30^3(.75)[.18867 + .18422 \quad - .37288]$

$I_1 = 0.2025 FT^4$

$I_2 = R^3 t(\alpha - \sin\alpha\cos\alpha)$

$I_2 = 30^3(.75)(.18867 - \sin .18867 \cos .18867)$

$I_2 = 90.02 FT^4$

FOR FULL CIRCLE

$A = \frac{\pi}{4}(d_o^2 - d_i^2) = 139.4082 FT^2$

$I = \frac{\pi}{64}(d_o^4 - d_i^4) = 61013.0828 FT^4$

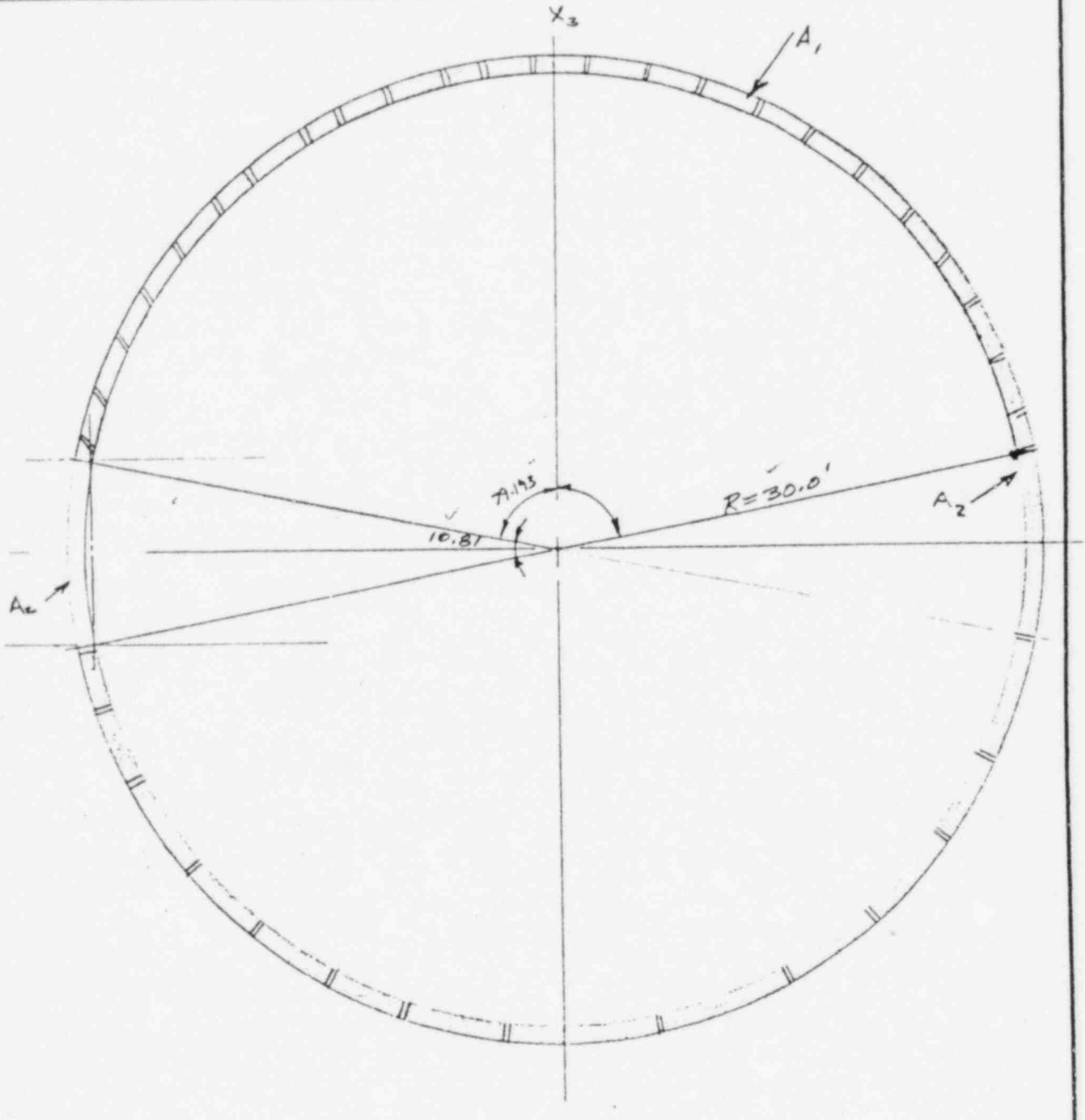
PROPERTIES FOR SECTION

$A = 139.41 - 8.49 FT^2 \quad \underline{130.92 FT^2}$

$I_{x2} = 61013.08 - 90.02 = \underline{60923.06 FT^4}$

$I_{x3} = 61013.08 - 0.20 - 8.49(29.781)^2 = \underline{53483.03 FT^4}$

OUTTER SHIELD BLDG. | REF.



NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY RR DATE 5-1-79 PROJ. 5101 TASK 026
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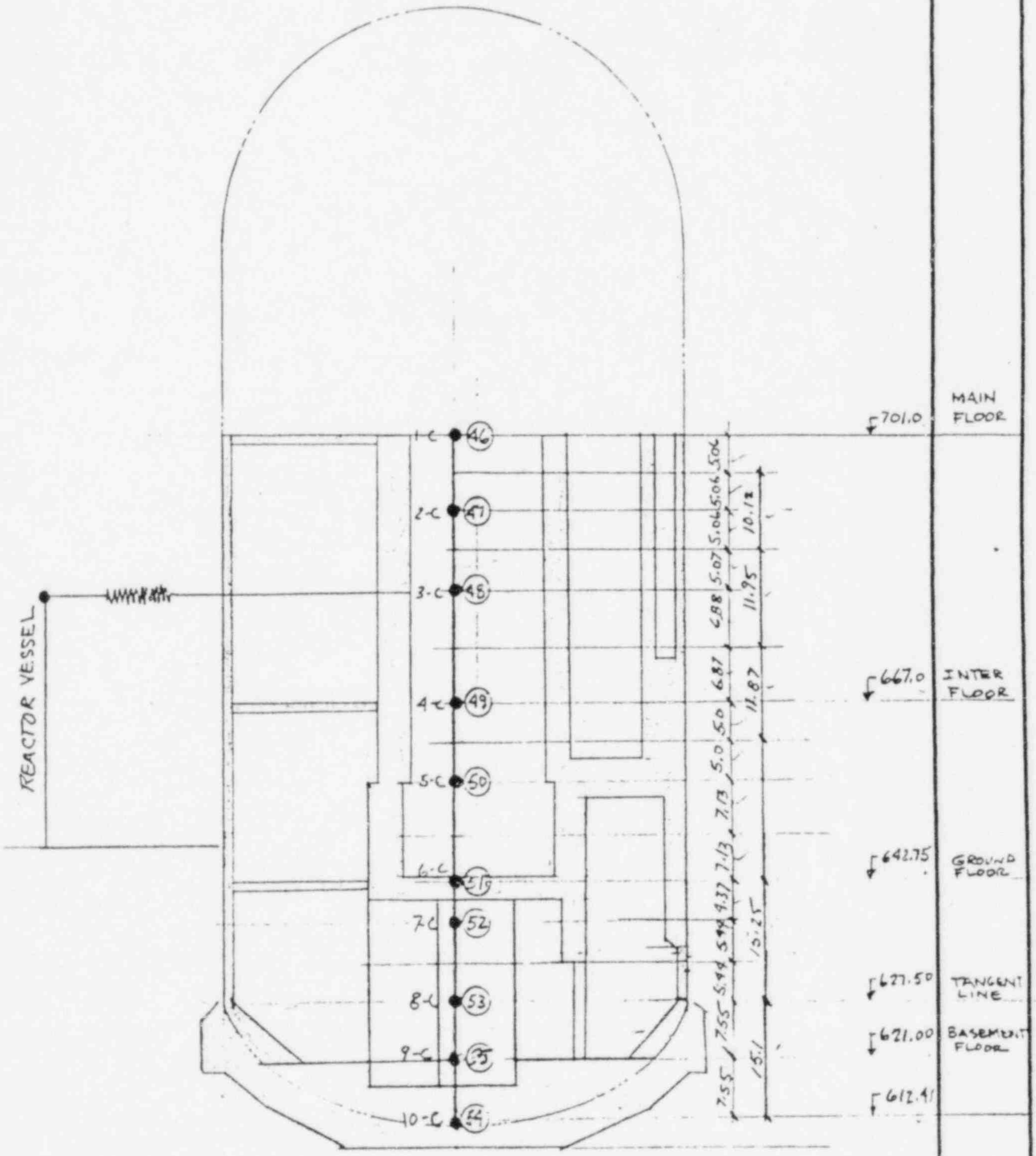
INNER SHIELD BLDG	REF.

MODEL



Summary For Inner Shield Bldg

	NODE No	TRIBUTARY WEIGHT	LIVE LOAD	AREA (IN²)	I_{x2} x10⁸	I_{x3} x10⁸	K x10⁸	SF2.	SF3.
46	1-C	909.44^k	1065.01^k	7.3028 x10⁴	5.3114	11.7458	5.9788	0.527	0.706
47	2-C	923.75^k	——	7.3028 x10⁴	5.3114	11.7458	5.9788	0.527	0.706
48	3-C	1116.31^k FUEL 71.50 > (1187.81)	——	7.3028x10⁴	5.3119	11.7458	5.9788	0.527	0.706
49	4-C	1460.17^k FUEL 143.00 > (1603.17)	603.94^k	8.9232x10⁴	6.4939	15.9625	6.9977	0.520	0.635
50	5-C	892.77 FUEL 171.50 > (1064.27)	——	8.7783x10⁴	11.5807	14.8361	11.0547	0.433	0.477
51	6-C	1330.18^k	640.32^k	7.0205x10⁴	16.8304	19.7665	3.0733	0.786	0.703
52	7-C	557.53	——	7.0205x10⁴	16.8304	19.7665	3.0733	0.786	0.703
53	8-C	527.67		5.4972x10⁴	12.4895	19.0501	0.2726	0.764	0.759

REF.

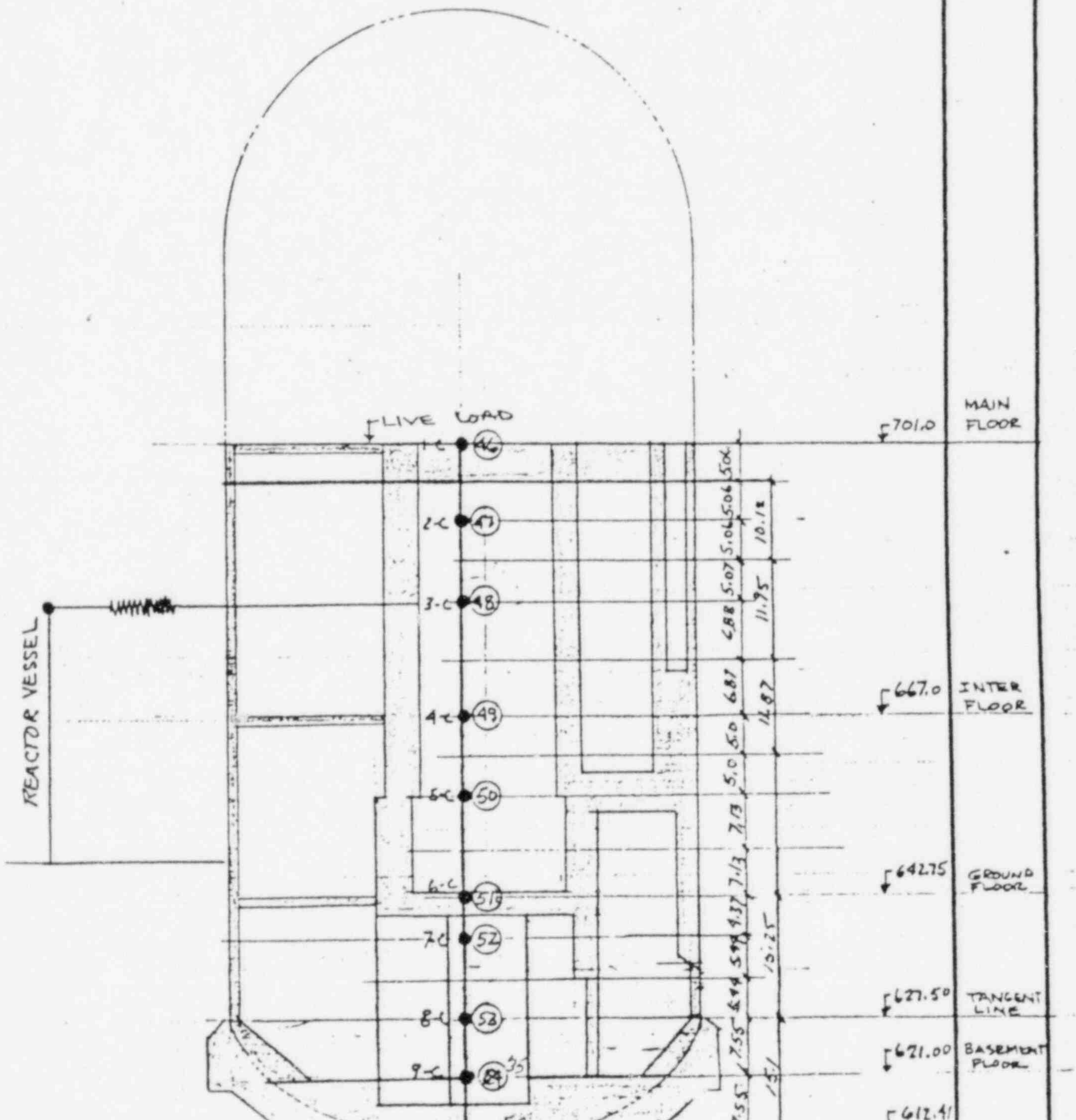
INNER SHIELD BLDG

REF.

NODE 1-C

INNER SHIELD BLDG NODE (1-c) | REF.

MODEL



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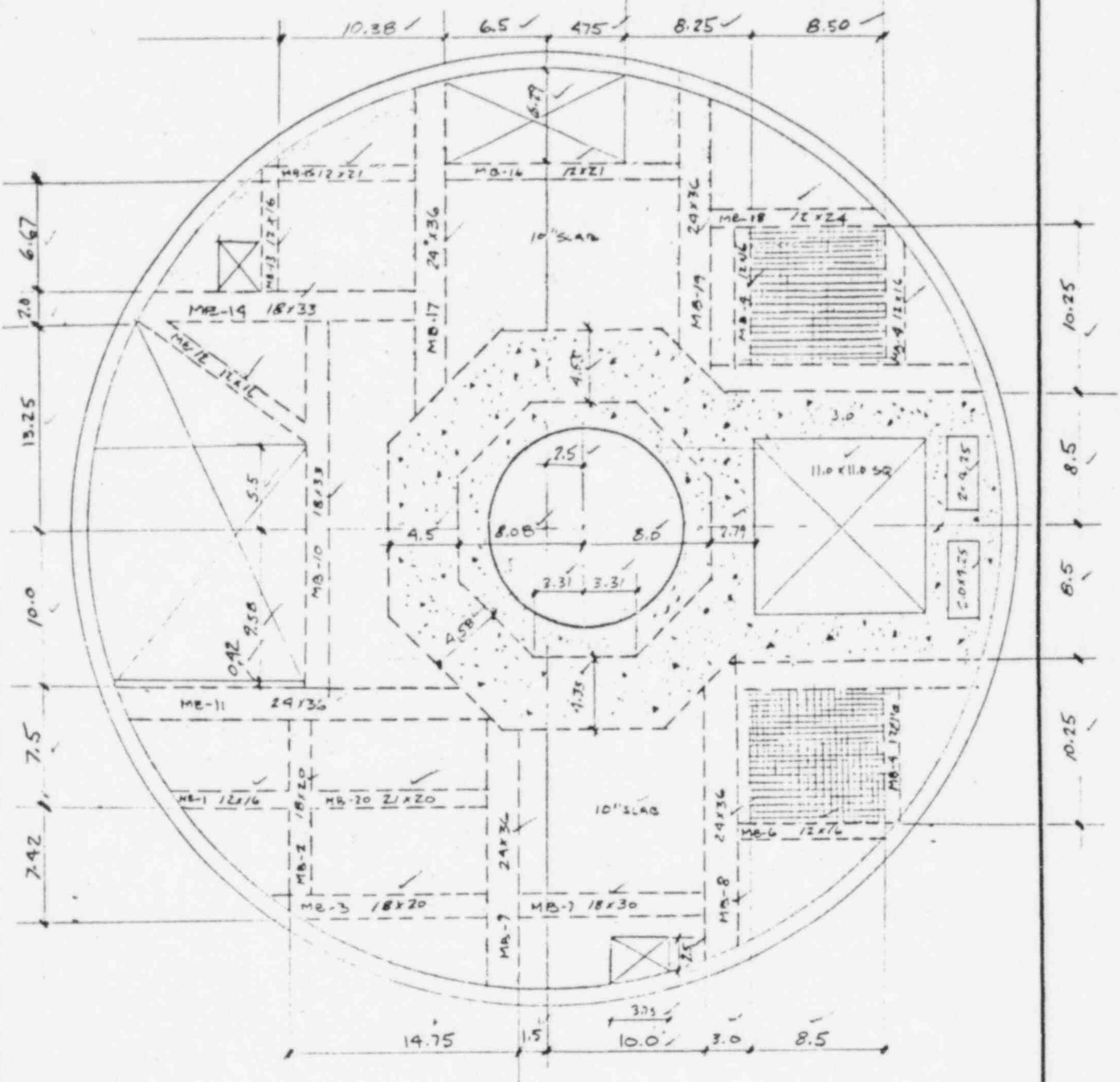
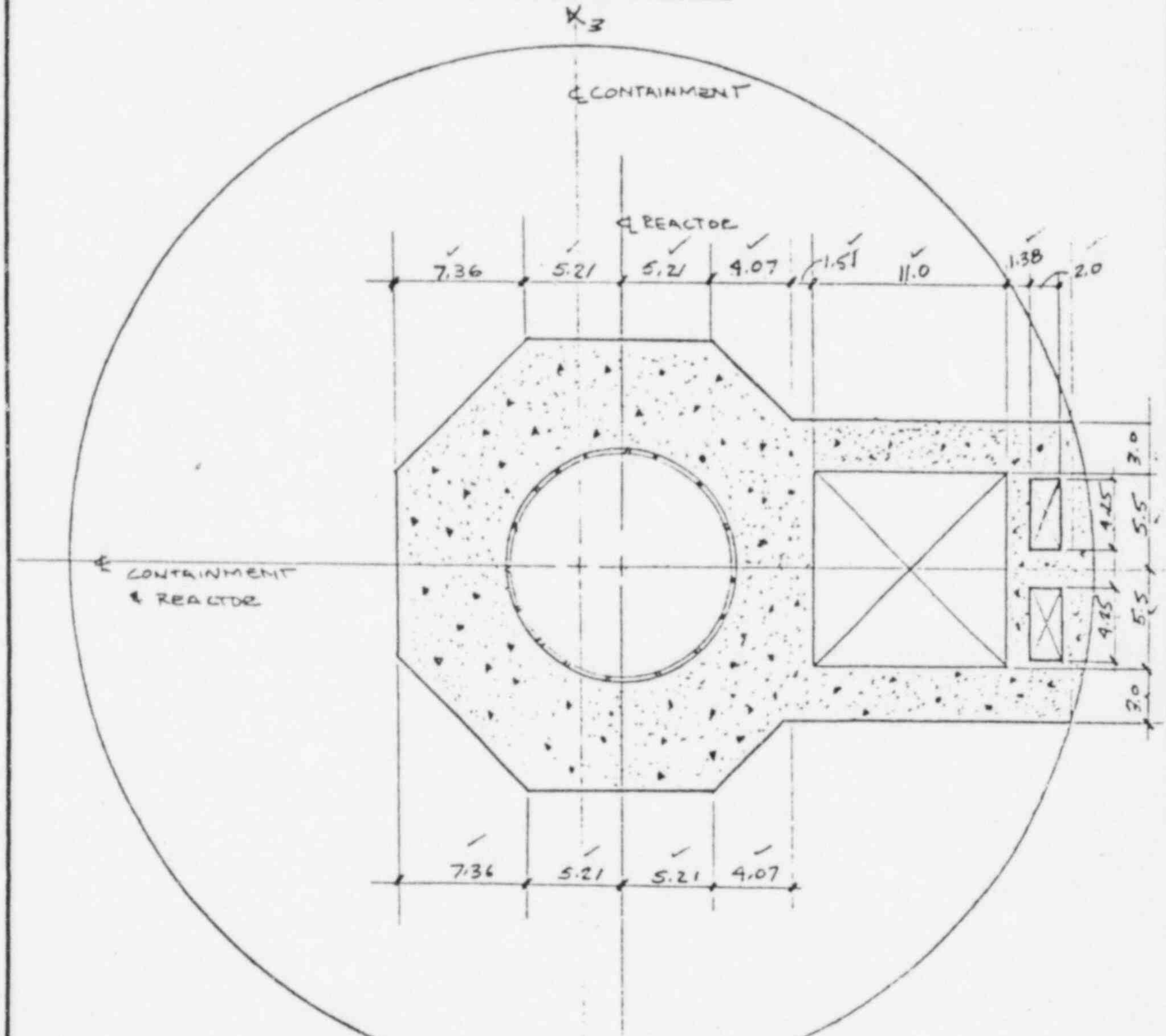
INNER SHIELD BLDG (WEIGHTS MAIN FLOOR NODE 1-C)	REF.



INNER SHIELD BLDG (NODE 1-C) | REF.

PROPERTIES FOR NODE 1-C

DWG 41-503443



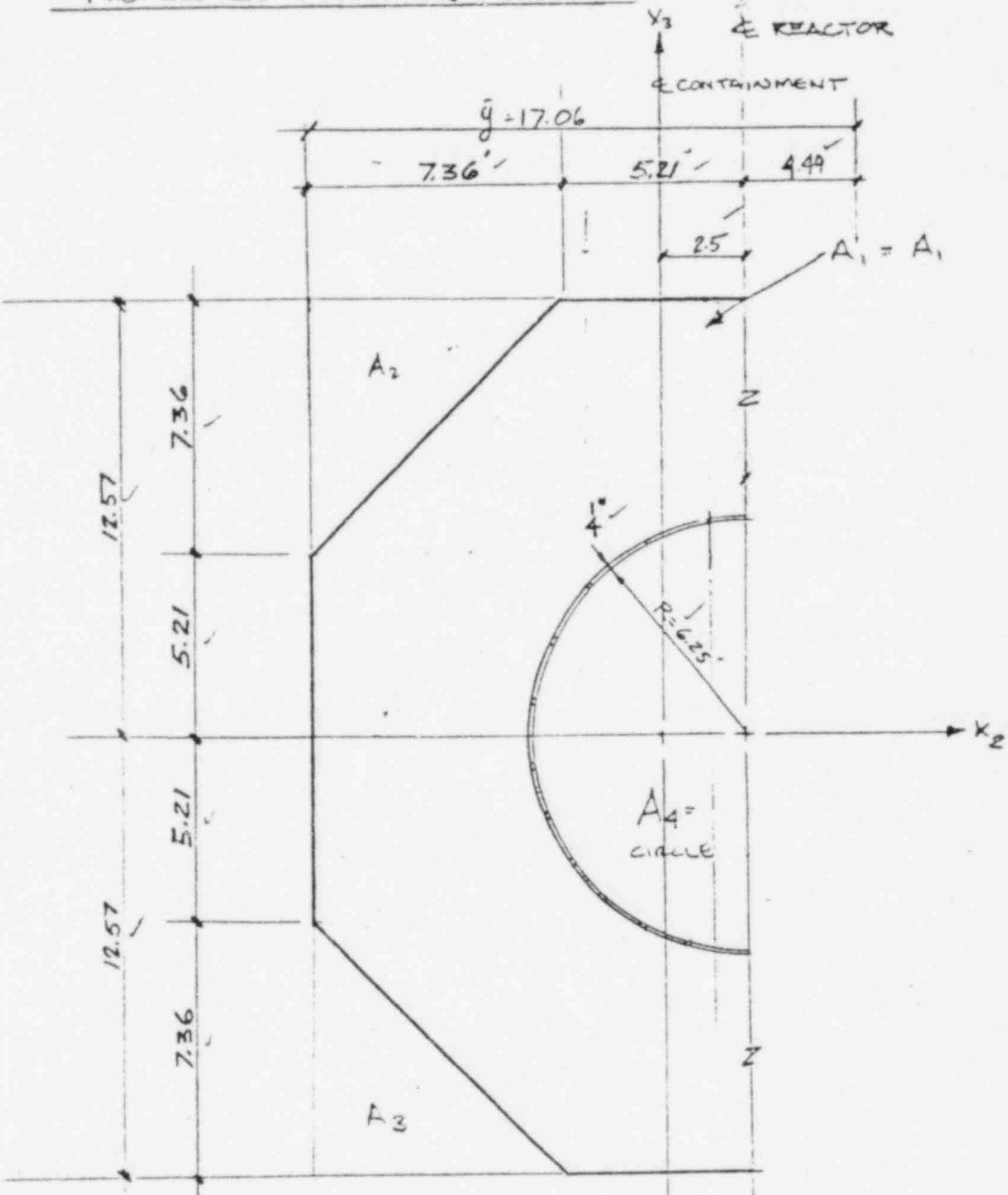
$H_2 = (30 - 7)2 \times 12 = 552''$

$H_3 = 2($[illegible]$) \times 12 = 301.7''$

$C_{73} = \frac{301.7}{2} = 150.85''$

INNER SHIELD BLDG	NODE 1-C	REF.
		DWG 41-503458

PROPERTIES FOR MAIN FLOOR

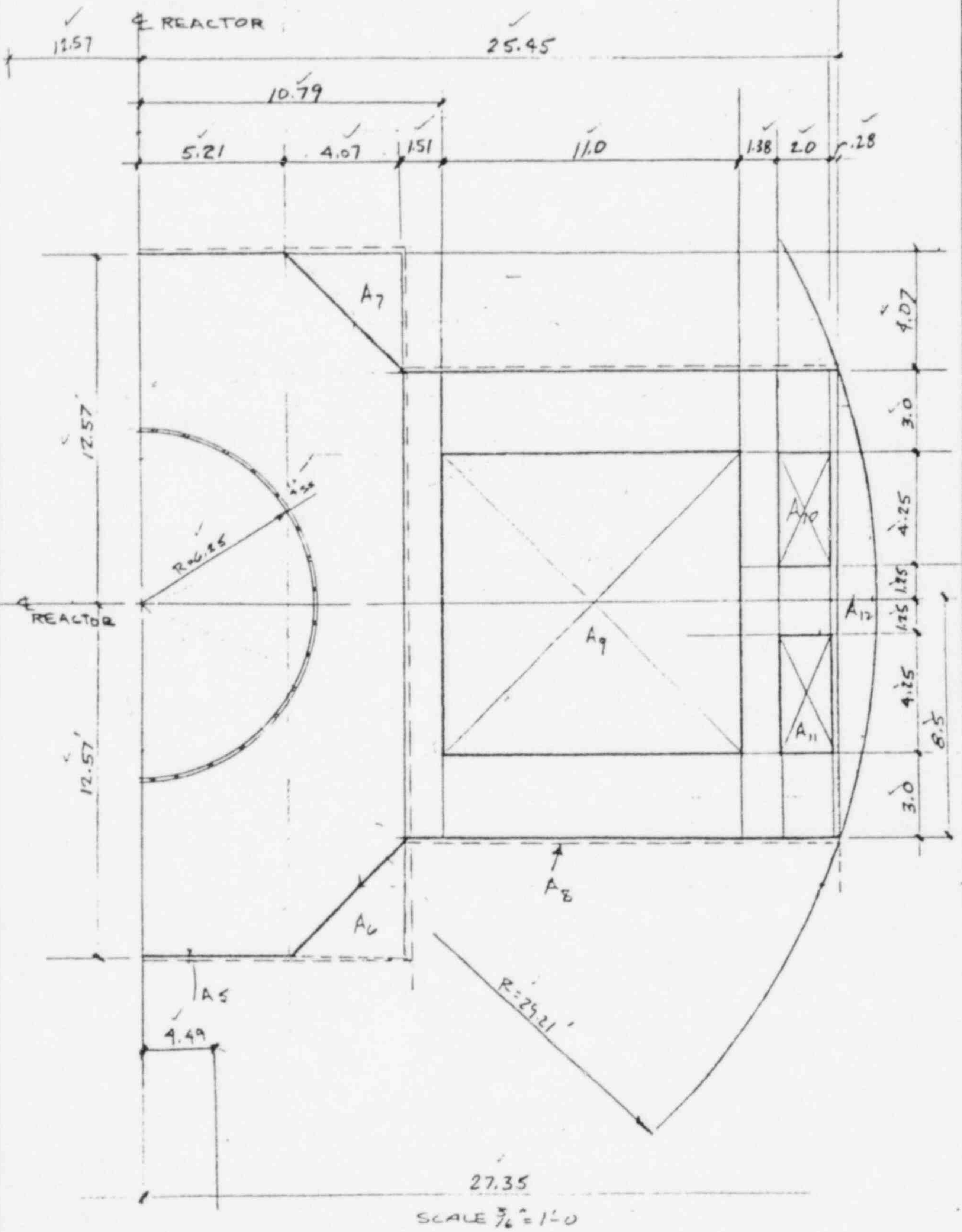


RED INDICATES OPENINGS &
NEGATIVE AREAS

SCALE 3/16" = 1'-0

INNER SHIELD BLDG.	NODE 1-C	REF.

PROPERTIES FOR MAIN FLOOR



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INNER SHIELD BLDG. MODE 1-C | REF.

PROPERTIES FOR MAIN FLOOR

	AREA	b	h	d_{x2}	d_{x3}
REC	+ A1	12.57 ✓	25.14 ✓	0 ✓	3.79 ✓✓
TRI	− A2	7.36 ✓	7.36 ✓	10.12 ✓	7.61 ✓✓
TRI	− A3	7.36 ✓	7.36 ✓	10.12 ✓	7.61 ✓✓
CIR	− A4	R=6.25 ✓		0 ✓	2.5 ✓
REC	+ A5	9.28 ✓	25.14 ✓	0 ✓	7.14 ✓
TRI	− A6	4.07 ✓	4.07 ✓	11.21 ✓	10.92 ✓
TRI	− A7	4.07	4.07 ✓	11.21 ✓	10.42 ✓
REC	+ A8	16.17 ✓	17.00 ✓	0 ✓	19.87 ✓
REC	− A9	11.00	11.00 ✓	0 ✓	18.79 ✓
REC	− A10	2.00	4.25 ✓	3.38 ✓	26.67 ✓
REC	− A11	2.00	4.25 ✓	3.38 ✓	26.67 ✓
CIR	+ A12	R=29.21 ✓	$\frac{1}{2}$CHORD=8.5 ✓	0 ✓	25.96 ✓

R = 6.25 ✓

CIRCLE − $A = \pi R^2 = 122.72\ FT^2$ ✓ AISC

$I = .785398 R^4 = 1198.42\ FT^4$ ✓

7P5278

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INNER SHIELD BLDG. (PROPERTIES FOR MAIN FLOOR) (NODE 1-2)

AREA	d_{x2}	I_{x2}	Ad^2_{x2}	$I_{x2}+Ad^2_{x2}$	d_{x3}	I_{x3}	Ad^2_{x3}	$I_{x3}+Ad^2_{x3}$	REF.
A_1 = 316.01	0	16643.70	0	16643.70	3.79	4160.92	4539.20	8700.12	
– A_2 = 27.08	-10.12	81.51	2773.87	-2855.38	7.61	81.51	1568.53	-1650.04	
– A_3 = 27.08	10.12	81.51	2773.87	-2855.38	7.61	81.51	1568.53	-1650.04	
– A_4 = 127.72	0	1198.42	0	-1198.42	2.5	1198.42	767	-1965.42	1195.42
A_5 = 233.30	0	12287.47	0	12287.47	7.14	1679.28	11893.50	13567.78	
– A_6 = 8.28	11.21	7.62	1040.50	-1048.42	10.42	7.62	899.01	-906.63	
– A_7 = 8.28	11.21	7.62	1040.50	-1048.42	10.42	7.62	899.01	-906.63	
A_8 = 274.89	0	6620.27	0	6620.27	19.87	5989.60	108531.21	114520.82	
– A_9 = 121.00	0	1220.08	0	-1220.08	18.79	1220.08	42720.76	-43940.84	
– A_{10} = 8.50	3.38	12.79	97.11	-109.90	26.67	2.83	6045.96	-6048.79	
– A_{11} = 8.5	3.38	12.79	97.11	-109.90	26.67	2.83	6045.96	-6048.79	
A_{12} = 14.38	0	208.98	0	208.98	25.96	1.57	9690.99	9692.56	
507.14				25314.52				~~83367.10~~ SEE NEXT SHEET	

A = 507.14 FT^2 — 7.303×10^4 IN^2

I_{x2} = 25314.52 FT^4 — 5.3114×10^8 IN^4

I_{x3} = 56649.66 FT^4 FROM NEXT SHT — 11.7458×10^8 IN^4

K = 28833.18 FT^4 — 5.9788×10^8

SF2 = 0.527

SF3 = 0.706

INNER SHIELD BLDG. (FOR EXCENTRIC MODEL) (NODE 1-C) | REF.

No Area	Area	$\bar{y}$	$A\bar{y}$	dx_3	Adx_3^2	$I_{x_1}+Adx_3^2$
A_1	316.01	6.29	1987.70	10.77	36654.92	40815.84
A_2	-27.08	2.45	-66.35	14.61	-5780.28	-5861.79
A_3	-27.08	2.45	-66.35	14.61	-5780.28	-5861.79
A_4	-122.72	12.57	-1542.59	4.49	-2474.05	-3672.47
A_5	233.30	17.21	4015.09	0.15	5.25	1203.67
A_6	-8.28	20.49	-169.66	3.43	-97.41	-1771.69
A_7	-8.28	20.49	-169.66	3.43	-97.41	-1771.69
A_8	274.89	29.94	8230.21	12.88	45602.71	51592.31
A_9	-121.00	28.86	-3492.06	11.80	-16848.09	-18068.12
A_{10}	-8.50	36.74	-312.29	19.68	-3292.07	-3294.9
A_{11}	-8.50	36.74	-312.29	19.68	-3292.07	-3294.9
A_{12}	14.38	38.53	554.06	21.47	6628.62	6620.19
	$\Sigma A = 507.14$		$\Sigma A\bar{y}$ 8655.81			$I_{x_3} = 56644.66\ FT^4$

$$\bar{y} = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{8655.81}{507.14} = 17.06'$$

CENTROID LIES 6.99 FT TO RIGHT SIDE OF CENTERLINE CONTAINMENT VESSEL SHELL

USE 7.0' = 84" ✓

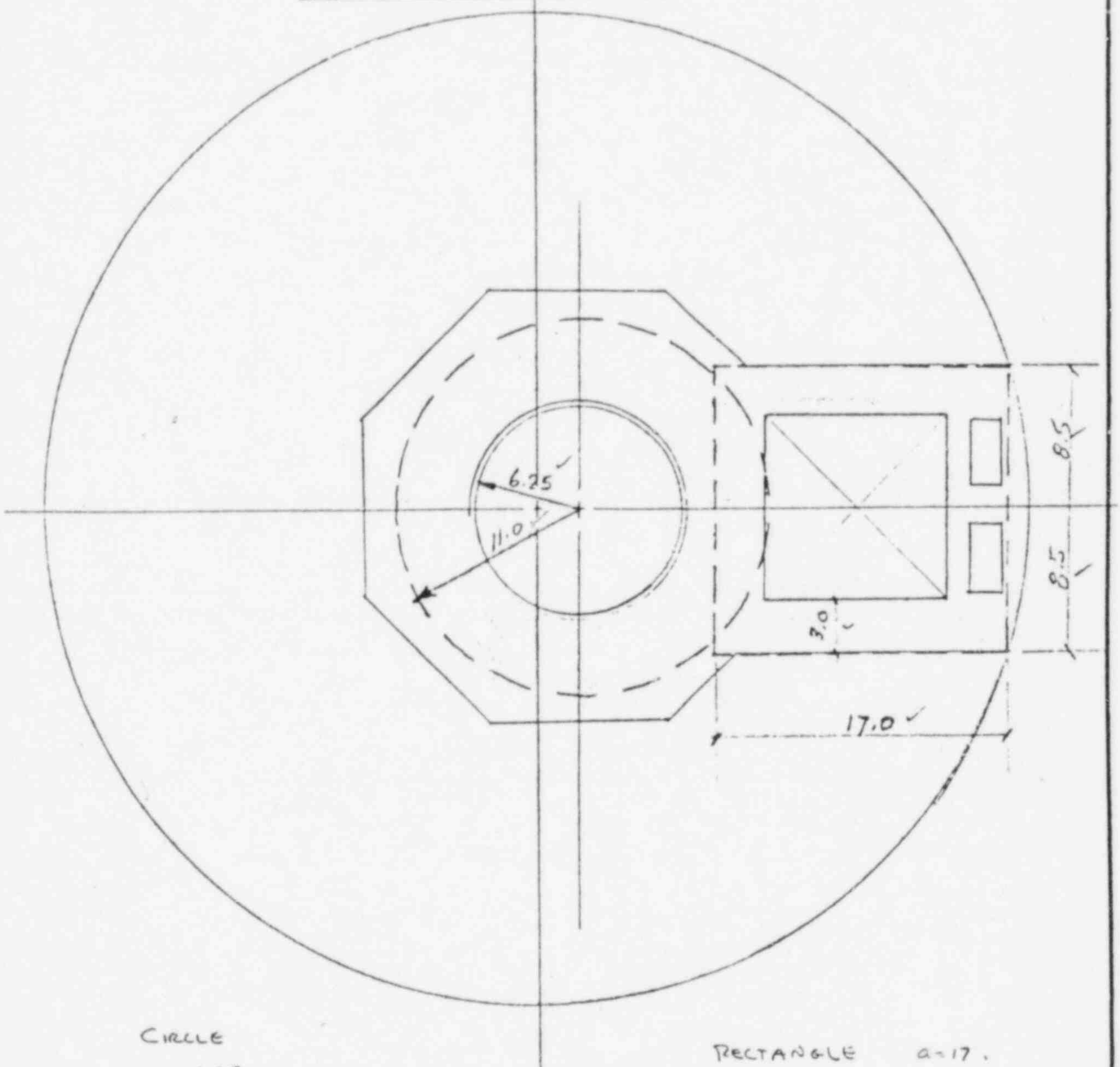
PROPERTIES FOR EXCENTRIC MODEL

AREA = 507.14 FT^2 ✓

I_{x_3} = 56644.66 FT^4

INNER SHIELD BLDG (NODE 1-C) | REF.

N-S TORSIONAL CONSTANT



CIRCLE
$r_i = 6.25$
$r_o = 11.0$

$K_{CIR} = \frac{1}{2}\pi(r_o^4 - r_i^4) = 20601.18\ FT^4$

RECTANGLE $a = 17$
$t = t_1 = 3.0$ $b = 17$

$$K_{REC} = \frac{2tt_1(a-t)^2(b-t_1)^2}{at + bt_1 - t^2 - t_1^2}$$

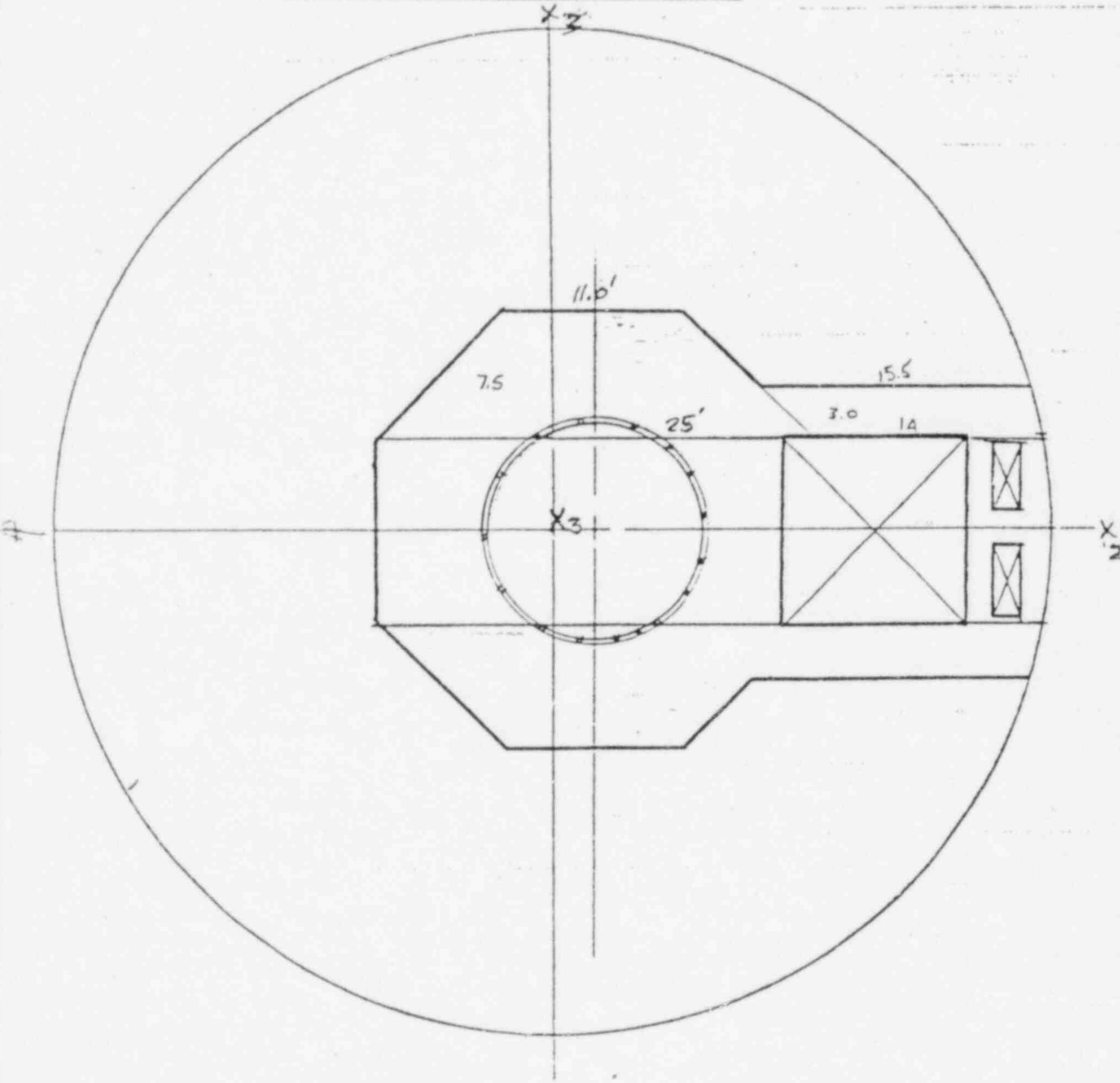
$$K_{REC} = \frac{2(3)^2(17-3)^2(17-3)^2}{17(3) + 17(3) - 3^2 - 3^2}$$

$K_{REC} = 8232\ FT^4$

$K_{TOTAL} = 28833.18\ FT^4$

INNER SHIELD BLDG (NODE 1-C) | REF.

SHEAR AREA FACTOR



TOTAL AREA = 507.14 ft²

SHEAR AREA FOR X_3 EARTHQUAKE

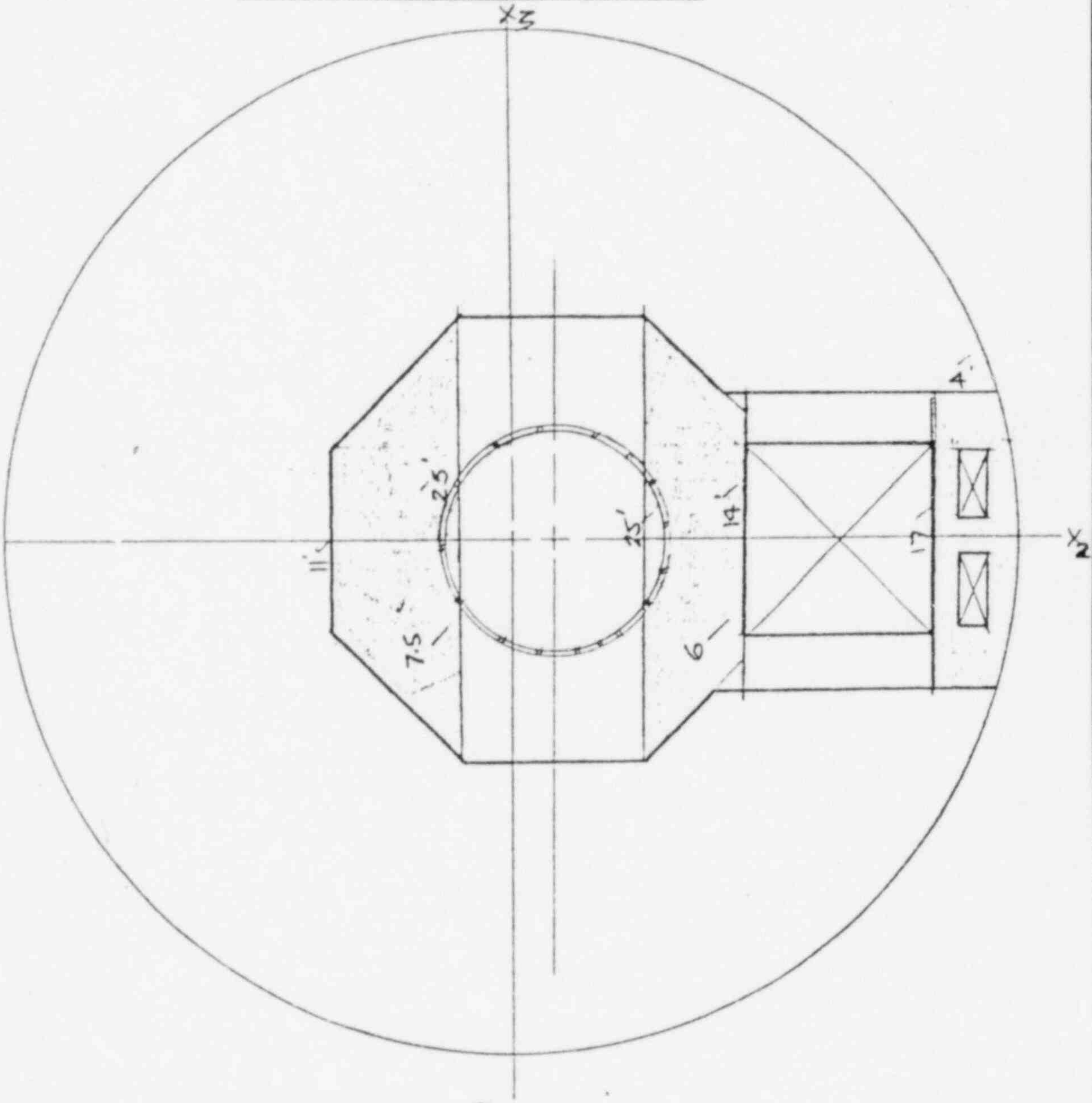
$$2\ A_{x_3} = \tfrac{1}{2}(25+11)(7.5) = 135$$
$$= \tfrac{1}{2}(15.5+14)(3.0) = \frac{44.25}{2(179.25\ \text{ft}^2)} = 358$$

$$S.F.3 = \frac{358.0}{507.14} = 0.706$$

SF3 = 0.706

INNER SHIELD BLDG (NODE 1-C) | REF.

SHEAR AREA FACTOR



TOTAL AREA = 507.19 ft²

SHEAR AREA FOR X_2 EARTHQUAKE

$A_{X2} = \frac{1}{2}(11+25)(7.5) = 99.25$
$\frac{1}{2}(14+25)(6) = 117.00$ ✓
$(17)(4) - 2(2\times4.25) = 51.00$ ✓
267.25

$S.F.2 = \frac{267.25}{507.19} = 0.527$

SF2 = 0.527

NODE 1-C | REF.

CENTER OF MASS CALCULATION

DEAD LOAD

	WEIGHT	X_3	WX_3
POOL WATER	38.21 ✓	18.79' ✓	717.97 ✓
CORE WATER	38.75	2.5' ✓	96.88 ✓
CORE	383.65 ✓	6.99' ✓	2681.71 ✓
PLUGS	186.00 ✓	2.5 ✓	465.00 ✓
	646.61 ✓		3961.56 ✓

$$X_3 = \frac{3961.56}{646.61} = 6.13^{FT}$$ ✓

INNER SHIELD BLDG. (NODE 1-C) | REF.

PROPERTIES FOR MAIN FLOOR

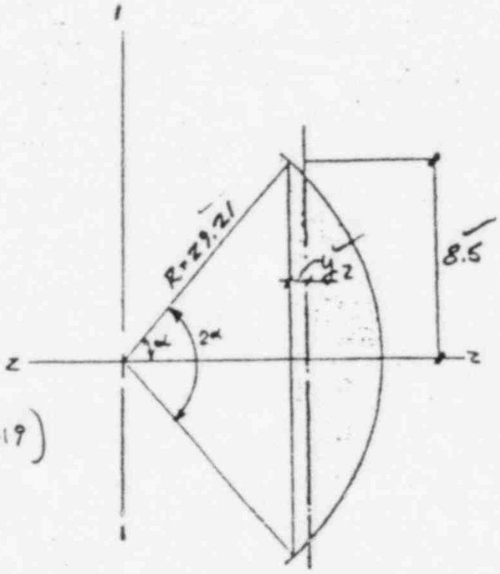
$\frac{1}{2}$ CHORD LENGTH = 8.5'
RADIUS = 29.21'

$A_{12} = \frac{1}{2}R^2(2\alpha - \sin 2\alpha)$

$\alpha = 16.91$

$\alpha = 16.91 \frac{2\pi}{360} = 0.295268$

$A = 14.38 \ FT^2$ ✓



$y_2 = R\left(\frac{4\sin^3\alpha}{6\alpha - 3\sin 2\alpha} - \cos\alpha\right)$

$y_2 = (29.21)\left(\frac{0.0985649}{1.771608 - 1.670919} - 0.95672419\right)$

$y_2 = 0.5066 \ FT$ ✓

$2\alpha = 0.590536$ $\cos\alpha = 0.956724$
$\sin\alpha = 0.2909963$ $\sin 2\alpha = 0.556806$ $\sin^3\alpha = 0.0246412$

$I_2 = R^4\left[\frac{1}{8}(2\alpha - \sin 2\alpha) - \frac{1}{12}\left(\frac{(2\alpha - \sin 2\alpha)\sin^3\alpha\cos\alpha}{\alpha - \sin\alpha\cos\alpha}\right)\right]$

$I_2 = 29.21^4\left[\frac{1}{8}(0.03373) - \frac{1}{12}\left(\frac{(0.03373)(0.0235748)}{0.01686486}\right)\right]$

$29.21^4[(0.00421625) - (0.00392917)]$

$I_2 = 208.99$ ✓

$I_1 = R^4\left[\frac{1}{8}(2\alpha - \sin 2\alpha)\left(1 + \frac{2\sin^3\alpha\cos\alpha}{\alpha - \sin\alpha\cos\alpha}\right) - \frac{8}{9}\frac{\sin^6\alpha}{(2\alpha - \sin 2\alpha)}\right]$

$I_1 = 29.21^4\left[(0.00421625)\left(1 + \frac{0.0471497054}{0.0168648364}\right) - \frac{.000539742}{0.0337296728}\right]$

$I_1 = 29.21^4\left[0.00421625)(3.795740453) - 0.160014656\right]$

$I_1 = 1.63 \ FT^4$

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INNER SHIELD BLDG. (WEIGHTS MAIN FLOOR NODE 1-C) | REF.

BEAM WEIGHTS — ASSUME 7" SLAB & PROGRAM FOR BEAM WEIGHTS

QUAN.	BEAM No	SIZE	LENGTH	WEIGHT	X_2	X_3
1	MB-1	12x16 ✓	7.5 ✓	0.844		
1	MB-2	18x20 ✓	12.75 ✓	3.108 ✓		
1	MB-3	18x20 ✓	11.00 ✓	2.681 ✓		
3	MB-4	12x16 ✓	7.75 ✓	2.616 ✓		
—	MB-5	— ✓	— ✓			
1	MB-6	12x16	9.50 ✓	1.069 ✓		
1	MB-7	18x30	12.00	5.175 ✓		
1	MB-8	24x36 ✓	18.00 ✓	13.050 ✓		
1	MB-9	24x36	16.75 ✓	12.144 ✓		
1	MB-10	18x33 ✓	23.50 ✓	11.456 ✓		
1	MB-11	24x36 ✓	22.50 ✓	16.313 ✓		
1	MB-12	12x16 ✓	12.50	1.406		
1	MB-13	12x16	7.33 ✓	0.825		
1	MB-14	18x33 ✓	17.16 ✓	8.366 ✓		
1	MB-15	12x21 ✓	10.00 ✓	1.750 ✓		
1	MB-16	12x21 ✓	15.00 ✓	2.625		
1	MB-17	24x36	20.50 ✓	14.863 ✓		
1	MB-18	12x29	12.25 ✓	2.603 ✓		
	MB-19	24x36	17.00 ✓	12.325 ✓		
				113.219^k TOTAL BM. WT.		

INNER SHEILD BLDG WEIGHTS MAINFLOOR | REF.

LARGE NORTHERN OPENING

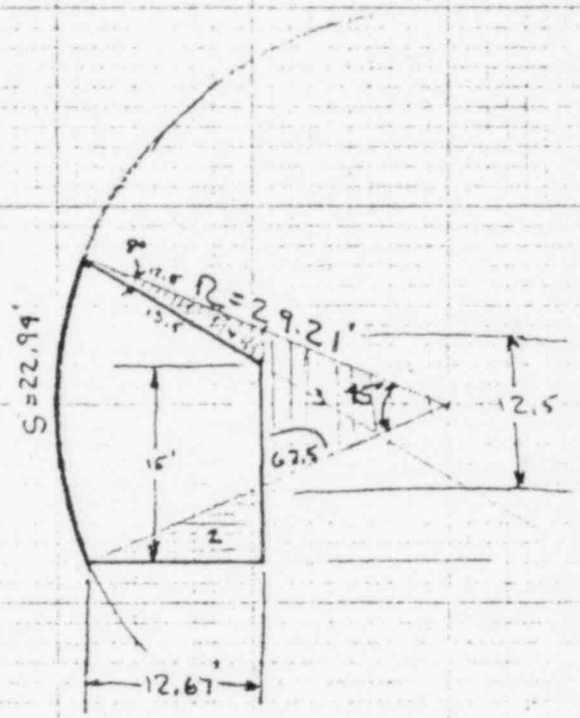
$S = \frac{\pi}{4}(29.21) = 22.99'$

AREA OF SECTOR
335.06

AREA OF OBTUSE Δ_1
= 11.74

AREA OF RIGHT Δ_2
= 28.125

AREA OF 67.5 - 45 - 67.5 Δ_3
= 94.31



AREA OF OPENING

335.06
- 11.74
+ 28.125
- 94.31

257.14'

PERTANENT FORMULII ARE
$S = r\theta$
SECTOR AREA = $\frac{Sr}{2}$
AREA OF OBTUSE Δ

$\sqrt{s(s-a)(s-b)(s-c)}$
WHERE $s = \frac{a+b+c}{2}$

AREA OF OTHER Δ's = $\frac{bh}{2}$

INNER SHIELD BLDG (WEIGHTS MAINFLOOR NODE 1-C)	REF.

SLAB WEIGHT

TOTAL FLOOR AREA = $\pi R^2 = \pi(29.21)^2 = 2680.48^{\#}$

OPENINGS	$\frac{1}{2}(23+15) \times 13.5$	= 256.50
	3 × 2.67	= 8.01 ✓
	6.25 × 11.25	= 70.31 ✓
	7.0' × 7.5	= 52.50
	11 × 11	= 121.00 ✓
	7.0 × 7.5	= 52.50
	3 × 2.67	= 8.01 ✓
	3.75 × 2.75	= 10.30 ✓
10" SLAB	10 × 15	= 150.00 ✓
	10 × 12	= 120.00 ✓
CORE AREA		= 507.14 ✓
		1356.27

7" SLAB WEIGHT = $(2680.48 - 1356.27)(\frac{7}{12})(.150) = 115.87$ K

10" SLAB WEIGHT = $(270)(.15)(\frac{10}{12}) = 33.75^{k}$ ✓

TOTAL SLAB WEIGHT = 149.61^{k} ✓

INNER SHIELD BLDG. (WEIGHTS MAIN FLOOR NODE 1-C)	REF.

CORE CONCRETE

AREA FROM PREVIOUS CALCULATIONS = 505.47 FT^2
HEIGHT OF CONCRETE = 5.06' ✓

WEIGHT = (505.47)(5.06)(.150) = 383.65 K ✓

CONCRETE PLUG A, B & C
FROM DWG 41-503464

WT WATER = (11 × 11 × 5.06) 0.0624) = 38.21 k ✓
(5.06) π 6.25^2) (0.0624) 38.75 ✓
76.96 k ✓

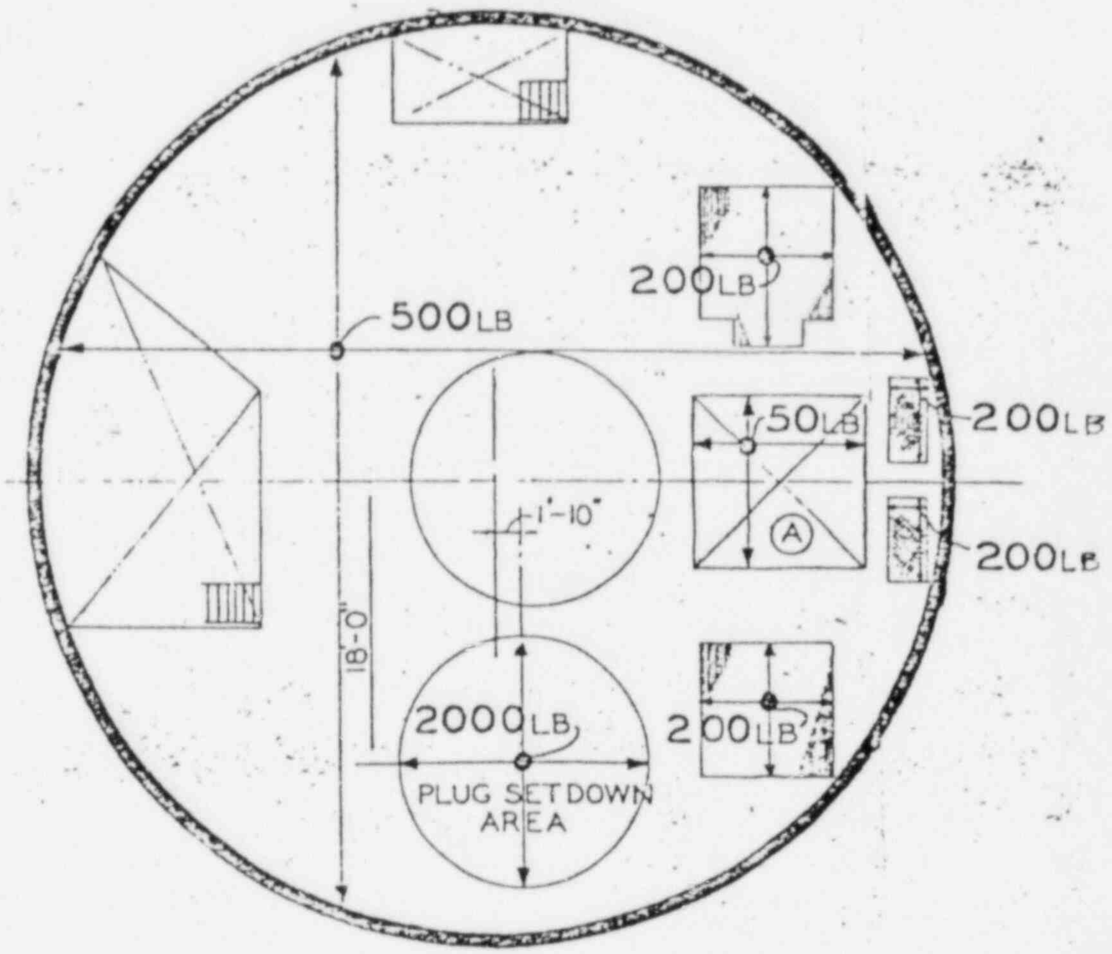
A = 64 k ✓
B = 62 k ✓
C = 60 k ✓

TOTAL PLUGS	= 186 k ✓
CORE	383.65 k ✓
SLABS	149.61 k ✓
BEAMS	113.22 k ✓
WATER	38.21 ✓
	38.75 ✓
	909.44 k

TOTAL DEAD WEIGHT
FOR NODE 1C = 909.44 K ✓

(NODE 1-C) | REF.

LIVE LOAD



CONTAINMENT VESSEL
MAIN FLOOR
EL.701'-0"

FROM DWG 41-503477

MAIN FLOOR (NODE 1-C) | REF.

LIVE LOAD WEIGHTS

GRATING AREAS
AREA = 2x 10.25 x 8.5 = 174.25 ☐
LOAD = 200 PSF ✓ 34.85 K

OVER FUEL POOL
AREA 11 x 11 = 121 ☐ ✓
LOAD = 50 PSF = ✓ 6.05 K ✓

NEW FUEL
AREA = 2 x 2 x 4.25 = 17 ☐ ✓
LOAD 200 PSF 3.40 K ✓

TOTAL AREA = $\pi R^2 = \pi\ 29.21^2$
= 2680.48

SEE PREVIOUS CALC MISC OPENINGS = 256.50
70.31 ✓
326.81

NET AREA = 2680.48 - 326.81 ✓
- 174.25 ✓
- 121.00 ✓
- 17.00 ✓
NET AREA = 2041.42 ☐ ✓

LOAD = .500 PSF 1020.71 K ✓

1065.01 K TOTAL LIVE LOAD ✓

INNER SHIELD BLDG. (46) NODE 1-C | REF.

SUMMARY FOR NODE 1-C (46)

DEAD LOAD = 909.44^k ✓

LIVE LOAD = 1065.01^k ✓

Core Only:

AREA = $7.3028 \times 10^4 \, IN^2$

$\bar{X}_2$ = 84 IN ✓

I_{x2} = $5.3114 \times 10^8 \, IN^4$

I_{x3} = $11.7458 \times 10^8 \, IN^4$ ✓

K = $5.9788 \times 10^8 \, IN^4$ ✓

SF2 = 0.527 ✓

SF3 = 0.706 ✓

INNER SHIELD BLDG NODE 2-C	REF.
NODE 2-C	

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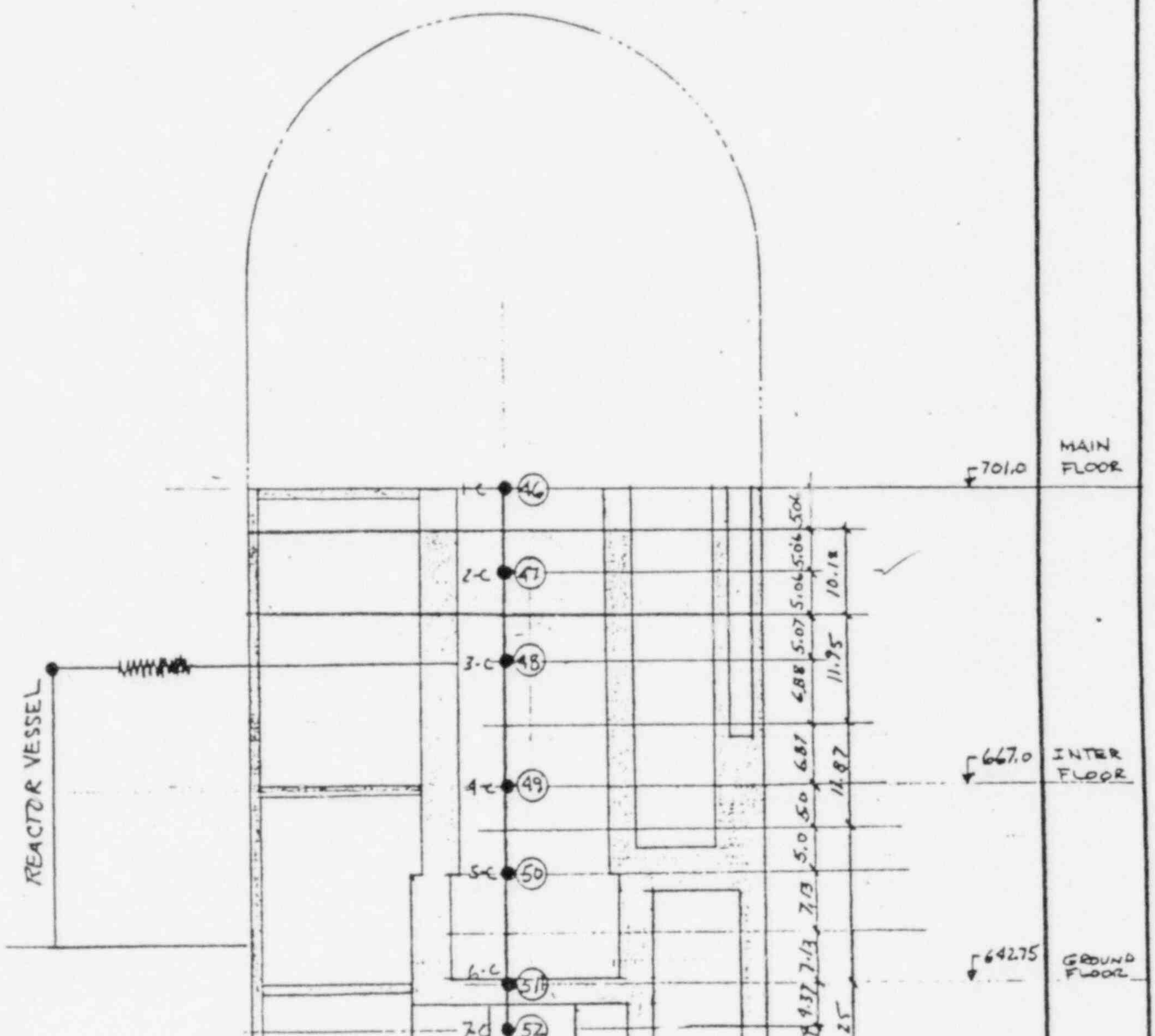
INNER SHIELD BLDG

REF.

MODEL



NODE 2-C	REF.

PROPERTIES – FROM NODE 1-C

$A = 507.14\ FT^2 = 7.3028 \times 10^4\ IN^2$

$I_{x2} = 25614.52\ FT^4 = 5.3114 \times 10^8\ IN^4$

$I_{x3} = 56694.66\ FT^4 = 11.7458 \times 10^8\ IN^4$

$K = 28833.18\ FT^4 = 5.9788 \times 10^8$

$SF2 = 0.527$

$SF3 = 0.706$

INNER SHIELD BLDG. NODE-2-C	REF.

CORE AREA IS APPROXIMATELY EQUAL TO THAT AT NODE 1-C.

AREA = 507.14 $^{\square'}$ ✓ LENGTH = 10.12' ✓

WEIGHT = 507.14 × 10.12 × .15 = 769.84^{K} ✓

WATER = 11 × 11 × 10.12 × .0624 = 76.41^{K} ✓

$\pi 6.25^2$ 10.12 × 0.0624 = 77.50^{K} ✓

923.75^{K} TOTAL WEIGHT ✓

INNER SHIELD BLDG (NODE 2-C) | REF.

CENTER OF MASS CALCULATION

DEAD LOAD	WEIGHT	X_3	WX_3
POOL WATER	76.41 ✓	18.79 ✓	1435.74 ✓
CORE WATER	77.50 ✓	2.5 ✓	193.75 ✓
CORE WT	769.84 ✓	6.99 ✓	5381.18 ✓
	923.75		7010.67 ✓

$$\bar{X}_3 = \frac{7010.67}{923.75} = 7.59^{FT}$$ ✓

INNER SHIELD BLDG. (47) NODE 2-C | REF.

SUMMARY FOR NODE 2-C (47)

DEAD LOAD = 923.75^{K}

LIVE LOAD = ———

AREA = $7.3028 \times 10^{4}\ IN^{2}$

$\bar{X}_2$ = 84 IN

I_{Y2} = $5.3119 \times 10^{8}\ IN^{4}$

I_{X3} = $11.7458 \times 10^{8}\ IN^{4}$

K = $5.9788 \times 10^{8}\ IN^{4}$

S.F.2 = 0.527

SF 3 = 0.706

INNER SHIELD BLDG NODE 3-C	REF.
NODE 3-C	

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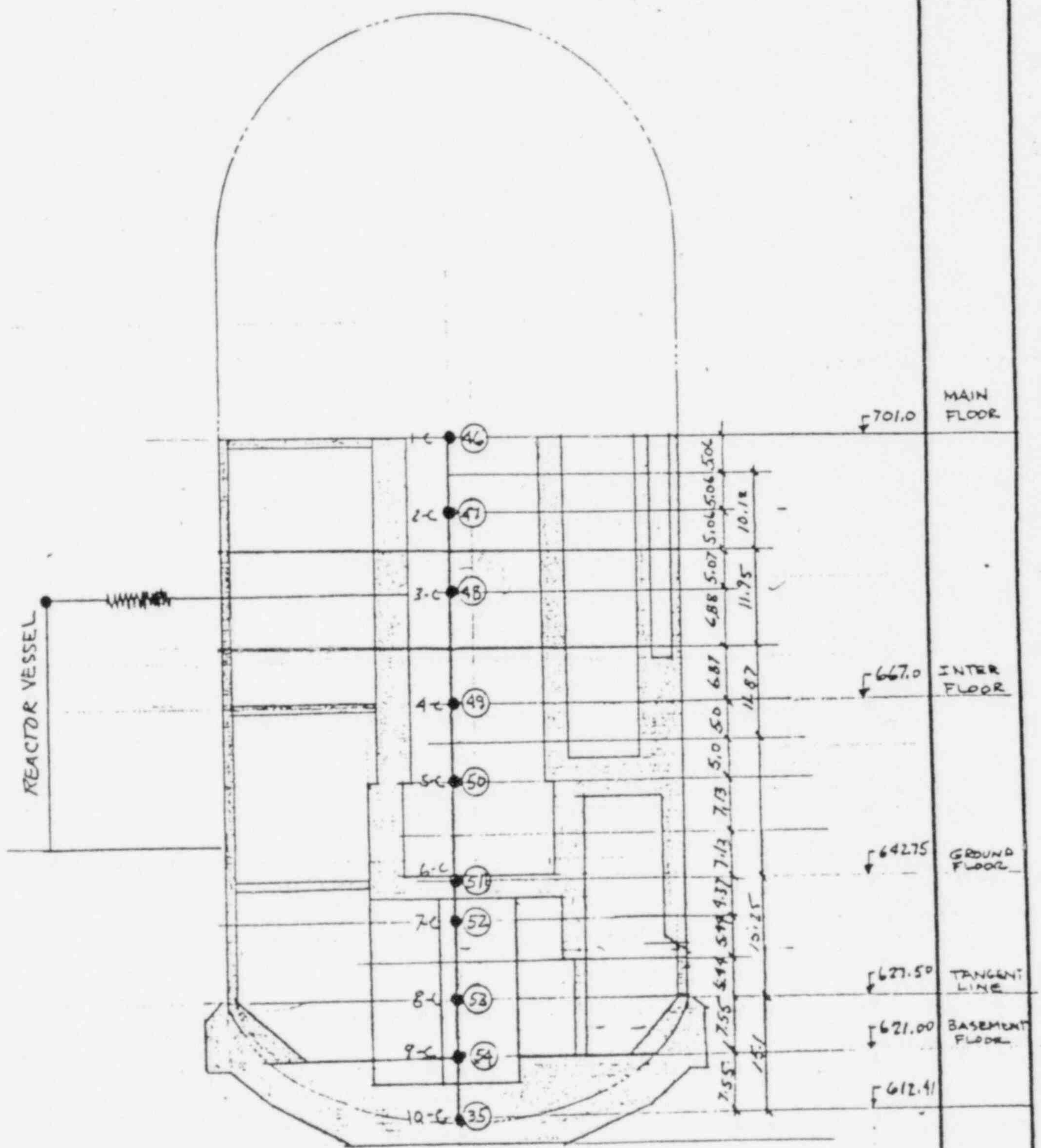
INNER SHIELD BLDG (NODE 3-C)	REF.

MODEL



NODE 3-C	REF.
PROPERTIES - FROM NODE 1-C	
✓ $A = 507.14\ FT^2 = 7.3028 \times 10^4\ IN^2$	
✓ $I_{x2} = 25614.52\ FT^4 = 5.3114 \times 10^8\ IN^4$	
$I_{x3} = 56644.66\ FT^4 = 11.7458 \times 10^8\ IN^4$	
✓ $K = 2883318\ FT^4 = 5.9788 \times 10^{10}\ IN^4$	
SF2 = 0.527	
✓ SF3 = 0.706	

INNER SHIELD BLDG. NODE 3-C	REF.
CORE AREA = TOP 5.07' SAME AS NODE 4-C $5.07 \times 507.14^{\#} \times .15 = 385.68^{k}$ ✓ BOTTOM 6.88 SAME AS NODE 4-C $6.88 \times 582.93^{\#} \times .15 = 601.58^{k}$ ✓ 987.26^{k} WATER $11 \times 11 \times 11.95 \times .0624 = 90.23^{k}$ ✓ $\pi 6.25^2 \times 5.07 \times .0624 = 38.82^{k}$ ✓ 1116.31^{k} TOTAL DEAD LOAD ✓ CORE PROPERTIES USE THOSE FROM 1-C	

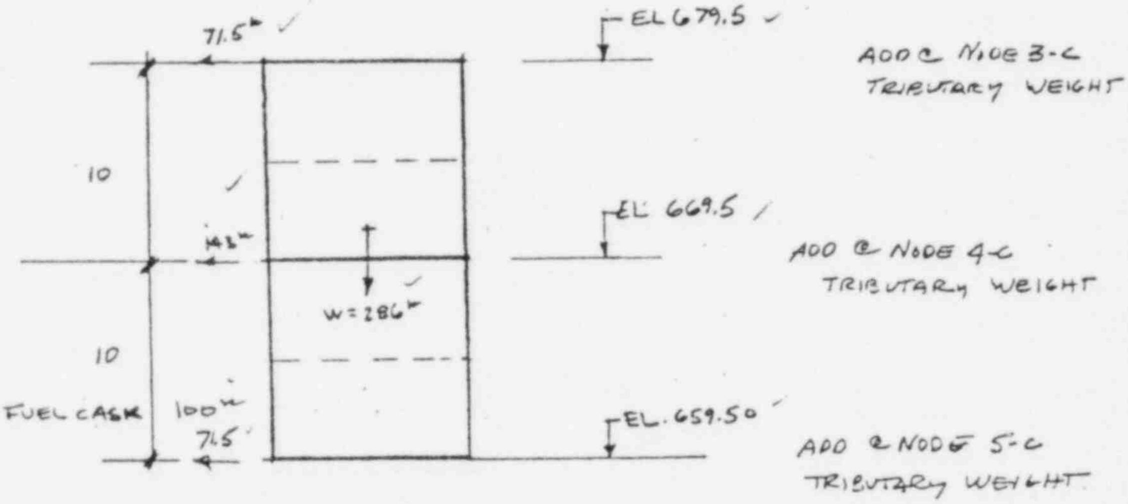
REF.

SPENT FUEL RACK

WEIGHT OF FUEL STORAGE RACK + FUEL = 286.0 K ✓
PRESSURE LOAD 0.026 K/IN²

CASK WEIGHT = 100K ✓

REF: "STRUCTURAL ANALYSIS REPORT FOR THE LACROSSE BOILING WATER REACTOR SPENT FUEL POOL STRUCTURE" BY NES INC



INNER SHIELD BLDG (NODE 3-C) | REF.

CENTER OF MASS CALCULATION

DEAD LOAD	WEIGHT	X_3	WX_3
POOL WATER	90.23 ✓	18.79 ✓	1695.42 ✓
CORE WATER	38.82 ✓	2.5 ✓	97.05 ✓
CORE WT.	385.68 ✓	-6.99 ✓	2695.90 ✓
	601.58	7.53	4525.53
SPENT FUEL	71.50 ✓	18.79 ✓	1343.49 ✓
	1187.81		10357.39

$$\bar{X}_3 = \frac{10357.39}{1187.81} = 8.72' \checkmark$$

INNER SHIELD BLDG. (48) NODE 3-C | REF.

SUMMARY FOR NODE 3-C (48)

✓ DEAD LOAD = 1116.31^{k} ✓

✓ LIVE LOAD = ——

✓ AREA = 7.3028×10^{4} IN^{2}

✓ $\bar{X}_{2}$ = 84 IN

✓ I_{x2} = 5.3114×10^{8} IN^{4}

✓ I_{x3} = 11.7458×10^{8} IN^{4}

✓ K = 5.9788×10^{8} IN^{4}

✓ SF.2 = 0.527

✓ SF.3 = 0.706

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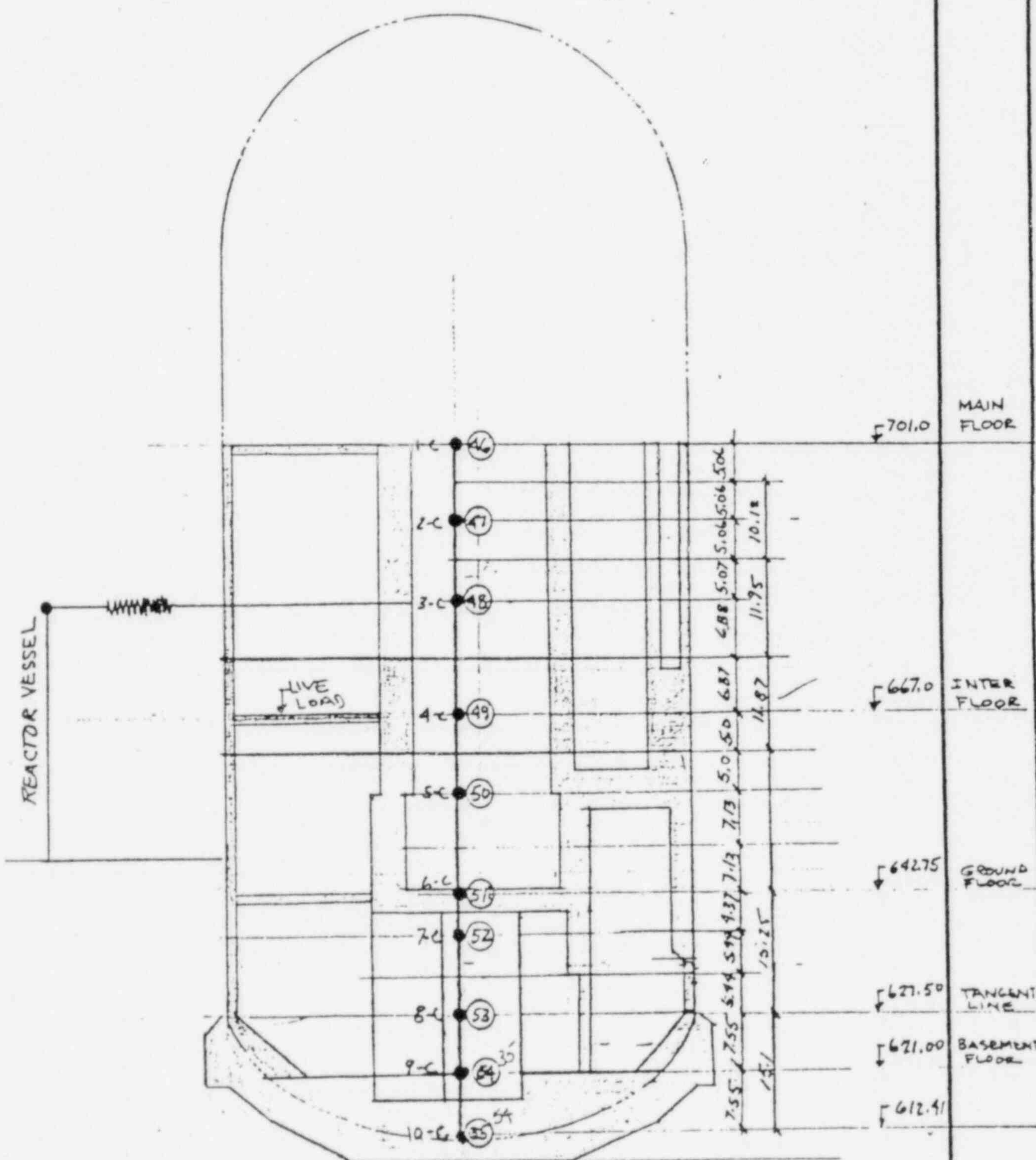
INNER SHIELD BLDG NODE 4-C REF.

NODE 4-C

INNER SHIELD BLDG (NODE 4-C)

REF.

MODEL



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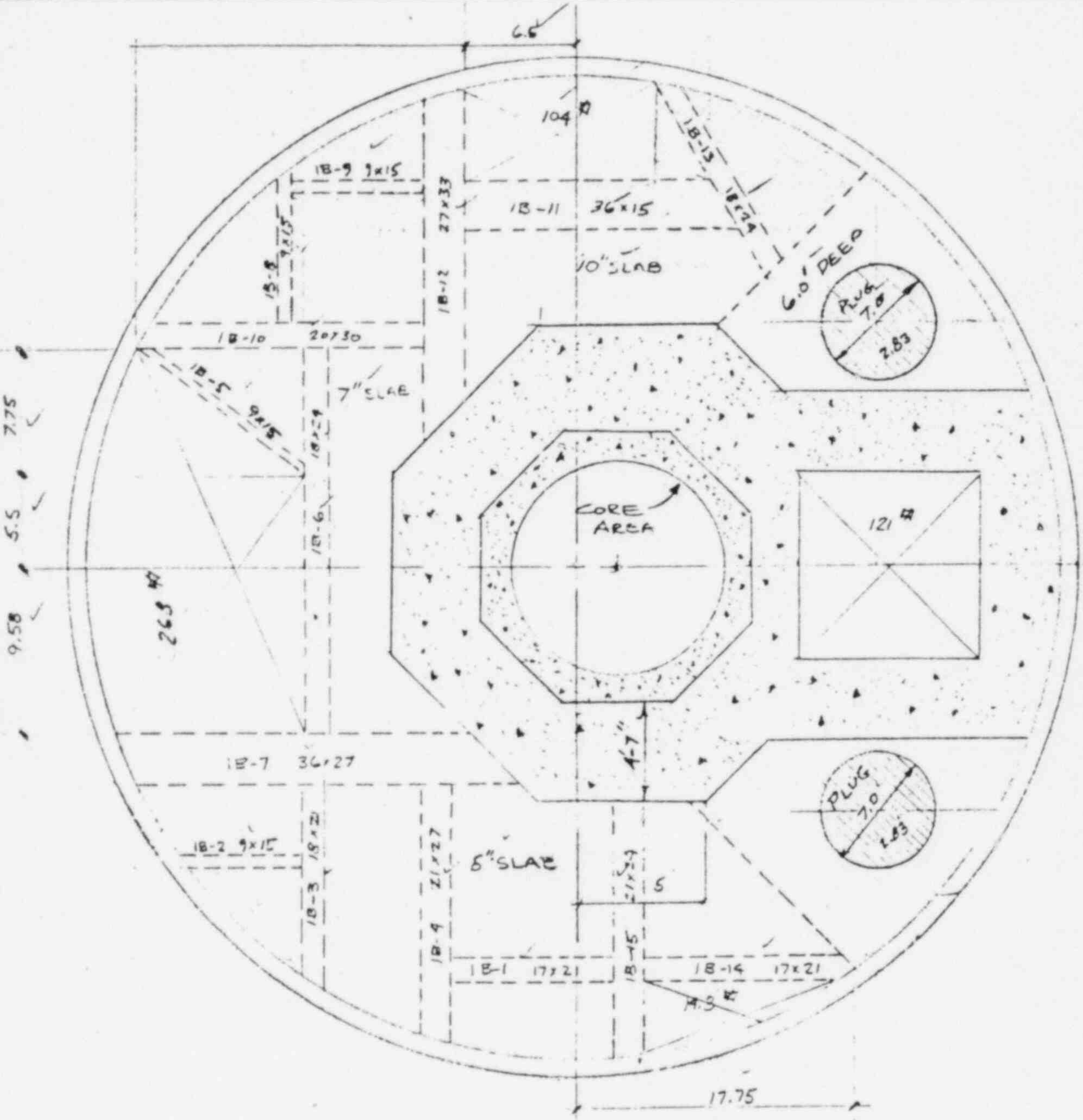
INNER SHIELD BLDG. (WEIGHTS FOR INTERMEDIATE FLOOR) NODE 4-C

REF.



PLAN INTERMEDIATE FLOOR

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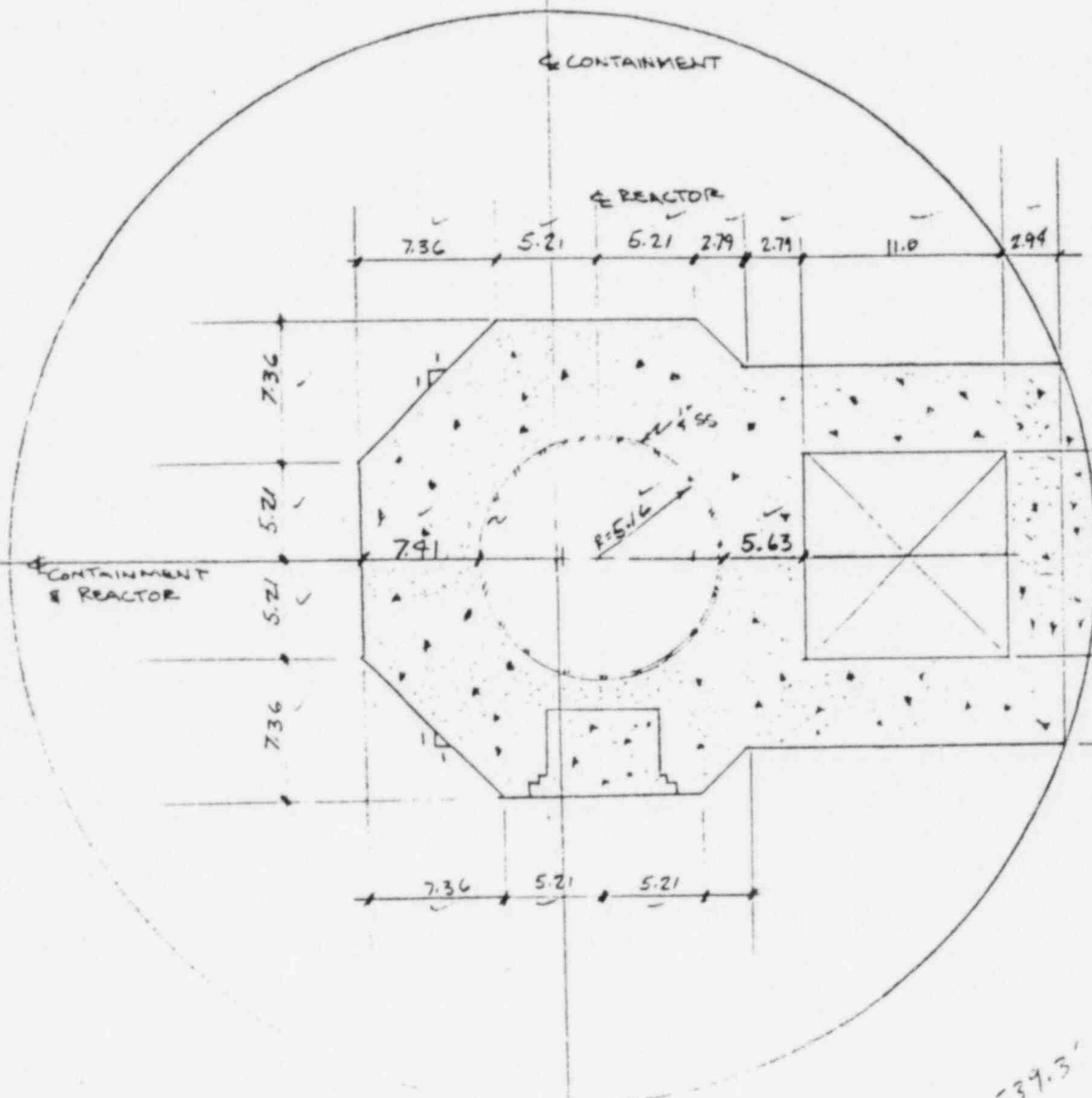
	REF.
INNER SHIELD BLDG NODE 4-C	

PROPERTIES FOR INTERMEDIATE FLOOR.



$H/2 = 2(30-7.53)12 = 539.3'$

$H_2/2 = 22.47'$

$H_1/2 = 12.57'$

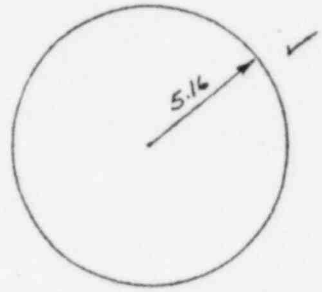
INNER SHIELD BLDG.	NODE 4-c	REF.

PROPERTIES FOR AREA A_4

$A = \pi R^2 = 83.65$ ✓

$I = .785398 R^4$ ✓

$I = 556.79\ FT^4$ ✓



(NODE 4-C) | REF.

$\frac{1}{2}$ CHORD LENGTH 10.25'
RADIUS = 29.21'

$y_2 = R\left(\frac{4\sin^3\alpha}{6\alpha - 3\sin 2\alpha} - \cos\alpha\right)$

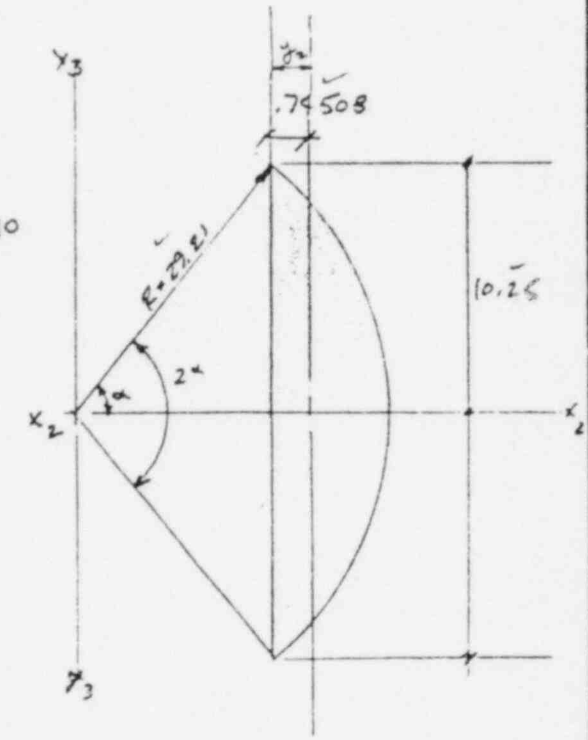
$\sin\alpha = \frac{10.25}{29.21} = .350907 \Rightarrow \alpha = .358540$

$y_2 = \left(\frac{.1728374}{2.15124 - 1.97156} - .93641\right) 29.21$

$y_2 = 0.74508$ ft

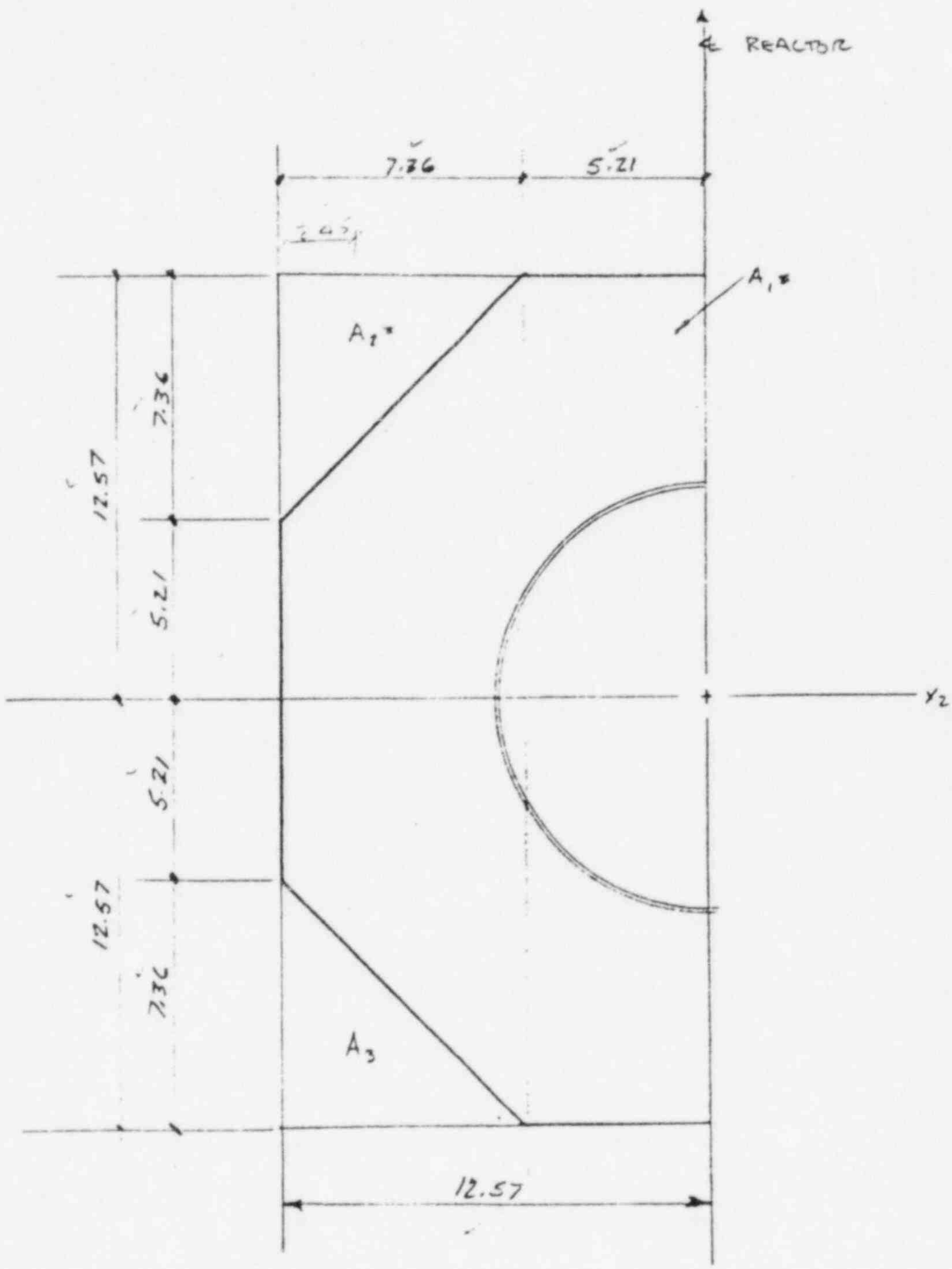
$A = 25.55 \text{ FT}^2$
$I_x = 540.94 \text{ FT}^4$
$I_y = 6.05 \text{ FT}^4$

COMPUTER PROG TI-59



INNER SHIELD BLDG

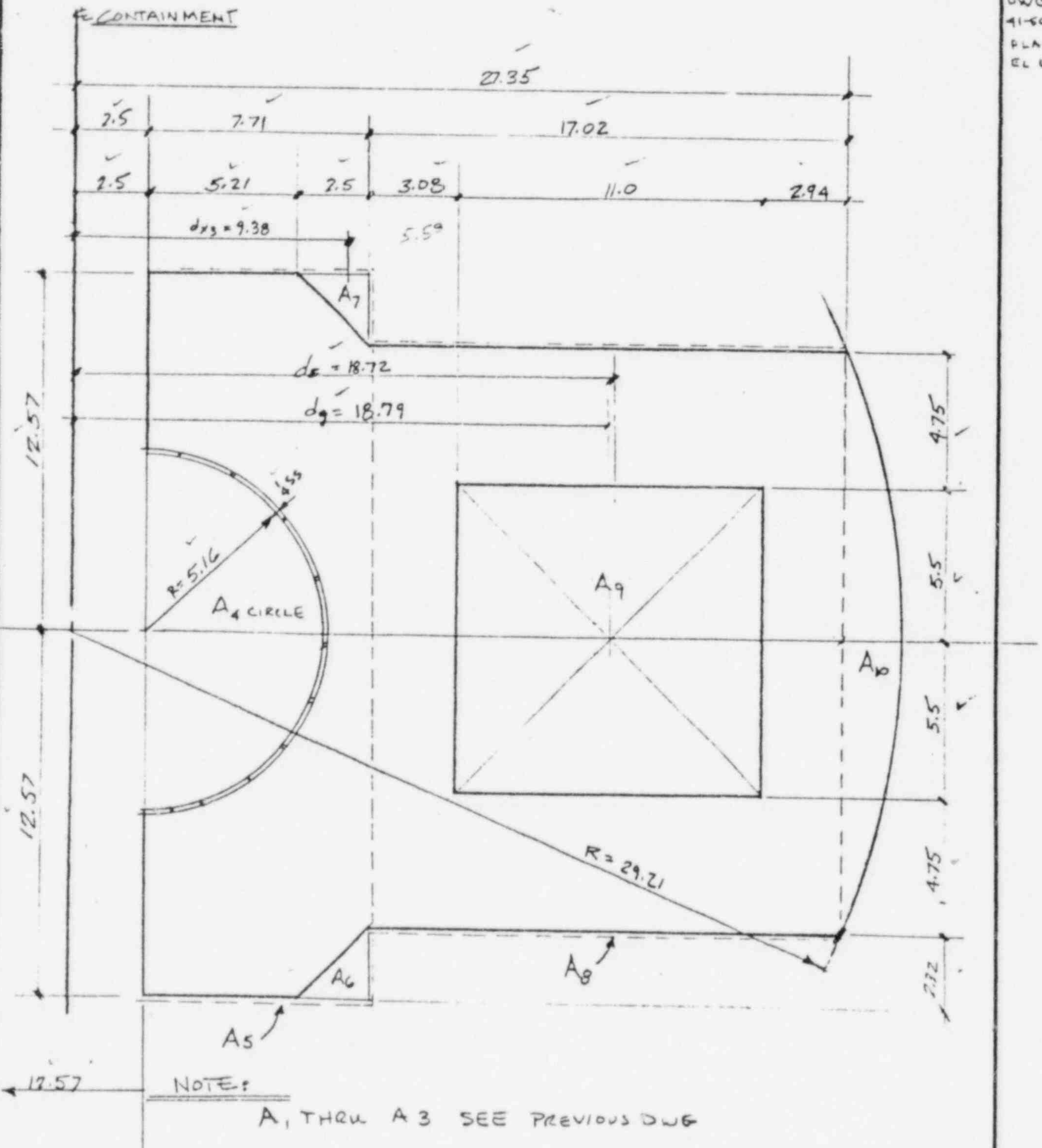
REF.



INNER SHIELD BLDG. NODE 4-C | REF.

PROPERTIES FOR

DWG 41-603457 PLAN EL 675'



NOTE:
A_1 THRU A 3 SEE PREVIOUS DWG

INNER SHIELD BLDG (NODE 4-C) | REF.

PROPERTIES FOR NODE

AREA		b	h	d_{x2}	d_{x3}
REC	A_1	12.57 ✓	25.14 ✓	0	3.79 ✓
TRI	A_2	7.36 ✓	7.36 ✓	10.12	7.62 ✓
TRI	A_3	7.36 ✓	7.36 ✓	10.12	7.62 ✓
CIRCLE	A_4	R=5.16 ✓	— ✓	0	2.5
REC	A_5	7.71 ✓	25.14	0	6.36
TRI	A_6	2.32	2.5	11.80	9.38 ✓
TRI	A_7	2.32	2.5	11.80	9.38 ✓
REC	A_8	17.02 ✓	20.5 ✓	0	18.72
REC	A_9	11.0 ✓	11.0 ✓	0	18.79 ✓
CHORD	A_{10}	R=29.21 ✓	½ CHORD=10.25 ✓		28.1 ✓

$$y_2 = R\left(\frac{4\sin^3\alpha}{6\alpha - 3\sin 2\alpha} - \cos\alpha\right)$$

$y = .75$

TRI $I = \frac{bh^3}{36}$

REC $I = \frac{bh^3}{12}$

INNER SHIELD BLDG. (PROPERTIES FOR NODE 4-C)

AREA	d_{x2}	I_{y2}	Ad_{x2}^2	$I_{x2}+Ad_{x2}^2$	d_{x3}	I_{x3}	Ad_{x3}^2	$I_{x3}+Ad_{x3}^2$	REF.
A_1 = 316.0	0	16643.70	0	16643.70	3.79	4160.92	4539.20	8700.12	
A_2 = −27.08	10.12	81.51	2773.37	−2855.38	7.62	81.51	1572.66	−1654.17	
A_3 = −27.08	10.12	81.51	2773.37	−2855.38	7.62	81.51	1572.66	−1654.17	
A_4 = −83.L5	0	556.79	0	−556.79	7.5	556.79	0	−556.79	
A_5 = 193.82	0	10208.66	0	10208.66	6.36	960.16	7840.32	8800.48	
A_6 = −2.90	11.80	NEG	403.80	−403.80	9.38	NEG	−255.15	−255.15	37.6
A_7 = −2.90	11.80	NEG	403.80	−403.80	9.38	NEG	255.15	−255.15	
A_8 = 348.91	0	12219.12	0	12219.12	18.72	8422.70	122271.46	130694.16	
A_9 = −121	0	1220.08	0	−1220.08	18.79	1220.08	42720.76	−43940.84	
A_{10} 25.55	0	540.94	0	540.94	28.1	6.05	20179.54	20180.59	
619.67				31317.19				~~120059.08~~ SEE ADD CALC	

AREA = 619.67 FT^2 = 8.9232 × 10^4 IN^2

I_{x2} = 31317.19 FT^4 = 6.4939 × 10^8 IN^4

I_{x3} = 76979.60 FT^4 = 15.9625 IN^4

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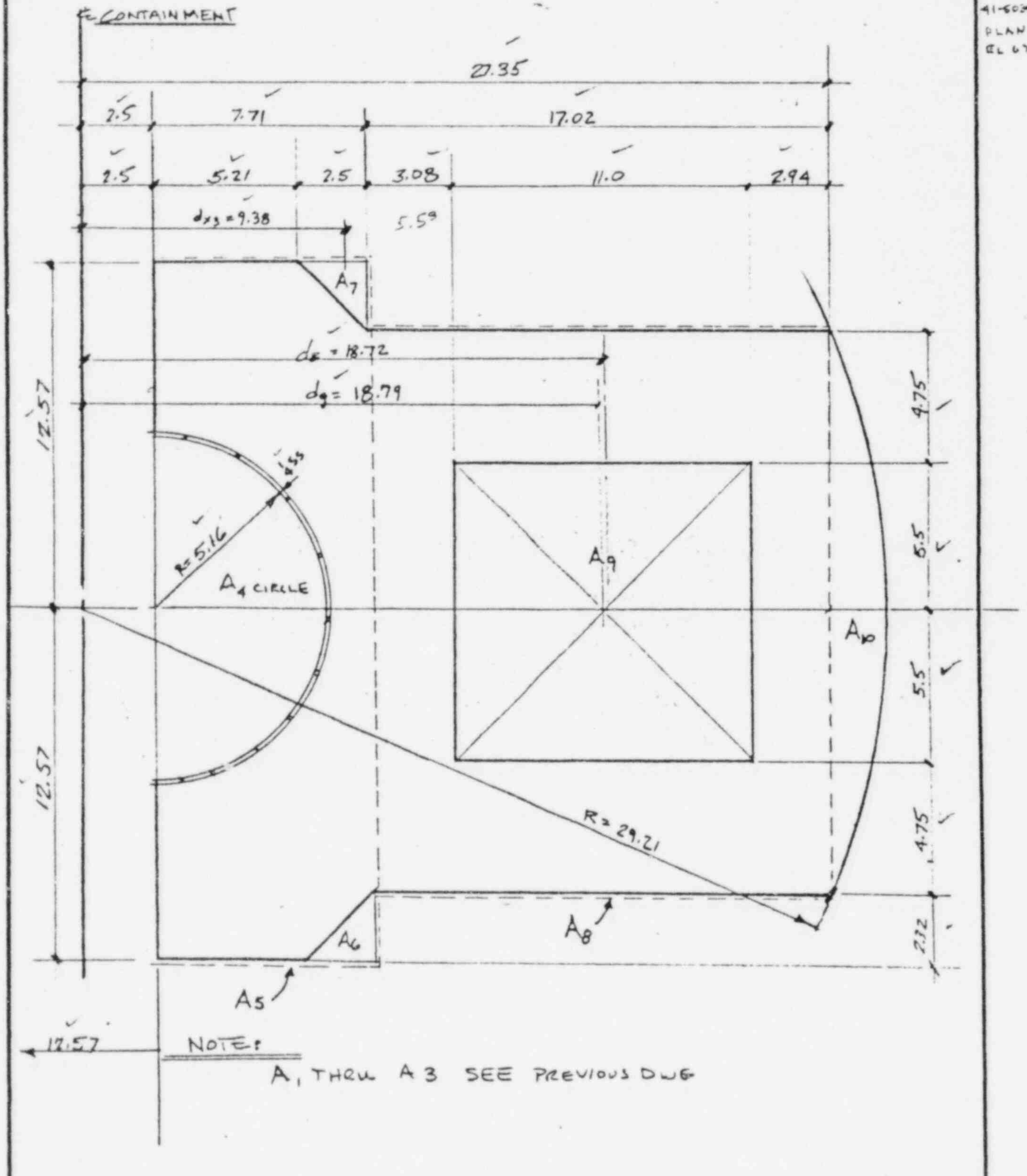
INNER SHIELD BLDG. NODE 4-C | REF.

PROPERTIES FOR

DWG 41-503457 PLAN EL 675'



NOTE:
A, THRU A 3 SEE PREVIOUS DWG

INNER SHIELD BLDG. (NODE 4-C) | REF.

No. AREA	AREA	y	Ay	d_{x3}	Ad_{x3}^2	I_{x3}	$I_{x3}+Ad_{x3}^2$
A_1	316.0	6.24	1987.70	11.32	40493.00	4160.92	44653.92
A_2	− 27.08	2.45	− 68.78	15.15	6215.47	− 81.51	− 6296.98
A_3	− 27.08	2.45	− 68.78	15.15	6215.47	− 81.51	− 6296.98
A_4	− 83.65	12.57	− 1542.59	5.03	2116.42	− 556.79	− 2673.21
A_5	193.82	16.43	3184.46	1.17	265.32	960.16	1225.49
A_6	− 2.90	19.45	− 56.41	1.85	NEG	− NEG	NEG
A_7	− 2.90	19.45	− 56.41	1.85	NEG	− NEG	NEG
A_8	348.91	28.79	10045.12	11.19	43689.15	8422.70	52111.85
A_9	− 121.00	28.86	− 3492.06	11.26	15341.30	− 1220.08	− 16561.38
A_{10}	25.55	38.17	975.24	20.57	10810.84	6.05	10816.89
	ΣA 619.67		ΣAy 10907.49			I_{x3}	76979.60 Ft⁴

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{10907.49}{619.67} = 17.60'$$

Cg IS 17.60 − 10.07 = 7.53' TO RIGHT OF ℄ CONTAINMENT

USE 90"

INNER SHIELD BLDG. (NODE 4-C)

No. AREA	AREA	y	Ay	d_{x3}	Ad_{x3}^2	I_{x3}	$I_{x3}+Ad_{x3}^2$
A_1	316.0	6.29	1987.70	11.32	40493.00	4160.92	44653.92
A_2	-27.08	2.45	-68.78	15.15	6215.47	-81.51	-6296.98
A_3	-27.08	2.45	-68.78	15.15	6215.47	-81.51	-6296.98
A_4	-83.65	12.57	-1542.59	5.03	2116.42	-556.79	-2673.21
A_5	193.82	16.43	3184.46	1.17	265.32	960.16	1225.49
A_6	-2.90	19.45	-56.41	1.85	NEG	-NEG	NEG
A_7	-2.90	19.45	-56.41	1.85	NEG	-NEG	NEG
A_8	348.91	28.79	10045.12	11.19	43689.15	8422.70	52111.85
A_9	-121.00	28.86	-3492.06	11.26	15341.30	-1220.08	-16561.38
A_{10}	25.55	38.17	975.24	20.57	10810.84	6.05	10816.89
	ΣA 619.67		ΣAy 10907.49			I_{x3}	76979.60 Ft^4

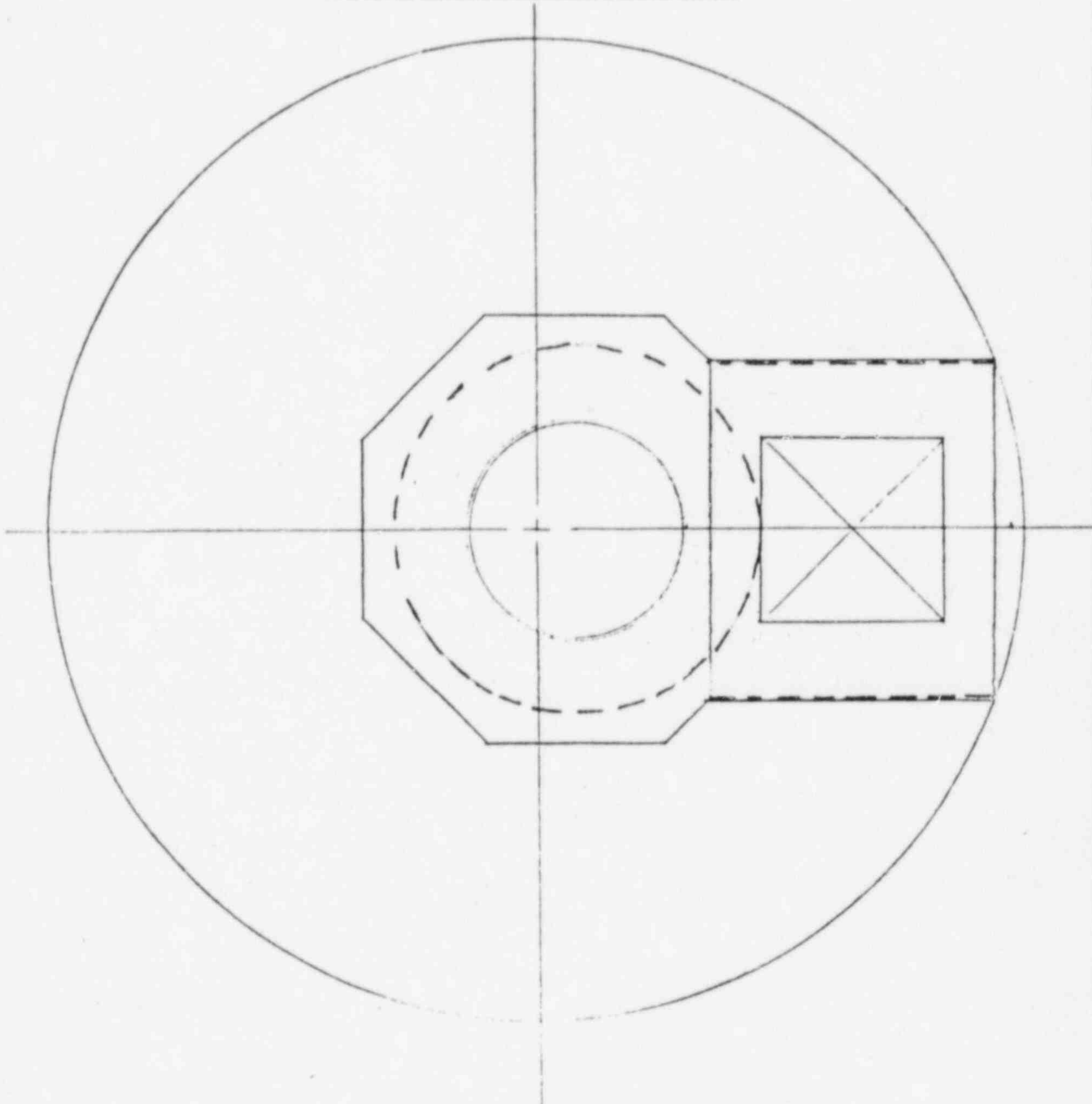
$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{10907.49}{619.67} = 17.60'$

Cg is 17.60 - 10.07 = 7.53' TO RIGHT OF ℄ CONTAINMENT

Use 90"

INNER SHIELD BLDG. NODE 4-C	REF.

TORSIONAL CONSTANT



K_{CIR}

$R_1 = 11.0$

$R_2 = 5.16$

$K = \frac{1}{2}\pi(R_1^4 - R_o^4)$

$K = \frac{1}{2}\pi(11.0^4 - 5.16^4)$

$K = 21884.46 \text{ FT}^4$

K_{REC}

$$K = \frac{2tt_1(a-t)^2(b-t_1)^2}{at + bt_1 - t^2 - t_1^2}$$

$t_1 = 4.75 \quad t = 3.0$

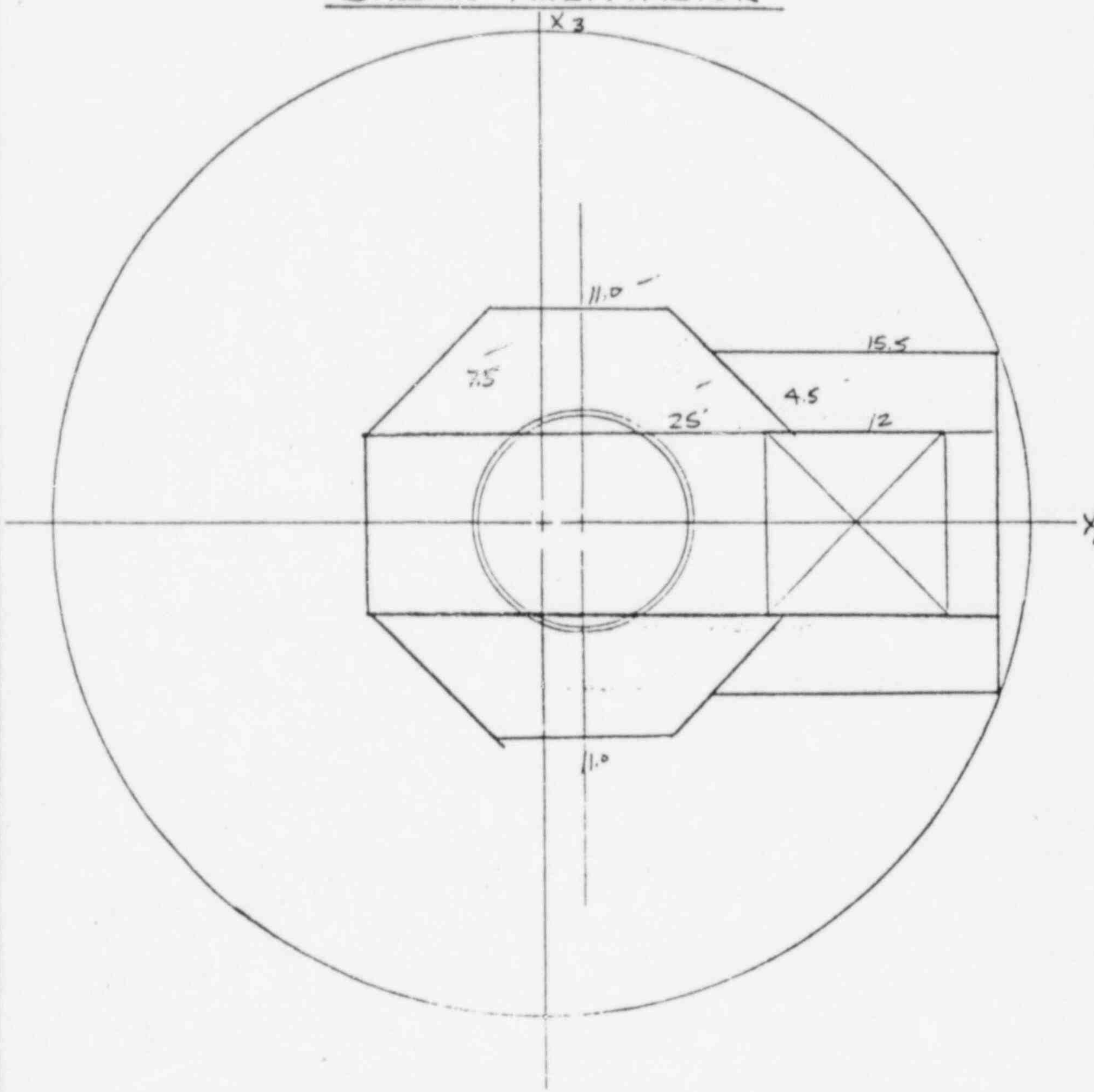
$a = 17 \quad b = 20.5$

$$K = \frac{2(4.75)(3)(17-3)^2(20.5-4.75)^2}{17(3) + 20.5(4.75) - 3^2 - 4.75^2} = 11862.40 \text{ FT}^4$$

$K_{TOT} = 33746.86 \text{ FT}^4 = 6.9977 \times 10^8 \text{ in}^4$

INNER SHIELD BLDG (NODE 4C) | REF.

SHEAR AREA FACTOR



TOTAL AREA = 619.67 FT^2

SHEAR AREA FOR X_2 EARTHQUAKE

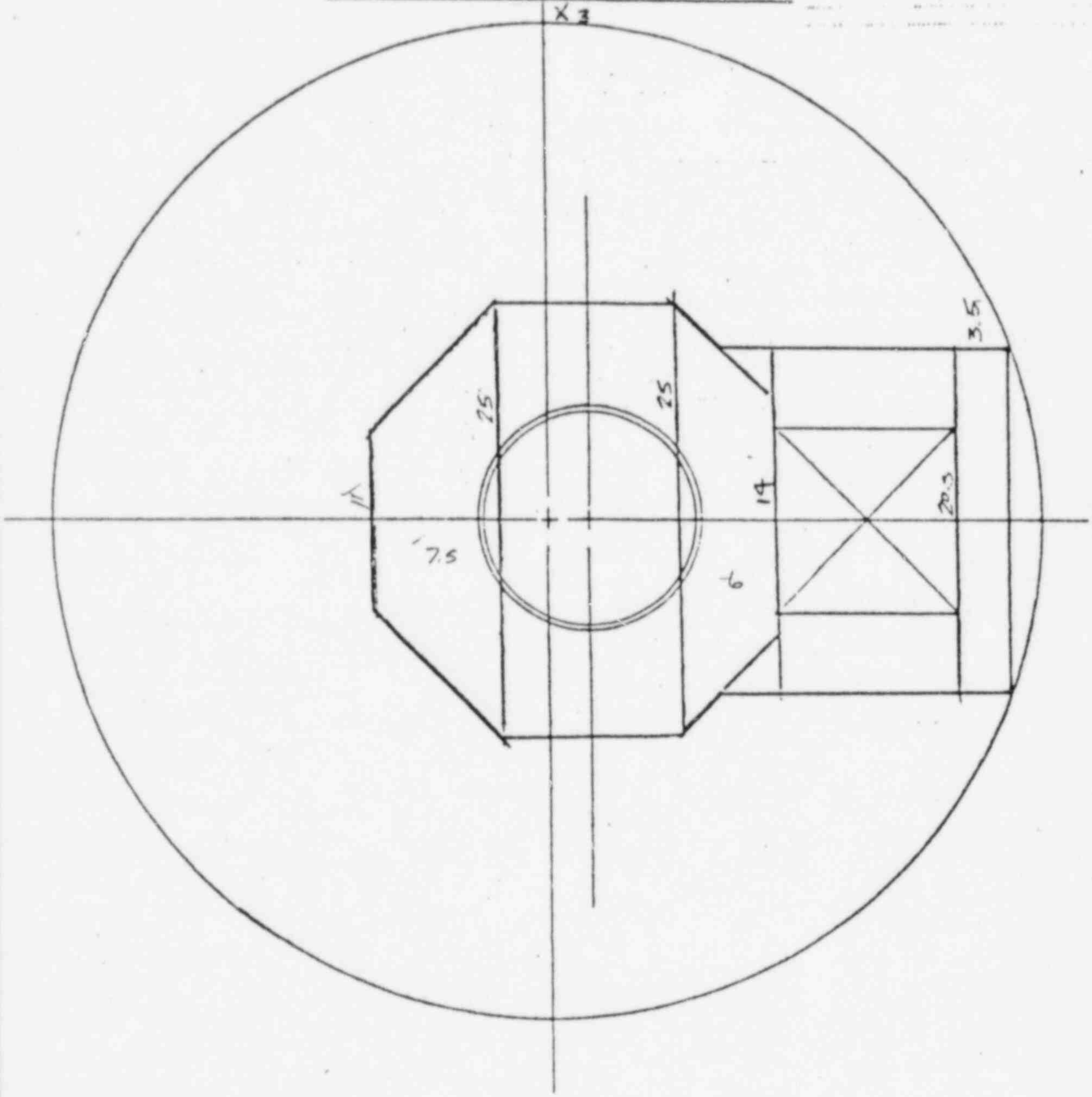
$$2\left[\begin{aligned} A_{x_3} &= \tfrac{1}{2}(11+25)(7.5) = 135.0 \\ &+ \tfrac{1}{2}(12+15.5)(4.5) = 61.88 \end{aligned}\right.$$

$2(196.88) = 393.76\ FT^2$

$$S.F.3 = \frac{393.76}{619.67} = 0.635$$

INNER SHIELD BLDG. (NODE 4-C) | REF.

SHEAR AREA FACTOR



TOTAL AREA = 619.67 ft²
SHEAR AREA FOR X3 EARTHQUAKE

$A_{X_2} = \frac{1}{2}(11+25)(7.5) = 135.0$
$+ \frac{1}{2}(14+25)(6) = 117.0$
$+ 20.(3.5) = 70.0$
322.0 ft²

$SF, Z = \frac{322.0}{619.67} = 0.520$

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INNER SHIELD BLDG (WEIGHT INTERMEDIATE FLOOR) | REF.

BEAM WEIGHTS

QUANTITY	BEAM NO	SIZE	LENGTH	WEIGHT
8"	IB-1	17×21	9.75	2.245
8"	IB-2	9×15	7.50	0.492
8"	IB-3	18×21	12.00	2.925
8"	IB-4	21×27	15.50	6.442
7"	IB-5	9×15	12.50	0.938
7"	IB-6	18×29	23.00	7.33
8"	IB-7	36×27	21.50	15.32
7"	IB-8	9×15	8.50	0.638
7"	IB-9	9×15	8.00	0.600
7"	IB-10	20×30	16.75	8.026
7"	IB-11	36×15	15.00	4.500
7"	IB-12	27×33	17.75	12.980
7"	IB-13	18×24	13.00	4.144
8"	IB-14	17×21	13.50	3.108
8"	IB-15	21×24	15.00	5.250
				74.938 K

NES 105 (2/74)

INNER SHIELD BLDG (NODE 4-C) | REF.

CENTER OF MASS CALCULATION

DEAD LOAD	WEIGHT	X_3	$W X_3$
POOL WATER	89.62 ✓	18.79 ✓	1683.96 ✓
CORE	1037.91	7.53	7815.46
SPENT FUEL	143.00 ✓	18.79 ✓	2685.97 ✓
	1270.53		12185.39

$$\bar{X}_3 = \frac{12185.39}{1270.53} = 9.59' \checkmark$$

REF.

10" SLAB $16 \times 6 \times \frac{10}{12} \times .150 = 12.0^k$ ✓

7" SLAB APPROXIMATELY $312^{\square} \times \frac{7}{12} \times .150 = 27.3^k$ ✓

8" SLAB APPROXIMATELY $525^{\square} \times \frac{8}{12} \times .150 = 52.5^k$ ✓

6'-0 SLAB $= 224^{\square} - 2\pi\frac{(7.0)^2}{4} = 147^{\square} \times 6 \times .15 = 132.3^k$ ✓

7'-0 PLUGS $= 2\pi\frac{(7.0)^2}{4} \times 2.83 \times .15 = 32.67^k$ ✓

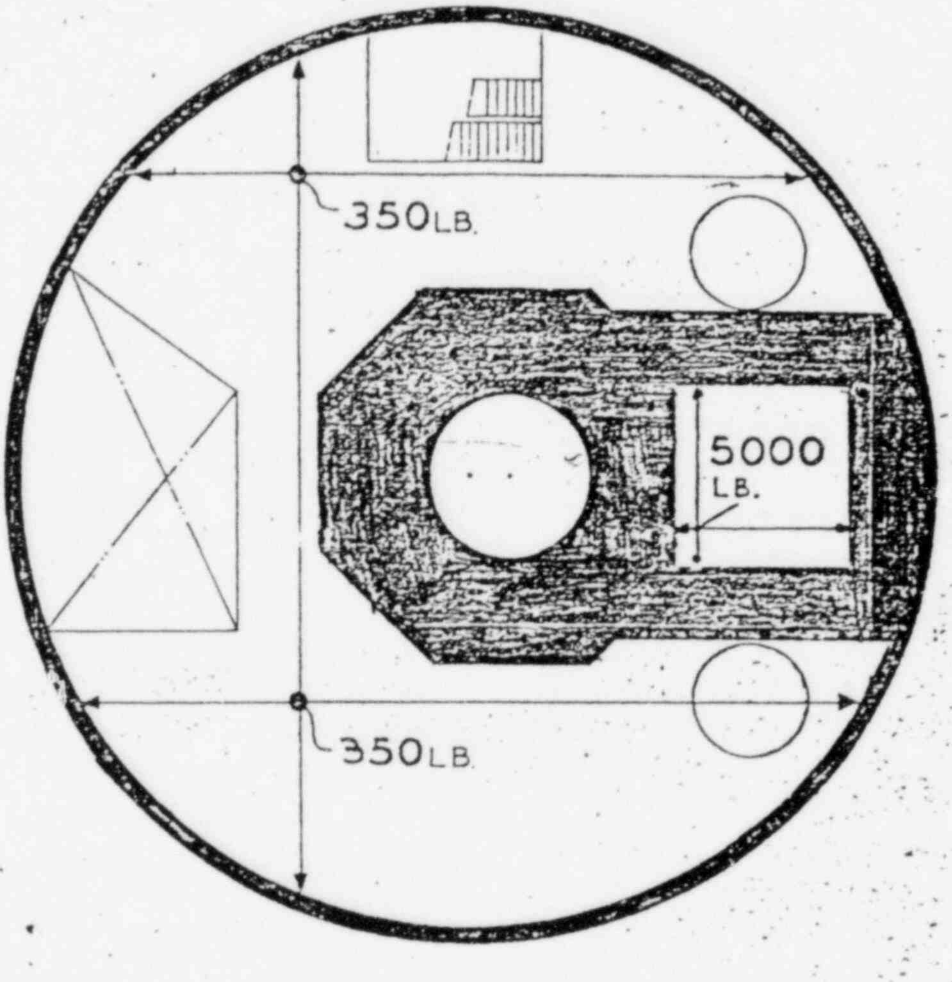
TOTAL SLAB WT 256.77^k ✓

CORE CONCRETE 11.87' HEIGHT AREA = $582.93^{\square}$ ✓

CORE WEIGHT =	11.87 × 582.93 × .15 =	1037.91^k ✓
SLAB WEIGHT =	=	257.70^k
BEAM WEIGHT =	=	74.94^k
WATER WT	= 11 × 11 × 11.87 × .0624 =	89.62^k ✓
		1460.17^k TOTAL DEAD LOAD

	REF.
4-C	

LIVE LOAD



CONTAINMENT VESSEL
INTERMEDIATE FLOOR
EL. 667'-0"

INNER SHIELD BLDG — INTERMEDIATE FLOOR — NODE 4-C | REF.

LIVE LOAD WEIGHTS

TOTAL AREA = $\pi R^2 = \pi\, 29.21^2$ = 2680.48 ✓
CORE AREA = − 507.14
POOL AREA = − 121.00 ✓
OPENINGS = − 256.50
= − 70.31 ✓
1725.53

LOAD = 350 PSF

603.94^{K} TOTAL FLOOR LIVE LOAD ✓

INNER SHIELD BLDG (49) NODE 4-C	REF.

SUMMARY FOR NODE 4-C (49)

DEAD LOAD = 1460.17^{k}

LIVE LOAD = 603.94^{k}

AREA = 8.9232×10^{4} IN^2

$\bar{X}_2$ = 90 IN

I_{x2} = 6.4939×10^{8} IN^4

I_{x3} = 15.9625×10^{8} IN^4

K = 6.9977×10^{8} IN^4

SF2 = 0.520

SF3 = 0.635

REF.

NODE 5-C

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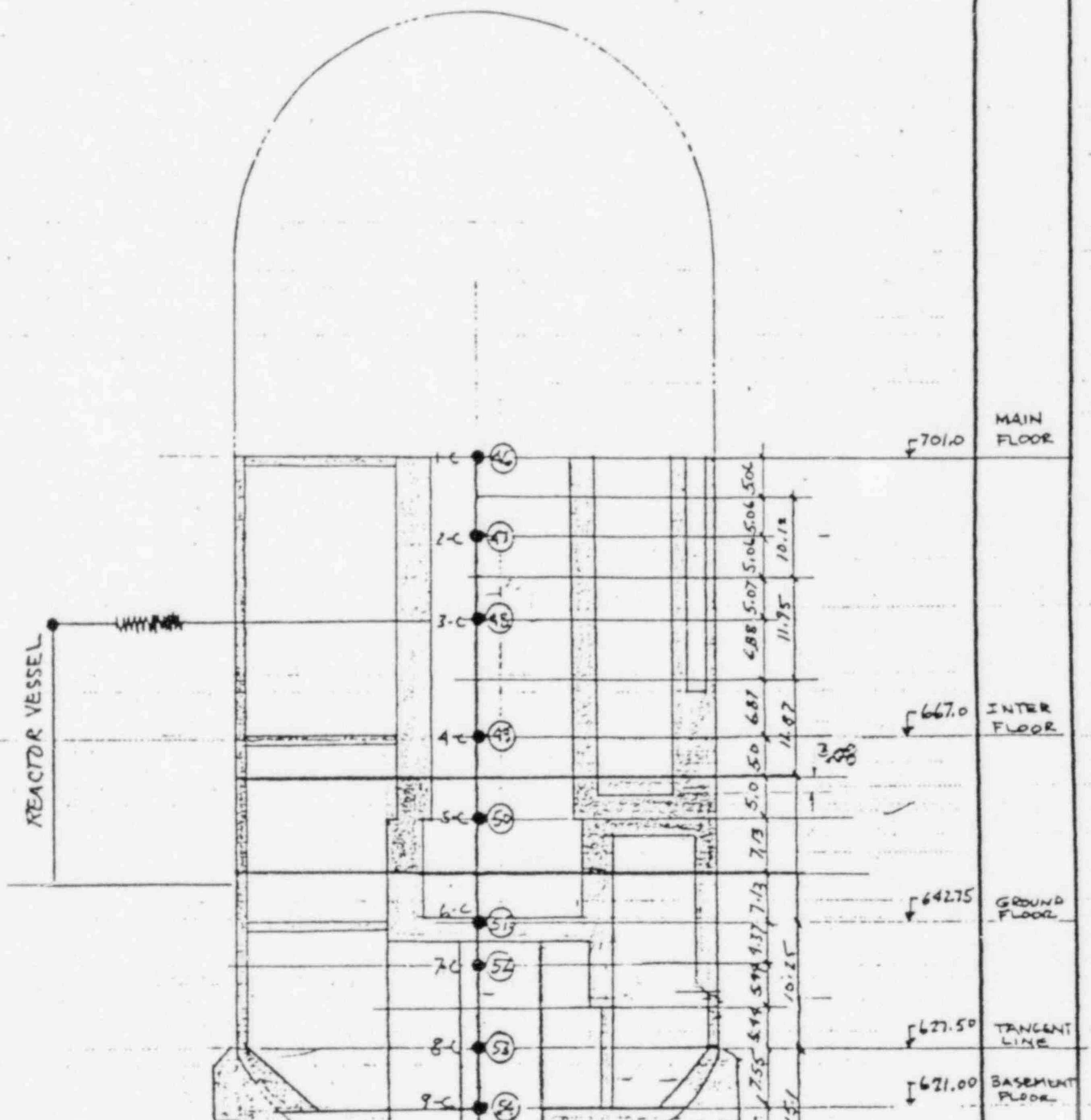
INNER SHIELD BLDG (NODE 5-C)	REF.

MODEL



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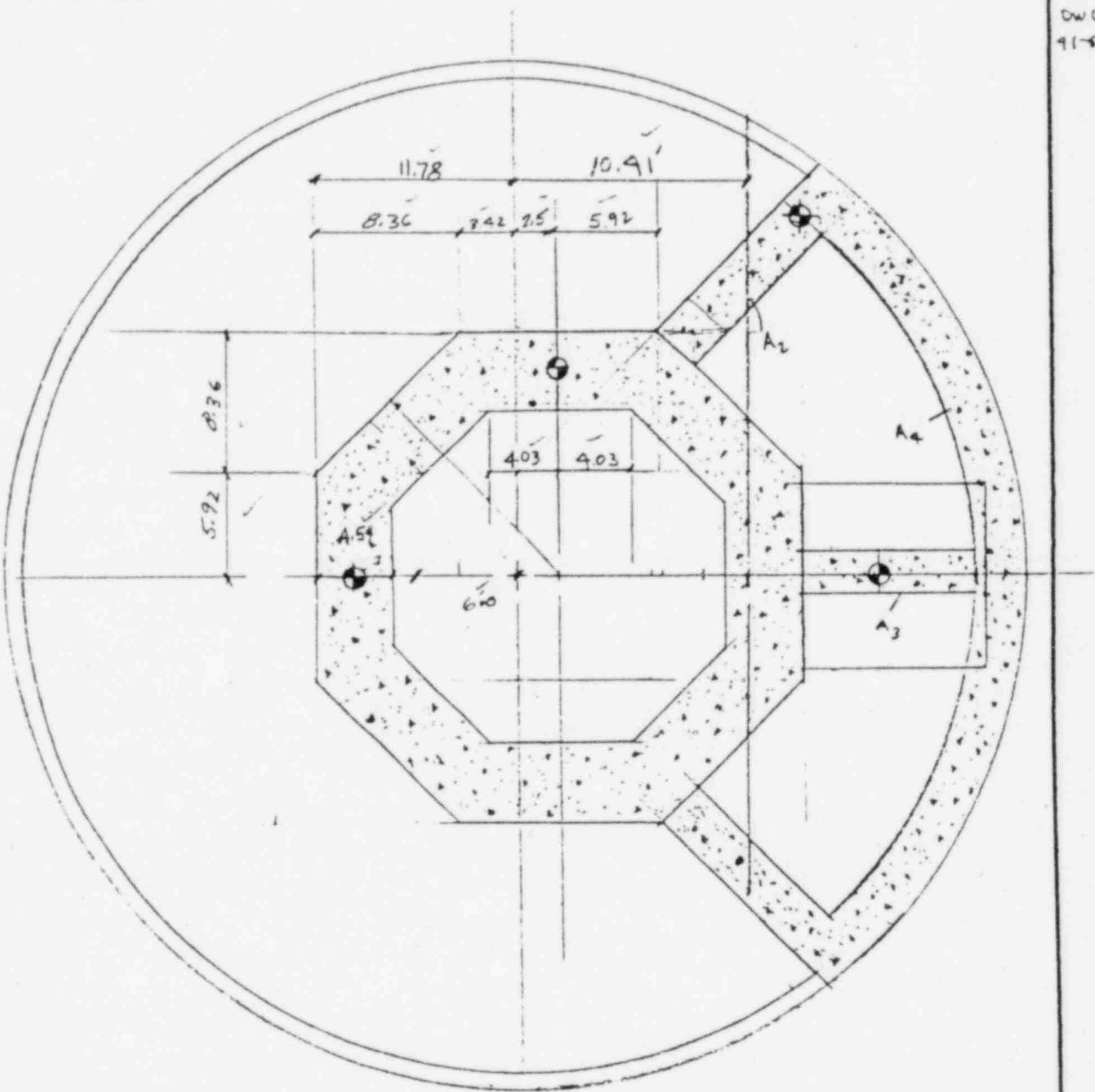
INNER SHIELD BLDG	NODE 5-C	REF.
		DWG 41-503442



$H_2 = (30 - 10.41)\,2 \times 12 = 470.0 = 39.17$

$H_3 = 2 \times 23.5 \times 12 = 564 = 47.0'$

$C = (11.78 + 2.5)\,12 = 171.4''$ 14.28

$\frac{H_2}{2} = 19.6'$

$\frac{H_3}{2} = 23.5$

INNER SHIELD BLDG | NODE 5-C | REF.

AREA A_1 REF AISC Pg 6-30

OUTSIDE
A REGULAR POLYGON

n = NUMBER OF SIDES = 8

$R_o = 14.28$ ✓ | $R = 10.54$ ✓
$R_1 = 15.46$ ✓ | $R_1 = 9.74$ ✓
$a = 11.89$ ✓ | $a = 8.06$ ✓

$\tan\phi = \frac{a}{2R_1} = \frac{11.89}{2 \times 15.46} = 0.3829$ ✓ | $\tan\phi = \frac{8.06}{2 \times 9.74} = 0.41376$

$\phi = 20.9502603$ ✓ | $\phi = 22.4777$

$A_o = n R_1^2 \tan\phi = 732.19\ FT^2$ ✓ | $A_{in} = 314.02\ FT^2$ ✓

$I_{1_o} = \frac{A(6R^2 - a^2)}{24}$ ✓

$I_1 = \frac{732.19(6 \times 14.28^2 - 11.89^2)}{24}$ | $I_{1_{in}} = \frac{314.02(6 \times 10.54^2 - 8.06^2)}{24}$ ✓

$I_{1_o} = 33049.98$ ✓ | $I_{1_{in}} = 7871.25$ ✓

$A = A_o - A_i$ | $I = I_o - I_{in}$ | $d_{x3} = 2.5$ ✓
$A = 418.17\ FT^2$ ✓ | $I_{x3} = I_{y2} = 25178.73\ FT^4$ ✓

$Ad_{x_3}^2 = 2613.56$ ✓ | $I_{x_3} + Ad_{x_3}^2 = 27792.29\ FT^4$ ✓

INNER SHIELD BLDG. NODE 5-C | REF.

AREA A_2

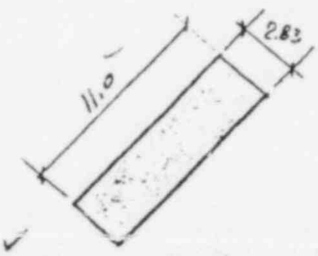
$A = bd = 2.83 \times 11.0 = 31.13\ FT^2$

$C = \frac{b \sin a + d \cos a}{2}$

$C = \frac{(2.83 + 11.0).707}{2} = 4.89$ ✓

$I = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$

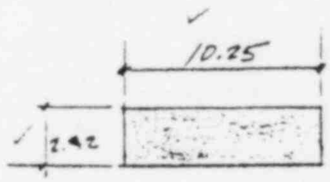
$I = \frac{2.83 \times 11.0 (2.83^2 + 11.0^2)(.707)^2}{12} = 167.23$ ✓



$d_{x2} = 12.28\ FT$ $\quad Ad^2_{x2} = 4694.36$ $\quad I_{x2} + Ad^2_{x2} = 4861.63\ FT^4$

$d_{x3} = 8.42\ FT$ $\quad Ad^2_{x3} = 2207.00$ $\quad I_{x3} + Ad^2_{x3} = 2374.23\ FT^4$

AREA A_3



$A = 2.42 \times 10.25 = 24.81$ ✓

$I_{x2} = \frac{bd^3}{12} = 12.1\ FT^4$ ✓

$I_{x3} = \frac{bd^3}{12} = 217.17\ FT^4$ ✓

$d_{x3} = 13.55$ $\quad Ad^2_{x3} = 4555.18\ FT^4$ $\quad I_{x3} + Ad^2_{x3} = 4772.35$

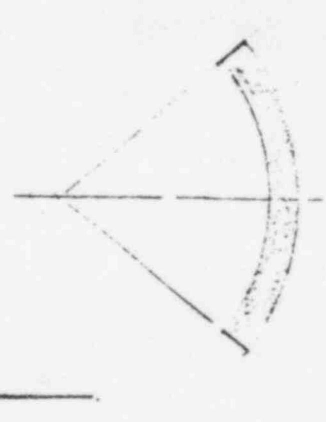
AREA A_4

USE AREA A_{12} OF BASEMENT

$A = 105.75\ FT^2$

$I_{x2} + Ad^2_{x2} = 20934.17\ FT^4$

$I_{x3} + Ad^2_{x3} = 60357.69\ FT^4$



$A_T = 2A_2 + A_3 + A_4 + A_1$

AREA	I_{x2}	I_{x3}
610.99 FT^2	55848.26 FT^4 $11.5807 \times 10^8\ IN^4$	

NODE 5-C | REF.

AREA No	AREA	y	Ay	d_{x3}	Ad_{x3}^2	I_{x3}	$I_{x3}+Ad_{x3}^2$
A_1 =	418.17	14.28	5971.47	5.36	12013.86	27792.29	39806.15
2 A_2 =	2(31.13)	(25.09)	1562.10	5.45	1849.28	167.28	2016.56
A_3 =	24.81	28.69	711.80	9.05	2032.00	217.17	2249.17
A_4 =	105.75	35.49	3753.07	15.85	26566.78	908.84	27475.62
	610.99		11998.45				I_{x3} = 71547.5 FT⁴

$$\bar{y} = \frac{\Sigma A_y}{\Sigma A} = \frac{11998.45}{610.99} = 19.64'$$

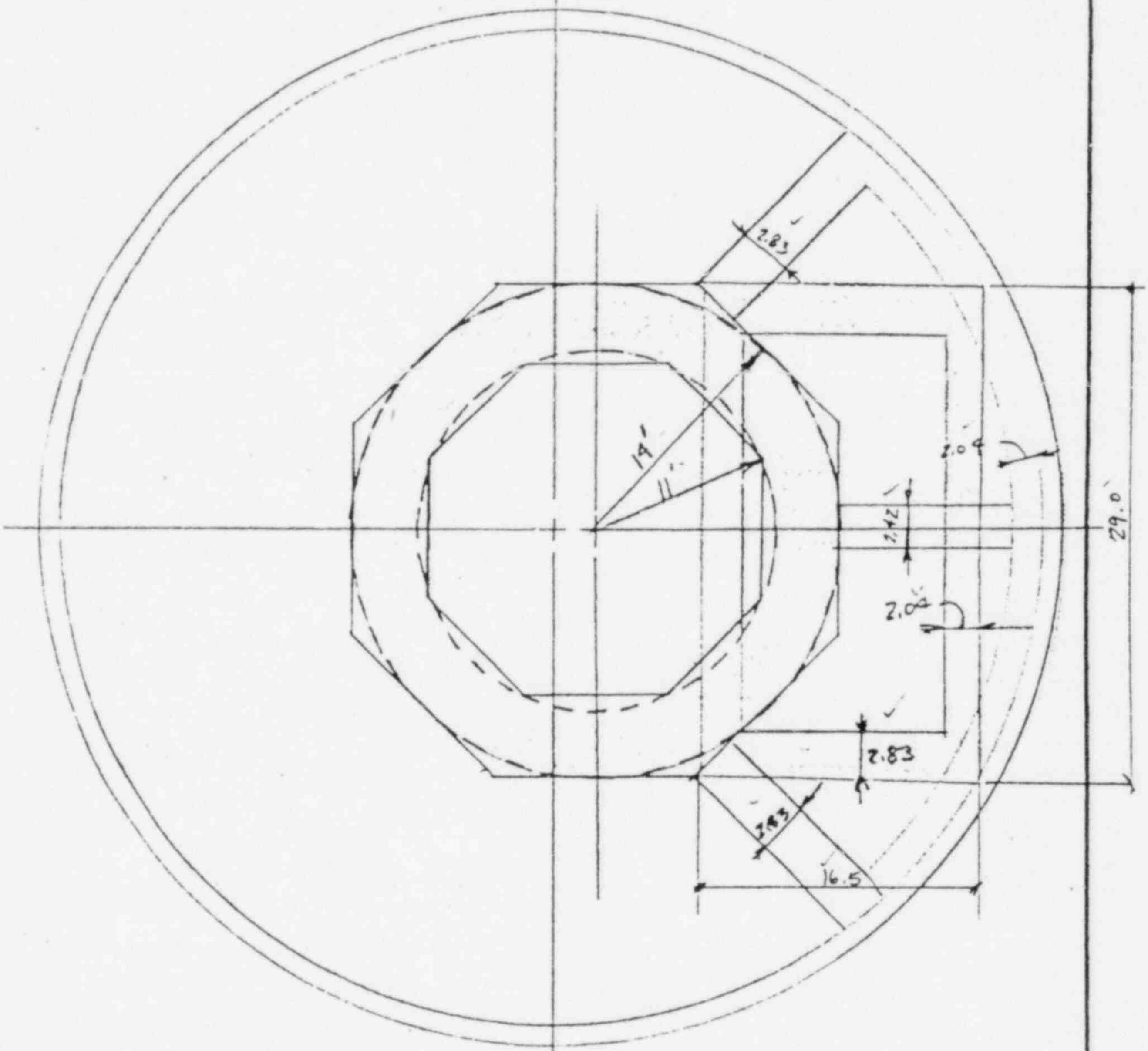
$\bar{y}$ = 19.64 − 11.78 = 7.86' TO RIGHT OF ℄ OF CONTAINMENT BLDG.

USE 94IN ✓

I_{x3} = 71547.50 FT^4 = 14.8361 X 10^8 IN^4 ✓

INNER SHIELD BLDG (NODE 5-C) | REF.

TORSIONAL CONSTANT



$K_{CIR} = \frac{1}{2}\pi (R_i^4 - R_o^4)$

$K_{CIR} = \frac{1}{2}\pi (14^4 - 11^4) = 37345.68 \text{ FT}^4$

K_{REC} $t = 2.04$ $t_1 = 2.83$
$a = 16.5$ $b = 29$

$$K = \frac{2 t t_1 (a-t)^2 (b-t_1)^2}{a t + b t_1 - t^2 - t_1^2}$$

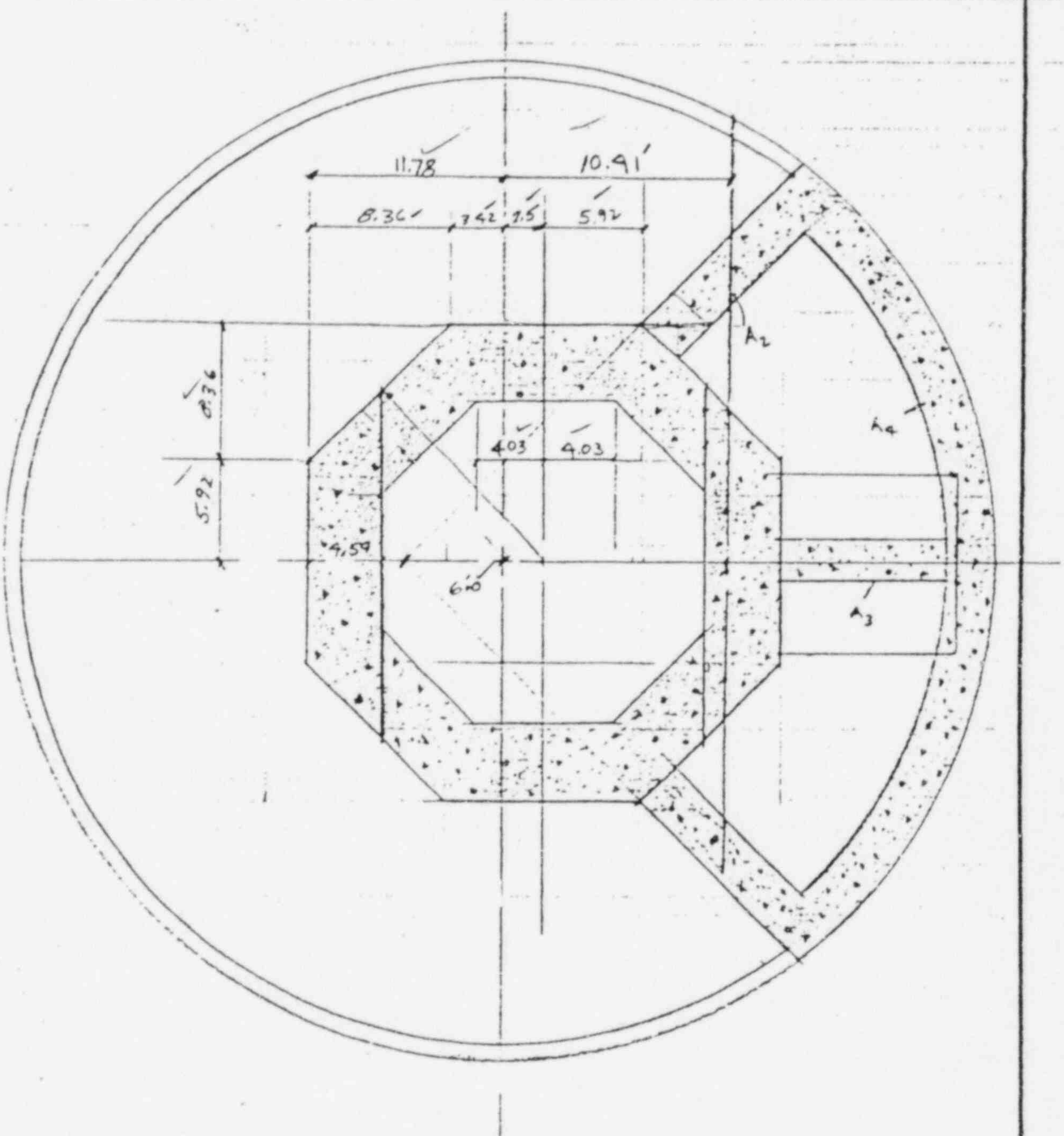
$$K = \frac{2(2.04)(16.5-2.04)^2(29-2.83)^2(2.83)}{(16.5)(2.04) + (29)(2.83) - 2.83^2 - 2.04^2}$$

33 82.07 8.01 - 4.16

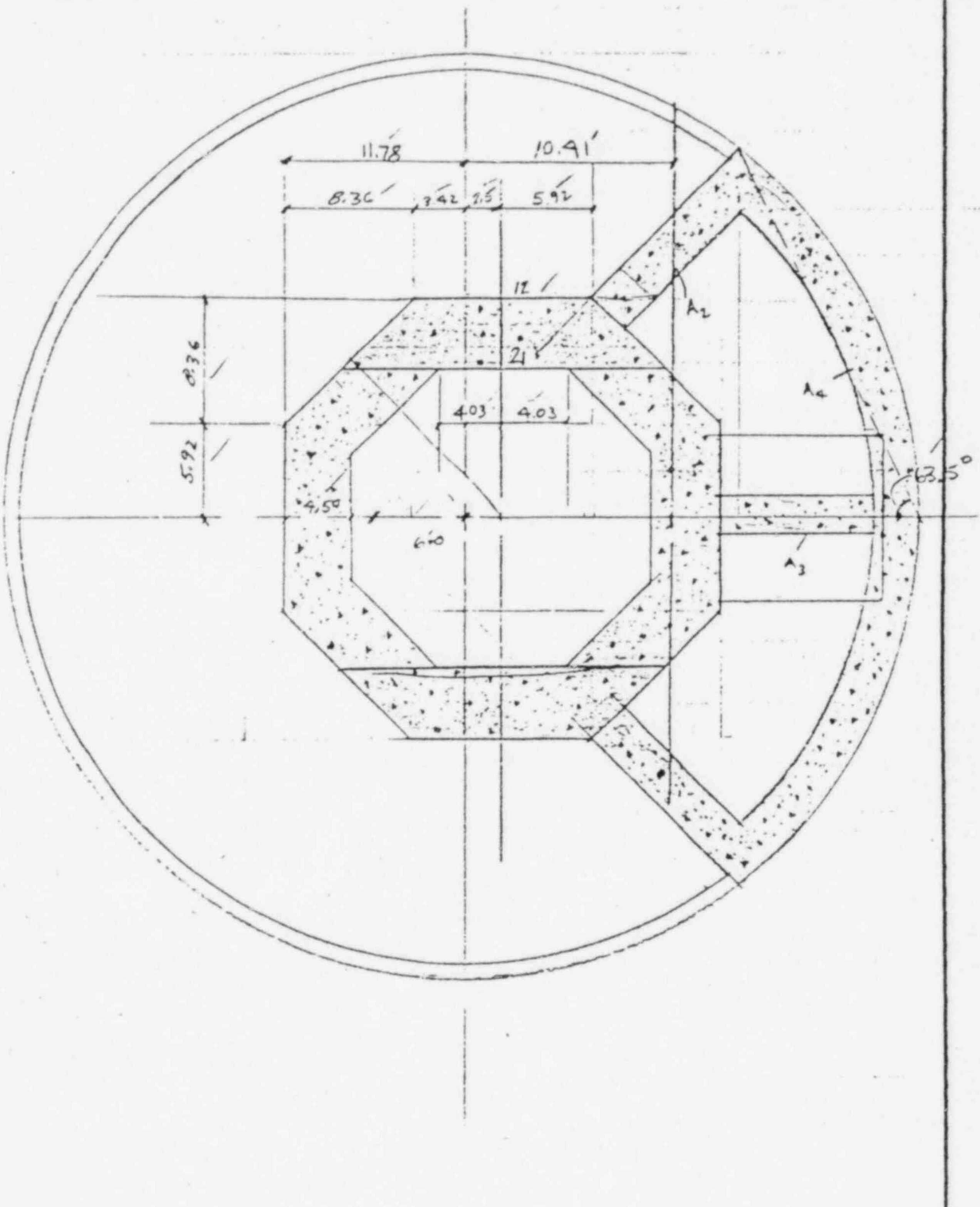
$K = 15,966.01$

$K_{TOTAL} = 53311.77 \text{ FT}^4$
$11.0547 \times 10^8 \text{ IN}^4$

INNER SHIELD BLDG | NODE 5-C | REF.



INNER SHIELD BLDG NODE 5-C REF.



INNER SHIELD BLDG (NODE 5-C) REF.

$A_1 = \frac{1}{2}(12+21)(4.5)(2) = 148.5$ ✓
$A_2 = 2(0.707)(31.13) = 44.02$ ✓
$A_3 = 24.81$ ✓
$A_4 = (\cos 63.5)(105.75) = 47.19$ ✓
264.52

TOTAL AREA = 610.99 FT² ✓

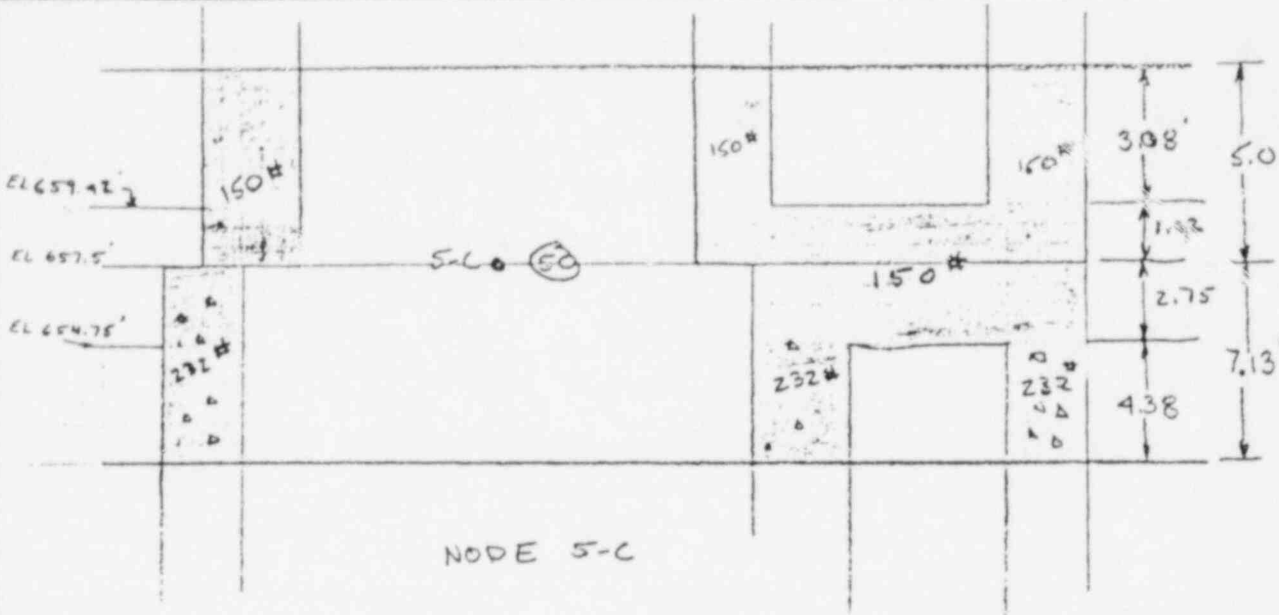
$$S.F.\ 3 = \frac{264.52}{610.99} = 0.433 ✓$$

$A_1 = \frac{1}{2}(12+21)(4.5)(2) = 148.5$ ✓
$A_2\ (.707)(2)(31.13) = 44.02$ ✓
$A_4\ (\sin 63.5)(105.70) = 94.59$
287.11 ✓

$$S.F.\ 2 = \frac{287.11}{610.99} = 0.470 ✓$$

SF.3. = 0.433 ✓
SF.2 = 0.470 ✓

INNER SHEILD BLDG NODE 5-C | REF.



WEIGHT CALCULATION

150#

4-C 5' @ 619.67 ¢ = 464.75 K

SLAB ABOVE 5-C 1.92' @ 121.00 ¢ = 34.85 K

SLAB BELOW 5-C 2.75' @ (10.5 × 17.5) ¢ = 75.80 K

TOTAL 5-C AREA IS 487.50 ¢

SUBTRACTED AREA
2A6 = 23.50 ¢
2A5 = 29.72 ¢
A12 = 105.75 ¢
158.97

} DATA FROM NODE 6-C

232#

EL 654.75' TO EL 657.5' 2.75' @ (487.50 − 158.97) ¢ = 209.60 K

5-C 4.38' @ 487.50 ¢ = 495.38 K

POOL WATER 3.08' @ 121 ¢ × 62.4# = 23.26 K

1268.79 K TOTAL DEAD WEIGHT

INNER SHIELD BLDG (NODE 5-C) REF.

CENTER OF MASS CALCULATION

	DEAD LOAD	WEIGHT	x_3	Wx_3
	POOL WATER	18.27	18.79	343.29
4-C		225.79	7.53	1700.20
	FUEL & CASK	171.50	18.79	3222.49
5-C	CORE & SLAB	648.71	10.41	6753.07
		1064.27		12019.05

$$\bar{x}_3 = \frac{12019.05}{1064.27} = 11.29 \text{ FT}$$ ✓

NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY RR DATE 5-10-79 PROJ. 5101 TASK 026
CHKD. [illegible] DATE 6-27-81 PAGE ____ OF ____

LACBWR SEP

INNER SHIELD BLDG NODE 5-C (50) REF.

SUMMARY FOR NODE 5-C (50)

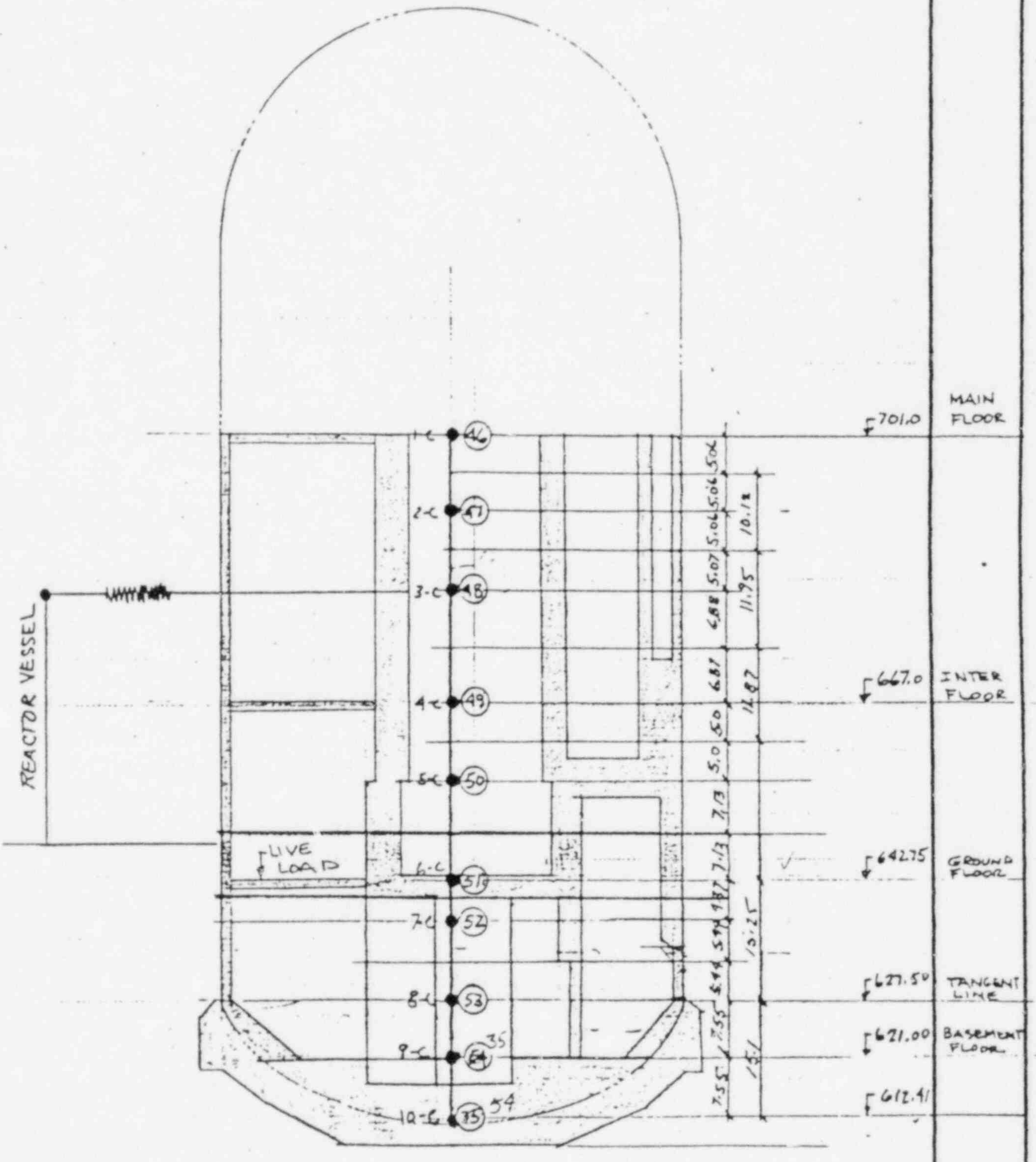
DEAD LOAD = 1268.79 K
LIVE LOAD = —
AREA = 8.7983×10^4
$\bar{x}_2$ = 94 IN
I_{x2} = 11.5807×10^9 IN^4
I_{x3} = 14.8361×10^8 IN^4
K = 11.0547×10^8 IN^4
SF.2 = 0.433
SF3 = 0.470

REF.

NODE 6-C

	REF.
INNER SHIELD BLDG (NODE 6-C)	

MODEL



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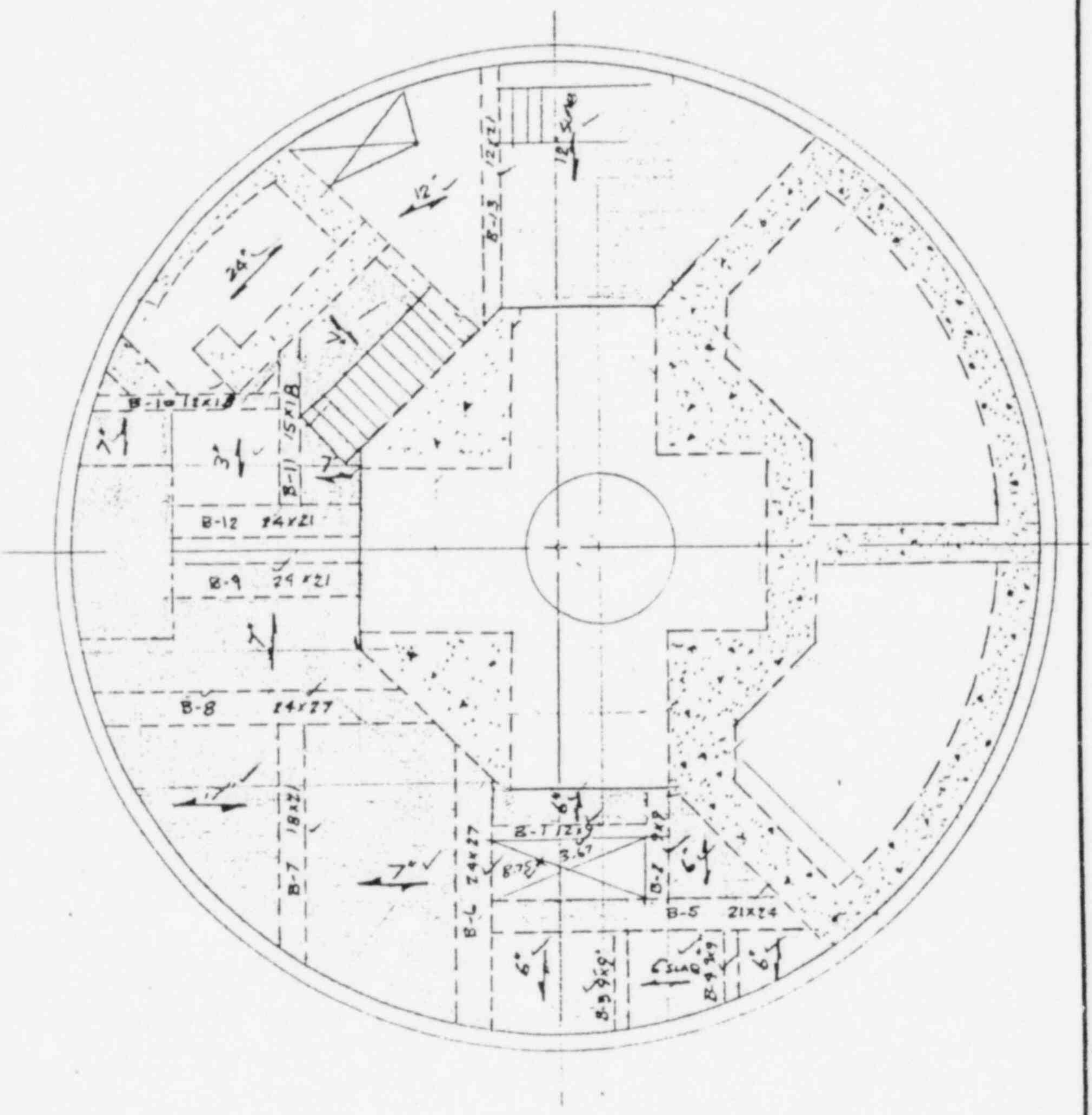
NES DIVISION

BY RR DATE 4-10-79 PROJ. 5701 TASK 026
CHKD. [illegible] DATE 6-17-81 PAGE ____ OF ____
LACBWR SEP

INNER SHIELD BLDG NODE 6-C REF.



PLAN @ GROUND FLOOR

$H_2 = (30 + 7.7)\,2 \times 12 = 904.8''$

$H_3 = 2 \times 23.5 \times 12 = 564''$

C =

INNER SHIELD BLDG (NODE 6-C)

TAKEN FROM y = 25.03 TO LEFT ℄ CONTAINMENT

AREA No	AREA	y	Ay	d_{x3}	Ad_{x3}^2	I_{x3}	$Ad_{x3}^2 + I_{x3}$
A_1	2(23.25)	34.91	1623.32	2.18	220.99	2(34.99)	290.97
A_2	2(15.17)	34.91	1059.17	2.18	144.19	2(22.84)	189.87
A_3	2(3.26)	39.43	257.08	6.7	292.68	2(6.23)	305.14
A_4	0.83	32.37	26.87	0.36	NEG	NEG	NEG
A_5	2(14.86)	41.08	1220.90	8.35	2072.15	2(9.92)	2091.99
A_6	2(11.75)	47.35	1112.73	14.62	5022.99	2(92.31)	5207.61
A_7	2(11.47)	38.63	886.17	5.90	798.54	2(14.62)	827.78
A_8	0.34	32.50	11.05	0.23	NEG	NEG	NEG
A_9	2(1.60)	34.64	110.85	1.91	11.67	NEG	11.67
A_{10}	2(1.60)	35.64	114.05	2.91	27.10	NEG	27.10
A_{11}	2(24.06)	41.03	1974.36	8.3	3314.99	2(80.42)	3475.83
A_{12}	105.75	48.74	5154.26	16.01	27105.85	908.84	28014.69
A_{13}	2(6.15)	21.94	269.86	10.79	1432.12	NEG	1432.12
A_{14}	2(5.68)	18.10	205.62	14.63	2431.46	2(33.10)	2497.66
A_{15}	2(34.94)	18.81	1314.44	13.92	13540.40	2(135.68)	13811.76
							53194.19
A_{17}	7.33	14.34	105.11	18.39	2478.95	200.52	2679.47
A_{18}	25.00	10.15	253.75	22.58	12746.41	166.88	12913.29
A_{19}	13.50	10.69	144.32	22.04	6557.78	27.87	6585.65
A_{20}	5.50	4.85	26.68	27.88	4275.12	2.65	4277.77
A_{21}	7.50	0	-	32.73	8034.40	5.64	85.98
A_{22}	12.71	4.14	52.62	28.59	10389.00	59.12	10448.12
A_{23}	1.00	22.78	22.78	9.95	99.00	NEG	99.00
A_{24}	0.50	22.61	11.31	10.12	51.21	NEG	51.21

ΣA 487.54 ΣAy 15957.3

$I_{x3} = 95324.68$ FT

$I_{x3} = 19.7665 \times 10^8$ IN⁴

$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{15957.3}{487.54} = 32.73'$

92 IN

32.73 - 25.03 = 7.7   c.g. is 7.7' TO RIGHT ℄ CONTAINMENT

NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY R.R DATE 6-17-79 PROJ. 5101 TASK 026
CHKD. aB DATE 6-19-81 PAGE ____ OF ____
LACBWR SEP

INNER SHIELD BLDG — NODE 6-C

	AREA	d_{x2}	I_{x2}	Ad^2_{x2}	$I_{x2}+Ad^2_{x2}$	d_{x3}	I_3	Ad^2_{x3}	$I_{13}+Ad^2_{x3}$	REF.
LBC Z	A_1 = 23.25	7.99	57.97	1484.12	1542.09	9.88	34.99	2269.29	2304.28	
Z	A_2 = 15.17	12.51	16.11	2374.50	2390.61	9.88	22.84	1481.05	1503.89	
Z	A_3 = 3.26	5.59	NEG	101.78	101.78	14.40	6.23	101.78	108.01	
—	A_4 = 0.83	13.79	NEG	157.84	157.84	7.34	NEG	44.72	44.72	
Z	A_5 = 14.86	2.63	34.13	102.77	136.89	16.05	9.92	3827.33	3837.25	
Z	A_6 = 11.75	0.61	1.43	4.37	5.81	22.32	92.31	5853.19	5945.51	
TRI Z	A_7 = 11.47	7.52	14.62	648.75	663.37	13.60	14.62	2121.87	2136.49	
—	A_8 = .34	13.01	NEG	58.30	58.30	7.47	NEG	19.22	19.22	
Z	A_9 = 1.60	14.89	NEG	355.19	355.19	9.61	NEG	147.95	147.95	
Z	A_{10} = 1.6	14.89	NEG	355.19	355.19	10.61	NEG	180.35	180.35	
Z	A_{11} = 24.06	18.29	80.42	8048.65	8129.07	16.0	80.42	6159.36	6239.78	
—	A_{12} = 105.75	0	20934.17	0	20934.17	23.71	908.8	59448.85	60357.69	
	320.96				48510.31				105228.65	
REC	A_{13} = 6.15	9.77	41.86	586.77	628.63	3.09	NEG	58.69	58.69	
REC	A_{14} = 5.68	5.59	NEG	177.64	177.64	6.93	33.10	273.01	306.12	
TRI	A_{15} = 34.44	8.72	135.68	2657.15	2792.83	6.22	135.68	1351.96	1487.64	
	93.59				7198.2				3709.9	
	A_{16} = ~~7.33~~	~~15.19~~	~~200.52~~	~~1691.30~~	~~1891.82~~	~~8.19~~	~~200.52~~	~~491.67~~	~~692.19~~	
	A_{17} = 7.33	12.69	200.52	1180.39	1380.91	10.69	200.52	836.64	1038.16	
	A_{18} = 25.0	14.63	166.88	5350.92	5577.80	14.88	166.88	5535.36	5702.24	
	A_{19} = 13.5	29.59	27.87	11820.17	11848.04	14.34	27.87	2276.08	2303.95	
	A_{20} = 5.5	12.68	2.65	884.30	886.95	20.18	2.65	2239.79	2242.44	
	A_{21} = 7.5	11.03	5.64	912.46	918.10	25.03	5.64	4698.76	4709.40	
	A_{22} = 12.71	18.89	59.12	4535.34	4594.46	20.89	59.12	5546.54	5605.66	
	A_{23} = 1.0	13.79	NEG	190.16	190.16	2.25	NEG	5.06	5.06	
	A_{24} = 0.5	10.96	NEG	60.06	60.06	2.42	NEG	2.93	2.93	
	73.04				25456.48				21604.89	
	A 487.50			J_{x2}	81164.99	FT^4			130538.39	

NES 105 (2/74)

INNER SHIELD BLDG (NODE 6-C)	REF.

PROPERTIES

FOR AREAS A_1 THRU A_{12}

USE TWICE THE VALUES EXCEPT A_4 A_{12} & A_8 ✓

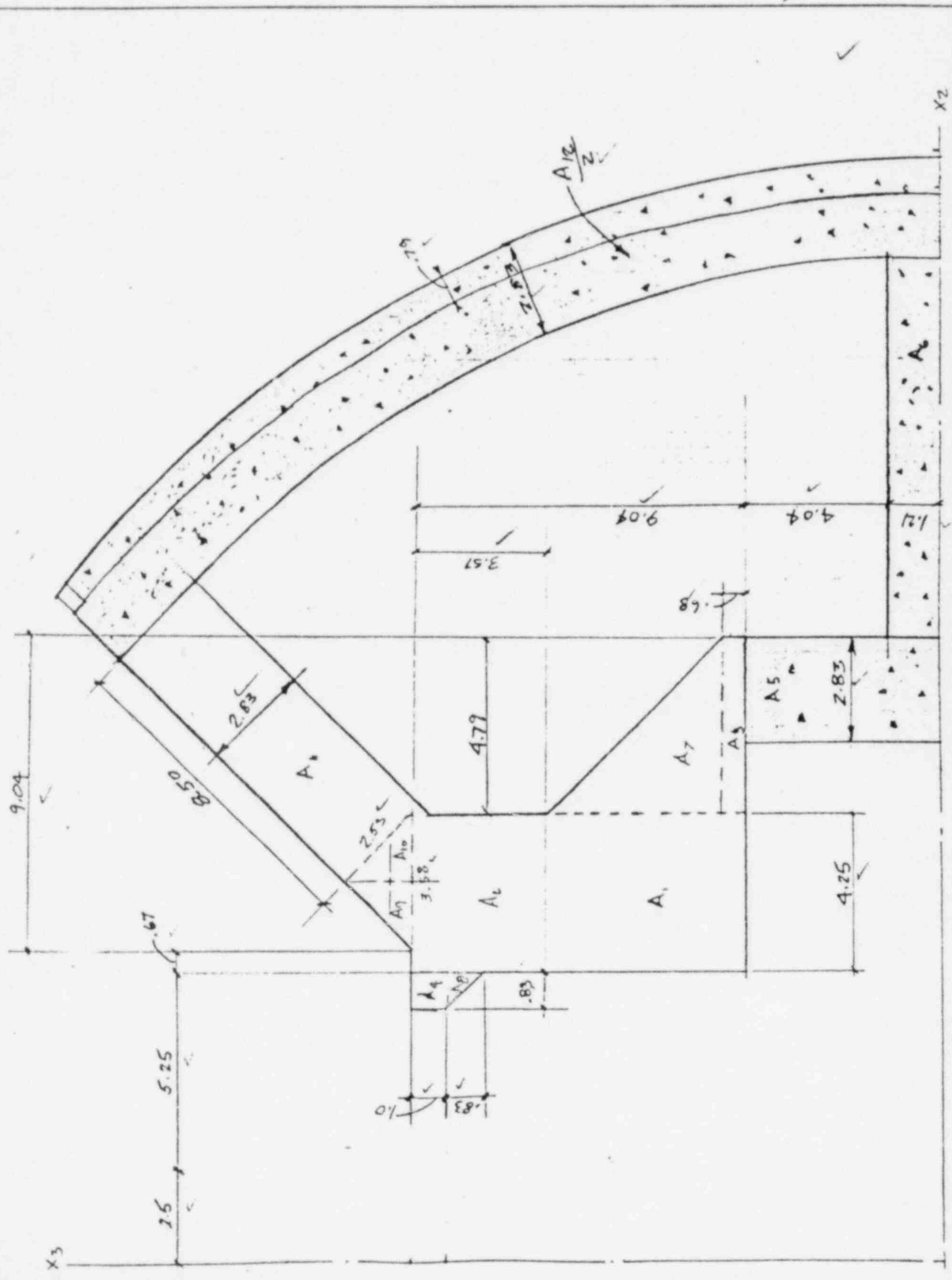
USE TWICE A_{13}, A_{14}, A_{15}

REF.

PROPERTIES FOR

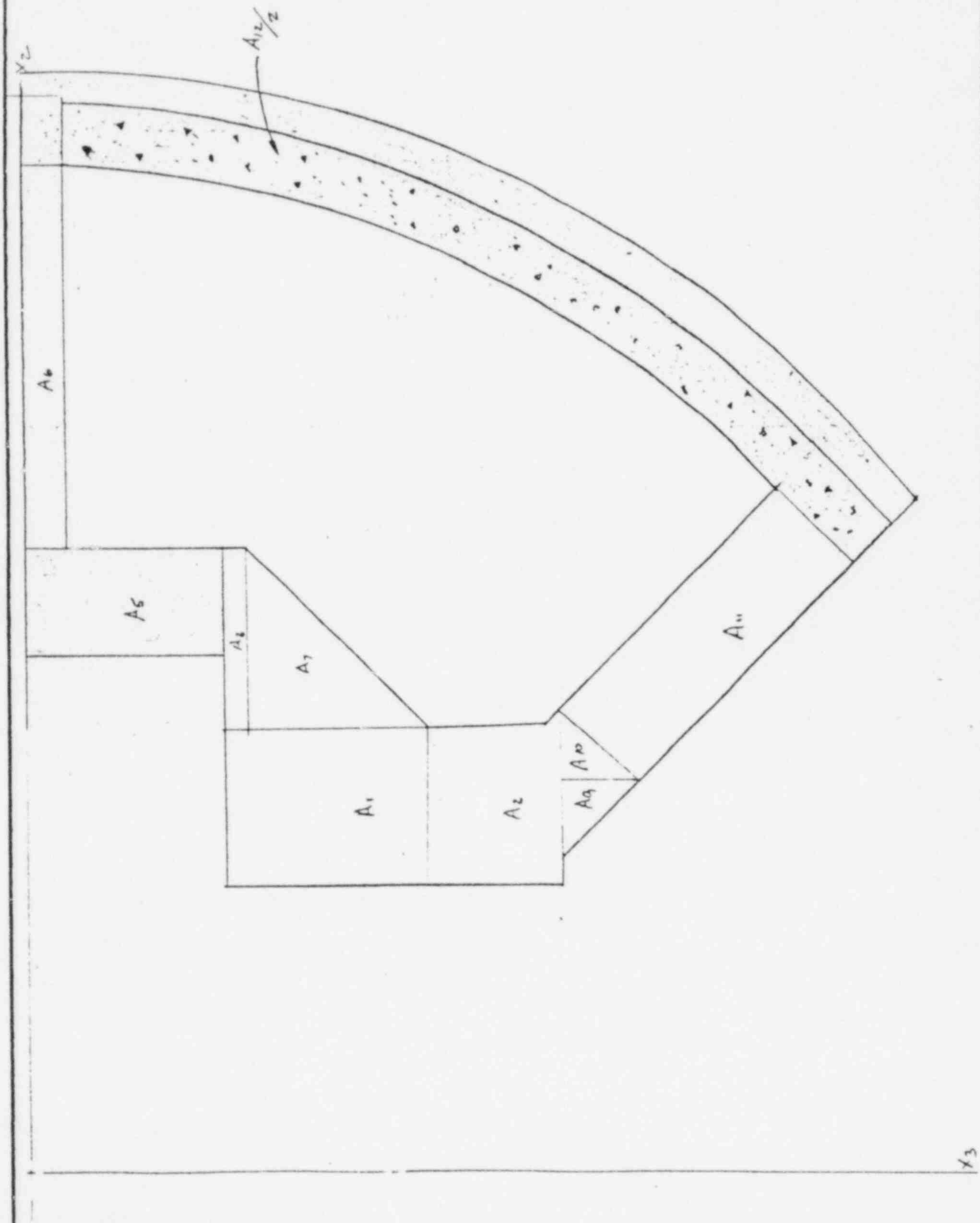
	AREA	b	h	d_{x2}	d_{x3}
REC.	A_1	4.25 ✓	5.47 ✓	7.99 ✓	9.88 ✓
	A_2	4.25 ✓	3.57 ✓	12.51 ✓	9.88 ✓
	A_3	4.79 ✓	0.68 ✓	5.59 ✓	14.40 ✓
	A_4	0.83 ✓	1.0 ✓	13.79 ✓	7.39 ✓
	A_5	2.83 ✓	5.25 ✓	2.63 ✓	16.05 ✓
	A_6	9.71 ✓	1.21 ✓	0.61 ✓	22.32 ✓
TRI	A_7	4.79 ✓	4.79	7.52 ✓	13.60 ✓
	A_8	0.83 ✓	0.83	13.01 ✓	7.47 ✓
	A_9	1.79 ✓	1.79 ✓	14.89 ✓	9.61 ✓
	A_{10}	1.79 ✓	1.79 ✓	14.89 ✓	10.61 ✓

INNER SHIELD BLDG (NODE 6-C) | REF.



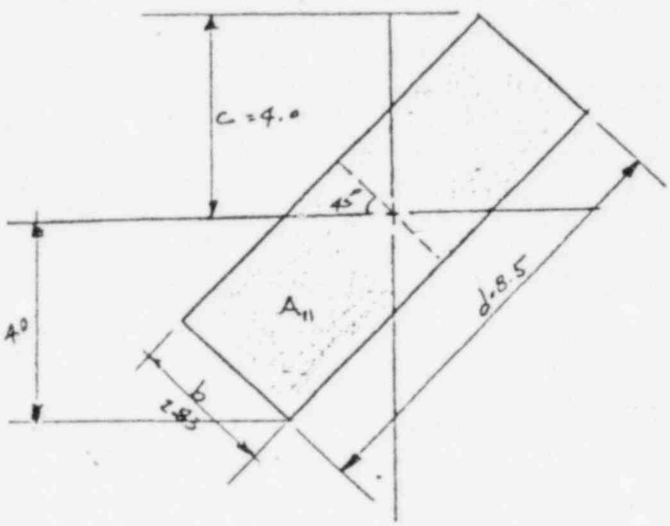
INNER SHIELD BLDG. (NODE 6-C)

REF.



INNER SHIELD BLDG (NODE 6-C)	REF.

AREA A_{11}



$A = bd$ ✓

$c = \frac{b \sin a + d \cos a}{2}$ ✓

$I = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$ ✓

REF: AISC 7TH ED
Pg 6-25

$C = \frac{2.83(.707) + (8.5)(.707)}{2} = 4.0$ FT ✓

$I_{x_2} = \frac{(2.83)((8.5))(2.83^2(.707)^2 + (8.5)^2(.707)^2)}{12} = 80.42$ FT⁴ ✓

$A = 24.06$ FT² ✓

$I_{x_2} = 80.42$ FT⁴ ✓

$d_{x2} = 18.29$ FT

$d_{x3} = 16.0$ FT ✓

$A d_{x2}^2 = 8048.65$ FT⁴ ✓

$A d_{x3} = 6159.36$ ✓

INNER SHIELD BLDG NODE 6-C | REF.

AREA A_{12}

REF R.J ROARK FORMULAS FOR STRESS AND STRAIN 4TH ED
PG 76

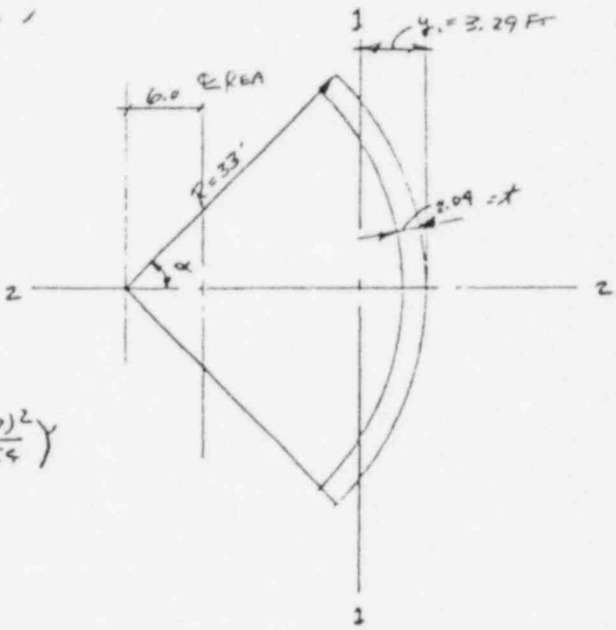
$A = 2\alpha R t$ $\alpha = 45° = 0.7854$ RAD ✓

$A = 2(.7854)33(2.04)$ ✓

$A = 105.75\ FT^2$ ✓

$y_1 = R(1 - \frac{\sin\alpha}{\alpha})$ ✓

$y_1 = 3.29$ FT ✓



$I_1 = R^3 t(\alpha + \sin\alpha\cos\alpha - \frac{2\sin^2\alpha}{\alpha})$ ✓

$I_1 = 33^3 \times 2.04(0.7854 + .707 \times .707 - \frac{2(.707)^2}{.7854})$ ✓

$I_1 = 908.89\ FT^4$ ✓

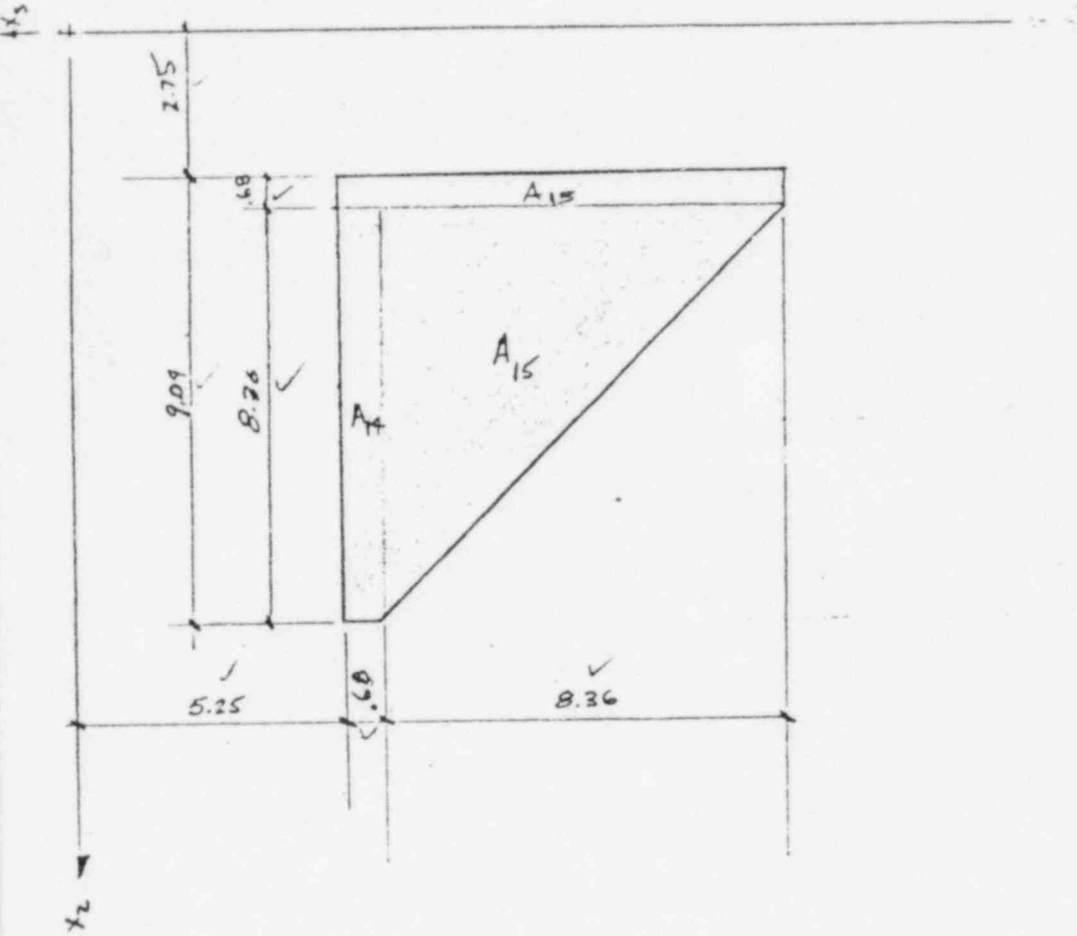
$I_2 = R^3 t(\alpha - \sin\alpha\cos\alpha)$ ✓

$I_2 = 33^3 \times 2.04(.7854 - .707^2)$ ✓

$I_2 = 20934.17\ FT^4$ ✓

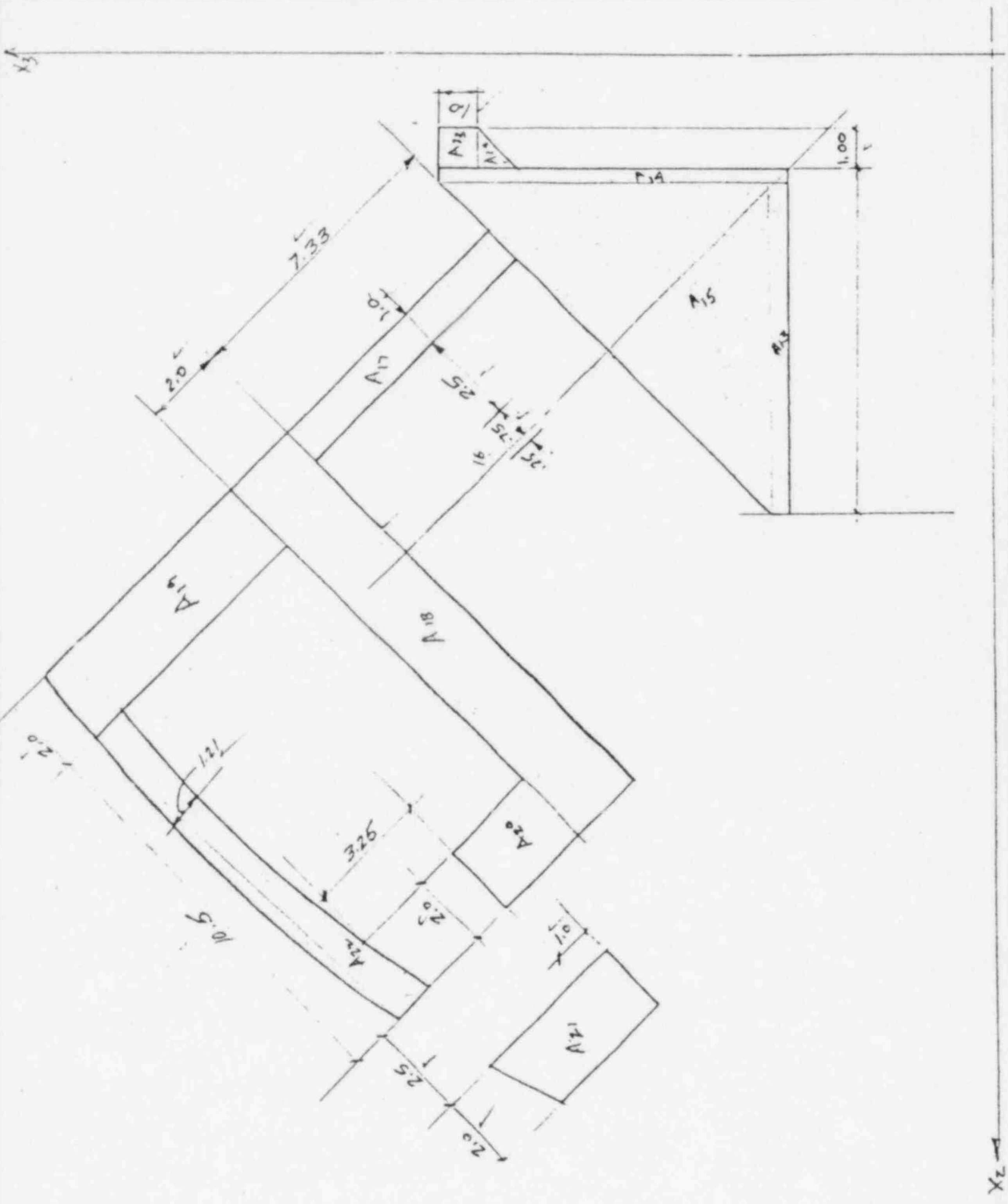
$d_{x3} = 23.71$ FT ✓

INNER SHIELD BLDG — NODE 6-C — REF.

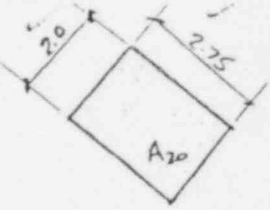


AREA	b	h	d_{x2}	d_{x3}
A_{13} ✓	.68 ✓	9.04 ✓	9.77 ✓	3.09 ✓
A_{14} ✓	8.36 ✓	.68 ✓	5.59 ✓	6.93 ✓
A_{15} ✓	8.36 ✓	8.36 ✓	8.72 ✓	6.22 ✓

INNER SHIELD BLDG. NODE 6-C REF.



INNER SHIELD BLDG — NODE 6-C — REF.



AREA A_{20}

$A = 5.50$ ✓

$C = \frac{b \sin a + d \cos a}{2}$ $a = 45°$ ✓

$C = \frac{2.0 \times .707 + 2.75 \times .707}{2} = 1.68'$ ✓

$I = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$ ✓

$I = \frac{2 \times 2.75(2^2 \times .707^2 + 2.75^2 \times .707^2)}{12} = 2.65$ ✓

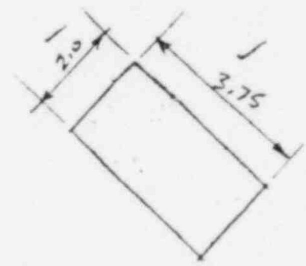
$d_{x2} = 11.0 + 1.68 = 12.68$ FT ✓ $Ad_{x2}^2 = 884.30$ FT^4 ✓ $I + Ad_{x2}^2 = 886.95$ FT^4 ✓

$d_{x3} = 18.5 + 1.68 = 20.18$ FT ✓ $Ad_{x3}^2 = 2239.79$ FT^4 ✓ $I + Ad_{x3}^2 = 2242.44$ FT^4 ✓

AREA A_{21}

$A = 7.5$ FT^2 ✓

$C = \frac{2 \times .707 + 3.75 \times .707}{2} = 2.03$ ✓



$I = \frac{2 \times 3.75[2^2 \times .707^2 + 3.75^2 \times .707^2]}{12} = 5.64$ ✓

$d_{x2} = 9.0 + 2.03 = 11.03$ ✓ $Ad_{x2}^2 = 912.46$ ✓

$d_{x3} = 23 + 2.03 = 25.03$ ✓ $Ad_{x3}^2 = 4698.76$ ✓

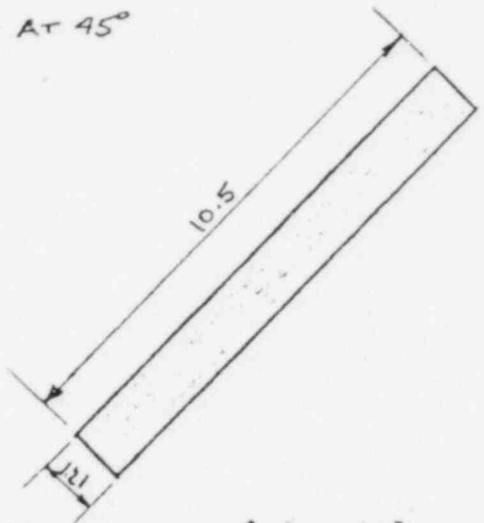
$I + Ad_{x2}^2 = 918.1$ FT^4 ✓

$I + Ad_{x3}^2 = 4704.4$ FT^4 ✓

INNER SHIELD BLDG — NODE 6C — REF.

AREA A_{22}

APPROXIMATE WITH RECTANGLE AT 45°



$A = 12.71\ FT^2$ ✓

$C = \frac{b \sin a + d \cos a}{2}$

$C = \frac{1.21 \times .707 + 10.5 \times .707}{2} = 4.14$ ✓

$I = \frac{bd\,(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$

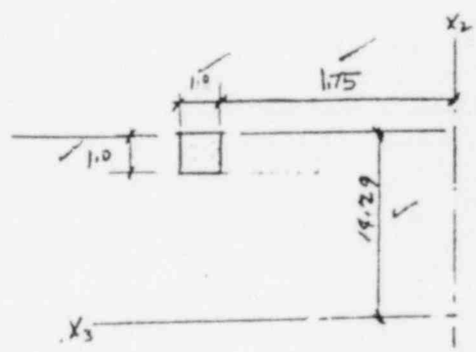
$I = \frac{(1.21)(10.5)[1.21^2 \times .707^2 + 10.5^2 \times .707^2]}{12}$

$I = 59.12\ FT^4$ ✓

$d_{x2} = 14.75 + 4.14 = 18.89\ FT$ ✓ $Ad_{x2}^2 = 4535.34\ FT^4$ ✓ $I + Ad_{x2}^2 = 4594.46\ FT^4$ ✓

$d_{x3} = 16.75 + 4.14 = 20.89\ FT$ ✓ $Ad_{x3}^2 = 5546.54\ FT^4$ ✓ $I + Ad_{x3}^2 = 5605.66\ FT^4$ ✓

AREA A_{23}



$A = 1\ FT^2$ ✓

$I = \frac{bd^3}{12}$, NEG ✓

$d_{x2} = 13.79$ ✓ $Ad_{x2}^2 = 190.16\ FT^4$ ✓

$d_{x3} = 2.25$ ✓ $Ad_{x3}^2 = 5.06\ FT^4$ ✓

AREA A_{24}

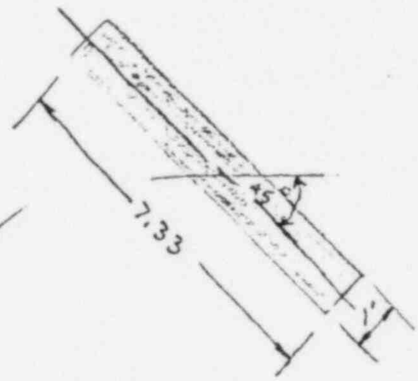
$A = .5\ FT^2$ ✓

$d_{x2} = 10.96$ ✓ $Ad_{x2}^2 = 60.06\ FT^4$ ✓

$d_{x3} = 2.42$ ✓ $Ad_{x3}^2 = 2.93\ FT^4$ ✓

INNER SHEILD BLDG NODE G-C | REF.

AREA A_{17}



$A = 7.33\ FT^2$ ✓

$C = \dfrac{b\sin a + d\cos a}{2}$

$= \dfrac{1(.707) + 7.33(.707)}{2} = 2.94\ FT$ ✓

$I = \dfrac{bd(b^2\sin^2 a + d^2\cos^2 a)}{12}$

$= \dfrac{1(7.33)(.707^2 + 7.33^2(.707^2))}{12} = 16.72\ FT^4$ ✓

$I = 16.72\ FT^4$ ✓

$d_{z_2} = 12.25 + 2.94 = 15.19$ ✓ $Ad_{z_2}^2 = 1691.30$ ✓ $I + Ad_{z_2}^2 = 1708.02$ ✓

$d_{z_3} = 4.33 + 2.94 = 7.27$ ✓ $Ad_{z_3}^2 = 387.41$ ✓ $I + Ad_{z_3}^2 = 404.13$ ✓

INNER SHIELD BLDG (NODE 6-C) | REF.

AREA A18

A= 25 FT² ✓

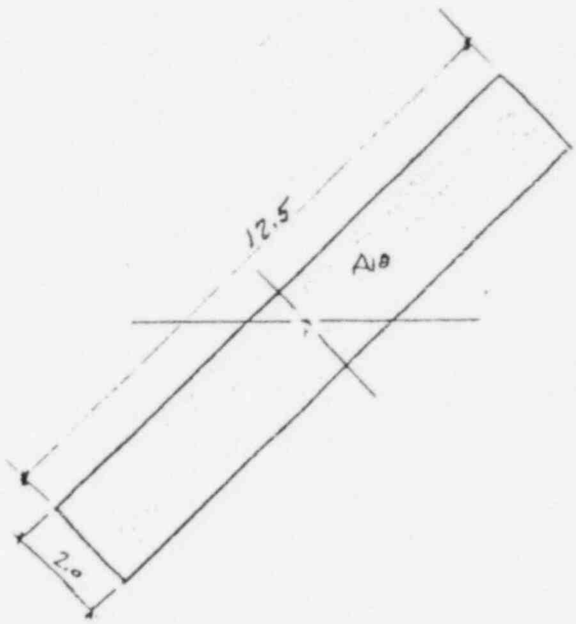
$C = \frac{b \sin a + d \cos a}{2}$ a = 45° ✓

$C = \frac{2(.707) + 12.5(.707)}{2} = 5.13'$ ✓

$I = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$

$I = \frac{2(12.5)(2^2 \times .707^2 + 12.5^2 \times .707^2)}{12}$

$I = 166.88\ FT^4$ ✓



$d_{x2} = 9.5 + 5.13 = 14.63$ FT ✓ $Ad_{x2}^2 = 5350.92\ FT^2$ ✓ $I + Ad_{x2}^2 = 5517.80$ ✓

$d_{x3} = 9.75 + 5.13 = 14.88$ FT ✓ $Ad_{x3}^2 = 5535.36\ FT^2$ ✓ $I + Ad_{x3}^2 = 5702.24$ ✓

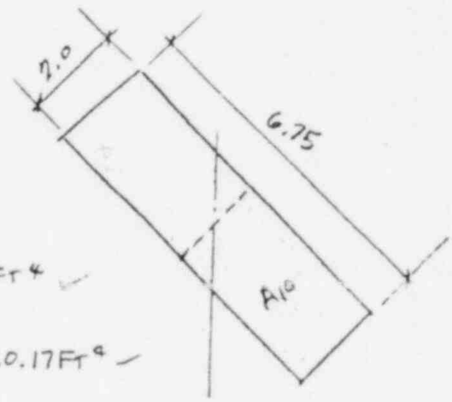
AREA 19

A = 13.5 ✓

$C = \frac{b \sin a + d \cos a}{2}$

$C = \frac{2 \times .707 + 6.75 \times .707}{2} = 3.09$ FT ✓

$I = \frac{2 \times 6.75(2^2 \times .707^2 + 6.75^2 \times .707^2)}{12} = 27.87\ FT^4$ ✓



$d_{x2} = 18.50 + 3.09 = 21.59$ FT ✓ $Ad_{x2}^2 = 11820.17\ FT^4$ ✓

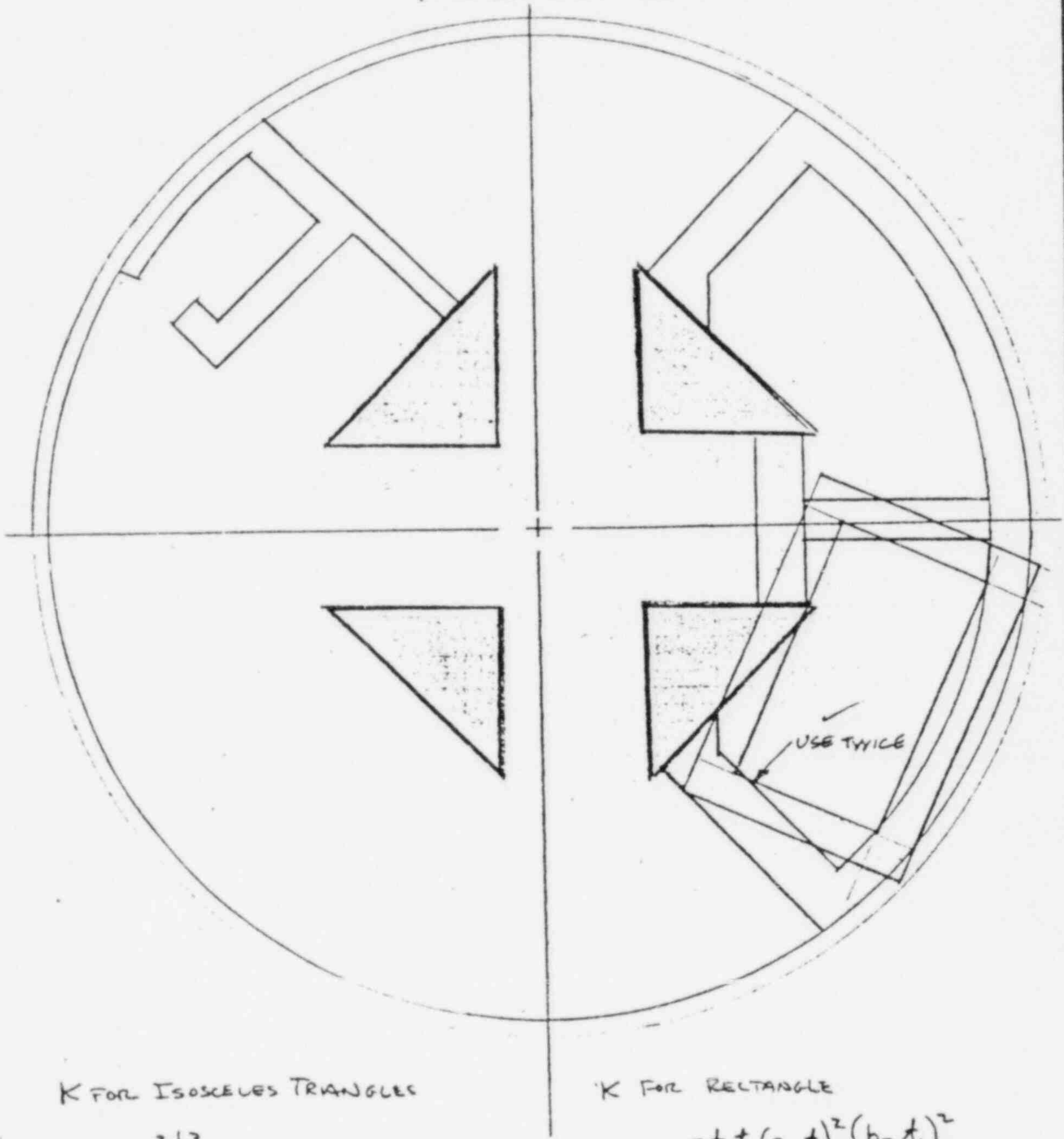
$d_{x3} = 11.25 + 3.09 = 14.34$ FT ✓ $Ad_{x3}^2 = 2276.08\ FT^4$ ✓

$I_{x2} + Ad_{x2}^2 = 11848.04$ ✓

$I_{x2} + Ad_{x2}^2 = 2303.95\ FT^4$ ✓

INNER SHIELD BLDG | NODE 6-C | REF.

TORSIONAL CONSTANT



K FOR ISOSCELES TRIANGLES

$$K = \frac{a^3 b^3}{15a^2 + 20b^2}$$

$$K = \frac{(7^3)(14^3)}{15(14^2) + 20(7)^2} = 240.1$$

$4K = 960.4 \text{ FT}^4$

K FOR RECTANGLE

$$K = \frac{2 t t_1 (a-t)^2 (b-t_1)^2}{a t + b t_1 - t^2 - t_1^2}$$

$t = 2.83$ $t_1 = 2.04$
$b = 14$ $a = 20.5$

$$K = \frac{2(2.83)(2.04)(20.5-2.83)^2(14.0-2.04)^2}{20.5(2.83) + 14(2.04) - 2.04^2 - 2.83^2}$$

58.02 4.16 - 8.01

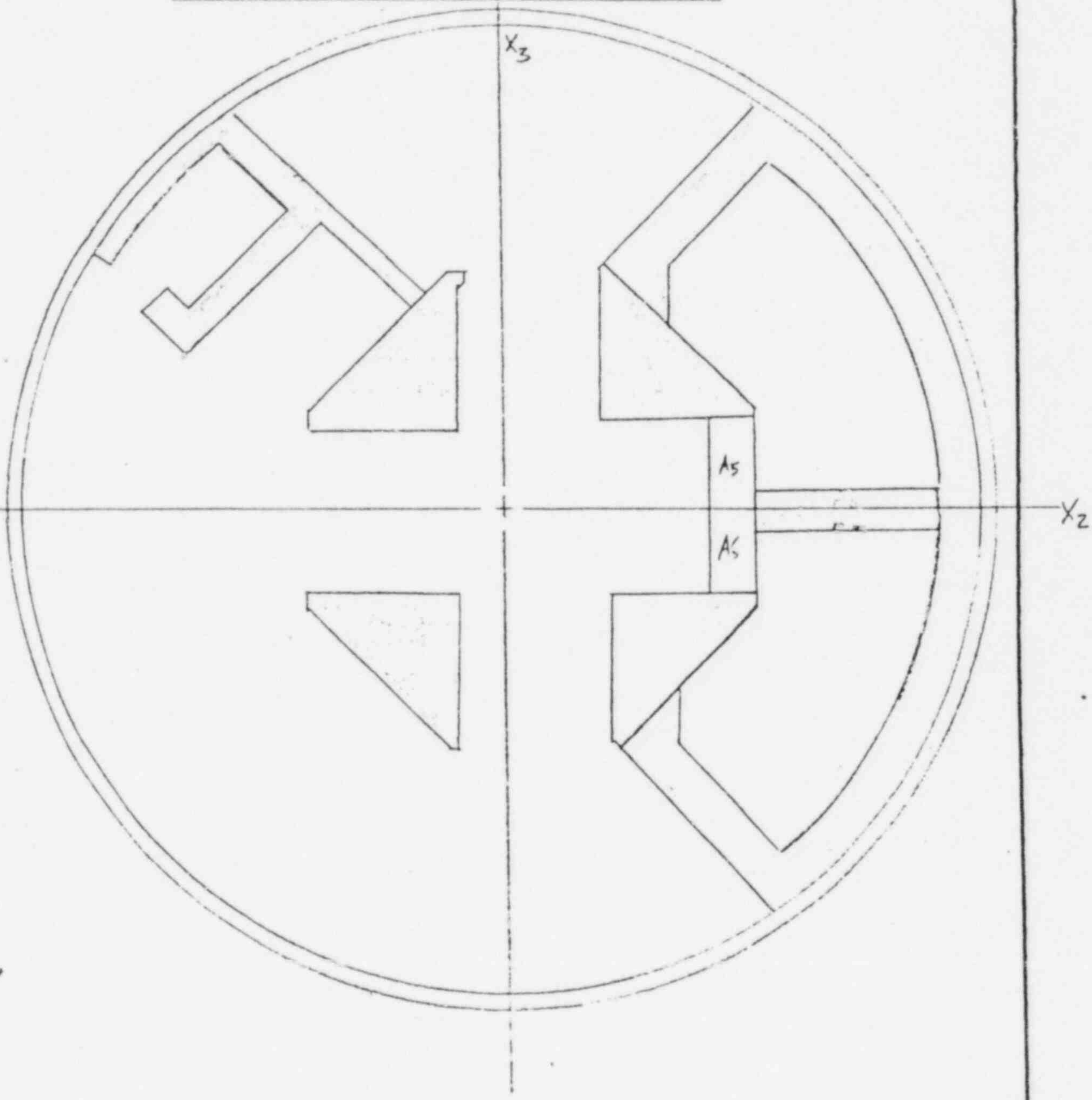
$K = 6930.28 \text{ FT}^4$

$2K = 13860.56 \text{ FT}^4$

TOTAL K = 14820.96 FT^4 = $3.0733 \times 10^8 \text{ IN}^4$

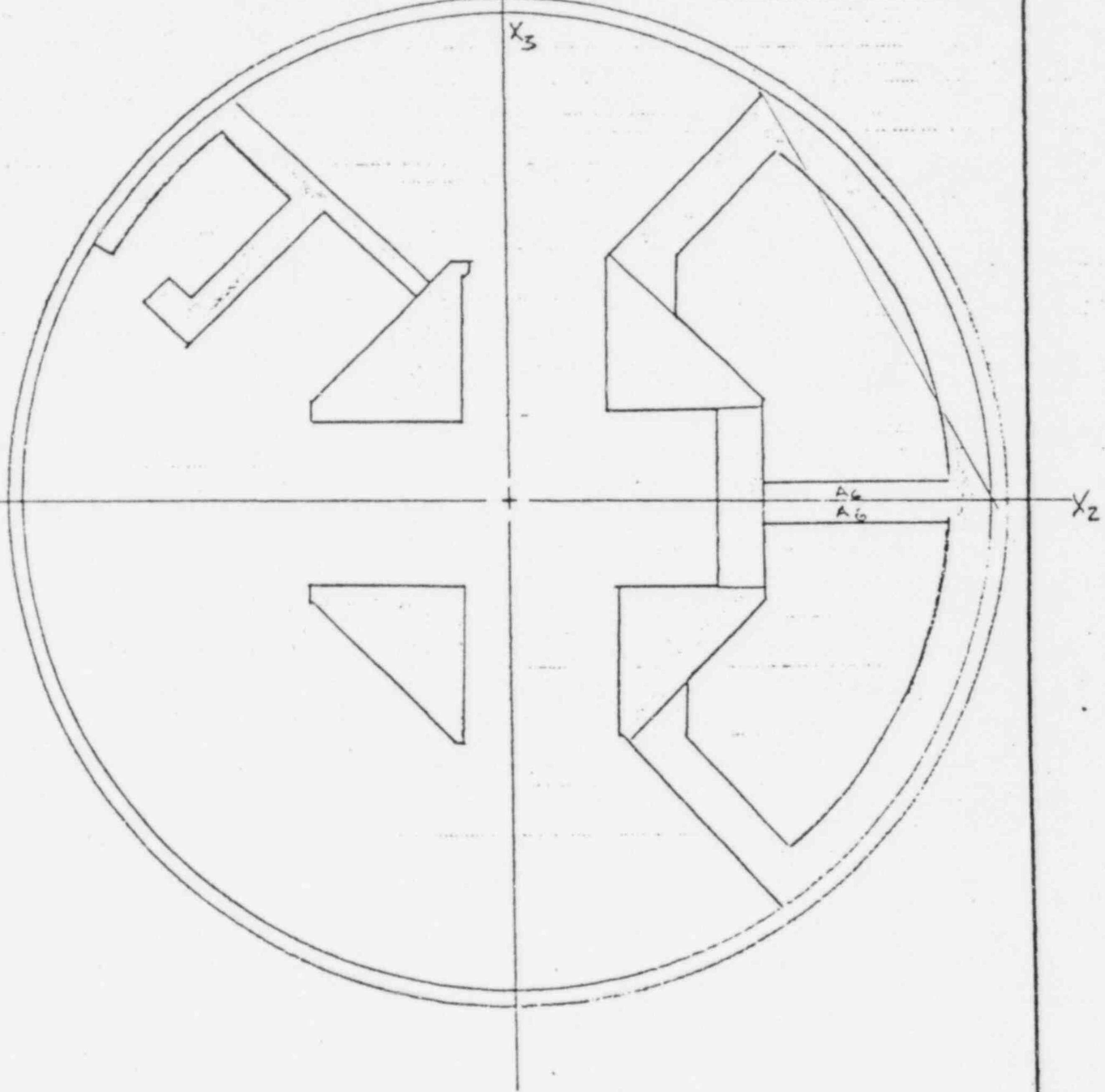
INNER SHIELD BLDG (NODE 6-C) | REF.

SHEAR AREA FACTOR



INNER SHIELD BLDG (NODE 6-C) | REF.

SHEAR AREA FACTOR



INNER SHIELD BLDG. NODE 6-C | REF.

SHEAR AREA FACTORS

USE 1/2 THE AREAS OF 4-CENTRAL TRIANGLES AND ANGULAR COMPONENTS OF REMAINDER OF AREA.

FOR EARTHQUAKE ALONG X_3 AXIS - SF2

AREA TRIANGLE = $\frac{1}{2}bh = \frac{1}{2}(14)(7) = 49^{\square}$ ✓

$\frac{4}{2}$ TRIANGLES = $98^{\square}$ ✓

SUBTRACT $2A_6$ = 23.5 ✓
79.5 ✓ ←

TOTAL AREA = $487.5^{\square}$ ✓

REMAINING AREA 413 ✓

AREA A_{12} = 105.75 ✓
307.25 ✓

USE $\sin 45°(307.25) + \sin 60°(105.75) = 308.81$ ←
79.5 ✓
383.30 ✓

$$S.F.2 = \frac{383.30}{487.50} = 0.786$$ ✓

FOR EARTHQUAKE ALONG X_2 AXIS SF.3

$\frac{4}{2}$ TRIANGLES = $98^{\square}$ ✓

SUBTRACT $2A_5$ = 29.72 ✓
$68.28^{\square}$ ✓

TOTAL AREA = 487.5 ✓

REMAINING AREA = 419.22 ✓

AREA A_{12} = 105.75 ✓
313.47 ✓

USE $\sin 45°(313.47) + \cos 60°(105.75) = 274.50$ ✓
68.28
342.78 ✓

$$S.F.3 = \frac{342.78}{487.50} = 0.703$$ ✓

✓ SF.2 = 0.786
✓ S.F.3 = 0.703

GROUND FLOOR | REF.

SLAB WEIGHT

12" APPROX. $\frac{1}{2}(4+34)(15)(1)(.15) = 54^{K}$ ✓

7" APPROX $\frac{7}{12}\frac{1}{2}13(10+15)(.15) =$ 14.2188

$\frac{7}{12}\frac{1}{2}(8)(8)(.15) =$ 2.800

$\frac{7}{12}(13)(8)(.15) =$ 9.100

$\frac{7}{12}\frac{1}{2}(8)(9)(.15) =$ 3.150

$\frac{7}{12}\frac{1}{2}(8)(3)(.15) =$ 1.050

$\frac{7}{12}(11)(16)(.15) =$ 15.400

6" APPROX $\frac{6}{12}(15\times10)(.15) =$ 11.25 ✓

$\frac{6}{12}(10\times10)(.5)(.15) =$ 3.75 ✓

114.7189^{k}

GROUND FLOOR | REF.

BEAM WEIGHTS

SLAB	BEAM	b	h	L	WEIGHT
	B-1	12 ✓	9 ✓	8.75 ✓	0.3281 ✓
	B-2	9 ✓	9 ✓	7' ✓	0.1969 ✓
6"	B-3	9 ✓	9 ✓	6' ✓	0.1688 ✓
	B-4	9 ✓	9 ✓	4.5' ✓	0.1266 ✓
	B-5	21 ✓	24 ✓	20' ✓	7.8750 ✓
—	B-6	24 ✓	27 ✓	16' ✓	8.4000 ✓
7"	B-7	18 ✓	21 ✓	15' ✓	3.9375 ✓
	B-8	24 ✓	27 ✓	19.5 ✓	9.7500 ✓
	B-9	24 ✓	21 ✓	12.75 ✓	4.4625 ✓
	B-10	12 ✓	18 ✓	12.50 ✓	1.7188 ✓
	B-11	15 ✓	18 ✓	10.75 ✓	1.8476 ✓
	B-12	24	21 ✓	12.75 ✓	4.4625 ✓
12	B-13	12	21 ✓	15.25 ✓	1.7156 ✓
					44.9899 K ✓

GROUND FLOOR (NODE 6-C) REF.

CORE WEIGHT

232#/FT³ FROM 5-C 7.13' @ 610.99 FT² = 1010.68^K ✓

150#/FT³ FROM 6-C 4.37/2 @ 487.50 FT² = 159.79^K ✓

SLAB WT 114.72^K ✓
BEAM WT 44.99^K ✓
DEAD WEIGHT TOTAL WT 1330.18^K TOTAL ✓

DEAD LOAD

INNER SHIELD BLDG. (NODE 6-C) | REF.

CENTER OF MASS CALCULATION

* APPROXIMATION

	DEAD LOAD	WEIGHT	X_3	WX_3
5-C	CORE AREA	1016.63	10.41	10583.64
	7" SLAB & BEAMS	-90.76* ✓	-20* ✓	-1815.2
6-C	CORE AREA	159.79 ✓	7.7 ✓	1230.38 ✓
		1267.23		7538.06

$$\bar{X}_3 = \frac{7538.06}{1267.23} = 5.95 \text{ FT}$$

RICH HAGNER →
HACKNER

NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY R.R. DATE 4-13-79 PROJ. 5101 TASK 026
CHKD. [illegible] DATE 6-17-81 PAGE ____ OF ____
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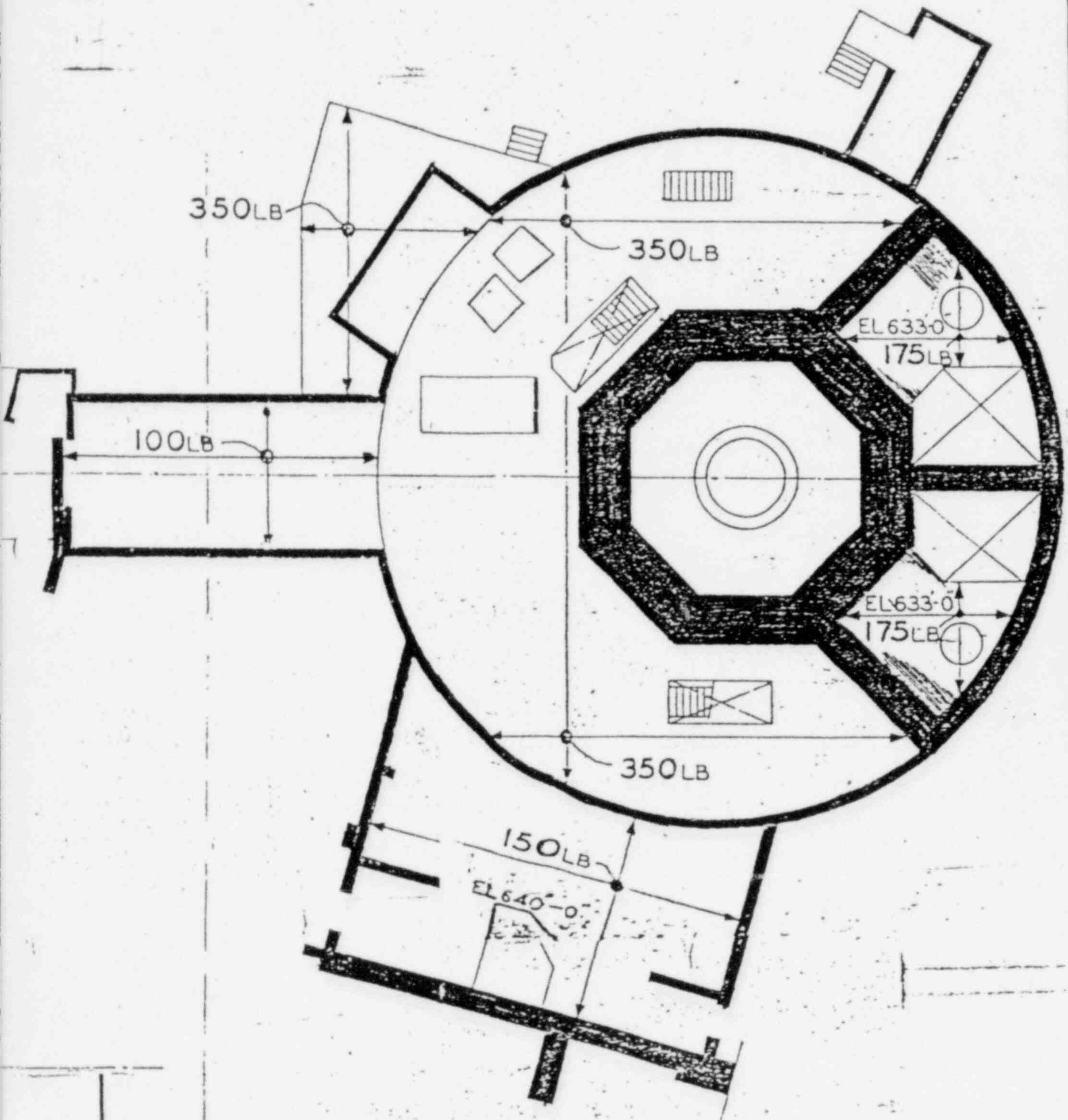
REF.



CONTAINMENT VESSEL
GROUND FLOOR
EL. 642'-9"

GROUND FLOOR (NODE 6-C)	REF.

LIVE LOAD

TOTAL AREA = $\pi R^2 = \pi\, 29.21^2$ = 2680.48 # ✓
CORE AREA (FROM NODE 5-C) = 610.99 #
2(9x10) ½(5+10)(10) = 330 #

350 PSF AREA = 2680.48 − 610.99 − 330.00 = 1739.49 #
175 PSF AREA = 180 # ✓

TOTAL LIVE LOAD = (1739.49)(.350) + (180)(.175) = 640.3215 k ✓

INNER SHIELD BLDG — NODE 6-C (51) — REF.

SUMMARY FOR NODE 6-C 50

✓DEAD LOAD = 1330.18^k

✓LIVE LOAD = 640.32^k

✓AREA = $7.0205 \times 10^4 \ IN^2$

✓$\bar{X}_2$ = 92 IN

✓I_{Y2} = $16.8304 \times 10^8 \ IN^4$

✓I_{Y3} = $19.7665 \times 10^8 \ IN^4$

✓K = $3.0733 \times 10^8 \ IN^4$

✓SF2 = 0.786

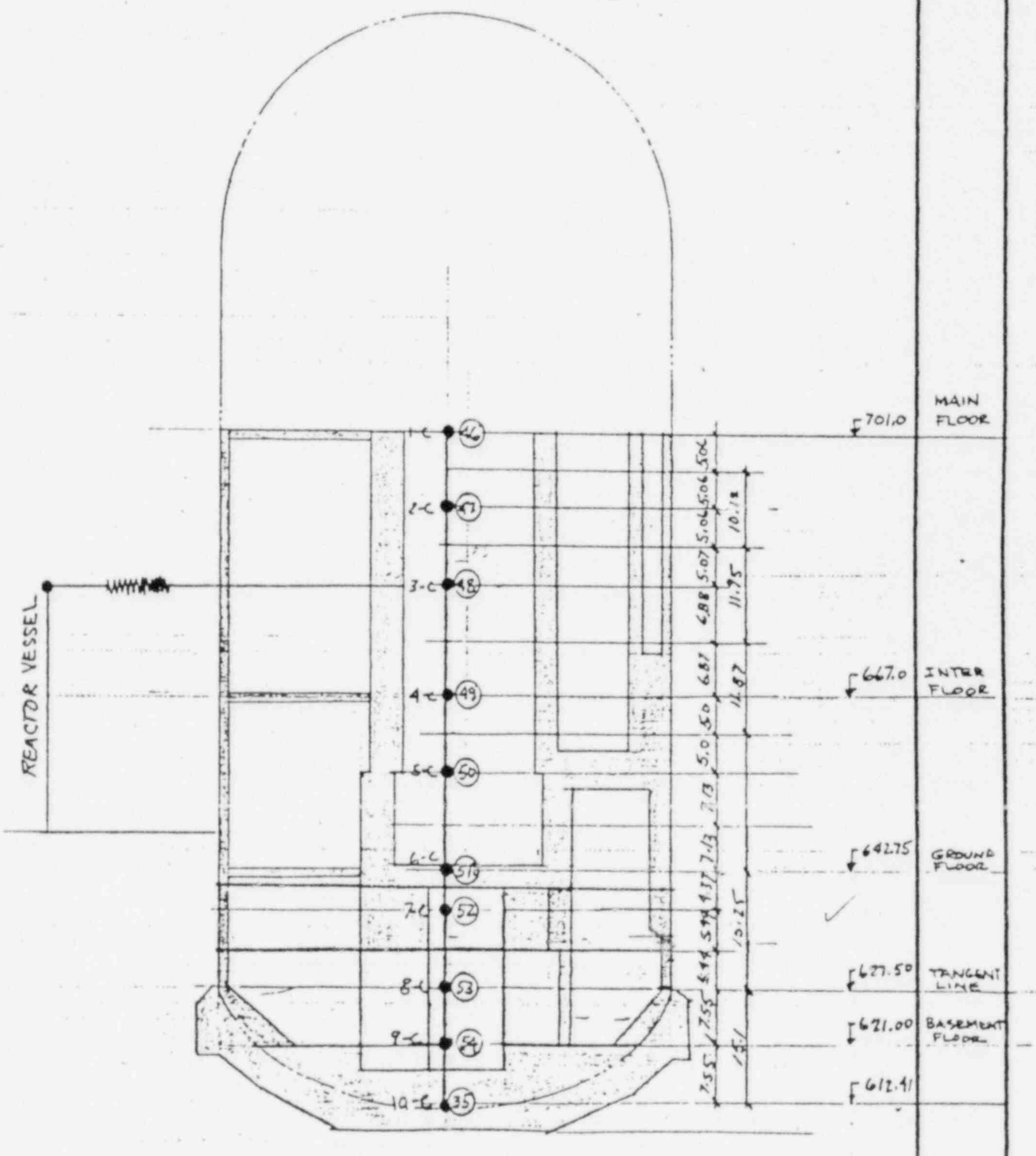
✓SF3 = 0.703

	REF.

NODE 7-C

INNER SHIELD BLDG NODE 7-C	REF.

MODEL



NODE 7-C | REF.

DEAD LOAD

USE AREA OF CORE FROM 6-C 487.50 ✓

LOAD = $\left[\frac{4.37}{2} + (5.49)\right]$ (.150)(487.50) = 557.58 TOTAL DEAD LOAD

USE PROPERTIES FROM 6-C ✓

A = 487.50 ✓ = 7.0200×10^4 IN² ✓

I_{x2} = 81164.99 FT⁴ ✓ = 16.8304×10^8 IN⁴ ✓

I_{x3} 95324.68 FT⁴ ✓

INNER SHIELD BLDG NODE 7-C REF.

CENTER OF MASS CALCULATION

DEAD LOAD	WEIGHT	X_3	$W X_3$
CORE	557.58[k]	7.7	

$\bar{X}_3 = 7.7 \text{ FT}$ ✓

INNER SHIELD BLDG NODE 7-C (52) REF.

SUMMARY FOR NODE 7-C (52)

DEAD LOAD = 557.58ᵏ

LIVE LOAD = ——

✓AREA = 7.0205×10^4 IN²

✓$\bar{X}_2$ = 92 IN

✓I_{x2} = 16.8304×10^8 IN⁴

✓I_{x3} = 19.7665×10^8 IN⁴

✓K = 3.0733×10^8 IN⁴

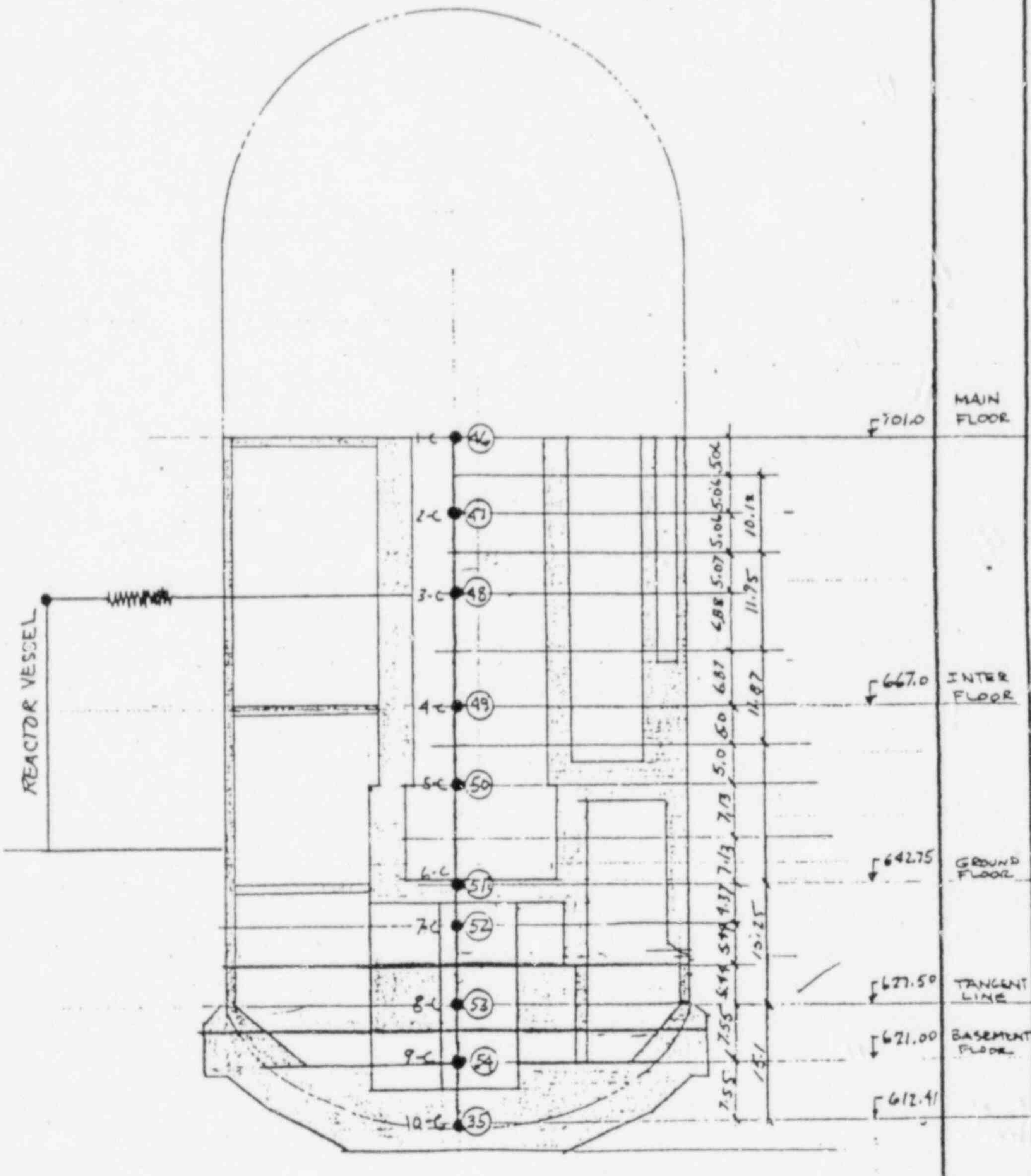
✓SF2 = 0.786

✓SF3 = 0.703

	REF.
NODE 8-C	

INNER SHIELD BLDG (NODE 8-C) | REF.

MODEL



NODE 8-C | REF.

USE PROPERTIES OF NODE 6-C EXCEPT REMOVE A_{12}

Area = 487.50
A_{12} = -105.75
381.75 FT²
→ 5.4972 x10⁴ IN² ✓

$I_{y2} + Ad_{x2}^2$ = 81164.99
- 20934.17
60230.82 FT⁴
→ 12.4895 x10⁸ IN⁴ ✓

$I_{x3} + Ad_{x3}^2$ = 130538.39
60357.69
70180.70 FT⁴

WEIGHT $(5.44 + \frac{7.55}{2})$ (AREA FROM 8-C = 381.75)(.15) = 527.67ᴷ ✓

INNER SHIELD BLDG. NODE 8-C | REF.

USING PROPERTIES FROM NODE 6-C AND SUBTRACTING OUT AREA A_{12}

$\Sigma A = 381.75\ FT^2$ ✓ ΣA_y 10803.04 ✓

$d_{x3} = \frac{10803.04}{381.75} - 25.03 = 3.27'$ (39 IN) TO RIGHT OF CENTER

AREA	d_{x3}	A	Ad_{x3}^2	I_3	$I_{x3} + Ad_{x3}^2$
2 A_1	6.61 ✓	46.5 ✓	2031.68 ✓	69.98 ✓	2101.66 ✓
2 A_2	6.61 ✓	30.34 ✓	1325.62 ✓	45.68 ✓	1371.30 ✓
2 A_3	11.13 ✓	6.52 ✓	807.68 ✓	12.46 ✓	820.14 ✓
A_4	4.07 ✓	0.83 ✓	13.75 ✓	NEG ✓	13.75 ✓
2 A_5	12.78 ✓	29.72 ✓	4854.12 ✓	19.84 ✓	4873.96
2 A_6	19.05 ✓	23.50 ✓	8528.21 ✓	184.62 ✓	8712.83 ✓
2 A_7	10.33 ✓	22.94 ✓	2447.90 ✓	29.24 ✓	2477.14 ✓
A_8	4.20 ✓	0.34 ✓	6.00 ✓	NEG ✓	6.00 ✓
2 A_9	6.34 ✓	3.2 ✓	128.63 ✓	NEG ✓	128.63 ✓
2 A_{10}	7.34 ✓	3.2 ✓	172.40 ✓	NEG ✓	172.40 ✓
2 A_{11}	12.73	48.12 ✓	7797.99 ✓	160.89 ✓	7958.83
2 A_{13}	6.36 ✓	12.3 ✓	497.53 ✓	NEG ✓	497.53 ✓
2 A_{14}	10.20	11.36 ✓	1181.89 ✓	66.20 ✓	1248.09 ✓
2 A_{15}	9.49 ✓	69.88 ✓	6293.40 ✓	271.36 ✓	6564.76 ✓
A_{17}	13.96 ✓	7.33 ✓	1428.48	200.52 ✓	1629.00 ✓
A_{18}	18.15 ✓	25.00 ✓	8235.56 ✓	166.88 ✓	8402.44
A_{19}	17.61 ✓	13.50 ✓	4186.51 ✓	27.87 ✓	4214.38 ✓
A_{20}	23.45 ✓	5.50 ✓	3024.46 ✓	2.65 ✓	3027.11 ✓
A_{21}	28.30 ✓	7.50 ✓	6006.68 ✓	5.64 ✓	6012.32 ✓
A_{22}	24.16 ✓	12.71 ✓	7418.90 ✓	59.12 ✓	7478.02 ✓
A_{23}	5.52 ✓	1.00 ✓	30.47 ✓	NEG ✓	30.47
A_{24}	5.69 ✓	0.50 ✓	16.19 ✓	NEG ✓	16.19 ✓

I_{x3} = 67756.95 FT^4

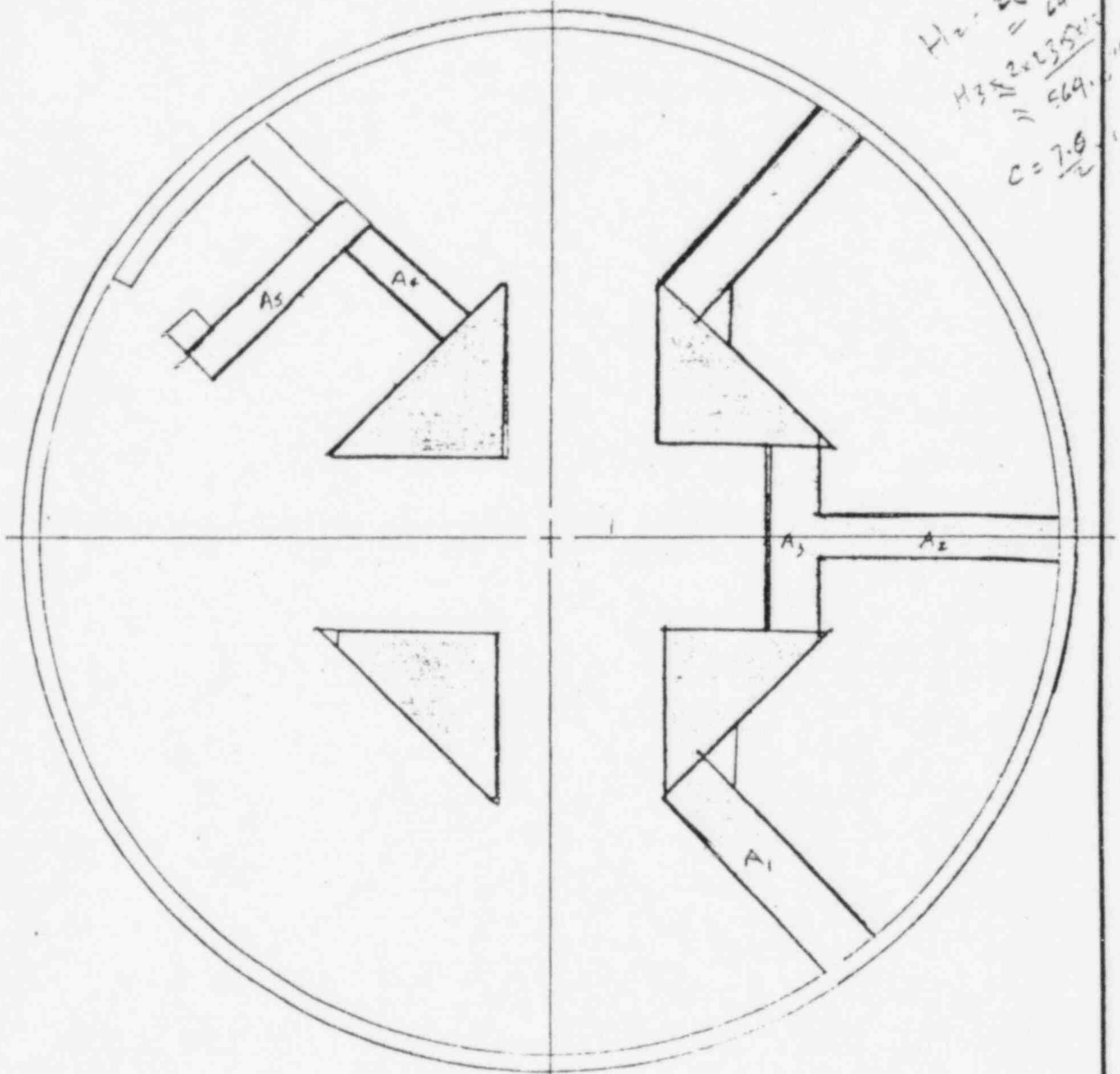
14.0501 $\times 10^8\ IN^4$

INNER SHIELD BLDG.	NODE 8-C	REF.

$H_2 = 2(30-3.\ldots)12 = 641.5''$ 58.6

$H_3 = 2 \times 235 \ldots = 569.\ldots''$

$C = \frac{7.0}{2} \cdot 12 = 42''$



K FOR TRIANGLES FROM NODE 6-C

K = 960.4 FT^4

$2 A_1 = \frac{bt^3}{3} \quad \frac{(12.0)(2.83)^3}{3} = 90.66$

$1 A_2 = (12) \frac{(2.42)^3}{3} = 56.69$

$A_3 = 11 \frac{(2.83)^3}{3} = 83.11$

$A_4 = \frac{(7.33)(1)^3}{3} = \text{NEG}$

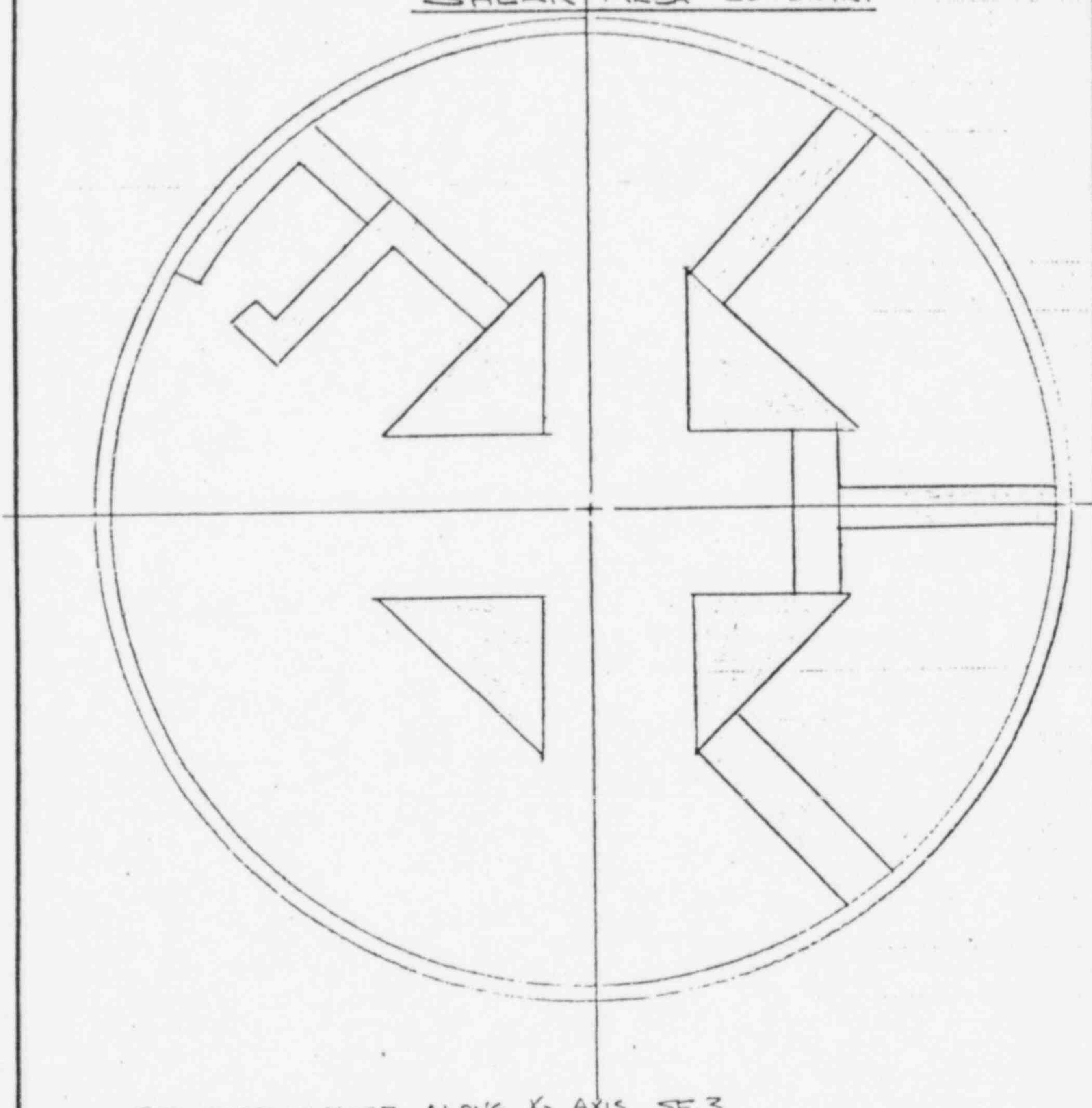
$A_5 \quad \frac{12.5(2)^3}{3} = 33.33$

359.45 FT^4

$K_{TOT} = 1319.85 \text{ FT}^4 = 0.2726 \times 10^8 \text{ IN}^4$ ✓

INNER SHIELD BLDG	NODE 8-C	REF.

SHEAR AREA CONSTANT



FOR EARTHQUAKE ALONG X_3 AXIS SF.3

TOTAL AREA = 381.75

$\frac{1}{2}$·4 TRIANGLES = 98.#

SUBTRACT $2A_5$ = 29.72

68.28 #

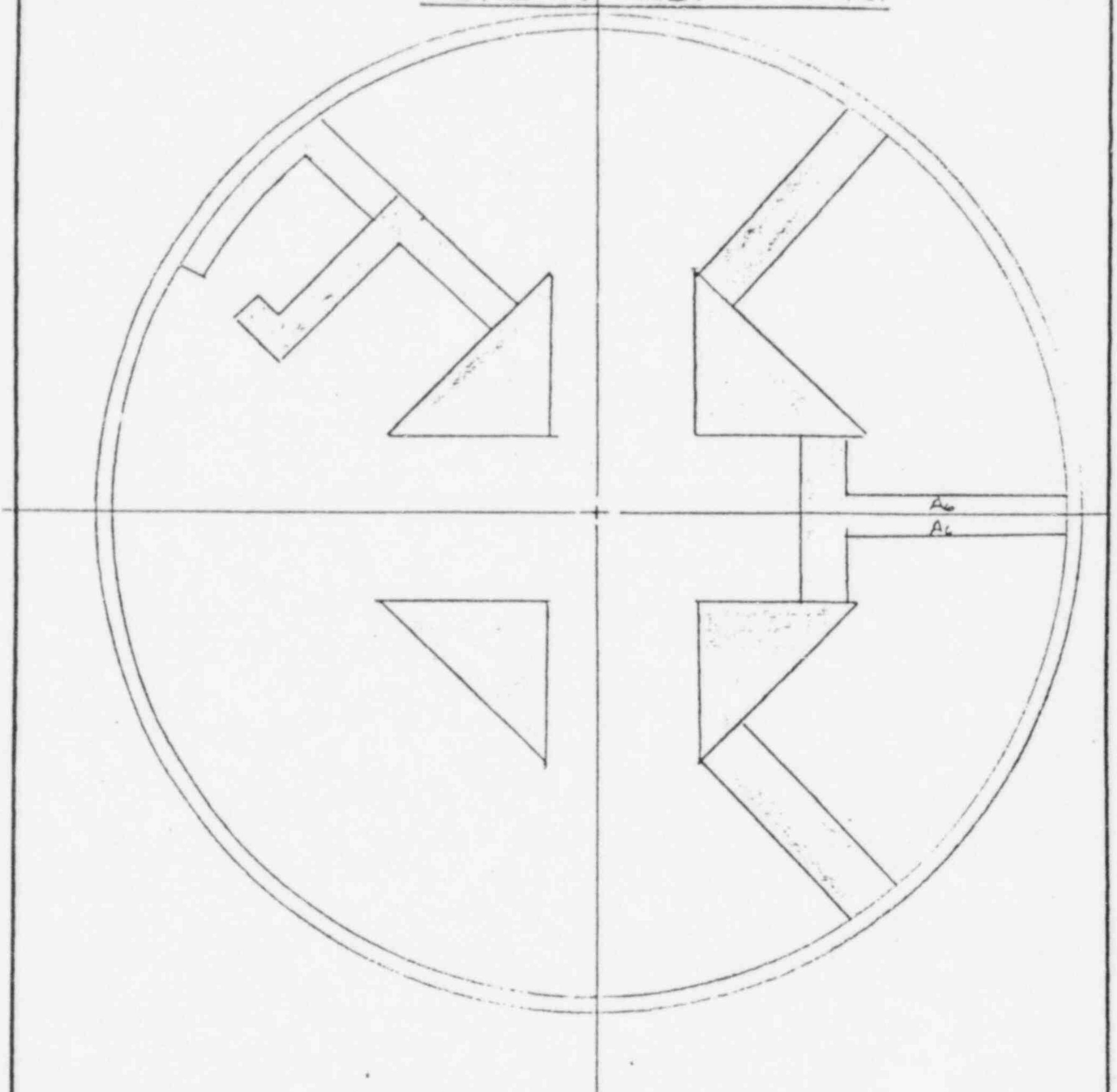
REMAINING AREA = 381.75 - 68.28 = 313.47 #

USE .707 (313.47) = 221.62 #

$$SF\ 3 = \frac{221.62 + 68.28}{381.75} = 0.759 ✓$$

INNER SHIELD BLDG	NODE 8-C	REF.

SHEAR AREA CONSTANT



FOR EARTHQUAKE ALONG X_3 AXIS SF.2

TOTAL AREA = 381.75
½-4 TRIANGLES = 98.#
SUBTRACT 2-A_6 = 23.5
74.5 #

REMAINING AREA = 381.75 - 74.5 = 307.25
USE .707 (307.25) = 217.23

SF. 2 = $\frac{217.23 + 74.5}{381.75}$ = .764 ✓

INNER SHIELD BLDG (NODE 8-C)	REF.
CENTER OF MASS CALCULATION CORE 527.67 k ✓ $\bar{x}_3$ = 3.27 FT PUMP - 80 k ✓ 607.67 k	

INNER SHIELD BLDG NODE 8-C (53)	REF.

SUMMARY FOR NODE 8-C (53)

✓DEAD LOAD = 527.67^{k}

✓LIVE LOAD = —

✓AREA = 5.4972×10^4 IN^4

✓$\bar{X}_2$ = 39 IN

✓I_{x2} = 12.4895×10^8 IN^4

✓I_{x3} = 14.0501×10^8 IN^4

✓K = 0.2726×10^8 IN^4

✓SF2 = 0.764

✓SF3 = 0.759

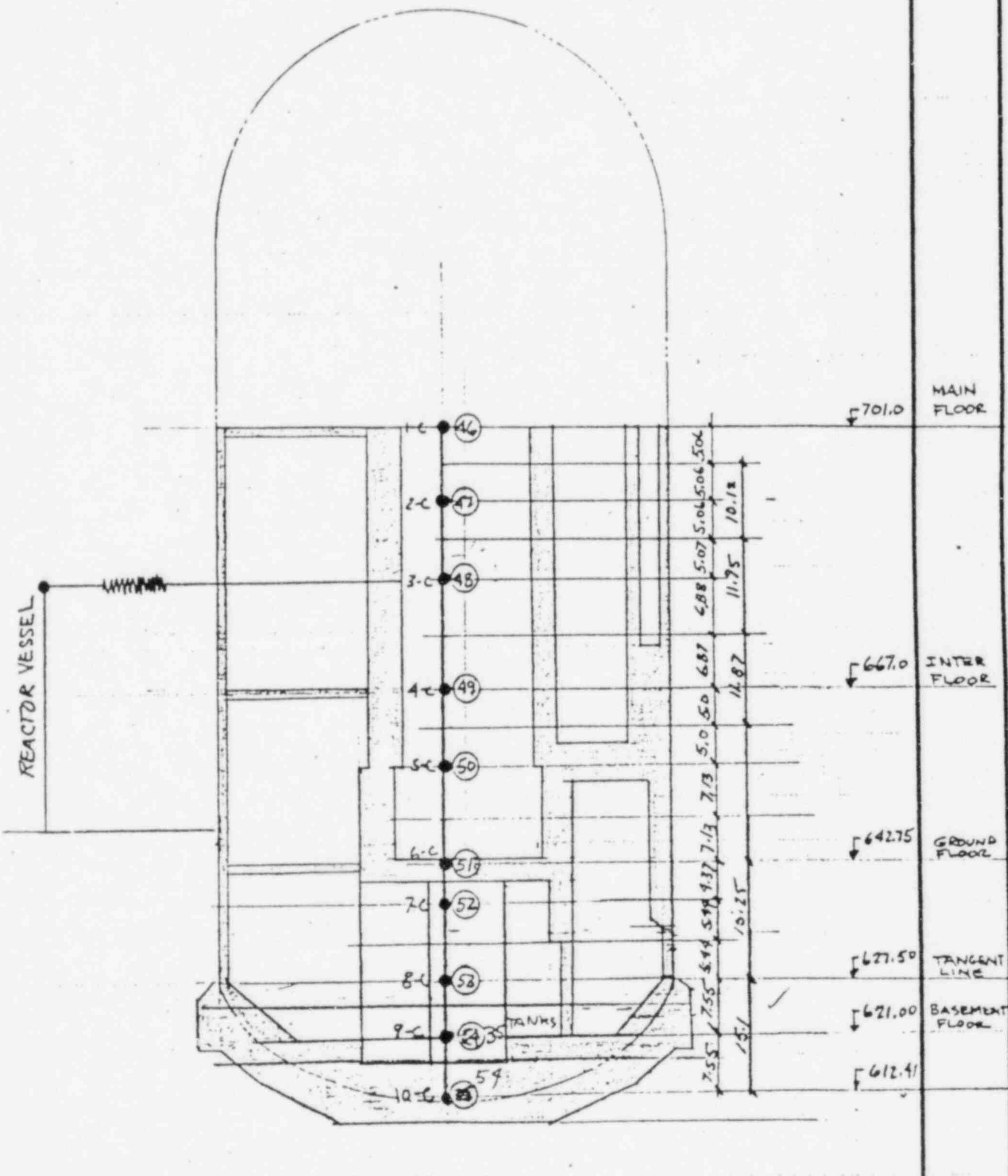
REF.

NODE 9-C

INNER SHIELD BLDG

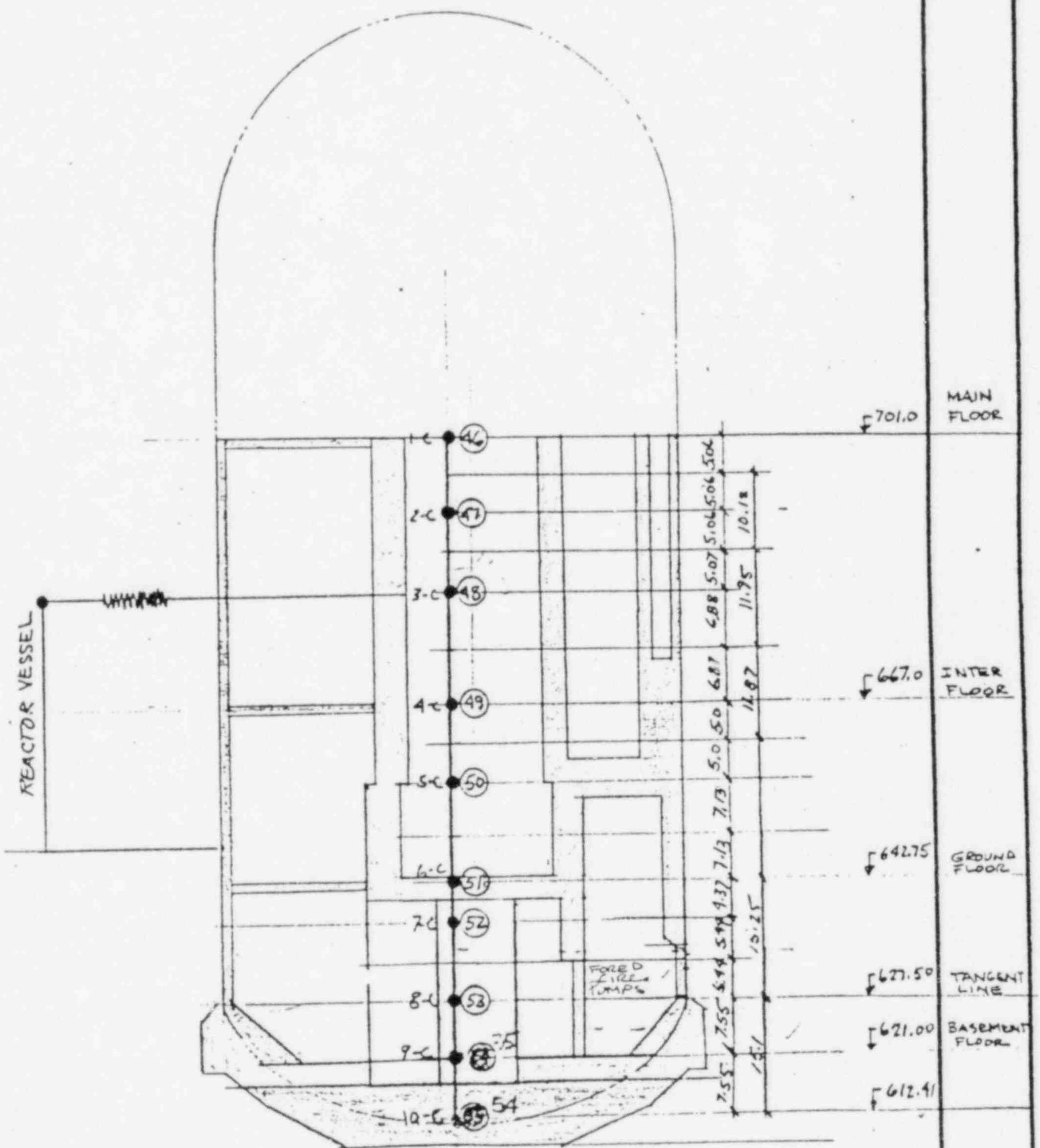
REF.

MODEL



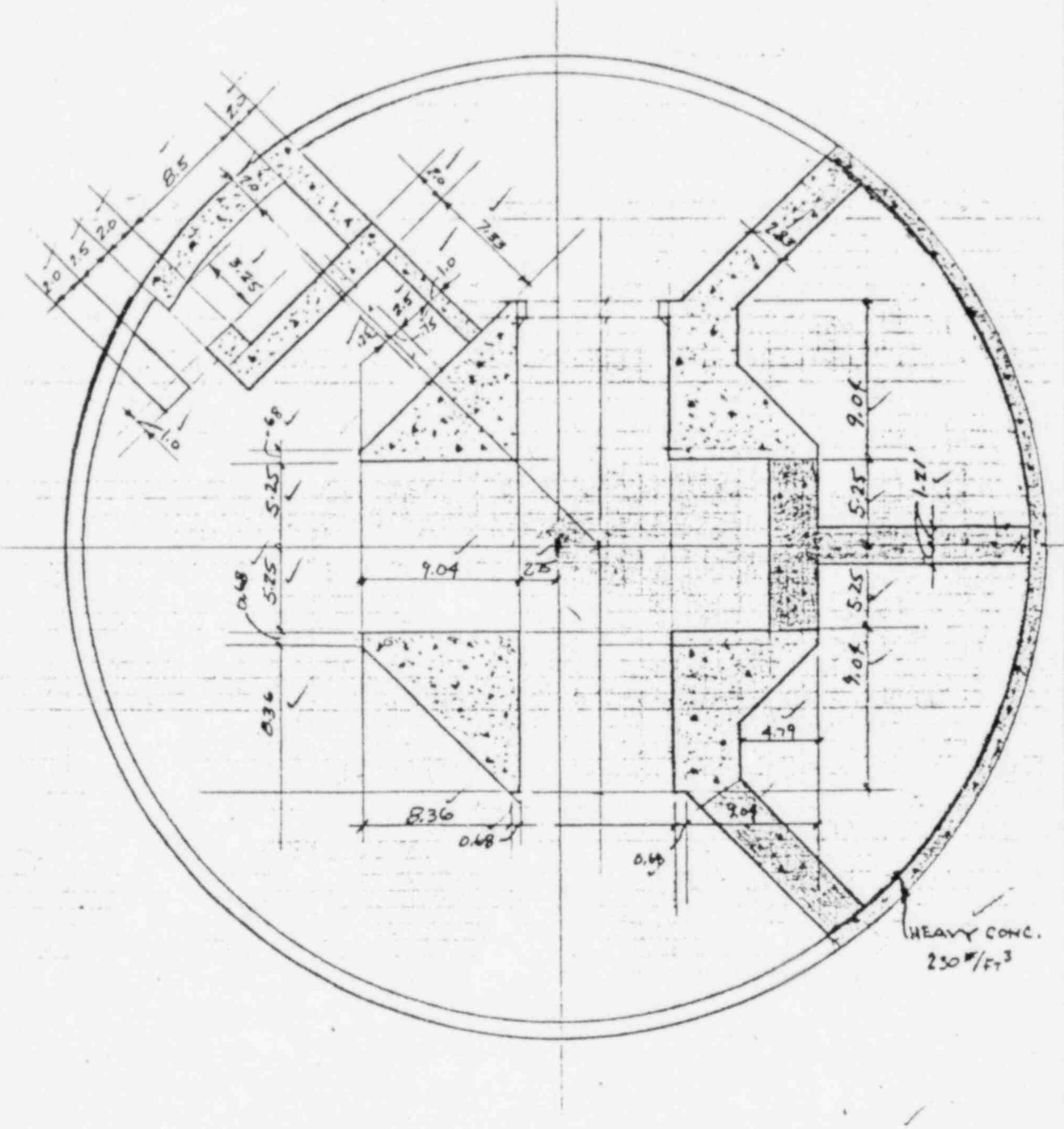
INNER SHIELD BLDG	REF.

MODEL



INNER SHIELD BLDG. (BASEMENT LEVEL

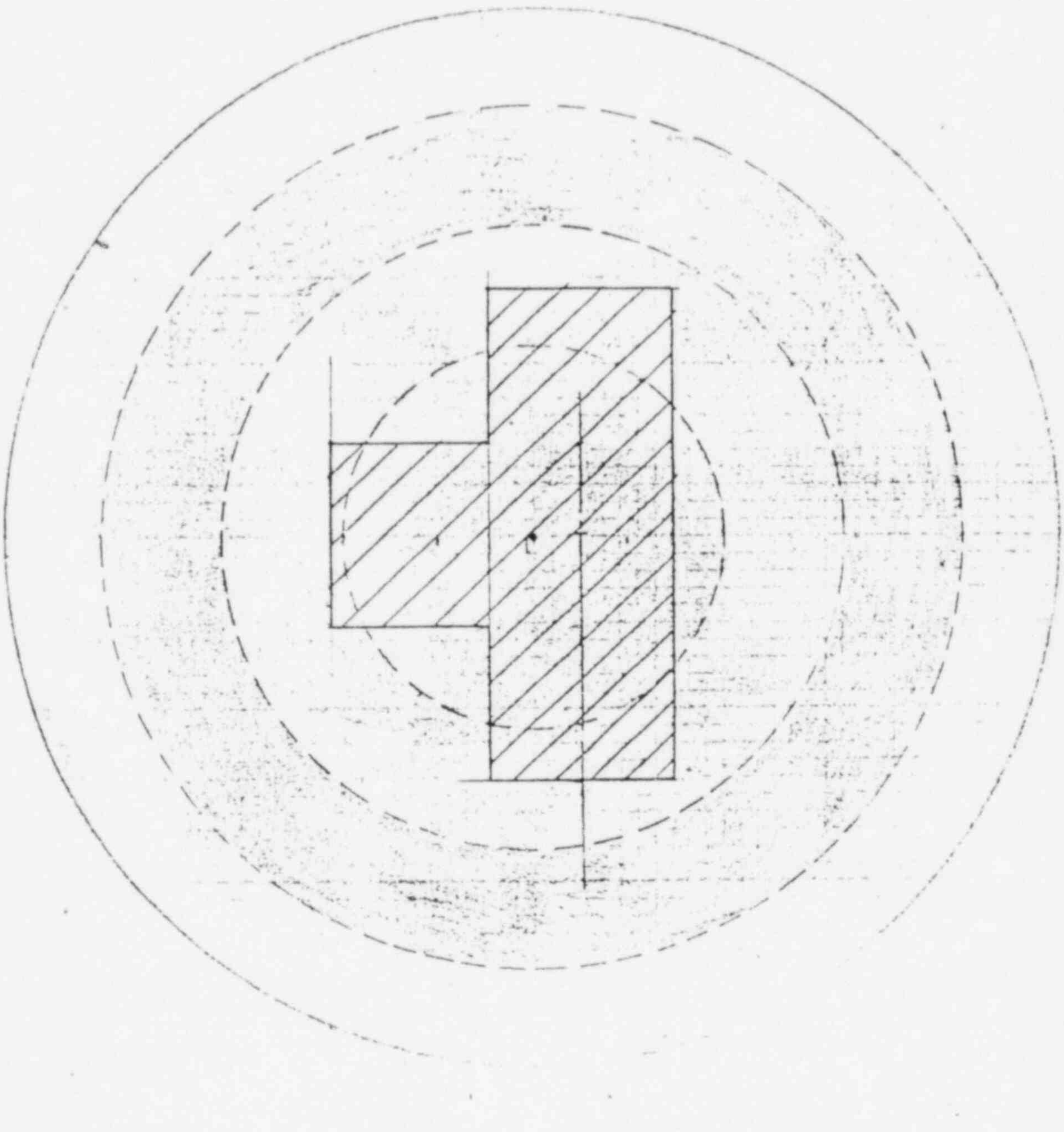
REF.



PLAN @ BASEMENT

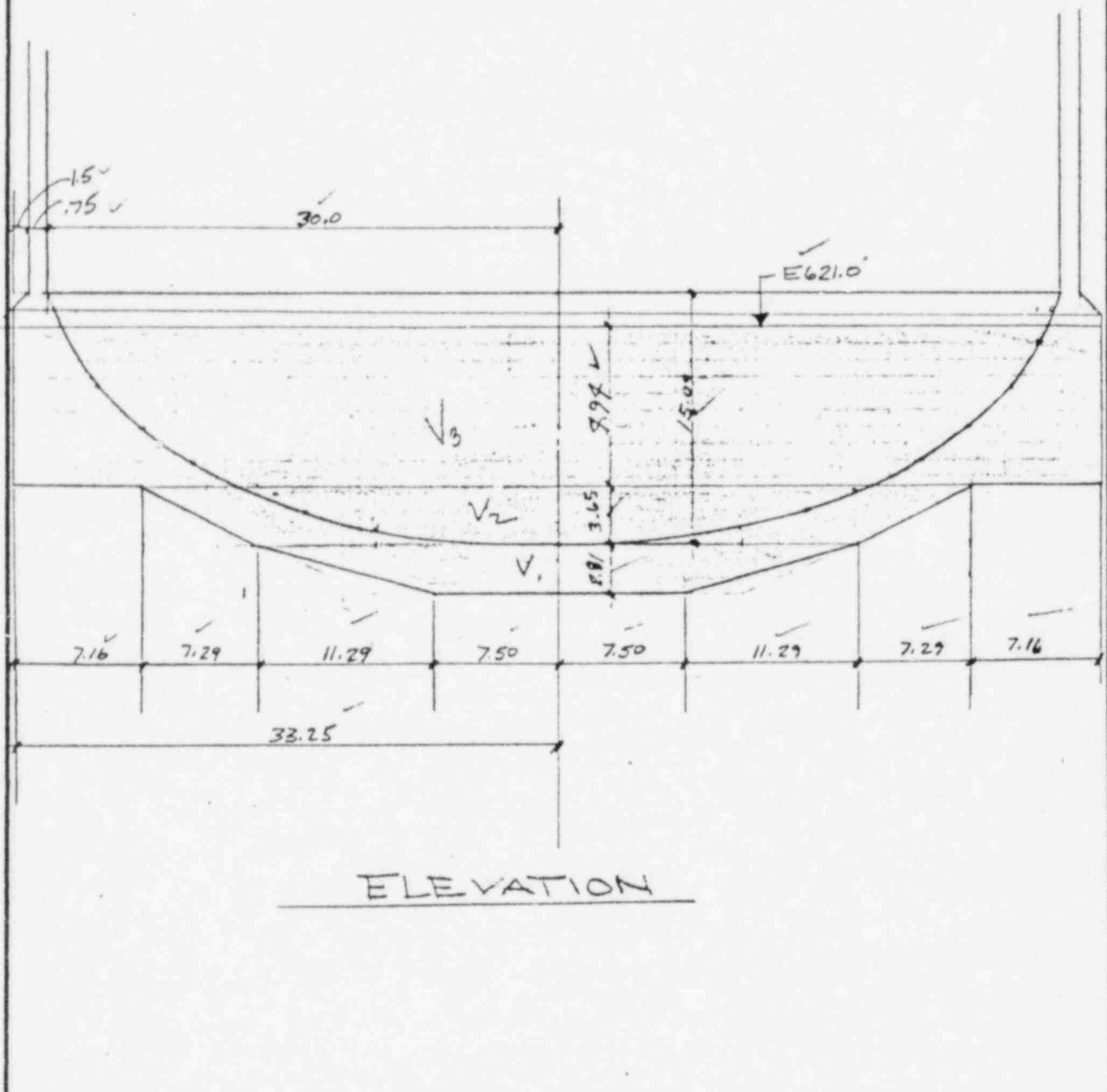
FOUNDATION WEIGHT

REF.



PLAN @ BASEMENT FLOOR

FOUNDATION WEIGHT | REF.



ELEVATION

FOUNDATION WEIGHT CALCULATION (BELOW 621.0)	REF.

VOLUME V_1

BOTTOM AREA = $\pi R^2 = \pi\, 7.5^2 = 176.71$ FT² ✓
TOP AREA = $\pi R^2 = \pi\, 18.79^2 = 1109.18$ FT² ✓

VOLUME = $\frac{2.81}{3}\left(176.71 + 1109.18 + \sqrt{176.71 \times 1109.18}\right) = 1619.13$ FT³ ✓

VOLUME V_2

BOTTOM AREA = 1109.18 FT²
TOP AREA = $\pi R^2 = \pi (26.08)^2 = 2136.81$ FT² ✓

VOLUME = $\frac{3.65}{3}\left(1109.18 + 2136.81 + \sqrt{1109.18 \times 2136.81}\right) = 5822.36$ FT³ ✓

VOLUME V_3

AREA = $\pi R^2 = \pi\, 33.25^2 = 3473.23$ FT² ✓

VOLUME = $3473.23 \times 4.94 = 17157.76$ FT³ ✓

NEGATIVE VOLUME

FROM SEC A-A & B-B

DEPTH = 3.5'

AREA = 9-0½
5-3
5-3
9-0½
28'-7" x 10-6"
9-0½
37-7½ x 10-6 x 3-6"

AREA 9-0½ x 10-6"

VOLUME = 1382.72 FT³

NET VOLUME = 17157.76
− 1382.72
= 15775.04 FT³ ✓

15775.04
5822.36
1619.13
23216.53 FT³ ✓

WEIGHT = .15 × 23216.53 = 3482.5^K ✓

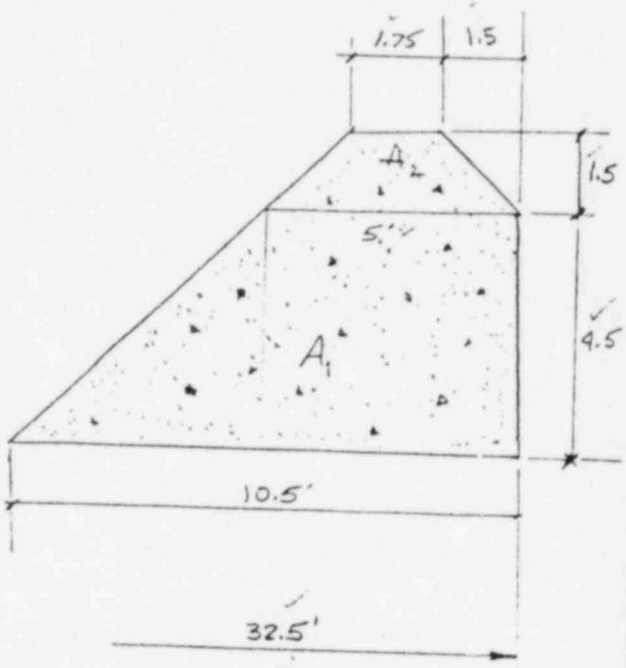
CORE WT = (487.50#)(5.44)(.150) = 487.5^K ✓

3970.0^K

NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY R.R DATE 4-26-79 PROJ. 5101 TASK 026
CHKD. [illegible] DATE 6-23-81 PAGE ____ OF ____
LACBWR SEP

FOUNDATION WEIGHT | REF.



BASE AREA A_1

$A = .785398 (d^2 - d_1^2)$

$A = .785398 (32.5^2 - 20^2) = 515.42^{\#}$ ✓

TOP AREA A_1

$A = .785398 (32.5^2 - 27.5^2) = 235.62^{\#}$ ✓

VOLUME: $\frac{1}{2} (515.42 + 235.62)(4.5)$
$= 1689.84 \text{ FT}^3$

WEIGHT = 253.48^k

AREA A_2

TOP

$A = .785398 (31^2 - 29.25^2) = 82.81^{\#}$

Volume $= \frac{1}{2} (82.81 + 235.62)(1.5) = 238.82 \text{ FT}^3$ ✓

WEIGHT = 35.82^k ✓

9" CONC. OUTSIDE CYLINDER

$A = .785398 (30.91^2 - 30.16^2) = 35.97 \text{ FT}^2$

WEIGHT = $12 \times 35.97 \times .15 = 64.75^K$ ✓

3482.50
487.50
253.48
35.82
64.75
4324.05

TOTAL FOUNDATION WEIGHT

Use 1/2 weight at 9-C and 1/2 at 10C

(NODE 9-C) | REF.

PROPERTIES OF FOUNDATION

$A = \pi\, 33.25^2 = 3473.23\ FT^2 \times 144 = 50.015 \times 10^4\ in.^2$

$I_{x_2} = I_{x_3} = .785398\, R^4 = 959967.1893\ FT^4 = 199.06 \times 10^8\ in.^4$

$J = 398.12 \times 10^8\ in.^4$

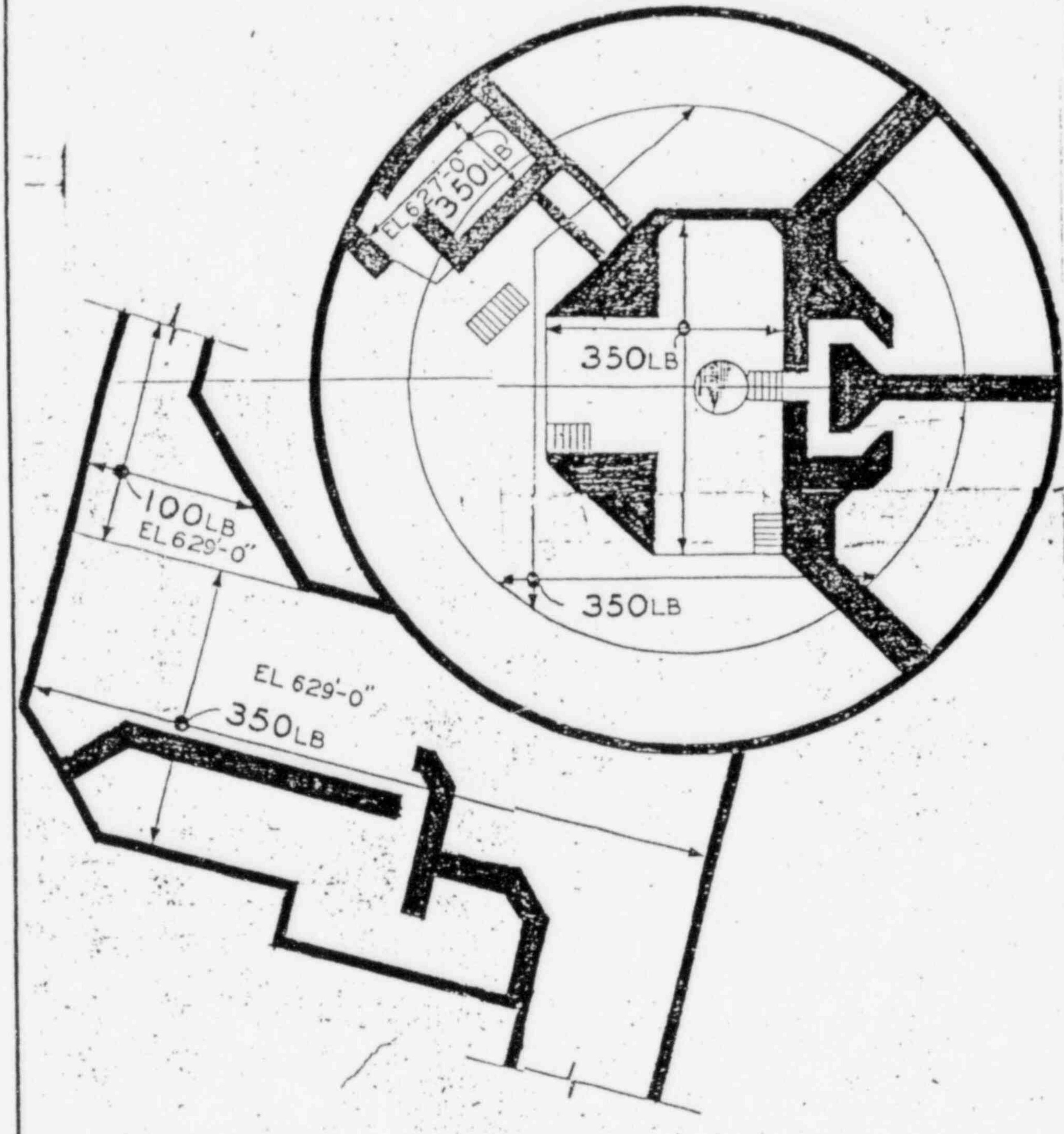
TOTAL FNDN WEIGHT 3970.0K

LIVE LOAD = 767.54^k

WEIGHT OF 9-C = 1985.0 USING ½ FNDN WT
2 TANKS 6000GAL = 130.00 ✓
LIVE LOAD = 767.54
2882.54
STEEL CONTAINMENT 62.12
2944.66^k → 9-C weight

WEIGHT OF 10-C = 1985.0 (1/2 Foundation weight).

REF.



CONTAINMENT VESSEL
BASEMENT FLOOR
EL 621'-0"

BASEMENT FLOOR	REF.

LIVE LOAD

TOTAL AREA = $\pi R^2 = \pi\, 29.21^2 = 2680.48$ ⊅ ✓

CORE AREA = 487.50 ⊅ ✓

350 PSF LOAD $(2680.48 - 487.50)(.350) = 767.54^K$ ✓
LIVE LOAD

	REF.

REACTOR

VESSEL

NUCLEAR ENERGY SERVICES INC.
NES DIVISION

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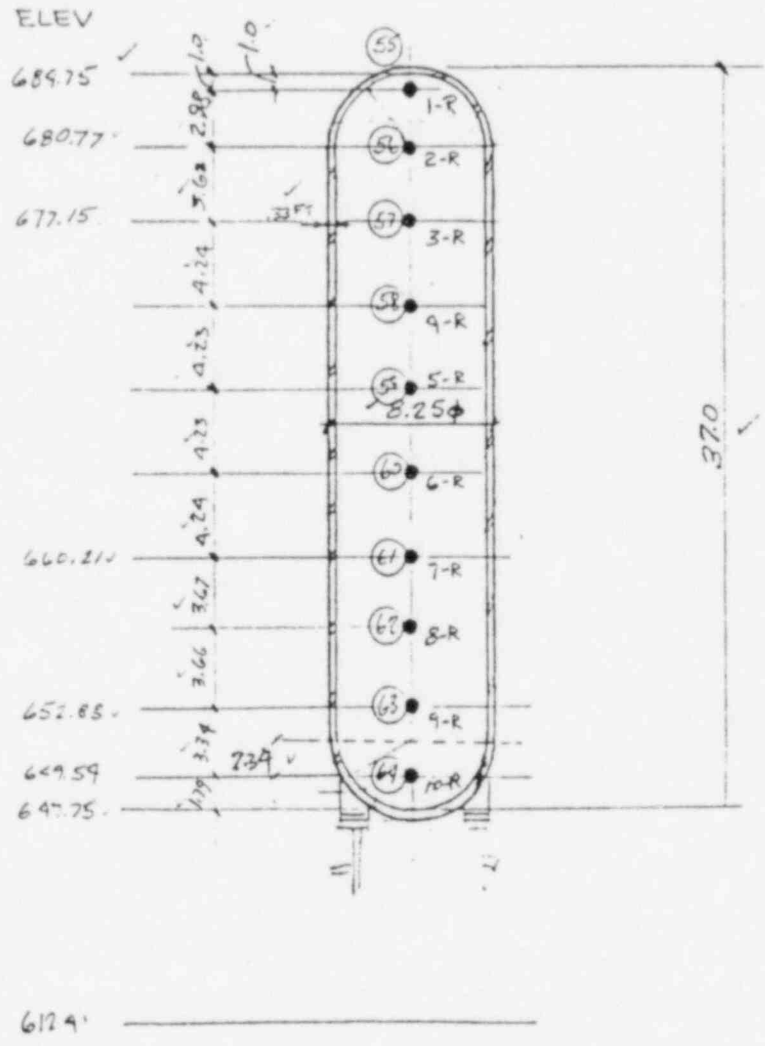
CHKD. [illegible] DATE 6-24-81 PAGE ___ OF ___
LACBWR SEP

REACTOR VESSEL

REF.

WALL THICKNESS = 4"



REACTOR VESSEL | REF.

PROPERTIES OF VESSEL

* FOR CALCULATIONS FOR NODES 1-R AND 10-R SEE PAGE 2b. (next page)

NODES 2-R → 9-R

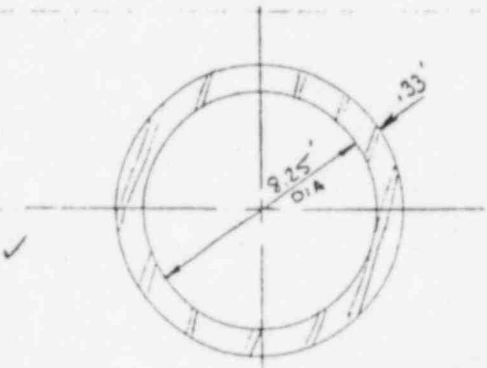
$$A = \frac{\pi}{4}(d^2 - d_i^2) = \frac{\pi}{4}(8.91^2 - 8.25^2) = 8.895 \text{ FT}^2 \checkmark$$

$$I = \frac{\pi}{64}(d^4 - d_i^4) = \frac{\pi}{64}(8.91^4 - 8.25^4) = 81.9742 \text{ FT}^4 \checkmark$$

WEIGHT LOADS (TONS)

22
6
143
9
35
—
215 = 430K TOTAL OPERATING WEIGHT
9.4K REACTOR SUPPORT SKIRT ✓

REF: LACBWR SAR 4.8-1 TABLE 4-1

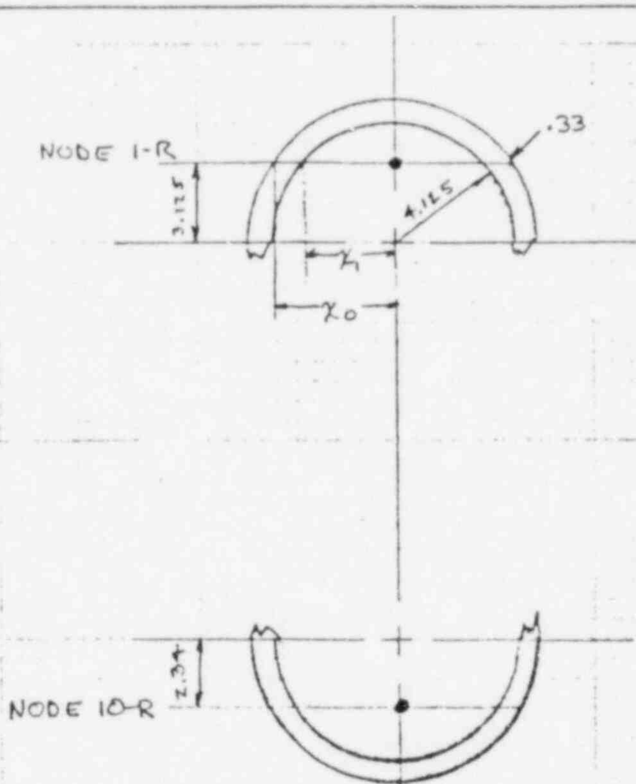


$$\frac{439.4}{37 \text{ FT}} = 11.88 \frac{\text{KIPS}}{\text{LIN. FT.}} \checkmark$$

NODE	A(FT²)	A(IN²)	I(FT⁴)	I(IN⁴)	J(IN⁴)	L(FT)	TRIB. WT.	
55 1-R	8.94	1287.36	38.69	0.8023×10⁶	1.6046×10⁶	2.49	34.93 K	✓
56 2-R	8.895	1280.88	81.9742	1.6998×10⁶	3.3996×10⁶	3.30	39.20 K	✓
57 3-R	↓	↓	↓	↓	↓	3.93	46.69 K	✓
58 4-R						4.24	50.37 K	✓
59 5-R						4.23	50.25 K	✓
60 6-R						4.23	50.25 K	✓
61 7-R						3.96	47.04 K	✓
62 8-R	↓	↓	↓	↓	↓	3.67	43.60 K	✓
63 9-R	8.895	1280.88	81.9742	1.6998×10⁶	3.3996×10⁶	3.50	41.58 K	✓
64 10-R	8.81	1268.64	57.01	1.1922×10⁶	2.3643×10⁶	3.46	41.10 K	✓
						TOTAL	439.4 K	✓

REACTOR VESSEL

REF.



EQUATION OF A CIRCLE

$x^2 + y^2 = r^2$

NODE 1-R

$y = 4.125 - 1.0 = 3.125'$

$r_i = 4.125$

$x_i = \sqrt{4.125^2 - 3.125^2} = 2.69'$

$\Rightarrow d_i = 5.38'$

$r_o = 4.125 + .33 = 4.455$

$x_o = \sqrt{4.455^2 - 3.125^2} = 3.175'$

$\Rightarrow d_o = 6.350'$

AREA @ NODE 1-R

$\frac{\pi}{4}(6.35^2 - 5.38^2) = \underline{8.94\ FT^2}$

$I_{x_2} = I_{x_3} = \pi/64\,(6.35^4 - 5.38^4)$

$= \underline{38.69\ FT^4}$

NODE 10-R

$y = 2.34$

$r_i = 4.125$

$x_i = \sqrt{4.125^2 - 2.34^2} = 3.40$

$\Rightarrow d_i = 6.80'$

$r_o = 4.455$

$x_o = \sqrt{4.455^2 - 2.34^2} = 3.79$

$\Rightarrow d_o = 7.58$

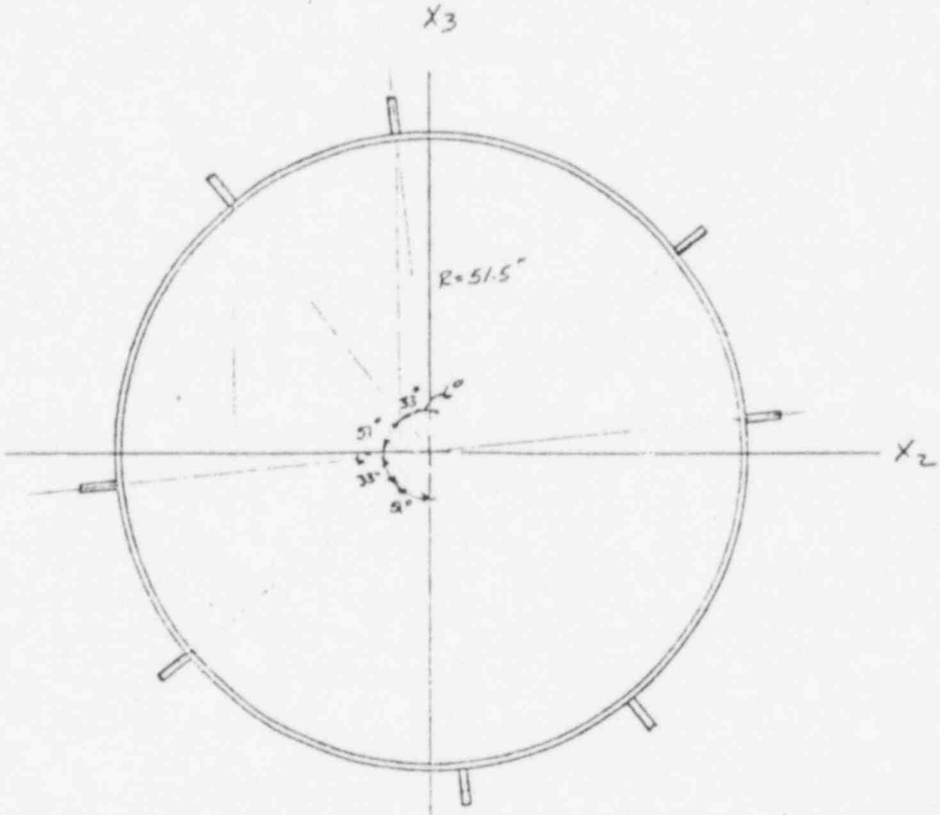
AREA @ NODE 10-R

$\frac{\pi}{4}(7.58^2 - 6.80^2) = \underline{8.81\ FT^2}$

$I_{x_2} = I_{x_1} = \pi/64\,(7.58^4 - 6.80^4)$

$= \underline{57.01\ FT^4}$

REACTOR SUPPORT SKIRT PROPERTIES | REF.

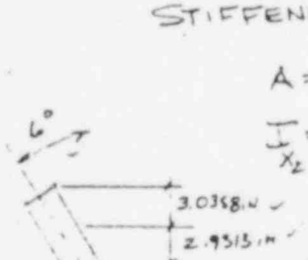


AREA OF A CYLINDER $= \frac{\pi}{4}(d_o^2 - d_i^2) = \frac{\pi}{4}(103^2 - 101^2) = 320.44\ IN^2$

MOMENT OF INERTIA OF A CYLINDER $= \frac{\pi}{64}(d_o^4 - d_i^4)$

$= \frac{\pi}{64}(103^4 - 101^4) = 416{,}775\ IN^4$

STIFFENER @ 6°



$A = 6\ IN^2$

$I_{X_2} = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{12} = \frac{1\times6(1\times.104528^2 + 6^2\times0.99452^2)}{12}$

$= 17.8088\ IN^4$

$C = \frac{b \sin a + d \cos a}{2} = \frac{(1\times.104528 + 6\times.99452)}{2}$

$= 3.0358$

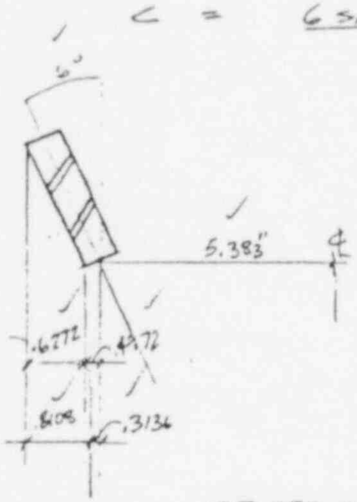
$d_{Y_2} = R\cos a + 2.9313 + .05226 = 54.2014\ IN$

REACTOR SUPPORT SKIRT PROPERTIES | REF.

$I_2 + Ad_{x_2}^2 = 17.8088 + 6(54.2014)^2 = \underline{17644.5594}\ IN^4$ ✓

$I_{x3} = \frac{1 \times 6 (6^2 \times .104529^2 + 1^2 \times .99452^2)}{12} = 0.6412\ IN^4$ ✓

$c = \frac{6 \sin 6° + 1 \cos 6°}{2} = 0.8108\ IN$ ✓



$d = 5.383 + .3136 = 5.6966\ IN$ ✓

$I_3 + Ad_{x_3}^2 = 0.6412 + 6(5.6966)^2 = \underline{195.3987}\ IN^4$ ✓

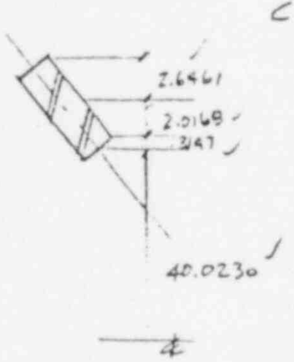
STIFFENER @ 39°

$A = 6\ IN$ ✓

$I_{x2} = \frac{bd(b^2 \sin a + d^2 \cos a)}{12} = \frac{1 \times 6(1^2 \sin^2 39 + 6^2 \cos^2 39)}{12}$ ✓

$= 11.0692\ IN^4$ ✓

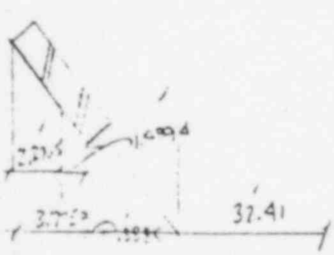
$c = \frac{1 \sin 39° + 6 \cos 39°}{2} = 2.6961\ IN$ ✓



$d = 40.0230 + 2.0168 + .3147 = 42.3545\ IN$ ✓

$I_{x2} + Ad_{x2}^2 = 10774.4912\ IN^4$

$I_{x3} = \frac{1 \times 6 (6^2 \sin^2 39 + 1^2 \cos^2 39)}{12} = 7.43\ IN^4$ ✓



$c = \frac{6 \sin 39° + 1 \cos 39°}{2} = 2.2765$ ✓

$d = 1.4994 + .3885 + 32.41 = 34.2979\ IN$

$I_{x3} + Ad_{x3}^2 = 7065.51$ ✓

	REF.

STIFFENERS @ 84°

I_{x2} IS EQUAL TO I_{x3} OF STIFFENER @ 6°

$I_{x2} + Ad_{x2}^2 = 195.3987 \text{ IN}^4$ ✓

I_{x3} IS EQUAL TO I_{x2} OF STIFFENER @ 6°

$I_{x3} = 17644.5594 \text{ IN}^4$ ✓

STIFFENER @ 51°

I_{x2} IS EQUAL TO I_{x3} OF STIFFENER @ 39°

$I_{x2} + Ad_{x2}^2 = 7065.51 \text{ IN}^4$ ✓

I_{x3} IS EQUAL TO I_{x2} OF STIFFENER @ 39°

$I_{x3} + Ad_{x3}^2 = 10774.4912$ ✓

TOTAL	416,775	416,775
2 I @ 6°	35289.0	390
2 I @ 39°	21549.0	14131
2 I @ 84	390.0	35289
2 I @ 51	14131.02	21549
I_{x2}	488134.02 IN⁴	488134.02 IN⁴

$A = 8(6) = 48 + 320.44 = 368.44 \text{ in}^2$ ✓

$\text{WEIGHT} = \frac{368.44}{144} = 2.5586 \text{ FT}^2$ ✓

SUPPORT SKIRT WEIGHT = $2.5586 \times 490 \times 7.5 = 9.4^K$ ✓

REACTOR SUPPORT SKIRT PROPERTIES | REF.

Polar moment of Inertia.

$$J = \Sigma A d_{x_2}^2 + \Sigma A d_{x_3}^2 + J(\text{cylinder})$$

J cylinder $= \frac{\pi}{32}(d_o^4 - d_i^4) = 833{,}551 \text{ in}^4$ ✓

$\Sigma A d^2$ of stiffener.

$\Sigma A d_{x_2}^2 = 2(6 \times 54.2014^2 + 6 \times 42.3545^2 + 6 \times 5.6966^2 + 6 \times 34.2979^2)$ ✓

$= 71286 \text{ in}^4$ ✓

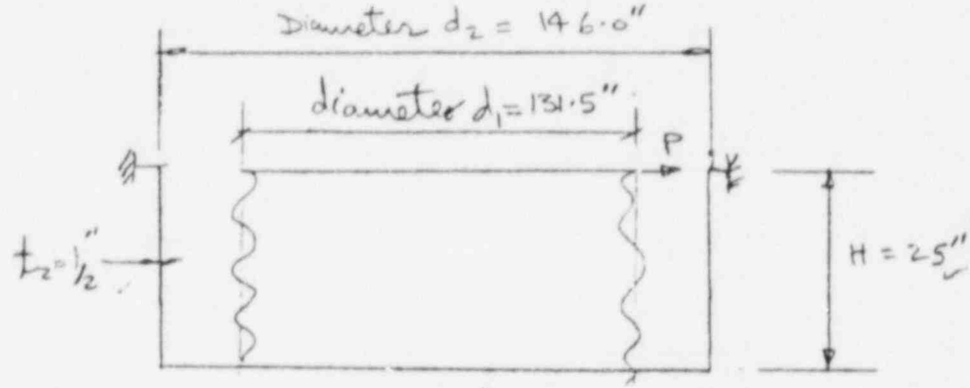
$\Sigma A d_{x_3}^2 = 2 \times 6 (5.6966^2 + 34.2979^2 + 54.2014^2 + 42.3545^2)$

$= 71286 \text{ in}^4$ ✓

$$J = 71286 \text{ in}^4 + 71286 \text{ in}^4 + 833{,}551 \text{ in}^4 = 976{,}123 \text{ in}^4$$ ✓

REF.

STIFFNESS OF BELLOWS SEAL.



Ref. Dwg. Sargent & Lundy Dwg. 41-503383

Material 304 Stainless Steel

Thickness t_1 = 14 Gage. $t_1 = 0.0747''$

Bellow seal:

Cross-sectional Area $A = \pi \times 131.5 \times 0.0747 = 30.86 \text{ in.}^2$

Moment of Inertia $I = \pi \left(\frac{131.5}{2}\right)^3 \times 0.0747 = 66704.9 \text{ in.}^4$

Deflection due to lateral Load $P = \delta = \frac{PH}{\bar{A}G} + \frac{PH^3}{3EI}$

Shear Area $\bar{A} = 0.53 \times A$ (Page B1-112 STARDYNE Manual)

$G = 0.4 \times 28600$ KSI; $E = 28600$ KSI

$$\therefore \delta = P\left\{\frac{25.0}{0.53 \times 30.86 \times 0.4 \times 28600} + \frac{(25.0)^3}{3 \times 28600 \times 66704.9}\right\}$$

$$= 1.363 \times 10^{-4} P$$

Bellow Stiffness $K_b = \frac{P}{\delta} = 7334.5$ K/in.

	REF.

Stiffness of $\frac{1}{2}$" thick, 146.0" diameter cyclindrical tube:

Cross-Sectional Area $A_z = \pi \times 146 \times 0.5 = 229.3$ in.^{2}

Moment of Inertia $I_z = \pi(73)^3 \times 0.5 = 611066.5$ in.^{4}

Shear Area $\bar{A} = 0.53 \times A_z = 0.53 \times 229.3 = 121.55$ in.^{2}

$G = 0.4 \times 28600$ Ksi; $E = 28,600$ Ksi.

$$\therefore \delta = P\left\{\frac{25.0}{121.55 \times 0.4 \times 28600} + \frac{(25.0)^3}{3 \times 28600 \times 611066.5}\right\}$$

$\delta = 1.8277 \times 10^{-5}\ P$

$\therefore$ Tube Stiffness $K_T = \frac{P}{\delta} = 54,714.3$ K/in

The Bellow Seal and the Tube acts in series

$\therefore$ The Combined Stiffness

$$K = \left\{\frac{1}{K_b} + \frac{1}{K_T}\right\}^{-1}$$

$= 6467.5$ K/in

For Beam in X2 Direction

Effective Spring Length = 0.01"

$\therefore$ Area of Beam $= \frac{KL}{E} = \frac{0.01 \times 6467.5}{25.7 \times 10^3}$

$= 0.002517$ in.^{2}

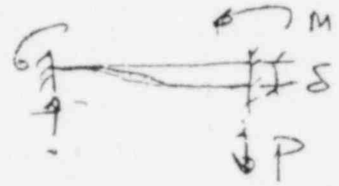
For Equivalent Beam in X1 Direction

Effective Length = 86 - 30 = 56"

$\therefore$ " Area of Beam $= \frac{KL}{E} = \frac{6467.5 \times 56}{25.7 \times 10^3} = 14.093$ in.

BELLOW SEAL | REF.

Equivalent I_{eq} for the Beam (86" Long).



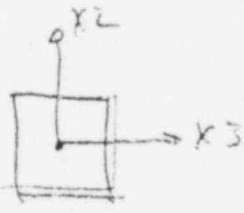
$$M = \frac{6EI_{eq}\delta}{L^2}$$

$$P = \frac{2M}{L} = \frac{12EI_{eq}\delta}{L^3}$$

$\therefore$ Lateral stiffness $K = \frac{P}{\delta} = \frac{12EI_{eq}}{L^3}$ ✓

$$\therefore I_{eq.} = \frac{KL^3}{12E} = \frac{6467.5(86)^3}{12 \times 25.7 \times 10^3}$$

$$= 1.33 \times 10^4 = \underline{13300.} ✓$$



$$I_{X2} = I_{eq}$$

Equivalent I_3.
from Zallea Brothers Dwg. C 227953

$$P = 10^K \; ; \; \delta = 1.5''.$$

$$\therefore K = \frac{P}{\delta} = \frac{10.}{1.5} = 6.67 \text{ K/in}$$

$$\therefore I_{eq} = \frac{6.67 \times (86)^3}{12 \times 25.7 \times 10^3} = \underline{13.756 \text{ in.}^4} ✓$$

REF.

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.

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

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

where γ = Effective Radius of Foundation Mat

μ = Poisson's Ratio of Soil

G = Shear Modulus of Soil

The soil properties are taken from Reference 1. For the standard foundation spring, the soil properties correspond to averaged values for boring number 3

G = Shear Modulus of Soil = 2.40×10^6 lbs/ft.^{2} ✓
(Tables 3.1 and 2.2 of Reference 1)

μ = Poisson's Ratio = 0.24 (Calculated from data given in Table 3.1) ✓

γ = Effective Radius of Foundation Mat = 33.5 feet ✓

$$K_x = \frac{32\ (1-0.24)\ 2.40 \times 10^6 \times 33.5}{7 - 8 \times 0.24}$$ ✓

$K_x = 384.9 \times 10^6$ lbs/ft. = 32.08×10^3 K/in. ✓

$$K_\theta = \frac{8 \times 2.40 \times 10^6\ (33.5)^3}{3\ (1 - 0.24)}$$

$K_\theta = 316.59 \times 10^9$ lbs.ft./radian ✓

$K_\theta = 3799.11 \times 10^6$ K.in./radian ✓

REF.

Vertical Spring Constant $K_Z = \frac{4 G r}{1-\mu}$ ✓

$= \frac{4 \times 2.4 \times 10^6 \times 33.5}{1-0.24}$

$= 4.2316 \times 10^8$ lbs/ft. ✓

$= 35.26 \times 10^3$ K/in. ✓

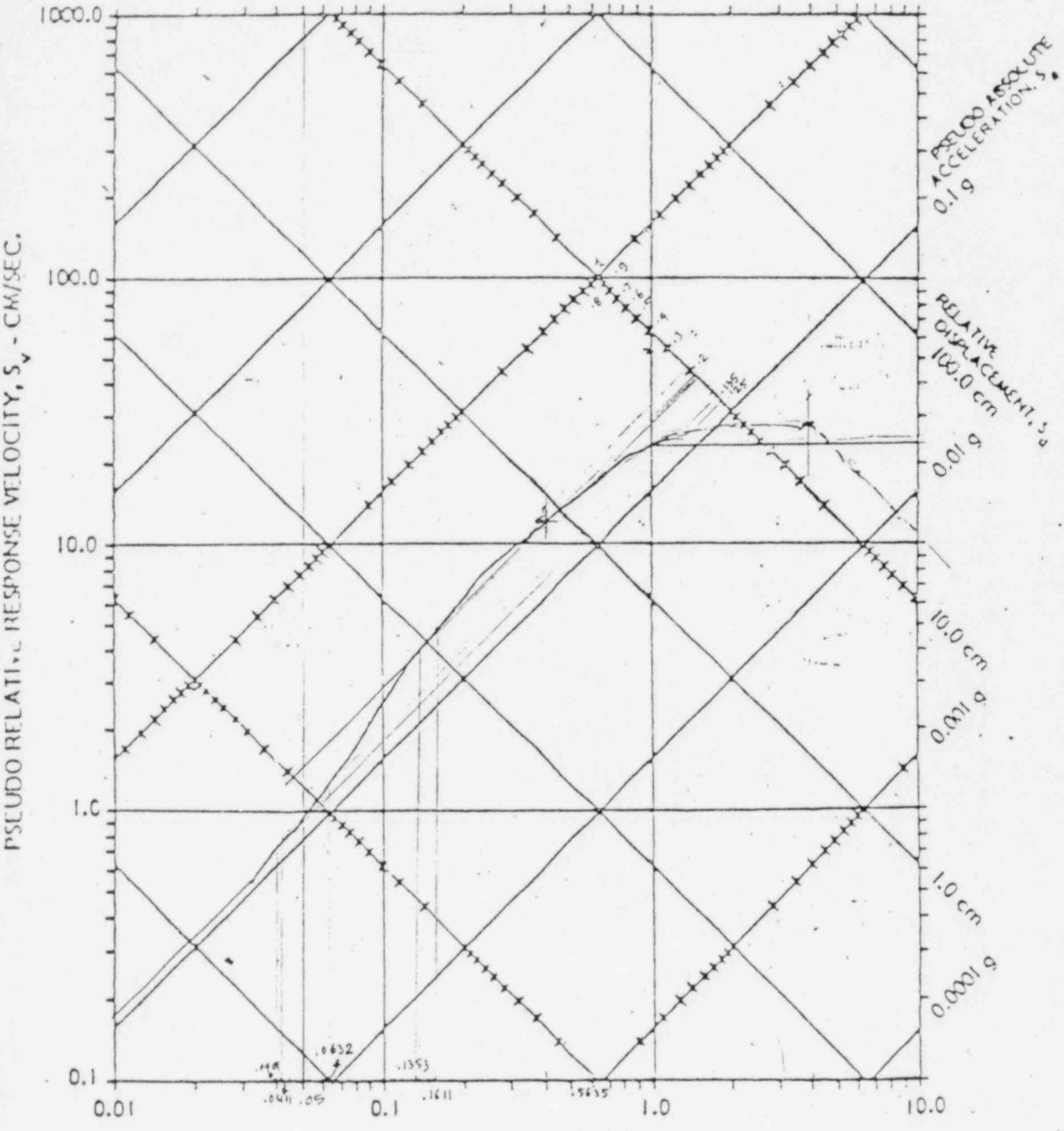
TORSIONAL Spring Constant $K_\theta = \frac{16}{3} G r^3$ ✓

$= \frac{16}{3} \times 2.4 \times 10^6 \times (33.5)^3$

$= 481{,}220.8 \times 10^6$ lbs-ft/radians. ✓

$= 5774.65 \times 10^6$ Kin/radians ✓

LACROSSE



5% damping

X1 Direction

LACROSSE CONTAINMENT BLDG EVALUATION | REF.

5% SPECTRA

FREQ/PERIOD	a. m/sec²
1/1	0.154 ✓
2.5/.4	0.199 ✓
3.33/.3	0.206 ✓
5 /.2	0.218 ✓
10 /.1	0.183 ✓
12.5/.08	0.155 ✓
20/.05	0.133 ✓
25/.04	0.135 ✓
30/.033	0.104 ✓
31/.032	0.104 ✓

$$\frac{a}{2.54 \times 386.4}$$

SYSTEMATIC EVALUATION PROGRAM
SITE SPECIFIC SPECTRA
PSEUDO SPECTRAL ACCELERATIONS (cm/sec^2)

Yankee Rowe	Oyster Creek	Ginna	Haddam Neck	Millstone	Big Rock Pt.	LaCrosse	Palisades	Dresd[illegible]
[illegible]3.09	172.61	17[illegible].95	215.91	196.23	122.29	122.29	122.29	134.[illegible]
212.69	178.17	192.52	228.92	210.91	130.19	130.19	130.19	142.[illegible]
247.74	206.77	[illegible].16	279.47	253.44	152.05	152.05	152.05	166.[illegible]
275.53	229.93	2[illegible].38	318.00	287.00	179.69	179.69	179.69	181.[illegible]
434.80	363.77	353.92	475.17	433.65	213.50	213.50	214.77	270.[illegible]
455.49	376.59	375.92	455.79	415.45	201.96	201.96	224.41	237.[illegible]
403.76	339.90	326.79	395.71	360.53	171.68	195.71	218.32	249.[illegible]
224.32	180.93	165.10	183.25	165.68	122.90	151.98 ←	174.57	195.[illegible]
195.20	161.23	169.65	202.48	184.16	102.50	102.50	102.50	124.[illegible]
22.43	18.41	16.92	19.66	17.82	11.39	13.50	15.18	16.0[illegible]

CONVERSION TO OTHER DAMPING VALUES (RANGE 2% - 20%)

$$PSA_{X\%} = PSA_{5\%} \times 10^{(-C_T \times (\text{new damping}(x) - .05))}$$

mult.

C_T	Frequency
**	25
**	20
-0.290	15.365
-0.600	12.5
-0.904	10
-1.270	7.69
-1.700	5
-1.990	4.0[illegible]
-1.980	2.5
-1.810	1.0[illegible]
-1.960	1
	.5

* VELOCITY = cm/sec

*cm/sec
**Highly Insignificant Coefficient, Use 5% PSA Value
[illegible]

NES

NUCLEAR ENERGY SERVICES

BY NC DATE 3/12/82 PROJ. 5101 TASK 247
CHKD. JC DATE 3/15/82 PAGE ____ OF ____
LACROSSE SEP – SITE SPECIFIC SPECTRA

	REF.
COTAINMENT BUILDING – RESPONSE SPECTRA – X1 DIRECTION – NORMAL SPRING	

From Computer Output SG200W

Mode N°	Frequency/Period	Composite Damping	5% Damping Site Spe. Spectra (g's)	C_T	Factor	Result (g's)	Group
2 ✓	1.876/.5332 ✓	.06356 ✓	.17 ✓	-1.915 ✓	.942 ✓	.160 ✓	1
3 ✓	4.972/.2011 ✓	.06651 ✓	.218 ✓	-1.703 ✓	.937 ✓	.204 ✓	2
5 ✓	6.485/.1542 ✓	.04510 ✓	.19 ✓	-1.419 ✓	1.016 ✓	.193 ✓	3
7 ✓	9.987/.1001 ✓	.06373 ✓	.183 ✓	-.904 ✓	.972 ✓	.178 ✓	4
8 ✓	16.491/.0606 ✓	.04046 ✓	.133 ✓	-.29 ✓	1.106 ✓	.134 ✓	5
10 ✓	23.829/.0420 ✓	.04354 ✓	.125 ✓		1. ✓	.125 ✓	6
12 ✓	24.549/.0407 ✓	.04176 ✓	.125 ✓		1. ✓	.125 ✓	6
14 ✓	28.399/.0352 ✓	.06791 ✓	.120 ✓		1.	.12 ✓	7
15 ✓	32.417/.0308 ✓	.04085 ✓	.104 ✓		1. ✓	.104 ✓	8

CONTAINMENT BUILDING - RESPONSE SPECTRA - X2 DIRECTION-NORMAL SPRING | REF.

From Computer Output S6200W

Mode N°	Freq./Period	Composite Damping	5% Damping Site Spe. Spectra (g's)	C_T	Factor	Result (g's)	Group
1 ✓	1.871/.5345 ✓	.06442 ✓	.17 ✓	-1.915 ✓	.938 ✓	.159 ✓	1
4 ✓	6.442/.1552 ✓	.04575 ✓	.19 ✓	-1.425 ✓	1.014 ✓	.193 ✓	2
6 ✓	9.840/.1016 ✓	.06613 ✓	.185 ✓	-.924 ✓	.966 ✓	.179 ✓	3
9 ✓	21.506/.0465 ✓	.04309 ✓	.125 ✓		1.	.125 ✓	4
11 ✓	24.117/.0415 ✓	.04899 ✓	.125 ✓		1.	.125 ✓	5
13 ✓	25.267/.0396 ✓	.05637 ✓	.125 ✓		1.	.125 ✓	5

CONTAINMENT BUILDING - RESPONSE SPECTRA - X3 DIRECTION - NORMAL SPRING | REF.

From Computer Output S6200W

Mode N°	Frq./Period	Composite Damping	5% Damping Site Spe. Spectra (g's)	C_T	Factor	Result (Vertical = 2/3 Horizontal)	Group
2 ✓	1.876/.5332 ✓	.06356 ✓	.17 ✓	-1.915	.942	.107	1
3 ✓	4.972/.2011 ✓	.06651 ✓	.218 ✓	-1.703 ✓	.937 ✓	.136 ✓	2
5 ✓	6.485/.1542 ✓	.04510 ✓	.19 ✓	-1.419 ✓	1.016 ✓	.129 ✓	3
7 ✓	9.987/.1001 ✓	.06373 ✓	.183 ✓	-.904 ✓	.972 ✓	.118 ✓	4
10 ✓	23.829/.0420 ✓	.04354 ✓	.125 ✓		1.	.083 ✓	5
14 ✓	28.399/.0352 ✓	.06791 ✓	.120 ✓		1.	.080 ✓	6

NUCLEAR ENERGY SERVICES

BY NC DATE 3/11 PROJ. 5101 TASK 247
CHKD. JC DATE 3/15/82 PAGE ____ OF ____
LACROSSE SFP - SITE SPECIFIC SPECTRA

CONTAINMENT BUILDING — RESPONSE SPECTRA - X2 DIRECTION (STIFFENED SPRINGS) | REF.

From Computer Output S6200QB

Mode Nº	Frq/Period	Composite Damping	(g's) 5% Damping Site Sp. Spectra	C_T	Factor	(g's) Result	Group
2 ✓	2.253/.4438 ✓	.0635186 ✓	.196 ✓	-1.959 ✓	.941 ✓	.184 ✓	1
3 ✓	6.033/.1658 ✓	.0666024 ✓	.206 ✓	-1.490 ✓	.945 ✓	.195 ✓	2
5 ✓	6.552/.1526 ✓	.0453619 ✓	.190 ✓	-1.409 ✓	1.015 ✓	.193 ✓	2
7 ✓	11.607/.0647 ✓	.0652246 ✓	.162 ✓	-.671 ✓	.977 ✓	.158 ✓	3
8 ✓	16.540/.0605 ✓	.0403261 ✓	.133 ✓	-.29 ✓	1.006 ✓	.134 ✓	4
10 ✓	23.849/.0419 ✓	.0434536 ✓	.125 ✓		1	.125 ✓	5
12 ✓	24.577/.0407 ✓	.0420097 ✓	.125 ✓		1	.125 ✓	5
14 ✓	28.849/.0347 ✓	.0678376 ✓	.120 ✓		1	.12 ✓	6
15 ✓	32.431/.1308 ✓	.0407828 ✓	.104 ✓		1	.104 ✓	7

NES 105 (2/74)

CONTAINMENT BUILDING - RESPONSE SPECTRA - X2 DIRECTION (STIFFENED SPRING). | REF.

From Computer Output S6200 Q8

Mode N°	Frq/Period	Composite Damping	(g's) 5% Damping Site Sp. spectra	C_T	Factor	(g's) Result	Group
1 ✓	2.244/.4457 ✓	.0644427 ✓	.196 ✓	-1.958 ✓	.937 ✓	.184 ✓	1
4 ✓	6.507/.1537 ✓	.0460114 ✓	.190 ✓	-1.416 ✓	1.013 ✓	.192 ✓	2
6 ✓	11.591/.0863 ✓	.0674163 ✓	.164 ✓	-.696 ✓	.972 ✓	.159 ✓	3
9 ✓	21.601/.0463 ✓	.0422083 ✓	.130 ✓		1 ✓	.130 ✓	4
11 ✓	24.295/.0412 ✓	.0457678 ✓	.125 ✓		1	.125 ✓	5
13 ✓	25.991/.0385 ✓	.0610623 ✓	.125 ✓		1	.125 ✓	5

NES NUCLEAR ENERGY SERVICES

BY Ncc DATE 3/11 PROJ. 5101 TASK 247
CHKD. JC DATE 3/15/82 PAGE ___ OF ___
LACBWR SEP - SITE SPECIFIC SPECTRA

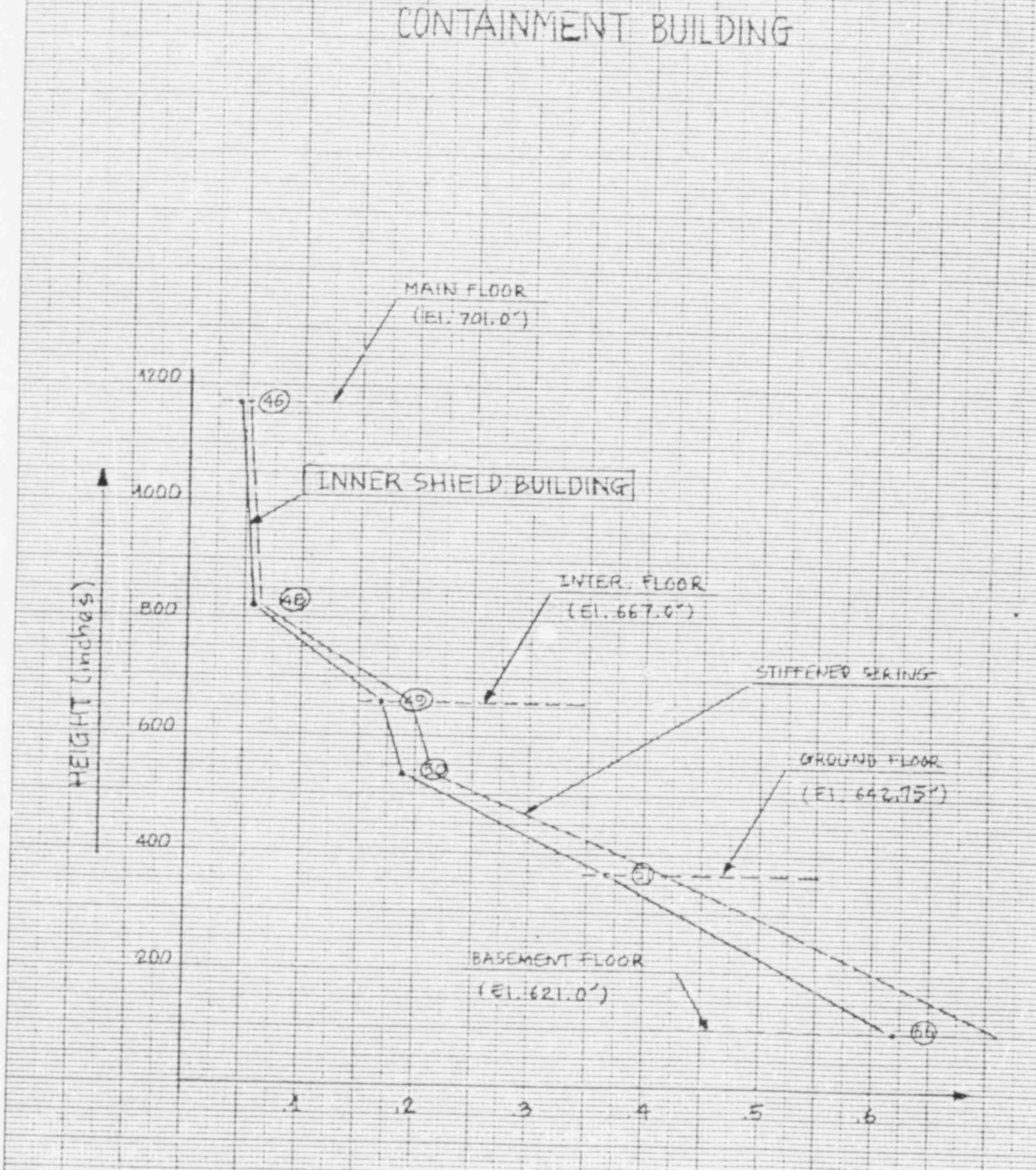
CONTAINMENT BUILDING - RESPONSE SPECTRA - X3 DIRECTION (STIFFENED SPRING) | REF.

From Computer output S620UQ8

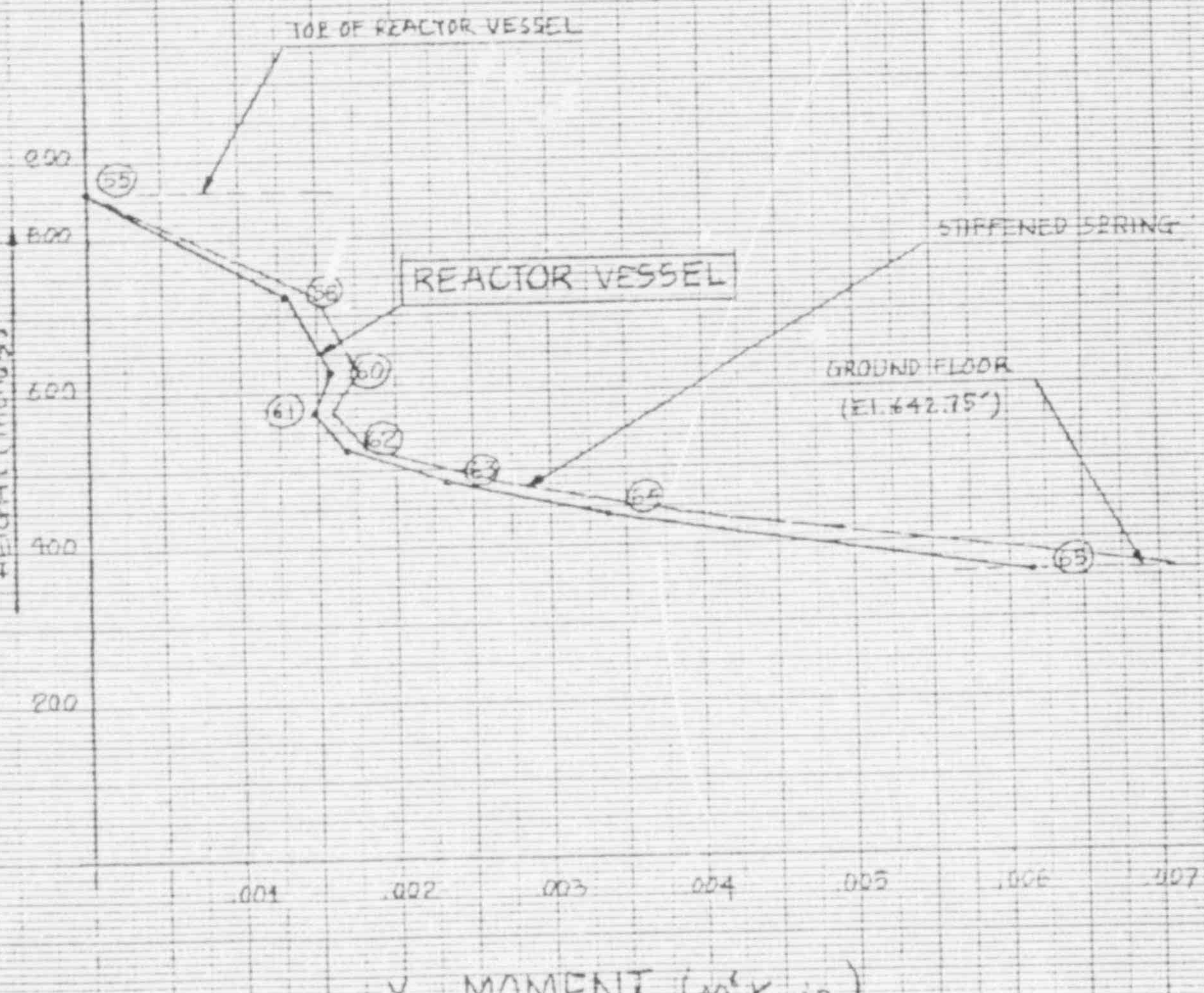
Mode No	Freq/Period	Composite Damping	(g's) 5% Damping Site Sp. Spectra	C_T	Factor	(g's) result (2/3 Vertical)	Group
2 ✓	2.253/.4438 ✓	.0635186 ✓	.196 ✓	-1.959 ✓	.941 ✓	.123 ✓	1
3 ✓	6.033/.1658 ✓	.0666024 ✓	.206 ✓	-1.490 ✓	.945 ✓	.130 ✓	2
5 ✓	6.552/.1526 ✓	.0453619 ✓	.190 ✓	-1.409 ✓	1.015 ✓	.129 ✓	2
7 ✓	11.807/.0847 ✓	.0652246 ✓	.162 ✓	-.671 ✓	.977 ✓	.106 ✓	3
10 ✓	23.849/.0419 ✓	.0434536 ✓	.125 ✓		1 ✓	.083 ✓	4
14 ✓	28.849/.0347 ✓	.0678376 ✓	.120 ✓		1 ✓	.080 ✓	5

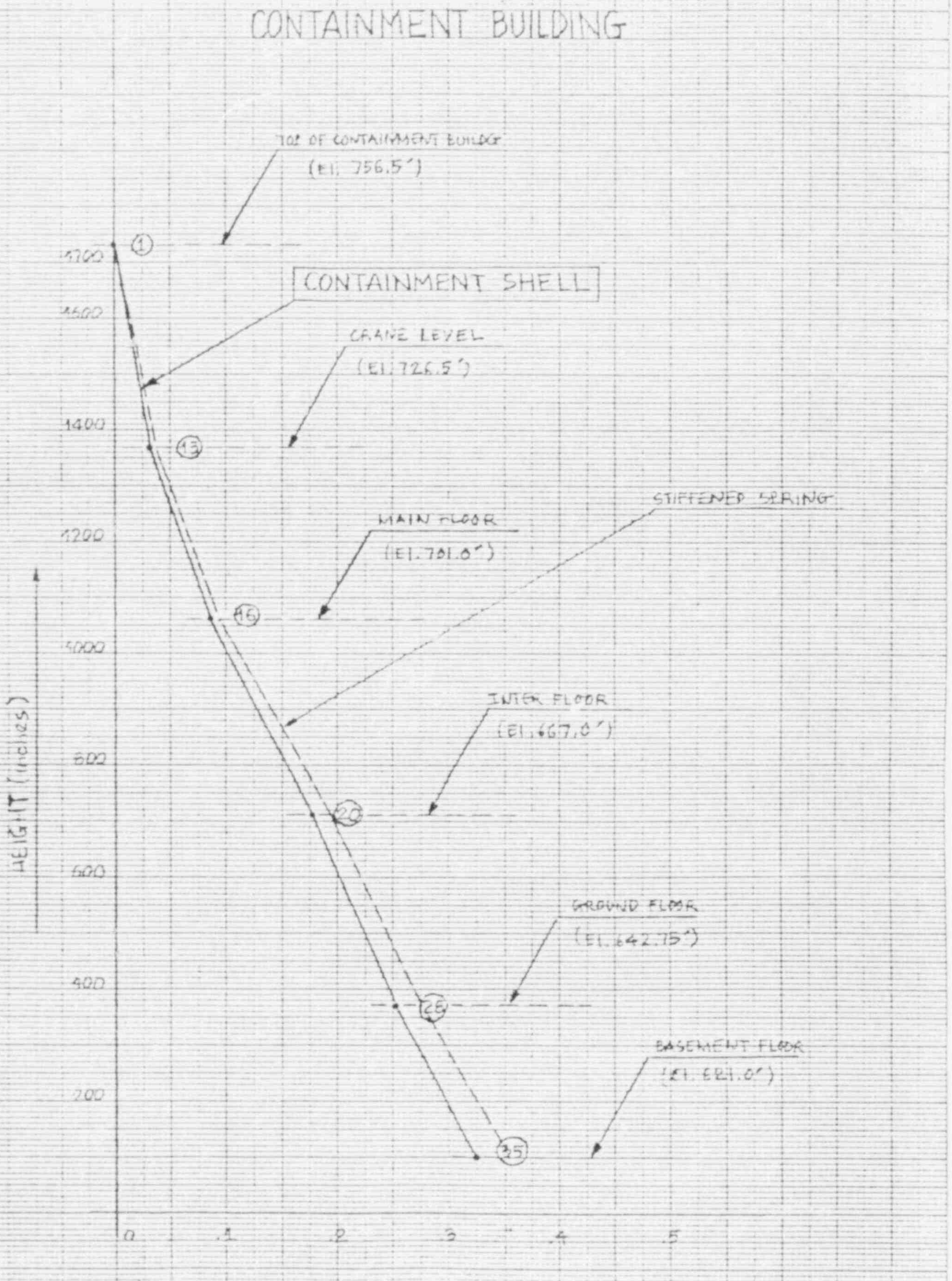
REF.

ANALYSIS AND RESULTS

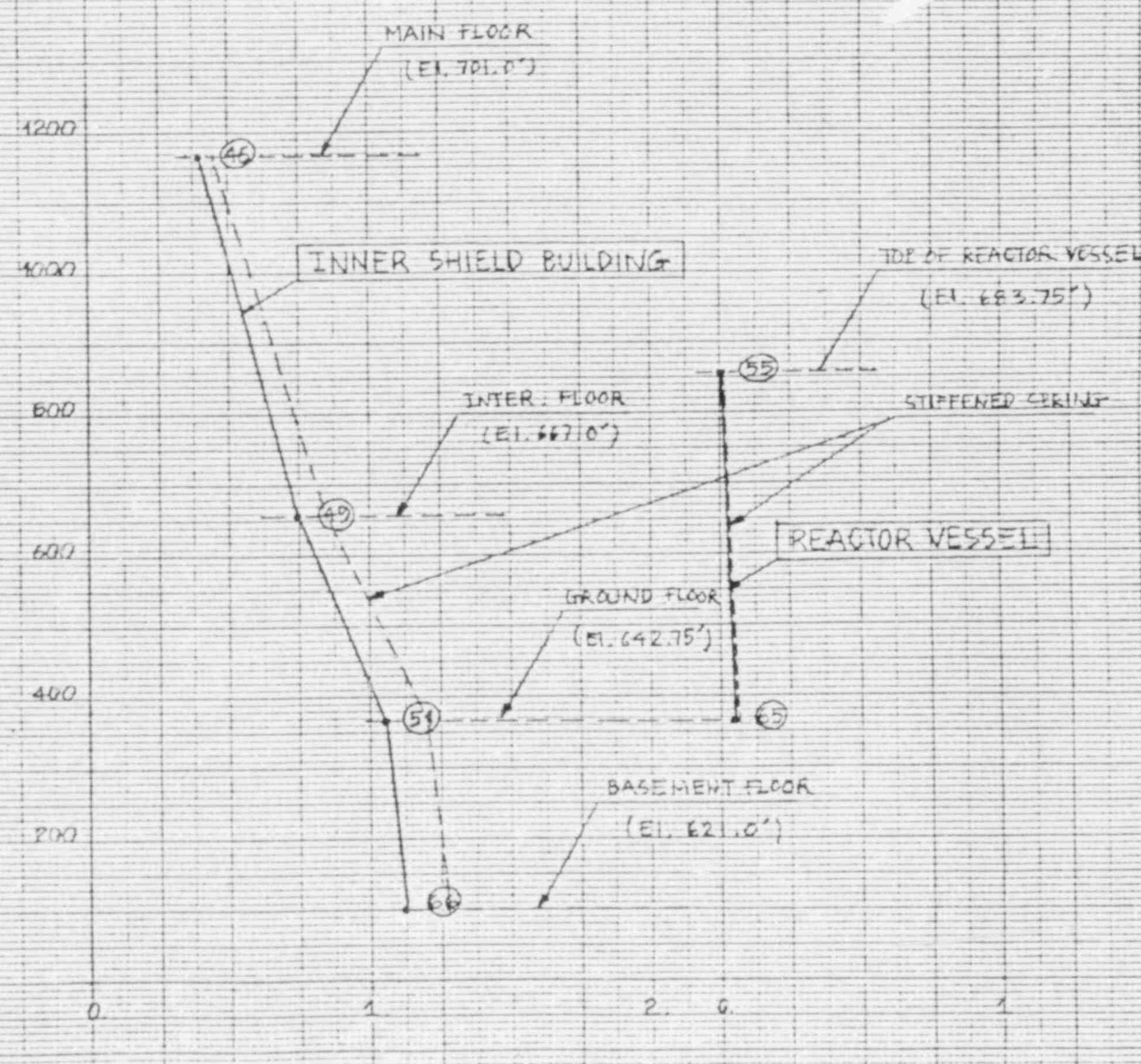

CONTAINMENT BUILDING
MAIN FLOOR
(El. 701.0')
INNER SHIELD BUILDING
INTER. FLOOR
(El. 667.0')
STIFFENED SPRING
GROUND FLOOR
(El. 642.75')
BASEMENT FLOOR
(El. 621.0')
46
48
49
50
51
66
1200
1000
800
600
400
200
HEIGHT (inches)
.1
.2
.3
.4
.5
.6
X1 MOMENT (10^6 K-in)

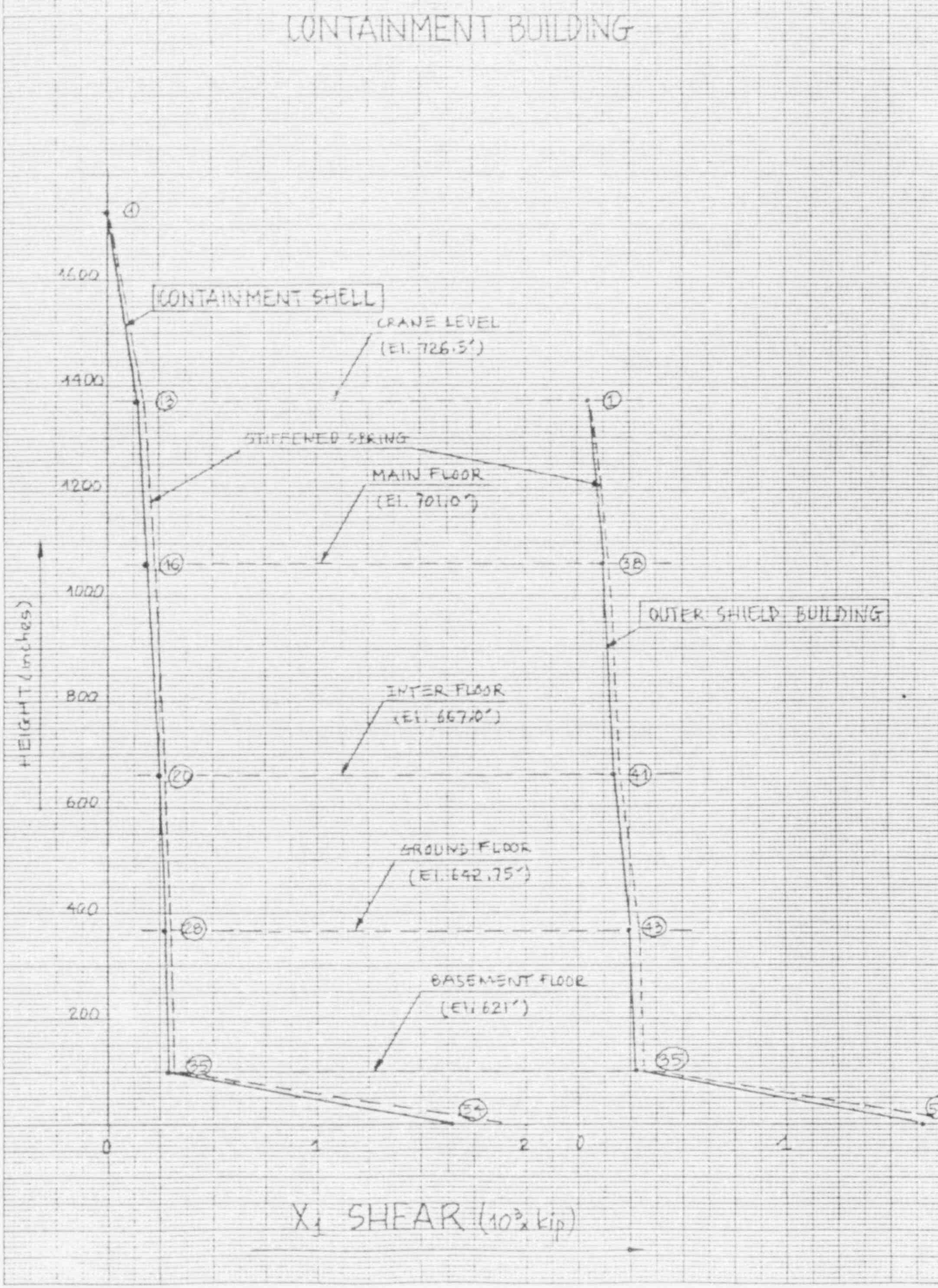
CONTAINMENT BUILDING



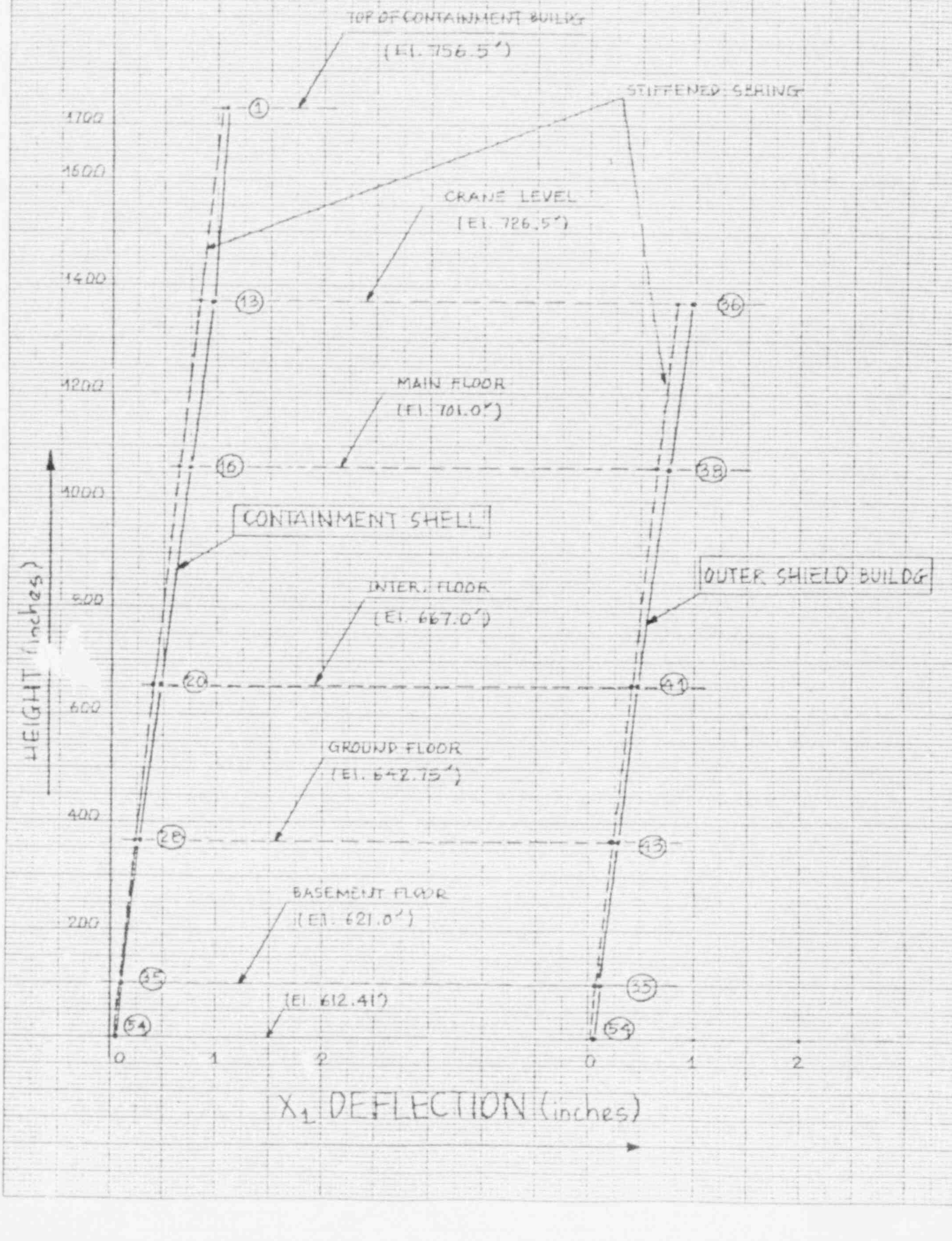

CONTAINMENT BUILDING
TOP OF CONTAINMENT BUILDING
(El. 756.5')
CONTAINMENT SHELL
CRANE LEVEL
(El. 726.5')
STIFFENED SPRING
MAIN FLOOR
(El. 701.0')
INTER FLOOR
(El. 667.0')
GROUND FLOOR
(El. 642.75')
BASEMENT FLOOR
(El. 627.0')
1
13
16
20
28
35
1700
1600
1400
1200
1000
800
600
400
200
HEIGHT (inches)
0
.1
.2
.3
.4
.5
X1 MOMENT (10⁶ K-in)

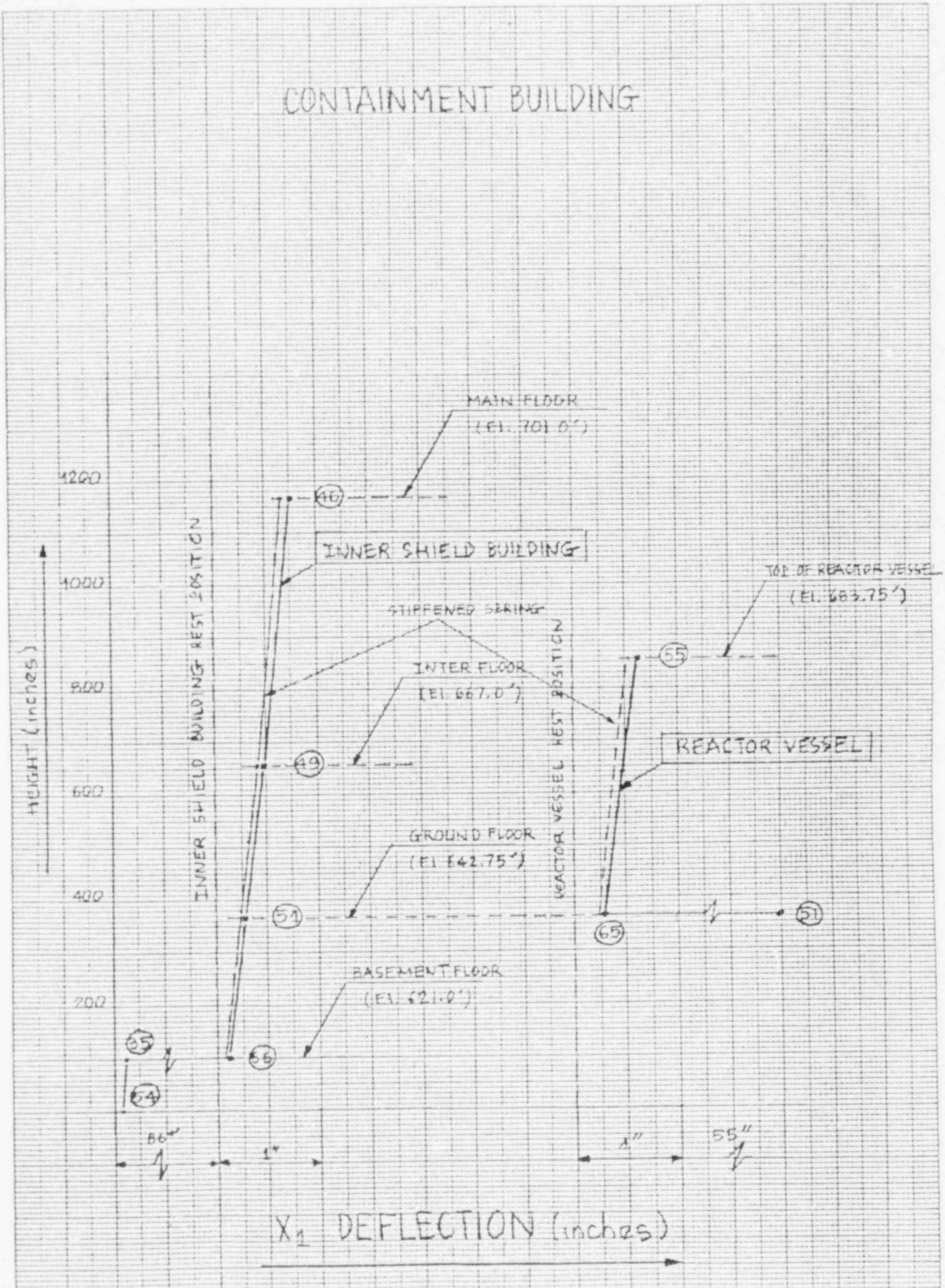
CONTAINMENT BUILDING



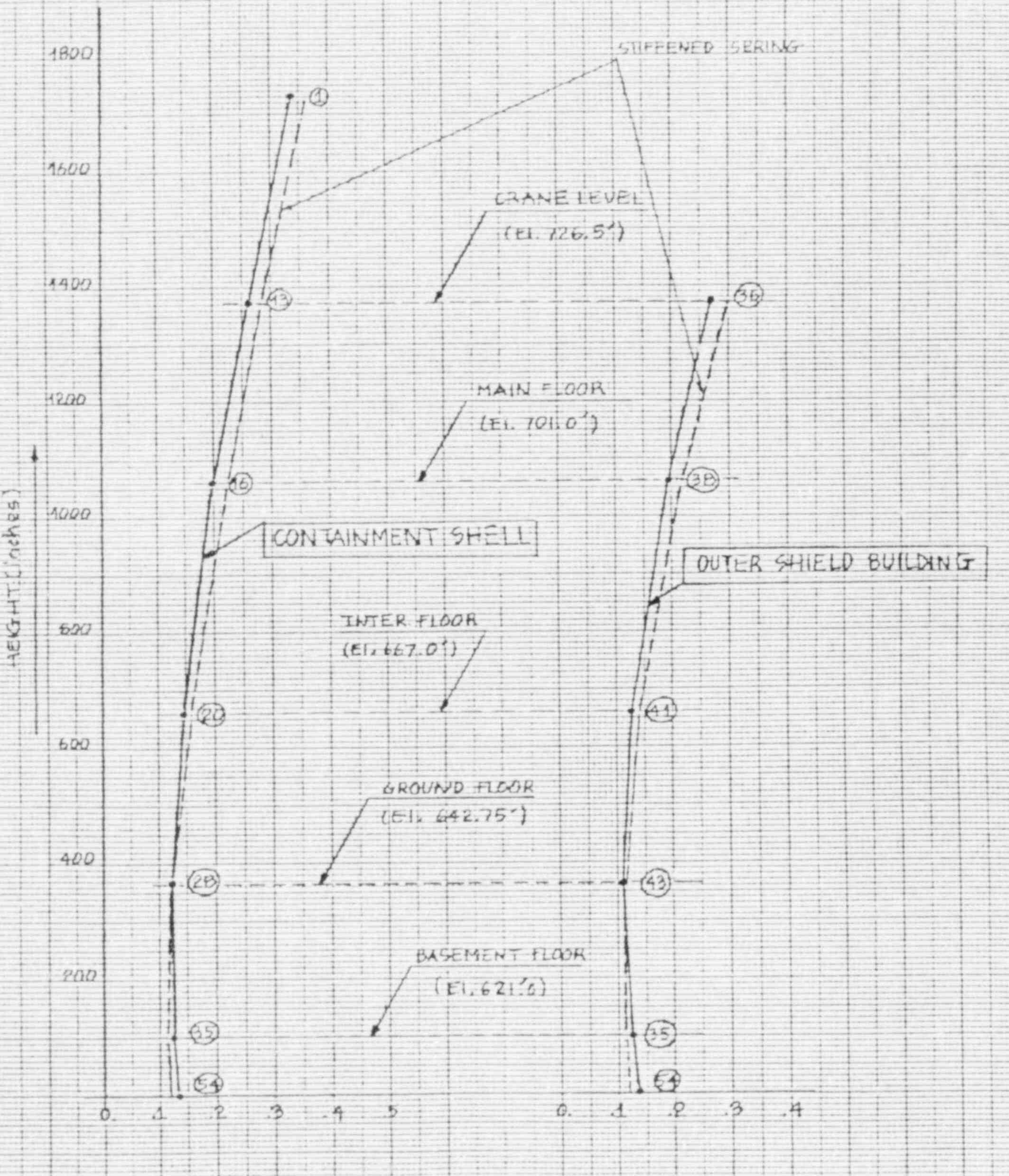

CONTAINMENT BUILDING
CONTAINMENT SHELL
CRANE LEVEL
(El. 726.5')
STIFFENED SPRING
MAIN FLOOR
(El. 701.0')
OUTER SHIELD BUILDING
INTER FLOOR
(El. 667.0')
GROUND FLOOR
(El. 642.75')
BASEMENT FLOOR
(El. 621')
HEIGHT (inches)
1600
1400
1200
1000
800
600
400
200
0
1
2
X1 SHEAR (10³ x kip)
1
3
16
20
28
35
54
38
41
43

CONTAINMENT BUILDING

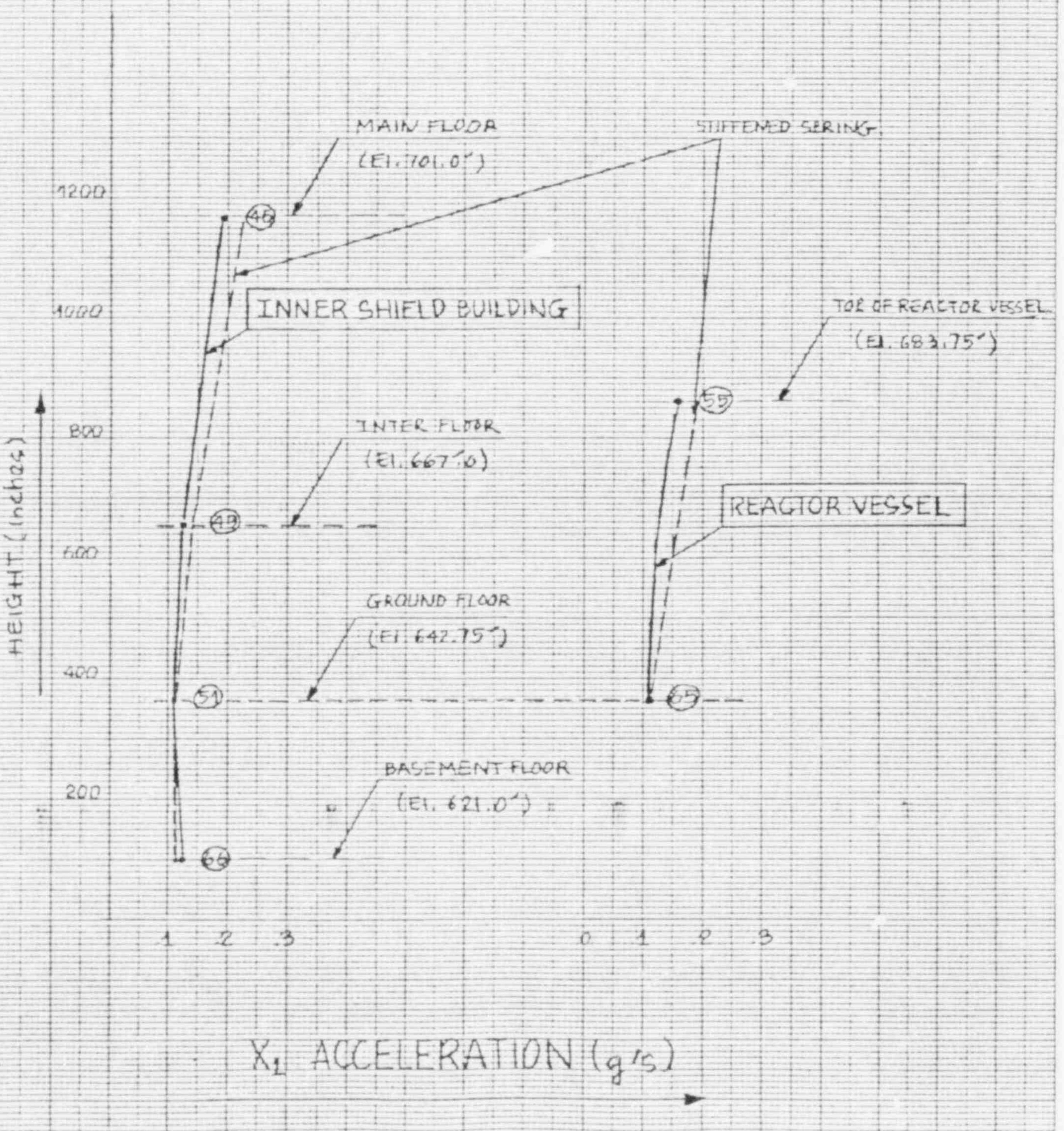


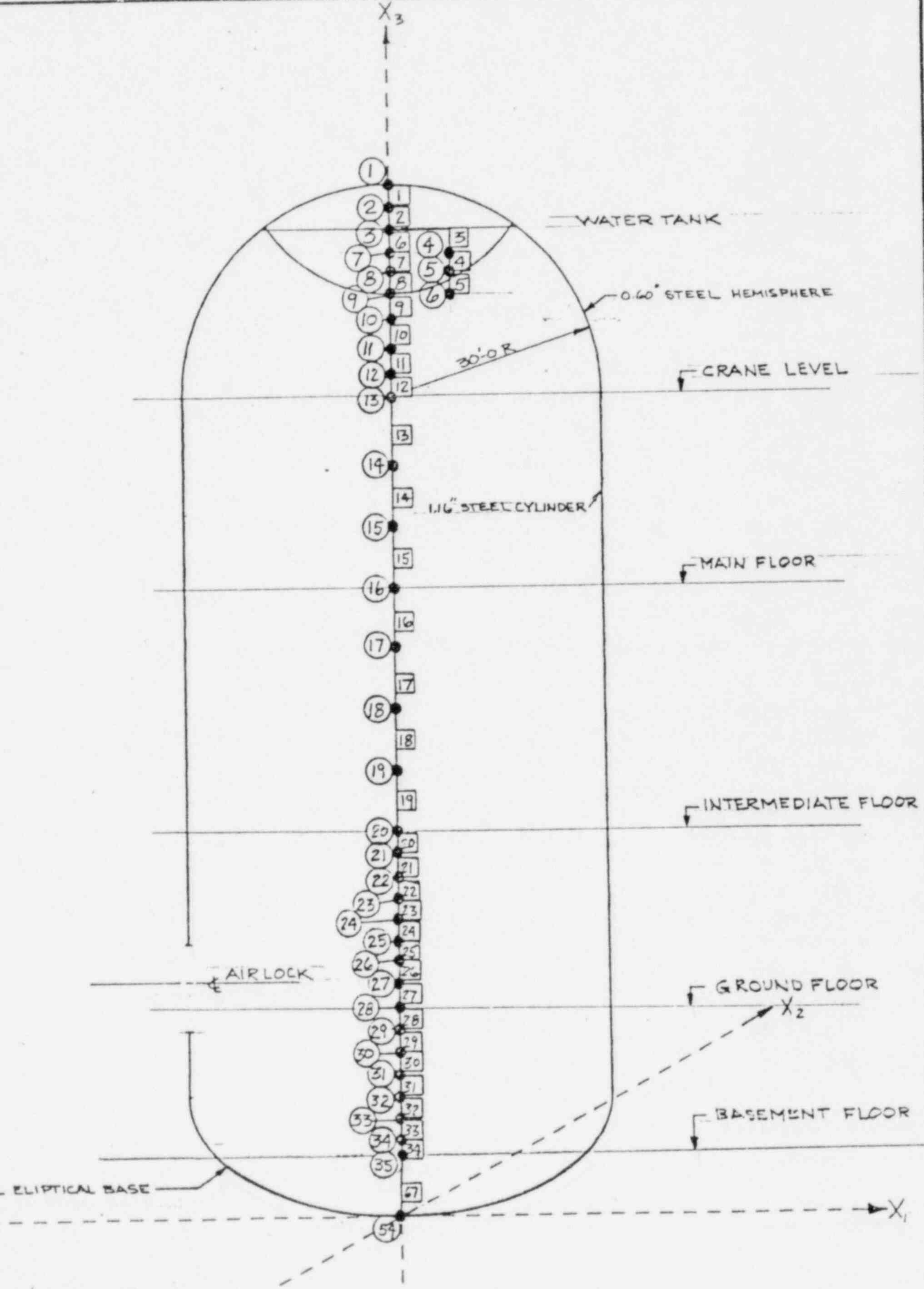

CONTAINMENT BUILDING
MAIN FLOOR
(El. 701.0')
1200
1000
800
600
400
200
HEIGHT (inches)
INNER SHIELD BUILDING REST POSITION
INNER SHIELD BUILDING
TOP OF REACTOR VESSEL
(El. 683.75')
STIFFENED SPRING
INTER FLOOR
(El. 667.0')
REACTOR VESSEL REST POSITION
REACTOR VESSEL
GROUND FLOOR
(El. 642.75')
BASEMENT FLOOR
(El. 621.0')
46
55
49
51
65
56
35
54
86"
1"
1"
55"
X1 DEFLECTION (inches)

CONTAINMENT BUILDING

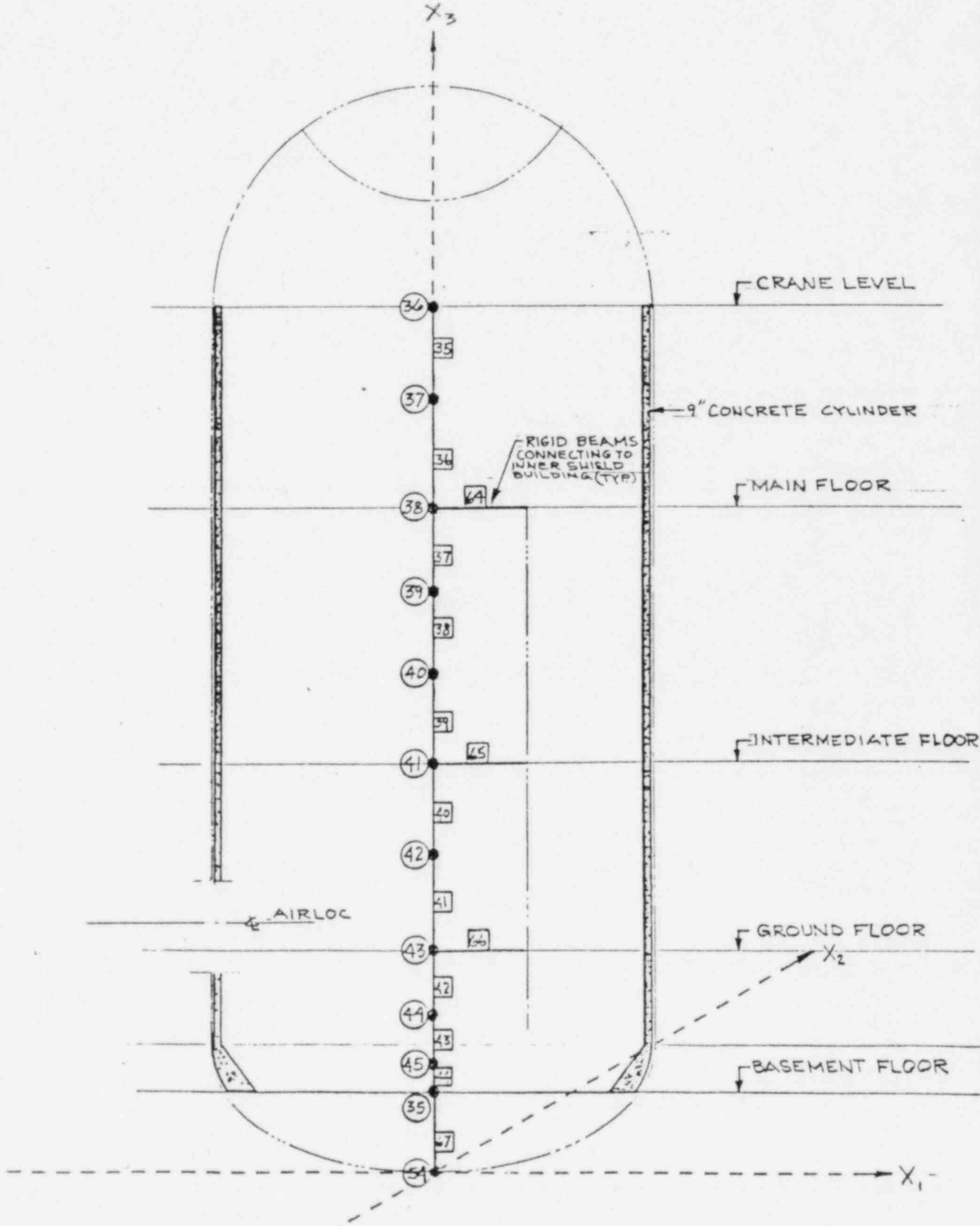


CONTAINMENT BUILDING



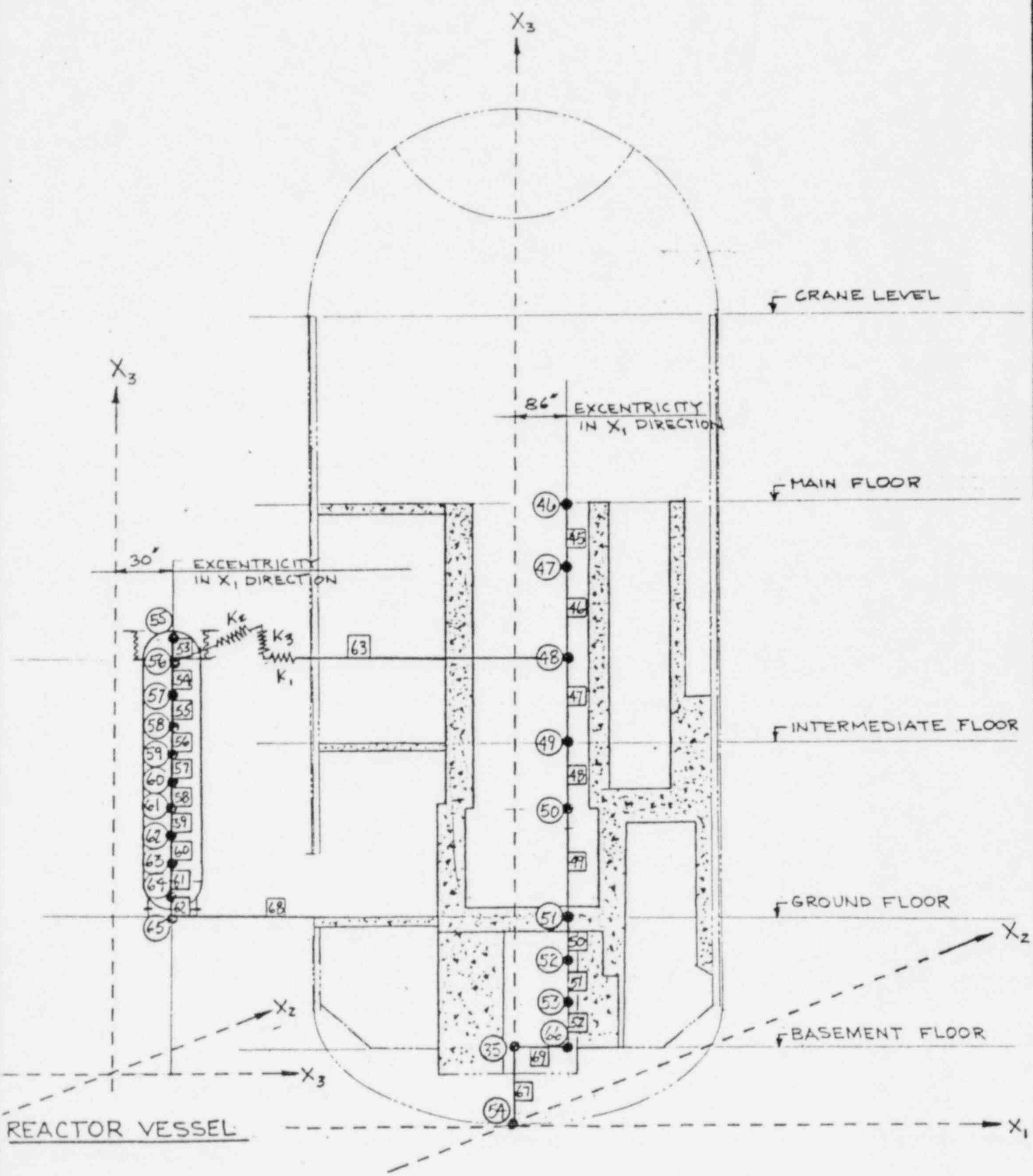


STEEL CONTAINMENT SHELL

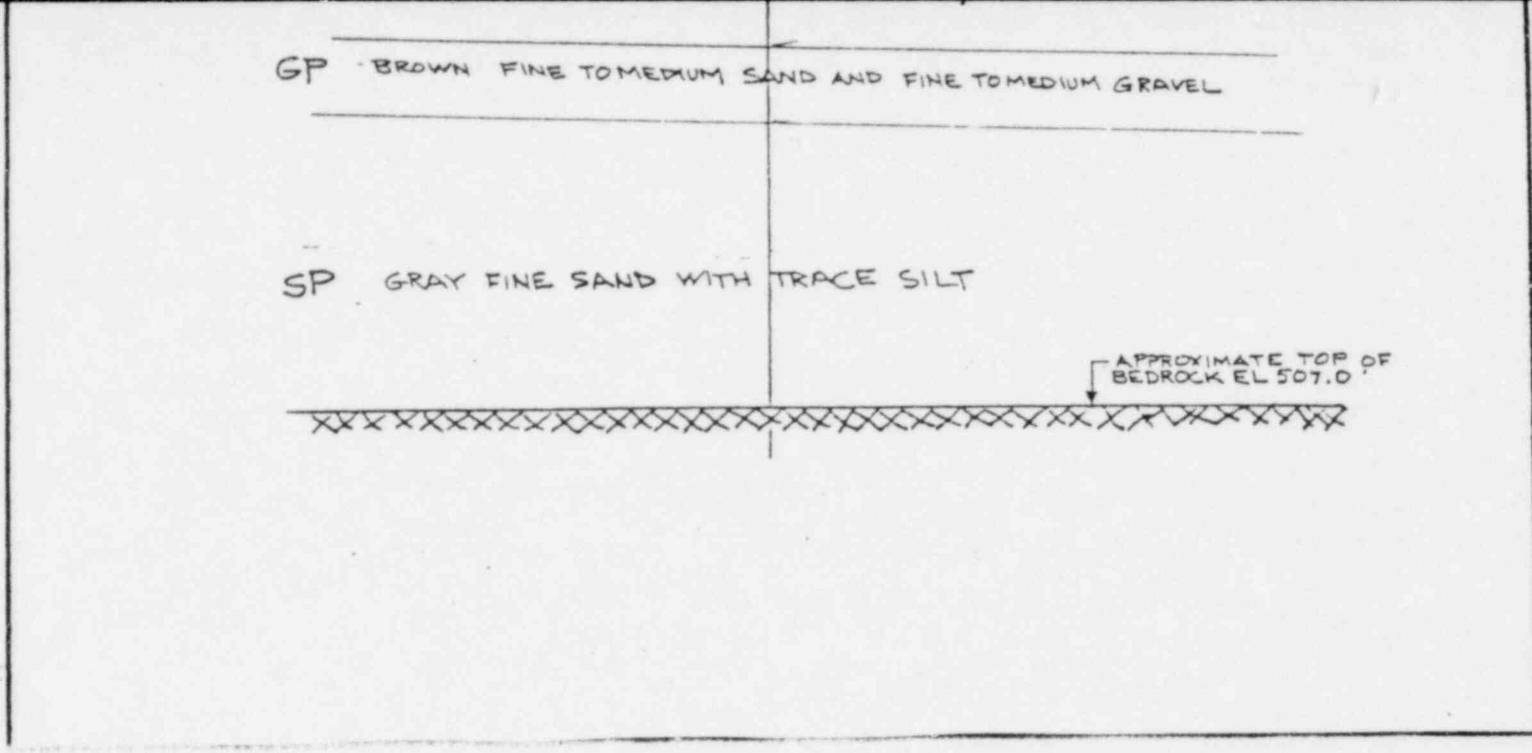


OUTER SHIELD BUILDING

(4)



INNER SHIELD BUILDING



GP BROWN FINE TO MEDIUM SAND AND FINE TO MEDIUM GRAVEL
SP GRAY FINE SAND WITH TRACE SILT
APPROXIMATE TOP OF BEDROCK EL 507.0'

	REF.

CONTAINMENT SHELL AND REACTOR VESSEL ACCEPTANCE CRITERIA BASED ON ASME SECTION VIII, DIV 2, ALTERATE RULES, 1977 ED.

FROM 4-130 BASIC STRESS INTENSITY LIMITS

STRESS INTENSITY	LIMIT
P_m	kS_m
$P_m + P_b$	$1.5 k S_m$

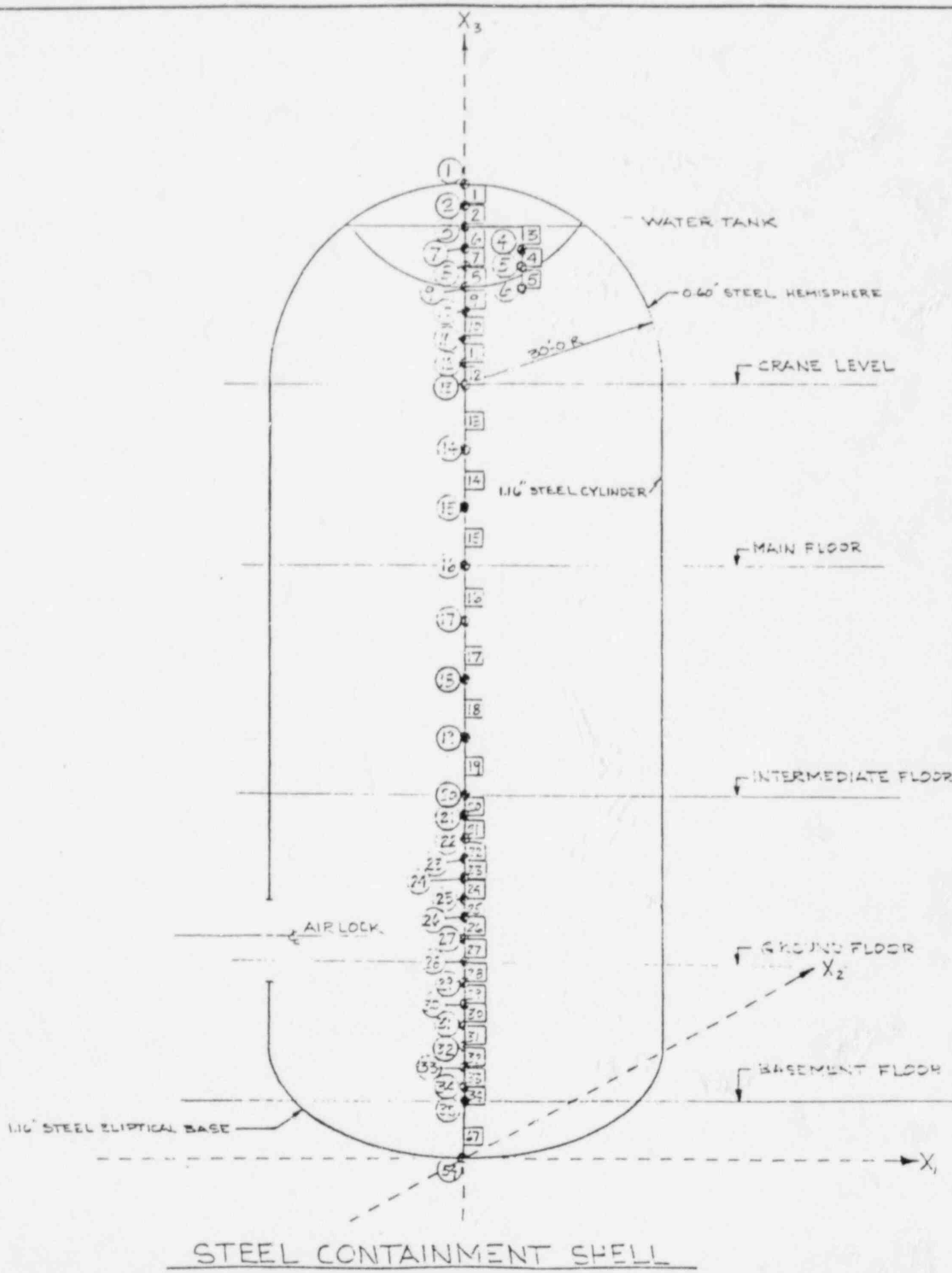
WHERE P_m = GENERAL PRIMARY MEMBRANE STRESS

P_b = PRIMARY BENDING STRESS

S_m = DESIGN STRESS INTENSITY

k = FACTOR GIVEN IN TABLE AD-150.1

Containment shell material : A 201 (change to A 515, A 516)



STEEL CONTAINMENT SHELL

CONTAINMENT SHELL | REF.

ASME Section VIII Analysis

From: Article 4-221, page 364 — REF: ASME SECTION VIII DIV 2, ALT RULES, 1977

Principal stress due to pressure:

$\sigma_1 = \sigma_t = p(1+Z^2)/(Y^2-1)$ ✓

$\sigma_2 = \sigma_\ell = p/(Y^2-1)$ ✓

$\sigma_3 = \sigma_r = p(1-Z^2)/(Y^2-1)$ ✓

in which p = internal pressure, $Y = \frac{\text{outside radius}}{\text{inside radius}}$, $Z = \frac{\text{outside radius}}{\text{interested point radius}}$

Maximum stress occur at r = internal radius, thus: $Z = R_o/R_i$

$$\sigma_1 = \sigma_t = p\frac{R_o^2+R_i^2}{R_o^2-R_i^2}$$

$$\sigma_2 = \sigma_\ell = \frac{pR_i^2}{R_o^2-R_i^2}$$

$$\sigma_3 = \sigma_r = -p.$$

CONTAINMENT SHELL

* Principal stress due to pressure: $R_i = 30'$, $R_o = 30.0967'$, $p = 52$ psi

$$\sigma_1 = \sigma_t = .052 \times \frac{30.0967^2 + 30^2}{30.0967^2 - 30^2} = 16.158 \text{ ksi}$$ ✓

$$\sigma_2 = \sigma_\ell = \frac{.052 \times 30^2}{30.0967^2 - 30^2} = 8.053 \text{ ksi}$$ ✓

$$\sigma_3 = \sigma_r = -p = -.052 \text{ ksi}$$ ✓

$\sigma_1 - \sigma_2 = 16.158 - 8.053 = 8.105$ ksi ✓

$\sigma_2 - \sigma_3 = 8.053 - (-.052) = 8.105$ ksi ✓

$\sigma_3 - \sigma_1 = -.052 - 16.158 = -16.21$ ksi

⇒ Stress intensity = 16.21 ksi ✓ — ASME SECT VIII DIV 2, ALT. 1977 SECT 4-120

CONTAINMENT SHELL | REF.

* Principal stress due to Dead load:

From Ouput S6200YZ, stress due to D.L = −.618 ksi

Since this is the only term cause by D.L, principal stress due to dead load = −.618 ksi ⇒ stress intensity = .618 ksi

* Principal stress due to Seismic (bending)

$$\sigma_y = \pm 1.127 \text{ ksi}, \quad \tau = 1.173 \text{ ksi} \quad (S6200YZ).$$

Principal stress: $\sigma_1, \sigma_2 = \frac{1.127}{2} \pm \sqrt{\left(\frac{1.127}{2}\right)^2 + 1.173^2}$

$\sigma_1 = 1.865$ ksi, $\sigma_2 = -.737$ ksi } Stress intensity = 1.865 − (−.737) = 2.602 ksi

LOAD COMBINATION	P_m (ksi)	LIMIT (ksi)	P_b (ksi)	$P_m + P_b$ (ksi)	LIMIT (ksi)	
D + L + Pa	16.21 + .618 = 16.828	(1.0)(18.9) = 18.9	0	16.828	(1.5)(18.9) = 28.35	OK
D + L + Pa + E′	16.828	18.9	2.602	19.43	28.35	OK

ASSUME K=1.0 FOR BOTH COMBINATIONS

PLATE MATERIAL A 201 REPLACED BY A515, A516

S_m = 18.9 ksi @ 300° FOR A515, A516 GRADE 60 – TABLE ACS-1 ASME SECTION VIII DIV 2, ALT RULES, 1977

CONTAINMENT BUILDING - SHELL ANALYSIS - NORMAL SPRING | REF.

Node 1 to node 35.

- Material: Steel A201 changed to A515 & A516

S_y for A-516 class I = 30 ksi ✓ (From APPENDIX I - Table I7.1, page 100 ASME APPENDICES 1980)

at 100°F = 13.7 ksi ✓

- From Output S6200 FH

Maximum bending stress at beam 34, node 35: σ_{M_1} = .7213 ksi ✓

σ_{M_2} = .7415 ksi ✓

Axial stress: σ_A = -.4726 ksi (compression) ✓

Resulting stress:

$$-.4726 - \sqrt{.7415^2 + .7213^2} = -1.507 \text{ ksi (Compression)}$$ ✓

$$-.4726 + \sqrt{.7415^2 + .7213^2} = .562 \text{ ksi (Tension)}$$ ✓

MAXIMUM SHEAR: At node 3 (beam 3 & beam 6)

	SHEAR X1 direction	SHEAR X2 direction
- Beam 3:	.2184 ✓	.2122 ✓
- Beam 6:	.554 ✓	.5384 ✓
	.7724 ✓	.7506 ✓

Resulting shear $= \sqrt{.7724^2 + .7506^2} = 1.077$ ksi. ✓

Allowable steel stress:

$1.6 \times .6\, S_y = .96 \times 30 = 28.8$ ✓

$3 S_m = (13.7 \text{ ksi @ } 100°F)(3) = 41.1$ ksi ✓

CONTAINMENT BUILDING - SHELL ANALYSIS - STIFFENED SPRING | REF.

Node 1 to node 35

From output S6200YZ.

Max. bending stress at beam 34 node 35: ✓ σ_{M_1} = .786694 ksi ✓

σ_{M_2} = .806398 ksi ✓

Axial stress: σ_A = -.618411 (compression) ✓

= -.475787 (compression) ✓

Resulting stress:

$-.618411 - \sqrt{.786694^2 + .806395^2} = -1.745$ ksi (Compression) ✓

$-.475787 + \sqrt{.786694^2 + .806395^2} = .651$ ksi (Tension) ✓

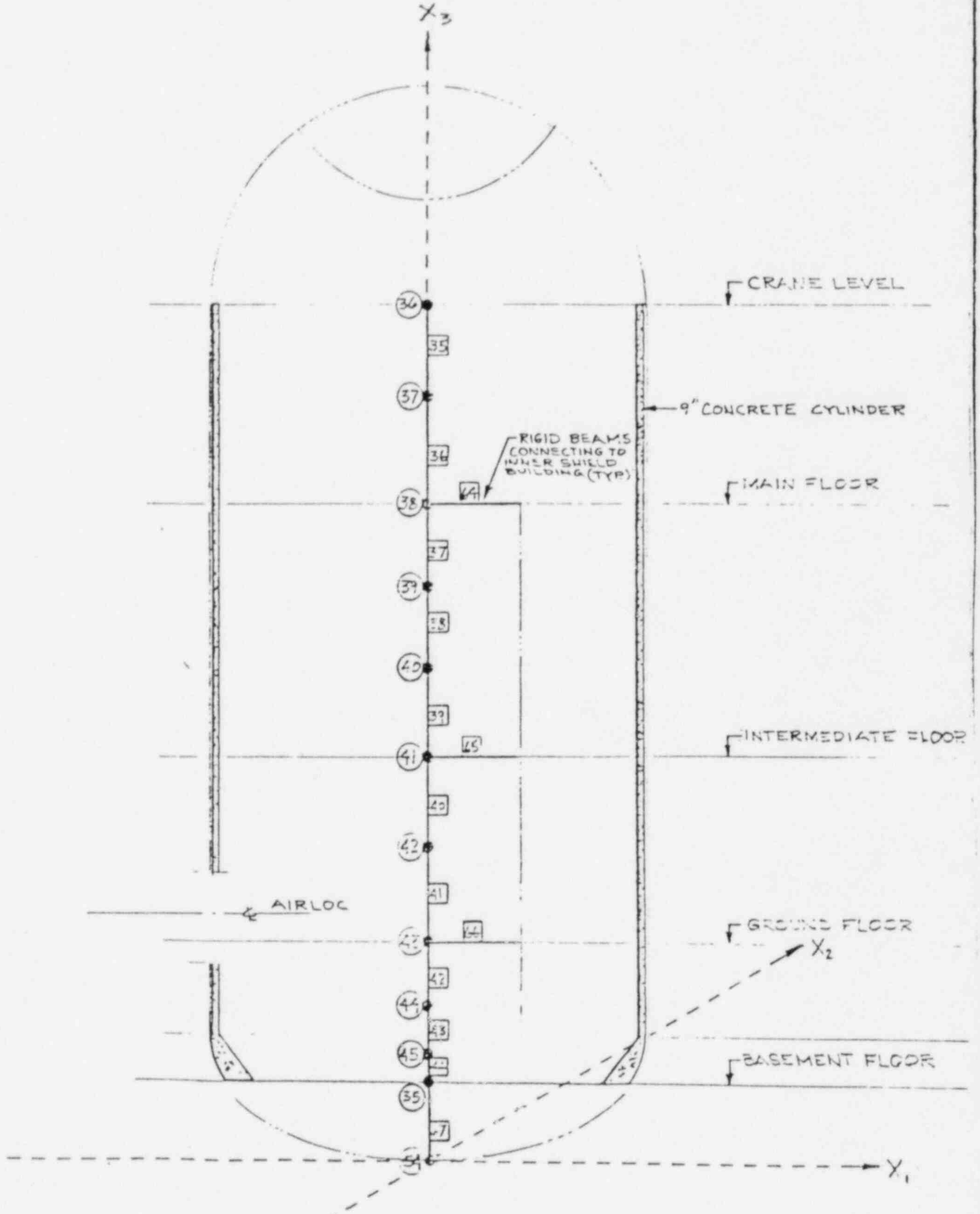
MAX. SHEAR: at node 3 (beam 3 & beam 6) ✓

	X_1 SHEAR	X_2 SHEAR
- Beam 3	.237517 ✓	.231432 ✓
- Beam 6	.602791 ✓	.58735 ✓
	.840308 ✓	.818782 ✓

Resulting shear $\sqrt{.840308^2 + .818782^2} = 1.173$ ksi ✓

Allowable SSE shear: 1.6 x .4 x 30 = 19.2 ksi.

*A 178–73 Electric-Resistance-Welded Carbon Steel Boiler Tubes, Spec. for, 1
*A 179–66(1973) Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes, Spec. for, 1
A 180 Discontinued—Replaced by A 27
*A 181–68 Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service, Spec. for, 1
*A 182–74 Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service, Spec. for, 1
*A 183–68 Heat-Treated Carbon Steel Track Bolts and Carbon Steel Nuts, Spec. for, 4
*A 184–65(1972) Fabricated Steel Bar or Rod Mats for Concrete Reinforcement, Spec. for, 4
*A 185–73 Welded Steel Wire Fabric for Concrete Reinforcement, Spec. for, 4
A 186 Discontinued—Replaced by A 504
A 187 Discontinued
A 188 Discontinued
A 189 Discontinued
A 190 Discontinued
A 191 Discontinued—Replaced by A 239
*A 192–73 Seamless Carbon Steel Boiler Tubes for High-Pressure Service, Spec. for, 1
*A 193–74 Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service, Spec. for, 1
*A 194–73 Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service, Spec. for, 1
A 195 Discontinued—Replaced by A 502
A 196 Discontinued
*A 197–47(1971) Cupola Malleable Iron, Spec. for, 2
A 198 Discontinued—Replaced by A 296, A 297
*A 199–73 Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes, Spec. for, 1
*A 200–72 Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service, Spec. for, 1
[illegible] *Discontinued—Replaced by A 515, A 516*
*A 202–74a Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon, Spec. for, 4
*A 203–74a Pressure Vessel Plates, Alloy Steel, Nickel, Spec. for, 4
*A 204–74a Pressure Vessel Plates, Alloy Steel, Molybdenum, Spec. for, 4
A 205 Discontinued—Replaced by A 233, A 251
A 206 Discontinued—Replaced by A 335
A 207 Discontinued
A 208 Discontinued—Replaced by A 239
*A 209–73 Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes, Spec. for, 1
*A 210–73 Seamless Medium-Carbon Steel Boiler and Superheater Tubes, Spec. for, 1
*A 211–73 Spiral-Welded Steel or Iron Pipe, Spec. for, 1
A 212 Discontinued—Replaced by A 515, A 516
*A 213–74 Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater, and Heat Exchanger Tubes, Spec. for, 1
*A 214–71 Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes, Spec. for, 1
A 215 Discontinued—Replaced by A 27
*A 216–74b Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service, Spec. for, 1, 2
*A 217–74a Martensitic Stainless Steel and Alloy Steel Castings for Pressure-Containing Parts Suitable for High-Temperature Service, Spec. for, 1, 2
A 218 Discontinued—Replaced by A 475
A 219 Discontinued—Replaced by B 487, B 489, B 504, B 529, B 530
*A 220–71 Pearlitic Malleable Iron Castings, Spec. for, 2
A 221 Discontinued—Replaced by A 296, A 297
A 222 Discontinued—Replaced by A 296, A 297
A 223 Discontinued—Replaced by A 296, A 297
A 224 Discontinued—Replaced by G 4
*A 225–74a Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium, Spec. for, 4
*A 226–73 Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service, Spec. for, 1
*A 227–71 Steel Wire, Hard-Drawn for Mechanical Springs, Spec. for, 5
*A 228–71 Steel Wire, Music Spring Quality, Spec. for, 5
*A 229–71 Steel Wire, Oil-Tempered, for Mechanical Springs, Spec. for, 5
*A 230–71 Steel Wire, Oil-Tempered Carbon Valve Spring Quality, Spec. for, 5
*A 231–68 Chromium-Vanadium Alloy Steel Spring Wire, Spec. for, 5
*A 232–68 Chromium-Vanadium Alloy Steel Valve Spring Quality Wire, Spec. for, 5
A 233 Discontinued—Available from American Welding Society
*A 234–74 Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures, Spec. for, 1
*A 235–67 Carbon Steel Forgings for General Industrial Use, Spec. for, 5
A 236–69a Carbon Steel Forgings for Railway Use, Spec. for, 4, 5
A 237–67 Alloy Steel Forgings for General Industrial Use, Spec. for, 4, 5
A 238–69 Forgings, Alloy Steel, for Railway Use, Spec. for, 5
A 239–73 Locating the Thinnest Spot in a Zinc (Galvanized) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip), Test for, 3
*A 240–74 Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels, Spec. for, 3, 4
A 241–68 Hot-Worked High-Carbon Steel Tie Plates, Spec. for, 4
*A 242–74 High-Strength Low-Alloy Structural Steel, Spec. for, 4
*A 243–64(1970) Carbon and Alloy Steel Ring, Hollow Cylinder, and Disk Forgings for General Industrial Use, Spec. for, 5
A 244 Discontinued—Replaced by A 504
A 245 Discontinued—Replaced by A 570, A 611
A 246 Discontinued—Replaced by A 245
A 247–67(1972) Evaluating the Microstructure of Graphite in Iron Castings 2, 11
A 248 Discontinued—Replaced by A 273, A 274
*A 249–74 Welded Austenitic Stainless Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes, Spec. for, 3
*A 250–73 Electric-Resistance-Welded Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes, Spec. for, 1
A 251 Discontinued—Available from American Welding Society
A 252–73 Welded and Seamless Steel Pipe Piles, Spec. for, 4
A 253 Discontinued
*A 254–70 Copper Brazed Steel Tubing, Spec. for, 1
*A 255–67(1974) End-Quench Test for Hardenability of Steel 5
A 256–46(1971) Compression Testing of Cast Iron 2
A 257 Discontinued—Replaced by A 34
A 258 Discontinued—Replaced by A 34
A 259 Discontinued—Replaced by A 34
A 260 Discontinued
A 261 Discontinued
A 262–70 Detecting Susceptibility to Intergranular Attack in Stainless Steels, Rec. Practices for, 3
*A 263–74 Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip, Spec. for, 3, 4
*A 264–74 Stainless Chromium-Nickel Steel Clad Plate, Sheet, and Strip, Spec. for, 3, 4
*A 265–74 Nickel and Nickel-Base Alloy Clad Steel Plate, Spec. for, 3, 4
*A 266–69 Carbon Steel Forgings for Seamless Drums, Heads, and Other Pressure Vessel Components, Spec. for, 1, 5
A 267 Discontinued
*A 268–73 Seamless and Welded Ferritic Stainless Steel Tubing for General Service, Spec. for, 1
*A 269–73 Seamless and Welded Austenitic Stainless Steel Tubing for General Service, Spec. for, 1
*A 270–73 Seamless and Welded Austenitic Stainless Steel Sanitary Tubing, Spec. for, 1
*A 271–73 Seamless Austenitic Chromium-Nickel Steel Still Tubes for Refinery Service, Spec. for, 1
A 272 Discontinued—Replaced by E 109
*A 273–64(1969) Carbon-Steel Blooms, Billets, and Slabs for Forgings, Spec. for, 5
*A 274–64(1969) Alloy Steel Blooms, Billets, and Slabs for Forgings, Spec. for, 5
*A 275–71 Magnetic Particle Examination of Steel Forgings 5
*A 276–73 Stainless and Heat-Resisting Steel Bars and Shapes, Spec. for, 5
A 277 Discontinued—Replaced by A 338
A 278–64(1971) Gray Iron Castings for



OUTER SHIELD BUILDING

CONTAINMENT BUILDING – OUTER SHIELD BUILDING ANALYSIS – NORMAL SPRING	REF.

NODE 36 to node 35 (Outer Shield Building)

From output 56200FH

Maximum bending stress at node 35 (beam 44) ✓

$\sigma_{b_1} = .12344$ ksi ✓ $\sigma_{b_2} = .11572$ ksi. ✓

$SRSS = \sqrt{.12344^2 + .11572^2} = .169$ ksi ✓

Axial stress at node 35 ✓

$\sigma_a = -.17478$ ksi (compression) (Output case 3) ✓

$\sigma_a = -.1261$ ksi (compression) (Output case 2) ✓

Resulting:

$\sigma_a + SRSS = -.17478 + .169 = -.00578$ (compression) ✓

$\sigma_a - SRSS = -.17478 - .169 = -.344$ ksi (compression) < allowable OK ✓

Tension: $\sigma_a + SRSS = -.1261 + .169 = .0429$ ksi ✓

SHEAR STRESS

Maximum at node 35: ✓

$\tau_1 = .02644$ ✓ $\tau_2 = .02518$ ✓

Resulting: $\tau = \sqrt{.02644^2 + .02518^2} = .0365$ ksi < allowable OK ✓

ALLOWABLE STRESS

Maximum allowable compression stress: $.85 f_c' = .85(3500) = 2975$ psi ✓

Maximum shear stress $= 2\sqrt{f_c'} = 2\sqrt{3500} = 118.32$ psi. ✓

CONTAINMENT BUILDING — OUTER SHIELD BUILDING ANALYSIS — NORMAL SPRING	REF.
REINFORCING CHECKING : 2# 5 BARS @ 12" o/c both faces E.W.	
Reinforcing take tension load of concrete	
Max tension from previous case :	
σ_t = .0429 ksi ✓	
Tension force in steel : (.0429.)(9)(12) = 4.633 k. < allowable ✓	OK
Maximum force in steel : 40 x 2 x .31 = 24.8 k ✓	
Max tension stress : $\frac{24.8}{9 \times 12}$ = .23 ksi ✓	

CONTAINMENT BUILDING – OUTER SHIELD BUILDING ANALYSIS – STIFFENERS SCALING | REF.

Node 36 to node 35 (Outer Shield building)

From output SG200YZ

Max. bending stress at node 35 (beam 44) ✓

$\sigma_{b_1} = .141677$ ksi ✓ $\sigma_{b_2} = .131411$ ksi ✓

$SRSS = \sqrt{.141677^2 + .131411^2} = .193$ ksi ✓

Axial stress at node 35: ✓

$\sigma_a = -.124499$ ksi (Comp.) ✓ $\sigma_a = -.176389$ ksi (Comp.) ✓

Max resulting compression: $-.176389 - .193 = -.369$ ksi < 2.975 ksi OK ✓

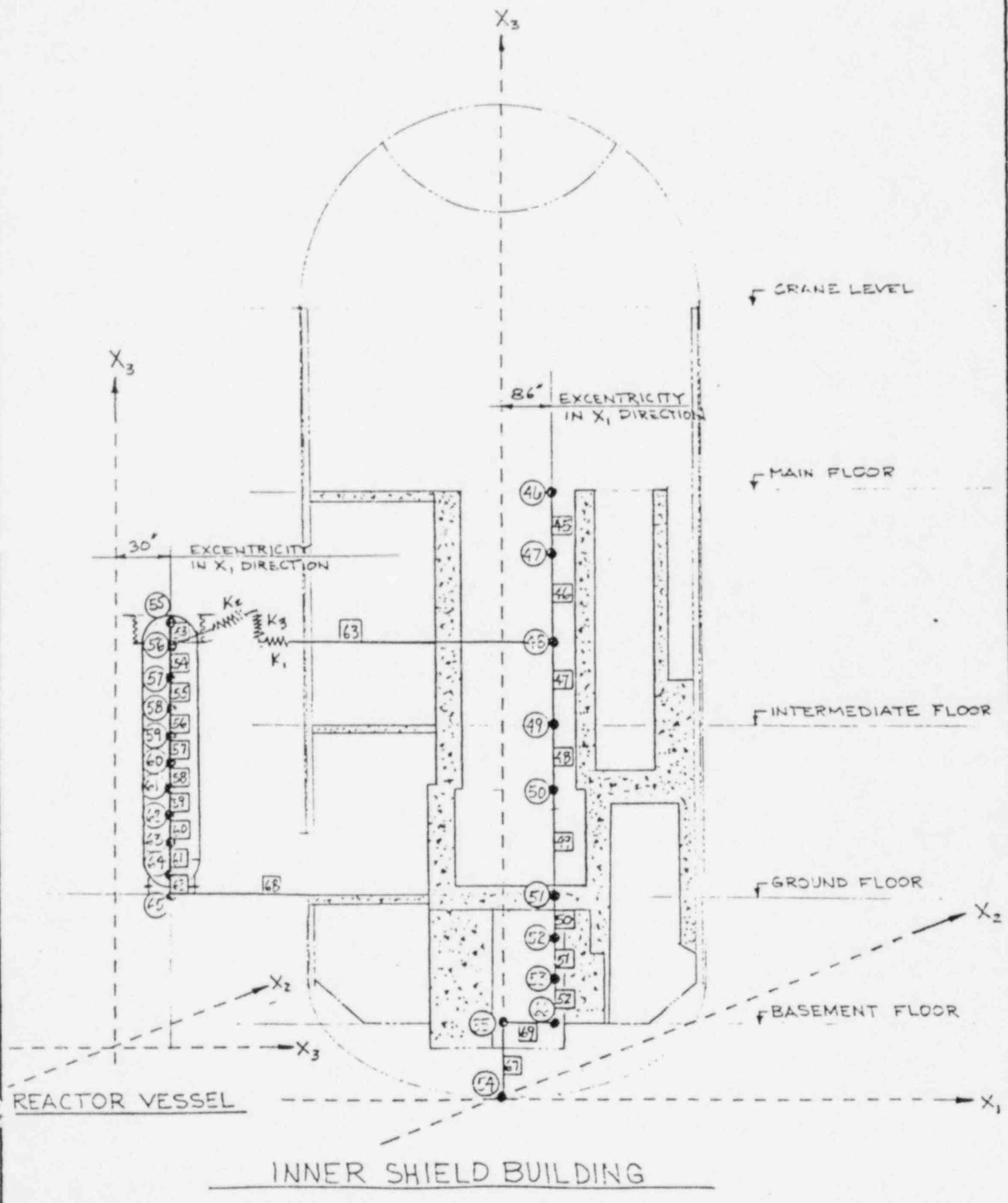
Max resulting tension: $-.124499 + .193 = .069$ ksi < .23 ksi OK ✓

SHEAR STRESS

Max. at node 35 ✓

$\tau_1 = .0301577$ ksi ✓ $\tau_2 = .0288576$ ksi ✓

Resulting Shear: $\sqrt{.0301577^2 + .0288576^2} = .0418$ ksi < 116.32 psi OK ✓

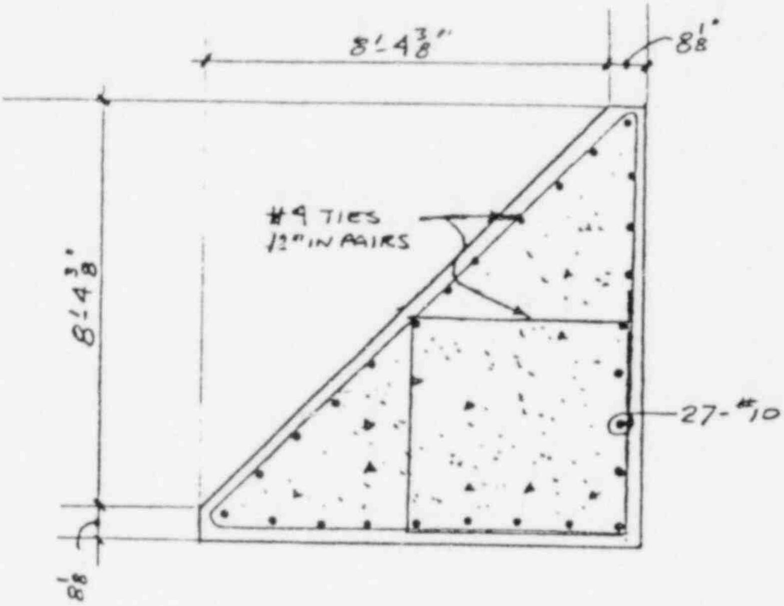


INNER SHIELD BUILDING

INNER SHIELD BLDG | REF.

MAIN SUPPORT COLUMNS

$f'_c = 3500$ PSI
$F_y = 40$ KSI



GROSS AREA CONCRETE = 8.125(100.375) + 8.125(108.50) + ½(101.375)(101.375)
= 6835.6 IN^2

AREA STEEL = 27(1.27) = 34.29 IN^2 $A_{s_{\#10}} = 1.27 IN^2$

$$\rho = \frac{A_s}{A_g} = \frac{34.29}{6835.6} = 0.005$$

SECTION 10.5 - MINIMUM REINFORCEMENT OF FLEXURAL MEMBER

$$\rho_{MIN} = \frac{200}{F_y} = \frac{200}{40000} = 0.005$$

LIMITS FOR REINFORCEMENT OF COMPRESSION MEMBERS

$A_{MIN} = .01\ A_g = .01\ (6835.6) = 68.36\ IN^2$ N.G.

TIES DON'T CONFORM W ACI-318-77

	REF.
INNER SHIELD BLDG	

NODE 46 → 53 & 66

APPROXIMATE MOMENT CAPACITY

$F_y = 40\,ksi$ w/27-#10 $A_s = 34.29$

$F = (40)(34.29) = 1371.6^k$

USING TWICE THIS / FOR 2 COLUMNS

$d_{APP} = 8.25'$

$M_u = 2(1371.6)(8.25)(12) = 2.71577 \times 10^5$ (k-in)

ALLOWABLE STRESS $= \frac{(40)(34.29)}{6835.6} = 0.201\,ksi$

MODULUS OF RUPTURE OF CONCRETE $= f_r = 7.5\sqrt{f_c'} = 443.7\,psi = 0.444\,ksi$

CHECK SHEAR

FOR CONCRETE ALONE $v_c = \phi\, 2\sqrt{f_c'} = (.85)2\sqrt{3500} = 100.57\,psi$

Moment from C.E. 6200 FH at beam 52 node 66.

$M = 6.1816 \times 10^5$ kip-in (case 2)
$M = 6.575849 \times 10^5$ kip-in (case 2) (Normal spring)

From C.E. $M = 7.0991 \times 10^5$ kip-in (case 2)
$M = 7.39543 \times 10^5$ kip-in (case 3) (Stiffened spring)

Reinforced not good but O.K. with modulus of rupture of concrete (at node 66)

CONTAINMENT BUILDING – INNER SHIELD BUILDING ANALYSIS – NORMAL SPECTRA | REF.

NODE 46 → 53 & 66 (Inner shield building)

From output S6200.FH

Maximum bending stress at node 66 (Beam 52) ✓

$\sigma_{b_1} = .13957$ ksi ✓ $\sigma_{b_2} = .14852$ ksi. ✓

$SRSS = \sqrt{.13957^2 + .14852^2} = .2038$ ksi ✓

Axial stress at node 66

$\sigma_a = -.1562$ ksi (Output case 2) ✓ (Compression)

$\sigma_a = -.19705$ ksi (Output case 3) ✓

Resulting

$\sigma_a + SRSS = -.1562 + .2038 = .0476$ ksi (Tension) ✓

$\sigma_a - SRSS = -.19705 - .2038 = -.40085$ ksi (Compression) < 2975 psi

OK ✓

SHEAR STRESS

Max. at node 66

$\tau_1 = .2699 \times 10^{-1}$ ksi ✓ $\tau_2 = .2704 \times 10^{-1}$ ksi ✓

Resulting : $\tau = \sqrt{\tau_1^2 + \tau_2^2} = \sqrt{.2699^2 + .2704^2} \times 10^{-1} = .0382$ ksi ✓

For concrete alone :

$v_c = \phi\, 2 \sqrt{f'_c} = .85 \times 2 \sqrt{3500} = 100.57$ psi

$v_u = \tau = 38.2$ psi < 100.57 psi OK

CONTAINMENT BUILDING – INNER SHIELD BUILDING ANALYSIS – STIFFENED SPRING | REF.

NODE 46 → 53 & 66 (Inner shield Building)

From Output S6200YZ.

Max bending stress at node 66 (Beam 52)

$\sigma_{b_1} = .160289$ ksi ✓ $\sigma_{b_2} = .168834$ ksi ✓

$SRSS = \sqrt{.160289^2 + .168834^2} = .233$ ksi ✓

Axial stress at node 66

$\sigma_A = -.156274$ ksi (Comp) ✓ $\sigma_A = -.196984$ ksi (Comp) ✓

Resulting max compression: $-.196984 - .233 = .43$ ksi < 2.975 ksi OK ✓

– – max tension : $-.156274 + .233 = .0767$ ksi ✓

SHEAR STRESS

Max at node 66

$\tau_1 = .030825$ ksi ✓ $\tau_2 = .0310668$ ksi ✓

Resulting shear $\tau = \sqrt{.030825^2 + .0310668^2} = .0438$ ksi < 150.57 OK. ✓

CHECK OUTER REINFORCING

TYPICAL REINFORCING = #6 @ 12" o/c FOR 2' wall, As = .44 in²

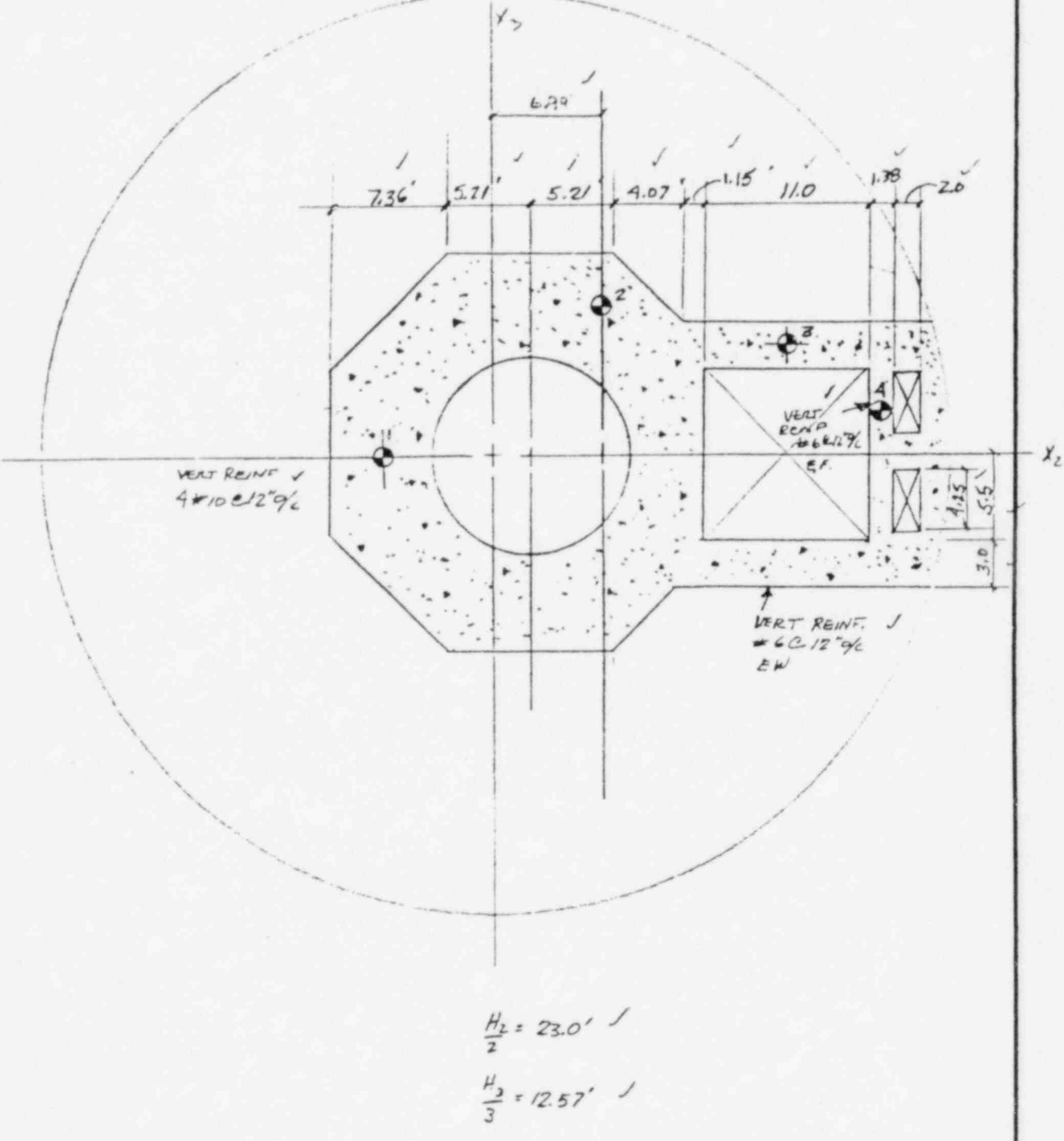
$\sigma_T = .0767$ ksi

Tension in steel = .0767 × 24 × 12 = 22.09 k. < 35.2 k OK

Max, Force in steel : 40 × 2 × .44 = 35.2 k

INNER SHIELD BLDG. | REF.

LOCATIONS FOR STRESS INVESTIGATIONS
(FOR BEAM 45 NODE 47)



$\frac{H_2}{2} = 23.0'$

$\frac{H_3}{3} = 12.57'$

CONTAINMENT BUILDING - INNER SHIELD BUILDING | REF.

BEAM 45 NODE 47

Find stresses at different locations of cross sections using linear interpolation and combine RSS.

LOCATION	d_2	d_3	D.L. (compression) Stress (ksi)	E.Q. Bending stress (ksi) σ_{x_2}	σ_{x_3}	(ksi) $\sqrt{\sigma_{x_2}^2+\sigma_{x_3}^2}$	$\sigma_{Tension}$	Allowable Tension
1	14.0 ✓	0 ✓	-.02458 ✓	0 ✓	.00265 ✓	.00265 ✓	No ✓	
2	0 ✓	9.5 ✓	-.02458 ✓	.00122 ✓	0 ✓	.00122 ✓	No ✓	
3	12.0 ✓	7.0 ✓	-.02458 ✓	.00090 ✓	.00227 ✓	.00244 ✓	No ✓	
4	18.0 ✓	3.0 ✓	-.02458 ✓	.00038	.00341 ✓	.00343 ✓	No ✓	

E.Q. + Dead load minimum axial compression at node 47 beam 45 : -.02458 ksi (Output S6200 FH)

Bending stress due to earthquake:
σ_{x_2} = .00161 ksi (Output S6200 FH) ✓
σ_{x_3} = .00436 ksi (Output S6200 FH). ✓

No tension occur.

⇒ Minimum steel required.

CONTAINMENT BUILDING – INNER SHIELD BUILDING – STIFFENED SPRING CONSTANT	REF.

NODE 47 BEAM 45

From Output S6200 YZ:

Bending stress: $\sigma_{x_2} = 1.6213 \times 10^{-3}$ ksi ✓

$\sigma_{x_3} = 5.74912 \times 10^{-3}$ ksi ✓

$SRSS = \sqrt{1.6213^2 + 5.74912^2} \times 10^{-3} = 6.031 \times 10^{-3}$ ksi ✓

Axial stress: $\sigma_A = -2.46 \times 10^{-2}$ ksi ✓ (Compression)

$\sigma_A = -3.211 \times 10^{-2}$ ksi ✓

MAX COMPRESSION: $-3.211 \times 10^{-2} - .6031 \times 10^{-2} = -3.8141 \times 10^{-2}$ ksi ✓

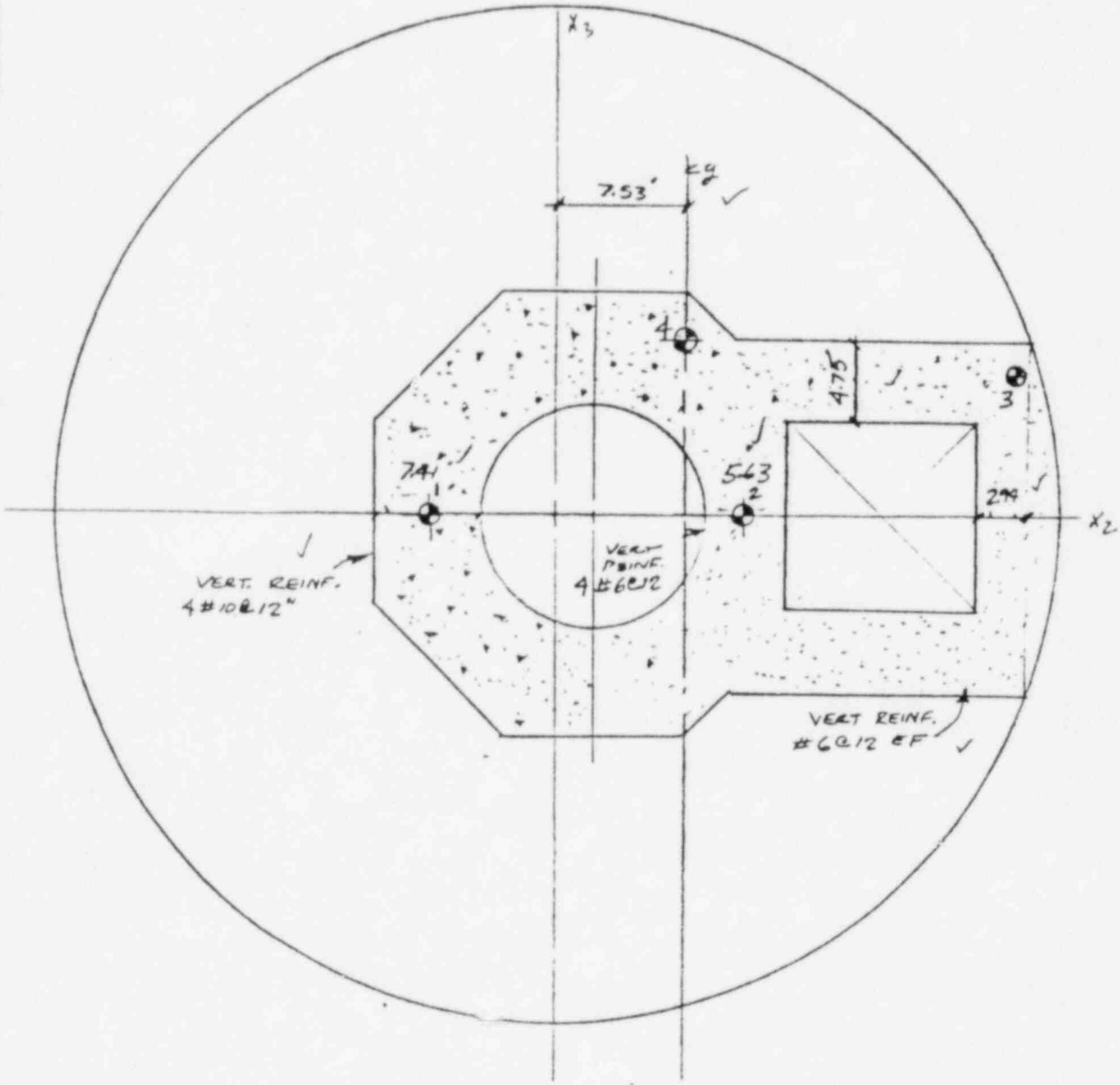
NO TENSION! ✓

Since no tension, minimum steel required for reinforced concrete.

INNER SHIELD BLDG.

REF.

LOCATIONS FOR STRESS INVESTIGATIONS
(FOR BEAM 47 NODE 49)



$\frac{H_2}{2} = 22.47'$

$\frac{H_3}{2} = 12.57'$

CONTAINMENT BUILDING – INNER SHIELD BUILDING – NORMAL SPRING | REF.

BEAM 47 NODE 49

Find stresses at different locations of cross section using linear interpolation and combine RSS.

From output S6200 FH : Minimum axial Compression by dead load + E.Q. = −.04955 ksi

From output S6200 FH (CASE 1) = Bending: σ_{x2} : 4.90525 x10⁻² ksi ✓ ; σ_{x3} : 4.92718 x10⁻² ksi ✓

LOCATION	d_2	d_3	D.L. (Comp) stress (ksi)	E.Q. Bending (ksi) σ_2	σ_3	$\sqrt{\sigma_2^2+\sigma_3^2}$	σ_{Ten} (ksi)	Allowable tension (ksi)	
1	9.5	0	−.04955 ✓	0 ✓	.02083 ✓	.02083 ✓	No ✓		
2	3.5	0	−.04955 ✓	0 ✓	.00767 ✓	.00767 ✓	No ✓		
3	19.	8.0	−.04955 ✓	.03122 ✓	.04166 ✓	.05206 ✓	.00251 ✓	< .0515	OK
4	0	10	−.04955 ✓	.03902 ✓	0 ✓	.03902 ✓	No ✓		

LOCATION 3

Reinforced 2 #6 @ 12, As = 2 x .44 ✓

Width = 4.75' ✓

Allowable tension stress : $\frac{40 \times 2 \times .44}{12 \times 4.75 \times 12}$ = .0515 ksi ✓

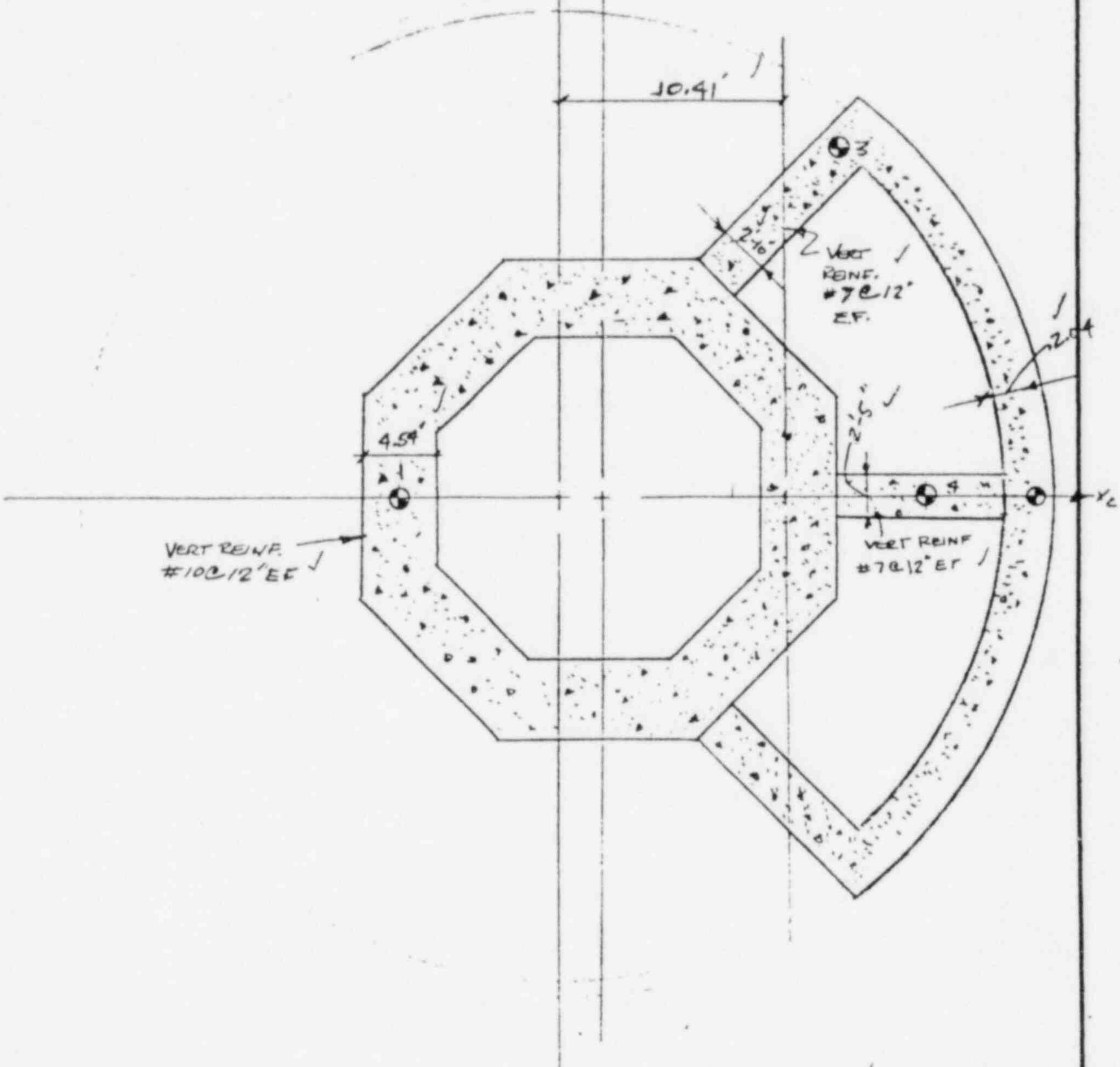
NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY R.R DATE 7-17-79 PROJ. 5101 TASK 026
CHKD. JC DATE 9/7/82 PAGE 1 OF

LACBWR SEP

INNER SHIELD BLDG (NODE 5-C) | REF.

LOCATIONS OF STRESS INVESTIGATION
(FOR BEAM 49 NODE 51)



$\frac{H_2}{2} = 19.6'$

$\frac{H_1}{2} = 23.5'$

CONTAINMENT BUILDING – INNER SHIELD BUILDING – NORMAL SPRING | REF.

BEAM 49 NODE 51

Find stresses at different locations of cross sections using linear interpolation and combine by RSS.

From Output S6200FH : Minimum axial Compression by dead load + E.Q. : – .07283 ksi. ✓

From Output S6200FH (Case 1) : Bending by earthquake : $\sigma_{x2} = 8.94899 \times 10^{-2}$ ✓, $\sigma_{x3} = 6.58971 \times 10^{-2}$ ✓

LOCATION	d_2	d_3	D.L. (Comp) Stress, ksi	E.Q. Bending (ksi) σ_{x2}	E.Q. Bending (ksi) σ_{x3}	(ksi) $\sqrt{\sigma_{x2}^2+\sigma_{x3}^2}$	(ksi) $\sigma_{tension}$	(ksi) Allowable tension	REF.
1	19.6 ✓	0	-.07283 ✓	0 ✓	.0659 ✓	.0659 ✓	No tension ✓		
2	19.6 ✓	0	-.07283 ✓	0 ✓	.0659 ✓	.0659 ✓	– ✓		
3	3.5 ✓	21.0 ✓	-.07283 ✓	.07997 ✓	.01177 ✓	.08083 ✓	.008 <	.118	OK
4	8.5 ✓	0	-.07283 ✓	0	.02858	.02858 ✓	No tension ✓		

Allowable tension stress:

LOCATION 3

2 #7 @ 12 ✓ EF , $A_s = 2 \times .6 = 1.2 \text{ in}^2$ ✓ ✓

Width 2'-10" ✓

Allowable tension stress on steel : $\frac{(40) \times 2 \times .6}{12 \times 2.83 \times 12} = .118$ ksi. ✓

CONTAINMENT BUILDING – INNER SHIELD BUILDING – STIFFENED SPRING | REF.

NODE 51 BEAM 49

From Output S6200YZ.

Max Bending stress: $\sigma_{x_2} = .102637$ ksi ✓

$\sigma_{x_3} = .0754699$ ksi ✓

$SRSS = \sqrt{.102637^2 + .0754699^2} = .1274$ ksi ✓

Axial stress: $\sigma_A = -7.29961 \times 10^{-2}$ ksi (Compression) ✓

$\sigma_A = -9.55239 \times 10^{-2}$ ksi (Compression) ✓

Max Compression: $-.0955239 - .1274 = -.223$ ksi ✓

Max Tension: $-.0729961 + .1274 = .0544$ ksi ✓

Find stresses at different locations of Cross Section using linear interpolation & combine by SRSS

LOCATION	d_2	d_3	D.L. (Comp.) Stress, ksi	Bending (ksi) σ_{x_2}	Bending (ksi) σ_{x_3}	(ksi) $\sqrt{\sigma_{x_2}^2+\sigma_{x_3}^2}$	(ksi) $\sigma_{Tension}$	Allowable tension (ksi)
1	19.6 ✓	0	-.07299 ✓	0 ✓	.07547 ✓	.07547 ✓	.00248 ✓	< .155 ✓
2	19.6 ✓	0	-.07299 ✓	0 ✓	.07547 ✓	.07547 ✓	.00248 ✓	< .12
3	3.5 ✓	21. ✓	" " ✓	.09172 ✓	.01348 ✓	.09271 ✓	.01972 ✓	< .118 ✓
4	8.5 ✓	0 ✓	" " ✓	0 ✓	.03273	.03273	No tension ✓	

OK

LOCATION #1 #10 @ 12" EF $A_s = (1.27 \times 2) = 2.54\ in^2$ ✓

width = 4.54 ft ✓

Allowable tension: $\frac{40 \times 2.54}{12 \times 4.54 \times 12} = .155$ ksi ✓

LOCATION #2 #6 @ 12" EF $A_s = .44$ ✓

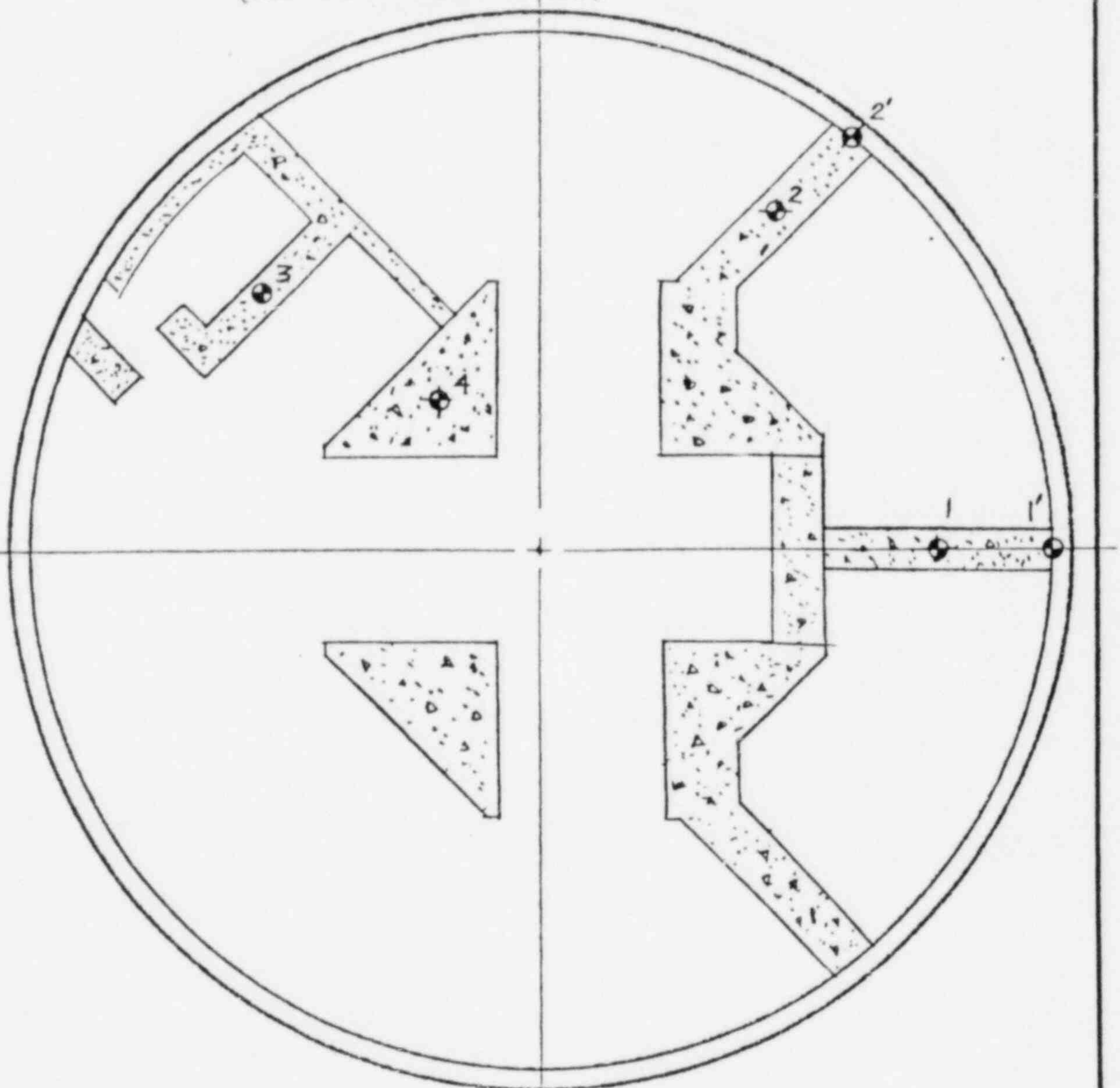
Width = 2.04' ✓

Allowable tension: $\frac{2 \times 40 \times .44}{2.04 \times 12 \times 12} = .12$ ksi ✓

REF.

INNER SHIELD BLDG.

LOCATIONS OF STRESS INVESTIGATION
(FOR BEAM 52 NODE 66)



$\frac{H_2}{2}$ = 26.7' ✓

$\frac{H_3}{2}$ = 23.5' ✓

PLAN @ BASEMENT

CONTAINMENT BUILDING - INNER SHIELD BUILDING - NORMAL SPRING | REF.

NODE 66 BEAM 52

Find stresses at different locations of cross-sections using linear interpolation and combine by RSS.

From Output S6200FH : Minimum axial compression by dead load + E.Q. : -.15621 ksi ✓

From Output S6200FH : Bending by earthquake < σ_{x2} = .13957 ksi ✓, σ_{x3} = .14852 ksi ✓

LOCATION	d_2	d_3	Axial Compression stress (ksi)	Bending stress (ksi) σ_{x2}	σ_{x3}	(ksi) $\sqrt{\sigma_{x2}^2+\sigma_{x3}^2}$	$\sigma_{Tension}$	Allowable Tension (ksi)
1	21.1 ✓	0 ✓	-.15621 ✓	0 ✓	.11681 ✓	.11681 ✓	No tension ✓	
1'	26.7 ✓	0 ✓	-.15621 ✓	0 ✓	.14852 ✓	.14852 ✓	" " ✓	
2	11.5 ✓	20.0 ✓	-.15621 ✓	.11878 ✓	.06397 ✓	.13491 ✓	" " ✓	
2'	18.0 ✓	23.5 ✓	-.15621 ✓	.13957 ✓	.1001 ✓	.17176 ✓	.01555 <	.118 ✓
3	18.0 ✓	15.0 ✓	-.15621 ✓	.08909 ✓	.1001 ✓	.134 ✓	No tension ✓	
4	8.0 ✓	9.0 ✓	-.15621 ✓	.05345 ✓	.0445 ✓	.06955 ✓	No tension ✓	

Location 2' : Allowable Tension.

2 #7 @ 12 EF $A_s = (2 \times .6) = 1.2 \, in^2$ ✓

Width 2'-10"

Allowable stress on steel $= \frac{40 \times 1.2}{12 \times 2.83 \times 12} = .118$ ksi ✓

CONTAINMENT BUILDING – INNER SHIELD BUILDING – STIFFENED SPRING. | REF.

NODE 66 BEAM 52

From output S6200YZ:

bending stress: σ_{x_2} = .160289 ksi ✓ σ_{x_3} = .168834 ksi ✓

SRSS: $\sqrt{.160289^2 + .168834^2}$ = .2328 ksi ✓

Axial stress . σ_A = –.156274 ksi ✓ σ_A = –.19698 ksi ✓

Max Compression stress: –.19698 – .2328 = –.42978 ksi ✓

Max Tension : –.156274 + .2328 = .07653 ksi ✓

Find stresses at different locations of cross sections using linear interpolation and combine by RSS

LOCATION	d_2	d_3	Axial Compression Stress (ksi)	Bending stress σ_{x_2}	σ_{x_3}	$\sqrt{\sigma_{x_2}^2 + \sigma_{x_3}^2}$	σ Tension (ksi)	Allowable Tension (ksi)
1	21. ✓	0 ✓	–.15627 ✓	0 ✓	.13279 ✓	.13279 ✓	No ✓	
1'	26.7 ✓	0 ✓	"	0 ✓	.16883 ✓	.16883 ✓	.01256 ✓	<.138 ✓
2	11.5 ✓	20. ✓	"	.13641 ✓	.07272 ✓	.15458 ✓	No ✓	
2'	16. ✓	23.5 ✓	"	.16029 ✓	.11379 ✓	.19657 ✓	.0403 ✓	<.118 ✓
3	18. ✓	15. ✓	"	.10232 ✓	.11379 ✓	.15303 ✓	No ✓	
4	8. ✓	9. ✓	"	.06138 ✓	.05059 ✓	.07954 ✓	No ✓	

LOCATION 1': Allowable Tension

\# 7 @ 12" EF As = 2 x .6 = 1.2 in² ✓

Width 2'5" ✓

Allowable stress : $\frac{40 \times 1.2}{12 \times 2.417 \times 12}$ = .138 ksi. ✓

CONTAINMENT BUILDING - REACTOR VESSEL ANALYSIS - NORMAL SPRING | REF.

NODE 55 → NODE 65 (REACTOR VESSEL) : Material ASTM A302 Gr B

$S_y = 45$ ksi

SM = 25 ksi @ 100°F,

From output S6200FH

Maximum moment at node 65 (beam 62)

$\sigma_{b_1} = .725226$ ksi ✓ $\sigma_{b_2} = .749476$ ksi ✓

$SRSS = \sqrt{.725226^2 + .749476^2} = 1.0429$ ksi. ✓

Axial stress at node 65

$\sigma_a = -1.63571$ ksi (compression) ✓

Resulting

$\sigma_a + SRSS = -1.6357 + 1.0429 = -.5928$ ksi. (compr.) ✓

$\sigma_a - SRSS = -1.6357 - 1.0429 = -2.6786$ ksi. (compression) ✓

Allowable bending stress: $1.6 \times .6 \times 45 = 43.2$ ksi

SHEAR STRESS

Max at node 65 ✓

$\tau_1 = .209989$ ksi ✓ $\tau_2 = .204543$ ksi ✓

Resulting : $\tau = \sqrt{\tau_1^2 + \tau_2^2} = \sqrt{.209989^2 + .204543^2} = .293$ ksi. ✓

Allowable shear stress:

$1.6 \times .4 \times S_y = 1.6 \times .4 \times 45 = 28.8$ ksi

	REF.
CONTAINMENT BUILDING - REACTOR VESSEL ANALYSIS - STIFFENED SPRING.	

NODE 55 → NODE 65

From Output S6200 YZ.

Maximum moment is at node 65 (beam 62)

$\sigma_{b_1} = .83595$ ksi ✓ $\sigma_{b_2} = .866896$ ksi. ✓

$SRSS = \sqrt{.83595^2 + .866896^2} = 1.204$ ksi ✓

Axial stress at node 65: $\sigma_A = -1.24954$ (Comp) ksi $\sigma_A = -1.6277$ ksi (Comp) ✓

Max Compression stress: $-1.6277 - 1.204 = -2.8317$ ksi ✓

No tension ✓

SHEAR STRESS

Max at node 65

$\tau_1 = .243304$ ✓ $\tau_2 = .233921$ ✓

Resulting $\tau = \sqrt{.243304^2 + .233921^2} = .338$ ksi ✓

Pressure Stress Pressure = 1265 psia

σ_1 = meridional or longitudinal = $\frac{pr}{2t}$

$= \frac{(1265)(51.48'')}{(2)(4)}$

$= 8140$ psi $= 8.14$ ksi

σ_2 = circumferential stress or hoop $= \frac{pr}{t} = \frac{(1265)(51.48)}{4}$

$= 16,281$ psi 16.281 ksi

REACTOR VESSEL | REF.

REACTOR VESSEL

* Principal stress due to Pressure: $R_i = 4.125'$, $R_o = 4.458$, $p = 1.256$ ksi.

$$\sigma_1 = \sigma_t = 1.256 \times \frac{4.458^2 + 4.125^2}{4.458^2 - 4.125^2} = 16.21 \text{ ksi}$$

$$\sigma_2 = \sigma_\ell = 1.256 \times \frac{4.458^2}{4.458^2 - 4.125^2} = 8.733 \text{ ksi}$$

$$\sigma_3 = -p = -1.256 \text{ ksi.}$$

$$\sigma_1 - \sigma_2 = 16.21 - 8.733 = 7.477 \text{ ksi}$$
$$\sigma_2 - \sigma_3 = 8.733 - (-1.256) = 9.989 \text{ ksi}$$
$$\sigma_3 - \sigma_1 = -1.256 - 16.21 = -17.466 \text{ ksi}$$

⇒ Stress intensity = 17.466 ksi.

* Principal stress due to Dead load:

stress due to d.l: -1.628 ksi (S6200YZ)

⇒ stress intensity = 1.628 ksi (Since only 1 stress term)

* Principal stress due to Seismic (Bending)

$\sigma_y = \pm 1.204$ ksi, $\tau = .338$ ksi (S6200YZ).

$$\sigma_1, \sigma_2 = \frac{1.204}{2} \pm \sqrt{\left(\frac{1.204}{2}\right)^2 + .338^2}$$

$\sigma_1 = 1.292$ ksi, $\sigma_2 = -.088$ ksi

Stress intensity: $\sigma_1 - \sigma_2 = 1.292 + .088 = 1.380$ ksi.

REACTOR VESSEL

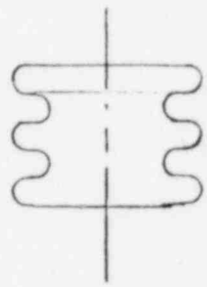
LOAD COMBINATION	P_m (ksi)	Limit (ksi)	P_b (ksi)	$P_m + P_b$ (ksi)	Limit (ksi)	REF.
D + L + Pa	17.466 + 1.628 = 19.094	(1.0) × 25 = 25	0	19.094	(1.5)(25) 37.5	O/C
D + L + Pa + E'	19.094	25	1.38	20.474	37.5	O/C

K = 1.0 FOR BOTH COMBINATIONS
VESSEL MATERIAL A302 GRADE B
S_m = 25.0 ksi @ 650°

CONTAINMENT BUILDING – BELLOW SEAL ANALYSIS – NORMAL SPRING | REF.

Bellow description

#14 Guage SS #304 Bellows, 8 Corrugations



From Computer Output S6200FH
At node 56, BEAM 63

$F_{x_1} = 31.913^K$ ✓

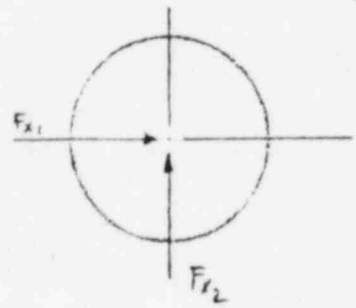
$F_{x_2} = 31.173\ K$ ✓

$SRSS = \sqrt{31.913^2 + 31.173^2} = 44.61\ K$ ✓

SHEAR SHAPE FACTOR

$\bar{A} = .53A = .53 \times 30.86 = 16.36\ in^2$ ✓

(Page B1-112 STARDYNE MANUAL)



$f_v = \dfrac{44.61}{16.36} = 2.73\ ksi$ ✓

nes

NUCLEAR ENERGY SERVICES

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LACROSSE SEP - SITE SPECIFIC SPECTRA

CONTAINMENT BUILDING - BELLOW SEAL ANALYSIS - STIFFENED SPRING.	REF.

From Computer out put S6200 YZ

At node 56 : BEAM63

$F_{x_1} = 38.507$ k ✓ $F_{x_2} = 36.204$ k ✓

$S_{RSS} = \sqrt{38.507^2 + 36.204^2} = 52.85$ K. ✓

$f_v = \frac{52.85}{16.36} = 3.23$ ksi ✓

REACTOR BASE CONNECTION

REF.

Material:

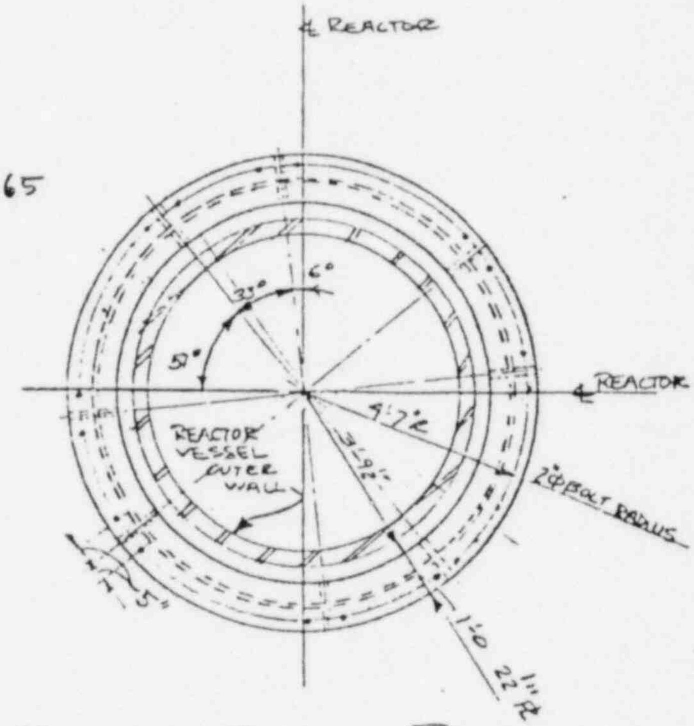
304 SS

From COMPUTER OUPUT S6200FH, at node 65

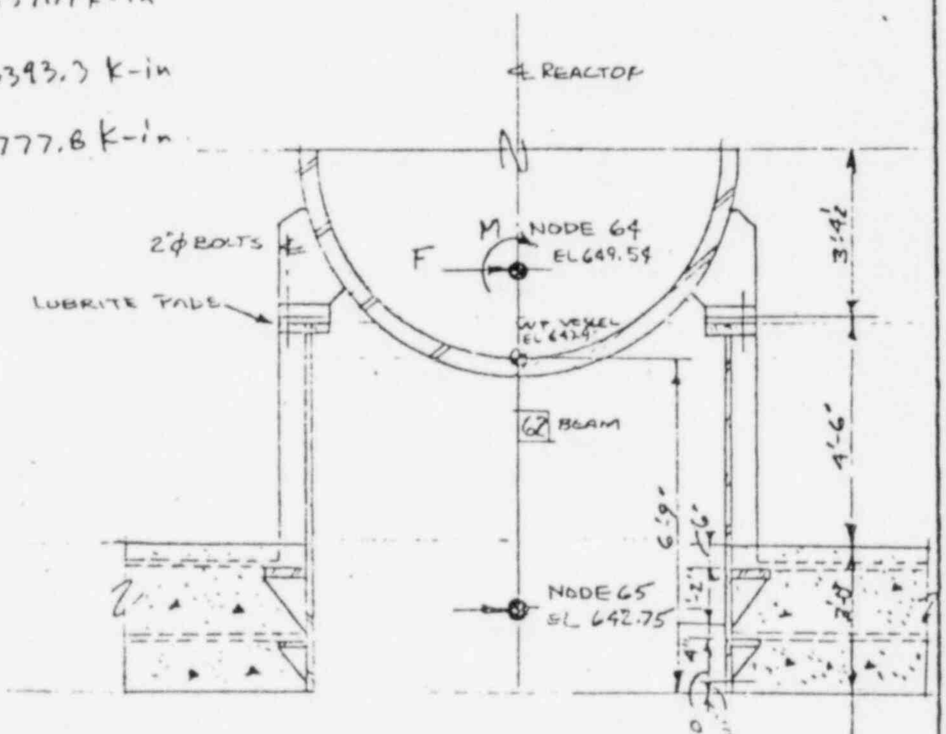
Fx_1 =	38.68 K	38.61 K
Fx_2 =	37.68 K	37.68 K
Fx_3 =	602.68 K	457.42 K
Mx_1 =	6158.2 K-in	6158.2 K-in
Mx_2 =	6362.1 K-in	6331.09 K-in
Mx_3 =	777.8 K-in	777.8 K-in

And at node 64.

Fx_1 =	38.61 K	38.68 K
Fx_2 =	37.68 K	37.68 K
Fx_3 =	457.42	602.68 K
Mx_1 =	3371.4 K-in	3371.7 K-in
Mx_2 =	3393.3 K-in	3393.3 K-in
Mx_3 =	777.8 K-in	777.8 K-in



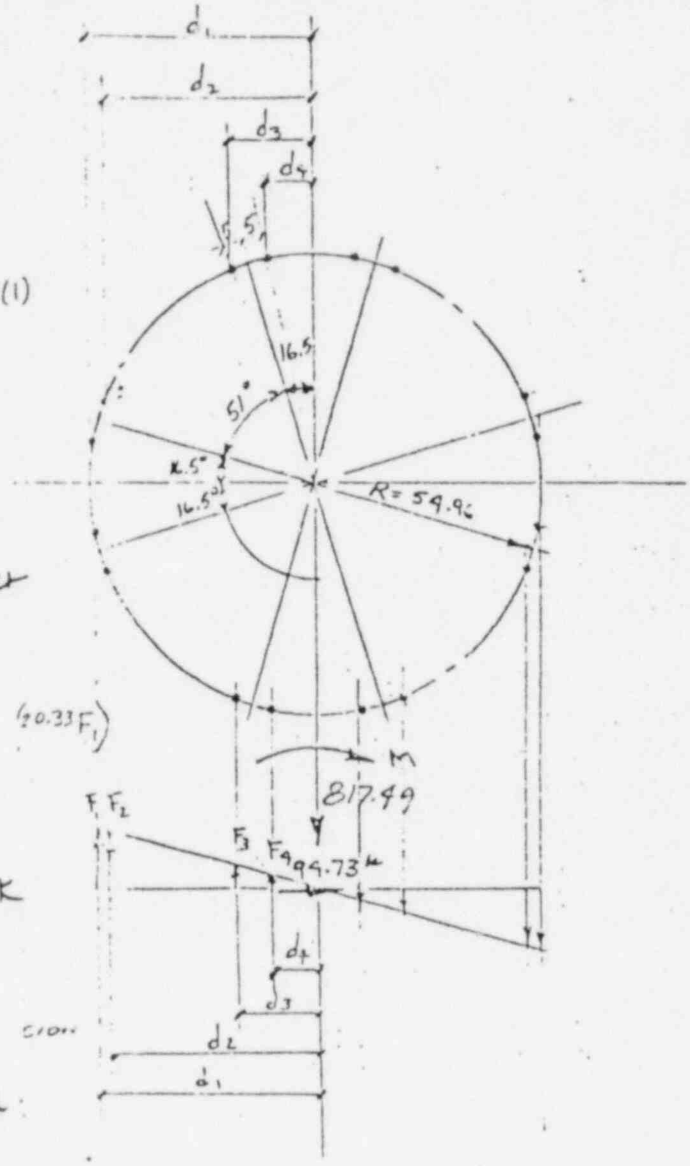
REACTOR SUPPORT PLAN



TYPICAL SECTION

REVISION BASE CONNECTION | REF.

$d_4 = 10.54$
$d_3 = 20.33$
$d_2 = 48.65$
$d_1 = 52.48$



$4F_1d_1 + 4F_2d_2 + 4F_3d_3 + 4F_4d_4 = M$ (1)

$F_2 = \frac{48.65}{52.48} F_1$

$F_3 = \frac{20.33}{52.48} F_1$

$F_4 = \frac{10.54}{52.48} F_1$

Substituting into (1) solving for F_1 we get

$430.29 F_1 = M$

* For $M_{x_1} = 3371.7$ K-in at node 64
$F_1 = 7.84K$, $F_2 = 7.26K$, $F_3 = 3.04K$
$F_4 = 1.57K$.

* For $M_{x_2} = 3393.3$ k-in
$F_1 = 7.89K$, $F_2 = 7.31K$, $F_3 = 3.05K$
$F_4 = 1.58K$.

Max tension by SRSS: $\sqrt{7.89^2 + 1.57^2}$
$= 8.04$ K.

Minimum Compression due to earthquake + dead load:

$-\frac{457.42}{16} = -28.57$ K

NO TENSION IN BOLTS

CHECK SHEAR

SRSS Shear force: $\sqrt{38.68^2 + 37.68^2} = 54$ K.

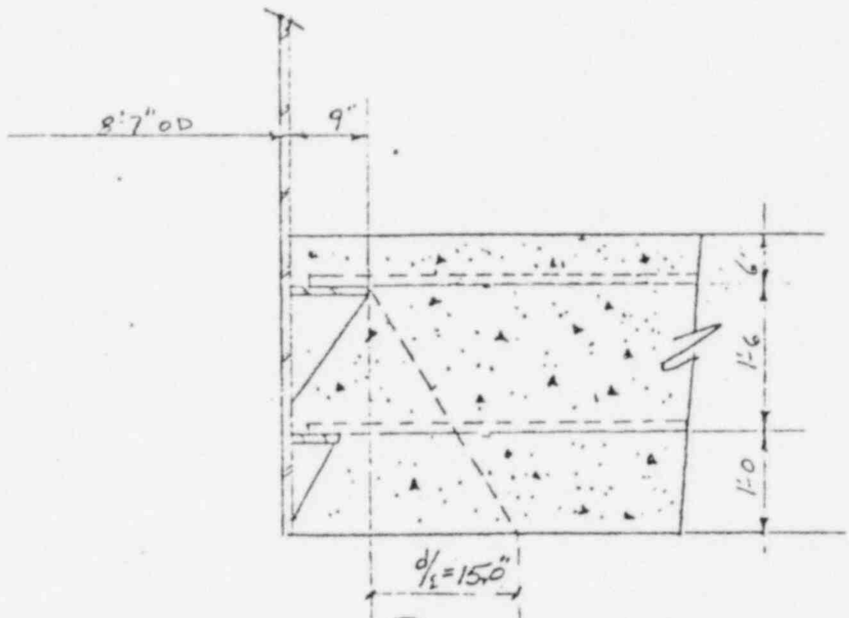
Shear/bolt $= \frac{54}{16} = 3.375$ K/bolt (Neglecting any friction).

Bolt area $= \frac{\pi d^2}{4} = \frac{\pi 2^2}{4} = 3.142$ in²

Shear stress on bolt: $\frac{3.375}{3.142} = 1.074$ ksi < 19.2 ksi OK

Allowable shear: $1.6 \times .4 \times (36) = 19.2$ ksi

REACTOR BASE CONNECTION | REF.



DETAIL (1)

$v_u = \frac{V_u}{\phi b_o d}$ with $d = 30"$

$D = 8'7" + 9" + 15" = 127"$

$b_o = \pi D = \pi \times 127 = 398.98"$

$\phi = .85$

At node 65, F_{x_3} of (DL+SRSS Ea) = 602.68 K = V_u.

$\Rightarrow v_u = \frac{602.68}{.85 \times 398.98 \times 30} = .0592$ Ksi.

Allowable ultimate punching stress = $4\sqrt{f'_c} = 4\sqrt{3500} = 236.6$ psi

$v_u = 59.2$ psi < 236.6 psi OK

NUCLEAR ENERGY SERVICES

BY ____ DATE ____ PROJ. ____ TASK ____

CHKD. JC DATE 3/18/82 PAGE ____ OF ____

CONTAINMENT BUILDING — REACTOR BASE CONNECTION — STIFFENED SEATING | REF.

From computer output ..., at node 65

F_{x_1} = 44.32 K ✓ | F_{x_1} = 44.75 K ✓

F_{x_2} = 43.09 K ✓ | F_{x_2} = 43.09 K ✓

F_{x_3} = 579.71 K ✓ | F_{x_3} = 460.39 K ✓

M_{x_1} = 7096.4 K-in ✓ | M_{x_1} = 7096.4 K-in ✓

M_{x_2} = 7358.69 K-in ✓ | M_{x_2} = 7327.89 K-in ✓

M_{x_3} = 903.43 K-in ✓ | M_{x_3} = 903.43 K-in ✓

At node 64

F_{x_1} = 44.75 K ✓ | F_{x_1} = 44.32 K ✓

F_{x_2} = 43.09 K ✓ | F_{x_2} = 43.09 K ✓

F_{x_3} = 460.39 K ✓ | F_{x_3} = 579.71 K ✓

M_{x_1} = 3853.3 K-in ✓ | M_{x_1} = 3853.3 K-in ✓

M_{x_2} = 3863.11 K-in ✓ | M_{x_2} = 3903.12 K-in ✓

M_{x_3} = 903.43 K-in ✓ | M_{x_3} = 903.43 K-in ✓

CONTAINMENT BUILDING — REACTOR BASE CONNECTION - STIFFENED SEATING | REF.

Using same reactor base of vertical spring case

$4F_1d_1 + 4F_2d_2 + 4F_3d_3 + 4F_4d_4 = M$

$F_2 = \frac{45.55}{52.48} F_1$

$F_3 = \frac{19.??}{52.48} F_1$

$F_4 = \frac{10.54}{52.48} F_1$

$\Rightarrow 430.29 F_1 = M$

For $M_{x_1} = 3853.3$ K-in (node 64)

$F_1 = 8.96\text{ K}$, $F_2 = 8.31\text{ K}$, $F_3 = 3.47\text{ K}$, $F_4 = 1.80\text{ K}$

for $M_{y_2} = 3908.12$ K-in (node 64)

$F_1 = 9.08\text{K}$, $F_2 = 8.42\text{ K}$, $F_3 = 3.52\text{K}$, $F_4 = 1.82\text{ K}$

Max tension by SRSS $= \sqrt{8.96^2 + 1.82^2} = 9.14$ K.

Minimum compression due to earthquake + dead load

$\frac{-466.39}{16} = -29.77$ k

No TENSION

CHECK SHEAR

SRSS shear force. $\sqrt{44.32^2 + 43.69^2} = 62.17$ ksi.

Shear bolt. $62.17/16 = 3.88$ K/bolt.

bolt area $= \frac{\pi d^2}{4} = \frac{\pi 2^2}{4} = 3.142$ in²

Shear stress on bolt : $\frac{3.88}{3.142} = 1.23$ ksi < 13.2 ksi OK

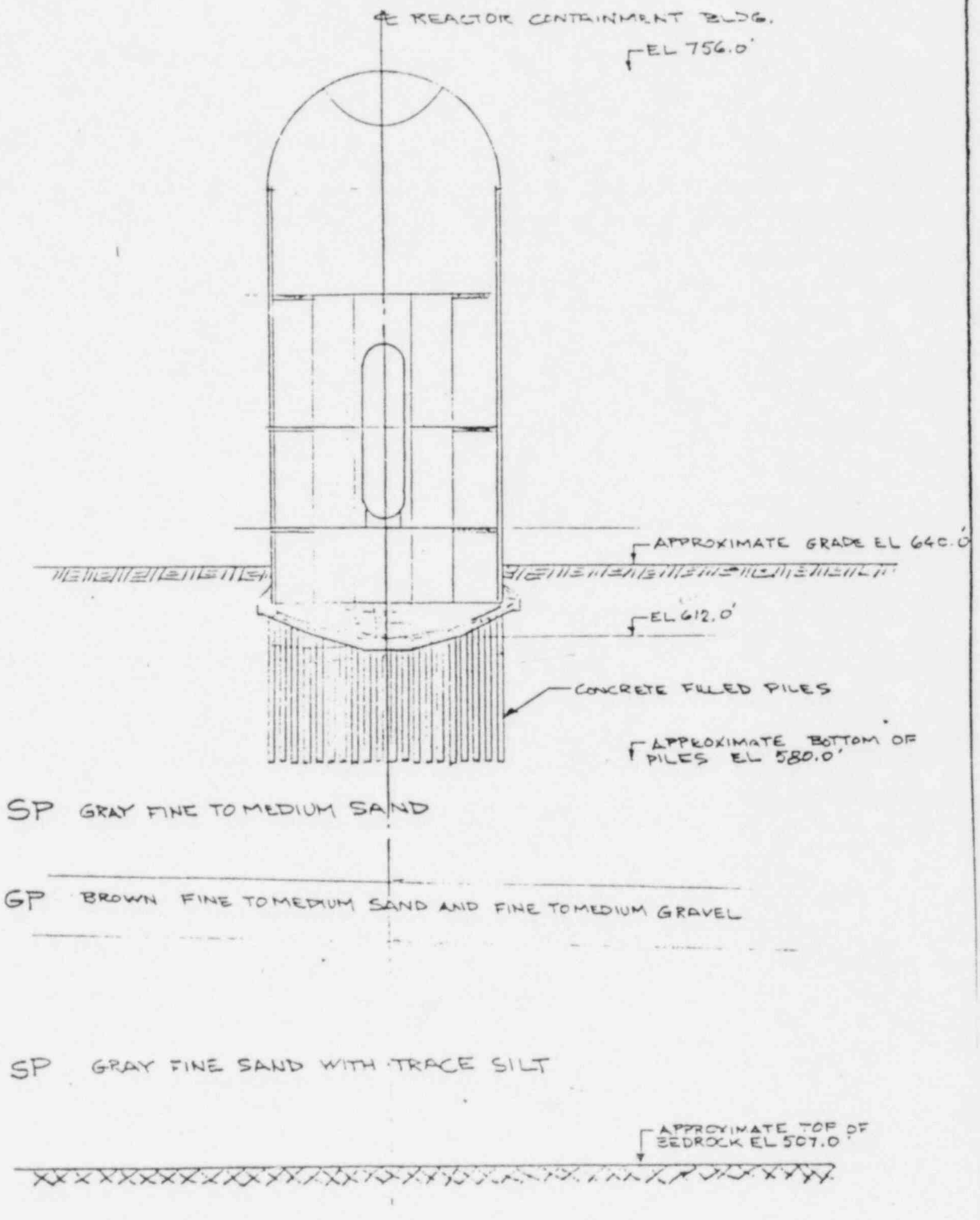
CONTAINMENT BUILDING - REACTOR BASE CONNECTION - STIFFENED SPRING

REF.

$$v_u = \frac{V_u}{\phi b_o d}$$

At node 85, F_{xy} = 579.71 K = V_u

$$v_u = \frac{579.71}{.85 \times 395.15 \times 30} = .0582 \text{ ksi} < .23 \text{ Ksi}$$


℄ REACTOR CONTAINMENT BLDG.
EL 756.0'
APPROXIMATE GRADE EL 640.0'
EL 612.0'
CONCRETE FILLED PILES
APPROXIMATE BOTTOM OF PILES EL 580.0'
SP GRAY FINE TO MEDIUM SAND
GP BROWN FINE TO MEDIUM SAND AND FINE TO MEDIUM GRAVEL
SP GRAY FINE SAND WITH TRACE SILT
APPROXIMATE TOP OF BEDROCK EL 507.0'

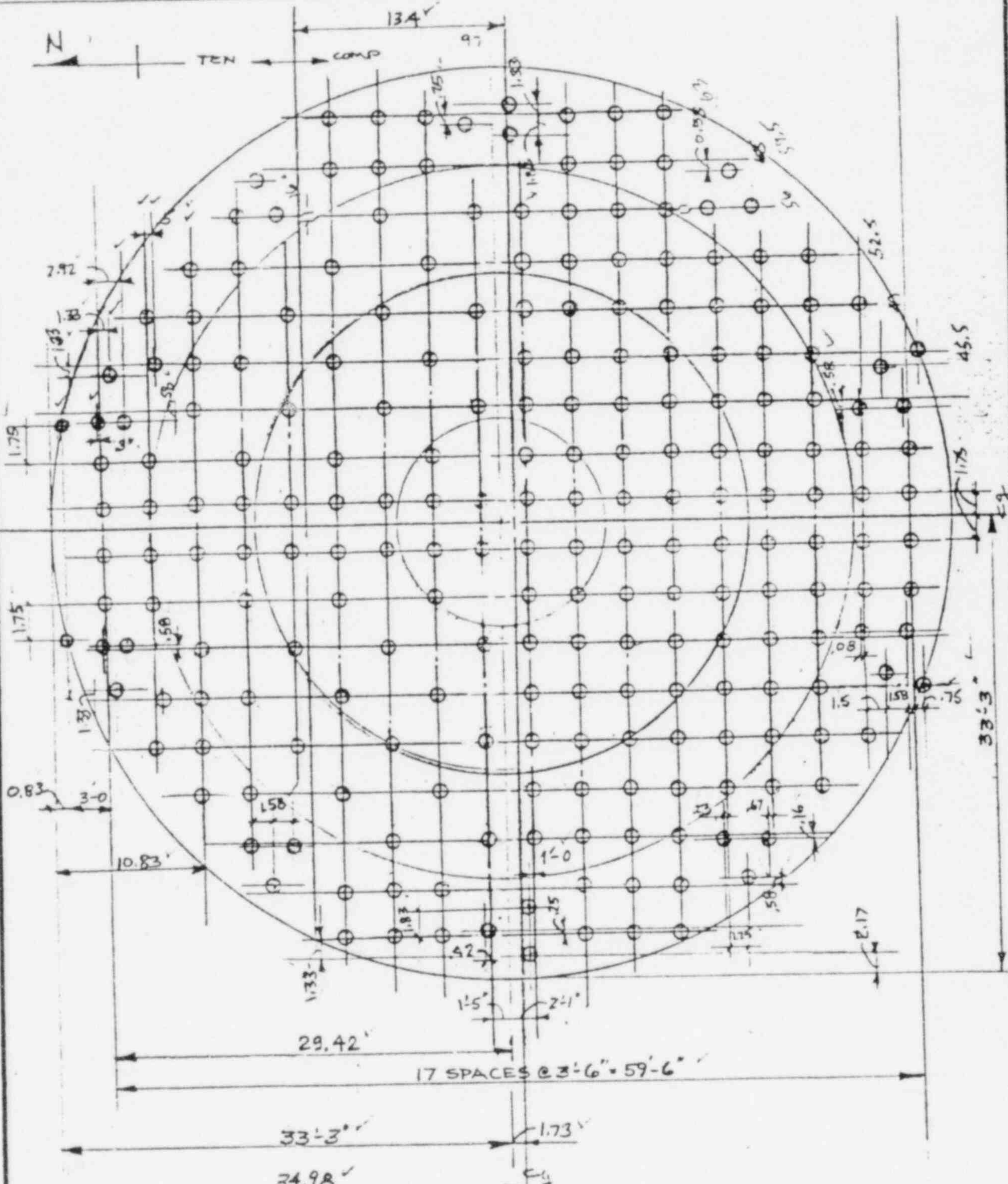
NUCLEAR ENERGY SERVICES INC.
NES DIVISION

BY R.R DATE 6-6-79 PROJ. 5101 TASK 026
CHKD. NC DATE 11/07/02 PAGE 1 OF

LACBWR SEP

PILE ANALYSIS

REF.



PILE PLAN

REF. DWG. 41-503433 REV D
& REPORT SL-2003 - SARGENT & LUNDY
FEB 25, 1963

PROPERTIES ABOUT X_1 AXIS FOR X_2 EARTHQUAKE | REF.

$\frac{\Sigma Nd}{\Sigma N}$ =

Nd	=	d^2	Nd^2
1 (2.17)	2.17	965.97	965.97
6 (3.50)	21.00	885.06	5310.38
1 (3.75)	3.75	870.25	870.25
1 (5.33)	5.33	779.53	779.53
6 (7.00)	42.00	689.06	4134.38
2 (7.58)	15.16	658.95	1317.90
6 (10.50)	63.00	517.56	3105.38
4 (10.34)	41.36	524.87	2099.47
11 (14.00)	154.00	370.56	4076.19
13 (17.50)	227.50	248.06	3224.81
13 (21.00)	273.00	150.06	1950.81
2 (22.33)	44.66	119.25	238.49
11 (24.50)	269.50	76.56	842.19
4 (25.08)	100.32	66.75	267.00
14 (28.00)	392.00	27.56	385.88
18 (31.50)	567.00	3.06	55.13
18 (35.00)	630.00	3.06	55.13
14 (38.50)	539.00	27.56	385.83
11 (42.00)	462.00	76.56	842.19
4 (41.42)	165.68	66.75	267.00
1 (40.25)	40.25	49.00	49.00
13 (45.50)	591.50	150.06	1950.81
2 (44.17)	88.34	119.25	238.49
13 (49.00)	637.00	248.06	3224.81
11 (52.50)	577.5	370.56	4076.19
6 (56.00)	336.0	517.56	3105.38
4 (56.16)	224.64	524.87	2099.47
6 (59.50)	357.00	689.06	4134.38
2 (58.92)	117.84	658.95	1317.90
6 (63.00)	378.00	885.06	5310.38
1 (62.75)	62.75	870.25	870.25
1 (61.17)	61.17	779.53	779.53
1 (64.33)	64.33	965.97	965.97
1 (26.25)	26.25	49.00	49.00
228	7581.0		59395.52 FT^2

$$C_g = \frac{\Sigma Nd}{\Sigma N} = \frac{7581.0}{228} = 33.25'$$

PROPERTIES OF PILEGROUP ABOUT X_z AXIS | REF.

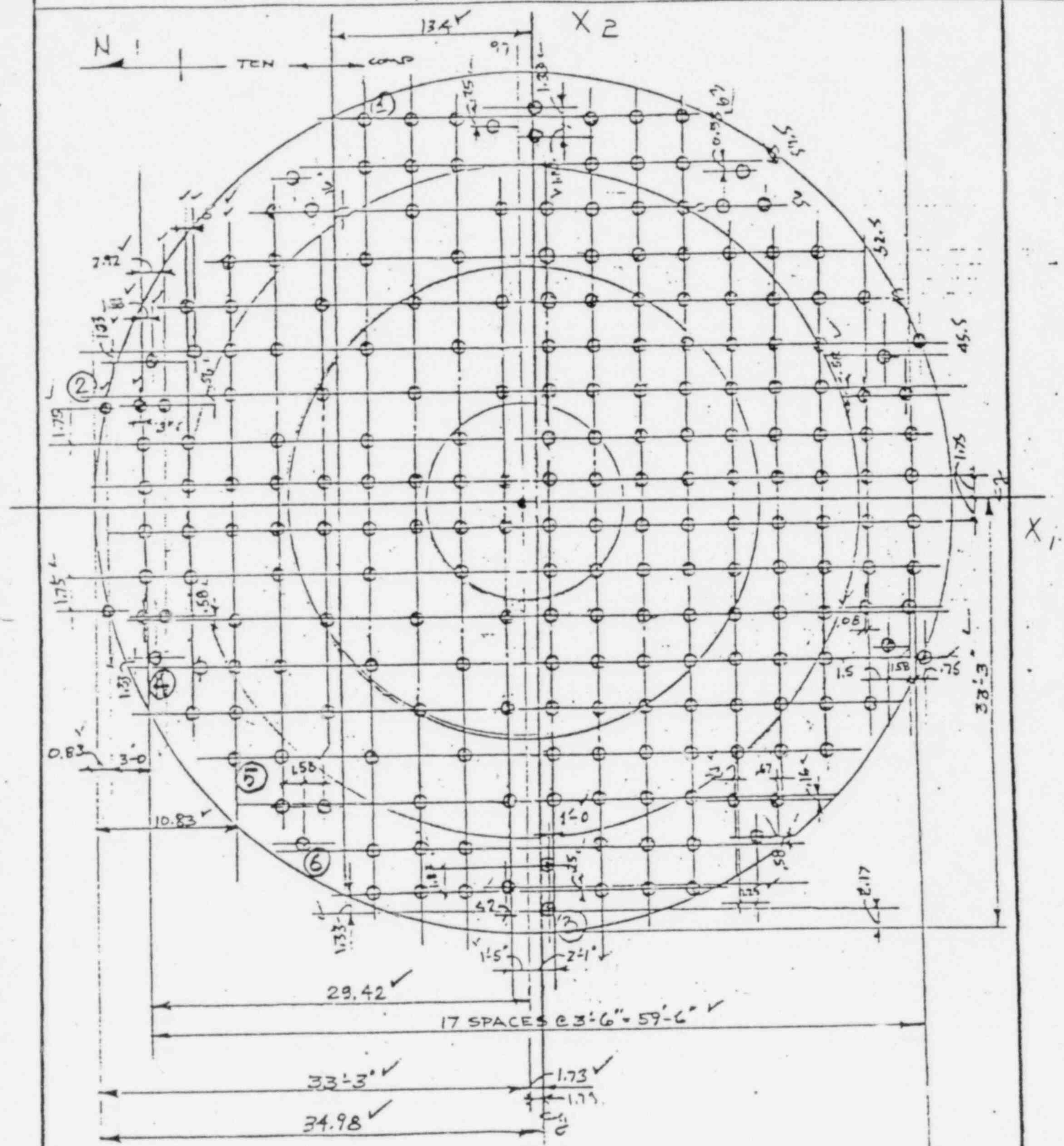
FOR X. EARTHQUAKE

No	d_1	$N_o d_1$	d^2	$N d^2$
2	0.83	1.66	1166.22	2332.45
2	3.58	7.16	985.96	1971.92
4	3.83	15.32	970.32	3881.29
2	5.16	10.32	889.23	1778.46
2	6.75	13.50	796.93	1593.87
6	7.33	43.98	764.52	4587.14
2	7.83	15.66	737.12	1474.25
10	10.83	108.30	583.22	5832.23
10	14.33	143.30	426.42	4264.23
2	15.91	31.82	363.66	727.33
2	17.49	34.98	[illegible]5.90	611.80
6	17.83	106.98	[illegible]94.12	1764.74
12	21.33	255.96	186.32	2235.87
12	24.83	297.96	103.02	1236.27
12	28.33	339.96	44.22	530.67
8	31.83	254.64	9.92	79.38
2	31.41	62.82	12.74	25.49
4	34.16	136.64	0.67	2.69
14	35.33	494.62	0.12	1.72
18	38.83	698.94	14.82	266.81
18	42.33	761.94	54.02	972.41
18	45.83	824.94	117.72	2119.00
12	49.33	591.96	205.92	2471.07
2	49.00	98.00	196.56	393.12
2	50.58	101.16	243.36	486.72
2	52.16	104.32	295.15	590.30
12	52.83	633.96	316.62	3823.47
12	56.33	675.96	455.82	5469.87
6	59.83	358.98	617.52	3705.14
2	59.75	119.50	613.55	1227.11
2	61.33	122.66	694.32	1388.65
2	62.91	125.82	780.08	1560.17
4	63.33	253.32	803.72	3214.89
2	64.08	128.16	846.81	1693.62
228 PILES		7975.20		64314.15 FT²

$$C_g = \frac{\Sigma N d_1}{\Sigma N} = \frac{7975.20}{228} = 34.98 \text{ FT}$$

PILE ANALYSIS - NORMAL SPRING

REF.



PILE PLAN

* C Piles under compression only.

REF. DWG. 41-503433 REV D
& REPORT SL-2003 - SARGENT & LUNDY
FEB 25, 1963

CONTAINMENT BUILDING – FOUNDATION ANALYSIS. – NORMAL SPRING | REF.

CHECK SHEAR STRESS IN CONCRETE

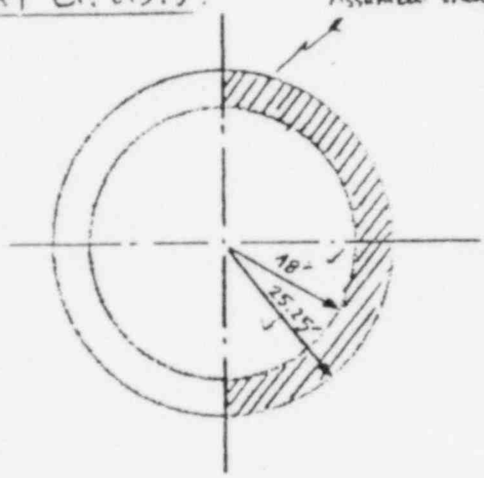
FROM OUTPUT S6200FH, at node 54

$F_{x_1} = 1655.7\ K$ ✓ $F_{x_2} = 1651\ K$. ✓

$SRSS = \sqrt{1655.7^2 + 1651^2} = 2338.2\ K$. ✓

* AT El. 615.5'

Assumed Shear Area

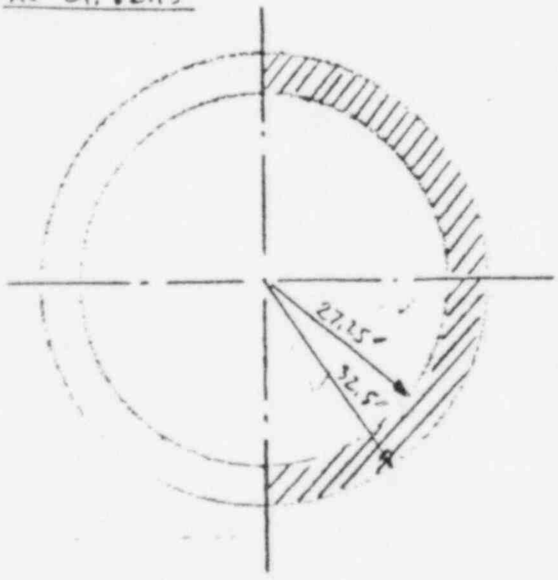


Assume shear Area $= \frac{\pi}{4 \times 2}(50.5^2 - 36^2) = 492.5\ ft^2$ ✓

$f_v = \frac{2338.2}{492.5 \times 144} = .03297\ ksi = 33\ psi$ ✓

Allowable shear $= .85(2\sqrt{f'_c}) = .85 \times 2 \times \sqrt{3500}$
$= 100.6\ psi > 33\ psi$ ✓

* At El. 621.5'



Assume shear area $= \frac{\pi}{4 \times 2}(65^2 - 55.5^2)$
$= 449.5\ ft^2$ ✓

$f_v = \frac{2338.2}{449.5 \times 144} = .03612\ ksi = 36\ psi$ < allowable ✓

	REF.

TENSILE STRENGTH OF CONCRETE

AVERAGE SPLITTING TENSILE STRENGTH OF CONCRETE

$f_{CT} = (6.85)(7.5)\sqrt{f'_c}$ ✓ $f'_c = 3500$ PSI

$f_{CT} = 377.2$ PSI

CONTAINMENT BUILDING – PILE ANALYSIS – NORMAL SPRING.	REF.

LOADS AT NODE 54

From Output S6200 RW:

Vertical load due to dead load : $F_{V_D} = -1.70762 \times 10^4$ K (Compression)

From Output S6200 FH:

Vertical load due to SRSS earthquake : $F_{VE} = 1.572832 \times 10^3$ K.

From Output S6200 FH:

Moment in X_1 direction : $M_{x_1} = 1.5012 \times 10^6$ K-in

Moment in X_2 direction : $M_{x_2} = 2.381256 \times 10^6$ K-in

Pile load due to Dead load : $P_{V_D} = -\frac{1.70762 \times 10^4}{228} = -74.9$ K. (Compression)

Pile load due to earthquake vertical load : $P_{VE} = \frac{1.572832 \times 10^3}{228} = 6.9$ K.

Max pile load due to moment M_{x_1} : $P_{m_1} = \frac{1.5012 \times 10^6 \times 31.08}{(5.93455 \times 10^4) 12} = 65.52$ K.

Max pile load due to moment M_{x_2} : $P_{m_2} = \frac{2.381256 \times 10^6 \times 34.15}{(6.43153 \times 10^4) \times 12} = 105.37$ K.

Pile load investigation at different locations using linear interpolation.

Location	d_1 (ft)	d_2 (ft)	P_{V_D} (K)	P_{VE} (K)	P_{m_1} (K)	P_{m_2} (K)	$\sqrt{P_{VE}^2+P_{m_1}^2+P_{m_2}^2}$ (K)	Results: Comp. (K)	Results: Tension (K)
1	13.65	29.75	-74.9	6.9	62.72	42.12	75.86	-150.76	.96
2	34.15	7	-74.9	6.9	14.76	105.37	106.62	-181.52	31.72
3	.82	31.08	-74.9	6.9	65.52	2.53	65.93	-140.83	No tension
4	30.17	10.92	-74.9	6.9	23.02	93.09	96.14	-171.04	21.24
5	24.15	19.25	-74.9	6.9	40.58	74.51	85.12	-160.02	10.22
6	19.07	25.67	-74.9	6.9	54.12	58.84	80.24	-155.14	5.34

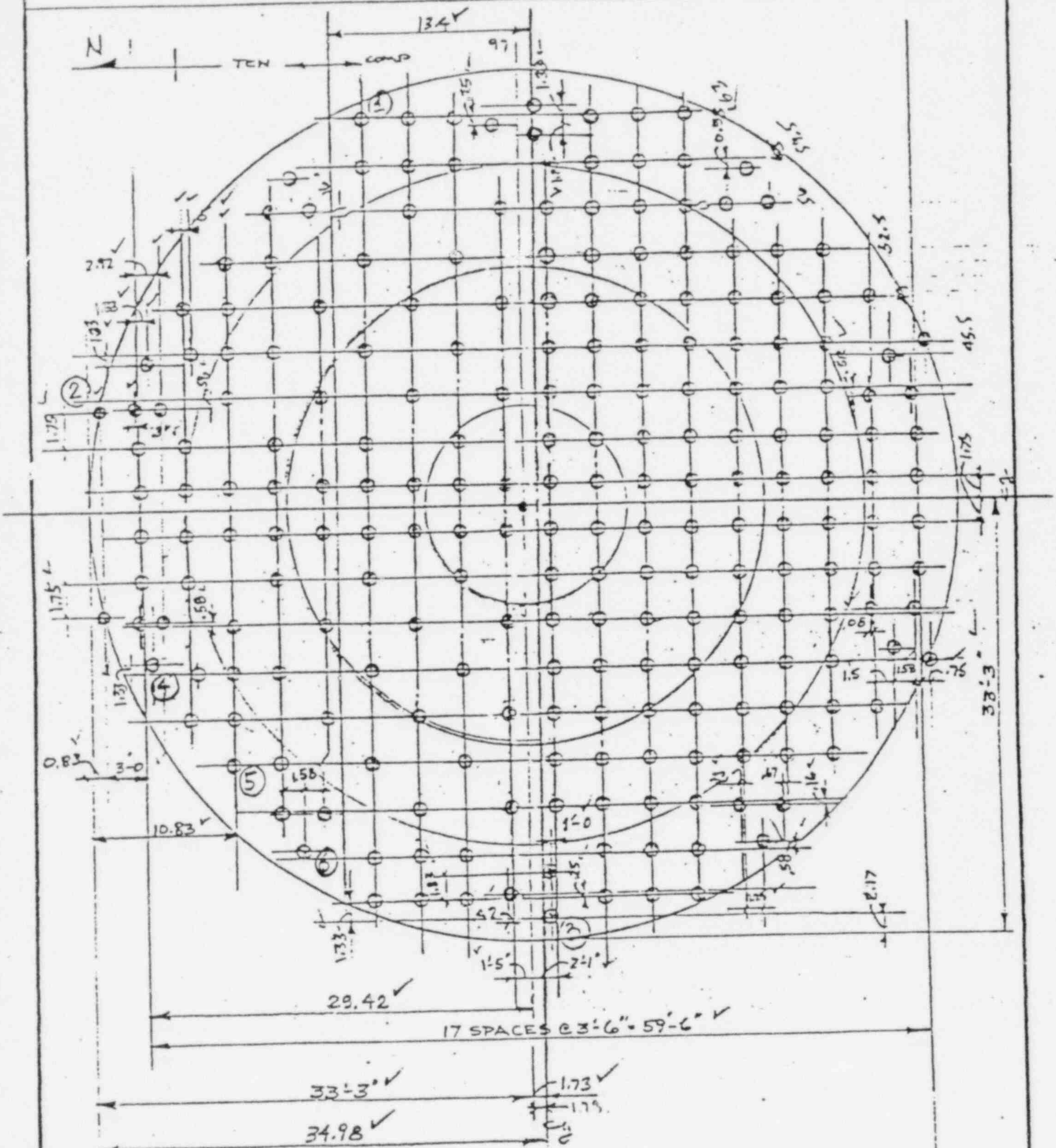
Compression : -181.52 K.

Tension : 31.72 K

~~At~~ location 2.

PILE ANALYSIS - STIFFENED SPRING

REF.



PILE PLAN

* ⊖ Piles under compression only.

REF. DWG. 41-503433 REV D
& REPORT SL-2003 - SARGENT & LUNDY
FEB 25, 1963

CONTAINMENT BUILDING – PILE ANALYSIS – STIFFENED SPRING. | REF.

LOADS AT NODE 54

From Output S6200RW:

Vertical load due to dead load : $F_{V_0} = 1.70762 \times 10^4$ K. ✓

From Output S6200YZ:

Vertical load due to SRSS earthquake : $F_{V_E} = 1.511173 \times 10^3$ K. ✓

Moment in x_1 direction : $M_{x_1} = 1.7322 \times 10^6$ kip-in ✓

Moment in x_2 direction : $M_{x_2} = 2.6037965 \times 10^6$ kip-in ✓

Pile load due to dead load : $P_{V_0} = \frac{1.70762 \times 10^4}{228} \approx 74.9$ K. ✓

Pile load due to EQ vertical load : $P_{V_E} = \frac{1.511173 \times 10^3}{228} = 6.63$ K ✓

Max Pile load due to moment M_{x_1} : $P_{m_1} = \frac{1.7322 \times 10^6 \times 31.08}{(5.93455 \times 10^4)12} = 75.6$ K ✓

Max Pile load due to moment M_{x_2} : $P_{m_2} = \frac{2.6037965 \times 10^6 \times 34.15}{(6.43153 \times 10^4)12} = 115.21$ K ✓

Pile loads investigation at different locations using linear interpolation

Location	d_1 (ft)	d_2 (ft)	P_{V_0} (K)	P_{V_E} (K)	P_{m_1} (K)	P_{m_2} (K)	$\sqrt{P_{V_E}^2 + P_{m_1}^2 + P_{m_2}^2}$ (K)	Results Comp. (K)	Tens. (K)
1	13.65 ✓	29.75 ✓	-74.9 ✓	6.63 ✓	72.36 ✓	46.05 ✓	86.03 ✓	-160.93 ✓	11.1
2	34.15 ✓	7 ✓	-74.9 ✓	6.63 ✓	17.03 ✓	115.21 ✓	116.65 ✓	-191.55 ✓	41.7
3	.82 ✓	31.08 ✓	-74.9 ✓	6.63 ✓	75.6 ✓	2.77 ✓	75.94 ✓	-150.84 ✓	1.0
4	30.17 ✓	10.92 ✓	-74.9 ✓	6.63 ✓	26.56 ✓	101.78 ✓	105.4 ✓	-180.3 ✓	30.5
5	24.15 ✓	19.25 ✓	-74.9 ✓	6.63 ✓	46.82 ✓	81.47 ✓	94.2 ✓	-169.1 ✓	19.3
6	19.07 ✓	25.67 ✓	-74.9 ✓	6.63 ✓	62.44 ✓	64.34 ✓	89.9 ✓	-164.8 ✓	15.

Max Piles load : Compression : – 191.55 K

At location 2.

Tension : 41.75 K ✓

CHECK SHEAR :

SRSS Lateral load : $\sqrt{1843.192^2 + 1899.079^2} = 2681.43$ K.

Shear load on pile : $\frac{2681.43}{225} = 11.76$ K/pile ✓

CHECK BEARING : Bearing area $(12)(6) = 72$ in^2

Bearing stress : $\frac{11.76}{72} = .163$ ksi < 2.083 ksi (allowable) OK

CONTAINMENT BUILDING - FOUNDATION ANALYSIS - STIFFENED SPRING. | REF.

SHEAR STRESS

FROM OUTPUT S620 YZ, at node 54

$F_{x1} = 1893.192^K \quad F_{x2} = 1899.009^K$ ✓

$SRSS = \sqrt{1893.192^2 + 1899.009^2} = 2681.49K$ ✓

* At El. 615.5': Shear area = 492.5 ft² ✓

$f_v = \frac{2681.49}{492.5 \times 144} = .03781$ ksi $= 37.81$ psi < 100.6 psi — 01C

* At El. 621.5': Shear area = 449.5 ft² ✓

$f_v = \frac{2681.49}{449.5 \times 144} = .04143 = 41.43$ psi < 100.6 psi — 01

FOUNDATION ANALYSIS | REF.

CHECK BOND BETWEEN BOTTOM OF VESSEL & CONCRETE

APPROXIMATE BASE SURFACE AREA

ASSUME SPHERICAL SEGMENT

RADIUS = $R = \frac{4b^2+c^2}{8b}$ = ✓

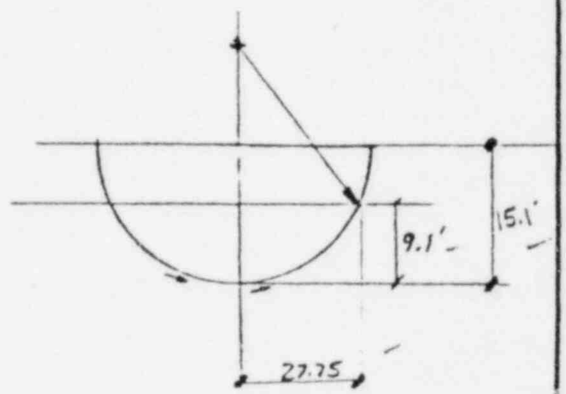
$c = 2(27.75)$ ✓

$b = 9.1'$ ✓

$R = 46.86$ FT ✓

SURFACE AREA = $\frac{1}{4}\pi R(4b+c)$

SURFACE AREA = 3382 FT^2 ✓



BOND STRESS ASSUMING FORMULA FROM 318-63

$(\frac{1}{2})6\sqrt{f'_c}$ OR 250 PSI

$\frac{1}{2}(6)\sqrt{3500}$

177.5 PSI ✓

TOTAL BOND RESISTANCE = 0.1775 (3382)(144) = 86,443.9^k

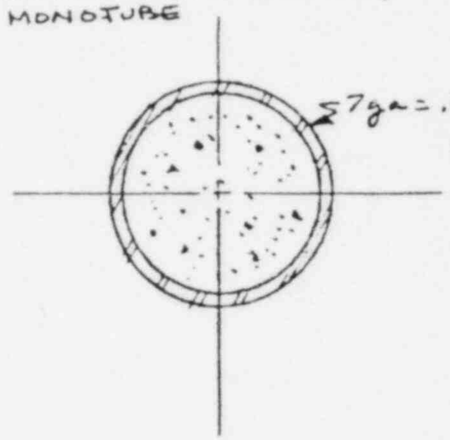
TOTAL LATERAL FORCE = 2681.49^k < 86,443.9^k

PILE ANALYSIS

REF.

PILES

UNION METAL COMPANY
MONOTUBE



ASSUME BUTT DIA = 12 INCHES ✓
CONCRETE = 3500 PSI ✓

$A_s = \pi \frac{d^2 - d_1^2}{4} = \frac{\pi}{4} \; 12^2 - 11.6414^2$

$A_s = 6.66 \text{ IN}^2$ ✓

$A_c = \frac{\pi}{4} \; 11.6414^2 = 106.4 \text{ IN}^2$ ✓

T = 8 IN ✓
TAPER .14 IN/FT ✓
BUTT = 12 IN ✓

$f_c' = .85(3500)$ ✓

MAX LOAD = $(106.4)(.85)(3.5) = 316.6^K$ IF CONCRETE ALONE IS USED
COMPRESIVE CAPACITY

CONSIDERING STEEL ALSO

$N = \frac{E_s}{E_c} = \frac{29{,}000}{3372} = 8.6$ ✓

TRANSFORMED AREA = $A_c + n A_s = 106.4 + 8.6(6.66) = 163.68 \text{ IN}^2$ ✓

MAX LOAD = $158.92(.85)(3.5) = 486.93^K$ ✓ COMPRESSIVE CAPACITY

CHECK BOND STRESS OF CONCRETE TO STEEL
(ASSUME SMOOTH STEEL BAR A-305)

H = DEPTH EMBED. = 6" ✓
D = 12" ϕ ✓

TENSILE CAPACITY OF STEEL = $6.66 \times 46 = 306.4^K$

ASSUME ULTIMATE STEEL STRESS = 46 KSI

BOND AREA $A = \pi D 6"$ (EMBEDMENT) $= 226.19 \text{ IN}^2$ ✓

*ASSUME BOND STRESS LESS THAN 160 PSI — ACI-318-63

$F_u = (226.19)\left(\frac{160^*}{1000}\right)(1.4) = 50.67^K$ BOND FORCE ✓ (1.4 = CONSERVATIVE LOAD FACTOR)

TENSION IN CONCRETE: MODULUS OF RUPTURE = $7.5\sqrt{f_c'} = 443.7$ PSI ✓ — ACI-318-77, EQ(9-9)

AREA = $\frac{\pi 12^2}{4}$ 113.10 IN^2 ✓ $F = \frac{(113.1)(443.7)}{1000} = 50.41^K$ ✓

CONTAINMENT BUILDING – PILE ANALYSIS – NORMAL SPRING CONSTANT. | REF.

PILE CAPACITY USING SPEC. W-1735 Page 4 ✓
HAMMER – Mc KIERNAN – TERRY C-5 DOUBLE ACTING — REPORT SL-2003 (12/23/63)

$E = 16{,}000$ Ft-lbs/BLOW ✓

$S = \frac{1}{6''} = .1667$ in/Blow ✓

ENGINEERING NEWS FORMULA — "FOUNDATION ENGINEERING HANDBOOK", Eqn 19.53 p 591 ©1975

ALLOWABLE PILE LOAD:

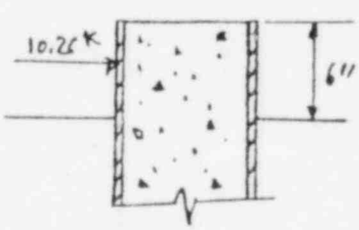
$$R = \frac{2E}{S+.1} = \frac{2(16000)}{(.1667+.1)} = 119{,}985^{\#} \simeq 120K ✓$$

CHECK SHEAR

SRSS Lateral load : 2681.49 — COMPUTER OUTPUT: SG200YZ — BINDER 567

$$\frac{2338.2}{228} = 11.76 \ ^{K}/\text{pile}$$

CHECK BEARING



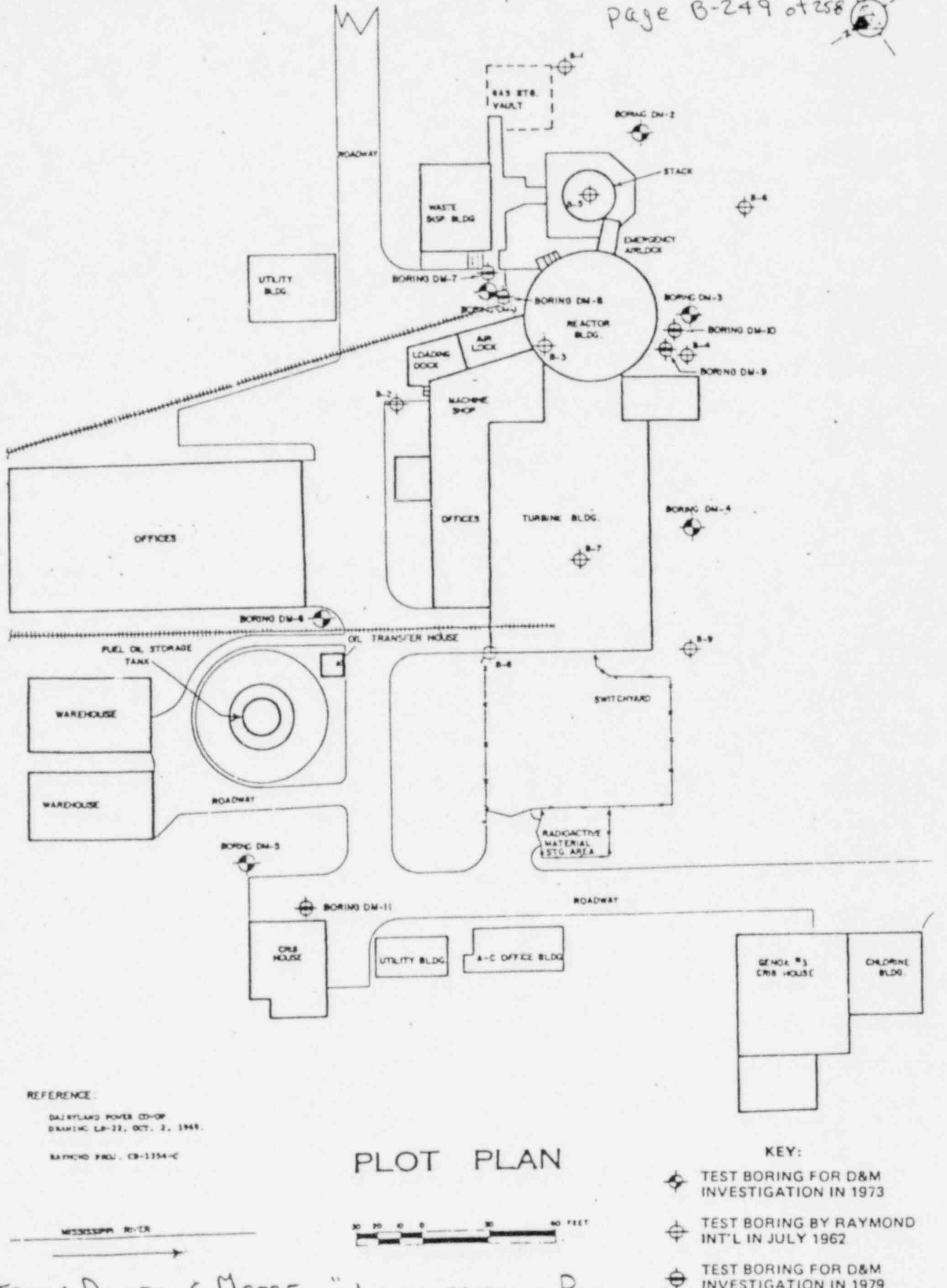
BEARING AREA = (12)(6) = 72 in² ✓

BEARING STRESS = $\frac{8.76}{72}$ = .163 ksi

Allowable = $\phi(.85 f'_c)$ ✓
= .7(.85)(3.5) = 2.083 ksi ✓

.163 ksi < 2.083 ksi **OK** ✓

CONTAINMENT BLDG PILE ANALYSIS



From: Dames & Moore, "Liquifaction Potential at LACBWR, ..." Sept 28, 1979, p.13

DAMES & MOORE

REF.

CONTAINMENT BUILDING - PILE ANALYSIS, Uplift Single

Uplift Capacity of a single pile, (approximation). Assume upward frictional resistance approximately = $f_s = \frac{\bar{N}}{50}$. ✓ Where $\bar{N}$ = the average standard penetration resistance, in blows/ft. within the embeded length of pile.

*DM-7	*DM-8	*DM-9	*DM-10
13	10	P	10
13	13	↓	14
30	14	P	17
	16		17
	26		22
	25		41
56 ✓	104 ✓	P	121 ✓

(blows/ft.)

$\bar{N} = \frac{\Sigma \text{ blows/ft.}}{\Sigma i} = \frac{281}{15} = 18.7\bar{3}$ ✓

average dia. of pile = $\frac{12'' + 8''}{2} = 10''$ ✓

surface area of one pile = $\pi(\text{dia.})(\text{depth}) = \pi(10)\,32\left(\frac{1}{12}\right) = 83.78 \text{ ft}^2$ ✓

** $f_s = \frac{\bar{N}}{50} = 18.73/50 = .374\bar{6}$ T.S.F. ✓

Total uplift resistance is;

$P_u = 83.78(.3746)\,2 \;\text{ft}^2 \left(\frac{T}{\text{ft}^2}\right)\left(\frac{K}{T}\right)$

$P_u = 62.78^K$ ✓

$P_u > 41.75^K$ = (the largest tension on a single pile) ✓

** "ASCE Journal of Geotechnical Engineering" Vol. 102, No. GT3 March 1979, pg 206

* Report prepared by Dames + Moore, "Liquefaction Potential At LA Cross Boiling Water Reactor (LACBWR) Site Near Genoa, Vernon County, Wisconsin", Sept. 28, 1979 pg A-3 → A-6

PILE ANALYSIS | REF.

UPLIFT CAPACITY OF A SINGLE PILE APPROXIMATION

ASSUME FRICTIONAL RESISTANCE UPWARD APPROXIMATELY EQUAL TO

$$f_s = \frac{\bar{N}}{50} \ *$$

WHERE $\bar{N}$ = AVERAGE STANDARD PENETRATION RESISTANCE, IN BLOWS PER FOOT, WITHIN EMBEDDED LENGTH OF PILE.

*

B-1	B-2	B-3
12	20	13
18	24	27
13	46	25
16	23	65
19	113	
34		
112		

$$\Sigma = \frac{290}{13} = 22.3 = \bar{N}$$

ULTIMATE FRICTION RESISTANCE

$$f_s = \frac{22.3}{50} = 0.446 \text{ T.S.F.}$$

$$\text{AREA} = \frac{1}{12}\pi\left(\frac{12+8}{2}\right)(32') = 83.8'$$

TOTAL UPLIFT RESISTANCE

$$P_u = 0.446(83.8) = 37.4 \text{ TONS}$$

74.8 KIPS

* REFER TO ASCE "JOURNAL OF THE GEOTECHNICAL ENGINEERING" VOL. 102 NO. GT3 MARCH 1976 Pg 206

* SEE CALCULATIONS USING BORINGS: DM-7, DM-8, DM-9, DM-10.

(PREVIOUS PAGE)

NUCLEAR ENERGY SERVICES

BY D.L. Summers DATE 5/27/82 PROJ. 5101 TASK 247
CHKD. AZ DATE 7/9/82 PAGE ____ OF ____
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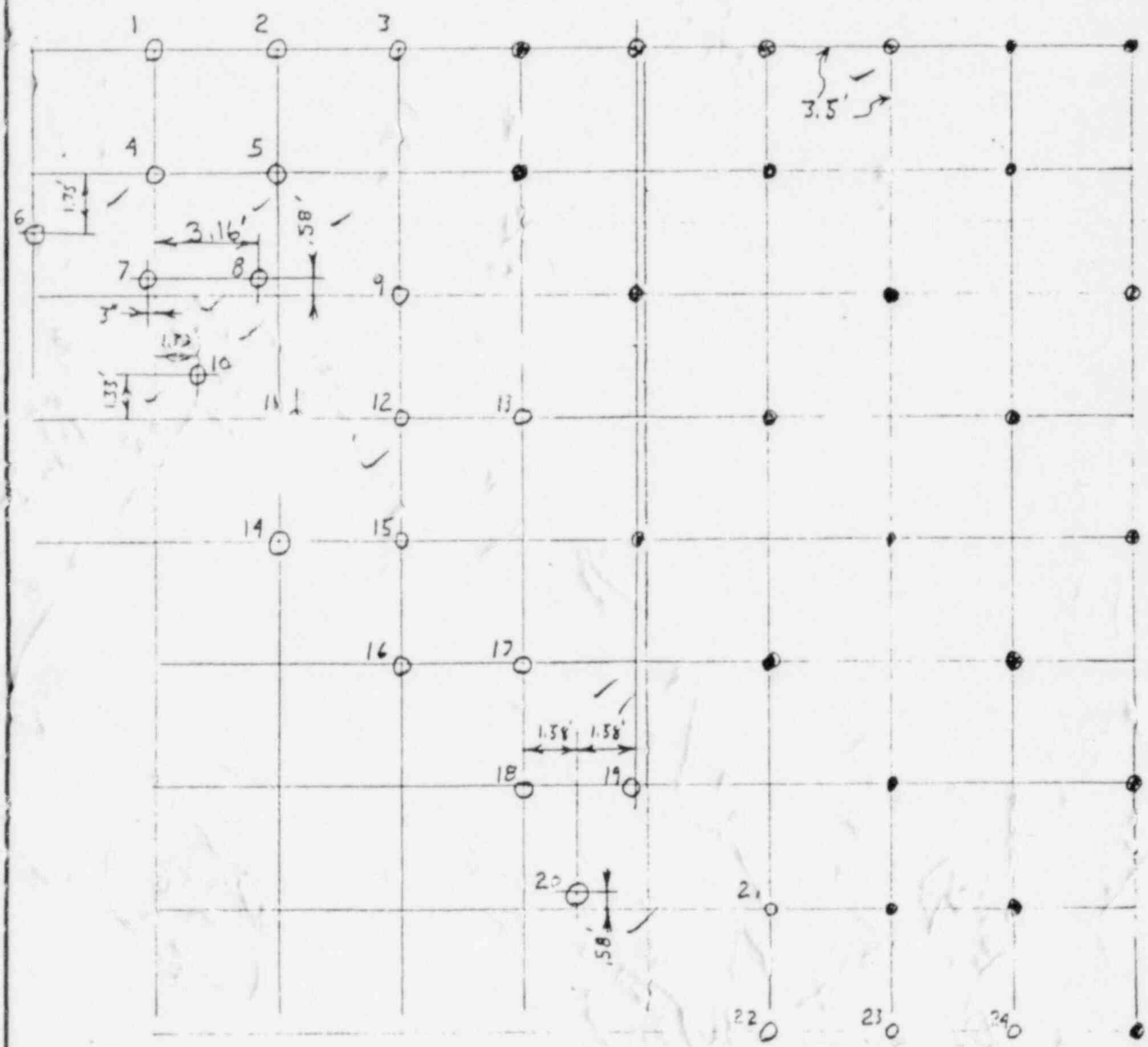
CONTAINMENT BUILDING - PILE ANALYSIS, Uplift

REF.

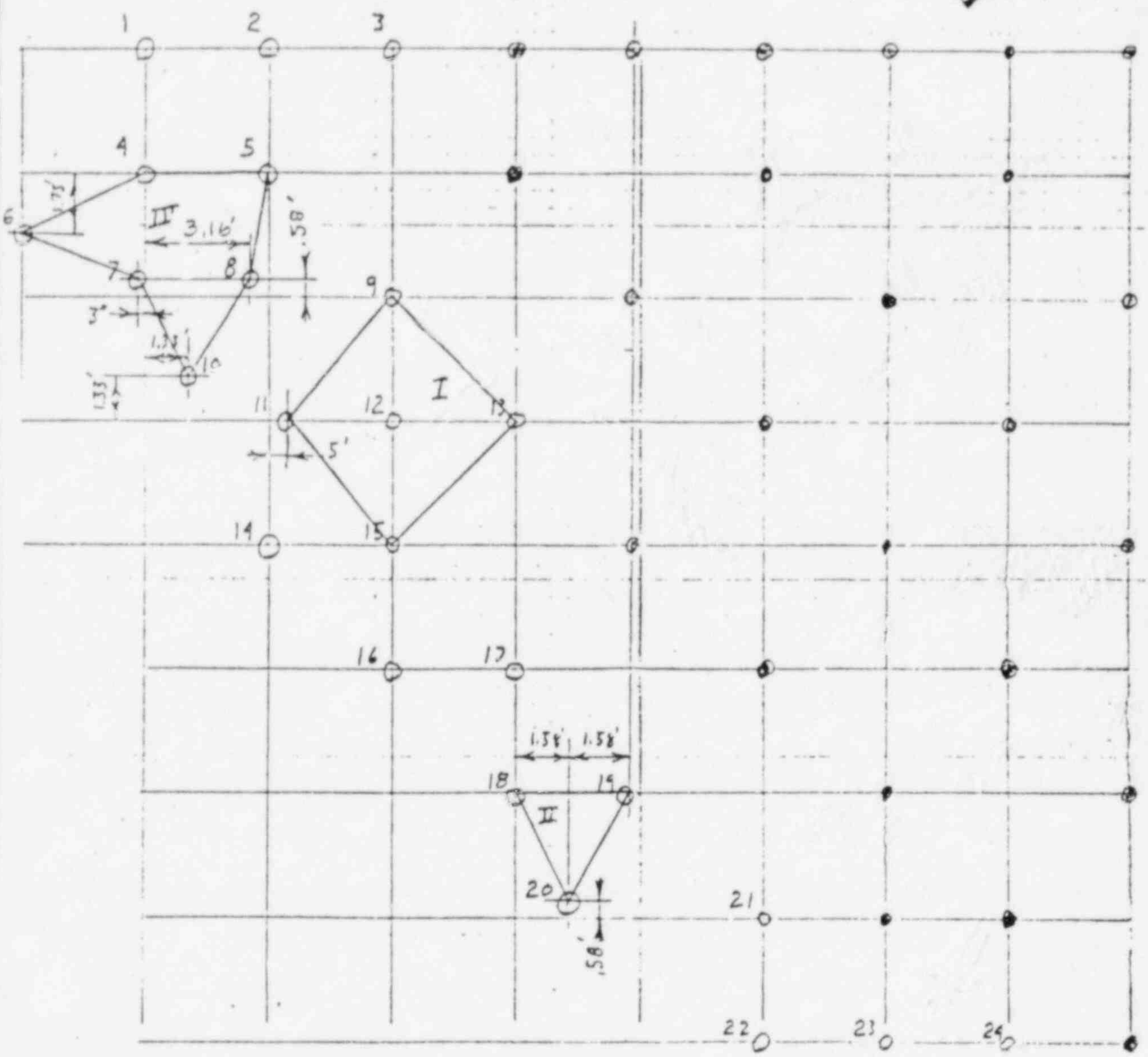
"1/4 of foundation"



NES 105 (2/74)

CONTAINMENT BUILDING - PILE ANALYSIS, Uplift

REF.



Find the area which contains the most piles per area

$A_I = 3.5^2 + 3.5(3) = 22.75\ ft^2 \rightarrow 5\ piles = 4.55\ ft^2/pile$

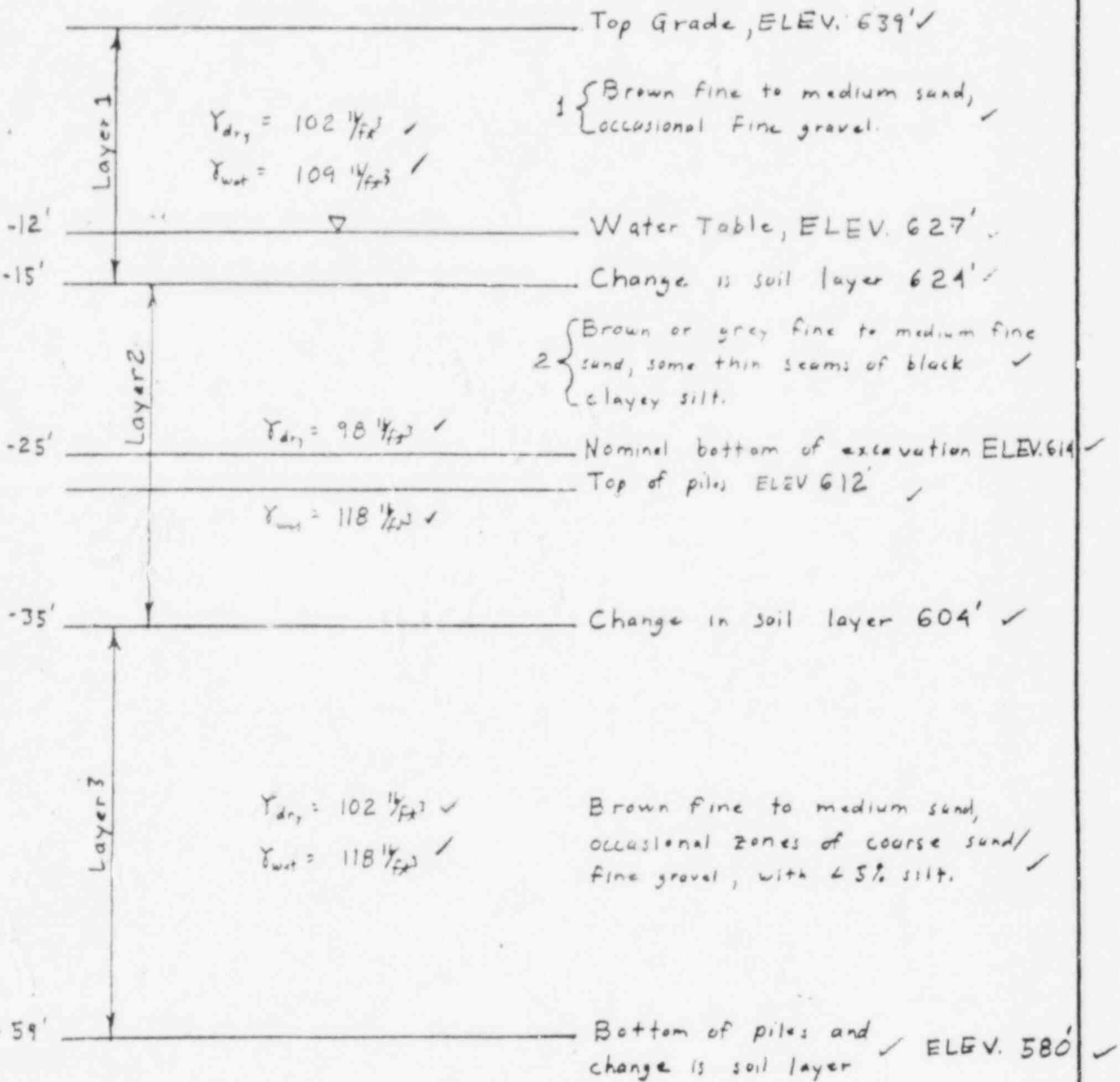
$A_{II} = 1.58(3.5-.58) = 4.6136\ ft^2 \rightarrow 3\ piles = 1.54\ ft^2/pile$

By inspection A_{II} is the lowest $\frac{ft^2}{pile}$ (SAME AS Δ 7-8-10)

The Linear Perimeter of $A_{II} = \left(\sqrt{1.58^2 + (3.5-.58)^2}\right)2 + 2(1.58) = 9.800'$

CONTAINMENT BUILDING - PILE ANALYSIS, uplift	REF.

The generalized soil strata and properties are from ref. ①. Notice that this soil data is generalized for the whole area, the specific Containment Building site data not available. (REF.: FIG. 1 OR DWG 41-503433)

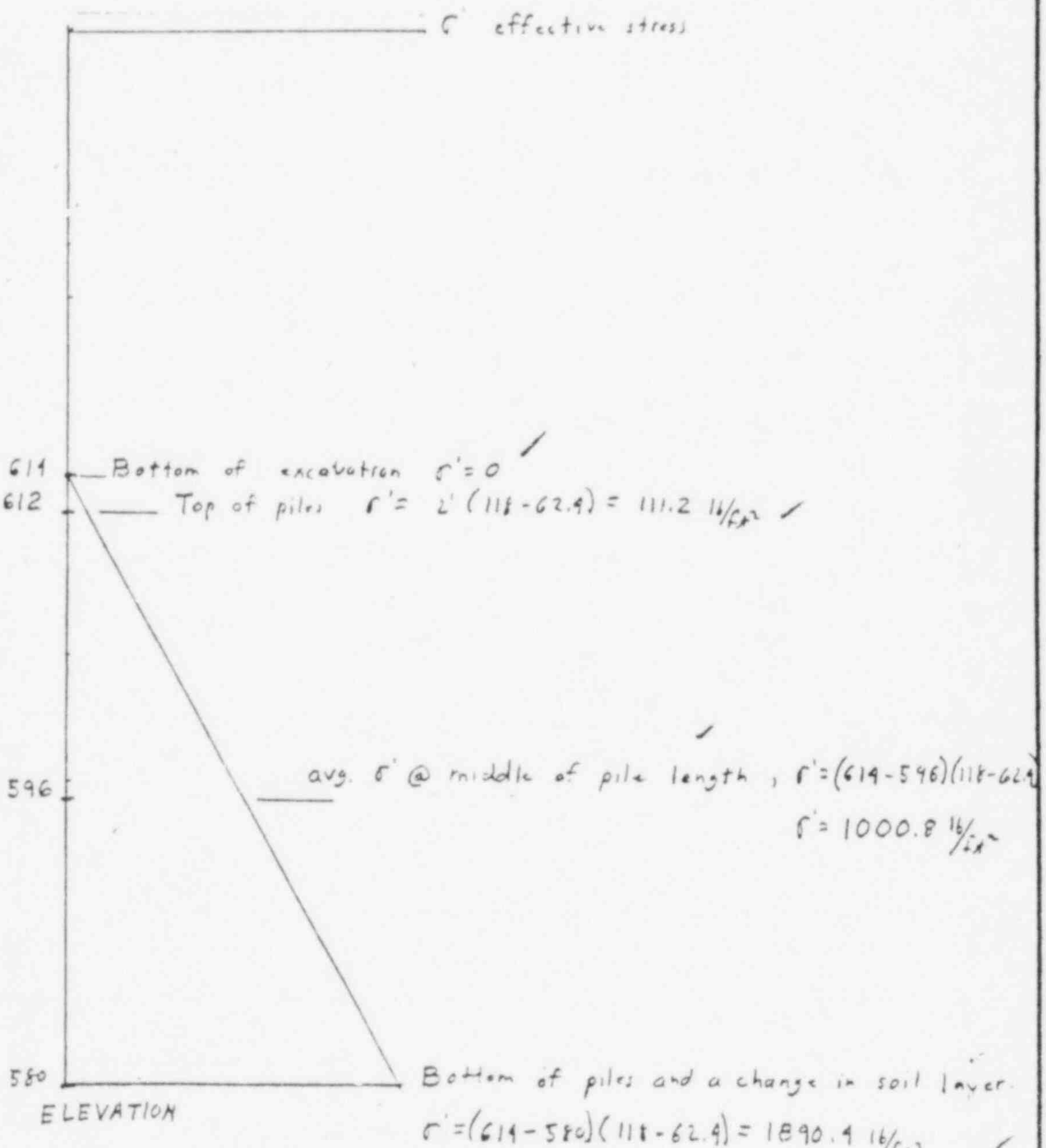


Elevations and lengths of piles are from previous calculations, specifically for the Containment Building.

CONTAINMENT BUILDING - PILE ANALYSIS, Uplift | REF.

The concrete filled piles reach an average depth of about 32' below the concrete footing/slab. The soil they penetrate is SP gray fine to medium sand.

Effective Overburden Stress vs. Depth



CONTAINMENT BUILDING - PILE ANALYSIS, Uplift	REF.

P_s = friction resistance = $\int_0^L P \bar{q} K \tan\delta \, dz$; $\int_0^L dz = 32'$ ✓ (from ④ p530)

where

P = perimeter = 9.8' ✓

$\bar{q}$ = effective over burden pressure at dz = 1000.8 psf (@ center of pile)

K = coefficient of laterial earth pressure = .5 ✓

*δ = friction angle of soil (interal ∡) = 31 ✓

P_s = 9.8' (1000.8) .5 (tan 31) 32' ✓

P_s = 94.290 kips ✓

P_s > the actual pull out force of the system of piles.

$P_s > 91.55^K = 41.75^K + 30.5^K + 19.3^K$ (by Nhan Huu Cao) $= P_a = 91.55^K$ ✓

* Arriving at δ

N (blows/ft)	∡ of internal friction	
8	30° ✓	use 31° ✓
16 ✓	32° ✓	
(ref 1)	(ref 3)	

Weight of pile = $\pi(5^2)\, 32' \, \frac{1}{144} \left(145 \frac{lb}{ft^3}\right) = 2530 \text{ lb} = P_w$ ✓

avg. dia. = (12" + 8") ÷ 2 = 10"

Length = 32' ✓

$\gamma_{conc.} = 145 \text{ lb/ft}^3$ ✓

(the difference between γ_{conc} and γ_{steel} neglected)

$P_T = P_s + P_w = 94.29^K + 2.53^K = 96.82^K$ ✓

$P_T > P_a$

$96.82^K > 91.55^K$ ✓

CONTAINMENT BUILDING - PILE ANALYSIS, Uplift	REF.

The tribrutary volume of soil that resists the pull out force of the pile is conical in shape, the bottom of the pile being the point of the cone. As the elevation increases the cone broadens. The tribrutary cones are not describable mathematically at present. A simplified conservative procedure was used. Within the perimeter bounded by the piles was considered the volume effective in resisting pullout. The soil that would be in this cone was ignore if outside the straight line perimeter pile to pile.

The friction value is larger for round piles (of diameter = D) as compared to a square pile whose side = D by about 4:3 respectively. Tapper is an asset if the tapper ≥1%, the friction capacity is likely to increase by 1.5 to 2.5. Although the piles used here are tappered >1% (4"/32' = 1.04%) this was not considered because the accuracy of how much of an increase can not be pin-pointed.

The cohesion (effective in upper portions of piles) was ignored due to simplifying and so variable with piles at different lengths. The 32' length of pile was used as a represenative average of all the piles. This is conservative because on the outside edge of the building where pullout forces exist, the floor/foundation curves closer to the surface more contact with soil. This in turn allows more friction area on the pile and deeper soil increasing the effective overburden stress, (P and $\bar{q}$ respectively).

The coefficient of lateral earth pressure was chosen from the lower end of the spectrum of pullout tests. The actual pull out force was assumed to be the three piles experiencing the highest pull out force. Assuming they act together is conservative. In

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CONTAINMENT BUILDING - PILE ANALYSIS, Uplift | REF.

reality they do not.

References.

1. "Liquefaction Analysis for Lacross Nuclear Power Station", by W. F. Marcuson II and W. A. Bieganousky from Geotechnical Laboratory U.S. Army Engineer Waterways Experiment Station Vicksburg, Mississippi

2. "Foundation Engineering" edt. by G. A. Leonards, pub. by McGraw Hill Book Company 1962.

3. "Foundation Engineering Handbook", edt. by H. F. Winterkorn and H. Y. Fang, pub. by McGraw Hill Book Company.

4. "Foundation Analysis and Design", by J. E. Bowels, 2nd edt, pub. by McGraw Hill Book Company.