CALCULATION COVER SHEET

CEC

JOB NO. 1083-000 / 1083

FILE NO.

CALC NO. SC(PO17)-1

NO. OF SHEETS 184

PROJECT Private Fuel Storage Facility (PFSF)

SUBJECT Storage Pad Analysis and Design

RECORD OF ISSUES

NO.	DESCRIPTION	BY	DATE	CHKD	DATE	APPRD	DATE	
0	Initial Issue	MT DH MY	6/20/97	KL	6/20/97	WT	6/20/97	

This set of calculations presents the analyses and detailed design calculations required for the structural design of the reinforced-concrete spent-fuel cask storage pads to be constructed at the PFSF project site.

This set of calculations has been prepared in accordance with CEC's quality assurance procedure for nuclear projects.

NAME		INITIAL	SIGNATURE
Ming T. Tsay	(Preparer)	MT	Ming T. Tsay
Donald Hamasaki	(Preparer)	DH	Donald Hamasaki
Ming S. Yang	(Preparer)	MY	Ming S. Yang
Kiat Lilhanand	(Checker)	KL	K. Lilhanand
Wen S. Tseng	(Independent Reviewer)	WT	W. S. Tseng

International Civil Engineering Consultants, Inc.

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PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 1

1. OBJECTIVE

The objective of this set of calculations is to present the analyses and detailed calculations required for the design of the reinforced-concrete spent-fuel cask storage pads to be constructed at the PFSF project site.

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SUBJECT Storage Pad Analysis and Design SHEET NO. 2

2. ANALYSIS AND DESIGN SUMMARY

A. Pad Geometry and Support Condition

(a) Pad Dimensions: Length - 64′-0″

Width - 30′-0″

Thickness - 3′-0″

(b) Support Condition: Pad directly support on in-situ soil with soil fills on its side walls

(c) Pad Top Surface Elevation: 3.5″ above finished grade elevation

(d) Pad Bottom Surface Elevation: 2′-8½″ below finished grade elevation

B. Pad Structural Design

(a) Concrete: Normal weight concrete; f'_c=4,000 psi at 28 days

(b) Reinforcing: ASTM A615 Grade 60 deformed bar; F_y=60 ksi

(c) Horizontal (Flexural) Reinforcement:

Top Face - Two-way reinforcement with #10 @ 12″ o.c. each way; longitudinal bars at the top at 2.875″ below the top surface of the pad

Bottom Face - Two-way reinforcement with # 10 @ 6″ o.c. each way; longitudinal bars at the bottom at 3.875″ above the bottom surface of the pad

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(d) Vertical (Shear) Reinforcement: One #7 @ 12″ o.c. each way in two ways distributed uniformly over the entire pad; each vertical bar with a 135° hook anchored to the top longitudinal bars and a 90° bend anchored to the bottom longitudinal bars.

C. Structural Strengths

(a)	Ultimate static moment capacity (ϕM_n)	=	338 k-ft/ft
(b)	Ultimate dynamic moment capacity ($DIF \times \phi M_n$)	=	423 k-ft/ft
(c)	Ultimate static out-of-plane shear capacity (ϕV_n)	=	123 k/ft
(d)	Ultimate dynamic out-of-plane shear capacity ($DIF \times \phi V_n$)	=	135 k/ft

D. Structural Demand Loads

(a) Normal Loading condition (1.4D + 1.7L + 1.7H):

Maximum moment	=	145.4 k-ft/ft
Maximum (flexural) shear force	=	19.2 k/ft

(b) Accident-Level Loading Condition (D + L + H + E):

Maximum moment	=	383.3 k-ft/ft
Maximum (flexural) shear force	=	83.2 k/ft
Maximum punching shear force	=	111.1 k/ft

E. Soil Bearing and Sliding Stabilities

(a) Maximum soil bearing pressure under the static (dead plus live plus cask transporter) loading condition: 3.50 k/ft^2

(b) Maximum soil bearing pressure under dynamic (dead plus live plus the design earthquake) loading condition: 5.77 k/ft^2

(c) Minimum factor of safety against allowable soil bearing pressure under the long-term static (dead plus live) loading condition: 1.14

(d) Minimum factor of safety against sliding failure under the dynamic (dead plus live plus design earthquake) loading condition: 2.03

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3. REFERENCES

1. Stone & Webster Engineering Corporation (SWEC) Calculation No. 05996.01 G(PO5)-1, "Development of Soil and Foundation Parameters in Support of Dynamic Soil-Structure Interaction Analysis", Rev. 1 by Geomatrix Consultants, Inc., June 9, 1997.

2. Fax-Transmittal from Stan Macie of SWEC to Wen S. Tseng of International Civil Engineering Consultants, Inc.(CEC) on "Revised Table 1-Dynamic Soil Parameters for SASSI Model", dated June 4, 1997.

3. Holtec Report HI-971631, "Multi-Cask Seismic Response at PFS ISFSI", Transmitted through transmittal from Stephen Agace of Holtec to Wen S. Tseng of CEC, dated May 19, 1997.

4. Fax Transmittal from Stan Macie of SWEC to Wen S. Tseng of CEC on "Sketches of J & R Engineering Cask Transporter", dated May 22, 1997.

5. Holtec Document Transmittal from Maria C. Pepe of Holtec to Wen S. Tseng of CEC on "Storage Pad Seismic Response Acceleration Time History", dated May 20 and 22, 1997.

6. Fax Transmittal from Stan Macie of SWEC to Wen S. Tseng of CEC on "Storage Cask Base Details", dated May 29, 1997.

7. Fax Transmittal from Stan Macie of SWEC to Wen S. Tseng of CEC on "Private Fuel Storage Facility Safety Analysis Report" Chapter 3, Revision 0, dated May 9, 1997

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3. REFERENCES (CONT'D)

8. Stone & Webster Engineering Corporation (SWEC) Document, "Geotechnical Design Criteria for the PFSF Storage Facility", Revision 1, June 9, 1997.

9. Transmittal from Stan Macie of SWEC to Wen S. Tseng of CEC on "Drawing 0599601-EC-1-B (Rev. B)", dated May 16, 1997.

10. Fax Transmittal from Stan Macie of SWEC to Wen S. Tseng of CEC on "Latest Drawing (0599601-EC-1-B)", dated June 4, 1997.

11. International Civil Engineering Consultants, Inc., "Computer Program SASSI for IMB/RS-6000 Workstation, Version 1.2 - User's Manual," March 1997.

12. International Civil Engineering Consultants, Inc., "Computer Program CECSAP, Version 1.0 - User's Manual," October 1996.

13. ACI 349-85 (1990), "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute, March 1990.

14. ASCE Standard 4-86, "Seismic Analysis of Safety Related Nuclear Structures and Commentary," American Society of Civil Engineers, September 1986.

4. DESIGN INPUT PARAMETERS AND CRITERIA

4.1 Codes and Standards

The codes and standards used in the analysis and design of the storage pad are as follows:

1. ACI 349-85 (1990), "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute, March 1990.

2. ASCE Standard 4-86, "Seismic Analysis of Safety Related Nuclear Structures and Commentary," American Society of Civil Engineers, September 1986.

4.2 Site Soil Condition

The local site soil profile at the cask storage area consists basically of three layers: an uppermost layer of silt, silty clay and clayey silt with layered thickness of 25 to 35 ft; followed by a layer of 25 to 30 ft thick of very dense fine sand overlying a silty layer, as shown in Fig. 1 (Ref. 8). Results of geophysical survey program indicate that the ground water table is at about 100 to 130 ft and the bedrock is between 520 ft and 880 ft below the ground surface.

The properties of the top soil layer based on the results of geotechinecal investigations are as estimated in Ref. 8 as follows:

(a) Effective-stress strength parameters for drained analyses:
Angle of internal friction $\phi = 30°$ and cohesion c = 0 ksf.

(b) Total-stress strength parameters for undrained analyses (e.g., dynamic loadings):

$$\phi = 0° \text{ and } c = 2.2 \text{ ksf.}$$

(c) Coefficients of earth pressure, K_o:

- At-rest, $K_o = 0.5$
- Active, $K_a = 0.33$
- Passive, $K_p = 3.0$

(d) Coefficient of vertical subgrade reaction of in-situ soil, k:

$$k = 20 \text{ kips/ft/ft}^2$$

The strain-compatible dynamic soil properties given in Refs. 1 and 2 used in the pad dynamic response analyses using SASSI computer program (Ref. 11) are shown in Table 1.

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Table 1

Dynamic Soil Parameters for SASSI Model

(Source: Ref. 2)

Depth (ft)		Density	Wave Velocity (fps)		Damping Ratio (%)	
Top	Bottom	(pcf)	Shear	Compressional	Shear	Compressional
0	5	81	637	1500	5	5
5	10	81	520	1500	10	10
10	15	81	469	1500	12	10
15	20	81	353	1500	15	10
20	25	81	327	1500	15	10
25	30	81	280	1500	15	10
30	60	115	1809	4000	4	4
60	120	120	1861	4000	8	8
120	300	130	2080	5600	8	8
300	600	130	2440	5600	8	8
600		150	5000	10000	2	1

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Figure 1

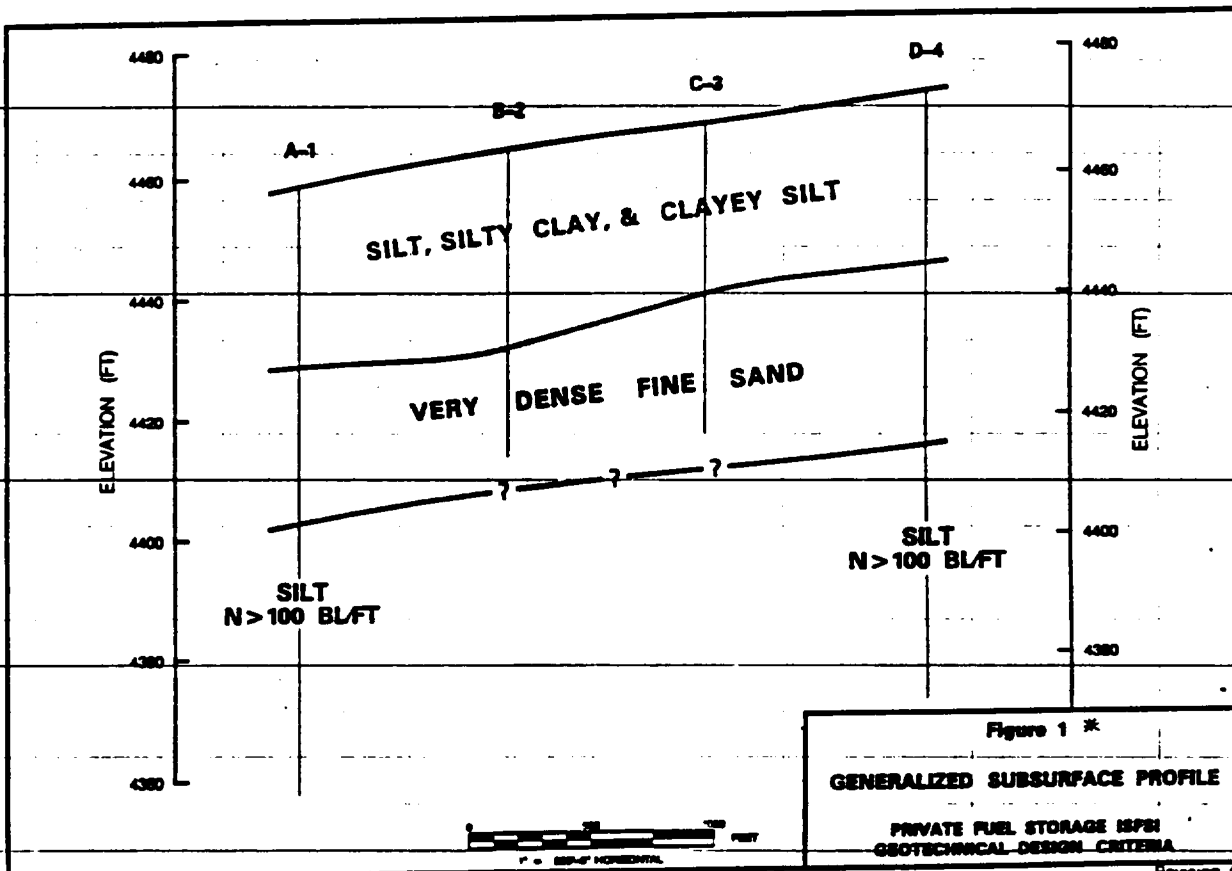

Figure 1 *

GENERALIZED SUBSURFACE PROFILE

PRIVATE FUEL STORAGE ISFSI
GEOTECHNICAL DESIGN CRITERIA

Revision 0

* SOURCE: REF. 8

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SUBJECT Storage Pad Analysis and Design SHEET NO. 11

The soil spring stiffnesses, damping coefficient, and mass value used to represent the soil foundation for dynamic analyses of the pad using CECSAP program (Ref. 12) are, as devloped by Holtech (Ref. 3), shown in Table 2 below.

Table 2

Soil Masses, Spring Stiffnesses, and Damping Constants

Horizontal motion parallel to the long direction of pad

M_{HL} = 882.512 lb-sec^2/in

K_{HL} = 6.641×10^6 lb/in

C_{HL} = 1.836×10^5 lb-sec/in

Horizontal motion parallel to the short direction of pad

M_{HS} = 882.512 lb-sec^2/in

K_{HS} = 6.991×10^6 lb/in

C_{HS} = 1.933×10^5 lb-sec/in

Vertical motion

M_v = 4.766×10^3 lb-sec^2/in

K_v = 9.679×10^6 lb/in

C_v = 3.949×10^5 lb-sec/in

4.3 Geometry and Material Specifications

4.3.1 Geometry

The configuration of the storage pad having dimensions of 64′ × 30′ × 3′ supporting 8 dry storage casks considered in the analysis and design of the pad is as specified in Ref. 10 and shown on the following two pages.

4.3.2 Material Specifications

The properties of concrete and reinforcing bars used for the design of the pad are as specified in Ref. 2 as follows:

Concrete: Normal Weight Concrete

f'_c = Compressive strength = 4,000 psi

E_c = Modules of elasticity = $5{,}7000\sqrt{f_c}$ = 3.60×10^6 psi

γ_c = Unit weight = 150 lb/ft^3

~~ν_c = Poission's ratio = 0.17~~

Reinforcing Bar: ATSM A615 Grade 60 Billet Steel

F_y = Specified minimum yield strength = 60 ksi

E_s = Modulus of elasticity = 29,000 ksi

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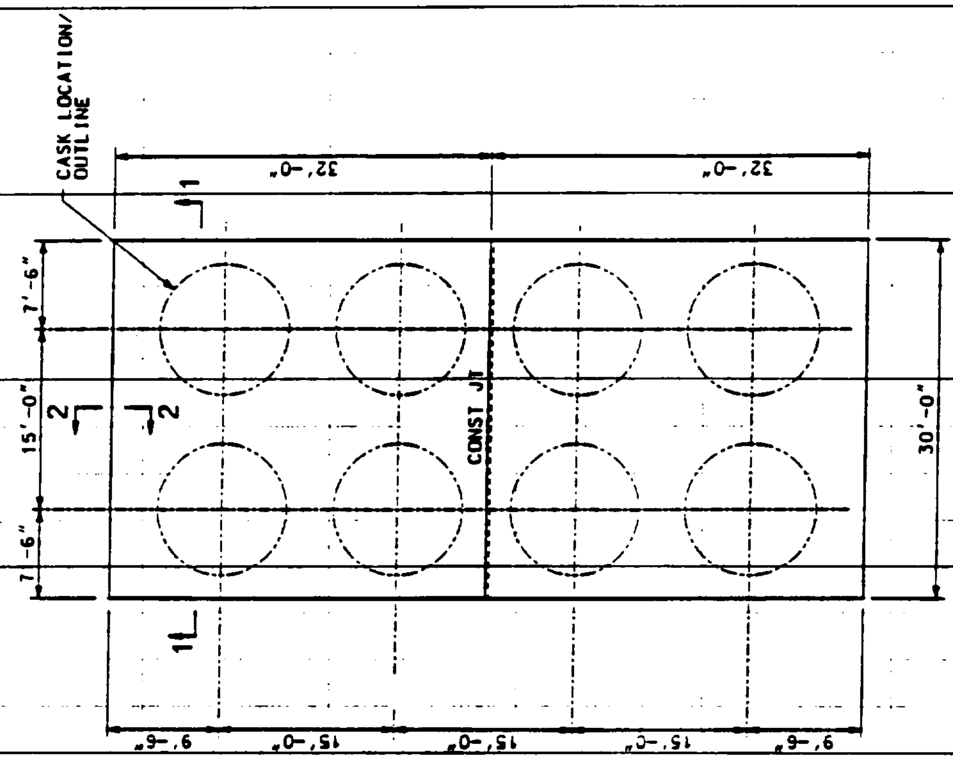
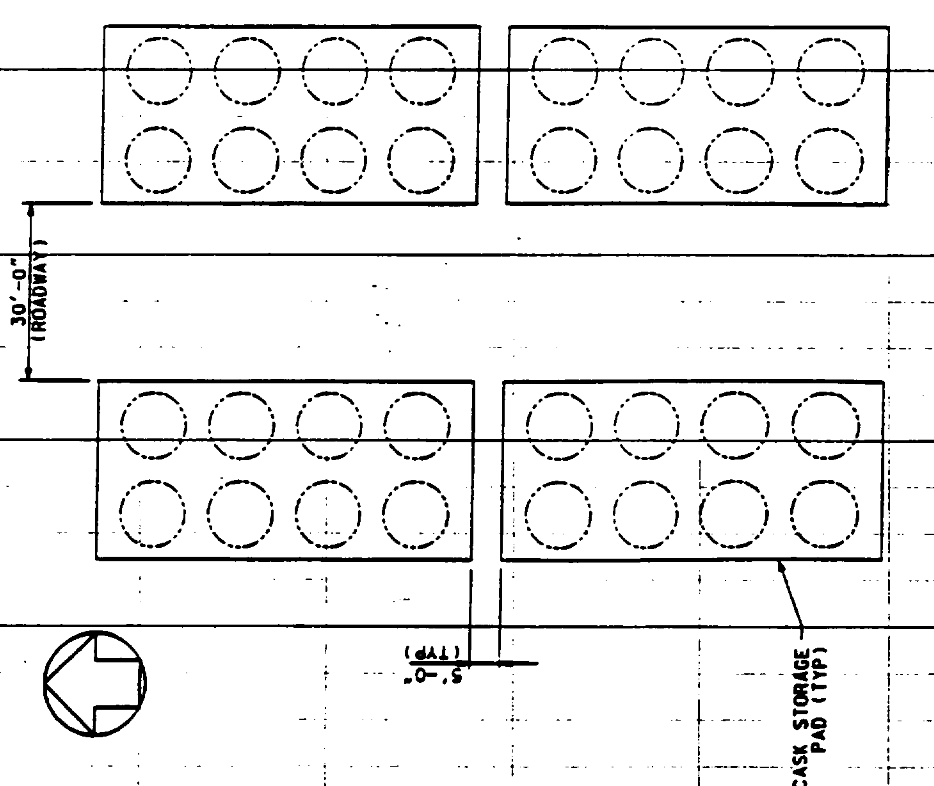
SUBJECT Storage Pad Analysis and Design SHEET NO. 13



PLAN
CASK STORAGE PAD
(500 REQD)



PARTIAL PLAN
TYPICAL CASK STORAGE PAD SPACING

SOURCE: LATEST DWG 0599601-EC-1-B (REF. 10)

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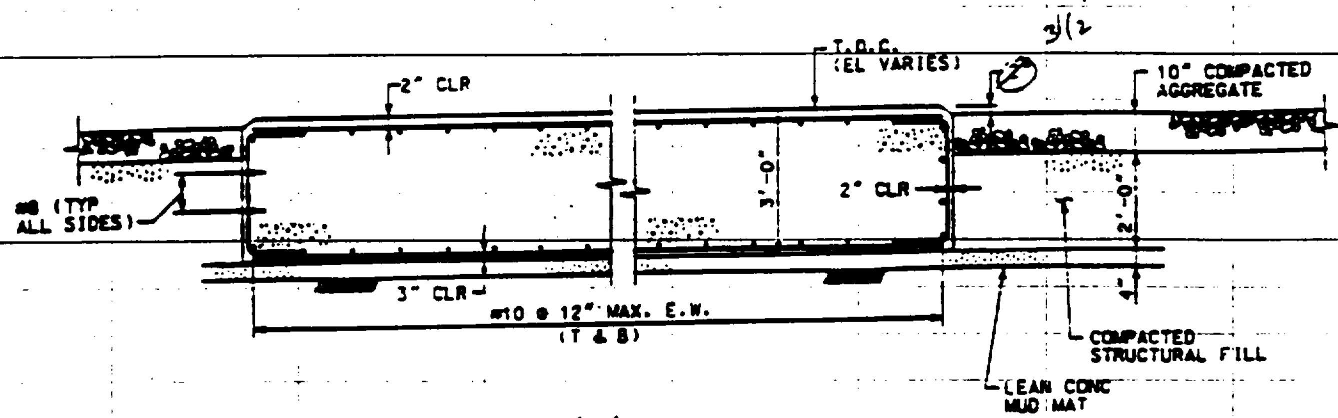
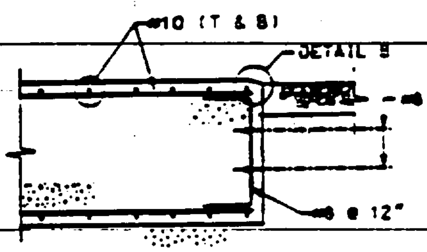
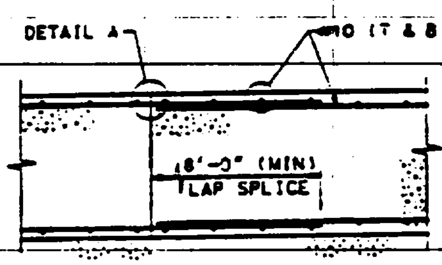


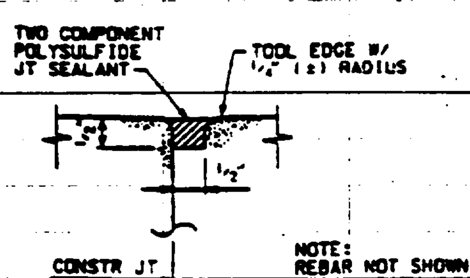
1-1
SCALE: 1/2" = 1'-0"



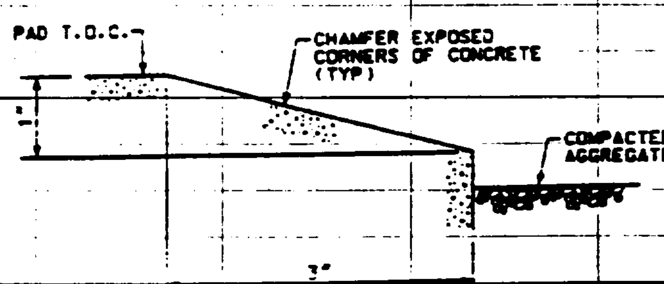
2-2
SCALE: 1/2" = 1'-0"



TYP CONSTRUCTION JT
CASK STORAGE PAD
SCALE: 1/2" = 1'-0"



NOTE:
REBAR NOT SHOWN
FOR CLARITY



DETAIL A
SCALE: NTS

DETAIL B
SCALE: NTS

SOURCE: LATEST DWG 0599601-EC-1-B (REF. 10)

4.4 Design Loads

Design loads considered in the analysis and design of the pad consists of the following:

4.4.1 Dead Load (D)

The dead load (D) considered is the gravitational dead weight of the reinforced concrete pad based on:

- Gross unit weight of the concrete pad = 150 pcf

4.4.2 Live Load (L)

The live load (L) considered is the gravitational dead weight of the fully loaded dry cask.

- Weight of each fully-loaded dry cask = 356.5 kips (Ref.2)

Four dry cask storage configurations are considered:

- 2, 4, and 8 casks
- 7 casks with one cask being transported on the pad by cask transporter
- Weight of transporter = 135 kips (Ref. 4)
- An impact factor of 1.0 is conservatively assumed and applied to the total weight of transporter plus one fully- loaded cask, i.e. (135 + 356.5 =) 491.5 kips to account for the dynamic effect associated with cask transporting

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4.4.3 Lateral Soil Pressure (H)

The lateral soil pressure (H) acting on the pad's perimeter wall considered is based on the properties of structural backfill soil as follows:

Unit weight of soil = 125 pcf (Ref. 8)

At-rest earth pressure coefficient (K_o) = 0.43 (Ref.8)

Passive earth pressure coefficient (kp) = 3.7 (Ref. 8).

4.4.4 Operating and Accident Thermal Loads (T and T_a)

Since the storage pad is supported freely on the ground surface, the loads due to T and T_a are assumed to produce negligible effect for the design of the pad.

4.4.5 Wind Load (W) and Tornado Wind and Missile Load (W_t)

For the design of the pad, the wind load (W) and tornado wind and missile load (W_t) are assumed to affect only the storage casks but not the pad. Thus, its effects are not considered in the design of the pad.

4.4.6 Earthquake Load (E)

The earthquake load (E) considered for the design of the pad is based on the horizontal and vertical design ground motion response spectra (Ref. 8) developed for the site.

For design of the pad, the maximum horizontal (a_h) and vertical (a_v) pad response accelerations based on the Holtec's seismic response analysis results (Ref. 5) coupled with the dry cask seismic response reaction force time histories acting on the pad (Ref. 5) with 2, 4, and 8 cask storage configurations are considered. Values of a_h = 0.67g and a_v = 0.69g are used in the design.

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For checking seismic sliding stability of the storage pad, the dynamic active soil pressure is computed using the ASCE 4-86 (Ref. 13) procedure.

4.5 Load Combinations

Load combinations in accordance with ACI 349-85 (1990) are considered in the pad design as follows:

Loading Condition		Load Combinations
Normal Condition	(1)	1.4D + 1.7L
	(2)	1.4D + 1.7L + 1.7H
Off-Normal Condition	(1)	0.75 (1.4D + 1.7L + 1.7H + 1.7T)
	(2)	0.75 (1.4D +1.7L + 1.7H + 1.7T + 1.7W)
Accident-Level Condition	(1)	D + L + H + T + E
	(2)	D + L + H + T_a

Since T, T_a, W, and W_t are assumed negligible for the design of the pad, the governing load combinations considered in design become:

Loading Condition	Load Combination
Normal condition	1.4D + 1.7L + 1.7H
Accidental-level condition	D + L + H + E

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4.6 Acceptance Criteria

4.6.1 Reinforced Concrete Pad

The acceptance criteria for design are in accordance with the strength design (U_c) provisions of ACI-349-85 (1990) as follows:

Loading Condition	Acceptance Criteria
Normal condition	$U_c > 1.4D + 1.7L + 1.7H$
Accident-level condition	$U_c > D + L + H + E$

~~4.6.2 Soil Bearing and Sliding Stability~~

(a) Vertical Bearing Stability

- Minimum factor of safety for static (dead plus live) loads = 3.0 (Ref. 8).
- Gross allowable static bearing pressure = 4.0 ksf (Ref. 8).
- Minimum factor of safety for static plus design earthquake load = 1.1 (Ref. 8).
- ~~Gross allowable bearing capacity for static plus earthquake load - see Table 3.~~

(b) Horizontal Sliding and Overturning Stability

- Minimum factor of safety for static (dead plus live) load = 1.5 (Ref. 8).
- Minimum factor of safety for static plus design earthquake load = 1.1 (Ref. 8).

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Table 3

Gross Allowable Bearing Capacity for Static Plus Earthquake Loads

Coefficient of Friction Between Casks and Pad μ	Gross Allowable Bearing Pressure $q_{allowable}$ ksf
0.00	8.97
0.10	8.06
0.20	7.22
0.30	6.47
0.40	5.79
0.50	5.18
0.60	4.64
0.67	4.30

5 DESIGN ANALYSIS

5.1 Static and Dynamic Analyses Using CECSAP

5.1.1 Mathematical Model

5.1.2 Static Analyses

5.1.3. Dynamic Loadings

5.1.4. Dynamic Analysis Output Selection

5.1.5 Static and Dynamic Analysis Inputs and Outputs

5.1.6 Static and Dynamic Analysis Results

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5.1.1. Mathematical model

A mathematical model was developed for the analyses using Program CECSAP.

Total number of nodes: 299

Elements used:

- 264 plate elements were used to model the pad

to model soil properties:

- 299 vertical boundary elements
- 299 horizontal boundary elements in X-direction
- 299 horizontal boundary elements in Y-direction

These boundary elements are used to model soil stiffness associated with three motion directions. In other words, each node has three soil springs attached for the three directions of motion.

- Likewise, there are three damper elements assigned to every node to model the soil damping effect. There are a total of 897 damper elements.

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The finite element mesh is shown in the next page with node number plotted. The 299 node are arranged in 23 rows of 13 nodes. The distances between consecutive nodes in each row are, from left to right, 1.98', 2.76', 2.76', 2.76', 2.76', 1.98', 1.98', 2.76', 2.76', 2.76', 2.76', 1.98'. The distances between rows are, from bottom to top, 3.98', 2.76', 2.76', 2.76', 2.76', 3.96', 2.76', 2.76', 2.76', 2.76', 1.98', 1.98', 2.76', 2.76', 2.76', 2.76', 3.96', 2.76', 2.76', 2.76', 2.76', 3.98'.

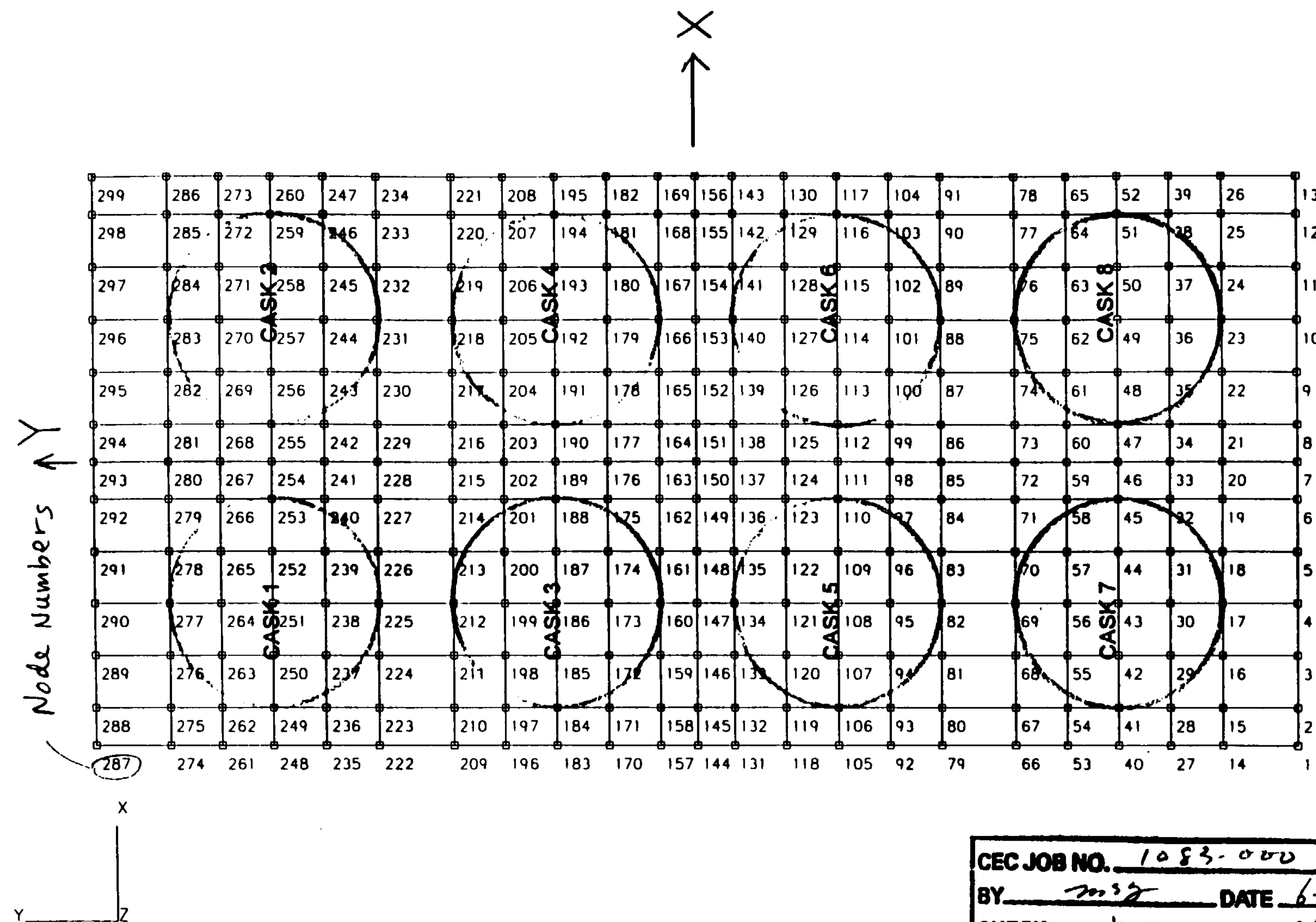
The mesh is symmetrical with respect to both centerlines. Node No. 150 is at the center of the pad. A node is assigned to every loading point for each cask. The loading nodes for all cask are

	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
Cask 1	277	249	225	253
Cask 2	283	255	231	259
Cask 3	212	184	160	188
Cask 4	218	190	166	194
Cask 5	134	106	82	110
Cask 6	140	112	88	116
Cask 7	69	41	17	45
Cask 8	75	47	23	51

Finite Element Mesh - Plate Elements and Nodes

CECSAP MODEL

CECSAPLOT



PRIVATE FUEL STORAGE FACILITY, CASK STORAGE PAD

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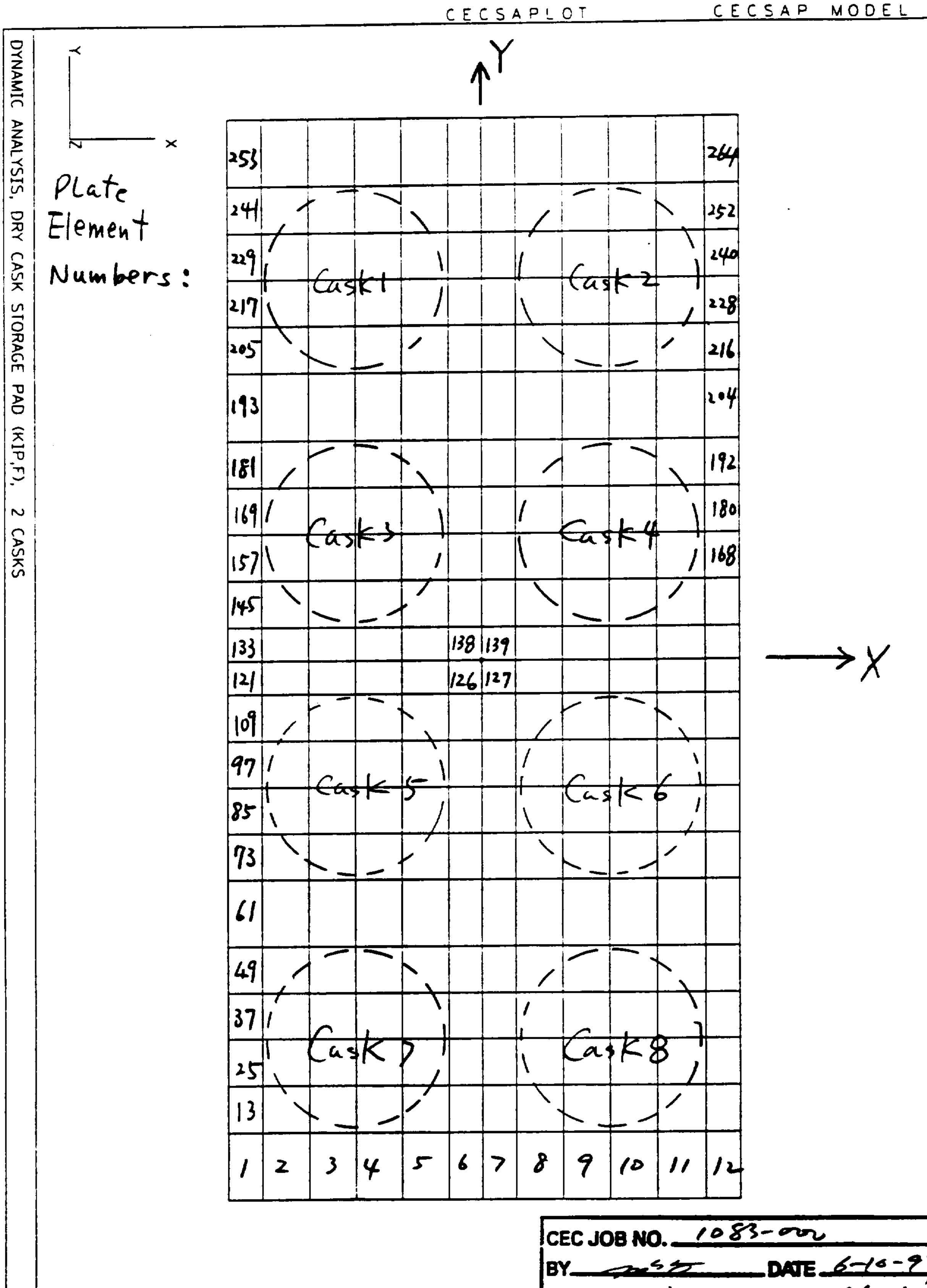
Finite Element Mesh (Plate Element Numbers)

CECSAPLOT CECSAP MODEL



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Local axes of plate elements

In the CECSAP model, the local plate coorinate system is in coincidence with the global system. Thus, the moment M_{xx} of a plate element is for bending about the global Y-axis, and M_{yy} is for bending about global X-axis.

Material properties of Pad (Plate Elements)

Young's modulus, E

$E = 57000\sqrt{f_c'}$ $\quad f_c' = 4000$ psi (reference)

$= 3605$ ksi

$= 519120$ ksf

Poisson's Ratio $\nu = 0.17$

Thus, the plane stress material matrix is as follows

$$\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \tau_{xy}\end{Bmatrix} = \frac{E}{1-\nu^2}\begin{bmatrix}1 & \nu & 0\\ \nu & 1 & 0\\ 0 & 0 & (1-\nu)/2\end{bmatrix}\begin{Bmatrix}\varepsilon_{xx}\\ \varepsilon_{yy}\\ \varepsilon_{xy}\end{Bmatrix} = \begin{bmatrix}534570 & 90880 & 0\\ 90880 & 534570 & 0\\ 0 & 0 & 221850\end{bmatrix}\begin{Bmatrix}\varepsilon_{xx}\\ \varepsilon_{yy}\\ \varepsilon_{xy}\end{Bmatrix}$$

where $\sigma_{xx}, \sigma_{yy}, \tau_{xy}$ are normal and shear stresses,

and ε_{xx} ε_{yy}, ε_{xy} are the corresponding strains.

Reference: HOLTEC Report # HI-971631 Appendix C P. C-2
5-19-97

The mass density of the Pad is $0.15/32.2 = 0.0046584 \frac{k}{f^3}\frac{s^2}{f}$.

units: k = kip
s = second
f = foot

CALCULATION SHEET

CALC. NO. sc(P017)-1	REV. NO. 0		
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Soil Properties: Stiffness, Damping and Mass

Soil stiffness, damping and mass are distributed evenly, according to the tributary area of each node, to all nodes modelling the pad. The values were taken from HOLTEC Report NO. HI-971631, Appendix C (Ref. 3)

The values below are the total values for the entire pad:

Vibration Mode			
Vertical	Mass	$4.766 \times 10^3 \frac{LB\text{-}s^2}{in}$	= 57,192 k-s/f
	stiffness	9.679×10^6 Lb/in	= 116148 k/f
	damping	$3.949 \times 10^5 \frac{lb\text{-}s}{in}$	= 4738.8 k-s/f
horizontal (x)	mass	882.512 lb-s²/in	= 10.59 k-s²/f
	stiffness	6.991×10^6 lb/in	= 83892 k/f
	damping	1.933×10^5 lb-s/in	= 2319.6 k-s/f
horizontal (Y)	mass	882.512 lb-s²/in	= 10.59 k-s²/f
	stiffness	6.641×10^6 lb/in	= 79692 k/f
	damping	1.836×10^5 lb-s/in	= 2203.2 k-s/f

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CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR [illegible] DATE 5/22/97 CHECKED [illegible] DATE 5-24-97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 29

MODELING OF SOIL FOUNDATION SUPPORTING THE PAD BY SPRING, DASHPOT AND MASS

SOIL FOUNDATION SUPPORTING THE PAD IS MODELLED BY SOIL SPRING STIFFNESSES, DASHPOT CONSTANTS AND MASSES DEVELOPED BY HOLTEC (APP. C, REPORT NO. HI-971631, "MULTI-CASK SEISMIC RESPONSE AT THE PSF ISFSI) AS LISTED BELOW :

VIBRATION MODE	SOIL PARAMETER	VALUES	Page No. (HI-971631) Ref. 3
VERTICAL	M_V	$4.766 \times 10^3 \frac{LB-SEC^2}{IN}$	P. C-8
	K_V	$9.679 \times 10^6 \frac{LB}{IN}$	P. C-6
	C_V	$3.949 \times 10^5 \frac{LB-SEC}{IN}$	P. C-7
HORIZONTAL	M_H	$882.512 \frac{LB-SEC^2}{IN}$	P. C-9
	K_{HL}	$4.641 \times 10^6 \frac{LB}{IN}$	P. C-5
	C_{HL}	$1.836 \times 10^5 \frac{LB-SEC}{IN}$	P. C-7
	K_{HS}	$6.991 \times 10^6 \frac{LB}{IN}$	P. C-5
	C_{HS}	$1.933 \times 10^5 \frac{LB-SEC}{IN}$	P. C-7

NOTES: M = SOIL MASS, C = SOIL DASHPOT CONSTANT, K = SOIL SPRING STIFFNESS

SUBSCRIPTS H = HORIZONTAL, V = VERTICAL, L AND S = LONG AND SHORT SIDES OF PAD

CALCULATION SHEET

CALC. NO. SC(PO17)-1	REV. NO. 0		
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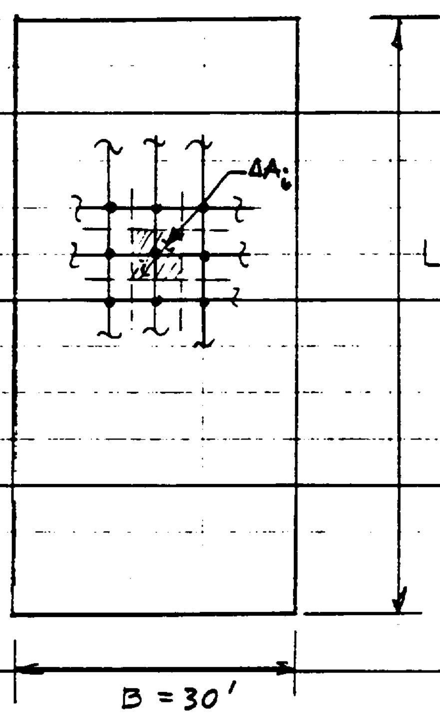
THE SOIL PARAMETERS GIVEN IN THE ABOVE TABLE ARE DISTRIBUTED OVER TRIBUTARY AREA OF EACH NODE ON THE PAD AS SHOWN BELOW:



ΔA_i = TRIBUTARY AREA AT NODE i

A = TOTAL AREA OF THE PAD

$= 64 \times 30 = 1920 \text{ FT}^2$

(DRY CASK STORAGE FOOTPRINTS ARE NOT SHOWN ON THE SKETCH)

LUMPED PARAMETERS FOR SOIL SPRING STIFFNESS, DASHPOT CONSTANT, AND MASS TO BE ATTACHED TO NODE "i" ON THE PAD ARE CALCULATED AS

$$M_i = M \times \Delta A_i / A$$

$$K_i = K \times \Delta A_i / A$$

$$C_i = C \times \Delta A_i / A$$

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CALCULATION SHEET

CALC. NO. SC(POIN)-1 REV. NO. 0

ORIGINATOR KL DATE 5/22/97 CHECKED [illegible] DATE 5-26-97

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IN THE ABOVE MODELING OF THE VERTICAL SOIL PARAMETERS, THE VERTICAL RESPONSE OF THE PAD IS ASSUMED TO BE MAINLY CONTRIBUTED BY VERTICAL VIBRATION MODE AND THAT DUE TO ROCKING VIBRATION MODE IS ASSUMED TO BE RELATIVELY SMALL. THUS, THE VERTICAL SOIL PARAMETERS DUE TO VERTICAL VIBRATION MODE WERE USED IN THE SOIL FOUNDATION MODEL.

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CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

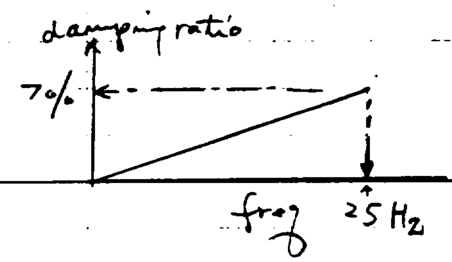
ORIGINATOR msz DATE 5-10-97 CHECKED [illegible] DATE 6/10/97

PROJECT PFSF JOB NO. 1083-00[illegible]

SUBJECT Storage Pad Analysis SHEET NO. 32

Proportional damping for Pad

Stiffness proportional damping $\beta[K]$ was used



$$[C]_{pad} = \beta[K]_{pad}$$

For 7% @ 25 Hz $\rightarrow$ $\beta = \dfrac{\alpha T}{\pi} = \dfrac{\alpha}{f\pi} = \dfrac{0.07}{25 \cdot \pi} = 0{,}00089127$

$\lambda_n = \beta \pi f_n$, damping ratio is proportional to freq. f_n

Note: $\beta[K]$ and the soil dampers constitute the damping matrix of the structure (pad)-soil system.

5.1.2 Static Analyses

There are two types of static analysis carried out by CECSAP

- Dead Load Analysis

The loading is the weight of the pad only

- Live load Analyses

There are four load cases

1. 2 Casks Nos. 1 and 2
2. 4 Casks Nos. 1, 2, 3 and 4
3. 8 Casks all 8 casks
4. 8 Casks plus Transporters

The weight of a cask is 356.5 Kips. It is evenly distributed at four loading points of the four quadrants of the cask.

Nodes at which a downward load of 89.125 Kip is applied:

Cask NO.	1	2	3	4	5	6	7	8
	225	231	160	166	82	88	17	23
Loaded	249	255	184	190	106	112	41	47
Nodes	253	259	188	194	110	116	45	51
NOs.	277	283	212	218	134	140	69	75

CALCULATION SHEET

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CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR mgz DATE 6-13-97 CHECKED M DATE 6/13/97

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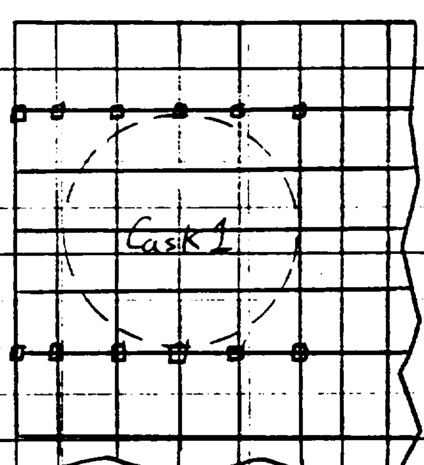
Application of Live loads

For Cases 1, 2 and 3, The weight of each cask was applied evenly @ four loading points of The four quadrants

Case 1	Casks 1 and 2
Case 2	Casks 1, 2, 3, and 4
Case 3	Casks 1, 2, 3, 4, 5, 6, 7, and 8
Case 4*	Casks 2, 3, 4, 5, 6, 7, 8 and transporter carrying cask 1



*Note:
Only half of The transport weight was used. a dynamic impact factor of 2 was used ; i.e $(0.5 \times 135 + 365.5)\,2 = 866$ kips. This 866 kips are applied evenly to Nodes 222 to 227 and Nodes 274 to 279 as shown in The drawing on The left.

▫ — Nodes at which The transporter load was applied.

Mathematical Model for Static Analyses

The mathematical model used for static analyses is the same as the one used for dynamic analyses with the following changes

1. The vertical soil spring stiffness is 20 kip/ft^3 (Ref. 8).

2. No damper elements were used in static analyses.

5.1.3 Dynamic Analysis

Dynamic Loading

The dynamic loading on the pad is defined by force time histories. For each cask, there are six force time histories: 4 vertical force time histories defining the vertical (z) loading at four quadrants of the cask and two force time histories defining horizontal loadings in the x and y directions.

There are three dynamic load cases:

Case 1 – 2 casks : Casks 1 and 2

Case 2 – 4 casks : Casks 1, 2, 3, and 4

Case 3 – 8 Casks : Casks 1, 2, 3, 4, 5, 6, 7, and 8

Therefore, for Case 1, loading is defined by 12 force time histories. Similarly, 24 and 48 time histories were used to define loadings for cases 1 and 2, respectively.

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CALCULATION SHEET

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Force Time History Assignment

The force time history data provided by Holtec consist of two sets corresponding to two friction values, 0.2 and 0.8, between pad and casks. The time history plots for both set are included in Attachment A-1. By examining the plots, it was determined that the set associated with the friction value of 0.8 was the governing load. Note that the static gravity load was not included in the dynamic loads. In the following, the loading time histories are assigned to proper loading nodes. Note that the horizontal loads for a cask were distributed evenly to the four loading nodes for the four quadrants. This is achieved by assigning each horizontal component to four loading points of the four quadrants of the associated cask and then using a scale factor of 0.25 to return the total effect back to one.

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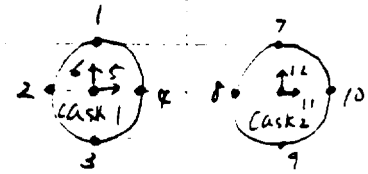
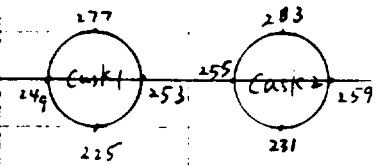
2-Casks nodal force loads time histories



TH NO.



Node. NO.

Node #	Comp #	TH #	arrival #	Scale f.
277	1	5	0	-0.25
277	2	6	0	-0.25
277	3	1	0	-1
249	1	5	0	-0.25
249	2	6	0	-0.25
249	3	2	0	-1
225	1	5	0	-0.25
225	2	6	0	-0.25
225	3	3	0	-1
253	1	5	0	-0.25
253	2	6	0	-0.25
253	3	4	0	-1
283	1	11	0	-0.25
283	2	12	0	-0.25
283	3	7	0	-1
255	1	11	0	-0.25
255	2	12	0	-0.25
255	3	8	0	-1
231	1	11	0	-0.25
231	2	12	0	-0.25
231	3	9	0	-1
259	1	11	0	-0.25
259	2	12	0	-0.25
259	3	10	0	-1

Factor of 0.25 was used to distribute horizontal loads evenly to four loading points. Negative signs imply the loads are acting downward on the pad.

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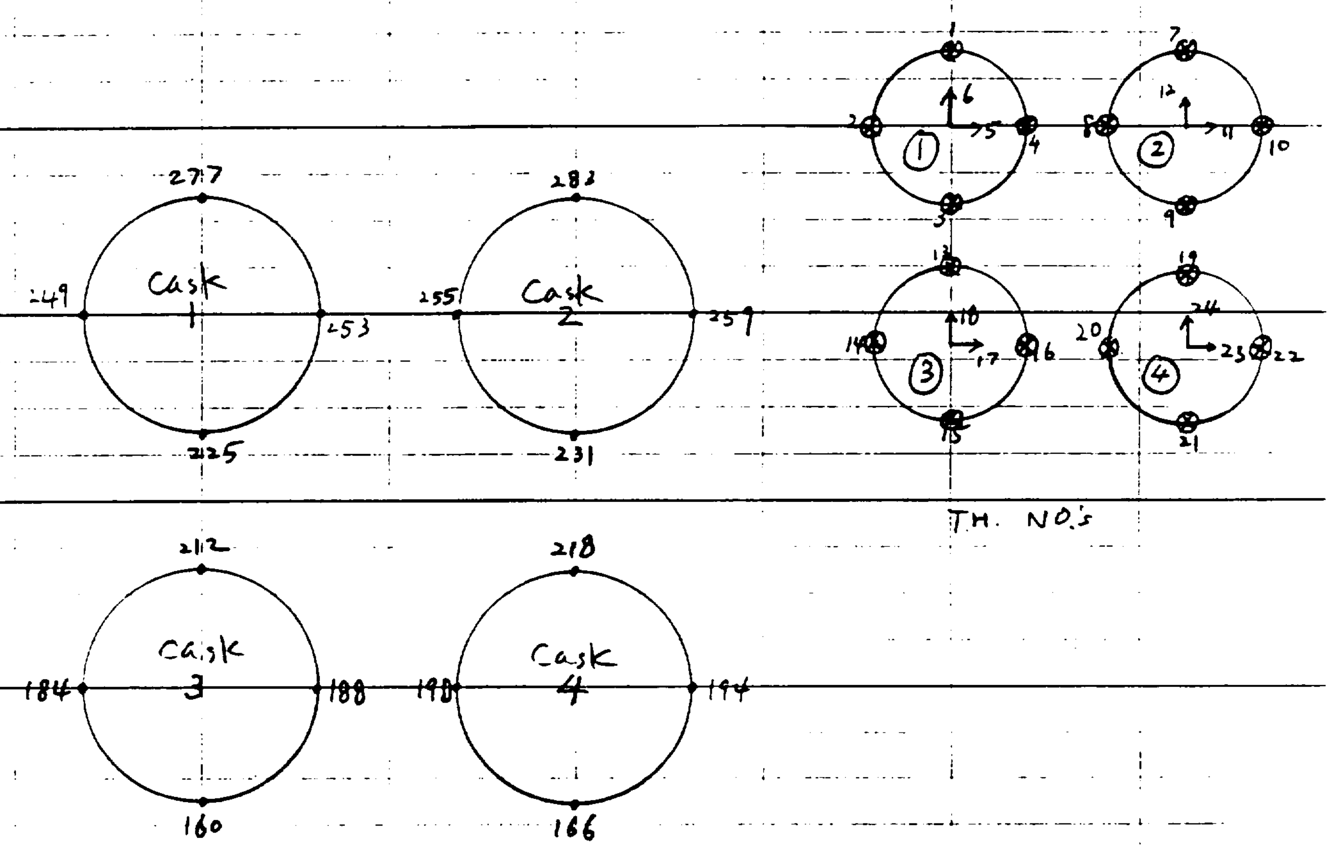
PROJECT	PFSF	JOB NO.	1083-00
SUBJECT	Storage Pad Analysis	SHEET NO.	39

4-Cask nodal force load time history number assignment



Node Numbers of Loaded Nodes for Coal 2, 4-Cask Case

CALCULATION SHEET

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CALC. NO. SC(PO17)-1 REV. NO. 0

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PROJECT PFSF JOB NO. 1085-00[illegible]

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4-Cask Nodal Load time history assignment (cont'd)

For Casks 1 & 2, use previous data.

For Casks 3 & 4, use the following assignment.

Node #	Comp #	TH. #	arrival #	Scale f.
160	1	17	0	-0.25
160	2	18	0	-0.25
160	3	15	0	-1
166	1	23	0	-0.25
166	2	24	0	-0.25
166	3	21	0	-1
184	1	17	0	-0.25
184	2	18	0	-0.25
184	3	14	0	-1
188	1	17	0	-0.25
188	2	18	0	-0.25
188	3	16	0	-1
190	1	23	0	-0.25
190	2	24	0	-0.25
190	3	20	0	-1
194	1	23	0	-0.25
194	2	24	0	-0.25
194	3	22	0	-1
212	1	17	0	-0.25
212	2	18	0	-0.25
212	3	13	0	-1
218	1	23	0	-0.25
218	2	24	0	-0.25
218	3	19	0	-1

CEC

CALCULATION SHEET

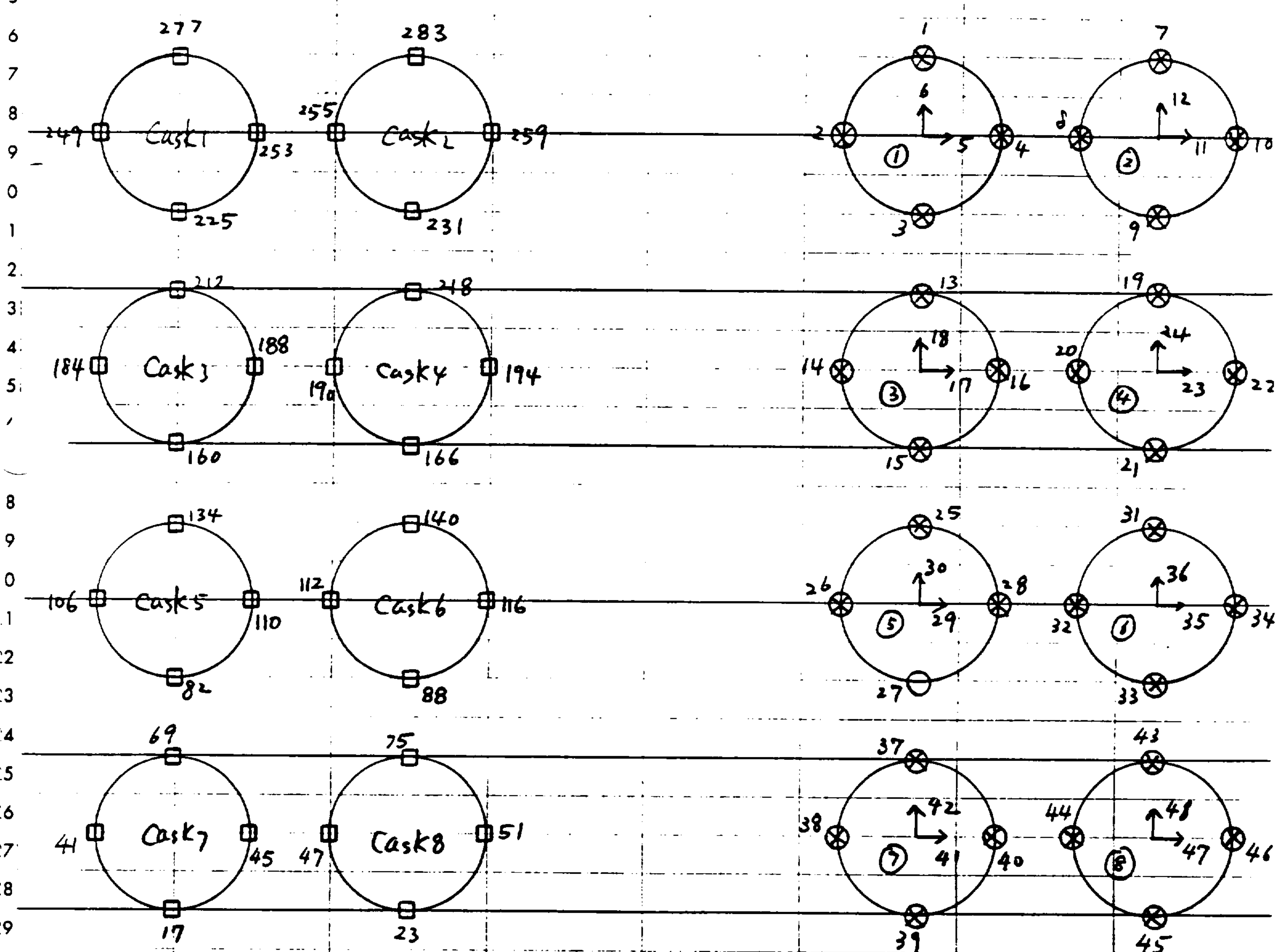
CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR MSR DATE 5-28-97 CHECKED KR DATE 6/10/97

PROJECT PFSF JOB NO. 1083-00C

SUBJECT Storage Pad Analysis SHEET NO. 41

8-cask Nodal force Time History number assignment



Loaded Node Numbers

T.H. Numbers

CALCULATION SHEET

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CALC. NO. SC(PO17)-1	REV. NO. 0
ORIGINATOR [illegible]	DATE 5-28-97
CHECKED [illegible]	DATE 6/10/97
PROJECT PFSF	JOB NO. 1683-002
SUBJECT Storage Pad Analysis	SHEET NO. 42

8-cask Nodal Load Time History Assignment (cont'd)

Assignment for Casks 1 to 4 is not repeated here. The assignment used for 4-cask case applies. Only casks 5 to 8 are assigned here.

Node #	Comp #	TH #	arrival #	Scale factor
17	1	41	0	-0.25
17	2	42	0	-0.25
17	3	39	0	-1
23	1	47	0	-0.25
23	2	48	0	-0.25
23	3	45	0	-1
41	1	41	0	-0.25
41	2	42	0	-0.25
41	3	38	0	-1
45	1	41	0	-0.25
45	2	42	0	-0.25
45	3	40	0	-1
47	1	47	0	-0.25
47	2	48	0	-0.25
47	3	44	0	-1
51	1	47	0	-0.25
51	2	48	0	-0.25
51	3	46	0	-1
69	1	41	0	-0.25
69	2	42	0	-0.25
69	3	37	0	-1
75	1	47	0	-0.25
75	2	48	0	-0.25
75	3	43	0	-1

Node #	Comp #	TH #	arrival #	Scale factor
82	1	29	0	-0.25
82	2	30	0	-0.25
82	3	27	0	-1
88	1	35	0	-0.25
88	2	36	0	-0.25
88	3	33	0	-1
106	1	29	0	-0.25
106	2	30	0	-0.25
106	3	26	0	-1
110	1	29	0	-0.25
110	2	30	0	-0.25
110	3	28	0	-1
112	1	35	0	-0.25
112	2	36	0	-0.25
112	3	32	0	-1
116	1	35	0	-0.25
116	2	36	0	-0.25
116	3	34	0	-1
134	1	29	0	-0.25
134	2	30	0	-0.25
134	3	25	0	-1
140	1	35	0	-0.25
140	2	36	0	-0.25
140	3	31	0	-1

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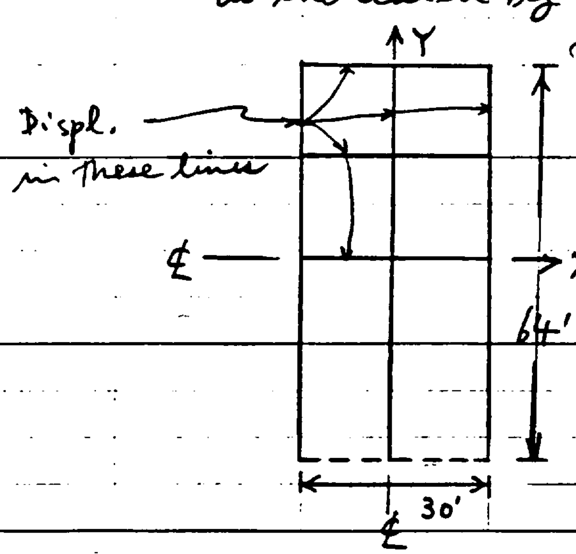
SUBJECT Storage Pad Analysis and Design			SHEET NO. 43

5.1.4 Dynamic Analyses Output Selection

The following response quantities were selected for output for all three cases of dynamic analyses

Displacements: Three components (u_x, u_y, u_z) of displacements for all nodes in the two long side edges of pad, the long center line, the short center line, the top short edge and one section in the short direction (x) between the top edge and short center line as indicated by the solid lines in the left figure.



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CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR [signature] DATE 6-10-97 CHECKED [signature] DATE 6/10/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

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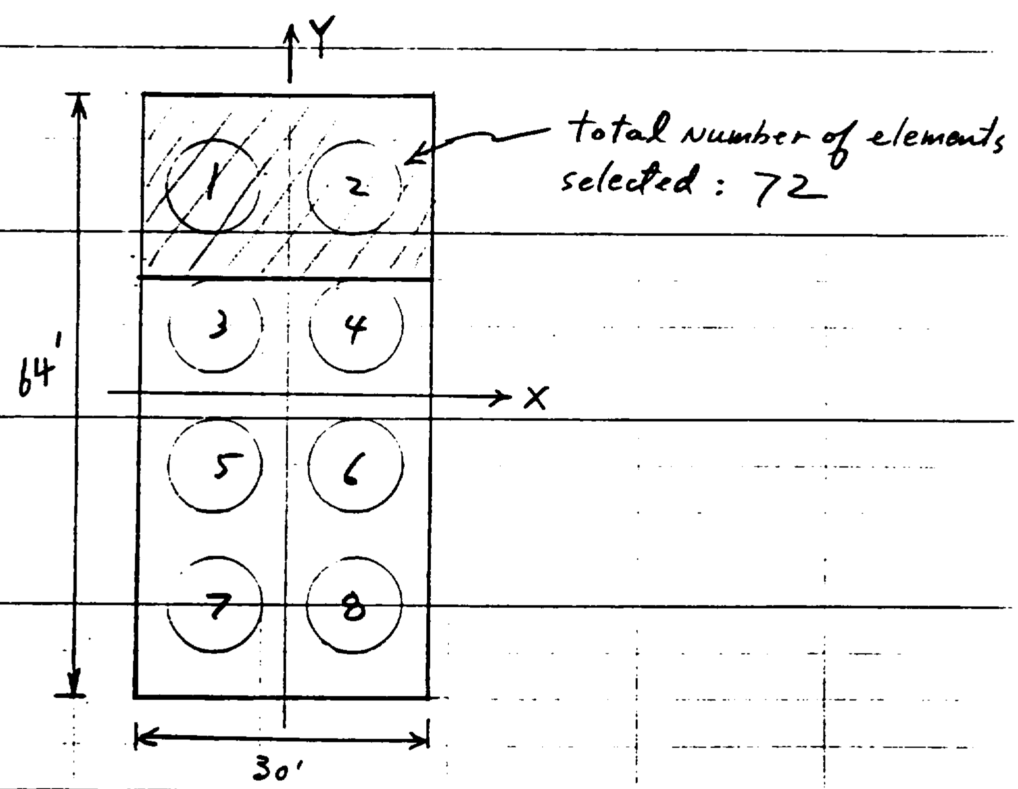
Dynamic output Selection (cont'd)

Pad stresses output Selection

Plate bending moments (M_{xx}, M_{yy}) and shell membrane forces (S_{xx}, S_{yy}) were selected for output. Plate elements numbered 193 to 264 were selected. These elements represent the pad from the edge of Casks Nos. 3 and 4 to the upper edge of the pad as shown in the following sketch:



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CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR msz DATE 6-10-97 CHECKED [illegible] DATE 6/10/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

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Dynamic output selection (cont'd)

Soil Spring force output Selection

Forces in vertical soil springs attached to Nodes numbered from 183 to 299 were selected for output. The vertical springs selected are located from the center line of casks 3 and 4 to the upper edge of the pad.

All selected response quantities were output in terms of maximum values printed in the output file and in terms of time history data files, which were used for plotting and post processing for the retrieval of concurrent values and shear force calculations.

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR MWB DATE 6-10-97 CHECKED KW DATE 6/10/97

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Dynamic Output Selection (Cont'd)

Shear Force Output

Since the plate element used in CECSAP does not output shear force values. The shear forces in the pad were calculated by moment gradient

CEC

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ORIGINATOR [signature] DATE 6-13-97 CHECKED [initials] DATE 6/13/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 47

5.1.5 Inputs and Outputs of Static and Dynamic Analyses

Complete input file listings are provided in Attachment A-2. To avoid lengthy listing, only partial output listings, The first and last four pages of all outputs are provided in Attachment A-3. The complete outputs are provided on computer diskettes.

The filenames used for the input and output files are as follows:

	Input filename	Output filename
Dead Load Analysis	D.INP	D.OUT
Live Load Analysis	LL.INP	LL.OUT
Dynamic Analysis (2 Casks)	2.INP	2.OUT
Dynamic Analysis (4 Casks)	4.INP	4.OUT
Dynamic Analysis (8 Casks)	8.INP	8.OUT

CEC **CALCULATION SHEET**

ORIGINATOR: [signature] DATE: 6-13-97 CALC. NO.: SC(P017)-1 REV. NO.: 0
CHECKED: [initials] DATE: 6/13/97
PROJECT: PFSF JOB NO.: 1083000
SUBJECT: Pad Analysis and Design SHEET NO.: 48

5.1.6. Static and Dynamic Analysis Results

Static Analysis Results

Maximum static Analysis results in Bending are tabulated in the following. The values were taken from Attachment A-4, which contains partial listing of results of Nodal displacements and element forces and bending moments.

Max. Bending Moments (kip-ft/ft)

			M_{yy}
Dead load			0
Live load:			
Load case 1		2 casks	-21.8
	2.	4 casks	-57.1
	3.	8 casks	-37.4
	4.	8 cask + Transporter	-45.6

~~M_{yy} values are used. However, The max. value of M_{yy} for 2 cask case is +52.3, which is generated by artificial soil tension under unloaded portions of Pad~~

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

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Therefore, the maximum negative value of 21.8 is picked instead. The maxima of M_{xx} (bending about y-axis) and M_{yy} (bending about x-axis) are listed in the following table, where the picked values are circled.

CECSAP OUTPUT FILE NAME=LL.OUT

**** MAXIMUM **** BENDING VALUES

LOAD CASE NO.=	ELEM.NO.	MXMAX	ELEM.NO.	MYMAX
1	150	3.73	133	52.31
2	258	4.75	73	22.34
3	6	3.59	0	0.00
4	260	27.22	133	29.68

**** MINIMUM **** BENDING VALUES

LOAD CASE NO.=	ELEM.NO.	MXMIN	ELEM.NO.	MYMIN
1	234	-8.71	229	-21.84
2	196	-12.85	169	-57.12
3	124	-11.36	97	-37.36
4	70	-14.73	205	-45.61

CALCULATION SHEET

CEC

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR msz DATE 6-13-97 CHECKED [illegible] DATE 6/13/97

PROJECT PFSF JOB NO. 1083-[illegible]

SUBJECT Pad Analysis and Design SHEET NO. 50

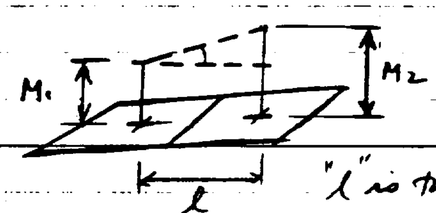
Max. static shear force

Dead Load case

The bending moment due to dead load is essentially zero, so, the shear force is also immaterial in dead load case.

Life Load Case

The shear force is calculated using the method of taking moment gradient between two neighboring elements



"l" is the distance between the centroids, where, the bending moments are calculated.

Shear force V is

$$V = (M_2 - M_1)/l$$

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-/ REV. NO. 0

ORIGINATOR [illegible signature] DATE 6-13-97 CHECKED [illegible initials] DATE 6/13/97

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Max. static shear forces (cont'd)

The shear forces of the four live load cases were obtained by calculating the moment gradients of Mxx and Myy. The calculated maximum shear force ~~values~~ are listed in the following table

CECSAP OUTPUT FILE NAME=LL.OUT
MAXMIMUM LIVE LOAD SHEAR..FOR MXX

2 casks → LOAD CASE NO.= 1

ELEM1	ELEM2	MAX.SHEAR
255	254	-2.518

4 Casks → LOAD CASE NO.= 2

ELEM1	ELEM2	MAX.SHEAR
195	194	-3.773

8 Casks → LOAD CASE NO.= 3

ELEM1	ELEM2	MAX.SHEAR
125	124	3.855

8 casks + transporter → LOAD CASE NO.= 4

ELEM1	ELEM2	MAX.SHEAR
129	128	-4.691

MAXMIMUM LIVE LOAD SHEAR..FOR MYY

2 Casks → LOAD CASE NO.= 1

ELEM1	ELEM2	MAX.SHEAR
217	205	-6.867

4 Casks → LOAD CASE NO.= 2

ELEM1	ELEM2	MAX.SHEAR
135	123	-8.358

8 Casks → LOAD CASE NO.= 3

ELEM1	ELEM2	MAX.SHEAR
25	13	-5.746

8 Casks and Transporter → LOAD CASE NO.= 4

ELEM1	ELEM2	MAX.SHEAR
217	205	-11.286

The circled ones are the selected maximum values.

The unit of the shear force is kip/ft.

CALCULATION SHEET

CEC

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR [illegible] DATE 6-13-97 CHECKED [illegible] DATE 6/13/97

PROJECT PFSF JOB NO. 1683-0000

SUBJECT Pad Analysis & Design SHEET NO. 52

5.1.6 Static and Dynamic Analysis Results (cont'd)

Dynamic Analysis Results

The maximum values of selected dynamic response quantities are listed in attachment A-5. The time history plots for all selected output quantities are attached in Attachment A-6

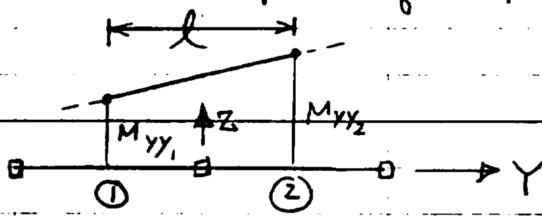
In the following sections, dynamic shear force calculation is presented. Maximum bending moments and total soil reaction forces are also presented below.

CALCULATION SHEET

CALC. NO. SC(PO17)-1		REV. NO. 0	
ORIGINATOR		DATE 6-10-97	CHECKED
DATE 6/13/97			
PROJECT	Private Fuel Storage Facility	JOB NO.	1083-000
SUBJECT	Storage Pad Analysis and Design	SHEET NO.	53

Shear Force Calculation

The shear force is calculated using moment gradient. For example, if m_{yy_1} and m_{yy_2} are



The bending moments per unit length about the x-axis for two neighboring elements 1 and 2. In CECSAP, the plate bending moments are defined at the centroid of the plate element, thus the shear force between the two elements is calculated by calculating the moment gradient as follows:

$$V = \frac{M_{yy_2} - M_{yy_1}}{l}$$

where

V : shear force per unit length in x direction (points out from the paper)

l : distance between two centroids of the two neighboring elements

M_{yy_1}, M_{yy_2} : Moments per unit length about the x-axis.

CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR MZ DATE 6-10-97 CHECKED KV DATE 6/13/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-002

SUBJECT Storage Pad Analysis and Design SHEET NO. 54

Shear Force Calculation For sections in X-direction

By Using moment gradients, the shear forces in 5 selected sections in the X-direction were calculated for the three dynamic cases. The 5 selection sections are indicated in the following sketch and designated by the beginning node numbers

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1		REV. NO. 0	
ORIGINATOR [illegible]	DATE 6-11-97	CHECKED [illegible]	DATE 6/13/97
PROJECT Private Fuel Storage Facility		JOB NO. 1083-000	
SUBJECT Storage Pad Analysis and Design		SHEET NO. 55	

Total Shear Force in Sections In X-Direction

The total shear forces in the pad were calculated at the five sections in X-direction. The node numbers along the four sections are

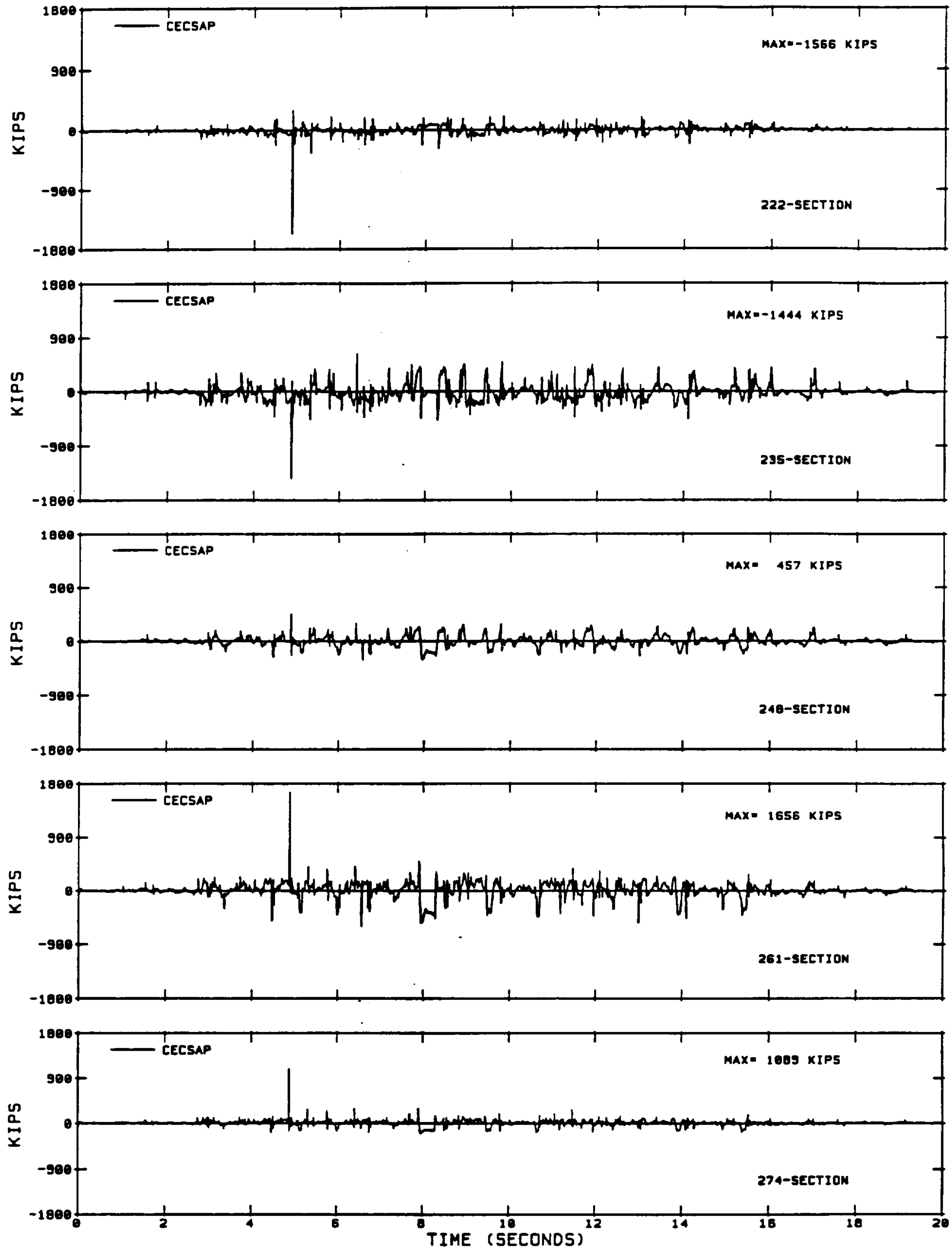
Section 1	222 → 234	13 nodes, 12 elements
Section 2	235 → 247	13 nodes, 12 elements
Section 3	248 → 260	13 nodes, 12 elements
Section 4	261 → 273	13 nodes, 12 elements
Section 5	274 → 286	13 nodes, 12 elements

Total shear forces at these five sections were calculated for the three dynamic cases and are listed in the following:

	Case 1 2 Casks	Case 2 4 Casks	Case 3 8 Casks
Section 1	1566 kips	378 kips	357 kips
2	1444	455	438
3	456	295	258
4	1656	482	416
5	1089	355	260

As shown in the above table, the 2-cask case generated the greatest shear force. The time history of the shear forces at the five sections for Case 1 is shown in the following page. The shear forces for each of the 12 elements of the five sections for all three dynamic cases are also included after the plot.

TOTAL SHEAR FORCE (ENTIRE X-SECTION)



CEC JOB NO. 1083-000
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CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 56

FILE: C:\JOB\STONEWEB\2\SHEARY.MAX

MAXIMUM DYNAMIC SHEAR FORCE (KIPS/FT) IN TRANSVERSE SECTIONS (2-CASK CASE)

GRADIENT OF MYY (BENDING ABOUT X-AXIS OR TRANVERSE AXIS)

SECTION 1 (293-SECTION)

1ST EL.	193-YY	194-YY	195-YY	196-YY	197-YY	198-YY	199-YY	200-YY	201-YY	202-YY	203-YY	204-YY
2ND EL.	205-YY	206-YY	207-YY	208-YY	209-YY	210-YY	211-YY	212-YY	213-YY	214-YY	215-YY	216-YY
MAXIMUM	12.11	9.85	12.65	14.69	13.15	10.36	7.82	6.91	8.37	9.28	10.93	12.54
@TIME	4.885	4.885	4.890	4.890	4.890	4.890	4.890	9.800	4.895	4.895	4.890	4.890
MINIMUM	-93.81	-84.05	-72.00	-60.86	-53.27	-51.19	-50.76	-49.46	-44.77	-33.79	-21.72	-23.99
@TIME	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.880	5.315

SECTION 2 (205-SECTION)

1ST EL.	205-YY	206-YY	207-YY	208-YY	209-YY	210-YY	211-YY	212-YY	213-YY	214-YY	215-YY	216-YY
2ND EL.	217-YY	218-YY	219-YY	220-YY	221-YY	222-YY	223-YY	224-YY	225-YY	226-YY	227-YY	228-YY
MAXIMUM	15.50	19.22	26.90	26.67	18.70	15.28	15.46	18.98	26.69	26.48	18.26	19.40
@TIME	6.405	6.405	6.405	6.405	6.405	6.405	6.405	6.405	6.405	6.405	6.405	4.890
MINIMUM	-154.26	-110.94	-52.79	-27.61	-37.25	-59.71	-91.67	-72.32	-24.38	-20.80	-34.43	-45.15
@TIME	4.870	4.875	4.875	4.875	4.875	4.875	4.870	4.870	4.875	4.880	5.315	5.315

← maximum shear between elements 205 and 217

SECTION 3 (217 SECTION)

1ST EL.	217-YY	218-YY	219-YY	220-YY	221-YY	222-YY	223-YY	224-YY	225-YY	226-YY	227-YY	228-YY
2ND EL.	229-YY	230-YY	231-YY	232-YY	233-YY	234-YY	235-YY	236-YY	237-YY	238-YY	239-YY	240-YY
MAXIMUM	21.13	20.70	20.15	19.13	17.45	15.75	14.25	12.66	11.25	10.69	10.45	10.50
@TIME	4.885	4.885	4.885	4.885	4.885	4.885	4.885	4.885	4.885	6.405	4.890	4.890
MINIMUM	-15.17	-14.17	-13.09	-11.68	-10.45	-9.91	-9.88	-10.31	-10.97	-10.83	-10.07	-9.38
@TIME	4.895	4.895	4.895	4.895	6.570	7.975	7.975	7.975	6.570	6.570	7.975	7.975

SECTION 4 (229-SECTION)

1ST EL.	229-YY	230-YY	231-YY	232-YY	233-YY	234-YY	235-YY	236-YY	237-YY	238-YY	239-YY	240-YY
2ND EL.	241-YY	242-YY	243-YY	244-YY	245-YY	246-YY	247-YY	248-YY	249-YY	250-YY	251-YY	252-YY
MAXIMUM	149.46	111.12	59.53	41.41	40.58	61.45	91.32	77.54	40.69	25.69	31.13	41.88
@TIME	4.875	4.875	4.875	4.880	4.875	4.875	4.870	4.870	4.875	4.880	7.905	5.315
MINIMUM	-16.24	-17.87	-26.53	-26.62	-17.88	-15.70	-15.67	-17.55	-26.37	-26.48	-17.77	-15.36
@TIME	7.945	7.945	6.565	6.565	6.565	7.945	7.975	6.565	6.565	6.565	6.565	7.975

SECTION 5 (241-SECTION)

1ST EL.	241-YY	242-YY	243-YY	244-YY	245-YY	246-YY	247-YY	248-YY	249-YY	250-YY	251-YY	252-YY
2ND EL.	253-YY	254-YY	255-YY	256-YY	257-YY	258-YY	259-YY	260-YY	261-YY	262-YY	263-YY	264-YY
MAXIMUM	64.04	56.67	47.06	42.28	39.79	37.15	36.49	35.31	31.42	27.36	24.64	22.02
@TIME	4.875	4.875	4.875	4.880	4.880	4.880	4.875	4.875	4.875	4.880	4.880	4.880
MINIMUM	-9.41	-8.04	-6.25	-6.32	-6.87	-7.20	-7.13	-6.62	-5.65	-6.57	-7.32	-9.07
@TIME	7.940	7.945	11.960	4.890	7.955	7.955	7.955	7.955	11.960	4.890	4.470	4.895

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SHEET NO. 57

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MAXIMUM DYNAMIC SHEAR FORCE (KIPS/FT) IN TRANSVERSE SECTIONS (4-CASK CASE)

GRADIENT OF MYY (BENDING ABOUT X-AXIS OR TRANVERSE AXIS)

SECTION 1

1STDATA	193-YY	194-YY	195-YY	196-YY	197-YY	198-YY	199-YY	200-YY	201-YY	202-YY	203-YY	204-YY
2NDDATA	205-YY	206-YY	207-YY	208-YY	209-YY	210-YY	211-YY	212-YY	213-YY	214-YY	215-YY	216-YY
MAXIMUM	19.33	16.85	21.11	19.64	12.58	15.49	16.45	15.70	18.20	18.64	15.78	14.16
@TIME	3.010	9.865	9.865	9.865	6.580	6.580	6.580	6.580	8.450	8.450	8.450	8.450
MINIMUM	-20.45	-16.47	-12.93	-13.09	-14.25	-13.48	-12.66	-12.43	-15.36	-19.52	-23.20	-25.88
@TIME	11.505	11.505	9.430	2.990	2.990	2.990	11.475	11.095	11.095	7.015	7.015	7.015

SECTION 2

1STDATA	205-YY	206-YY	207-YY	208-YY	209-YY	210-YY	211-YY	212-YY	213-YY	214-YY	215-YY	216-YY
2NDDATA	217-YY	218-YY	219-YY	220-YY	221-YY	222-YY	223-YY	224-YY	225-YY	226-YY	227-YY	228-YY
MAXIMUM	16.09	16.08	20.21	18.65	16.08	16.57	17.57	18.63	21.37	21.43	19.64	18.44
@TIME	11.965	11.495	11.495	11.495	8.445	6.580	6.580	8.450	8.450	8.450	8.450	8.450
MINIMUM	-42.33	-34.25	-23.36	-17.84	-28.99	-32.29	-32.06	-28.24	-17.56	-19.81	-30.80	-41.92
@TIME	11.505	11.505	11.505	2.990	2.990	2.990	11.475	11.475	11.475	11.095	11.095	7.015

SECTION 3

1STDATA	217-YY	218-YY	219-YY	220-YY	221-YY	222-YY	223-YY	224-YY	225-YY	226-YY	227-YY	228-YY
2NDDATA	229-YY	230-YY	231-YY	232-YY	233-YY	234-YY	235-YY	236-YY	237-YY	238-YY	239-YY	240-YY
MAXIMUM	13.61	11.89	11.35	10.80	9.80	10.20	11.23	12.01	13.72	15.73	16.98	17.97
@TIME	3.015	3.015	8.445	8.445	8.445	8.450	8.450	8.450	3.000	3.000	3.000	3.000
MINIMUM	-12.25	-11.47	-11.30	-10.83	-10.13	-9.57	-9.41	-9.51	-10.69	-11.21	-11.19	-11.09
@TIME	3.005	4.495	4.495	4.495	4.495	4.495	4.495	4.495	4.510	4.510	4.510	4.510

SECTION 4

1STDATA	229-YY	230-YY	231-YY	232-YY	233-YY	234-YY	235-YY	236-YY	237-YY	238-YY	239-YY	240-YY
2NDDATA	241-YY	242-YY	243-YY	244-YY	245-YY	246-YY	247-YY	248-YY	249-YY	250-YY	251-YY	252-YY
MAXIMUM	37.92	28.03	15.99	14.99	26.65	30.56	29.38	22.10	14.12	21.98	34.88	45.74
@TIME	11.505	11.505	4.895	2.990	2.990	2.990	11.475	11.475	7.915	11.095	7.015	7.015
MINIMUM	-17.72	-16.52	-18.79	-18.36	-15.30	-14.18	-14.05	-15.47	-20.18	-21.84	-16.39	-15.51
@TIME	3.005	4.495	4.495	4.495	4.495	4.495	4.495	4.500	6.745	6.745	4.500	4.500

SECTION 5

1STDATA	241-YY	242-YY	243-YY	244-YY	245-YY	246-YY	247-YY	248-YY	249-YY	250-YY	251-YY	252-YY
2NDDATA	253-YY	254-YY	255-YY	256-YY	257-YY	258-YY	259-YY	260-YY	261-YY	262-YY	263-YY	264-YY
MAXIMUM	15.36	13.05	11.77	14.20	15.12	14.57	13.12	12.47	13.55	15.05	16.63	17.28
@TIME	11.505	11.505	2.990	2.990	2.990	2.990	2.990	11.095	11.095	11.095	11.095	11.095
MINIMUM	-9.86	-8.53	-6.85	-6.22	-7.28	-8.45	-8.79	-8.23	-7.10	-8.50	-9.20	-10.27
@TIME	4.500	4.500	4.500	4.500	6.580	6.580	6.580	6.580	11.085	11.085	11.085	4.500

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MAXIMUM DYNAMIC SHEAR FORCE (KIPS/FT) IN TRANSVERSE SECTIONS (8-CASK CASE)
GRADIENT OF MYY (BENDING ABOUT X-AXIS OR TRANVERSE AXIS)

SECTION 1

1STDATA	193-YY	194-YY	195-YY	196-YY	197-YY	198-YY	199-YY	200-YY	201-YY	202-YY	203-YY	204-YY
2NDDATA	205-YY	206-YY	207-YY	208-YY	209-YY	210-YY	211-YY	212-YY	213-YY	214-YY	215-YY	216-YY
MAXIMUM	22.76	20.96	18.50	14.44	15.66	17.74	17.59	21.37	25.61	24.43	18.90	15.29
@TIME	9.415	9.415	9.415	9.415	13.340	13.340	13.340	13.335	13.335	13.335	13.335	13.335
MINIMUM	-26.71	-21.28	-13.43	-11.17	-10.88	-11.51	-10.99	-10.06	-13.13	-18.11	-20.73	-22.85
@TIME	9.405	9.405	9.405	13.350	2.980	2.980	2.980	9.395	16.325	16.325	16.325	16.325

SECTION 2

1STDATA	205-YY	206-YY	207-YY	208-YY	209-YY	210-YY	211-YY	212-YY	213-YY	214-YY	215-YY	216-YY
2NDDATA	217-YY	218-YY	219-YY	220-YY	221-YY	222-YY	223-YY	224-YY	225-YY	226-YY	227-YY	228-YY
MAXIMUM	18.82	17.21	17.89	20.91	20.46	18.45	14.35	13.54	19.92	21.98	16.32	19.04
@TIME	9.410	8.485	13.340	13.340	13.340	13.340	13.340	16.120	16.120	15.055	16.120	16.330
MINIMUM	-47.11	-37.23	-23.95	-22.00	-31.11	-30.90	-24.40	-21.97	-15.82	-27.45	-43.55	-55.03
@TIME	9.405	9.405	9.405	7.900	7.900	7.900	2.980	14.785	7.925	7.925	7.925	7.925

SECTION 3

1STDATA	217-YY	218-YY	219-YY	220-YY	221-YY	222-YY	223-YY	224-YY	225-YY	226-YY	227-YY	228-YY
2NDDATA	229-YY	230-YY	231-YY	232-YY	233-YY	234-YY	235-YY	236-YY	237-YY	238-YY	239-YY	240-YY
MAXIMUM	9.11	9.05	10.05	11.08	10.70	11.21	11.31	10.92	9.87	10.37	10.03	9.43
@TIME	14.185	8.490	13.345	13.345	13.345	13.340	13.340	13.340	13.340	16.120	16.120	16.120
MINIMUM	-9.46	-8.51	-8.84	-8.50	-7.95	-8.28	-8.83	-14.18	-18.84	-19.73	-17.21	-16.00
@TIME	7.940	7.940	7.935	7.935	7.930	7.930	15.905	15.890	15.890	15.890	15.890	15.905

SECTION 4

1STDATA	229-YY	230-YY	231-YY	232-YY	233-YY	234-YY	235-YY	236-YY	237-YY	238-YY	239-YY	240-YY
2NDDATA	241-YY	242-YY	243-YY	244-YY	245-YY	246-YY	247-YY	248-YY	249-YY	250-YY	251-YY	252-YY
MAXIMUM	44.87	33.58	17.52	18.34	29.01	30.44	26.29	25.33	17.14	15.50	26.41	38.26
@TIME	9.400	9.400	9.400	7.900	7.900	7.900	14.785	14.785	14.785	16.325	7.925	7.925
MINIMUM	-19.31	-14.96	-17.25	-17.27	-13.53	-12.00	-12.39	-19.47	-42.38	-45.05	-27.78	-20.36
@TIME	9.410	3.385	8.215	8.215	8.215	8.215	15.905	15.890	15.890	15.890	15.890	15.900

SECTION 5

1STDATA	241-YY	242-YY	243-YY	244-YY	245-YY	246-YY	247-YY	248-YY	249-YY	250-YY	251-YY	252-YY
2NDDATA	253-YY	254-YY	255-YY	256-YY	257-YY	258-YY	259-YY	260-YY	261-YY	262-YY	263-YY	264-YY
MAXIMUM	18.43	15.36	10.93	9.96	11.66	12.15	11.79	10.86	13.89	12.02	9.76	13.35
@TIME	9.405	9.405	9.405	13.350	13.350	13.350	13.350	13.350	15.890	15.890	16.325	16.325
MINIMUM	-11.55	-9.51	-6.74	-7.58	-7.71	-7.68	-8.07	-9.21	-9.63	-9.99	-10.14	-9.03
@TIME	9.415	9.415	15.905	13.340	13.340	13.340	15.900	15.900	15.900	15.900	15.900	15.900

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BY. [signature] DATE 6-17-97
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SHEET NO. 59

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

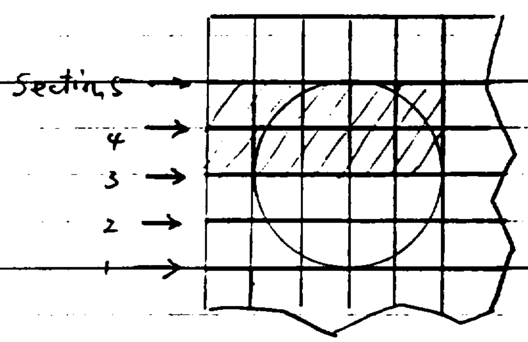
ORIGINATOR [illegible] DATE 6-17-97 CHECKED [illegible] DATE 6/17/97

PROJECT PFSF JOB NO. 1083-000

SUBJECT Pad Analysis SHEET NO. 60

Max. shear Force under Casks in Transverse Direction

	2 Casks	4 casks	8 casks @ section 4 (transverse)	
1.98	149.46	37.92	44.87	Dynamic Analysis
2.76	111.12	28.03	33.58	
2.76	59.53	18.79	17.52	
2.76	41.41	18.36	18.34	
2.76	40.58	26.65	29.01	
average	76.3	25.23	27.69 K/f	



Cask 1

section 4 has the greatest averaged shear force under the Cask.

The max. averaged shear force under cask is used as an estimate of the punching shear.

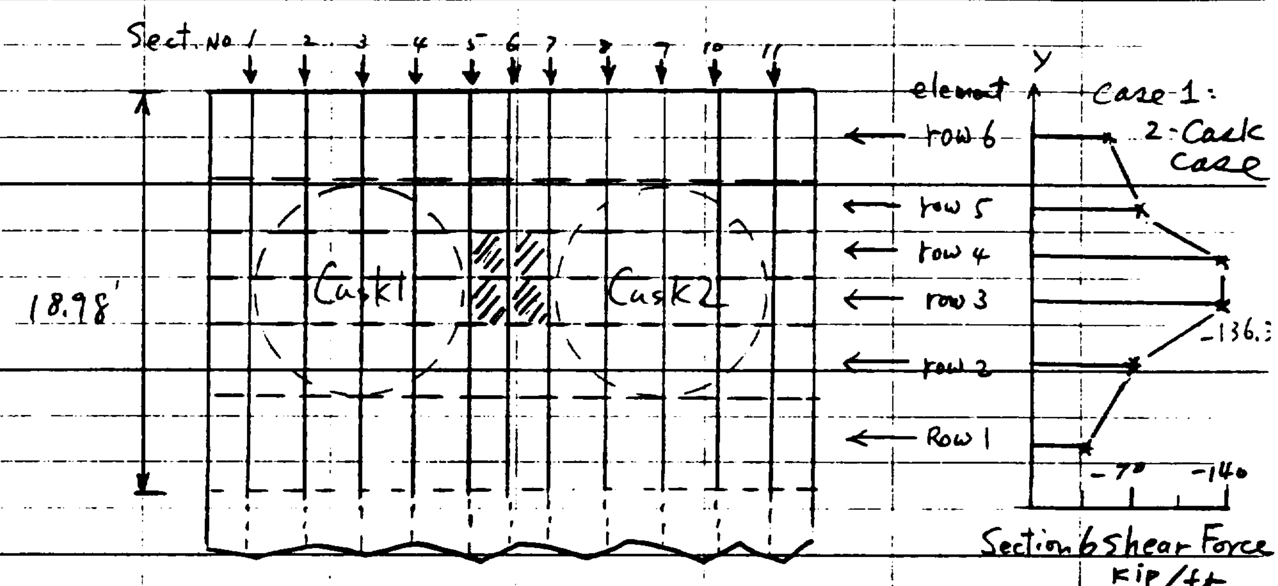
CALCULATION SHEET

CEC		CALC. NO. sc(P017)-1	REV. NO. 0
ORIGINATOR [signature]	DATE 6-11-97	CHECKED [signature]	DATE 6/17/97
PROJECT Private Fuel Storage Facility			JOB NO. 1083-000
SUBJECT Storage Pad Analysis and Design			SHEET NO. 61

Dynamic Analysis Results (cont'd)

Shear Force for Sections in Y-direction

The method of Moment gradient of M_{xx} (bending about the y-axis) is used to calculate the shear force. The 11 sections indicated in the following drawing are used.



The maxima and minima for the six rows of elements for each section are listed later in this calculation package. From the table, it is found that the maximum shear forces occur at Section 6 between the two casks (shaded above).

The shear forces in Section 6 is plotted on the right in the Figure above for the 2-cask case.

Dynamic Analysis Results (cont'd)

Summary of Maximum Shear Forces in Pad

By using the method of Moment Gradients described above, the shear forces in 11 selected longitudinal (y) and 5 selected transverse (x) section were calculated for each analysis time step. The maximum shear forces were presented in the following table

Maximum Shear Forces (kip/ft)

	Transeverse Sections		Longitudinal Sections	
2 Casks	#205 #217	154	#234 #235	136
4 Casks	#240 #252	46	#222 #223	36
8 Casks	#216 #228	55	#262 #263	66
2 Cask	154			136 ← max. of the 3 cases

Note: The two numbers to the left of a shear force value are the element numbers of the two plate elements between which the moment gradient was calculated

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR [illegible] DATE 6-11-97 CHECKED [illegible] DATE 6/13/97

PROJECT PFSF JOB NO. 1083-000

SUBJECT Storage Pad Analysis (Dynamic) 2 Casks SHEET NO. 63

Dynamic Analysis Results (cont'd)

~~Shear Force Calculation From Gradient of Mxx (2-Cask Case)~~

Plate El. No.	File No.	Col. no.	Mxx @ Time 4.880	Max Shear $x\ell = 2.37'$
205	207.str	3	-16.34	[17.99-(-16.34)]/2.37
206	207.str	7	+17.99	= 14.49
			@ 4.875 sec	
217	213.str	3	-148.1	+31.89 K/
218	213.str	7	-72.52	
			@ 4.875 sec	
229	19.str	3	-148.6	+32.88 K/
230	19.str	7	-70.69	
			@ 4.880 sec	
241	25.str	7	-7.05	+23.61 K/
242	25.str	3	+48.91	
			@ 4.880	$xL = 2.76'$
206	7.str	7	+17.99	(92.28-17.99)/2.76
207	8.str	3	+ 92.28	= +26.92 K/
			@ 4.880	
218	13.str	7	-41.07	+66.66 K/
219	14.str	3	+142.9	
			@ 4.880	
230	19.str	7	-30.23	+71.71 K/
231	20.str	3	+167.7	
242	25.str	7	+48.91	+41.95 K/
243	26.str	3	+164.7	

The procedure was programmed to process other elements in time history steps. Results are in the following pages. The above hand calculation is used to verify the program.

FILE: C:\JOB\STONEWEB\2\SHEARX.MAX

MAXIMUM DYNAMIC SHEAR FORCE (KIPS/FT) IN LONGITUDINAL SECTIONS (2-CASK CASE)
GRADIENT OF MXX (BENDING ABOUT Y-AXIS OR LONGITUDINAL AXIS)

SECTION 1

1STDATA	193-XX	205-XX	217-XX	229-XX	241-XX	253-XX
2NDDATA	194-XX	206-XX	218-XX	230-XX	242-XX	254-XX
MAXIMUM	13.78	14.49	31.89	32.87	23.61	28.63
@TIME	4.875	4.875	4.870	4.870	4.875	4.875
MINIMUM	-10.74	-11.93	-6.58	-8.04	-12.08	-14.13
@TIME	4.885	4.885	6.405	11.955	4.885	4.885

VERIFIED by hand calculation

SECTION 2

1STDATA	194-XX	206-XX	218-XX	230-XX	242-XX	254-XX
2NDDATA	195-XX	207-XX	219-XX	231-XX	243-XX	255-XX
MAXIMUM	17.49	26.92	66.66	71.71	41.95	25.23
@TIME	4.880	4.875	4.875	4.875	4.875	4.880
MINIMUM	-17.03	-21.07	-12.57	-12.23	-22.81	-22.55
@TIME	6.405	6.405	6.405	12.995	12.995	12.995

SECTION 3

1STDATA	195-XX	207-XX	219-XX	231-XX	243-XX	255-XX
2NDDATA	196-XX	208-XX	220-XX	232-XX	244-XX	256-XX
MAXIMUM	10.18	18.59	23.59	23.08	17.28	8.15
@TIME	4.875	4.875	4.875	4.875	4.875	4.875
MINIMUM	-5.31	-7.32	-9.45	-9.50	-7.79	-7.28
@TIME	6.415	6.415	5.315	5.315	13.005	13.005

SECTION 4

1STDATA	196-XX	208-XX	220-XX	232-XX	244-XX	256-XX
2NDDATA	197-XX	209-XX	221-XX	233-XX	245-XX	257-XX
MAXIMUM	21.57	25.29	16.14	17.94	29.95	30.67
@TIME	4.870	6.405	6.405	12.995	12.995	12.995
MINIMUM	-19.86	-19.01	-18.21	-19.09	-21.08	-22.76
@TIME	4.880	4.880	7.905	4.875	6.575	4.880

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SECTION 5

1STDATA	197-XX	209-XX	221-XX	233-XX	245-XX	257-XX
2NDDATA	198-XX	210-XX	222-XX	234-XX	246-XX	258-XX
MAXIMUM	10.93	11.59	10.59	11.94	14.84	20.49
@TIME	4.885	6.405	6.405	11.955	4.885	4.885
MINIMUM	-24.28	-47.86	-64.87	-69.32	-60.11	-43.12
@TIME	4.875	4.875	4.875	4.875	4.875	4.875

SECTION 6

1STDATA	198-XX	210-XX	222-XX	234-XX	246-XX	258-XX
2NDDATA	199-XX	211-XX	223-XX	235-XX	247-XX	259-XX
MAXIMUM	13.49	23.34	42.91	43.64	25.83	23.22
@TIME	4.885	5.315	5.315	5.315	5.315	4.885
MINIMUM	-37.82	-72.81	-135.81	-136.30	-79.97	-52.53
@TIME	4.875	4.875	4.870	4.870	4.875	4.875

Maximum between Elm. 234 & ELM. 235

SECTION 7

1STDATA	199-XX	211-XX	223-XX	235-XX	247-XX	259-XX
2NDDATA	200-XX	212-XX	224-XX	236-XX	248-XX	260-XX
MAXIMUM	13.28	17.60	23.43	24.32	20.30	20.05
@TIME	4.885	5.315	4.885	4.885	4.885	4.885
MINIMUM	-32.53	-35.65	-24.18	-23.59	-35.57	-39.24
@TIME	4.875	4.875	4.875	4.875	4.875	4.875

SECTION 8

1STDATA	200-XX	212-XX	224-XX	236-XX	248-XX	260-XX
2NDDATA	201-XX	213-XX	225-XX	237-XX	249-XX	261-XX

MAXIMUM	12.26	14.74	59.60	65.66	19.04	20.12
@TIME	6.415	4.885	4.870	4.870	6.575	13.005
MINIMUM	-20.98	-24.44	-15.34	-18.22	-29.03	-29.50
@TIME	4.870	6.405	6.405	4.880	6.565	6.565

SECTION 9

1STDATA	201-XX	213-XX	225-XX	237-XX	249-XX	261-XX
2NDDATA	202-XX	214-XX	226-XX	238-XX	250-XX	262-XX
MAXIMUM	10.58	22.90	30.65	31.34	24.96	14.42
@TIME	4.875	4.875	4.875	4.875	4.875	4.875
MINIMUM	-2.62	-5.29	-6.95	-6.93	-5.43	-5.72
@TIME	5.315	5.315	5.315	5.315	4.885	4.885

SECTION 10

1STDATA	202-XX	214-XX	226-XX	238-XX	250-XX	262-XX
2NDDATA	203-XX	215-XX	227-XX	239-XX	251-XX	263-XX
MAXIMUM	30.42	40.00	34.59	31.67	31.91	28.55
@TIME	4.875	4.875	4.875	4.875	4.875	4.875
MINIMUM	-8.50	-14.97	-23.05	-23.33	-19.62	-19.71
@TIME	7.905	7.905	5.315	5.315	4.885	4.890

SECTION 11

1STDATA	203-XX	215-XX	227-XX	239-XX	251-XX	263-XX
2NDDATA	204-XX	216-XX	228-XX	240-XX	252-XX	264-XX
MAXIMUM	14.31	13.96	13.92	15.37	15.47	21.34
@TIME	4.875	4.875	4.880	4.880	4.875	4.875
MINIMUM	-9.19	-12.94	-14.93	-16.84	-18.64	-19.76
@TIME	4.885	4.885	4.885	4.885	4.885	4.885

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MAXIMUM DYNAMIC SHEAR FORCE (KIPS/FT) IN LONGITUDINAL SECTIONS (4-CASK CASE)
GRADIENT OF MXX (BENDING ABOUT Y-AXIS OR LONGITUDINAL AXIS)

SECTION 1

1STDATA	193-XX	205-XX	217-XX	229-XX	241-XX	253-XX
2NDDATA	194-XX	206-XX	218-XX	230-XX	242-XX	254-XX
MAXIMUM	8.46	8.63	11.15	11.23	8.87	10.76
@TIME	4.925	4.925	4.925	8.280	8.280	8.280
MINIMUM	-8.16	-7.52	-7.93	-8.77	-9.01	-10.97
@TIME	9.865	11.485	2.995	2.995	2.995	9.890

SECTION 2

1STDATA	194-XX	206-XX	218-XX	230-XX	242-XX	254-XX
2NDDATA	195-XX	207-XX	219-XX	231-XX	243-XX	255-XX
MAXIMUM	15.58	20.28	25.40	24.14	16.63	16.21
@TIME	4.925	11.505	11.505	11.505	11.505	11.510
MINIMUM	-17.07	-16.99	-11.83	-12.83	-15.82	-16.22
@TIME	9.865	6.410	11.485	2.990	9.890	9.890

SECTION 3

1STDATA	195-XX	207-XX	219-XX	231-XX	243-XX	255-XX
2NDDATA	196-XX	208-XX	220-XX	232-XX	244-XX	256-XX
MAXIMUM	10.07	10.05	11.51	13.00	13.99	14.92
@TIME	4.925	14.825	11.510	11.510	11.510	11.510
MINIMUM	-9.53	-11.54	-14.94	-16.11	-14.91	-17.73
@TIME	14.165	2.990	2.990	2.990	11.480	11.485

SECTION 4

1STDATA	196-XX	208-XX	220-XX	232-XX	244-XX	256-XX
2NDDATA	197-XX	209-XX	221-XX	233-XX	245-XX	257-XX
MAXIMUM	18.36	18.14	15.33	15.70	20.50	21.16
@TIME	8.440	5.420	3.020	7.930	7.930	7.930
MINIMUM	-13.93	-17.38	-26.81	-24.68	-23.05	-22.43
@TIME	6.420	2.985	2.985	2.985	11.480	11.480

SECTION 5

1STDATA	197-XX	209-XX	221-XX	233-XX	245-XX	257-XX
2NDDATA	198-XX	210-XX	222-XX	234-XX	246-XX	258-XX
MAXIMUM	10.80	11.52	11.81	11.35	13.37	14.74
@TIME	9.865	3.015	3.015	7.930	6.760	6.760
MINIMUM	-14.92	-19.06	-25.51	-26.17	-21.46	-18.09
@TIME	6.575	11.475	11.475	11.475	11.475	11.480

SECTION 6

1STDATA	198-XX	210-XX	222-XX	234-XX	246-XX	258-XX
2NDDATA	199-XX	211-XX	223-XX	235-XX	247-XX	259-XX
MAXIMUM	10.85	16.70	36.22	35.87	18.09	16.61
@TIME	11.970	7.910	11.085	11.085	11.090	6.760
MINIMUM	-16.01	-16.26	-29.22	-29.73	-19.88	-15.96
@TIME	6.575	4.900	8.285	8.285	11.475	11.475

SECTION 7

1STDATA	199-XX	211-XX	223-XX	235-XX	247-XX	259-XX
2NDDATA	200-XX	212-XX	224-XX	236-XX	248-XX	260-XX
MAXIMUM	12.86	16.03	20.03	21.21	18.21	16.48
@TIME	11.970	7.910	2.990	2.990	7.910	2.995
MINIMUM	-11.74	-10.85	-11.81	-13.89	-14.35	-14.59
@TIME	11.255	11.255	11.260	11.260	11.260	11.260

SECTION 8

1STDATA	200-XX	212-XX	224-XX	236-XX	248-XX	260-XX
2NDDATA	201-XX	213-XX	225-XX	237-XX	249-XX	261-XX

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MAXIMUM	15.32	15.46	21.21	19.12	18.41	20.33
@TIME	2.980	11.485	11.475	11.485	2.995	2.995
MINIMUM	-22.49	-16.79	-12.42	-15.63	-21.28	-22.08
@TIME	8.445	9.540	11.260	11.260	6.745	11.965

SECTION 9

1STDATA	201-XX	213-XX	225-XX	237-XX	249-XX	261-XX
2NDDATA	202-XX	214-XX	226-XX	238-XX	250-XX	262-XX
MAXIMUM	9.42	12.11	15.02	15.39	13.51	14.58
@TIME	2.980	11.475	11.475	11.475	11.480	11.480
MINIMUM	-9.28	-10.54	-11.01	-11.66	-12.29	-12.96
@TIME	13.455	14.825	14.825	7.930	7.930	14.830

SECTION 10

1STDATA	202-XX	214-XX	226-XX	238-XX	250-XX	262-XX
2NDDATA	203-XX	215-XX	227-XX	239-XX	251-XX	263-XX
MAXIMUM	22.24	14.77	13.50	17.87	26.56	26.74
@TIME	8.450	6.420	11.475	11.475	6.745	6.745
MINIMUM	-13.33	-14.31	-16.85	-17.68	-15.66	-15.56
@TIME	14.050	14.050	14.050	7.920	6.755	6.760

SECTION 11

1STDATA	203-XX	215-XX	227-XX	239-XX	251-XX	263-XX
2NDDATA	204-XX	216-XX	228-XX	240-XX	252-XX	264-XX
MAXIMUM	10.33	10.11	8.72	10.80	11.43	13.83
@TIME	8.450	3.000	9.400	9.400	9.400	11.475
MINIMUM	-6.73	-7.02	-9.10	-9.67	-9.16	-11.41
@TIME	6.760	14.055	7.910	6.760	6.760	6.435

EC JOB NO. 1083-000
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FILE: C:\JOB\STONEWEB\8\SHEARX.MAX

MAXIMUM DYNAMIC SHEAR FORCE (KIPS/FT) IN LONGITUDINAL SECTIONS (8-CASK CASE)
GRADIENT OF MXX (BENDING ABOUT Y-AXIS OR LONGITUDINAL AXIS)

SECTION 1

1STDATA	193-XX	205-XX	217-XX	229-XX	241-XX	253-XX
2NDDATA	194-XX	206-XX	218-XX	230-XX	242-XX	254-XX
MAXIMUM	11.78	11.48	12.50	12.21	10.73	11.44
@TIME	6.610	6.610	6.610	6.610	6.610	5.245
MINIMUM	-13.70	-11.73	-10.17	-9.11	-8.99	-9.62
@TIME	13.345	13.345	13.345	7.910	7.910	7.910

SECTION 2

1STDATA	194-XX	206-XX	218-XX	230-XX	242-XX	254-XX
2NDDATA	195-XX	207-XX	219-XX	231-XX	243-XX	255-XX
MAXIMUM	19.28	19.51	20.91	20.43	18.17	16.43
@TIME	6.605	6.605	6.605	6.605	6.610	6.610
MINIMUM	-21.71	-23.18	-18.42	-13.58	-17.20	-17.58
@TIME	13.345	13.345	13.345	13.345	7.955	7.955

SECTION 3

1STDATA	195-XX	207-XX	219-XX	231-XX	243-XX	255-XX
2NDDATA	196-XX	208-XX	220-XX	232-XX	244-XX	256-XX
MAXIMUM	16.59	17.45	17.61	17.55	18.75	21.39
@TIME	7.935	7.935	7.935	7.935	7.940	7.940
MINIMUM	-15.92	-13.86	-13.53	-13.49	-12.34	-13.77
@TIME	13.340	13.345	13.345	7.900	13.350	13.350

SECTION 4

1STDATA	196-XX	208-XX	220-XX	232-XX	244-XX	256-XX
2NDDATA	197-XX	209-XX	221-XX	233-XX	245-XX	257-XX
MAXIMUM	20.03	19.57	19.59	23.07	26.55	27.32
@TIME	7.930	13.305	7.935	7.935	7.935	7.935
MINIMUM	-16.66	-23.12	-31.57	-30.24	-19.04	-15.05
@TIME	7.900	7.900	7.900	7.900	7.900	15.895

SECTION 5

1STDATA	197-XX	209-XX	221-XX	233-XX	245-XX	257-XX
2NDDATA	198-XX	210-XX	222-XX	234-XX	246-XX	258-XX
MAXIMUM	16.96	17.77	18.37	18.21	17.55	19.28
@TIME	7.930	7.930	7.930	7.930	7.935	7.935
MINIMUM	-23.18	-15.01	-15.08	-14.81	-14.90	-20.74
@TIME	13.335	9.405	14.785	14.785	15.895	15.895

SECTION 6

1STDATA	198-XX	210-XX	222-XX	234-XX	246-XX	258-XX
2NDDATA	199-XX	211-XX	223-XX	235-XX	247-XX	259-XX
MAXIMUM	12.18	17.79	40.14	40.28	18.02	14.72
@TIME	7.925	7.900	7.900	7.900	7.900	7.930
MINIMUM	-24.48	-16.67	-32.27	-31.69	-21.13	-26.15
@TIME	13.335	15.060	15.060	15.060	15.890	15.890

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SECTION 7

1STDATA	199-XX	211-XX	223-XX	235-XX	247-XX	259-XX
2NDDATA	200-XX	212-XX	224-XX	236-XX	248-XX	260-XX
MAXIMUM	12.46	15.93	18.86	18.99	16.23	10.63
@TIME	13.345	7.900	2.980	7.900	7.900	7.930
MINIMUM	-13.76	-13.65	-13.39	-23.45	-32.95	-40.91
@TIME	6.610	6.610	15.890	15.890	15.890	15.890

SECTION 8

1STDATA	200-XX	212-XX	224-XX	236-XX	248-XX	260-XX
2NDDATA	201-XX	213-XX	225-XX	237-XX	249-XX	261-XX

MAXIMUM	17.14	18.42	22.84	22.74	17.57	15.32
@TIME	13.340	13.345	14.785	14.785	2.985	13.350
MINIMUM	-20.67	-21.07	-16.45	-25.43	-51.23	-55.65
@TIME	6.610	15.660	7.935	15.890	15.890	15.890

SECTION 9

1STDATA	201-XX	213-XX	225-XX	237-XX	249-XX	261-XX
2NDDATA	202-XX	214-XX	226-XX	238-XX	250-XX	262-XX
MAXIMUM	17.25	13.21	14.10	14.37	12.98	12.54
@TIME	13.335	13.340	13.345	13.345	13.345	2.990
MINIMUM	-17.48	-18.03	-18.24	-18.21	-17.94	-17.57
@TIME	7.930	7.935	7.935	7.935	7.935	7.935

SECTION 10

1STDATA	202-XX	214-XX	226-XX	238-XX	250-XX	262-XX
2NDDATA	203-XX	215-XX	227-XX	239-XX	251-XX	263-XX
MAXIMUM	23.91	19.31	21.08	38.63	62.83	66.22
@TIME	13.335	15.055	15.890	15.890	15.890	15.890
MINIMUM	-22.10	-24.32	-29.39	-27.34	-20.88	-16.76
@TIME	9.420	7.930	7.925	7.930	7.930	3.020

SECTION 11

1STDATA	203-XX	215-XX	227-XX	239-XX	251-XX	263-XX
2NDDATA	204-XX	216-XX	228-XX	240-XX	252-XX	264-XX
MAXIMUM	12.82	12.35	15.93	22.96	28.17	33.40
@TIME	13.335	13.335	15.890	15.890	15.890	15.890
MINIMUM	-13.58	-13.67	-17.43	-18.13	-16.74	-19.81
@TIME	7.925	7.930	7.925	7.930	7.930	7.930

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CEC **CALCULATION SHEET**

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR [signature] DATE 6-5-97 CHECKED [initials] DATE 6/10/97

PROJECT PFSF JOB NO. 1083-000

SUBJECT Pad Dynamic Analysis SHEET NO. 70

Maximum Dynamic Response

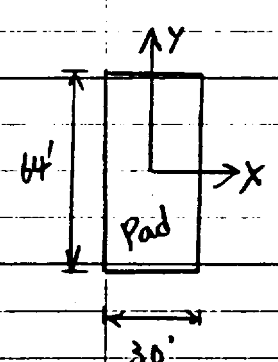
By examining the maximum values in attachment A-3 and time history plots in attachment A-4, the maximum response was found to occur in 2-cask case @ time = 4.88 seconds:

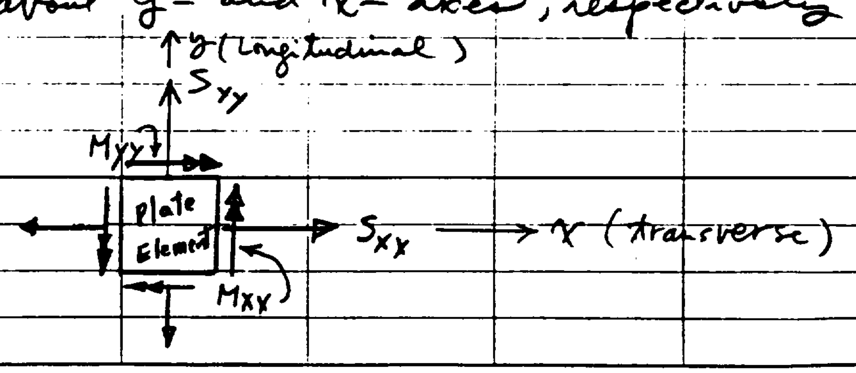
Elem. No	S_{xx} (KIP/ft)	M_{xx} (KIP-ft/ft)	S_{yy} (KIP/ft)	M_{yy} (KIP-ft/ft)	
217	−6.06	−109.2	23.04	−695.0	← Local max.
218	38.89	−41.07	−4.44	−571.3	
219	19.27	142.9	−12.42	−408.8	
220	−2.08	208.0	−8.74	−311.4	
221	−23.67	171.9	−15.79	−303.5	
222	12.83	18.16	−14.80	−353.4	
223	−13.12	−242.7	−22.97	−419.8	
224	23.85	−300.0	−19.34	−398.6	
225	0.99	−203.0	−13.52	−295.9	
226	−20.30	−118.4	−9.31	−201.1	
227	−38.48	−22.92	−29.14	−131.9	
228	6.31	9.12	−57.86	−92.33	
				ave = 344.3 k-f/f	

2-cask case @ time = 4.880 seconds

Note: S_{xx}, S_{yy}: in-plane membrane forces in the x- and y-directions, respectively

M_{xx}, M_{yy}: bending moments per unit length about y- and x-axes, respectively





CEC

CALCULATION SHEET

CALC. NO. SC(POIN)-1 REV. NO. 0

ORIGINATOR [illegible] DATE 6-5-97 CHECKED [illegible] DATE 6/17/97

PROJECT PFSF JOB NO. 1083-000

SUBJECT Pad Dynamic Analysis SHEET NO. 71

Dynamic Analysis Results (cont'd)

Average max. bending moments in transverse section, M_{yy} (K-ft/ft)

(Section NO. 4)

Plate Element		4 casks	8 casks
Length	No.	Max. M (K-ft/ft)	max. M (K-ft/ft)
1.98	217	161.6	173.1
2.76	218	123.9	132.4
2.76	219	91.89	78.25
2.76	220	111.7	83.17
2.76	221	142.6	117.3
1.98	222	147.7	122.1
1.98	223	126.5	108.5
2.76	224	116.3	106.8
2.76	225	107.4	100.7
2.76	226	132.1	109.8
2.76	227	166.0	116.6
1.98	228	191.0	145.0
average →		132.6	114.0

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR [illegible] DATE 6-5-97 CHECKED [illegible] DATE 6/17/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 72

Total Maximum Horizontal Soil Reactions of Dynamic Analyses

Maximum total shear forces between Pad and soil were calculated by the following equation

$$F_x = K_{s,x} * d_{max,x}$$

where F_x is the shear force in kips in the x-direction

K_{s_x} is the total shear stiffness in x-direction

$d_{max,x}$ = averaged maximum displacement of pad in x-direction

The equation was also applied to y-shear force calculation with appropriate values associated with motions in y direction.

		K_{s_x} (k/")	d_x (")	F_x (k)
x-direction	2 Casks	6991	0.104	727k
	4 Casks	6991	0.13	909k
	8 Casks	6991	0.29	2027k ←
		$K_{s,y}$ (k/")	d_y (")	F_y
y-direction	2 casks	6641	0.10	664k
	4 Casks	6641	0.18	1195k
	8 Casks	6641	0.20	1328k ←

Note: dx and dy values are taken from the Maximum values in attachment A-3.

CEC **CALCULATION SHEET**

CALC. NO. SC(PO17)-1 REV. NO. 0

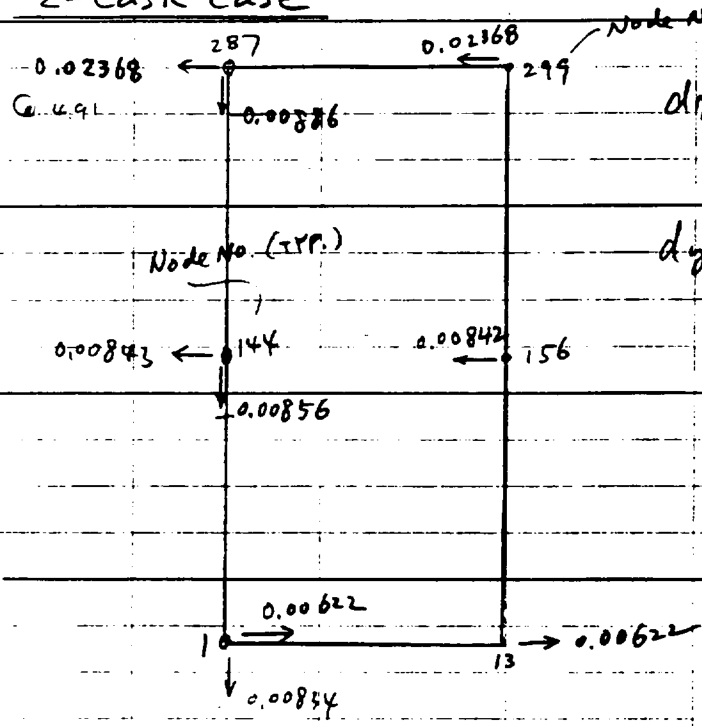
ORIGINATOR [signature] DATE 6-5-97 CHECKED [initials] DATE 6/17/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 73

Eestimation of Pad Averaged Displacements (Dynamic)

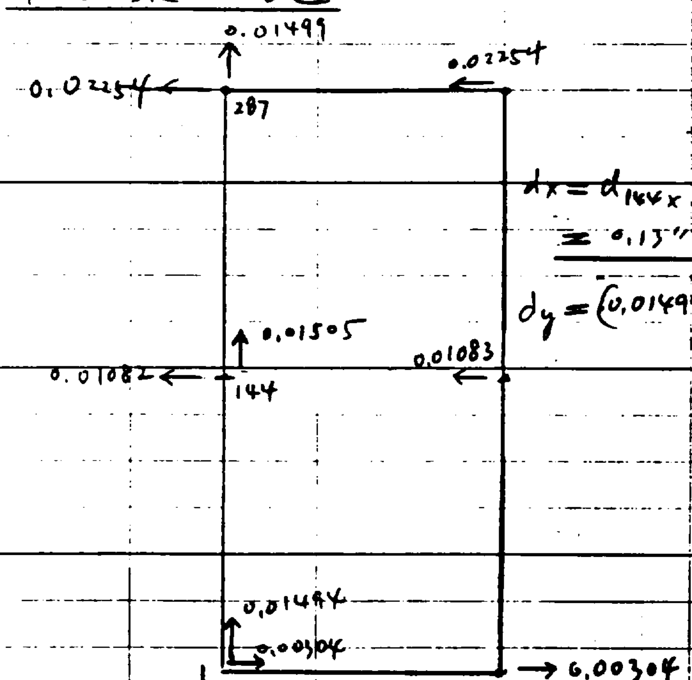
2-Cask Case



$dx = (-0.02368 - 0.00843 + 0.00622)/3 = -0.00863$
$= \underline{-0.104''}$

$dy = (0.00886 + 0.00856 + 0.00854)/3$
$= 0.00859 = \underline{0.103''}$

4-Cask Case



$dx = d_{144x} = \underline{0.13''}$ (Note: dx's are not concurrent, so take the center value as the average)

$dy = (0.01499 + 0.01505 + 0.01494)/3 \times 12 = 0.0150' = \underline{0.18''}$

CALCULATION SHEET

CEC

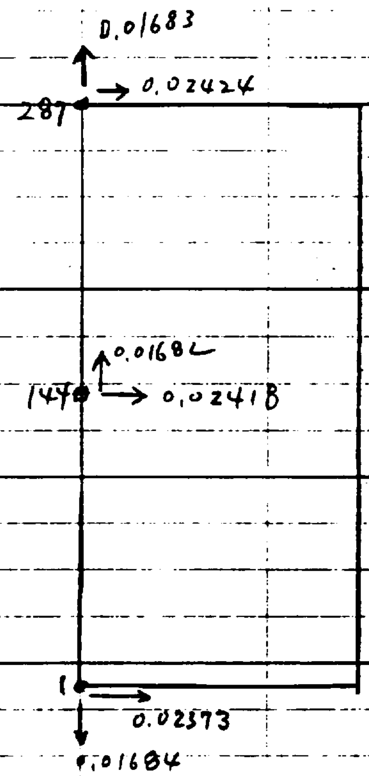
CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR msj DATE 6-5-97 CHECKED [illegible] DATE 6/17/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 74

8-Cask Case



$dx = (0.02373 + 0.02418 + 0.02424)/3 = 0.0241'$

$= 0.289''$

$dy = (0.01683 + 0.01682)/2 = 0.0168$

$= 0.202''$

The displacements used here were extracted from response time history plots in Attachment A-6.

CEC CALCULATION SHEET

CALC. NO. 54(P017)-1 REV. NO. 0

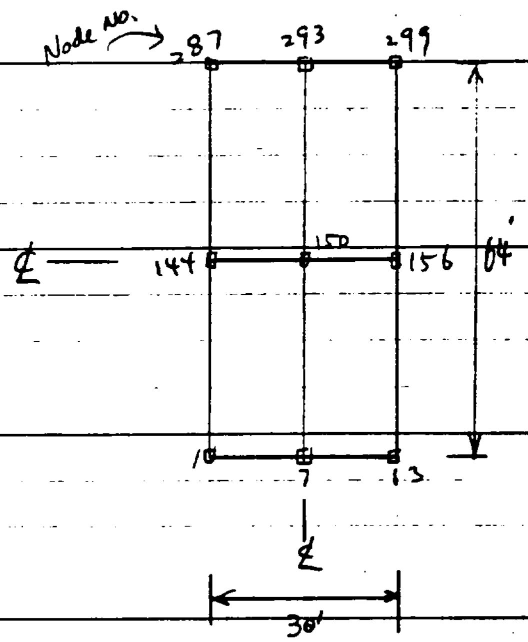
ORIGINATOR [signature] DATE 6-5-97 CHECKED [initials] DATE 6/17/97

PROJECT PFSF JOB NO. 1083-002

SUBJECT Storage Pad Analysis SHEET NO. 75

Dynamic Analysis Results

Total Vertical Soil Pressure was estimated by multiplying the averaged vertical displacement and total vertical soil stiffness, which is 116148 K/ft.



	Max. Displ. (vertical) (ft)		
Node No.	2 Casks	4 Casks	8 Casks
1	-0.00711	-0.00742**	0.03139
7	-0.00455	-0.00360	0.01733
13	-0.00697	-0.00786	0.04200
144	0.01230	0.01082	0.03869
150	0.00532	0.00742	0.01106
156	0.00681	0.01832	0.04559
287	0.05525	0.03156	0.03410
293	0.03314	0.02408	0.01831
299	0.02391	0.03466	0.04046
Average*	0.01726	0.01619	0.03099
Total Force	2005 K	1881 K	3600 K

Note: The displacement values were taken from maximum value listings in Attachment A-5

* Averages were taken by ignoring sign for conservatism

** positive displacements imply downward movements.

Maximum Soil Pressure (Static and Dynamic Analysis)

Dead load Analysis $= (20\ k/f/f^2) \times \delta_{z\,max}$

$\delta_{z\,max}$: max. vertical displ. = 0.0225'

Thus max. soil pressure $P = 0.45\ k/f^2$

Live Load analysis

Similar equation was used

	$\delta_{z\,max}$		P_{max}
2 casks	0.06530'	@ Node 294	1.31 ksf
4 Casks	0.08254'	@ Node 289	1.65 ksf
8 Casks	0.07842'	@ Node 147	1.57 ksf
8 casks + transporter	0.1525'	@ Node 287	3.05 ksf

Dynamic Load Analysis

$P = 60.5\ k/f/f^2 * \delta_{z\,max}$

	$\delta_{z,max}$		P_{max}
2 casks	0.05525	@ Node 287	3.34 Ksf
4 Casks	0.03466'	@ Node 299	2.10 Ksf
8 Casks	0.04625'	@ Node 117	2.80 Ksf

CEC

CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR mg DATE 6-17-97 CHECKED w DATE 6/17/97

PROJECT PFSF JOB NO. 1083-000

SUBJECT Pad Analysis and Design SHEET NO. 77

Summary of CECSAP Analysis Results

Static Analysis Results				
		Max. Moment (K-ft/ft)	Max. Shear (K/ft)	Max. Soil Pressure (ksf)
Dead Load		0	0	0.45
Live Load	2 Casks	21.8	6.9	1.31
	4 Casks	57.1	8.4	1.65
	8 Casks	37.4	5.7	1.57
	8 casks and Transporter	45.6	11.3	3.05

Dynamic Analysis Results						
		Max. Moment (kip-ft/ft)	Max. Shear (kip/ft)	Max. Soil Pressure (ksf)	Max. total Horizontal Soil Reaction (kips)	
					Longit.	Transv.
Earthquake Load	2 casks	344.3	76.3	3.34	727	664
	4 Casks	132.6	25.2	2.70	1195	909
	8 Casks	114.0	27.7	2.80	1328	2027

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR DH DATE 6/6/97 CHECKED [initials] DATE 6/17/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 78

5.2 DYNAMIC ANALYSIS USING SASSI MODEL

THIS SECTION DOCUMENTS A SASSI DYNAMIC ANALYSIS OF THE PAD. THIS ANALYSIS WAS PERFORMED AS A CHECK OF THE CEC-SAP ANALYSIS.

THE ANALYSIS WAS PERFORMED FOR ONE LOAD CASE, CONSISTING OF A SINGLE VERTICAL FORCE, APPLIED TO QUADRANT 2 OF CASK 1. THE 2 CASK CONFIGURATION WAS USED, WITH A FRICTION COEFFICIENT OF 0.8.

RESULTS IN THE FORM OF VERTICAL DISPLACEMENTS AND BENDING MOMENTS IN THE PAD WILL BE CALCULATED AND COMPARED TO CEC-SAP RESULTS.

CEC	**CALCULATION SHEET**	CALC. NO. SC(P017)-1	REV. NO. 0
ORIGINATOR M. Tsay	DATE 5/22/97	CHECKED DH	DATE 6/2/97
PROJECT Private Fuel Storage Facility			JOB NO. 1083-000
SUBJECT Storage Pad Analysis and Design			SHEET NO. 79

5.2.1 SASSI MODEL

From dynamic soil parameters for SASSI model, the average strain-compatible shear wave velocity for the first 6 layers, $V_s = (637+520+469+353+327+280)/6$

$= 431$ fps

Applying $f_{max} = V_s / 5 H_{max} = 431 / 5 \times 3.98 = 21.66$ cps

where $H_{max} = 3.98'$ is the max. FE model dimension Say 22 cps

For $V_s = 1809$ fps, $H_{max} = V_s / 5 f_{max} = 1809 / 5 \times 22 = 16$ ft use 15

$V_s = 1861$, $H_{max} = V_s / 5 f_{max} = 1861 / 5 \times 22 = 16.9$ ft. use 15

$V_s = 2080$, $H_{max} = 2080 / 5 \times 22 = 18.9$ ft use 20'

$V_s = 2440$, $H_{max} = 2440 / 5 \times 22 = 22.2$ ft use 20'

$V_s = 637$, $H_{max} = 637 / 5 \times 22 = 5.79'$ use 5'

$V_s = 520$, $H_{max} = 520 / 5 \times 22 = 4.73'$ use 5'

$V_s = 469$, $H_{max} = 469 / 5 \times 22 = 4.26'$ use 2.5'

$V_s = 353$, $H_{max} = 353 / 5 \times 22 = 3.2'$ use 2.5'

$V_s = 327$ fps $H_{max} = 327/5 \times 22 = 2.97'$ use $2.5'$

$V_s = 280$ fps $H_{max} = 280/5 \times 22 = 2.54'$ use $2.5'$

The soil layers to be used in SITE module for SASSI will be:

$V_s = 637$ fps, $H = 5'$; 1 layer @ 5' ← (MAKE 2' THICK BECAUSE THE PAD IS 3' THICK)

$V_s = 520$ fps. $H = 5'$; 1 layer @ 5'

$V_s = 469$ fps, $H = 5'$; 2 layers @ 2.5'

$V_s = 353$ fps, $H = 5'$; 2 layers @ 2.5'

$V_s = 327$ fps, $H = 5'$; 2 layers @ 2.5'

$V_s = 280$ fps, $H = 5'$; 2 layers @ 2.5'

$V_s = 1809$ fps, $H = 30'$; 2 layers @ 15'

$V_s = 1861$ fps, $H = 60'$; 4 layers @ 15'

$V_s = 2080$ fps, $H = 180'$; 9 layers @ 20'

$V_s = 2440$ fps, $H = 300'$; 15 layers @ 20'

CALCULATION SHEET

CEC

CALC. NO. SC(0017)-1		REV. NO.	0
ORIGINATOR	M. Tsay	DATE	5/20/97
CHECKED	DH	DATE	6/2/97
PROJECT	Private Fuel Storage Facility	JOB NO.	1083-000
SUBJECT	Storage Pad Analysis and Design	SHEET NO.	81

FIG. 5.2.1-1

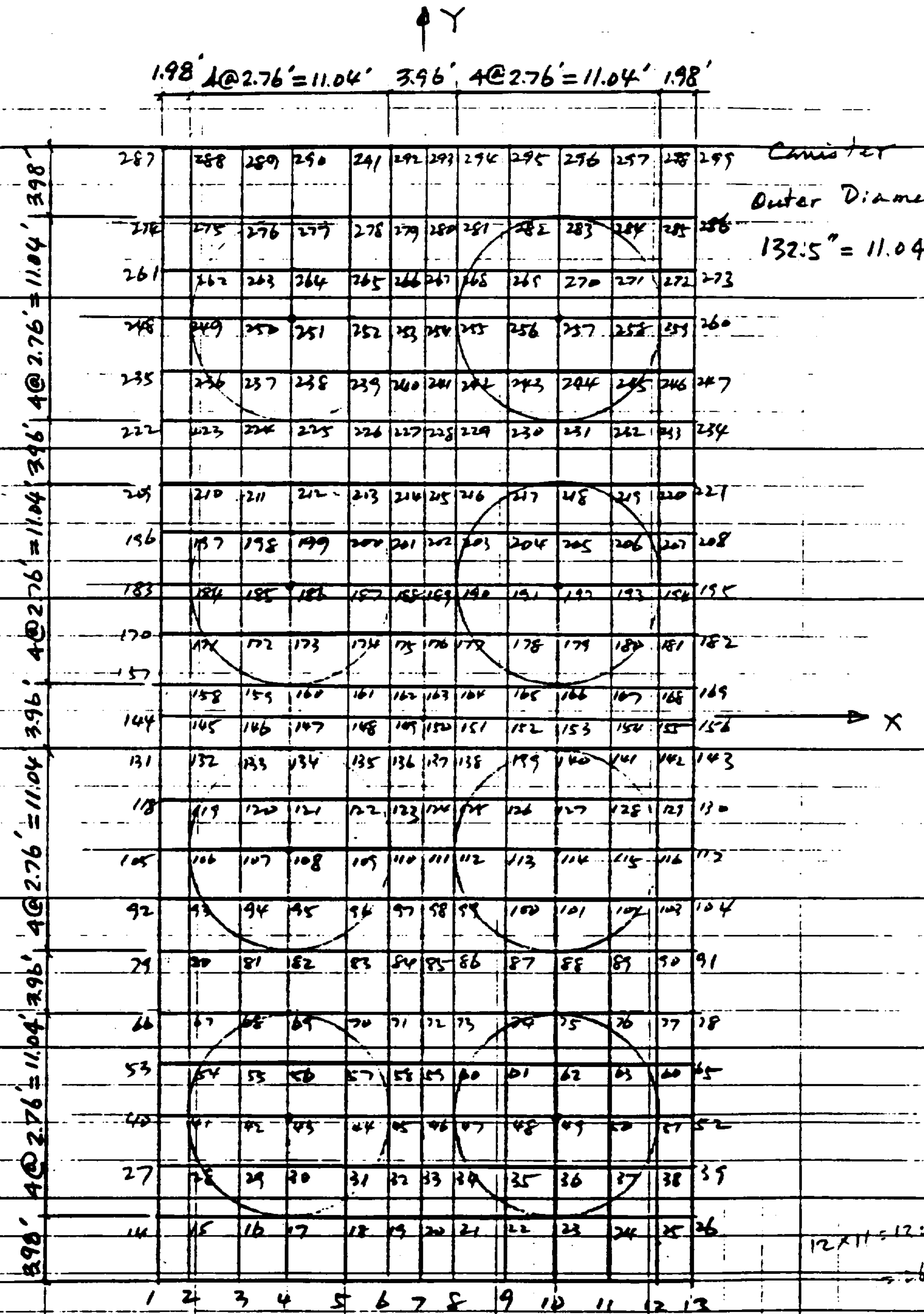
~~PLATE~~

NODES

PUT BACK

NODES

~~EL. 0.0'~~



Canister Outer Diameter

132.5" = 11.04'

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 5/20/97 CHECKED DH DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 82

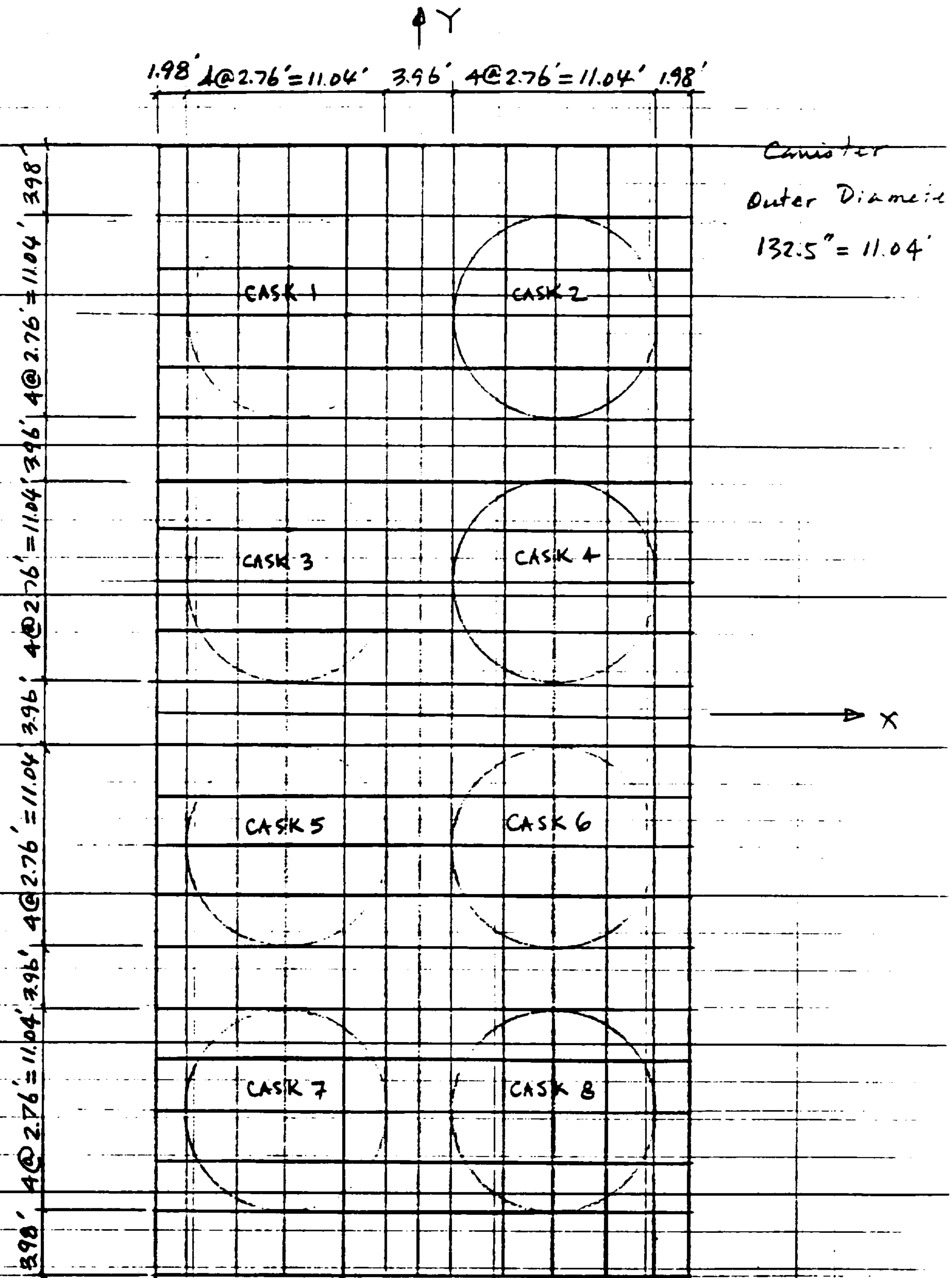


FIG. 5.2.1-2

CALCULATION SHEET

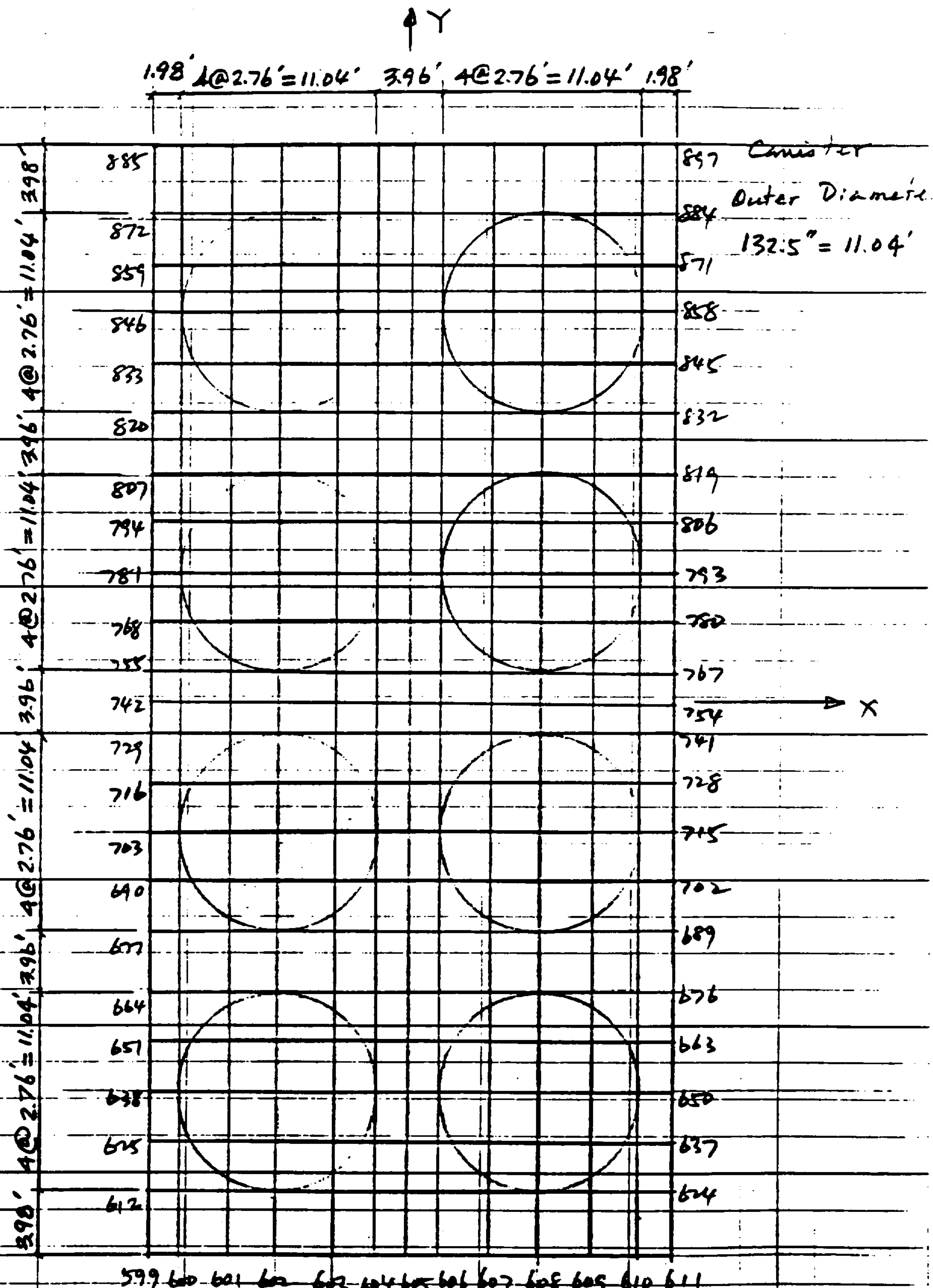
ORIGINATOR	M. Tsau	DATE	5/20/97
CALC. NO.	SC(PO17)-1	REV. NO.	0
CHECKED	DF	DATE	6/2/97
PROJECT	Private Fuel Storage Facility	JOB NO.	1083-000
SUBJECT	Storage Pad Analysis and Design	SHEET NO.	83

FIG. 5.2.1-3

BRICK NODES

EXCAVATE NODES

EL. 0.0



CALCULATION SHEET

ORIGINATOR m Tsay DATE 5/20/97 CALC. NO. SC(PO17)-1 REV. NO. 0

CHECKED DH DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

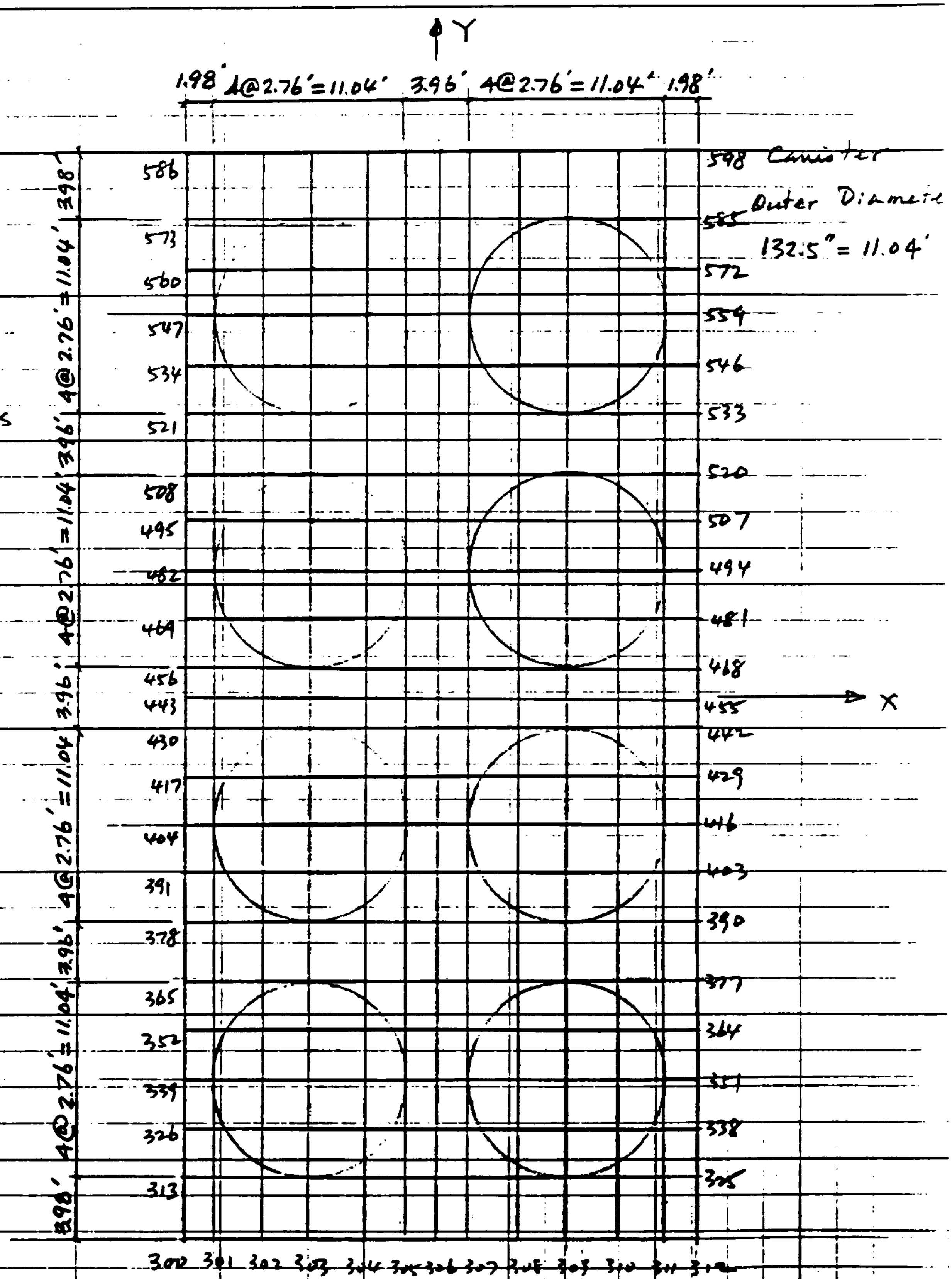
SUBJECT Storage Pad Analysis and Design SHEET NO. 84

FIG. 5.2.1-4

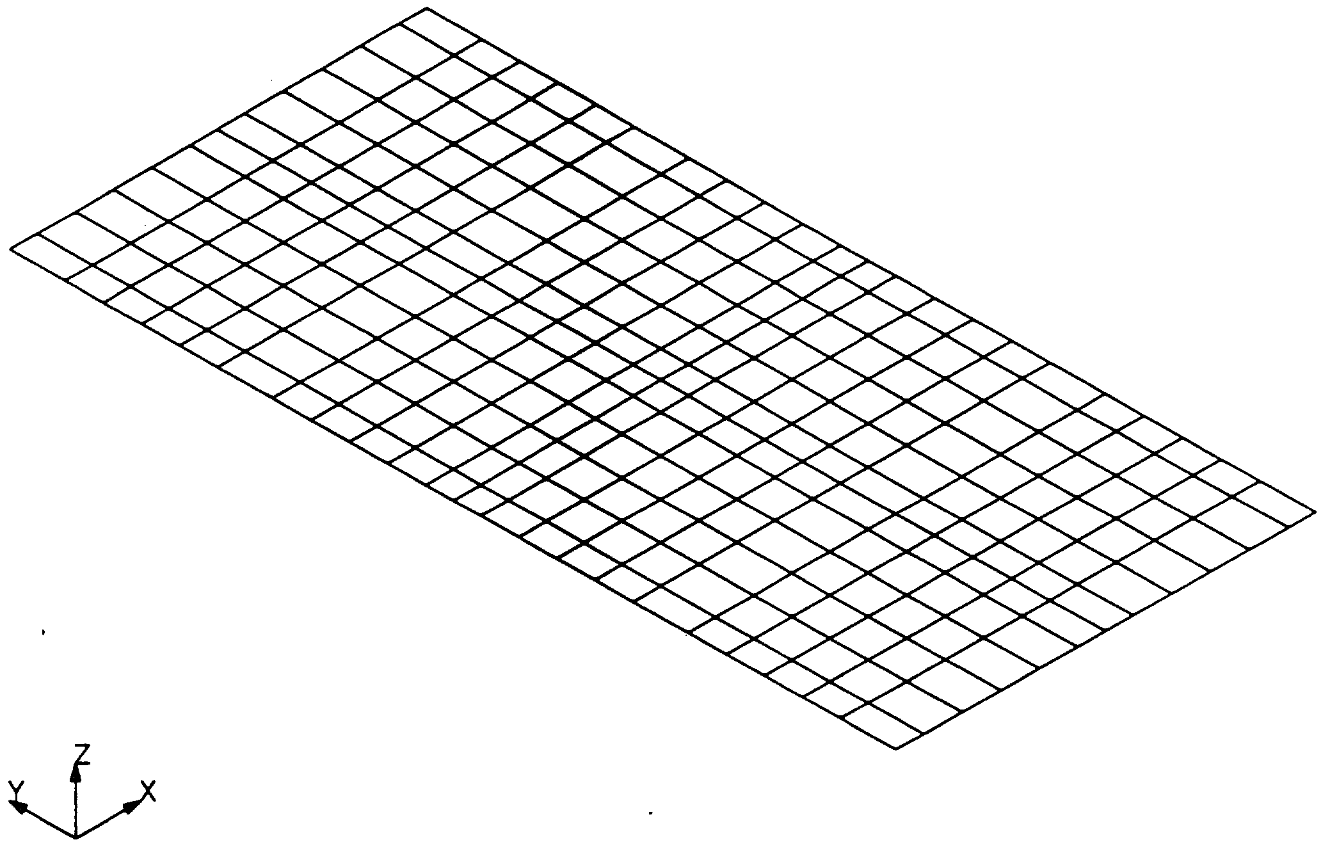
BRICK NODES

EXCAVATE, PUT BACK NODES

EL. -2.0'



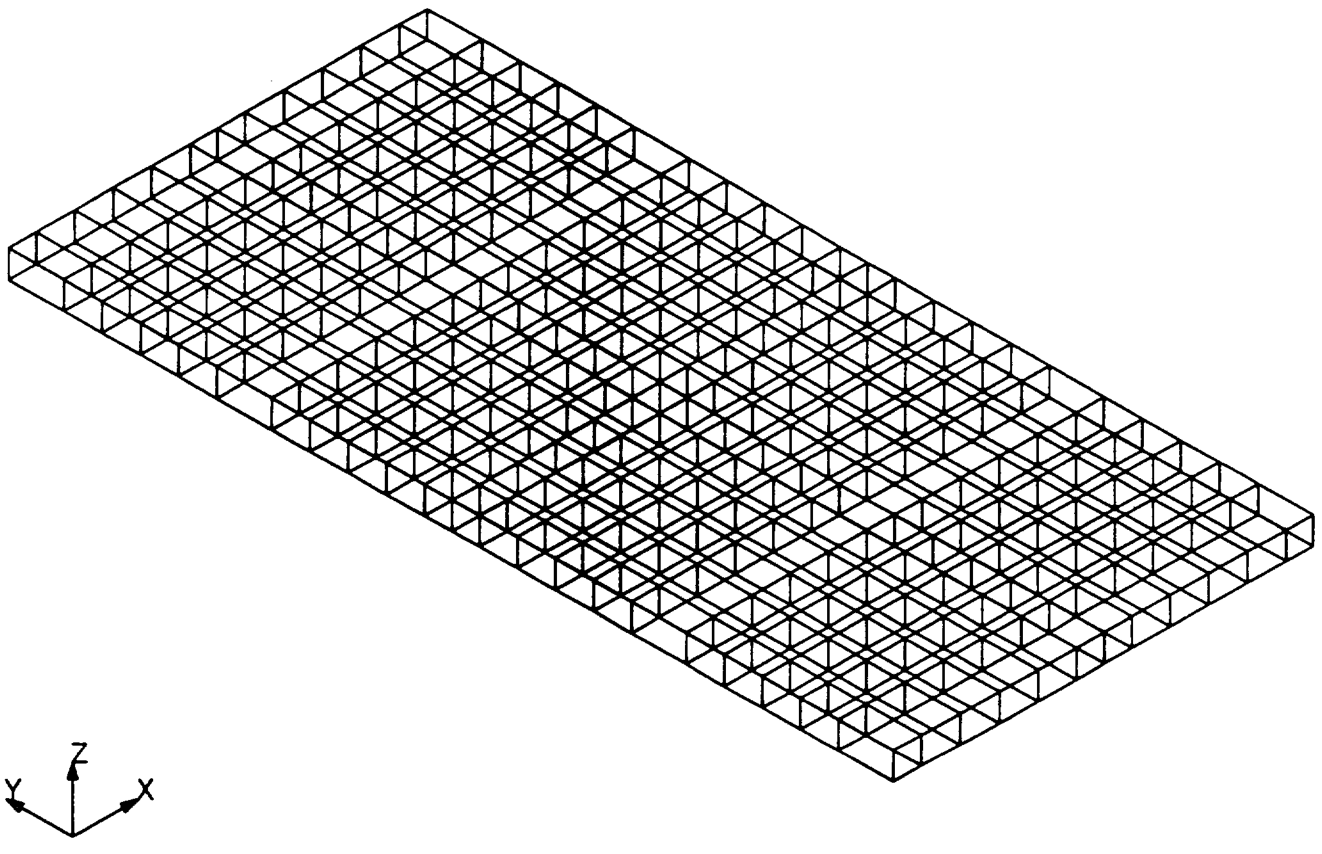
CEC JOB NO. 1083-000	
BY DH	DATE 6/6/97
CHECK [illegible]	DATE 6/10/97
CALC. NO. SC(POM)-1	REV. NO. 0
SHEET NO. 85	



3-D PLATE

FIG. 5.2.1-5

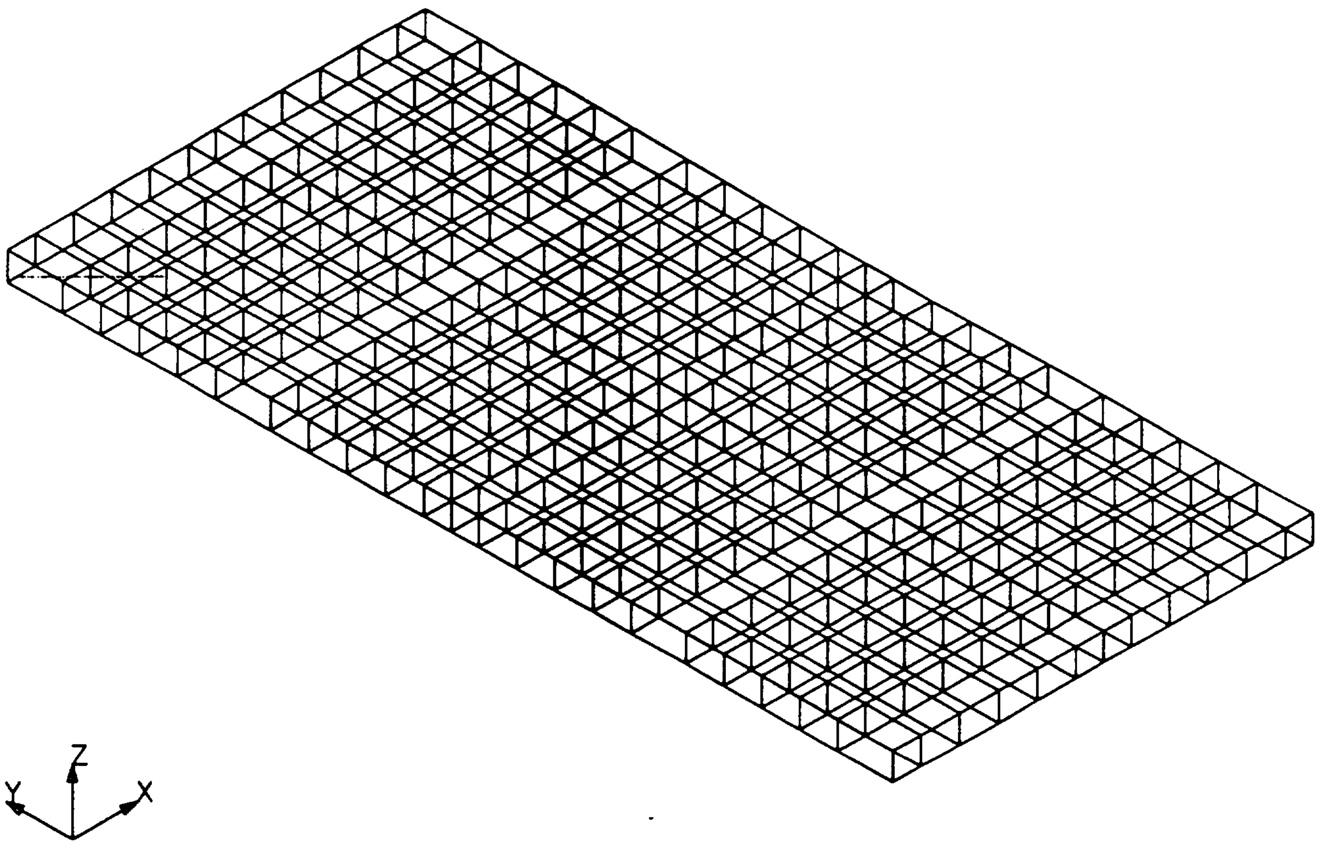
CEC JOB NO. 1083-000	
BY DH	DATE 6/6/97
CHECK kr	DATE 6/10/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 86	



3-D SOLID (PUT BACK SOIL)

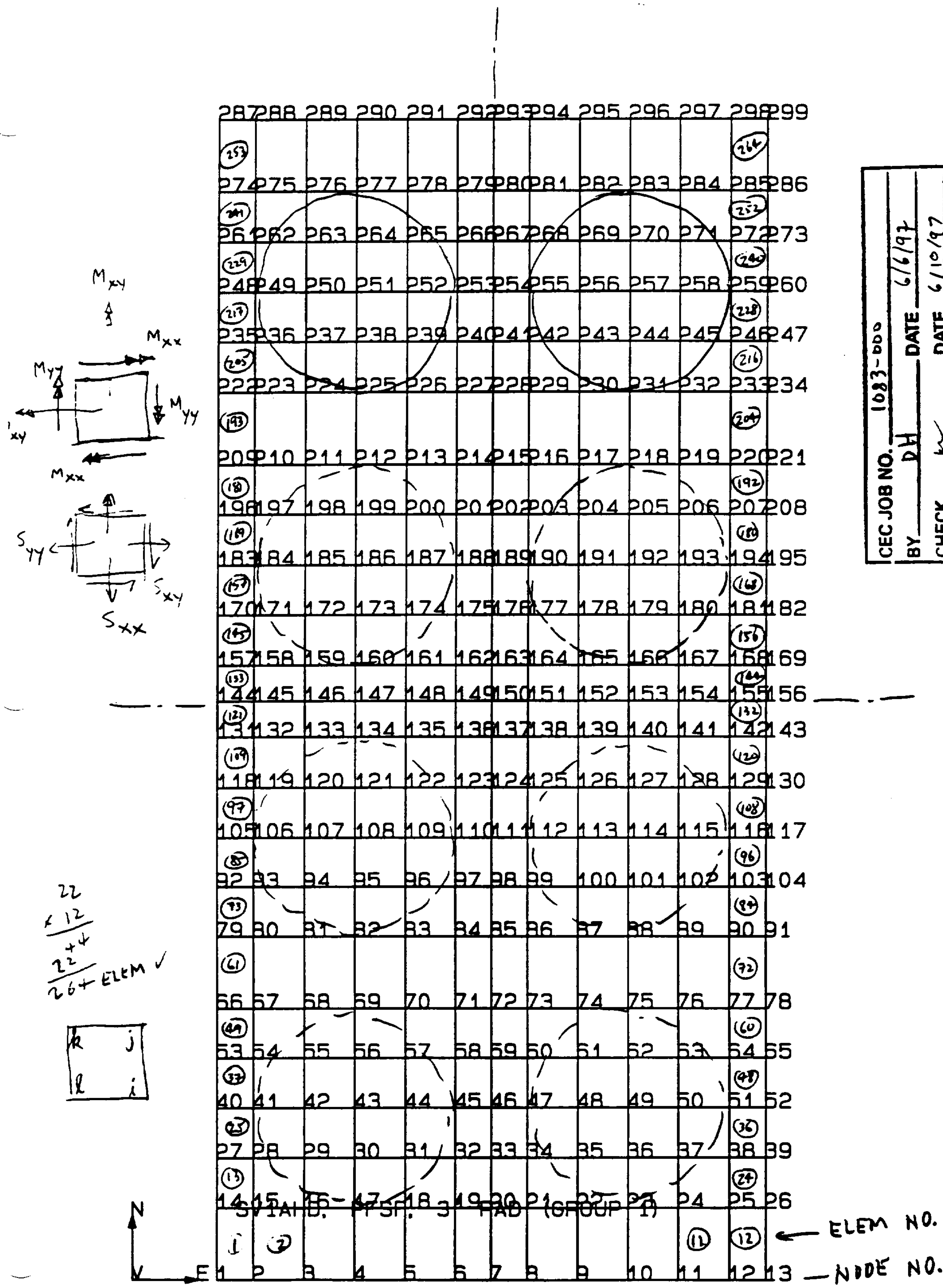
FIG. 5.2.1-6

CEC JOB NO.	1083-000		
BY	DH	DATE	6/6/97
CHECK	KC	DATE	6/10/97
CALC. NO.	SC(P017)-1	REV. NO.	0
SHEET NO.	87		



3-D SOLID (EXCAVATE SOIL)

FIG. 5.2.1-7



CEC JOB NO.	1083-000
BY	DH
DATE	6/6/97
CHECK	
DATE	6/10/97
REV. NO.	0
CALC. NO.	SC(P017)-1
SHEET NO.	88

FIG. 5.2.1-8

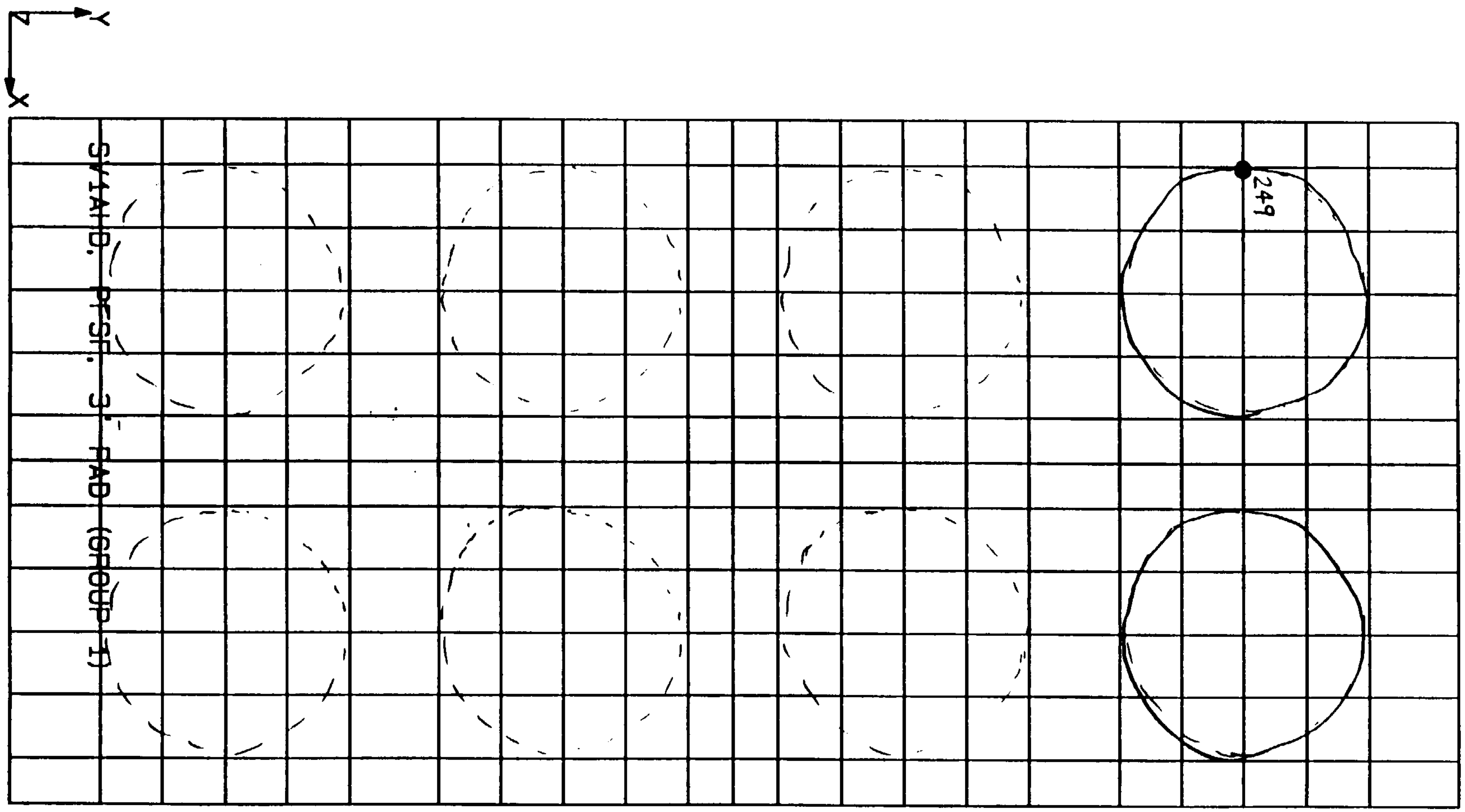


FIG. 5.2.1-9

CEC JOB NO. 1083-000
BY DH DATE 6/6/97
CHECK [illegible] DATE 6/10/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 89

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR DH DATE 6/6/97 CHECKED [illegible] DATE 6/12/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 90

5.2.2 DYNAMIC LOADING

THE LOADING CONSISTS OF A VERTICAL FORCE APPLIED TO NODE 249. THE INPUT TIME HISTORY IS DESIGNATED "V20812" WHICH STANDS FOR VERTICAL FORCE, 2 CASK CONFIGURATION, FRICTION COEFFICIENT = 0.08, LOADING ON CASK 1, QUADRANT 2. THE TIME HISTORY IS SHOWN IN FIGURE 5.2.2-2.

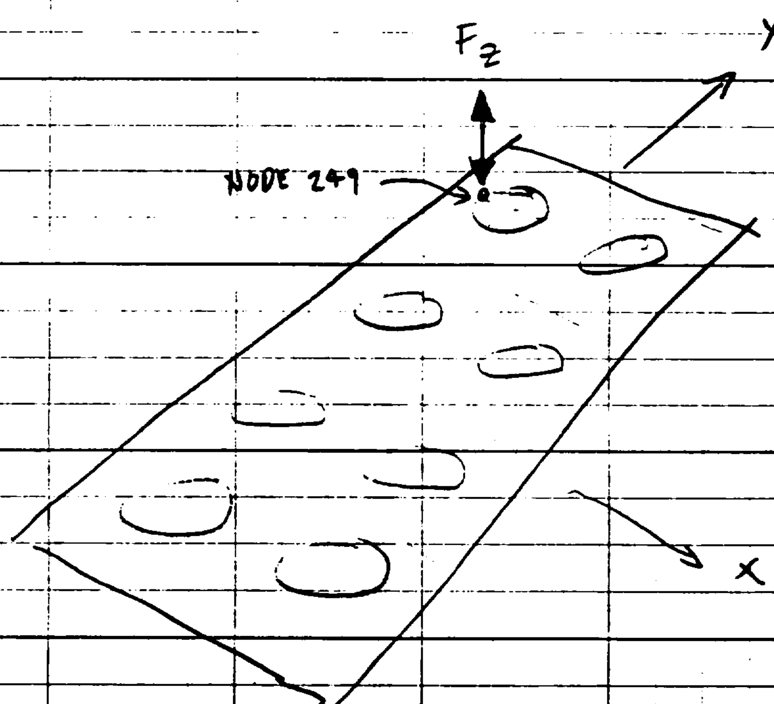
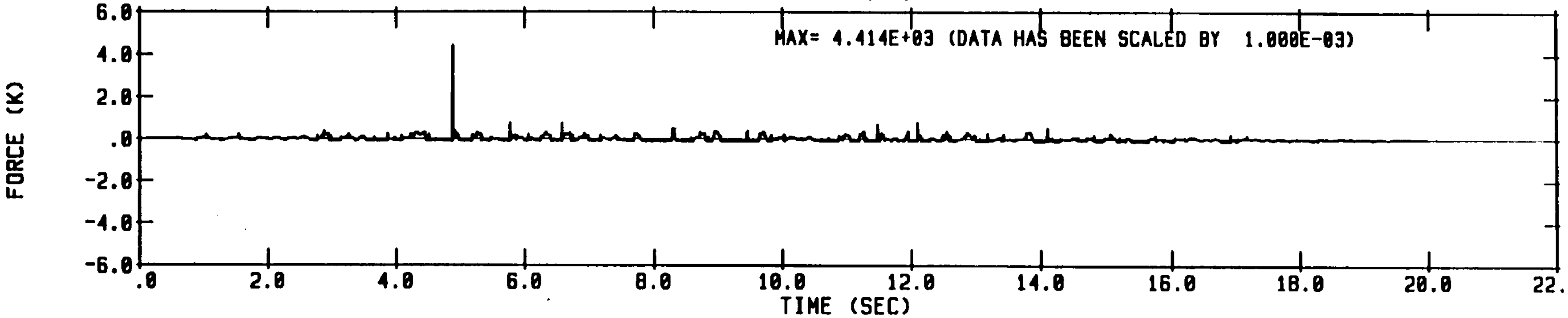


FIG. 5.2.2-1

VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)



CEC JOB NO. 1083-000
BY DH DATE 6/6/97
CHECK [illegible] DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 91

FIG. 5.2.2-2 INPUT TIME HISTORY APPLIED TO NODE 249.

TIME HISTORY FILE = V20812.TH2

CALCULATION SHEET

CEC

		CALC. NO. SC(PO17)-1	REV. NO. 0
ORIGINATOR DH	DATE 6/2/97	CHECKED [illegible]	DATE 6/12/97
PROJECT Private Fuel Storage Facility			JOB NO. 1083-000
SUBJECT Storage Pad Analysis and Design			SHEET NO. 92

5.2.3 ANALYSIS PROCEDURE

THE SASSI ANALYSIS PROCEDURES IS SHOWN IN FIGURES 5.2.3-1 THROUGH 5.2.3-4.

THE STEPS ARE AS FOLLOWS:

STEP 1. CALCULATE IMPEDANCE FOR FREQUENCIES 1-8. SEE FIG. 5.2.3-1.

STEP 2. CALCULATE IMPEDANCE FOR FREQUENCIES 9-16. SEE FIG. 5.2.3-2.

STEP 3. CALCULATE IMPEDANCE FOR FREQUENCIES 17-23. SEE FIG. 5.2.3-3

STEP 4. COMBINE IMPEDANCES CALCULATED IN STEPS 1-3. RUN MOTION AND STRESS TO CALCULATE DISPLACEMENTS AND BENDING MOMENTS. SEE FIG. 5.2.3-4.

CALCULATION SHEET

CEC

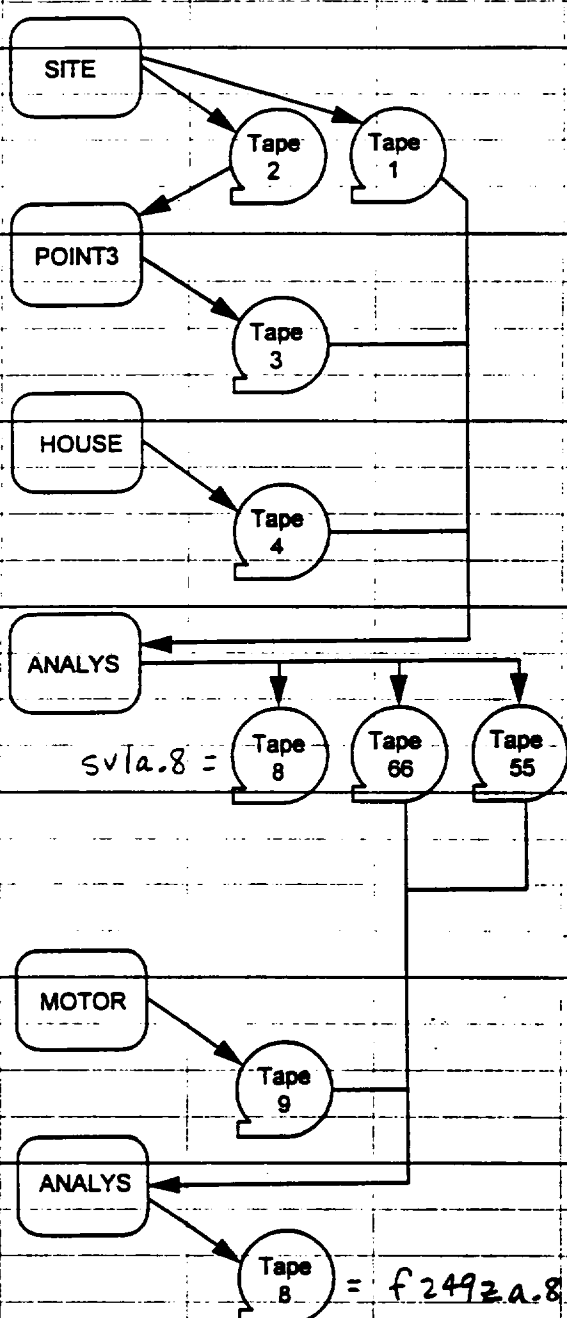
CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR DH DATE 6/7/97 CHECKED [illegible] DATE 6/12/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 93

SASSI Analysis Procedure



Step 1. Run the SITE module.
INPUT = svlasd

Step 2. Run the POINT3 module.
INPUT = svlapd

Step 3. Run the HOUSE module.
INPUT = svlahd

Step 4. Run the ANALYS module.
INPUT = svlaad

Step 5. Run the MOTOR module.
INPUT = f249zamd

Step 6. Run the ANALYS module.
INPUT = f249zaad

FIG. 5.2.3-1. IMPEDANCE FOR FREQUENCIES 1-8

sassiv3c.drw

CEC

CALCULATION SHEET

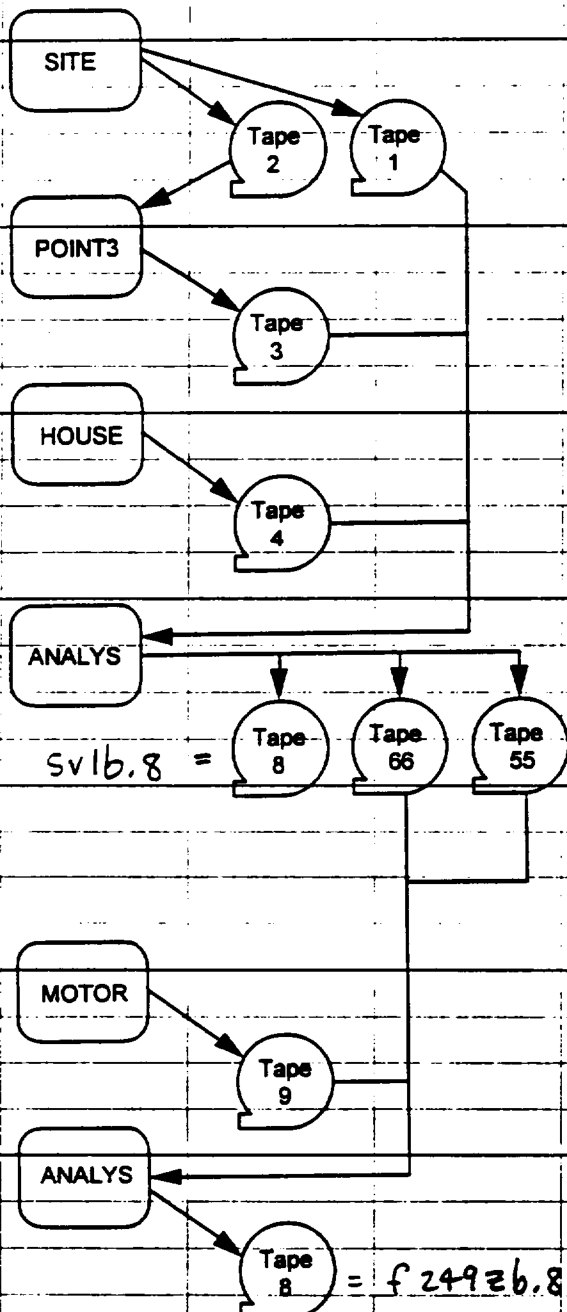
CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR DH DATE 6/3/97 CHECKED KW DATE 6/12/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 94

SASSI Analysis Procedure



Step 1. Run the SITE module.
INPUT= svlbsd (same as svlasd)

Step 2. Run the POINT3 module.
INPUT= svlbpd (same as svlapd)

Step 3. Run the HOUSE module.
INPUT= svlbhd (same as svlahd)

Step 4. Run the ANALYS module.
INPUT= svlbad

Step 5. Run the MOTOR module.
INPUT= f249zbmd

Step 6. Run the ANALYS module.
INPUT= f249zbad

FIG. 5.2.3-2 IMPEDANCE FOR FREQUENCIES 9-16

sassiv3c.drw

CEC

CALCULATION SHEET

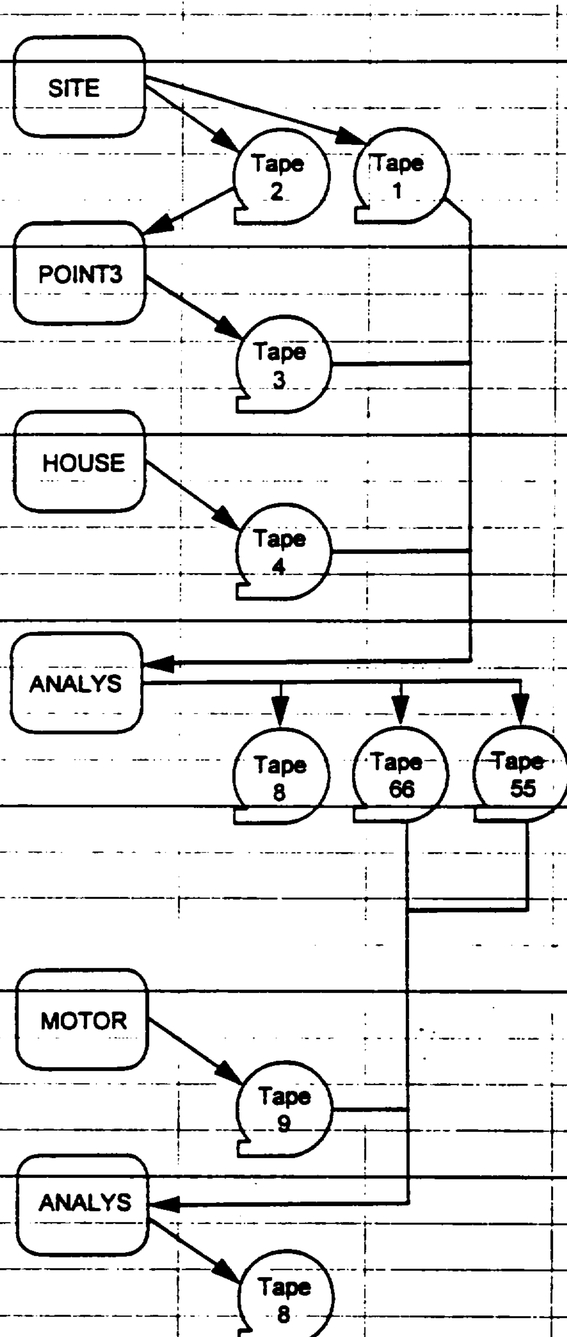
CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR DH DATE 6/7/97 CHECKED [illegible] DATE 6/12/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 95

SASSI Analysis Procedure



Step 1. Run the SITE module.
INPUT= svlcsd (same as svlasd)

Step 2. Run the POINT3 module.
INPUT= svlcpd (same as svlapd)

Step 3. Run the HOUSE module.
INPUT= svlchd (same as svlahd)

Step 4. Run the ANALYS module.
INPUT= svlcad

Step 5. Run the MOTOR module.
INPUT= f249zcmd

Step 6. Run the ANALYS module.
INPUT= f249zcad

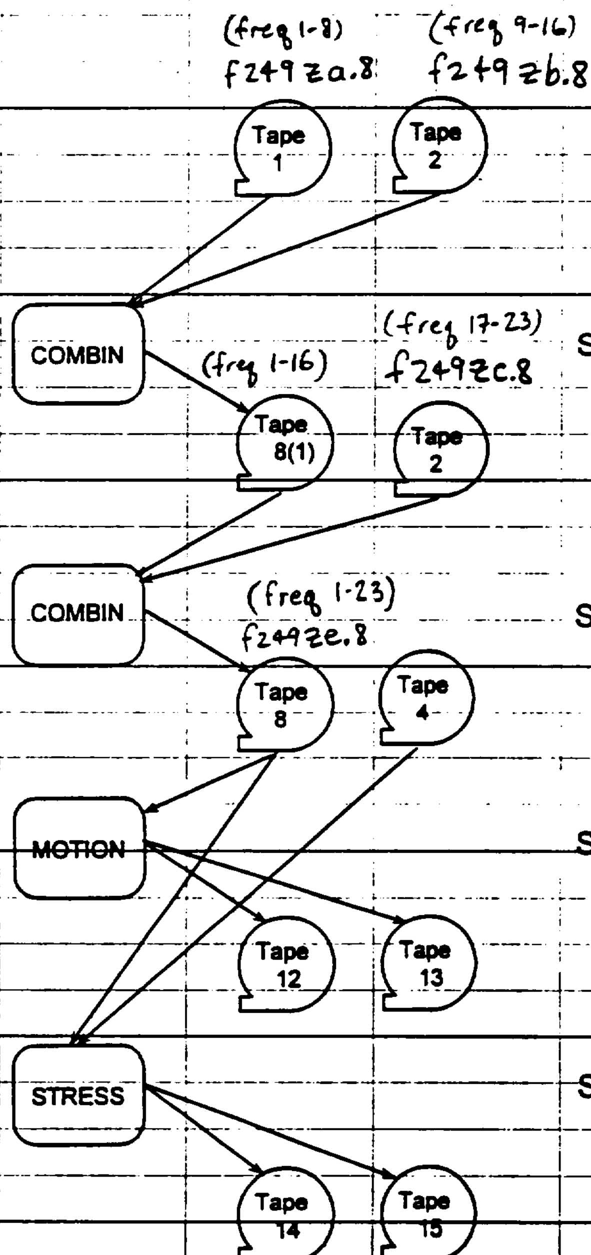
FIG. 5.2.3-3 IMPEDANCE FOR FREQUENCIES 17-23

sassiv3c.drw

CALCULATION SHEET

		CALC. NO. SC(PO177)-1	REV. NO. 0
ORIGINATOR DH	DATE 6/2/97	CHECKED [initials]	DATE 6/12/97
PROJECT Private Fuel Storage Facility			JOB NO. 1083-000
SUBJECT Storage Pad Analysis and Design			SHEET NO. 96

SASSI Analysis Procedure



Step 1. Run the COMBIN module.
INPUT = f249zdcd

Step 2. Run the COMBIN module.
INPUT= f249zecd

Step 3. Run the MOTION module.
INPUT= f249zeod
INPUT= V20812aod

Step 4. Run the STRESS module.
INPUT= V20812atd
INPUT= V20812btd

FIG. 5.2.3-4 COMBINE TAPE 8'S, RUN MOTION AND STRESS

sassiv1e.dsf

5.2.4 SASSI ANALYSIS RESULTS

THIS SECTION PRESENTS RESULTS DUE TO THE VERTICAL FORCE ON NODE 249. FIGURES 5.2.4-1 THROUGH 5.2.4-5 SHOW FORCE-TO-DISPLACEMENT TRANSFER FUNCTIONS FOR SELECTED NODES. FIGURES 5.2.4-6 THROUGH 5.2.4-13 SHOW FORCE-TO-MOMENT TRANSFER FUNCTIONS FOR SELECTED ELEMENT COMPONENTS.

THE MAXIMUM DISPLACEMENTS AT SELECTED NODES ARE SHOWN IN TABLE 5.2.4-1, AND FIG. 5.2.4-14. THE TIME HISTORIES ARE SHOWN IN FIGS. 5.2.4-15 THROUGH 5.2.4-26.

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR DH DATE 6/7/97 CHECKED [illegible] DATE 6/12/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 98

THE MAXIMUM BENDING MOMENTS IN SELECTED PLATE ELEMENTS ARE SHOWN IN TABLE 5.2.4-2. THE TIME HISTORIES ARE SHOWN IN FIGS. 5.2.4-27 THROUGH 5.2.4-30.

THE MAXIMUM BENDING MOMENTS OF SELECTED PLATE ELEMENTS ARE SHOWN IN FIG. 5.4.2-31. THE MAXIMUM TRANSVERSE SHEAR BETWEEN THESE ELEMENTS, BASED ON THE MAXIMUM MOMENTS, IS CALCULATED ON THE FOLLOWING TWO PAGES.

CALCULATION SHEET

CEC

ORIGINATOR: DH	DATE: 6/13/97	CALC. NO. SCCP0172-1	REV. NO. 0
		CHECKED: [illegible]	DATE: 6/16/97
PROJECT: PRIVATE FUEL STORAGE FACILITY			JOB NO. 1083-000
SUBJECT: STORAGE PAD ANALYSIS AND DESIGN			SHEET NO. 99

LOADING V20812 (SEE FIG. 5.2.4-31)

X-DIR

ELEMENTS	L_x [FT]	$V = \frac{\Delta M_{yy}}{L_x}$ [K/FT OF ELEMLENGTH]
205-206	2.37	$(-18.8+14.8)/2.37 = -1.69$
217-218	2.37	$(-82.6+46.1)/2.37 = -15.40$

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR DH DATE 6/13/97 CHECKED [illegible] DATE 6/16/97

PROJECT PRIVATE FUEL STORAGE FACILITY JOB NO. 1083-000

SUBJECT STORAGE PAD ANALYSIS AND DESIGN SHEET NO. 100

LOADING V20812 (SEE FIG. 5.2.4-31)

Y-DIR

ELEMENTS	L_y [FT]	$V = \frac{\Delta M_{xx}}{L_y}$ [K/FT OF ELEM LENGTH]
205-217	2.76	(-163.6 + 411.5)/2.76 = 89.82
206-218	2.76	(-147.9 + 336.0)/2.76 = 68.15

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TABLE 5.2.4-1

1MOTION - V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK KL DATE 6/12/97
CALC NO. SC(P017)-1 REV. NO. 0
SHEET NO. 101

M A X I M U M   A B S O L U T E   D I S P L .

N.P.	X-DIS	AT TIME	Y-DIS	AT TIME	Z-DIS	AT TIME
144					.0087	4.9200
157					.0099	4.9200
170					.0116	4.9200
183					.0136	4.9200
196					.0156	4.9150
209					.0184	4.8900
222					.0234	4.8850
235					.0267	4.8850
248					.0285	4.8850
249					.0245	4.8850
250					.0194	4.8900
251					.0154	4.8900
252					.0124	4.8950
253					.0097	4.9000
254					.0081	4.9000
255					.0063	4.9300
256					.0045	4.9350
257					.0031	4.9450
258					.0039	4.8950
259					.0068	4.8950
260					.0089	4.8950
261					.0280	4.8850
274					.0259	4.8900
287					.0240	4.8900
288					.0209	4.8900
289					.0169	4.8950
290					.0143	4.8950
291					.0116	4.8950
292					.0095	4.9300
293					.0080	4.9300
294					.0065	4.9350
295					.0051	4.8800
296					.0049	4.8850
297					.0064	4.8900

TABLE 5.2.4-1 (CONT'D)

298	.0089	4.8950
299	.0112	4.8950

BLANKS IN THE ABOVE TABLES ARE DOFS WHERE OUTPUT HAS NOT BEEN REQUESTED

CEC JOB NO.	1083-000		
BY	DH	DATE	6/7/97
CHECK	K	DATE	6/12/97
CALC. NO.	SC(P017)-1	REV. NO.	0
SHEET NO.	102		

Sat Jun 14 10:35:21 PDT 1997 v20812bto.prn Page 1

1STRESS - V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

C O M P U T E D   S T R E S S E S / F O R C E S / M O M E N T S

3D PLATE/SHELL ELEMENTS

[K-Ft/Ft]

TABLE 5.2.4-2

GROUP	ELEMENT	SXX(MAX) (F/L)	SYY(MAX) (F/L)	SXY(MAX) (F/L)	MXX(MAX) (F-L/L)	MYY(MAX) (F-L/L)	MXY(MAX) (F-L/L)
1	169				.1002E+03	.1028E+02	
1	170				.8597E+02	.3087E+02	
1	171				.7029E+02	.5315E+02	
1	172				.5603E+02	.7175E+02	
1	173				.4357E+02	.8232E+02	
1	174				.3427E+02	.8348E+02	
1	175				.2748E+02	.7808E+02	
1	176				.2022E+02	.6532E+02	
1	177				-.1288E+02	.4867E+02	
1	178				-.8345E+01	.2954E+02	
1	179				-.9626E+01	.1210E+02	
1	180				-.1024E+02	.2240E+01	
1	181				.8198E+02	.1118E+02	
1	182				.6776E+02	.3049E+02	
1	183				.5149E+02	.5684E+02	
1	184				.3748E+02	.8189E+02	
1	185				-.3360E+02	.9698E+02	
1	186				-.3113E+02	.9985E+02	
1	187				-.2776E+02	.9400E+02	
1	188				-.2283E+02	.7915E+02	
1	189				-.1666E+02	.5765E+02	
1	190				-.1301E+02	.3629E+02	
1	191				-.1423E+02	.1603E+02	
1	192				-.1461E+02	.3509E+01	
1	193				-.6062E+02	.4952E+01	
1	194				-.5881E+02	.2268E+02	
1	195				-.5549E+02	.6154E+02	
1	196				-.5017E+02	.9868E+02	
1	197				-.4355E+02	.1189E+03	
1	198				-.3858E+02	.1222E+03	
1	199				-.3390E+02	.1146E+03	
1	200				-.2761E+02	.9643E+02	
1	201				-.2031E+02	.6960E+02	
1	202				-.1872E+02	.4422E+02	
1	203				-.1885E+02	.2060E+02	
1	204				-.1884E+02	.4792E+01	
1	205				-.1636E+03	-.1876E+02	
1	206				-.1479E+03	-.1475E+02	
1	207				-.1230E+03	.7318E+02	
1	208				-.9769E+02	.1205E+03	
1	209				-.7267E+02	.1428E+03	
1	210				-.5402E+02	.1449E+03	
1	211				-.4387E+02	.1350E+03	
1	212				-.3382E+02	.1129E+03	
1	213				-.2435E+02	.8126E+02	
1	214				-.2337E+02	.5131E+02	

CEC JOB NO. 1083-000
BY DH DATE 6/14/97
CHECK [illegible] DATE 6/17/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 103

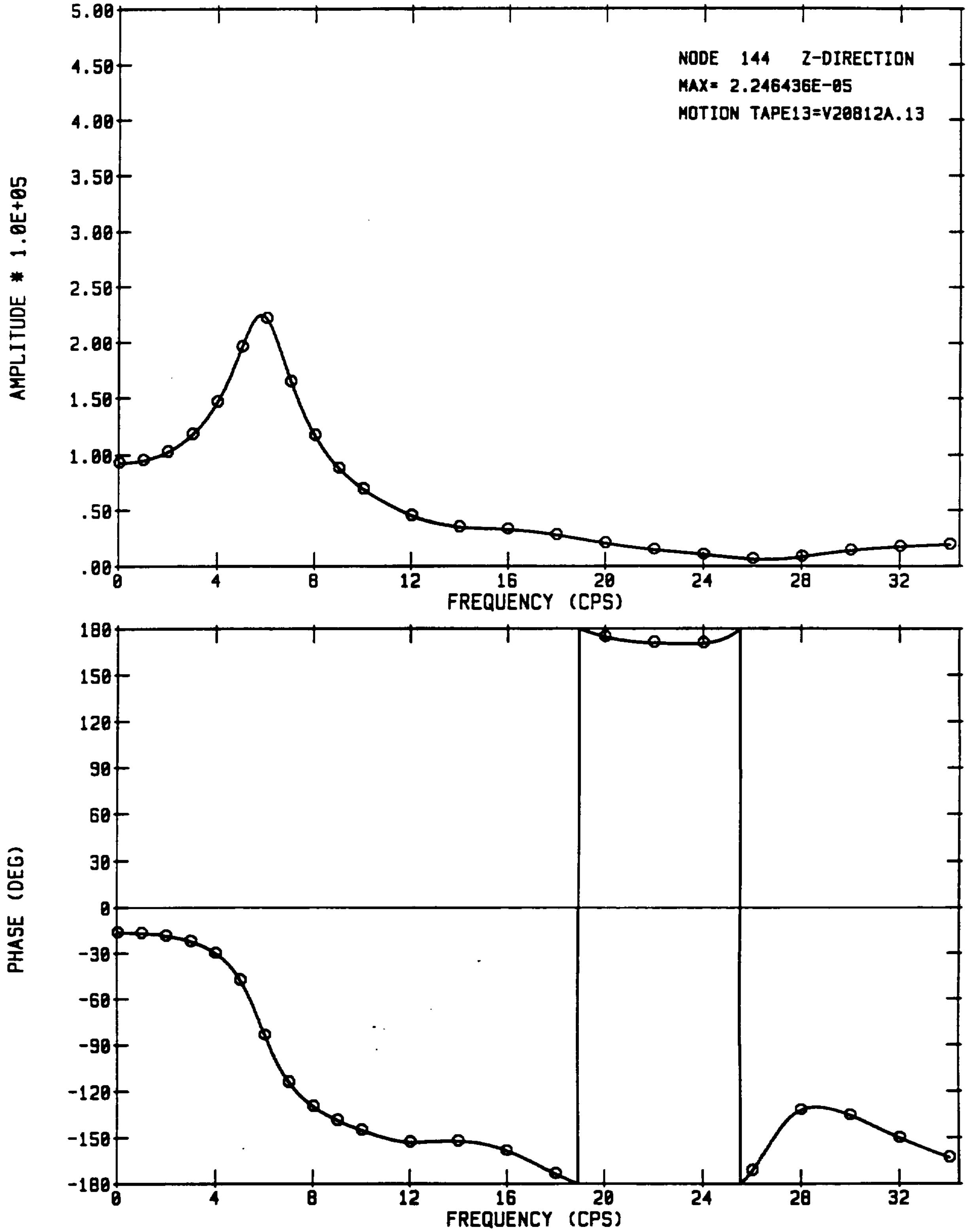
TABLE 5.2.4-2 (CONT'D)

1	215	-.2350E+02	.2441E+02
1	216	-.2306E+02	.5848E+01
1	217	-.4115E+03	-.8256E+02
1	218	-.3360E+03	-.4609E+02
1	219	-.2255E+03	.8727E+02
1	220	-.1459E+03	.1394E+03
1	221	-.9456E+02	.1603E+03
1	222	-.6827E+02	.1604E+03
1	223	-.5181E+02	.1480E+03
1	224	-.3736E+02	.1226E+03
1	225	-.2592E+02	.8755E+02
1	226	-.2516E+02	.5518E+02
1	227	-.2550E+02	.2635E+02
1	228	-.2542E+02	.6421E+01
1	229	-.4144E+03	-.8102E+02
1	230	-.3410E+03	-.4159E+02
1	231	-.2319E+03	.9530E+02
1	232	-.1525E+03	.1496E+03
1	233	-.9941E+02	.1706E+03
1	234	-.6940E+02	.1695E+03
1	235	-.5174E+02	.1554E+03
1	236	-.3610E+02	.1274E+03
1	237	-.2457E+02	.8962E+02
1	238	-.2471E+02	.5658E+02
1	239	-.2524E+02	.2673E+02
1	240	-.2531E+02	.6471E+01
1	241	-.1739E+03	-.1425E+02
1	242	-.1648E+03	-.1520E+02
1	243	-.1445E+03	.9884E+02
1	244	-.1146E+03	.1525E+03
1	245	-.8100E+02	.1749E+03
1	246	-.5690E+02	.1725E+03
1	247	-.4097E+02	.1568E+03
1	248	-.2688E+02	.1267E+03
1	249	-.2179E+02	.8676E+02
1	250	-.2162E+02	.5487E+02
1	251	-.2185E+02	.2496E+02
1	252	-.2131E+02	.6054E+01
1	253	-.4791E+02	.1774E+02
1	254	-.5003E+02	.5847E+02
1	255	-.4951E+02	.1192E+03
1	256	-.4338E+02	.1679E+03
1	257	-.3254E+02	.1833E+03
1	258	-.2366E+02	.1738E+03
1	259	-.1778E+02	.1529E+03
1	260	-.1176E+02	.1194E+03
1	261	-.9830E+01	.8009E+02
1	262	-.9770E+01	.4618E+02
1	263	-.9551E+01	.1787E+02
1	264	-.9246E+01	-.5682E+01

BLANKS IN THE ABOVE TABLES ARE COMPONENTS WHERE OUTPUT HAS NOT BEEN REQUESTED.

CEC JOB NO. 1083-000
BY DH DATE 6/14/97
CHECK [illegible] DATE 6/17/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 104

V20812ADD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

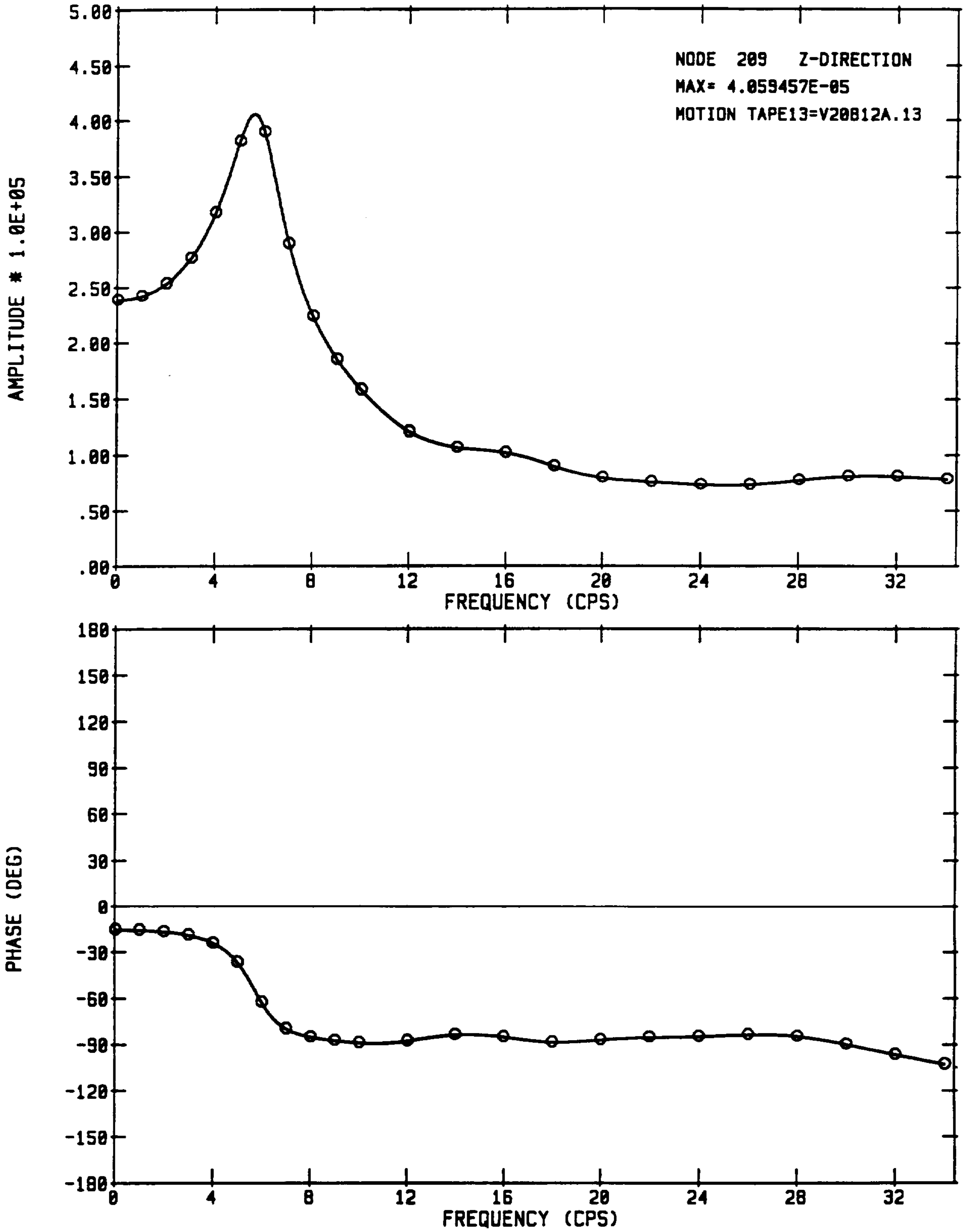


CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK w DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 105

FIG. 5.2.4-1

D:\PFSF\SASSI\plotf\FZ144Z.INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

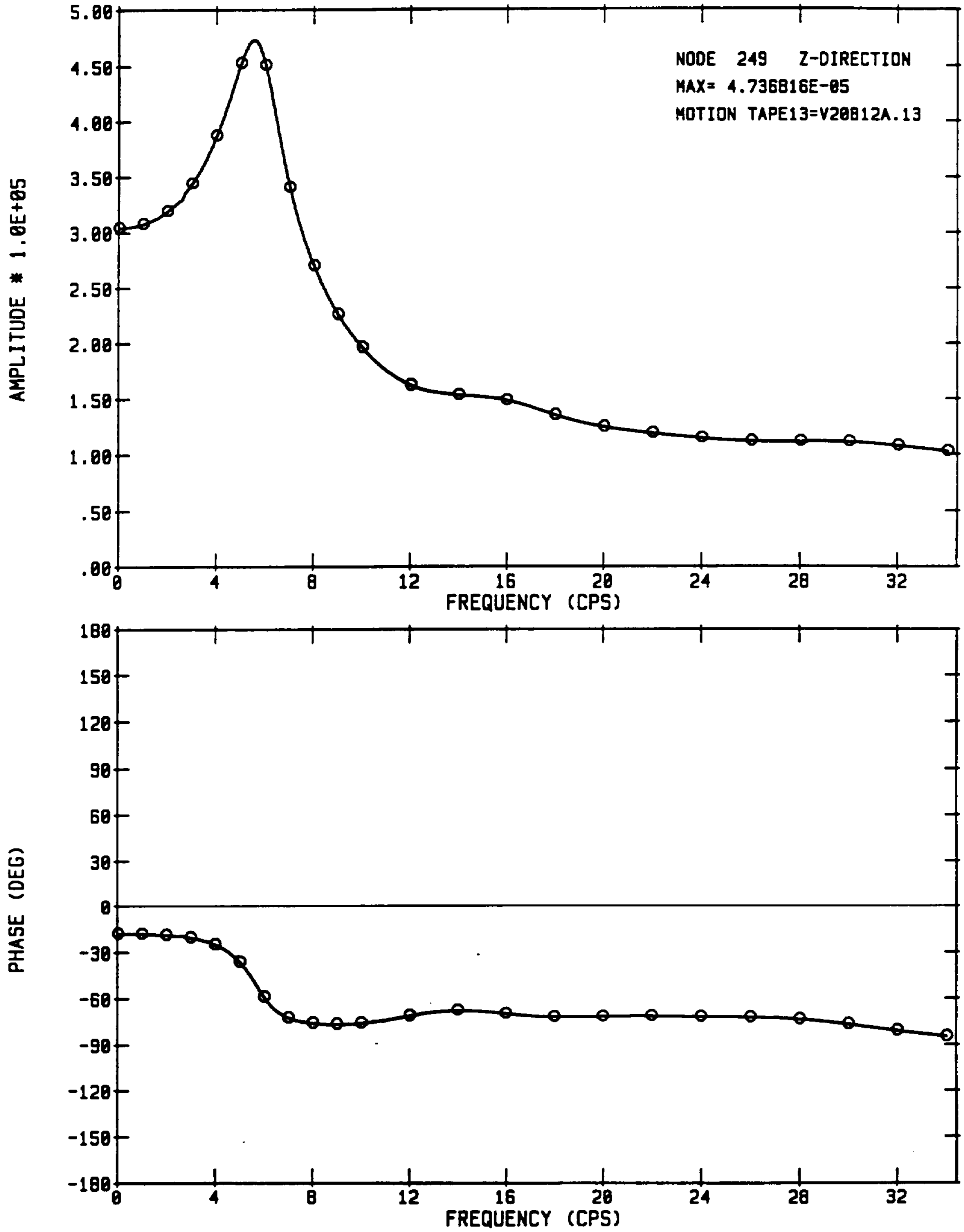


CEC JOB NO.	1083-000
BY DH	DATE 6/7/97
CHECK kn	DATE 6/12/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 106	

FIG. 5.2.4-2

D:\PFSF\SASSI\plotff\FZ209Z.INP 6/ 6/97

V20812ADD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

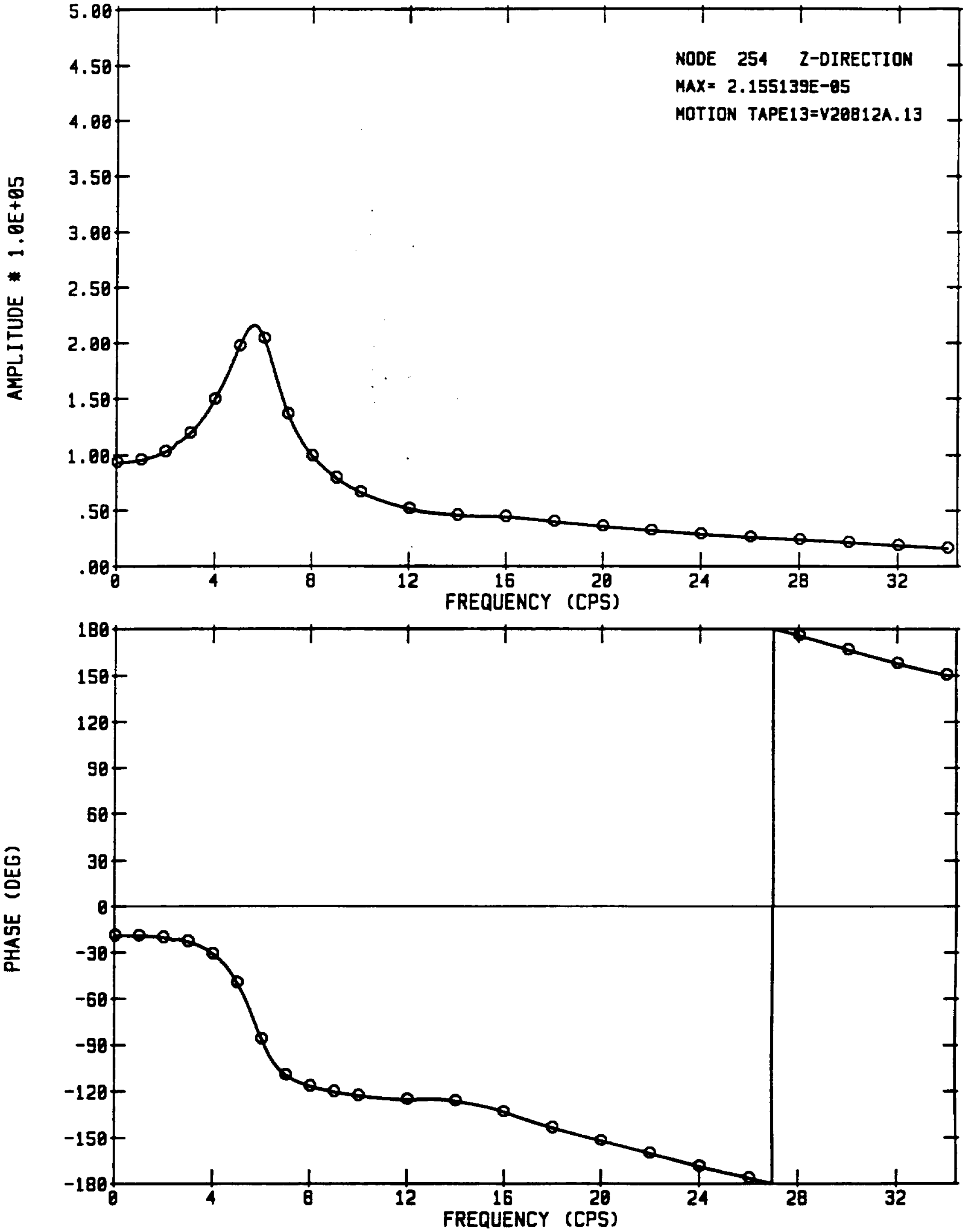


CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK K DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 107

FIG. 5.2.4-3

D:\PFSF\SASSI\plotf\FZ249Z.INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

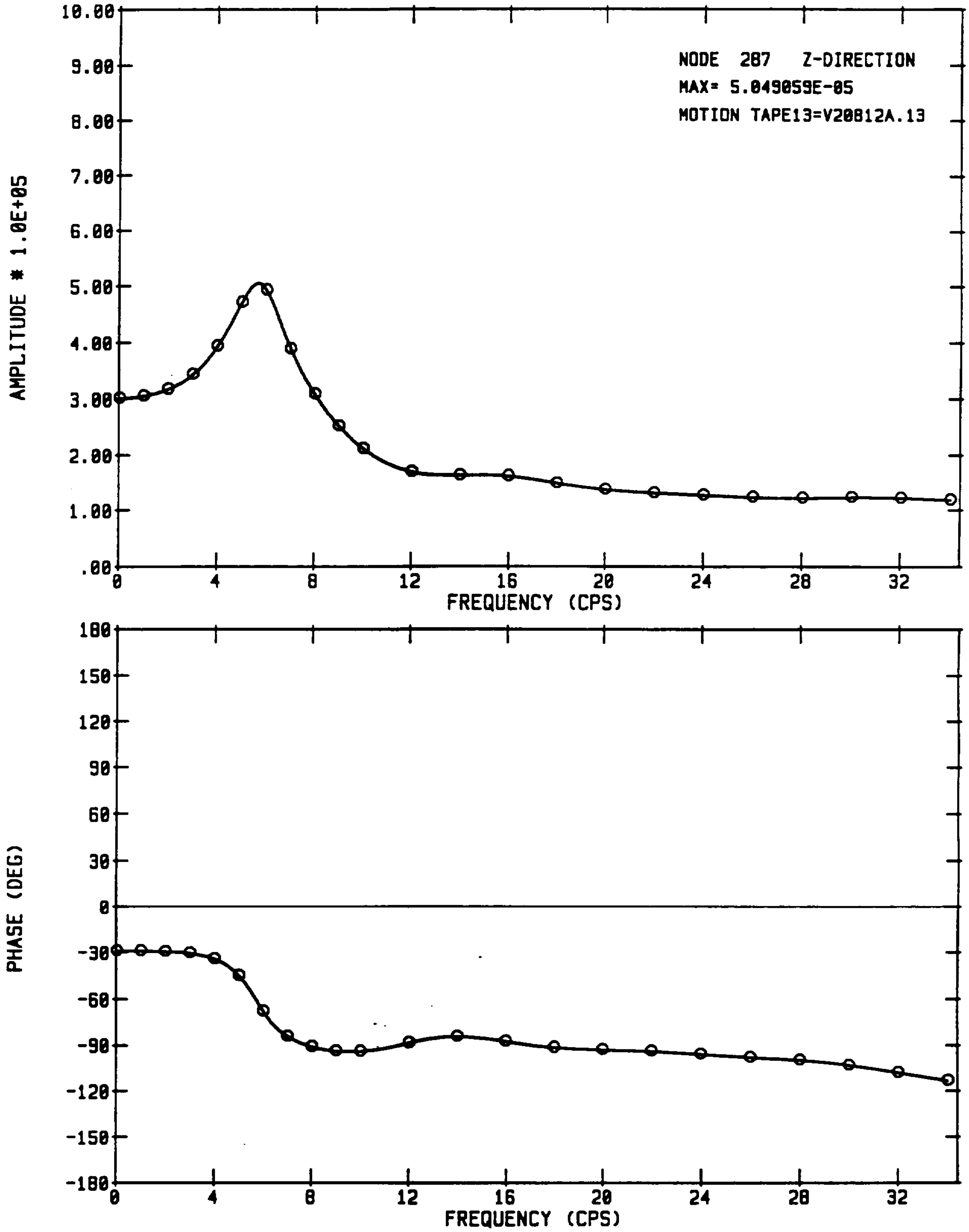


CEC JOB NO.	1083-000
BY	DLT
DATE	6/7/97
CHECK	[illegible]
DATE	6/12/97
CALC. NO.	SC(PO17)-1
REV. NO.	0
SHEET NO.	108

FIG. 5.2.4-4

D:\PFSF\SASSI\plottf\FZ254Z.INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

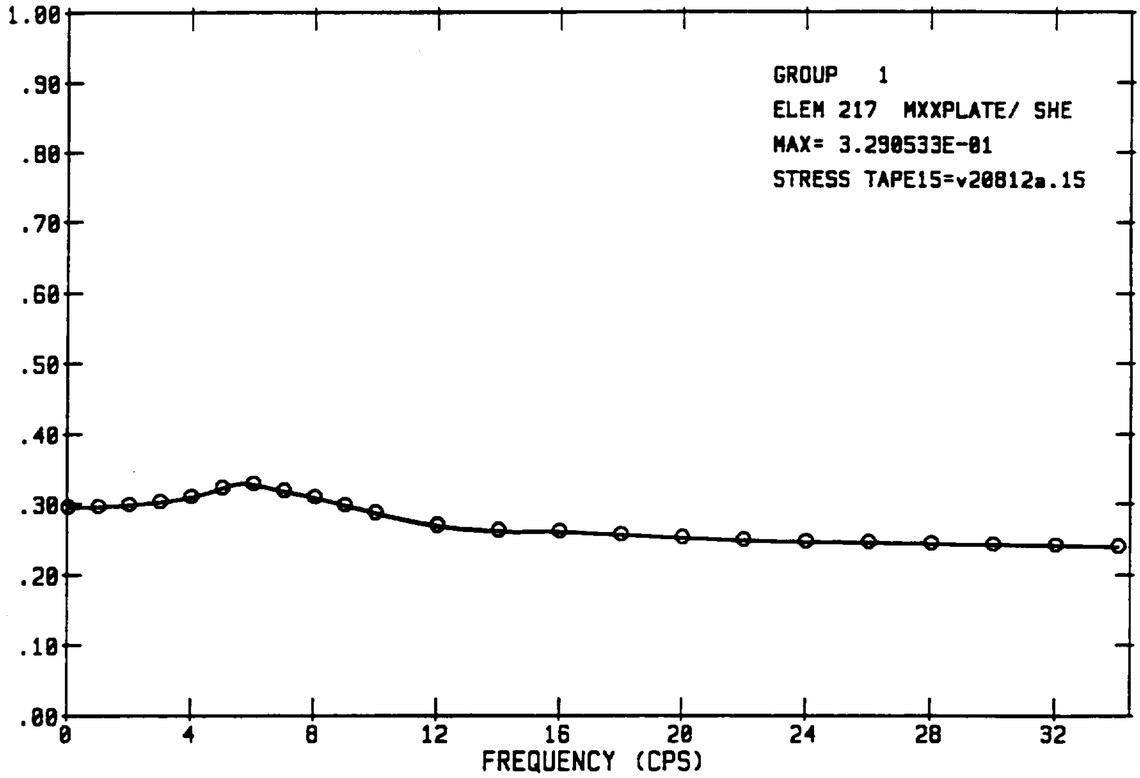


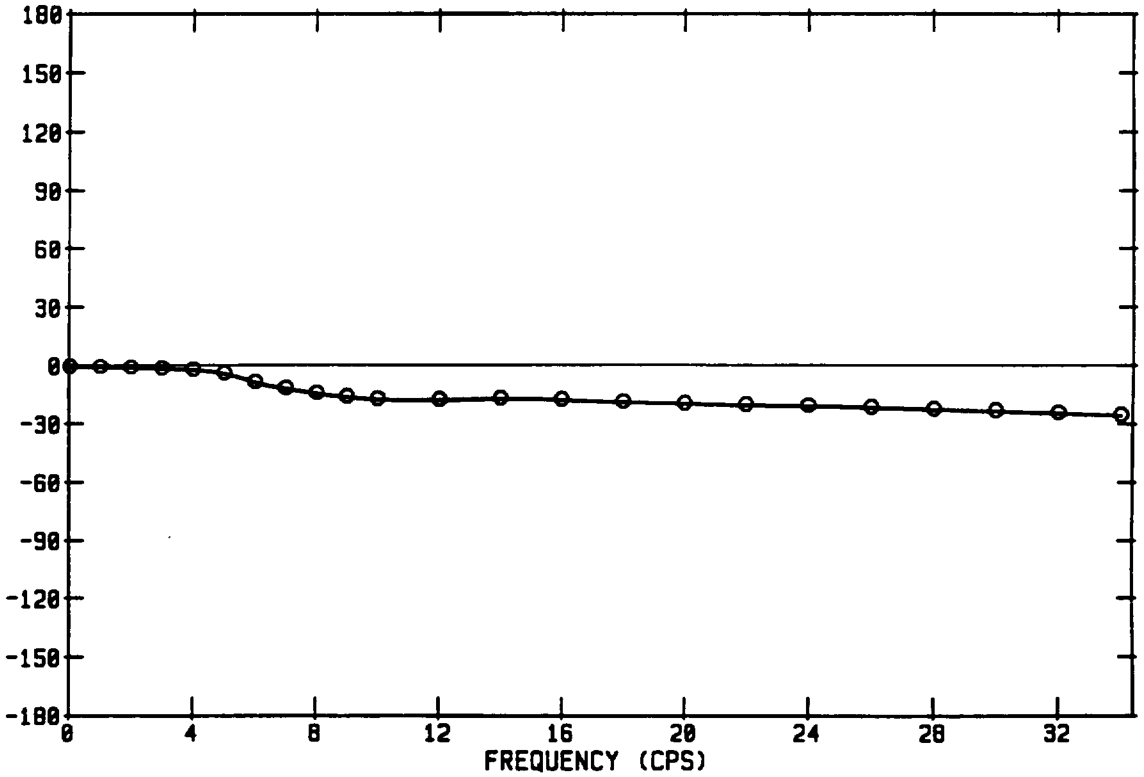
CEC JOB NO. 1083-000	
BY DH	DATE 6/7/97
CHECK [initials]	DATE 6/12/97
CALC. NO. SC(PO17)-1	REV. NO. 0
SHEET NO. 109	

FIG. 5.2.4-5

D:\PFSF\SASSI\plotf\FZ287Z.INP 6/ 6/97

V20812ATD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

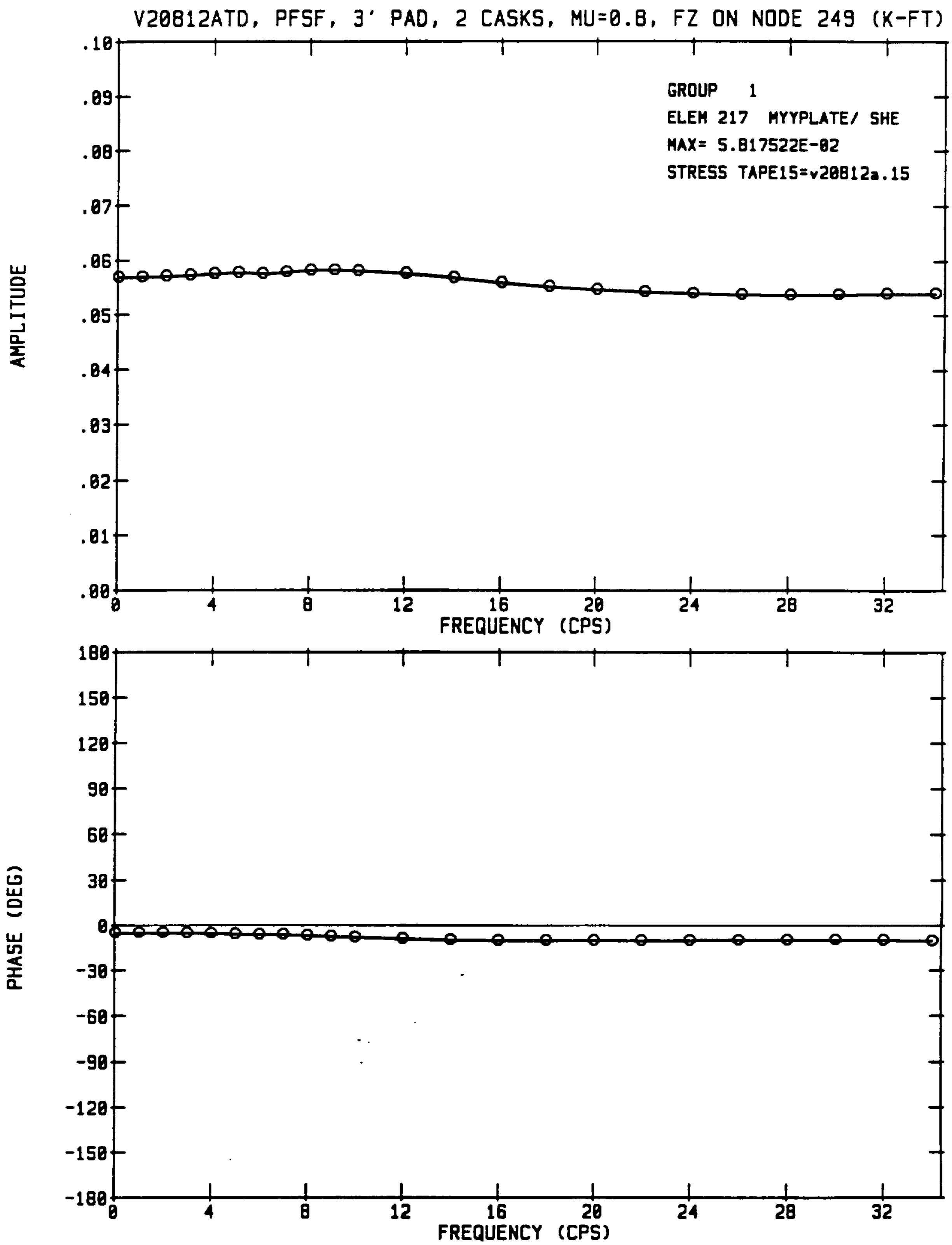




CEC JOB NO. 1083-000	
BY DH	DATE 6/7/97
CHECK KL	DATE 6/12/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 110	

FIG. 5.2.4 - 6

D:\PFSF\SASSI\plottf\1217MXX.INP 6/ 6/97

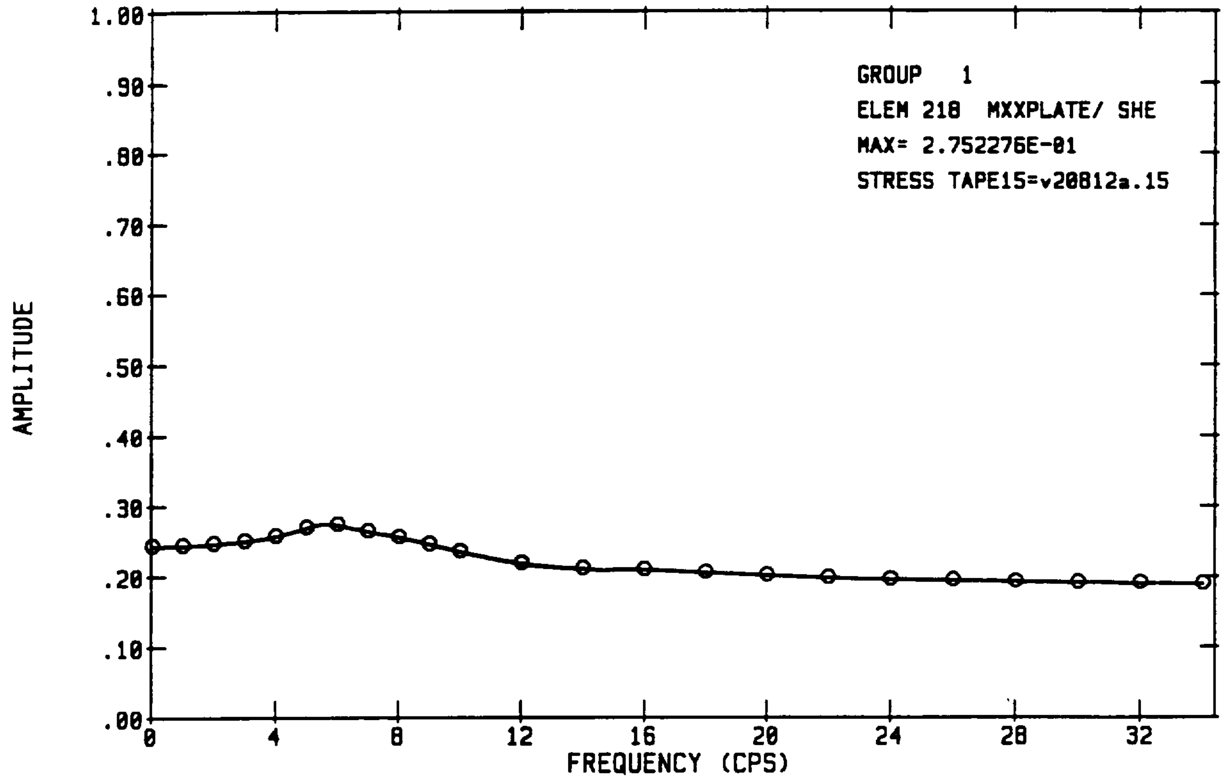


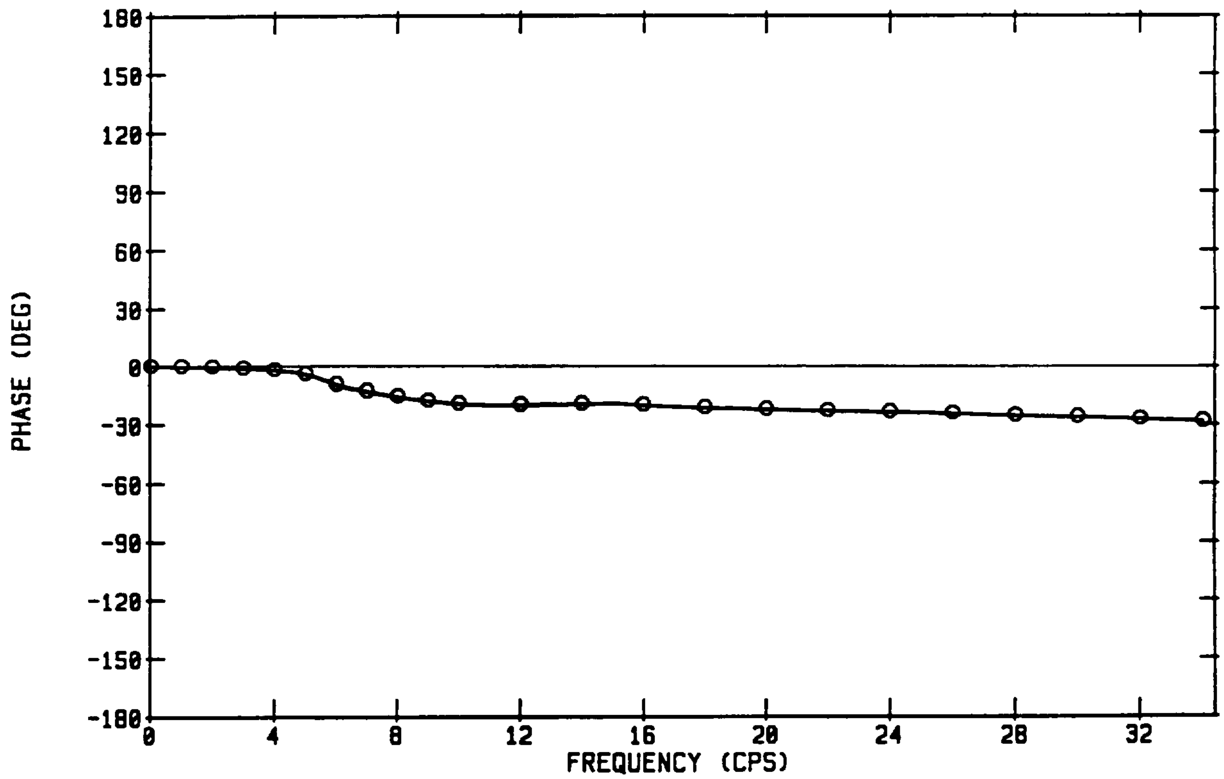
CEC JOB NO.	1D83-000
BY	DH
DATE	6/7/97
CHECK	[illegible]
DATE	6/12/97
CALC. NO.	SC(PO17)-1
REV. NO.	0
SHEET NO.	111

FIG. 5.2.4-7

D:\PFSF\SASSI\plottf\1217MYY.INP 6/ 6/97

V20812ATD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



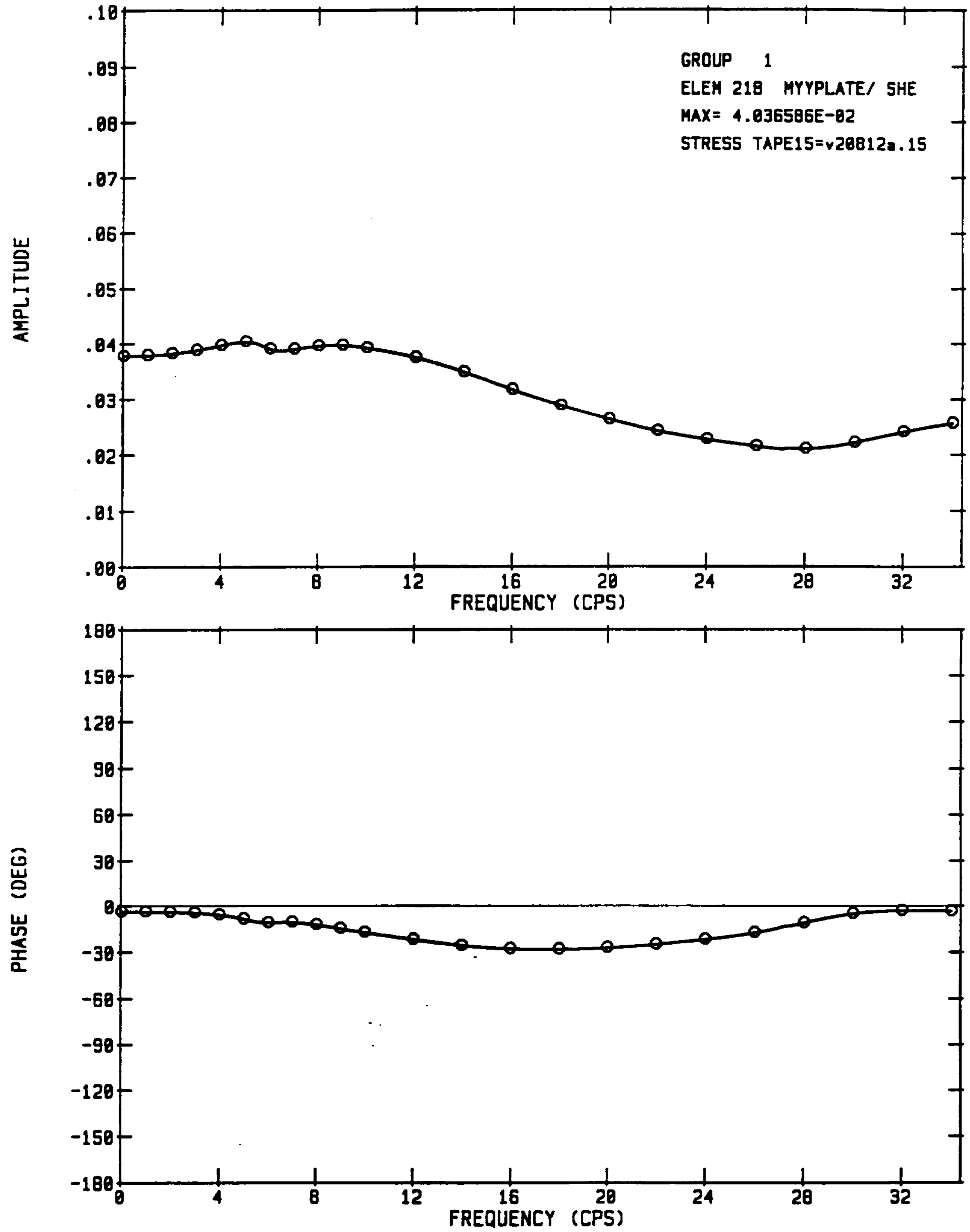


CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK [illegible] DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 112

FIG. 5.2.4-8

D:\PFSF\SASSI\plottf\1218MXX.INP 6/ 6/97

V20812ATD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

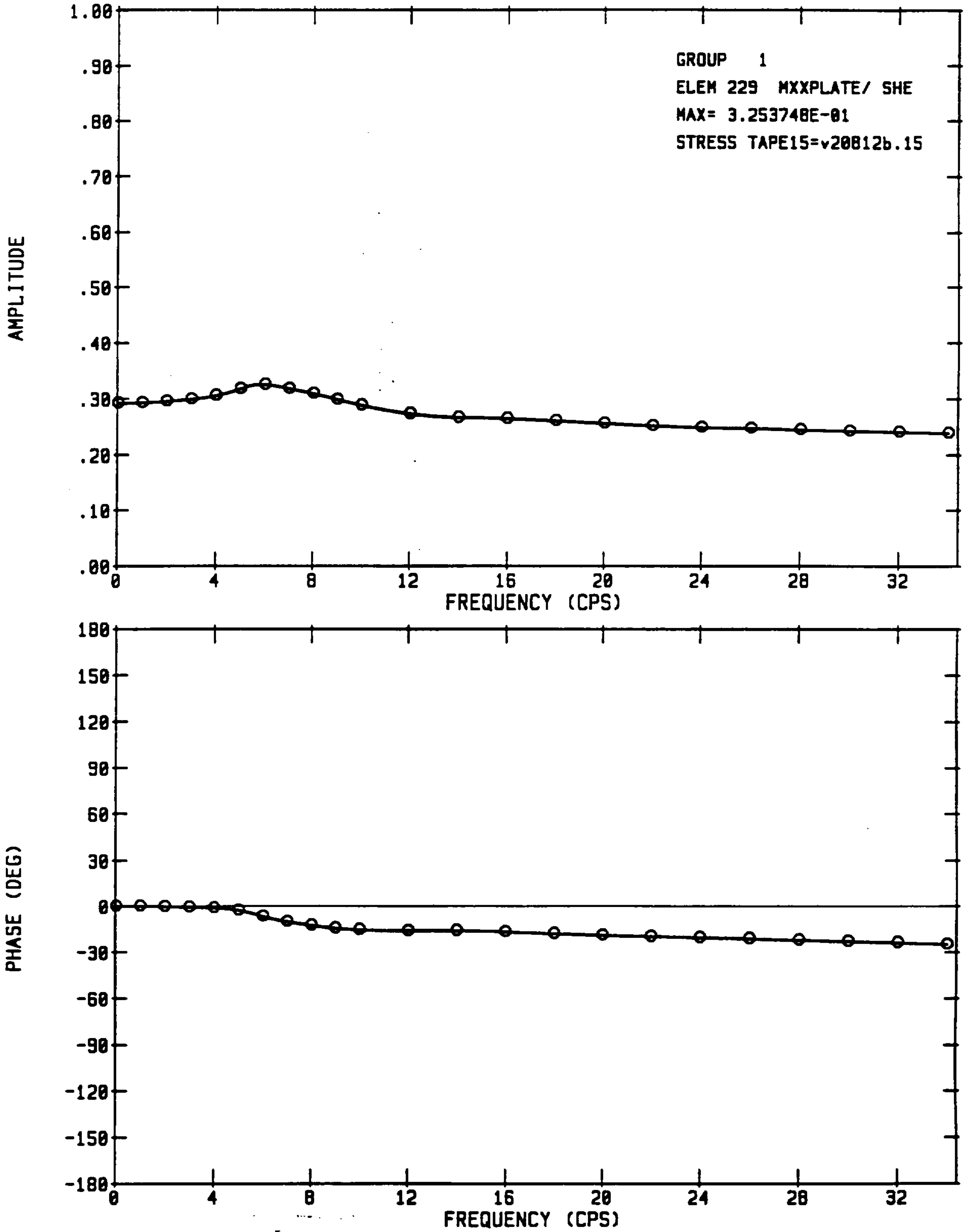


CEC JOB NO. 1083-000	
BY DH	DATE 6/7/97
CHECK [initials]	DATE 6/12/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 113	

FIG. 5.2.4-9

D:\PFSF\SASSI\plottf\1218MYY.INP 6/ 6/97

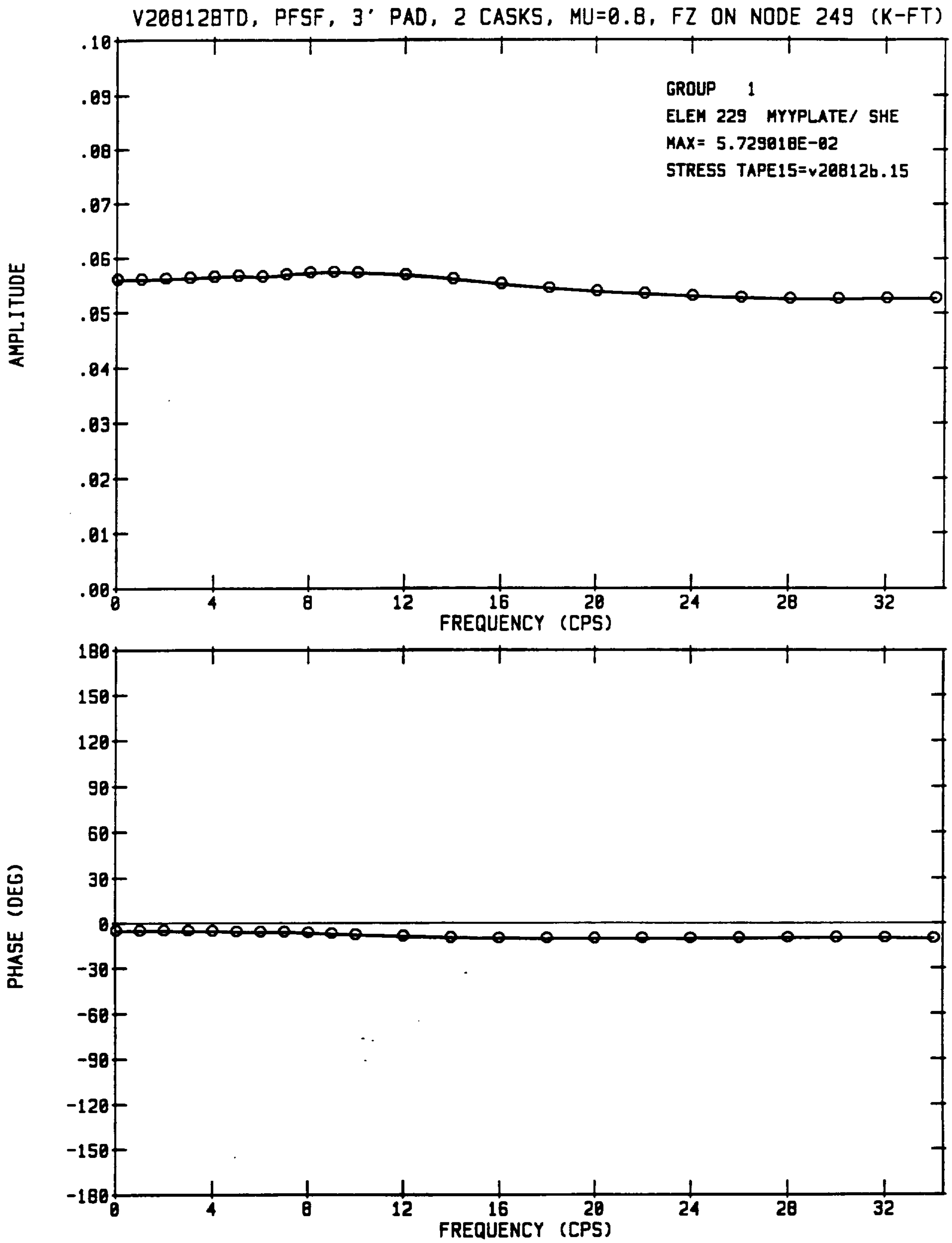
V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



CEC JOB NO.	1083-000
BY	DH
DATE	6/13/97
CHECK	KV
DATE	6/13/97
CALC. NO.	SC(P017)-1
REV. NO.	0
SHEET NO.	114

FIG. 5.2.4-10

D:\PFSF\SASSI\PLOTTF\1229MXX.INP 6/13/97

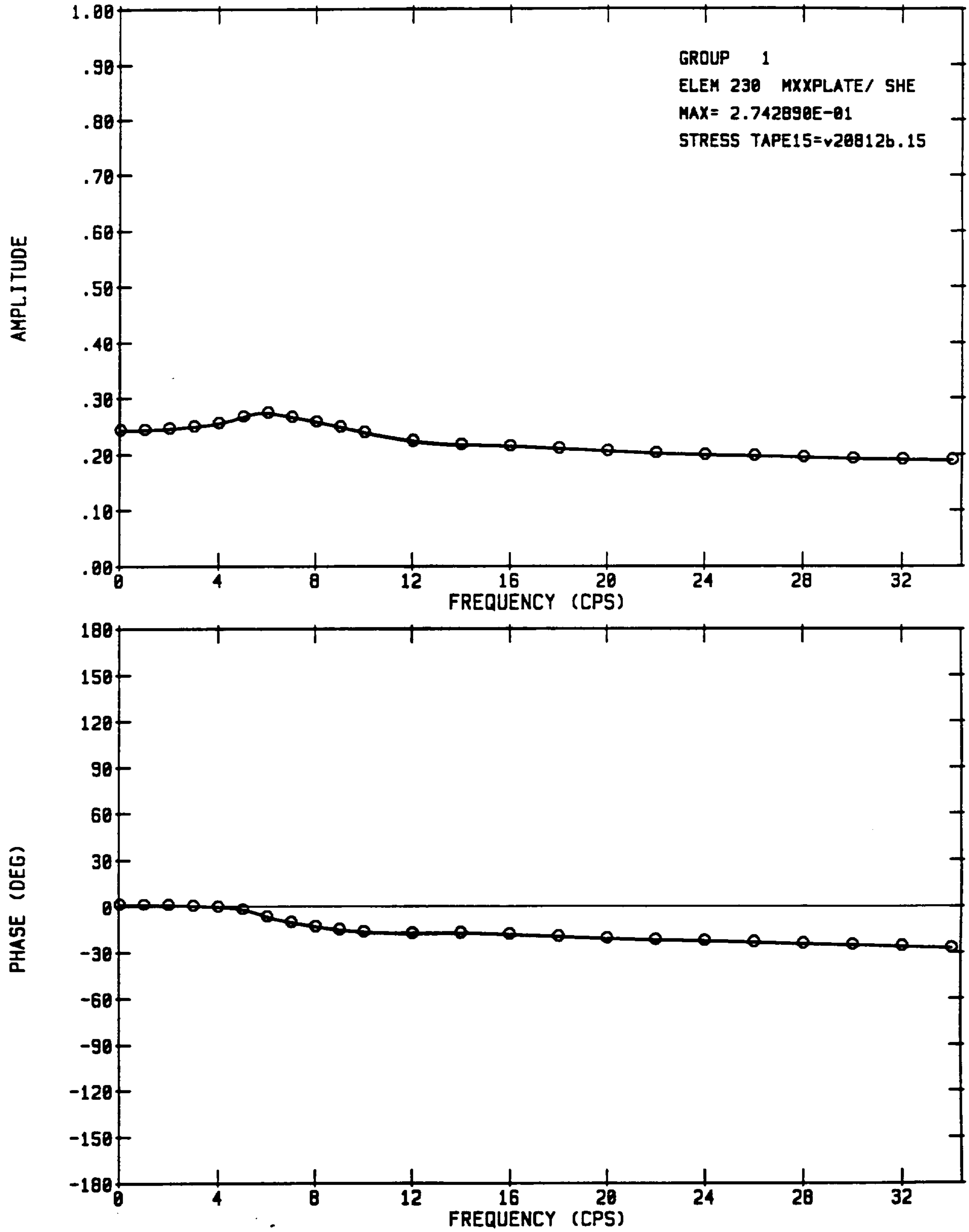


CEC JOB NO. 1083-000	
BY DH	DATE 6/13/97
CHECK [illegible]	DATE 6/13/97
CALC. NO. SC(PO17)-1	REV. NO. 0
SHEET NO. 115	

FIG. 5.2.4-11

D:\PFSF\SASSI\PLOTTF\1229MYY.INP 6/13/97

V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

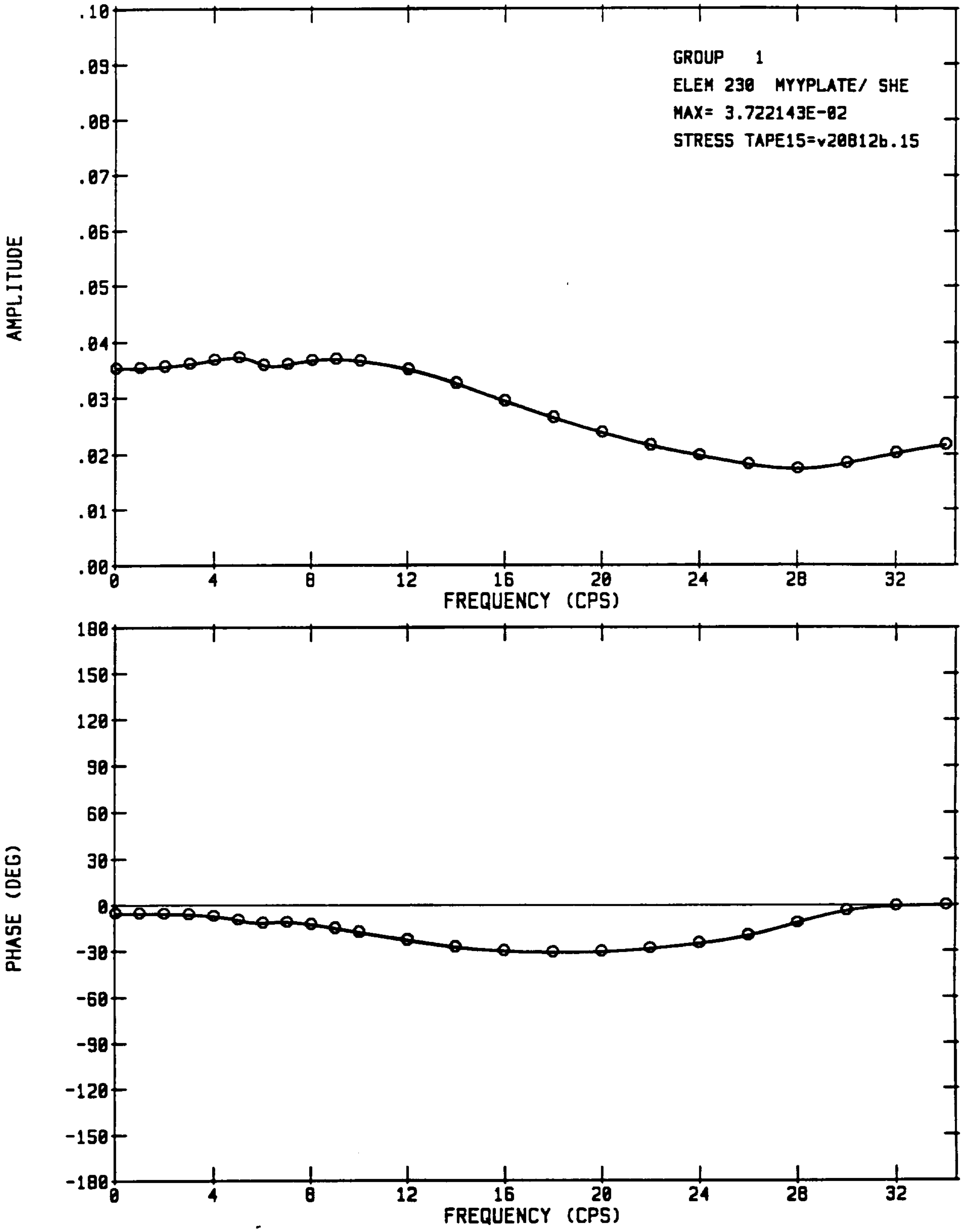


CEC JOB NO. 1083-000	
BY DH	DATE 6/13/97
CHECK [illegible]	DATE 6/13/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 116	

FIG 5.2.4-112

D:\PFSF\SASSI\PLOTTF\1230MXX.INP 6/13/97

V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



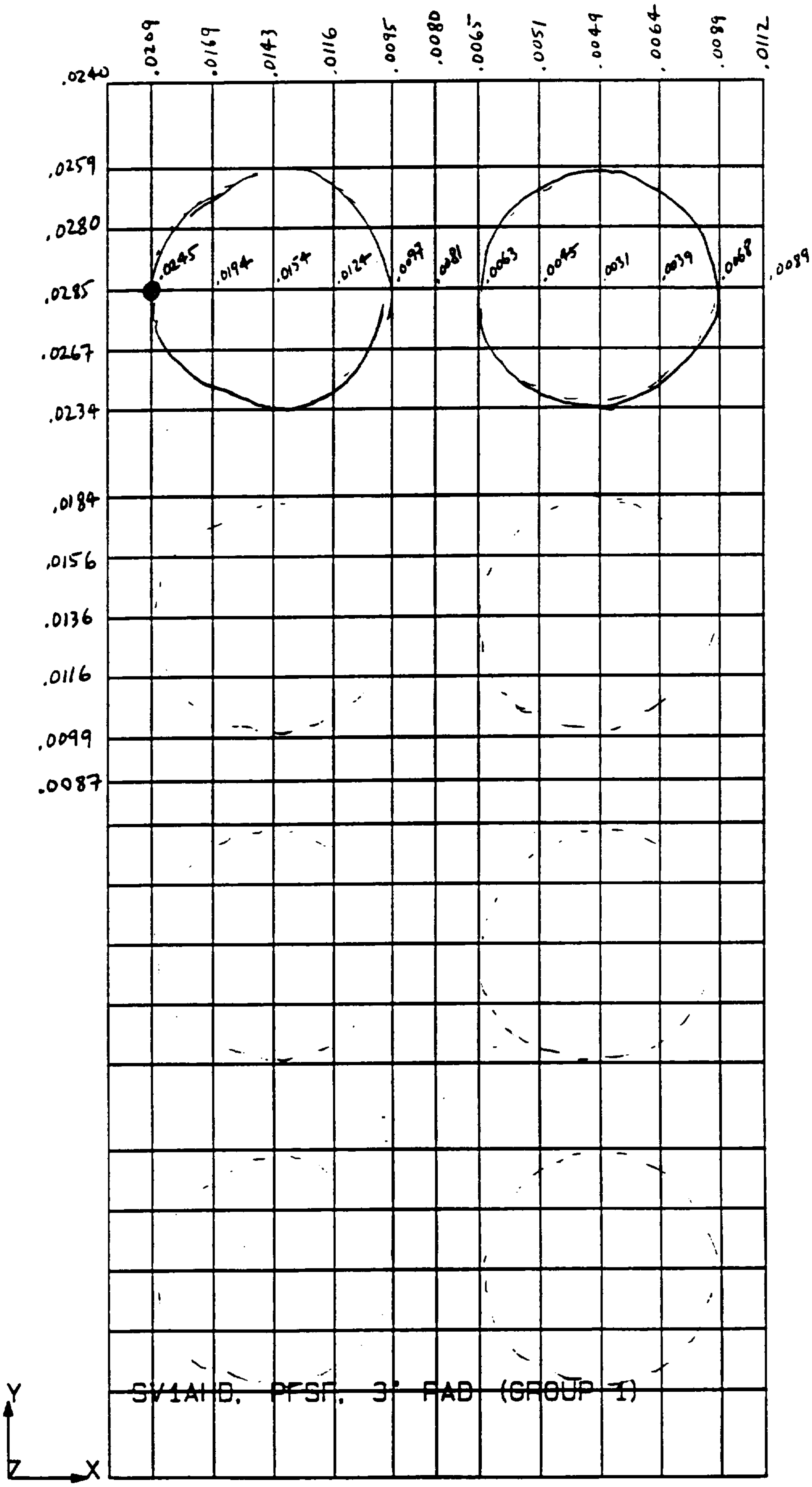
CEC JOB NO. 1083-000	
BY DH	DATE 6/13/97
CHECK K	DATE 6/13/97
CALC. NO. SC(PO17)-1	REV. NO. 0
SHEET NO. 117	

FIG. 5.2.4-13

D:\PFSF\SASSI\PLOTTF\1230MYY.INP 6/13/97

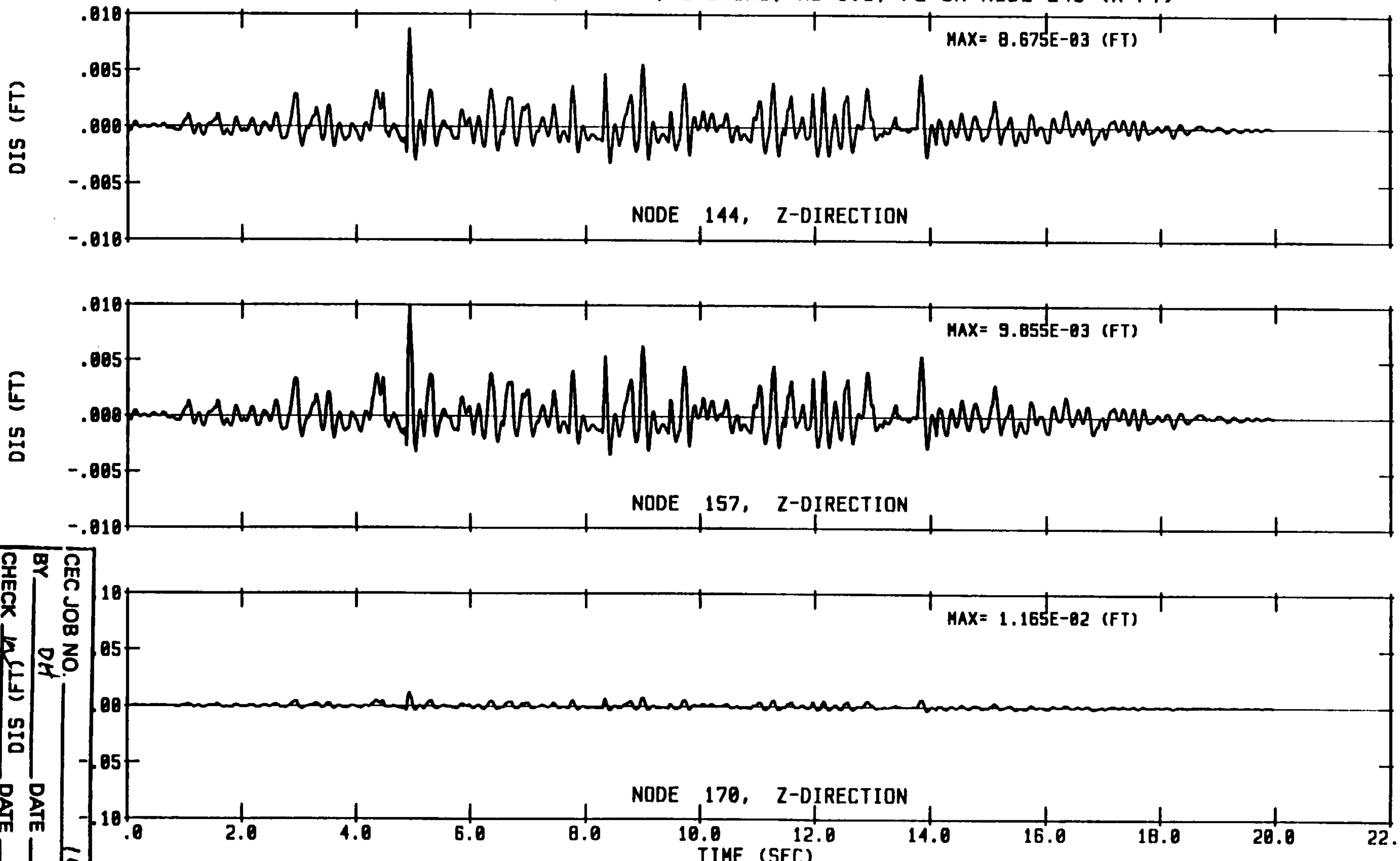
SASSI-MAXIMUM Z-DISPL. DUE TO FZ ON NODE 249 (REF. OUTPUT f249za00.ibm)

FIG. 5.2.4-14



CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK KL DATE 6/12/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 118

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



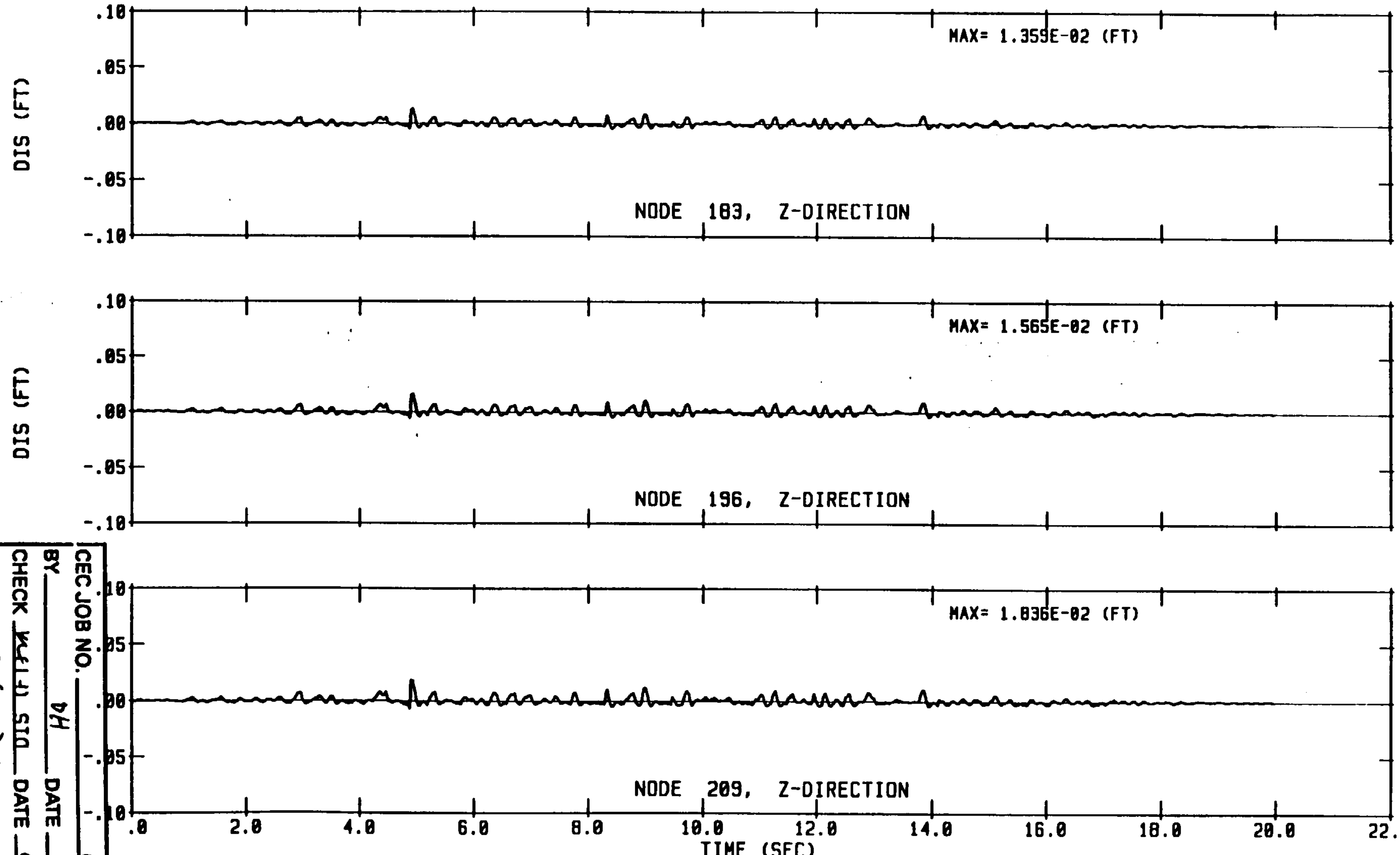
CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK LN (LT) SIO DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 119

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-15

D:\PFSF\SASSI\plotth\FZ144Z__.INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

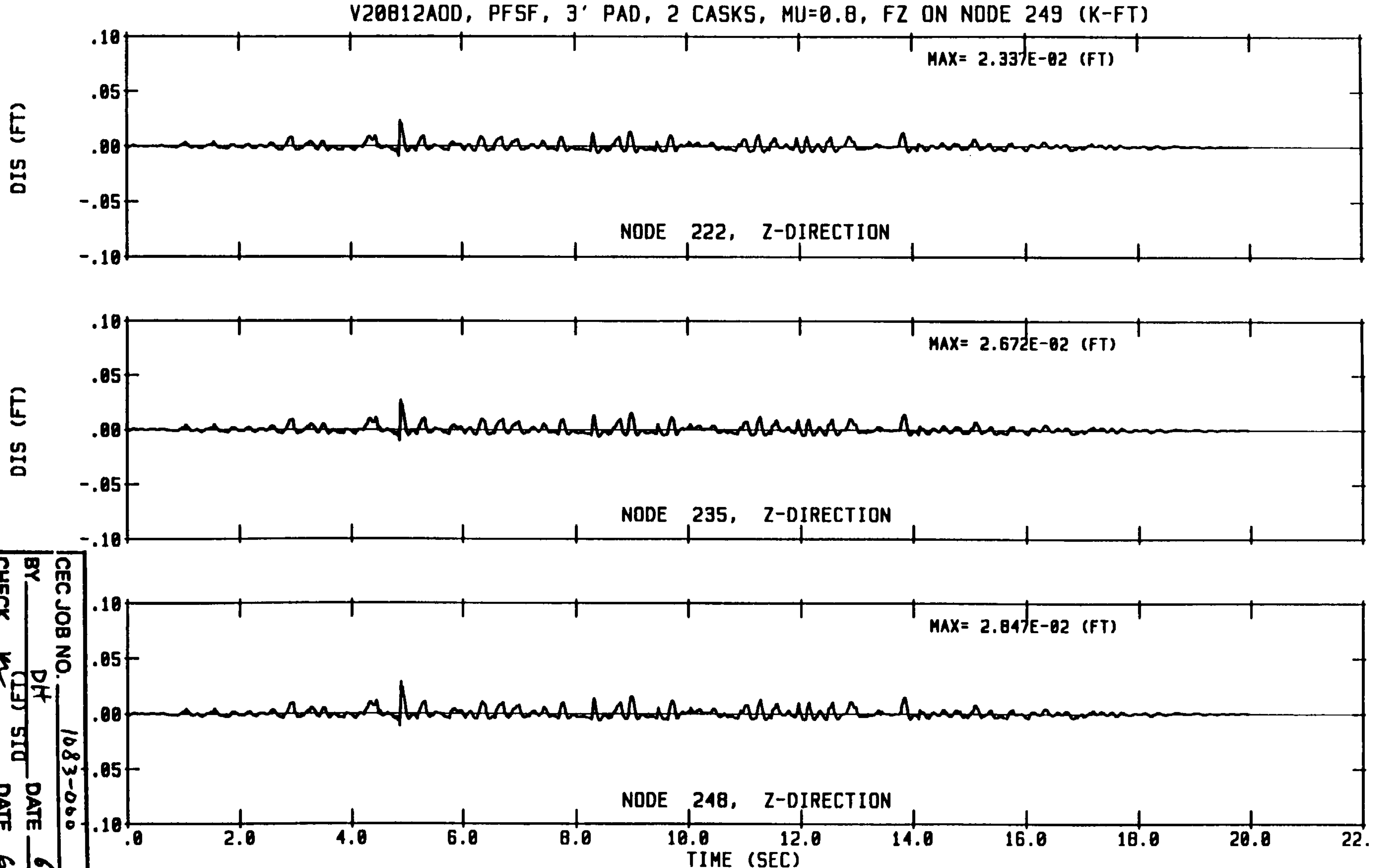


CEC JOB NO. 1083-000
BY VH DATE 6/7/97
CHECK K.L.I.U SIO DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 126

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-16

D:\PFSF\SASSI\plotth\FZ183Z__.INP 6/ 6/97

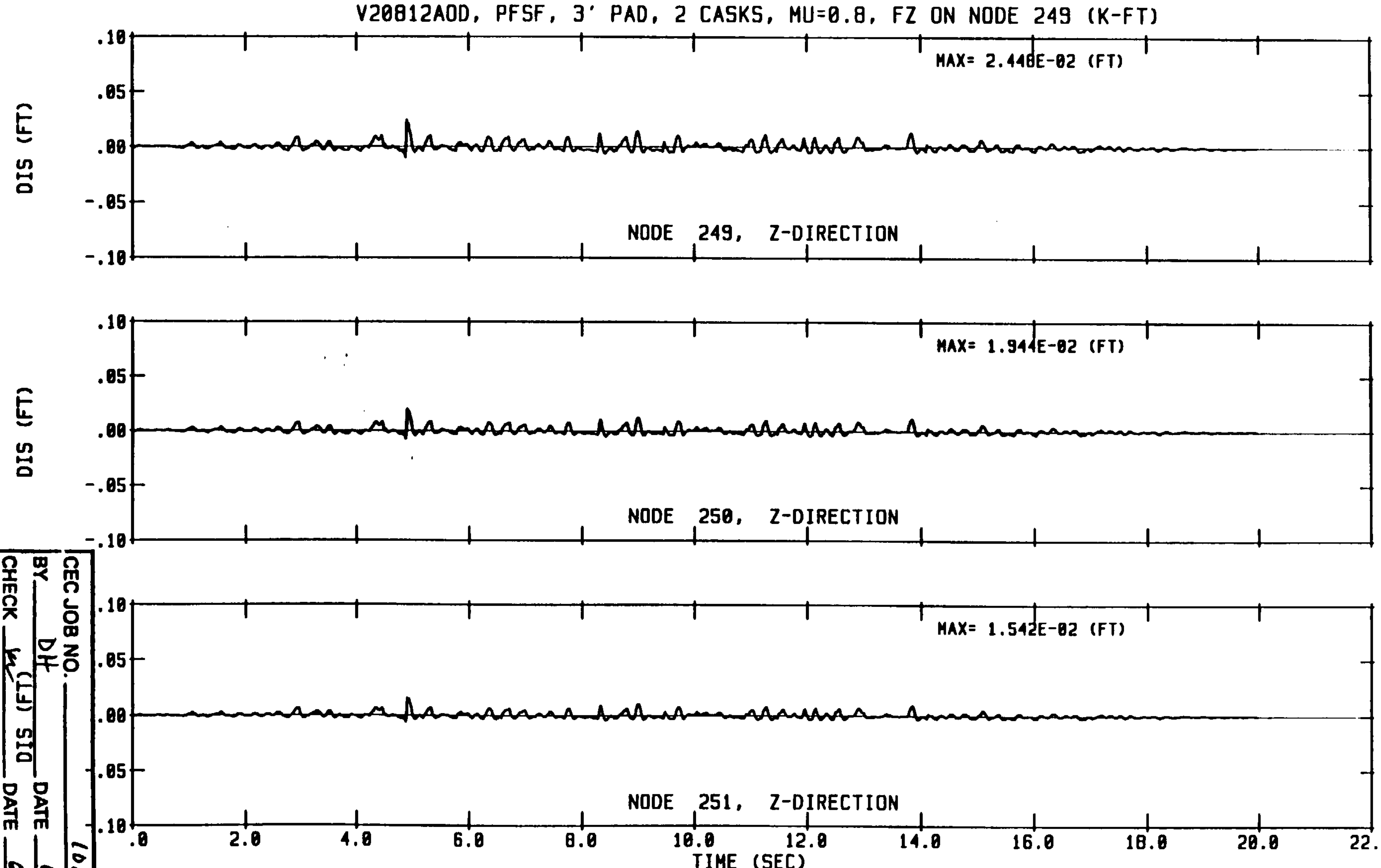


SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-17

CEC JOB NO. 1083-060
BY DH DATE 6/7/97
CHECK DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 1A1

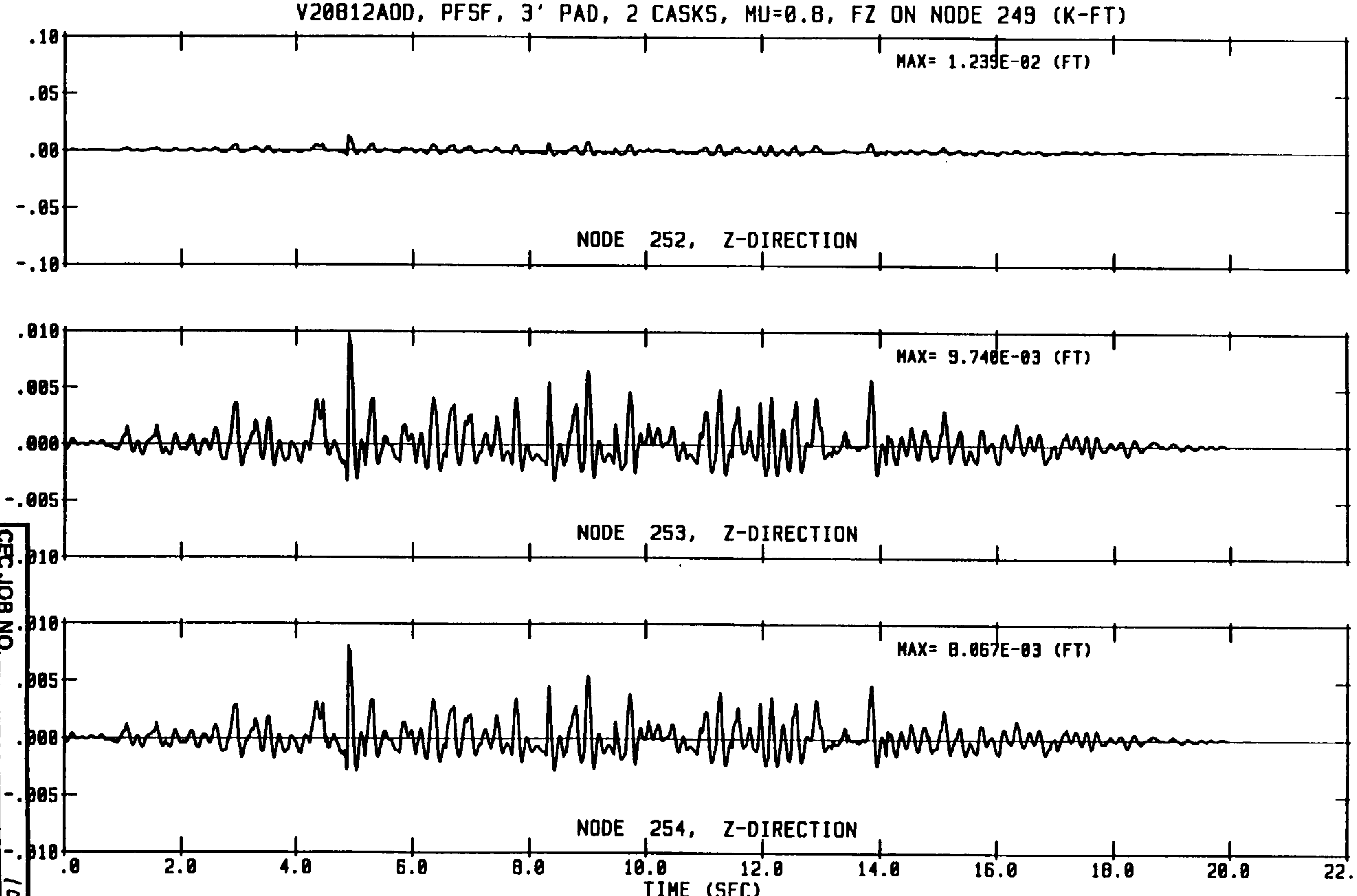
D:\PFSF\SASSI\plotth\FZ2222....INP 6/ 6/97



CEC JOB NO. 1083-000
BY DH DATE 6/3/97
CHECK [illegible] DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 122

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-18



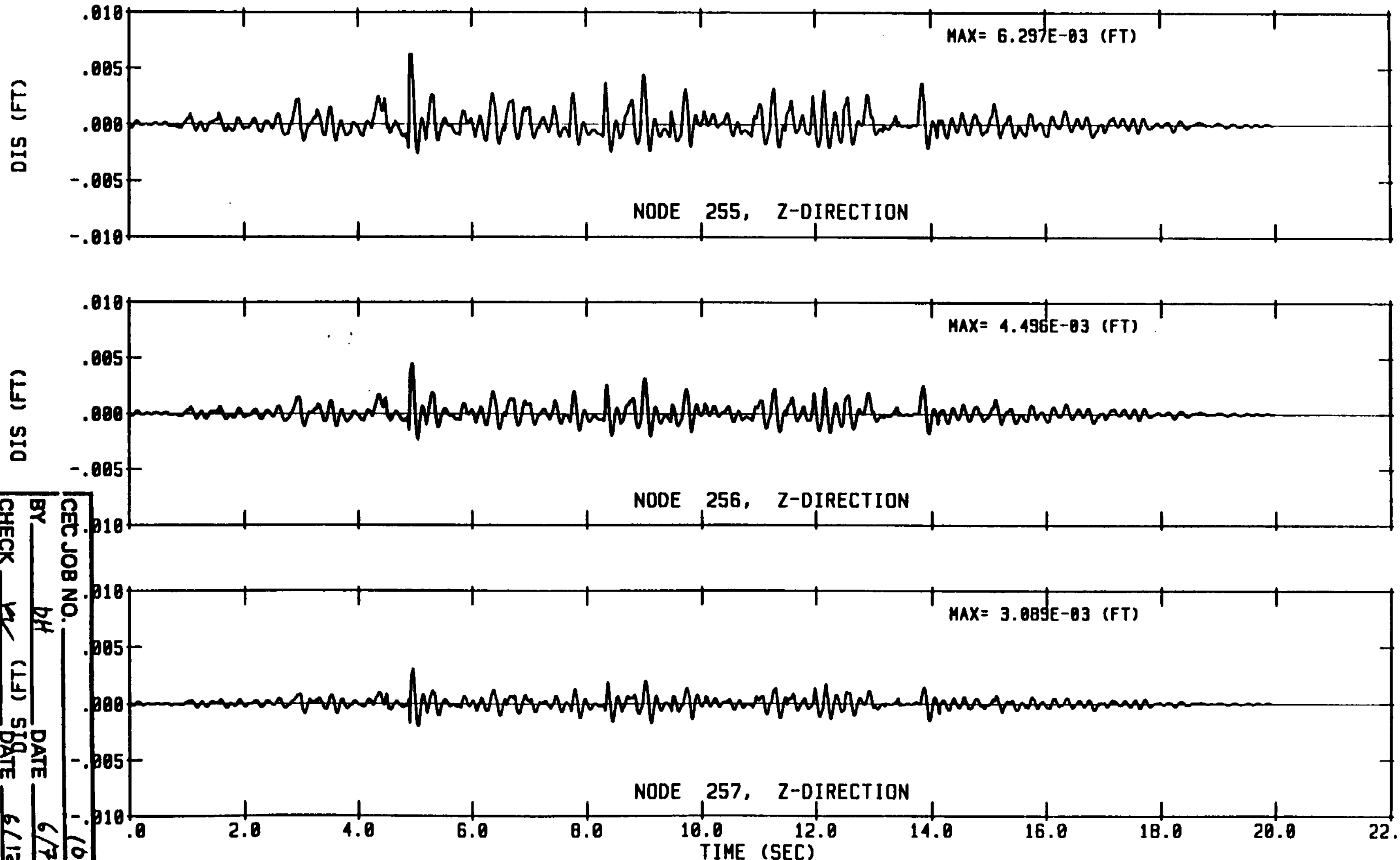
CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK KV (LT) SID DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 123

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4 - 19

D:\PFSF\SASSI\plotth\FZ252Z....INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



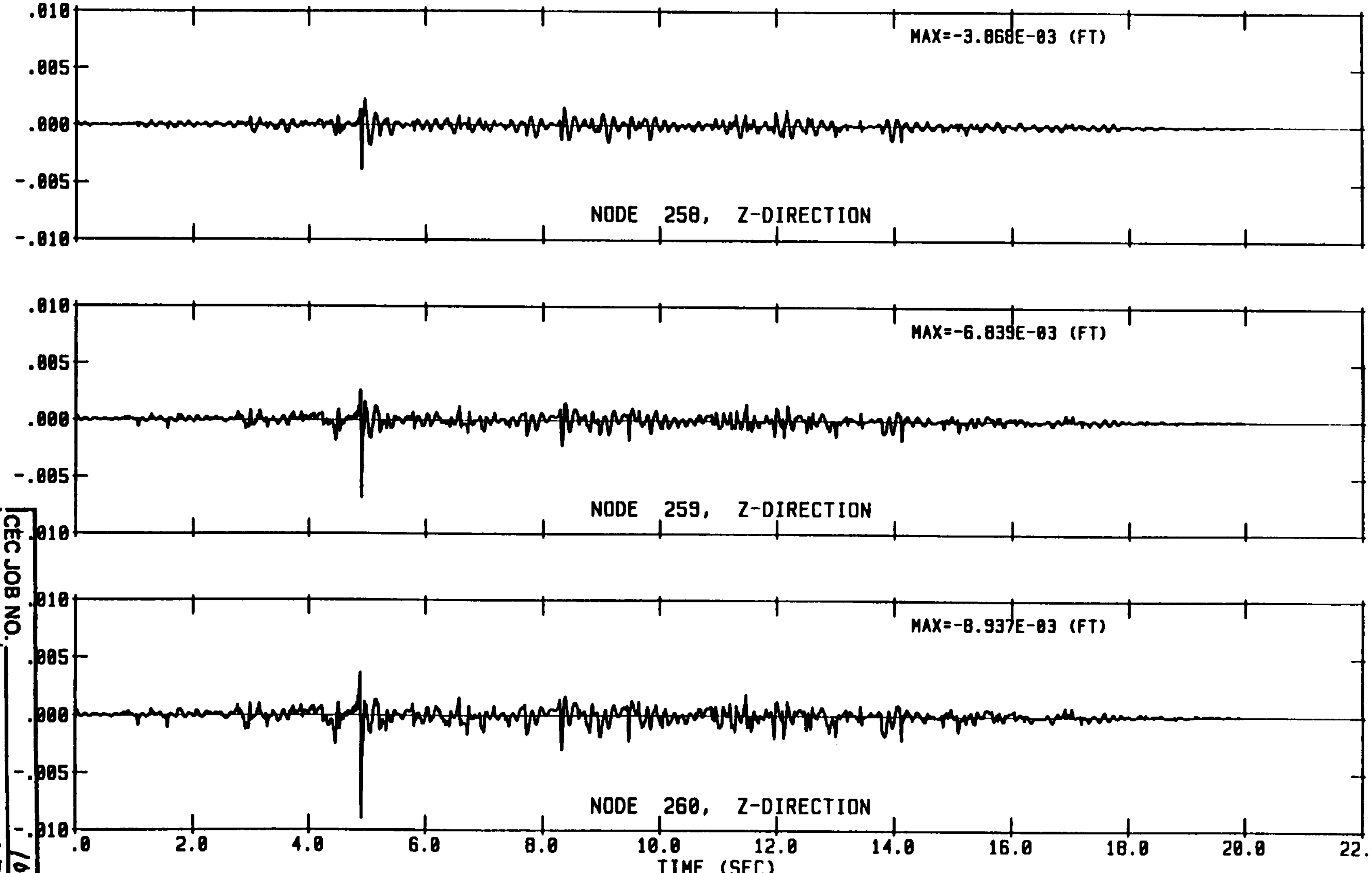
CEC JOB NO. 1083-060
BY bH DATE 6/7/97
CHECK KK DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 124

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-20

D:\PFSF\SASSI\plotth\FZ255Z...INP 6/ 6/97

V20812A0D, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



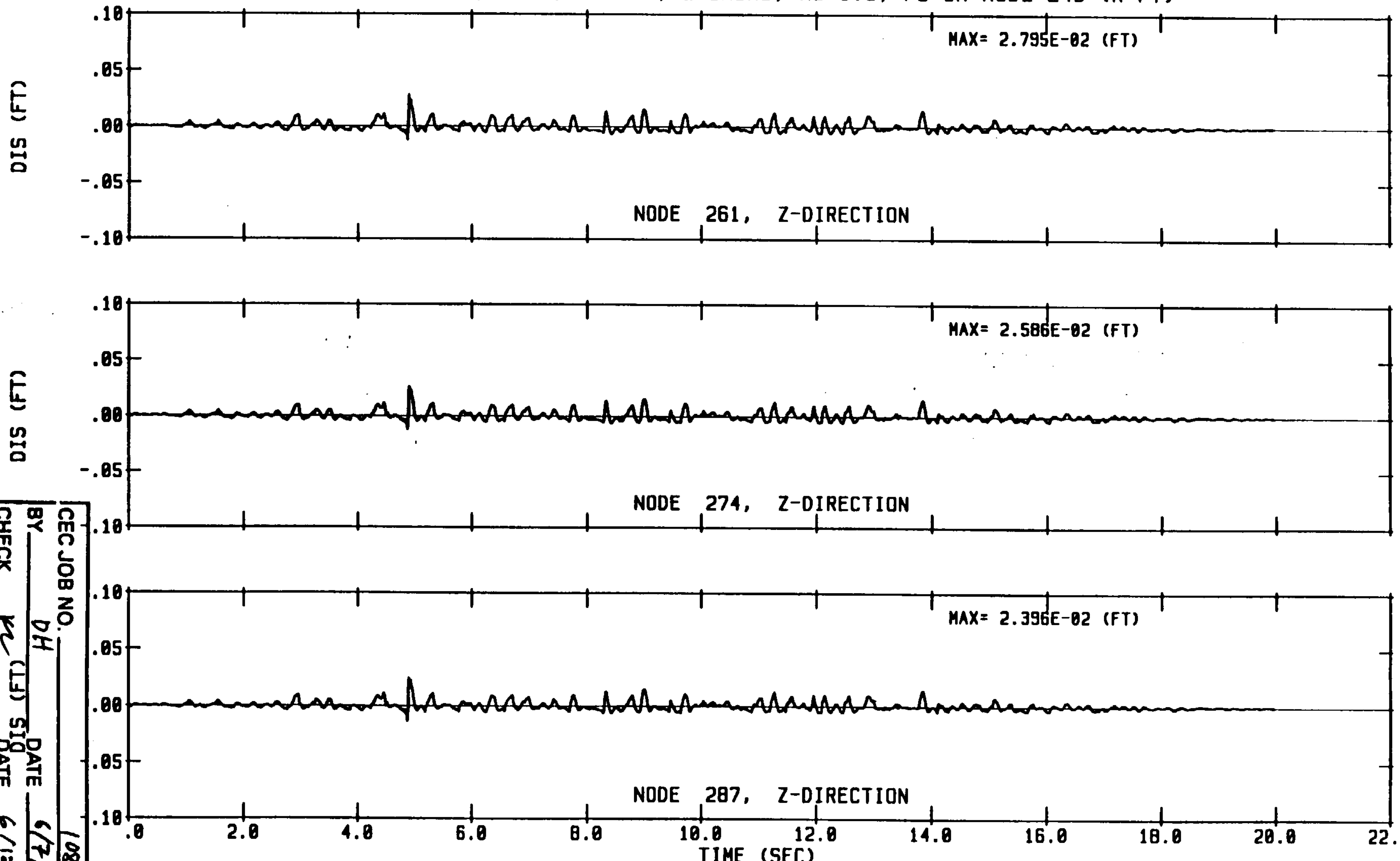
CEC JOB NO. 1683-000
BY DH DATE 6/7/97
CHECK (LJ) SIG DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 125

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-21

D:\PFSF\SASSI\plotth\FZ25BZ__.INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



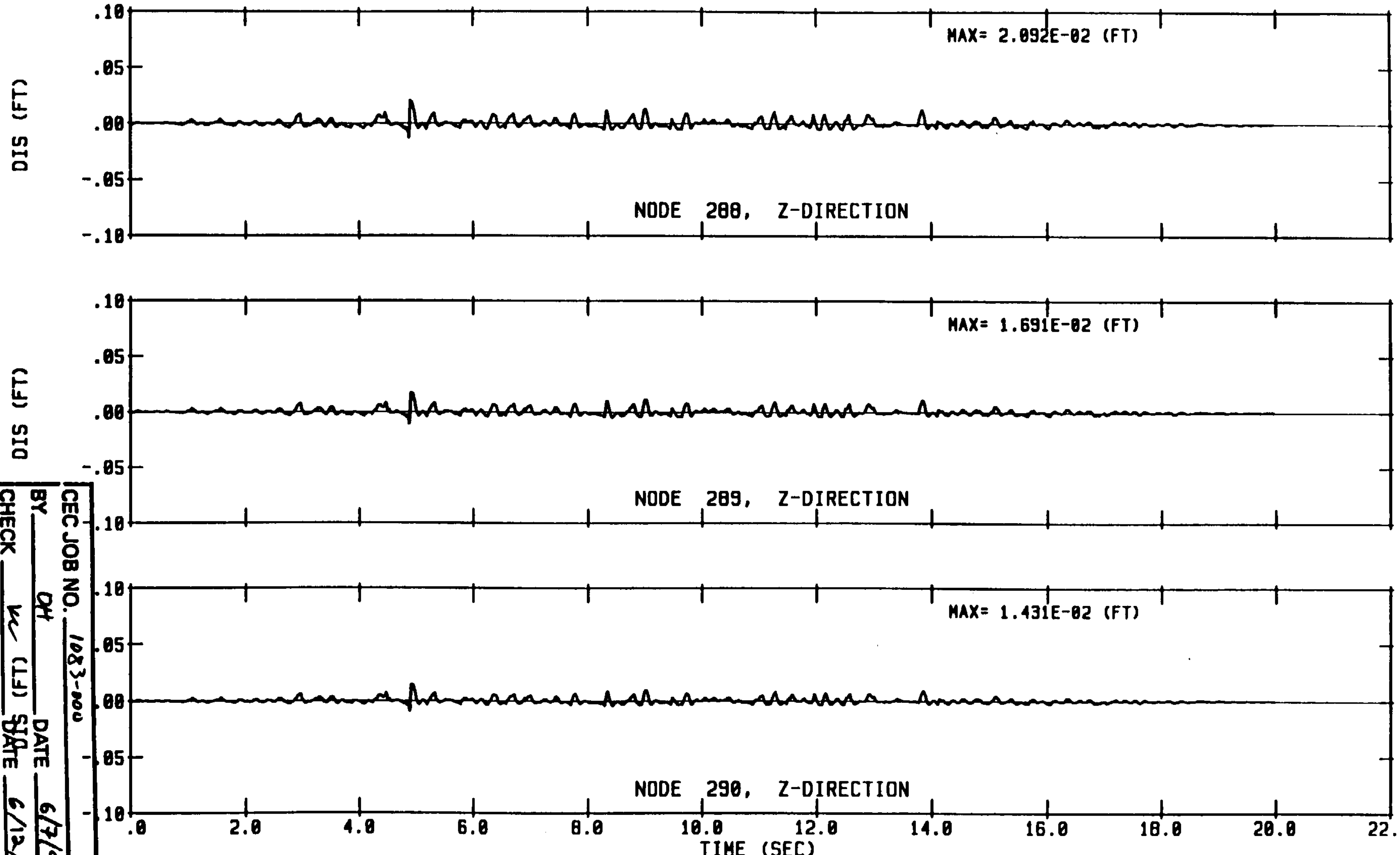
CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK KL (LF) SIG DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 126

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-22

D:\PFSF\SASSI\plotth\FZ261Z__.INP 6/ 6/97

V20812A0D, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)

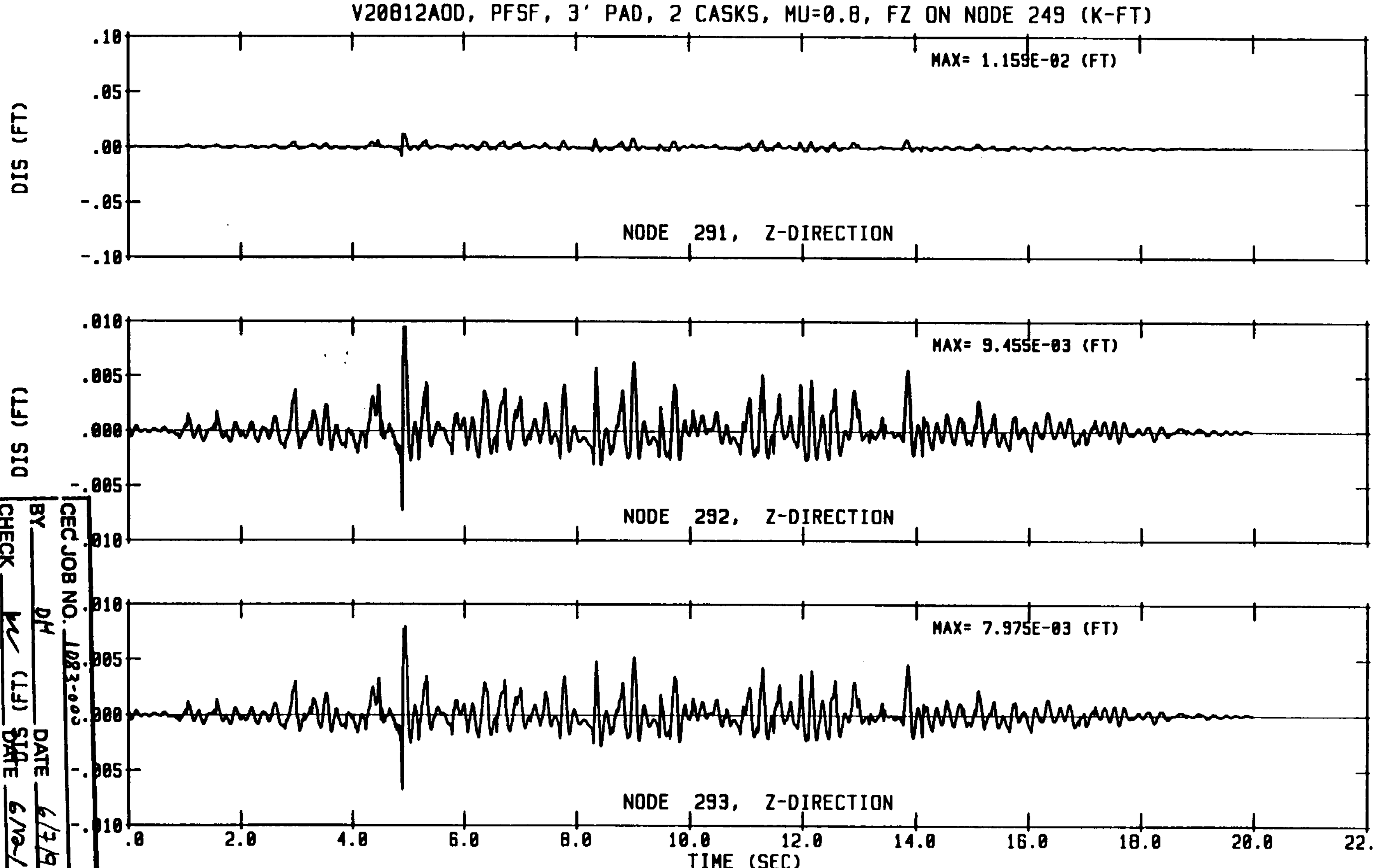


CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK KL (LJ) DATE 6/12/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 127

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-23

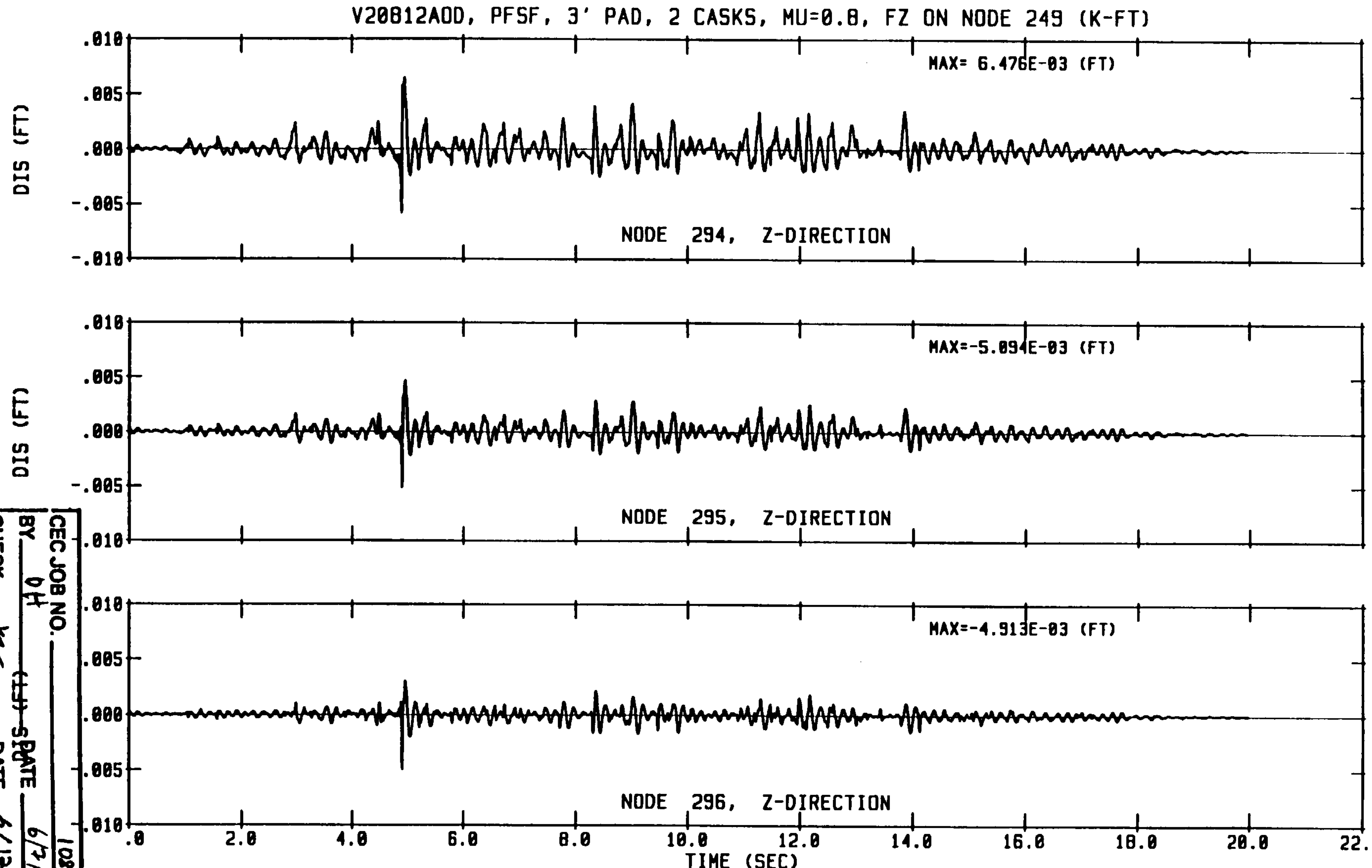
D:\PFSF\SASSI\olotth\FZ288Z__.INP 6/ 6/97



SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-24

CEC JOB NO. 1083-003
BY DH DATE 6/3/97
CHECK (LT) STD DATE 6/10/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 128



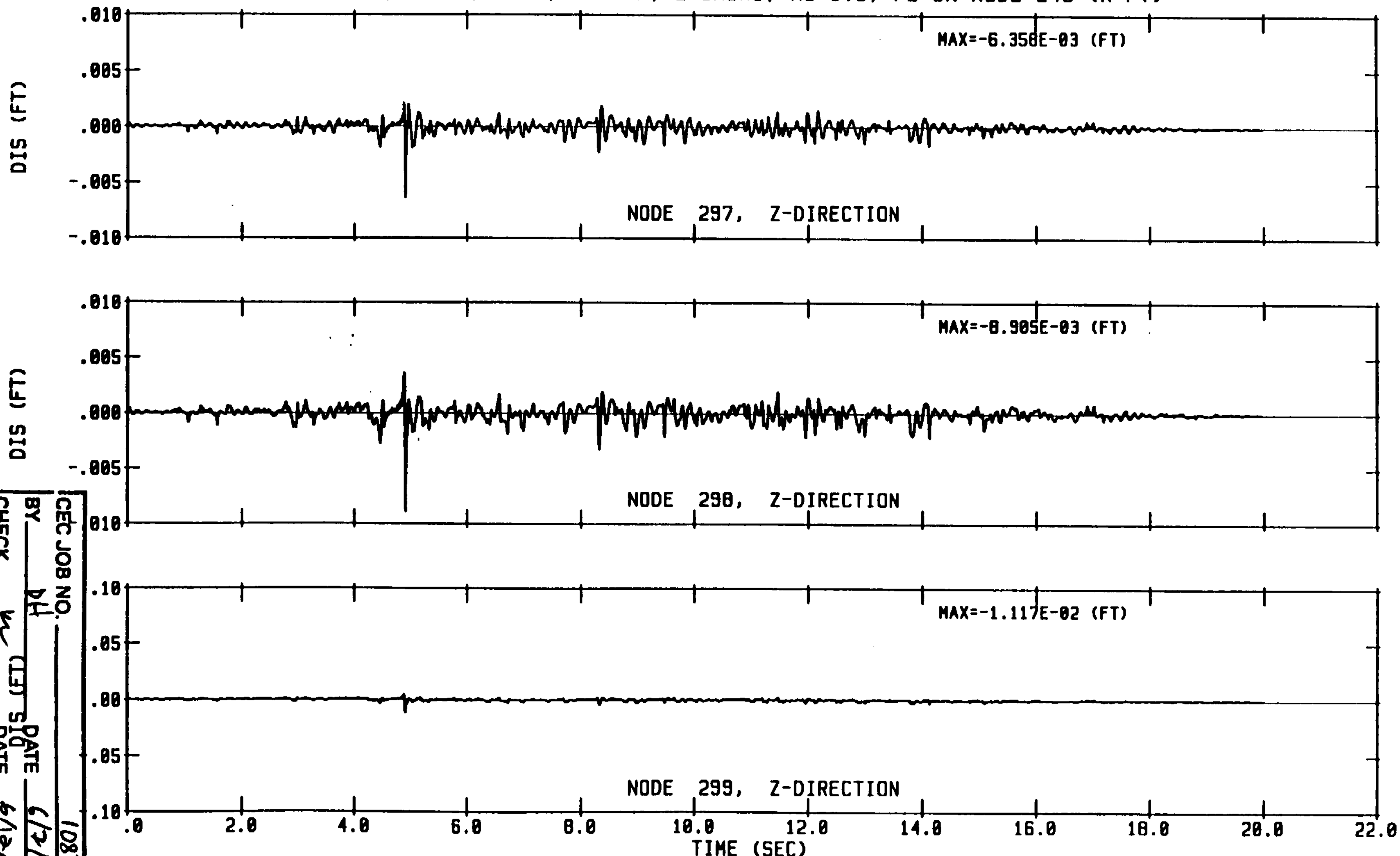
CEC JOB NO. 1083-000
BY DH DATE 6/7/97
CHECK DATE 6/12/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 129

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-25

D:\PFSF\SASSI\plotth\FZ2942 .INP 6/ 6/97

V20812AOD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



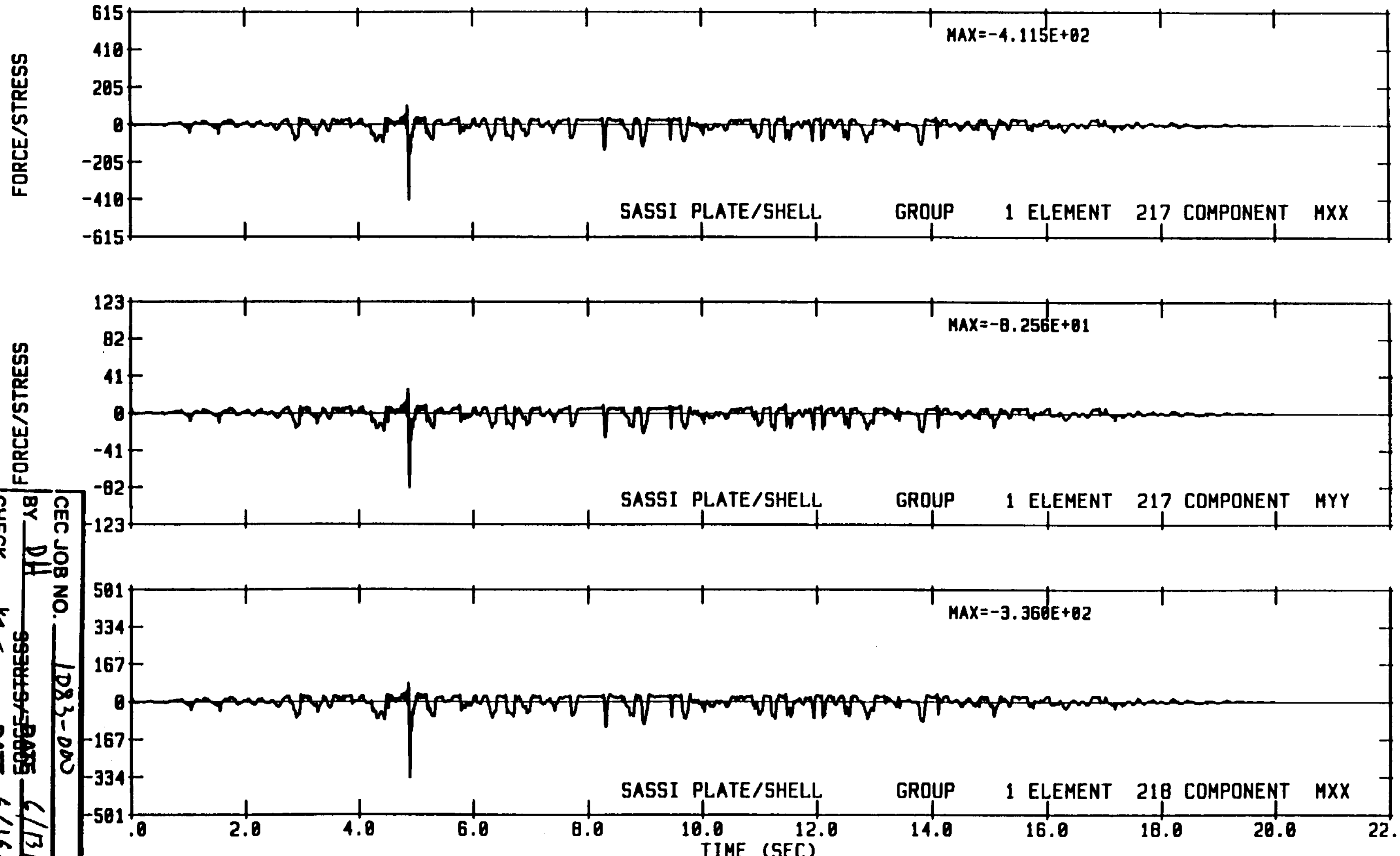
CEC JOB NO. 1083-060
BY DH DATE 6/2/97
CHECK [illegible] (LT) SIG DATE 6/12/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 130

SASSI TAPE 12 = V20812A.12
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-26

D:\PFSF\SASSI\plotth\FZ297Z__.INP 6/ 6/97

V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



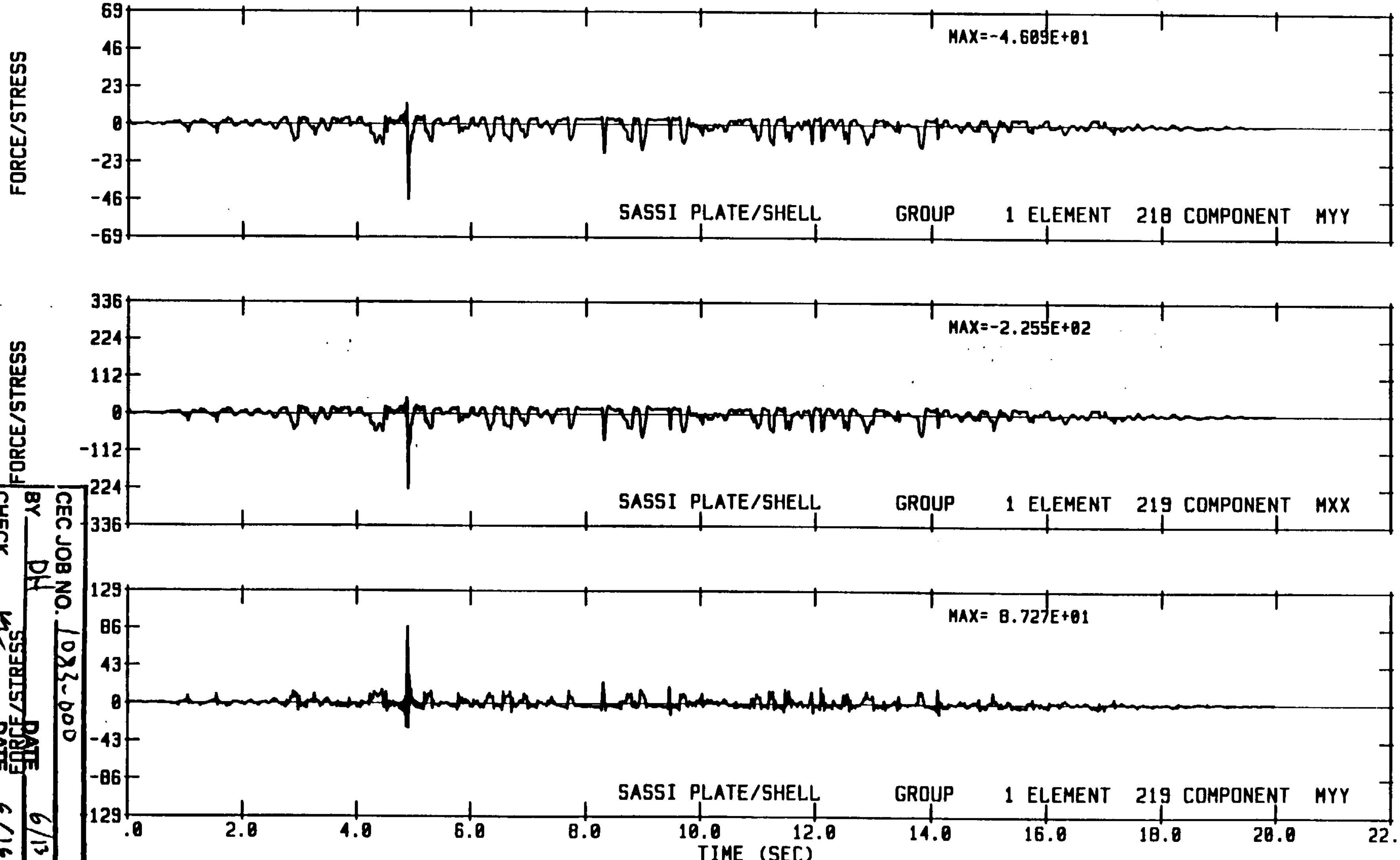
CEC JOB NO. 1083-003
BY DH DATE 6/13/97
CHECK [illegible] DATE 6/16/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 131

FIG. 5.2.4-27

SASSI TAPE 14 = v20812b.14
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

D:\PFSF\SASSI\PLOTTH\fz217MX.INP 6/13/97

V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



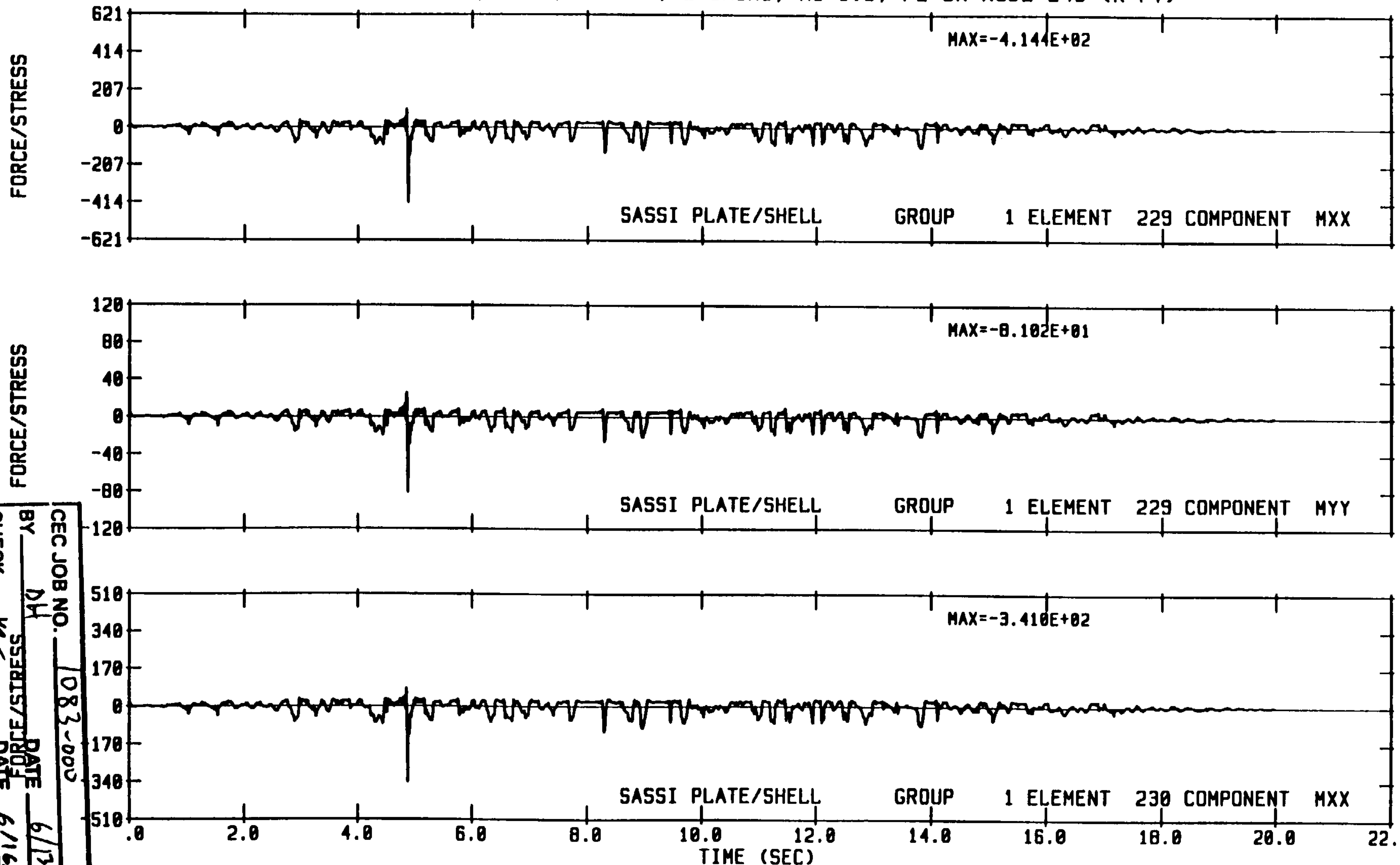
CEC JOB NO. 1023-000
BY DH DATE 6/13/97
CHECK [illegible] DATE 6/16/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 132

SASSI TAPE 14 = v20812b.14
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-28

D:\PFSF\SASSI\PLOTTH\fz2181MY.INP 6/13/97

V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



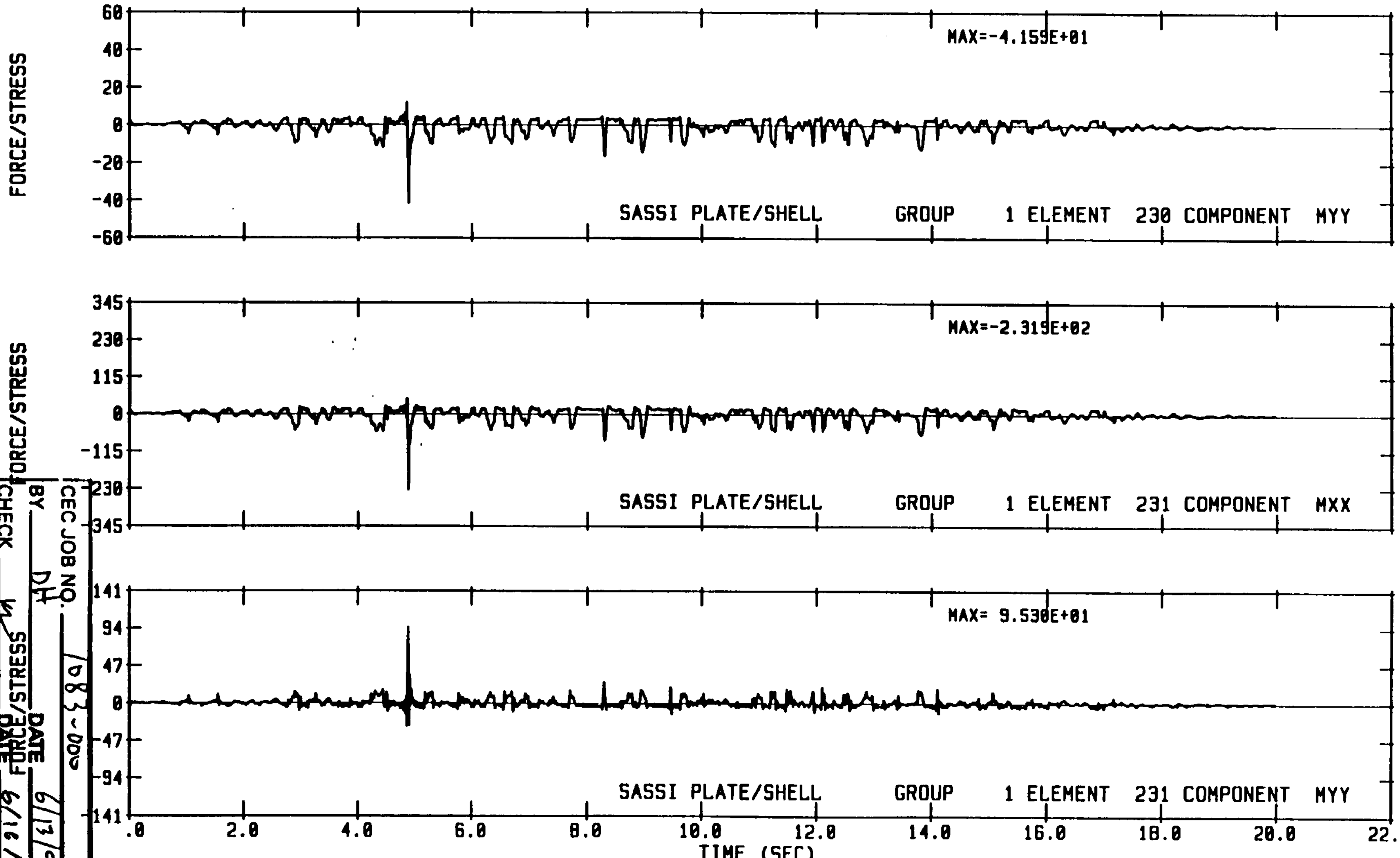
CEC JOB NO. 1083-000
BY DH DATE 6/13/97
CHECK [illegible] DATE 6/16/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 133

SASSI TAPE 14 = v20812b.14
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-29

D:\PFSF\SASSI\PLOTTH\fz2291MX.INP 6/13/97

V20812BTD, PFSF, 3' PAD, 2 CASKS, MU=0.8, FZ ON NODE 249 (K-FT)



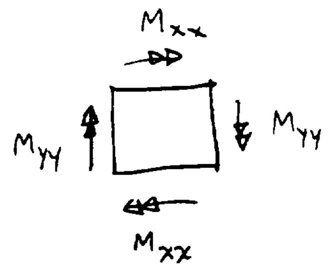
SASSI TAPE 14 = v20812b.14
INPUT TIME HISTORY = VERTICAL, 2 CASKS, FR=0.8, 1ST CASK, QUAD NO.2 (KIPS)
UNITS OF FORCE ARE K, UNITS OF LENGTH ARE FT AND RADIANS

FIG. 5.2.4-30

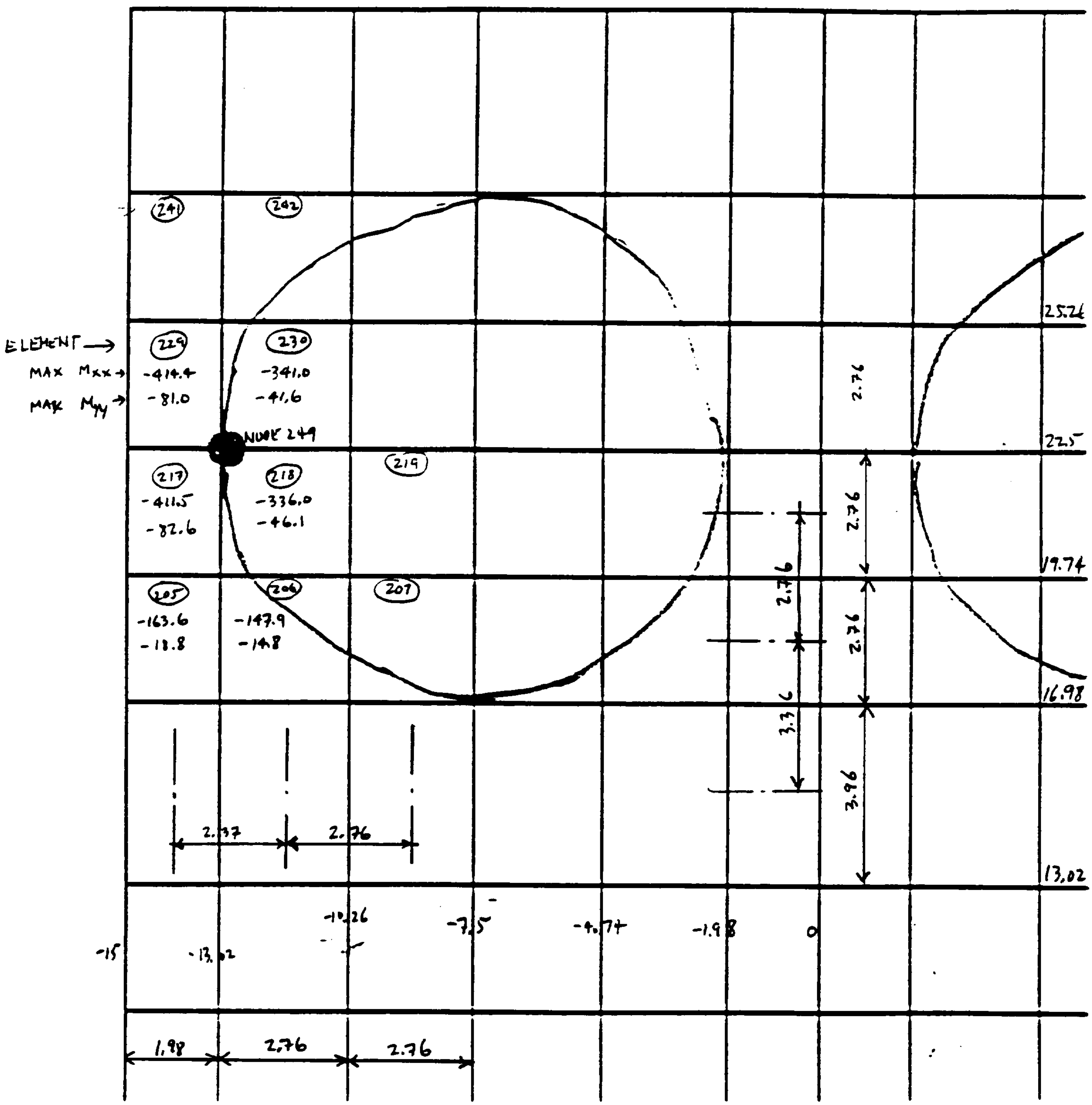
CEC JOB NO. 1083-006
BY DH DATE 6/13/97
CHECK KL DATE 6/16/97
CALC. NO. SC(PO17)-1 REV. NO. 0
SHEET NO. 134

D:\PFSF\SASSI\PLOTTH\fz2301MY.INP 6/13/97

FIG. 5.2.4-31 SASSI RESULTS (REF. V20812bto.ibm)
(SEE ALSO TABLE 5.2.4-2)



CEC JOB NO. 1083-000	
BY DH	DATE 6/14/97
CHECK [illegible]	DATE 6/16/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 135	



5.2.5 COMPARISON OF CECSAP AND SASSI RESULTS

RESULTS OF THE CECSAP AND SASSI ANALYSES, IN TERMS OF MAXIMUM DISPLACEMENTS AND BENDING MOMENTS, ARE COMPARED IN TABLES 5.2.5-1 AND 5.2.5-2.

THE DISPLACEMENT TIME HISTORIES AT SELECTED NODES ARE PLOTTED TOGETHER FOR COMPARISON ON FIG. 5.2.5-1.

THE MOMENT TIME HISTORIES FOR ELEMENT 217 HAVE BEEN PLOTTED TOGETHER FOR COMPARISON IN FIGS. 5.2.5-2 THROUGH 5.2.5-4.

MAXIMUM SHEARS ARE COMPARED IN TABLE 5.2.5-3.

THE CECSAP RESULTS ARE CONSISTENTLY HIGHER THAN THE SASSI RESULTS. THUS, DESIGNING THE PAD USING THE CECSAP RESULTS WILL RESULT IN A MORE CONSERVATIVE DESIGN.

CEC

CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR MSD DATE 6-6-97 CHECKED DH DATE 6/9/97

PROJECT PFSF JOB NO. 1083-000

SUBJECT SHEET NO. 137

TABLE 5.2.5-1

Comparison between CECSAP and SASSI

Loading : a single force time history for the 2nd quadrant of the 1st cask for the 2 cask case was applied at Node 249, Node for the center of the 2nd quadrant of the 1st cask

Displacement Comparison

Left edge Node No.	(A) SASSI	(B) CECSAP	((B)/(A)-1) 100%
144	0.0087'	0.0121'	+39
157	0.0099'	0.0135'	+36
170	0.0116	0.0158	+36
183	0.0136	0.0182	+34
196	0.0156	0.0208	+33
209	0.0184	0.0237	+29
222	0.0234	0.0279	+19
235	0.0267	0.0307	+15
248	0.0285	0.0332	+16
261	0.0280	0.0352	+26
274	0.0259	0.0367	+42
287	0.0240	0.0385	+60
Top Edge			
287	0.0240	0.0385	+60
288	0.0209	0.0350	+67
289	0.0169	0.0305	+80
290	0.0143	0.0266	+86
291	0.0116	0.0226	+95
292	0.0095	0.0183	+93
293	0.0080	0.0151	+89
294	0.0065	0.0116	+78

TABLE 5.2.5-2

Pad Bending Moment Comparison

Four elements around the loading point (Node 249) were chosen for comparison between CECSAP and SASSI in plate bending maximum values

Element No.	(A) SASSI*	(B) CECSAP	% [(B)/(A)-1]100
	M_{yy}	m_{xx}	
217	-82.56	-152.8	+85
218	-46.09	-79.78	+73
229	-81.02	-151.8	+87
230	-41.59	-77.78	+87
	m_{xx}	m_{yy}	
217	-411.5	-638.0	+55
218	-336.0	-498.1	+48
229	-414.4	-651.5	+57
230	-341.0	-514.2	+51

Conclusions

CECSAP calculates higher peak values. Especially the moment peaks by CECSAP are much higher than those by SASSI.

* NOTE: THE PLATE LOCAL X AND Y AXES IN THE SASSI MODEL CORRESPOND TO THE PLATE LOCAL Y AND X AXES IN THE CECSAP MODEL.

CALCULATION SHEET

CALC. NO. SC(PO17)-1	REV. NO. 0		
ORIGINATOR DH	DATE 6/14/97	CHECKED [illegible]	DATE 6/16/97
PROJECT Private Fuel Storage Facility		JOB NO. 1083-000	
SUBJECT Storage Pad Analysis and Design		SHEET NO. 139	

TABLE 5.2.5-3

PAD SHEAR COMPARISON

X-DIR

ELEMENTS	(A) SASSI = $\Delta M_{yy}/L$ [K-FT/FT]	(B) CECSAP = $\Delta M_{xx}/L$ [K-FT/FT]	$(\frac{B}{A}-1)\times 100$
205-206	1.69		
217-218	15.40	30.81 (1)	100%

Y-DIR

ELEMENTS	(A) SASSI = $\Delta M_{xx}/L$ [K-FT/FT]	(B) CECSAP = $\Delta M_{yy}/L$ [K-FT/FT]	$(\frac{B}{A}-1)\times 100$
205-217	89.82		
206-218	68.15		

(1) FROM TABLE 5.2.5-2

$(152.8-79.78)/2.37 = 30.81$

DISPLACEMENT TIME HISTORIES (CECSAP vs SASSI)

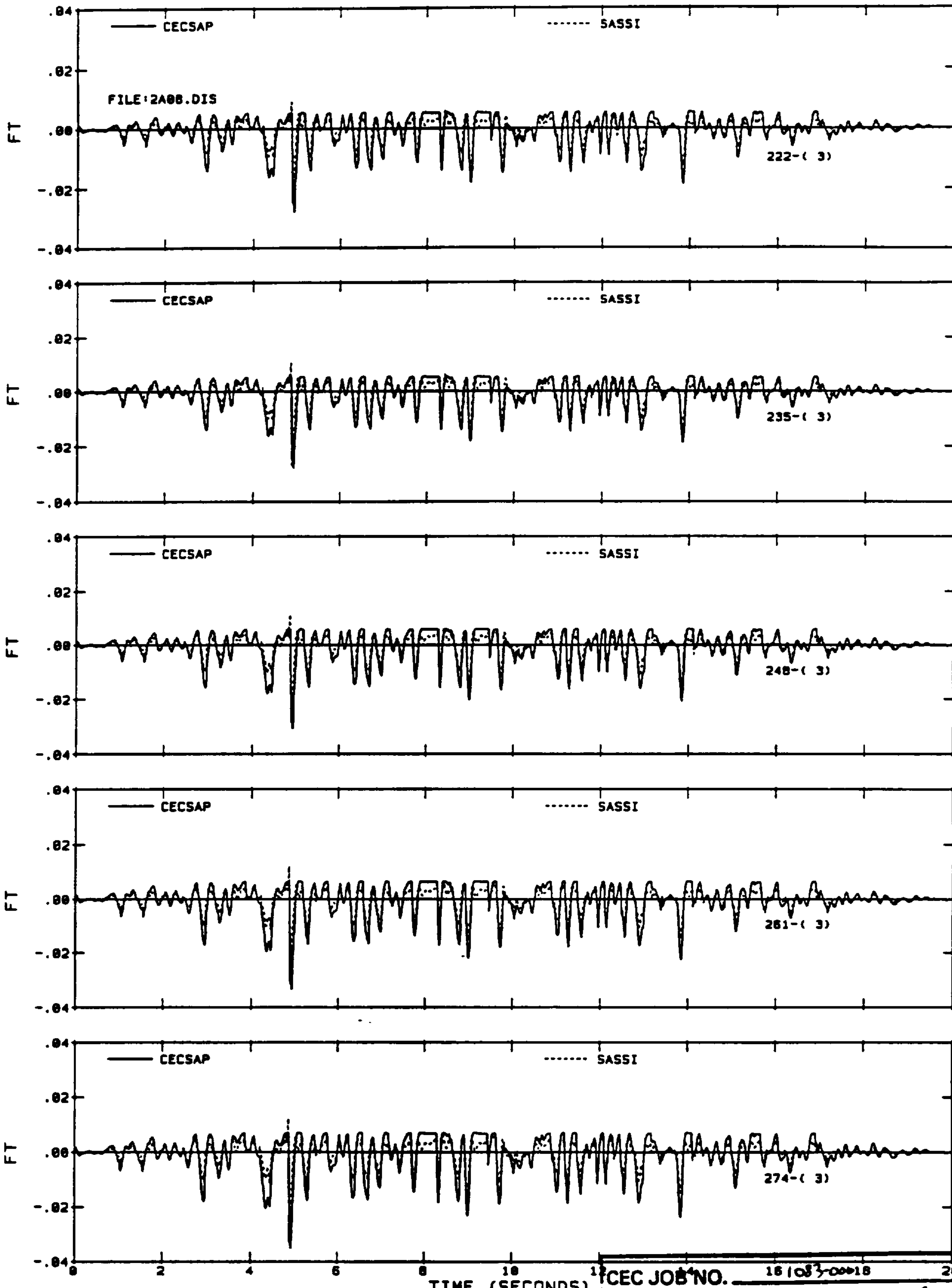


FIG. 5.2.5-1.

CEC JOB NO. 18 1083-00018	
BY [signature]	DATE 6-9-97
CHECK OH	DATE 6/9/97
CALC. NO. SC(P017)-1	REV. NO. 0
SHEET NO. 160	

MOMENT TIME HISTORIES (CECSAP vs SASSI)

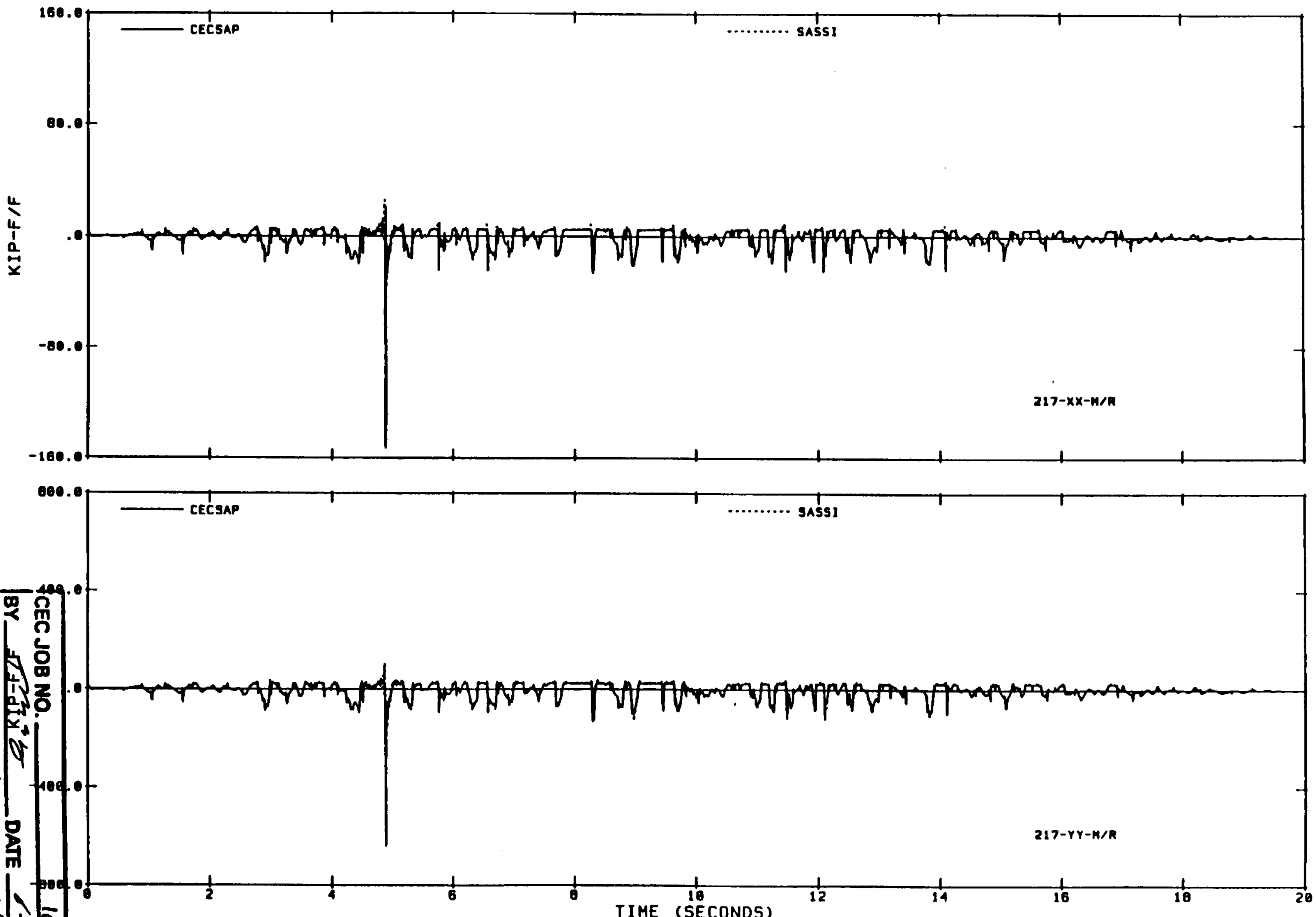


FIG. 5.2.5-2

CEC JOB NO. 1083-000
BY [illegible] DATE 1-9-97
CHECK DH DATE 6/9/97
CALC. NO. SC(R017)-1 REV. NO. 0
SHEET NO. 141

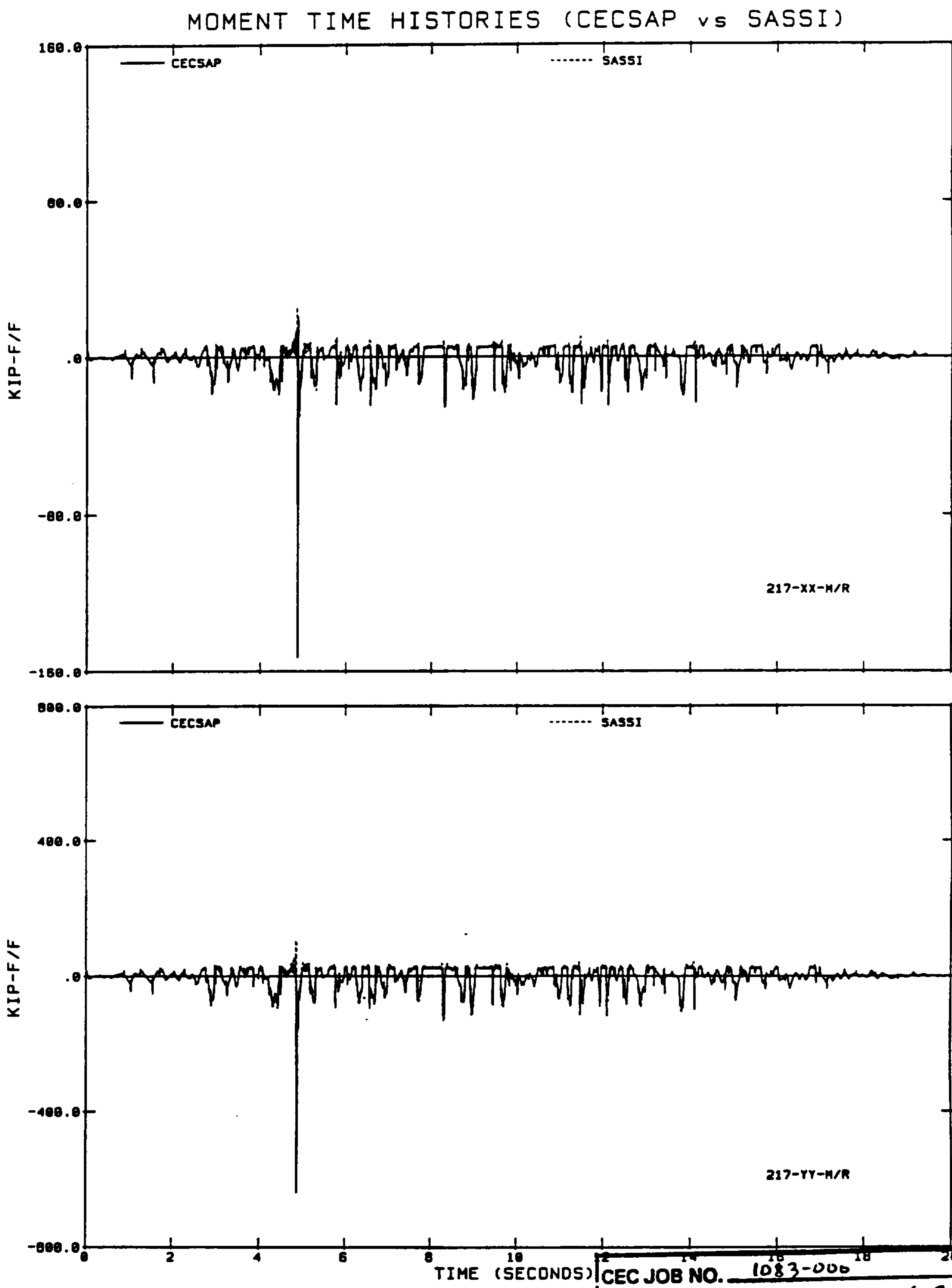


FIG. 5.2.5-3

CEC JOB NO. 1083-006
BY ______ DATE 6-9-97
CHECK DH DATE 6/9/97
CALC. NO. SC(P017)-1 REV. NO. 0
SHEET NO. 142

MOMENT TIME HISTORIES (CECSAP vs SASSI)

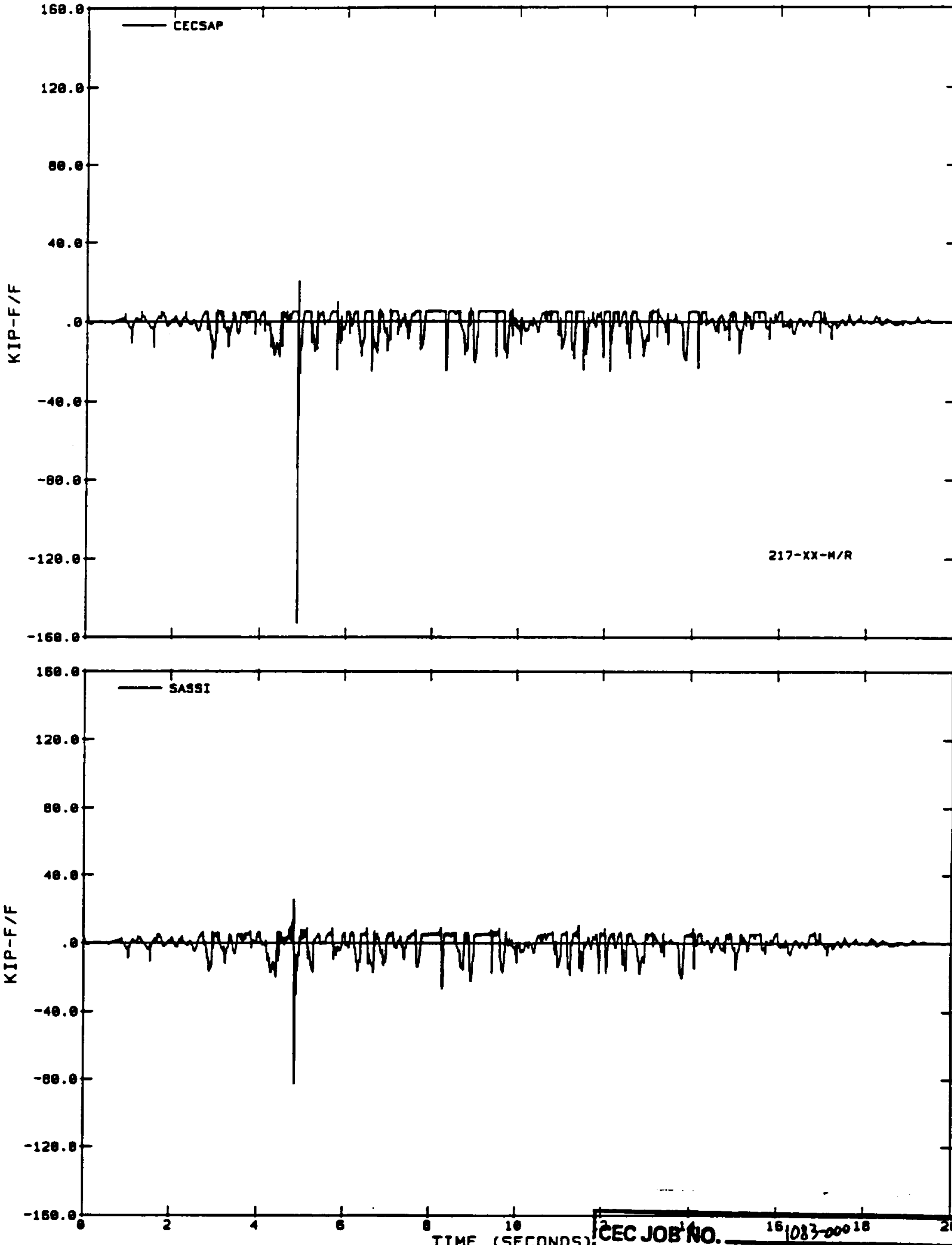


FIG 5.2.5-4

CEC JOB NO. 16083-000

BY [signature] DATE 6-9-97

CHECK DH DATE 6/9/97

CALC. NO. SC(P017)-1 REV. NO. 0

SHEET NO. 143

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

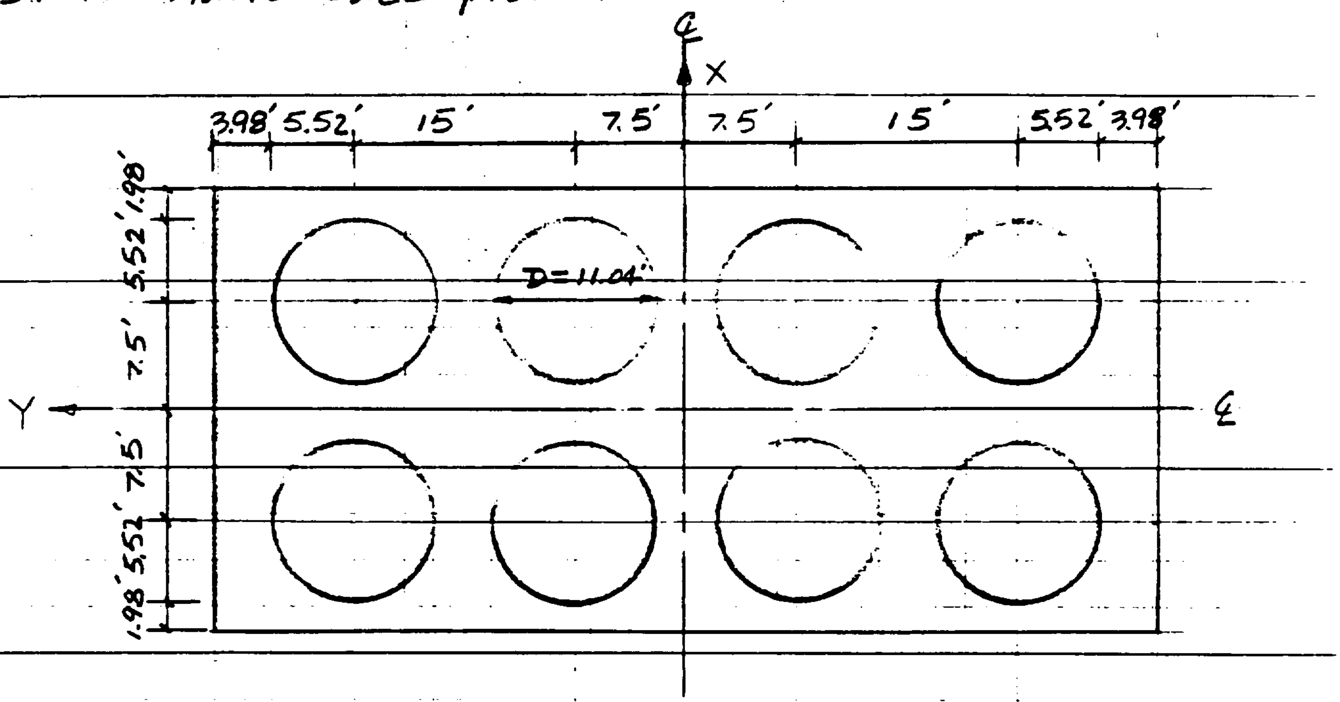
ORIGINATOR M. Tsay DATE 5/28/97 CHECKED w DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 144

5.3 SOIL PRESSURE

5.3.1 static soil pressure



L : Live Load

D : Dead Load

Load Case 1

~~2 casks~~

Load Case 2

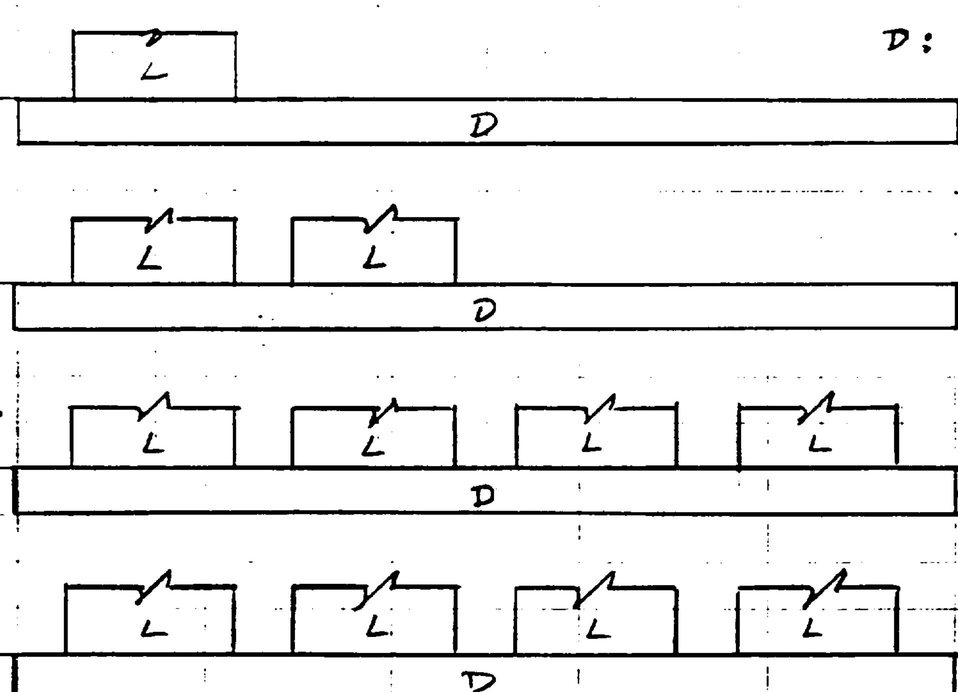
~~4 casks~~

Load Case 3

8 casks

Load Case 4

7 Casks + One transporter with one cask



CEC **CALCULATION SHEET**

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 5/28/97 CHECKED [illegible] DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

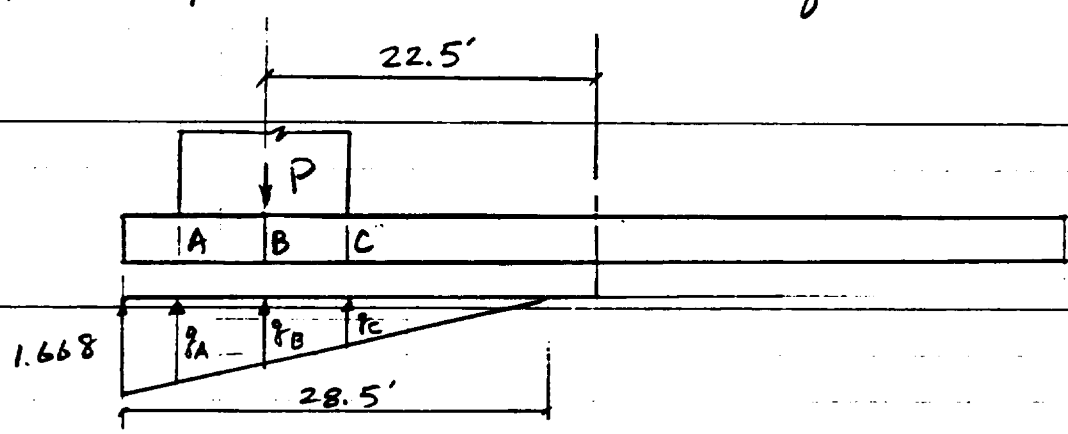
SUBJECT Storage Pad Analysis and Design SHEET NO. 145

The soil pressure under dead load and live load are to be checked with simplified procedure and later compare to computer analysis results.

Load case 1 with 2 casks acting

a. Soil pressure due to dead load $p_d = 0.150 \times 3 = 0.450$ ksf

b. soil pressure due to live Load of 2 casks



e = eccentricity = $22.5' > L/6 = 64/6 = 10.67'$

Let $L'/3 = L/2 - e$; $P = qL'B/2$, $L' = 3 \times (64/2 - 22.5) = 28.5'$

$q = \dfrac{2P}{3B(L/2 - e)}$; $P = 2 \times 356.521$, $B = 30'$, $L = 64'$

$q = 2 \times (2 \times 356.521) / (3 \times 30 (64/2 - 22.5)) = 1.668$ k/ft^2

$p = p_d + q = 0.450 + 1.668 = 2.12$ ksf < 4 ksf (Ref. 8, P. 4-5)

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 5/28/97 CHECKED ur DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 146

Under the dead load, there will be no bending moment, since the downward concrete load always equal upward soil bearing pressure.

Sections A, B, C are to be checked for the bending moment due to live load

$q_A = 1.668 \times (28.5 - 3.98)/28.5$

$= 1.435$ KSF

$q_B = 1.668 \times (28.5 - 3.98 - 11.04/2)/28.5$

$= 1.112$ KSF

$q_c = 1.668 \times (28.5 - 3.98 - 11.04)/28.5$

$= 0.789$

The bending moment at section A

$M/_{B0} = 1.7 \times (1.435 \times \frac{1}{2} \times 3.98^2 + \frac{2}{3} \times \frac{1}{2} \times 3.98^2 \times (1.668 - 1.435))$

$= 1.7 \times (11.365 + 1.230)$

$= 1.7 \times 12.595$

$= 21.412$ K-ft/ft

The bending moment at section B

$$M/30 = 1.7\times(1.112\times\tfrac{1}{2}\times9.5^2+\tfrac{1}{3}\times9.5^2\times(1.668-1.112)$$
$$-\tfrac{1}{2}\times2\times356.521\times0.4244\times5.52/30)$$
$$=1.7\times(50.179+16.726-27.841)$$
$$=1.7\times39.064$$
$$=66.409 \text{ k-ft/ft}$$

The bending moment at section C

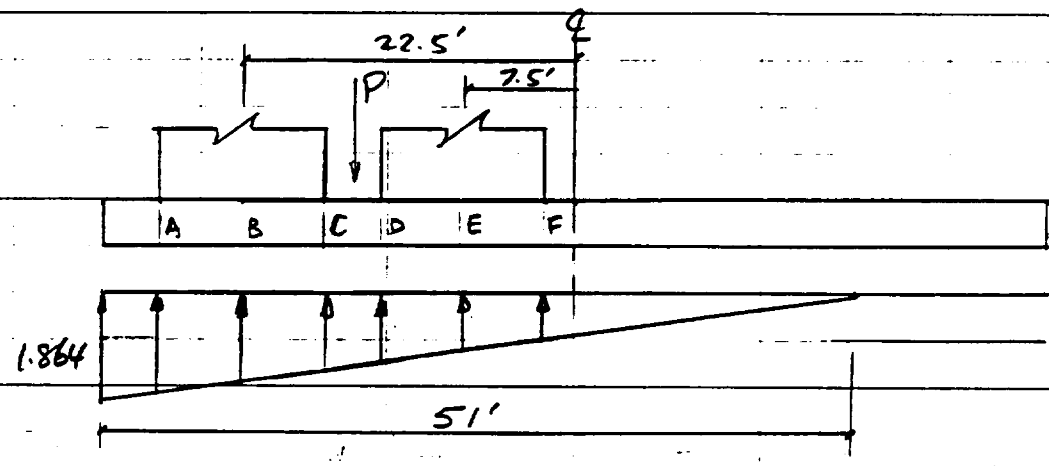
$$M/30 = 1.7\times(0.789\times\tfrac{1}{2}\times(11.04+3.98)^2+\tfrac{1}{3}\times(11.04+3.98)^2\times$$
$$(1.668-0.789)-2\times356.521\times5.52/30)$$
$$=1.7\times(88.999+66.101-131.2)$$
$$=1.7\times23.90$$
$$=40.63 \text{ k-ft/ft}$$

Section B has the max. moment of <u>66.41 k-ft/ft</u>.

Load Case 2 with 4 casks

a. Soil pressure due to dead load $p_d = 0.150 \times 3 = 0.450$ KSF

b. Soil pressure due to live load of 4 casks



e = eccentricity $= 15' > L/6 = 64/6 = 10.67'$

Let $L'/3 = L/2 - e$, $P = q L' B/2$; $L' = (64/2 - 15) \times 3 = 51'$

$$q = \frac{2P}{3B(L/2 - e)} \quad ; \quad P = 4 \times 356.521,\ B = 30$$

$$q = \frac{2 \times 4 \times 356.521}{3 \times 30 \times (32 - 15)} = 1.864 \text{ ksf}$$

$p = p_d + q = 0.450 + 1.864 = 2.31$ ksf $<$ 4 ksf.

Soil pressure under section A, B, C, D, E, F

$q_A = 1.864 \times (51 - 3.98)/51 = 1.719$

$q_B = 1.864 \times (51 - 3.98 - 5.52)/51 = 1.517$

CEC

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 5/29/97 CHECKED [illegible] DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

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$$\gamma_C = 1.864 \times (51 - 3.98 - 11.04)/51 = 1.315$$

$$\gamma_D = 1.864 \times (51 - 3.98 - 11.04 - 3.96)/51 = 1.170$$

$$\gamma_E = 1.864 \times (51 - 3.98 - 11.04 - 3.96 - 11.04/2)/51 = 0.969$$

$$\gamma_F = 1.864 \times (51 - 3.98 - 11.04 \times 2 - 3.96)/51 = 0.767$$

Moment at section A

$$M_A/30 = 1.7 \times (1/2 \times 3.98^2 \times 1.719 + 1/3 \times 3.98^2 \times (1.864 - 1.719))$$

$$= 1.7 \times (13.615 + 0.766)$$

$$= 1.7 \times 14.381$$

$$= 24.447 \text{ k-ft/ft}$$

Moment at section B

$$M_B/30 = 1.7 \times (1/2 \times (3.98 + 5.52)^2 \times 1.517 + 1/3 \times 9.5^2 \times (1.864 - 1.517)$$

$$- 1/2 \times 2 \times 356.521 \times 0.4244 \times 5.52/30)$$

$$= 1.7 \times (68.455 + 10.439 - 27.841)$$

$$= 1.7 \times 51.053$$

$$= 86.791 \text{ k-ft/ft}$$

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 5/29/97 CHECKED [illegible] DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

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Moment at section C

$$M_C/_{30} = 1.7\times(\tfrac{1}{2}\times(9.5+5.52)^2\times1.315+\tfrac{1}{3}\times(1.864-1.315)\times15.02^2$$
$$-2\times356.521\times5.52/_{30})$$
$$=1.7\times(148.332+41.285-131.20)$$
$$=1.7\times58.417$$
$$=99.31\ \text{k-ft}/\text{ft}$$

Moment at section D

$$M_D/_{30} = 1.7\times(\tfrac{1}{2}\times(15.02+3.96)^2\times1.17+\tfrac{1}{3}\times(1.864-1.17)\times18.98^2$$
$$-2\times356.521\times(5.52+3.96)/_{30})$$
$$=1.7\times(210.741+83.336-225.321)$$
$$=1.7\times68.756$$
$$=116.885\ \text{k-ft}/\text{ft}$$

Moment at section E

$$M_D/_{30} = 1.7\times(\tfrac{1}{2}\times(18.98+5.52)^2\times0.969+\tfrac{1}{3}\times(1.864-0.969)\times24.5$$
$$-2\times356.521\times(5.52\times2+3.96)/_{30}-\tfrac{1}{2}\times2\times356.521\times0.4244$$
$$\times5.52/_{30})$$

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CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

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$= 1.7 \times (290.821 + 179.075 - 356.521 - 27.841)$

$= 1.7 \times 85.534$

$= 145.408$ k-ft/ft

Moment at section F

$M_{F/30} = 1.7 \times \frac{1}{2} \times 0.767 \times (51 - 2\times 11.04 - 3.98 - 3.96)^2 \times \frac{1}{3}$

$= 1.7 \times 56.267$

$= 95.654$ k-ft/ft

Max. moment occur under section E

$M_{max.} = 1.7 \times 85.534 = 145.41$ k-ft/ft

CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR M. Tsai DATE 5/29/97 CHECKED [illegible] DATE 6/2/97

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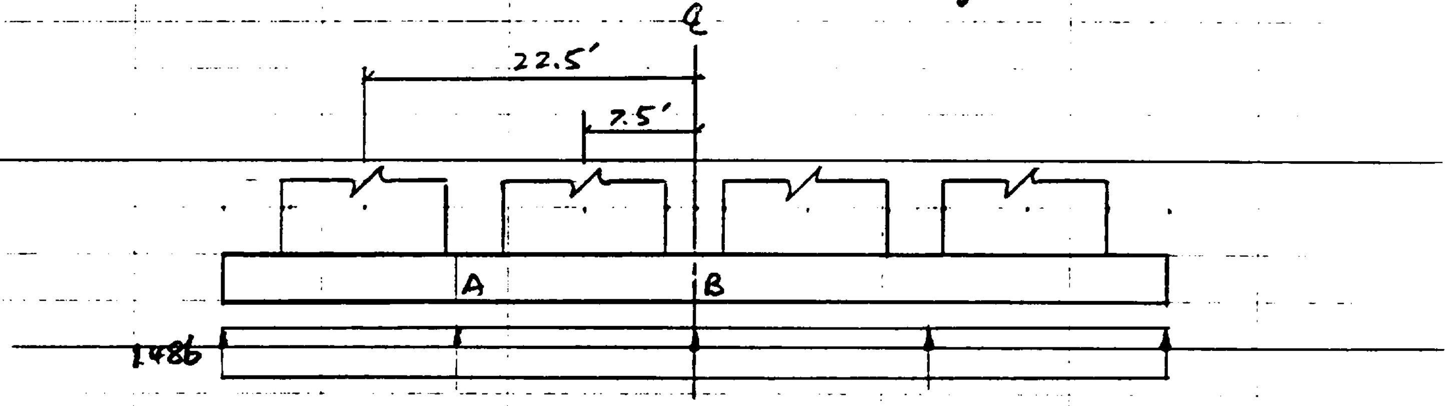
SUBJECT Storage Pad Analysis and Design SHEET NO. 152

Load case 3 with 8 casks

a. Soil pressure due to dead load $p_a = 0.150 \times 3 = 0.450$ ksf

b. Soil pressure due to live load of 8 casks



$$p_b = \frac{8 \times 356.521}{64 \times 30} = 1.486 \text{ ksf}$$

$$p = p_a + p_b = 0.450 + 1.486 = \underline{1.94 \text{ ksf} < 4 \text{ ksf}}$$

It is obvious that the shear equal zero occurs at center and 16' away from center

Bending moment at section A (16' from center)

$$M_A/30 = 1.7 \times (1.486 \times \tfrac{1}{2} \times 16^2 - 2 \times 356.521 \times (16 - 3.98 - 5.52)/30)$$

$$= 1.7 \times (190.208 - 154.492)$$

$$= 1.7 \times 35.716 = 60.717 \text{ k-ft/ft}$$

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1	REV. NO. 0		
ORIGINATOR M. Tsay	DATE 5/25/97	CHECKED [illegible]	DATE 6/2/97
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SUBJECT Storage Pad Analysis and Design		SHEET NO. 153	

Bending moment at section B (at center)

$$M_B/30 = 1.7 \times (1.486 \times \tfrac{1}{2} \times 32^2 - 2 \times 356.52) \times (22.5 + 7.5)/30)$$

$$= 1.7 \times (760.832 - 713.042)$$

$$= 1.7 \times 47.79$$

$$= 81.243 \text{ k-ft/ft}$$

Max. moment at section B = $\underline{81.243 \text{ k-ft/ft}}$

CEC

CALCULATION SHEET

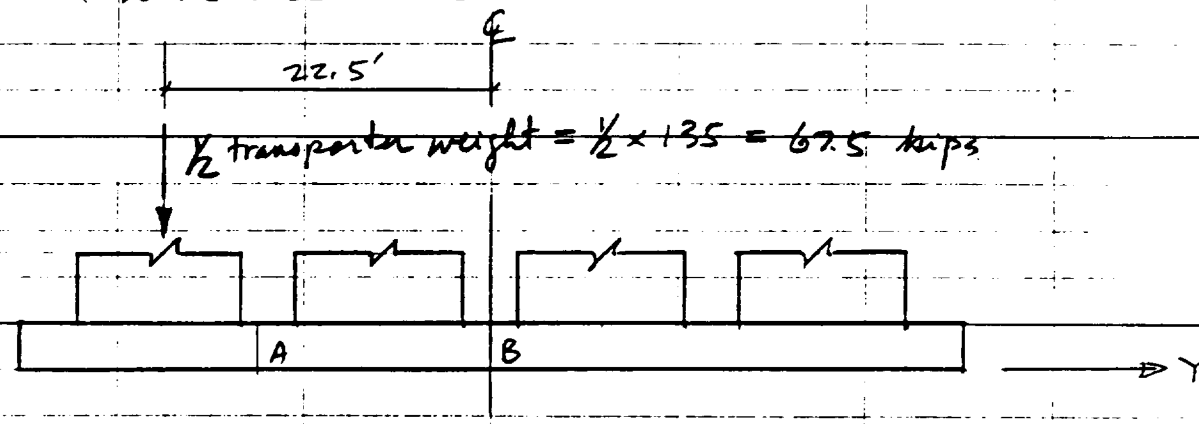
CALC. NO. SC(PD17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 5/29/97 CHECKED KW DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 154

Load case 4 with 7 casks and one transporter loaded with one cask



In this load case, half of the transporter weight with one cask will be assumed at location where the last cask is supposed to be positioned.

This case is load case 3 plus 67.5 kips at $Y = -22.5'$ and $X = 7.5'$

Additional soil pressure $p_t = \frac{67.5}{64 \times 30} + \frac{67.5 \times 22.5}{30 \times 64^2/6} + \frac{67.5 \times 7.5}{64 \times 30^2/6}$

$= 0.035 + 0.074 + 0.053$

$= 0.162$ ksf

total soil pressure $p = 0.450 + 1.486 + 0.162 = 2.1$ ksf < 4.0 ksf

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M Tsay DATE 5/29/97 CHECKED [illegible] DATE 6/2/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

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Soil pressure at section A, B with 67.5 kips transporter wt

$$p_A = 67.5/_{64\times30} + \frac{67.5\times22.5\times16}{30\times64^3/12} = 0.035 + 0.037 = 0.072 \text{ ksf}$$

$$p_B = 67.5/_{64\times30} + \frac{67.5\times22.5\times0}{30\times64^3/12} = 0.035 \text{ ksf}$$

Bending moment at A, B due to 67.5 kips transporter wt.

$$M_A/_{30} = 1.7\times(0.072\times\tfrac{1}{2}\times16^2 + \tfrac{1}{3}\times(0.035+0.074-0.072)\times16^2$$
$$- 67.5\times(22.5-16)/_{30})$$
$$= 1.7\times(9.216+3.157-14.625)$$
$$= 1.7\times(-2.252)$$
$$= -3.828 \text{ k-ft/ft}$$

$$M_B/_{30} = 1.7\times(0.035\times\tfrac{1}{2}\times32^2 + \tfrac{1}{3}\times0.074\times32^2 - 67.5\times22.5/_{30})$$
$$= 1.7\times(17.92+25.259-50.625)$$
$$= 1.7\times(-7.446)$$
$$= -12.658 \text{ k-ft/ft}$$

moment at A = 60.717 − 3.828 = 56.889 k-ft/ft

moment at B = 81.243 − 12.658 = 68.585 k-ft/ft

CEC — **CALCULATION SHEET**

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR M. Tsau DATE 6/10/97 CHECKED [illegible] DATE 6/10/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 156

If 100% impact is assumed for the operating transporter lifting one cask

$$W_i = 2\times\tfrac{1}{2}\times135 + 356.5 = 491.5 \text{ kips}$$

Additional soil pressure $p_t = \frac{491.5}{64\times30} + \frac{491.5\times22.5}{30\times64^2/6} + \frac{491.5\times7.5}{64\times30^2/6}$

$= 0.256 + 0.540 + 0.384$

$= 1.180$ ksf

total soil pressure $p = 0.450 + 1.486 + 1.180$

$= 3.12$ ksf < 4.0 ksf o.k

Soil pressure at section A, B with 491.5 kips load

$$p_A = 491.5/64\times30 + \frac{491.5\times22.5\times16}{30\times64^3/12} = 0.256 + 0.270 = 0.526 \text{ ksf}$$

$$p_B = 491.5/64\times30 + \frac{135\times22.5\times0}{30\times64^3/12} = 0.256 \text{ ksf}$$

Bending moment at A, B due to 491.5 kips load

$M_{A/B0} = 1.7\times(0.526\times\tfrac{1}{2}\times16^2 + \tfrac{1}{3}\times(0.256+0.540-0.526)\times16^2$

$- 491.5\times(22.5-16)/30$

$= 1.7\times(67.328 + 23.04 - 106.492)$

$= 1.7\times(-16.124) = -27.410$ k-ft/ft

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 6/10/97 CHECKED [illegible] DATE 6/10/97

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$$M_{B/30} = 1.7 \times \left(0.256 \times \tfrac{1}{2} \times 32^2 + \tfrac{1}{3} \times 0.540 \times 32^2 - 491.5 \times \tfrac{22.5}{30}\right)$$

$$= 1.7 \times (131.072 + 184.32 - 368.625)$$

$$= 1.7 \times (-53.233)$$

$$= -90.496 \text{ k-ft/ft}$$

Moment at A $M_A = 60.717 - 27.410 = 33.307$ k-ft/ft

Moment at B $M_B = 81.743 - 90.496 = -9.253$ k-ft/ft

CEC CALCULATION SHEET

CALC. NO. SC(PO17-1) REV. NO. 0

ORIGINATOR M. Tsai DATE 6/10/97 CHECKED [illegible] DATE 6/10/97

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SUBJECT Storage Pad Analysis and Design SHEET NO. 158

In comparison, the static analysis using CECSAP computer program has the following results:

Under Dead Load, soil pressure $= 4.186 / (3.98+2.76)(2\times2.76)/4$

$= 0.45$ ksf

(sht No 76)

Bending moment $M_{YY} = -4.703\times10^{-5}$ k-ft/ft

$\doteq 0$ negligible

Live Load,

2 casks: Soil pressure, $p_{max} = 6.530E-02 \times 20$

$= 1.31$ ksf at node 294
(sht. No. 76)

$M_{YY,max} = -21.8$ k-ft/ft at element 229
(Sht. No. 49)

4 casks: $p_{max} = 8.254E-02 \times 20$

$= 1.65$ ksf at node 289
(sht. No. 76)

$M_{YY,max} = -57.1$ k-ft/ft at element 169
(sht. No. 49)

8 casks: $p_{max} = 7.842E-02 \times 20$

$= 1.57$ ksf at node 147
(sht. No. 76)

CEC

CALCULATION SHEET

		CALC. NO. SC(PO17)-1	REV. NO. 0
ORIGINATOR M. Tsay	DATE 6/10/97	CHECKED M	DATE 6/10/97
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SUBJECT Storage Pad Analysis and Design			SHEET NO. 159

~~$M_{YY,max}$ = −37.4 k-ft/ft at element 97~~
(Sht. No. 49)

For dead load, hand calculations and computer analysis have same results of soil pressure 0.45 ksf with no bending moment.

For live load,

		hand calculation	computer analysis (Sheet No. 77)
2 casks,	soil pressure	1.67 ksf	1.31 ksf
	bending moment	39.06 k-ft/ft	21.8 k-ft/ft
4 casks,	soil pressure	1.86 ksf	1.65 ksf
	bending moment	85.53 k-ft/ft	57.1 k-ft/ft
8 casks,	soil pressure	1.486 ksf	1.57 ksf
	bending moment	47.79 k-ft/ft	37.4 k-ft/ft
8 casks with one transporter	soil pressure	2.67 ksf	3.05 ksf (3.05+0.45 = 3.5 < 4.0)
	bending moment	33.31/1.7 = 19.59 k-ft/ft	45.6 k-ft/ft

It is concluded that the hand calculations are generally more conservative. Conservative values are used for static loading in design

CEC

CALCULATION SHEET

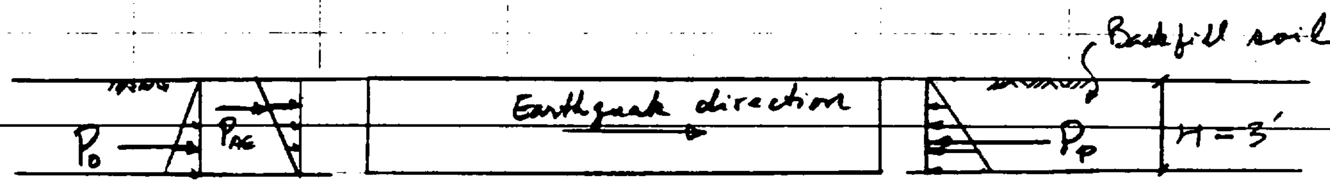
CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 6/7/97 CHECKED [illegible] DATE 6/17/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 160

5.3.2 Dynamic Lateral soil pressure



For dynamic lateral soil pressure considered, there will have at rest pressure P_o, earthquake active pressure P_{AE} and passive soil pressure P_p

$$P_o = \frac{1}{2} K_o \gamma H^2$$

where $K_o = 0.43$, $\gamma = 0.125$ (backfill soil) Ref. 8

$$P_o = \frac{1}{2} \times 0.43 \times 0.125 \times 3^2 = 0.24 \text{ k/ft}$$

$$P_{AE} = \frac{1}{2} \Delta K_{AE} \gamma H^2$$

where $\Delta K_{AE} = \frac{3}{4} \alpha_h$, $\alpha_h = 0.67$ and $\gamma = 0.125$ Ref. 8

$$P_{AE} = \frac{1}{2} \times \frac{3}{4} \times 0.67 \times 0.125 \times 3^2 = 0.28 \text{ k/ft}$$

$$P_p = \frac{1}{2} K_p \gamma H^2$$

where $K_p = 3.7$, $\gamma = 0.125$, Ref. 8

$$P_p = \frac{1}{2} \times 3.7 \times 0.125 \times 3^2 = 2.08 \text{ k/ft}$$

6. DESIGN CALCULATIONS

6.1 Design of Reinforced Concrete Pad

The cask storage pad individual dimensions are taken from Stone & Webster drawing No. 0599601-EC-1-B.

The canister diameter used is in accordance with Holtec TSAR submittal for Docket Number 72-1008, outer diameter = 132.5" = 11.04'

Concrete properties:

$f_c' = 4000$ psi , $E_c = 57{,}000\sqrt{f_c'} = 57{,}000\sqrt{4000}$

$= 3.605 \times 10^6$ psi $= 5.19 \times 10^5$ KSF

$\nu = 0.17$

$f_y = 60{,}000$ psi for ASTM A615 Grade 60

CEC

CALCULATION SHEET

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 6/6/97 CHECKED Kr DATE 6/10/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 162

The following axial forces and bending moments per unit length are extracted from the computer dynamic analysis for maximum response case across 30 ft. section for 2 casks acting case @ time = 4.880 seconds

Element No.	Syy (k-ft/ft)	Myy (k-ft/ft)	Width (ft)	Syy*Width	Myy*Width
217	23.04	-695.00	1.98	45.62	-1376.10
218	-4.44	-571.30	2.76	-12.25	-1576.79
~~219~~	~~-12.42~~	~~-408.80~~	~~2.76~~	~~-34.28~~	~~-1128.29~~
220	-8.74	-311.40	2.76	-24.12	-859.46
221	-15.79	-303.50	2.76	-43.58	-837.66
222	-14.80	-353.40	1.98	-29.30	-699.73
223	-22.97	-419.80	1.98	-45.48	-831.20
224	-19.34	-398.60	2.76	-53.38	-1100.14
225	-13.52	-295.90	2.76	-37.32	-816.68
226	-9.35	-201.10	2.76	-25.81	-555.04
227	-29.14	-131.90	2.76	-80.43	-364.04
228	-57.86	-92.33	1.98	-114.56	-182.81
	~~SUM~~		~~30~~	~~-454.89~~	~~-10327.95~~
			Weighted Ave.	-15.16	-344.26

The weighted average of axial force and bending moment are to be used for design

This calculation is same as sheet No. 70

CALCULATION SHEET

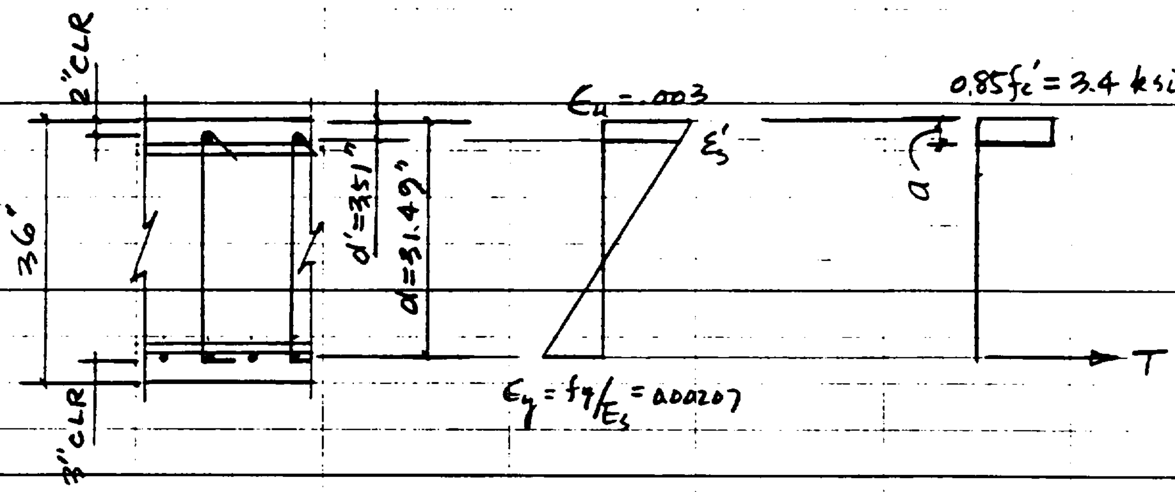
CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 6/6/97 CHECKED [illegible] DATE 6/10/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 163

Moment capacity per unit length (about X-X)



Using 2 #10 Each way at bottom per foot,
1 #10 each way at top per foot

$A_s = 2 \times 1.27 = 2.54$ □" (ACI 349-85(90) section 10.5 ~~require $\rho_{min} = 200/f_y = 200/60,000 = 0.002$~~

$A_s' = 1.27$ □" 1 #10 provide $\rho = 1.27/(12 \times 32.34) = 0.0033$

For $f_c' = 4000$ psi, $\beta_1 = 0.85$

$f_y = 60,000$ psi

$d = 36" - 3" - 1.27"/2 - 0.875 = 31.49"$ (#7 crosstie)

$d' = 2 + 1.27/2 + 0.875 = 3.51"$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{2 \times 1.27 \times 60}{0.85 \times 4 \times 12} = 3.74''$$

(Neglecting compressive rebar)

$$M_u = \phi M_n = \phi [A_s f_y (d - a/2)] = \phi [2 \times 1.27 \times 60 \times (31.49 - 3.74/2)]$$

$$= \phi \times 4514.1 \text{ k-in}$$

$$= \phi \times 376.2 \text{ k-ft}$$

use $\phi = 0.9$; $DIF = 1.25$ (ACI 349-85, sec. C.2.1)

$$M_u = 0.9 \times 376.2 = 338.6 \text{ k-ft}$$

$$(M_u)_{DIF} = 1.25 \times 0.9 \times 376.2 = 1.125 \times 376.2 = 423.2 \text{ k-ft}$$

The required strength

$$U_c > D + L + H + T + E$$

For bending moment, $M_D = M_H = M_T = 0$

$$M_U = M_L + M_E = 39.06 + 344.26 = 383.3 \text{ k-ft}$$

$$< 423.2 \text{ k-ft}$$

($M_L = 39.06$ from sheet No. 156, $M_E = 344.26$ sheet No. 162)

CEC **CALCULATION SHEET**

CALC. NO. 3C(P017)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 6/6/97 CHECKED [illegible] DATE 6/10/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 165

moment capacity per unit length (about Y-Y)

$d = 36'' - 3'' - 1.5 \times 1.27'' - 0.875'' = 30.22''$

$d' = 2'' + 1.5 \times 1.27'' + 0.875'' = 4.78''$

$a = \dfrac{A_s f_y}{0.85 f_c' b} = \dfrac{2 \times 1.27 \times 60}{0.85 \times 4 \times 12} = 3.74''$

(neglecting compressive rebar)

$M_u = \phi M_n = \phi \left[A_s f_y (d - a/2) \right] = \phi \left[2 \times 1.27 \times 60 \times (30.22 - 4.78/2) \right]$

$= \phi \times 4{,}241.3$ k-in.

$= \phi \times 353.4$ k-ft

use $\phi = 0.9$, DIF $= 1.25$ (ACI 349-85, sec. C.2.1)

$M_u = 0.9 \times 353.4 = 318.1$ k-ft

$(M_u)_{DIF} = 0.9 \times 1.25 \times 353.4 = 397.6$ k-ft

the required strength

$U_c > D + L + H + T + E$

For bending moment, $M_D = M_H = M_T = 0$

$M_u = M_L + M_E = 8.7 + 300 = 308.7$ ft-kips < 397.6 ft-kips

($M_L = 8.7$, $M_E = 300$ from computer output sheet Nos. 49 & 70)

CALCULATION SHEET

CEC

CALC. NO. SC(PO17)-1 REV. NO. 0

ORIGINATOR M. Tsay DATE 6/2/97 CHECKED [illegible] DATE 6/13/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 166

Shear stress across the section

Maximum shear stresses over the width of one cask

$$V_E = (149.457 \times 1.58 + (111.123 + 59.529 + 41.413 + 40.58) \times 2.76) / (1.98 + 4 \times 2.76)$$

(see calculation sheet No. 60)

$$= (295.92 + 697.3) / 13.02$$

$$= 76.3 \ k/ft$$

$$V_c = \phi 2 \sqrt{f_c'}\, d = 0.85 \times 2 \times \sqrt{4000} \times 32.0 = 0.85 \times 4,048.0 \ {}^{lb}/_{in}$$

$$= 0.85 \times 49.0 \ k/ft = 41.7 \ k/ft$$

Shear force at section for 2 casks

$$V_d = 6.9 \ kips/ft \quad \text{(sht. NO. 77)}$$

$$V = V_E + V_d = 76.3 + 6.9 = 83.2 \ k/ft$$

$$V_s = V - V_c = 83.2 - 41.7 = 41.5 \ k/ft$$

$$V_s = A_v f_y d / s \qquad \text{ACI 349-85(90) eqn. (11-17)}$$

$$S = 12'' ; \quad f_y = 60 \text{ ksi} , \quad d = 32.0'' ,$$

$$A_v = V_s S / \phi f_y d = 41.5 \times 12 / 0.85 \times 60 \times 32.0 = 0.31 \ \square''/ft$$

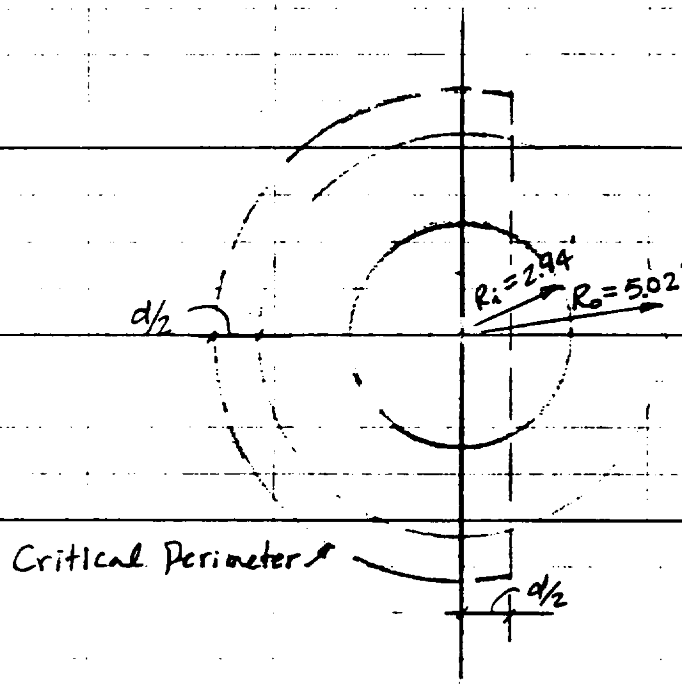
1 - #5 provide 0.31 □"

use 1 - #7 provide 0.6 □"

CALCULATION SHEET

CALC. NO. SC(PO17)-1 REV. NO. 0
ORIGINATOR M. Tsau DATE 5/ -12- CHECKED KL DATE 6/13/07
PROJECT Private Fuel Storage Facility JOB NO. 1083-000
SUBJECT Storage Pad Analysis and Design SHEET NO. 167

Punching shear

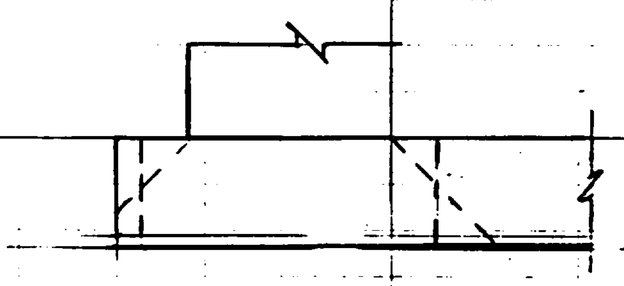


Punching shear failure critical perimeter

$$b_o = \pi\,(5.02 + d/2) + d + (5.02 + d/2) \times 2$$

for $d = 32.0'' = 2.7'$

$$b_o = \pi\,(5.02 + 1.35) + 2.7 + (5.02 + 1.35) \times 2$$
$$= 20.02 + 2.7 + 12.74$$
$$= 35.46'$$



$$V_u = \phi V_c = \phi\, 4\sqrt{4000} \times b_o d$$
$$= 0.85 \times 4 \times \sqrt{4000} \times (35.46 \times 12) \times 32.0$$
$$= 0.85 \times 3{,}445{,}000 \text{ lbs}$$
$$= 2{,}928 \text{ kips}$$

from Holtec, 2-casks case (Ref. 3)

$$V = 4503 + \tfrac{1}{2}\,(1800.2 + 1236) = 6021.1 \text{ kips}$$

Dynamic Demand $V = 6{,}021.1 - \dfrac{356.5}{2} = 5843$ kips

CALCULATION SHEET

CEC

CALC. NO. SC(P017)-1 REV. NO. 0

ORIGINATOR M. Ieu DATE 6/12/97 CHECKED [illegible] DATE 6/13/97

PROJECT Private Fuel Storage Facility JOB NO. 1083-000

SUBJECT Storage Pad Analysis and Design SHEET NO. 168

ACI 349-85, sect. C.3.7 (b), $\mu = 1.6$ (μ = ductility ratio)

$R_m = R_e / \sqrt{2\mu - 1}$ (See following sheets for derivation)

$R_m = V_m = 5843 / \sqrt{3.2 - 1} = 3939.$ kips

ACI 349-85, sect. 11.11.3.2,

$V_u \le \phi V_n = \phi\, 6 \sqrt{f_c'}\, b_o d = 0.85 \times 6 \times \sqrt{4000} \times (35.46 \times 12) \times 32.34$

$= 0.85 \times 5{,}222$ kips $= 4439$ kips $> 3{,}939$ kips

Shear force required by rebar (ACI 349-85, sect 11.11.3.4, & (ACI 349-85, sect. C.2.1)

$3{,}939 - \overbrace{1.1}^{\text{DIF}} \times \phi \times 2 \sqrt{4000}\, b_o d / 1000 = 3939 - 1.1 \times 0.85 \times 2 \times \sqrt{4000} \times 35.46 \times 12 \times 32 / 1000$

$= 3939 - 1610 = 2329$ kips

$V_s = 2329 / 35.46 = 65.7$ kips/ft

$A_v = \dfrac{V_s \cdot s}{\phi f_y d}$

$s = 12''$, $f_y = 60$, $d = 32.34$

$A_v = 65.7 \times 12 / (0.85 \times 60 \times 32.34) = 0.48$ □"/ft

1-#7 provide 0.6 □"

or 2-#5 provide 0.62 □"

Shear capacity $= V_c + V_s = \phi\, 2 \sqrt{4000}\, d \times 12 + \phi f_y d \cdot A_v / s$

$= 0.85 \times 2 \times \sqrt{4000} \times 32.0 \times 12 + 0.85 \times 60000 \times 32.0 \times 0.6 / 12$

$= 41{,}300 + 81{,}600$ lb/ft

$= 123.0$ k/ft $> 3939 / 35.46 = 111.1$ k/ft $\Rightarrow$ O.K.

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CALC. NO SC(PD17)-1 REV. NO.

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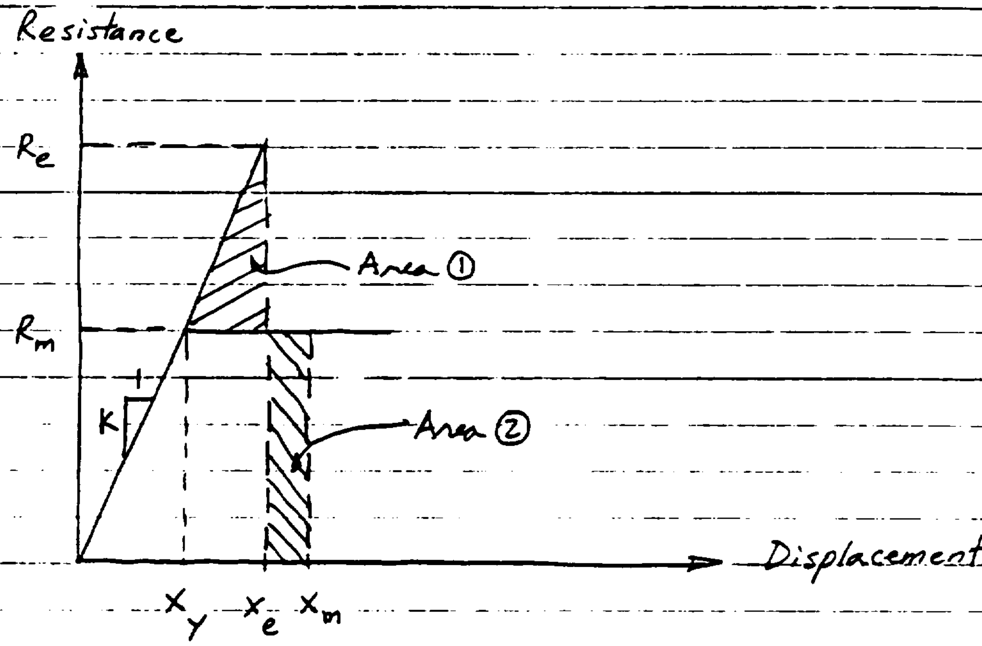
PROJECT PRIVATE FUEL STORAGE FACILITY (PFSF) JOB NO. 1083-000

SUBJECT STORAGE PAD ANALYSIS AND DESIGN SHEET NO. 169

DERIVATION OF REDUCED CAPACITY TAKING CREDIT OF PERMISSIBLE DUCTILITY RATIO (μ) AS PER ACI 349-85 (1990) SECTION C.3.7(b

DEFINITION :



$$\mu = \frac{x_m}{x_y} = \text{Ductility Ratio} \quad ; \quad x_m = \mu x_y$$

R_e = Elastic Resistance Capacity Required

R_m = Inelastic Resistance Capacity Required

k = Equivalent Stiffness

CALCULATION SHEET

		CALC. NO SC(P017)-1	REV. NO.
ORIGINATOR W. S. Tseng	DATE 6/13/97	CHECKED MNT	DATE 6/13/97
PROJECT PRIVATE FUEL STORAGE FACILITY (PFSF)			JOB NO. 1083-000
SUBJECT STORAGE PAD ANALYSIS AND DESIGN			SHEET NO. 170

$$x_y = \frac{R_m}{K} \quad ; \quad x_e = \frac{R_e}{K}$$

Use "Energy Balance Principle" $\Rightarrow$ Area ① = Area ②

$$\text{Area ①} = \frac{1}{2}(R_e - R_m)(x_e - x_y)$$

$$= \frac{1}{2}(R_e - R_m)(R_e - R_m)/K$$

$$= \frac{1}{2K}(R_e - R_m)^2$$

$$\text{Area ②} = R_m(x_m - x_e) = R_m\left(\mu\frac{R_m}{K} - \frac{R_e}{K}\right)$$

$$= \frac{1}{K}(\mu R_m^2 - R_e R_m)$$

Area ① = Area ② leads to :

$$\frac{1}{2\cancel{K}}(R_e - R_m)^2 = \frac{1}{\cancel{K}}(\mu R_m^2 - R_e R_m)$$

$$R_e^2 + R_m^2 - \cancel{2R_e R_m} = 2\mu R_m^2 - \cancel{2R_e R_m}$$

$$R_e^2 = (2\mu - 1)R_m^2$$

$$\therefore \quad \boxed{R_m = \frac{R_e}{\sqrt{2\mu - 1}}}$$

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CALC. NO SC(P017)-1 REV. NO.

ORIGINATOR C. C. Tseng DATE 6/13/97 CHECKED mzt DATE 6/13/97

PROJECT PRIVATE FUEL STORAGE FACILITY (PFSF) JOB NO. 1083-000

SUBJECT STORAGE PAD ANALYSIS & DESIGN SHEET NO. 171

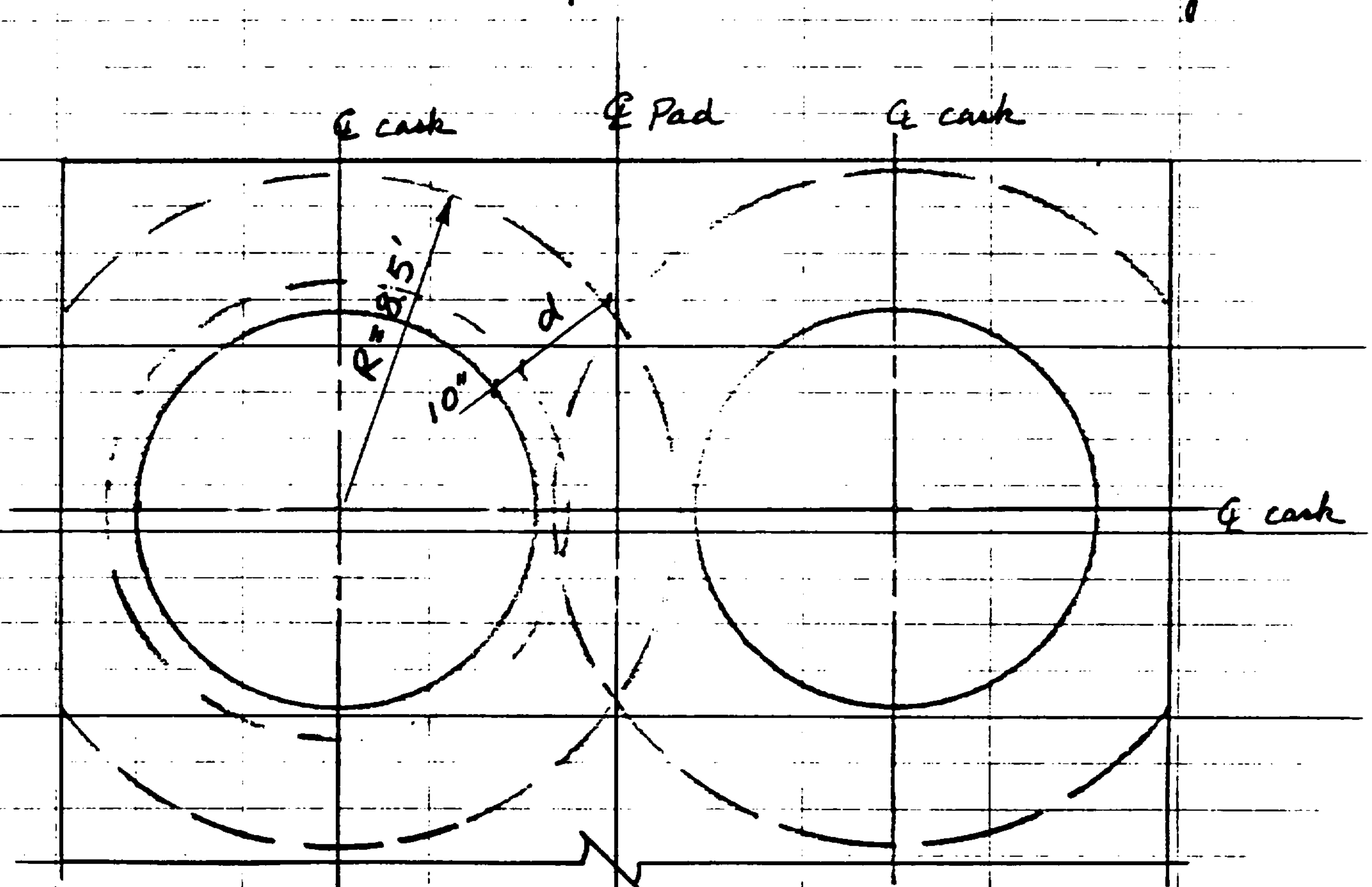
As per ACI 349-85 (1990), Section C.3.7 (b) : $\mu = 1.6$

$$\therefore \quad R_m = \frac{R_e}{\sqrt{2 \times 1.6 - 1}} = \frac{R_e}{\sqrt{2.2}} = 0.674 R_e$$

$$\boxed{R_m = 0.674\, R_e \quad \text{for } \mu = 1.6}$$

Shear reinforcement area for punching shear

From Holtec Report HI-971631, Ref. 3, the cask will move about 10" radially. With semicircle punching



shear failure mode assumed, the shear reinforcement area to be covered thus become $R = 120.4/2 + 10'' + d$

$= 5.02 + 0.83 + 32/12 = 8.5'$

Required shear reinforcement will be placed equally everywhere.

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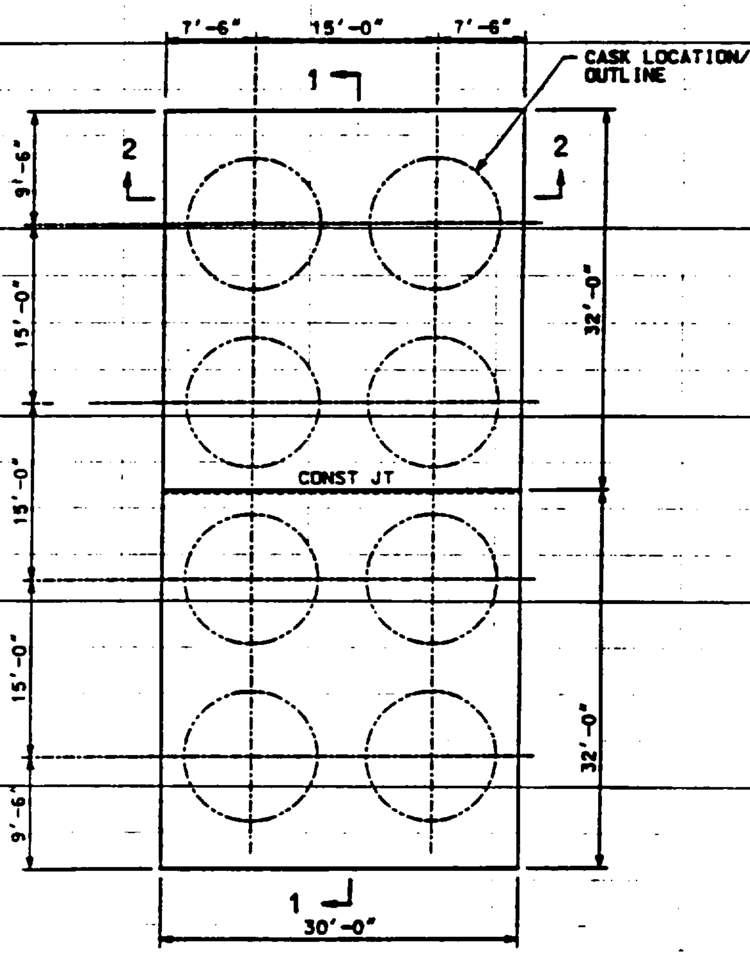
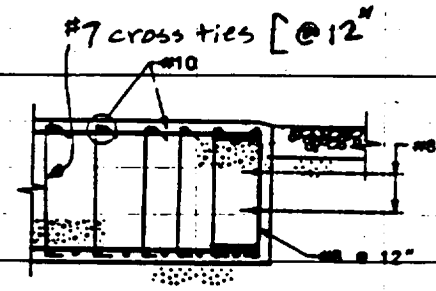
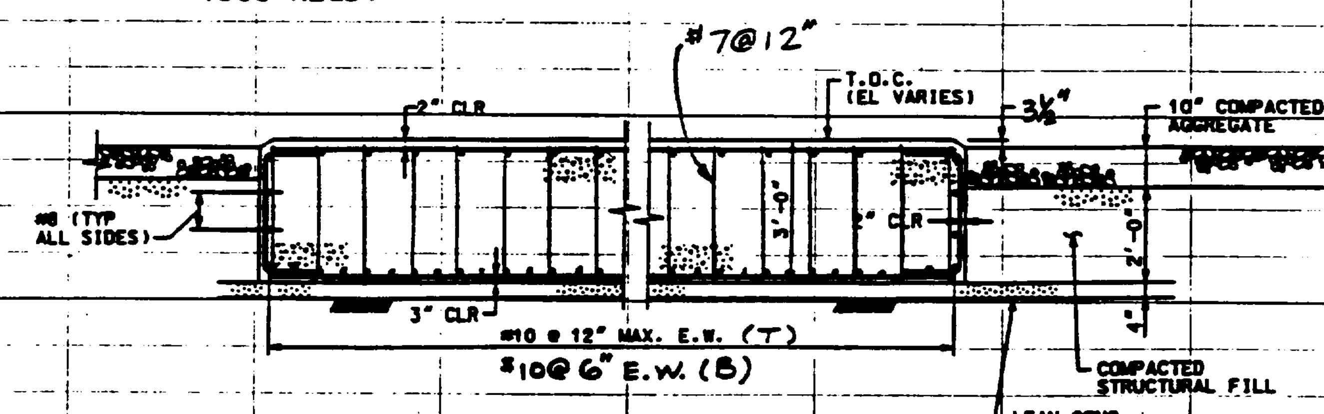


PLAN
CASK STORAGE PAD
(500 REQD)



2-2
SCALE: ½" = 1'-0"



1-1
SCALE: ½" = 1'-0"

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PROJECT Private Fuel Storage Facility			JOB NO. 1083-000
SUBJECT Storage Pad Analysis and Design			SHEET NO. 174

6.2 Site Bearing stability checks

6.2.1 Vertical soil bearing pressure and horizontal soil shear stresses

The soil pressures due to 7 casks with one transporter plus one cask and 100% impact from CECSAP (Attachment A):

nodes	displacement (ft)	K_s (subgrade modulus)	P_s (ksf)
287	-1.525E-01	20 k/ft^3	3.05
293	-1.135E-01	20	2.27
299	-7.743E-02	20	1.55
157	-1.141E-01	20	2.28
163	-8.931E-02	20	1.77
169	-6.477E-02	20	1.30
1	-7.444E-02	20	1.49
7	-4.836E-02	20	1.17
3	-4.20E-02	20	0.84

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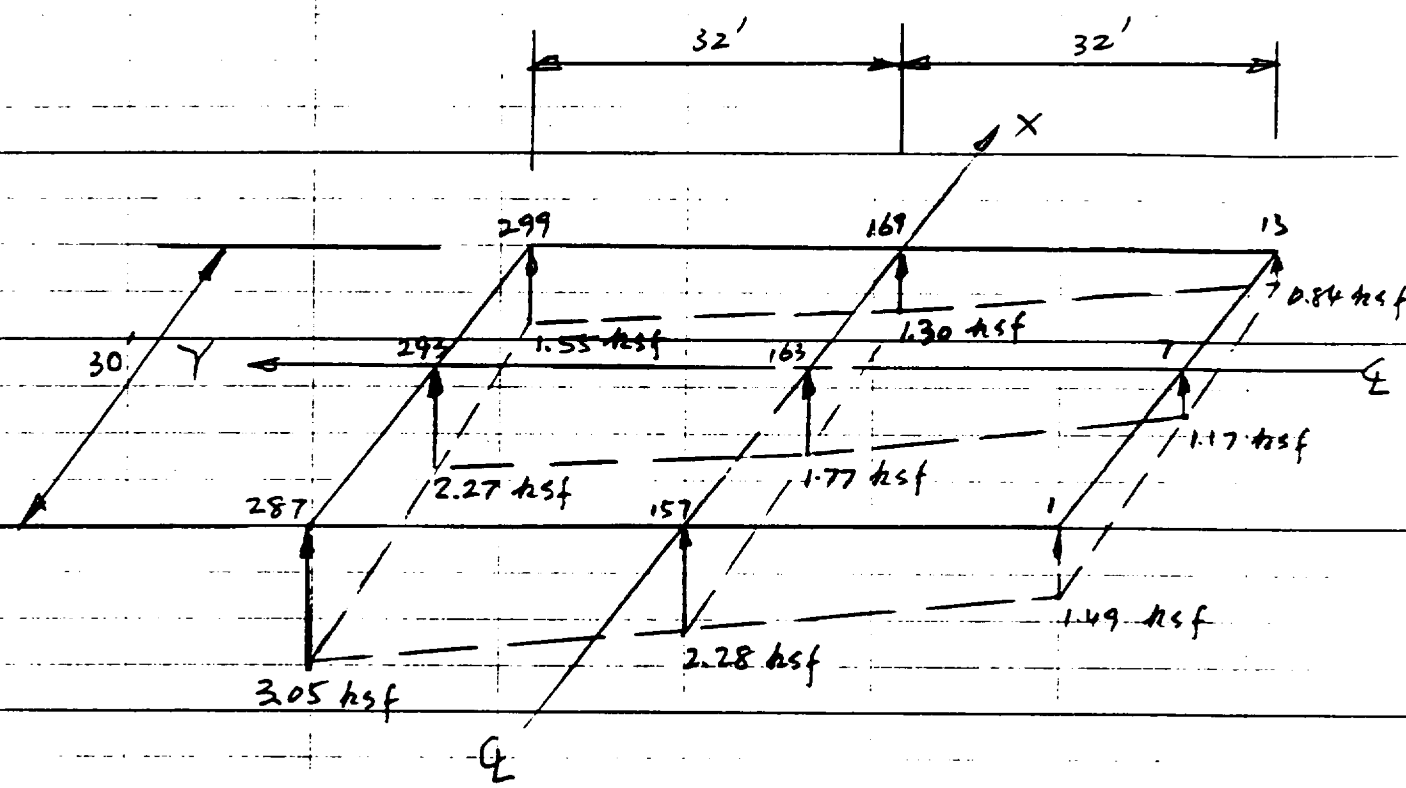

Vertical soil pressure for live load of 7 casks plus one cask on Transporter with a dynamic impact factor of 1.0

FIG. P-1

CALCULATION SHEET

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PROJECT Private Fuel Storage Facility JOB NO. 1083-000

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SUMMARY OF DYNAMIC VERTICAL SOIL BEARING PRESSURES

Node No.	2 CASKS $\Delta_{max}^{(1)}$ (ft)	2 CASKS $P^{(2)}$ (k/ft^2)	4 CASKS $\Delta_{max}^{(1)}$ (ft)	4 CASKS $P^{(2)}$ (k/ft^2)	8 CASKS $\Delta_{max}^{(1)}$ (ft)	8 CASKS $P^{(2)}$ (k/ft^2)
1	NA	0.	NA	0.	.03139	1.899
7	NA	0.	NA	0.	.01733	1.048
13	NA	0.	NA	0.	.04200	2.541
144	.01230	0.744	.01082	0.655	.03868	2.340
150	.00532	0.322	.00742	0.449	.01106	0.669
156	.00681	0.412	.01832	1.108	.04559	2.758
287	.05525	3.342	.03156	1.909	.03410	2.063
293	.03314	2.005	.02408	1.457	.01831	1.108
299	.02391	1.446	.03466	2.097	.04046	2.448

Notes : (1) – Δ_{max} obtained from CECSAP shown on p. 75

(2) $P = \Delta_{max} \cdot K_v' = 60.494$ K/FT/FT^2

where $K_v' = \dfrac{K_v}{30' \times 64'}$, and $K_v = 9.679 \times 10^6 \dfrac{LB}{IN} = 1.1615 \times 10^5 \dfrac{K}{FT}$

(REF. 3, p. C-6)

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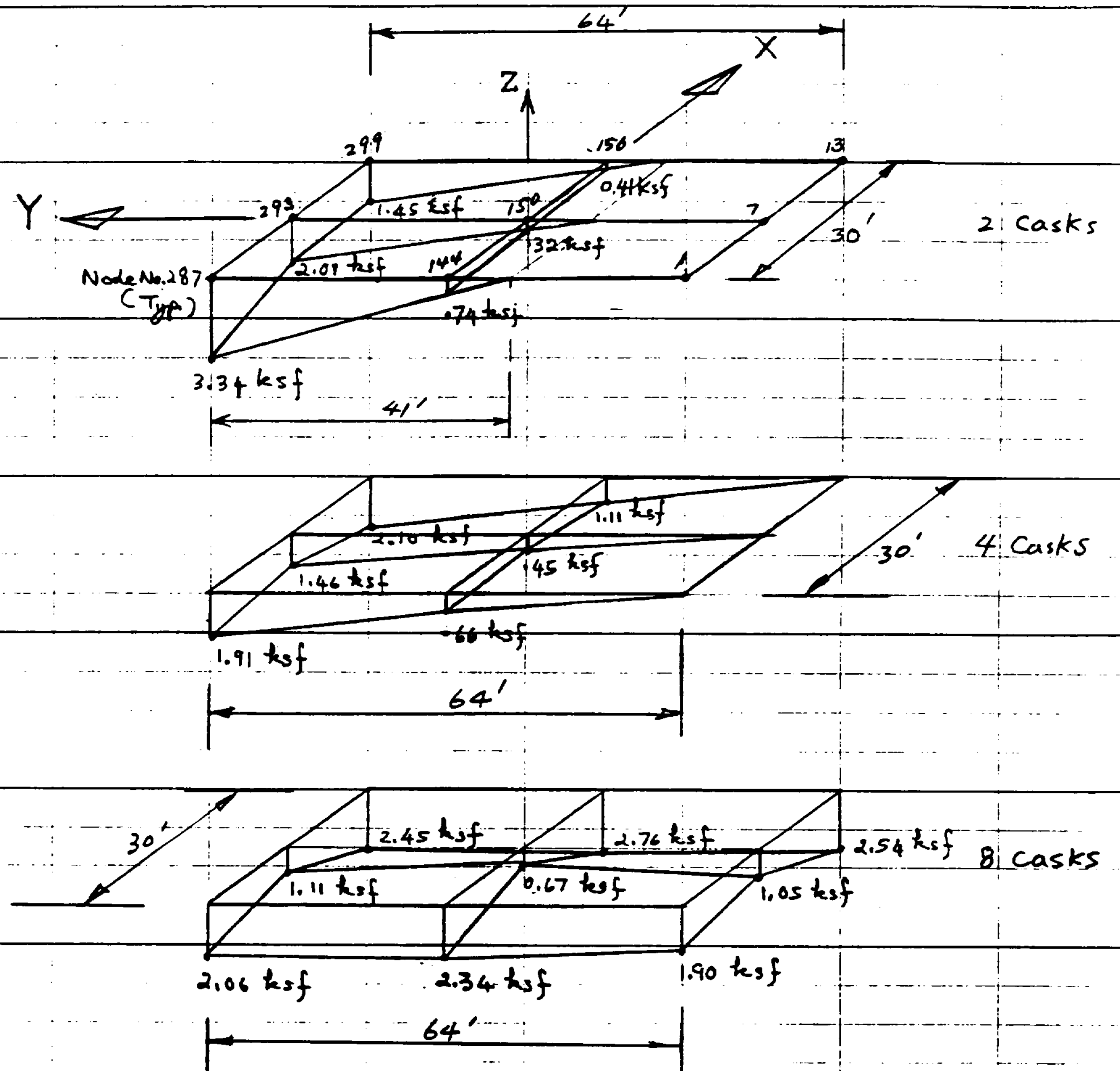

FIG. P-2

Maximum Vertical Soil Pressure (P_v) Due To Design Earthquake

(Excluding Pad Inertial Force)

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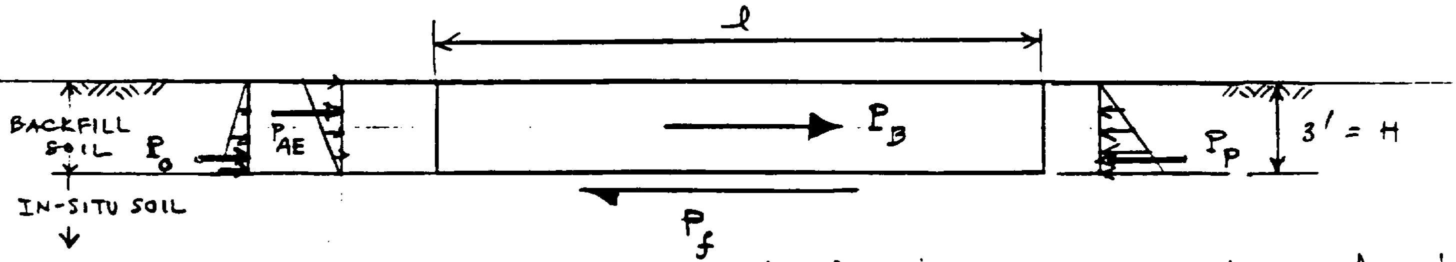
SUMMARY TABLE FOR
VERTICAL SOIL BEARING PRESSURES AND
HORIZONTAL SOIL SHEAR FORCES OR STRESSES

LOADING CONDITION	P_V (1) (K/FT^2)	F_{HL} (2) (KIPS)	F_{HT} (2) (KIPS)
D	0.45	0.	0.
L (2 CASKS)	1.67	0.	0.
L (4 CASKS)	1.86	0.	0.
L (8 CASKS)	1.57	0.	0.
L (7 CASKS + 1 TRANSPORTER WITH A DYNAMIC IMPACT FACTOR)	SEE FIG. P-1	0.	0.
E (PAD INERTIA)	0.31	580	580
E (2 CASKS)	SEE FIG. P-2	670	730
E (4 CASKS)	SEE FIG. P-2	1195	910
E (8 CASKS)	SEE FIG. P-2	1330	2030

NOTES: (1) P_V = VERTICAL SOIL BEARING PRESSURES PER UNIT AREA

(2) F_{HL} AND F_{HT} ARE TOTAL FORCES FOR THE ENTIRE PAD TO BE DISTRIBUTED OVER THE CONTACT AREA SHOWN IN FIG. P-2

6.2.2 Horizontal Sliding Stability Check



~~To be conservative in lateral soil pressures, backfill soil is used as side soil as shown above~~

Total at-rest pressure: $P_o = \frac{1}{2} K_o \cdot \gamma H^2$

where $K_o = 0.43$ and $\gamma = 0.125$ KCF (Backfill soil, see Ref. 8)

Total earthquake active pressure: $P_{AE} = \frac{1}{2} \Delta K_{AE} \gamma H^2$

where $\Delta K_{AE} = \frac{3}{4} \alpha_h$, $\alpha_h = 0.67$, and $\gamma = 0.125$ KCF (Ref. 8)

Total dynamic force acting on the pad:

$$P_B = (P_C^2 + P_I^2)^{1/2}$$

where P_C = dynamic force acting on the pad resulting from applying dynamic loads exerted by the casks on top of the pad as obtained from CECSAP analyses on p. 72 , and $P_I = W_{pad} \times \alpha_h = W_{pad} \times 0.67$

Allowable passive pressure: $P_p = \frac{1}{2} K_p \gamma H^2$

where $K_p = 3.7$, $\gamma = 0.125$ KCF (Ref. 8)

Allowable cohesive force: $P_f = c \times l \times w$

where $c = 2.2$ KSF , l = length of the pad in y-direction = 64' , and w = width of the pad = 30' (Ref. 8)

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Forces acting in the x-direction (short direction of the pad, 30′) are calculated as follows:

$$P_o = \frac{1}{2} \times 0.43 \times 0.125 \times 3^2 \times 64 = 15.5 \text{ kips}$$

$$P_{AE} = \frac{1}{2} \times \left(\frac{3}{4} \times 0.67 \right) \times .125 \times 3^2 \times 64 = 18.1 \text{ kips}$$

$P_c = F_x = 2030$ kips (from CEESAP, 8 casks, see p. 72)

$$P_I = .150 \times 30 \times 64 \times 3 \times 0.67 = 579 \text{ kips}$$

$$P_B = (2030^2 + 579^2)^{1/2} = 2111 \text{ kips}$$

$$P_p = \frac{1}{2} \times 3.7 \times .125 \times 3^2 \times 64 = 133 \text{ kips}$$

$$P_f = 2.2 \times 64 \times 30 = 4224 \text{ kips}$$

Forces acting in the y-direction (long direction of the pad, 64′)

$$P_o = \frac{1}{2} \times .43 \times .125 \times 3^2 \times 30 = 7.3 \text{ kips}$$

$$P_{AE} = \frac{1}{2} \times \left(\frac{3}{4} \times 0.67 \right) \times .125 \times 3^2 \times 30 = 8.5 \text{ kips}$$

$P_c = F_y = 1330$ kips (from CECSAP, 8 casks, see p. 72)

$$P_I = .150 \times 30 \times 64 \times 3 \times 0.67 = 579 \text{ kips}$$

$$P_B = (1330^2 + 579^2)^{1/2} = 1451 \text{ kips}$$

$$P_p = \frac{1}{2} \times 3.7 \times .125 \times 3^2 \times 30 = 62 \text{ kips}$$

$$P_f = 2.2 \times 64 \times 30 = 4224 \text{ kips}$$

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PROJECT Private Fuel Storage Pad JOB NO. 1083-000

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		x-direction	y-direction
	P_o	15.5 kips	7.3 kips
	P_{AE}	18.1 kips	8.5 kips
	P_B	2111 kips	1451 kips
Total Lateral Force =	P_D =	2145 kips	1467 kips
	P_p	133 kips	62 kips
	P_f	4224 kips	4224 kips
Total resistance =	P_R =	4357 kips	4286 kips

Factor of safety against sliding ($FS_{sliding}$) in the x-direction can be calculated as:

$$FS_{sliding,x} = \frac{P_R}{P_D} = \frac{4357}{2145} = 2.03 > 1.1 \Rightarrow \text{no sliding}$$

(allowable, Ref. 8)

$FS_{sliding}$ in the y-direction can be calculated as:

$$FS_{sliding,y} = \frac{P_R}{P_D} = \frac{4286}{1467} = 2.92 > 1.1 \Rightarrow \text{no sliding}$$

Appendix A and B

available upon request