ORNL/ER-257

LOCKHEED MARTIN

ENVIRONMENTAL
RESTORATION
PROGRAM

Structural Analysis of Underground Gunite Storage Tanks

MANAGED BY
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ENERGY SYSTEMS
ER

UCN-17560 (6 8-95)

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

ORNL/ER-257

Energy Systems Environmental Restoration Program

Structural Analysis of Underground Gunite Storage Tanks

Date Issued—August 1995

Prepared for
U.S. Department of Energy
Office of Environmental Management
under budget and reporting code EW 20

Environmental Restoration and Waste Management Programs
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6285
managed by
LOCKHEED MARTIN ENERGY SYSTEMS
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

TABLE OF CONTENTS

FIGURES

TABLES

PREFACE

The original analysis report on the gunite tank was issued in July 1994 as SAIC-94/1106. During the review process, a computer code validation was performed. A cantilever beam was modeled using the GTSTRUDL program and its eight-node brick "IPSL" finite elements. The result showed that GTSTRUDL significantly underpredicts the beam deflections and stresses for a certain geometry and aspect ratios of the finite elements. To confirm the analysis results, it was considered necessary to check the tank stresses using a different finite element program In addition, the earth loading on top of the dome has been incorrectly applied. Therefore, the loading was corrected and the analysis was performed using GTSTRUDL and a program named SUPERSAP. There were no significant differences between the results. It was concluded that GTSTRUDL is applicable for this geometry and produced acceptable results. The updated analysis results from GTSTRUDL are reported here and the verification results from SUPERSAP are documented in a revised Appendix C. This work was performed under Work Breakdown Structure 1.4.12.6.1.06.01.01 (Activity Data Sheet 3306).

EXECUTIVE SUMMARY

LOCATION

This report documents the structural analysis of the 50-ft diameter underground gunite storage tanks constructed in 1943 and located in the Oak Ridge National Laboratory (ORNL) South Tank Farm, known as Facility 3507 in the 3500-3999 area. The six gunite tanks (W-5 through W-10) are spaced in a 2 × 3 matrix at 60 ft on centers with 6 ft of soil cover.

GEOMETRY

Each tank (Figures 1, 2, and 3) has an inside diameter of 50 ft, a 12-ft vertical sidewall having a thickness of 6 in. (there is an additional 1.5-in. inner liner for much of the height), and a spherical domed roof (nominal thickness is 10 in.) rising another 6 ft, 3 in. at the center of the tank. The thickness of both the sidewall and the domed roof increases to 30 in. near their juncture. The tank floor is nominally 3-in. thick, except at the juncture with the wall where the thickness increases to 9 in.

CONSTRUCTION

The tanks are constructed of gunite (a mixture of Portland cement, sand, and water in the form of a mortar) sprayed from the nozzle of a cement gun against a form or a solid surface. The floor and the dome are reinforced with one layer of welded wire mesh and reinforcing rods placed in the radial direction. The sidewall is reinforced with three layers of welded wire mesh, vertical ½-in. rods, and 21 horizontal rebar hoops (attached to the vertical rods) post-tensioned to 35,000 psi stress. The haunch at the sidewall/roof junction is reinforced with 17 horizontal rebar hoops post-tensioned with 35,000 to 40,000 psi stress. The yield strength of the post-tensioning steel rods is specified to be 60,000 psi, and all other steel is 40,000 psi steel. The specified 28-day design strength of the gunite is 5,000 psi.

PENETRATIONS IN THE DOME

Penetrations in the dome were made at different stages. The size, number, and location of the penetrations varies from tank to tank. In one case, five 24-in. and one 30-in. penetrations exist on one tank. This analysis considered a conservative structural model (Figure ES-1) with seven non-symmetrical penetrations (Figure ES-2). The assumed penetrations include one 24-in.-diameter hole in the center, four 24-in.-diameter holes along a 20-ft radius circle, one 30-in.-diameter hole and one 12-in.-diameter holes along a 22-ft radius circle. The actual penetrations are reinforced with concrete pads. For simplicity, the structural model did not include the pads nor any penetrations smaller than 12-in. diameter.

ANALYSIS

Engineering analysis of the tanks in recent years was carried out in 1986 and an additional report on further evaluation of the results was published in 1993. In 1995, a simplified calculation performed by Hanskat reported that the tension in the dome ring reinforcement steel has exceeded the code allowable stresses. The 1986 analysis had a limited scope and, as a result, simplified finite element model of a partial tank was used. The 1995 simplified calculation provided safety factors against buckling but not against tensile failure on the dome ring which is the controlling failure mechanism. This current report uses 3-D finite elements (eight-node bricks) to model the entire tank (Figure ES-1). The liner inside the wall is observed to have partially deteriorated in two of the tanks (W-5 and W-6) and has limited structural strength. Therefore the liner is not included in the structural model.

STRUCTURAL LOADINGS

Static and dynamic loading are considered in this analysis. Dynamic loading is applied to the structure as equivalent static loading. Loads considered are dead load, static soil pressure, static hydraulic load, tank earthquake load, dynamic seismic soil load, and dynamic seismic hydraulic load.

The scope of this report does not include miscellaneous loads such as equipments on the super structure, occasional live loads, etc. Buoyancy effects analyzed previously by Martin Marietta Energy Systems, Inc. concluded uplift was an unlikely event.

SEISMIC HAZARDS

As a result of a hazard screening, the South Tank Farm was placed in the general hazard category. Therefore, following the guidelines of UCRL-15910, the methodology used is a static-equivalent seismic analysis on a three-dimensional model representing the entire tank. Seven however, the tanks have a high safety factor against buckling in both the dome and the vertical wall. Seismic-induced stresses range from 7 to 12% of the maximum static stresses. The maximum principal compressive stress is 642 psi, which is a low value compared to the allowable compressive stress of concrete having an f'c=5000 psi. The maximum directional tensile and shear stresses, and the maximum principal stresses from three typical sections of the model are presented in Table ES-1. Maximum stresses at the top of the wall are presented in Table ES-2. These typical sections are situated at 0°, 90°, and 180°, with respect to the direction of seismic loading. Total stress was due to static load plus seismic load. Loading case 4 represents the case of earthquake applied to an empty tank. It can be seen that the earthquake increases the stress levels by approximately 10%.

For all loading cases considered, the concrete at the top of the tank wall has a high potential to form horizontal cracks on the exterior face according to the maximum principal tensile stress theory. The vertical reinforcement at the top of the wall is insufficient to satisfy flexural requirements and this region of the tank wall is not in compliance with ACI 318, for resisting moments. However, reinforcement is adequate to withstand the hoop tensile forces in the wall and the dome ring as required by ACI 318, ACI 334, and ACI 344R. Another area not fully in compliance with these ACI codes is a 3-ft wide band at the edge of dome adjacent to the dome ring. This region is noncompliant in that the reinforcement cross section provided is not sufficient, by itself, to resist the tensile load on the gross cross section. However, the concrete tensile stress in this area is smaller than the allowable tensile stress limit for flexure in plain concrete and much smaller than the modulus of rupture, therefore cracking is not expected to occur in this region of the tank dome for the load conditions considered.

Openings in the dome do not induce significant stress concentrations. The maximum principal stress, 524 psi, is high, but less than the maximum principal stress, 689 psi, at the top of the wall. Any additional openings larger than 30-in. diameter may induce higher stresses. Further analysis of openings larger than 30-in. diameter is recommended.. Reduction in section at the top of the wall may induce cracks under all loadings. At elevations 2 ft below the top of the wall, a reduction of the wall thickness from 6 in. to 5 in., does not increase the concrete stress beyond the rupture stress limit. At 3 ft below the ring, a 2-in. reduction in wall thickness does not overstress the concrete. Deflections from all loading combinations are less than 0.1 in.

It is the conclusion of this analysis that the gunite tank is structurally stable with respect to the load conditions considered. This analysis shows that the dome shell exhibits a safety factor of 51 against buckling. This factor is considerably larger than safety factor of 4 to 6 recommended by ACI 344-70. The structural stability of the tank dome is, however, dependant on the peripheral confinement provided by the dome ring. The dome ring is primarily subjected to tensile loading which is resisted by embedded reinforcement having a yield strength of 60 ksi. This analysis shows the dome ring reinforcement exhibits a capacity to demand ratio of 1.88 with respect to the recommended ACI 318-89 working stress tensile allowable of 24 ksi for prestressed reinforcement (reinforcement resisting all tension in the cross section). With respect to yield, the ring reinforcement exhibits a capacity to demand ratio of 3.5. The cylindrical wall exhibits a safety factor of 44 against buckling.

Some horizontal cracking is expected to occur in a narrow band of the tank wall just below the dome ring. Cracking will primarily be confined to the exterior surface of the wall. The narrow band at the top of the wall below the dome ring was one of two regions of the tank found not to be in compliance with applicable ACI codes. A 3 ft. wide ring at the edge of the dome adjacent to the dome ring was also found to be non-compliant with respect to ACI 344 requirements for tensile reinforcement. With respect to the former noncompliant finding, it should be noted that many tanks of this type have been designed with a through wall joint in this location (e.g. Fig. 2.5.4.2b ACI 344-70). It is evident that should a through wall crack develop in the subject region of the tank wall, the structural integrity of the tank will be maintained. With respect to the latter, calculations show that the tensile stress level on the gross section of plain concrete in the subject region is so low that the section will not crack and the integrity of the section will be maintained when subjected to the load conditions considered. Noncompliance with respect to applicable codes in these instances clearly does not affect the structural integrity or stability of the tanks. The confinement capability of the tanks may be compromised by a through wall crack below the dome ring, however, controlling the elevation of fluids stored in the tanks administratively will mitigate that potential problem.

Table ES-1. Maximum stresses of overall tank structure (psi)

Type of Stress		Location*	Node	Static and Seismic Loads		Static Load		Ratio**
				Loading Case	Stress (psi)	Loading Case	Stress (psi)	
Directional Tensile and Shear Stresses	Sxx	1	8128	6	542	2	488	1.11
	Syy	5	4071	4	549	1	489	1.12
	Szz	3	8592	4	833	1	781	1.07
	Sxy	6	4071	4	544	1	491	1.11
	Sxz	4	8903	8	453	3	410	1.10
	Syz	6	41	4	523	1	488	1.07
Principal Stresses	Tension	6	4071	4	689	1	621	1.11
	Compression	2	8595	4	642	1	597	1.08
	Tmax	6	4071	4	467	1	420	1.11

NOTES:

Stresses shown above are finite fiber stresses for an uncracked section. Stresses may have been recast in calculations in order to evaluate reinforced cross sections.

*Locations 1: 30-in. opening, bottom surface
2: 30-in. opening, middle surface
3: 30-in. opening, top surface
4: Edge of dome, bottom surface
5: Bottom of ring
6: Top of wall, exterior surface

**Ratio = Stress due to static plus seismic load/stress due to static load

Table ES-2. Maximum stresses at top of wall (psi)

Type of stress at Node 4071		Static and Seismic Loads (Loading Case 4)	Static Load (Loading Case 1)	Ratio*
Directional Tensile and Shear Stresses	Sxx	215	196	1.10
	Syy	200	189	1.06
	Szz	250	249	1.00
	Sxy	544	491	1.11
	Sxz	1	1	1.00
	Syz	7	10	0.70
Principal Stresses	S1	689	621	1.11
	S2	250	249	1.00
	S3	-246	-218	1.13

NOTES:

Stresses shown above are finite fiber stresses for an uncracked section. Stresses may have been recast in calculations in order to evaluate reinforced cross sections.

*Ratio = Stress due to static plus seismic load/stress due to static load.

SUGGESTIONS

The structural integrity of the dome ring is very important. As long as the ring is intact, the tank will not collapse regardless of localized spalling in the vertical tank wall. Presently the ring has a reserve capacity of more than 80% with respect to tensile working stress code allowables and a capacity to demand ratio of approximately 3.5 with respect to ultimate tensile capacity. Provided the ring maintains its integrity, the dome has a safety factor of 51 against buckling for the load conditions considered. The cylindrical wall has a safety factor of 44 (assumes hinges form at the top and bottom of the wall, i.e. worst case boundary conditions). The most likely path to failure is that the stiffening ring becomes overstressed due to additional dome loading or severe reduction of the dome ring reinforcing steel cross section, cracks develop in the dome ring and the tank wall immediately below, followed by large deformations in the dome ring in both radial and circumferential directions causing the dome shell to loose edge constraint, eventually the dome collapse follows. Therefore the integrity of the dome ring must be insured. The following precautions are recommended:

Drilling in or near the ring should be avoided as such activity could cause severe weakening of the structure.

The dome roof should not be subjected to any additional soil or equipment load without engineering evaluation. If cracking in the tank wall below the dome ring is acceptable, the dome will accommodate a good deal of additional load.

Any additional openings larger than 30-in. diameter in the dome should be evaluated on a case-by-case basis.

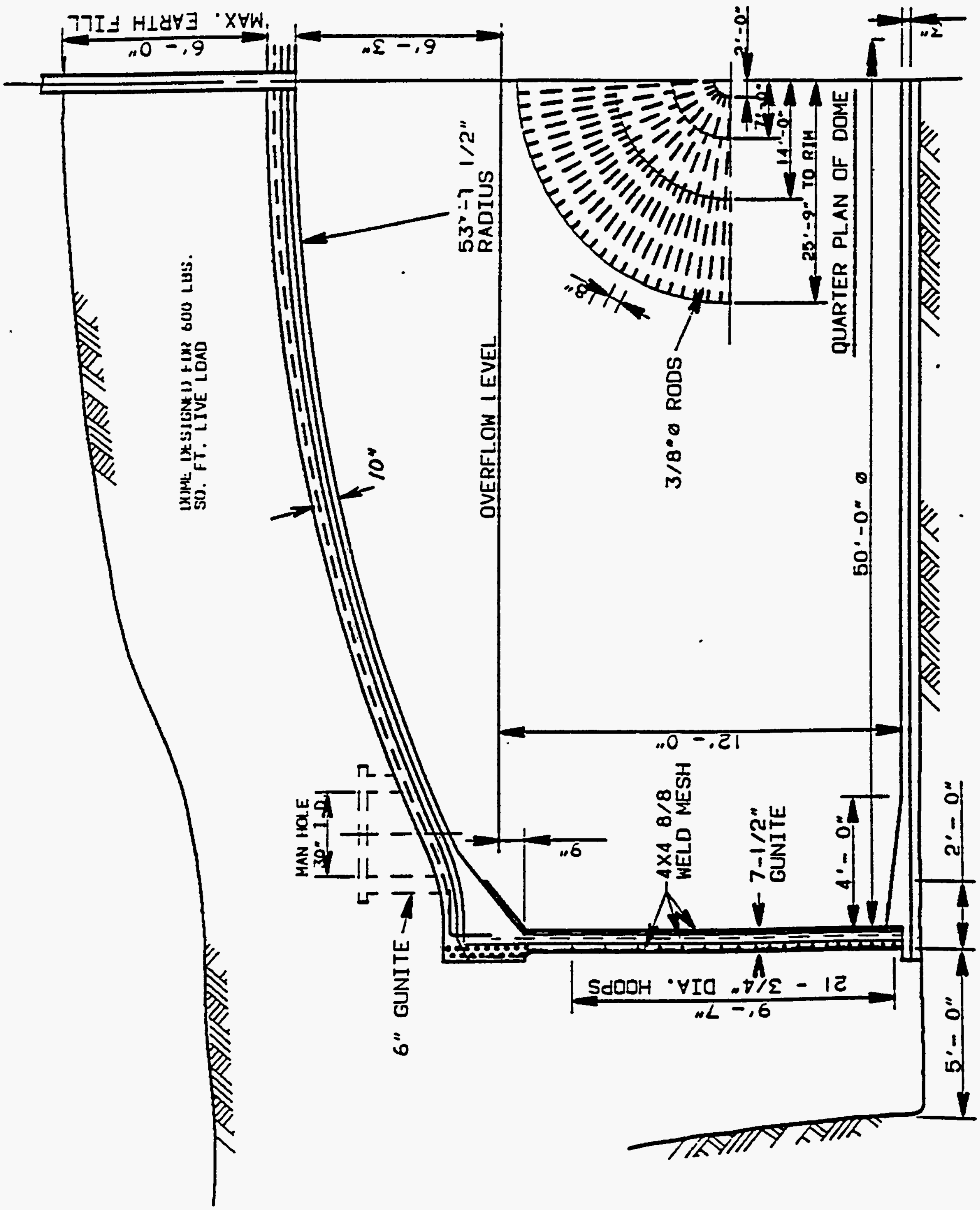


Fig. ES-1. Cut-up Tank Section of Finite Element Model

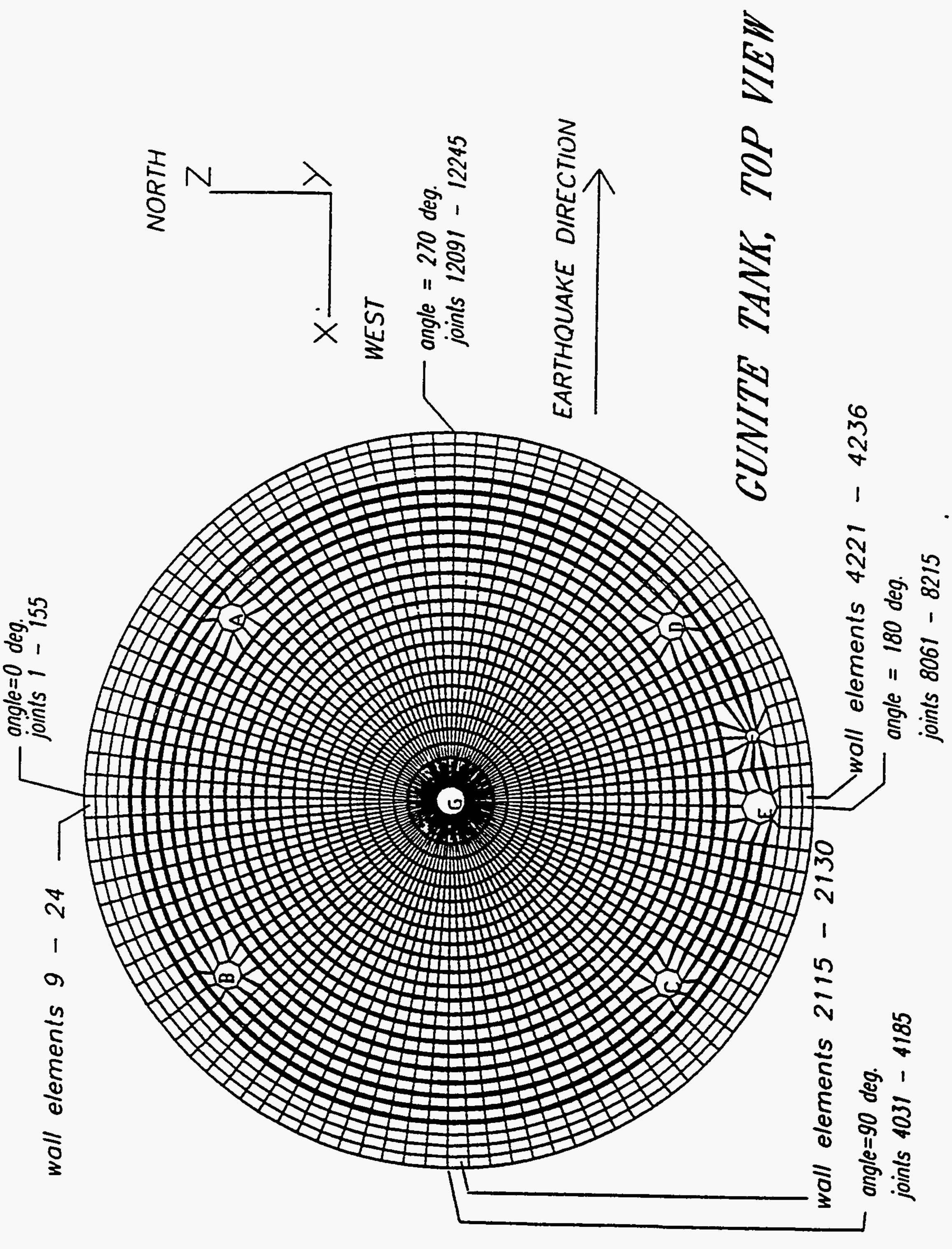


Fig. ES-2. Dome Opening Locations

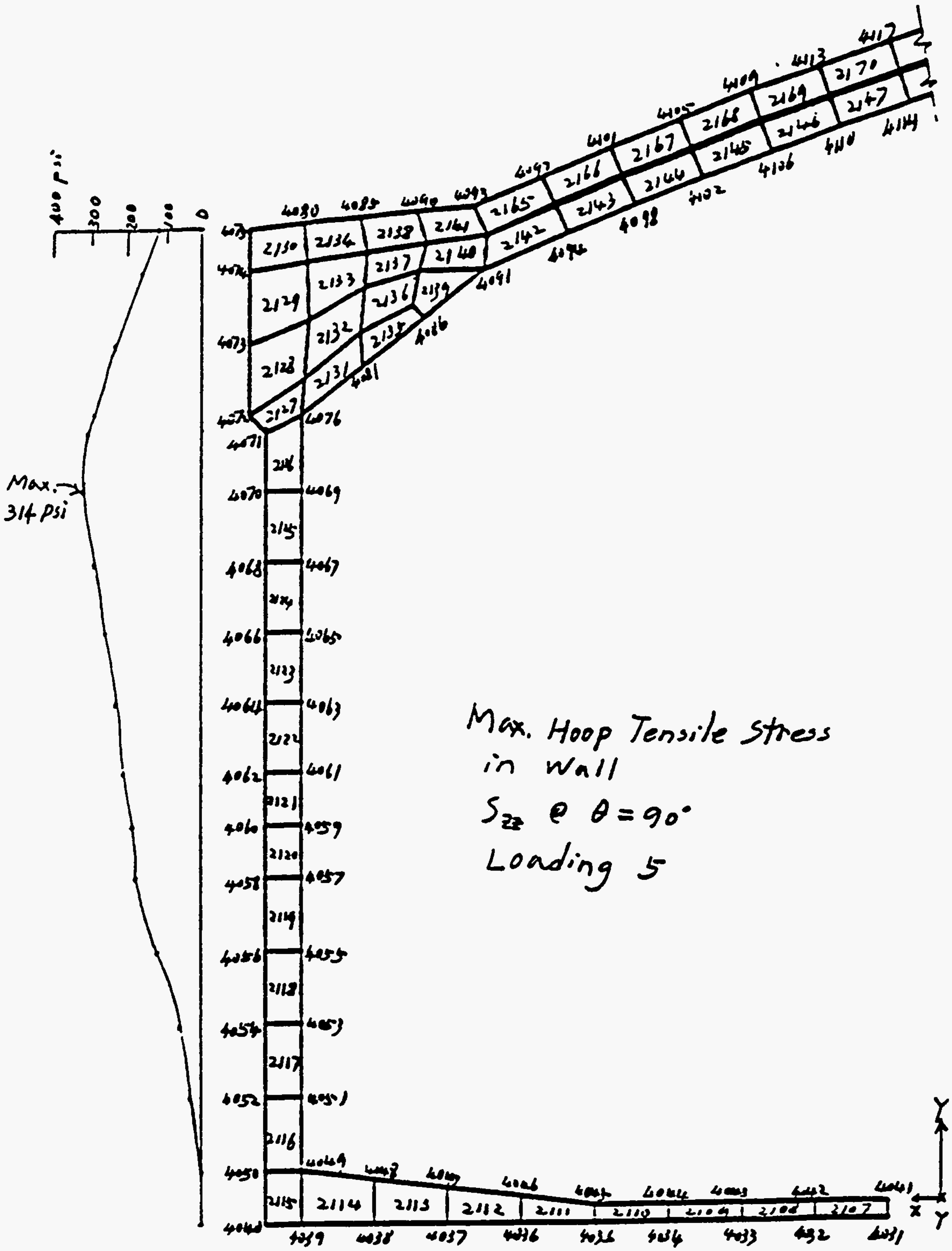


Fig. ES-3. Maximum Hoop Tensile Stress

1. INTRODUCTION

This report documents the seismic analysis of the underground gunite storage tanks located in the South Tank Farm at the Oak Ridge National Laboratory (ORNL). The South Tank Farm, known as Facility 3507, is a storage facility located in the 3500-3999 area of the main plant area of ORNL. This analysis was performed in support of the Gunite and Associated Tanks (GAAT) Treatability Study which is being performed to study the feasibility of various remedial action techniques.

The analysis does not represent the behavior of any specific tank, but rather is considered a typical analysis representing a reasonably conservative behavior of the tanks in general. Physical inspection of the tanks was not possible. Remote inspection (Energy Systems, 1992a) indicates some deterioration of the tank inner liners especially in Tank W-5. Effects of deterioration were accounted for in the mathematical model and calculation.

The hand calculations are attached in Appendix A. The peer review comments and resolutions are included in Appendix B. The SuperSAP computer code verification and selection of the finite elements are attached in Appendix C. The input file for the analysis is attached in Appendix D.

This analysis did not address uncertainties in soil or material properties (e.g. degradation of concrete strength), undocumented stress risers (e.g. irregularities in penetration cross section), or undocumented abrupt changes in cross section (e.g. wall spalling). Some simplification in the math model was required due to model size limitations.

2. DESCRIPTION OF TANKS

Section 2.1 provides a description of the tanks as they were constructed in 1943. Section 2.2 gives a description of the tanks based on information obtained more recently during the Sludge Removal Project in 1981 (Fricke, 1993). Section 2.3 discusses the penetrations in the dome. A second video review of these tanks was made in 1992 (Bechtel, 1992). There has been no apparent deterioration of the tanks in addition to that visible in 1981. The details of the condition of the outside of the shell is not known.

2.1 GENERAL DESCRIPTION

Facility 3507 consists of six inactive below-ground waste storage gunite tanks. All pipelines feeding the tanks have been capped, and the tanks are no longer part of the active LLLW system. They were used to collect and store the liquid portion of the radioactive and/or hazardous chemical wastes produced as part of normal facility operations at ORNL. As the tanks were taken out of service, the liquid waste from these tanks was pumped out, although some residual liquid and sludge may be left in them.

The six gunite tanks (W-5 through W-10), originally constructed in 1943, are located at 60-ft centers in a 2×3 matrix in the South Tank Farm (Ref. UCC-ND Drawing C3E-20539 X006). A limited amount of information is available concerning details of tank construction. The following data are obtained from Fricke (1986, 1993). Figures 1 and 2 show the major details of the tanks; these figures are taken from UCC-ND drawings E-56866 and D-56867, respectively. Each tank has an inside diameter of 50 ft, a 12-ft vertical sidewall with a nominal thickness of 6 in. (there is an additional 1.5-in. inner liner for much of the height), and a spherical domed roof (nominal thickness is 10 in.) rising another 6 ft, 3 in. at the center of the tank. The thickness of both the sidewall and the domed roof increases to 30 in. near their juncture. The tank floor is nominally 3-in. thick, except at the juncture with the wall where the thickness increases to 9 in.

The tanks are constructed of gunite (a mixture of Portland cement, sand, and water in the form of a mortar) sprayed from the nozzle of a cement gun against a form or a solid surface (Fricke, 1986). The floor is reinforced with one layer and the dome with two layers of 4 × 4 − W2.1 × W2.1 welded wire mesh and 3/8-in.-diameter reinforcing rods placed in the radial direction. The sidewall is reinforced with three layers of welded wire mesh, vertical 1/2-in. rods, and 21 horizontal rebar hoops (attached to the vertical rods) post-tensioned to 35,000 psi stress. The haunch at the sidewall/roof junction is reinforced with 17 horizontal rebar hoops post-tensioned with 35,000 to 40,000 psi stress. The yield strength of the post-tensioning steel rods is specified to be 60,000 psi, and all other steel is 40,000 psi steel. The specified 28-day design strength of the gunite is 5,000 psi (Union Carbide drawing E-56866). Each tank has approximately 8,000 ft^2 of wire mesh and over six tons of reinforcing steel rods within the concrete (Fricke, 1986).

Each tank sits on an individual concrete pad. The thickness of soil between tank foundation and top of rock varies from 0 (near Tank W-6) to 14 ft (near Tank W-9). The concrete pad has a raised rim that forms a saucer (Figure 3) which directs drainage and any leakage into a dry well and drain system. The tank sidewall has a 3-ft-thick backfill of crushed stone forming a French drain and providing for passage of groundwater drainage and any leakage to the dry well and drain system. The rest of the surrounding soil is composed of compacted available fill, and clay. The tank domes are covered with 6 ft of compacted earth.

2.2 EXISTING CONDITION OF THE TANKS

The existing condition of the tanks is not well known since a hands-on inspection is not permitted. The details of the condition of the outside of the shell are not known.

As part of the Sludge Removal Project (Fricke, 1993): 1) Schmidt Rebound Hammer readings, to estimate concrete strength, were taken of the dome of all tanks except for W-9, 2) core samples were taken from the dome of Tanks W-5 and W-10 at various locations and cylinder strength tests performed on the cores, and 3) a television camera was lowered into each tank where black and white videotapes and photographs of the interior of the tanks were made. The Schmidt Rebound Hammer test results indicate that the concrete strength (for the dome) varies between 4,700 and 6,400 psi. The cylinder tests of the cores from Tanks W-5 and W-10 show concrete strengths consistently higher than those obtained from the Schmidt Hammer tests; the cores produce strengths between 5,500 and 16,000 psi (10,200 psi average). Since the construction techniques were similar, it is reasonable to assume the walls have the same strength as the dome. A compressive strength of 5,000 psi for the concrete was specified in the design drawing and is assumed for this analysis.

It is obvious from the photographs and the videos of the tank interiors that the existing condition of the tanks varies (Fricke, 1993). Tank W-5 is in the worst condition of the six tanks; parts of its inner 1.5-in. liner appear to be so thin that, in some areas, the wire mesh is exposed; in some areas, the wire mesh has folded back on itself (probably at overlap boundaries where the inner liner is thin). There are also indications that there may be more extensive deterioration of the walls of Tank W-5, such as areas of discoloration indicating possible holes or erosion. The past history of the six tanks indicates that Tank W-5 has been used more extensively as a holding tank for chemicals and has been, on several occasions, exposed to highly acidic liquids, which probably accounts to a large degree for its present condition. Tank W-6 shows similar, but less deterioration. The video tapes and photographs of the remaining four tanks do not reveal deterioration like those found in Tanks W-5 and W-6. None of the other tanks have exposed wire mesh, holes, or discoloration (Fricke, 1993).

2.3 PENETRATION IN THE DOME

Penetrations in the dome were made at different times in the life of each tank. The size, number, and location of the penetrations varies from tank to tank. In one case, five 24-in. and one 30-in. penetrations exist on one tank. This analysis used a conservative structural model with seven nonsymmetrical penetrations. The assumed penetrations include one 24-in. diameter hole in the center, four 24-in. diameter holes along a 20-ft radius circle, one 30-in. diameter hole, and one 12-in. diameter hole along a 22-ft radius circle. The actual penetrations in the field are reinforced with concrete caisson of additional thickness and diameter. For simplicity, the finite element model did not include the caisson nor any penetrations smaller than 12-in. diameter.

3. ANALYSES

This section discusses the methods used in the analysis of the typical gunite tank. Section 3.1 summarizes the methodology, while Section 3.2 discusses the seismic hazard level used in this analysis. Sections 3.3 and 3.4 describe in detail the finite element model and the structural loads applied to the model. Section 3.5 discusses the various loading combinations required to describe the state of stress in a tank accurately.

3.1 METHODOLOGY

The finite element technique was used to perform this study. This approach was selected for modeling the tanks and the loads because it can easily handle complex structures with varied material properties, geometric configurations, and boundary conditions. The computer program selected was GTSTRUDL (GTICES Systems Laboratory, 1991) which is available on the ORNL-RISC computer workstation.

A nonlinear soil-structure interaction (SSI) is beyond the scope of this study. Therefore, only the tank structure is included in the mathematical (three-dimensional finite element using solid elements) model of the system. An equivalent static analysis was performed for the evaluation of the dynamic effects of the surrounding soil.

3.2 SEISMIC HAZARD CLASSIFICATION

The only non-standard industrial hazards associated with the South Tank Farm are a radiation source hazard and a toxic hazard associated with the radioactive liquid waste. Resulted from a hazard screening (Energy Systems, 1992b), the South Tank Farm was placed in the general hazard category. The DOE seismic requirement (UCRL-15910) for a general hazard category structure is to withstand an earthquake with return period of 500 years using the static-equivalent seismic analysis procedures specified in Uniform Building Code (UBC 1994). As shown in Figure 4, the Oak Ridge Site Specific rock PGA for a 500-year return period is 0.08g (Beavers and Hunt, 1994). To account for different site geology and soil characteristics, UBC code specifies a soil and site correction factor S established from substantiated geotechnical data. In locations where the soil properties are not known in sufficient detail to determine the soil profile type, as is the case in this analysis, UBC codes recommends a soil profile factor of S = 1.5. This analysis conservatively used a PGA of 0.14g. The tank structure is therefore subjected to static and seismic (dynamic) loads induced by a 0.14-g horizontal and a 0.09-g vertical ground accelerations. (The vertical earthquake component is typically defined to be two-thirds of the horizontal component.)

3.3 FINITE ELEMENT MODEL

The gunite tanks are upright cylindrical tanks having domed roofs and buried 6 ft underground. A three-dimensional model of the full-size tank, as shown in Figure 5, was constructed of eight-node elements using GTSTRUDL's tridimensional "IPSL" elements. Since local stress conditions around the various openings in the tank dome are required by Energy Systems, the entire tank has been modeled. The bottom of the tank was not modeled completely as it contributes little to the stiffness of the tank. The tank wall and the modeled portion of the tank floor were modeled one layer thick. Because of uncertain structural strength and integrity, the inner liner of the wall was assumed to provide no additional structural capacity and was not included in the model.

The dome was modeled as being two layers thick, as shown in Figure 6, with the bottom of the upper layer connected to the lower layer via rigid space trusses (mathematically equivalent to a gap element that transfers only compressive axial force to the lower dome). The dome was modeled in two layers because the original 5-in.-thick dome was thickened after original construction by the addition of a 5-in.-thick over-layer. Available drawings (see list at the end of Attachment A) indicate that a cold joint exists between the two dome layers. The two 5-in. layers of dome may behave like a single 10-in. layer of dome, but uncertainties remain, and it is conservative to assume the two 5-in. layers configuration. The model consists of 8,424 elements, 2,392 rigid links and 16,120 joints. The model is axi-symmetric except for seven openings in the dome (as shown in Figures 7). The tank model is restrained in all translational directions at nodes along the bottom face of the tank floor. All other nodes are free to translate and rotate in three directions.

The material property of the finite element represents uncracked concrete strength. the strength of the reinforcing steel is not included in the element but considered in hand calculations after the stresses in the finite element are reported by the computer. The tank floor, wall, and dome elements are assumed to be homogenous and isotropic (ACI Committee 344, 1981). Wall elements are modeled as being 6-in. thick, dome elements as being 5-in. thick (each layer), and floor elements as being 3-in. thick. Floor elements within a 4-ft band near the wall thicken in the radial direction from 3 in. to 9 in. at the inside face of the tank wall. The stiffening ring at the edge of the dome was represented by a cross section of 15 finite elements. The finite element model is axi-symmetric except the seven openings in the dome are not located axi-symmetrically. See Figure 8 for detailed configuration.

The selection of the 8-node elements over 20-node elements was based on computer capacity, computing time, accuracy of results, and effort required to interpret the results. Detailed assessment of element applicability and accuracy is reported in Appendix C. The most critical stresses used in the analysis are the maximum principal stress and Syy. The maximum principal stress was used for screening purpose. The direction stress Syy is used for the evaluation of vertical wall strength below the haunch. These stresses are almost identical between two programs. It is concluded the results predicted by GTSTRUDL are adequate and compatible with the results obtained from the program SuperSAP.

The model consists of 104 identical pie segments representing the entire tank. Earthquake induced dynamic soil and fluid pressures were treated as static loading conditions. Soils were considered as loads, not as a part of the finite element model. Group behavior due to tank-to-tank interaction during a seismic event was not considered in the model, but was later evaluated (see Appendix A) and found to add only 3% to the maximum combined stresses.

3.4 STRUCTURAL LOADING

Static and dynamic loading considered in this analysis. Dynamic loading is applied to the structure as equivalent static loading. Loads considered are dead load (DL), static soil pressure (H_S), static hydraulic load (F_S), post-tensioning in reinforcing steel (T_S), tank earthquake load (E), dynamic seismic soil load (H_D), and dynamic seismic hydraulic load (F_D).

The scope of this report does not include miscellaneous loads such as equipment on the super structure, occasional live loads, etc. The uplift from buoyancy effects was analyzed previously by Energy Systems and was determined to be unlikely.

3.4.1 Static Loads

Static loads applied to the structure include:

Dead Load (DL) Structure self-weight is accounted for by GTSTRUDL. The unit density of the gunite (0.0868 lb/in^3) is input and GTSTRUDL computes unit weights by applying the density to the element volume at 1 g. Element weight is distributed to structural joints in proportion to tributary volume.

Static Soil Pressure (H_S) Consists of dome pressure (H_{SD}) and wall pressure (H_{SW}) :

Dome Pressure (H_{SD}). The 6-ft.-thick soil overburden on the dome is applied to the model as a surface pressure on dome elements. Soil dome pressure is computed based on a unit weight of soil of 110 lb/ft^3. The soil overburden is applied in the vertical (global) direction as an element surface load.

Wall Pressure (H_{SW}). Lateral at-rest earth pressures are applied externally and normal to the tank walls. The load diagram is trapezoidal, being 1.604 psi at the top of the tank wall and 5.306 psi at the bottom.

Hydrostatic Pressure (F_S) Hydrostatic pressures from stored fluids are applied to the interior face of the tank wall based on a fluid having a specific gravity of 1.25 (Fricke, 1986) for the full (11-ft fluid depth) and the half full (6.2-ft fluid depth) conditions. Hydrostatic loading is applied internally and normal to the tank walls. Hydrostatic loading is investigated for both the full (F_S) and half-full condition ($F_{½S}$).

Post-Tensioning (T_S) The hoop reinforcement in the tank walls and the confinement ring at the edge of the tank dome are fabricated from steel with a 60-ksi yield. (ACI Committee 344,1981) recommends that, unless precise methods are used to determine prestress losses, 32-ksi losses should be assumed (Friction loss was compensated in the construction stage to achieve the design prestress). Fricke (1986) predicts that 90% of pretension has been lost. This analysis assumes that all prestress has been lost.

3.4.2 Dynamic Loads

The dynamic loads considered include seismically induced soil pressure, hydrodynamic pressure, seismically induced sloshing, and structural inertial forces. Dynamic loading is applied to the tank model as a set of equivalent static loads. In each case, the equivalent static loads are derived from the estimated peak dynamic loading. The tank is very stiff with respect to lateral loading (height to diameter ratio ≈ 0.25); similarly, in the vertical direction the walls and the dome (as a result of its geometry and applied load distribution) are also stiff. This analysis accounts for that stiffness by neglecting dynamic amplification and damping effects of the structure.

Inertial Loads (E) Equivalent static loading is determined by multiplying model element mass by Design Basis Earthquake (DBE) peak ground accelerations. In reality, the inertia load (E) acts in the opposite direction to the dynamic soil loads (H_D) discussed below. In this analysis, both inertia loads and dynamic soil loads are conservatively combined as if both loads acted together in the same direction.

Dynamic soil loading (H_D) Dynamic soil loading is determined as though the tank were a retaining wall. The methods of Prakash (1981) are used to determine lateral dynamic pressures. Dynamic soil pressures also act along the direction of seismic motion and are distributed to the structure according to proportion of mass acting on each element in that direction. The resulting pressure bulb in plan is crescent shaped at a given elevation above the tank. Vertically, the dynamic earth pressure distribution is non-linear. The resultant in a typical vertical slice is located 0.6 of the wall height (h) from the bottom of the tank. This analysis uses an equivalent trapezoidal stress distribution. Horizontal pressures are distributed over the wall height with pressure intensities in a vertical slice being zero at the bottom, increasing linearly to a maximum value at 0.5h, remaining constant to 0.8h, then decreasing linearly to 0 at the top of wall. The resultant from this equivalent distribution is located at $0.56h \approx 0.6h$.

Dynamic soil pressures on the "leeward" side of tank are neglected. The 6-ft-thick soil blanket is treated as dead weight and accelerated vertically at peak ground acceleration.

Hydrodynamic Loads (F_D) When subjected to random vibrations, confined fluids develop inertial forces due to ground acceleration and sloshing forces due to wave action. This analysis uses the methodology of Newmark (1971) to develop equivalent static loadings for both loading types. Newmark's methodology determines the magnitude of the equivalent static forces and their location with respect to the bottom of the tank. These equivalent static loadings are applied to the interior face of the tank shell as a surface pressure on a horizontal band of elements at the elevation of the force center determined by the Newmark method. Distribution of the equivalent load as an equivalent localized pressure is conservative (local stress levels near the loaded elements are overestimated), but is computationally expedient.

Hydrodynamic fluid pressure acts along the direction of seismic motion. The hydrodynamic pressure in each pressure band is distributed to the face of each tank wall (band) element in proportion to the fluid mass acting dynamically on the element. Because of the geometry of the circular tank wall, the resulting pressure bulbs are crescent shaped. Pressures are maximum at the center of the pressure band (e.g., at the 0° azimuth of the tank in plan), tapering off to zero at the pressure band extremes 90° and 180° azimuths). Hydrodynamic loading is investigated for both the full (F_{D+}), half-full condition ($F_{½D+}$) and in-phase with the earthquake soil pressure and for (F_{D-}) and ($F_{½D-}$) out-of-phase (against) the earthquake soil pressure direction.

When the inertia force and the sloshing force are in phase, the forces exert on the same direction against the same wall. When the forces are out-of-phase, they were exerted on opposite sides of the tank wall. Observation indicates that the total loads on the tank wall are more conservative when the forces act on the same side of the tank wall. In this analysis, the inertia force is added to the sloshing forces as if they act in-phase with each other.

3.5 LOAD COMBINATIONS

The purpose of this analysis is to determine whether the tank has the capacity to resist the DBE for the ORNL site. During a seismic event the probability that the hydrodynamic and dynamic soil loading will occur simultaneously is remote. Structural response to these loadings should be combined probabilistically (e.g., Square

Root of the Sum of the Squares). This analysis conservatively combines responses algebraically. Loading combinations analyzed by the GTSTRUDL program include:

Static Load Cases:

1. $DL + H_{SD} + H_{SW}$ .... Empty Tank
2. $DL + H_{SD} + H_{SW} + F_S$ .... Full Tank
3. $DL + H_{SD} + H_{SW} + F_{½S}$ .... Half-full Tank

Dynamic Load Cases:

4. $DL + H_{SD} + H_{SW} + E + H_D$ .... Empty Tank + Earthquake
5. $DL + H_{SD} + H_{SW} + E + H_D + F_S + F_{D+}$ .... Full Tank (in-phase) + Earthquake
6. $DL + H_{SD} + H_{SW} + E + H_D + F_S + F_{D-}$ .... Full Tank (out-of-phase) + Earthquake
7. $DL + H_{SD} + H_{SW} + E + H_D + F_{½S} + F_{½D+}$ .... Half Tank (in-phase) + Earthquake
8. $DL + H_{SD} + H_{SW} + E + H_D + F_{½S} + F_{½D-}$ .... Half Tank (out-of-phase) + Earthquake

where:

DL = tank structural self weight
H_{SD} = static soil top pressure from earth over dome
H_{SW} = static soil lateral pressure from earth adjacent to tank wall
E = tank structural force induced by earthquake
H_D = dynamic soil loading
F_S = hydrostatic liquid pressure of full tank
$F_{½S}$ = hydrostatic liquid pressure of half-full tank
F_{D+} = hydrodynamic liquid pressure of full tank that is in-phase with the earthquake
$F_{½D+}$ = hydrodynamic liquid pressure of half-full tank in-phase with the earthquake
F_{D-} = hydrodynamic liquid pressure of full tank that is out-of-phase with the earthquake
$F_{½D-}$ = hydrodynamic liquid pressure of half-full tank out-of-phase with the earthquake

3.6 BOUNDARY CONDITIONS AND ASSUMPTIONS

3.6.1 Tank Foundations

The soil boring log (Geotech, 1978) reveals that the soil layer beneath the tanks varies from 0- to 14.5-ft thick. It is very unlikely that fill concrete extends 14.5 ft. below the tank bottom. This analysis evaluates the behavior of the tanks in general. All tanks are considered as supported on soil. In accordance with the methodology of the Uniform Building Code (UBC) and this assumption a higher value, 0.14g, of the peak ground acceleration was used in this analysis.

3.6.2 Structural Integrity

Video inspection shows deterioration of concrete walls in Tanks W-5 and W-6 (Bechtel, 1992; Energy Systems, 1992a). The domes are in good condition. For the finite element analysis, wall section thickness without the inside liner is used. Then, evaluation of the wall sections with further deterioration is hand calculated.

3.6.3 Openings in Dome

Openings in dome vary from 3/8-in.-diameter small pipe penetrations to 30-in.-diameter manholes. The number and location of the openings are not uniform in all tanks (Appendix A). A configuration of one 30-in., five 24-in., and one 12-in. openings is used (Figure 7). All smaller openings (3/8 in. to 6 in.) are ignored; stress concentration around smaller openings is assumed not to be a problem.

3.7 MATERIAL PROPERTIES

f_c' = 5,000 psi, compressive strength of concrete

f_y = 40,000 psi, yield strength of non-prestressed reinforcement

f_{py} = 60,000 psi, yield strength of prestressed reinforcement

f_s = 18,000 psi, allowable tensile stress in non-prestressed reinforcement for static loadings with 33% increase for static loading plus seismic loading

f_c = 1,900 psi, allowable compressive stress of concrete

f_r = 300 psi, concrete tensile stress limit in terms of maximum principal tensile stress (S_1)

The yield strength of the post-tensioning steel f_{py} is specified to be 60 ksi in the original design. The steel was tensioned to 30 to 40 ksi. The stress loss can be as high as 32 ksi (ACI Committee 344, 1981). The post-tensioning steel behaves essentially as regular steel, assuming loss of the entire pre-stressing capability.

3.8 ACCEPTANCE CRITERIA

The underground reinforced gunite tank is evaluated as a shell structure. There is no record indicating the tank has been exposed to elevated temperature nor will be subjected to temperature higher than 150° F. Guiding criteria are from the work of ACI Committees 344 (1981& 1970), 318 (1989), and 334 (1982). High tensile stress areas in concrete are determined by the maximum principal tensile stress theory. Von Mises criterion was also considered, but it was dropped because the Von Mises stresses were driven by a large compression value, and not tension.

The acceptance criteria used in this analysis are based on the working strength design (WSD) design philosophy for design of reinforced concrete (ACI Committee 334 (1982). WSD is the reinforced concrete design criterion in general use during the time in which the tank was constructed.

Crack potential of the shell is determined by comparing computed maximum concrete tensile stresses to the tensile stress limit of concrete.

3.8.1 Tensile Stress in the Concrete

In this analysis, allowable tensile capacity for the comparison with principal tensile stress is taken as the concrete tensile stress limit recommended by Chen (1982) viz., $f_r = 4\sqrt{f'c}$, or approximately 300 psi. This tensile stress is only used as a screening criteria to determine whether a cross section is prone to cracking.

3.8.2 Compressive Stress in the Concrete

The compressive stress in concrete is limited to the WSD-bearing stress allowable for bearing on the full cross section, i.e., 0.38f'c or 1900 psi (ACI 344-70).

3.8.3 Tensile Stress in the Reinforcement

Ultimate tensile capacity is generally limited to the yield strength (Fy) of that grade of steel from which the reinforcement is fabricated. ACI Committee 344 (1981), however, suggests that the allowable tensile stress of the non-prestressed steel be taken as 18,000 psi with 33% increase for seismic loadings regardless of yield stress. The rational for this seemingly non-conservative treatment of reinforcement is that flexure is not the primary behavior in thin shells. Because of the geometry of the shell and the load distribution on the shell, stresses in shell structures are generally compressive or tensile (ACI Committee 318, 1989). ACI 344 (1981) and ACI 334 (1982) recommend that tension in shell structures be carried entirely by the reinforcement and that the reinforcement be sized accordingly. The low allowable stress is conservative for sizing steel in pure tension, however, in flexural situations sizing steel according to this guidance can ultimately lead to brittle behavior. Shell structures generally do not exhibit a large degree of flexural behavior (ACI Committee 334, 1982; ACI Committee 344, 1981; Billington, 1982). The gunite tank in question exhibits bending behavior at the top of the cylindrical wall.

For prestressed reinforcement, the allowable tensile stress is taken as 24,000 psi with 33% increase for seismic loadings.

4. ANALYSIS RESULTS

This section discusses the stresses, displacements, effects of holes in the dome, permissible overloads on top of the dome, permissible reduction in the wall section, tank stability, and structural integrity.

4.1 STRESSES

Of all the load cases considered, the empty tank during earthquake (load case 4) (with no internal hydrostatic pressure to provide counterbalance force to resist the external pressure from the soil) caused highest stress in the tank. The maximum principal stress distribution plot of tank top surface for load case 4 is shown in Figure 9. The stresses for different portions of the tank are discussed in the following paragraphs.

4.1.1 Dome Top Surface

The center portion of the dome is in compression. The maximum principal compressive stress is 642 psi (at midsurface not visible from the plot), which is a low value compared to the allowable compressive stress in concrete (1,900 psi). No further evaluation of compressive stress is needed. There is no significant stress increase near the hole openings. The perimeter of the dome is in tension with stresses less than 150 psi.

4.1.2 Dome Ring

The detailed dome ring stress distribution of Figure 9 is magnified in Figure 10. The dome ring is in tension with stresses ranging from less than 250 psi (in Figure 9) at the top surface to 350 psi at the bottom of the ring in (Figure 10), with an average tensile stress of about 300 psi. The highest principal stress above 650 psi occurs, in a highly localized region viz., at the junction between the dome ring and the top of the wall. The stress decreases very rapidly as the location drops below the dome-wall junction.

4.1.3 Tank wall

As shown in Figure 9, the tank wall is in compression primarily at locations four feet below the top ring-wall junction. The bottom junction with the floor displays slight tensile stress, less than 150 psi, due to flexure caused by lateral earthquake motion.

4.1.4 Dome Ring Bottom Surface

As shown in Figure 11, the center portion of the dome is in compression. Similar to the dome top surface, at locations closer to the edge of the dome, the stresses become tensile. The principal stresses increase to about 200 psi.

4.1.5 Penetrations on Dome

The close-up view of stress distribution around the holes shown in Figure 11 is magnified in Figure 12. The stresses are intensified at the edges of the penetrations. The stress increases around the hole intensify more rapidly at hole locations closer to the dome perimeter (dome ring). The stresses at the bottom edge surface of hole E increase from less than 100 psi to more than 250 psi. The Inner surface of hole E has stress well above 300 psi. Figures 13, 14, and 15 depict the global stress of Sxx, Syy, and Szz respectively. The stress intensification around the holes influences only areas within approximately 1.5 diameters of the hole. It can be seen that when additional holes are drilled, the impact on dome structural integrity can be minimized if the holes are spaced at least three diameters away from other hole center and one diameter away from the dome ring.

4.2 MAXIMUM STRESSES DUE TO TOTAL LOAD

Maximum stresses due to static and seismic loads are presented in Table 1. The directional stresses for node 4071 of element 2126 where stress is maximum are show on page 73 of Appendix A.

For all loading cases, concrete at the top of the wall has a high potential to form horizontal cracks on the exterior surface according to the maximum principal tensile stress theory. The vertical reinforcement at the top of the wall is not in compliance with ACI codes for resisting moments. However, reinforcement is adequate to withstand hoop tensile forces in the wall, dome ring, and stresses in most of the dome as required by ACI-318, ACI-334, and ACI-344. Another area not fully in compliance with the ACI codes on the requirement of reinforcement is the 3-ft band at the edge of dome; however, the concrete tensile stress in this area is relatively low failure is not expected to occur. Figures 16 through 18 show the distribution of stresses.

Table 1. Maximum stresses of overall tank structure (psi)

Type of Stress		Location*	Node	Static and Seismic Loads		Static Load		Ratio**
				Loading Case	Stress (psi)	Loading Case	Stress (psi)	
Directional Tensile and Shear Stresses	Sxx	1	8128	6	542	2	488	1.11
	Syy	5	4071	4	549	1	489	1.12
	Szz	3	8592	4	833	1	781	1.07
	Sxy	6	4071	4	544	1	491	1.11
	Sxz	4	8903	8	453	3	410	1.10
	Syz	6	41	4	523	1	488	1.07
Principal Stresses	Tension	6	4071	4	689	1	621	1.11
	Compression	2	8595	4	642	1	597	1.08
	Tmax	6	4071	4	467	1	420	1.11

NOTES:

Stresses shown above are finite fiber stresses for an uncracked section. Stresses may have been recast in calculations in order to evaluate reinforced cross sections.

*Locations 1: 30-in. opening, bottom surface
2: 30-in. opening, middle surface
3: 30-in. opening, top surface
4: Edge of dome, bottom surface
5: Bottom of ring
6: Top of wall, exterior surface

**Ratio = Stress due to static plus seismic load/stress due to static load

Table 2. Maximum stresses at top of wall (psi)

Type of stress at Node 4071		Static and Seismic Loads (Loading Case 4)	Static Load (Loading Case 1)	Ratio*
Directional Tensile and Shear Stresses	Sxx	215	196	1.10
	Syy	200	189	1.06
	Szz	250	249	1.00
	Sxy	544	491	1.11
	Sxz	1	1	1.00
	Syz	7	10	0.70
Principal Stresses	S1	689	621	1.11
	S2	250	249	1.00
	S3	-246	-218	1.13

NOTES:

Stresses shown above are finite fiber stresses for an uncracked section. Stresses may have been recast in calculations in order to evaluate reinforced cross sections.

*Ratio = Stress due to static plus seismic load/stress due to static load.

4.3 DISPLACEMENTS

All displacements are small. Displacements are listed below and are illustrated in Figures 19 and 20. Although temperature change and shrinkage effects are not included in the analysis, these small displacements indicate that no further evaluation is needed. They also reveal that monitoring the displacements of the dome will not give adequate indication of any potential overall structural failure.

	Maximum Displacement (in.)	Location	Element	Node	Loading Combination
Vertical	0.093	Center of dome	58	152	5
Horizontal	0.023	Top of wall	20	41	5

4.4 EFFECTS OF HOLES IN DOME

The maximum principal tensile stress around the 30-in. manhole is 316 psi. The stress is not high compared to other locations. It is reasonable to conclude that any additional openings smaller than 30-in. diameter and not located within three diameters of another opening or the edge of the dome ring can be made in the dome without inducing stress concentration problems (Timoshenko and Goodier, 1951). Any openings larger than 30-in. diameter should be evaluated on a case-by-case basis.

4.5 ADDITIONAL DOME LOADS

Additional soil or equipment load on the dome may cause horizontal cracks on the exterior surface of the wall in a narrow band just below the dome ring. However, stresses exceeding the cracking strength of the concrete only exist in localized areas. The stability of the tank is not threatened since the stresses in the remainder of the tank wall and the dome ring are not high.

Further analysis should be performed to determine the effects of additional soil load and large concentrated loads on the dome (e.g., platform columns and footings).

4.6 REDUCTION IN SECTION

The 1.5-in. gunite liners on the interior surface of the wall in Tanks W-5 and W-6 show some degree of spalling, patches of welded mesh wires are exposed. Inspection did not show any deterioration in other tanks.

Deterioration at the top of the wall can be a problem. After exposure to the chemicals, the quality of gunite becomes uncertain. The maximum principal tensile stress, already at the code stress limits, may be intensified and additional cracking may occur. No reduction of the wall thickness in the top 2 ft is desirable. A reduction of 1 in. is acceptable for the portion of the wall 2 ft below the top. If the section reduction is located at 3 ft or more below the top of the wall, then a reduction of 2 in. in the wall thickness is acceptable.

4.7 STABILITY

This analysis shows that the dome shell exhibits a safety factor of 51 against buckling. This factor is considerably larger than safety factor of 4 to 6 recommended by ACI 344-70. The structural stability of the tank dome is, however, dependant on the peripheral confinement provided by the dome ring. The dome ring is primarily subjected to tensile loading which is resisted by embedded reinforcement having a yield strength of 60 ksi. This analysis shows the dome ring reinforcement exhibits a capacity to demand ratio of 1.88 with respect to the recommended ACI 318-89 working stress tensile allowable of 24 ksi for prestressed reinforcement (reinforcement resisting all tension in the cross section). With respect to yield, the ring reinforcement exhibits a capacity to demand ratio of 3.5. The cylindrical wall exhibits a safety factor of 44 against buckling.

4.8 STRUCTURAL INTEGRITY

It is the conclusion of this analysis that the gunite tanks are structurally sound and are adequate to perform the functions they were designed for. The structural stability of the tank dome is dependant on the integrity of the dome ring. For the load conditions considered the dome ring exhibits a capacity to demand ratio of 1.88 with respect to working stress limits and a demand capacity ratio of approximately 3.5 with respect to ultimate strength limits.

The hoop tension capacities in both the ring and cylindrical wall are more than adequate to resist the loads considered by this analysis.

Vertical tensile stresses at the top of the wall on the exterior face are high and reinforcement is not adequate to prevent surface cracking. The interior face of the wall in this region of the tank wall is in compression and should prevent both in and out leakage of liquids at this level. The tank will not loose its structural stability even if plastic hinges are formed along the top of the wall below the dome ring.. Historically, many tanks have been constructed with structural hinges between the dome and wall and have performed satisfactorily.

5. RECOMMENDATION AND SUGGESTIONS

These recommendations are presented as guidelines for future studies of the tanks and to reduce the chances of accidents during work in the area of the tanks.

5.1 CORE SAMPLING AND OPENINGS

Core samples should not be taken from the dome inside the three foot wide circumferential band adjacent to the dome ring or within three penetration diameters of an existing penetration. Core samples should not be taken from the wall in the two foot deep circumferential band adjacent to and immediately below the dome ring. Cores should not be taken from any location in the dome ring cross section. The integrity of the thickened ring must be maintained to prevent an overall structural failure.

Core samples may be from all other areas of the tank, however, main reinforcement steel should not be cut without approval of the cognizant engineer.

5.2 FINITE ELEMENT MODELING

For future analysis, a finer grid may be used to model the top 3 ft of the wall and in the areas within 3 ft of the dome edge where the high stresses exist. The finer grid will allow the evaluation of reduced thickness in the deteriorated portions of the wall.

A dynamic SSI analysis, if desired, can be performed on a 2-D slice of the tank and surrounding soils. A 3-D dynamic SSI analysis can be performed on a coarse-grid, simplified model in light of limited computer capability.

5.3 GROUP BEHAVIOR OF TANKS

The 50-ft tanks in the South Tank Farm are located 60 ft apart, center-to-center, and thus the clear distance between tanks is less than 10 ft. The behavior of a tank is modified by adjacent tanks. Different assumptions are made about soil and tank conditions when a single tank is considered than are made when a group of closely spaced tanks are considered. This analysis performed a limited investigation based on a study of the behavior of a group of tanks (Xu et al. 1994). The study found that the maximum stress increase due to tank-to-tank interaction is about 3% over the combined stress of a single tank and does not change the overall structural assessments. However, it is suggested that this phenomenon especially for groups of concrete tanks, be further investigated.

5.4 ADDITIONAL LOADING ON DOME

The dome roof should not be subjected to any additional soil or equipment load without engineering evaluation. Limited additional loads will cause cracking below the dome ring before buckling occurs, if the cracked tank can still meet the functional requirements.

5.5 SOIL SAMPLING AND TESTING

The existing soil boring log gives only limited information on soil; consequently, only conservative assumptions are used in the current analysis.

Standard Penetration Test (SPT) with blow counts, ground water level information, and lab index testing are all required for any important engineering evaluation.

If SSI analysis is attempted, then some additional lab testing of undisturbed soil samples is needed.

5.6 INSTRUMENTATION

It would appear to be ineffective to monitor the deflections of the dome for the detection of impending collapse of the tanks. The analysis shows that deflections are very small under all loading conditions. Monitoring the circumferential displacement or strain of the dome ring will be an effective method to predict impending dome failure.

Video inspection of the interior of the tank, concentrating on the areas near the top of the wall, offers the best chance for detecting structural deterioration.

5.7 OTHER CALCULATION METHODS

A hand calculation on the tank stress was performed by Hanskat (1995) based on design formula in ACI 344 (1988). The tensile stress of the dome ring reinforcement was reported to have exceeded the code-allowable stress of 32,000 psi. This method served well as a conservative design tool and provided favorable comparison of the finite element analysis. The overly conservative design approach does not provide sufficient information about the factor of safety needed to assess the existing dome-ring stress condition under current loads. The calculated safety factors against tank buckling are consistent with the finite element results.

6. REFERENCES

ACI Committee 318 (1989). "Building Code Requirements for Reinforced Concrete (ACI 318-89) and Commentary (ACI 318R-89)," American Concrete Institute, Detroit, MI.

ACI Committee 334 (1982). "Concrete Shell Structures Practice and Commentary (ACI 334.1R-64) (Revised 1982)," American Concrete Institute, Detroit, MI.

ACI Committee 344 (1981). "Design and Construction of Circular Prestressed Concrete Structures (ACI 344R-70) (Reaffirmed 1981)," American Concrete Institute, Detroit, MI.

ACI Committee 344 (1988). "Design and Construction of Circular Wire and Strand Wrapped Prestressed Concrete Structures (Report by ACI Committee 344, October 1988)" American Concrete Institute, Detroit, MI.

Bechtel National, Inc. (1992). "Video Inspection Data Manual for Inactive LLLW Storage Tanks at Oak Ridge National Laboratory, Oak Ridge, Tennessee," Report No. ORNL/ER/Sub/87-990053/45, Martin Marietta Energy Systems, Inc., prepared by Bechtel National, Inc./CH2M Hill/OGDEN/PEER, September 1992 (DRAFT).

Beavers, J and Hunt, J. (1994). "Site Specific Earthquake Response Spectra for The DOE Oak Ridge Reservation." PVP-Vol.271, Proceedings, ASME Pressure Vessels and Piping Conference on Natural Hazard Phenomena and Mitigation, Minneapolis, Minnesota, 1994, pp65-72.

Billington, D. P. (1982). Thin Shell Concrete Structures, McGraw-Hill Book Co., New York.

Chen, W. F. (1982). Plasticity in Reinforced Concrete, McGraw-Hill Book Co., New York.

Fricke, K. (1986). "Seismic Analysis of the Underground Gunite Tank at the ORNL South Tank Farm," Report No. X-OE-313, Martin Marietta Energy Systems, Inc., Oak Ridge, TN, January 10.

Energy Systems (1992a). "ORNL Inactive Liquid Low Level Waste Storage Tank Video Inspection Summary," Videotape No. 1095, Oak Ridge, Tennessee.

Energy Systems (1992b). "Phase 1 - Safety Analysis Report (SAR) Update Program, Hazard Screening for South Tank Farm Facility 3507", HS/3507/F/1/RO, July 28, 1992.

Fricke, K. (1993). "Seismic Analysis of the Underground Gunite Tanks at the ORNL South Tank Farm," Martin Marietta Energy Systems, Inc., Oak Ridge, TN, May.

Geotek, Inc. (1978). "Subsurface Investigation for Gunite Tank Decommissioning Building at Oak Ridge, Tennessee," Geotek Project No. 78-552 for Union Carbide Corp., Oak Ridge, Tennessee.

GTICES Systems Laboratory (1991). GTSTRUDL User's Manual, Rev. M, Georgia Institute of Technology, Atlanta, GA.

Henskat, C (1995) "Gunite and Associated Tanks Operable Unit (GAAT), Evaluation of Dome and Wall Strength Under Current Loading." Report from The Crom Corporation to James Blank of Advanced Systems Technology, Inc. at Oak Ridge, TN. May 11, 1995

Newmark, N. M. and Rosenblueth, E. (1971). Fundamentals of Earthquake Engineering, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Prakash, S. (1981). Soil Dynamics, McGraw-Hill Book Co., New York.

Timoshenko, S. and Goodier, J. N. (1951). Theory of Elasticity, McGraw-Hill Book Co., New York.

UBC (1994). Uniform Building Code - Structural Engineering Design Provisions, 1994, Section 1627 and Table 16-J.

Xu, J., Bandyopadhyay, K., Miller, C., and Costantino, C. (1994). "Spacing Effects on Seismic Responses of Underground Waste Storage Tanks. PVP-Vol. 271, Proceedings, ASME Pressure Vessels and Piping Conference on Natural Hazard Phenomena and Mitigation," Minneapolis, Minnesota, 1994, pp. 13-18.

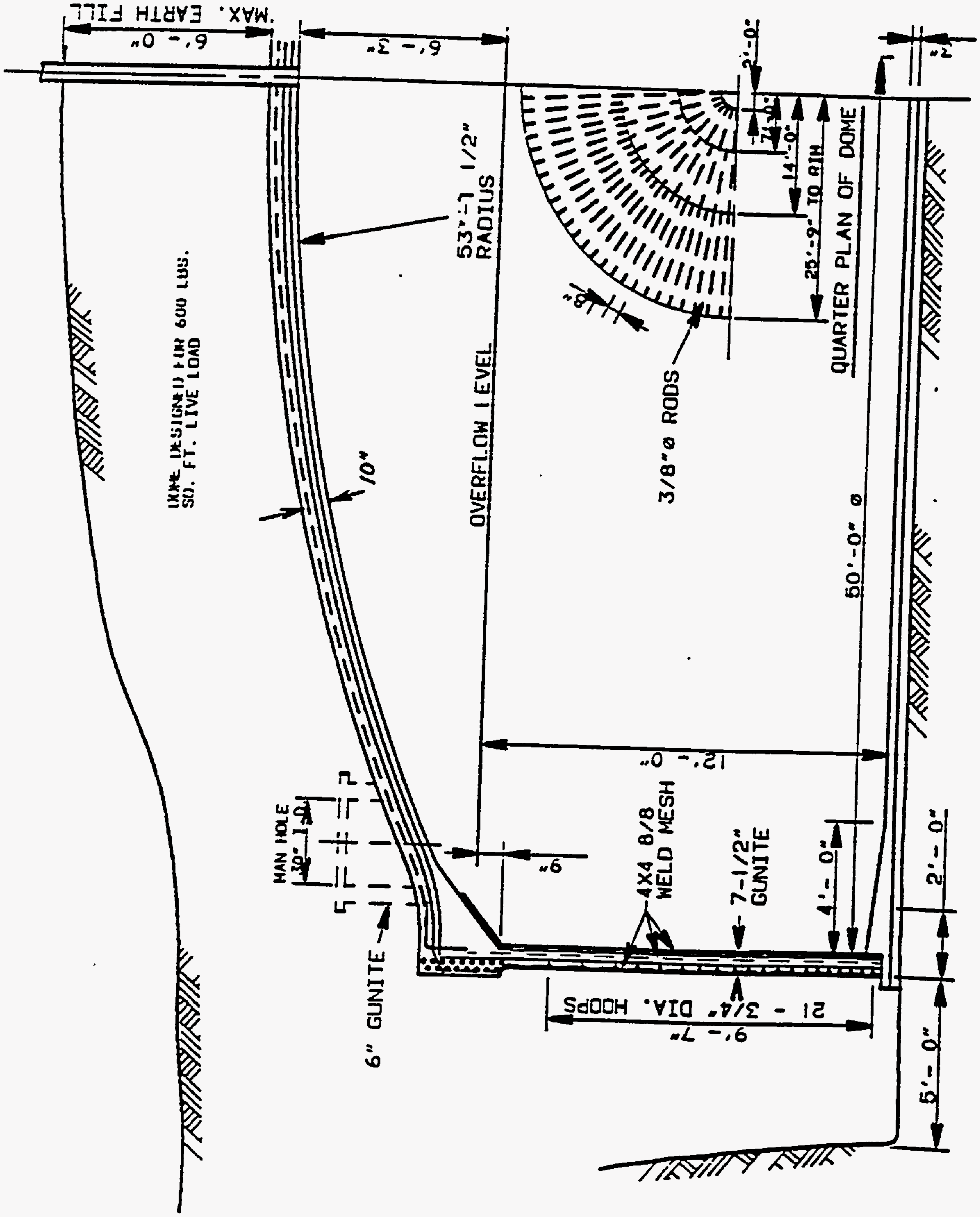


Fig. 1. Cross-Sectional View of Tank.

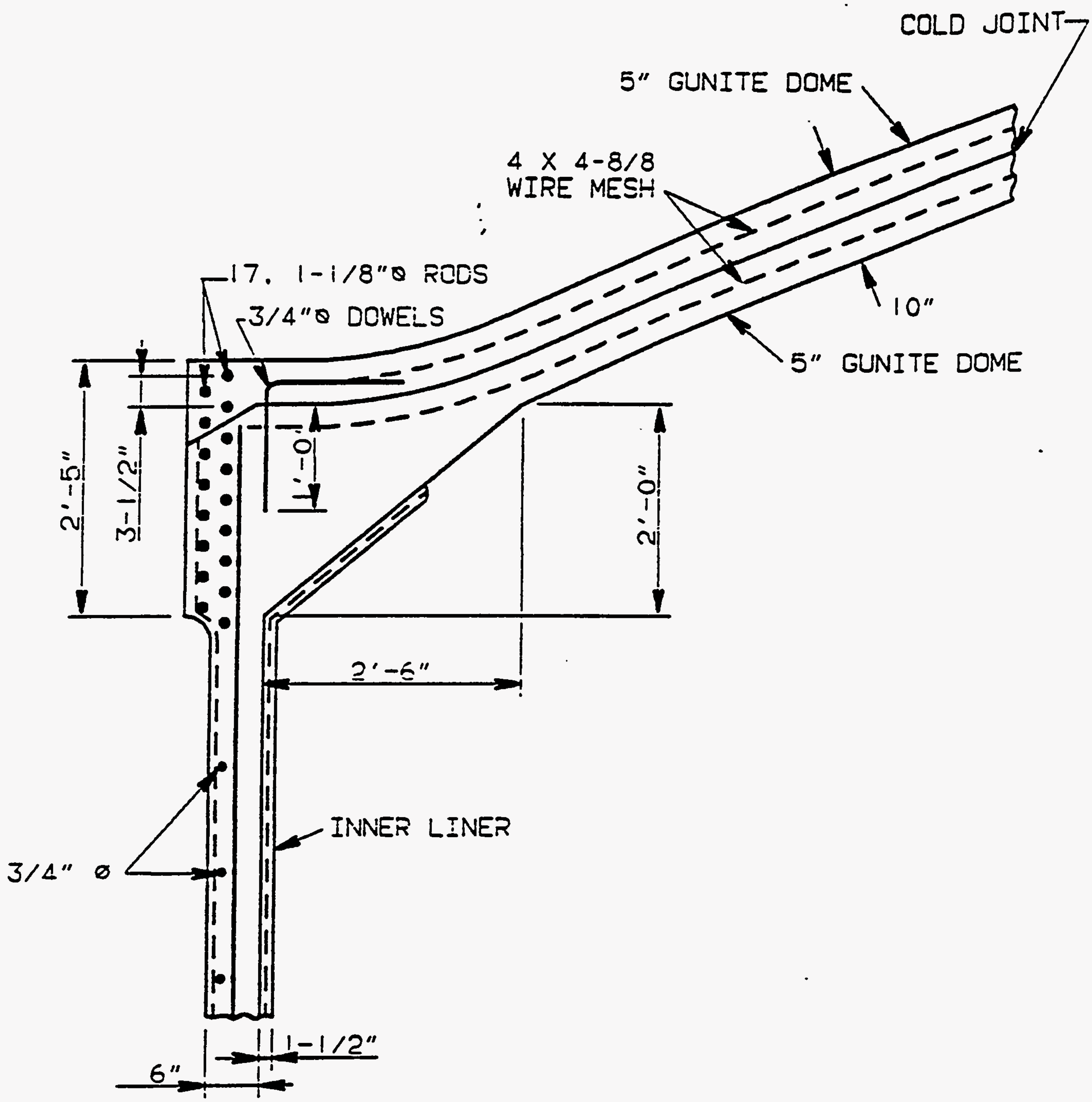


Fig. 2. Section View Through Dome

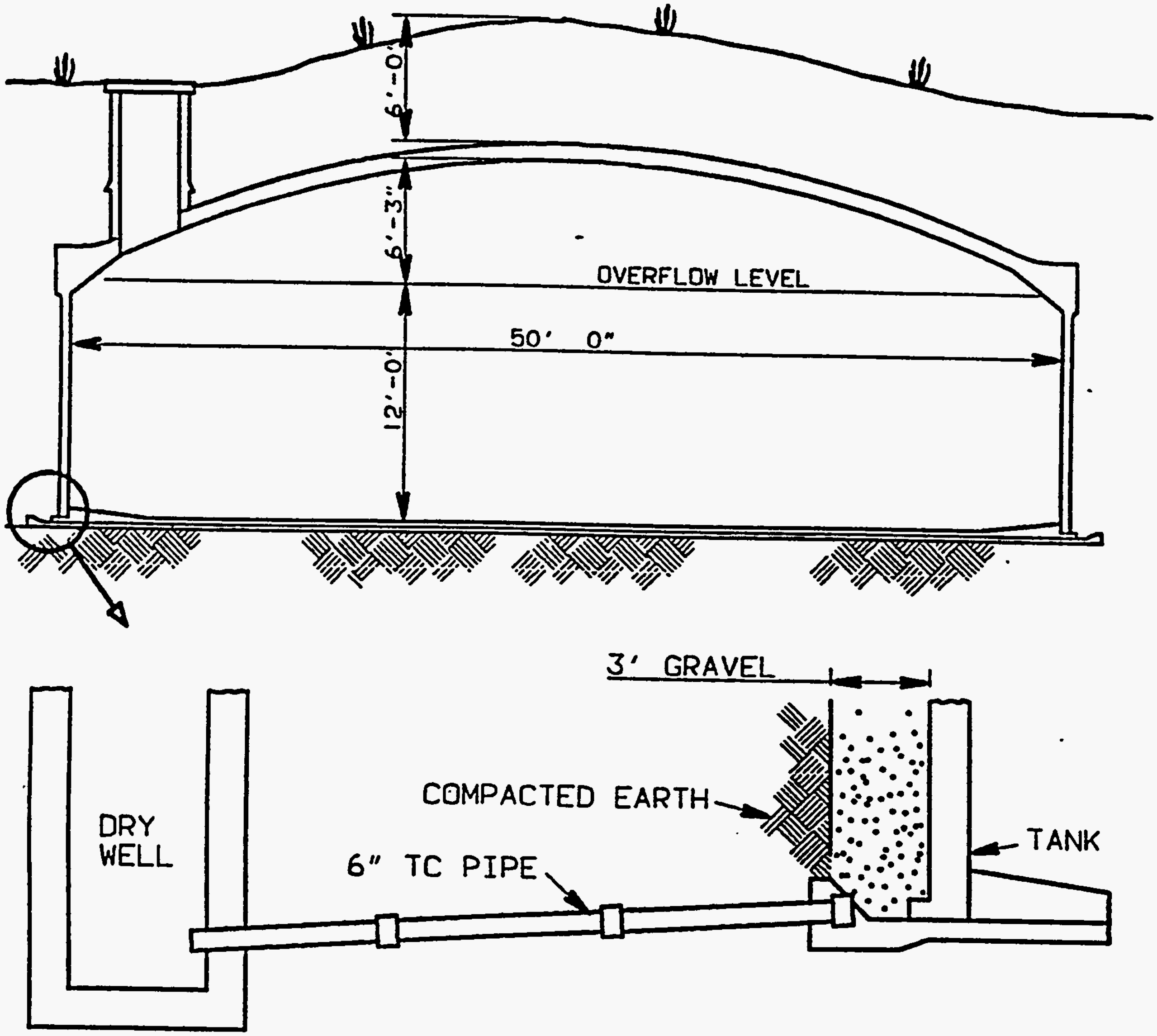


Fig. 3. Full Cross-Sectional View of Tank.

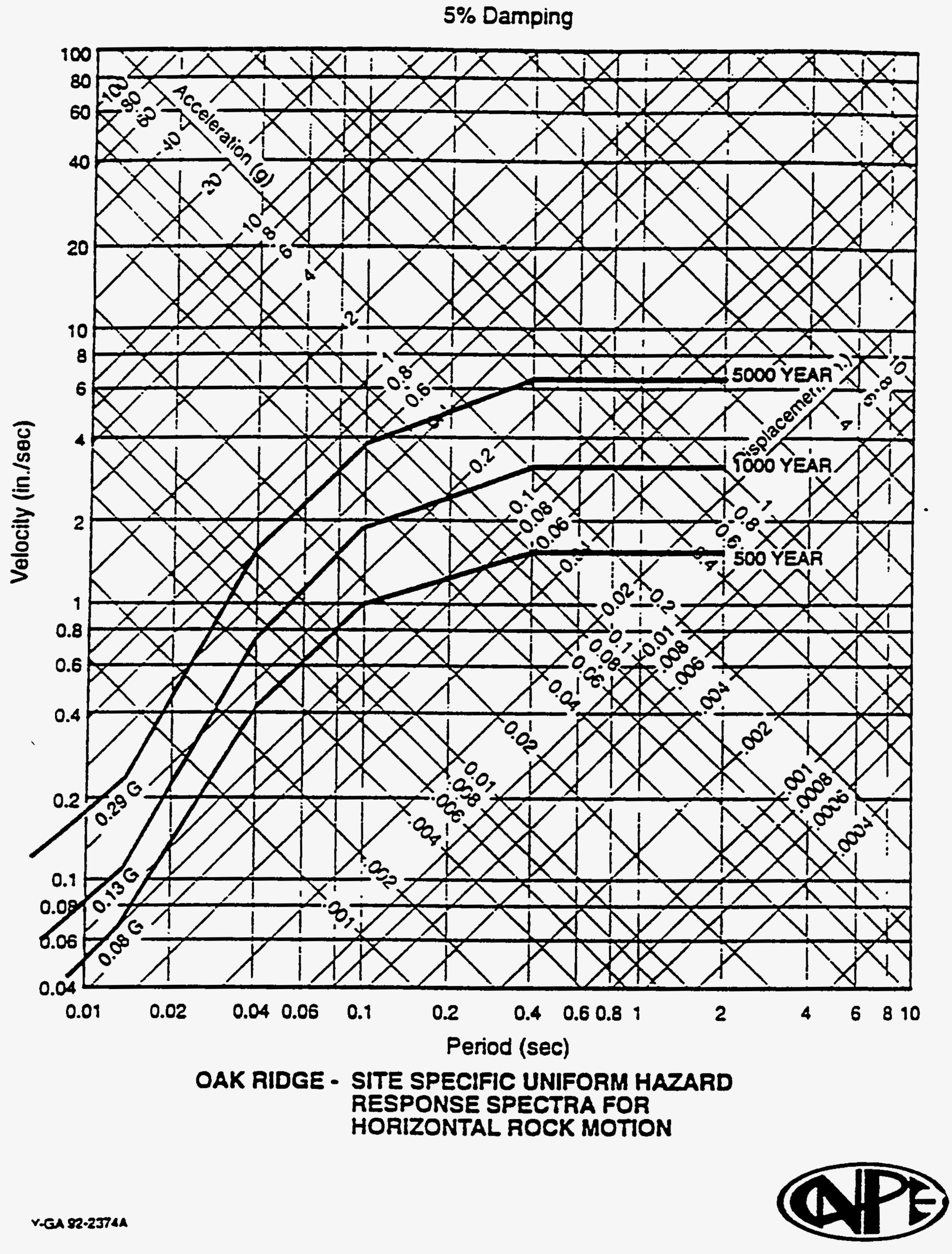


Fig. 4. Oak Ridge-Site Specific Response Spectra For Horizontal Rock Motion

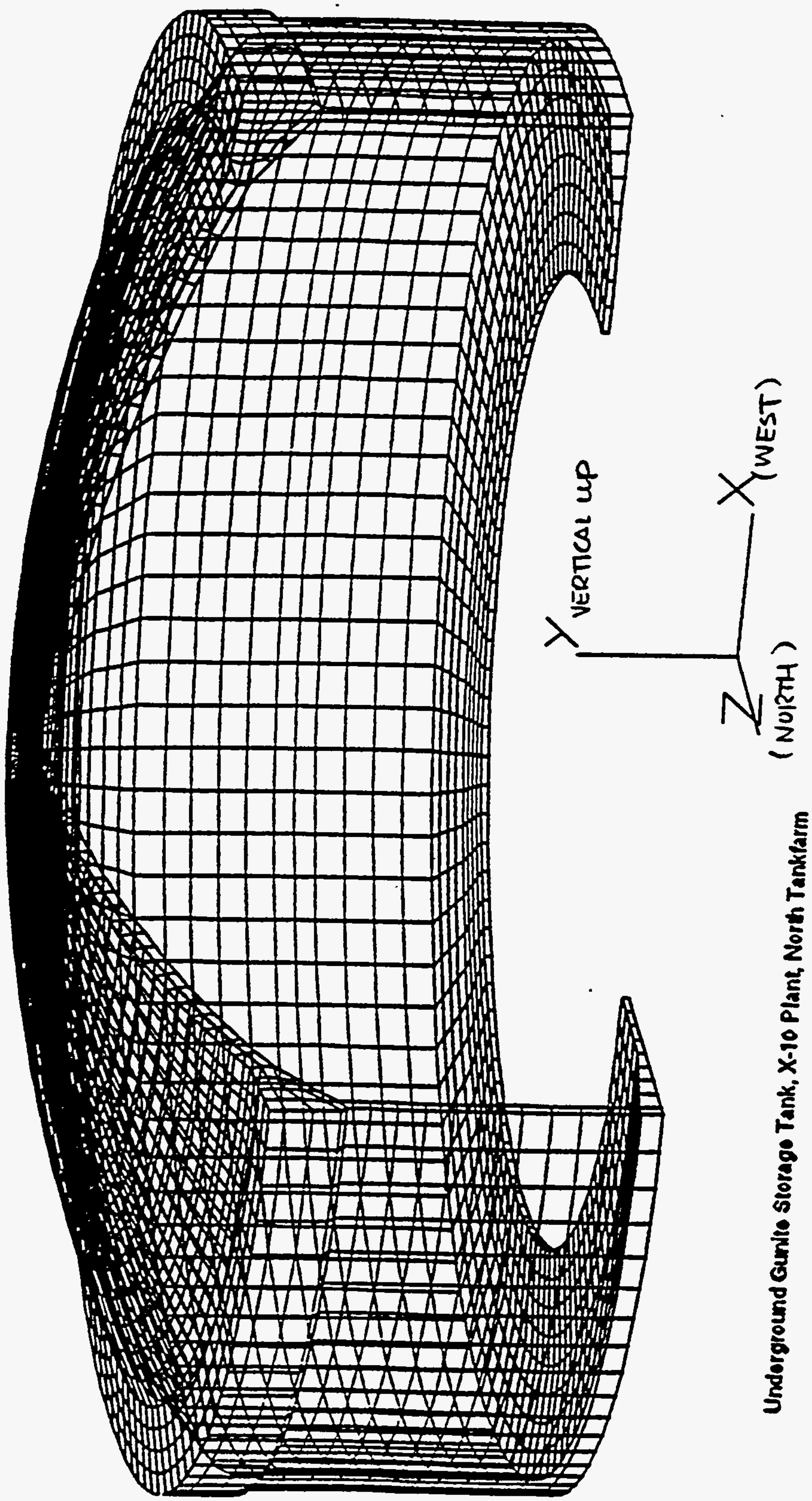


Fig. 5. Cut-up Section of Tank

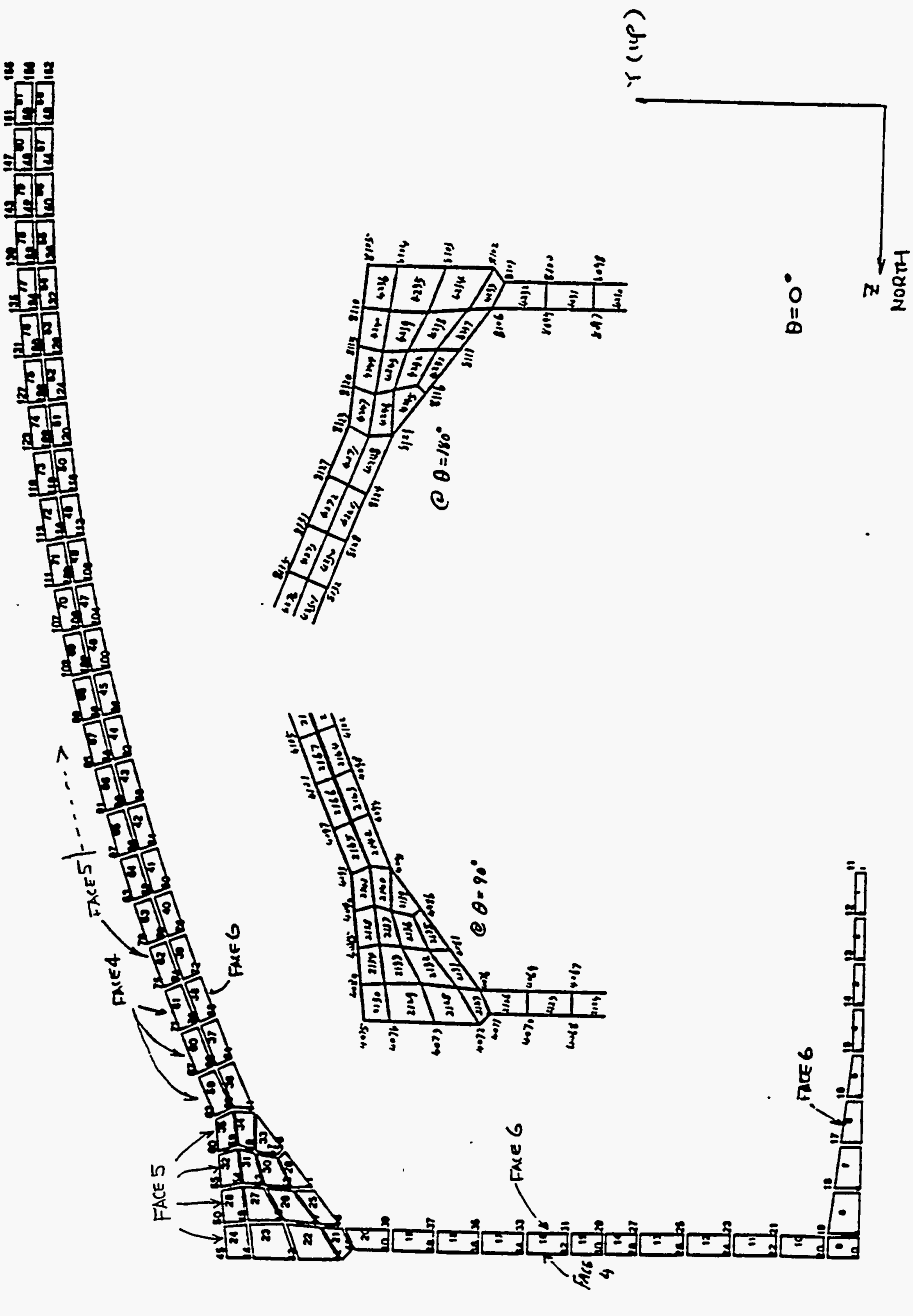


Fig. 6. Finite Element Numbering System

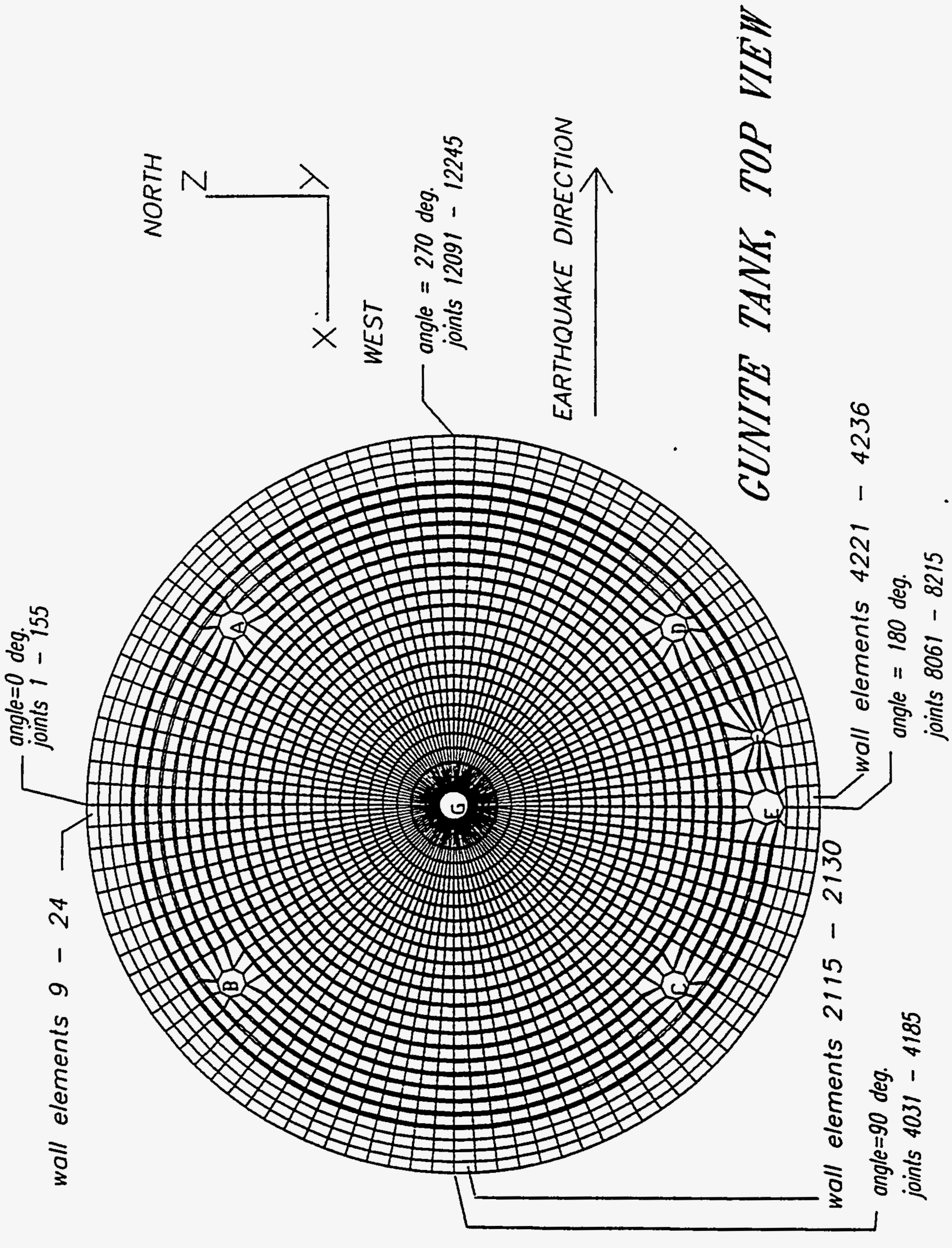


Fig. 7. Dome Opening Locations

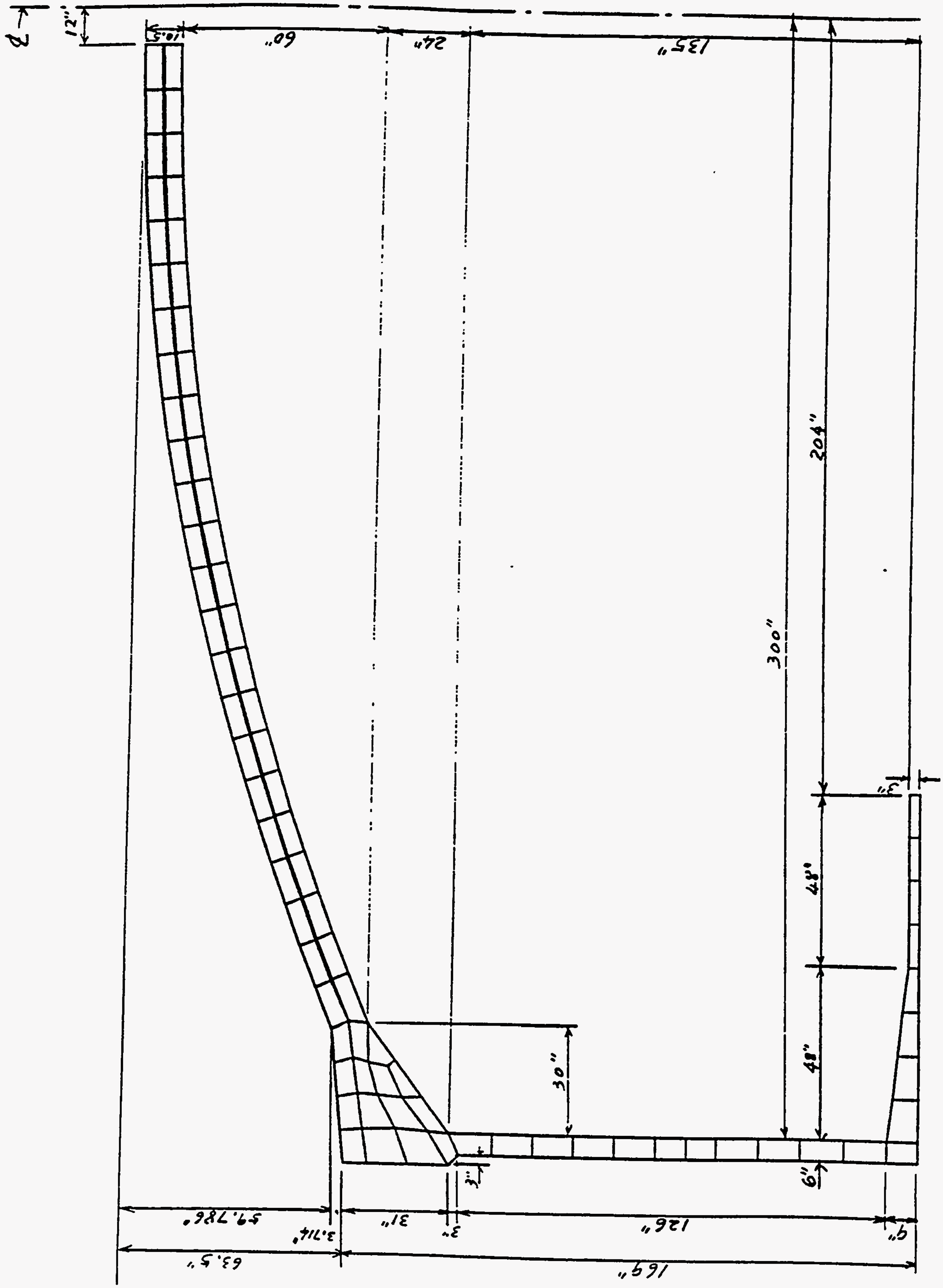


Fig. 8. General Tank Section Dimensions

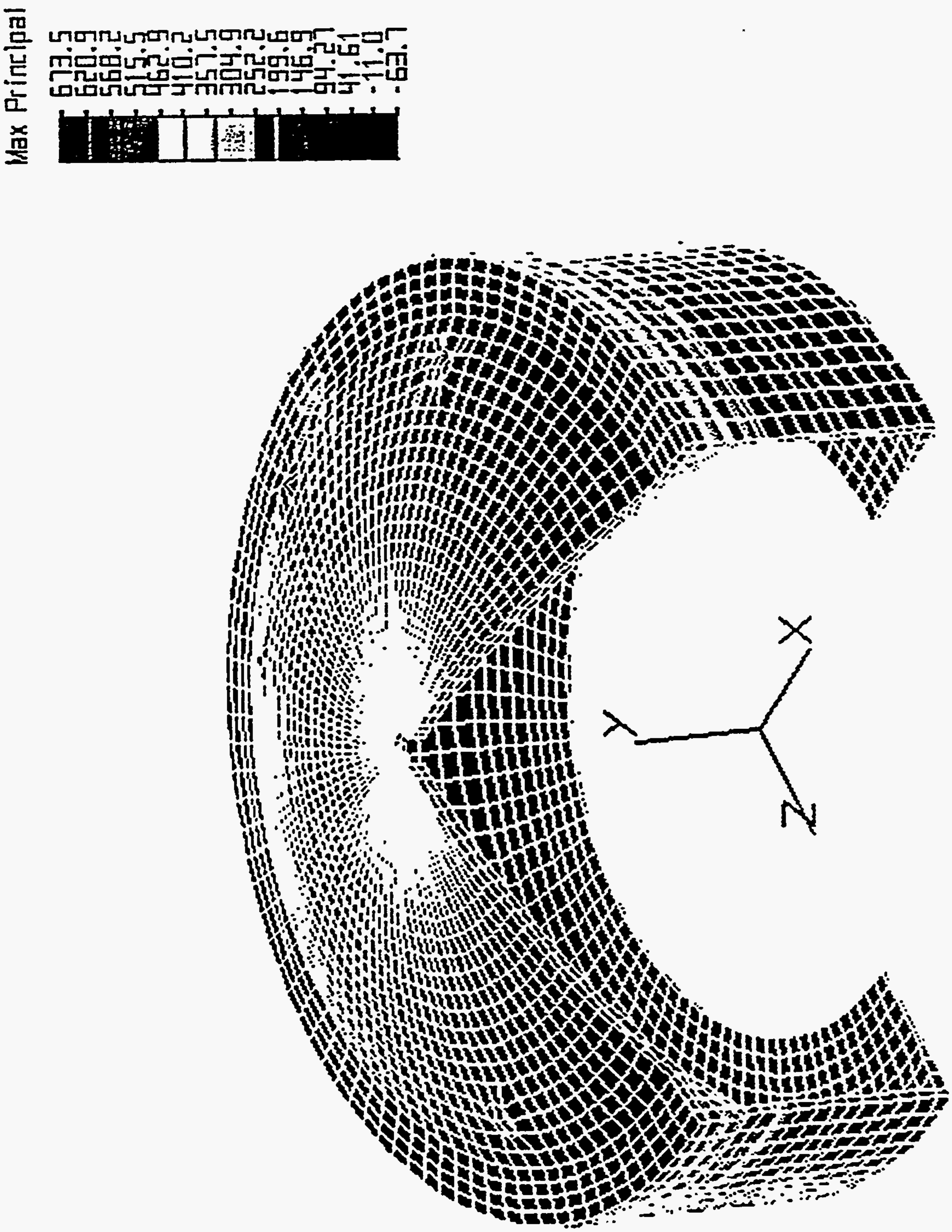


Fig. 9. Stress Distribution of External Tank Surface

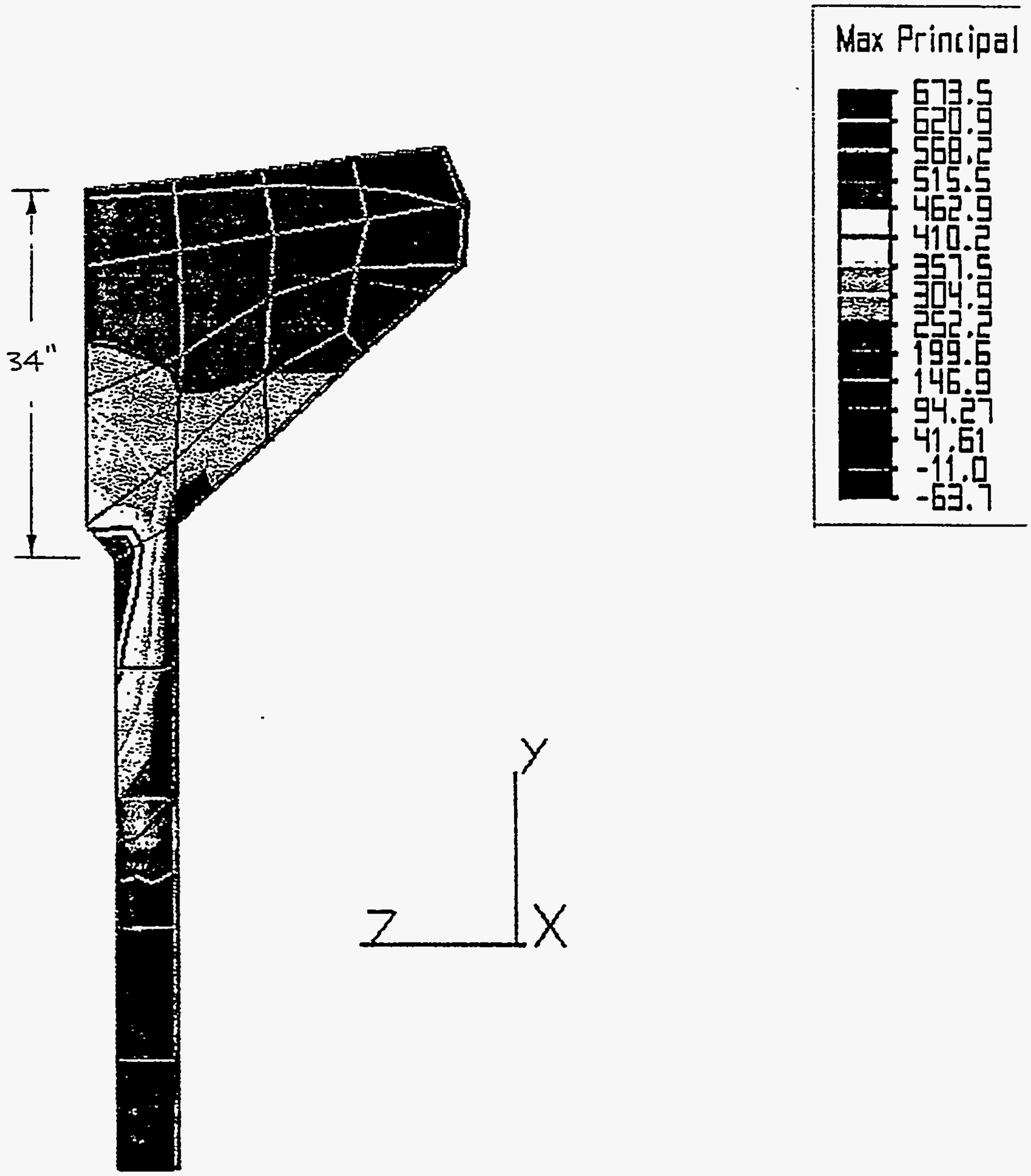


Fig. 10. Stress Distribution at Tank Wall and Dome Ring Junction

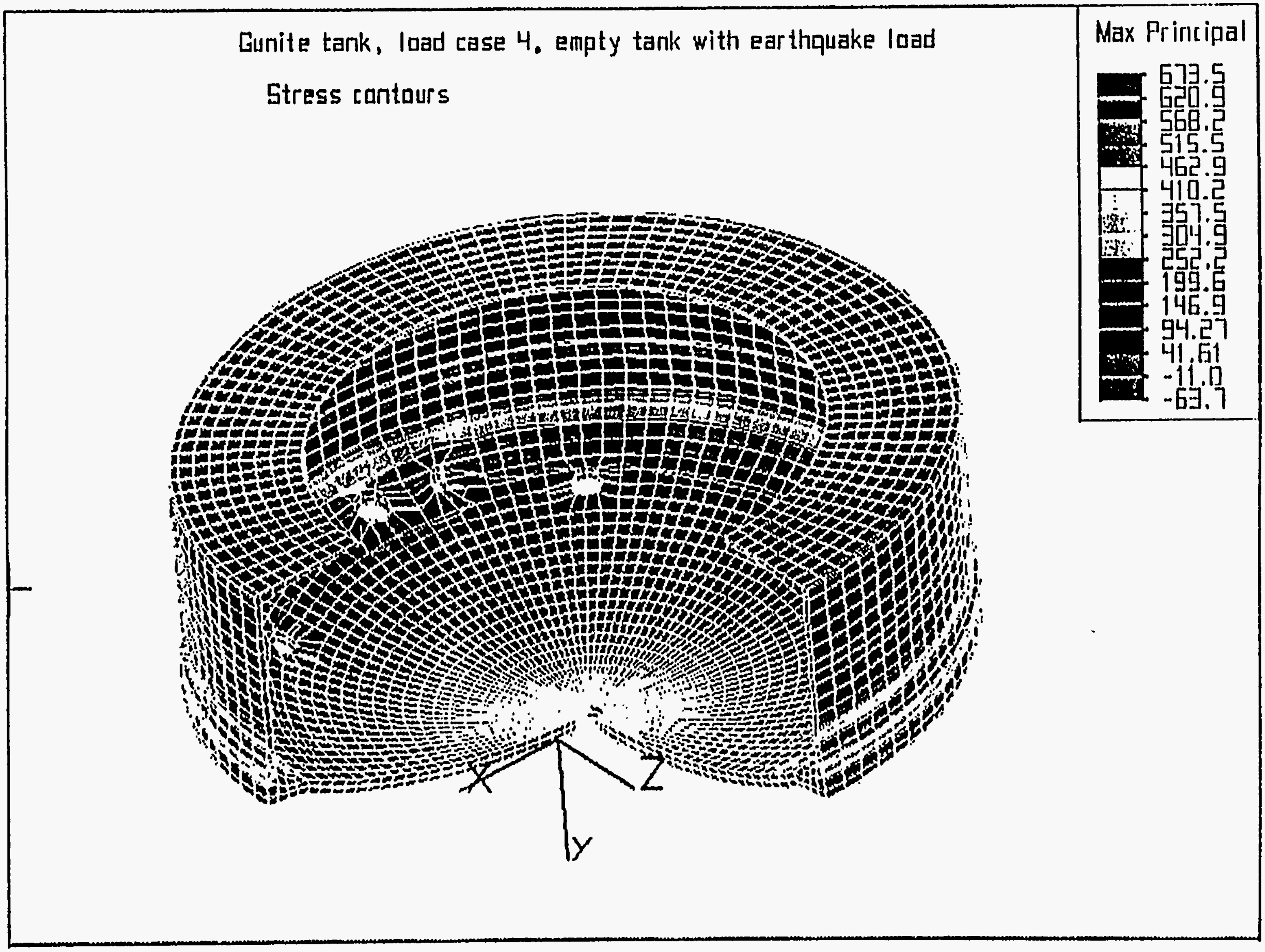


Fig. 11. Principal Stress Distribution of Tank Internal Surface

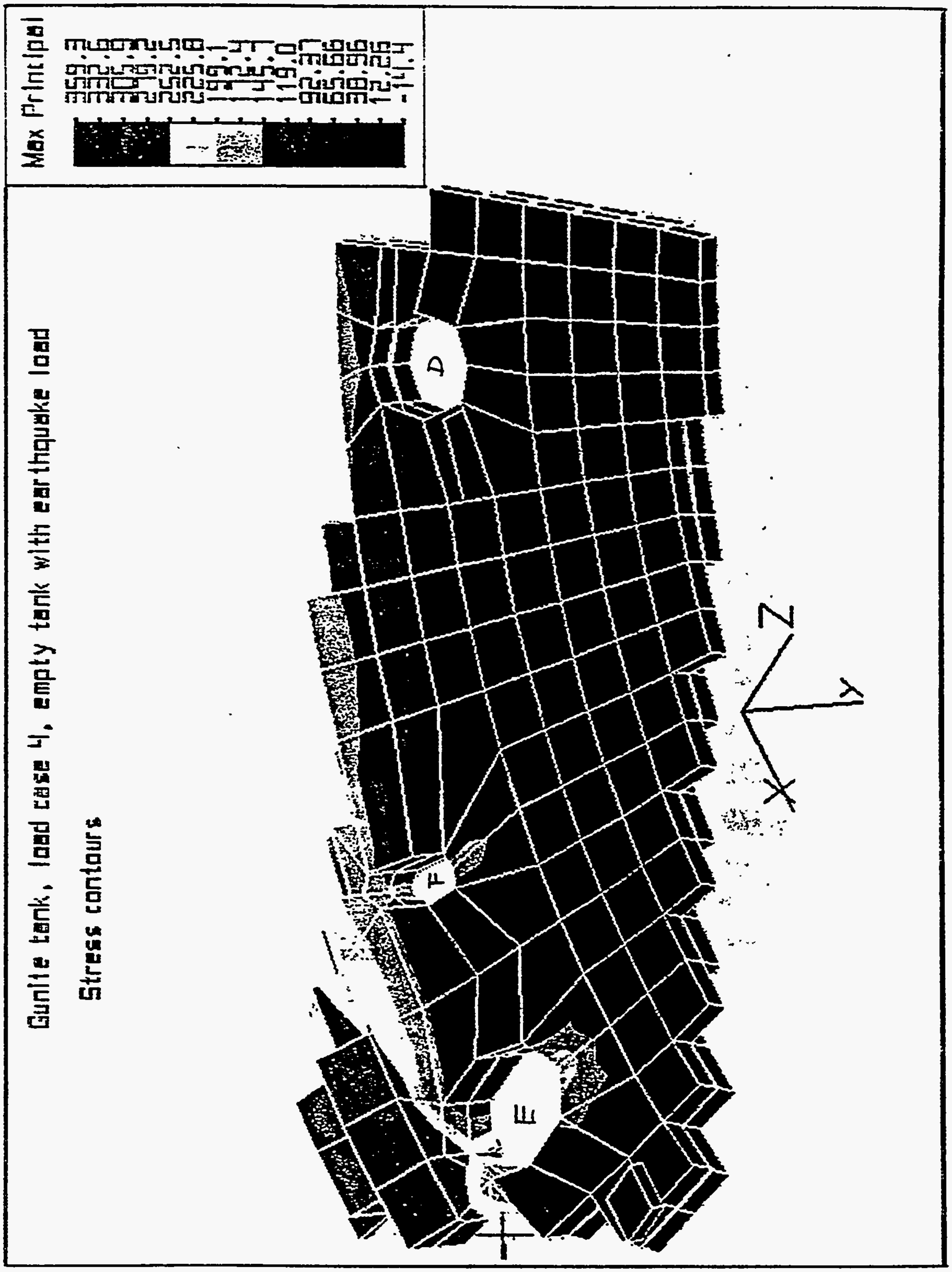


Fig. 12. Principal Stress Distribution Around Dome Penetrations

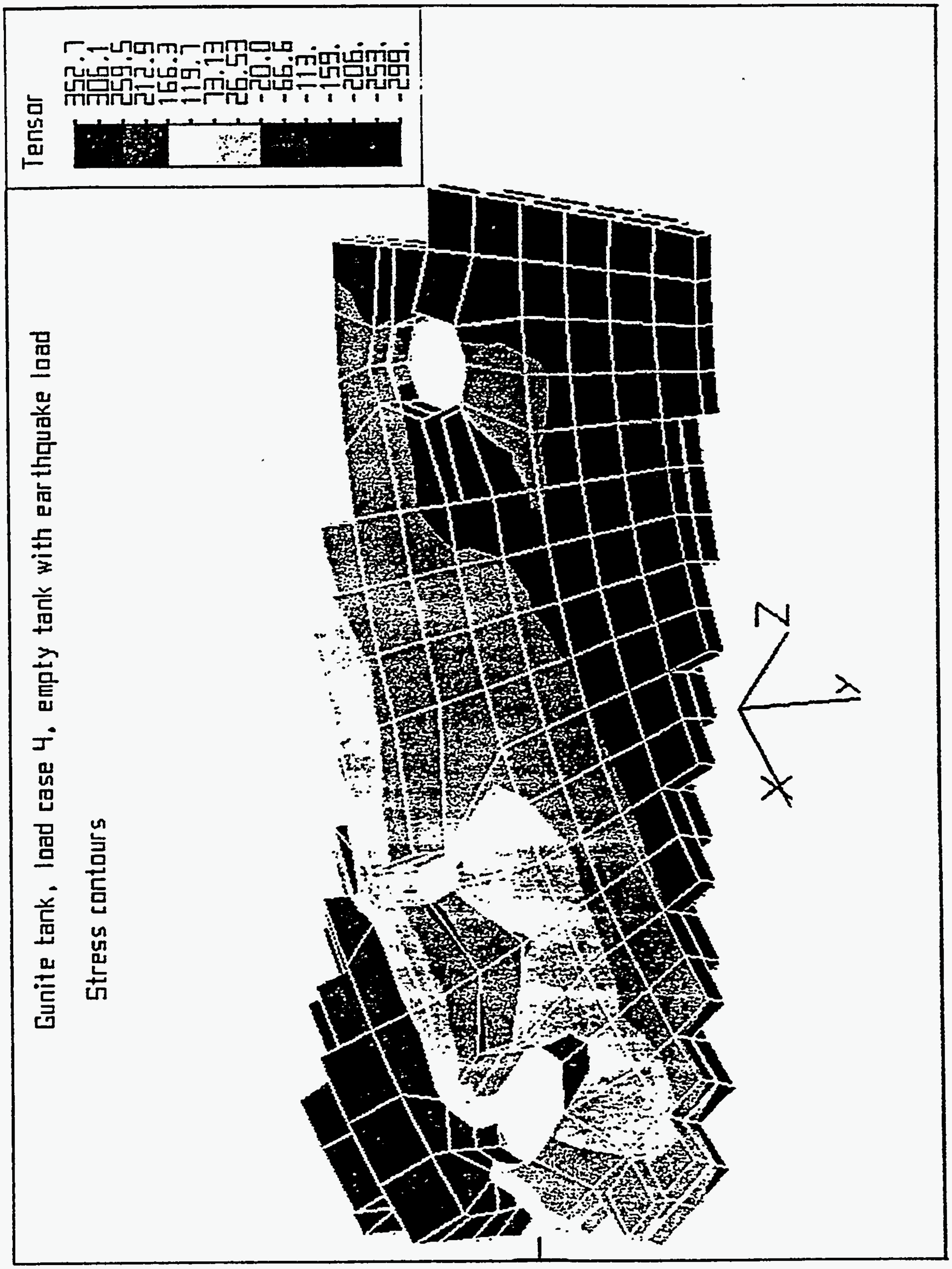


Fig. 13. Stress Distribution of Global Stress Sxx Around Dome Penetrations

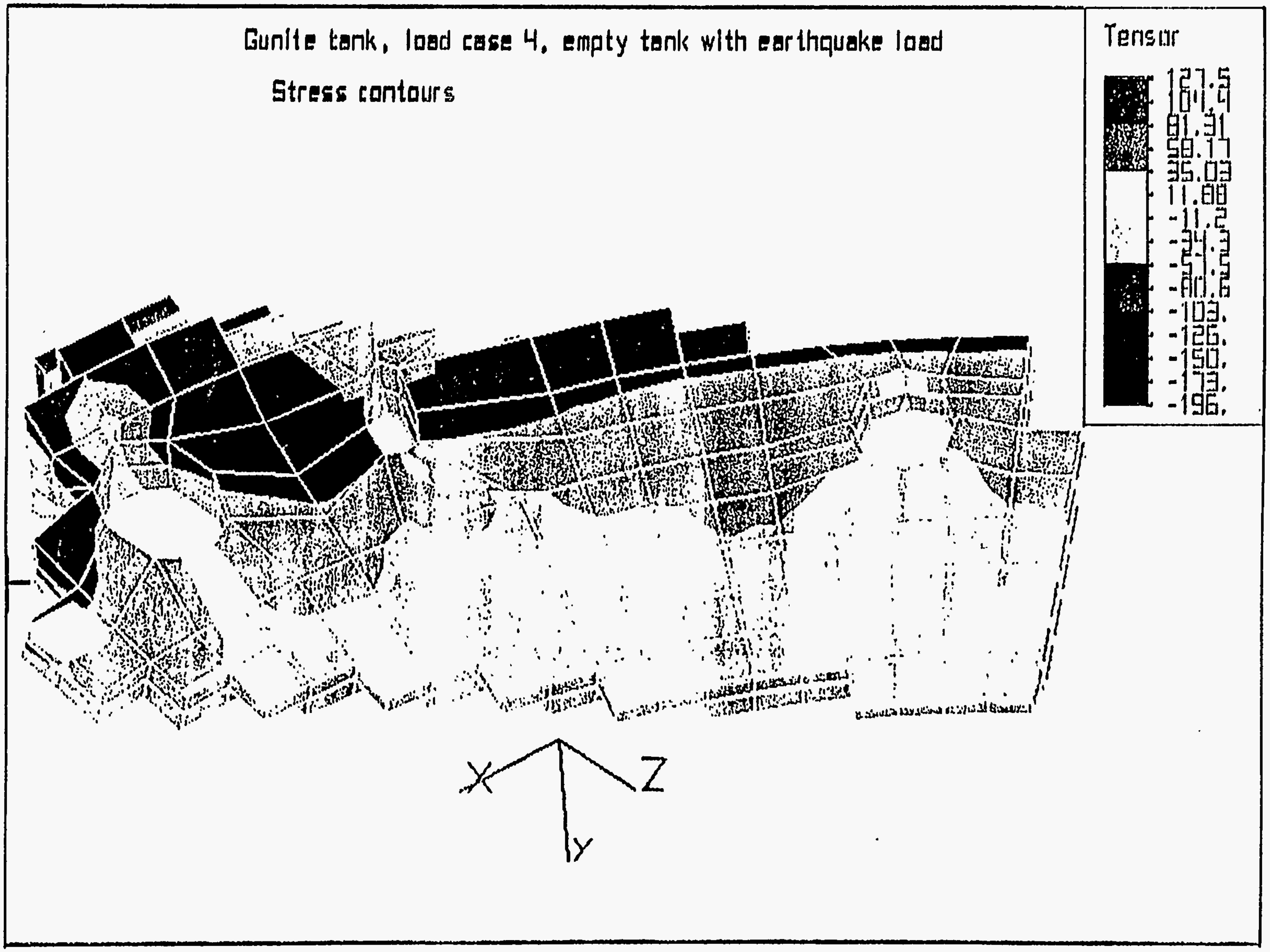


Fig. 14. Stress Distribution of Global Stress Syy Around Dome Penetrations

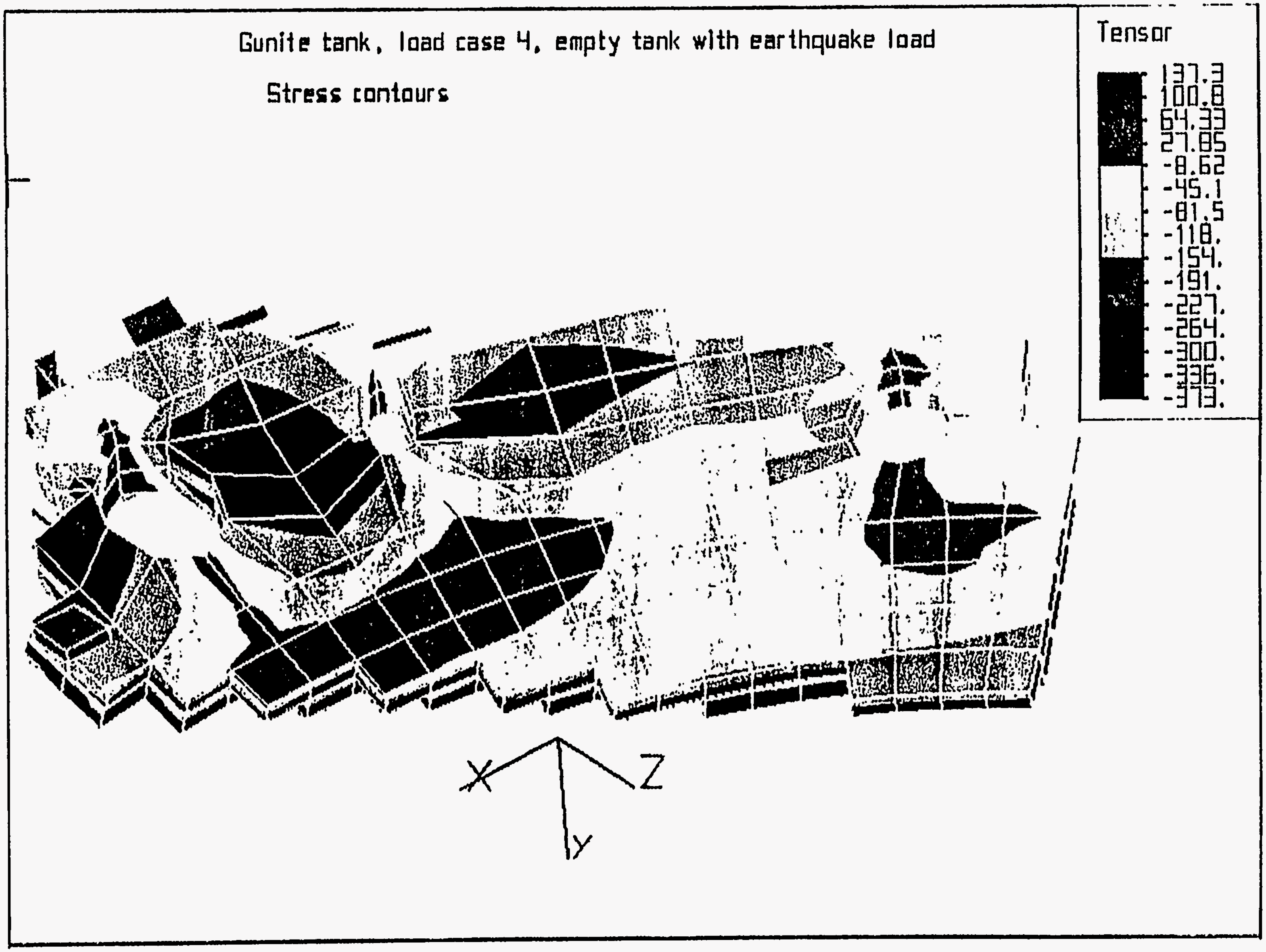


Fig. 15. Stress Distribution of Global Stress Szz Around Dome Penetrations

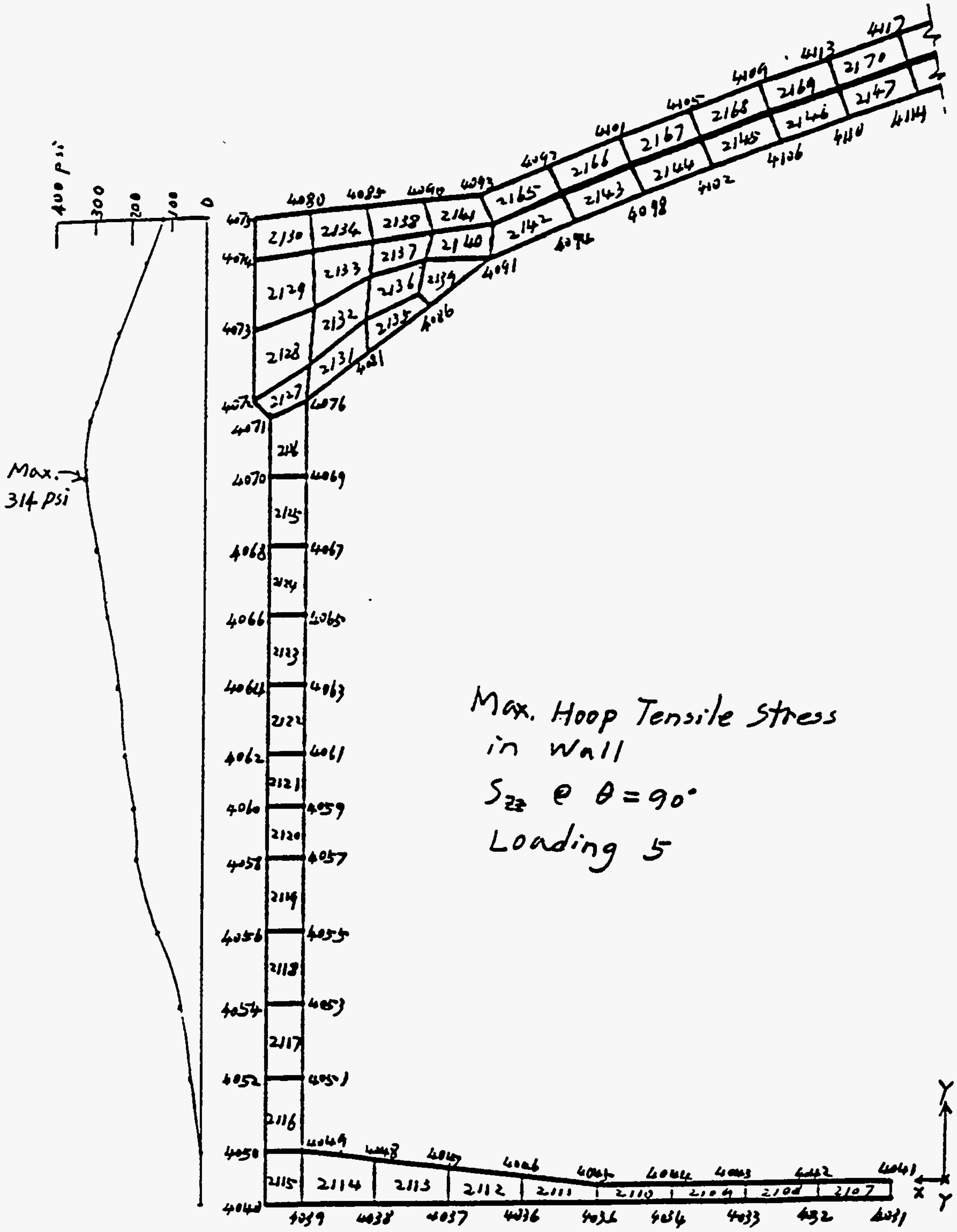


Fig. 16. Maximum Hoop Tensile Stress

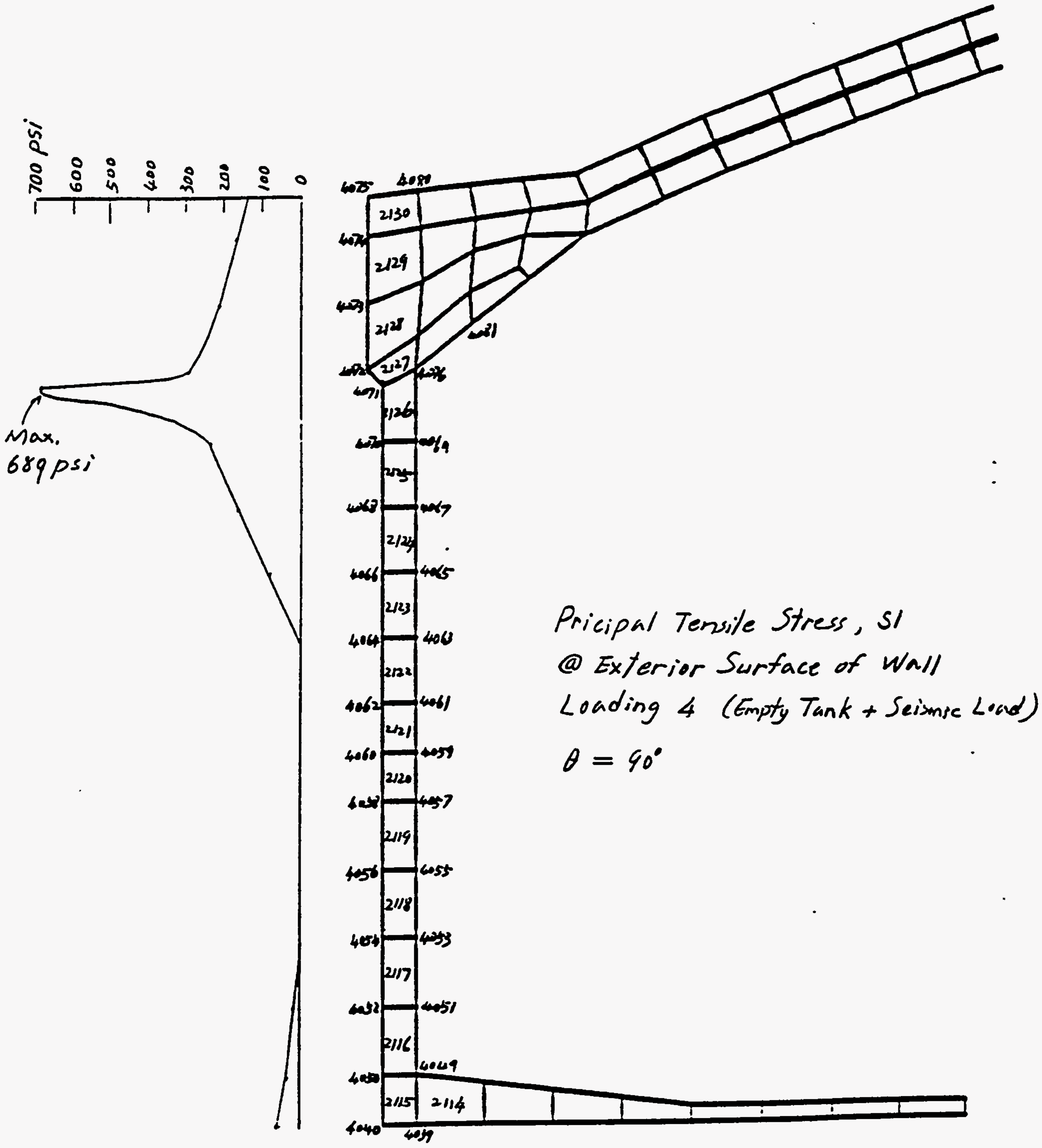


Fig. 17. Principal Tensile Stress on Exterior Surface of Wall

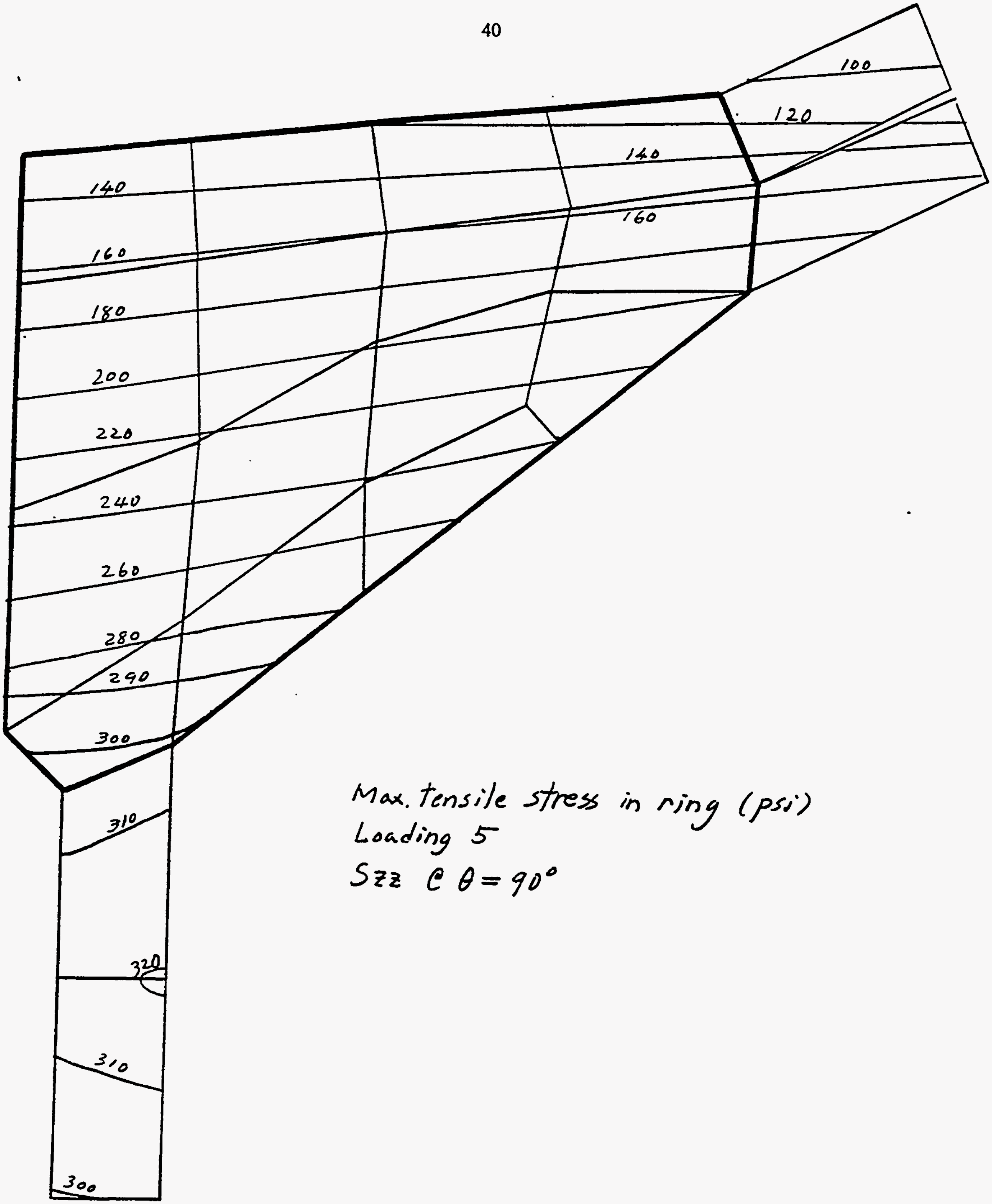


Fig. 18. Maximum Tensile Stress Distribution in Ring

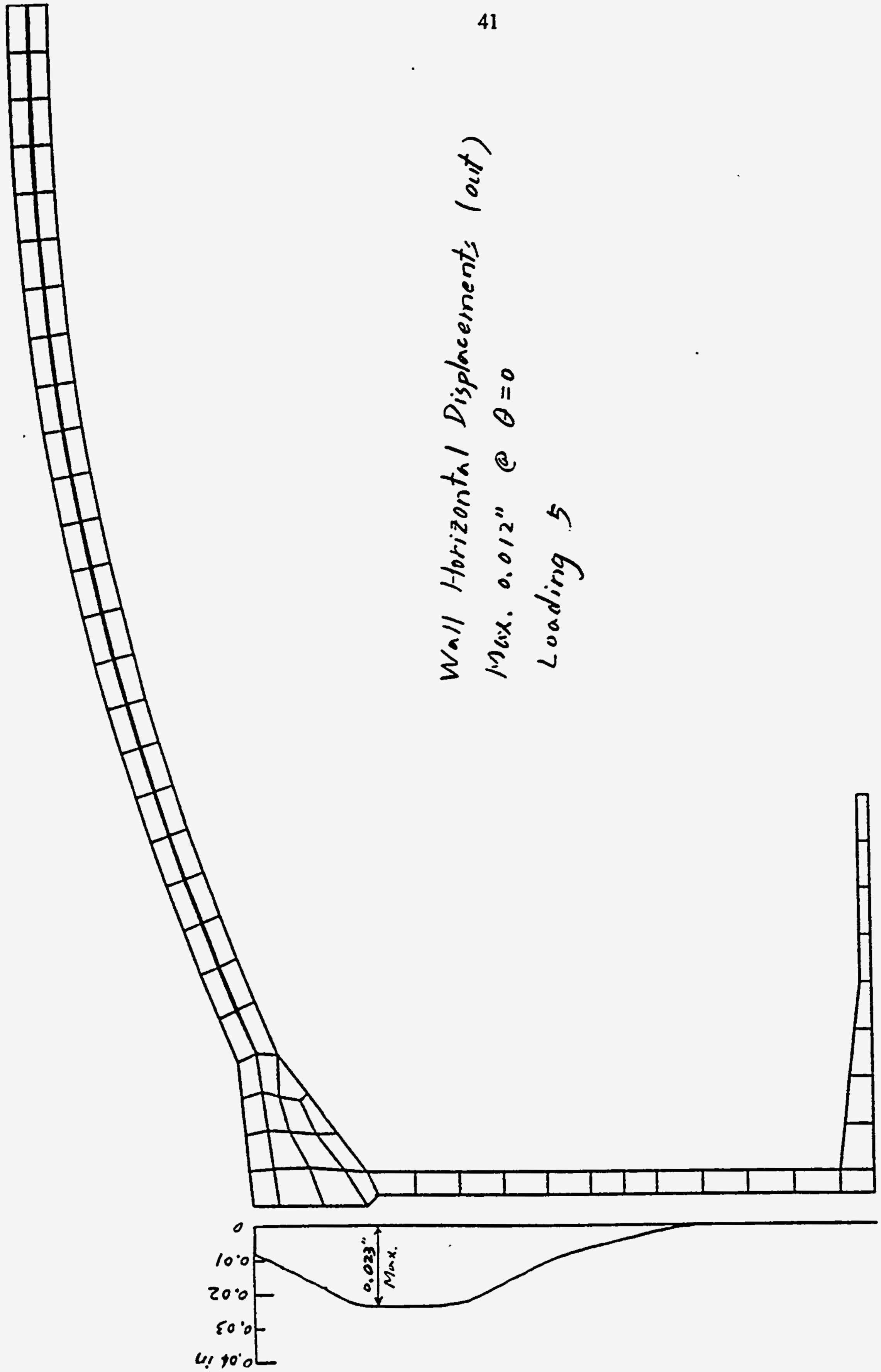


Fig. 19. Horizontal Displacement of Wall

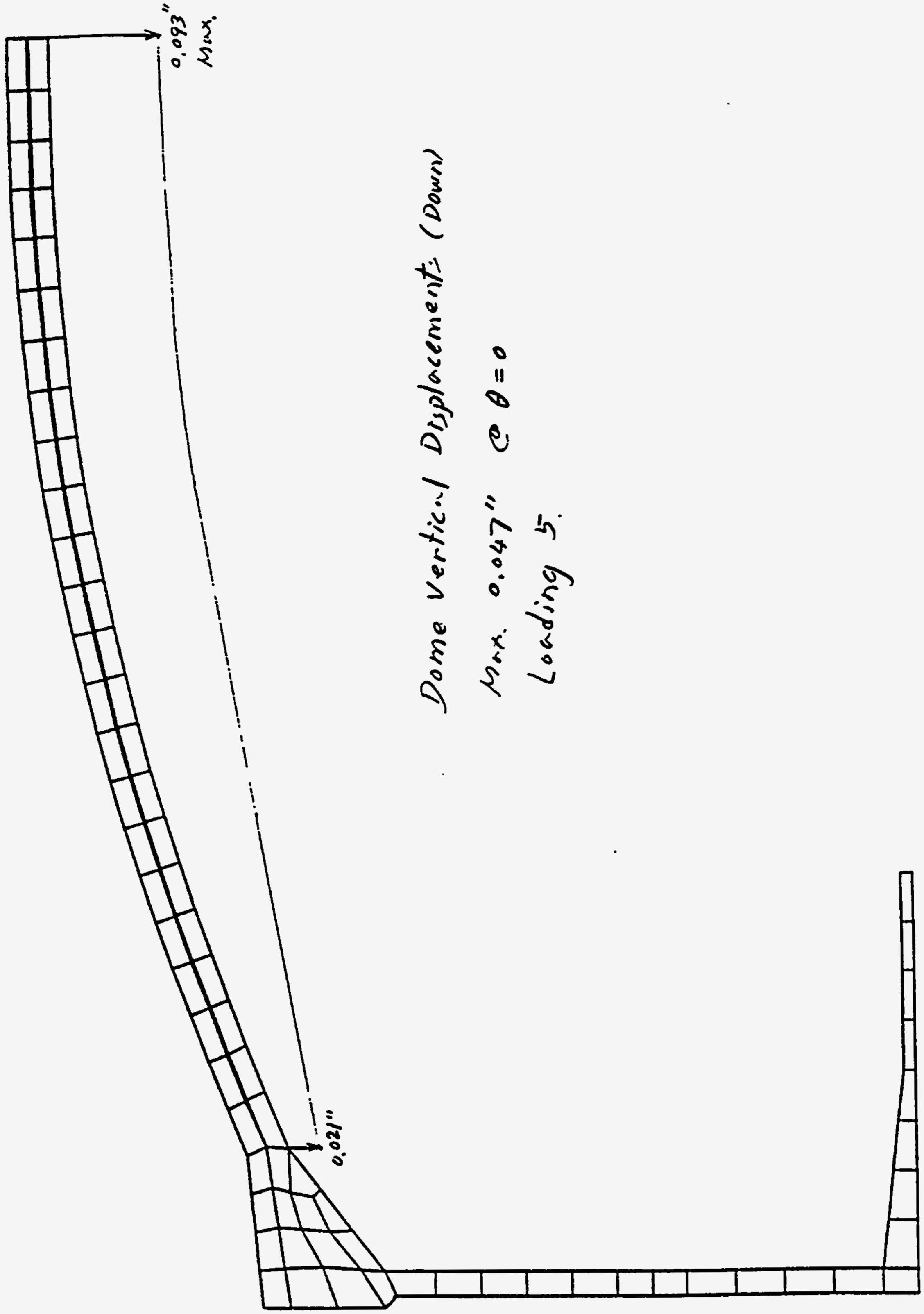


Fig. 20. Vertical Displacements of Dome

APPENDIX A
Calculations

SAIC	SCIENCE APPLICATIONS INTERNATIONAL CORPORATION	DIVISION 147
Calculation ID: 010147038832001-1		

JOB DESCRIPTION GUNITE TANK - X-10 TANK FARM

CLIENT MARTIN MARIETTA ENERGY SYSTEMS

ABSTRACT:

This calculation examines the behavior of a typical underground gunite tank in the 6 tank matrix of the X-10 storage tank farm at DOE's Oak Ridge facility. The typical tank is investigated for seismically induced soil, fluid and inertial loading. Local stress conditions around penetrations in the roof dome are investigated. The typical tank configuration investigated the behavior of the a tank dome having 5 - 24" holes (a central hole at dome top and 4 additional holes symmetrically spaced on a concentric circle having a radius of 20 feet). The investigation also considered a 30" diameter manhole and a 12" diameter process piping penetration. Existing tanks typically had only 3 - 24" diameter holes in the dome in addition to the 30" diameter manhole and 12" diameter process penetration. Consideration of the additional holes was requested by Energy Systems. Dynamic soil and hydraulic loadings were applied to the structure as static equivalent loadings. The dynamic amplification of soil loading on a single tank resulting from the collective dynamic behavior of the tank farm matrix was considered. The effects of tank wall spalling due to degradation was considered. The 1-½" tank wall liner was not considered in analyses of the typical tank.

REVISION	PREPARED BY	DATE	REVIEWED BY	DATE	APPROVED	DATE
0	CNS	7/24/94	MOK	7/26/94	Tony Chung	7/26/94
1	CNS	3/30/95	MOK	3/31/95	Tony Chung	3/31/95

KEYNOUNS: Underground Tank, Gunite Tank, Waste Storage Tank, Seismic, Earthquake

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

DOCUMENT REVIEW RECORD

DOCUMENT PREPARER: M O KELLEY SHEET 1 of 1
DOCUMENT TITLE: GUNITE TANK
DOCUMENT NUMBER: 0101470306064009
REVISION: INITIAL ISSUE
DATE TRANSMITTED: 7/22/94 DATE COMMENTS REQUIRED: 7/25/94
REVIEW TYPE: [x] TECHNICAL [ ] EDITORIAL [ ] PEER [ ] DESIGN VERIFICATION

COMMENTS THAT ARE ANNOTATED WITH AN (*) ARE MANDATORY AND REQUIRE RESPONSE AND RESOLUTION.

PAGE OR SECT./ PARA.	REVIEWER COMMENTS	PREPARER RESPONSE	REVIEWER ACCEPT/ REJECT
	No EXCEPTIONS TAKEN		

REVIEWED BY

M O Kelley 7/24/94

Signature Date

RESPONSE BY

Signature Date

Science Applications International Corporation

REVISION LOG

SHEET NUMBER	DESCRIPTION
	INITIAL ISSUE PGG 1 – 78 CKD MDK 7/24/94

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Reference

Table of Contents

SAIC Science Applications International Corporation An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK

01014703066G9009 -

AUTHOR CNS DATE 7/22/94 JOB NO.

CHECKED BY MOK DATE 7/25/94 PAGE 4 of

Ref

Table of Contents (Cont.)

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Reference

Table of Contents (cont.)

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

TABLE OF CONTENTS (CONT)

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	01014703066 4 009		7 of
ESO NO.	COMPUTED CNS 4-16-94	CHECKED BY MOK 7-26-94	

<u>Top of Rock Elevation</u> (Soil Boring Log by D. Crawford 1-30-78) [Ref. 8]

Boring Number	Location		Top of Ground Elevation	Depth @ Refusal	Top of Rock Elevation
3507-1	N 21,920	E 30,810	804.4	20.5	783.9
-2	N 21,970	E 30,950	800.5	32.25	768.25
-3	N 21,910	E 31,000	800.2	21.3	778.9
-4	N 21,971	E 31,000	801.5	34.0	767.5
-5	N 22,030	E 31,000	803.9	35.0	768.9

The top of floor elevation of the tanks is @ 782' ± the soil layers beneath the tank floors have thickness varying from 0 to 14.5 ft.

The tanks are "on soil", not "on rock"
However, effects of SSI was not considered.

General Loading Conditions

Static Loadings

All loadings not due to earthquake:
D.L. Tank, vertical & horizontal static soil pressure, static fluid pressure.

Dynamic Loadings

Vertical & horizontal dynamic soil pressure, dynamic fluid pressure, dynamic force induced from D.L. of tank by seismic excitation. All applied as static loads.

Science Applications International Corporation
An Employee-Owned Company

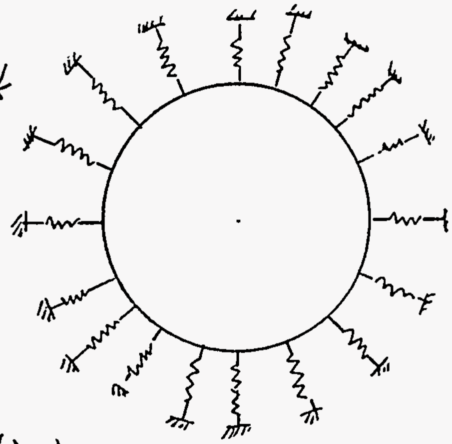
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01014703066 4009

AUTHOR CNS DATE 3-24-95 JOB NO.

CHECKED BY Tony Chng DATE 3/31/95 PAGE ___ of ___

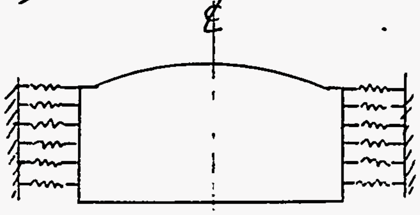
Lateral Soil Springs



Lateral soil restraint on the tank is represented by soil springs.

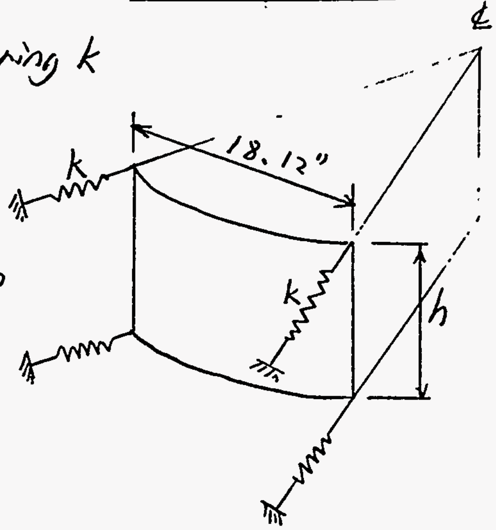
The modulus of subgrade reaction is used to calculate the equivalent cross-sectional area, A, of "truss members."

The modulus of subgrade reaction k_s is assumed to have a low (conservative) value of 40000 lb/ft^3 (pp. 409, Bowles, J. E, Foundation Analysis and design.)



$$k_s = 40000 \text{ lb/ft}^3 = 23.15 \text{ lb/in}^3$$

At each node, the value of the spring k depends on the contributing area of the element.



$$k = (18.12)(h)(k_s)$$
$$= (18.12)(h)(23.15) = 419.5\,(h) \text{ lb/in}$$

$$\Delta = \frac{PL}{EA} = \frac{P}{k} = \frac{P}{\left(\frac{EA}{L}\right)}$$

$$k = \frac{EA}{L} \quad \text{or} \quad A = \frac{kL}{E}$$

Let

$E = 1000 \text{ lb/in}^2$
$L = 10 \text{ in}$

Then the cross-sectional area of the equivalent truss member is

$$A = \frac{k(10)}{1000} = 0.01\,k = (0.01)(419.5)(h)$$
$$= 4.195\,h$$

Use

$A = 4.2\,h \text{ in}^2$

E, L, & A are input data for STRUDL. See next sheet for h.

FA 92006001 RE

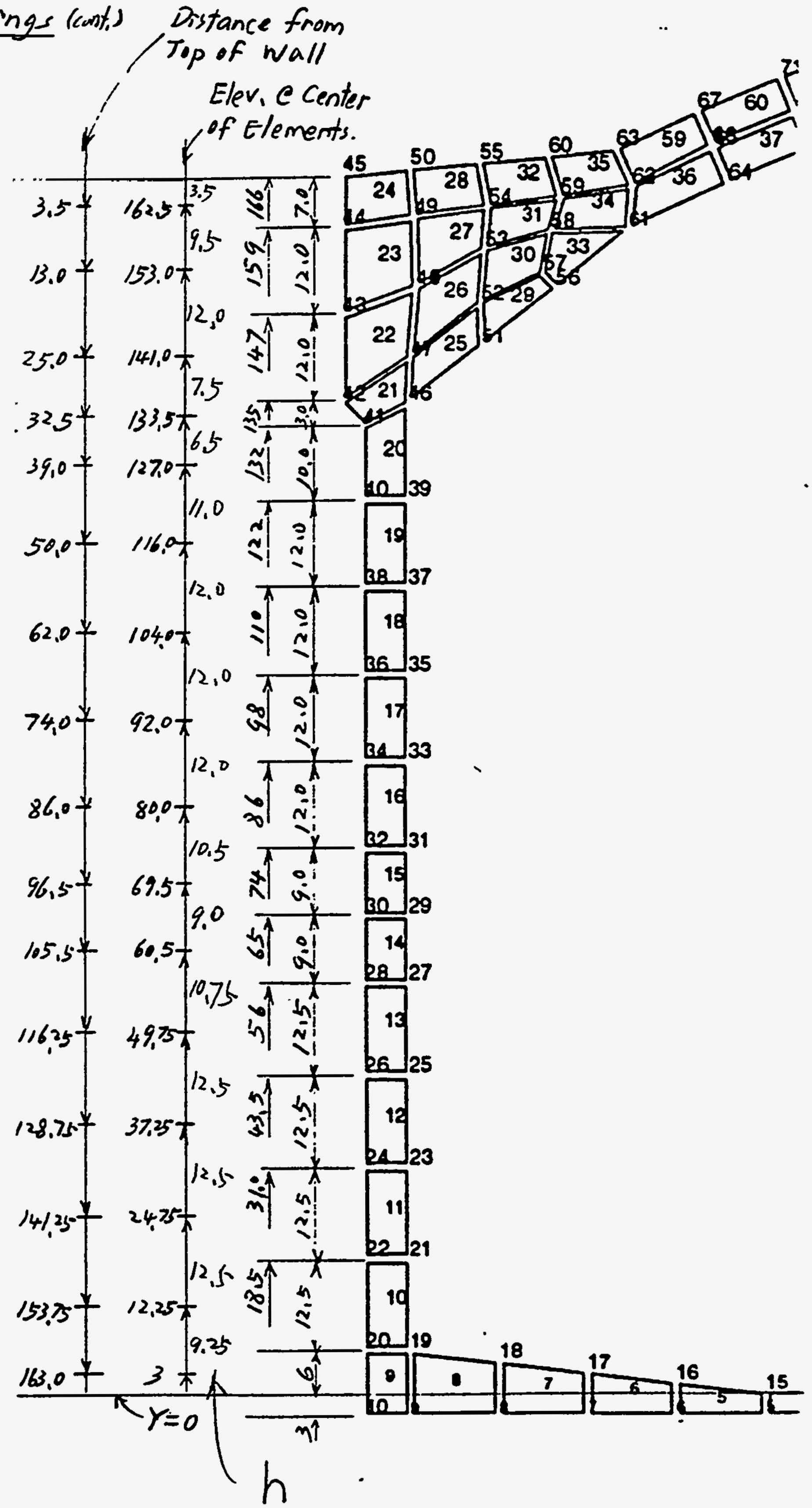
SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01014703066 4009

AUTHOR CNS DATE 3-24-95 JOB NO.

CHECKED BY TC DATE 3-31-95 PAGE ___ of ___

Lateral Soil Springs (cont.)



GENERAL DESIGN AND COMPUTATION SHEET

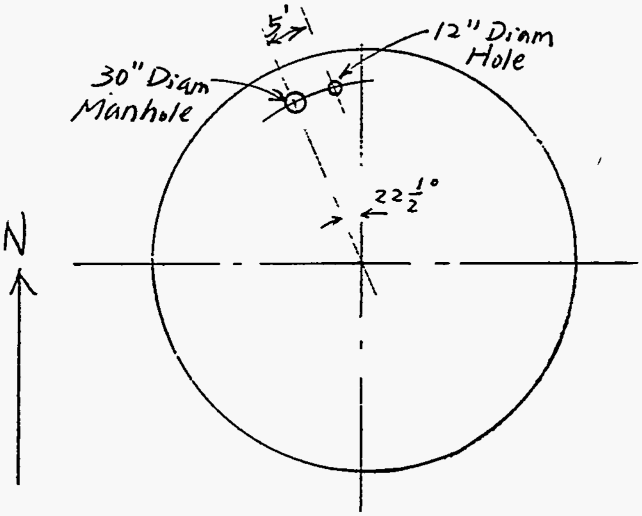
JOB		DATE	SHEET
GUNITE TANKS 0101470300664009			8 of
ESO NO.	COMPUTED CNS 4-15-94	CHECKED BY MOK 7-24-94	

Penetrations in Dome

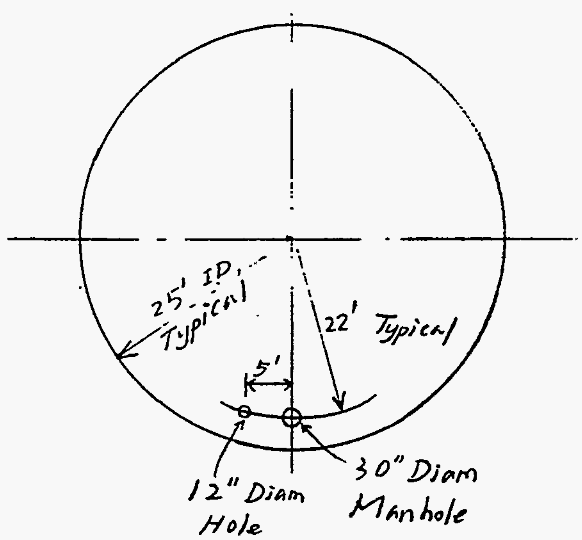
Penetrations in the dome were made at different stages. Size, number and locations varied.

Original Construction (Ref Dwgs V-68334, E-56860, E-56866, H3D-20539-G004, X3E-20539-

4 Penetrations : 30" Manhole
12" Connection
4" Spare connection } Small, will not consi
4" Vent



Typical For Tanks W-5, W-7, W-9



Typical For Tanks W-6, W-8, W-10

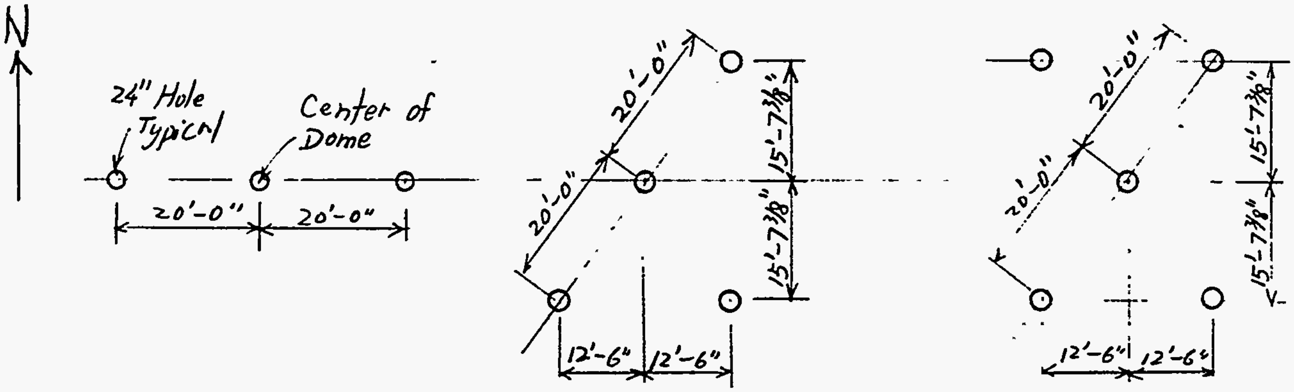
GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANKS	01014703066400 9		9 of
ESO NO.	COMPUTED CNS 4-15-94	CHECKED BY NOK 7-24-94	

Penetrations in Dome (Cont.)

24" Diam. Penetrations (for 34" Diam Caissons)

Later, more penetrations were drilled. There are three possible arrangements.



3 Penetrations	4 Penetrations	5 Penetrations
Ref Dwgs.	Ref. Dwgs.	Ref. Dwgs.
C3E-20539-A019	C3E-20539-A019	C3E-20539-X007
-A021	-A021	H3D-20539-G004
P3E-20539-C027	S3D-20539-B033	P3E-20539-C007
-C034		-C027
S3D-20539-B033		-C034
		S3D-20539-B011
		-B012
		-B013
		X3E-20539-B001
		-B002

Penetration & Caisson sections are shown in Dwgs.

H-20539-EG002
H3D-20539-G004
X3E-20539-0001
-0002

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANKS	0101470306664009		10 of
ESO NO.	COMPUTED CNS 4-16-94	CHECKED BY MOK 7-29-94	

Penetrations in Dome (Cont.)

Smaller Penetrations (Ref. Dwgs. J3E-20539-E006, P3D-20539-C014, P3E-20539-C028)

Smaller penetrations having diameters
3/8", 3/4", 1", 2", 5" & 6"
are small and will not be considered.

Increase of Concrete Thickness Around Penetrations (Ref. Dwgs. E-56866, V-68334, X3E-20539-A0)

Penetration Size	Additional Slab Size	Min. Thickness Increase
30"	42 ±	12"
24"	60 ±	4"
12"	22 ±	4"

Penetrations Considered for Analysis

Two penetrations, 12"φ and 30", typical for Tanks W-6, W-10. Plus the five 24"φ penetrations pattern shown on preceding page.

Increase of concrete thickness* around penetrations is ignored in the analysis.

*CKRS NOTE: SOME OPENINGS HAVE BEEN CASED. CASING IS IGNORED IN THESE CALCULATIONS

UCN-4032A
(5 2-84)

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

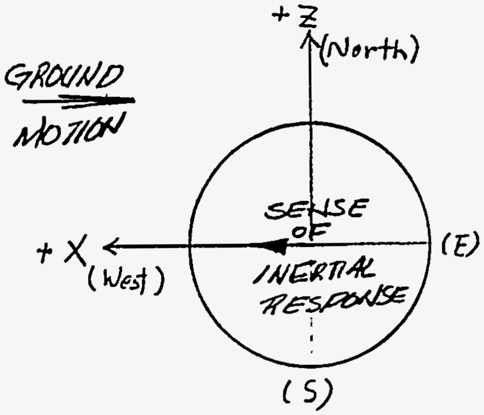
SUBJECT GUNITE TANK
61014703064009

AUTHOR CNS DATE 7-19-94 JOB NO.

CHECKED BY NOK DATE 7-29-94 PAGE 11 of

Reference

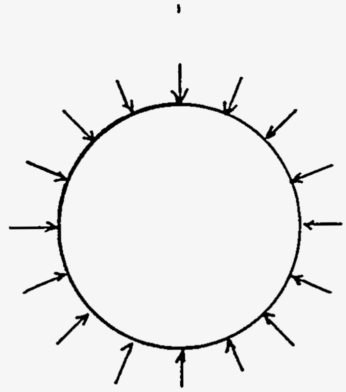
Horizontal Loadings Sketches



Earthquake Load on Tank

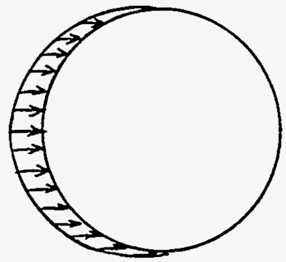
E

(+X direction)



Soil Static Load

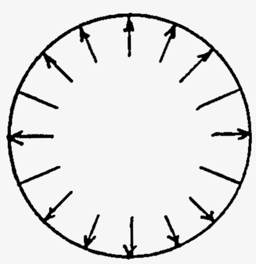
H_{SW}



Soil Dynamic Load

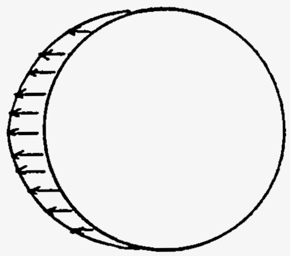
H_D

CKR'S NOTE: HYDRODYNAMIC LOAD ASSUMES FLUID INERTIAL RESPONSE & SLOSHING ARE INPHASE - CONSERVATIVE.



Hydrostatic Load

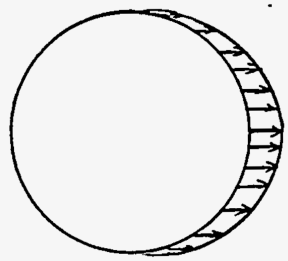
F_S, $F_{1/2 S}$



Hydrodynamic Load In-Phase

F_{D+}, $F_{1/2 D+}$

OR



Hydrodynamic Load Out-of-Phase

F_{D-}, $F_{1/2 D-}$

LOADS SHOWN ABOVE WERE USED IN ANALYSIS

RELATIVE DIRECTIONS USED ARE AS SHOWN ABOVE

SEE SECTION 3.5 OF THE REPORT FOR LOAD COMBINATIONS USED.

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	0101970306064009		12 of
ESO NO.	COMPUTED CNS 4-21-94	CHECKED BY MOK 7-26-94	

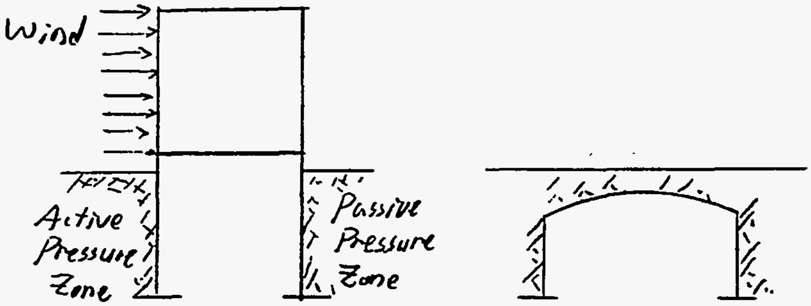
Dead Load Soil (Vertical)

$6 \times 110 = 660$ psf $= 4.58$ psi on dome elements (Global Coord
(Ref. 12)

Static Earth Pressure (Horizontal)

The flexible tank wall can easily move away from th soil mass and the soil pressure applied on the wall becon the active soil pressure which is smaller than the at-rest soil pressure. A movement of $0.001H = 0.159$" at the top of wall will induce the active earth pressure condition.

Passive earth pressure is much larger than the at-re. earth pressure and is generally more than 3 times of the active earth pressure. It can become a reality only if the tank wall can be pushed into the soil mass with a deflection of $0.05H = 7.95$" at the top of the wa. For a building having both superstructure and basement this is possible, the superstructure may apply large horizonta. loads on top of the basement wall as a result of wind or seismic loads. For underground tanks this is a very unli event, unless the mass of the tank and its contents is much greater than the mass of the soil of equal volume. (Ref. 16). The total mass of the concrete tank and the liq in the tank being analized is smaller than the mass of the soil of the same volume. No extra mass is introduced into the sy.



Superstructure Plus Basement

Underground Tank

UCN-4032A
(5 2-84)

GENERAL DESIGN AND COMPUTATION SHEET

6

JOB	DATE	SHEET
GUNITE TANK 0101470306640U9		13 of
ESO NO.	COMPUTED: CNS 4-22-94	CHECKED BY: MOK 7-24-94

Static Earth Pressures (Cont.)

Assume the angle of internal friction of combined crush stone and clay backfill $\phi = 40^\circ$ (Ref. 24, P. 117)

Then the at-rest earth pressure coeff.

$K_o = 1 - \sin\phi = 1 - 0.643 = 0.357$

Use $K_o = 0.35$ for comparison with previous analysis. (Ref. 12)

Unit weight $\gamma = 110$ pcf (Ref. 12)

The at-rest earth pressure

@ Top of Wall

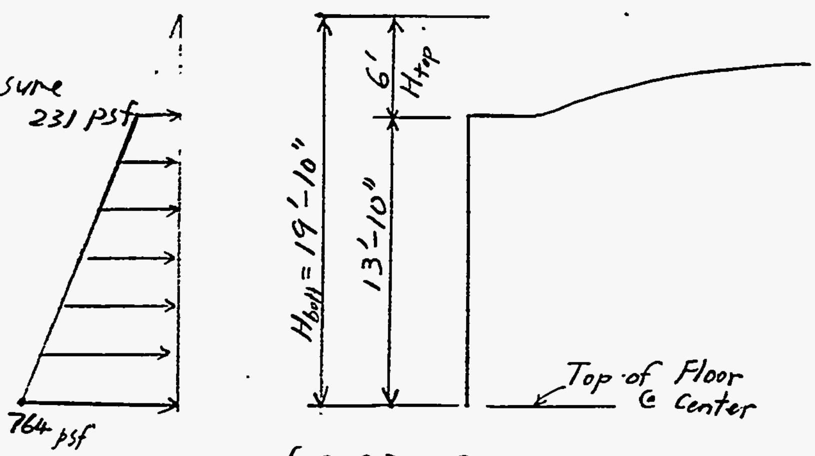
$= K_o \gamma H_{top} = 0.35 \times 110 \times 6$

$= 231$ psf

@ Bottom of Wall

$= K_o \gamma H_{bott} = 0.35 \times 110 \times 19.833$

$= 764$ psf

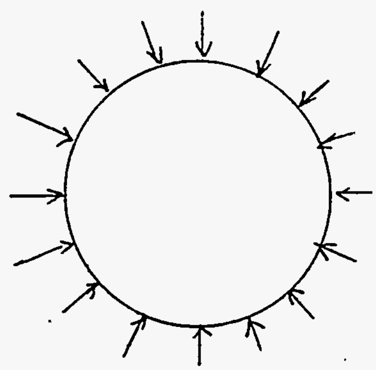


(Ref. Dwg. Cement Gun Co. -679A, -700)

Total static at-rest earth pressure for a 12" vertical strip wall area

$P_{stat.} = \frac{1}{2}(231 + 764)(13.83) = \underline{6,882 \text{ lb}}$

Static at-rest earth pressures apply in a direction normal to the entire wall surface.



Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK 01014703066400G

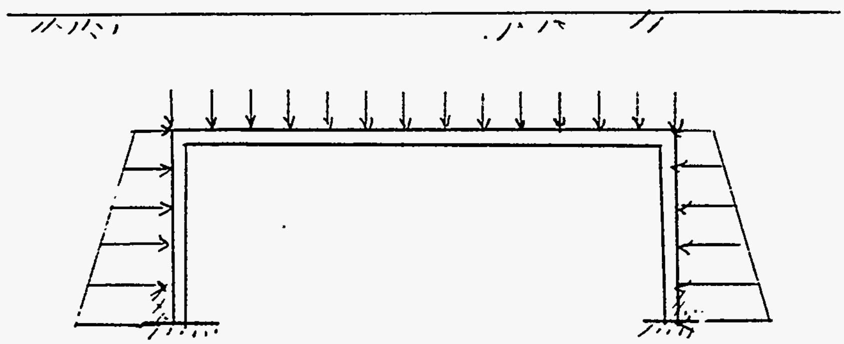
AUTHOR CNS DATE 7-25-94 JOB NO.

CHECKED BY MOK DATE 7-25-94 PAGE 14 of

Ref

Static Earth Pressures (Cont.)

Technical Justifications for Not Applying Lateral Soil Pressure on Dome



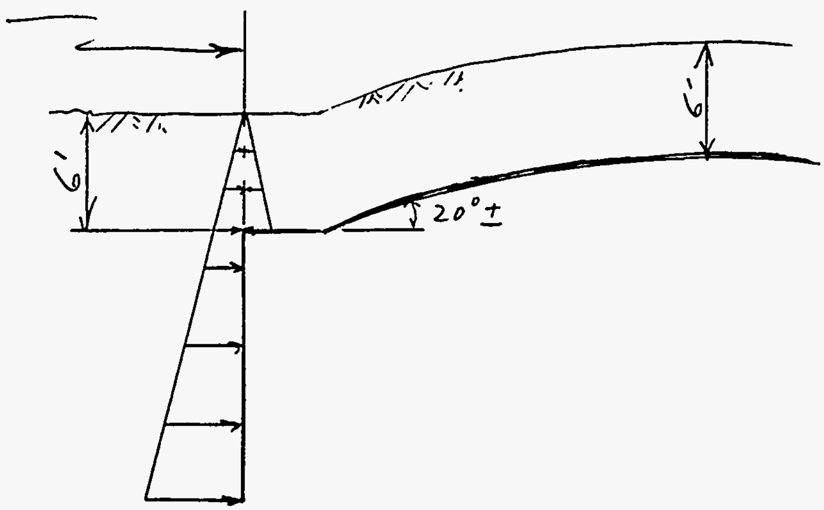
For an underground structure with flat top it is very clear that there is no lateral (horizontal) soil pressure on the roof top. Lateral soil pressure only applies on the vertical walls.

Reference

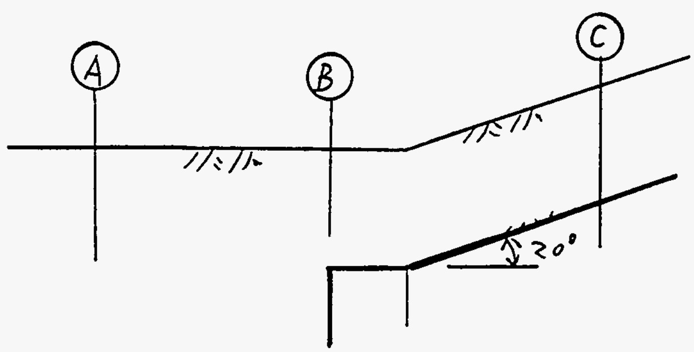
Static Earth Pressures (Cont.)

Technical Justifications for Not Applying Lateral Soil Pressure on Dome (Cont.)

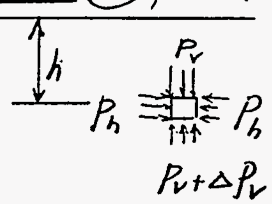
CKR'S NOTE: @ THIS SURFACE LATERAL SOIL PRESSURES ARE EQUAL & OPPOSITE ∴ NO NET LATERAL PRESSURE IS RESISTED BY THE DOME. MOK 7/25/94



Consider a simplified soil & structure form.



At section (A), look at a small soil cube



As the vertical pressure (soil's own weight or external load) is applied the soil cube expands until a lateral confining stress develops. (excluding consolidation effects).

By definition $P_h = k_o P_v = k_o \gamma h$ where k_o is the coefficient of earth pressure at rest.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

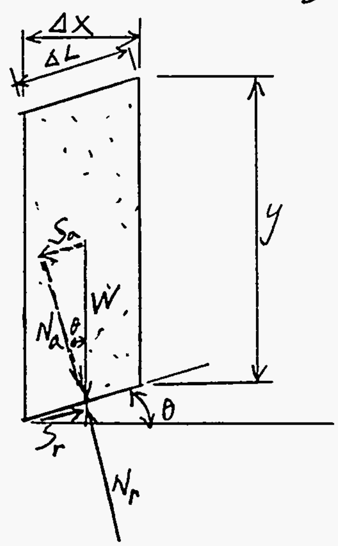
Ref

Static Earth Pressure (Cont.)

Technical Justification for Not Applying Lateral Soil Pressure on Dome (Cont.)

At section (B), it is the same situation as the left corner of the flat-top bldg with lateral stress on wall and vertical stress on roof.

At section (C), look at a typical slice.



$\Delta L = \frac{\Delta X}{\cos\theta}$

$W = xy\gamma$

The component parallel to the roof $S_a = W\sin\theta$

The component normal to the roof $N_a = W\cos\theta$

The resistance $N_r = N_a = W\cos\theta$

$S_r = S_a = W\sin\theta$

Max S_R, resistance along the top of roof

$= C\Delta L + N_r \tan\phi$

where C is cohesion

ΔL is the length along the base of the slice

ϕ is the angle of internal friction.

(See Ref. 29)

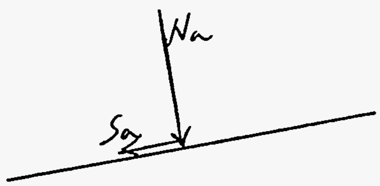
Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Reference

Static Earth Pressure (cont.)

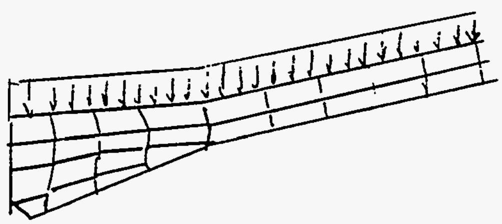
Technical Justification for Not Applying Lateral Soil Pressure on Dome

At section (c) the roof will see the following loads



These loads are the components of the gravity load of the soil slice.

When a vertical stress is applied on the finite element surface as shown below, the load is applied correctly.



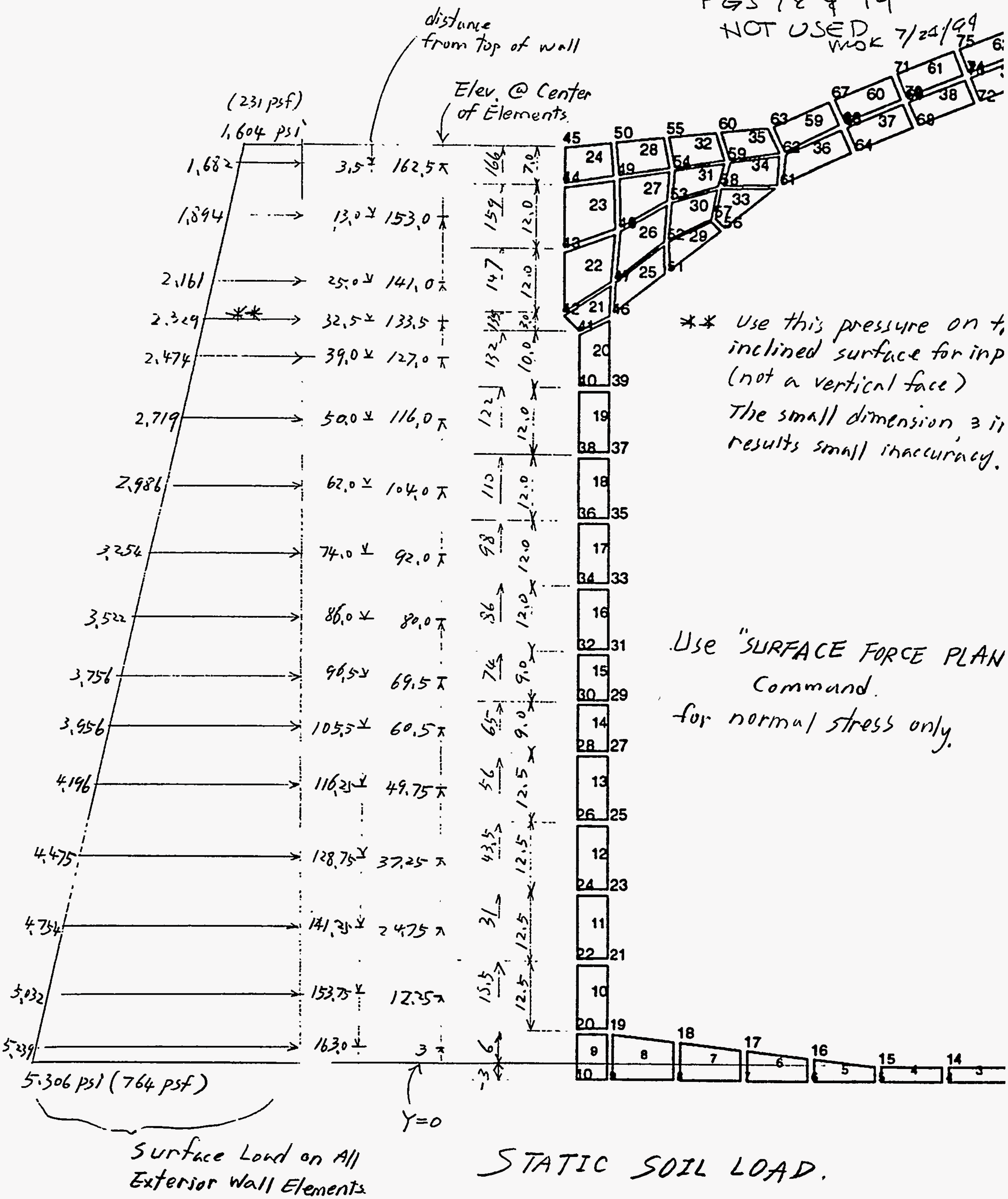
This distributed vertical loading is the only loading. No other loads, either lateral or other direction is necessary.

GUNITE TANK
01014703066400 9

CNS 4-22-94

MOK 7-20-94

CKRS NOTE:
PGS 18 & 19
NOT USED MOK 7/21/94



** Use this pressure on the inclined surface for inp (not a vertical face) The small dimension, 3 in results small inaccuracy.

Use "SURFACE FORCE PLAN Command. for normal stress only.

STATIC SOIL LOAD.

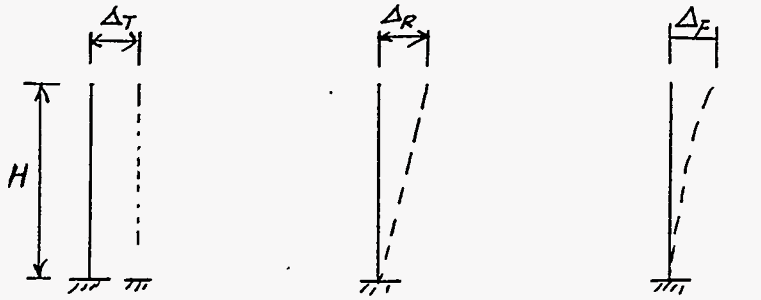
GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	01614763 0664009		21 of
ESO NO.	COMPUTED CNS 4-21-94	CHECKED BY MGK 7-24-94	

Dynamic Earth Pressures

General Properties of the Tank [16]

The active and passive earth pressures are related to the lateral deflections of the wall.



The wall of the tank has a height of 13' and a thickness of 6". It is flexible and will not behave like a thick retaining wall. The rigid body tranlation and rotation are relatively small and the flexural deformation are relatively large.

During earthquake, these deflections are the relative deflections between the tank and the surrounding soils. Starting from at-rest condition, the soil-structure system vibrates with small magnitudes and in-phase deflections when the ground input motions are small. As the magnitudes of ground accelerations increase, the deflections of the soil mass and the flexible tank wall are larger and possibly out-of-phase. Difference in movements between the soils and the tank induce dynamic earth pressures. As mentioned before, the larger passive dynamic earth pressure will not be matealized, only active dynamic earth pressure is considered.

GENERAL DESIGN AND COMPUTATION SHEET

JOB GUNITE TANK 01014703066 4009 | DATE | SHEET 22 of
ESO NO. | COMPUTED CNS 4-21-94 | CHECKED BY MOK 7-29-94

Dynamic Earth Pressures (Cont.)

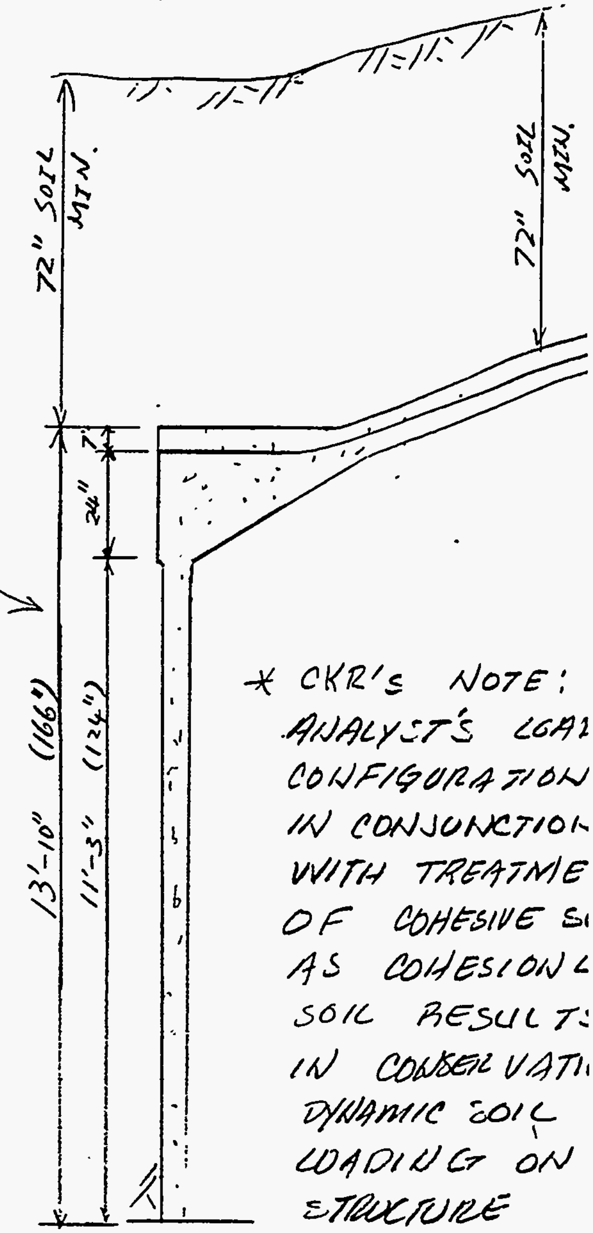
Loading Location

Horizontal Load

The horizontal dynamic earth pressure only applies on the portion of the wall below the dome (166" height).

This pressure applies on one side only (180° wall area) as an independent loading condition.

The dynamic soil pressure on the other half of the cylindrical wall is ignored. It will reduce the at-rest static pressure by an unknow amount.



* CKR'S NOTE: ANALYST'S LOAD CONFIGURATION IN CONJUNCTION WITH TREATMENT OF COHESIVE SOIL AS COHESIONLESS SOIL RESULTS IN CONSERVATIVE DYNAMIC SOIL LOADING ON STRUCTURE

The soil over the top of the dome is assumed to be self supporting for horizontal earth pressures. It will be considered as a static surcharge load. It will not induce any horizontal loads.*

Vertical Load

Vertical dynamic soil pressure is considered as an equivalent static load with a multiplier $1 + \frac{2}{3}(0.14) = 1.093$. See input data under "CREAT LOAD COMB."

UCN-4032A
(5 2-84)

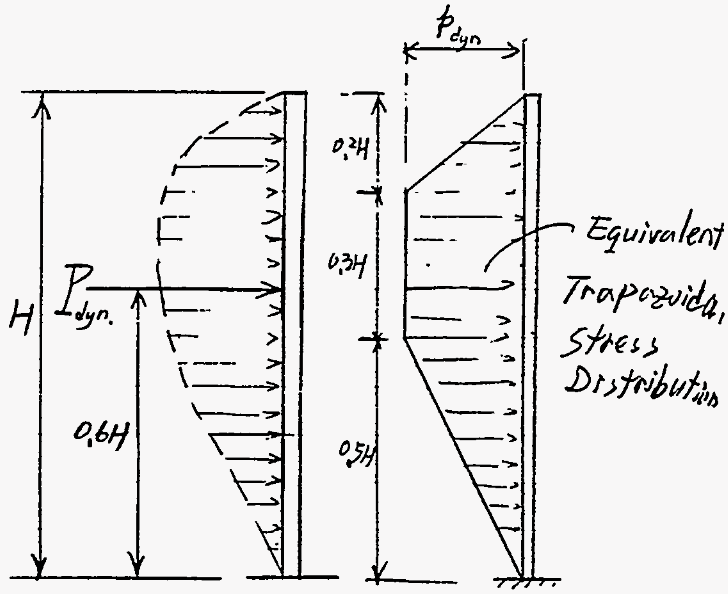
GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	0101470306064009		23 of
ESO NO.	COMPUTED: CNS 4-21-94	CHECKED BY: MOK 7-24-94	

Dynamic Earth Pressures (Cont.)

Load Distribution

The distribution of the dynamic earth pressure is nonlinear and the resultant is located @ 0.6 H from the bottom of wall. [5, 9, 16, 20]



An equivalent trapozoidal stress distribution is used here.

$$p_{dyn}\left[\frac{1}{2}(0.2H) + 0.3H + \frac{1}{2}(0.5H)\right] = P_{dyn} = 0.65 H p_{dyn}$$

$$p_{dyn} = 1.54\,(P_{dyn}/H)$$

The centroid of the this trapazoid is located @ 0.56 H from the bottom $\approx$ 0.6 H.

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	0101470306640069		24 of
ESO NO.	COMPUTED CNS 4-22-94	CHECKED BY MOK 7-24-94	

Dynamic Earth Pressure (Cont.)

Magnitude as a Percentage of Static Earth Pressure

The useful tank life < 20 yrs. From Ref 25, pg. 62 with hazard probability of 2×10^{-3} or 500 yr. return period, $ZPA = 140\ cm/sec^2 = 0.14g$.

By using the procedure proposed by Prakash [18]

$$P_{total} = P_{static} + P_{dynamic}$$

$$\frac{P_{total}}{P_{static}} = \lambda$$

From Fig. 5.15, ref. 18, the value of λ can be found by interpolation with $\phi = 40°$ (Ref. 24), ground accleration = 0.14 and $\delta = 0$ one obtains

$\lambda = 1.4$

$\therefore P_{dynamic} = 0.4 P_{static}$

From the calculation of dynamic load distribution th max. dynamic earth pressure

$$p_{dynamic} = 1.54 \left(P_{dyn} / H \right)$$

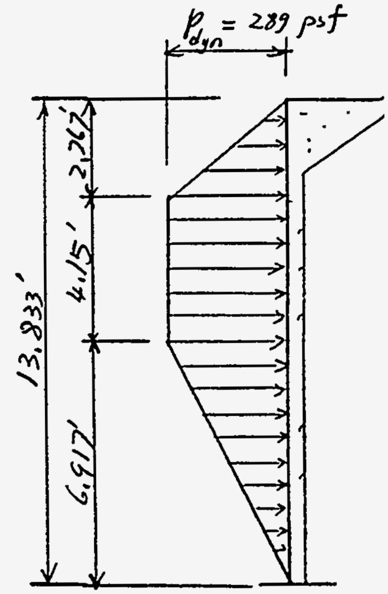
$$= 1.54 \left(0.4 P_{static} / H \right)$$

$$= 0.62 \left(P_{static} / H \right)$$

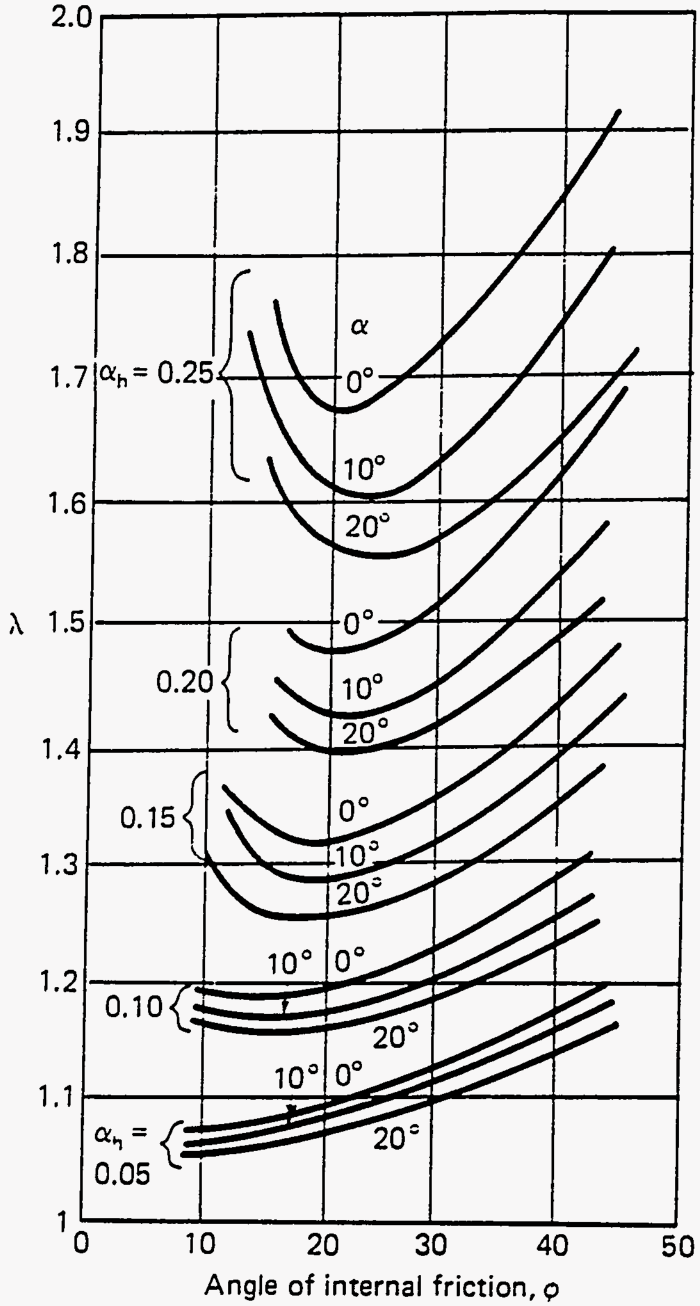
$$= 0.62 \left(6882 / 13.83 \right)$$

$$= 306\ psf$$

$$= 2.127\ psi$$



0101470306640009 25



$\alpha_h = \frac{\ddot{X}_h}{g} = 0.14$

FROM REFERENCE 18

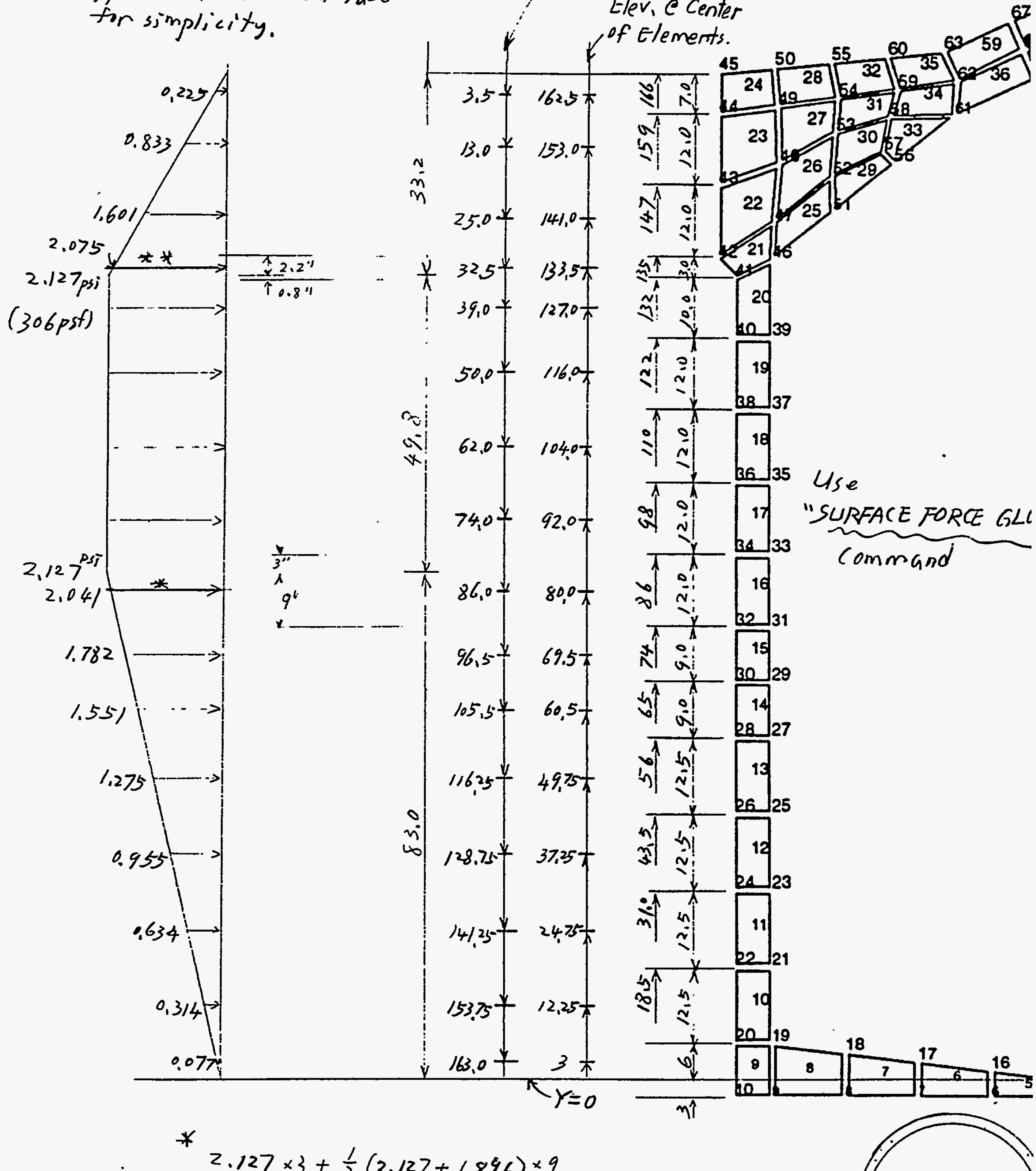
Figure 5.15 λ vs. angle of internal friction φ. (*After Prakash and Saran*, 1966.)

GUNITE TANK CNS 4-23-94 MOK 7-24-94

** 010147030664009

$$\frac{2.127 \times 0.8 + \frac{1}{2}(2.127+1.986)\times 2.2}{3} = 2.075$$

Applied normal to surface for simplicity.



*

$$\frac{2.127 \times 3 + \frac{1}{2}(2.127+1.896)\times 9}{12} = 2.041$$

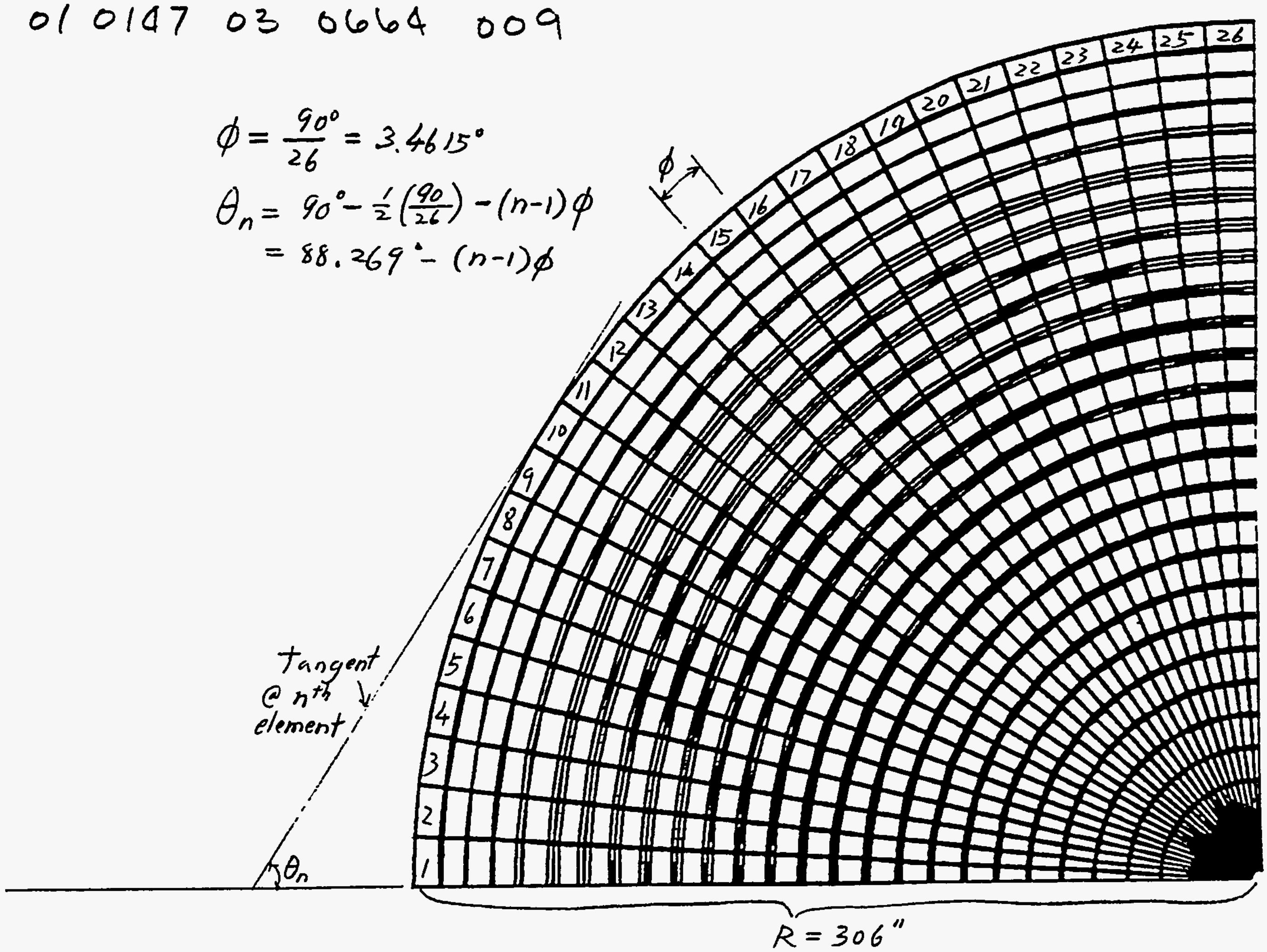
DYNAMIC SOIL LOAD NORMAL TO THE SURFACE

GUNITE TANK   CNS 4-23-94   MOK 7-24-94

01 0147 03 0664 009

$$\phi = \frac{90^\circ}{26} = 3.4615^\circ$$

$$\theta_n = 90^\circ - \frac{1}{2}\left(\frac{90}{26}\right) - (n-1)\phi$$
$$= 88.269^\circ - (n-1)\phi$$



Use "SUFACE LOAD GLOBAL" command

The intensity of the stress on an inclined element surface is reduced to $p\sin\theta$.

DYNAMIC SOIL LOAD

GENERAL DESIGN AND COMPUTATION SHEET

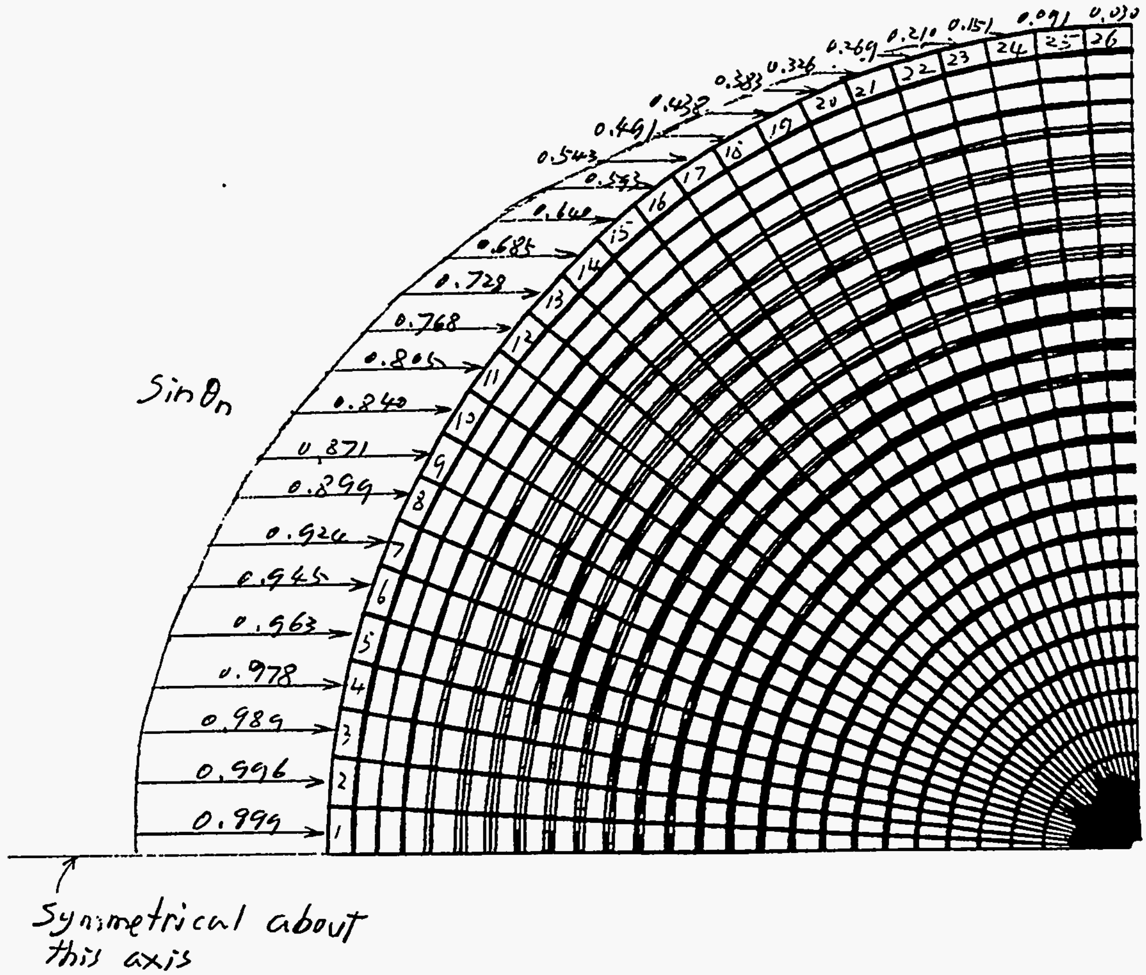
JOB		DATE	SHEET
GUNITE TANK	6101470306640009		28 of
ESO NO.	COMPUTED CNS 4-23-94	CHECKED BY MOK	7-24-94

Dynamic Earth Pressure (Cont.)

Coefficients of Dynamic Earth Pressure

n	θ_n	$\sin\theta_n$
1	88.269	0.999
2	84.808	0.996
3	81.346	0.989
4	77.885	0.978
5	74.423	0.963
6	70.962	0.945
7	67.500	0.924
8	64.038	0.899
9	60.577	0.871
10	57.115	0.840
11	53.654	0.805
12	50.192	0.768
13	46.731	0.728
14	43.269	0.685
15	39.808	0.640
16	36.346	0.593
17	32.885	0.543
18	29.423	0.491
19	25.961	0.438
20	22.500	0.383
21	19.038	0.326
22	15.577	0.269
23	12.115	0.210
24	8.654	0.151
25	5.192	0.091
26	1.731	0.030

Dynamic Earth Pressure Coeff.



Use "SURFACE LOAD GOBAL" Command.

Same for all elevations

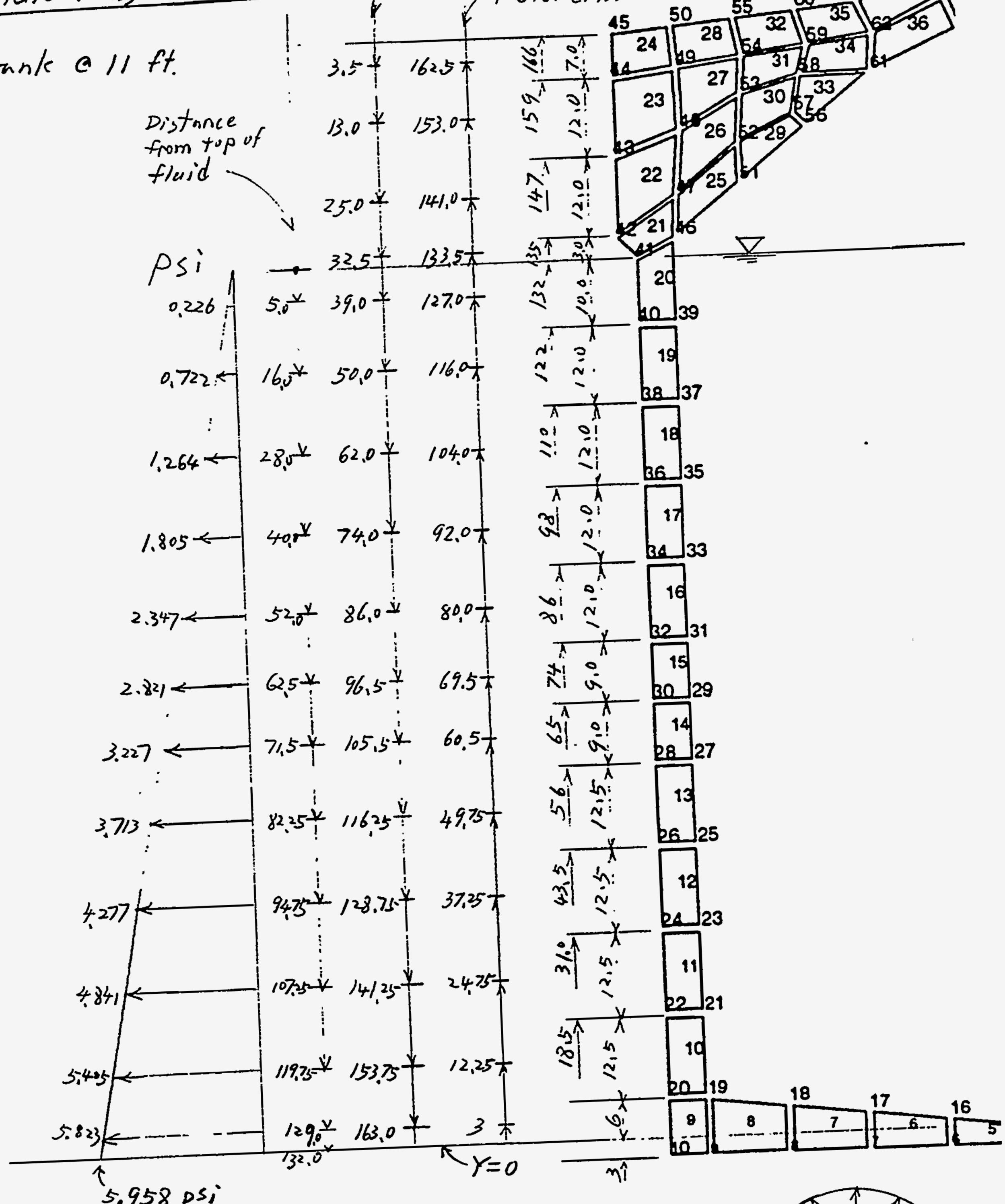
010147030664009

GUNITE TANK CHS 4-28-94

CKD MOK 7-24-94

Static Fluid Pressures — Full Tank

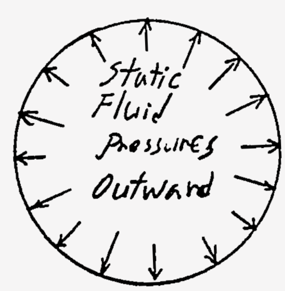
Full tank @ 11 ft.



$1.25 \times 62.4 \times 11 = 858.0\ psf = 5.958\ psi$

(Ref. 12)

Pressure on the bottom elements is ignored.



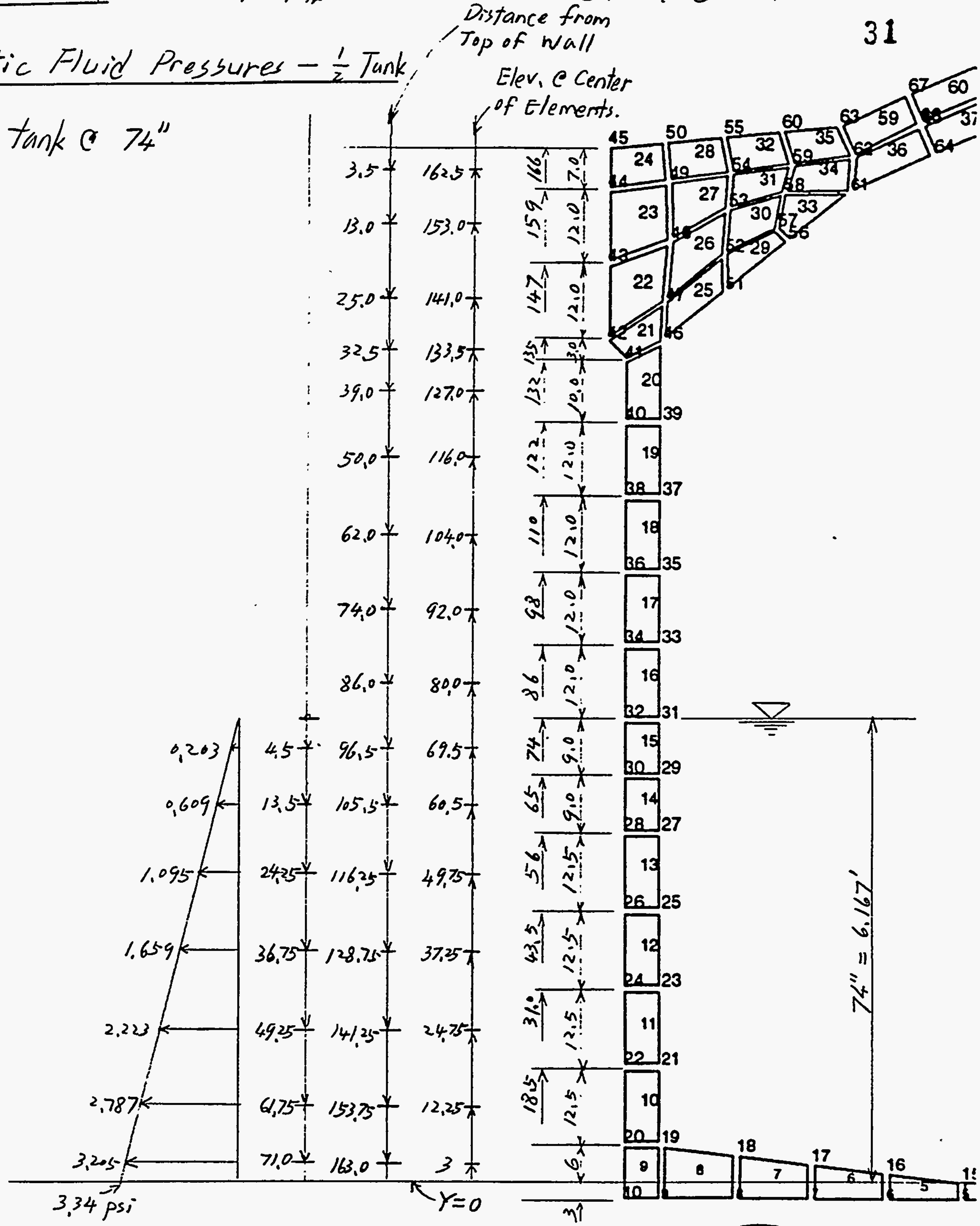
010147030664009

GUNITE TANK CNS 4-29-94 MOK 7-20-94

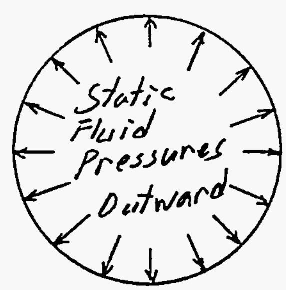
31

Static Fluid Pressures — ½ Tank

½ tank @ 74"



$$1.25 \times 62.4 \times \frac{74}{12} = 481 \text{ psf}$$
$$= 3.34 \text{ psi}$$



GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	01014703066 4009		32 of
ESO NO.	COMPUTED CNS 4-26-94	CHECKED BY MOK 7-24-94	

Hydrodynamic Loads — Full Tank [5, 17]

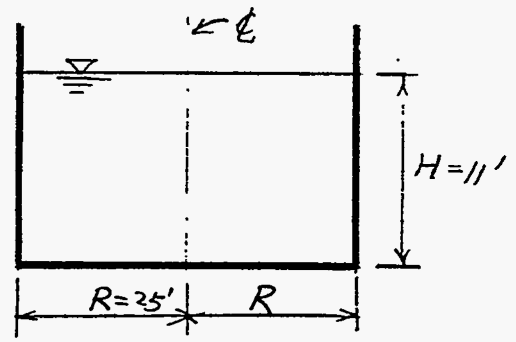
For the analysis of hydrodynamic pressures against dams, water compressibility is important and surface wave effec is negligible. For the analysis of tanks, the reverse is tru

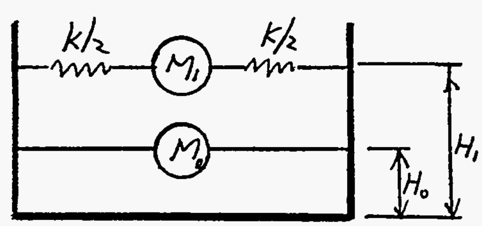
During movement of a tank, the contained fluid is separa into two zones. The upper zone of fluid tends to move in a sloshing mode while the lower zone moves as a rigi body with the tank.

The forces produced by the induced fluid motion are depende on tank geometry. Most of the fluid moves in a sloshing mode in shallow tank while most of the fluid moves with the tank as a rigid body in tall tanks.

For small vibrations, the solution can be formulated as a system of linear, conservative, multi-degree structure: The liquid may be replaced with a number of masse attached to the tank by means of linear spring, each mass being associated with each mode.

Bottom of tank is support by fill conc., pressure is ignored





The mass M_0 is the portion of the fluid mass moving with the tank as a rigid body. The mass M_1 is the portion of the fluid mass connected to the tank wall with springs.

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK 01014703066400 9			33 of
ESO NO.	COMPUTED CNS 4-26-94	CHECKED BY MOK 7-24-94	

Hydrodynamic Loads – Full Tank (cont.)

Rigid Mass [17]

$$M_0 = \left[\frac{\tanh(1.7R/H)}{1.7R/H}\right] M$$

$R/H = 25/11 = 2.273$

$1.7R/H = 1.7 \times 25/11 = 3.864$

$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$e^{3.864} = 47.656$

$\tanh(3.864) = 0.999$

$$\therefore M_0 = \frac{0.999}{3.864} M = 0.26 M$$

$H_0 = 0.38 H = 0.38 \times 11 = 4.18'$

Spring-Connected Mass [17]

$$M_1 = 0.71 \left[\frac{\tanh(1.8H/R)}{1.8H/R}\right] M$$

$1.8H/R = 1.8 \times 11/25 = 0.792$

$e^{0.792} = 2.208$

$\tanh(0.792) = 0.66$

$$\therefore M_1 = 0.71\left[\frac{0.66}{0.792}\right] M = 0.59 M, \qquad \frac{M}{M_1} = 1.695$$

$$H_1 = H\left[1 - 0.21\left(\frac{M}{M_1}\right)\left(\frac{R}{H}\right)^2 + 0.55\left(\frac{R}{H}\right)\sqrt{0.15\left(\frac{RM}{HM_1}\right)^2 - 1}\right]$$

$$= H\left[1 - 0.21(1.695)(2.273)^2 + 0.55(2.273)\sqrt{0.15(2.273)^2(1.695)^2 - 1}\right]$$

$$= 0.546 H = 0.546 \times 11 = 6.0'$$

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	01014703066 4009		34 of
ESO NO.	COMPUTED CNS 4-26-94	CHECKED BY MOK	7/25/94

Hydrodynamic Loads — Full Tank (Cont.)

Spring Constant & Fundamental Period [17]

$$K = \frac{4.75 g M_1^2 H}{M R^2}$$

$$= 4.75 (W_1)(M_1/M)(H/R^2)$$

where $W_1 = g M_1$

(Specific Gravity)

W = Total fluid weight $= 1.25 \times 62.4$ (Volume)

$$= 1.25 \times 62.4 \times 11 \times \pi \times (25)^2$$

$$= 1{,}684{,}679 \text{ lb} = 1{,}685 \text{ kips}$$

$$W_1 = W\left(\frac{M_1}{M}\right) = 1685 \times 0.59 = 994 \text{ kips}$$

$$\therefore K = 4.75(994)(0.59)(11/25^2) = 49 \text{ k/ft}$$

$$T = 2\pi\sqrt{M_1/K} = 2\pi\sqrt{\left(\frac{994}{32.2}\right)/49} = 4.99 \text{ sec}$$

Checking with the "Oak Ridge Site Specific Uniform Hazard Response Spectra for Horizontal Rock Motion"

There is no amplification of the ground acceleration for $T > 0.4$ sec.

The spectral displacement with 5% damping for $T = 4.99$ sec and $ZPA = 0.14g$, UCRL 53582 page 63 shows $\Delta \approx 0.14\left(\frac{1685}{32.2}\right) = 0.14(52.3) = 7.28$ in

GENERAL DESIGN AND COMPUTATION SHEET

JOB	DATE	SHEET
GUNITE TANK 0101470306064009		35 of
ESO NO.	**COMPUTED** CNS 4-28-94	**CHECKED BY** MOK 7-24-94

Hydrodynamic Loads — Full Tank (cont.)

Height of Sloshing Waves [17]

The amplitude (height) of slosh is ηx where

$$\eta = \frac{0.69\,KR/M_1 g}{1-0.92\left(\frac{x}{R}\right)\left(KR/M_1 g\right)^2}$$

$K = 49\ K/ft$, $R = 25\ ft$

$M_1 g = W_1 = 994\ k$

$x = 7.28\ in = 0.61\ ft$

$$\therefore \eta = \frac{0.69 \times 49 \times 25/994}{1-0.92\,(0.61/25)(49\times 25/994)^2} = 0.88$$

$\eta x = 0.88 \times 7.28 = 6.41$ in $> 0.02H$ $\therefore$ nonlinear [17]

The sloshing wave height of 6.41 inches will not become a loading condition for the dome. The fluid in the tank will not escape from the tank because of this wave height. It is not significant.

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	01014703066600 9		36 of
ESO NO.	COMPUTED CNS 4-28-94	CHECKED BY MOK 7-20-94	

Hydrodynamic Loads — Full Tank (cont.)

Hydrodynamic Pressures

(1) For empty-tank condition:

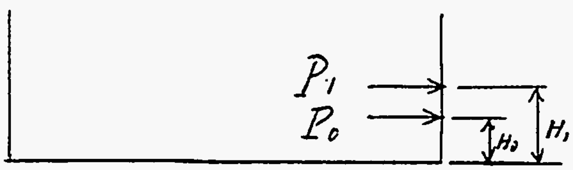
Only soil & tank are considered, see other sections.

(2) For full-tank condition (11-ft fluid):

Fluid, tank, & soil are all considered.

See other sections for soil and tank loadings.

For horizontal ground acceleration = 0.14 g.

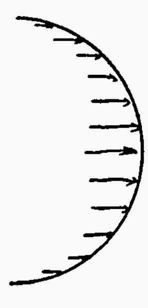


$$P_0 = 0.14 \left(\frac{M_0}{M}\right) W$$
$$= 0.14 \times 0.26 \times 1685$$
$$= 61.3 \text{ kips}$$

acting @ a height $H_0 = 4.1$

$$P_1 = 0.14 \left(\frac{M_1}{M}\right) W$$
$$= 0.14 \times 0.59 \times 1685 = 139.2 \text{ kips.}$$

acting @ a height $H_1 = 6.0$ ft.



These are total loads acting on a 180° half circle.

GUNITE TANK   CNS 4-28-94   CKD MOK 7-24-94

010147030664009

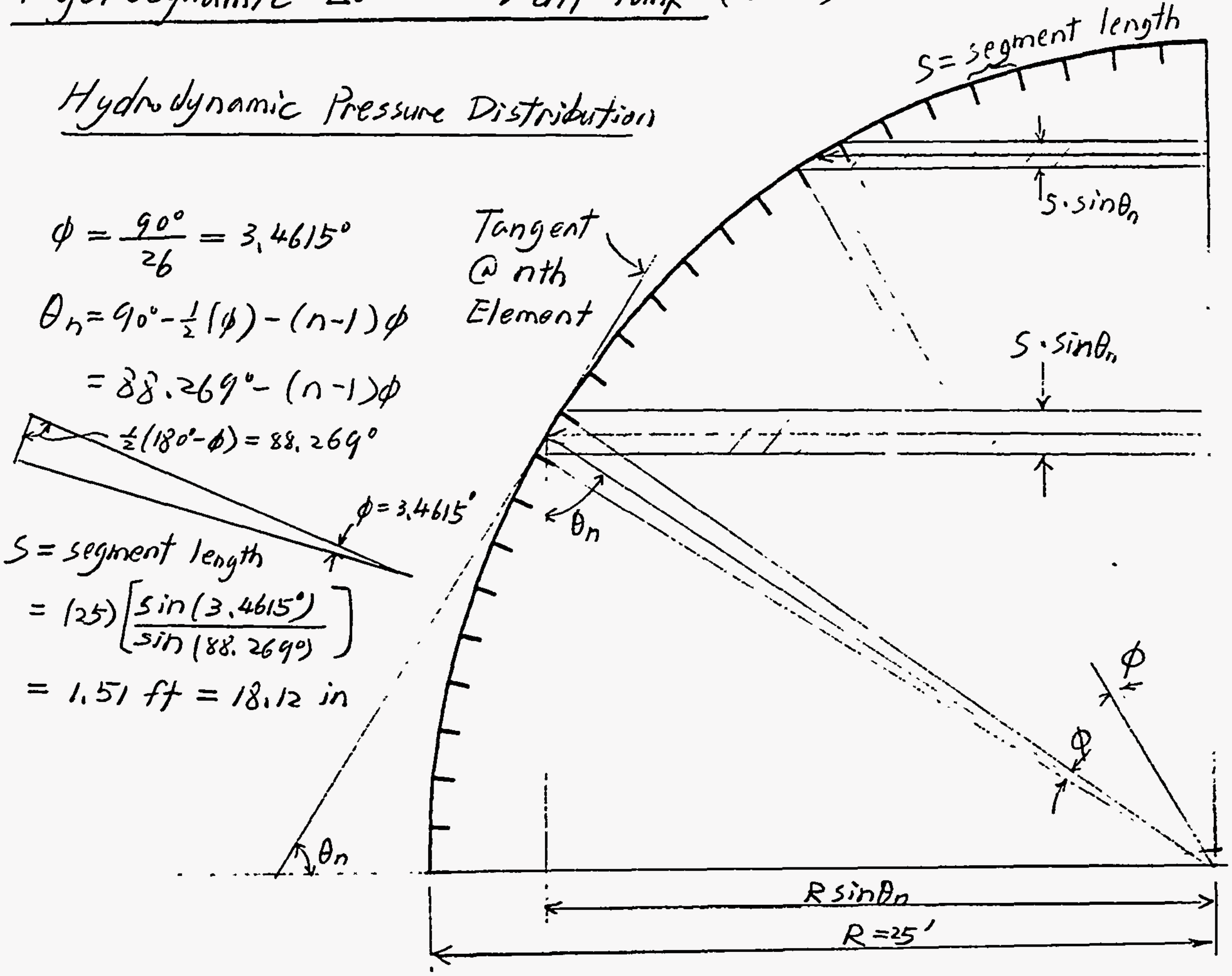
Hydrodynamic Load — Full Tank (Cont.)

Hydrodynamic Pressure Distribution

$$\phi = \frac{90^\circ}{26} = 3.4615^\circ$$

$$\theta_n = 90^\circ - \tfrac{1}{2}(\phi) - (n-1)\phi$$

$$= 88.269^\circ - (n-1)\phi$$



S = segment length

$$= (25)\left[\frac{\sin(3.4615^\circ)}{\sin(88.269^\circ)}\right]$$

$$= 1.51 \text{ ft} = 18.12 \text{ in}$$

M_0 and M_1 are distributed to each element in proportion to the contributing "area" shown above. It is proportional to $\sin^2\theta_n$

The rigid mass, less than 50% of the spring-connected mass, is assumed to induce a dynamic force in the same direction as that of the spring-connected mass. This assumption is conservative.

01014703066 4009

GUNITE TANK   CNS 4-28-94   CKD MOK 7-24-94

Hydrodynamic Loads — Full Tank (cont.)

Points of Application

$H_0 = 4.18' = 50.16''$

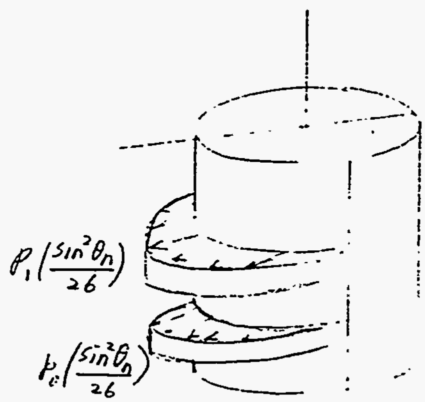
$P_0 = \frac{P_0}{Area} = \frac{61300}{12.5 \times 18.12}$

$= 270.7$ psi

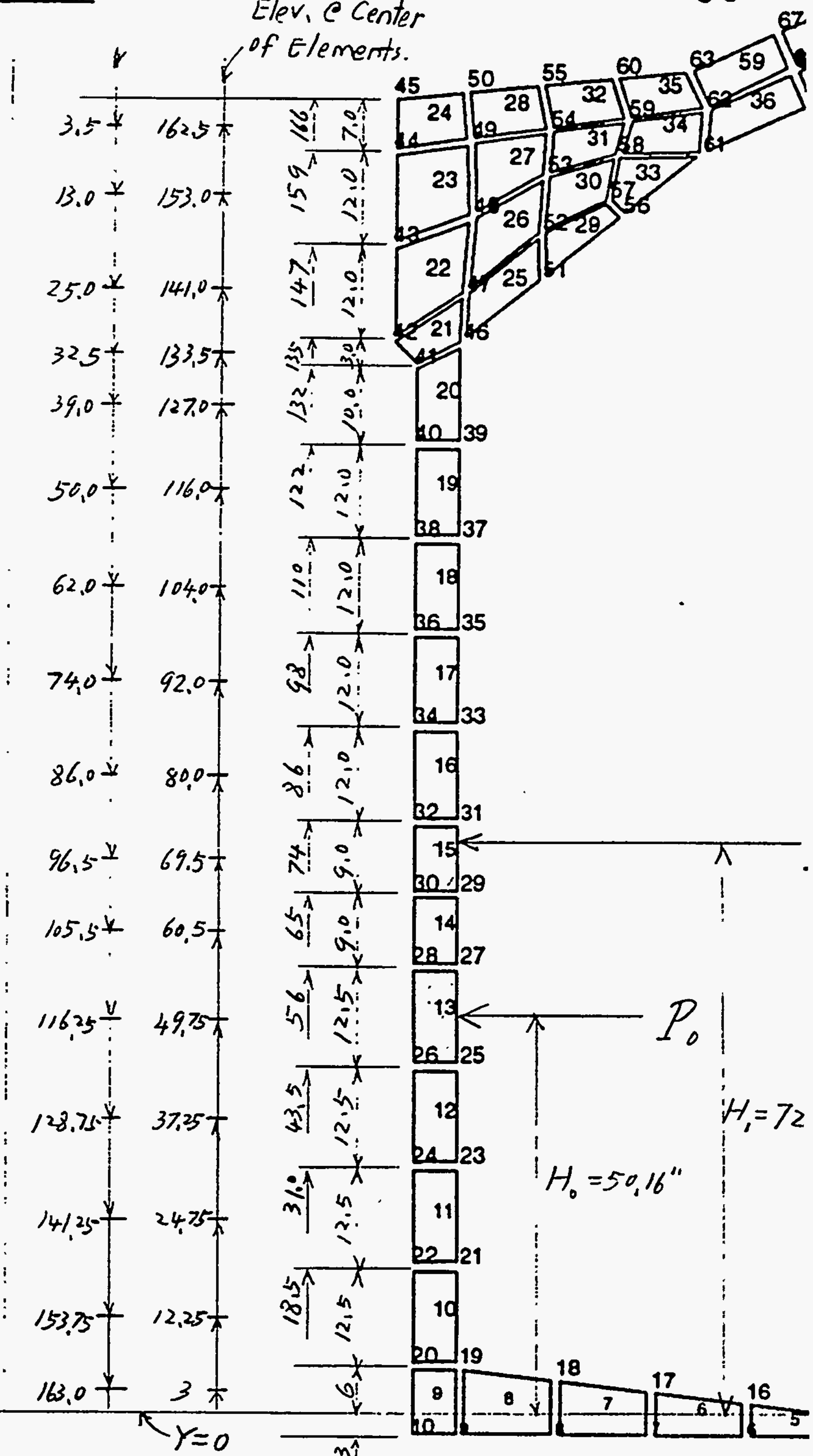
$H_1 = 6' = 72''$

$P_1 = \frac{P_1}{Area} = \frac{139200}{9 \times 18.12}$

$= 853.6$ psi



See next page for tabulated values.



Distribute total sloshing dynamic load over a band of elements @ the approximate elevation of the C.G. of the sloshing mass (M_1). Similarly, distribute total rigid body hydrodynamic load over a band of elements @ the approximate elevation of the C.G. of the rigid mass (M_0).

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	0101470306640009		39 of
ESO NO.	COMPUTED CNS 4-28-94	CHECKED BY MOK 7-24-94	

Hydrodynamic Pressure — Full Tank (Cont.)

Coefficients of Hydrodynamic Pressure

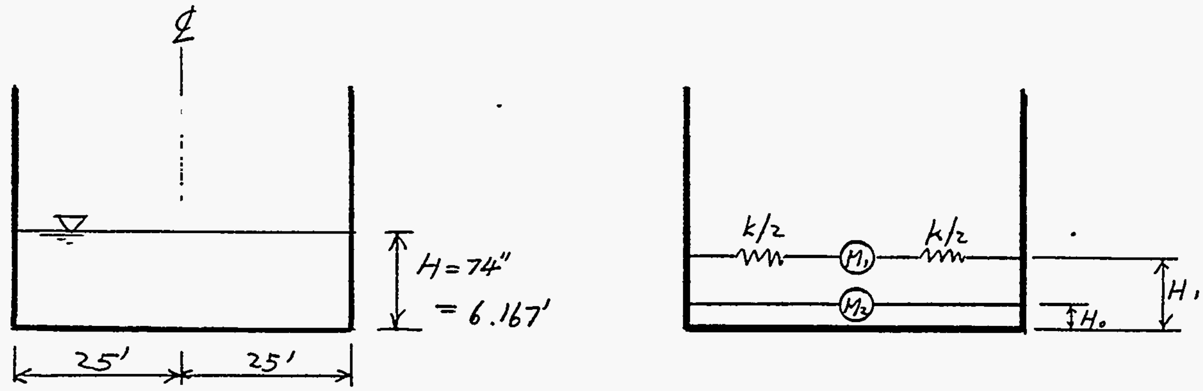
n	θ_n	$\sin^2\theta_n$	$\sin^2\theta_n / (2\sum\sin^2\theta)$ ($=26$)	$P_o(\sin^2\theta_n/26)$	$P_1(\sin^2\theta_n/26)$
1	88.269	0.999	0.0384	10.40	32.78
2	84.808	0.992	0.0382	10.34	32.61
3	81.346	0.977	0.0376	10.18	32.10
4	77.885	0.956	0.0368	9.96	31.41
5	74.423	0.928	0.0357	9.66	30.47
6	70.962	0.894	0.0344	9.31	29.36
7	67.500	0.854	0.0329	8.91	28.08
8	64.038	0.808	0.0311	8.42	26.55
9	60.577	0.759	0.0292	7.90	24.93
10	57.115	0.705	0.0271	7.34	23.13
11	53.654	0.649	0.0250	6.77	21.34
12	50.192	0.590	0.0227	6.14	19.38
13	46.731	0.530	0.0204	5.52	17.41
14	43.269	0.470	0.0181	4.90	15.45
15	39.808	0.410	0.0158	4.28	13.49
16	36.346	0.351	0.0135	3.65	11.52
17	32.885	0.295	0.0114	3.09	9.73
18	29.423	0.241	0.0093	2.52	7.94
19	25.961	0.192	0.0074	2.00	6.32
20	22.500	0.146	0.0056	1.52	4.78
21	19.038	0.106	0.0041	1.11	3.50
22	15.577	0.072	0.0028	0.76	2.39
23	12.115	0.044	0.0017	0.46	1.45
24	8.654	0.023	0.0009	0.24	0.77
25	5.192	0.008	0.0003	0.08	0.26
26	1.731	0.001	0.00004	0.01	0.03

$\sum \sin^2\theta = 13.$

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	0101470306664009		40 of
ESO NO.	COMPUTED CNS 4-29-94	CHECKED BY MOK 7-24-94	

Hydrodynamic Loads — Half Tank



Rigid Mass

$$M_0 = \left[\frac{\tanh(1.7R/H)}{1.7R/H}\right] M$$

$$1.7R/H = 1.7 \times 25/6.167 = 6.892$$

$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$$e^{6.892} = 476.6$$

$$\tanh(6.892) = 1.0$$

$$\therefore M_0 = \frac{M}{6.892} = 0.145\,M$$

$$H_0 = 0.38H = 0.38 \times 6.167$$

$$= 2.34'$$

Total Fluid Weight

$$W = 1.25 \times 62.4 \times 6.1667 \times \pi \times (25)^2$$

$$= 944{,}441 \text{ lb} = 944.4 \text{ kips}$$

GENERAL DESIGN AND COMPUTATION SHEET

28

JOB		DATE	SHEET
GUNITE TANK	01014703066 4609		41 of
ESO NO.	COMPUTED CNS 4-29-94	CHECKED BY MOK 7-24-94	

<u>Hydrodynamic Loads — Half Tank</u> (Cont.)

<u>Spring — Connected Mass</u>

$$M_1 = 0.71\left[\frac{\tanh(1.8H/R)}{1.8H/R}\right]M$$

$$1.8H/R = 1.8 \times 6.167/25 = 0.444$$

$$e^{0.444} = 1.559$$

$$\tanh(0.444) = 0.417$$

$$M_1 = 0.71\left(\frac{0.417}{0.444}\right)M = 0.667M$$

$$\frac{M}{M_1} = 1.5\,, \quad \frac{R}{H} = \frac{25}{6.1666} = 4.054$$

$$H_1 = H\left[1 - 0.21\left(\frac{M}{M_1}\right)\left(\frac{R}{H}\right)^2 + 0.55\left(\frac{R}{H}\right)\sqrt{0.15\left(\frac{RM}{HM_1}\right)^2 - 1}\right]$$

$$= H\left[1 - 0.21(1.5)(4.054)^2 + 0.55(4.054)\sqrt{0.15(4.054)^2(1.5)^2 - 1}\right]$$

$$= 0.577H = 0.577 \times 6.166 = 3.56'$$

<u>Spring Constant & Fundamental Period</u>

$$K = \frac{4.75\,gM_1^2H}{MR^2} = 4.75(W_1)(M_1/M)(H/R^2)$$

$$= 4.75 \times (0.667 \times 944.4)(0.667)(6.166/25^2) = 19.67\ k/ft$$

$$T = 2\pi\sqrt{M_1/K} = 2\pi\sqrt{\left(\frac{0.667 \times 944.4}{32.2}\right)/19.67} = 6.26\ sec.$$

No amplification of the ground acceleration.

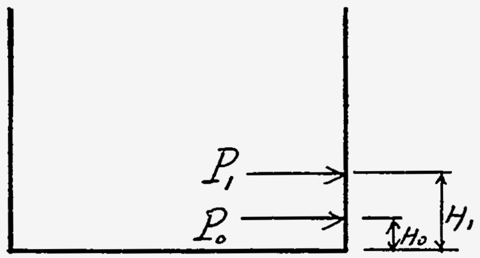
Height of sloshing waves in not significant.

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANK	01014703066400 9		42 of
ESO NO.	COMPUTED CNS 4-29-94	CHECKED BY MOK 7-20-94	

Hydrodynamic Loads — Half Tank (Cont.)

Hydrodynamic Forces



For horizontal ground acceleration = 0.1

$$P_0 = 0.14\left(\frac{M_0}{M}\right)W$$

$= 0.14 \times 0.145 \times 944.4$

$= 19.17$ kips

acting @ a height $H_0 = 2.34'$

$$P_1 = 0.14\left(\frac{M_1}{M}\right)W = 0.14 \times 0.667 \times 944.4 = 88.19 \text{ kips}$$

acting @ a height $H_1 = 3.56'$

These are the total hydrodynamic forces acting at certain heights on a 180° half circle.

UCN-4032A
(5 2-84)

Hydrodynamic Loads – Half Tank (Cont.)

Points of Application

$H_0 = 2.34' = 28.1''$

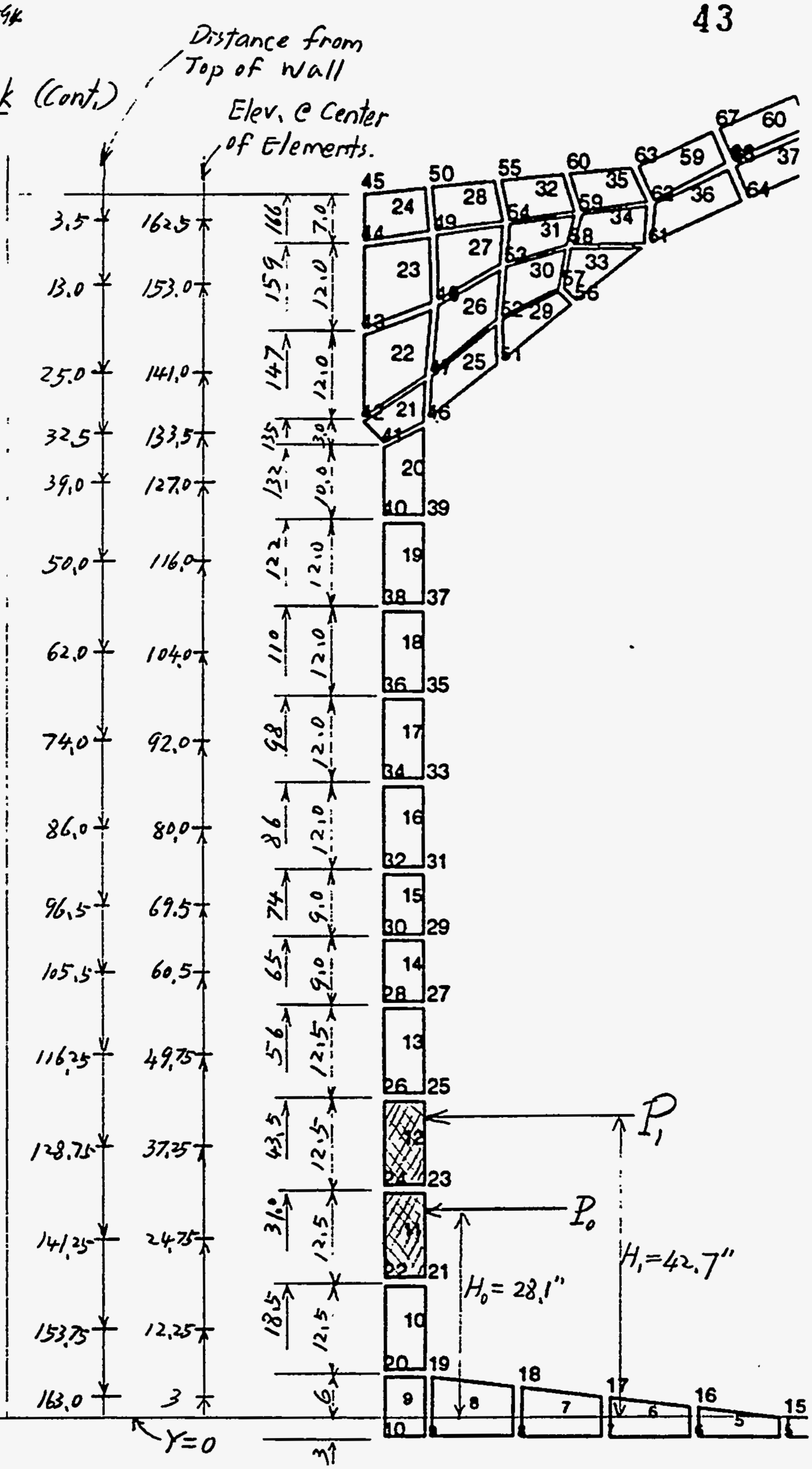
$p_0 = \frac{P_0}{Area} = \frac{19170}{12.5 \times 18.12}$

$= 84.6$ psi

$H_1 = 3.56' = 42.7''$

$P_1 = \frac{P_1}{Area} = \frac{88190}{12.5 \times 18.12}$

$= 389.4$ psi



GENERAL DESIGN AND COMPUTATION SHEET

JOB	DATE	SHEET
GUNITE TANK 010147030664009		44 of 31

ESO NO.	COMPUTED	CHECKED BY
	CNS 4-29-94	MOK 7-29-96

Hydrodynamic Pressure — Half Tank (Cont.)

Coefficients of Hydrodynamic Pressure

n	θ_n	$P_0 (\sin^2\theta_n/26)$	$P_1 (\sin^2\theta_n/26)$
1		3.25	14.95
2		3.23	14.88
3		3.18	14.64
4		3.11	14.33
5		3.02	13.90
6		2.91	13.40
7		2.78	12.81
8		2.63	12.11
9		2.47	11.37
10		2.29	10.55
11		2.12	9.74
12		1.92	8.84
13		1.73	7.94
14		1.53	7.05
15		1.34	6.15
16		1.14	5.26
17		0.96	4.44
18		0.79	3.62
19		0.63	2.88
20		0.47	2.18
21		0.35	1.60
22		0.24	1.09
23		0.14	0.66
24		0.08	0.35
25		0.03	0.12
26		0.003	0.02

$\theta_n = 90° - \frac{1}{2}(\phi) - (n-1)\phi = 90° - (n - \frac{1}{2})\phi$

$\phi = 90°/26$,

UCN-4032A
(5 2-84)

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANKS	0101970306604009		45 of
ESO NO.	COMPUTED CNS 5-20-94	CHECKED BY MOK 7-29-94	

Material Properties

Reinforcing Steel Allowable Stresses

Codes require that:

The full calculated tensile forces are carried by reinforcing steel [2].

The principal tensile stresses are resisted entirely by reinforcement [3].

For prestressed reinforcement

$f_s = 0.4 f_y = 0.4 \times 60{,}000 = 24{,}000$ psi [ACI 318-63]

for seismic load: allow. tensile stress $= 1.33 \times 24000 = 32{,}000$ psi

For nonprestressed reinforcement the allowable tensile stress should not exceed 18.0 ksi, exclusive of shrinkage and temperature effects, regardless of yield stress [4].

Use allowable $f_s = 18{,}000$ psi. (working stress design method)

For seismic load: allow. tensile stress $= 1.33 \times 18 = 24.0$ ksi

Concrete Properties

Gunite: $f_c' = 5{,}000$ psi (dwg E-56866), $\mu = 0.17$

$$E_c = 57000\sqrt{f_c'} = 4{,}030{,}000 \text{ psi} = 4{,}030 \text{ ksi}$$

$$f_r = \text{tensile stress limit} = 4\sqrt{f_c'} \approx 300 \text{ psi} \quad (\text{ref. } 30)$$

Criteria for Screening High Tensile Stress Areas

The "Maximum Principal Stress" is used to locate high tensile stress areas in concrete. The following limits are only for identifying these areas, not for code compliance; since all tensile stresses are resisted by reinforcing steel.

Max Principal Stress: Use $f_r = 300$ psi as screening reference.

GENERAL DESIGN AND COMPUTATION SHEET

JOB		DATE	SHEET
GUNITE TANKS	0101470306b4009		46 of
ESO NO.	COMPUTED CNS 5-20-94	CHECKED BY MOK 7-20-94	

Material Properties (cont.)

Concrete Properties (cont)

Von Mises Failure Theory

The concrete fails if the multi-axial state of stress reaches a certain leve; but concrete properties are determined generally by uniaxial test. To predict failure under a multiaxial state of stress from uniaxial material properties, various theories of failure have been utilized to predict the onset of failure of a material in a combined-stress state from uniaxial data. Failure signifies yielding or actual rupture, whichever is more critical [6].

General Formulation of Von Mises Theory [6]

For principal stresses:

$$\sigma_i = \left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2}$$

For non-principal stresses:

$$\sigma_i = \left[\frac{(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_z-\sigma_x)^2}{2}+3\left(\tau_{xy}^2+\tau_{yz}^2+\tau_{zx}^2\right)\right]$$

σ_i is compared with the allowable tensile stress

STRUDL Formulation of Von Mises Theory [14]

$$\sigma_i^{GT} = \left[\frac{\underline{S_{xx}}^2+\underline{S_{yy}}^2+\underline{S_{zz}}^2}{2}+S_{xy}^2+S_{yz}^2+S_{zx}^2\right]^{1/2}$$

Where $\underline{S_{xx}} = S_{xx} - S_{ave}$, $\underline{S_{yy}} = S_{yy} - S_{ave}$; $\underline{S_{zz}} = S_{zz} - S_{ave}$

$S_{ave} = (S_{xx}+S_{yy}+S_{zz})/3$

σ_i^{GT} is compared with $\frac{1}{\sqrt{3}}$(allow. tensile stress) The two formulations g. identical results.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANKS
01014703066A009

AUTHOR MOK DATE 7-31-94 JOB NO.
CHECKED BY CNS DATE 7-25-94 PAGE 47 of

Reference

CHECKER'S NOTE:

THE VON MISES STRESSES OUTPUT BY GTSTRUDL HAVE BEEN REDUCED BY A FACTOR OF $1/\sqrt{3}$ WITH RESPECT TO CLASSICAL VON MISES FORMULATIONS. GTSTRUDL VON MISES SHOULD ∴ BE COMPARED AGAINST ALLOWABLE STRESS LIMITS WHICH HAVE ALSO BEEN REDUCED BY $\frac{1}{\sqrt{3}}$. IN THIS EVALUATION VON MISES STRESSES WILL BE COMPARED TO $7.5\sqrt{f'_c}/\sqrt{3}$ TO DETERMINE THE MARGIN AGAINST TENSILE FAILURE IN UNREINFORCED CONCRETE. (SEE ALSO CAPACITY REDUCTION" IN FOLLOWING PAGES.)

VON MISES STRESSES WILL BE USED TO CHECK FOR GENERAL QUALIFICATION OF THE STRUCTURES CONCRETE SECTIONS. WHERE COMPUTED VON MISES STRESSES ARE LOWER THAN VON MISES ALLOWABLE LEVELS THE XSECTION OF INTEREST IS CONSIDERED QUALIFIED. WHERE VON MISES STRESS ALLOWABLES ARE EXCEEDED CONVENTIONAL REINFORCED CONCRETE ANALYSIS TECHNIQUES WILL BE USED TO ACCESS COMPLIANE WITH ANALYSIS CRITERIA.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Ref.

Evaluation of Existing Structures

Evaluation of the tanks was performed by analytical method. Concrete was assumed to be uncracked, homogeneous, and isotropic. The approach and material characteristics are depicted in codes summarized below.

In case load test is not feasible, evaluation by analytical method is permitted according to ACI 318-89 (Ref. 2)

Also in ACI 318-89, it is noted that for members other than simple flexural members (beams), an analytical method is preferred because the criterion for judging the results of load tests are not well established for structures such as shells.

ACI 334 Concrete Shell Structures Practice and Commentary (Ref. 3), states that for an elastic analysis, concrete may be assumed uncracked, homogeous, and isotropic. Elastic analysis should be used for supporting members such as rings. Similar statements are found in ACI 318-89 (Ref. 2).

Reinforcements are required to take the entire tensile force calculated for concrete as required by ACI 318-89 (Ref. 2) ACI 334 (Ref. 3), and ACI 344 (Ref. 4).

High tensile stress areas in concrete are identified by both maximum principal stress and Von Mises stress criteria.

Minimum dome & wall thickness required by ACI 344 is 3½ in. OK

Floor thickness required is 2½ inch OK

Concrete cover per ACI 334: ½" for bars not contacting ground, 3/8" for welded wire fabric, 1" for prestressed Tendons. OK

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Evaluation of Existing Structures (cont.)

Maximum Stresses

The maximum stresses due to both static and seismic loads are tabulated below.

Type of Stress		* Location	Node	Static + Seismic Loads		Static Load		** Ratio
				Loading Case	Stress (psi)	Loading Case	Stress (psi)	
Directional Tensile and Shear Stresses	Sxx	1	8128	6	542	2	488	1.11
	Syy	5	4071	4	549	1	489	1.12
	Szz	3	8592	4	833	1	781	1.07
	Sxy	6	4071	4	544	1	491	1.11
	Sxz	4	8903	8	453	3	410	1.10
	Syz	6	41	4	523	1	488	1.07
Principal Stresses	Tension	6	4071	4	689	1	621	1.11
	Compression	2	8595	4	642	1	597	1.08
	Tmax	6	4071	4	467	1	420	1.11

* Locations 1: 30-in opening, bottom surface.
2: 30-in opening, middle surface.
3: 30-in opening, top surface.
4. edge of dome, bottom surface.
5. bottom of ring.
6. top of wall, exterior surface.

** Ratio = Stress due to static plus seismic load / Stress due to static load

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Refe

Evaluation of Existing Structures (Cont.)

Reinforcements

ACI 334 (Ref. 3) requires providing reinforcement in the principal stress directions. A reduction of 5% in allowable stress for each degree of deviation from the principal stress direction beyond 15° IS REQUIRED. This means that reinforcements placed 35° from the principal stress direction become completely ineffective, the allowable stress becomes zero.

A structure may be subjected to many loads, and different combinations of them. In each situation, the stress pattern will change as well as the magnitude and direction of principal stresses. It is impossible to place reinforcement in principal stress directions for all load combinations. The ACI 334 requirements on placing reinforcements is impractical.

This evaluation proportions reinforcement according to the state of stress in concrete in terms of directional stresses relationship (Ref. 15).

SAIC Science Applications International Corporation An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01014703066 4 009
AUTHOR CNS DATE 6-9-94 JOB NO.
CHECKED BY MOK DATE 7-24-94

Reference

Evaluation of Existing Structures (Cont.)

Reinforcements (Cont.)

Hoop Reinforcements in the Wall [Ref. Dwg. E-56866, -56867]

The maximum hoop stress, 314 psi, occured in the top 2 feet of the wall, at node 4069 of element 2125 under loading condition 5 (See figure next page).

The ring @ THE TOP OF THE WALL has 17 $1\frac{1}{8}"\phi$ bars (13 original + 4 renovation). A part of the ring reinforcement can be counted to resist the hope tension near the top of the wall. Three $1\frac{1}{8}"\phi$ bars from the ring and one $3/4"\phi$ bar from the wall give a total steel area $A_s = 3 + 0.44 = 3.44\ in^2/2\,ft$ wall height.

The next 2 feet of wall seems to be more critical. The reinforcements are:

$3/4"\phi$ bar @ 8" (prestressed) $A_s = 0.44\ in^2/8\ in$

3 layers of welded mesh 4"x4"-8x8 $A_s = \frac{8}{12} \times 3 \times 0.062 = 0.124$

Allow. tensile force $= 32000 \times 0.44 + 24000 \times 0.124 = 17,056$ lb

Max. tensile force in 8"x6" concrete wall $= 8 \times 6 \times 314 = 15,072$ lb

$$\frac{\text{Demand}}{\text{Capacity}} = \frac{15072}{17056} = 0.88 < 1.0 \quad \text{OK}$$

$$\text{OR} \quad \text{CAPACITY}/\text{DEMAND} = \frac{17056}{15072} = 1.13$$

prepared CNS 3/27/95 checked by TC 3/31/95

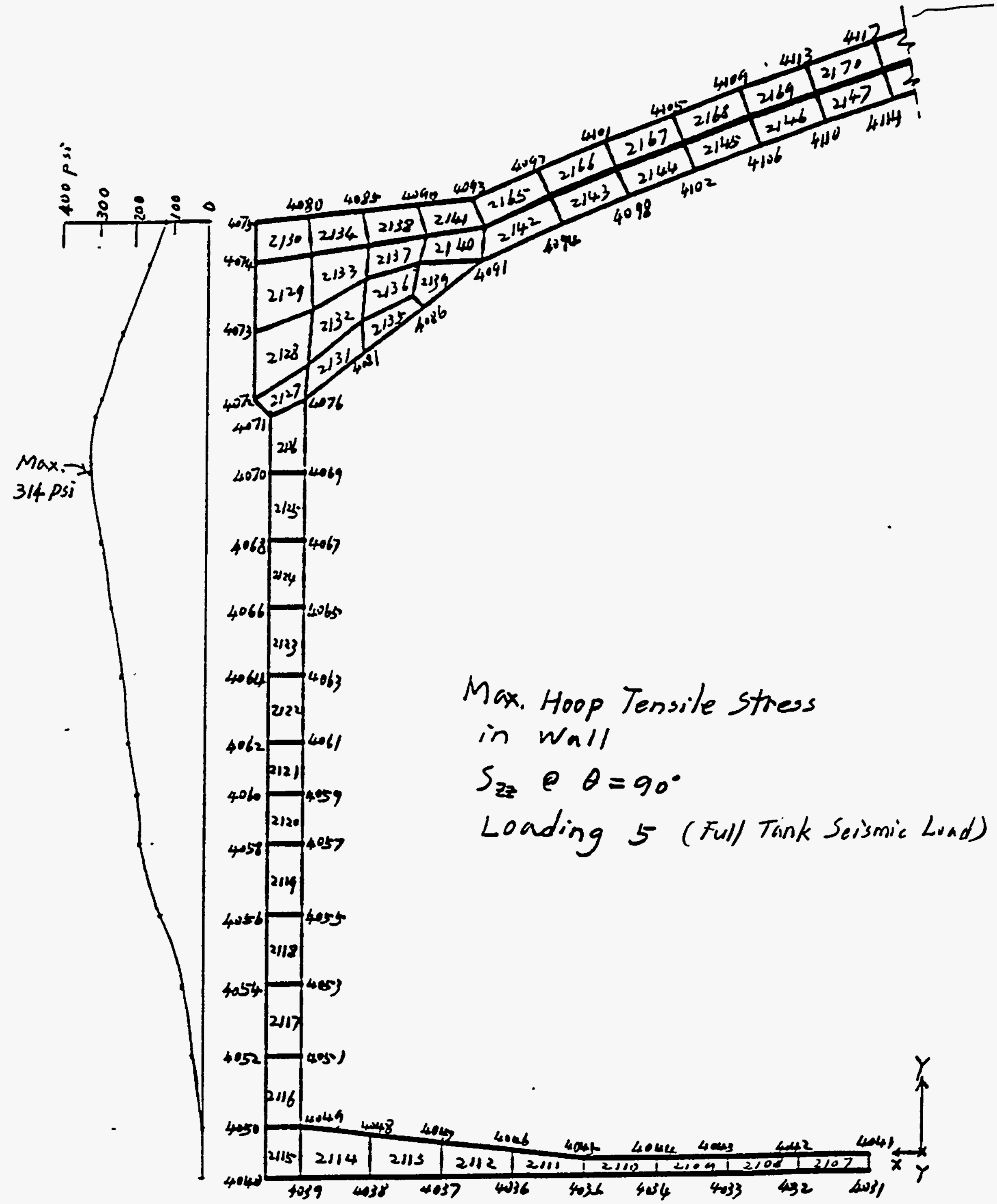


Fig. 1. Maximum Hoop Tensile Stress

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01014703066400 9
AUTHOR CNS DATE 6-9-94 JOB NO.
CHECKED BY MOK DATE 7-28-94 PAGE 53 of

Reference

Evaluation of Existing Structures (Cont.)

Reinforcements (Cont.)

Circumferential Reinf. in the Ring

Maximum tensile stress in the ring = 300 psi
(see figure next page)

Max. Tensile force in ring $= 300 \times \frac{1}{2} \times (3+6+30)[\cdot(31+3)+11]$
$= 300 \times 878 = 263{,}400$ lb

Reinforcement: 15 $1\frac{1}{8}$"φ bar As = 15 × 1 = 15
3 3/8"φ bar 3 × 0.11 = 0.33 } 15.33 in²
2 layers 4"×4"-#8×#8 mesh 2×2×0.062 = 0.248 in²
2-ft long

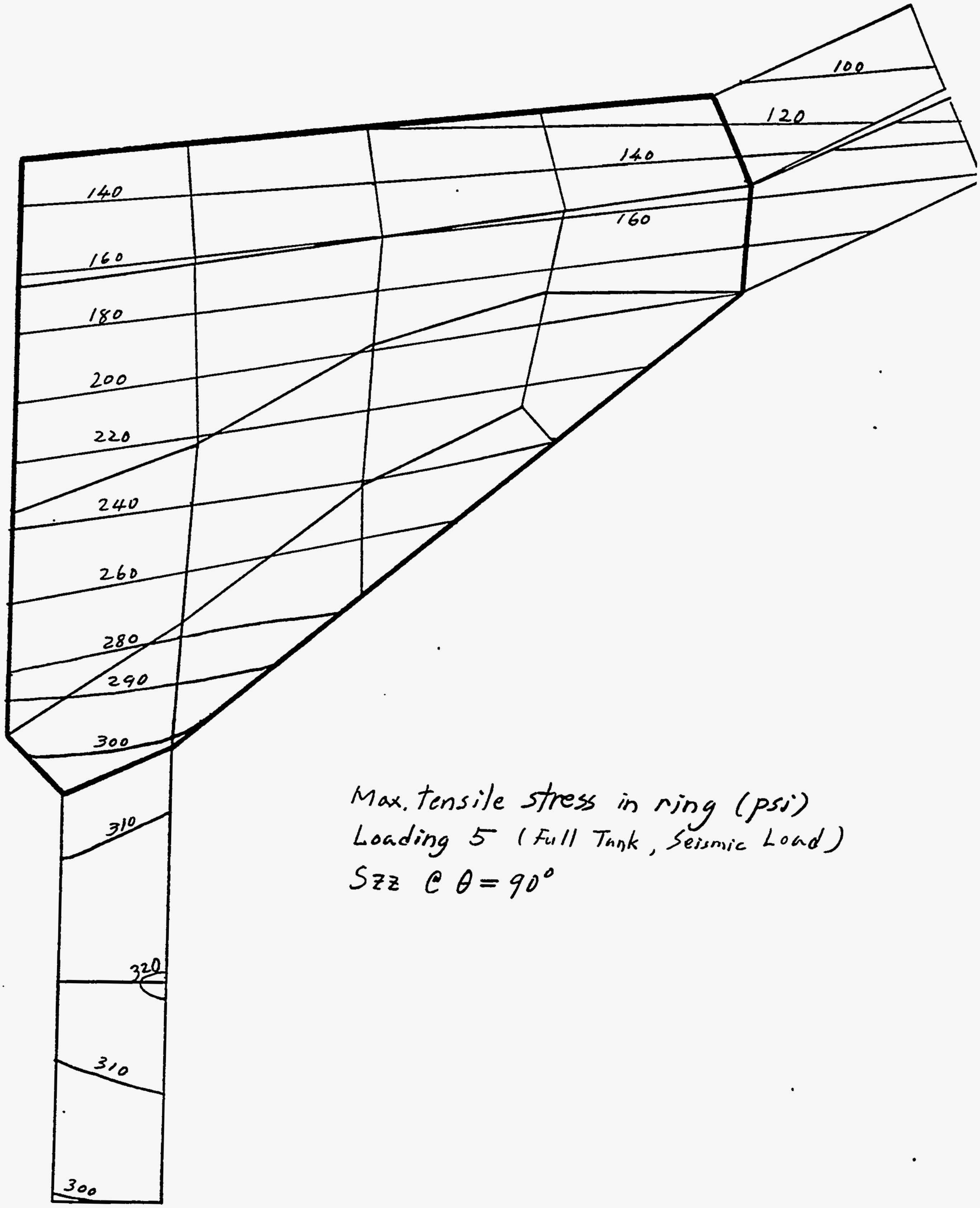
Allow. Tensile Force $= 32.0 \times 15.33 + 24 \times 0.248 = 496.51$ k
$= 496{,}510$ lb

$$\frac{\text{Demand}}{\text{Capacity}} = \frac{263400}{496510} = 0.53 < 1.0 \quad \text{OK}$$
(for code compliance)

Capacity at yield $= 60 \times 15.33 + 40 \times 0.248 = 929{,}702$ lb

$$\frac{\text{Capacity}}{\text{Demand}} \text{ at yield} = \frac{929{,}702}{263400} = 3.5$$

This is the reserved capacity the ring has.



Max. tensile stress in ring (psi)
Loading 5 (Full Tank, Seismic Load)
S_{zz} @ $\theta = 90°$

Fig. 2. Maximum Tensile Stress Distribution in Ring

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01014703066A009
AUTHOR CNS DATE 6-9-94 JOB NO.
CHECKED BY MOK DATE 7-24-94 PAGE 55 of

Reference

Evaluation of Existing Structures (cont.)

Reinforcements (cont.)

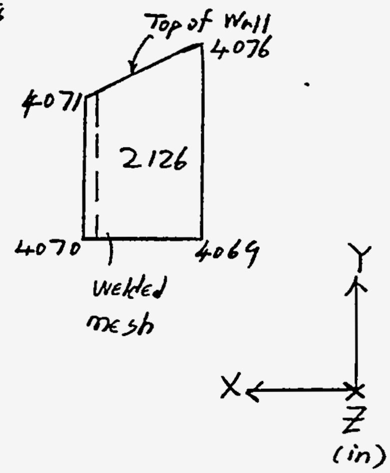
Vertical Reinforcement in the Wall

Tensile stress Criterion

Reinforcement is assumed to take all tensile force.

Empty Tank Plus Seismic Loading

This loading case (loading 4) results the max. principal tensile stress, 689 psi @ Node 4071, (see sketch next sheet)

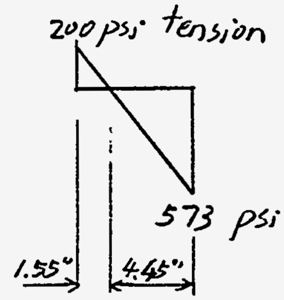


The corresponding directional stresss S_{yy} @ nodes 4071 and 4076 are 200 and -573 psi respectively.

Tensile force in the section

$= \frac{1}{2} \times 200 \times 1.55 = 155$ lb/in wall

$= 1860$ lb/12-in wall

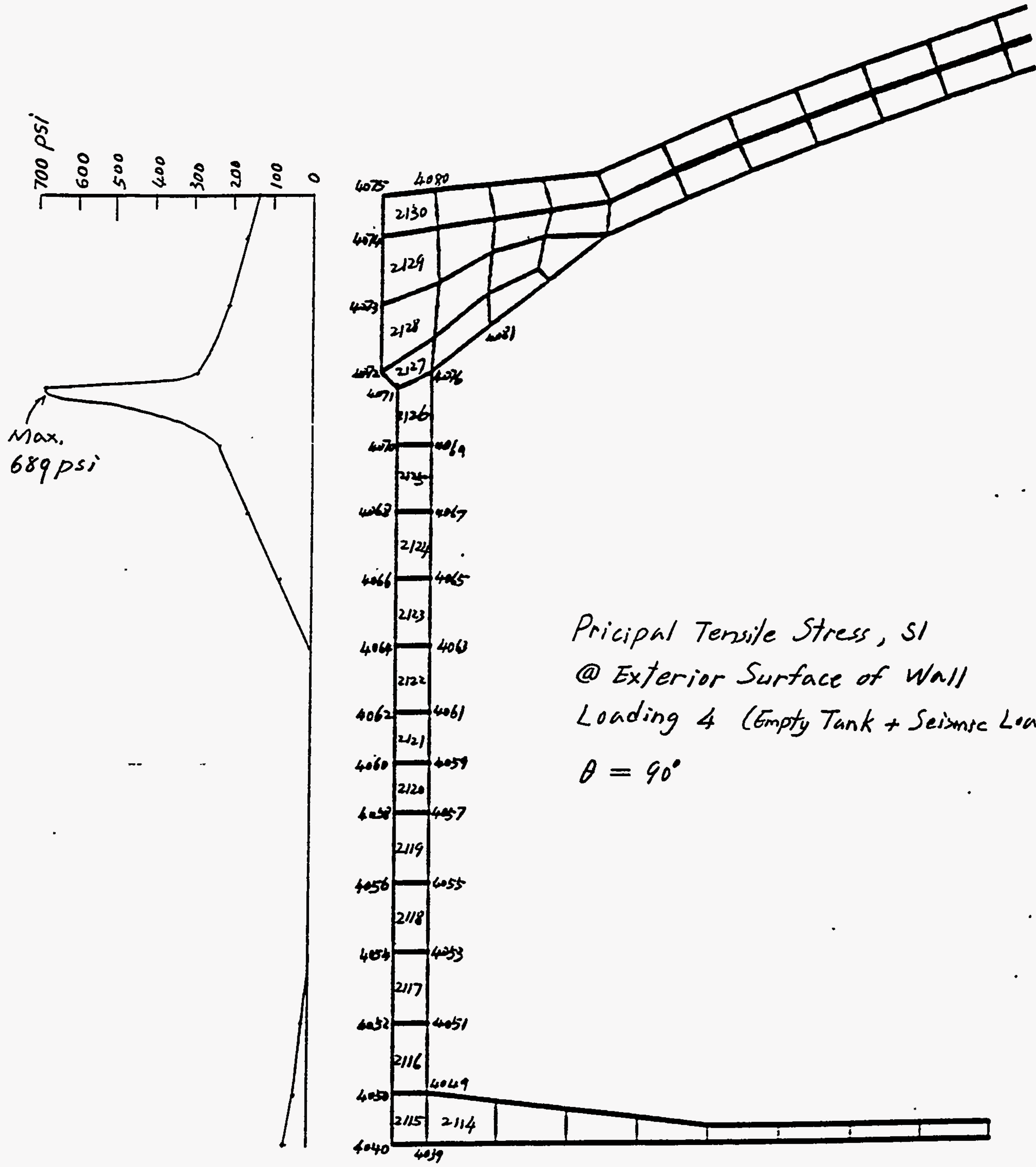


For one layer welded mesh
4"×4"—#8×#8 $A_s = 0.062$ in²/12-in

Allow. Tensile Force = 0.062 × 24000
= 1488 lb/12-in wall

$$\frac{\text{Demand}}{\text{Capacity}} = \frac{1860}{1488} = 1.25 > 1.0 \text{ NG.}$$

Other loading conditions need be further investigated.



Pricipal Tensile Stress, S1
@ Exterior Surface of Wall
Loading 4 (Empty Tank + Seismic Load)
$\theta = 90°$

Fig. 3 Principal Tensile Stress @ Exterior Surface of Wall prepared CNS 3/27/95 checked by TC 3/31/95

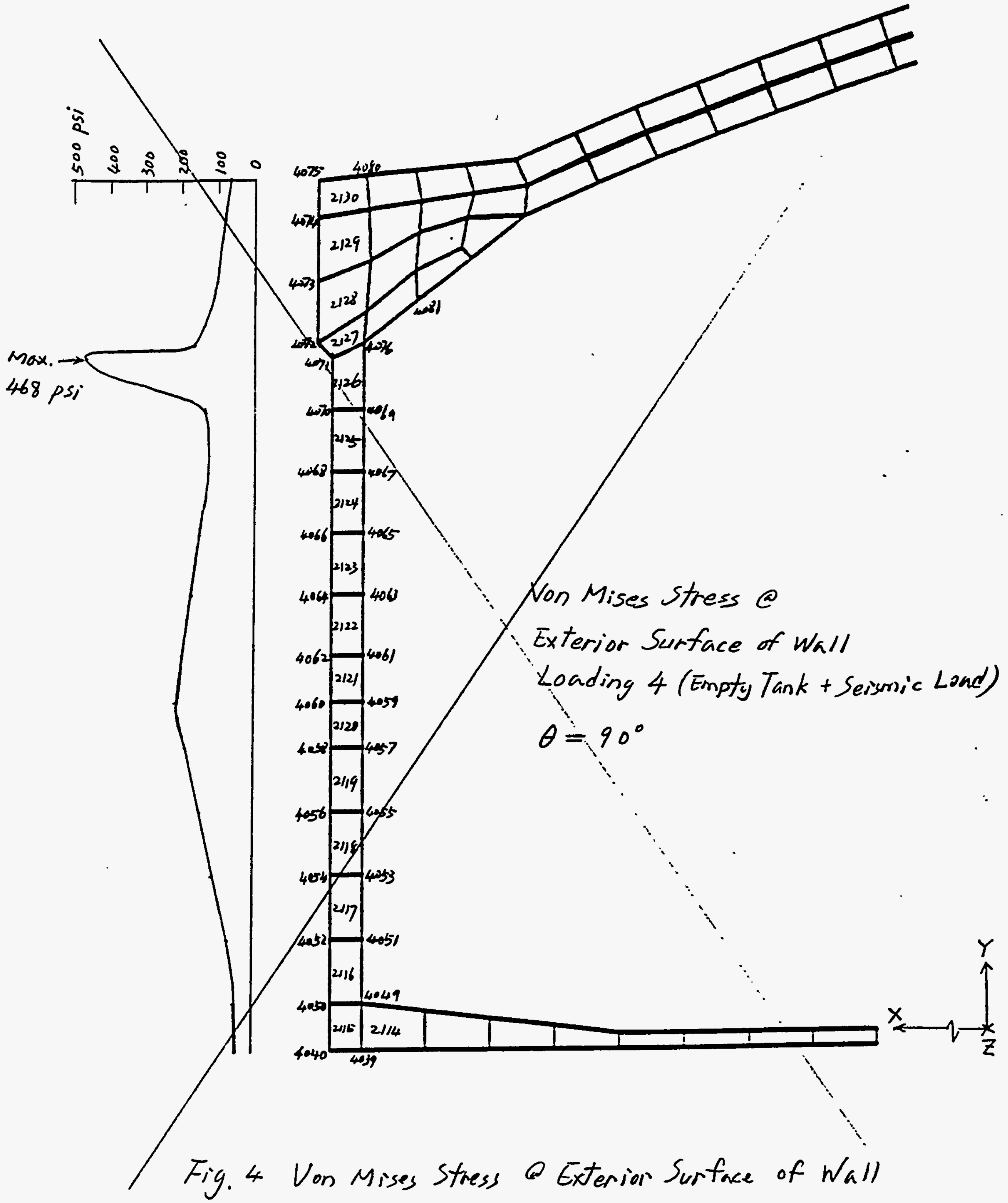


Fig. 4 Von Mises Stress @ Exterior Surface of Wall

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Evaluation of Existing Structures (cont.)

Reinforcements (cont.)

Vertical Reinforcement in the Wall (cont.)

Tensile Stress Criterion

Full Tank Plus Seismic Loading

Loading cases 5 and 6 represent the hydrodynamic loadings from opposit direction.

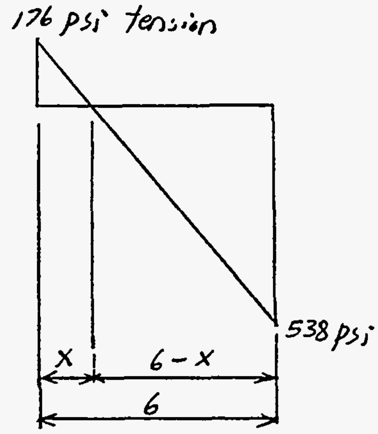
Loading Case	Syy @ Node 4071	Syy @ Node 4076
5	114	-467
6	176	-538

Loading case 6 controls for its larger tensile stress.

$X = \left(\frac{176}{176+538}\right) 6$

$= 1.48"$

$6 - X = 4.52"$



Tensile force in the section

$= \frac{1}{2}(176)(1.48) = 130$ lb/in

$= 1563$ lb/12-in wall

Allow. tensile force = 1488 lb/12-in wall

$\frac{\text{Demand}}{\text{Capacity}} = \frac{1563}{1488} = 1.05 \approx 1.0$ OK

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Evaluation of Existing Structures (cont.)

Reinforcements (cont.)

Vertical Reinforcement in the Wall (cont.)

Tensile Stress Criterion (cont.)

Other Loading Conditions

Loading Type	Loading Case	Condition	t: Tensile Stress @Node 4071 (psi)	c: Compressive Stress @Node 4076 (psi)	N: Tension in 12-in Long Wall (lb)	Demand / Capacity
Static	1	Empty Tank	189	516	1824	1.63
	2	Full Tank	169	495	1548	1.39
	3	Half Full Tank	184	511	1754	1.57
Static + Seismic	4	Empty Tank	200	573	1860	1.25
	5	Full Tank In-Phase	114	467	805	0.54
	6	Full Tank Out-of-Phase	176	538	1563	1.05
	7	Half Tank In-Phase	179	548	1587	1.07
	8	Half Tank Out-of-Phase	192	558	1769	1.19

$$N = 12\left[\tfrac{1}{2}(t)\left(\frac{t}{t+c}\right)(6)\right] = \frac{36t^2}{t+c}$$

Tensile Capacity for static loading cases = 0.062 × 18000 = 1116 lb/12-in

for seismic loading cases = 0.062 × 24000 = 1488 lb/12-in

The vertical reinforcement is not adequate to resist the tensile force as required by ACI 318 [2] and ACI 334 [3]. However, the stress, Syy, changes sign across the wall, an indication that the wall is under both axial compression load and bending moment. The wall can be evaluated as a "beam-column" subjected to both axial and flexural loads.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Ref

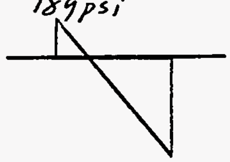
Evaluation of Existing Structure (Cont.)

Reinforcements (cont.)

Vertical Reinforcement in the Wall (cont.)

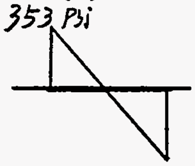
Bending Moment Criterion

The wall can be evaluated as a column or beam-column, Check for the most critical condition, loading ①



Resulting stress from M and P.

=



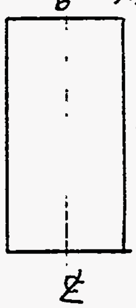
From Moment, M.

$\frac{1}{2}(189+516) = 353$ psi

+

From Axial Compressive Force, P.

$516 - 353 = 163$ psi



For a unit length of 12" wall

$A = \text{Area} = 6 \times 12 = 72 \text{ in}^2$

$SM = bh^2/6 = 12 \times 6^2/6 = 72 \text{ in}^3$

$P/A = P/72 = 163 \quad \therefore P = 11{,}736$ lb

$M/SM = M/72 = 353 \quad \therefore M = 25{,}416$ lb-in

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

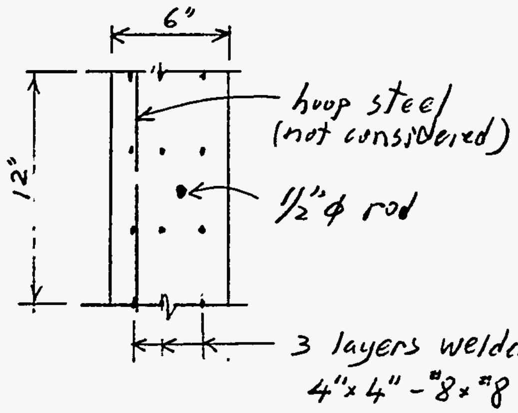
Reference

Evaluation of Existing Structure (cont.)

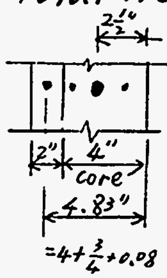
Reinforcements (cont.)

Vertical Reinforcement in the Wall (cont.)

Bending Moment Criterion (cont.)



Total steel $A_s = 0.2 + 3 \times 0.062 = 0.386$ in²



$d = \dfrac{0.062 \times 4.83 + 0.324 \times 2.5}{0.386}$

$= 2.874"$

Check this section as a beam-column, using ACI 318-63* Eq. 14-9 & 14-10

* USED FOR ASD METHODOLOGY

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1 \quad \text{--- (14-9)}$$

$$F_a = 0.34(1 + p_g m) f_c' \quad \text{--- (14-10)}$$

$f_a = 163$ psi, $f_b = 353$ psi

$p_g = \dfrac{A_s}{A_g} = \dfrac{0.386}{72} = 0.00536$

$m = f_y / (0.85 f_c') = 40{,}000 / (0.85 \times 5000) = 9.41$

$\therefore F_a = 0.34(1 + 0.00536 \times 9.41) \times 5000 = 1{,}786$ psi

Calculate F_b as follows:

$n = E_s/E_c = 29000/4030 = 7.2$

$f_s = 18{,}000$ psi, $f_c = 0.45 f_c' = 0.45 \times 5000 = 2250$ psi

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Refer

Evaluation of Existing Structure (cont.)

Reinforcement (cont.)

Vertical Reinforcement in the Wall (cont.)

Bending Moment Criterion (cont.)

$$k = \frac{1}{1+\frac{f_s}{nf_c}} = \frac{1}{1+\frac{18{,}000}{7.2\times 2250}} = 0.47$$

$$jd = d\left(1-\frac{k}{3}\right) = 2.874\,(1-0.47/3) = 2.874\,(0.84) = 2.42''$$

Moment capacity in steel $= M_s = A_s f_s jd = 0.386\times 18{,}000\times 2.42$
$= 16{,}814$ lb-in

Moment capacity in Conc. $= M_c = \frac{1}{2} f_c k j b d^2$
$= \frac{1}{2}\times 2250\times 0.45\times 0.85\times 12\times 2.874^2$
$= 42{,}652$ lb-in

M_s controls.

Eq. 14-10 can be rewritten as

$$\frac{f_a}{F_a} + \frac{\text{Applied Moment}}{\text{Moment Capacity}} = \frac{163}{1786} + \frac{25416}{16814} = 1.6$$

The demand/capacity ratio is similar to that obtained from the tensile-stress criterion.

Principal Tensile Stress

The principal tensile stress @ Node 4071 is 689 psi (loading 4) which is higher than 300 psi principal tensile stress limit.

It is concluded that the vertical reinforcement in the wall does not meet code requirements, tensile stress in concrete is too high. Cracks may have occured

GENERAL DESIGN AND COMPUTATION SHEET

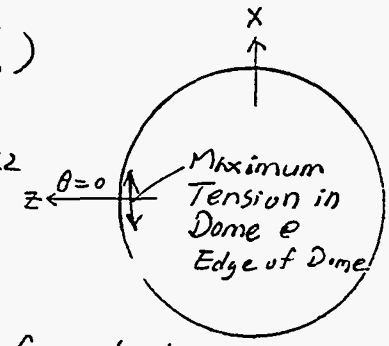
JOB		DATE	SHEET 62 of
GUNITE TANK	01014702066 1009		
ESO NO.	COMPUTED CNS 5-30-94	CHECKED BY MWK 7-28-94	

Evaluation of Structures (Cont.)

Reinforcements (cont.)

Reinforcement in Dome (Ref. Dwgs E-56866, -56867)

Max principal stress in the dome occured on node 4091 of element 2142 located at the bottom surface of the dome edge.



It is assumed that the max. circumferential tension existed at similar location.

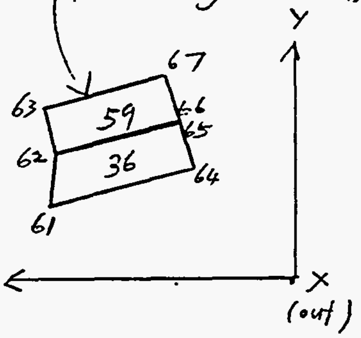
$\theta = 0$, Loading 5, $S_{xx} = 204$ psi @ node 61
160 psi @ node 62
118 psi @ node 63

Ave. Tensile Stress

$= \frac{1}{4}(204 + 2 \times 160 + 118)$

$= 161$ psi << 300 psi (f_r)

Concrete will not crack.



There are two 5-in thick layers.

For 12" wide band the tensile force is

$12 \times 10 \times 161 = 19{,}320$ lb

The only reinforcement provided in this direction is the 2 layers of welded mesh 4"x4"-#8 x #8 (see dwg. E-56866)

$A_s = 2 \times 0.062 = 0.124$ in²

Allow. Tension $= 0.124 \times 24000 = 2976$ lb $< 19{,}320$ lb

Non compliant with ACI-344

UCN-4032A
(5 2-84)

SAIC Science Applications International Corporation An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
0101470206604009

AUTHOR CNS DATE 7-21-94 JOB NO.

CHECKED BY MOK DATE 7-26-94 PAGE 63 of

Refe

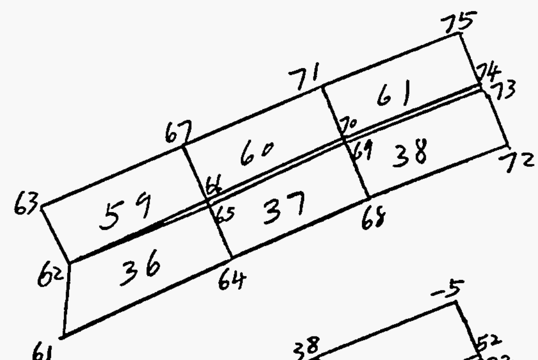
Evaluation of Structures (Cont.)

Reinforcements (Cont.)

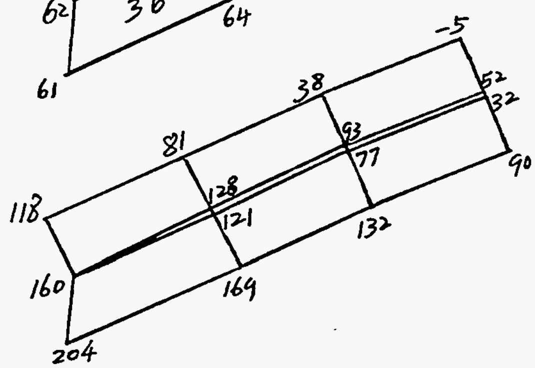
Reinforcement in Dome (cont.)

This requirement is in accordance of Ref. #3. Since the tensile stress in concrete is only 161 psi, structural integrity is not in jepordy.

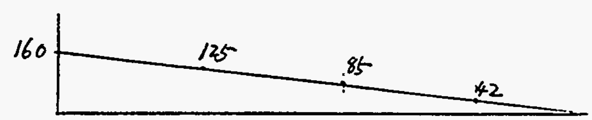
A detailed stress distribution from loading 5 is shown below.



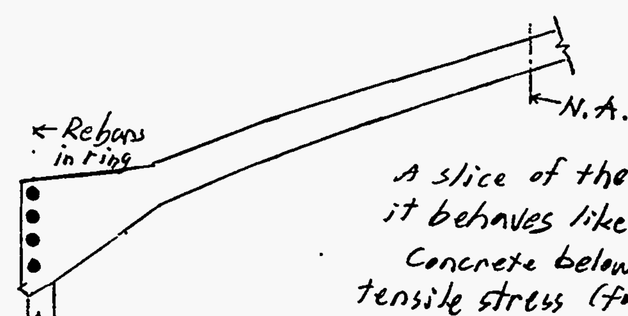
Elements & Nodes



Stresses Sxx psi
+ tension
− compression



Average Sxx (psi)



A slice of the dome-ring shows that it behaves like a beam with reinforcement. Concrete below the N.A. will have tensile stress (for strain compatability) which is OK.

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
010/4703 0664 009

AUTHOR CNS DATE 3-27-95 JOB NO.

CHECKED BY TC DATE 3/31/95 PAGE 64 of

Evaluation of Structures (cont.)

Concrete Stresses

Compressive Stress

The maximum principal compressive stress = 642 psi @ node 8595 from loading case 4.

Allowable compressive stress due to bending = $0.45 f_c' = 2250$ psi

Allowable bearing stress = $0.25 f_c' = 1250$ psi

Both of these allowable stress are greater than 642 psi OK

Tensile Stresses

Top of Wall @ Node 4071 from Loading 4

Principal Tensile Stress = 689 psi > f_r (f_r = 300 psi)

Directional Tensile Stress S_{yy} = 549 psi

The principal tensile stress only indicates the location of high stress areas. Comparing with f_r only gives reference as how high these stresses due to applied loads are; it is not an indication of failure of concrete.

If the reinforcement in this area is adequate to resist the entire tensile force then code compliance is met. If the reinforcement provided is not adequate then code compliance is not met and a situation of potential cracks does exist in this small local area; the section may not completely fail since most part of the section is under compression. Also, shear friction still exists at the cracked surface (ACI 318 §11.7).

Across the top of the wall only 1½" of the wall thickness (25%) has tensile stress. Cracks may exist along the exterior face, but 75% of the wall thickness is under compression and no crack will occur. Fluid will not leak through the wall.

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Evaluation of Structures (cont.)

Concrete Stresses (cont.)

Tensile Stresses (cont.)

Edge of the Dome

As discussed in the section of "Reinforcement in Dome" The reinforcement provided in the edge of dome is not adequate to resist the circumferential tension. But, the tensile stress in concrete is small, 160 psi. Comparing to $f_r = 300$ psi, it is concluded that the concrete will not fail in tension. If a typical slice, including the ring, is considered as a beam, then there is no need to check tensile stress in that area; the rebars in the ring takes all the tensile force.

Openings in Dome

The directional tensile stress, S_{zz}, at the top surface (node 8592) of the 30"ϕ opening is 833 psi, in global coordinates. This element 4434 is not located @ 0°, 90°, 180°, or 270°. The high tensile stress S_{zz} in a non-orthogonal direction and has no particular meaning.

The principal stresses at node 8592 are:

$S1 = 316$ psi, $S2 = 27$ psi (tension), $S3 = -204$ psi (compression)

The pricipal stresses are not high comparing to other locations. ∴ OK

Smaller openings are less critical.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Evaluation of Structures (cont.)

Stability

Dome Stability (Ref. 4, Sect. 2.6.3.1)

The safety factor, S, against buckling is

$$S = \frac{E_c (t/r)^2}{4(g+p)} \quad \text{(ACI 344 require } S \approx 4 \text{ to } 6\text{)}$$

where r = radius = 300"

t = thickness : use 5"

$g+p$ = total load

where $g = (\frac{10}{12})(150)/144 = 0.87$ psi for 10" concrete.

$p = 6 \times 110/144 = 4.58$ psi for 6' soil.

$$\therefore S = \frac{4030000(5/300)^2}{4(0.87+4.58)} = 51.4 > 6 \quad \text{OK}$$

Cylindrical Wall Stability (Ref. 26)

The buckling stress for a cylinder is

$$\frac{0.3Et}{r} = \frac{0.3(4030000)(6)}{300} = 24180 \text{ psi} \gg \text{maximum } S_{yy} \ (= 549 \text{ psi})$$

$S = 24180/549 = 44$ OK

Structural Integrity

Overall, the gunite tank is structurally sound and adequate to function as a liquid container.

The hoop tension capacities in both the ring and cylindrical wall are more than adequate to resist the loads and to meet the code requirements.

Vertical tensile stress at the top of wall on the exterior face is high and reinforcement is not adequate. The interior face of the wall is under compression and adequate to contain the liquid in the tank.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

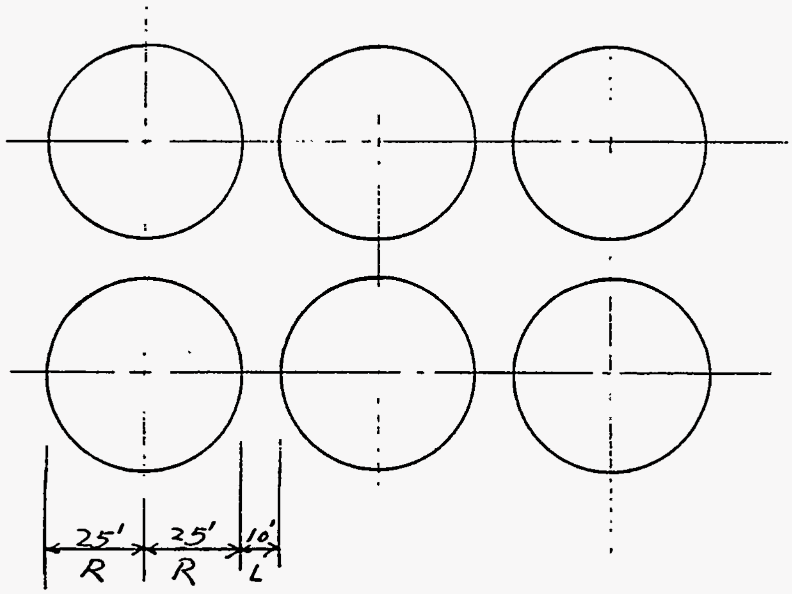
Ref

Evaluation of Structures (Cont.)

Group Behavior [27, 28]

The behavior of a single tank is different from that of a group of tanks. The tank-to-tank interaction becomes significant when the clear spacing between the tanks is in the same order as the radii of the tanks.

The procedure in PVP-Vol. 271 [28] is used to calculate the increased horizontal and vertical accelerations of the tank, and the increased soil dynamic load on the tank wall.



$L/R = 10/25 = 0.4$

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
C1C147C30664009

AUTHOR CNS DATE 7-19-94 JOB NO.

CHECKED BY MOK DATE 7-20-94 PAGE 68 of

Reference

Evaluation of Structures (Cont.)

Group Behavior (Cont.)

Increased Horizontal Acceleration (see figures on following pages)

	Left Wall	Right Wall
Top of Wall	1.23	1.09
Middle of Wall	1.11	1.00
Bottom of Wall	1.19	1.06

Average = 1.113 Use 1.12 (12% increase)

Increased Vertical Acceleration (see figures on following pages)

	Left Wall	Right Wall
Top of Wall	1.16	1.21
Middle of Wall	1.16	1.14
Bottom of Wall	1.16	1.17

Average = 1.167 Use 1.17 (17% increase)

This increased acceleration is also used for the vertical soil load over the dome of the tank.

Increased Soil Dynamic Loading (one side only, see figures on following pages)

Top of Wall	2.7	Average = 1.73
Middle of Wall	1.05	
Bottom of Wall	1.45	

Use 2.00 to account the importance of soil masses at higher elevations.
(100% increase)

CNS 7-19-94

Evaluation of Structures (cont.)

Group Behavior (cont.)

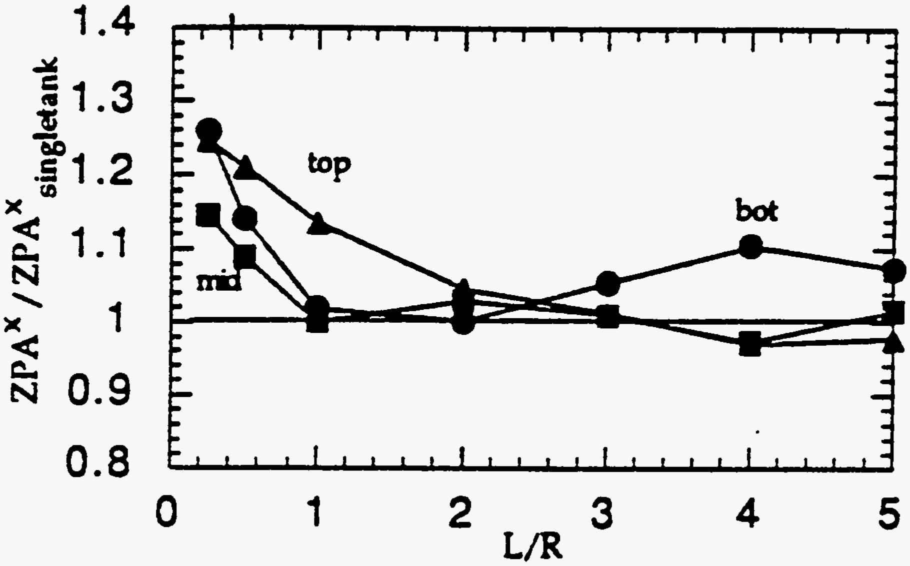


Figure 4a. Horizontal maximum accelerations on the Left wall of Tank A.

FOR INFORMATION ONLY
NO CHECKING REQUIRED

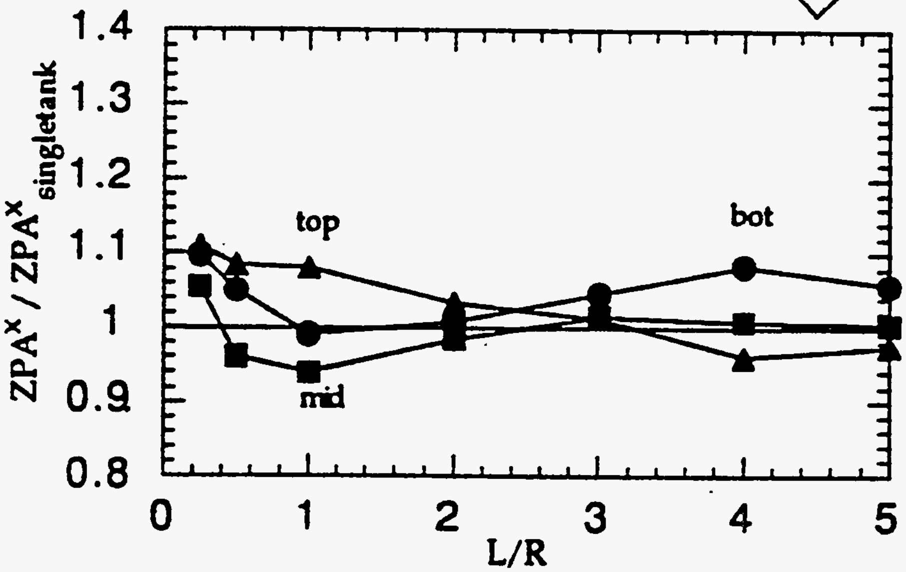


Figure 3a. Horizontal maximum accelerations on the right wall of Tank A.

FROM REF. 28

CNS 7-19-94

Evaluation of Structures (cont.)

Group Behavior (cont.)

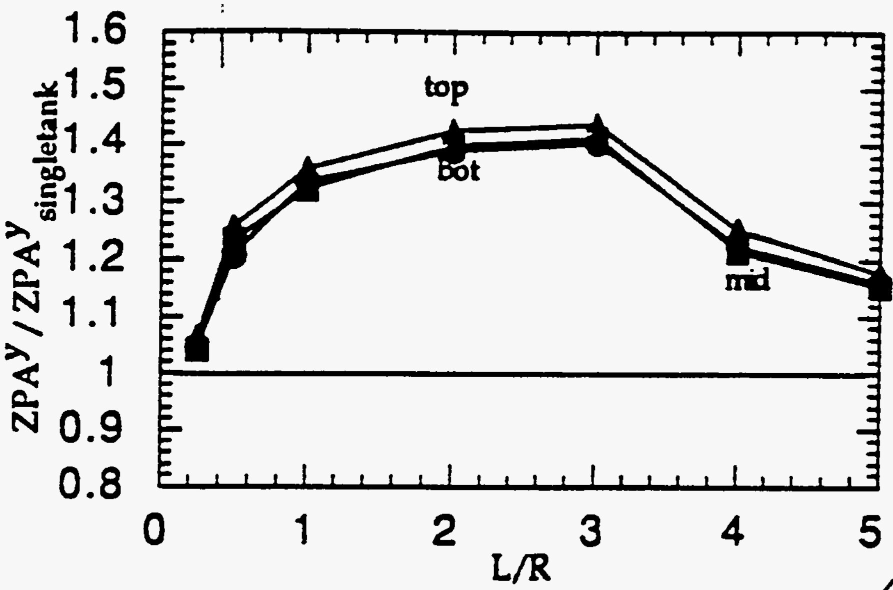


Figure 4b. Vertical maximum accelerations on the left wall of Tank A.

FOR INFORMATION ONLY
NO CHECKING REQUIRED

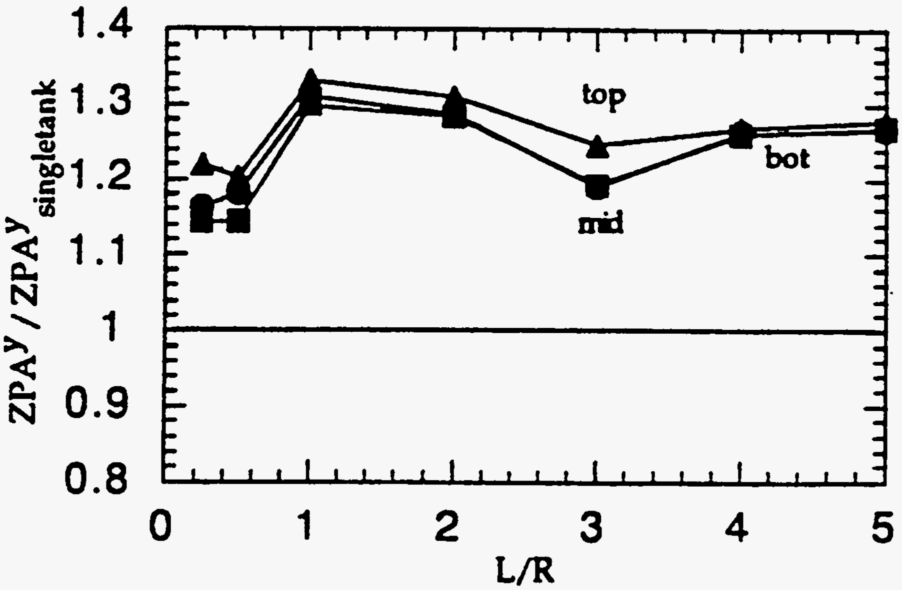


Figure3b. Vertical maximum accelerations on the right wall of Tank A.

FROM REF. 28

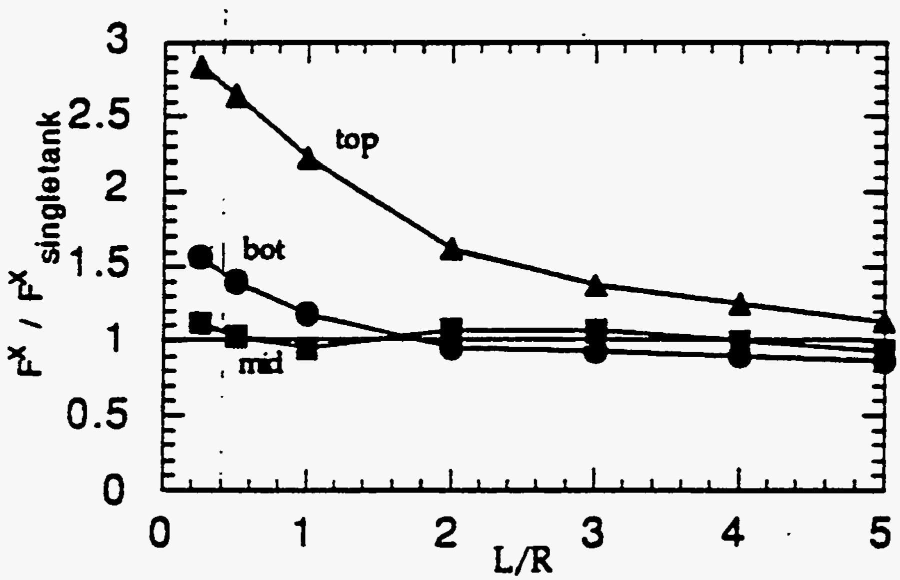


Figure 6. Horizontal nodal forces on the right wall of Tank A.

FROM REF. 28

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01014703066 4009

AUTHOR CNS DATE 7-19-94 JOB NO.
CHECKED BY MOK DATE 7-24-94 PAGE 72 of

Reference

Evaluation of Structures (cont.)

Group Behavior (Cont.)

Effects on Node 4071

The maximum Von Mises stress is at node 4071 : 297 psi for loading cases 4. which is the empty tank condition.

Loading case 4 has the following loading combination

Loading	Direction	Multiplier	New Multiplier* see below
DEADLOAD	Vert.	1.093	1.109
OVERDOME	Vert.	1.093	1.109
EQ-TANK	Horiz.	1.0	1.12
SIDESOIL	Horiz.	1.0	1.0
DYNASOIL	Horiz.	1.0	2.0

* The new multiplier for vertical loads is

$$1 + 1.17 \times 0.093 = 1.109$$

The new multiplier for EQ-TANK is 1.12

The multiplier for SIDESOIL is the same: 1.0

The new multiplier for DYNASOIL is 2.0

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Ref

Evaluation of Structures (cont.)

Group Behavior (cont.)

Effects on Node 4071 (cont.)

Von Mises Stress @ Node 4071 For Loading Case 4. From STRUDL

From Loading		1.093×DEADLOAD	1.093×OVERDOME	EQ-TANK	SIDESOIL	DYNASOIL	TOTAL	
		Stress (psi)						
S_{xx}	ELE 2126	35.99	175.05	1.46	2.85	0.04	215.39	
	ELE 2127	−12.66	−60.96	−0.52	−1.58	−1.50	−77.22	
	Ave.						69.09	*
S_{yy}	ELE 2126	29.64	176.60	1.18	0.72	−7.94	200.20	
	ELE 2127	82.69	429.53	3.30	20.50	13.07	549.09	
	Ave						374.65	*
S_{zz}	ELE 2126	58.13	291.32	5.32	−70.74	−34.16	249.87	
	ELE 2127	58.13	291.32	5.32	−70.74	−34.16	249.87	
	Ave						249.87	*
S_{xy}	ELE 2126	89.98	437.55	3.62	8.72	4.41	544.28	
	ELE 2127	54.59	264.77	2.18	9.24	8.13	338.91	
	Ave						441.60	*
S_{xz}	ELE 2126	0.35	1.83	0.14	−1.11	−1.44	−0.23	
	ELE 2127	1.09	5.43	0.17	−1.04	−1.42	4.23	
	Ave.						2.00	*
S_{yz}	ELE 2126	−3.56	−16.34	0.17	8.16	4.50	−7.07	
	ELE 2127	−3.95	−18.18	0.15	8.01	4.34	−9.63	
	Ave.						−8.35	*

* Calculated

~~Following STRUDL's procedure:~~

$S_{ave} = (S_{xx} + S_{yy} + S_{zz})/3 = (69.09 + 374.65 + 249.87)/3 = 231.20$ psi

$\underline{S_{xx}} = S_{xx} - S_{ave} = 69.09 - 231.20 = -162.11$ psi

$\underline{S_{yy}} = S_{yy} - S_{ave} = 374.65 - 231.20 = 143.45$ psi

$\underline{S_{zz}} = S_{zz} - S_{ave} = 249.87 - 231.20 = 18.67$ psi

Von Mises Stress $\sigma_i = \left[(\underline{S_{xx}}^2 + \underline{S_{yy}}^2 + \underline{S_{zz}}^2)/2 + S_{xy}^2 + S_{yz}^2 + S_{zx}^2\right]^{1/2}$

$= \left\{\left[(-162.11)^2 + (143.45)^2 + (18.67)^2\right]/2 + (441.6)^2 + (2.0)^2 + (-8.35)^2\right\}^{1/2}$

$= 467.64$ psi vs. 467.635 from STRUDL output.

(calculation crossed out)

SAIC Science Applications International Corporation An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK
01 0147030664009
AUTHOR CNS DATE 7-19-94 JOB NO.
CHECKED BY MOK DATE 7-20-94 PAGE 74 of

Reference

Evaluation of Structures (Cont.)
Group Behavior (Cont.)

Effects on Node 4071 (cont.)

Von Mises Stress @ Node 4071 for Modified Loading Case 4

From \ Loading		Stress (psi) 1.109×DEADLOAD	1.109×OVERDOME	1.12×EQ-TANK	SIDESOIL	2×DYNASOIL	TOTAL
S_{xx}	ELE 2126	36.52	177.61	1.64	2.85	0.04	218.66
	ELE 2127	-12.85	-61.85	-0.58	-1.58	-3.00	-79.86
	Ave						69.40
S_{yy}	ELE 2126	30.07	179.19	1.32	0.72	-15.88	195.42
	ELE 2127	83.90	435.82	3.70	20.50	26.14	570.06
	Ave						382.74
S_{zz}	ELE 2126	58.98	295.59	5.96	-70.74	-68.32	221.47
	ELE 2127	58.98	295.59	5.96	-70.74	-68.32	221.47
	Ave						221.47
S_{xy}	ELE 2126	91.30	443.96	4.05	8.72	8.82	556.85
	ELE 2127	55.39	268.65	2.44	9.24	16.26	351.98
	Ave						454.42
S_{xz}	ELE 2126	0.36	1.86	0.16	-1.11	-2.88	-1.61
	ELE 2127	1.11	5.51	0.19	-1.04	-2.84	2.93
	Ave						0.66
S_{yz}	ELE 2126	-3.61	-16.58	0.19	8.16	9.00	-2.84
	ELE 2127	-4.01	-18.45	0.17	8.01	8.68	-5.60
	Ave						-4.22

Use STRUDL's procedure:

$S_{ave} = (S_{xx} + S_{yy} + S_{zz})/3 = (69.4 + 382.74 + 221.47)/3 = 224.54$ psi

$\underline{S_{xx}} = S_{xx} - S_{ave} = 69.4 - 224.54 = -155.14$

$\underline{S_{yy}} = S_{yy} - S_{ave} = 382.74 - 224.54 = 158.20$

$\underline{S_{zz}} = S_{zz} - S_{ave} = 221.47 - 224.54 = -3.07$

Von Mises Stress $\sigma_i = [(\underline{S_{xx}}^2 + \underline{S_{yy}}^2 + \underline{S_{zz}}^2)/2 + S_{xy}^2 + S_{yz}^2 + S_{zx}^2]^{1/2}$

$= \{[(-155.14)^2 + (158.2)^2 + (-3.07)^2]/2 + (454.42)^2 + (.66)^2 + (-4.22)^2\}^{1/2}$

$= 480.70$ psi

$480.7 / 467.64 = 1.03$ a 3% increase in Von Mises stress.

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

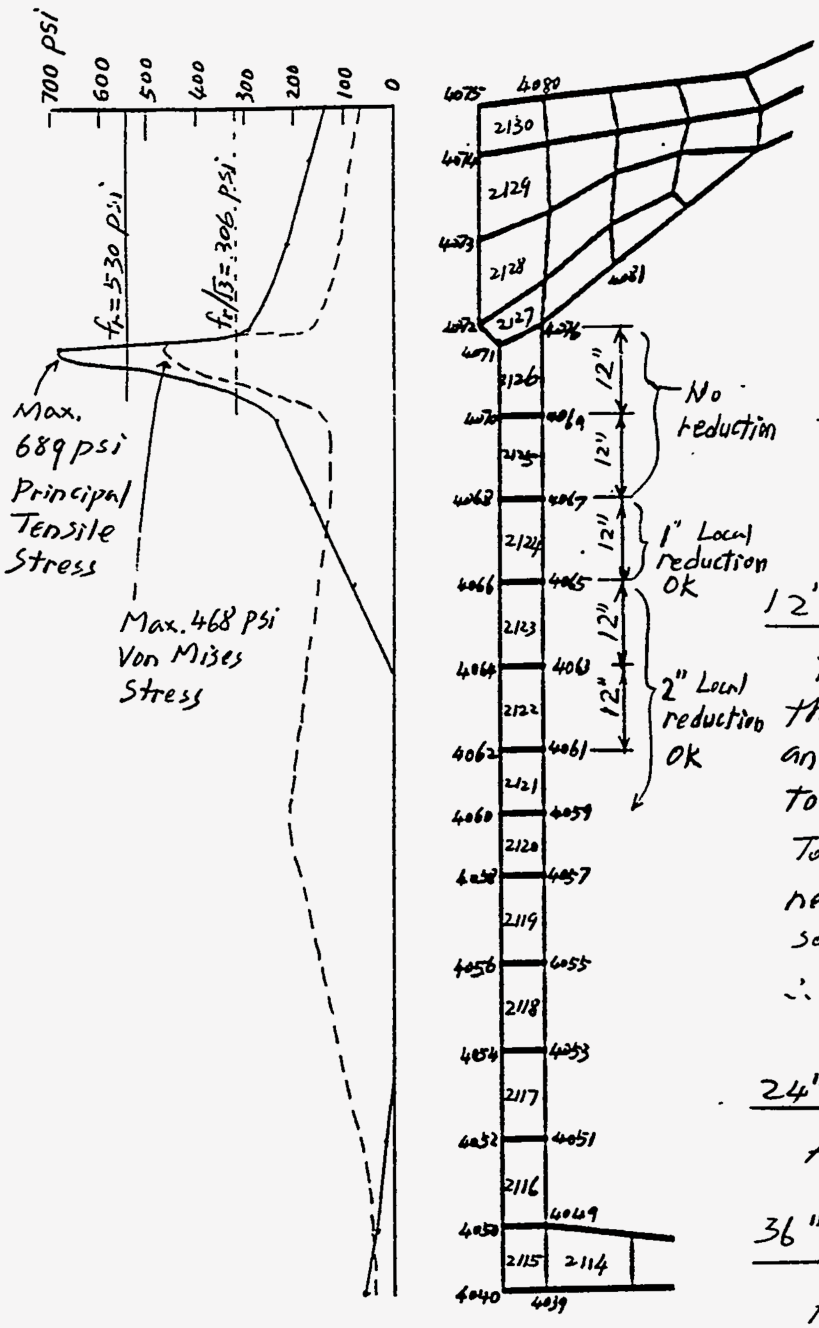
SUBJECT GUNITE TANK
01014703066400 9

AUTHOR CNS DATE 3-28-95 JOB NO. ____

CHECKED BY TC DATE 3/31/95 PAGE 75 of ____

Evaluation of Structures (cont.)

Allowable Reduction in Wall Thickness



@ Exterior Surface of Wall
Loading 4
$\theta = 90°$

Top of the Wall

Both the plots of principal stress and Von Mises stress indicate the top 12" of the wall is the critical zone.

The principal tensile stress exceeds the threshold $f_r = 530$ psi and the Von Mises stress exceeds the threshold $f_r/\sqrt{3} = 306$ psi.

No reduction in wall thickness is allowed.

12" Below the Top of the Wall

The vertical reinforcement in the wall is determined by Syy and Syy is essentially proportional to the principal tensile stress.

To comply with the code, Syy needs to be smaller than 110 psi, so is principal tensile stress.

∴ No reduction in top 24 inches

24" Below Top of the Wall

A 1" local spalling is OK.

36" Below Top of the Wall

A 2" local spalling is OK.

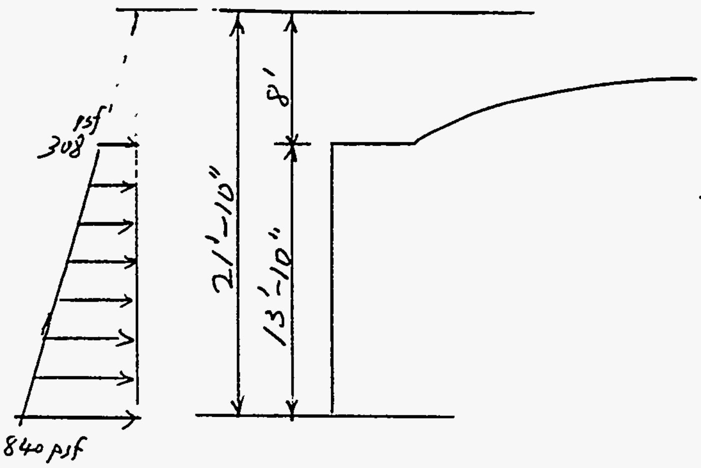
Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Reference

Evaluation of Structures (cont.)

Additional Soil Load on Dome

Check the condition of 8' soil on dome (2 ft additional soil).



@ Top of Wall:

At-rest pressure

$= K_0 \gamma H_{top} = 0.35 \times 110 \times 8$

$= 308$ psf (231 psf for 6' soil)

@ Bottom of Wall

At rest pressure

$= 0.35 \times 110 \times 21.833$

$= 840$ psf (764 psf for 6' soil)

Total soil load for a 12" vertical strip is

$\frac{1}{2}(308+840) \times 13.833 = 7940$ lb

Original total soil load = 6882 lb for 6' soil over dome

$7940/6882 = 1.15$

∴ The static lateral soil pressure increases by 15%

The over dom soil load increases by 33%
(8' vs 6' soil)

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK 01014703066400 9

AUTHOR CNS DATE 7-25-94 JOB NO.
CHECKED BY MOIC DATE 7-25-94 PAGE 77 of

Ref

Evaluation of Structures (Cont.)

Additional Soil Load on Dome

Loading Case 4 has the following loading combination

Load	Direction	Multiplier	New Multiplier	
DEADLOAD	Vert.	1.093	1.093	
OVERDOME	Vert.	1.093	1.457	(=1.33×1.093)
EQ-TANK	Horiz	1.0	1.0	
SIDESOIL	Horiz	1.0	1.15	(15% increase)
DYNASOIL	Horiz	1.0	1.15	(" ")

From Loading		stress (psi) 1.093×DEADLOAD	1.457×OVERDOME	EQ-TANK	1.15×SIDESOIL	1.15×DYNASOIL	TOTAL
S_{xx}	ELE 2126	35.99	233.35	1.46	3.28	0.05	274.13
	ELE 2127	-12.66	-81.26	-0.52	-1.82	-1.73	-97.99
	Ave						88.07
S_{yy}	ELE 2126	29.64	235.41	1.18	0.83	-9.13	257.93
	ELE 2127	82.69	572.58	3.30	23.58	15.03	697.18
	Ave						477.56
S_{zz}	ELE 2126	58.13	388.34	5.32	-81.35	-39.28	331.16
	ELE 2127	58.13	388.34	5.32	-81.35	-39.28	331.16
	Ave						331.16
S_{xy}	ELE 2126	89.98	583.27	3.62	10.03	5.07	691.97
	ELE 2127	54.59	352.95	2.18	10.63	9.35	429.70
	Ave						560.84
S_{xz}	ELE 2126	0.35	2.44	0.14	-1.28	-1.66	-0.01
	ELE 2127	1.09	7.24	0.17	-1.20	-1.63	5.67
	Ave						2.83
S_{yz}	ELE 2126	-3.56	-21.78	0.17	9.38	5.18	-10.61
	ELE 2127	-3.95	-24.23	0.15	9.21	4.99	-13.83
	Ave						-12.22

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Reference

Evaluation of Structures (Cont.)

Additional Soil Load on Dome (cont.)

Von Mises Stress @ Node 4071 For Added Soil Load

Following STRUDL's procedure:

$S_{ave} = (S_{xx} + S_{yy} + S_{zz})/3 = (88.07 + 477.56 + 331.16)/3 = 298.93$ psi

$\underline{S_{xx}} = S_{xx} - S_{ave} = 88.07 - 298.93 = -210.86$

$\underline{S_{yy}} = S_{yy} - S_{ave} = 477.56 - 298.93 = 178.63$

$\underline{S_{zz}} = S_{zz} - S_{ave} = 331.16 - 298.93 = 32.23$

Von Mises stress $J_1 = \left[(\underline{S_{xx}}^2 + \underline{S_{yy}}^2 + \underline{S_{zz}}^2)/2 + S_{xy}^2 + S_{yz}^2 + S_{zx}^2 \right]^{1/2}$

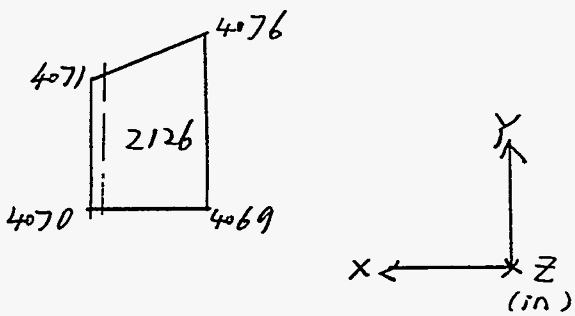
$= \left\{ \left[(-210.86)^2 + (178.63)^2 + (32.23)^2 \right]/2 + (560.84)^2 + (2.83)^2 + (-12.22)^2 \right\}^{1/2}$

$= 594.48$ psi

$594.48 / 467.64 = 1.27$ a 27% increase in Von Mises stress

Vertical Reinf. in Wall

S_{yy} @ Node 4071 = 257.93 psi (last page)



S_{yy} @ Node 4076 is calculated in next page.

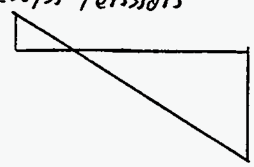
Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

Evaluation of Structures (Cont.)

Additional Soil Load on Dome (Cont.)

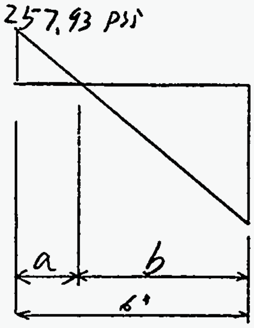
Vertical Reinf. in Wall (cont.)

For loading case 4 S_{yy}:
(P. 55)



For additional 2" soil S_{yy}:

$$X = \left(\frac{257.93}{200}\right)(573)$$
$$= 739 \text{ psi}$$



$$b = \left(\frac{739}{258+739}\right) \times 6 = 4.4''$$

$$a = 6 - 4.4 = 1.6''$$

Tensile Force in The Section

$= \frac{1}{2} \times 258 \times 1.6 = 206$ lb/in of wall)

$= 2472$ lb/ 12 in of wall)

Capacity of welded mesh $= A_s \times f_s = 0.062 \times 24000$
$= 1488$ lb/12 in of wall

$$\frac{\text{Demand}}{\text{Capacity}} = \frac{2472}{1488} = 1.66$$

The original loading 4 demand/capacity ratio = 1.25
(P. 58)

It is concluded that no additional soil or other loads can be added to the top of the existing 6' soil layer.

CALCULATION REFERENCES

1. ACI Committee 318, *Building Code Requirements for Reinforced Concrete (ACI 318-63)*, American Concrete Institute, Detroit, MI, 1963.

2. ACI Committee 318, *Building Code Requirements for Reinforced Concrete (ACI 318-89) and Commentary (ACI 318R-89)*, American Concrete Institute, Detroit, MI, 1989.

3. ACI Committee 334, *Concrete Shell Structures Practice and Commentary (ACI 334.1R-64) (Revised 1982)*, American Concrete Institute, Detroit, MI, 1982.

4. ACI Committee 344, *Design and Construction of Circular Prestressed Concrete Structures (ACI 344R-70) (Reaffirmed 1981)*, American Concrete Institute, Detroit, MI, 1981.

5. ASCE Manuals and Reports on Engineering Practice - No. 58, "Structural Analysis and Design of Nuclear Plant Facilities," 1980, pp. 237-241, 443-453.

6. Baker, E. H., Kovalevsky, L., and Rish, F. L., *Structural Analysis of Shells*, McGraw-Hill Book Co., 1972.

7. Billington, D. P., *Thin Shell Concrete Structures*, McGraw-Hill Book Co., 1982.

8. Crawford, D., "Gunite Tank Decommissioning Drilling Log," 1978.

9. Das, Braja M., *Fundamentals of Soil Dynamics*, Elsevier Science Publishing Co., New York, 1983.

10. DOE-STD-1020-Draft, *Natural Phenomena Hazards Design and Evaluation Criteria for DOE Facilities*, February 1994.

11. Freedman, S., "Properties of Materials for Reinforced Concrete," Ch. 6, *Handbook of Concrete Engineering*, Mark Fintel editor, Van Nostrand Reinhold Co., 1974.

12. Fricke, K., *Seismic Analysis of the Underground Gunite Tank at the ORNL South Tank Farm*, Report No. X-OE-313, Martin Marietta Energy Systems, Inc., Oak Ridge, TN, January 10, 1986.

13. Fricke, K., *Seismic Analysis of the Underground Gunite Tanks at the ORNL South Tank Farm*, Martin Marietta Energy Systems, Inc., Oak Ridge, TN, May 1993.

14. GTICES Systems Laboratory, *GTSTRUDL User's Manual*, Rev. M, Georgia Institute of Technology, Atlanta, GA, 1991.

15. Gupta, A. K., "Membrane Reinforcement in Shells," ASCE J. of the Structural Division, Vol. 107, No. ST1, January 1981, pp. 41-56.

16. Nazarian, H. N. and Hadjian, A. H., "Earthquake-Induced Lateral Soil Pressures on Structures," ASCE J. of the Geotechnical Eng. Div., Vol. 105, No. GT9, September 1979, pp. 1049-1066.

17. Newmark, N. M. and Rosenblueth, E., *Fundamentals of Earthquake Engineering,* Prentice-Hall, Inc., 1971, pp. 197-201.

18. Prakash, S., *Soil Dynamics,* McGraw-Hill Book Co., 1981, pp. 128-169.

19. Schnubrich, W. C., "Thin Shell Structure," Ch. 14, *Handbook of Concrete Engineering,* Mark Fintel editor, Van Nostrand Reinhold Co., 1974.

20. Seed, H. B. and Whitman, R. V., "Design of Earth Retaining Structures for Dynamic Loads," Proceedings, ASCE Specialty Conference on Lateral Stresses in the Ground and Design of Earth Retaining Structures, Ithaca, N.Y., 1970, pp. 103-147.

21. Timoshenko, S. and Goodier, J. N., *Theory of Elasticity,* McGraw-Hill Book Co., 1951.

22. Uniform Building Code, International Conference of Building Officials, Whittier, CA, 1991.

23. Video and Motion Picture Services, "ORNL Inactive Liquid Low Level Waste Storage Tank Video Inspection Summary," 1992.

24. Winterkorn, H.F. and Fang, H.Y., *Foundation Engineering Handbook,* Van Nostrand Reinhold Company, 1975.

25. Coats, D.W. and Murray, R.C., *Natural Phenomena Hazards Modeling Project: Seismic Hazard Models for Department of Energy Sites,* Lawerence Livermore National Laboratory, November 1984.

26. Roark, R.J. and Young, W.C., *Formulas for Stress and Strain,* McGraw-Hill Book Company, 1980.

27. Bandyopadhyay, K., Cornell, A., Costantino, C., Kennedy, R., Miller, C. and Veletsos, A., *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances.* BNL 52361 UC-406 UC-510, January 1993

28. Xu, J., Bandyopadhyay, K., Miller, C., and Costantino, C. *Spacing Effects on Seismic Responses of Underground Waste Storage Tanks.* PVP-Vol. 271, Proceedings, ASME Pressure Vessels and Piping Conference on Natural Hazard Phenomena and Mitigation, Minneapolis, Minnesota, 1994, pp. 13-18.

29. Spangler, M.G., Handy, R.L. *Soil Engineering.* 4th ed. 1982 Harper & Row, Publishers, N.Y.

30. Chen, W.F. *Plasticity in Reinforced Concrete,* 1982, McGraw-Hill Book Company.

LIST OF REFERENCE DRAWINGS

C3D-20539-X008	GUNITE TANK SLUDGE REMOVAL - LOCALITY MAP
C3E-20539-A019	GUNITE TANK SLUDGE REMOVAL - ALTERNATE MECHANICAL PLOT PLAN
C3E-20539-A021	GUNITE TANK SLUDGE REMOVAL - ALTERNATE ACTIVE SLURRY PIPING ARRANGEMENT
C3E-20539-X006	GUNITE TANK SLUDGE REMOVAL - SITE TOPOGRAPH AND SUBSURFACE DATA
C3E-20539-X007	GUNITE TANK SLUDGE REMOVAL - PLOT PLAN
C3E-20539-X009	GUNITE TANK SLUDGE REMOVAL - LOCATION PLAN
D-12205	PROCESS WASTE COLLECTION, RETENTION AND DISPOSAL
E-56866	25' & 50' DIA. GUNITE TANKS W-3 THRU W-10 DETAILS FROM 1943 DWGS.
E-56867	50' GUNITE TANKS W-5 THRU W-10 (5" GUNITE SLAB OVER EXISTING DOME) DETAILS FROM 1943 DWGS.
H-20539-EG002	AIR INLET & EXHAUST - PLAN & SECTIONS
H3D-20539-G004	GUNITE TANK SLUDGE REMOVAL - CONCEPTUAL VENTILATION SCHEMATIC
H3E-20539-G005	GUNITE TANK SLUDGE REMOVAL - TANK CONTAINMENT VENTILATION - ALTERNATE PLAN & NOTES
H3E-20539-G006	GUNITE TANK SLUDGE REMOVAL - TANK CONTAINMENT VENTILATION - DETAILS SH 1 (ALTERNATE)
H3E-20539-G007	GUNITE TANK SLUDGE REMOVAL - TANK CONTAINMENT VENTILATION - DETAILS SH 2 (ALTERNATE)
J3E-20539-E002	GUNITE TANK SLUDGE REMOVAL - MATERIAL BALANCE CONCEPTUAL DESIGN
J3E-20539-E006	GUNITE TANK SLUDGE REMOVAL - SLUICING OPERATION
P3D-20539-C014	GUNITE TANK SLUDGE REMOVAL - LIQUID LEVEL/DENSITY TUBING INSTALLATION & DETAILS
P3D-20539-C007	GUNITE TANK SLUDGE REMOVAL - SOUTH TANK FARM PIPING PLAN
P3E-20539-C027	GUNITE TANK SLUDGE REMOVAL - ALTERNATE SLURRY PIPING PLAN
P3E-20539-C028	GUNITE TANK SLUDGE REMOVAL - ALTERNATE SLURRY PIPING PLAN - SECTIONS & DETAILS
P3E-20539-C034	GUNITE TANK SLUDGE REMOVAL - ALTERNATE UTILITY PIPING PLAN
P3E-20539-C035	GUNITE TANK SLUDGE REMOVAL - ALTERNATE UTILITY PIPING PLAN - ELEV. & DETAILS TANK W-10
P3D-20539-C036	GUNITE TANK SLUDGE REMOVAL - ALTERNATE UTILITY PIPING PLAN - ELEV. & DETAILS TANKS W-5 THRU W-9
S3D-20539-B011	GUNITE TANK SLUDGE REMOVAL - WORK PLATFORMS - FOUNDATION PLAN
S3D-20539-B012	GUNITE TANK SLUDGE REMOVAL - FIXED WORK PLATFORM PLAN
S3D-20539-B013	GUNITE TANK SLUDGE REMOVAL - MOVABLE WORK PLATFORM PLAN
S3D-20539-B014	GUNITE TANK SLUDGE REMOVAL - WORK PLATFORMS SECTIONS
S3D-20539-B015	GUNITE TANK SLUDGE REMOVAL - FOUNDATION PLAN
S3D-20539-B033	GUNITE TANK SLUDGE REMOVAL - ALTERNATE FOUNDATION PLAN
V-68334	50-FT DIA. TANKS ARRANGEMENT PLAN & SECTIONS
X3E-20539-0001	GUNITE TANK SLUDGE REMOVAL - SLUICER ASSEMBLY LAYOUT
X3E-20539-0002	GUNITE TANK SLUDGE REMOVAL - SLUICER ASSEMBLY
X3E-20539-A001	GUNITE TANK SLUDGE REMOVAL - 34" CAISSON INSTALLATION DETAILS - ALTERNATE
X3E-20539-A050	GUNITE TANK SLUDGE REMOVAL - ALTERNATE SIDE OUTLET CAISSONS ORIENTATION - SH. NO. 1
X3E-20539-A051	GUNITE TANK SLUDGE REMOVAL - ALTERNATE SIDE OUTLET CAISSONS ORIENTATION - SH. NO. 2
X3E-20539-A068	GUNITE TANK SLUDGE REMOVAL - PUMP J-03 - SUCTION LEG SUPPORT AND PLATFORM ADAPTOR - DETAIL SH. NO. 3
X3E-20539-B001	GUNITE TANK SLUDGE REMOVAL - PROCESS EQUIPMENT LOCATION - PLAN VIEW
X3E-20539-B002	GUNITE TANK SLUDGE REMOVAL - PROCESS EQUIPMENT LOCATION - SECTIONS
X3E-20539-M100	GUNITE TANK SLUDGE REMOVAL - ALTERNATE - MIXING JET INSTALLATION

APPENDIX B
Peer Review Comments and Resolutions

Eric C. Drumm, P.E.
1239 Forest Brook Road
Knoxville, Tennessee 37919
(615) 584 - 9296

June 2, 1994

Mr. Tony Chung
SAIC
301 Laboratory Rd.
Oak Ridge, TN 37830

RE: Structural Analysis of Underground Gunite Tank

Dear Mr. Chung:

I have completed the requested peer review of the analysis of the underground buried gunite tanks. This review concentrated on the analysis assumptions and the estimation of lateral earth pressures acting on the tank.

It should be kept in mind that dynamic lateral earth pressures are difficult to estimate, and most methods assume cohesionless backfill materials. In this case, very limited information was available on the backfill soil. The crushed stone and clay material could have a wide range of properties depending upon the amount of clay, ranging from behavior expected of pure clay to that expected of pure gravel. This material was treated as crushed stone in the analysis, which is consistent with available design methods for estimating lateral earth pressures.

The calculations I reviewed were well organized, complete, and well documented. My review yielded the following comments which are listed by page number in the calculations:

pp 1 Dynamic loadings - only horizontal dynamic soil pressures were used in the analysis. While this is perhaps appropriate, statement about vertical dynamic pressures is misleading.

pp 2 UBC provisions for lateral forces yield 0.065g. On pp 12 and in subsequent calculations, horizontal acceleration of 0.14g was used. This is a reasonable value, and presumably was given by owner. It should be stated if this was an assumption.

pp 7 Angle of internal friction for crushed stone and clay backfill assumed to be 40 degrees. Seems high if significant clay content, but conservative for static earth pressures.

pp 8 Is "SURFACE FORCE PLANAR" command for uniformly distributed pressure (stress), with units of psi?

pp 9 Dynamic earth pressure - assumption of flexible wall is valid. Rough check with characteristic length from beam-on-elastic foundation yields same conclusion. Calcs state that only active earth pressure is considered. In fact, at-rest pressures were used which is appropriate.

pp 10 Dynamic earth pressure - the dynamic lateral earth pressures on the tank dome were neglected, assuming the "soil is self-supporting for horizontal earth pressure." The height of the dome is about half the height of the tank walls. Perhaps these pressures should be investigated. Lateral pressures on the dome are likely to induce significant stresses in the tank. However, this condition could be neglected if it is assumed that the induced stresses would be confined to the dome area, and hence would not affect the containment function.

Dynamic soil pressure was applied to one half of the tank as an independent loading condition. A reduction of the at-rest static pressures on the opposite side of the tank was acknowledged, but not considered since amount of reduction is unknown. Perhaps conditions with both static and dynamic pressures applied to one side and zero pressure to other side would govern, since the dynamic loading could reduce or remove static pressure. (Nice treatment of vertical and radial distribution of dynamic earth pressures.)

pp 12 Dynamic earth pressure - assume ground acceleration of 0.14g (Same as pp 2 comment.) Is this OK? Dynamic earth pressures based on at-rest pressures are appropriate.

Computed earth pressures were compared with those from an alternative method (Richards et al. 1990). This method yields dynamic earth pressure coefficients equal to at-rest coefficients (0.35) provided the acceleration ratio, tan θ, is below 0.295, where:

$$\tan \theta = \frac{\frac{a_h}{g}}{1 - \frac{a_v}{g}}$$

For $a_h = 0.14g$, and assuming $a_v = 0.67\ a_h$, $\tan \theta = 0.13$. This would yield $P_{total} = 1.35\ P_{static}$ which compares with $P_{total} = 1.40\ P_{static}$ used in analysis.

Reference: Richards, R., Elms, D.G., and Budhu, M. (1990) "Dynamic Fluidization of Soils" Journal of Geotechnical Engineering, ASCE, Vol. 116, No. 5, pp. 740-759.

pp 17 Static and dynamic fluid pressures based on specific gravity of fluid = 1.25. Is this conservative, or representative of actual conditions? Was analysis conducted with no fluid? Do results support use of heavy fluid?

pp 19 Hydrodynamic pressures - assumed hydrodynamic pressures act on tank walls only, neglected pressures on floor. Appropriate assumption perhaps, but it should be stated.

pp 26 Hydrodynamic pressures - Applied pressures for the full tank case appear to be about 15% low, based on my understanding of the approach. Attached page shows sum of element stresses*contributory element area yields force of about 52 kips, when assumed force is 61 kips. Mistake could be mine, but this should be checked. Similar approach was used for loading due to half-full tank.

Most of these comments pertain to documentation of the calculations and the relevant assumptions, and therefore do not impact the calculations. However, the comments related to pages 10 and 26 should be reviewed. In spite of the comments above, this was a very well prepared series of calculations. If you have any questions about my review, please contact me at 974-7715 or 584-9296.

Sincerely,

Eric C. Drumm

Eric C. Drumm, P.E., Ph.D.

ECD

SAIC tank analysis, June 2, 1994
Hydro dynamic pressure check full tank, rigid part

	theata n	Area	Ele stress	Ele Force
check	90	226.50	270.7	61313.55
	88.27	226.40	10.4	2354.53
	84.8	225.57	10.34	2332.37
	81.3	223.89	10.18	2279.24
	77.9	221.47	9.96	2205.82
	74.4	218.16	9.66	2107.39
	70.9	214.03	9.31	1992.63
	67.5	209.26	8.91	1864.50
	64	203.58	8.42	1714.12
	60.6	197.33	7.9	1558.91
	57.1	190.17	7.34	1395.88
	53.6	182.31	6.77	1234.23
	50.2	174.02	6.14	1068.46
	46.7	164.84	5.52	909.92
	43.3	155.34	4.9	761.16
	39.8	144.98	4.28	620.54
	36.3	134.09	3.65	489.43
	32.9	123.03	3.09	380.16
	29.4	111.19	2.52	280.20
	26	99.29	2	198.58
	22.5	86.68	1.52	131.75
	19	73.74	1.11	81.85
	15.6	60.91	0.76	46.29
	12.1	47.48	0.46	21.84
	8.65	34.07	0.24	8.18
	5.19	20.49	0.08	1.64
	1.73	6.84	0.01	0.07

total 26039.66 pounds

for 2 sides of tank x 2 52079.32

compare with 61300 lbf ≈ 85 %

SAIC Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK

AUTHOR CNS DATE 6-10-94 JOB NO.

CHECKED BY DATE PAGE of

Ref

Response to Comments by Dr. Eric C. Drumm

1. Vertical dynamic soil pressure was treated as an equivalent static load in the "load combination" with a multiplier $1+\frac{2}{3}(0.14)=1.093$ to the vertical static soil pressure. See added statement on page 9.

2. Agree. See added statement on page 11.

3. Agree. see added reference on page 6

4. Yes. The "SURFACE FORCE PLANAR" denotes surface stress (psi) normal to the surface.

5. Agree. At-rest static soil pressure is an independent loading condition. Active lateral dynamic soil pressure is another independent loading condition with a magnitude as a fraction of the at-rest static soil pressure.

6. A Look at the static lateral earth pressure first. The soil on the top of the dome has a tendency to slide down hill. No part of the dome will be subjected to a lateral earth pressure in the same direction as the pressure on vertical wall.

(See next page for sketch)

SAIC Science Applications International Corporation
An Employee-Owned Company

301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT

AUTHOR CNS DATE 6-10-94 JOB NO.

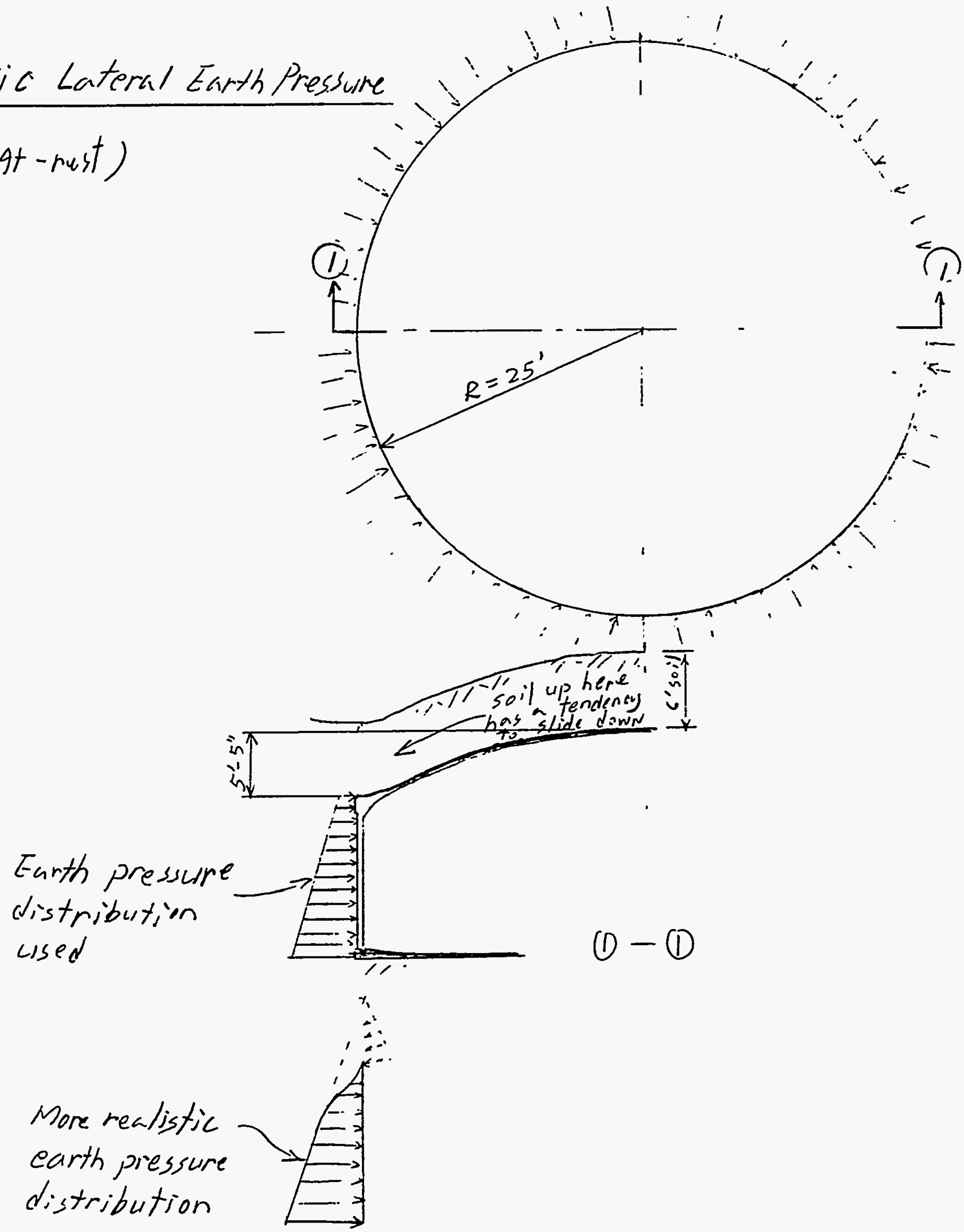
CHECKED BY DATE PAGE of

Reference

Response to comments by Dr. Eric C. Drumm (cont.)

Static Lateral Earth Pressure

(At-rest)



Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK

AUTHOR CNS DATE 6-16-94 JOB NO.

CHECKED BY DATE PAGE of

Response to Comments by Dr. Eric C. Drumm (Cont.)

6. (Cont.)

B. Dynamic lateral earth pressure on dome is also not important. The reasoning is as follows:

a. Newmark stated in a paper published in 1965 (Fifth Rankine Lecture, "Effects of Earthquakes on Dams and Embankments." Geotechnique, Vol. 15, No. 2, Jan. 1965, pp. 139 to 159") that "Ground motions in the direction of the downward slope tend to move the mass downhill, but ground motions in the upward direction along the slope leave the mass without relative additional motion except where these are extremely large in magnitude." Our ZPA is 0.14g, a relatively small siesmic input for the tank. Newmark's statement indicates that the soil over the dome may have an earthquake induced movement away from the dome, not toward the dome. Stress follows movement, also away from the dome.

b. According to the theory on dynamic earth pressure: dynamic earth pressure is a fraction of static earth pressure and is applied to the structure in the same direction. If the static earth pressure is zero then the dynamic earth pressure is zero. If the static earth pressure is in the "opposite" direction, then the dynamic earth pressure is also in the "opposite" direction.

SAIC Science Applications International Corporation An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK

AUTHOR CNS DATE 6-10-94 JOB NO.

CHECKED BY DATE PAGE of

Reference

Response to Comments by Dr. Eric C. Druinm (Cont.)

6. (Cont.)

B. (Cont.)

c. Although the composite structure of the soil-tank system is very strong, the structural character of the surrounding soil was ignored in the FE model. Soil could have been modeled as tridimensional elements. Soil was treated as load, not a part of the structure. This, in reality, states that there is no structural tie between soil and concrete. The portion of the soil cover (crosshatched area, sect. ①-① next page) higher than the top of dome is ineffective as far as lateral dynamic earth pressure is concerned.

d. In over 50% of the roof area the lateral soil pressure is very small, if there is any, due to the small slope of the roof. See sketch next page.

e. Because the soil mass over the dome statically tends to act in a direction 180° out of phase with the soil mass acting on the tank wall, any lateral dynamic earth pressure on the dome would be also out of phase with the dynamic earth pressure on the tank wall.

C. Dynamic soil load only applied from one half of the tank. A reduction of of at-rest static soil pressure on the opposite side is possible. The soil dynamic theory available currently is only about increasing in soil pressure, not decreasing. We actually need to include soil on both sides of the tank as a part of the FE model which would be a SSI analysis with seismic input at the supports of the soil-tank system, currently unachievable with our computing facility.

Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT: GUNITE TANK

AUTHOR: CNS DATE: 6-10-94 JOB NO.

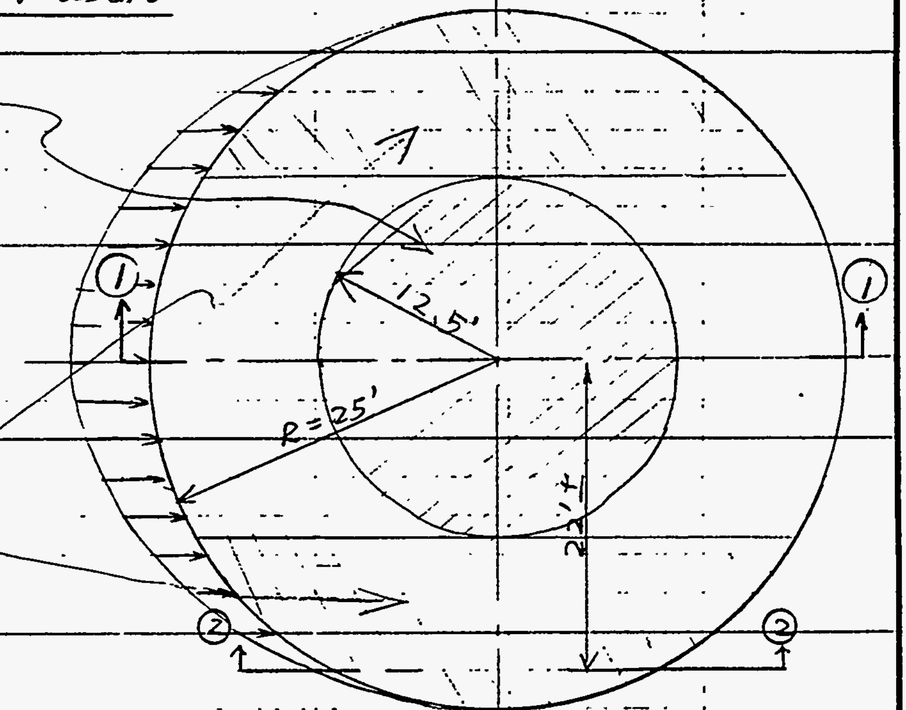
CHECKED BY: DATE: PAGE: of

Response to Comments by Dr. Eric C. Drumm

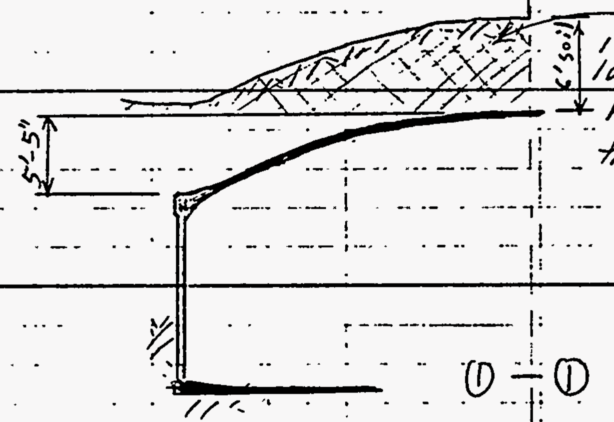
Dynamic Lateral Earth Pressure

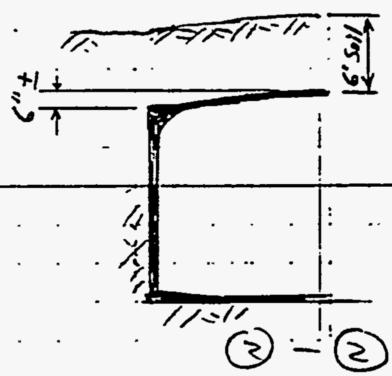
In this area the top of dome is almost flat, lateral force can be ignored. See Section ①-①

In these two areas slope of roof is also small, see Section ②-②.



This part of soil is considered as vertical load only, will not have any effect in the horizontal direction





Science Applications International Corporation
An Employee-Owned Company
301 Laboratory Road • P. O. Box 2501
Oak Ridge, Tennessee 37830
Phone: (615) 482-9031

SUBJECT GUNITE TANK

AUTHOR CNS DATE 6-13-94 JOB NO.

CHECKED BY DATE PAGE of

Reference

Response to Comments by Dr. Eric C. Drumm (Cont.)

7. ZPA = 0.14g is OK.

8. Spec. Grav. of fluid = 1.25 is consistent with what was used in previous analysis

9. All elements of fundation are assumed supported, any vertical load will go to the ground and have no effect on the tank. See added statement on page 19.

10. The calculated stress will be applied to the entire area of the elements, not projected area. Input data are correct.

Eric C. Drumm, P.E.
1239 Forest Brook Road
Knoxville, Tennessee 37919
(615) 584 - 9296

July 21, 1994

Mr. Mike Kelly
SAIC
301 Laboratory Rd.
Oak Ridge, TN 37830

RE: Peer review of the analysis of the underground buried gunite tanks

Dear Mr. Kelly:

I have completed a review of the SAIC response to my peer review (comments of letter dated June 2, 1994) of the analysis of the underground buried gunite tanks. Each of my concerns has been adequately addressed in the response and revised calculations.

If there are further questions about my review, please contact me at 974-7715 or 584-9296.

Sincerely,

Eric C. Drumm

Eric C. Drumm, P.E., Ph.D.

APPENDIX C
Computer Code Verification

Computer Code Verification

In order to confirm that the computer program GTSTRUDL used in this analysis produces reliable results, another finite element program SuperSAP was used to duplicate the same problem and compare the predicted stresses at critical structural locations. The program SuperSAP, maintained and enhanced by Algor, Inc. of Pittsburgh, Pennsylvania., is a commercial version of SAP-IV (Structural Analysis Program). The following are the eight load cases that were analyzed by GTSTRUDL program and reported in the main text.

Static Load Cases:

1. $DL + H_{SD} + H_{SW}$ .... Empty Tank
2. $DL + H_{SD} + H_{SW} + F_S$ .... Full Tank
3. $DL + H_{SD} + H_{SW} + F_{½S}$ .... Half-full Tank

Dynamic Load Cases:

4. $DL + H_{SD} + H_{SW} + E + H_D$ .... Empty Tank + Earthquake
5. $DL + H_{SD} + H_{SW} + E + H_D + F_S + F_{D+}$ .... Full Tank (in-phase) + Earthquake
6. $DL + H_{SD} + H_{SW} + E + H_D + F_S + F_{D-}$ .... Full Tank (out-of-phase) + Earthquake
7. $DL + H_{SD} + H_{SW} + E + H_D + F_{½S} + F_{½D+}$ .... Half Tank (in-phase) + Earthquake
8. $DL + H_{SD} + H_{SW} + E + H_D + F_{½S} + F_{½D-}$ .... Half Tank (out-of-phase) + Earthquake

where:

DL = tank structural self weight
H_{SD} = static soil top pressure from earth over dome
H_{SW} = static soil lateral pressure from earth adjacent to tank wall
E = tank structural force induced by earthquake
H_D = dynamic soil loading
F_S = hydrostatic liquid pressure of full tank
$F_{½S}$ = hydrostatic liquid pressure of half-full tank
F_{D+} = hydrodynamic liquid pressure of full tank that is in-phase with the earthquake
$F_{½D+}$ = hydrodynamic liquid pressure of half-full tank in-phase with the earthquake
F_{D-} = hydrodynamic liquid pressure of full tank that is out-of-phase with the earthquake
$F_{½D-}$ = hydrodynamic liquid pressure of half-full tank out-of-phase with the earthquake

To minimize the duplicated analysis efforts, only six load cases are analyzed using the SuperSAP program. The 6 load cases are:

Static Load Cases:

1. $DL + H_{SD} + H_{SW}$ .... Empty Tank

2. $DL + H_{SD} + H_{SW} + F_S$ .... Full Tank

3. $DL + H_{SD} + H_{SW} + F_{½ S}$ .... Half-full Tank

Dynamic Load Cases:

4. $DL + H_{SD} + H_{SW} + E + H_D$ .... Empty Tank + Earthquake

5. $DL + H_{SD} + H_{SW} + E + H_D + F_S + F_{D+}$ .... Full Tank (in-phase) + Earthquake

7. $DL + H_{SD} + H_{SW} + E + H_D + F_{½ S} + F_{½ D+}$ .... Half Tank (in-phase) + Earthquake

The applied loading conditions and the exaggerated deflections for each loading condition are presented graphically in the pages that follow (Figures D-1 to D-16). In each of the graphic presentations, only one slice-cross-section view of the tank is shown. The uniform normal pressure, derived from static soil/fluid pressure to the element surfaces, is scaled and represented by an arrow head pointed perpendicular to the element surface. The nodal forces, derived from dynamic soil/fluid pressure, are scaled and represented by horizontal arrow heads. The deflections are exaggerated to show the direction of deflections.

Figure D-17 shows the predicted maximum tensile stress Syy distribution along the vertical direction at the haunch during load case 1, empty tank during gravity load only. The maximum tensile stress occurs on the exterior surface just below the haunch.

Figure D-18 shows the predicted maximum tensile stress Syy distribution along the vertical direction at the haunch during load case 4, empty tank during earthquake load. The maximum vertical tensile stress of 549 psi occurs on the exterior surface immediately below the haunch.

Figure D-19 is the comparison of predicted wall lateral (Z-direction) deflections by GTSTRUDL and SuperSAP.

Figure D-20 is the comparison of predicted tank dome (Y-direction) deflections by GTSTRUDL and SuperSAP.

Figure D-21 is the summary of stress predictions by GTSTRUDL and SuperSAP.

Comparative results from the two programs are summarized in the following paragraphs.

Deflections:

The maximum lateral wall expansion predicted by SuperSAP is 0.024 in. GTSTRUDL predicted the maximum displacement is 0.019 in. SuperSAP predicted the wall will cave in 0.009 in. GTSTRUDL predicted the wall will cave in 0.005 in. The point of curvature reversal predicted by both programs are at the same wall location. The vertical deflections predicted by both programs are about the same. However, the deflected curvature predicted by GTSTRUDL exhibits the characteristics of a stiffer structure.

Principle stress:

SuperSap program predict higher minimum principal stress (compression) by 50% . The maximum principal stress and shear stress are about the same.

Von Mises Stress:

SuperSap predicted higher Von Mises stress by 30%.

Directional Stress:

SuperSAP predicted overall lower shear stresses (Sxy, Sxz, and Syz) by 40%. and lower radial stress (Szz) by 50%. The vertical stress Syy are about the same between GTSTRUDL and SuperSAP program.

Location of maximum stresses:

The general location of maximum stresses predicted by GTSTRUDL and SuperSAP are very close when the stresses are similar (e.g. maximum principal stress and Syy).

Conclusion

The most critical stresses used in the analysis are the maximum principal stress and Syy. The maximum principal stress was used for screening purpose. The direction stress Syy is used for the evaluation of vertical wall strength below the haunch. These stresses are almost identical between two programs. It is concluded the results predicted by GTSTRUDL is adequate and compatible with the results obtained from the program SuperSAP.

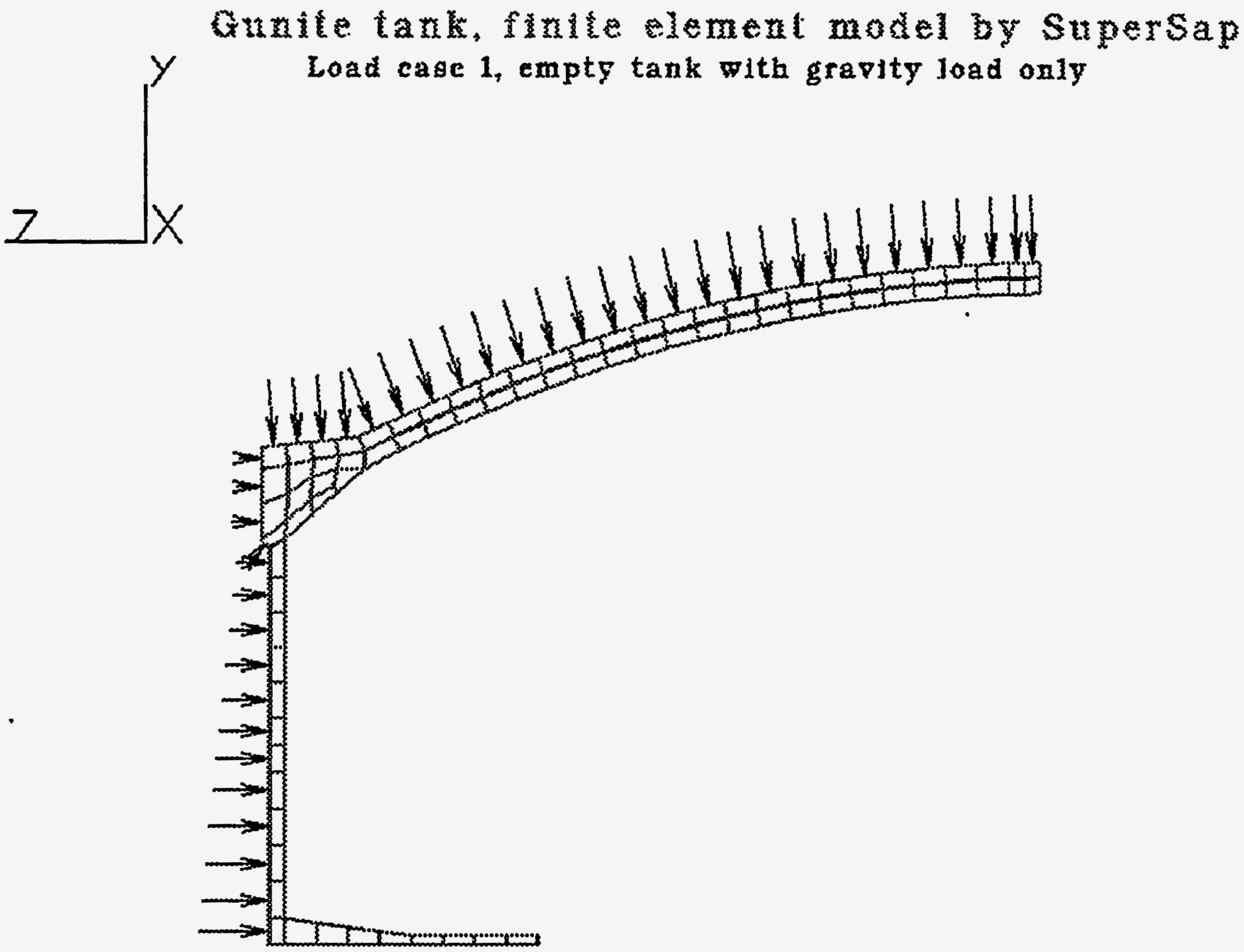


Figure D-1. Load case 1, empty tank with gravity load only

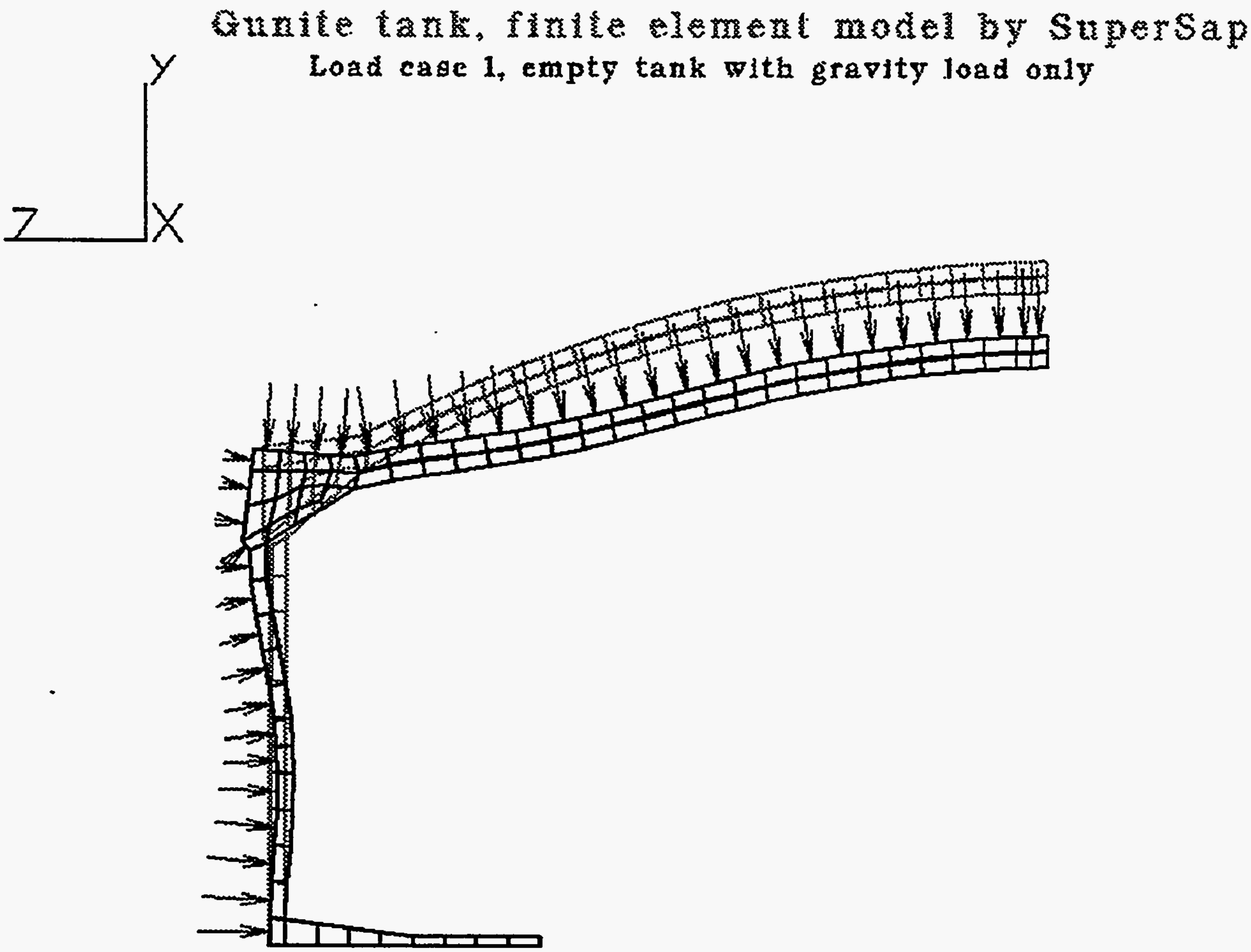


Figure D-2. Load case 1, deflection of empty tank with gravity load only

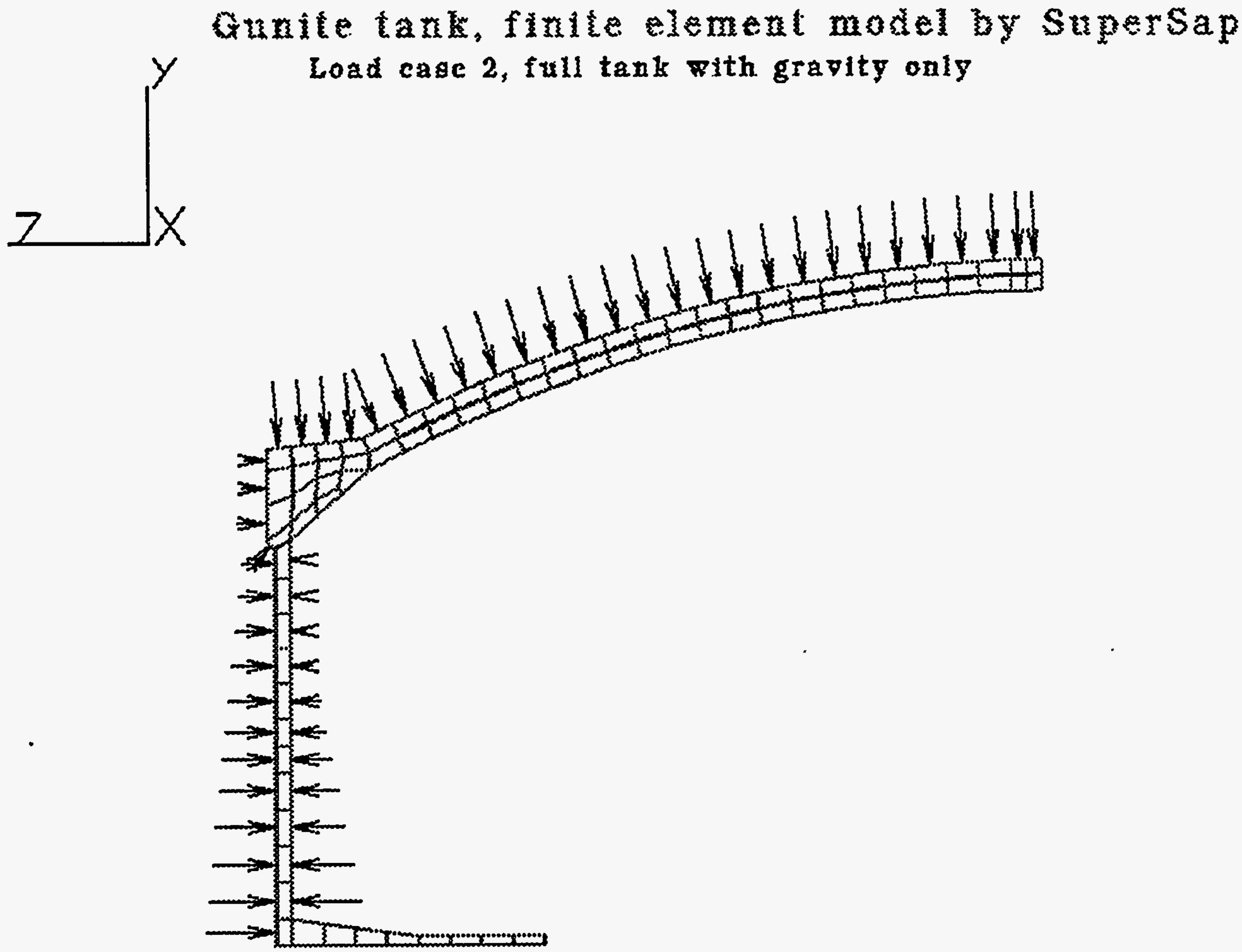


Figure D-3. Load case 2, full tank with gravity load only

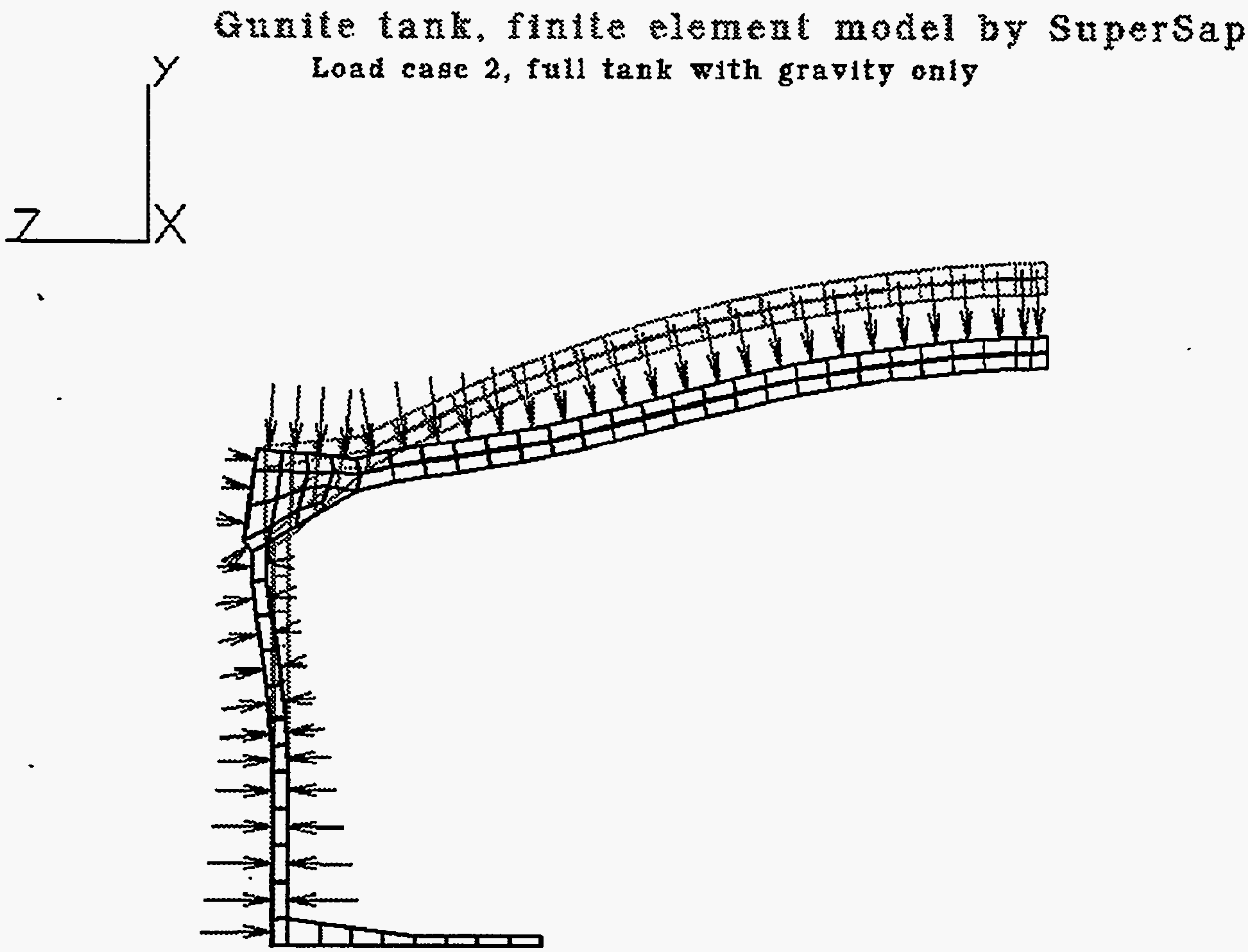


Figure D-4. Load case 2, deflection of full tank with gravity load only

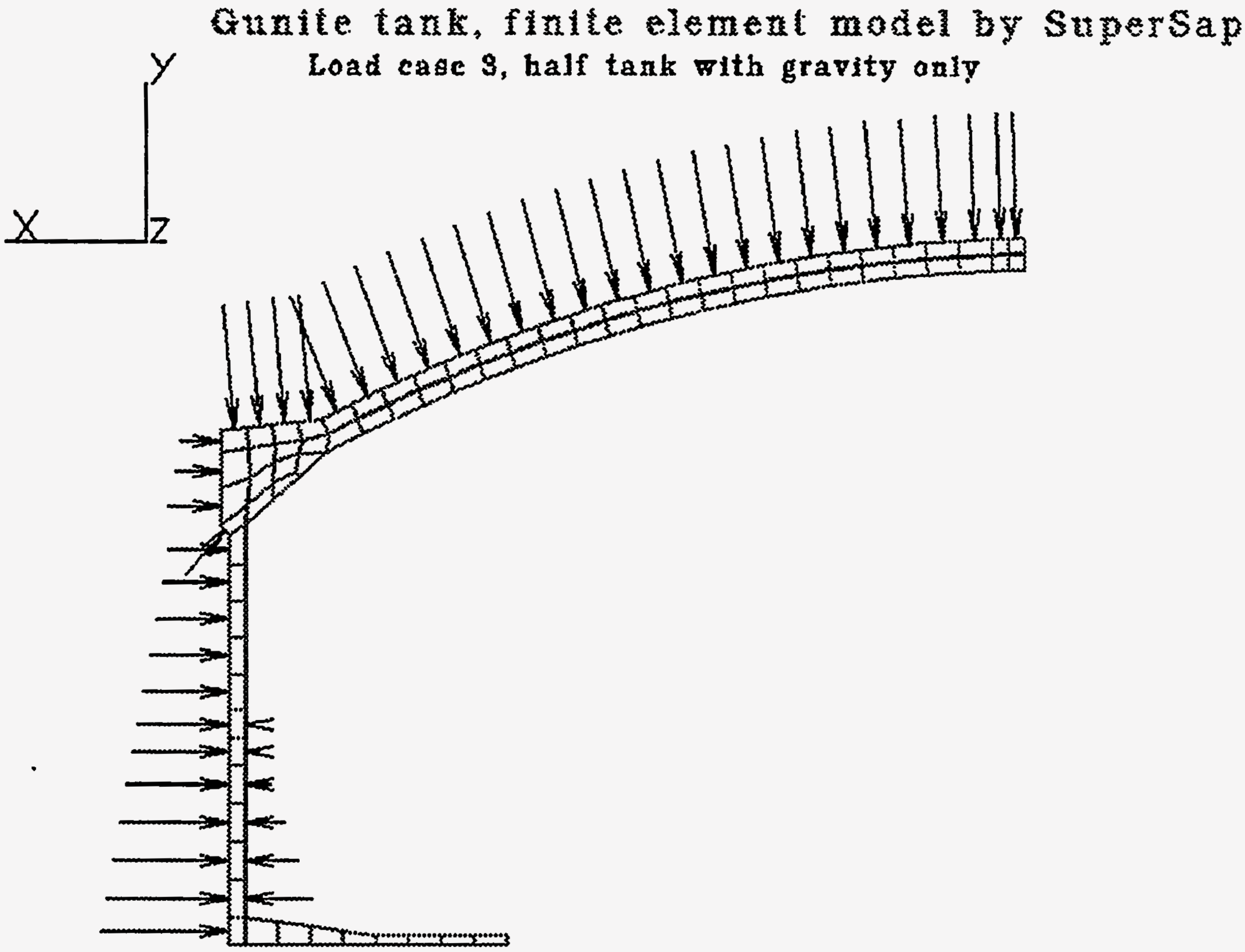


Figure D-5. Load case 3, half tank with gravity load only

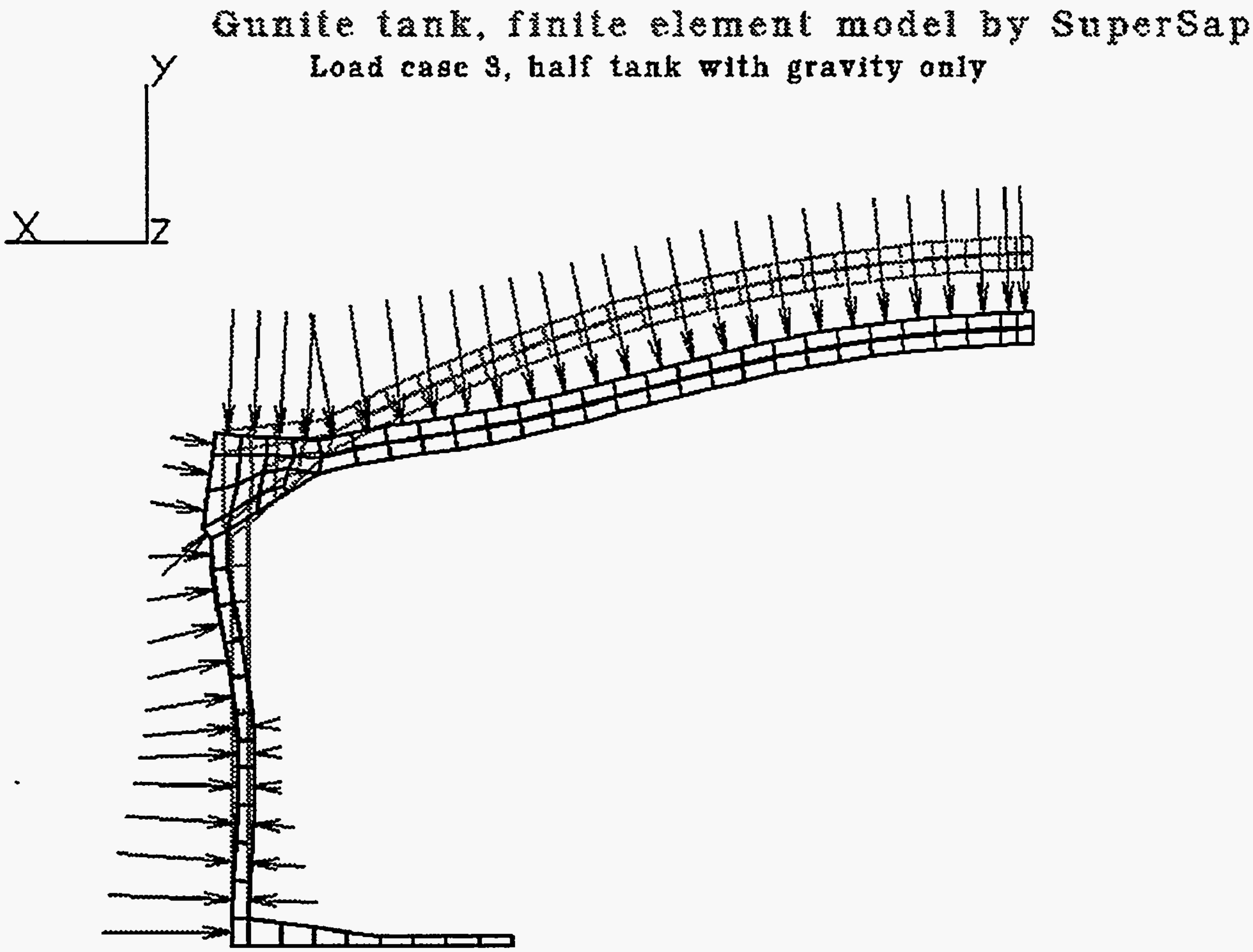


Figure D-6. Load case 3, deflection of half tank with gravity load only

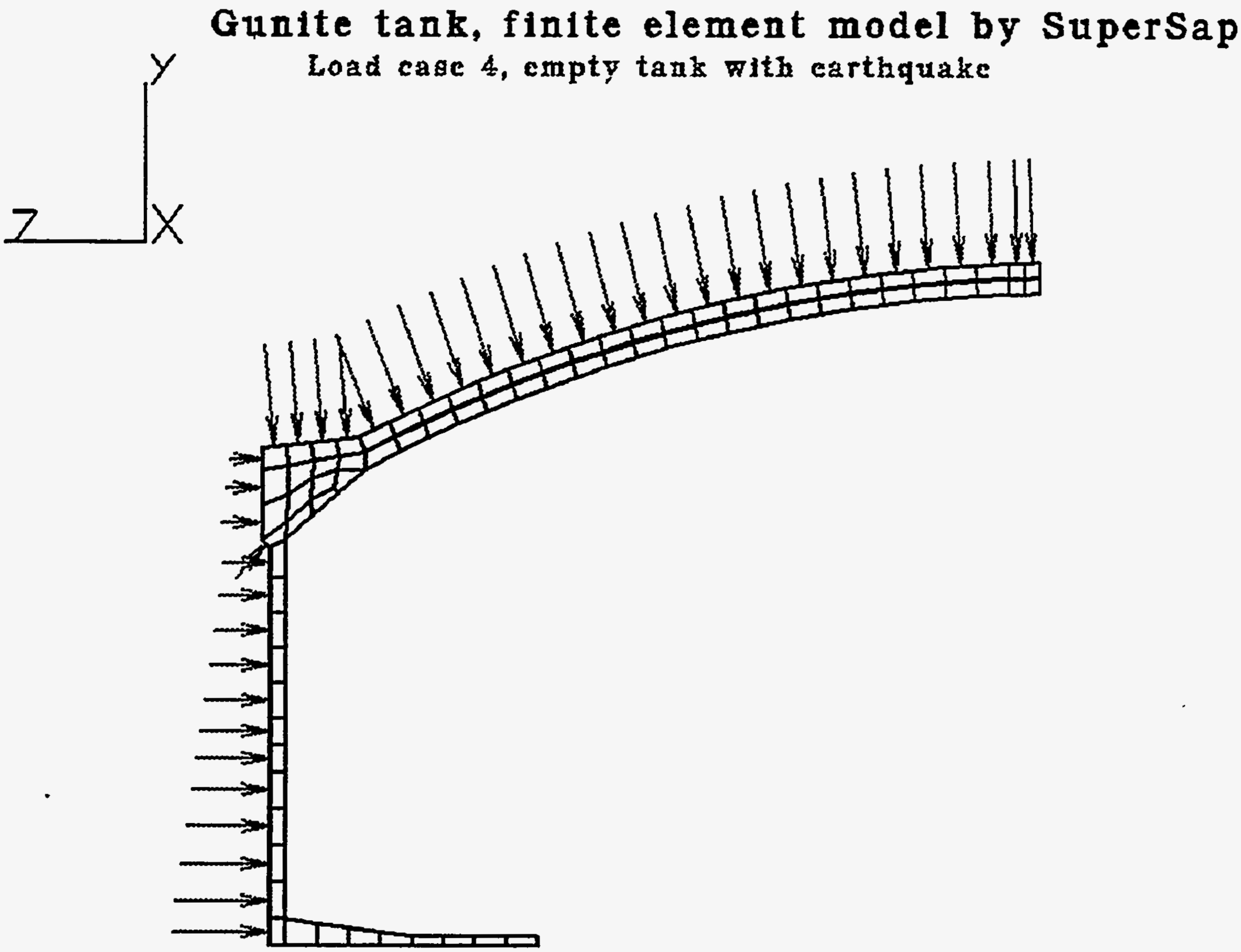


Figure D-7. Load case 4, empty tank with earthquake (East) load, slice angle = 90 degree from East direction

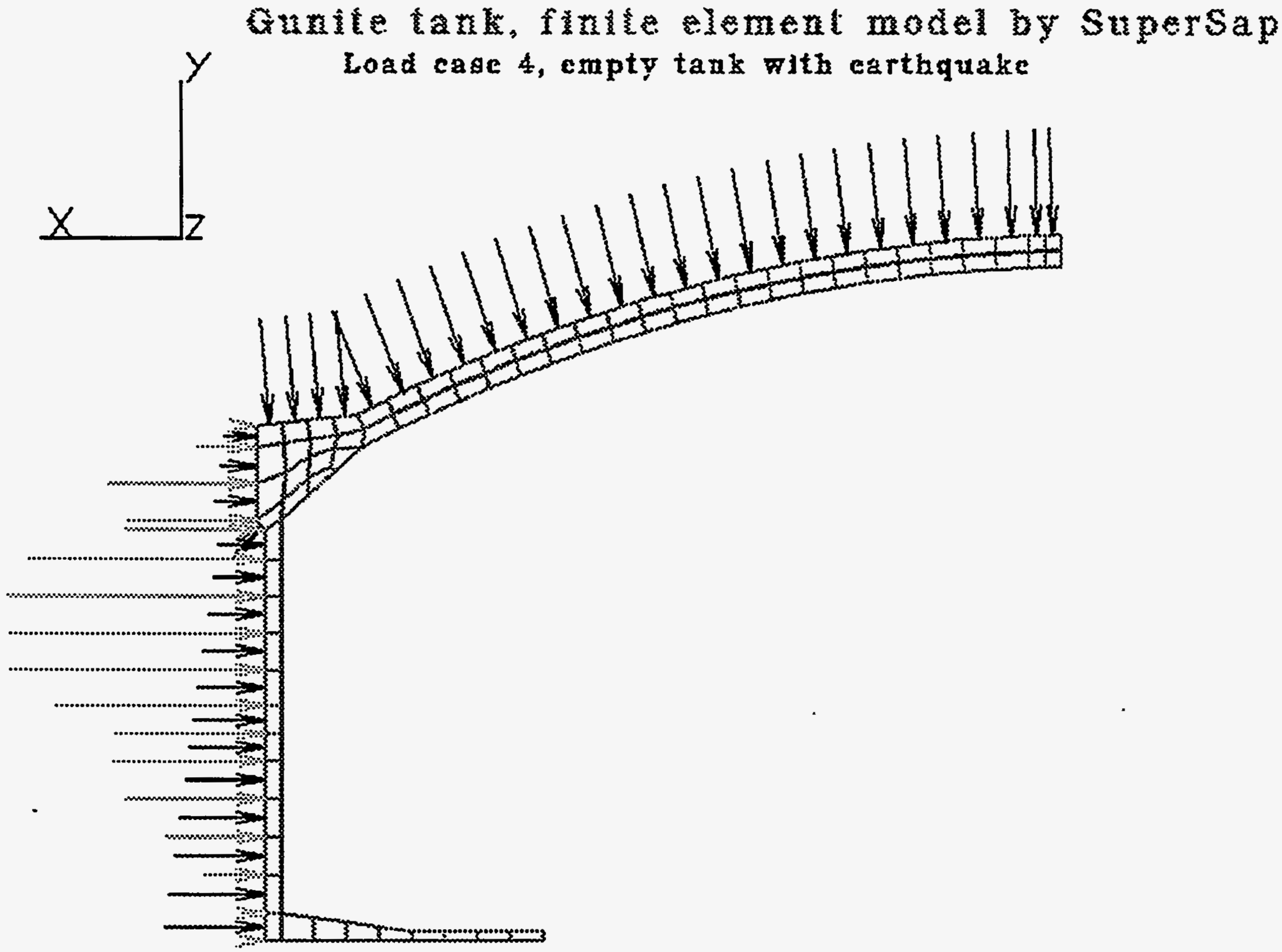


Figure D-8. Load case 4, empty tank with earthquake (East) load, slice angle = 0 degree from East direction

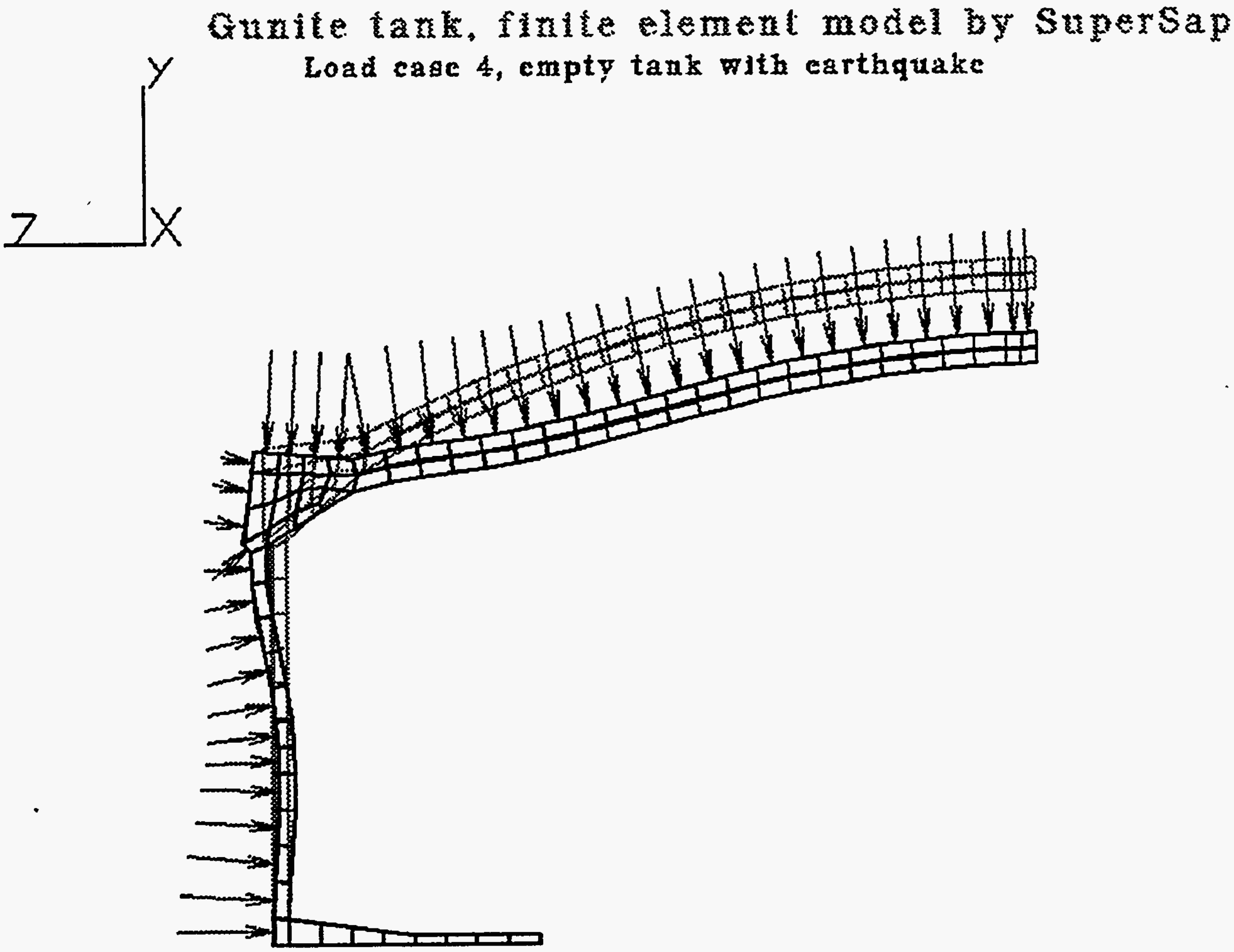


Figure D-9. Load case 4, deflection of empty tank with earthquake (East) load, slice angle = 90 degree from East direction

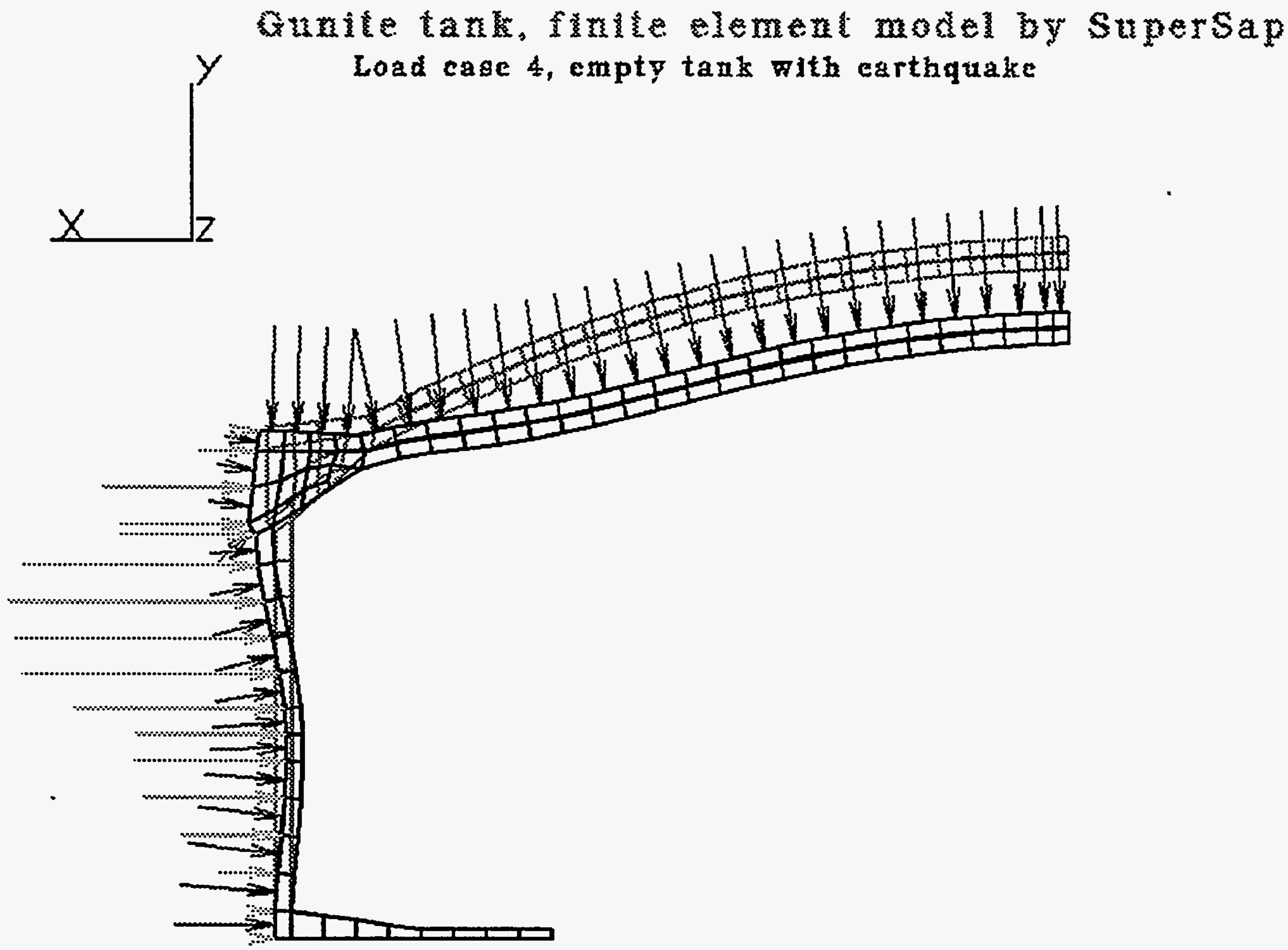


Figure D-10. Load case 4, deflection of empty tank with earthquake (East) load, slice angle = 0 degree from East direction

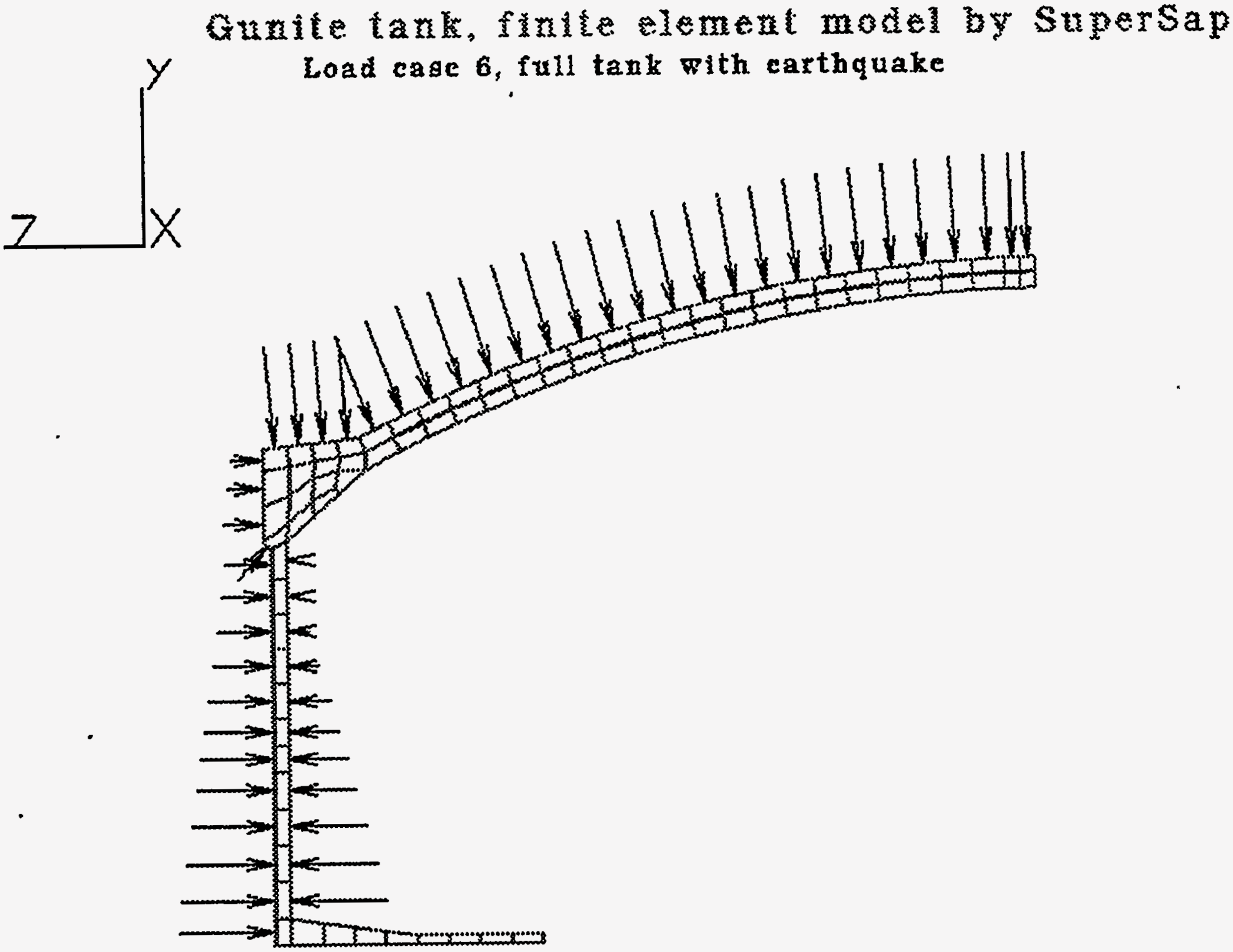


Figure D-11. Load case 6, full tank with earthquake (East) load, slice angle = 90 degree from East direction

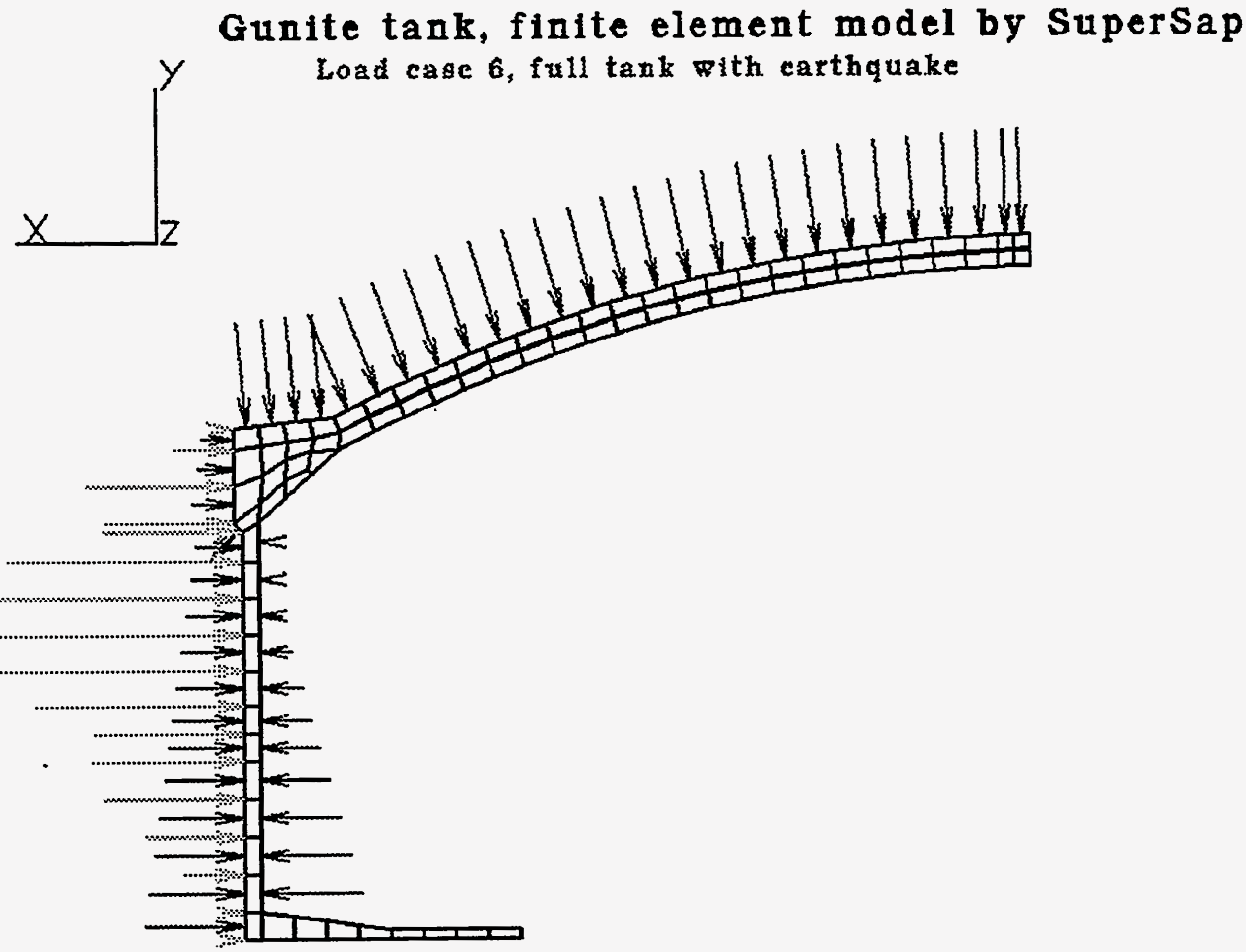


Figure D-12. Load case 6, full tank with earthquake (East) load, slice angle = 0 degree from East direction

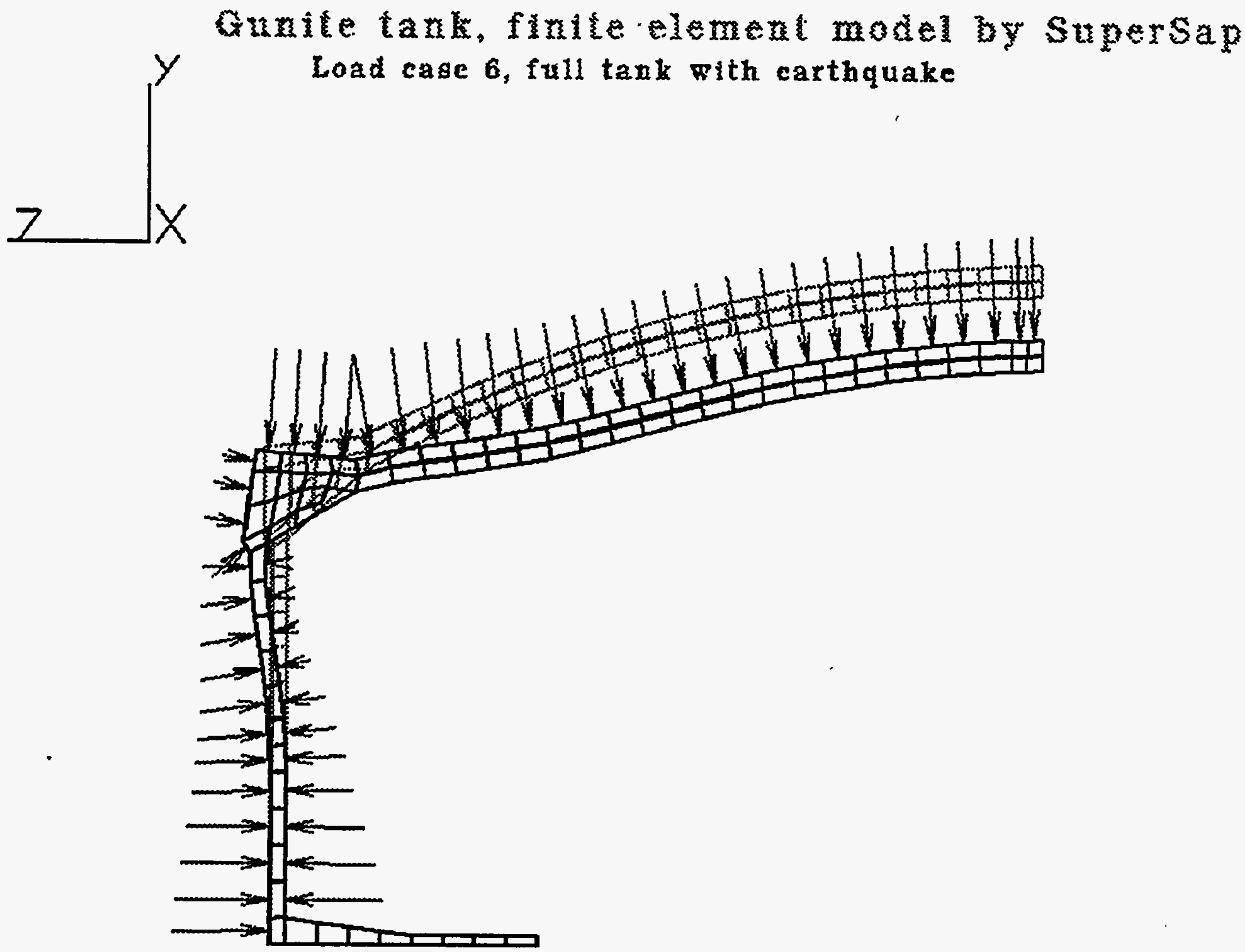


Figure D-13. Load case 6, deflection of full tank with earthquake (East) load, slice angle = 0 degree from East direction

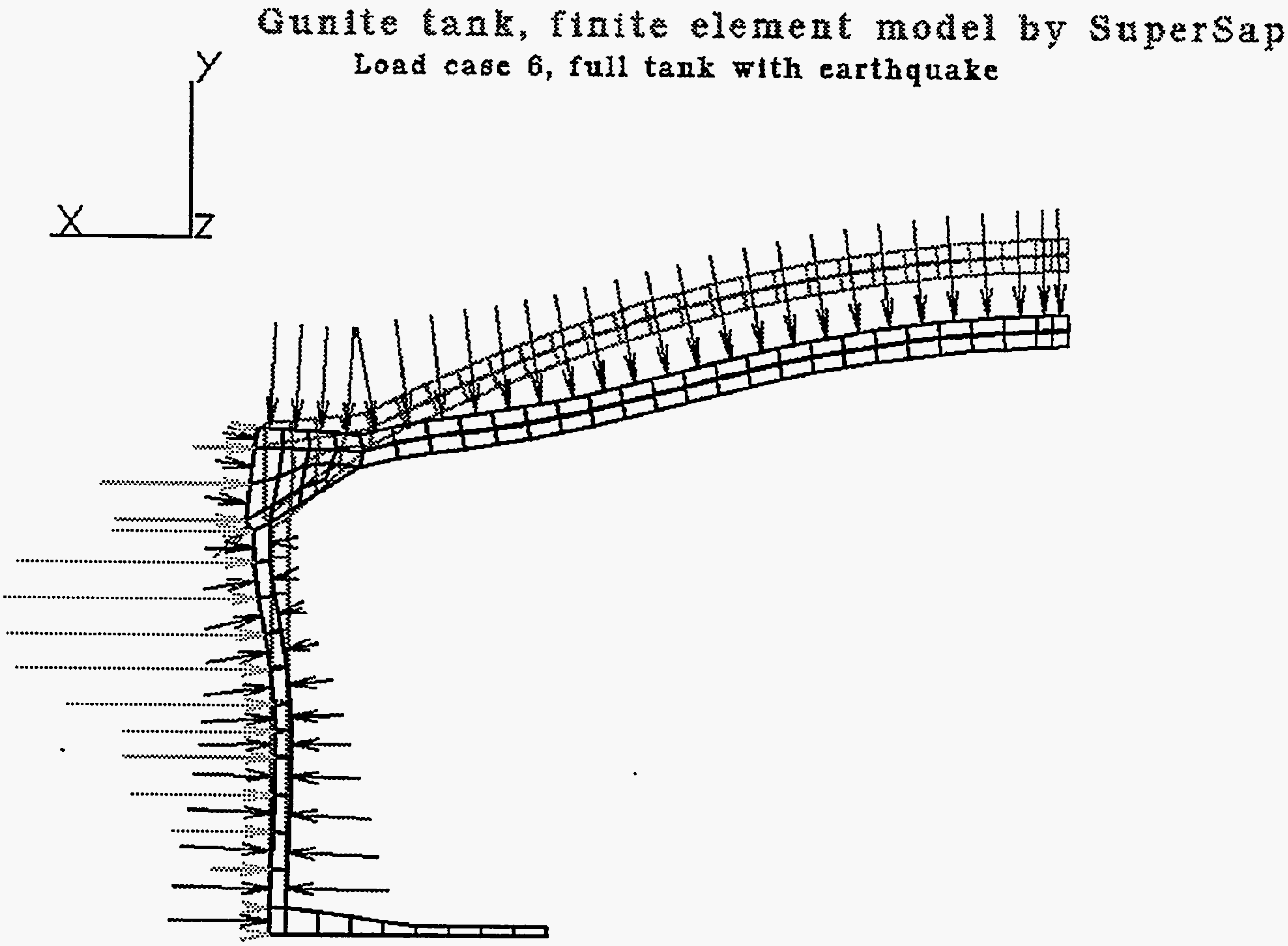


Figure D-14. Load case 6, deflection of full tank with earthquake (East) load, slice angle = 0 degree from East direction

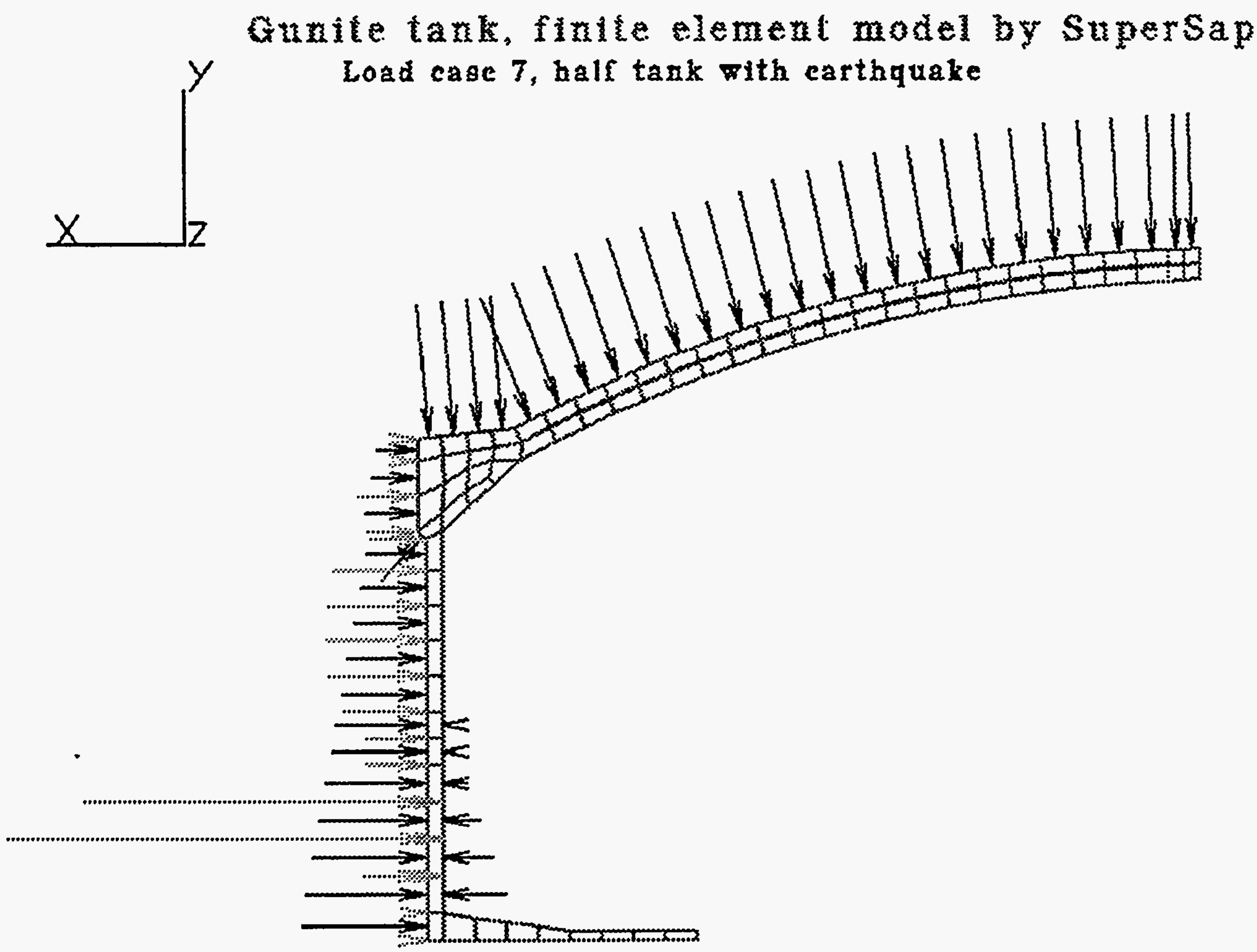


Figure D-15. Load case 7, half ·k with earthquake (East) load, slice angle = 0 degr… from East direction

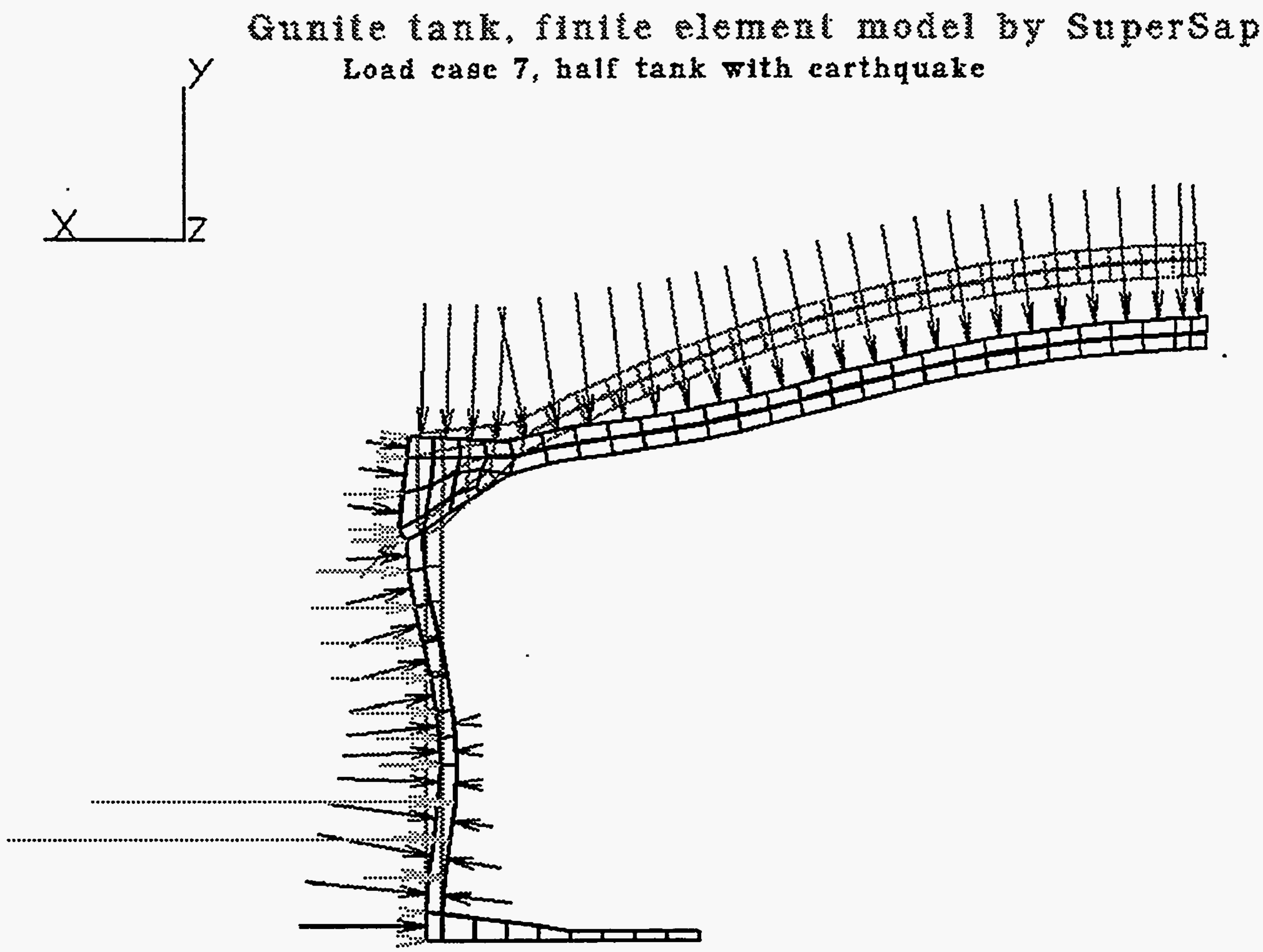


Figure D-16. Load case 7, deflection of half tank with earthquake (East) load, slice angle = 0 degree from East direction

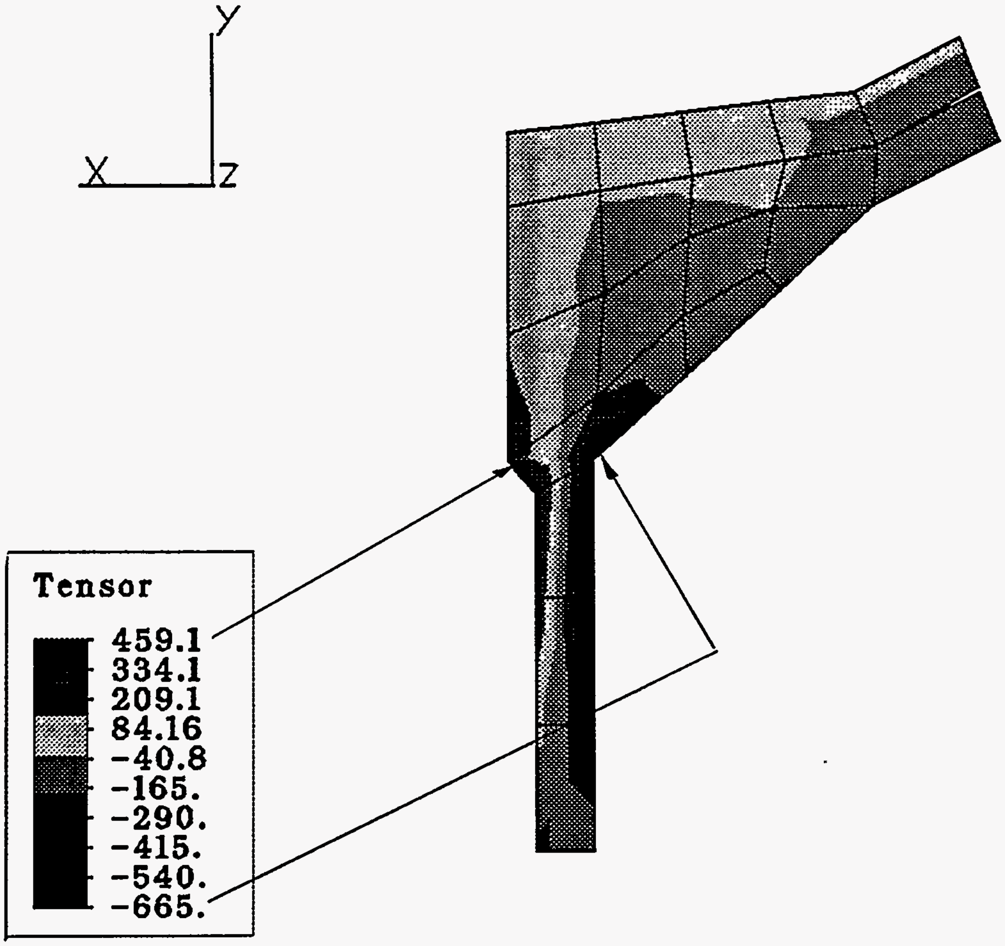


Figure D-17. Load case 1, stress contour of Syy at the haunch, empty tank with gravity load only

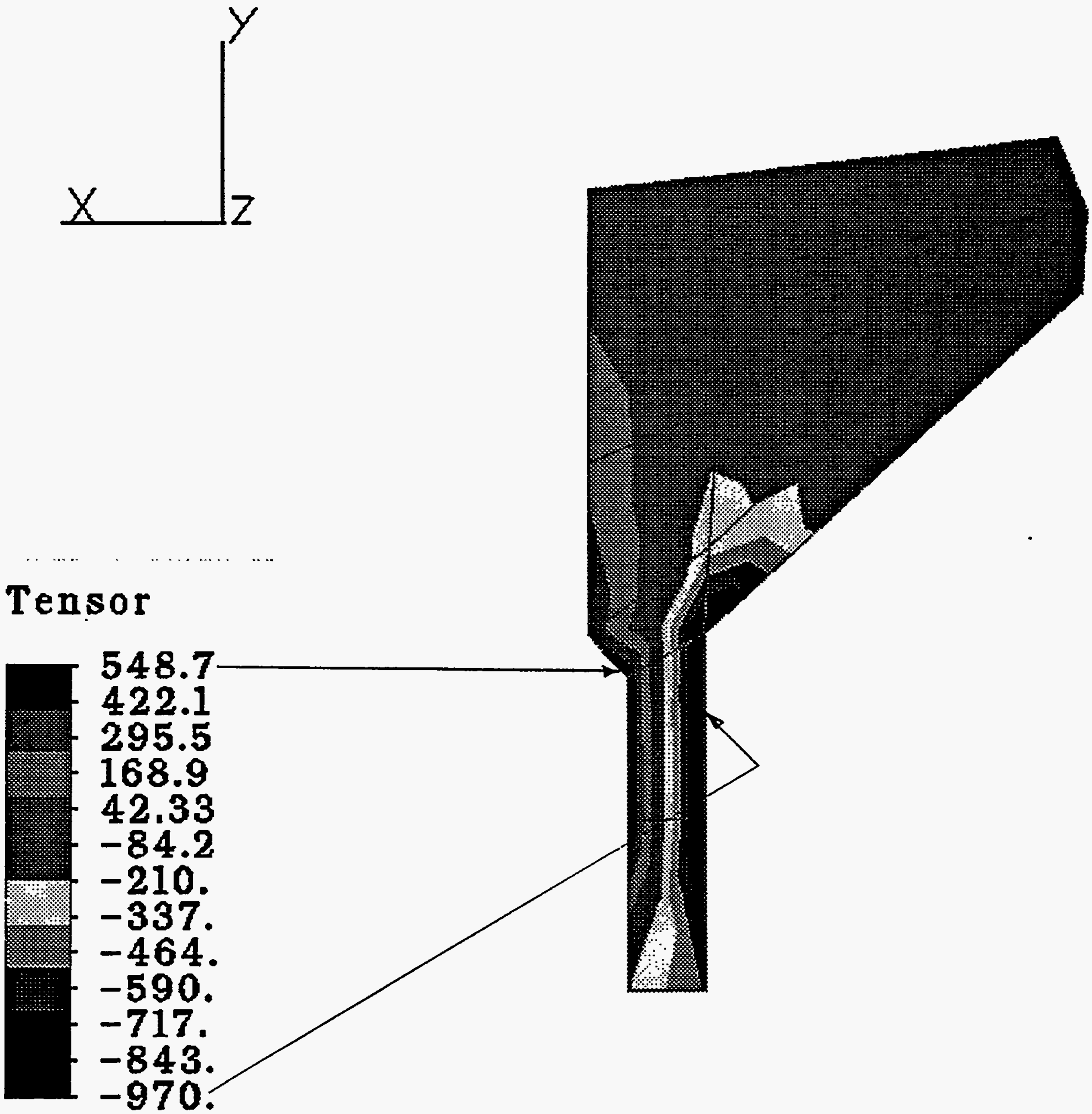


Figure D-18. Load case 4, stress contour of Syy at the haunch, empty tank with earthquake load

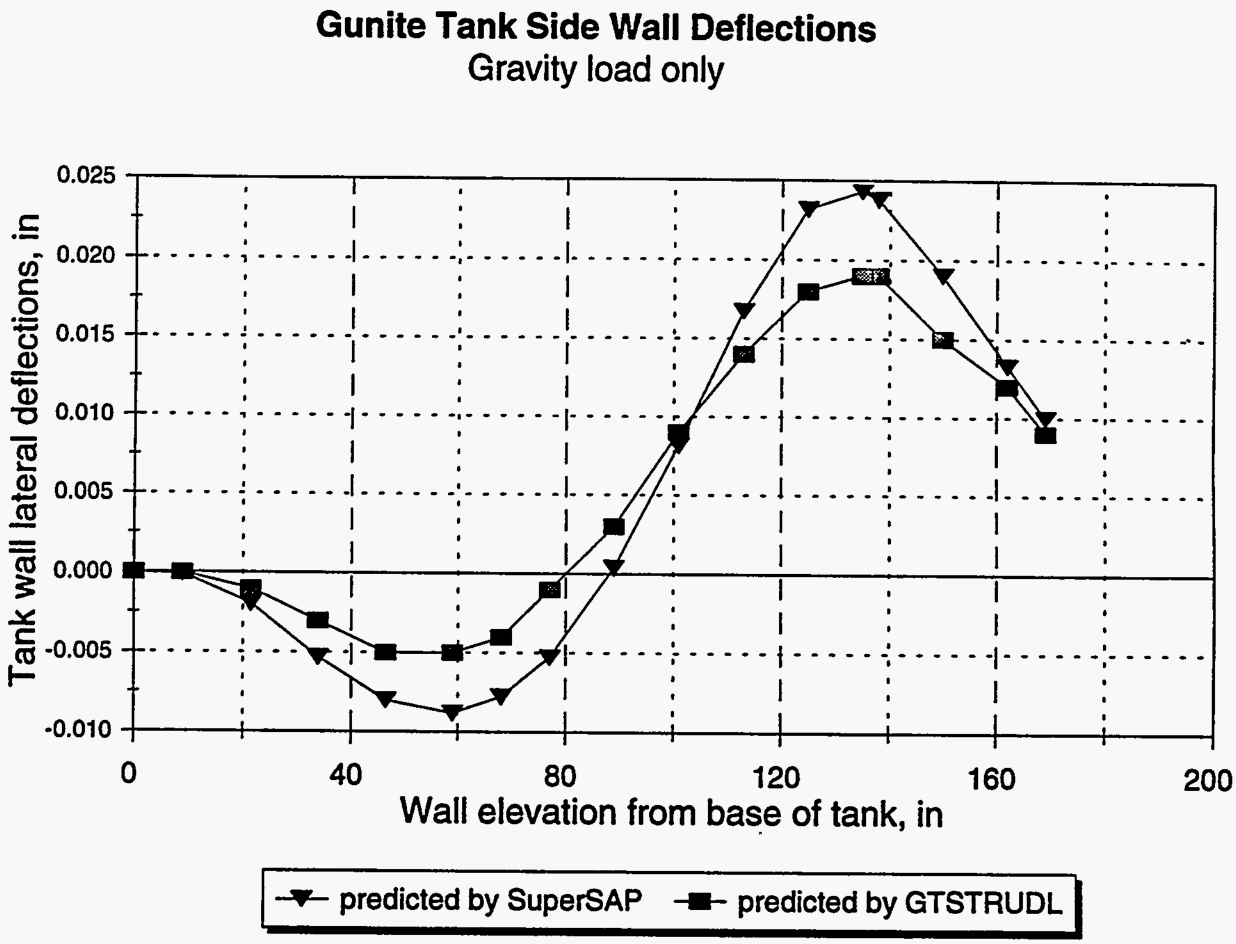


Figure D-19. Load case 1, tank side-wall deflections, predicted by GTSTRUDL and SuperSAP, empty tank with gravity load only

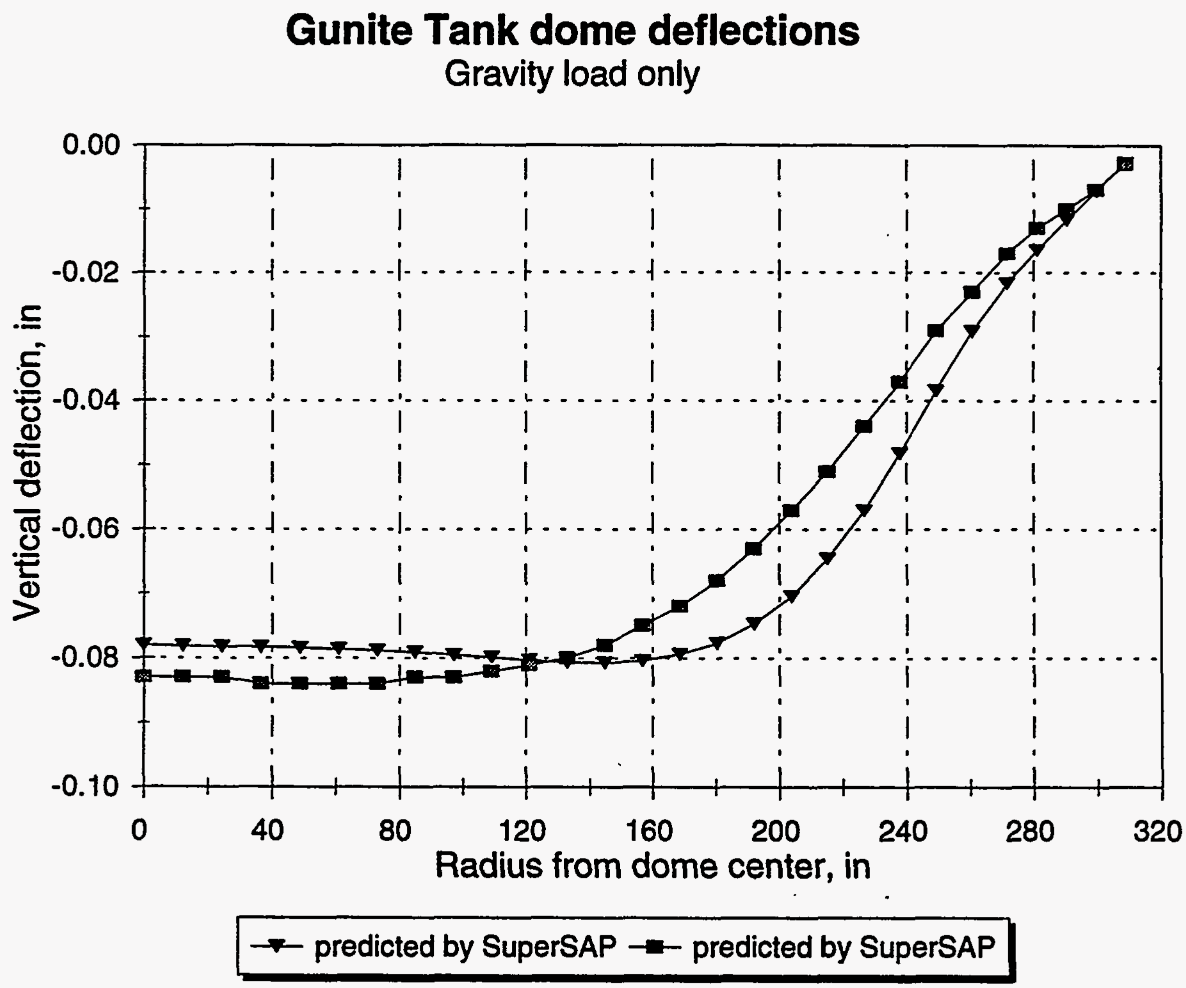


Figure D-20. Load case 1, tank dome deflection, predicted by GTSTRUDL and SuperSAP, empty tank with gravity load only

Summary of SuperSap's Evaluation of Gunite Tank

Type of Stress	stress	static+seismic load node	location	loading case	stress psi	static load node	location	loading case	stress psi
directional	Sxx	8123	edge of 30-in. (E) opening, top surface	6	529	8123	edge of 30-in. (E) opening, top surface	1	482
tensile	Syy	4070	one element below top of wall, exterior surface	4	549	4070	one element below top of wall, exterior surface	1	488
and	Szz	12130	one element below top of wall, exterior surface	4	457	8592	edge of (F)-opening, top surface	1	420
shear	Sxy	12131	top of wall, exterior surface	4	330	11976	top of wall, exterior surface	1	302
stresses	Sxz	13991	top of wall, exterior surface	5	276	13991	top of wall, exterior surface	2	246
	Syz	16006	top of wall, exterior surface	4	324	41	top of wall, exterior surface	1	302
Principle	Prin_max	4071	top of wall, exterior surface	4	674	13066	top of wall, interior surface	1	585
Stress	Prin-min	4076	top of wall, interior surface	4	978	4386	top of wall, interior surface	1	862
	Tmax	12129	one element below top of wall, interior surface	4	474	4386	top of wall, interior surface	1	516
Von Mises Stress		12129	one element below top of wall, interior surface	4	611	4386	top of wall, interior surface	1	545

Summary of GTSTRUDL's Evaluation of Gunite Tank

Type of Stress	stress	static+seismic load node	location	loading case	stress psi	static load node	location	loading case	stress psi
directional	Sxx	8128	edge of 30-in. (E) opening, bottom surface	6	542	8128	edge of 30-in. (E) opening, bottom surface	2	488
tensile	Syy	4071	top of wall, exterior surface	4	549	4071	top of wall, exterior surface	1	489
and	Szz	8592	edge of (F)-opening, top surface	4	833	8592	edge of (F)-opening, top surface	1	781
shear	Sxy	4071	top of wall, exterior surface	4	544	4071	top of wall, exterior surface	1	491
stresses	Sxz	41	top of wall, exterior surface	4	523	41	top of wall, exterior surface	1	488
	Syz	8903	edge of (F)-opening, top surface	8	453	8903	edge of (F)-opening, top surface	3	410
Principle	Prin_max	4071	top of wall, exterior surface	4	689	4071	top of wall, exterior surface	1	621
Stress	Prin-min	8595	edge of 30-in. (E) opening, top surface	4	642	8595	edge of 30-in. (E) opening, top surface	1	597
	Tmax	4071	top of wall, exterior surface	4	467	4071	top of wall, exterior surface	1	420
Von Mises Stress		4071	top of wall, exterior surface	4	468	4071	top of wall, exterior surface	1	421

Figure D-21. Summary of stress predictions by GTSTRUDL and SuperSAP

APPENDIX D
GTSTRUDL Input File

```
*TITLE 'X-10 TANK FARM GUNITE TANK ANALYSIS - SAIC 1995'
STRUDL 'GUNITE96.GTS' '3-D MODEL OF X-10 TANK FARM GUNITE TANK, STATIC LOAD'
$
$ INPUT FILE NAME: GUNITE96.GTS
$ DATE PREPARED:
$ RUN NUMBER: 01                03/21/95
$  OVERDOME EARTH PRESSURE IS APPLIED TO THE CORRECT (EXPOSED) FACE
$  ADD SOIL SPRING FROM SIDE        03/24/95
$
$ R-DIRECTION, HORIZONTAL
$ THETA-DIRECTION, ANGLE PIVOTED ABOUT Y-AXIS, 0 DEG MEASURED FROM Z-AXIS,
$ Y-DIRECTION, VERTICAL UP
$
$ X-DIRECTION, WEST
$ Y-VERTICAL, VERTICAL UP
$ Z-NORTH
$
UNIT INCH DEGREE POUND
JOINT COORDINATES CYLINDRICAL
GENERATE 104 JOINTS CYL ID  1, 155 R 204.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  2, 155 R 216.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  3, 155 R 228.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  4, 155 R 240.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  5, 155 R 252.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  6, 155 R 264.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  7, 155 R 276.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  8, 155 R 288.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  9, 155 R 300.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID 10, 155 R 306.00 TH 0.0, 3.4615 LY  -3.0 SUPPORT
GENERATE 104 JOINTS CYL ID  11, 155 R 204.00 TH 0.000, 3.4615 LY  0.000
GENERATE 104 JOINTS CYL ID  12, 155 R 216.00 TH 0.000, 3.4615 LY  0.000
GENERATE 104 JOINTS CYL ID  13, 155 R 228.00 TH 0.000, 3.4615 LY  0.000
GENERATE 104 JOINTS CYL ID  14, 155 R 240.00 TH 0.000, 3.4615 LY  0.000
GENERATE 104 JOINTS CYL ID  15, 155 R 252.00 TH 0.000, 3.4615 LY  0.000
GENERATE 104 JOINTS CYL ID  16, 155 R 264.00 TH 0.000, 3.4615 LY  1.500
GENERATE 104 JOINTS CYL ID  17, 155 R 276.00 TH 0.000, 3.4615 LY  3.000
GENERATE 104 JOINTS CYL ID  18, 155 R 288.00 TH 0.000, 3.4615 LY  4.500
GENERATE 104 JOINTS CYL ID  19, 155 R 300.00 TH 0.000, 3.4615 LY  6.000
GENERATE 104 JOINTS CYL ID  20, 155 R 306.00 TH 0.000, 3.4615 LY  6.000
GENERATE 104 JOINTS CYL ID  21, 155 R 300.00 TH 0.000, 3.4615 LY  18.500
GENERATE 104 JOINTS CYL ID  22, 155 R 306.00 TH 0.000, 3.4615 LY  18.500
GENERATE 104 JOINTS CYL ID  23, 155 R 300.00 TH 0.000, 3.4615 LY  31.000
GENERATE 104 JOINTS CYL ID  24, 155 R 306.00 TH 0.000, 3.4615 LY  31.000
GENERATE 104 JOINTS CYL ID  25, 155 R 300.00 TH 0.000, 3.4615 LY  43.500
GENERATE 104 JOINTS CYL ID  26, 155 R 306.00 TH 0.000, 3.4615 LY  43.500
GENERATE 104 JOINTS CYL ID  27, 155 R 300.00 TH 0.000, 3.4615 LY  56.000
GENERATE 104 JOINTS CYL ID  28, 155 R 306.00 TH 0.000, 3.4615 LY  56.000
GENERATE 104 JOINTS CYL ID  29, 155 R 300.00 TH 0.000, 3.4615 LY  65.000
GENERATE 104 JOINTS CYL ID  30, 155 R 306.00 TH 0.000, 3.4615 LY  65.000
GENERATE 104 JOINTS CYL ID  31, 155 R 300.00 TH 0.000, 3.4615 LY  74.000
GENERATE 104 JOINTS CYL ID  32, 155 R 306.00 TH 0.000, 3.4615 LY  74.000
GENERATE 104 JOINTS CYL ID  33, 155 R 300.00 TH 0.000, 3.4615 LY  86.000
GENERATE 104 JOINTS CYL ID  34, 155 R 306.00 TH 0.000, 3.4615 LY  86.000
GENERATE 104 JOINTS CYL ID  35, 155 R 300.00 TH 0.000, 3.4615 LY  98.000
GENERATE 104 JOINTS CYL ID  36, 155 R 306.00 TH 0.000, 3.4615 LY  98.000
GENERATE 104 JOINTS CYL ID  37, 155 R 300.00 TH 0.000, 3.4615 LY  110.000
GENERATE 104 JOINTS CYL ID  38, 155 R 306.00 TH 0.000, 3.4615 LY  110.000
GENERATE 104 JOINTS CYL ID  39, 155 R 300.00 TH 0.000, 3.4615 LY  122.000
GENERATE 104 JOINTS CYL ID  40, 155 R 306.00 TH 0.000, 3.4615 LY  122.000
GENERATE 104 JOINTS CYL ID  41, 155 R 306.00 TH 0.000, 3.4615 LY  132.000
GENERATE 104 JOINTS CYL ID  42, 155 R 309.00 TH 0.000, 3.4615 LY  135.000
GENERATE 104 JOINTS CYL ID  43, 155 R 309.00 TH 0.000, 3.4615 LY  147.000
GENERATE 104 JOINTS CYL ID  44, 155 R 309.00 TH 0.000, 3.4615 LY  159.000
GENERATE 104 JOINTS CYL ID  45, 155 R 309.00 TH 0.000, 3.4615 LY  166.000
GENERATE 104 JOINTS CYL ID  46, 155 R 300.00 TH 0.000, 3.4615 LY  135.000
GENERATE 104 JOINTS CYL ID  47, 155 R 299.62 TH 0.000, 3.4615 LY  141.036
GENERATE 104 JOINTS CYL ID  48, 155 R 298.84 TH 0.000, 3.4615 LY  150.768
GENERATE 104 JOINTS CYL ID  49, 155 R 299.13 TH 0.000, 3.4615 LY  160.430
GENERATE 104 JOINTS CYL ID  50, 155 R 299.71 TH 0.000, 3.4615 LY  166.929
GENERATE 104 JOINTS CYL ID  51, 155 R 290.00 TH 0.000, 3.4615 LY  143.000
GENERATE 104 JOINTS CYL ID  52, 155 R 290.23 TH 0.000, 3.4615 LY  148.705
GENERATE 104 JOINTS CYL ID  53, 155 R 289.70 TH 0.000, 3.4615 LY  156.110
GENERATE 104 JOINTS CYL ID  54, 155 R 289.27 TH 0.000, 3.4615 LY  161.861
GENERATE 104 JOINTS CYL ID  55, 155 R 290.43 TH 0.000, 3.4615 LY  167.857
GENERATE 104 JOINTS CYL ID  56, 155 R 280.00 TH 0.000, 3.4615 LY  151.000
GENERATE 104 JOINTS CYL ID  57, 155 R 281.77 TH 0.000, 3.4615 LY  152.936
GENERATE 104 JOINTS CYL ID  58, 155 R 280.71 TH 0.000, 3.4615 LY  158.754
GENERATE 104 JOINTS CYL ID  59, 155 R 279.41 TH 0.000, 3.4615 LY  163.291
GENERATE 104 JOINTS CYL ID  60, 155 R 281.14 TH 0.000, 3.4615 LY  168.786
GENERATE 104 JOINTS CYL ID  61, 155 R 270.00 TH 0.000, 3.4615 LY  159.000
GENERATE 104 JOINTS CYL ID  62, 155 R 269.55 TH 0.000, 3.4615 LY  164.722
GENERATE 104 JOINTS CYL ID  63, 155 R 271.86 TH 0.000, 3.4615 LY  169.714
GENERATE 104 JOINTS CYL ID  64, 155 R 256.51 TH 0.000, 3.4615 LY  165.114
GENERATE 104 JOINTS CYL ID  65, 155 R 258.52 TH 0.000, 3.4615 LY  169.692
```

```
GENERATE 104 JOINTS CYL ID  66, 155 R 258.73 TH 0.000, 3.4615 LY  170.150
GENERATE 104 JOINTS CYL ID  67, 155 R 260.74 TH 0.000, 3.4615 LY  174.727
GENERATE 104 JOINTS CYL ID  68, 155 R 245.48 TH 0.000, 3.4615 LY  169.839
GENERATE 104 JOINTS CYL ID  69, 155 R 247.41 TH 0.000, 3.4615 LY  174.454
GENERATE 104 JOINTS CYL ID  70, 155 R 247.60 TH 0.000, 3.4615 LY  174.915
GENERATE 104 JOINTS CYL ID  71, 155 R 249.53 TH 0.000, 3.4615 LY  179.530
GENERATE 104 JOINTS CYL ID  72, 155 R 234.36 TH 0.000, 3.4615 LY  174.356
GENERATE 104 JOINTS CYL ID  73, 155 R 236.20 TH 0.000, 3.4615 LY  179.005
GENERATE 104 JOINTS CYL ID  74, 155 R 236.39 TH 0.000, 3.4615 LY  179.470
GENERATE 104 JOINTS CYL ID  75, 155 R 238.22 TH 0.000, 3.4615 LY  184.120
GENERATE 104 JOINTS CYL ID  76, 155 R 223.16 TH 0.000, 3.4615 LY  178.662
GENERATE 104 JOINTS CYL ID  77, 155 R 224.91 TH 0.000, 3.4615 LY  183.346
GENERATE 104 JOINTS CYL ID  78, 155 R 225.09 TH 0.000, 3.4615 LY  183.814
GENERATE 104 JOINTS CYL ID  79, 155 R 226.84 TH 0.000, 3.4615 LY  188.498
GENERATE 104 JOINTS CYL ID  80, 155 R 211.88 TH 0.000, 3.4615 LY  182.757
GENERATE 104 JOINTS CYL ID  81, 155 R 213.55 TH 0.000, 3.4615 LY  187.472
GENERATE 104 JOINTS CYL ID  82, 155 R 213.71 TH 0.000, 3.4615 LY  187.944
GENERATE 104 JOINTS CYL ID  83, 155 R 215.37 TH 0.000, 3.4615 LY  192.660
GENERATE 104 JOINTS CYL ID  84, 155 R 200.53 TH 0.000, 3.4615 LY  186.638
GENERATE 104 JOINTS CYL ID  85, 155 R 202.10 TH 0.000, 3.4615 LY  191.385
GENERATE 104 JOINTS CYL ID  86, 155 R 202.26 TH 0.000, 3.4615 LY  191.859
GENERATE 104 JOINTS CYL ID  87, 155 R 203.83 TH 0.000, 3.4615 LY  196.605
GENERATE 104 JOINTS CYL ID  88, 155 R 189.10 TH 0.000, 3.4615 LY  190.306
GENERATE 104 JOINTS CYL ID  89, 155 R 190.59 TH 0.000, 3.4615 LY  195.081
GENERATE 104 JOINTS CYL ID  90, 155 R 190.74 TH 0.000, 3.4615 LY  195.558
GENERATE 104 JOINTS CYL ID  91, 155 R 192.22 TH 0.000, 3.4615 LY  200.333
GENERATE 104 JOINTS CYL ID  92, 155 R 177.61 TH 0.000, 3.4615 LY  193.757
GENERATE 104 JOINTS CYL ID  93, 155 R 179.01 TH 0.000, 3.4615 LY  198.559
GENERATE 104 JOINTS CYL ID  94, 155 R 179.14 TH 0.000, 3.4615 LY  199.039
GENERATE 104 JOINTS CYL ID  95, 155 R 180.54 TH 0.000, 3.4615 LY  203.841
GENERATE 104 JOINTS CYL ID  96, 155 R 166.06 TH 0.000, 3.4615 LY  196.992
GENERATE 104 JOINTS CYL ID  97, 155 R 167.36 TH 0.000, 3.4615 LY  201.819
GENERATE 104 JOINTS CYL ID  98, 155 R 167.49 TH 0.000, 3.4615 LY  202.302
GENERATE 104 JOINTS CYL ID  99, 155 R 168.79 TH 0.000, 3.4615 LY  207.129
GENERATE 104 JOINTS CYL ID 100, 155 R 154.44 TH 0.000, 3.4615 LY  200.009
GENERATE 104 JOINTS CYL ID 101, 155 R 155.65 TH 0.000, 3.4615 LY  204.860
GENERATE 104 JOINTS CYL ID 102, 155 R 155.77 TH 0.000, 3.4615 LY  205.345
GENERATE 104 JOINTS CYL ID 103, 155 R 156.99 TH 0.000, 3.4615 LY  210.196
GENERATE 104 JOINTS CYL ID 104, 155 R 142.77 TH 0.000, 3.4615 LY  202.806
GENERATE 104 JOINTS CYL ID 105, 155 R 143.89 TH 0.000, 3.4615 LY  207.679
GENERATE 104 JOINTS CYL ID 106, 155 R 144.00 TH 0.000, 3.4615 LY  208.166
GENERATE 104 JOINTS CYL ID 107, 155 R 145.12 TH 0.000, 3.4615 LY  213.039
GENERATE 104 JOINTS CYL ID 108, 155 R 131.05 TH 0.000, 3.4615 LY  205.383
GENERATE 104 JOINTS CYL ID 109, 155 R 132.08 TH 0.000, 3.4615 LY  210.277
GENERATE 104 JOINTS CYL ID 110, 155 R 132.18 TH 0.000, 3.4615 LY  210.766
GENERATE 104 JOINTS CYL ID 111, 155 R 133.21 TH 0.000, 3.4615 LY  215.659
GENERATE 104 JOINTS CYL ID 112, 155 R 119.29 TH 0.000, 3.4615 LY  207.740
GENERATE 104 JOINTS CYL ID 113, 155 R 120.22 TH 0.000, 3.4615 LY  212.651
GENERATE 104 JOINTS CYL ID 114, 155 R 120.32 TH 0.000, 3.4615 LY  213.142
GENERATE 104 JOINTS CYL ID 115, 155 R 121.25 TH 0.000, 3.4615 LY  218.054
GENERATE 104 JOINTS CYL ID 116, 155 R 107.48 TH 0.000, 3.4615 LY  209.874
GENERATE 104 JOINTS CYL ID 117, 155 R 108.32 TH 0.000, 3.4615 LY  214.802
GENERATE 104 JOINTS CYL ID 118, 155 R 108.41 TH 0.000, 3.4615 LY  215.295
GENERATE 104 JOINTS CYL ID 119, 155 R 109.25 TH 0.000, 3.4615 LY  220.224
GENERATE 104 JOINTS CYL ID 120, 155 R 95.637 TH 0.000, 3.4615 LY  211.786
GENERATE 104 JOINTS CYL ID 121, 155 R 96.387 TH 0.000, 3.4615 LY  216.729
GENERATE 104 JOINTS CYL ID 122, 155 R 96.462 TH 0.000, 3.4615 LY  217.223
GENERATE 104 JOINTS CYL ID 123, 155 R 97.212 TH 0.000, 3.4615 LY  222.167
GENERATE 104 JOINTS CYL ID 124, 155 R 83.756 TH 0.000, 3.4615 LY  213.474
GENERATE 104 JOINTS CYL ID 125, 155 R 84.413 TH 0.000, 3.4615 LY  218.431
GENERATE 104 JOINTS CYL ID 126, 155 R 84.479 TH 0.000, 3.4615 LY  218.926
GENERATE 104 JOINTS CYL ID 127, 155 R 85.136 TH 0.000, 3.4615 LY  223.883
GENERATE 104 JOINTS CYL ID 128, 155 R 71.846 TH 0.000, 3.4615 LY  214.939
GENERATE 104 JOINTS CYL ID 129, 155 R 72.410 TH 0.000, 3.4615 LY  219.907
GENERATE 104 JOINTS CYL ID 130, 155 R 72.466 TH 0.000, 3.4615 LY  220.404
GENERATE 104 JOINTS CYL ID 131, 155 R 73.030 TH 0.000, 3.4615 LY  225.372
GENERATE 104 JOINTS CYL ID 132, 155 R 59.911 TH 0.000, 3.4615 LY  216.179
GENERATE 104 JOINTS CYL ID 133, 155 R 60.381 TH 0.000, 3.4615 LY  221.157
GENERATE 104 JOINTS CYL ID 134, 155 R 60.428 TH 0.000, 3.4615 LY  221.654
GENERATE 104 JOINTS CYL ID 135, 155 R 60.898 TH 0.000, 3.4615 LY  226.632
GENERATE 104 JOINTS CYL ID 136, 155 R 47.954 TH 0.000, 3.4615 LY  217.194
GENERATE 104 JOINTS CYL ID 137, 155 R 48.330 TH 0.000, 3.4615 LY  222.180
GENERATE 104 JOINTS CYL ID 138, 155 R 48.368 TH 0.000, 3.4615 LY  222.678
GENERATE 104 JOINTS CYL ID 139, 155 R 48.744 TH 0.000, 3.4615 LY  227.664
GENERATE 104 JOINTS CYL ID 140, 155 R 35.981 TH 0.000, 3.4615 LY  217.984
GENERATE 104 JOINTS CYL ID 141, 155 R 36.263 TH 0.000, 3.4615 LY  222.976
GENERATE 104 JOINTS CYL ID 142, 155 R 36.291 TH 0.000, 3.4615 LY  223.475
GENERATE 104 JOINTS CYL ID 143, 155 R 36.573 TH 0.000, 3.4615 LY  228.467
GENERATE 104 JOINTS CYL ID 144, 155 R 24.    TH 0.000, 3.4615 LY  218.55
GENERATE 104 JOINTS CYL ID 145, 155 R 24.    TH 0.000, 3.4615 LY  223.55
GENERATE 104 JOINTS CYL ID 146, 155 R 24.    TH 0.000, 3.4615 LY  224.05
GENERATE 104 JOINTS CYL ID 147, 155 R 24.    TH 0.000, 3.4615 LY  229.06
GENERATE 104 JOINTS CYL ID 148, 155 R 18.    TH 0.000, 3.4615 LY  218.75
GENERATE 104 JOINTS CYL ID 149, 155 R 18.    TH 0.000, 3.4615 LY  223.75
```

GENERATE 104 JOINTS CYL ID 150, 155 R 18. TH 0.000, 3.4615 LY 224.25
GENERATE 104 JOINTS CYL ID 151, 155 R 18. TH 0.000, 3.4615 LY 229.25
GENERATE 104 JOINTS CYL ID 152, 155 R 12. TH 0.000, 3.4615 LY 219.00
GENERATE 104 JOINTS CYL ID 153, 155 R 12. TH 0.000, 3.4615 LY 224.00
GENERATE 104 JOINTS CYL ID 154, 155 R 12. TH 0.000, 3.4615 LY 224.50
GENERATE 104 JOINTS CYL ID 155, 155 R 12. TH 0.000, 3.4615 LY 229.50

$ ECHO CONSOLE 'JOINT COORDIANTES FINISHED......'

$ MODIFY DOME GEOMETRY TO PUT IN MANHOLES

DELETIONS

JOINTS -
1618 1619 1620 1621 1622 1623 1624 1625 1626 1627 1628 1629 -
1773 1774 1775 1776 1777 1778 1779 1780 1781 1782 1783 1784 -
1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 -
6268 6269 6270 6271 6272 6273 6274 6275 6276 6277 6278 6279 -
6423 6424 6425 6426 6427 6428 6429 6430 6431 6432 6433 6434 -
6578 6579 6580 6581 6582 6583 6584 6585 6586 6587 6588 6589 -
7966 7967 7968 7969 7970 7971 7972 7973 7974 7975 7976 -
8121 8122 8123 8124 8125 8126 8127 8128 8129 8130 8131 -
8276 8277 8278 8279 8280 8281 8282 8283 8284 8285 8286 -
8586 8587 8588 8589 8590 8591 8592 8593 8594 8595 8596 -
8741 8742 8743 8744 8745 8746 8747 8748 8749 8750 8751 -
8896 8897 8898 8899 8900 8901 8902 8903 8904 8905 8906 -
9678 9679 9680 9681 9682 9683 9684 9685 9686 9687 9688 9689 -
9833 9834 9835 9836 9837 9838 9839 9840 9841 9842 9843 9844 -
9988 9989 9990 9991 9992 9993 9994 9995 9996 9997 9998 9999 -
14328 14329 14330 14331 14332 14333 14334 14335 14336 14337 14338 14339 -
14483 14484 14485 14486 14487 14488 14489 14490 14491 14492 14493 14494 -
14638 14639 14640 14641 14642 14643 14644 14645 14646 14647 14648 14649

ADDITION

JOINT COORDINATES CARTESIAN

1618	148.74	169.839	199.23
1619	148.74	174.454	199.23
1620	148.74	174.915	199.23
1621	148.74	179.530	199.23
1622	140.69	174.356	194.81
1623	140.69	179.005	194.81
1624	140.69	179.470	194.81
1625	140.69	184.120	194.81
1626	138.13	178.662	185.99
1627	138.13	183.346	185.99
1628	138.13	183.814	185.99
1629	138.13	188.498	185.99
1773	157.56	169.839	196.67
1774	157.56	174.454	196.67
1775	157.56	174.915	196.67
1776	157.56	179.530	196.67
1777	150.06	174.356	187.3
1778	150.06	179.005	187.3
1779	150.06	179.470	187.3
1780	150.06	184.120	187.3
1781	142.56	178.662	177.94
1782	142.56	183.346	177.94
1783	142.56	183.814	177.94
1784	142.56	188.498	177.94
1928	161.99	169.839	188.62
1929	161.99	174.454	188.62
1930	161.99	174.915	188.62
1931	161.99	179.530	188.62
1932	159.42	174.356	179.8
1933	159.42	179.005	179.8
1934	159.42	179.470	179.8
1935	159.42	184.120	179.8
1936	151.38	178.662	175.38
1937	151.38	183.346	175.38
1938	151.38	183.814	175.38
1939	151.38	188.498	175.38
6268	161.99	169.839	-188.62
6269	161.99	174.454	-188.62
6270	161.99	174.915	-188.62
6271	161.99	179.530	-188.62
6272	159.42	174.356	-179.80
6273	159.42	179.005	-179.80
6274	159.42	179.470	-179.80
6275	159.42	184.120	-179.80
6276	151.38	178.662	-175.38
6277	151.38	183.346	-175.38
6278	151.38	183.814	-175.38
6279	151.38	188.498	-175.38

6423	157.56	169.839	-196.67
6424	157.56	174.454	-196.67
6425	157.56	174.915	-196.67
6426	157.56	179.530	-196.67
6427	150.06	174.356	-187.3
6428	150.06	179.005	-187.3
6429	150.06	179.470	-187.3
6430	150.06	184.120	-187.3
6431	142.56	178.662	-177.94
6432	142.56	183.346	-177.94
6433	142.56	183.814	-177.94
6434	142.56	188.498	-177.94
6578	148.74	169.839	-199.23
6579	148.74	174.454	-199.23
6580	148.74	174.915	-199.23
6581	148.74	179.530	-199.23
6582	140.69	174.356	-194.81
6583	140.69	179.005	-194.81
6584	140.69	179.470	-194.81
6585	140.69	184.120	-194.81
6586	138.13	178.662	-185.99
6587	138.13	183.346	-185.99
6588	138.13	183.814	-185.99
6589	138.13	188.498	-185.99
7966	10.61	159.00	-274.61
7967	10.61	162.82	-274.61
7968	10.61	168.34	-274.61
7969	15.00	161.57	-264.00
7970	15.00	167.06	-264.00
7971	15.00	167.61	-264.00
7972	15.00	173.09	-264.00
7973	10.61	166.38	-253.39
7974	10.61	171.83	-253.39
7975	10.61	172.37	-253.39
7976	10.61	177.81	-253.39
8121	.000	154.71	-279.00
8122	.000	160.82	-279.00
8123	.000	166.36	-279.00
8124	.000	161.77	-264.00
8125	.000	167.26	-264.00
8126	.000	167.80	-264.00
8127	.000	173.28	-264.00

8128	.000	168.36	-249.00
8129	.000	173.79	-249.00
8130	.000	174.33	-249.00
8131	.000	179.75	-249.00
8276	-10.61	156.73	-274.61
8277	-10.61	162.82	-274.61
8278	-10.61	168.34	-274.61
8279	-15.00	161.57	-264.00
8280	-15.00	167.06	-264.00
8281	-15.00	167.61	-264.00
8282	-15.00	173.09	-264.00
8283	-10.61	166.38	-253.39
8284	-10.61	171.83	-253.39
8285	-10.61	172.37	-253.39
8286	-10.61	177.81	-253.39
8586	-56.21	156.730	-262.32
8587	-56.21	162.82	-262.32
8588	-56.21	168.34	-262.32
8589	-53.54	165.114	-258.58
8590	-53.54	169.692	-258.58
8591	-53.54	170.150	-258.58
8592	-53.54	174.727	-258.58
8593	-54.3	169.839	-254.05
8594	-54.3	174.454	-254.05
8595	-54.3	174.915	-254.05
8596	-54.3	179.530	-254.05
8741	-60.74	154.71	-263.08
8742	-60.74	160.82	-263.08
8743	-60.74	166.36	-263.08
8744	-59.39	165.114	-257.23
8745	-59.39	169.692	-257.23
8746	-59.39	170.150	-257.23
8747	-59.39	174.727	-257.23
8748	-58.04	169.839	-251.39
8749	-58.04	174.454	-251.39
8750	-58.04	174.915	-251.39
8751	-58.04	179.530	-251.39
8896	-64.48	156.73	-260.41
8897	-64.48	162.82	-260.41
8898	-64.48	168.34	-260.41
8899	-65.23	165.114	-255.88
8900	-65.23	169.692	-255.88

8901	-65.23	170.150	-255.88
8902	-65.23	174.727	-255.88
8903	-62.57	169.839	-252.15
8904	-62.57	174.454	-252.15
8905	-62.57	174.915	-252.15
8906	-62.57	179.530	-252.15
9678	-148.74	169.839	-199.23
9679	-148.74	174.454	-199.23
9680	-148.74	174.915	-199.23
9681	-148.74	179.530	-199.23
9682	-140.69	174.356	-194.81
9683	-140.69	179.005	-194.81
9684	-140.69	179.470	-194.81
9685	-140.69	184.120	-194.81
9686	-138.13	178.662	-185.99
9687	-138.13	183.346	-185.99
9688	-138.13	183.814	-185.99
9689	-138.13	188.498	-185.99
9833	-157.56	169.839	-196.67
9834	-157.56	174.454	-196.67
9835	-157.56	174.915	-196.67
9836	-157.56	179.530	-196.67
9837	-150.06	174.356	-187.30
9838	-150.06	179.005	-187.30
9839	-150.06	179.470	-187.30
9840	-150.06	184.120	-187.30
9841	-142.56	178.662	-177.94
9842	-142.56	183.346	-177.94
9843	-142.56	183.814	-177.94
9844	-142.56	188.498	-177.94
9988	-161.99	169.839	-188.62
9989	-161.99	174.454	-188.62
9990	-161.99	174.915	-188.62
9991	-161.99	179.530	-188.62
9992	-159.42	174.356	-179.8
9993	-159.42	179.005	-179.8
9994	-159.42	179.470	-179.8
9995	-159.42	184.120	-179.8
9996	-151.38	178.662	-175.38
9997	-151.38	183.346	-175.38
9998	-151.38	183.814	-175.38
9999	-151.38	188.498	-175.38

14328	-161.99	169.839	188.62
14329	-161.99	174.454	188.62
14330	-161.99	174.915	188.62
14331	-161.99	179.530	188.62
14332	-159.42	174.356	179.8
14333	-159.42	179.005	179.8
14334	-159.42	179.470	179.8
14335	-159.42	184.120	179.8
14336	-151.38	178.662	175.38
14337	-151.38	183.346	175.38
14338	-151.38	183.814	175.38
14339	-151.38	188.498	175.38
14483	-157.56	169.839	196.67
14484	-157.56	174.454	196.67
14485	-157.56	174.915	196.67
14486	-157.56	179.530	196.67
14487	-150.06	174.356	187.3
14488	-150.06	179.005	187.3
14489	-150.06	179.470	187.3
14490	-150.06	184.120	187.3
14491	-142.56	178.662	177.94
14492	-142.56	183.346	177.94
14493	-142.56	183.814	177.94
14494	-142.56	188.498	177.94
14638	-148.74	169.839	199.23
14639	-148.74	174.454	199.23
14640	-148.74	174.915	199.23
14641	-148.74	179.530	199.23
14642	-140.69	174.356	194.81
14643	-140.69	179.005	194.81
14644	-140.69	179.470	194.81
14645	-140.69	184.120	194.81
14646	-138.13	178.662	185.99
14647	-138.13	183.346	185.99
14648	-138.13	183.814	185.99
14649	-138.13	188.498	185.99

$ END OF DOME MODIFICATION

$ ADD SOIL SPRINGS COORDINATES
GENERATE 104 JOINTS CYL ID 16121, 17 R 316.00 TH 0.000, 3.4615 LY -3.000
GENERATE 104 JOINTS CYL ID 16122, 17 R 316.00 TH 0.000, 3.4615 LY 6.000
GENERATE 104 JOINTS CYL ID 16123, 17 R 316.00 TH 0.000, 3.4615 LY 18.500

```
GENERATE 104 JOINTS CYL ID 16124, 17 R 316.00 TH 0.000, 3.4615 LY 31.000
GENERATE 104 JOINTS CYL ID 16125, 17 R 316.00 TH 0.000, 3.4615 LY 43.500
GENERATE 104 JOINTS CYL ID 16126, 17 R 316.00 TH 0.000, 3.4615 LY 56.000
GENERATE 104 JOINTS CYL ID 16127, 17 R 316.00 TH 0.000, 3.4615 LY 65.000
GENERATE 104 JOINTS CYL ID 16128, 17 R 316.00 TH 0.000, 3.4615 LY 74.000
GENERATE 104 JOINTS CYL ID 16129, 17 R 316.00 TH 0.000, 3.4615 LY 86.000
GENERATE 104 JOINTS CYL ID 16130, 17 R 316.00 TH 0.000, 3.4615 LY 98.000
GENERATE 104 JOINTS CYL ID 16131, 17 R 316.00 TH 0.000, 3.4615 LY 110.000
GENERATE 104 JOINTS CYL ID 16132, 17 R 316.00 TH 0.000, 3.4615 LY 122.000
GENERATE 104 JOINTS CYL ID 16133, 17 R 316.00 TH 0.000, 3.4615 LY 132.000
GENERATE 104 JOINTS CYL ID 16134, 17 R 319.00 TH 0.000, 3.4615 LY 135.000
GENERATE 104 JOINTS CYL ID 16135, 17 R 319.00 TH 0.000, 3.4615 LY 147.000
GENERATE 104 JOINTS CYL ID 16136, 17 R 319.00 TH 0.000, 3.4615 LY 159.000
GENERATE 104 JOINTS CYL ID 16137, 17 R 319.00 TH 0.000, 3.4615 LY 166.000
$ END OF SOIL SPRINGS

STATUS SUPPORT 16121 TO 17888

TYPE TRIDIMENSIONAL
ELEMENT INCIDENCE

GEN 103 ELE ID 1 INC 81 F 11 INC 155 T 1 T 2 T 12 T 166 T 156 T 157 T 167
GEN 103 ELE ID 2 INC 81 F 12 INC 155 T 2 T 3 T 13 T 167 T 157 T 158 T 168
GEN 103 ELE ID 3 INC 81 F 13 INC 155 T 3 T 4 T 14 T 168 T 158 T 159 T 169
GEN 103 ELE ID 4 INC 81 F 14 INC 155 T 4 T 5 T 15 T 169 T 159 T 160 T 170
GEN 103 ELE ID 5 INC 81 F 15 INC 155 T 5 T 6 T 16 T 170 T 160 T 161 T 171
GEN 103 ELE ID 6 INC 81 F 16 INC 155 T 6 T 7 T 17 T 171 T 161 T 162 T 172
GEN 103 ELE ID 7 INC 81 F 17 INC 155 T 7 T 8 T 18 T 172 T 162 T 163 T 173
GEN 103 ELE ID 8 INC 81 F 18 INC 155 T 8 T 9 T 19 T 173 T 163 T 164 T 174
GEN 103 ELE ID 9 INC 81 F 9 INC 155 T 10 T 20 T 19 T 164 T 165 T 175 T 174
GEN 103 ELE ID 10 INC 81 F 19 INC 155 T 20 T 22 T 21 T 174 T 175 T 177 T 176
GEN 103 ELE ID 11 INC 81 F 21 INC 155 T 22 T 24 T 23 T 176 T 177 T 179 T 178
GEN 103 ELE ID 12 INC 81 F 23 INC 155 T 24 T 26 T 25 T 178 T 179 T 181 T 180
GEN 103 ELE ID 13 INC 81 F 25 INC 155 T 26 T 28 T 27 T 180 T 181 T 183 T 182
GEN 103 ELE ID 14 INC 81 F 27 INC 155 T 28 T 30 T 29 T 182 T 183 T 185 T 184
GEN 103 ELE ID 15 INC 81 F 29 INC 155 T 30 T 32 T 31 T 184 T 185 T 187 T 186
GEN 103 ELE ID 16 INC 81 F 31 INC 155 T 32 T 34 T 33 T 186 T 187 T 189 T 188
GEN 103 ELE ID 17 INC 81 F 33 INC 155 T 34 T 36 T 35 T 188 T 189 T 191 T 190
GEN 103 ELE ID 18 INC 81 F 35 INC 155 T 36 T 38 T 37 T 190 T 191 T 193 T 192
GEN 103 ELE ID 19 INC 81 F 37 INC 155 T 38 T 40 T 39 T 192 T 193 T 195 T 194
GEN 103 ELE ID 20 INC 81 F 39 INC 155 T 40 T 41 T 46 T 194 T 195 T 196 T 201
GEN 103 ELE ID 21 INC 81 F 41 INC 155 T 42 T 47 T 46 T 196 T 197 T 202 T 201
GEN 103 ELE ID 22 INC 81 F 47 INC 155 T 42 T 43 T 48 T 202 T 197 T 198 T 203
GEN 103 ELE ID 23 INC 81 F 48 INC 155 T 43 T 44 T 49 T 203 T 198 T 199 T 204
GEN 103 ELE ID 24 INC 81 F 49 INC 155 T 44 T 45 T 50 T 204 T 199 T 200 T 205
GEN 103 ELE ID 25 INC 81 F 46 INC 155 T 47 T 52 T 51 T 201 T 202 T 207 T 206
GEN 103 ELE ID 26 INC 81 F 52 INC 155 T 47 T 48 T 53 T 207 T 202 T 203 T 208
GEN 103 ELE ID 27 INC 81 F 53 INC 155 T 48 T 49 T 54 T 208 T 203 T 204 T 209
GEN 103 ELE ID 28 INC 81 F 54 INC 155 T 49 T 50 T 55 T 209 T 204 T 205 T 210
GEN 103 ELE ID 29 INC 81 F 51 INC 155 T 52 T 57 T 56 T 206 T 207 T 212 T 211
GEN 103 ELE ID 30 INC 81 F 57 INC 155 T 52 T 53 T 58 T 212 T 207 T 208 T 213
GEN 103 ELE ID 31 INC 81 F 58 INC 155 T 53 T 54 T 59 T 213 T 208 T 209 T 214
GEN 103 ELE ID 32 INC 81 F 59 INC 155 T 54 T 55 T 60 T 214 T 209 T 210 T 215
GEN 103 ELE ID 33 INC 81 F 56 INC 155 T 57 T 58 T 61 T 211 T 212 T 213 T 216
GEN 103 ELE ID 34 INC 81 F 61 INC 155 T 58 T 59 T 62 T 216 T 213 T 214 T 217
GEN 103 ELE ID 35 INC 81 F 62 INC 155 T 59 T 60 T 63 T 217 T 214 T 215 T 218
GEN 103 ELE ID 36 INC 81 F 61 INC 155 T 62 T 65 T 64 T 216 T 217 T 220 T 219
GEN 103 ELE ID 37 INC 81 F 64 INC 155 T 65 T 69 T 68 T 219 T 220 T 224 T 223
GEN 103 ELE ID 38 INC 81 F 68 INC 155 T 69 T 73 T 72 T 223 T 224 T 228 T 227
GEN 103 ELE ID 39 INC 81 F 76 INC 155 T 72 T 73 T 77 T 231 T 227 T 228 T 232
GEN 103 ELE ID 40 INC 81 F 80 INC 155 T 76 T 77 T 81 T 235 T 231 T 232 T 236
GEN 103 ELE ID 41 INC 81 F 84 INC 155 T 80 T 81 T 85 T 239 T 235 T 236 T 240
GEN 103 ELE ID 42 INC 81 F 88 INC 155 T 84 T 85 T 89 T 243 T 239 T 240 T 244
GEN 103 ELE ID 43 INC 81 F 92 INC 155 T 88 T 89 T 93 T 247 T 243 T 244 T 248
GEN 103 ELE ID 44 INC 81 F 96 INC 155 T 92 T 93 T 97 T 251 T 247 T 248 T 252
GEN 103 ELE ID 45 INC 81 F 100 INC 155 T 96 T 97 T 101 T 255 T 251 T 252 T 256
GEN 103 ELE ID 46 INC 81 F 104 INC 155 T 100 T 101 T 105 T 259 T 255 T 256 T 260
GEN 103 ELE ID 47 INC 81 F 108 INC 155 T 104 T 105 T 109 T 263 T 259 T 260 T 264
GEN 103 ELE ID 48 INC 81 F 112 INC 155 T 108 T 109 T 113 T 267 T 263 T 264 T 268
GEN 103 ELE ID 49 INC 81 F 116 INC 155 T 112 T 113 T 117 T 271 T 267 T 268 T 272
GEN 103 ELE ID 50 INC 81 F 120 INC 155 T 116 T 117 T 121 T 275 T 271 T 272 T 276
GEN 103 ELE ID 51 INC 81 F 124 INC 155 T 120 T 121 T 125 T 279 T 275 T 276 T 280
GEN 103 ELE ID 52 INC 81 F 128 INC 155 T 124 T 125 T 129 T 283 T 279 T 280 T 284
GEN 103 ELE ID 53 INC 81 F 132 INC 155 T 128 T 129 T 133 T 287 T 283 T 284 T 288
GEN 103 ELE ID 54 INC 81 F 136 INC 155 T 132 T 133 T 137 T 291 T 287 T 288 T 292
GEN 103 ELE ID 55 INC 81 F 140 INC 155 T 136 T 137 T 141 T 295 T 291 T 292 T 296
GEN 103 ELE ID 56 INC 81 F 144 INC 155 T 140 T 141 T 145 T 299 T 295 T 296 T 300
GEN 103 ELE ID 57 INC 81 F 148 INC 155 T 144 T 145 T 149 T 303 T 299 T 300 T 304
GEN 103 ELE ID 58 INC 81 F 152 INC 155 T 148 T 149 T 153 T 307 T 303 T 304 T 308
GEN 103 ELE ID 59 INC 81 F 62 INC 155 T 63 T 67 T 66 T 217 T 218 T 222 T 221
GEN 103 ELE ID 60 INC 81 F 66 INC 155 T 67 T 71 T 70 T 221 T 222 T 226 T 225
GEN 103 ELE ID 61 INC 81 F 70 INC 155 T 71 T 75 T 74 T 225 T 226 T 230 T 229
GEN 103 ELE ID 62 INC 81 F 78 INC 155 T 74 T 75 T 79 T 233 T 229 T 230 T 234
GEN 103 ELE ID 63 INC 81 F 82 INC 155 T 78 T 79 T 83 T 237 T 233 T 234 T 238
```

```
GEN 103 ELE ID 64 INC 81 F 86 INC 155 T 82 T 83 T 87 T 241 T 237 T 238 T 242
GEN 103 ELE ID 65 INC 81 F 90 INC 155 T 86 T 87 T 91 T 245 T 241 T 242 T 246
GEN 103 ELE ID 66 INC 81 F 94 INC 155 T 90 T 91 T 95 T 249 T 245 T 246 T 250
GEN 103 ELE ID 67 INC 81 F 98 INC 155 T 94 T 95 T 99 T 253 T 249 T 250 T 254
GEN 103 ELE ID 68 INC 81 F 102 INC 155 T 98 T 99 T 103 T 257 T 253 T 254 T 258
GEN 103 ELE ID 69 INC 81 F 106 INC 155 T 102 T 103 T 107 T 261 T 257 T 258 T 262
GEN 103 ELE ID 70 INC 81 F 110 INC 155 T 106 T 107 T 111 T 265 T 261 T 262 T 266
GEN 103 ELE ID 71 INC 81 F 114 INC 155 T 110 T 111 T 115 T 269 T 265 T 266 T 270
GEN 103 ELE ID 72 INC 81 F 118 INC 155 T 114 T 115 T 119 T 273 T 269 T 270 T 274
GEN 103 ELE ID 73 INC 81 F 122 INC 155 T 118 T 119 T 123 T 277 T 273 T 274 T 278
GEN 103 ELE ID 74 INC 81 F 126 INC 155 T 122 T 123 T 127 T 281 T 277 T 278 T 282
GEN 103 ELE ID 75 INC 81 F 130 INC 155 T 126 T 127 T 131 T 285 T 281 T 282 T 286
GEN 103 ELE ID 76 INC 81 F 134 INC 155 T 130 T 131 T 135 T 289 T 285 T 286 T 290
GEN 103 ELE ID 77 INC 81 F 138 INC 155 T 134 T 135 T 139 T 293 T 289 T 290 T 294
GEN 103 ELE ID 78 INC 81 F 142 INC 155 T 138 T 139 T 143 T 297 T 293 T 294 T 298
GEN 103 ELE ID 79 INC 81 F 146 INC 155 T 142 T 143 T 147 T 301 T 297 T 298 T 302
GEN 103 ELE ID 80 INC 81 F 150 INC 155 T 146 T 147 T 151 T 305 T 301 T 302 T 306
GEN 103 ELE ID 81 INC 81 F 154 INC 155 T 150 T 151 T 155 T 309 T 305 T 306 T 310

$ CONNECT ELEMENTS BEWTEEN FIRST AND LAST SLICES PLAN
ELEMENT INCIDENCE
8344 15976 15966 15967 15977 11 1 2 12
8345 15977 15967 15968 15978 12 2 3 13
8346 15978 15968 15969 15979 13 3 4 14
8347 15979 15969 15970 15980 14 4 5 15
8348 15980 15970 15971 15981 15 5 6 16
8349 15981 15971 15972 15982 16 6 7 17
8350 15982 15972 15973 15983 17 7 8 18
8351 15983 15973 15974 15984 18 8 9 19
8352 15974 15975 15985 15984 9 10 20 19
8353 15984 15985 15987 15986 19 20 22 21
8354 15986 15987 15989 15988 21 22 24 23
8355 15988 15989 15991 15990 23 24 26 25
8356 15990 15991 15993 15992 25 26 28 27
8357 15992 15993 15995 15994 27 28 30 29
8358 15994 15995 15997 15996 29 30 32 31
8359 15996 15997 15999 15998 31 32 34 33
8360 15998 15999 16001 16000 33 34 36 35
8361 16000 16001 16003 16002 35 36 38 37
8362 16002 16003 16005 16004 37 38 40 39
8363 16004 16005 16006 16011 39 40 41 46
8364 16006 16007 16012 16011 41 42 47 46
8365 16012 16007 16008 16013 47 42 43 48
8366 16013 16008 16009 16014 48 43 44 49
8367 16014 16009 16010 16015 49 44 45 50
8368 16011 16012 16017 16016 46 47 52 51
8369 16017 16012 16013 16018 52 47 48 53
8370 16018 16013 16014 16019 53 48 49 54
8371 16019 16014 16015 16020 54 49 50 55
8372 16016 16017 16022 16021 51 52 57 56
8373 16022 16017 16018 16023 57 52 53 58
8374 16023 16018 16019 16024 58 53 54 59
8375 16024 16019 16020 16025 59 54 55 60
8376 16021 16022 16023 16026 56 57 58 61
8377 16026 16023 16024 16027 61 58 59 62
8378 16027 16024 16025 16028 62 59 60 63
8379 16026 16027 16030 16029 61 62 65 64
8380 16029 16030 16034 16033 64 65 69 68
8381 16033 16034 16038 16037 68 69 73 72
8382 16041 16037 16038 16042 76 72 73 77
8383 16045 16041 16042 16046 80 76 77 81
8384 16049 16045 16046 16050 84 80 81 85
8385 16053 16049 16050 16054 88 84 85 89
8386 16057 16053 16054 16058 92 88 89 93
8387 16061 16057 16058 16062 96 92 93 97
8388 16065 16061 16062 16066 100 96 97 101
8389 16069 16065 16066 16070 104 100 101 105
8390 16073 16069 16070 16074 108 104 105 109
8391 16077 16073 16074 16078 112 108 109 113
8392 16081 16077 16078 16082 116 112 113 117
8393 16085 16081 16082 16086 120 116 117 121
8394 16089 16085 16086 16090 124 120 121 125
8395 16093 16089 16090 16094 128 124 125 129
8396 16097 16093 16094 16098 132 128 129 133
8397 16101 16097 16098 16102 136 132 133 137
8398 16105 16101 16102 16106 140 136 137 141
8399 16109 16105 16106 16110 144 140 141 145
8400 16113 16109 16110 16114 148 144 145 149
8401 16117 16113 16114 16118 152 148 149 153
8402 16027 16028 16032 16031 62 63 67 66
8403 16031 16032 16036 16035 66 67 71 70
8404 16035 16036 16040 16039 70 71 75 74
8405 16043 16039 16040 16044 78 74 75 79
8406 16047 16043 16044 16048 82 78 79 83
```

```
8407  16051  16047  16048  16052  86   82   83   87
8408  16055  16051  16052  16056  90   86   87   91
8409  16059  16055  16056  16060  94   90   91   95
8410  16063  16059  16060  16064  98   94   95   99
8411  16067  16063  16064  16068  102  98   99   103
8412  16071  16067  16068  16072  106  102  103  107
8413  16075  16071  16072  16076  110  106  107  111
8414  16079  16075  16076  16080  114  110  111  115
8415  16083  16079  16080  16084  118  114  115  119
8416  16087  16083  16084  16088  122  118  119  123
8417  16091  16087  16088  16092  126  122  123  127
8418  16095  16091  16092  16096  130  126  127  131
8419  16099  16095  16096  16100  134  130  131  135
8420  16103  16099  16100  16104  138  134  135  139
8421  16107  16103  16104  16108  142  138  139  143
8422  16111  16107  16108  16112  146  142  143  147
8423  16115  16111  16112  16116  150  146  147  151
8424  16119  16115  16116  16120  154  150  151  155

TYPE SPACE TRUSS
MEMBER INCIDENCE
GEN 104 MEM ID  10001 INC 23 F 65  INC 155 T 66
GEN 104 MEM ID  10002 INC 23 F 69  INC 155 T 70
GEN 104 MEM ID  10003 INC 23 F 73  INC 155 T 74
GEN 104 MEM ID  10004 INC 23 F 77  INC 155 T 78
GEN 104 MEM ID  10005 INC 23 F 81  INC 155 T 82
GEN 104 MEM ID  10006 INC 23 F 85  INC 155 T 86
GEN 104 MEM ID  10007 INC 23 F 89  INC 155 T 90
GEN 104 MEM ID  10008 INC 23 F 93  INC 155 T 94
GEN 104 MEM ID  10009 INC 23 F 97  INC 155 T 98
GEN 104 MEM ID  10010 INC 23 F 101 INC 155 T 102
GEN 104 MEM ID  10011 INC 23 F 105 INC 155 T 106
GEN 104 MEM ID  10012 INC 23 F 109 INC 155 T 110
GEN 104 MEM ID  10013 INC 23 F 113 INC 155 T 114
GEN 104 MEM ID  10014 INC 23 F 117 INC 155 T 118
GEN 104 MEM ID  10015 INC 23 F 121 INC 155 T 122
GEN 104 MEM ID  10016 INC 23 F 125 INC 155 T 126
GEN 104 MEM ID  10017 INC 23 F 129 INC 155 T 130
GEN 104 MEM ID  10018 INC 23 F 133 INC 155 T 134
GEN 104 MEM ID  10019 INC 23 F 137 INC 155 T 138
GEN 104 MEM ID  10020 INC 23 F 141 INC 155 T 142
GEN 104 MEM ID  10021 INC 23 F 145 INC 155 T 146
GEN 104 MEM ID  10022 INC 23 F 149 INC 155 T 150
GEN 104 MEM ID  10023 INC 23 F 153 INC 155 T 154

$ ADD SOIL SPRINGS
TYPE SPACE TRUSS
MEMBER INCIDENCE
GEN 104 MEM ID  20001 INC 17 F 10  INC 155 T 16121 INC 17
GEN 104 MEM ID  20002 INC 17 F 20  INC 155 T 16122 INC 17
GEN 104 MEM ID  20003 INC 17 F 22  INC 155 T 16123 INC 17
GEN 104 MEM ID  20004 INC 17 F 24  INC 155 T 16124 INC 17
GEN 104 MEM ID  20005 INC 17 F 26  INC 155 T 16125 INC 17
GEN 104 MEM ID  20006 INC 17 F 28  INC 155 T 16126 INC 17
GEN 104 MEM ID  20007 INC 17 F 30  INC 155 T 16127 INC 17
GEN 104 MEM ID  20008 INC 17 F 32  INC 155 T 16128 INC 17
GEN 104 MEM ID  20009 INC 17 F 34  INC 155 T 16129 INC 17
GEN 104 MEM ID  20010 INC 17 F 36  INC 155 T 16130 INC 17
GEN 104 MEM ID  20011 INC 17 F 38  INC 155 T 16131 INC 17
GEN 104 MEM ID  20012 INC 17 F 40  INC 155 T 16132 INC 17
GEN 104 MEM ID  20013 INC 17 F 41  INC 155 T 16133 INC 17
GEN 104 MEM ID  20014 INC 17 F 42  INC 155 T 16134 INC 17
GEN 104 MEM ID  20015 INC 17 F 43  INC 155 T 16135 INC 17
GEN 104 MEM ID  20016 INC 17 F 44  INC 155 T 16136 INC 17
GEN 104 MEM ID  20017 INC 17 F 45  INC 155 T 16137 INC 17
$ END OF SOIL SPRINGS

MEMBER PROPERTY

 10001 TO 12392  AX 10

 20001  TO  21752 BY 17  AX  18.90
 20002  TO  21753 BY 17  AX  45.15
 20003  TO  21754 BY 17  AX  52.50
 20004  TO  21755 BY 17  AX  52.50
 20005  TO  21756 BY 17  AX  52.50
 20006  TO  21757 BY 17  AX  45.15
 20007  TO  21758 BY 17  AX  37.80
 20008  TO  21759 BY 17  AX  44.10
 20009  TO  21760 BY 17  AX  50.40
 20010  TO  21761 BY 17  AX  50.40
 20011  TO  21762 BY 17  AX  50.40
 20012  TO  21763 BY 17  AX  46.20
 20013  TO  21764 BY 17  AX  27.30
```

```
   20014  TO  21765 BY 17  AX   31.50
   20015  TO  21766 BY 17  AX   50.40
   20016  TO  21767 BY 17  AX   39.90
   20017  TO  21768 BY 17  AX   14.70

$ END OF SOIL SPRING AREA SPECIFICATION
$
 OUTPUT DECIMAL 3
$
 OUTPUT ORDERED

INACTIVE JOINTS -
1777 TO 1780 6427 TO 6430 8124 TO 8127 8744 TO 8747 9837 TO 9840 14487 TO 14490

$ REMOVE HOLES

INACTIVE ELEMENTS -
848 849 871 872 929 930 952 953 3278 3279 3301 3302 3359 3360 3382 3383 4167   -
4168 4190 4191 4248 4249 4271 4272 4491 4492 4514 4515 4572 4573 4595 4596 5060 -
5061 5083 5084 5141 5142 5164 5165 7490 7491 7513 7514 7571 7572 7594 7595

$ REMOVE TRUSSES
INACTIVE MEMBERS 10256 10946 11452 12142 11197 11289
UNITS KIPS INCH
ELEMENT PROPERTY
  1 TO 8424 TYPE 'IPSL' WITH INTEGRATION ORDER 4     $ FOR CONSTANT
DISPLACEMENTS
$
$ GUNITE PROPERTY
CONSTANT E 4030.    MEMBER 1 TO 8424
CONSTANT G 1722.    MEMBER 1 TO 8424
CONSTANT DENSITY 0.0000868 1 TO 8424
$
$ RIDGID LINKS BETWEEN DOME LAYERS
CONSTANT E 3000.    MEMBER 10001 TO 12392
CONSTANT DENSITY 0.0000001 10001 TO 12392

$ SOIL SPRINGS
CONSTANT E 1.000    MEMBER 20001 TO 21768
CONSTANT DENSITY 0.0000001 20001 TO 21768
```

```
$ PLOT DEVICE PLOTTER NEUTRAL
$ PLOT PLANE XZ PROJECTION
$
$MEMBER SELF WEIGHT LOAD CASE.  INCLUDES ONLY GUNITE TANK
$
$ BEGIN DEAD LOAD ON DOME
LOADING 'DEADLOAD' 'VERTICAL GRAVITY LOAD'
UNITS INCH LBS
ELEMENT LOADS
   1 THROUGH 8424 BODY FORCES GLOBAL UNIFORM BY -0.0868
$
LOADING 'EQ-TANK' 'HORIZONTAL ACCELERATION OF TANK MASS'
UNITS INCH LBS
ELEMENT LOADS
$ 0.14 G TIME DENSITY OF 150 #/CU.FT.
   1 THROUGH 8424 BODY FORCES GLOBAL UNIFORM BX 0.0122

$
LOADING 'OVERDOME' 'WEIGHT OF OVERBEARING SOIL ON DOME'
UNITS INCH LBS
ELEMENT LOADS
$ FACE 4 = NODE 2, 3, 6, 7
$ FACE 5 = NODE 3, 7, 8, 4
   24 THROUGH 8367 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   28 THROUGH 8371 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   32 THROUGH 8375 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   35 THROUGH 8378 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   59 THROUGH 8402 BY 81 SURFACE FACE 4 GLOBAL UNIFORM PY -4.58
   60 THROUGH 8403 BY 81 SURFACE FACE 4 GLOBAL UNIFORM PY -4.58
   61 THROUGH 8404 BY 81 SURFACE FACE 4 GLOBAL UNIFORM PY -4.58
   62 THROUGH 8405 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   63 THROUGH 8406 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   64 THROUGH 8407 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   65 THROUGH 8408 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   66 THROUGH 8409 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   67 THROUGH 8410 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   68 THROUGH 8411 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   69 THROUGH 8412 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   70 THROUGH 8413 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   71 THROUGH 8414 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   72 THROUGH 8415 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   73 THROUGH 8416 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
```

```
   74 THROUGH 8417 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   75 THROUGH 8418 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   76 THROUGH 8419 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   77 THROUGH 8420 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   78 THROUGH 8421 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   79 THROUGH 8422 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   80 THROUGH 8423 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
   81 THROUGH 8424 BY 81 SURFACE FACE 5 GLOBAL UNIFORM PY -4.58
UNITS INCH LBS
LOADING 'SIDESOIL' 'STATIC SIDE SOIL PRESSURE'
ELEMENT LOADS
$ POSITIVE PRESSURE IN THE LOCAL OR PLANAR SYSTEM ON FACE 2, 3, 4 OF "IPSL"
$ ELEMENTS MEANS PRESSURE ACTING INTO THE ELEMENT, CONTRARY TO THE
GTSTRUDL
$ MANUAL INSTRUCTIONS ON PAGE 2.3.5-32.  THE ERROR STATEMENT FROM GIT IS
ON
$ FILE WITH KEN FRICKE OF MMES --- TONY CHUNG (SAIC) 7/19/94
    9 THROUGH 8352 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  5.239
   10 THROUGH 8353 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  5.032
   11 THROUGH 8354 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  4.754
   12 THROUGH 8355 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  4.475
   13 THROUGH 8356 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  4.196
   14 THROUGH 8357 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  3.956
   15 THROUGH 8358 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  3.756
   16 THROUGH 8359 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  3.522
   17 THROUGH 8360 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  3.254
   18 THROUGH 8361 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  2.986
   19 THROUGH 8362 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  2.719
   20 THROUGH 8363 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  2.474

$ negative angle on wall, no effect
$   21 THROUGH 8364 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  2.329

   22 THROUGH 8365 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  2.161
   23 THROUGH 8366 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  1.894
   24 THROUGH 8367 BY 81 SURFACE FACE 4 PLANAR UNIFORM PZ  1.682
UNITS INCH LBS
LOADING 'DYNASOIL' 'DYNAMIC E/W EARTHQUAKE SOIL PRESSURE'
ELEMENT LOADS
$
    9    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.002
   10    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.009
   11    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.019
   12    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.029
   13    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.039
   14    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.047
   15    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.054
   16    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.064
   17    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.064
   18    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.064
   19    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.064
   20    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.064
   21    SURFACE FACE 3 GLOBAL UNIFORM PX     -0.063
   22    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.048
   23    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.025
   24    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.007
   90    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.007
   91    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.028
   92    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.057
   93    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.086
   94    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.115
   95    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.140
   96    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.161
   97    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.192
   98    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.192
   99    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.192
  100    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.192
  101    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.192
  102    SURFACE FACE 3 GLOBAL UNIFORM PX     -0.188
  103    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.145
  104    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.075
  105    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.020
  171    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.012
  172    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.047
  173    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.095
  174    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.144
  175    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.192
  176    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.233
  177    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.268
  178    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.320
  179    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.320
  180    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.320
  181    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.320
  182    SURFACE FACE 4 GLOBAL UNIFORM PX     -0.320
```

183	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.312
184	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.241
185	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.125
186	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.034
252	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.016
253	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.066
254	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.133
255	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.200
256	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.268
257	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.326
258	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.374
259	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
260	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
261	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
262	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
263	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
264	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.436
265	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.336
266	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.175
267	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.047
333	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.021
334	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.084
335	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.170
336	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.256
337	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.342
338	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.416
339	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.479
340	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
341	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
342	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
343	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
344	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
345	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.557
346	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.430
347	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.224
348	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.060
414	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.025
415	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.102
416	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.207
417	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.312
418	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.416
419	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.506
420	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.581
421	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
422	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
423	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
424	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
425	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
426	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.677
427	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.522
428	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.272
429	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.073
495	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.029
496	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.120
497	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.243
498	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.365
499	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.488
500	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.594
501	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.682
502	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
503	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
504	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
505	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
506	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
507	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.794
508	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.613
509	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.319
510	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.086
576	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.034
577	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.137
578	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.278
579	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.418
580	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.558
581	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.679
582	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.780
583	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
584	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
585	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
586	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
587	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
588	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.908
589	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.701
590	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.365
591	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.098

657	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.038
658	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.154
659	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.311
660	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.469
661	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.626
662	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.762
663	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.875
664	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
665	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
666	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
667	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
668	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
669	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.019
670	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.787
671	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.409
672	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.111
738	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.042
739	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.170
740	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.344
741	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.519
742	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.692
743	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.842
744	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.968
745	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
746	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
747	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
748	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
749	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
750	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.127
751	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.869
752	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.452
753	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.122
819	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.046
820	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.186
821	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.376
822	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.566
823	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.756
824	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.919
825	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.056
826	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
827	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
828	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261

829	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
830	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
831	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.230
832	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.949
833	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.494
834	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.133
900	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.049
901	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.201
902	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.406
903	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.611
904	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.816
905	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.993
906	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.141
907	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
908	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
909	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
910	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
911	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
912	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.328
913	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.025
914	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.533
915	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.144
981	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.053
982	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.215
983	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.435
984	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.655
985	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.874
986	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.063
987	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.221
988	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
989	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
990	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
991	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
992	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
993	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.422
994	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.097
995	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
996	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.154
1062	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.056
1063	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.229
1064	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.462
1065	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.695

1066	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.928
1067	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.129
1068	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.298
1069	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
1070	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
1071	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
1072	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
1073	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
1074	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.511
1075	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.166
1076	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.607
1077	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.164
1143	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.059
1144	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.241
1145	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.487
1146	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.734
1147	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.979
1148	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.191
1149	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.369
1150	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
1151	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
1152	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
1153	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
1154	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
1155	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.594
1156	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.230
1157	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.640
1158	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.173
1224	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.062
1225	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.253
1226	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.511
1227	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.769
1228	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.027
1229	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.249
1230	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.435
1231	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
1232	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
1233	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
1234	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
1235	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
1236	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.671
1237	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.290
1238	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.671
1239	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.181
1305	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.065
1306	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.264
1307	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.532
1308	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.802
1309	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.071
1310	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.302
1311	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.496
1312	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
1313	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
1314	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
1315	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
1316	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
1317	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.743
1318	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.344
1319	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.700
1320	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.189
1386	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.067
1387	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.273
1388	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.552
1389	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.832
1390	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.111
1391	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.351
1392	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.552
1393	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
1394	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
1395	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
1396	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
1397	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
1398	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.807
1399	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.394
1400	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.726
1401	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.196
1467	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.069
1468	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.282
1469	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.570
1470	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.859
1471	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.146
1472	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.394
1473	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.602
1474	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912

1475	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
1476	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
1477	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
1478	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
1479	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.866
1480	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.439
1481	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.749
1482	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.202
1548	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.071
1549	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.290
1550	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.586
1551	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.882
1552	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.178
1553	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.433
1554	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.646
1555	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
1556	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
1557	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
1558	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
1559	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
1560	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.917
1561	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.479
1562	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.770
1563	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.208
1629	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.073
1630	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.297
1631	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.599
1632	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.903
1633	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.205
1634	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.466
1635	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.685
1636	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
1637	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
1638	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
1639	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
1640	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
1641	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.961
1642	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.513
1643	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.787
1644	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.213
1710	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.074
1711	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.302
1712	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.611
1713	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.920
1714	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.228
1715	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.494
1716	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.717
1717	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
1718	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
1719	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
1720	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
1721	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
1722	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.999
1723	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.542
1724	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.802
1725	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.217
1791	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.075
1792	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.307
1793	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.620
1794	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.934
1795	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.247
1796	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.516
1797	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.742
1798	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
1799	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
1800	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
1801	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
1802	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
1803	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.029
1804	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.565
1805	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
1806	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.220
1872	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.076
1873	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.310
1874	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.627
1875	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.944
1876	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.260
1877	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.533
1878	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.762
1879	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
1880	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
1881	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
1882	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
1883	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103

1884	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.051
1885	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.583
1886	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.824
1887	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.222
1953	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.077
1954	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.313
1955	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.631
1956	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.951
1957	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.270
1958	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.545
1959	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.775
1960	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
1961	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
1962	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
1963	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
1964	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
1965	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.066
1966	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.594
1967	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.830
1968	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.224
2034	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.077
2035	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.314
2036	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.634
2037	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.955
2038	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.274
2039	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.550
2040	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.781
2041	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2042	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2043	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2044	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2045	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2046	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.074
2047	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.600
2048	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.833
2049	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.225
2115	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.077
2116	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.314
2117	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.634
2118	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.955
2119	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.274
2120	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.550
2121	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.781
2122	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2123	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2124	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2125	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2126	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.126
2127	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.074
2128	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.600
2129	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.833
2130	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.225
2196	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.077
2197	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.313
2198	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.631
2199	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.951
2200	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.270
2201	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.545
2202	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.775
2203	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
2204	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
2205	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
2206	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
2207	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.118
2208	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.066
2209	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.594
2210	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.830
2211	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.224
2277	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.076
2278	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.310
2279	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.627
2280	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.944
2281	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.260
2282	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.533
2283	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.762
2284	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
2285	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
2286	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
2287	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
2288	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.103
2289	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.051
2290	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.583
2291	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.824
2292	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.222

2358	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.075
2359	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.307
2360	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.620
2361	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.934
2362	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.247
2363	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.516
2364	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.742
2365	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
2366	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
2367	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
2368	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
2369	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.080
2370	SURFACE FACE 3 GLOBAL UNIFORM PX	-2.029
2371	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.565
2372	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
2373	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.220
2439	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.074
2440	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.302
2441	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.611
2442	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.920
2443	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.228
2444	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.494
2445	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.717
2446	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
2447	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
2448	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
2449	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
2450	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.049
2451	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.999
2452	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.542
2453	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.802
2454	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.217
2520	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.073
2521	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.297
2522	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.599
2523	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.903
2524	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.205
2525	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.466
2526	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.685
2527	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
2528	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
2529	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
2530	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
2531	SURFACE FACE 4 GLOBAL UNIFORM PX	-2.011
2532	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.961
2533	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.513
2534	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.787
2535	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.213
2601	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.071
2602	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.290
2603	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.586
2604	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.882
2605	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.178
2606	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.433
2607	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.646
2608	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
2609	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
2610	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
2611	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
2612	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.965
2613	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.917
2614	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.479
2615	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.770
2616	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.208
2682	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.069
2683	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.282
2684	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.570
2685	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.859
2686	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.146
2687	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.394
2688	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.602
2689	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
2690	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
2691	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
2692	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
2693	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.912
2694	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.866
2695	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.439
2696	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.749
2697	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.202
2763	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.067
2764	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.273
2765	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.552
2766	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.832

2767	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.111
2768	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.351
2769	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.552
2770	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
2771	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
2772	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
2773	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
2774	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.853
2775	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.807
2776	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.394
2777	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.726
2778	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.196
2844	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.065
2845	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.264
2846	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.532
2847	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.802
2848	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.071
2849	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.302
2850	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.496
2851	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
2852	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
2853	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
2854	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
2855	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.786
2856	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.743
2857	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.344
2858	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.700
2859	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.189
2925	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.062
2926	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.253
2927	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.511
2928	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.769
2929	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.027
2930	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.249
2931	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.435
2932	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
2933	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
2934	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
2935	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
2936	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.713
2937	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.671
2938	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.290
2939	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.671
2940	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.181
3006	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.059
3007	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.241
3008	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.487
3009	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.734
3010	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.979
3011	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.191
3012	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.369
3013	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
3014	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
3015	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
3016	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
3017	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.634
3018	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.594
3019	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.230
3020	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.640
3021	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.173
3087	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.056
3088	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.229
3089	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.462
3090	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.695
3091	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.928
3092	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.129
3093	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.298
3094	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
3095	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
3096	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
3097	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
3098	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.549
3099	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.511
3100	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.166
3101	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.607
3102	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.164
3168	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.053
3169	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.215
3170	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.435
3171	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.655
3172	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.874
3173	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.063
3174	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.221
3175	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458

3176	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
3177	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
3178	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
3179	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.458
3180	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.422
3181	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.097
3182	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
3183	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.154
3249	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.049
3250	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.201
3251	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.406
3252	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.611
3253	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.816
3254	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.993
3255	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.141
3256	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
3257	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
3258	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
3259	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
3260	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.362
3261	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.328
3262	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.025
3263	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.533
3264	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.144
3330	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.046
3331	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.186
3332	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.376
3333	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.566
3334	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.756
3335	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.919
3336	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.056
3337	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
3338	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
3339	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
3340	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
3341	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.261
3342	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.230
3343	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.949
3344	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.494
3345	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.133
3411	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.042
3412	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.170
3413	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.344
3414	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.519
3415	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.692
3416	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.842
3417	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.968
3418	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
3419	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
3420	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
3421	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
3422	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.155
3423	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.127
3424	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.869
3425	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.452
3426	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.122
3492	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.038
3493	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.154
3494	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.311
3495	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.469
3496	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.626
3497	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.762
3498	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.875
3499	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
3500	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
3501	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
3502	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
3503	SURFACE FACE 4 GLOBAL UNIFORM PX	-1.045
3504	SURFACE FACE 3 GLOBAL UNIFORM PX	-1.019
3505	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.786
3506	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.409
3507	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.111
3573	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.034
3574	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.137
3575	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.278
3576	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.418
3577	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.558
3578	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.679
3579	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.780
3580	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
3581	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
3582	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
3583	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931
3584	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.931

3585	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.908
3586	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.701
3587	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.365
3588	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.098
3654	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.029
3655	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.120
3656	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.243
3657	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.365
3658	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.488
3659	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.594
3660	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.682
3661	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
3662	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
3663	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
3664	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
3665	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.814
3666	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.794
3667	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.613
3668	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.319
3669	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.086
3735	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.025
3736	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.102
3737	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.207
3738	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.312
3739	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.416
3740	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.506
3741	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.581
3742	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
3743	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
3744	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
3745	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
3746	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.694
3747	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.677
3748	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.522
3749	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.272
3750	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.073
3816	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.021
3817	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.084
3818	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.170
3819	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.256
3820	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.342
3821	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.416
3822	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.479
3823	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
3824	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
3825	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
3826	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
3827	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.571
3828	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.557
3829	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.430
3830	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.224
3831	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.060
3897	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.016
3898	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.066
3899	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.133
3900	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.200
3901	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.268
3902	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.326
3903	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.374
3904	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
3905	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
3906	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
3907	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
3908	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.446
3909	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.435
3910	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.336
3911	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.175
3912	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.047
3978	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.012
3979	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.047
3980	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.095
3981	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.144
3982	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.192
3983	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.233
3984	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.268
3985	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.320
3986	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.320
3987	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.320
3988	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.320
3989	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.320
3990	SURFACE FACE 3 GLOBAL UNIFORM PX	-0.312
3991	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.241
3992	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.125
3993	SURFACE FACE 4 GLOBAL UNIFORM PX	-0.034

4059 SURFACE FACE 4 GLOBAL UNIFORM PX -0.007
4060 SURFACE FACE 4 GLOBAL UNIFORM PX -0.028
4061 SURFACE FACE 4 GLOBAL UNIFORM PX -0.057
4062 SURFACE FACE 4 GLOBAL UNIFORM PX -0.086
4063 SURFACE FACE 4 GLOBAL UNIFORM PX -0.115
4064 SURFACE FACE 4 GLOBAL UNIFORM PX -0.140
4065 SURFACE FACE 4 GLOBAL UNIFORM PX -0.161
4066 SURFACE FACE 4 GLOBAL UNIFORM PX -0.192
4067 SURFACE FACE 4 GLOBAL UNIFORM PX -0.192
4068 SURFACE FACE 4 GLOBAL UNIFORM PX -0.192
4069 SURFACE FACE 4 GLOBAL UNIFORM PX -0.192
4070 SURFACE FACE 4 GLOBAL UNIFORM PX -0.192
4071 SURFACE FACE 3 GLOBAL UNIFORM PX -0.188
4072 SURFACE FACE 4 GLOBAL UNIFORM PX -0.145
4073 SURFACE FACE 4 GLOBAL UNIFORM PX -0.075
4074 SURFACE FACE 4 GLOBAL UNIFORM PX -0.020
4140 SURFACE FACE 4 GLOBAL UNIFORM PX -0.002
4141 SURFACE FACE 4 GLOBAL UNIFORM PX -0.009
4142 SURFACE FACE 4 GLOBAL UNIFORM PX -0.019
4143 SURFACE FACE 4 GLOBAL UNIFORM PX -0.029
4144 SURFACE FACE 4 GLOBAL UNIFORM PX -0.039
4145 SURFACE FACE 4 GLOBAL UNIFORM PX -0.047
4146 SURFACE FACE 4 GLOBAL UNIFORM PX -0.054
4147 SURFACE FACE 4 GLOBAL UNIFORM PX -0.064
4148 SURFACE FACE 4 GLOBAL UNIFORM PX -0.064
4149 SURFACE FACE 4 GLOBAL UNIFORM PX -0.064
4150 SURFACE FACE 4 GLOBAL UNIFORM PX -0.064
4151 SURFACE FACE 4 GLOBAL UNIFORM PX -0.064
4152 SURFACE FACE 3 GLOBAL UNIFORM PX -0.063
4153 SURFACE FACE 4 GLOBAL UNIFORM PX -0.048
4154 SURFACE FACE 4 GLOBAL UNIFORM PX -0.025
4155 SURFACE FACE 4 GLOBAL UNIFORM PX -0.007
$

LOADING 'F-HYDYN+' 'FULL TANK HYDRODYNAMIC LOAD IN +X DIRECTION'
UNITS INCH LBS
ELEMENT LOADS
$ FULL TANK HYDRODYNAMIC FORCE
15 SURFACE FACE 6 GLOBAL UNIFORM PX 0.03
96 SURFACE FACE 6 GLOBAL UNIFORM PX 0.27
177 SURFACE FACE 6 GLOBAL UNIFORM PX 0.74
258 SURFACE FACE 6 GLOBAL UNIFORM PX 1.45
339 SURFACE FACE 6 GLOBAL UNIFORM PX 2.37
420 SURFACE FACE 6 GLOBAL UNIFORM PX 3.49
501 SURFACE FACE 6 GLOBAL UNIFORM PX 4.81
582 SURFACE FACE 6 GLOBAL UNIFORM PX 6.29
663 SURFACE FACE 6 GLOBAL UNIFORM PX 7.92
744 SURFACE FACE 6 GLOBAL UNIFORM PX 9.68
825 SURFACE FACE 6 GLOBAL UNIFORM PX 11.53
906 SURFACE FACE 6 GLOBAL UNIFORM PX 13.46
987 SURFACE FACE 6 GLOBAL UNIFORM PX 15.42
1068 SURFACE FACE 6 GLOBAL UNIFORM PX 17.41
1149 SURFACE FACE 6 GLOBAL UNIFORM PX 19.37
1230 SURFACE FACE 6 GLOBAL UNIFORM PX 21.30
1311 SURFACE FACE 6 GLOBAL UNIFORM PX 23.15
1392 SURFACE FACE 6 GLOBAL UNIFORM PX 24.91
1473 SURFACE FACE 6 GLOBAL UNIFORM PX 26.54
1554 SURFACE FACE 6 GLOBAL UNIFORM PX 28.02
1635 SURFACE FACE 6 GLOBAL UNIFORM PX 29.34
1716 SURFACE FACE 6 GLOBAL UNIFORM PX 30.46
1797 SURFACE FACE 6 GLOBAL UNIFORM PX 31.38
1878 SURFACE FACE 6 GLOBAL UNIFORM PX 32.09
1959 SURFACE FACE 6 GLOBAL UNIFORM PX 32.56
2040 SURFACE FACE 6 GLOBAL UNIFORM PX 32.80
2121 SURFACE FACE 6 GLOBAL UNIFORM PX 32.80
2202 SURFACE FACE 6 GLOBAL UNIFORM PX 32.56
2283 SURFACE FACE 6 GLOBAL UNIFORM PX 32.09
2364 SURFACE FACE 6 GLOBAL UNIFORM PX 31.38
2445 SURFACE FACE 6 GLOBAL UNIFORM PX 30.46
2526 SURFACE FACE 6 GLOBAL UNIFORM PX 29.34
2607 SURFACE FACE 6 GLOBAL UNIFORM PX 28.02
2688 SURFACE FACE 6 GLOBAL UNIFORM PX 26.54
2769 SURFACE FACE 6 GLOBAL UNIFORM PX 24.91
2850 SURFACE FACE 6 GLOBAL UNIFORM PX 23.15
2931 SURFACE FACE 6 GLOBAL UNIFORM PX 21.30
3012 SURFACE FACE 6 GLOBAL UNIFORM PX 19.37
3093 SURFACE FACE 6 GLOBAL UNIFORM PX 17.41
3174 SURFACE FACE 6 GLOBAL UNIFORM PX 15.42
3255 SURFACE FACE 6 GLOBAL UNIFORM PX 13.46
3336 SURFACE FACE 6 GLOBAL UNIFORM PX 11.53
3417 SURFACE FACE 6 GLOBAL UNIFORM PX 9.68
3498 SURFACE FACE 6 GLOBAL UNIFORM PX 7.92
3579 SURFACE FACE 6 GLOBAL UNIFORM PX 6.29
3660 SURFACE FACE 6 GLOBAL UNIFORM PX 4.81

3741 SURFACE FACE 6 GLOBAL UNIFORM PX 3.49
3822 SURFACE FACE 6 GLOBAL UNIFORM PX 2.37
3903 SURFACE FACE 6 GLOBAL UNIFORM PX 1.45
3984 SURFACE FACE 6 GLOBAL UNIFORM PX 0.74
4065 SURFACE FACE 6 GLOBAL UNIFORM PX 0.27
4146 SURFACE FACE 6 GLOBAL UNIFORM PX 0.03

13 SURFACE FACE 6 GLOBAL UNIFORM PX 0.01
94 SURFACE FACE 6 GLOBAL UNIFORM PX 0.09
175 SURFACE FACE 6 GLOBAL UNIFORM PX 0.24
256 SURFACE FACE 6 GLOBAL UNIFORM PX 0.46
337 SURFACE FACE 6 GLOBAL UNIFORM PX 0.75
418 SURFACE FACE 6 GLOBAL UNIFORM PX 1.11
499 SURFACE FACE 6 GLOBAL UNIFORM PX 1.52
580 SURFACE FACE 6 GLOBAL UNIFORM PX 2.00
661 SURFACE FACE 6 GLOBAL UNIFORM PX 2.51
742 SURFACE FACE 6 GLOBAL UNIFORM PX 3.07
823 SURFACE FACE 6 GLOBAL UNIFORM PX 3.66
904 SURFACE FACE 6 GLOBAL UNIFORM PX 4.27
985 SURFACE FACE 6 GLOBAL UNIFORM PX 4.89
1066 SURFACE FACE 6 GLOBAL UNIFORM PX 5.52
1147 SURFACE FACE 6 GLOBAL UNIFORM PX 6.14
1228 SURFACE FACE 6 GLOBAL UNIFORM PX 6.75
1309 SURFACE FACE 6 GLOBAL UNIFORM PX 7.34
1390 SURFACE FACE 6 GLOBAL UNIFORM PX 7.90
1471 SURFACE FACE 6 GLOBAL UNIFORM PX 8.42
1552 SURFACE FACE 6 GLOBAL UNIFORM PX 8.89
1633 SURFACE FACE 6 GLOBAL UNIFORM PX 9.30
1714 SURFACE FACE 6 GLOBAL UNIFORM PX 9.66
1795 SURFACE FACE 6 GLOBAL UNIFORM PX 9.95
1876 SURFACE FACE 6 GLOBAL UNIFORM PX 10.18
1957 SURFACE FACE 6 GLOBAL UNIFORM PX 10.33
2038 SURFACE FACE 6 GLOBAL UNIFORM PX 10.40
2119 SURFACE FACE 6 GLOBAL UNIFORM PX 10.40
2200 SURFACE FACE 6 GLOBAL UNIFORM PX 10.33
2281 SURFACE FACE 6 GLOBAL UNIFORM PX 10.18
2362 SURFACE FACE 6 GLOBAL UNIFORM PX 9.95
2443 SURFACE FACE 6 GLOBAL UNIFORM PX 9.66
2524 SURFACE FACE 6 GLOBAL UNIFORM PX 9.30
2605 SURFACE FACE 6 GLOBAL UNIFORM PX 8.89
2686 SURFACE FACE 6 GLOBAL UNIFORM PX 8.42
2767 SURFACE FACE 6 GLOBAL UNIFORM PX 7.90
2848 SURFACE FACE 6 GLOBAL UNIFORM PX 7.34
2929 SURFACE FACE 6 GLOBAL UNIFORM PX 6.75
3010 SURFACE FACE 6 GLOBAL UNIFORM PX 6.14
3091 SURFACE FACE 6 GLOBAL UNIFORM PX 5.52
3172 SURFACE FACE 6 GLOBAL UNIFORM PX 4.89
3253 SURFACE FACE 6 GLOBAL UNIFORM PX 4.27
3334 SURFACE FACE 6 GLOBAL UNIFORM PX 3.66
3415 SURFACE FACE 6 GLOBAL UNIFORM PX 3.07
3496 SURFACE FACE 6 GLOBAL UNIFORM PX 2.51
3577 SURFACE FACE 6 GLOBAL UNIFORM PX 2.00
3658 SURFACE FACE 6 GLOBAL UNIFORM PX 1.52
3739 SURFACE FACE 6 GLOBAL UNIFORM PX 1.11
3820 SURFACE FACE 6 GLOBAL UNIFORM PX 0.75
3901 SURFACE FACE 6 GLOBAL UNIFORM PX 0.46
3982 SURFACE FACE 6 GLOBAL UNIFORM PX 0.24
4063 SURFACE FACE 6 GLOBAL UNIFORM PX 0.09
4144 SURFACE FACE 6 GLOBAL UNIFORM PX 0.01
$
LOADING 'F-HYDYN-' 'FULL TANK HYDRODYNAMIC LOAD IN -X DIRECTION'
UNITS INCH LBS
ELEMENT LOADS
$ FULL TANK HYDRODYNAMIC FORCE
4227 SURFACE FACE 6 GLOBAL UNIFORM PX -0.03
4308 SURFACE FACE 6 GLOBAL UNIFORM PX -0.27
4389 SURFACE FACE 6 GLOBAL UNIFORM PX -0.74
4470 SURFACE FACE 6 GLOBAL UNIFORM PX -1.45
4551 SURFACE FACE 6 GLOBAL UNIFORM PX -2.37
4632 SURFACE FACE 6 GLOBAL UNIFORM PX -3.49
4713 SURFACE FACE 6 GLOBAL UNIFORM PX -4.81
4794 SURFACE FACE 6 GLOBAL UNIFORM PX -6.29
4875 SURFACE FACE 6 GLOBAL UNIFORM PX -7.92
4956 SURFACE FACE 6 GLOBAL UNIFORM PX -9.68
5037 SURFACE FACE 6 GLOBAL UNIFORM PX -11.53
5118 SURFACE FACE 6 GLOBAL UNIFORM PX -13.46
5199 SURFACE FACE 6 GLOBAL UNIFORM PX -15.42
5280 SURFACE FACE 6 GLOBAL UNIFORM PX -17.41
5361 SURFACE FACE 6 GLOBAL UNIFORM PX -19.37
5442 SURFACE FACE 6 GLOBAL UNIFORM PX -21.30
5523 SURFACE FACE 6 GLOBAL UNIFORM PX -23.15
5604 SURFACE FACE 6 GLOBAL UNIFORM PX -24.91
5685 SURFACE FACE 6 GLOBAL UNIFORM PX -26.54
5766 SURFACE FACE 6 GLOBAL UNIFORM PX -28.02

5847	SURFACE FACE 6 GLOBAL UNIFORM PX	-29.34
5928	SURFACE FACE 6 GLOBAL UNIFORM PX	-30.46
6009	SURFACE FACE 6 GLOBAL UNIFORM PX	-31.38
6090	SURFACE FACE 6 GLOBAL UNIFORM PX	-32.09
6171	SURFACE FACE 6 GLOBAL UNIFORM PX	-32.56
6252	SURFACE FACE 6 GLOBAL UNIFORM PX	-32.80
6333	SURFACE FACE 6 GLOBAL UNIFORM PX	-32.80
6414	SURFACE FACE 6 GLOBAL UNIFORM PX	-32.56
6495	SURFACE FACE 6 GLOBAL UNIFORM PX	-32.09
6576	SURFACE FACE 6 GLOBAL UNIFORM PX	-31.38
6657	SURFACE FACE 6 GLOBAL UNIFORM PX	-30.46
6738	SURFACE FACE 6 GLOBAL UNIFORM PX	-29.34
6819	SURFACE FACE 6 GLOBAL UNIFORM PX	-28.02
6900	SURFACE FACE 6 GLOBAL UNIFORM PX	-26.54
6981	SURFACE FACE 6 GLOBAL UNIFORM PX	-24.91
7062	SURFACE FACE 6 GLOBAL UNIFORM PX	-23.15
7143	SURFACE FACE 6 GLOBAL UNIFORM PX	-21.30
7224	SURFACE FACE 6 GLOBAL UNIFORM PX	-19.37
7305	SURFACE FACE 6 GLOBAL UNIFORM PX	-17.41
7386	SURFACE FACE 6 GLOBAL UNIFORM PX	-15.42
7467	SURFACE FACE 6 GLOBAL UNIFORM PX	-13.46
7548	SURFACE FACE 6 GLOBAL UNIFORM PX	-11.53
7629	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.68
7710	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.92
7791	SURFACE FACE 6 GLOBAL UNIFORM PX	-6.29
7872	SURFACE FACE 6 GLOBAL UNIFORM PX	-4.81
7953	SURFACE FACE 6 GLOBAL UNIFORM PX	-3.49
8034	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.37
8115	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.45
8196	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.74
8277	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.27
8358	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.03

4225	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.01
4306	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.09
4387	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.24
4468	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.46
4549	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.75
4630	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.11
4711	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.52
4792	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.00
4873	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.51
4954	SURFACE FACE 6 GLOBAL UNIFORM PX	-3.07
5035	SURFACE FACE 6 GLOBAL UNIFORM PX	-3.66
5116	SURFACE FACE 6 GLOBAL UNIFORM PX	-4.27
5197	SURFACE FACE 6 GLOBAL UNIFORM PX	-4.89
5278	SURFACE FACE 6 GLOBAL UNIFORM PX	-5.52
5359	SURFACE FACE 6 GLOBAL UNIFORM PX	-6.14
5440	SURFACE FACE 6 GLOBAL UNIFORM PX	-6.75
5521	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.34
5602	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.90
5683	SURFACE FACE 6 GLOBAL UNIFORM PX	-8.42
5764	SURFACE FACE 6 GLOBAL UNIFORM PX	-8.89
5845	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.30
5926	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.66
6007	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.95
6088	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.18
6169	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.33
6250	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.40
6331	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.40
6412	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.33
6493	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.18
6574	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.95
6655	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.66
6736	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.30
6817	SURFACE FACE 6 GLOBAL UNIFORM PX	-8.89
6898	SURFACE FACE 6 GLOBAL UNIFORM PX	-8.42
6979	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.90
7060	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.34
7141	SURFACE FACE 6 GLOBAL UNIFORM PX	-6.75
7222	SURFACE FACE 6 GLOBAL UNIFORM PX	-6.14
7303	SURFACE FACE 6 GLOBAL UNIFORM PX	-5.52
7384	SURFACE FACE 6 GLOBAL UNIFORM PX	-4.89
7465	SURFACE FACE 6 GLOBAL UNIFORM PX	-4.27
7546	SURFACE FACE 6 GLOBAL UNIFORM PX	-3.66
7627	SURFACE FACE 6 GLOBAL UNIFORM PX	-3.07
7708	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.51
7789	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.00
7870	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.52
7951	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.11
8032	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.75
8113	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.46
8194	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.24
8275	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.09

```
8356  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.01
$

LOADING 'FULLSTAT' 'FULL TANK HYDROSTATIC LOAD'
UNITS INCH LBS
ELEMENT LOADS
$  FULL TANK HYDRODSTATIC FORCE

$ HYDROSTATIC PRESSURE
  10 THROUGH 8353 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -5.405
  11 THROUGH 8354 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -4.841
  12 THROUGH 8355 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -4.277
  13 THROUGH 8356 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -3.713
  14 THROUGH 8357 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -3.227
  15 THROUGH 8358 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -2.821
  16 THROUGH 8359 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -2.347
  17 THROUGH 8360 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -1.805
  18 THROUGH 8361 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -1.264
  19 THROUGH 8362 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -0.722
  20 THROUGH 8363 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -0.226

LOADING 'H-HYDYN+' 'HALF TANK DYDRODYNAMIC FORCE IN THE +X DIRECTION'
UNITS INCH LBS
ELEMENT LOADS
$  HALFTANK HYDRODYNAMIC FORCE
  12    SURFACE FACE 6 GLOBAL UNIFORM PX   0.01
  93    SURFACE FACE 6 GLOBAL UNIFORM PX   0.12
  174   SURFACE FACE 6 GLOBAL UNIFORM PX   0.34
  255   SURFACE FACE 6 GLOBAL UNIFORM PX   0.66
  336   SURFACE FACE 6 GLOBAL UNIFORM PX   1.08
  417   SURFACE FACE 6 GLOBAL UNIFORM PX   1.59
  498   SURFACE FACE 6 GLOBAL UNIFORM PX   2.19
  579   SURFACE FACE 6 GLOBAL UNIFORM PX   2.87
  660   SURFACE FACE 6 GLOBAL UNIFORM PX   3.61
  741   SURFACE FACE 6 GLOBAL UNIFORM PX   4.42
  822   SURFACE FACE 6 GLOBAL UNIFORM PX   5.26
  903   SURFACE FACE 6 GLOBAL UNIFORM PX   6.14
  984   SURFACE FACE 6 GLOBAL UNIFORM PX   7.04
  1065  SURFACE FACE 6 GLOBAL UNIFORM PX   7.94
  1146  SURFACE FACE 6 GLOBAL UNIFORM PX   8.84
  1227  SURFACE FACE 6 GLOBAL UNIFORM PX   9.72
  1308  SURFACE FACE 6 GLOBAL UNIFORM PX   10.56
1389  SURFACE FACE 6 GLOBAL UNIFORM PX   11.36
1470  SURFACE FACE 6 GLOBAL UNIFORM PX   12.11
1551  SURFACE FACE 6 GLOBAL UNIFORM PX   12.78
1632  SURFACE FACE 6 GLOBAL UNIFORM PX   13.38
1713  SURFACE FACE 6 GLOBAL UNIFORM PX   13.90
1794  SURFACE FACE 6 GLOBAL UNIFORM PX   14.32
1875  SURFACE FACE 6 GLOBAL UNIFORM PX   14.64
1956  SURFACE FACE 6 GLOBAL UNIFORM PX   14.85
2037  SURFACE FACE 6 GLOBAL UNIFORM PX   14.96
2118  SURFACE FACE 6 GLOBAL UNIFORM PX   14.96
2199  SURFACE FACE 6 GLOBAL UNIFORM PX   14.85
2280  SURFACE FACE 6 GLOBAL UNIFORM PX   14.64
2361  SURFACE FACE 6 GLOBAL UNIFORM PX   14.32
2442  SURFACE FACE 6 GLOBAL UNIFORM PX   13.90
2523  SURFACE FACE 6 GLOBAL UNIFORM PX   13.38
2604  SURFACE FACE 6 GLOBAL UNIFORM PX   12.78
2685  SURFACE FACE 6 GLOBAL UNIFORM PX   12.11
2766  SURFACE FACE 6 GLOBAL UNIFORM PX   11.36
2847  SURFACE FACE 6 GLOBAL UNIFORM PX   10.56
2928  SURFACE FACE 6 GLOBAL UNIFORM PX   9.72
3009  SURFACE FACE 6 GLOBAL UNIFORM PX   8.84
3090  SURFACE FACE 6 GLOBAL UNIFORM PX   7.94
3171  SURFACE FACE 6 GLOBAL UNIFORM PX   7.04
3252  SURFACE FACE 6 GLOBAL UNIFORM PX   6.14
3333  SURFACE FACE 6 GLOBAL UNIFORM PX   5.26
3414  SURFACE FACE 6 GLOBAL UNIFORM PX   4.42
3495  SURFACE FACE 6 GLOBAL UNIFORM PX   3.61
3576  SURFACE FACE 6 GLOBAL UNIFORM PX   2.87
3657  SURFACE FACE 6 GLOBAL UNIFORM PX   2.19
3738  SURFACE FACE 6 GLOBAL UNIFORM PX   1.59
3819  SURFACE FACE 6 GLOBAL UNIFORM PX   1.08
3900  SURFACE FACE 6 GLOBAL UNIFORM PX   0.66
3981  SURFACE FACE 6 GLOBAL UNIFORM PX   0.34
4062  SURFACE FACE 6 GLOBAL UNIFORM PX   0.12
4143  SURFACE FACE 6 GLOBAL UNIFORM PX   0.01

11    SURFACE FACE 6 GLOBAL UNIFORM PX   0.00
92    SURFACE FACE 6 GLOBAL UNIFORM PX   0.03
173   SURFACE FACE 6 GLOBAL UNIFORM PX   0.07
254   SURFACE FACE 6 GLOBAL UNIFORM PX   0.14
335   SURFACE FACE 6 GLOBAL UNIFORM PX   0.23
416   SURFACE FACE 6 GLOBAL UNIFORM PX   0.35
```

497	SURFACE FACE 6 GLOBAL UNIFORM PX	0.48
578	SURFACE FACE 6 GLOBAL UNIFORM PX	0.62
659	SURFACE FACE 6 GLOBAL UNIFORM PX	0.79
740	SURFACE FACE 6 GLOBAL UNIFORM PX	0.96
821	SURFACE FACE 6 GLOBAL UNIFORM PX	1.14
902	SURFACE FACE 6 GLOBAL UNIFORM PX	1.33
983	SURFACE FACE 6 GLOBAL UNIFORM PX	1.53
1064	SURFACE FACE 6 GLOBAL UNIFORM PX	1.73
1145	SURFACE FACE 6 GLOBAL UNIFORM PX	1.92
1226	SURFACE FACE 6 GLOBAL UNIFORM PX	2.11
1307	SURFACE FACE 6 GLOBAL UNIFORM PX	2.29
1388	SURFACE FACE 6 GLOBAL UNIFORM PX	2.47
1469	SURFACE FACE 6 GLOBAL UNIFORM PX	2.63
1550	SURFACE FACE 6 GLOBAL UNIFORM PX	2.78
1631	SURFACE FACE 6 GLOBAL UNIFORM PX	2.91
1712	SURFACE FACE 6 GLOBAL UNIFORM PX	3.02
1793	SURFACE FACE 6 GLOBAL UNIFORM PX	3.11
1874	SURFACE FACE 6 GLOBAL UNIFORM PX	3.18
1955	SURFACE FACE 6 GLOBAL UNIFORM PX	3.23
2036	SURFACE FACE 6 GLOBAL UNIFORM PX	3.25
2117	SURFACE FACE 6 GLOBAL UNIFORM PX	3.25
2198	SURFACE FACE 6 GLOBAL UNIFORM PX	3.23
2279	SURFACE FACE 6 GLOBAL UNIFORM PX	3.18
2360	SURFACE FACE 6 GLOBAL UNIFORM PX	3.11
2441	SURFACE FACE 6 GLOBAL UNIFORM PX	3.02
2522	SURFACE FACE 6 GLOBAL UNIFORM PX	2.91
2603	SURFACE FACE 6 GLOBAL UNIFORM PX	2.78
2684	SURFACE FACE 6 GLOBAL UNIFORM PX	2.63
2765	SURFACE FACE 6 GLOBAL UNIFORM PX	2.47
2846	SURFACE FACE 6 GLOBAL UNIFORM PX	2.29
2927	SURFACE FACE 6 GLOBAL UNIFORM PX	2.11
3008	SURFACE FACE 6 GLOBAL UNIFORM PX	1.92
3089	SURFACE FACE 6 GLOBAL UNIFORM PX	1.73
3170	SURFACE FACE 6 GLOBAL UNIFORM PX	1.53
3251	SURFACE FACE 6 GLOBAL UNIFORM PX	1.33
3332	SURFACE FACE 6 GLOBAL UNIFORM PX	1.14
3413	SURFACE FACE 6 GLOBAL UNIFORM PX	0.96
3494	SURFACE FACE 6 GLOBAL UNIFORM PX	0.79
3575	SURFACE FACE 6 GLOBAL UNIFORM PX	0.62
3656	SURFACE FACE 6 GLOBAL UNIFORM PX	0.48
3737	SURFACE FACE 6 GLOBAL UNIFORM PX	0.35
3818	SURFACE FACE 6 GLOBAL UNIFORM PX	0.23
3899	SURFACE FACE 6 GLOBAL UNIFORM PX	0.14
3980	SURFACE FACE 6 GLOBAL UNIFORM PX	0.07
4061	SURFACE FACE 6 GLOBAL UNIFORM PX	0.03
4142	SURFACE FACE 6 GLOBAL UNIFORM PX	0.00

$

LOADING 'H-HYDYN-' 'HALF TANK DYDRODYNAMIC FORCE IN THE -X DIRECTION'

UNITS INCH LBS

ELEMENT LOADS

$ HALFTANK HYDRODYNAMIC FORCE

4224	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.01
4305	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.12
4386	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.34
4467	SURFACE FACE 6 GLOBAL UNIFORM PX	-0.66
4548	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.08
4629	SURFACE FACE 6 GLOBAL UNIFORM PX	-1.59
4710	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.19
4791	SURFACE FACE 6 GLOBAL UNIFORM PX	-2.87
4872	SURFACE FACE 6 GLOBAL UNIFORM PX	-3.61
4953	SURFACE FACE 6 GLOBAL UNIFORM PX	-4.42
5034	SURFACE FACE 6 GLOBAL UNIFORM PX	-5.26
5115	SURFACE FACE 6 GLOBAL UNIFORM PX	-6.14
5196	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.04
5277	SURFACE FACE 6 GLOBAL UNIFORM PX	-7.94
5358	SURFACE FACE 6 GLOBAL UNIFORM PX	-8.84
5439	SURFACE FACE 6 GLOBAL UNIFORM PX	-9.72
5520	SURFACE FACE 6 GLOBAL UNIFORM PX	-10.56
5601	SURFACE FACE 6 GLOBAL UNIFORM PX	-11.36
5682	SURFACE FACE 6 GLOBAL UNIFORM PX	-12.11
5763	SURFACE FACE 6 GLOBAL UNIFORM PX	-12.78
5844	SURFACE FACE 6 GLOBAL UNIFORM PX	-13.38
5925	SURFACE FACE 6 GLOBAL UNIFORM PX	-13.90
6006	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.32
6087	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.64
6168	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.85
6249	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.96
6330	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.96
6411	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.85
6492	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.64
6573	SURFACE FACE 6 GLOBAL UNIFORM PX	-14.32
6654	SURFACE FACE 6 GLOBAL UNIFORM PX	-13.90
6735	SURFACE FACE 6 GLOBAL UNIFORM PX	-13.38
6816	SURFACE FACE 6 GLOBAL UNIFORM PX	-12.78

```
6897  SURFACE FACE 6 GLOBAL UNIFORM PX   -12.11
6978  SURFACE FACE 6 GLOBAL UNIFORM PX   -11.36
7059  SURFACE FACE 6 GLOBAL UNIFORM PX   -10.56
7140  SURFACE FACE 6 GLOBAL UNIFORM PX   -9.72
7221  SURFACE FACE 6 GLOBAL UNIFORM PX   -8.84
7302  SURFACE FACE 6 GLOBAL UNIFORM PX   -7.94
7383  SURFACE FACE 6 GLOBAL UNIFORM PX   -7.04
7464  SURFACE FACE 6 GLOBAL UNIFORM PX   -6.14
7545  SURFACE FACE 6 GLOBAL UNIFORM PX   -5.26
7626  SURFACE FACE 6 GLOBAL UNIFORM PX   -4.42
7707  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.61
7788  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.87
7869  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.19
7950  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.59
8031  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.08
8112  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.66
8193  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.34
8274  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.12
8355  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.01

4223  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.00
4304  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.03
4385  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.07
4466  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.14
4547  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.23
4628  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.35
4709  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.48
4790  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.62
4871  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.79
4952  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.96
5033  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.14
5114  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.33
5195  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.53
5276  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.73
5357  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.92
5438  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.11
5519  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.29
5600  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.47
5681  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.63
5762  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.78
5843  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.91
5924  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.02
6005  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.11
6086  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.18
6167  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.23
6248  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.25
6329  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.25
6410  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.23
6491  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.18
6572  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.11
6653  SURFACE FACE 6 GLOBAL UNIFORM PX   -3.02
6734  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.91
6815  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.78
6896  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.63
6977  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.47
7058  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.29
7139  SURFACE FACE 6 GLOBAL UNIFORM PX   -2.11
7220  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.92
7301  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.73
7382  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.53
7463  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.33
7544  SURFACE FACE 6 GLOBAL UNIFORM PX   -1.14
7625  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.96
7706  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.79
7787  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.62
7868  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.48
7949  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.35
8030  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.23
8111  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.14
8192  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.07
8273  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.03
8354  SURFACE FACE 6 GLOBAL UNIFORM PX   -0.00

$
LOADING 'HALFSTAT' 'HALF TANK DYDROSTATIC FORCE'
UNITS INCH LBS
ELEMENT LOADS
$ HYDROSTATIC PRESSURE
  10 THROUGH 8353 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -2.787
  11 THROUGH 8354 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -2.223
  12 THROUGH 8355 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -1.659
  13 THROUGH 8356 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -1.095
  14 THROUGH 8357 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -0.609
  15 THROUGH 8358 BY 81 SURFACE FACE 6 PLANAR UNIFORM PZ -0.203
```

```
$
 PRINT JOINT COORDINATE
 PRINT MEMBER INCIDENCES
$
STIFFNESS ANALYSIS REDUCE BAND
$
$
$ END OF MATRIX FORMULATION CHECK
$
$...LOAD COMBINATIONS
$

LOADING LIST 'DEADLOAD' 'OVERDOME' 'SIDESOIL' 'DYNASOIL' 'EQ-TANK' 'F-HYDYN+' -
        'F-HYDYN-' 'FULLSTAT' 'H-HYDYN+' 'H-HYDYN-' 'HALFSTAT'
$
$ STATIC LOADS
$
CREAT LOADING COMB 1 SPEC 'DEADLOAD' 1.0 'OVERDOME' 1.0 'SIDESOIL' 1.0
$

CREAT LOADING COMB 2 SPEC 'DEADLOAD' 1.0 'OVERDOME' 1.0 'SIDESOIL' 1.0 -
'FULLSTAT' 1.0

$

CREAT LOADING COMB 3 SPEC 'DEADLOAD' 1.0 'OVERDOME' 1.0 'SIDESOIL' 1.0 -
'HALFSTAT' 1.0

$
$ DYNAMIC LOADS

CREAT LOAD COMB 4 SPEC 'DEADLOAD' 1.093 'OVERDOME' 1.093 'EQ-TANK' 1.0 -
'SIDESOIL' 1.0 'DYNASOIL' 1.0

CREAT LOAD COMB 5 SPEC 'DEADLOAD' 1.093 'OVERDOME' 1.093 'EQ-TANK' 1.0 -
'SIDESOIL' 1.0 'DYNASOIL' 1.0 'FULLSTAT' 1.0 'F-HYDYN+' 1.0

CREAT LOAD COMB 6 SPEC 'DEADLOAD' 1.093 'OVERDOME' 1.093 'EQ-TANK' -1.0 -
'SIDESOIL' 1.0 'DYNASOIL' 1.0 'FULLSTAT' 1.0 'F-HYDYN-' 1.0

CREAT LOAD COMB 7 SPEC 'DEADLOAD' 1.093 'OVERDOME' 1.093 'EQ-TANK' 1.0 -
'SIDESOIL' 1.0 'DYNASOIL' 1.0 'HALFSTAT' 1.0 'H-HYDYN+' 1.0

CREAT LOAD COMB 8 SPEC 'DEADLOAD' 1.093 'OVERDOME' 1.093 'EQ-TANK' -1.0 -
'SIDESOIL' 1.0 'DYNASOIL' 1.0 'HALFSTAT' 1.0 'H-HYDYN-' 1.0

OUTPUT DECIMAL 3
OUTPUT ORDERED
OUTPUT BY MEMBER
OUTPUT BY ELEMENT

LOADING LIST 'DEADLOAD' 'OVERDOME' 'SIDESOIL' 'DYNASOIL' 'EQ-TANK' 'F-HYDYN+' -
'F-HYDYN-' 'FULLSTAT' 'H-HYDYN+' 'H-HYDYN-' 'HALFSTAT' 1 TO 8

LIST DISP  JOINTS 1 TO 155
LIST FORCES MEMBERS 10001 TO 12392
$ VERTICAL WALLS
LIST STRESS  ELEMENTS 1 TO 81 2107 TO 2187 4213 TO 4293

$ TOP LAYER
$ DOME HOLE 'D-TOP', 24 IN DIA.
LIST STRESS  ELEMENTS 4919 TO 5324 BY 81
LIST STRESS  ELEMENTS 4920 TO 5325 BY 81
LIST STRESS  ELEMENTS 4921 TO 5326 BY 81
LIST STRESS  ELEMENTS 4922 TO 5327 BY 81
LIST STRESS  ELEMENTS 4923 TO 5328 BY 81
LIST STRESS  ELEMENTS 4924 TO 5329 BY 81
$ DOME HOLE 'E-TOP', 30 IN DIA.
LIST STRESS  ELEMENTS 4001 TO 4406 BY 81
LIST STRESS  ELEMENTS 4004 TO 4409 BY 81
LIST STRESS  ELEMENTS 4028 TO 4433 BY 81
LIST STRESS  ELEMENTS 4029 TO 4434 BY 81
LIST STRESS  ELEMENTS 4030 TO 4435 BY 81
LIST STRESS  ELEMENTS 4031 TO 4436 BY 81


$ BOTTOM LAYER
$ DOME HOLE 'D-BOTTOM', 24 IN DIA.
LIST STRESS  ELEMENTS 4896 TO 5301 BY 81
LIST STRESS  ELEMENTS 4897 TO 5302 BY 81
LIST STRESS  ELEMENTS 4898 TO 5303 BY 81
LIST STRESS  ELEMENTS 4899 TO 5304 BY 81
LIST STRESS  ELEMENTS 4900 TO 5305 BY 81
LIST STRESS  ELEMENTS 4901 TO 5306 BY 81
$ DOME HOLE 'E-BOTTOM', 30 IN DIA. AND 'F-BOTTOM' 12 IN. DIA.
```

```
LIST STRESS  ELEMENTS 4000 TO 4729 BY 81
LIST STRESS  ELEMENTS 4003 TO 4732 BY 81
LIST STRESS  ELEMENTS 4005 TO 4734 BY 81
LIST STRESS  ELEMENTS 4006 TO 4735 BY 81
LIST STRESS  ELEMENTS 4007 TO 4736 BY 81
LIST STRESS  ELEMENTS 4008 TO 4737 BY 81
$
CALCULATE AVERAGE PRIN STRES VON AND ENVELOPE AT MID SURFACES FOR
ELEMENTS -
1 TO 81 2107 TO 2187 4213 TO 4293 -
4919 TO 5324 BY 81 -
4920 TO 5325 BY 81 -
4921 TO 5326 BY 81 -
4922 TO 5327 BY 81 -
4923 TO 5328 BY 81 -
4924 TO 5329 BY 81 -
4001 TO 4406 BY 81 -
4004 TO 4409 BY 81 -
4028 TO 4433 BY 81 -
4029 TO 4434 BY 81 -
4030 TO 4435 BY 81 -
4031 TO 4436 BY 81 -
4896 TO 5301 BY 81 -
4897 TO 5302 BY 81 -
4898 TO 5303 BY 81 -
4899 TO 5304 BY 81 -
4900 TO 5305 BY 81 -
4901 TO 5306 BY 81 -
4000 TO 4729 BY 81 -
4003 TO 4732 BY 81 -
4005 TO 4734 BY 81 -
4006 TO 4735 BY 81 -
4007 TO 4736 BY 81 -
4008 TO 4737 BY 81

CINPUT
FINISH
```