U-006-105 .15

5621

STUDY AND EVALUTATION EFFECT OF INTERNAL ATTENUATION LAYER ON K-65 SILOS VOLUME II DECEMBER 1988 (A CAMARGO REPORT)

03/28/89

DOE-FMPC USEPA
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REPORT

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U-006-105.15

STUDY AND EVALUATION

EFFECT OF INTERNAL ATTENUATION LAYER

ON

K-65 SILOS

DECEMBER 1988

PREPARED BY

CAMARGO ASSOCIATES, INC.
ARCHITECTS-ENGINEERS-INTERIOR DESIGNERS-PLANNERS
CINCINNATI, OHIO

000000

EFFECT OF INTERNAL ATTENUATION LAYER

ON

K-65 SILOS

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SECTION 2.0 - EXECUTIVE SUMMARY

The two K-65 silos, as analyzed for this report, are capable of sustaining the present static loads plus the internal radon attenuation sand layer. The addition of the sand layer to the existing silos produces slight additional bending in the silo walls. The stresses in the dome and base slab are essentially unaffected. All static stresses induced by the imposed loads are within allowable values as determined by ACI.

The silos are also capable of sustaining the static loads in conjuction with earthquake loads. Both silos would experience some cracking in the base slab but would remain functional as containers.

This report is intended to analyze an additional load condition not covered by Ref. [1]. In that respect, it does not supercede any of the conclusions or recommendations presented by that evaluation. The life expectancy of the silos as stated in Ref. [1] will remain unchanged by this report.

TABLE 4.0.1 ALLOWABLE STRESSES

NORTH SILO

LOCATION	ELEMENTS	f'c	COMP. 0.45f'c	TEN. 0.03f'c	COMP. HOOP 0.18f'c	SHEAR BASE/DOME $1.64\sqrt{f'c}$	SHEAR WALL $1.23\sqrt{f'c}$
BASE	1*368	3000	1350	90	540	90	--
WALL	369*536	3000	1350	90	540	--	67
	537*696	3500	1575	105	630	--	73
DOME	697*820	4000	1800	120	720	104	--
	821*908	3500	1575	105	630	97	--
	909*976	3000	1350	90	540	90	--
	977*1000	2500	1125	75	450	92	--

SOUTH SILO

LOCATION	ELEMENTS	f'c	COMP. 0.45f'c	TEN. 0.03f'c	COMP. HOOP 0.18f'c	SHEAR BASE/DOME $1.64\sqrt{f'c}$	SHEAR WALL $1.23\sqrt{f'c}$
BASE	1*368	3000	1350	90	540	90	--
WALL	369*392	3000	1350	90	540	--	67
	393*624	3500	1575	105	630	--	73
	625*696	4000	1800	120	720	--	78
DOME	697*776	4000	1800	120	720	104	--
	777*848	3500	1575	105	630	97	--
	849*976	3000	1350	90	540	90	--
	977*1000	2500	1125	75	450	92	--

SECTION 5.0 - RESULTS: COMBINED STATIC AND DYNAMIC

The final load combination analyzed was the static loads combined with dynamic earthquake loads. Appendix B.1 describes in detail the hypothetical earthquake acting alone on the silos. Superposition of loads is used to combine dynamic and static stresses. All combined stresses listed in this section are reduced by 1/3 in accordance with Section 917.4 of the Ohio Basic Building Code. The reduced stresses can then be compared directly to the allowable stresses listed in Table 4.0.1. Figures 5.0.1 through 5.0.12 present the maximum and minimum stresses occurring over the full duration of the seismic event. These figures provide a stress envelope expressed as a function of a given points distance outward from the silo centerline or upward from the base slab.

The base slab in the north silo would experience maximum compressive stresses of -172 psi longitudinal stress and -149 psi hoop stress. The south silo base slab would experience maximum compressive stresses of -231 psi longitudinal stress and -86 psi hoop stress. These values are well below their respective allowable stresses as listed in Table 4.0.1. Maximum base slab hoop tensile stresses are +52 psi in the north silo and +41 psi in the south silo. These values are also below allowable tensile stress levels. Maximum base slab longitudinal tensile stresses of +126 psi in the north silo and +170 psi in the south silo are above the 90 psi allowable stress level, but

below the modulus of rupture of 383 psi. Stress levels in the reinforcing steel would be 25,220 psi in the north silo and 33,900 psi in the south silo. While both values are above the 20,000 psi allowable reinforcing steel stress, they remain below the yield stress of 40,000 psi. Since the strain levels are elastic, the result of these high tensile stresses would be the occurrence of some microcracking of the base slab in each silo. The stress levels for the reinforcement steel are computed based on the full area of steel per the original design. The nondestructive testing performed in Reference [1] could not determine the condition of reinforcement in the base slab in areas such as this which are not directly under the side wall. Should less than the full area of steel be remaining, stresses could exceed yield, producing larger cracks in the base slab.

All stresses in the walls of both silos remain compressive. The maximum longitudinal stress of -323 psi and maximum hoop stress of -370 psi are both below allowable stresses presented in Table 4.0.1.

The maximum longitudinal stresses in the domes are +78 psi tension and -225 psi compression. The tensile value occurs in 4000 psi concrete in the north silo having an allowable tensile stress of 120 psi. The compressive value is well below allowable. Maximum hoop stresses in the domes are +56 psi tension and -260 psi compression. Both are below allowable stress levels.

Shear stresses for the static analysis and the dynamic analysis were both negligible. Combined values are, consequently, also negligible.

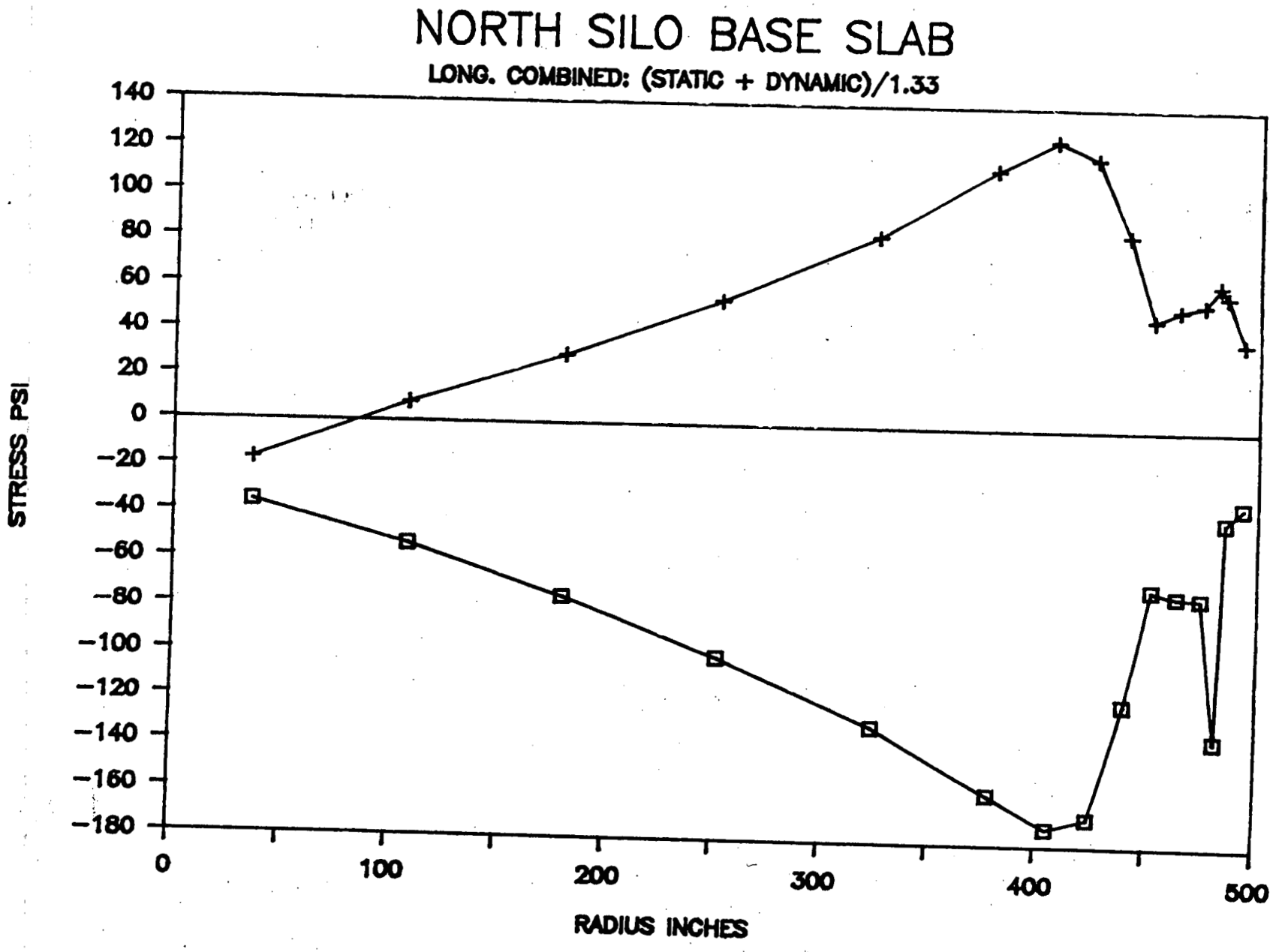
NORTH SILO BASE SLAB
LONG. COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
0
100
200
300
400
500
RADIUS INCHES

FIG. 5.0.1

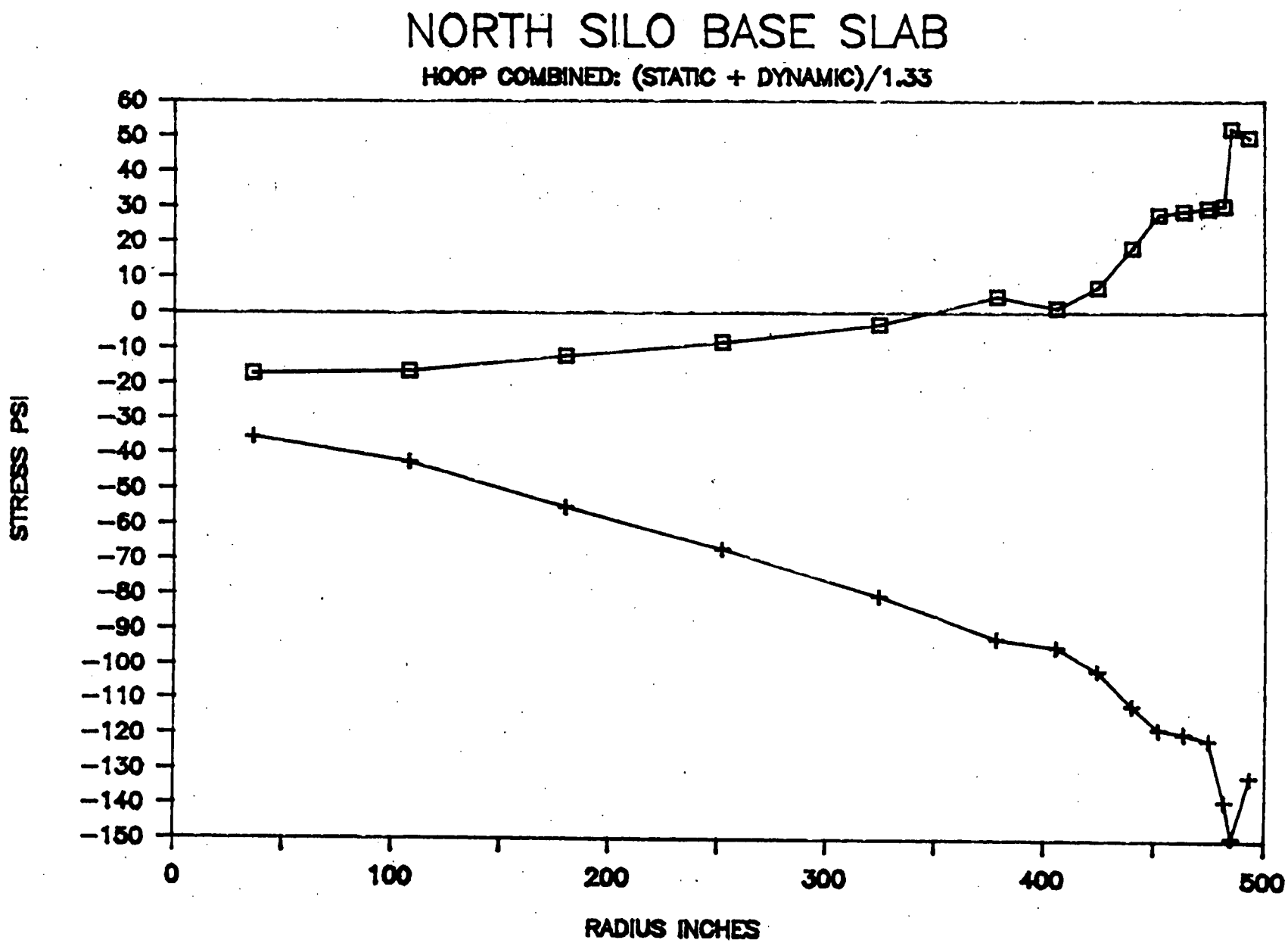
NORTH SILO BASE SLAB
HOOP COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
0
100
200
300
400
500
RADIUS INCHES

FIG. 5.0.2

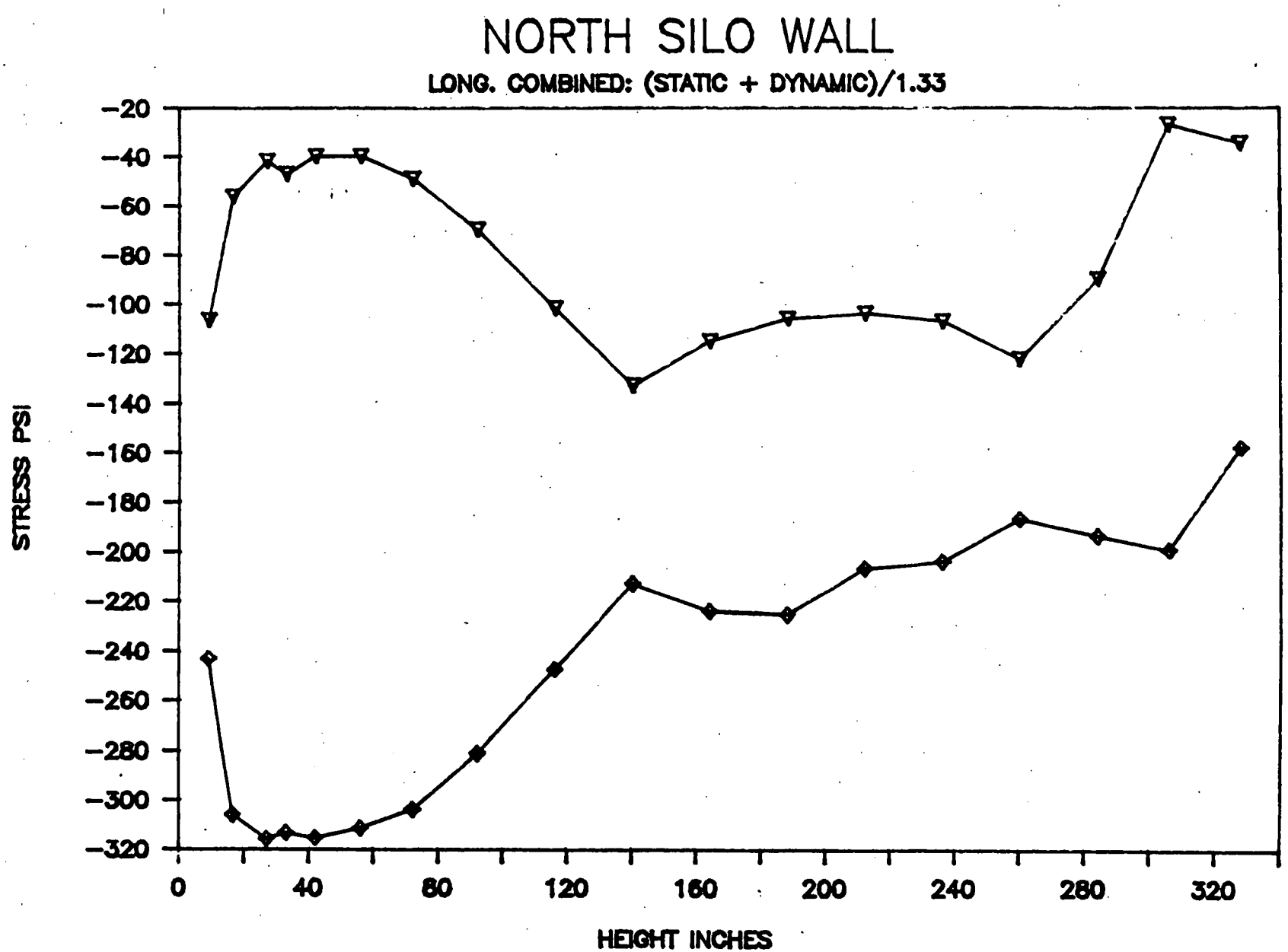
NORTH SILO WALL
LONG. COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
0
40
80
120
160
200
240
280
320
HEIGHT INCHES

FIG. 5.0.3.

59 21

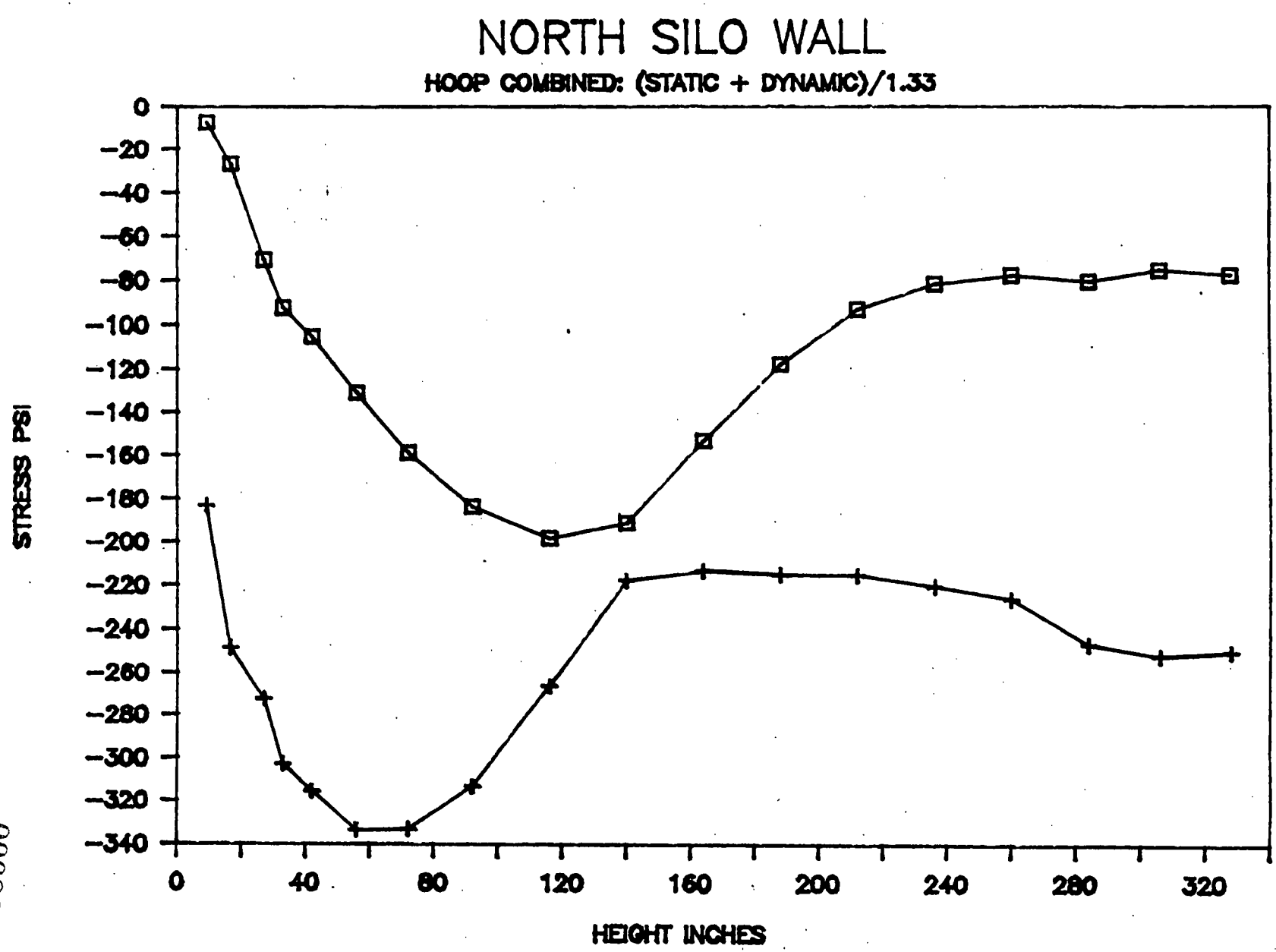
NORTH SILO WALL
HOOP COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
0
40
80
120
160
200
240
280
320
HEIGHT INCHES

FIG. 5.0.4

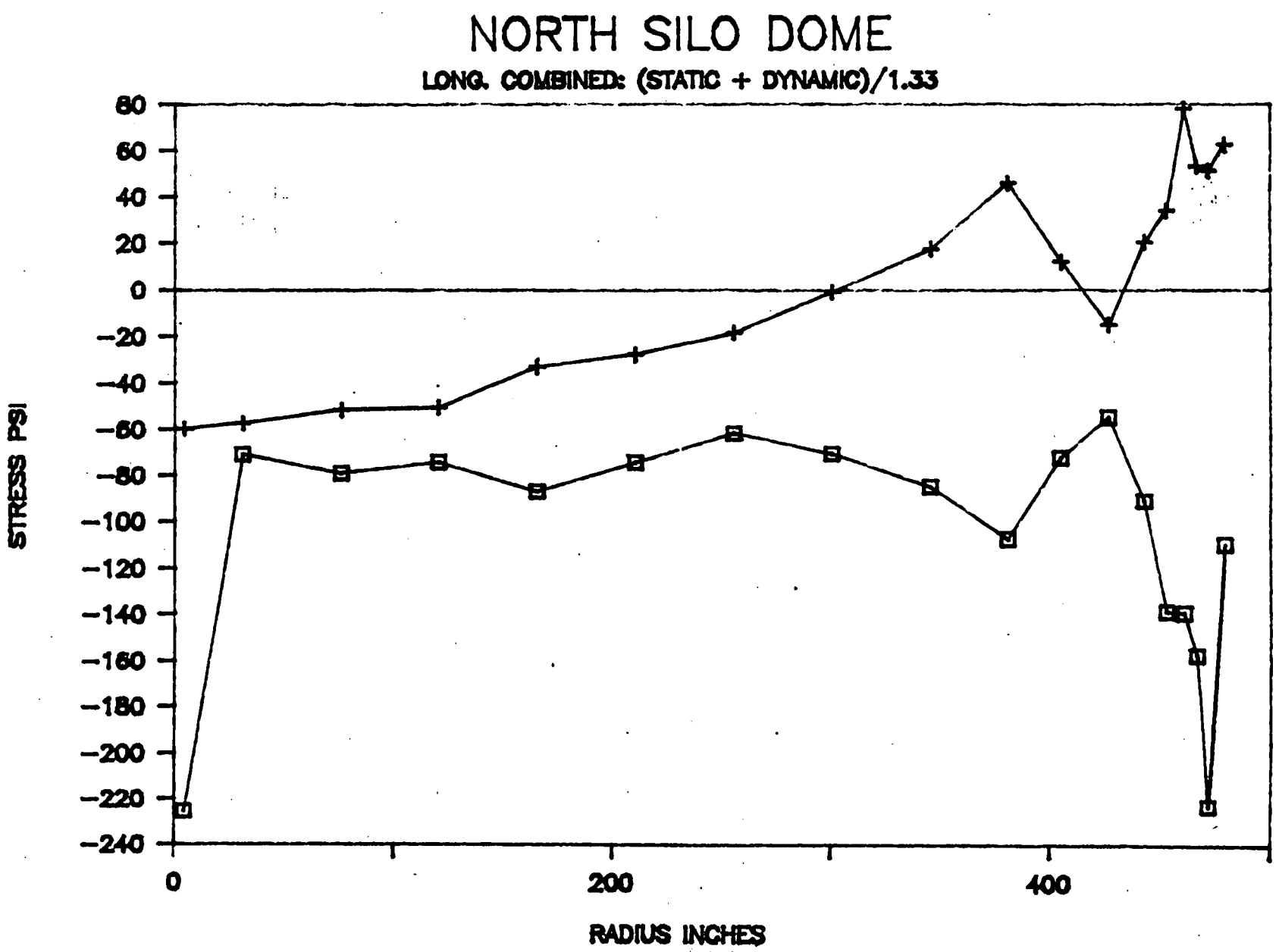
NORTH SILO DOME
LONG. COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
0
200
400
RADIUS INCHES

FIG. 5.0.5

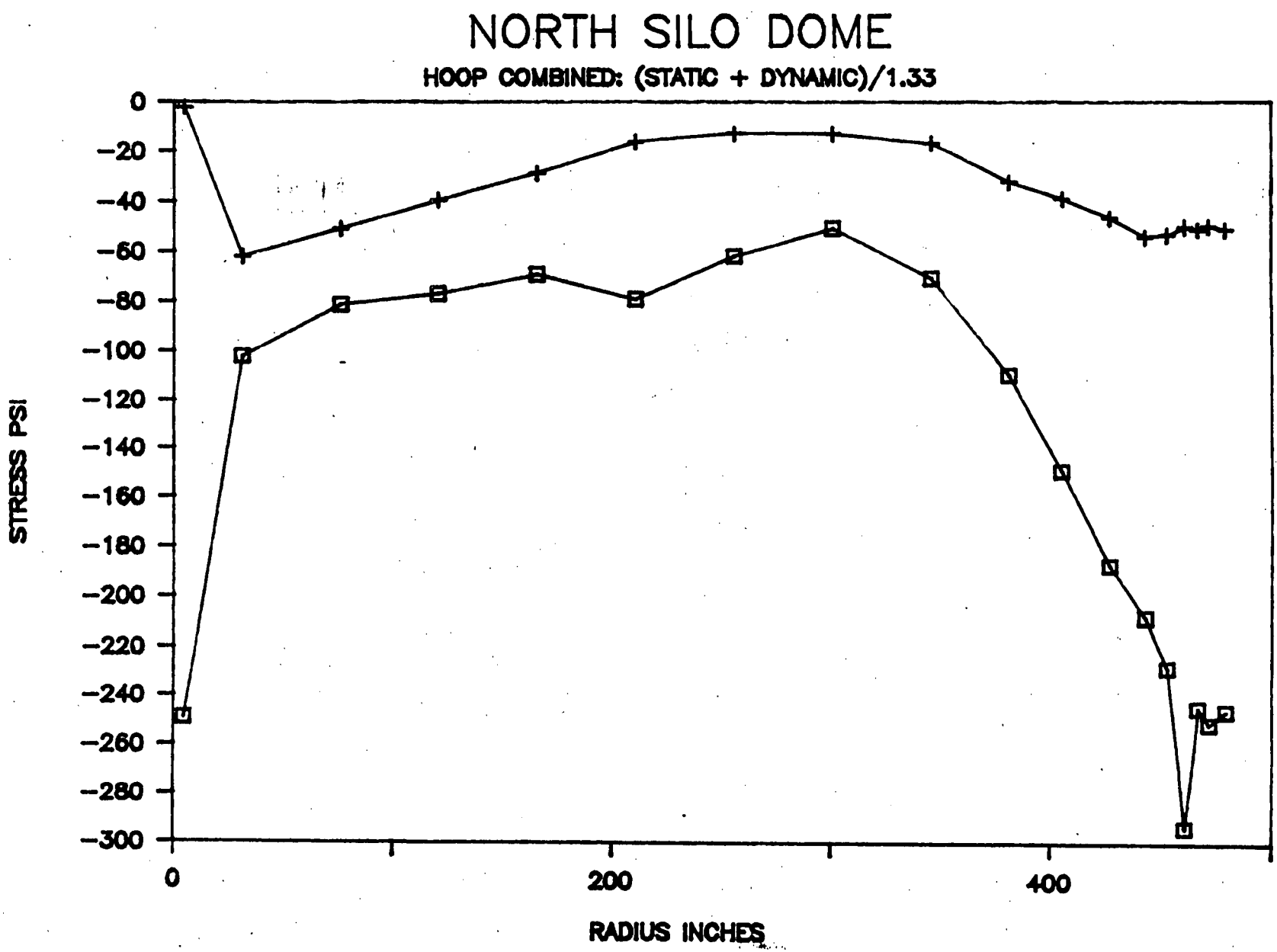
NORTH SILO DOME
HOOP COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
0
200
400
RADIUS INCHES

FIG. 5.0.6

SOUTH SILO BASE SLAB

LONG. COMBINED: (STATIC + DYNAMIC)/1.33

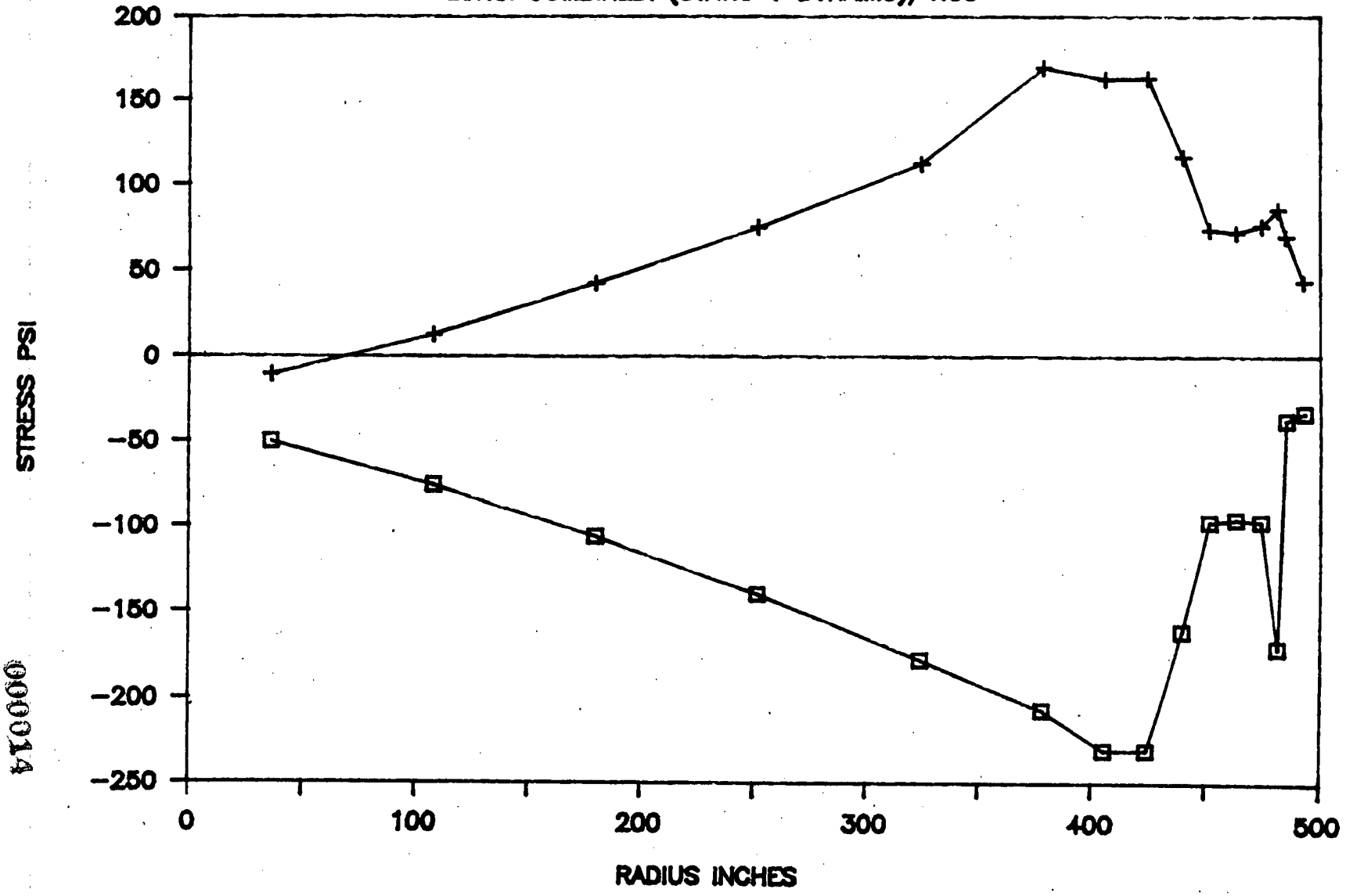

FIG. 5.0.7

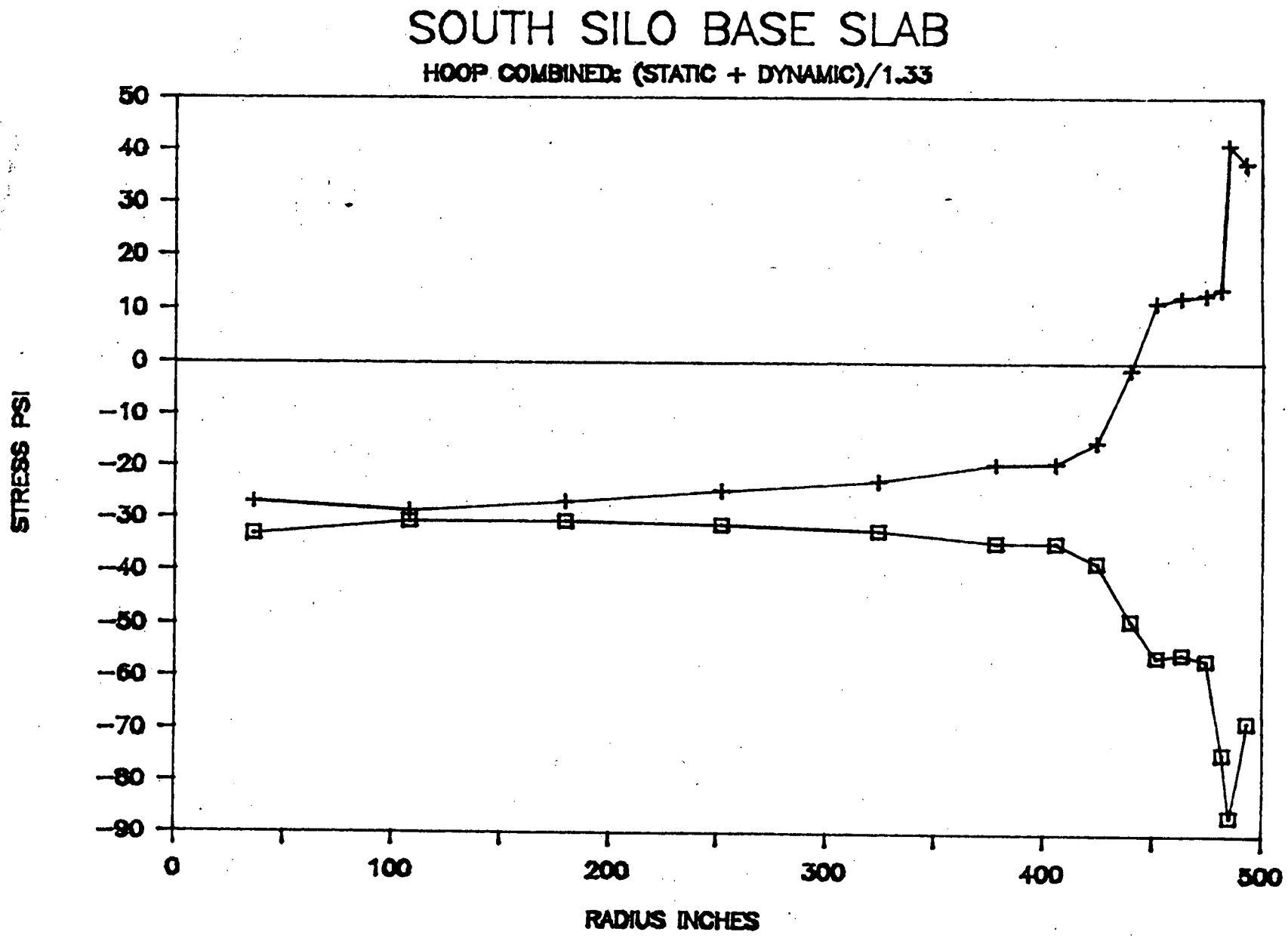
SOUTH SILO BASE SLAB
HOOP COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
100
200
300
400
500
RADIUS INCHES

FIG. 5.0.8

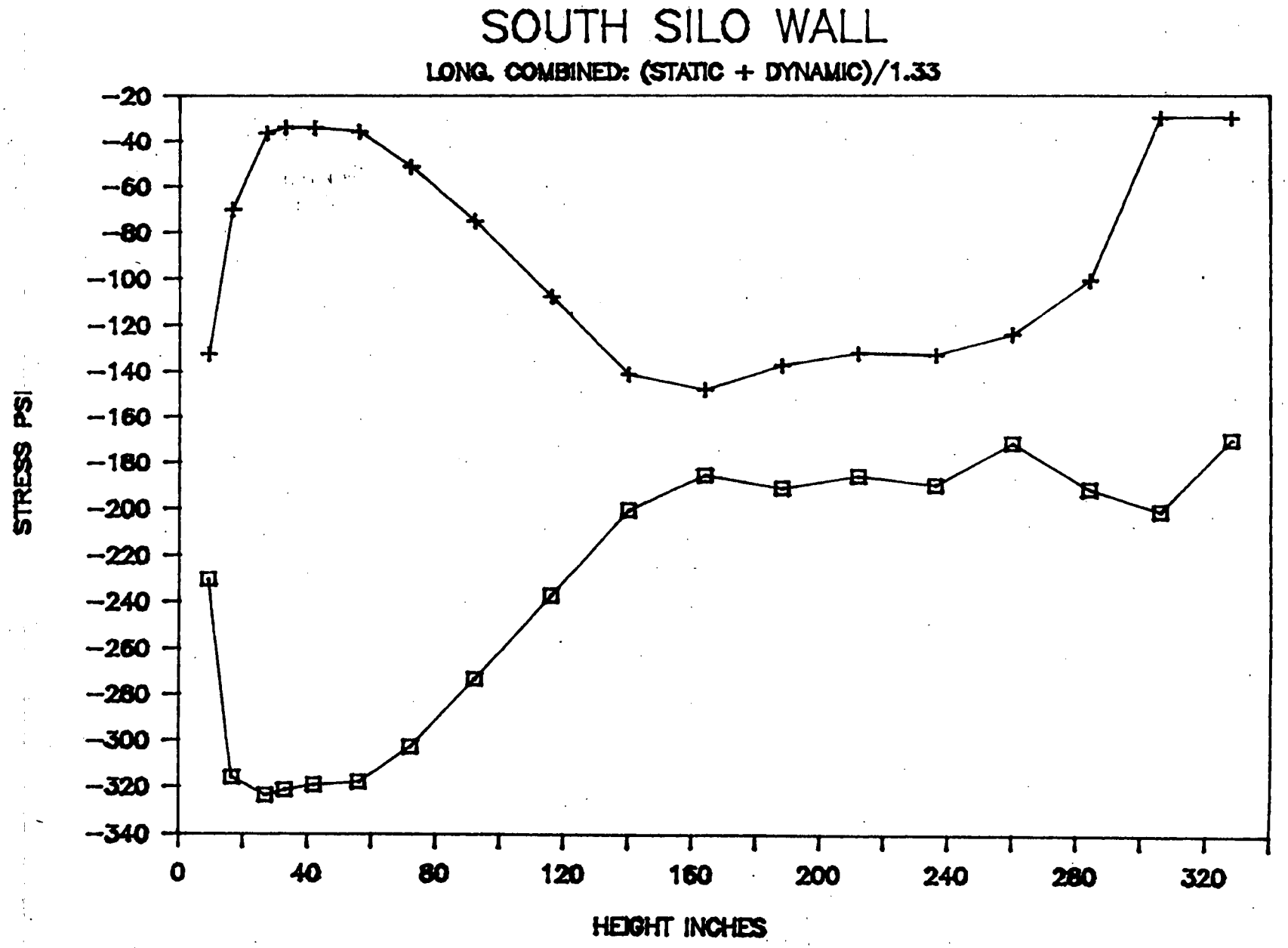
SOUTH SILO WALL
LONG. COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
0
40
80
120
160
200
240
280
320
HEIGHT INCHES

FIG. 5.0.9

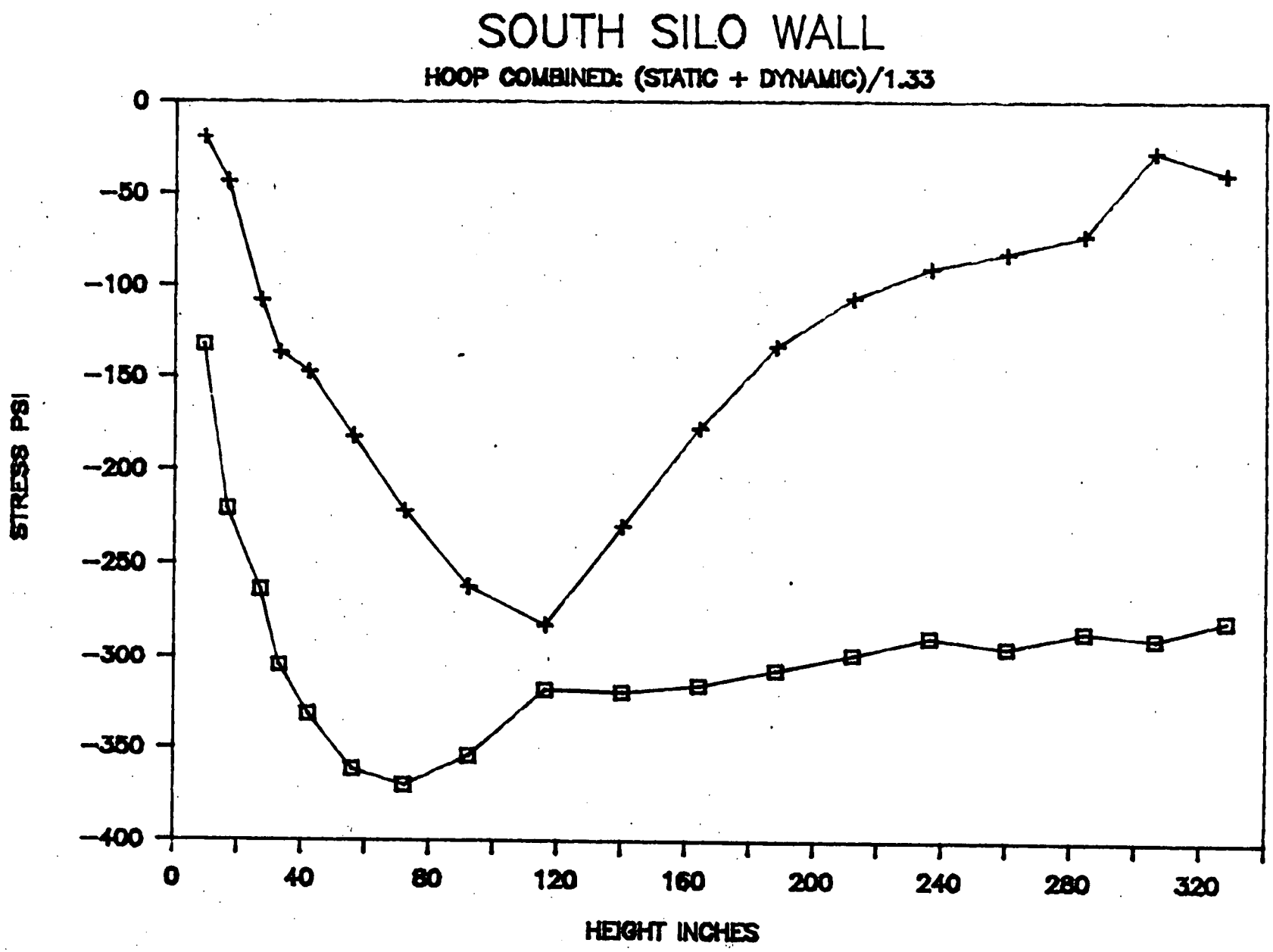
SOUTH SILO WALL
HOOP COMBINED: (STATIC + DYNAMIC)/1.33
STRESS PSI
0
-50
-100
-150
-200
-250
-300
-350
-400
0
40
80
120
160
200
240
280
320
HEIGHT INCHES

FIG. 5.0.10

56221

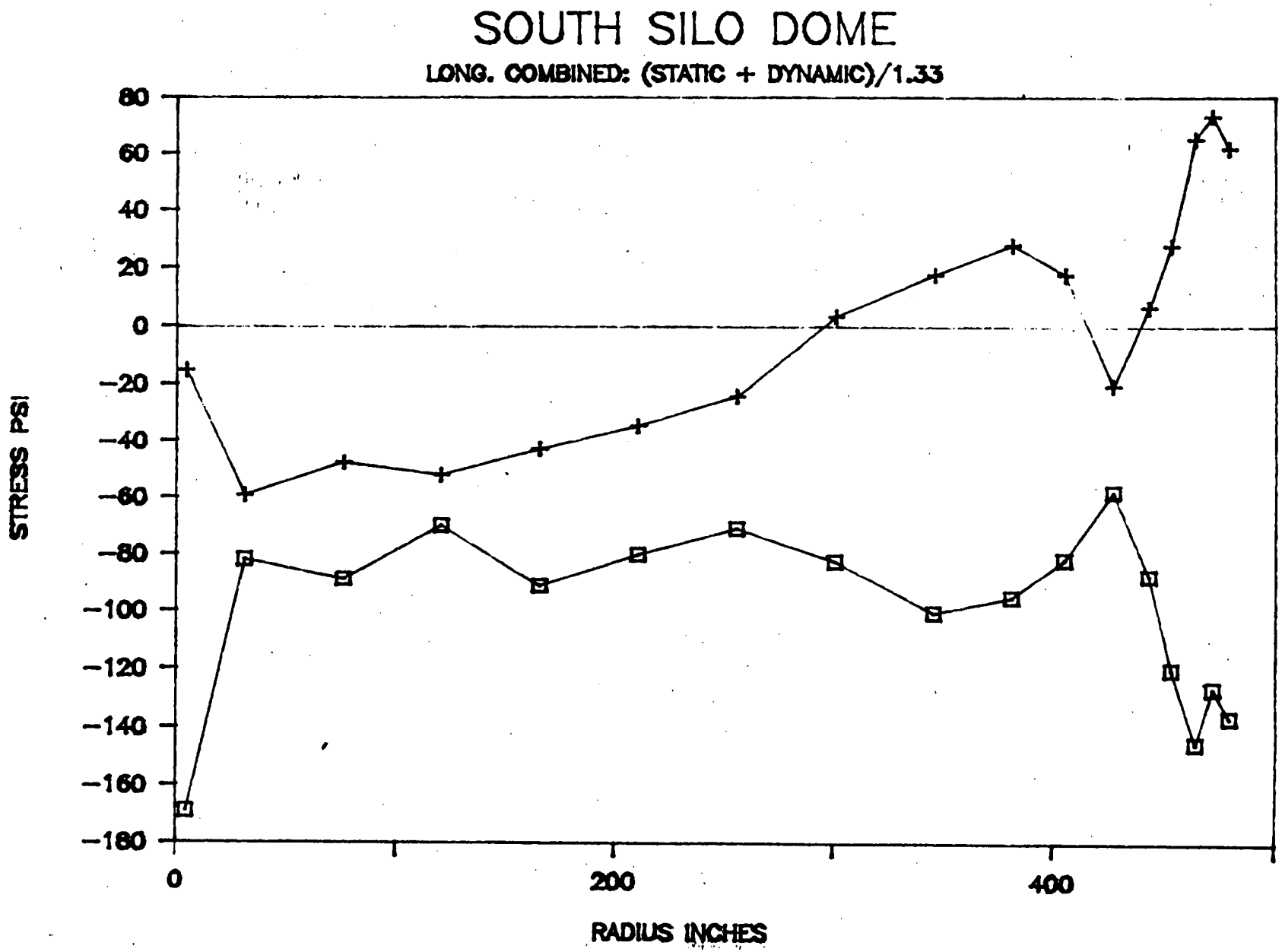

FIG. 5.0.11

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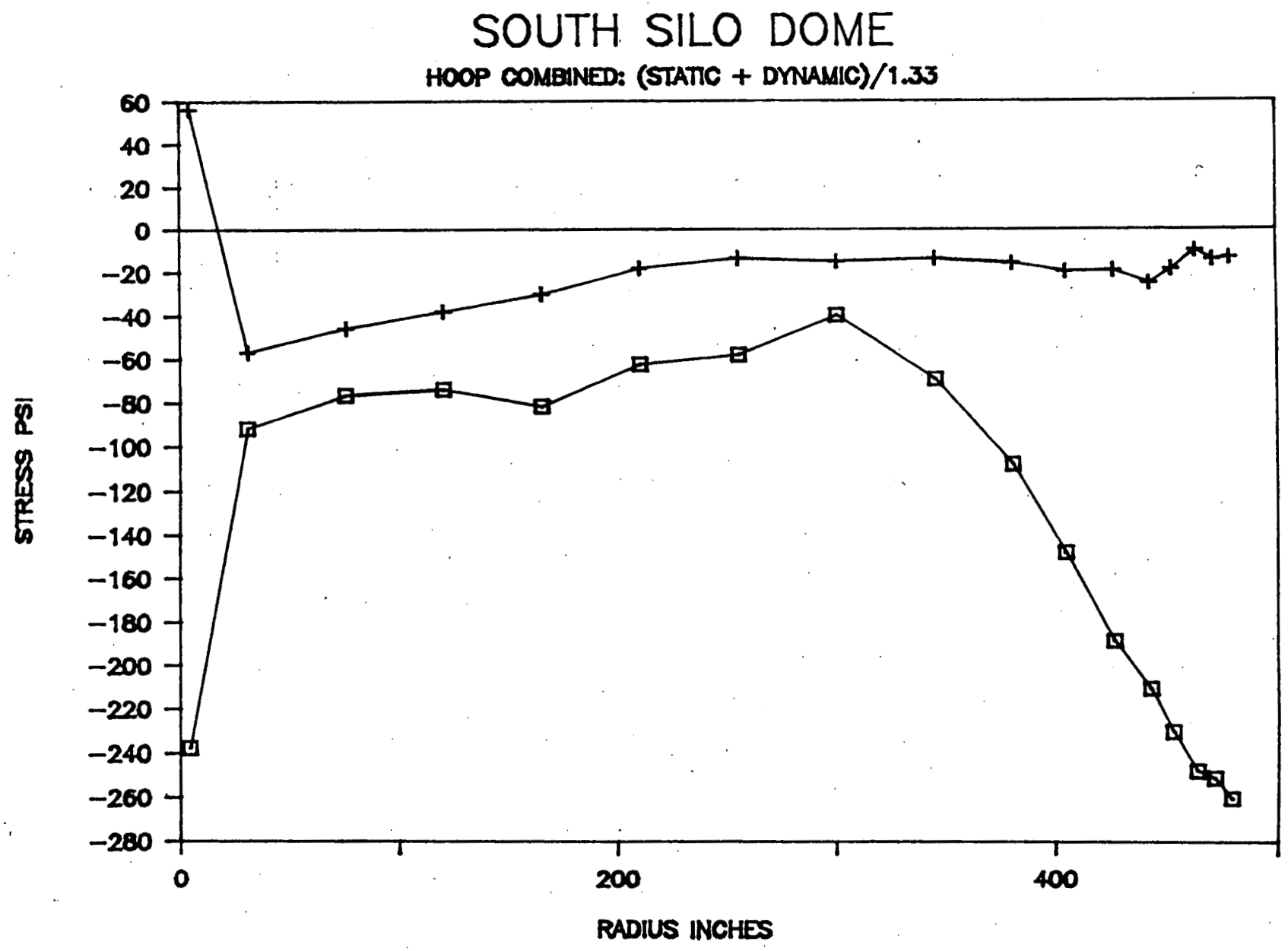

FIG. 5.0.12

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Client ASI

Location FERNALD OHIO

Subject K65 REANALYSIS

W.O. 806-01

Date 12-22-88

By BH

APENDIX B

CALCULATIONS

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Client ASI | CHECKED | W.O. 806-01

Location FERNALD, OHIO | Date 12-13-88

Subject KGS RE-ANALYSIS | By BC

NORTH SILO — HIGH TENSILE AREAS (CHECK REINF.)

BASE SLAB

T_{MAX} = 126.1 PSI @ 400" FROM ℄ OF SILO
(LONG. STRESS)

t = 4"

REINFORCEMENT = #4 @ 10" O.C. EA. WAY

FORCE IN CONC. = 126.1 (4")(10") = 5044 #

TENSION IN BARS = $\frac{5044}{.2}$ = 25,220 PSI

↑ AREA #4 BAR

20,000 PSI < 25,220 PSI < 40,000 PSI
(ALLOWABLE FOR DESIGN) (ACTUAL) (YIELD)

T_{MAX} = 52.2 PSI
(HOOP STRESS)

t = 12"

REINFORCEMENT = #4 @ 12" O.C. TOP & BOTT.

FORCE IN CONC. = 52.2 (12)(12) = 7517 #

TENSION IN BARS = $\frac{7517}{.2(2)}$ = 18,792 PSI < 20,000 PSI OK

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Date 12-13-88
By BC

DOME

T_{max} = 78.1 psi @ 38.25' FROM SILO ℄
(LONG. STRESS)

t = 5"
REINF. = #4 DOWELS @ 12" T&B

FORCE IN CONC. = 78.1 (5)(12) = 4686 #

TENSION IN BARS = $\frac{4686}{.2(2)}$ = 11,715 psi < 20,000 psi
ok

T = 46.1 psi @ 32' FROM SILO ℄
(LONG. STRESS)

t = 4"
REINF. 4x4 #4x#4 WWF

FORCE IN CONC. = 46.1 (4)(12) = 2213 #

TENSION IN REINF. = $\frac{2213}{.12}$ = 18,440 psi < 20,000 psi
ok

AREA OF MESH, ASSUMING NO REDUCED SECTION

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Subject K65 RE-ANALYSIS | By BC

SOUTH SILO – HIGH TENSILE AREAS (CHECK REINF.)

BASE SLAB

T_{MAX} = 169.5 psi @ 378"
(LONG. STRESS)

t = 4"
REINF. = #4@10"

FORCE IN CONC. = 169.5 (4)(10) = 6780 #

TENSION IN BARS = $\frac{6780}{.2}$ = 33,900 psi

20,000 < 33,900 < 40,000
(ALLOW.) (YIELD)

DOME

T = 56.4 psi @ DOME ℄ t = 2.5"
(HOOP STRESS) REINF. = 4x4 W4xW4 WWF

FORCE IN CONC. = 56.4(2.5)(12) = 1692 #

TENSION IN REINF. = $\frac{1692}{.12}$ = 14,100 psi < 20,000 psi OK

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Subject K65 RE-ANALYSIS | By BC

T = 126.6 psi @ 39'-4" FROM SILO ℄

t = 7.5"

REINF. = #4 @ 12" T&B

FORCE IN CONC. = 126.6 (7.5)(12) = 11,394 #

TENSION IN REINF. = $\frac{11394}{2(.2)}$ = 28,485 psi

20,000 < 28,485 < 40,000

T = 27.8 psi @ 8'-3" FROM WALL 27.8 < 120 psi (F_{ct}) OK

t = 4 3/4"

REINF. = 4x4 W4xW4 WWF

FORCE IN CONC. = 27.8 (4.75)(12) = 1585 #

TENSION IN REINF. = $\frac{1585}{.12}$ = 13,205 psi < 20,000 psi OK

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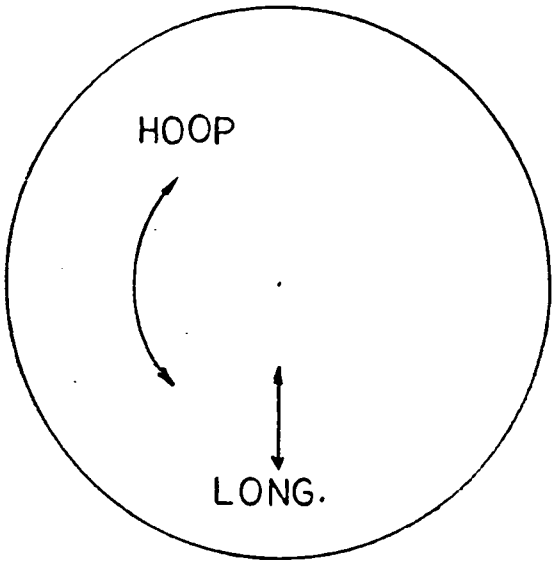
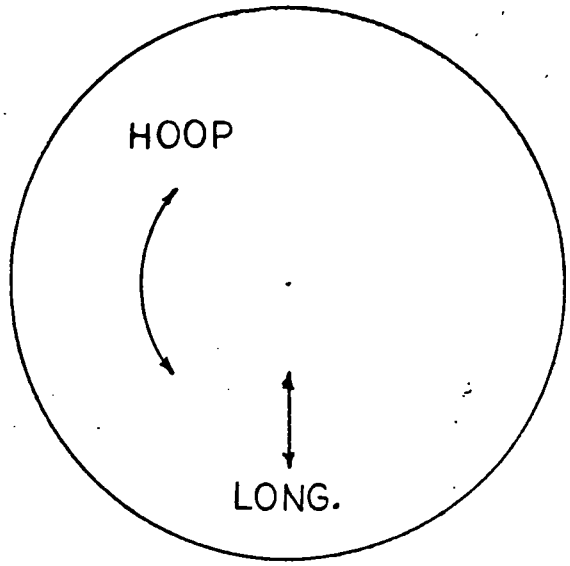
FIG B.O.1



PLAN
BASE SLAB



PLAN
DOME

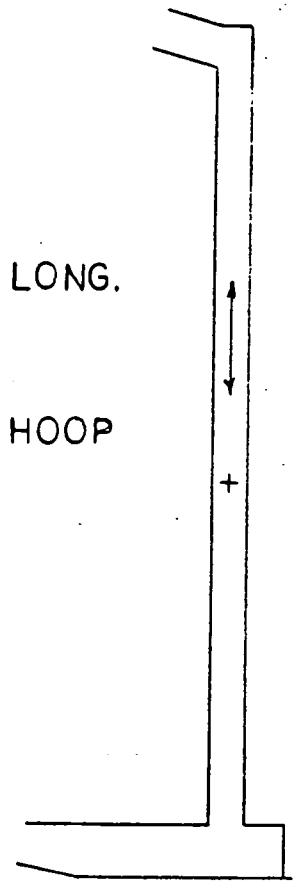
SIGN CONVENTION

+ TENSION

− COMPRESSION

STRESS TYPE AND DIRECTION

WALL
SECTION



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Subject K65 RE-ANALYSIS | By BC

NORTH

	POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
		DYNAMIC	130	-17.5	7.1	19.9	-17.3
		STATIC	6/21	-30.0	-29.9	-30.0	-29.9
		COMB./1.33		-35.7	-17.1	-7.6	-35.5
		DYNAMIC	131	-41.2	8.0	41.0	-26.6
		STATIC	49/61	-29.9	-29.9	-29.9	-29.9
		COMB./1.33		-53.5	-16.4	8.3	-42.5
BASE		DYNAMIC	132	-70.2	13.7	69.5	-43.5
		STATIC	77/105	-29.9	-29.9	-29.9	-29.9
		COMB./1.33		-75.3	-12.2	29.8	-55.2
		DYNAMIC	133	-103.9	18.8	102.7	-59.5
		STATIC	121/133	-29.9	-29.9	-29.9	-29.9
		COMB./1.33		-100.6	-8.3	54.7	-67.2
		DYNAMIC	134	-143.0	25.4	141.1	-77.1
		STATIC	176/169	-29.9	-29.9	-29.9	-29.9
		COMB./1.33		-130.0	-3.4	83.6	-80.5

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NORTH

	POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
		DYNAMIC	135	-173.8	31.4	172.2	-90.7
		STATIC	188/189 185/190	-36.2	-25.4	-21.4	-32.0
		COMB./1.33		-157.9	4.5	113.4	-92.3
		DYNAMIC	136	-199.2	30.9	197.0	-95.9
		STATIC	198/197 200/200	-30.0	-29.2	-29.3	-30.0
		COMB./1.33		-172.3	1.3	126.1	-94.7
BASE		DYNAMIC	137	-191.8	38.9	187.5	-105.0
		STATIC	213/216 215/213	-31.4	-29.4	-29.5	-30.1
		COMB./1.33		-167.8	7.1	118.8	-101.6
		DYNAMIC	138	-133.0	51.6	129.4	-119.3
		STATIC	217/224 223/217	-24.8	-27.1	-15.8	-29.2
		COMB./1.33		-118.6	18.4	85.4	-111.7
		DYNAMIC	139	-76.0	62.1	72.6	-130.8
		STATIC	237/249 249/233	-15.1	-25.0	-7.6	-26.5
		COMB./1.33		-68.5	27.9	48.9	-118.3

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ARCHITECTS — ENGINEERS — PLANNERS

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Client ASI

Location FERNALD, OHIO

Subject K-65 RE-ANALYSIS

CHECKED

W.O. 806-01

Date 12-8-88

By BC

NORTH

BASE

Point	Model	Element No	Long. Stress PSI (Time 6.1)	Hoop Stress PSI (Time 6.1)	Long. Stress PSI (Time 8.3)	Hoop Stress PSI (Time 8.3)
	Dynamic	140	-83.5	63.3	80.6	-132.7
	Static	270/272 273/273	-11.2	-24.9	-9.3	-26.1
	Comb./1.33		-71.2	28.9	53.6	-119.4
	Dynamic	141	-83.5	64.4	79.7	-134.5
	Static	282/284 285/286	-12.2	-24.7	-5.4	-26.7
	Comb./133		-72.0	29.8	55.9	-121.2
	Dynamic	142	-89.0	64.7	84.9	-135.2
	Static	320/310 312/319	-88.7	-24.3	0.8	-49.1
	Comb./133		-133.6	30.4	64.4	-138.6
	Dynamic	143	39.4	83.6	-41.2	-153.9
	Static	344/344 342/331	39.9	-14.2	-11.0	-44.1
	Comb./133		59.6	52.2	-39.2	-148.9
	Dynamic	144	37.8	81.5	-40.0	-152.3
	Static	356/356 350/346	13.7	-15.4	-3.5	-22.7
	Comb./133		38.7	49.7	-32.7	-131.6

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Form 10-CS

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD, OHIO | Date 12-8-88

Subject K-65 RE-ANALYSIS | By BC

NORTH

WALL f'_c = 3000 PSI

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
	DYNAMIC	145	-46.5	72.2	60.4	-140.2
	STATIC	373/370 369/378	-276.5	-82.0	-201.8	-103.3
	COMB./1.33		-242.9	-7.4	-106.3	-183.1
	DYNAMIC	146*148	-65.7	76.7	83.4	-143.9
	STATIC	392/377 386/392	-341.1	-112.4	-157.9	-186.4
	COMB./133		-305.9	-26.8	-56.0	-248.3
	DYNAMIC	149	-60.8	79.5	80.1	-146.3
	STATIC	400/393 392/399	-359.0	-173.4	-135.4	-216.2
	COMB./133		-315.6	-70.6	-41.6	-272.6
	DYNAMIC	150	-46.2	84.4	62.5	-151.7
	STATIC	408/402 401/408	-370.3	-207.2	-124.7	-250.8
	COMB./133		-313.2	-92.3	-46.8	-302.6
	DYNAMIC	151	-44.4	84.1	64.0	-151.0
	STATIC	416/409 409/415	-374.9	-224.2	-116.7	-268.4
	COMB./133		-315.3	-105.3	-39.6	-315.3

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD, OHIO | Date 12-9-88

Subject K65 RE-ANALYSIS | By BC

NORTH

	Point	Model	Element No	Time 6.1 Long. Stress PSI	Time 6.1 Hoop Stress PSI	Time 8.3 Long. Stress PSI	Time 8.3 Hoop Stress PSI
WALL f'c = 3000 PSI		DYNAMIC	152	-43.2	74.9	63.2	-142.0
		STATIC	432 417 / 417 432	-370.8	-249.0	-115.9	-301.6
		COMB./1.33		-311.3	-130.9	-39.6	-333.5
		DYNAMIC	153	-40.5	61.6	60.2	-129.2
		STATIC	440 433 / 433 448	-363.4	-272.9	-125.2	-313.9
		COMB./133		-303.7	-158.9	-48.9	-333.2
		DYNAMIC	154	-34.6	34.4	54.4	-102.2
		STATIC	456 449 / 465 456	-339.0	-278.7	-146.9	-314.2
		COMB./133		-280.9	-183.7	-69.5	-313.1
		DYNAMIC	155	-36.9	-5.1	56.1	-63.1
		STATIC	480 473 / 490 480	-292.1	-258.8	-190.9	-291.3
		COMB./133		-247.4	-198.4	-101.4	-266.5
		DYNAMIC	156	-29.7	-35.9	48.7	-32.3
		STATIC	504 520 / 503 520	-253.2	-254.0	-225.1	-222.2
		COMB./133		-212.7	-218.0	-132.6	-191.4

Form 10-CS

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD, OHIO | Date 12-9-88

Subject K-65 RE-ANALYSIS | By DC

NORTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
	DYNAMIC	157	-28.3	-61.2	46.4	-6.3
	STATIC	537/521 544/536	-269.5	-222.8	-198.9	-197.5
	COMB./1.33		-223.9	-213.5	-114.7	-153.2
	DYNAMIC	158	-23.5	-81.1	40.6	14.5
	STATIC	545/545 568/568	-276.2	-205.1	-180.8	-171.0
	COMB./133		-225.3	-215.2	-105.4	-117.7
	DYNAMIC	159	-15.2	-102.8	30.5	32.1
	STATIC	585/569 592/592	-259.6	-184.1	-168.2	-155.7
	COMB./133		-206.6	-215.7	-103.5	-92.9
	DYNAMIC	160	-12.1	-113.4	25.5	44.3
	STATIC	593/609 600/608	-259.0	-180.4	-167.2	-152.4
	COMB./133		-203.8	-220.9	-106.5	-81.3
	DYNAMIC	161	-8.0	-114.2	20.1	53.3
	STATIC	617/634 624/624	-240.4	-187.2	-182.3	-156.4
	COMB./133		-186.8	-226.6	-122.0	-77.5

WALL f'_c = 3500 PSI

Form 10-CS

CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD, OHIO | Date 12-9-88

Subject K-65 RE-ANALYSIS | By BC

NORTH

	POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
WALL $f'_c = 3500$ PSI		DYNAMIC	162	-6.4	-123.2	16.7	57.9
		STATIC	664/664 657/657	-251.2	-205.4	-135.8	-164.8
		COMB./1.33		-193.7	-247.1	-89.5	-80.4
		DYNAMIC	163	1.4	-123.0	5.6	59.2
		STATIC	680/680 681/682	-266.5	-212.8	-41.3	-159.2
		COMB./133		-199.3	-252.5	-26.8	-75.2
		DYNAMIC	164	6.5	-113.3	2.9	57.5
		STATIC	689/692 692/689	-52.2	-220.3	-212.9	-160.6
		COMB./133		-34.4	-250.8	-157.9	-77.5
DOME $f'_c = 4000$ PSI		DYNAMIC	165	-103.9/89.9	-146.5/-116.2	49.7/-44.5	75.7/58.8
		STATIC	699/697 697/698	-48.4/-6.7	-181.2		-143.6
		COMB./133		-110.0/62.6	-246.4		-51.1
		DYNAMIC	166	-202.3/-21.3	-143.6/-117.5	46.2/-42.3	74.8/60.0
		STATIC	700/700 701/701	-94.3	-191.1	22.1	-140.9
		COMB./133		-223.0	-251.7	51.4	-49.7

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client AS I

Location FERNALD, OHIO

Subject K-65 RE-ANALYSIS

CHECKED

W.O. 806-01

Date 12-9-88

By BC

NORTH

	Point	Model	Element No	Time 6.1 Long. Stress PSI	Time 6.1 Hoop Stress PSI	Time 8.3 Long. Stress PSI	Time 8.3 Hoop Stress PSI
DOME P_i = 4000 PSI		Dynamic	167	-101.8/91.4	-141.9/-116.1	49.5/-46.0	74.5/60.0
			708/708				
		Static	706/706	-107.6/-20.6	-183.9		-142.5
		Comb./1.33		-157.4/53.2	-245.0		-51.1
		Dynamic	168	-109.1/99.7	-139.3/-113.0	53.9/51.0	73.9/59.1
			711/711				
		Static	709/709	-76.4/4.2	-179.4		-140.5
		Comb./133		-139.5/78.1	-239.6		-50.1
		Dynamic	169	-86.0/78.6	-127.8/-111.1	43.9/-42.0	69.3/59.0
			716/716				
		Static	714/714	-98.8/-33.1	-175.8		-139.8
		Comb./133		-138.9/34.2	-228.3		-53.1
		Dynamic	170	-40.4/36.4	-107.6	22.7/-22.1	60.6
			724/719				
		Static	717/723	-80.7/-9.1	-169.3		-132.3
		Comb./133		-91.1/20.5	-208.2		-53.9
		Dynamic	171	-6.5/7.2	-77.2/-92.4	-1.2	52.4
			727/726				
		Static	725/736	-65.9/-27.2	-156.9		-114.0
		Comb./133		-54.4/-15.0	-187.4		-46.3

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

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Client ASI | CHECKED | W.O. 806-01

Location FERNALD, OHIO | Date 12-9-88

Subject K-65 RE-ANALYSIS | By BC

NORTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
	DYNAMIC	172	36.8 / -31.4	-66.1	-14.7 / 11.3	41.0
	STATIC	748 / 741	-20.6 / -64.8	-132.1		-92.3
	COMB. / 1.33	737 / 748	12.2 / -72.3	-149.0		-38.6
	DYNAMIC	173	70.3 / -61.8	-39.7	-18.5 / 13.8	29.0
	STATIC	764 / 757	-9.0 / -81.5	-105.5		-71.6
	COMB. / 133	749 / 763	46.1 / -107.7	-109.2		-32.0
	DYNAMIC	174	32.0 / -22.3	-15.2	-15.2 / 10.0	17.2
	STATIC	772 / 765 781 / 783	-8.6 / -90.6	-78.6		-39.2
	COMB. / 133		17.6 / -84.9	-70.5		-16.5
	DYNAMIC	175	11.7 / -3.6	-5.1	-6.2 / 1.8	11.4
	STATIC	788 / 789 789 / 804	-12.9	-62.1	-87.6	-28.4
	COMB. / 133		-0.9	-50.5	-70.5	-12.8
	DYNAMIC	176	4.4	-13.0	-2.1	12.2
	STATIC	812 / 827 805 / 812	-29.1	-69.1	-79.7	-29.1
	COMB. / 133		-18.6	-61.7	-61.5	-12.7

DOME $f'_c = 4000$ PSI

(820 * 828 = 3500 PSI)

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI

Location FERNALD, OHIO

Subject K-65 RE-ANALYSIS

CHECKED

W.O. 806-01

Date 12-9-88

By BC

NORTH

	Point	Model	Element No	Time 6.1 Long. Stress PSI	Time 6.1 Hoop Stress PSI	Time 8.3 Long. Stress PSI	Time 8.3 Hoop Stress PSI
		Dynamic	177	-3.2	13.1	5.2	-10.3
		Static	852/831 836/855	-95.7	-34.4	-41.8	-94.7
		Comb./1.33		-74.4	-16.0	-27.5	-78.9
		Dynamic	178	-2.3	10.8	3.3	8.6
		Static	860/857 861/860	-113.0	-49.0	-47.1	-100.5
		Comb./133		-87.0	-28.7	-32.9	-69.1
		Dynamic	179	-2.5	8.0	1.6	-6.4
		Static	913/885 908/889	-96.3	-60.4	-68.6	-95.9
		Comb./133		-74.3	-39.4	-50.4	-76.9
		Dynamic	180	-1.1	5.1	1.4	-4.0
		Static	925/921 924/952	-104.1	-72.8	-69.9	-104.0
		Comb./133		-79.1	-50.9	-51.5	-81.2
		Dynamic	181	-0.8	2.8	1.0	-2.2
		Static	953/953 956/968	-93.5	-85.2	-77.0	-133.7
		Comb./133		-70.9	-62.0	-57.1	-102.2

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI

Location FERNALD, OHIO

Subject K-65 RE-ANALYSIS

CHECKED

W.O. 806-01

Date 12-9-88

By BC

NORTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 8.3 LONG. STRESS PSI	TIME 8.3 HOOP STRESS PSI
	DYNAMIC	182	-1.3	-1.1	1.1	0.9
	STATIC	1000/973 / 1000/997	-298.5	-330.2	-80.4	-3.8
	COMB./1.33		-225.4	-249.1	-59.6	-2.2
	DYNAMIC					
	STATIC					
	COMB./133					
	DYNAMIC					
	STATIC					
	COMB./133					
	DYNAMIC					
	STATIC					
	COMB./133					
	DYNAMIC					
	STATIC					
	COMB./133					

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client: ASI | CHECKED | W.O. 806-01

Location: FERNALD | Date: 12-13-88

Subject: K65 REANALYSIS | By: BH

SOUTH

BASE SLAB

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
1	DYNAMIC	130	-25.0	4.7	24.2	-2.9
	STATIC	6/4	-41.5	-40.5	-38.8	-41.3
	COMB./1.33	3/33	-50.0	-26.9	-10.9	-33.2
2	DYNAMIC	131	-59.5	2.8	58.3	0.3
	STATIC	53/40	-41.3	-41.1	-41.1	-41.3
	COMB./133	72/61	-75.8	-28.7	12.9	-30.8
3	DYNAMIC	132	-99.8	5.3	97.6	0.4
	STATIC	77/92	-41.3	-41.1	-41.1	-41.3
	COMB./133	92/92	-106.1	-26.9	42.5	-30.8
4	DYNAMIC	133	-145.0	8.3	141.3	-.5
	STATIC	109/116	-41.3	-41.1	-41.1	-41.3
	COMB./133	136/109	-140.1	-24.7	75.3	-31.4
5	DYNAMIC	134	-196.0	10.8	190.8	-1.9
	STATIC	157/164	-41.3	-41.1	-41.1	-41.3
	COMB./133	148/145	-178.4	-22.8	112.5	-32.5

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD OHIO | Date 12-13-88

Subject K65 REANALYSIS | By BH

SOUTH

BASE SLAB

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
6	DYNAMIC	135	-234.0	15.0	266.6	-4.9
	STATIC	177 / 184	-41.3	-41.1	-41.1	-41.3
	COMB./1.33	184 / 177	-207.0	-19.6	169.5	-34.7
7	DYNAMIC	136	-265.7	15.3	257.5	-4.9
	STATIC	197 / 204	-41.3	-41.1	-41.1	-41.3
	COMB./133	200 / 197	-230.8	-19.4	-162.7	-34.7
8	DYNAMIC	137	-263.6	20.4	256.8	-9.5
	STATIC	213 / 216	-43.2	-40.8	-39.7	-41.6
	COMB./133	216 / 213	-230.7	-15.3	163.2	-38.4
9	DYNAMIC	138	-181.2	37.4	176.5	-25.3
	STATIC	217 / 220	-34.0	-39.0	-21.8	-40.2
	COMB./133	223 / 217	-161.8	-1.2	116.3	-49.2
10	DYNAMIC	139	-108.9	49.6	108.9	-37.7
	STATIC	237 / 249	-20.5	-34.6	-11.2	-36.6
	COMB./133	249 / 237	-97.3	11.3	73.5	-55.9

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client: ASI | CHECKED | W.O. 806-01

Location: FERNALD, OHIO | Date: 12-13-88

Subject: K65 RE ANALYSIS | By: BH

SOUTH

	Point	Model	Element No	Time 6.1 Long. Stress PSI	Time 6.1 Hoop Stress PSI	Time 6.8 Long. Stress PSI	Time 6.8 Hoop Stress PSI
BASE SLAB	11	DYNAMIC	140	-112.1	50.7	108.9	-37.7
		STATIC	270/272	-15.4	-34.4	-13.1	-35.9
		COMB./1.33	273/273	-95.9	12.3	72.0	-55.3
	12	DYNAMIC	141	-112.4	51.2	109.3	-38.7
		STATIC	282/284	-16.8	-34.2	-8.3	-36.3
		COMB./133	285/286	-97.1	12.8	75.9	-56.4
	13	DYNAMIC	142	-117.9	52.0	114.6	-38.7
		STATIC	320/310	-110.2	-53.5	-1.0	-60.0
		COMB./133	312/319	-171.5	13.9	85.4	-74.2
	14	DYNAMIC	143	41.9	75.6	-40.3	-61.6
		STATIC	344/344	50.6	-21.1	-9.1	-53.3
		COMB./133	342/331	69.5	41.0	-37.1	-86.4
	15	DYNAMIC	144	41.0	73.4	-39.5	-59.4
		STATIC	365/352	16.5	-23.4	-4.2	-31.3
		COMB./133	346/346	43.2	37.6	-32.9	-68.2

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD | Date 12-13-88

Subject K-65 REANALYSIS | By BH

SOUTH

POINT	MODEL	ELEMENT No.	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.88 LONG. STRESS PSI	TIME 6.88 HOOP STRESS PSI
16	DYNAMIC	145	-27.8	67.7	19.0	-55.5
	STATIC	373/370	-278.6	-93.5	-195.1	-120.6
	COMB./1.33	369/373	-230.4	-19.4	-132.4	-132.4
17	DYNAMIC	146 * 148	-45.8	74.8	35.3	-62.9
	STATIC	392/377	-374.2	-132.4	-128.4	-231.2
	COMB./133	385/392	-315.8	-43.3	-70.0	-221.1
18	DYNAMIC	149	-39.1	78.8	28.9	-67.1
	STATIC	400/393	-391.0	-222.3	-77.3	-283.7
	COMB./133	393/399	-323.4	-107.9	-36.4	-263.8
19	DYNAMIC	150	-26.5	87.6	17.4	-75.3
	STATIC	408/402	-400.5	-269.3	-62.5	-330.2
	COMB./133	401/408	-321.1	-136.6	-33.9	-304.8
20	DYNAMIC	151	-21.3	99.7	12.1	-86.2
	STATIC	416/409	-403.0	-295.4	-57.3	-355.0
	COMB./133	409/415	-319.0	-147.1	-34.0	-331.7

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client: ASI | CHECKED | W.O. 806-01

Location: FERNALD | Date: 12-13-88

Subject: K-65 REANALYSIS | By: BH

SOUTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
21	DYNAMIC	152	-21.5	90.3	12.3	-77.5
	STATIC	424/417	-401.1	-332.4	-59.8	-403.1
	COMB./1.33	417/432	-317.7	-182.0	-35.7	-361.4
22	DYNAMIC	153	-20.7	76.6	8.0	-64.7
	STATIC	440/433	-381.7	-371.9	-76.0	-427.1
	COMB./133	433/448	-302.6	-222.0	-51.1	-369.8
23	DYNAMIC	154	-11.5	44.7	3.7	-34
	STATIC	456/449	-351.7	-392.9	-103.2	-433.8
	COMB./133	449/456	-273.1	-261.8	-74.8	-354.0
24	DYNAMIC	155	-14.4	-2.8	7.6	11.8
	STATIC	480/480	-301.1	-420.0	-150.6	-387.3
	COMB./133	473/490	-237.2	-317.9	-107.5	-282.3
25	DYNAMIC	156	-8.6	-40.0	2.3	47.8
	STATIC	504/502	-257.9	-384.8	-189.9	-353.8
	COMB./133	497/520	-200.4	-319.4	-141.1	-230.1

Form 10-CS

CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client: ASI | CHECKED | W.O. 806-01

Location: FERNALD | Date: 12-13-88

Subject: K-65 REANALYSIS | By: BH

SOUTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
26	DYNAMIC	157	8.1	-70.6	2.6	77.2
	STATIC	537/521	-238.3	-349.2	-199.3	-312.9
	COMB./1.33	544/543	-185.3	-315.6	-147.9	-177.2
27	DYNAMIC	158	-4.5	-94.4	-0.4	100.0
	STATIC	561/546	-249.3	-313.8	-182.1	-276.8
	COMB./133	568/568	-190.8	-306.9	-137.2	-132.9
28	DYNAMIC	159	1.6	-108.1	-5.0	112.6
	STATIC	584/569	-177.2	-288.1	-251.7	-253.9
	COMB./133	569/591	-132.0	-297.9	-185.5	-106.2
29	DYNAMIC	160	3.3	-115.8	-5.9	119.3
	STATIC	600/593	-179.8	-267.9	-246.3	-239.1
	COMB./133	593/616	-137.7	-288.5	-189.6	-90.1
30	DYNAMIC	161	5.2	-126.3	-6.7	129.1
	STATIC	633/625	-169.9	-265.0	-220.9	-238.3
	COMB./133	617/623	-123.8	-294.2	-171.1	-82.1

Form 10-CS

5621

CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client: ASI | CHECKED | W.O. 806-01

Location: FERNALD | Date: 12-13-88

Subject: K 65 REANALYSIS | By: B H

SOUTH

	Point	Model	Element No	Time 6.1 Long. Stress PSI	Time 6.1 Hoop Stress PSI	Time 6.8 Long. Stress PSI	Time 6.8 Hoop Stress PSI
	27	DYNAMIC	162	6.4	-118.2	-6.0	120.0
		STATIC	657/648	-140.2	-261.7	-248.1	-216.2
		COMB./1.33	664/657	-100.6	-285.6	-191.1	-72.3
	28	DYNAMIC	163	8.0	-130.9	-8.4	132.2
		STATIC	681/672	-47.2	-253.7	-258.7	-168.8
		COMB./133	672/681	-29.5	-289.2	-200.8	-27.5
	29	DYNAMIC	164	14.0	-128.9	-14.1	129.1
		STATIC	689/692	-53.5	-242.6	-211.3	-181.4
		COMB./133	692/689	-29.7	-279.3	-169.5	-59.3
dome	30	DYNAMIC	165	-98.8/86.0	-143.9	97.5/-85.4	142.9
		STATIC	700/700	-82.6	-202.4	-15.0	-160.4
		COMB./133	697/699	-136.4	-260.4	62.0	-13.2
	31	DYNAMIC	166	-90.7/80.6	-140.8	89.1/-79.8	139.6
		STATIC	704/703	-77.7	-192.9	8.4	-158.3
		COMB./133	70 /704	126.6	-250.9	73.3	-14.1

Form 10-CS

CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD | Date 12-13-88

Subject K65 REANALYSIS | By BH

SOUTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
38	DYNAMIC	167 * 168	-101.4 / 93.4	-138.8	98.8 / -91.8	137.5
	STATIC	708 / 708	-92.0	-190.7	-11.9	-150.7
	COMB. / 1.33	709 / 712	-145.4	-247.7	65.3	-9.9
39	DYNAMIC	169	-78.7 / 72.8	-124.3	76.0 / -71.1	122.7
	STATIC	716 / 713	-81.0	-181.7	-39.4	-147.4
	COMB. / 133	714 / 715	-120.1	-230.1	27.5	-18.6
40	DYNAMIC	170	-35.2 / 32.6	-105.2	33.1 / -31.4	104.3
	STATIC	716 / 718	-81.0	-174.7	-24.5	-137.3
	COMB. / 133	717 / 723	-87.4	-210.5	6.5	-24.8
41	DYNAMIC	171	9.7 / -8.0	-90.4	-11.1 / 8.4	89.3
	STATIC	735 / 726	-36.9	-160.0	-65.8	-114.7
	COMB. / 133	733 / 736	-20.5	-188.3	-57.8	-19.1
42	DYNAMIC	172	37.1 / -31.0	-64.5	-37.8 / 30.9	63.4
	STATIC	748 / 737	-13.7	-132.2	-70.8	-89.6
	COMB. / 133	741 / 748	17.6	-147.9	-81.7	-19.7

Form 10-CS

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CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

Client ASI | CHECKED | W.O. 806-01

Location FERNALD | Date 12-13-88

Subject K65 REANALYSIS | By BH

SOUTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
43	DYNAMIC	173	42.9 / -33.8	-39.0	-43.2 / 33.4	38.0
	STATIC	764 / 749	-5.9	-104.5	-83.4	-58.9
	COMB. / 1.33	757 / 764	27.8	-107.9	-95.2	-157
44	DYNAMIC	174	31.1 / -20.9	-15.6	-31.2 / 20.4	14.7
	STATIC	772 / 765	-7.6	-76.0	-102.5	-32.6
	COMB. / 133	781 / 783	17.7	-68.9	-100.5	-13.5
45	DYNAMIC	175	11.2 / -2.8	-5.4	-11.4 / 2.3	4.8
	STATIC	788 / 789	-15.8	-57.9	-98.0	-24.6
	COMB. / 133	789 / 804	-3.5	-39.5	-82.3	-14.9
46	DYNAMIC	176	4.5	-6.8	-4.9	8.2
	STATIC	812 / 827	-36.7	-70.2	-89.2	-25.9
	COMB. / 133	805 / 807	-24.2	-57.9	-70.8	-13.3
47	DYNAMIC	177	5.1	-10.8	-5.3	10.3
	STATIC	831 / 855	-51.0	-93.5	-101.0	-34.3
	COMB. / 133	852 / 830	-34.5	-62.2	-79.9	-18.0

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Form 10-CS

CAMARGO ASSOCIATES, INC.

ARCHITECTS — ENGINEERS — PLANNERS

5621

Client ASI

Location FERNALD

Subject K65 REANALYSIS

CHECKED

W.O. 806-01

Date 12-13-88

By BH

SOUTH

POINT	MODEL	ELEMENT No	TIME 6.1 LONG. STRESS PSI	TIME 6.1 HOOP STRESS PSI	TIME 6.8 LONG. STRESS PSI	TIME 6.8 HOOP STRESS PSI
48	DYNAMIC	178	3.1	-9.1	-3.3	8.6
	STATIC	864/860	-60.0	-99.1	-118.0	-48.2
	COMB./1.33	860/857	-42.8	-81.4	-91.2	-42.7
49	DYNAMIC	179	2.0	-7.0	-2.2	6.7
	STATIC	908/889	-71.3	-91.2	-90.6	-57.0
	COMB./133	909/885	-52.1	-73.8	-69.8	-37.8
50	DYNAMIC	180	1.3	-4.4	-1.4	4.2
	STATIC	924/952	-64.7	-97.2	-116.9	-64.8
	COMB./133	941/921	-47.7	-76.4	-88.9	-45.6
51	DYNAMIC	181	1.2	-2.4	-1.2	2.3
	STATIC	956/968	-80.0	-119.6	-107.6	-77.7
	COMB./133	957/953	-59.2	-91.7	-81.8	-56.7
52						
	DYNAMIC	182	1.2	1.0	-1.2	-0.9
	STATIC	997/997	-21.3	74.0	-223.7	-315.1
	COMB./133	1000/1000	-15.1	56.4	-169.1	-237.6

Appendix B- Dynamic Earthquake Run Results

for

Two Concrete Storage Silos Holding Solid K-65
and a 4 ft sand blanket over the K-65

by

Dr. J.. Leroy Hulsey, P.E., S.E.

November 1988

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY AND CONCLUSIONS.....

2. RESULTS AND FINDINGS.....

1. EXECUTIVE SUMMARY & CONCLUSIONS

The earthquake analysis was performed on both the North and South NLO concrete Silos. A three-dimensional analysis was conducted through the time domain (time history analysis). Each time step was 0.01 sec and the earthquake was described at every 0.01 seconds over 10 seconds. The investigator conservatively made the following assumptions:

1) The solid K-65 stored in the Silos and the added sand blanket adds mass but not stiffness;
2) Earlier tests showed that the structural integrity of the concrete dome had deteriorated. Later, a video display of the dome indicated that the concrete dome thickness was still intact. Thus, provision for this deterioration was accounted for by adding the mass of the concrete dome but stiffness was reduced.
3) Added weight was imposed on the dome to account for a dome cap, and a foam of 1psf was also introduced as added dead weight.
4) Damping was neglected (the damping in a facility of this type could be taken approximately to be 10 - 15%);
5) The Silo was assumed to be a homogenous isotropic uncracked concrete;
6) All connections between the walls and base slab, and walls and the dome have enough tendons to cause the system to act as a unit through the majority of the earthquake; and
7) All stresses reported herein are a result of the earthquake and do not account for the compression stresses existing in the Silo due to post tensioning and induced by other loads such as self weight, etc. Further, the analysis is based on the assumption that the foundation system is not subject to liquification due to the imposed earthquake loading. This conditions should be examined by a qualified geotechnical engineer.

<u>Dome</u>-The dome on both structures moved as a rigid body in the radial direction, vertical movements were negligible and the maximum Hoop Stresses were +75/-146 psi for the North Silo and +140/-144 psi for the South Silo. Longitudinal stresses were +54/-202 psi for the North and -101/99 psi for the South Silo. The stresses described above were near the top of the Silo walls.

Stresses near the middle of the dome were negligible because the dome is extremely flexible and therefore does not significantly resist the earthquake movements. Shear stresses were found to be negligible.

Walls-The stresses in the walls may be considered insignificant except near the bottom of the Silo. The stresses approximately 3 ft above the base slab were found to experience Hoop stresses of -152/84 psi for the North, and -86/100 psi for the South Silo. Longitudinal stresses were -66/83 psi for the North and -46/35 psi for the South Silo. Shear stresses were negligible.

Base Slab-The Hoop stresses in the base slab were found to be -154/84 psi in the North Silo and -59/76 psi in the South Silo. Longitudinal stresses were 188/-199 for the north silo and 258/-266 psi for the south Silo. Shear stresses were neglibible.

5. RESULTS AND FINDINGS

It was the objective of this investigation to perform a time history analysis on the three (3) dimensional concrete storage silo described earlier in this report. Before a detailed time history analysis is conducted, it is advisable to perform a free vibration analysis to obtain the natural period and frequency of the soil-structure system. Therefore, an analysis was conducted to examine the first 10 to 15 modes. The results of this study showed that the fundamental frequency was 6.03 hz for the North Silo and 5.51 hz for the South Silo.. The results of the first 5 modes are presented below for review.

Table B-1 Natural Fequency

	North Silo		South Silo	
Mode Number	Period (Sec.)	Frequency (hz)	Period (Sec.)	Frequency (hz)
1	0.166	6.03	0.182	5.51
2	0.136	7.34	0.142	7.05
3	0.117	8.53	0.122	8.18
4	0.094	10.69	0.105	9.47
5	0.089	11.22	0.100	9.99

Time history analysis gives the response of the structure at selected points in time. The earthquake analysis reported herein was conducted using an incremental time step of 0.01 sec and 10 modes were used to conduct a modal analysis.

<u>North Silo</u>-The silo responded to the simulated earthquake record with negligible vertical movements and small radial displacements over the time period. The structure moved overall as a rigid body and the maximum radial displacement occured near the top of the silo wall (nodes 115 to 121). These displacements were -0.24" at 6.1 sec and 0.23" at 8.3 sec. The radial

displacements of the top of the silo wall versus time was plotted and at each 0.10 sec and are presented in Fig. B-1. The maximum radial displacements for the silo are presented in Fig. B-2.

Shell stresses consist of longitudinal and hoop stresses and shear stresses. The maximum stresses occured at two points of time 6.1 and 8.3 sec. A summary of the results are presented in tables B-2 and B-3. The results for the longitudinal and hoop stresses for each of these two time steps were calculated at the center of each element instead of the node as presented in the 1985 analysis. The results of the longitudinal and hoop stresses for 6.1 sec are presented in Figs. B-3 thru B-8. The results for the longitudinal and hoop stresses for 8.3 sec are presented in Figs. B-9 thru B-14.

South Silo -The Silo responed in much the same way as the North Silo did. The structure also displaced as a rigid body and the maximum radial displacements occured near the top of the wall (nodes 115-121). These displacements were -0.29 at 6.1 sec and 0.27 at 6.8 sec. into the earthquake, see Fig. B-15. The displacements at the top of the wall, Node 121 were plotted at every 0.10 sec and are presented in Fig. B-16.

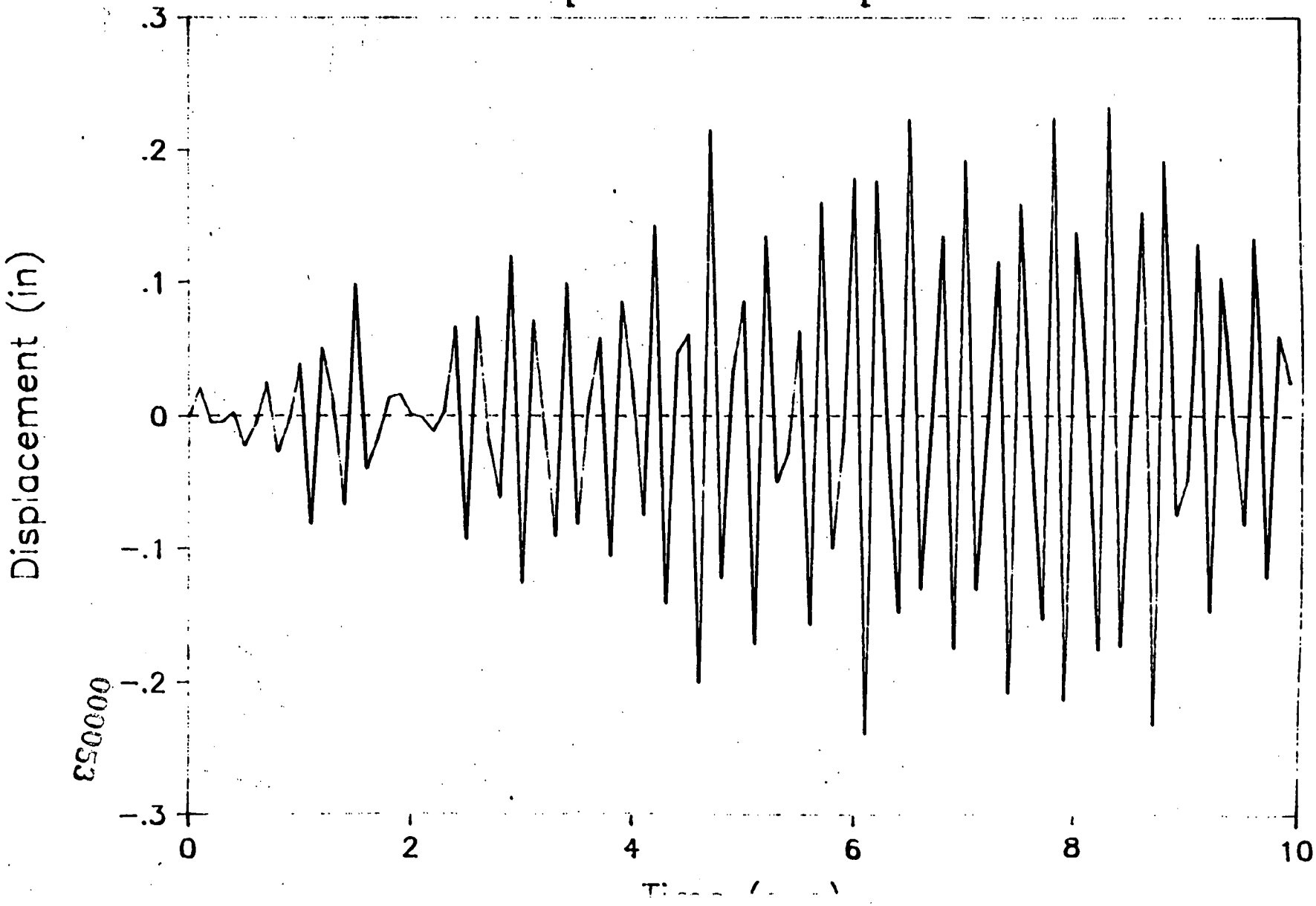
The maximum shell stresses in the South Silo occured at the time periods 6.1 and 6.8, respectively. A summary of the results are presented in tables B-4 and B-5 for consideration.

The longitudinal and hoop stresses in the shell are presented in Figs. B-17 thru B-28.

North Silo Nov. '88

Fig B-1

Radial Displacements top of wall



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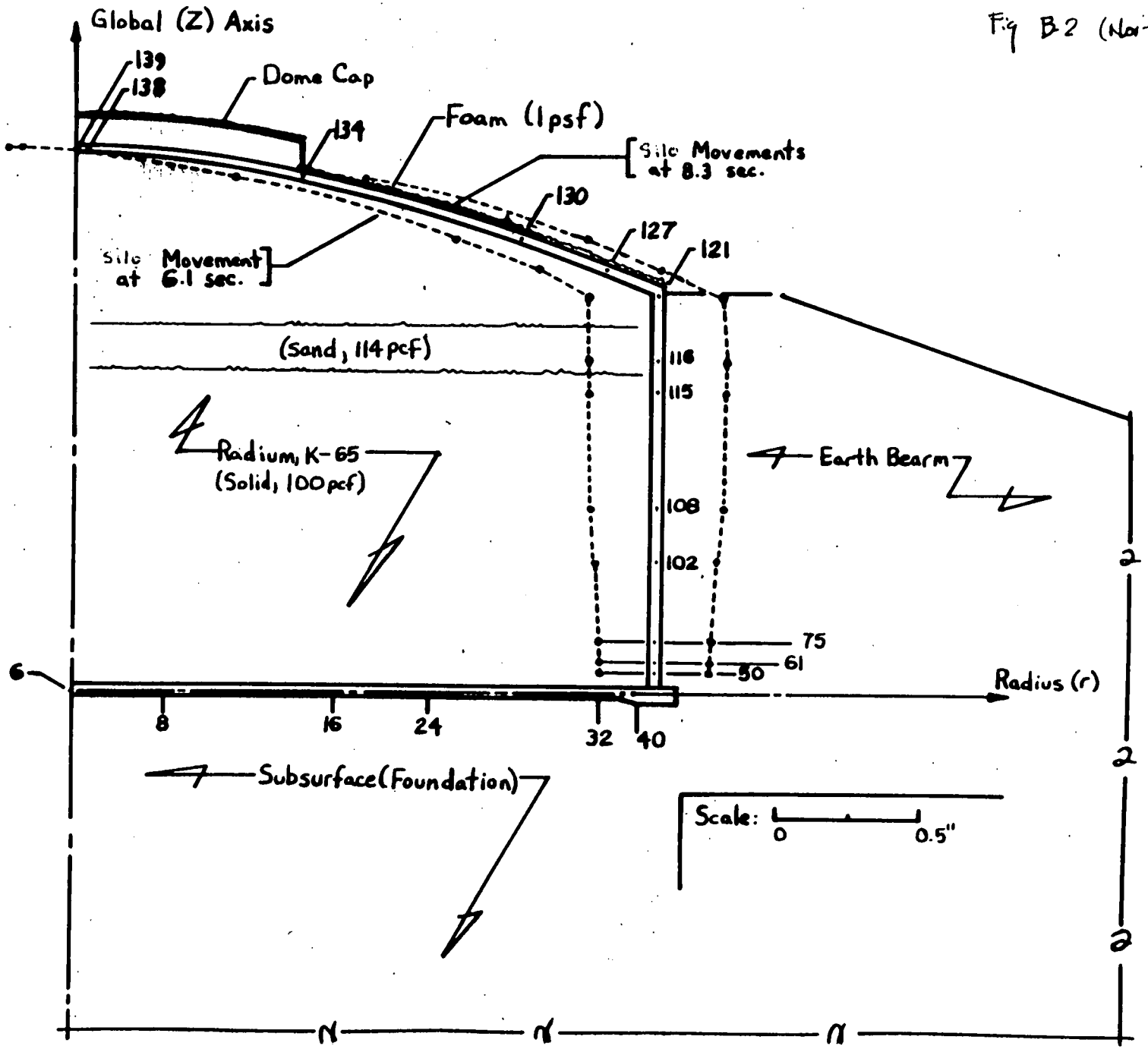

Fig B2 (Nor[illegible])

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Table B2,

NORTH S/C TIME STEP = 6.1

Elem	t(ave) (in)	Element Coord's. R-ORD	Z-ORD	MERI-MOM	CIRC-MOM	X-MOM	MERI-F	CIRC-F	SHEAR-F	Long. Stress (psi)- (1)	(2)	Hoop Stress (psi) (1)	(2)	Shear St (psi)
130	4	36.5		.95	6.36	-5.4	-68.68	18.97	30.62	-16.8158	-17.5263	7.1276	2.3575	-2.025
131	4	108		.11	.75	-.64	-164.71	30.68	96.79	-41.1363	-41.2188	7.95125	7.30875	-.24
132	4	180		.31	2.08	-1.77	-280.4	51.62	160.71	-69.9038	-70.2163	13.605	12.125	-.66375
133	4	252		.16	1.06	-.9	-415.2	73.5	251.84	-103.74	-103.86	18.7725	17.9775	-.3375
134	4	324		.34	2.28	-1.94	-571.3	98.3	355.7	-142.698	-142.953	25.43	23.72	-.7275
135	4	378		.63	4.2	-3.57	-694.4	119.4	452.5	-173.364	-173.836	31.426	28.275	-1.33875
136	4	405.5		.31	2.08	-1.77	-796.3	120.3	522.7	-198.959	-199.191	30.855	29.295	-.66375
137	4	424.5		.29	1.96	-1.67	-766.6	152.6	552.3	-191.541	-191.759	38.085	37.415	-.62625
138	6	440		.74	4.92	-3.4	-797.3	304.9	602	-132.76	-133.007	51.63667	49.99667	-.566667
139	10	452		-1.33	-8.85	10.3	-759	615.7	635.3	-75.9790	-75.8202	61.039	62.101	.618
140	12	463.5		-4.47	-29.82	25.35	-1000	744.2	728.6	-83.5196	-83.1471	60.77417	63.25917	1.05625
141	12	474.5		-4.28	-28.5	24.2	-999.8	758.8	800	-83.495	-83.1383	62.04583	64.42083	1.008333
142	12	481.75		-4.92	-32.8	.9	-1065.3	759.5	836.8	-88.98	-88.57	61.925	64.65833	.0375
143	12	485.25		-5.05	-33.7	28.6	470.6	986.8	-842.3	39.00625	39.42708	80.02917	83.6375	1.191667
144	12	493		-5.74	-38.3	32.5	450.6	959	-803.3	37.31083	37.70917	78.32083	81.5125	1.354167
145	9.5	483.5	9	1.78	11.8	-7.4	-440.8	678.2	-1726.4	-46.2817	-46.5183	72.17396	70.60499	-.491967
146	7	483.5	13.5	.73	4.9	-6.5	-459.4	497.3	-1457.2	-65.5392	-65.7180	71.64286	70.44286	-.795918
147	7	483.5	16.5	.75	5	-6.4	-434.2	515.3	-1440	-61.9367	-62.1204	74.22653	73.00204	-.703673
148	7	483.5	21	.77	5.2	2.1	-427.5	532.7	-1443	-60.9771	-61.1657	76.73673	75.46327	.2571429
149	7	483.5	27	.8	5.3	2	-425	551.9	-1466	-60.6163	-60.8122	79.49184	78.19388	.2448980
150	7	483.5	33	.82	5.5	1.5	-323	586.3	-1427.4	-46.0424	-46.2433	84.43061	83.08367	.1836735
151	7	483.5	42	.82	5.4	30.6	-310	584.2	-1448	-44.1053	-44.3061	84.11837	82.79592	3.746939
152	7	483.5	56	.73	4.9	52.9	-302	519.9	-1437	-43.0535	-43.2322	74.87143	73.67143	6.477551
153	7	483.5	72	.61	4.1	46.1	-283	428	-1406	-40.3539	-40.5033	61.64490	60.64082	5.644898
154	7	483.5	92	.36	2.4	84.9	-242	238.6	-1369	-34.5273	-34.6155	34.37959	33.79184	10.33592
155	7	483.5	116	0	.02	68.4	-250	-36	-1206	-36.8571	-36.8571	-5.14041	-5.14531	8.375510
156	7	483.5	140	-.28	-1.9	59.1	-200	-249.5	-1200	-29.7486	-29.68	-35.0755	-35.4102	7.236735
157	7	483.5	164	-.51	-3.4	45.7	-198	-425.8	-1087	-28.3482	-28.2233	-61.2449	-60.4122	5.595918
158	7	483.5	188	-.7	-4.7	39.6	-164	-563.8	-963.7	-23.5143	-23.3429	-81.1184	-79.9673	4.848980
159	7.25	483.5	212	-1	-6.7	28.8	-109.5	-739.7	-822.6	-15.2176	-14.9833	-102.792	-101.263	3.287515
160	7.5	483.5	236	-1.24	-8.2	22.6	-89.5	-843.6	-603	-12.0656	-11.8011	-113.355	-111.605	2.410667
161	7.5	483.5	260	-1.32	-8.8	11.9	-59.2	-849.6	-513	-8.03413	-7.75253	-114.219	-112.341	1.269333
162	7.75	483.5	284	-1.49	-9.9	2.3	-48.3	-946.8	-398	-6.38110	-6.08341	-123.157	-121.179	.2297607
163	8	483.5	306	-1.65	-11	-1.3	9.7	-976	-268	1.057013	1.367188	-123.031	-120.969	-.121875
164	8	483.5	328	-1.53	-10.2	-7.5	50.8	-898.5	-162.7	6.206563	6.493438	-113.269	-111.356	-.703125
165	8	479.5		-1033.8	-161.9	4	-55.9	-1050.9	-139	-103.906	89.93125	-146.541	-116.184	.375
166	7.5	472		-848.4	-122.5	-7.7	-838.6	-979	-126.3	-202.309	-21.3173	-143.6	-117.467	-.821333
167	6.5	467		-680.2	-90.9	-12.6	-34	-838.6	-118.4	-101.827	91.36568	-141.924	-116.107	-1.78935
168	5.5	461		-526.2	-66.3	-13.7	-25.9	-693.8	-106.2	-109.079	99.66116	-139.296	-112.995	-2.71736
169	5	453		-343	-34.9	-17.2	-18.4	-597.2	-95.9	-86	78.64	-127.816	-111.064	-4.128
170	5	443		-159.3	-.94	-23.3	-9.9	-537	-84	-40.356	36.396	-107.626	-107.174	-5.592
171	5	427		28.8	31.8	-27.1	1.6	-424	-67.4	7.16	-6.52	-77.168	-92.432	-6.504
172	5	405		142.2	47.3	-35	13.4	-273.5	-49.7	36.808	-31.448	-43.348	-66.052	-8.4
173	4.75	381		248.3	38.9	-15.7	20.2	-139.5	-37.7	70.28255	-61.7773	-19.0238	-39.7138	-4.17507
174	4.5	345.5		81.7	19.3	-5.1	21.9	-42.7	-30.2	32.03704	-22.3037	-3.77037	-15.2074	-1.51111
175	4.25	300.5		23.1	2.4	1	17.2	-18.2	-27.6	11.72042	-3.62638	-3.48512	-5.07958	.3321799
176	4	258.5		-3.3	-2.8	2.1	12.5	-47.9	-26.2	1.8875	4.3625	-13.025	-10.925	.7875
177	3.75	210.5		-6.7	-2.4	1.2	8.6	-34.8	-21.8	-.565333	5.152	-10.304	-8.256	.512
178	3.25	165.5		-2.6	-.6	.18	5.8	-27	-15.6	.3076923	3.261538	-8.64852	-7.96606	.1022485
179	3	120.5		.11	-.03	.04	4.7	-19	-11	1.64	1.483333	-6.35333	-6.31333	.0266667
180	2.75	75.95		-.28	-.07	.02	3.3	-10.9	-6.6	.9778818	1.422149	-4.01917	-3.90810	.0158678
181	2.5	30.95		.09	.14	-.11	2.3	-5.1	-2.6	1.0064	.8336	-1.9056	-2.1744	-.1056
182	2.25	4.5		-.73	-.34	.2	.7	1.1	.02	-.554074	1.176296	.0859259	.0910519	.2370370

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Table B 3

NORTH S10 TIME STEP = 0.3

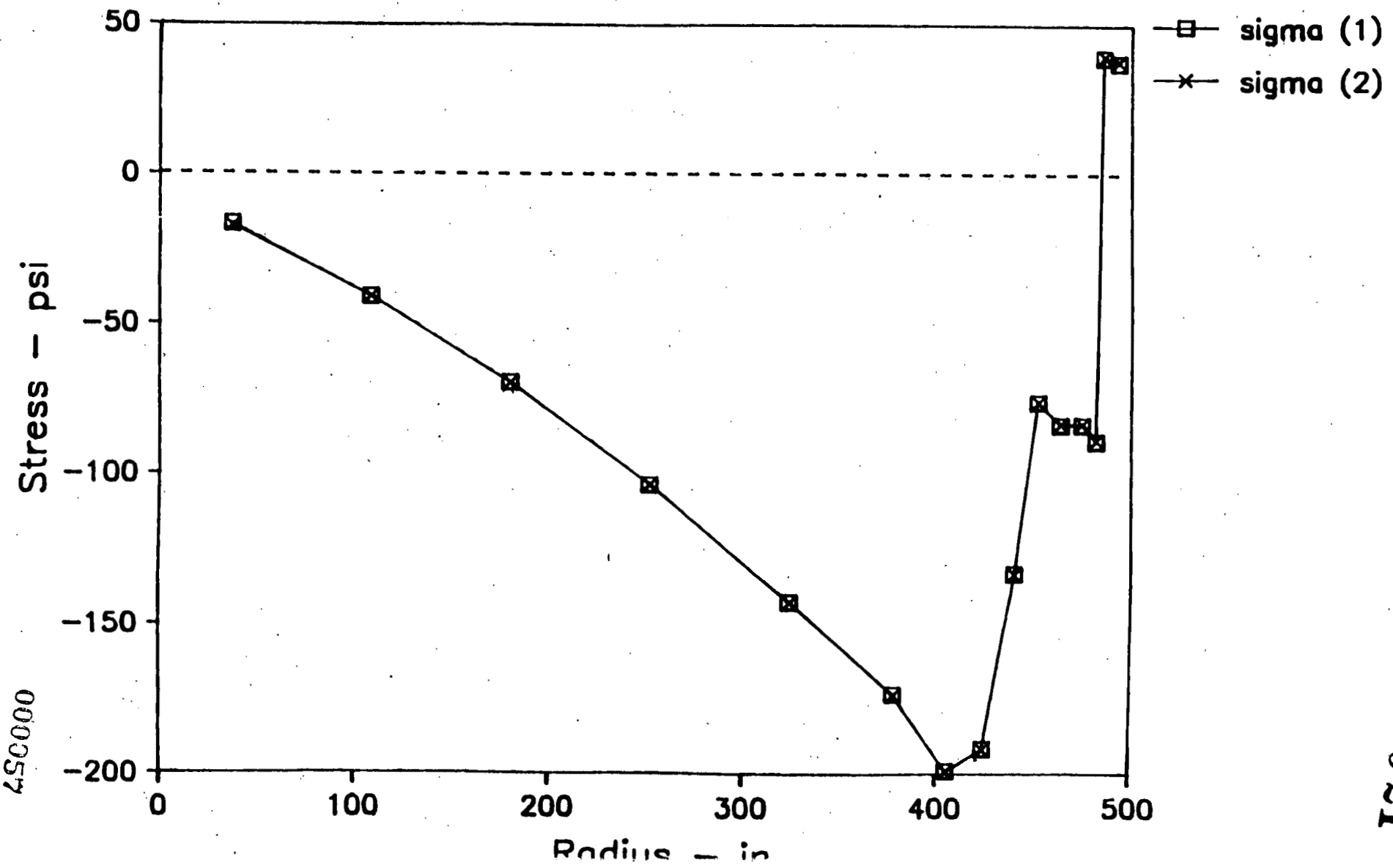
Elem	t(ave) (in)	Element Coord's. R-ORD	Z-ORD	MERI-MOM	CIRC-MOM	X-MOM	MERI-F	CIRC-F	SHEAR-F	Long. Stress (psi)- (1)	(2)	Hoop Stress (psi) (1)	(2)	Shear Str (psi)
130	4	36.5		-1.21	-0.1	6.9	77.9	-56.9	-37.7	19.02125	19.92075	-17.2625	-11.1075	2.5075
131	4	108		-.19	-1.3	1.1	163.0	-104.3	-130.3	40.07075	41.02125	-26.5625	-25.5075	.4125
132	4	180		-.4	-2.7	2.3	277.5	-169.0	-223.1	69.225	69.525	-43.4625	-41.4375	.8625
133	4	252		-.23	-1.5	1.3	410.5	-235.0	-326.7	102.5300	102.7113	-59.5125	-60.3075	.4875
134	4	324		-.46	-3.1	2.6	563.9	-303.9	-449.1	140.0025	141.1475	-77.1375	-74.0125	.975
135	4	370		-.79	-5.2	4.5	687.5	-354.9	-550.3	171.5700	172.1713	-90.675	-86.775	1.6875
136	4	405.5		-.44	-2.96	2.5	707.3	-379.3	-633.2	196.66	196.99	-95.935	-93.715	.9375
137	4	424.5		-.46	-3.1	2.6	749.5	-415.5	-666.4	107.2025	107.5475	-105.030	-102.713	.975
138	6	440		-.74	-4.96	3.1	775.0	-710.7	-720.0	129.1767	129.4233	-119.277	-117.623	.5166667
139	10	452		1.86	12.4	-14.6	725.2	-1300.4	-766.0	72.6316	72.4084	-129.296	-130.704	-.876
140	12	463.5		5.99	39.9	-33.95	964.7	-1572.5	-872.4	80.64125	80.14200	-129.379	-132.704	-1.41458
141	12	474.5		5.71	38	-32.3	953.9	-1594.0	-935.1	79.72950	79.25375	-131.317	-134.403	-1.34583
142	12	481.75		6.63	43.5	-37	1015.1	-1600.4	-995.1	84.86375	84.31950	-131.554	-135.179	-1.54167
143	12	485.25		6.7	44.6	-37.9	-491.2	-1025	700.8	-40.6542	-41.2125	-150.225	-153.942	-1.57917
144	12	493		7.64	50.9	-43.3	-475.7	-1801.9	646.1	-39.3233	-39.96	-148.038	-152.279	-1.80417
145	9.5	403.5	9	-3.35	-22.3	5.9	571.5	-1317.5	17554	59.93510	60.38061	-140.167	-137.202	.3922438
146	7	403.5	13.5	-1.36	-9.00	6.5	502.9	-963.1	1560.9	83.10490	83.43796	-138.698	-136.474	.7959184
147	7	403.5	16.5	-1.38	-9.2	6.4	545.3	-982.3	1536.1	77.73102	78.06898	-141.455	-139.202	.7836735
148	7	403.5	21	-1.4	-9.3	-1.9	542.9	-999.6	1540.8	77.38571	77.72857	-143.393	-141.661	-.232653
149	7	403.5	27	-1.43	-9.5	-1.0	559.6	-1016	1571.5	79.76776	80.11796	-146.306	-143.980	-.220408
150	7	403.5	33	-1.45	-9.7	-1.3	436.2	-1053.6	1523.9	62.13673	62.49184	-151.702	-149.327	-.159184
151	7	403.5	42	-1.45	-9.6	-29.6	447.1	-1048.7	1549.9	63.69388	64.04898	-150.990	-148.639	-3.62449
152	7	403.5	56	-1.36	-9.1	-51.7	441.5	-986.2	1533.4	62.90490	63.23796	.142	-139.771	-6.33061
153	7	403.5	72	-1.24	-8.3	-45	420.3	-897	1495.3	59.89102	60.19469	-129.159	-127.127	-5.51020
154	7	403.5	92	-.99	-6.6	-83.5	380.3	-709.7	1450.6	54.20735	54.44980	-102.194	-100.578	-10.2245
155	7	403.5	116	-.64	-4.3	-67	392.1	-438.1	1355.4	55.93592	56.09265	-63.1122	-62.0592	-8.20408
156	7	403.5	140	-.36	-2.4	-58.7	340.4	-223.8	1257.1	48.58449	48.67265	-32.2653	-31.6776	-7.18776
157	7	403.5	164	-.12	-.79	-45.3	324.8	-43.7	1121.2	46.38531	46.41469	-6.33959	-6.14612	-5.54694
158	7	403.5	188	.08	.51	-40.1	284	101.2	993.3	40.58122	40.56163	14.51959	14.39469	-4.91020
159	7.25	403.5	212	.27	1.8	-29	221.2	230.9	837.6	30.54117	30.47952	32.05375	31.64281	-3.31034
160	7.5	403.5	236	.45	3	-23.7	190.8	330	685.7	25.488	25.392	44.32	43.68	-2.528
161	7.5	403.5	260	.56	3.7	-12.7	160.1	396.7	502.4	20.07307	19.9536	53.288	52.49867	-1.35467
162	7.75	403.5	284	.68	4.5	-4.4	128.6	445	378.3	16.66148	16.52562	57.86889	56.96902	-.439542
163	8	403.5	306	.70	5.2	-1.2	43.98	470	242	5.570625	5.424375	59.2375	58.2625	-.1125
164	8	403.5	328	.77	5.1	5	22.8	456	125.8	2.922188	2.777813	57.47813	56.52188	.46875
165	8	479.5		502.6	90.3	-11.9	20.6	538.2	100.1	49.69375	-44.5438	75.74063	58.80938	-1.11563
166	7.5	472		414.6	69.3	-4.3	14.7	505.5	93.3	46.184	-42.264	74.792	60.008	-.458667
167	6.5	467		336.1	51.2	.76	11.4	437.2	87.6	43.48402	-45.9763	74.53254	59.99053	.1079290
168	5.5	461		264.3	37.3	3.5	8	365.7	82.9	53.87769	-50.9686	73.88926	59.09256	.6942149
169	5	453		179	21.5	6.1	4.9	320.7	77.6	43.94	-41.98	69.3	58.98	1.464
170	5	443		93.5	5.41	9.2	1.5	296.7	71.5	22.74	-22.14	60.6384	58.0416	2.208
171	5	427		2.07	-10.8	11.4	-3.3	248.9	62.7	-.1632	-1.1568	47.188	52.372	2.736
172	5	405		-54.1	-19.1	10.9	-8.4	182.1	52.5	-14.664	11.304	31.836	41.004	2.616
173	4.75	381		-60.8	-16.3	7.2	-11.3	117.1	44.7	-18.5474	13.78947	20.31801	28.98726	1.914681
174	4.5	345.5		-42.5	-8.8	2.5	-11.9	65.7	38.2	-15.2370	9.948148	11.99259	17.20741	.7407407
175	4.25	300.5		-12.1	-1.06	-.53	-9.4	46.8	33.8	-6.23114	1.807612	10.65965	11.36388	-.176055
176	4	255.5		.88	1.7	-1.35	-7	46.3	30.3	-1.42	-2.08	12.2125	10.9375	-.50625
177	3.75	210.5		4.6	1.9	-.95	-4.7	46.1	24.5	.7093333	-3.216	13.104	11.48267	-.405333
178	3.25	165.5		2.4	.54	-.11	-3.1	34	17.6	.4094675	-2.31716	10.76828	10.15479	-.062485
179	3	120.5		-2.4	.04	-.04	-2.7	23.8	12.3	-2.5	.7	7.96	7.906667	-.026667
180	2.75	75.95		.41	.14	-.06	-2.1	13.8	7.4	-.438347	-1.08893	5.129256	4.907107	-.047603
181	2.5	30.95		-.04	-.17	.15	-1.9	6.6	2.6	-.7984	-.7216	2.4768	2.8032	.144
182	2.25	4.5		.8	.37	-.22	-.76	-1.6	-.13	.6103704	-1.20893	-.272593	-1.14963	-.260741

000056

North Silo at 6.1 sec.

Base slab long. stresses

B-3



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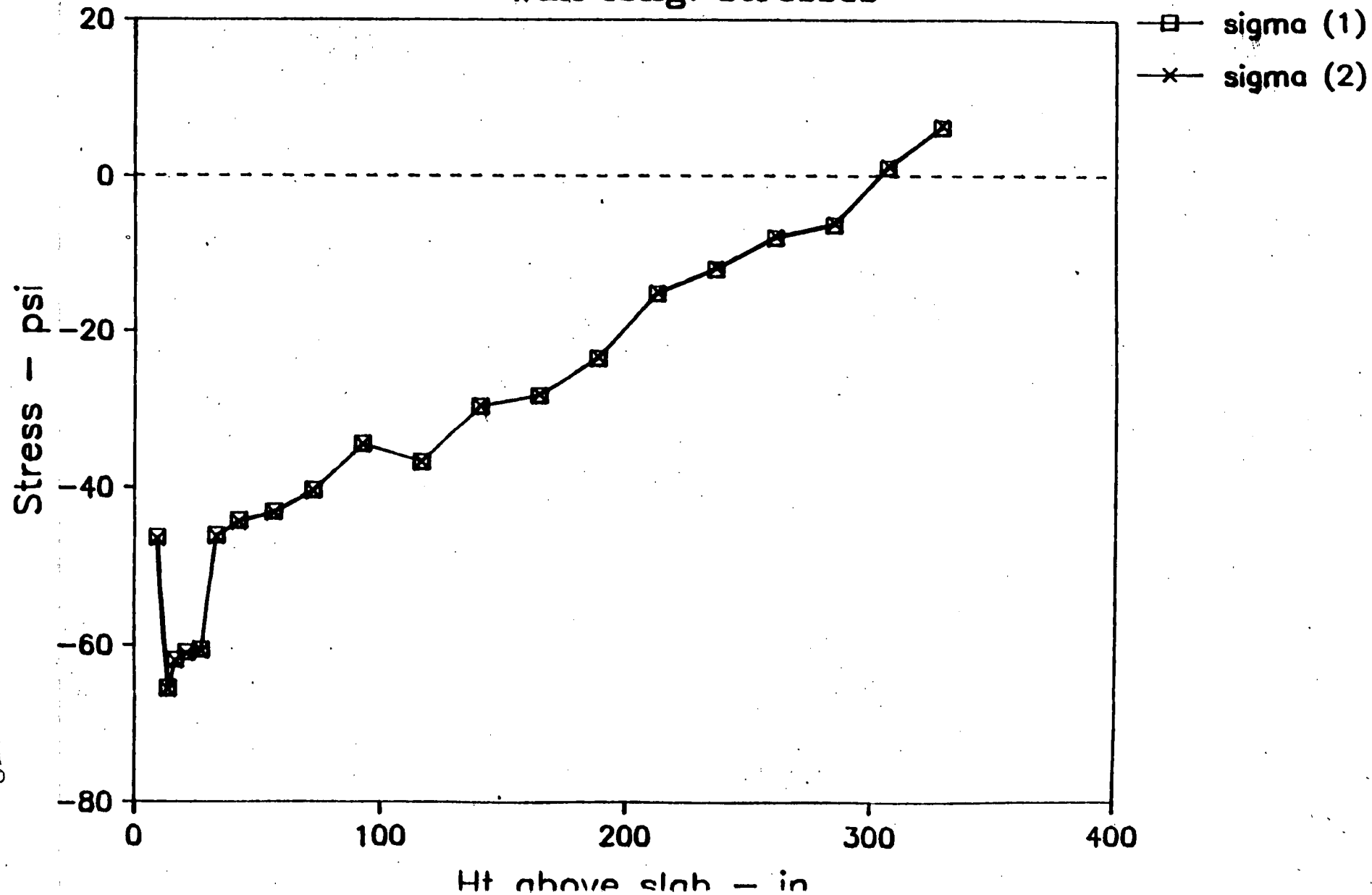
5621

North silo at 6.1 sec.

B-4

Wall long. stresses



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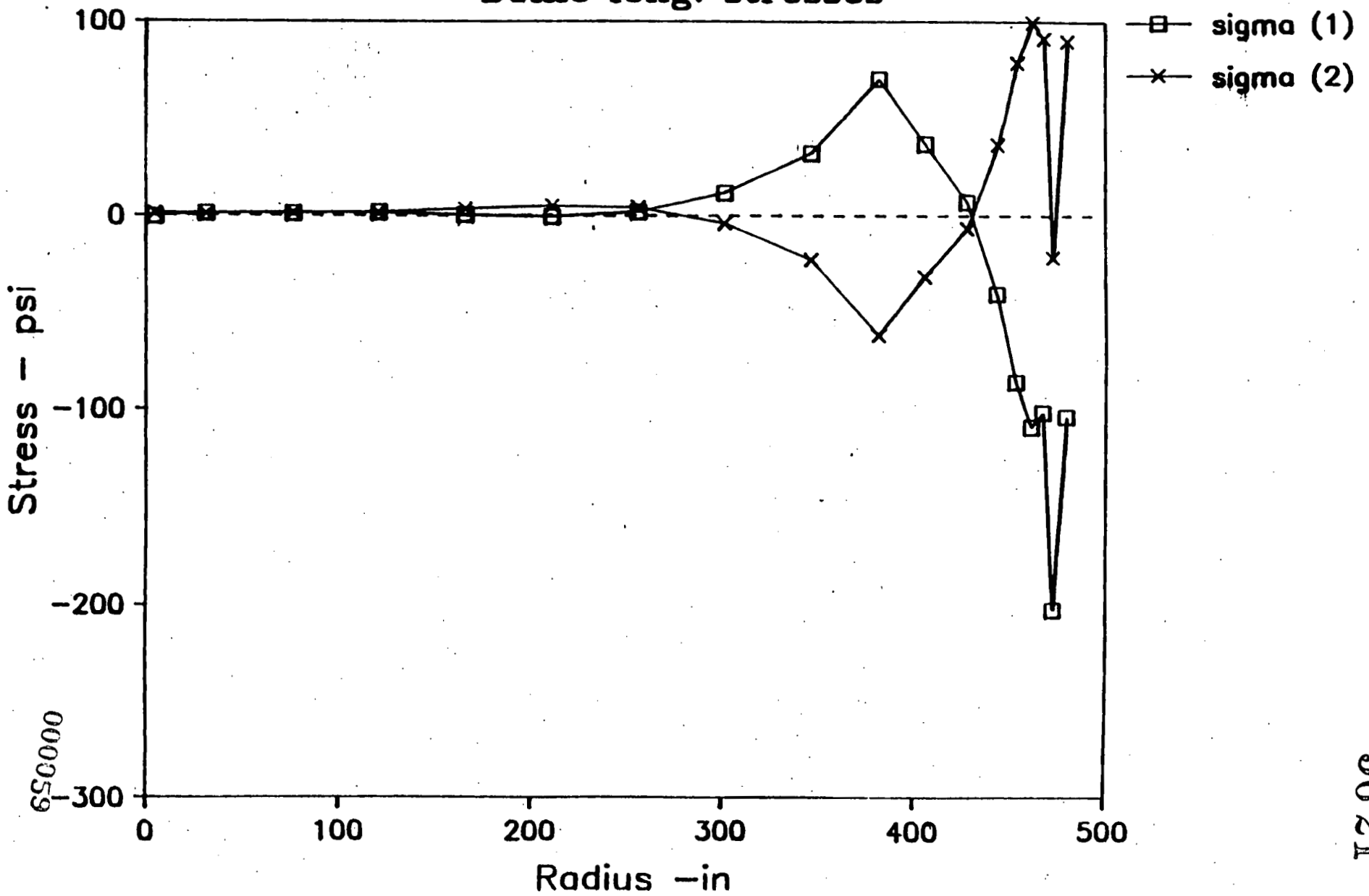
1295

5.

North silo at 6.1 sec.

B-5

Dome long. stresses



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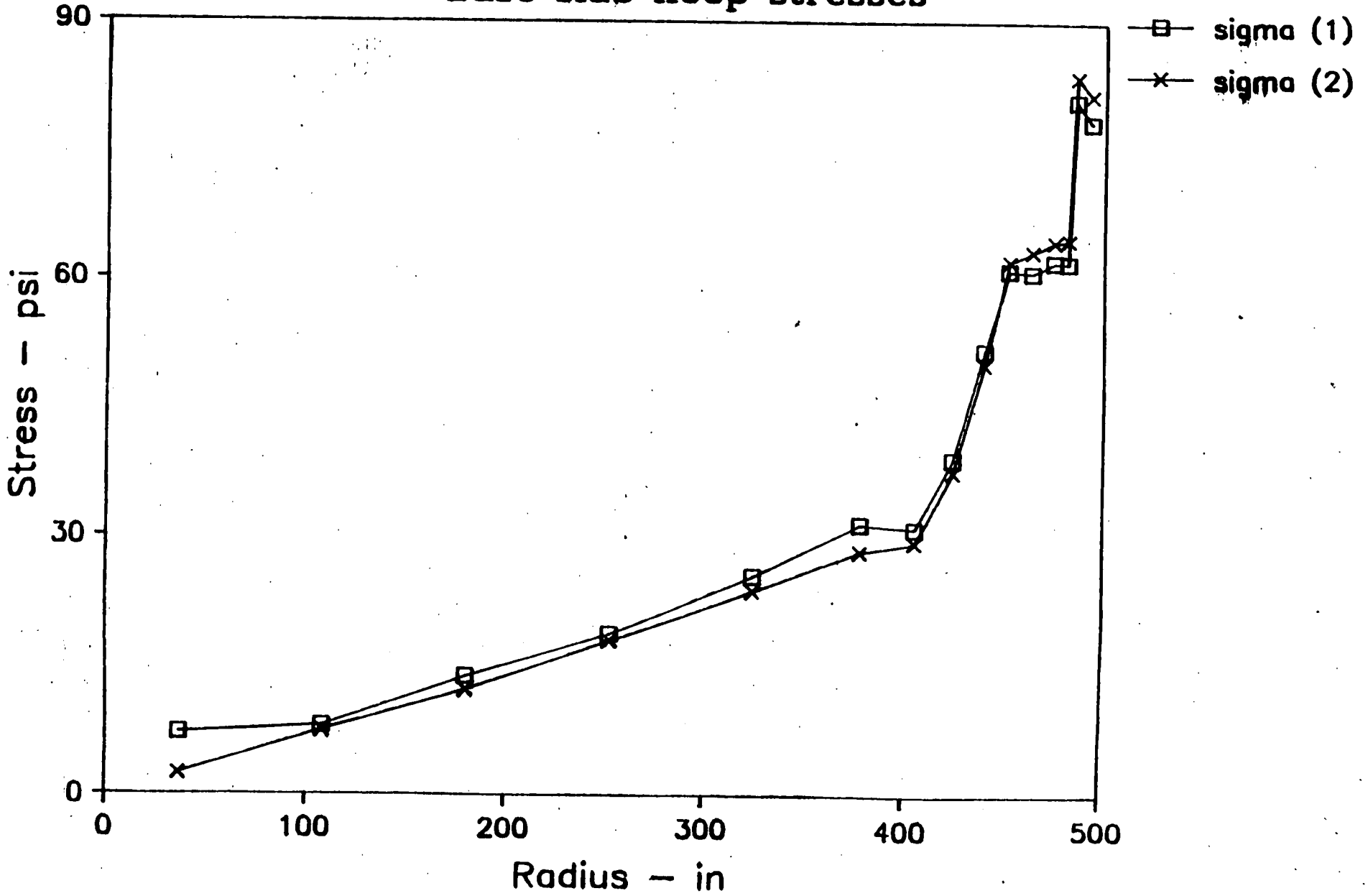
5621

North Silo at 6.1 sec.

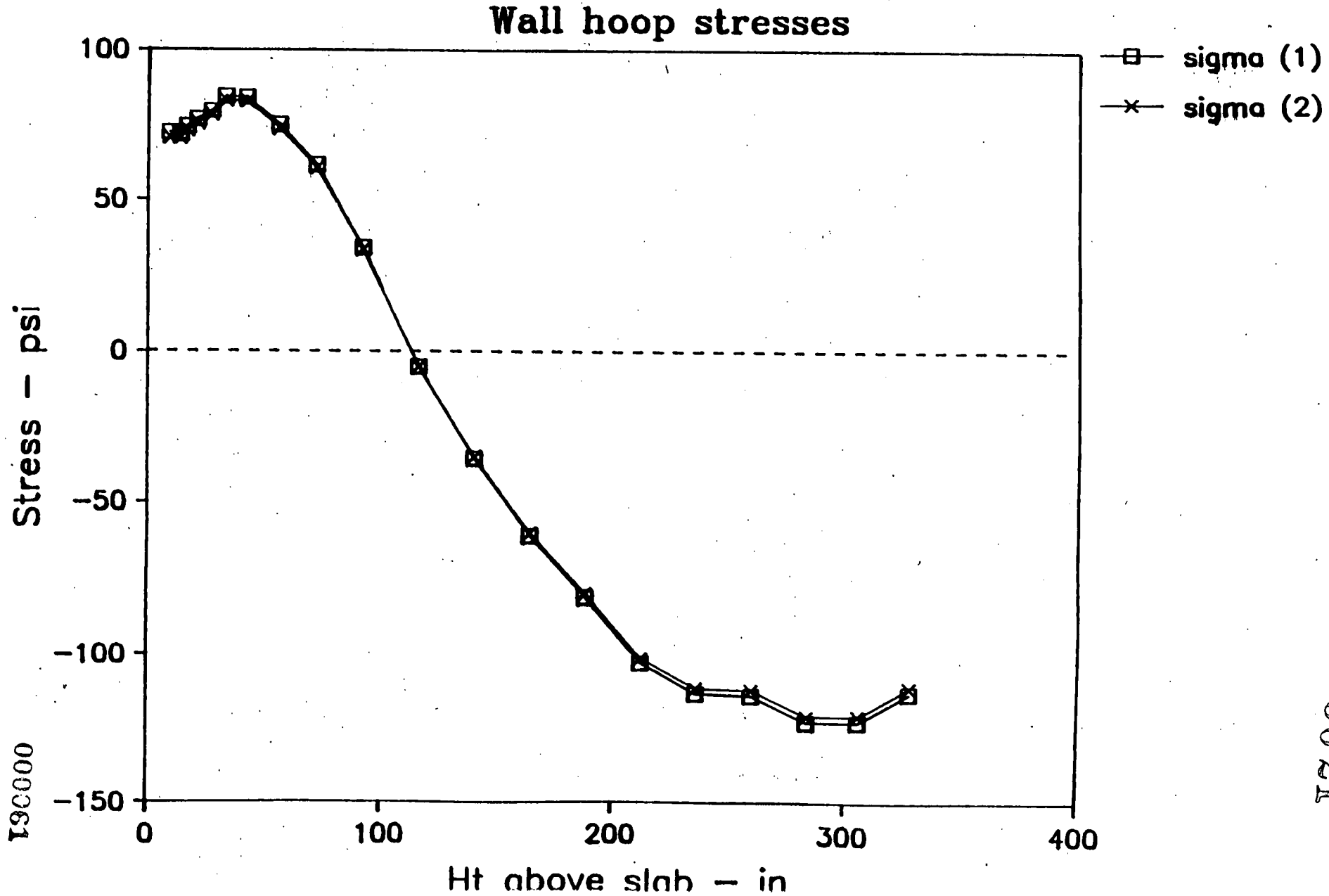
B-6

Base slab hoop stresses



North Silo at 6.1 sec.

B-7



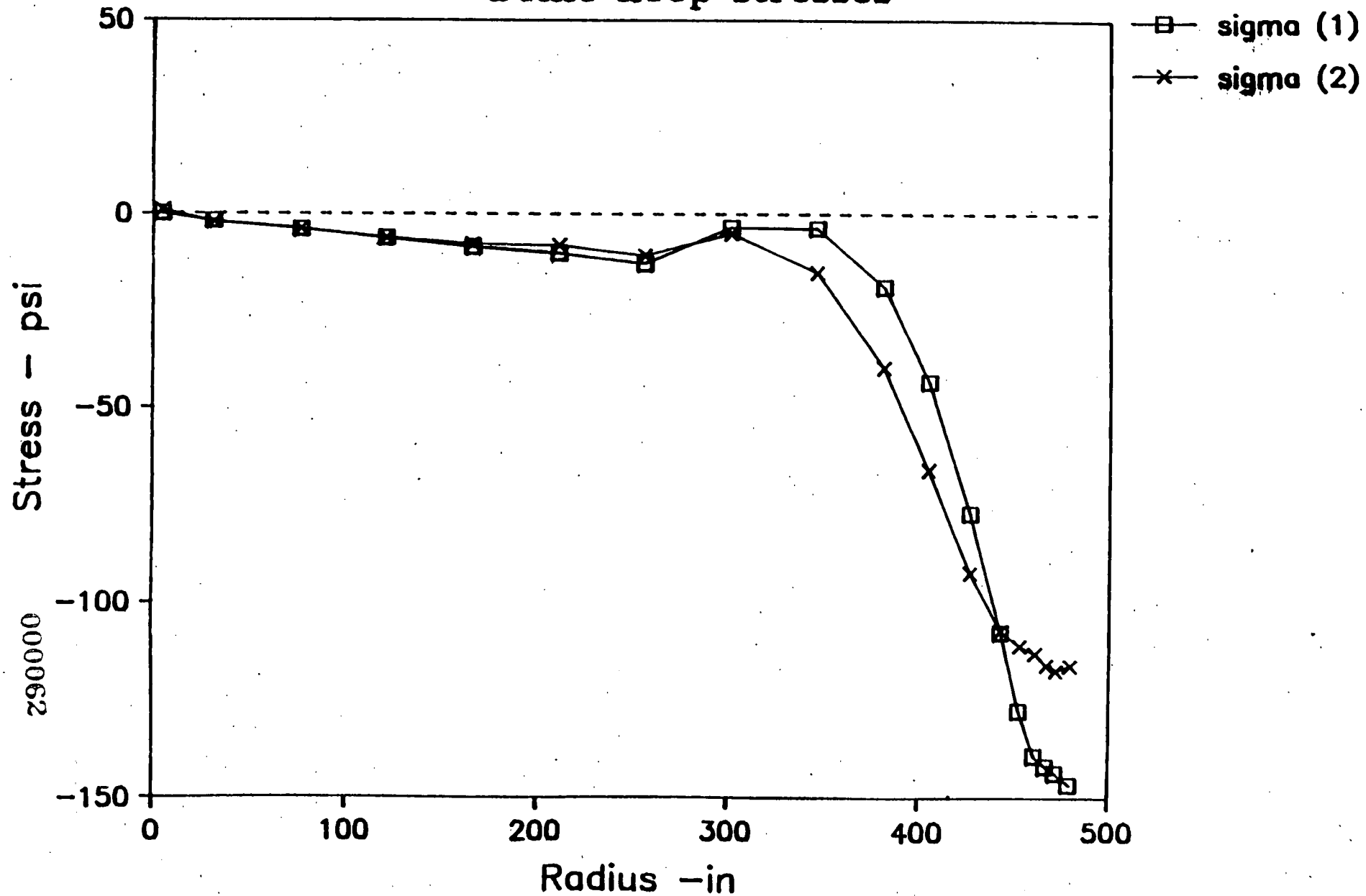
5621

190000

North Silo at 6.1 sec.

B-8

Dome hoop stresses

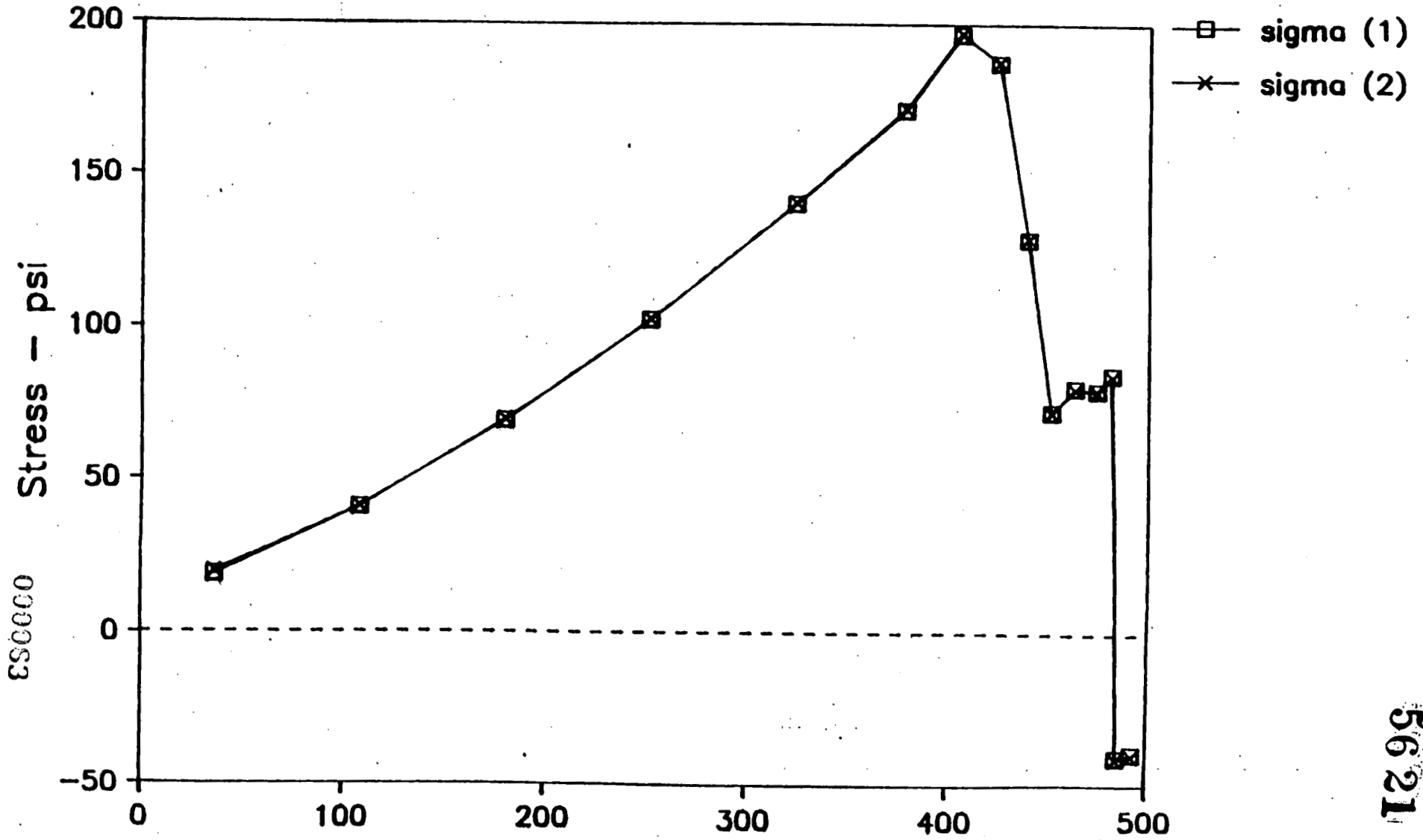


290000

5621

North Silo at 8.3 sec. B-9

Base slab long. stresses



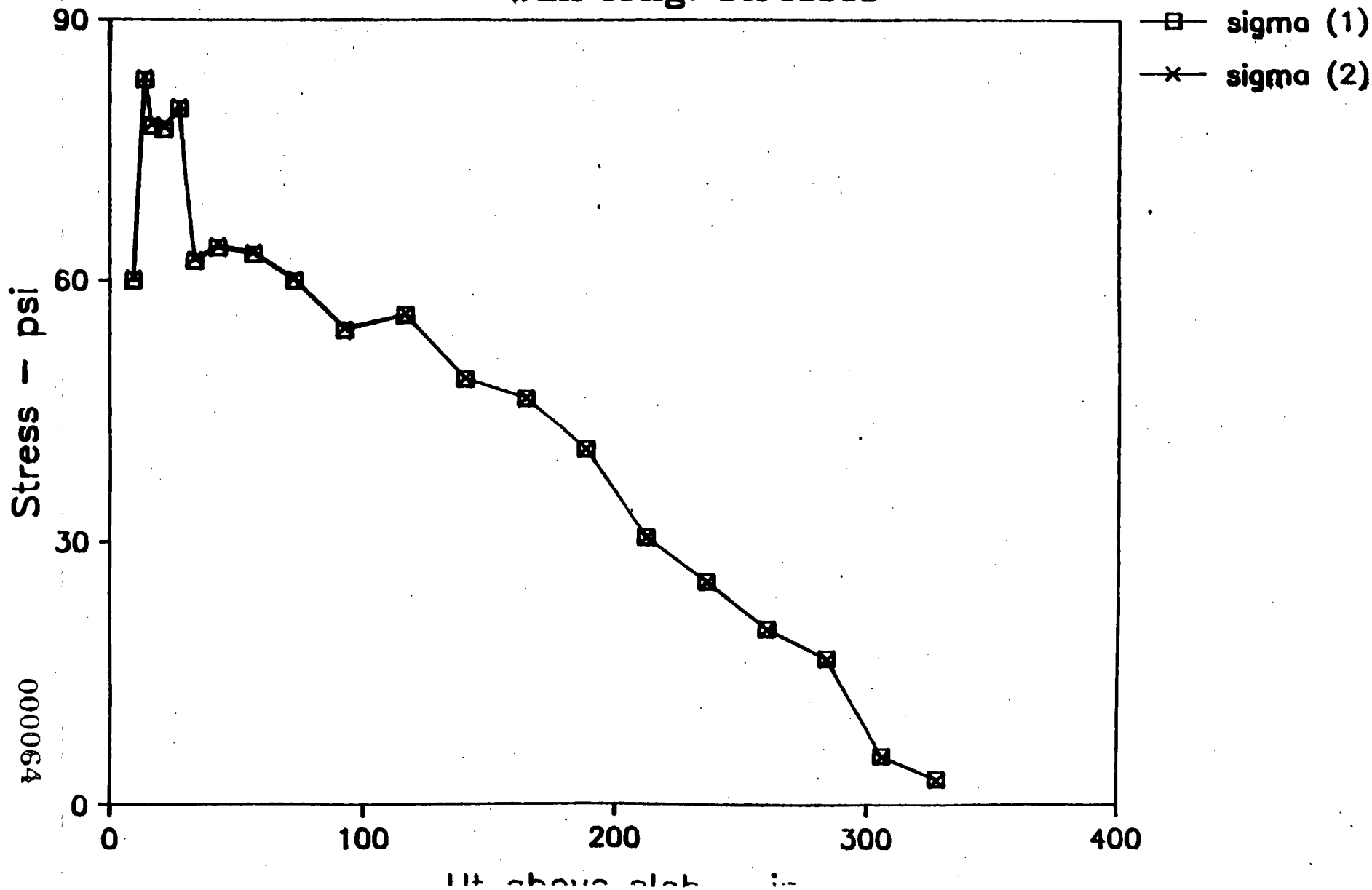
000063

5621

North Silo at 8.3 sec.

B-10

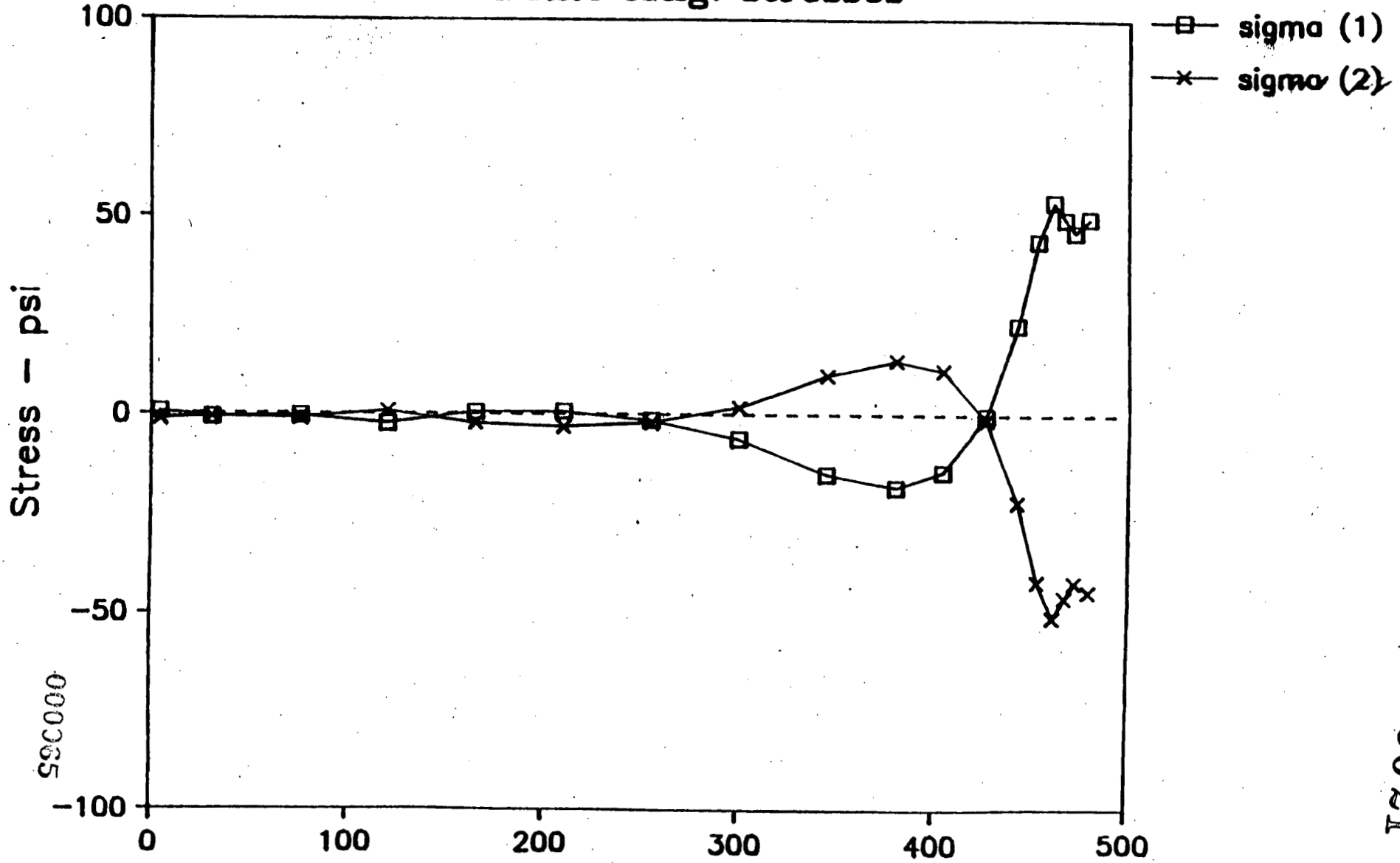
Wall long. stresses



5

North Silo at 8.3 sec. B-11

Dome long. stresses



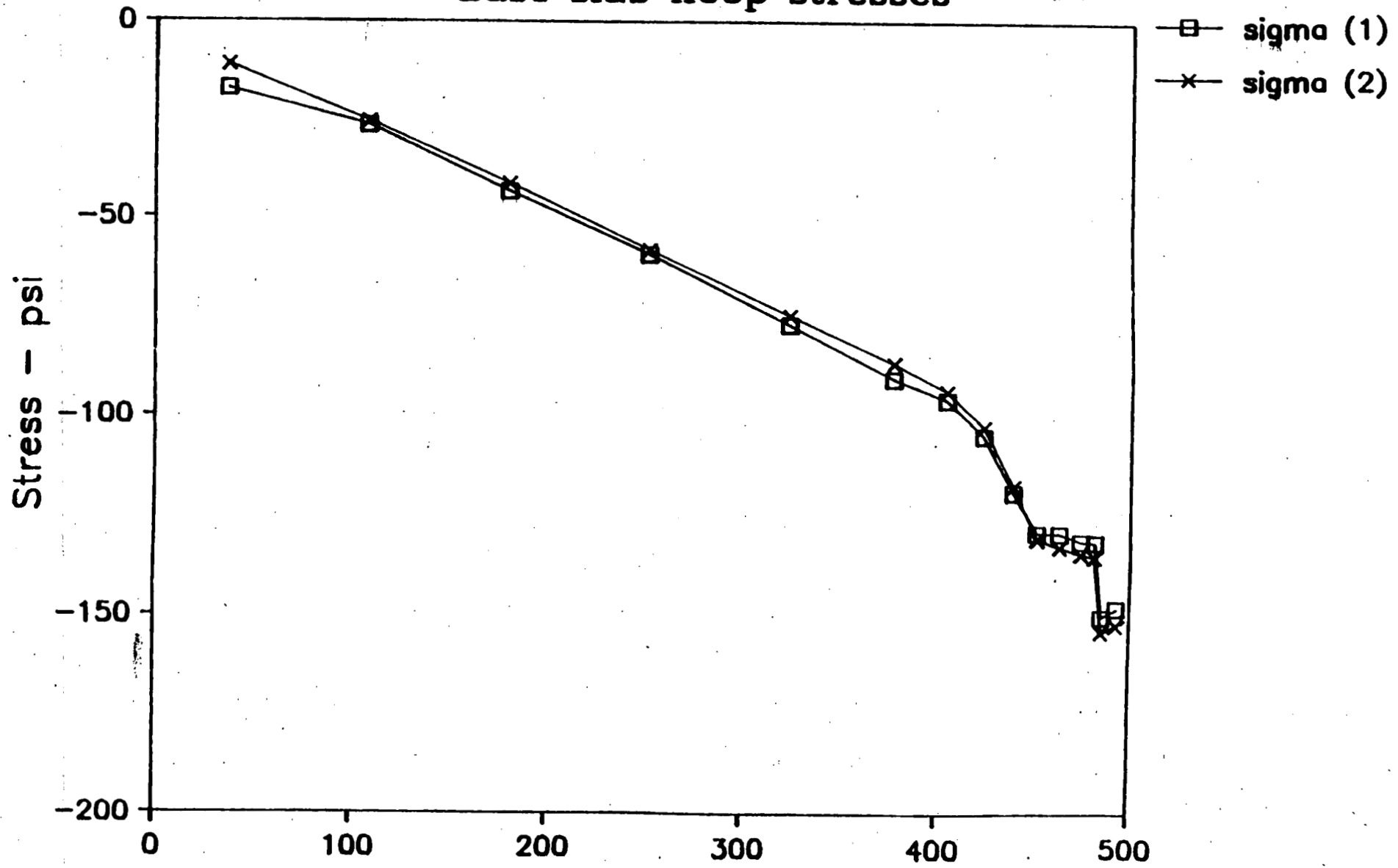
S9C000

5621

North Silo at 8.3 sec.

Base slab hoop stresses

B-12



990000

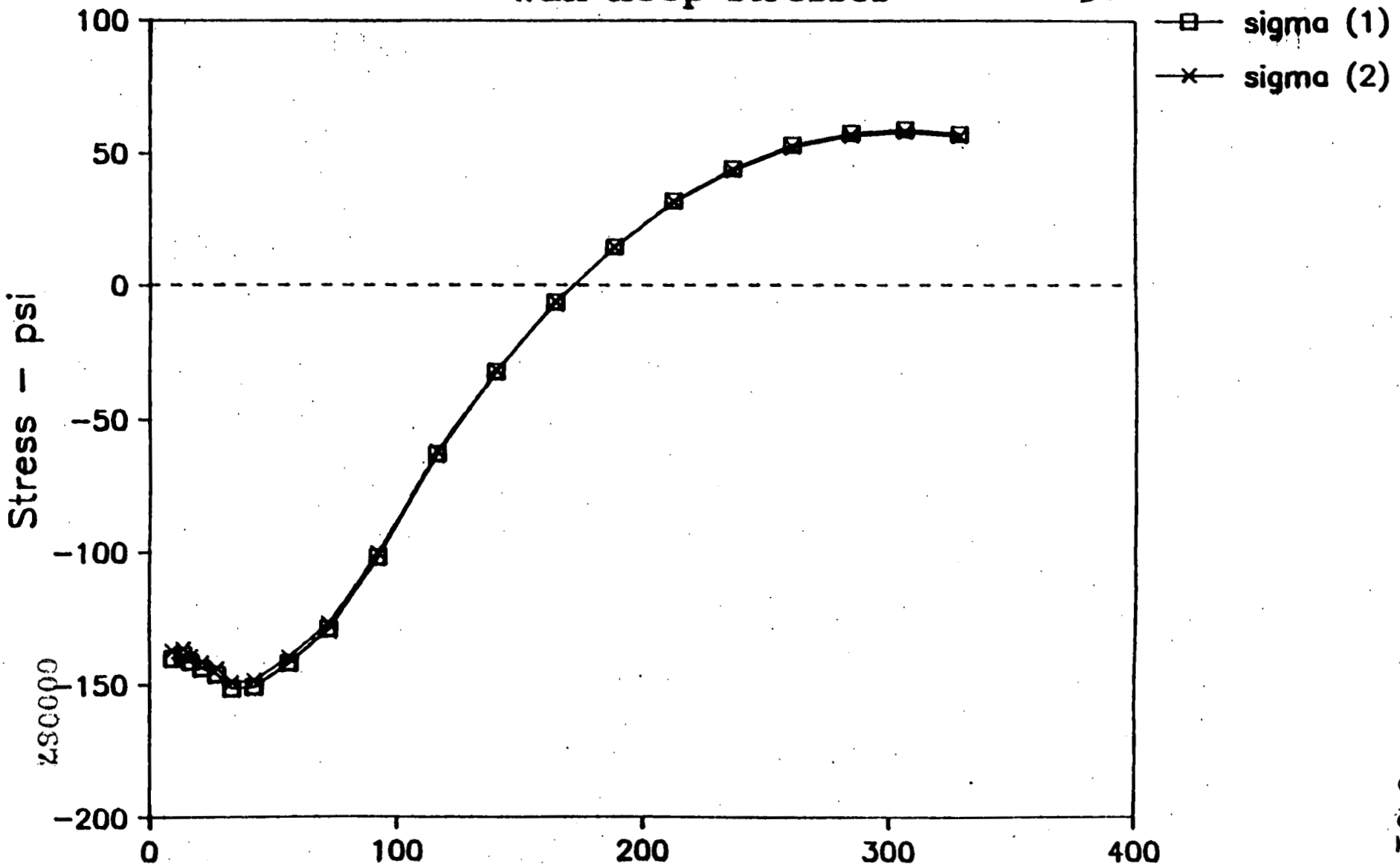
56421

4

North Silo at 8.3 sec.

Wall hoop stresses

B-13



280000

5621

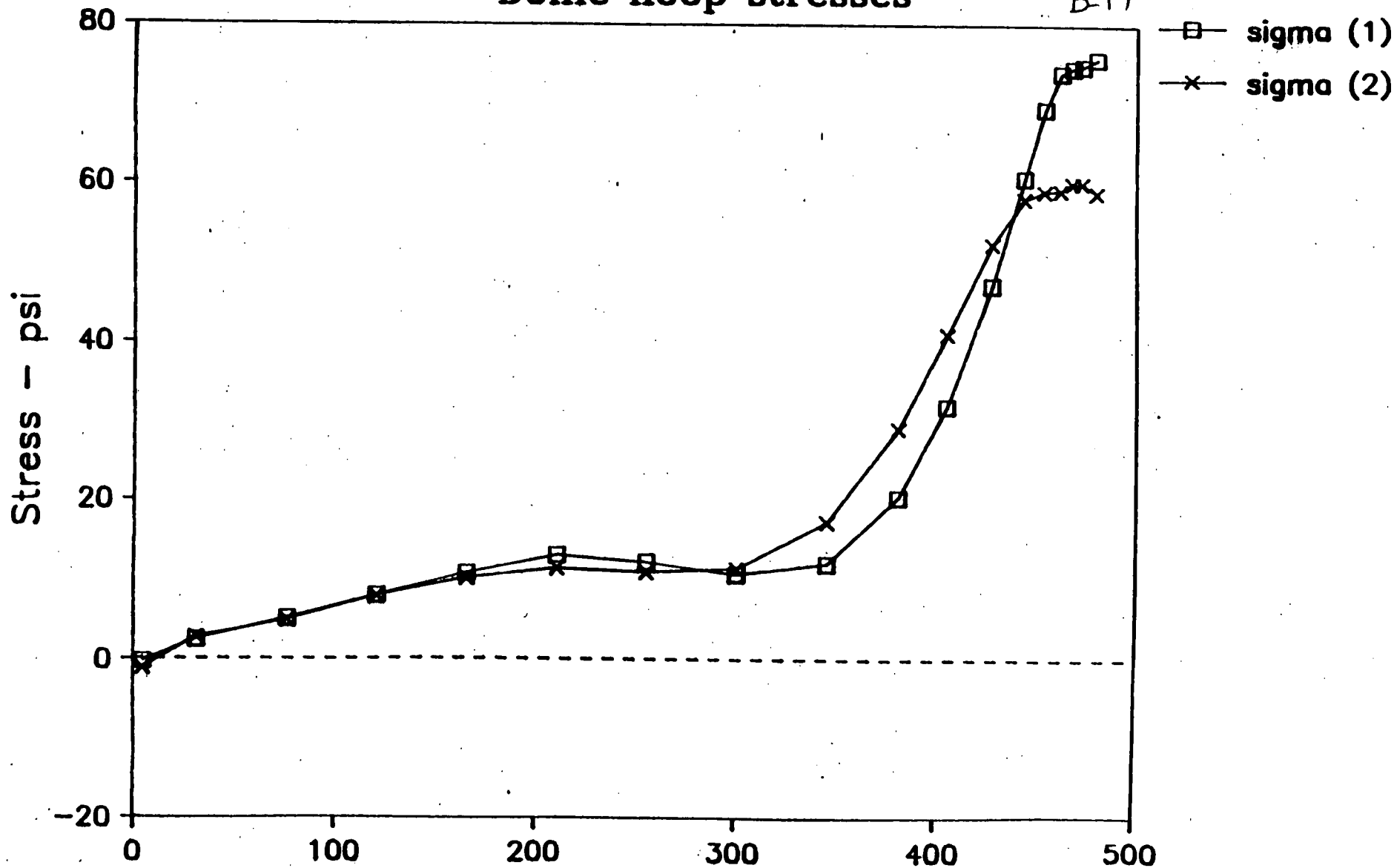
5621

000068

North Silo at 8.3 sec.

Dome hoop stresses

B-14



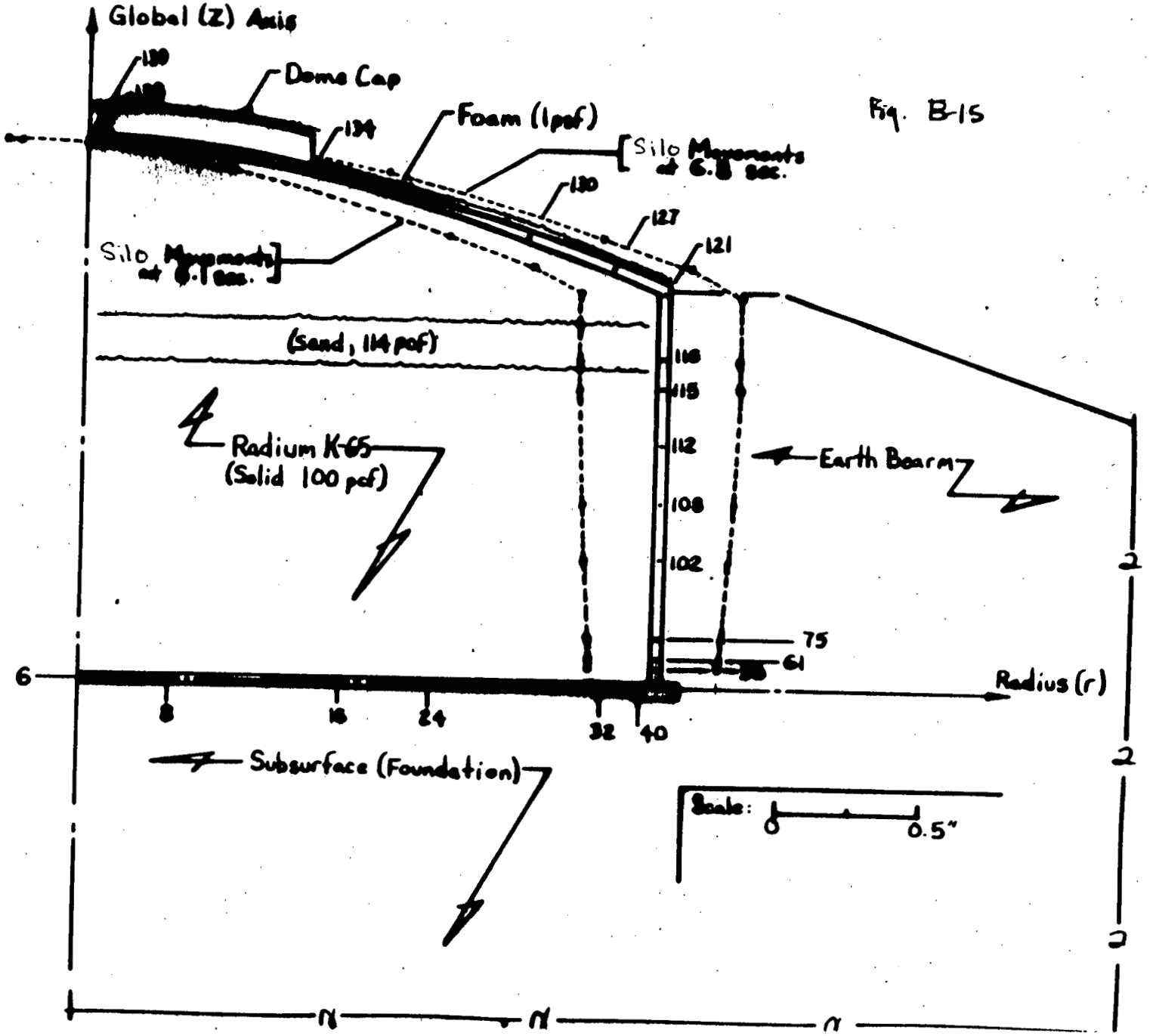


Fig. B-15

000069

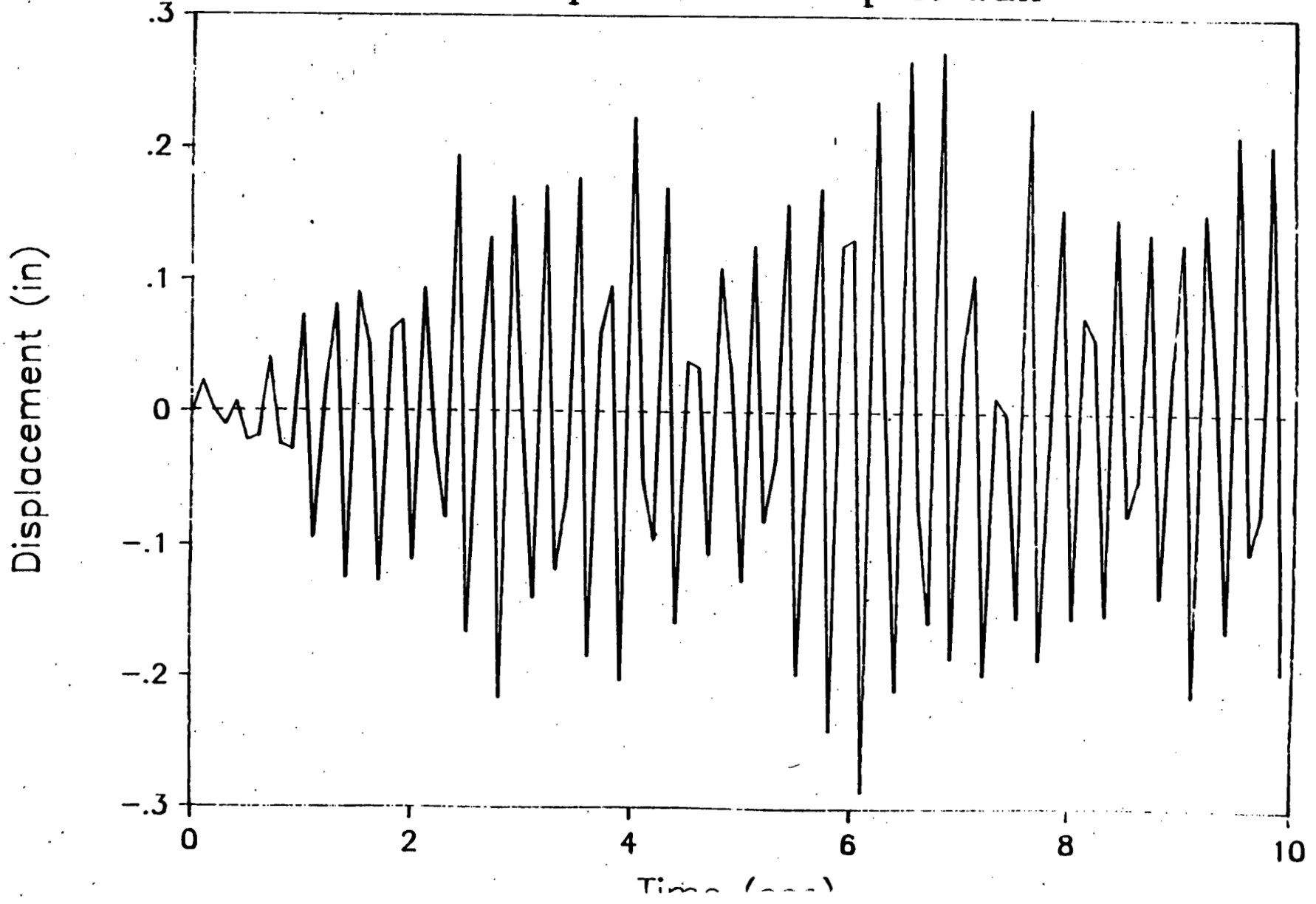
56 21

5621

South Silo Nov. '88

Fig. B-16

Radial Displacements top of wall



000070

Table B4

000071

SOUTH side TIME STEP = 6.1

Elem	t(ave) (in)	Element Coord's. R-ORD	Z-ORD	MERI-MOM	CIRC-MOM	X-MOM	MERI-F	CIRC-F	SHEAR-F	Long. Stress (psi)- (1)	(2)	Hoop Stress (psi) (1)	(2)	Shear Str (psi)
130	4	36.5		.74	4.9	-4.2	-90.8	11.4	42.8	-24.4225	-24.9775	4.6875	1.0125	-1.575
131	4	108		0	-.05	-.04	-238	11	122.9	-59.5	-59.5	2.73125	2.76875	-.015
132	4	180		.19	1.3	-1.1	-399	19.2	212.1	-99.6788	-99.8213	5.2875	4.3125	-.4125
133	4	252		.04	2.9	-.25	-579.8	29	313	-144.935	-144.965	8.3375	6.1625	-.09375
134	4	324		.11	.76	-.65	-784.1	42	456.3	-195.984	-196.066	10.785	10.215	-.24375
135	4	378		.36	2.4	-2	-935.4	56.5	548.8	-233.715	-233.985	15.025	13.225	-.75
136	4	405.5		.06	.39	-.33	-1062.8	60.8	628.8	-265.678	-265.723	15.34625	15.05375	-.12375
137	4	424.5		-.05	-.3	.26	-1054.4	81.2	663.6	-263.619	-263.581	20.1875	20.4125	.0975
138	6	440		1	6.7	-4.8	-1086.1	217.8	718.7	-180.85	-181.183	37.41667	35.18333	-.8
139	10	452		0	.03	3.03	-1058.7	495.5	756.1	-105.87	-105.87	49.5518	49.5482	.1818
140	12	463.5		-2.4	-15.9	13.5	-1343.8	600.8	860.2	-112.083	-111.883	49.40417	50.72917	.5625
141	12	474.5		-2.3	.15.5	13.1	-1348.2	614.3	915.4	-112.446	-112.254	51.19167	51.19167	.5458333
142	12	481.75		-2.7	-17.8	15.1	-1413.8	614.8	975.6	-117.929	-117.704	50.49167	51.975	.6291667
143	12	485.25		-2.8	-18.3	15.6	500.9	898.4	-915.9	41.625	41.85833	74.10417	75.62917	.65
144	12	493		-3.1	-20.5	17.4	490.9	870.3	-871.4	40.77917	41.0375	71.67083	73.37917	.725
145	9.5	483.5	9	1.6	10.8	-10.8	-262.9	636.7	-1944.9	-27.5673	-27.7801	67.73906	66.30305	-.718006
146	7	483.5	13.5	.68	4.5	-8.7	-320.3	474	-1660.1	-45.6739	-45.8404	68.26531	67.16327	-1.06531
147	7	483.5	16.5	.7	4.7	-8.6	-301.9	495.6	-1636.7	-43.0429	-43.2143	71.37551	70.22449	-1.05306
148	7	483.5	21	.73	4.9	2.3	-290.3	519.2	-1640.5	-41.3820	-41.5608	74.77143	73.57143	.2816327
149	7	483.5	27	.76	5.1	2.2	-272.9	547.1	-1669.3	-38.8927	-39.0788	78.78163	77.53265	.2693878
150	7	483.5	33	.08	5.9	.03	-184.5	607.9	-1624.2	-26.2494	-26.4649	87.56531	86.12041	.1016327
151	7	483.5	42	1.1	7.1	38.6	-149.7	691.9	-1661.4	-21.2510	-21.5204	99.71224	97.97347	4.726531
152	7	483.5	56	.96	6.4	69.4	-149.6	626.7	-1647.8	-21.2539	-21.4890	90.31224	88.74490	8.497959
153	7	483.5	72	.82	5.4	61.5	-144.2	531.9	-1610.3	-20.4996	-20.7004	76.64694	75.32449	7.530612
154	7	483.5	92	.48	3.2	118.3	-79.9	310.2	-1565.3	-11.3555	-11.4731	44.70612	43.92245	14.48571
155	7	483.5	116	0	-.04	97.7	-100.8	-19.5	-1464.2	-14.4	-14.4	-2.79061	-2.78082	11.96327
156	7	483.5	140	-.4	-2.7	82.8	-60.2	-277.8	-1357.3	-8.64898	-8.55102	-40.0163	-39.3551	10.13878
157	7	483.5	164	-.72	-4.8	66.4	-55.9	-490.1	-1208.3	-8.07388	-7.89755	-70.6020	-69.4265	8.130612
158	7	483.5	188	-.97	-6.4	54.8	-50.7	-655.4	-1063.9	-4.50449	-4.26694	-94.4122	-92.8449	6.710204
159	7.25	483.5	212	-1.16	-7.7	39.1	10.4	-777.1	-881.5	1.302069	1.566897	-108.065	-106.307	4.465238
160	7.5	483.5	236	-1.29	-8.6	27.1	23.7	-861.3	-711.4	3.0224	3.2976	-115.837	-114.003	2.890667
161	7.5	483.5	260	-1.5	-10	13.6	37.9	-939.1	-504.6	4.893333	5.213333	-126.28	-124.147	1.450667
162	7.75	483.5	284	-1.5	-10.3	-.22	48.3	-908.1	-356.4	6.082414	6.382102	-110.203	-116.145	-.021977
163	8	483.5	306	-1.8	-11.8	-2.6	62.9	-1038.7	-252.8	7.69375	8.03125	-130.944	-128.731	-.24375
164	8	483.5	328	-1.76	-11.7	-.45	110.6	-1022.4	-177.4	13.66	13.99	-128.897	-126.703	-.042188
165	8	479.5		-985.4	-148.9	-1.1	-51.1	-1039.9	-140.2	-98.7688	85.99375	-143.947	-116.028	-.103125
166	7.5	472		-803.2	-111.5	-11.2	-37.7	-966.5	-127.1	-90.7013	80.640	-140.76	-118.973	-1.19467
167	6.5	467		-639.7	-82.5	-14.5	-29.9	-825.8	-116.3	-95.4450	86.24497	-130.762	-115.330	-2.05917
168	5.5	461		-491	.6	-14.5	-22	-681.4	-107.1	-101.388	93.38043	-123.772	-124.010	-2.07603
169	5	453		-315.6	-30.4	-17.4	-14.8	-584.8	-96.9	-78.704	72.784	-124.256	-109.664	-4.176
170	5	443		-141.3	1.7	-23	-6.6	-524.2	-85.3	-35.252	32.592	-104.432	-105.248	-5.52
171	5	427		36.8	32.3	-20.3	-4.3	-413.4	-69.1	9.692	-7.972	-74.920	-90.432	-6.312
172	5	405		141.8	46.2	-23.3	15.3	-267.2	-51.8	37.092	-30.972	-42.352	-64.528	-5.736
173	4.75	381		144.2	37.5	-14.3	21.5	-138.1	-40	42.87313	-33.8205	-19.1014	-39.0460	-3.96233
174	4.5	345.5		87.8	18.4	-4.7	22.8	-45.5	-32.3	31.08148	-20.9481	-4.65926	-15.5830	-1.39259
175	4.25	300.5		21	1.8	1.3	17.9	-20.2	-29.5	11.18754	-2.76401	-4.15502	-5.35087	.4318339
176	4	255.5		-3.5	-2.5	1.8	13.1	-30.8	-28	1.9625	4.5875	-8.6375	-6.7625	.675
177	3.75	210.5		-6.2	-1.9	.84	9.2	-37.4	-23.3	-.192	5.098667	-10.784	-9.16267	.3584
178	3.25	165.5		-2.1	-.32	0	6.3	-28.9	-16.9	.7455621	3.131361	-9.07400	-8.71033	0
179	3	120.5		.54	.2	-.11	5	-20.6	-11.9	2.026667	1.306667	-6.73333	-7	-.073333
180	2.75	75.95		.03	.09	-.77	3.6	-12	-7.2	1.332893	1.205289	-4.29223	-4.43504	-.610909
181	2.5	30.95		.21	.2	-.14	2.5	-5.5	-2.6	1.2016	.7984	-2.000	-2.392	-.1344
182	2.25	4.5		-.77	-.4	.21	.73	1.2	.02	-.588148	1.237037	.0592593	1.007407	.2488889

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Table B-5

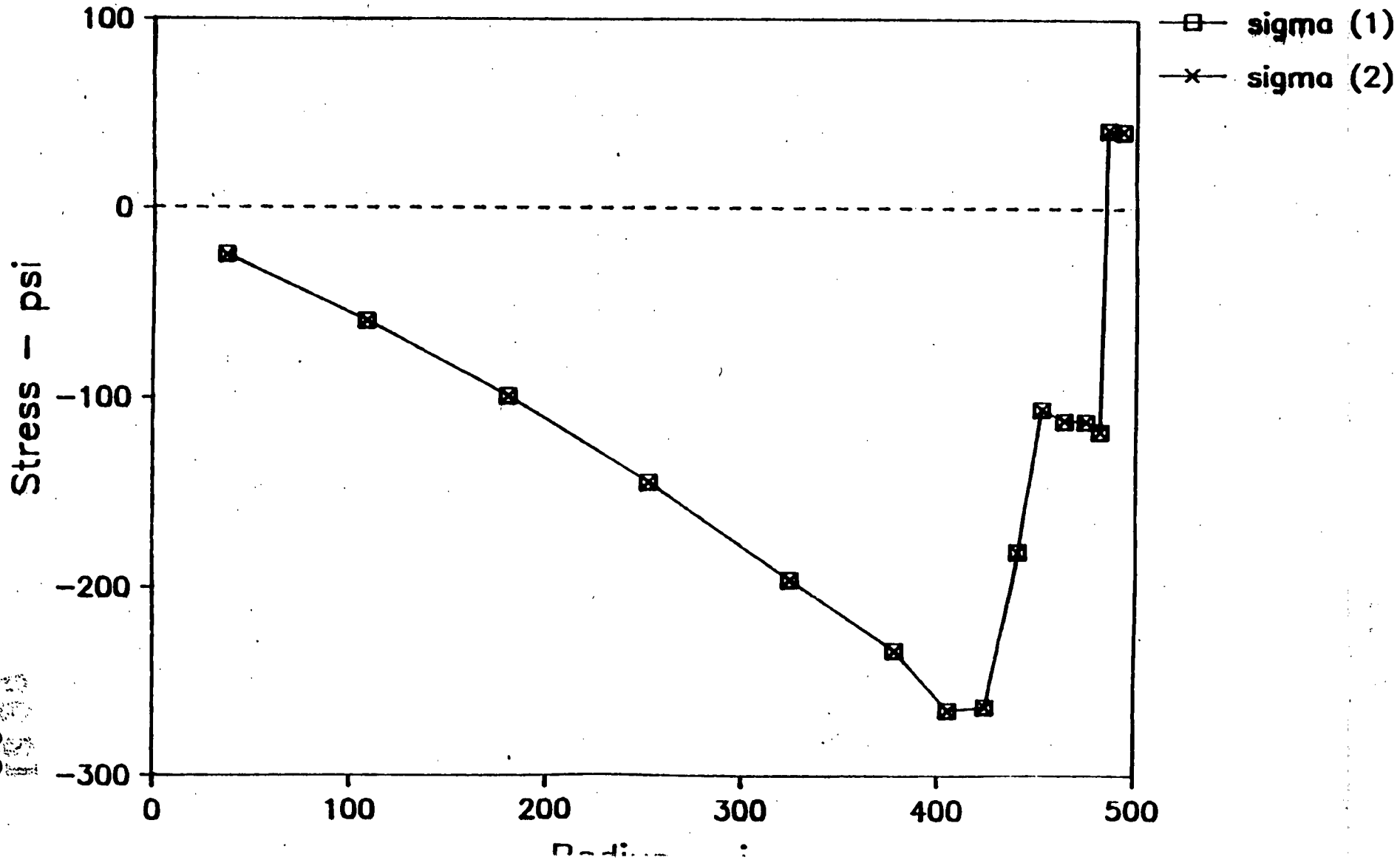
SOUTH Silo TIME STEP = 6.0

Elem	t(ave) (in)	Element R-ORD	Coord's. Z-ORD	MERI-MOM	CIRC-MOM	X-MOM	MERI-F	CIRC-F	SHEAR-F	Long. Stress (psi)- (1)	(2)	Hoop Stress (psi) (1)	(2)	Shear str (psi)
130	4	36.5		-.63	-4.2	3.6	95.8	-5.3	-40.9	23.71375	24.18625	-2.9	.25	1.35
131	4	108		.03	.19	-.16	233.3	1	-114.9	58.33625	58.31375	.32125	.17875	-.06
132	4	180		-.12	-.82	.7	390.2	.42	-198.1	97.505	97.595	-.2025	.4125	.2625
133	4	252		0	.06	-.05	566.2	-2	-292.3	141.3	141.3	-.4775	-.5225	-.01875
134	4	324		0	.04	-.03	762.7	-7.6	-404.1	190.675	190.675	-1.005	-1.915	-.01125
135	4	370		-.21	-1.4	1.21	906	-17.3	-514.3	226.4213	226.5700	-4.05	-3.0	.45375
136	4	405.5		.05	.35	-.3	1030	-19	-590.6	257.5100	257.4013	-4.61875	-4.00125	-.1125
137	4	424.5		.10	1.2	-1.03	1027	-36	-623.5	256.8175	256.6825	-8.55	-9.45	-.38625
138	6	440		-.96	-6.4	4.64	1050	-145.3	-676	176.1733	176.4933	-25.2033	-83.15	.7733333
139	10	452		-.42	-2.77	-.4	1034	-368.6	-710	103.3740	103.4252	-37.0262	-36.8930	-.024
140	12	463.5		1.4	9.5	-8.1	1306	-447.5	-800	108.0917	108.775	-36.0950	-37.6075	-.3375
141	12	474.5		1.4	9.4	-8	1311	-459.4	-860	109.3083	109.1917	-37.0917	-38.675	-.333333
142	12	481.75		1.6	10.7	-9.1	1374	-459.3	-917.6	114.5667	114.4333	-37.0292	-38.7208	-.379167
143	12	485.25		1.7	11.1	-9.4	-482.6	-734	914.7	-40.1458	-40.2875	-60.7042	-61.6292	-.391667
144	12	493		1.9	12.5	-10.6	-473	-706	874.4	-39.3375	-39.4958	-58.3125	-59.3542	-.441667
145	9.5	483.5	9	-1.3	-8.73	11.0	180	-622	1882	18.86094	19.03380	-55.5270	-54.3670	.7844875
146	7	483.5	13.5	-.55	-3.7	8.0	247	-392	1591	35.21837	35.35306	-56.4531	-55.5469	1.077551
147	7	483.5	16.5	-.58	-3.9	8.7	232	-413	1571	33.07104	33.21308	-59.4776	-58.5224	1.065306
148	7	483.5	21	-.61	-4.1	-1.9	221	-437	1574	31.49673	31.64812	-62.3306	-61.9265	-.232653
149	7	483.5	27	-.64	-4.3	-1.8	202	-468.7	1601	28.77878	28.93551	-67.0551	-66.0020	-.220408
150	7	483.5	33	-.75	-5	-.4	121	-522.6	1559	17.19388	17.37755	-75.2694	-74.0449	-.048980
151	7	483.5	42	-.91	-6	-37.1	83.6	-598	1595	11.83143	12.05429	-86.1633	-84.6939	-4.54286
152	7	483.5	56	-.82	-5.5	-67.2	85.7	-530	1583	12.14245	12.34327	-77.5306	-76.1837	-8.22857
153	7	483.5	72	-.68	-4.5	-59.7	55.5	-440.9	1540	7.845306	8.011837	-64.4796	-63.5776	-7.31020
154	7	483.5	92	-.36	-2.4	-116.5	25.3	-236.3	1506	3.670204	3.658367	-34.0510	-33.4633	-14.1429
155	7	483.5	116	.11	.74	-95.8	52.9	82.2	1411	7.570612	7.543673	11.03347	11.65224	-11.7306
156	7	483.5	140	.5	3.3	-81.3	15.5	331.4	1309	2.275510	2.153061	47.74694	46.93878	-9.95510
157	7	483.5	164	.79	5.3	-65.3	17.8	536	1166	2.639592	2.446122	77.22041	75.92245	-7.99592
158	7	483.5	188	1	6.9	-54	-2.2	694.2	1027	-.191837	-.436735	100.0163	98.32653	-6.61224
159	7.25	483.5	212	1.2	8.1	-38.5	-35.4	809.6	851	-4.74578	-5.01974	112.5936	110.7444	-4.39477
160	7.5	483.5	236	1.3	8.9	-26.7	-43.1	888	687	-5.608	-5.88533	119.3493	117.4507	-2.848
161	7.5	483.5	260	1.5	10.2	-13	-49	960	486	-6.37333	-6.69333	129.088	126.912	-1.38667
162	7.75	483.5	284	1.6	10.5	1	-45.6	922	342	-5.72404	-6.04370	120.0166	117.9188	.0998959
163	8	483.5	306	1.8	11.9	3.46	-65.9	1049	241.7	-8.06875	-8.40625	132.2406	130.0094	.324375
164	8	483.5	328	1.76	11.7	5.2	-111.1	1024	172.6	-13.7225	-14.0525	129.0969	126.9031	.4875
165	8	479.5		975.8	144.8	3.4	48.4	1035	138.7	97.53125	-85.4313	142.95	115.8	.31875
166	7.5	472		791.9	107.8	13	35	961	125.6	89.136	-79.8027	139.632	116.6347	1.386667
167	6.5	467		628.5	79.6	15.6	27.2	820.3	114.8	93.43905	-85.0698	137.5041	114.8959	2.215385
168	5.5	461		480.4	57.7	15.1	19.4	676	105.7	88.81322	-91.7587	134.3537	111.4645	2.995041
169	5	453		306.6	28.7	17.6	12.2	579	95.5	76.024	-71.144	122.688	108.912	4.224
170	5	443		134.4	-2.9	23.1	4.2	518	84	33.096	-31.416	102.904	104.296	5.544
171	5	427		-40.6	-33	26.2	-6.6	407	68	-11.064	8.424	73.48	89.32	6.288
172	5	405		-143.1	-46.3	23.8	-17.4	261.3	50.8	-37.824	30.864	41.148	63.372	5.712
173	4.75	381		-144	-37.3	14.7	-23.3	133.5	39.1	-43.1989	33.38837	18.10615	38.02438	3.909141
174	4.5	345.5		-86.96	-18.1	4.6	-24.3	42.4	31.6	-31.1659	20.36593	4.059259	14.78519	1.362963
175	4.25	300.5		-20.6	-1.7	-1.3	-19.2	18.2	29	-11.3606	2.325260	3.717647	4.847059	-.431034
176	4	255.5		3.6	2.4	-1.7	-14.2	29.1	27.6	-2.2	-4.9	8.175	6.375	-.6375
177	3.75	210.5		6.1	1.8	-.81	-10	38.7	22.9	-.064	-5.26933	10.288	8.752	-.3456
178	3.25	165.5		2	.3	0	-7	27.5	16.6	-1.01775	-3.28994	8.631953	8.291124	0
179	3	120.5		-.5	-.2	.1	-5.5	19.6	11.7	-2.16667	-1.5	6.4	6.666667	.0666667
180	2.75	75.95		0	-.08	.07	-3.9	11.5	7.1	-1.41818	-1.41818	4.118347	4.245289	.0555372
181	2.5	30.95		-.2	-.19	.13	-2.6	5.2	2.5	-1.232	-.848	1.8976	2.2624	.1248
182	2.25	4.5		.77	.36	-.21	-.73	-1.1	0	.5881481	-1.23704	-.062222	-.915556	-.248889

South Silo at 6.1 sec.

Base slab long. stresses

B-17



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B-18

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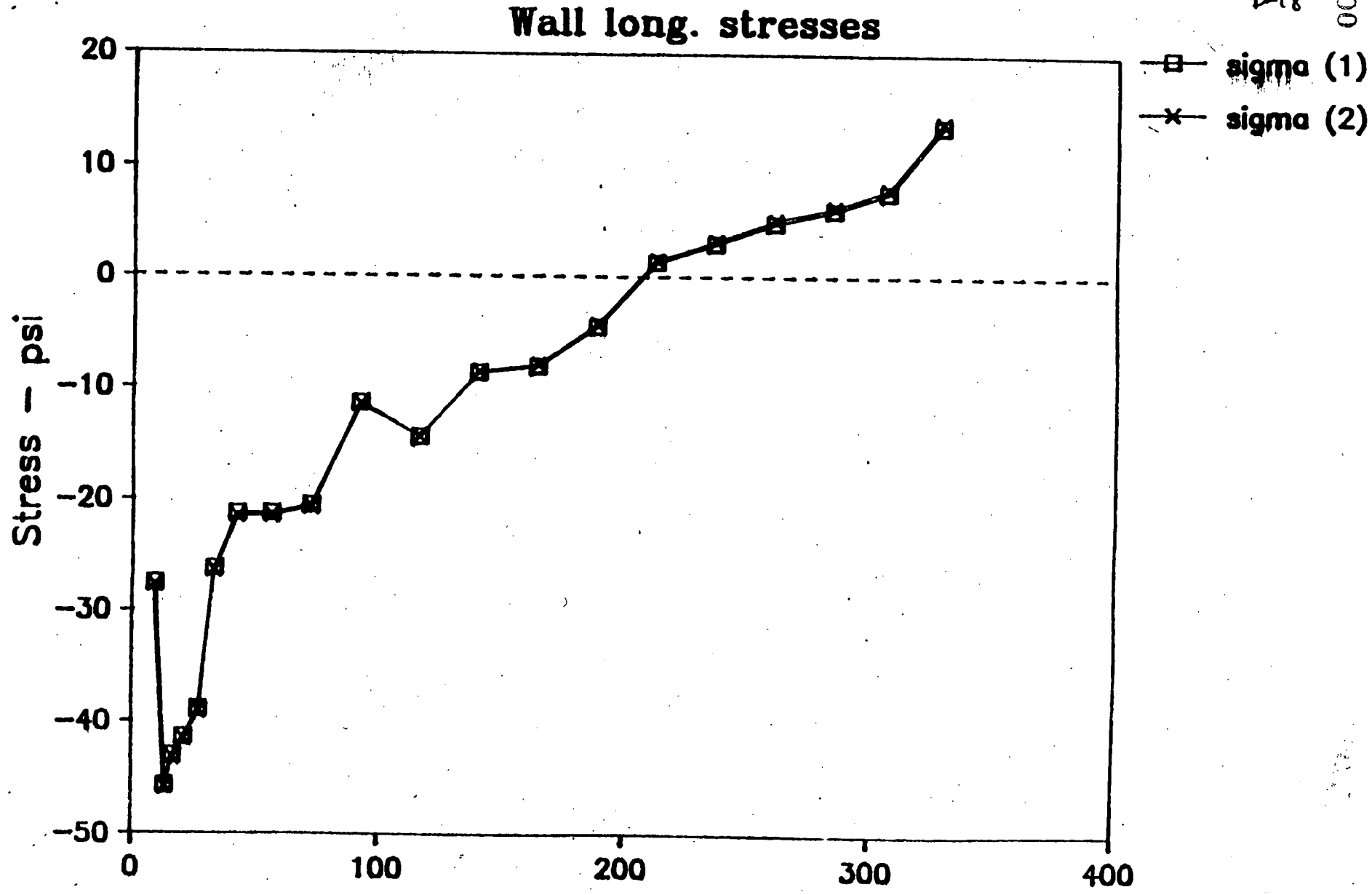
South Silo at 6.1 sec.

Wall long. stresses

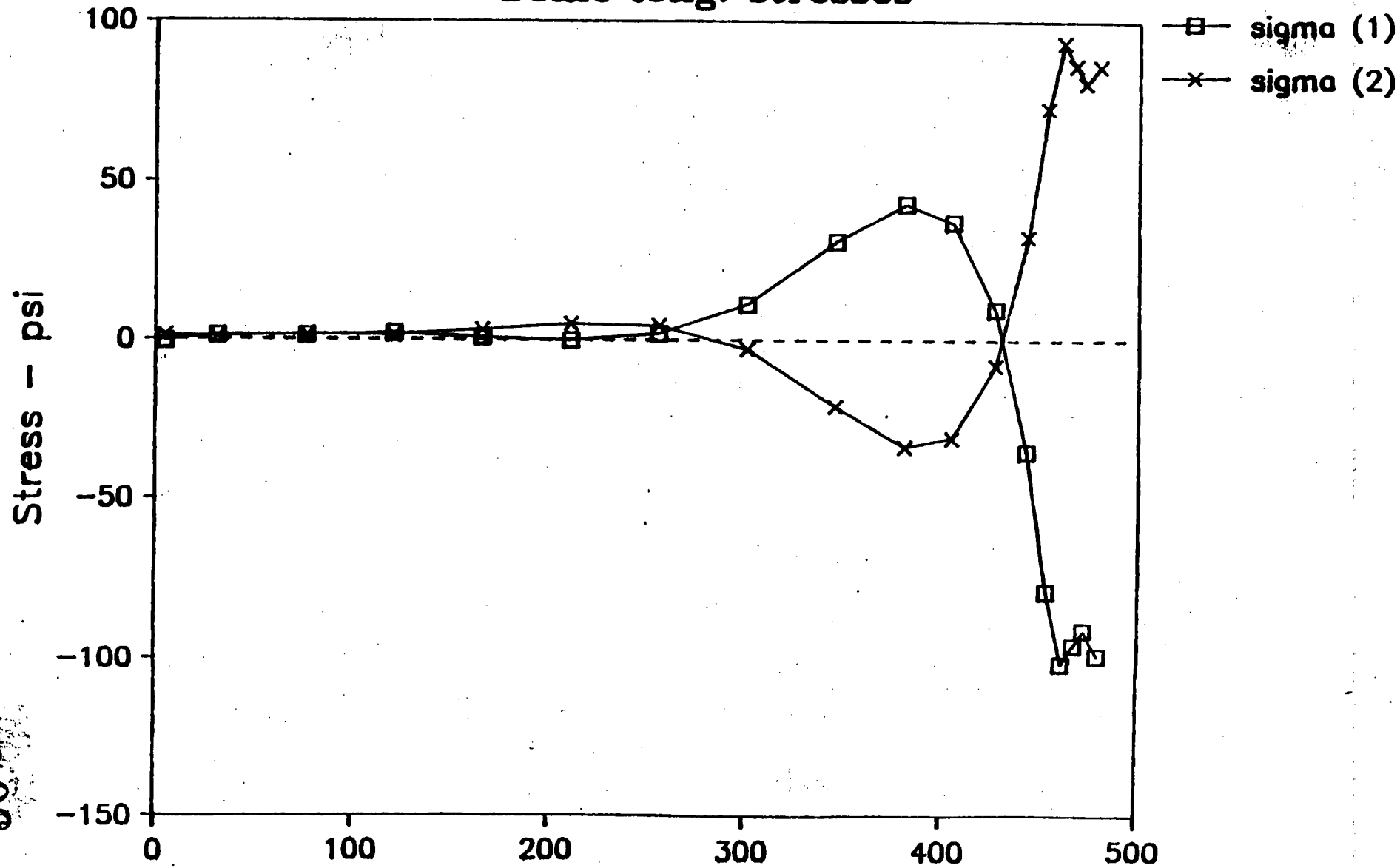


South Silo at 6.1 sec.

B-19

000075

Dome long. stresses



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2

B-20

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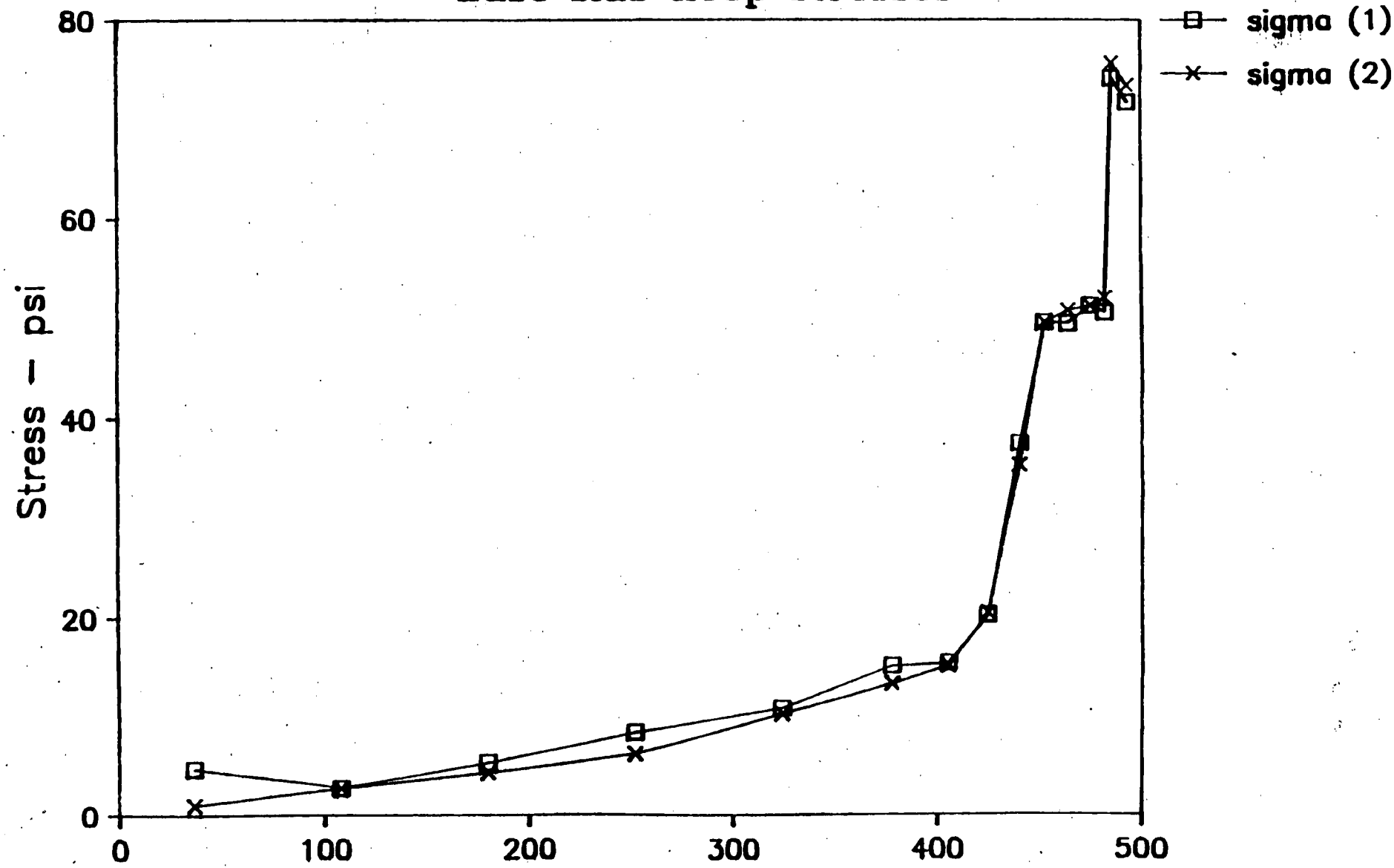
South Silo at 6.1 sec.

Base slab hoop stresses



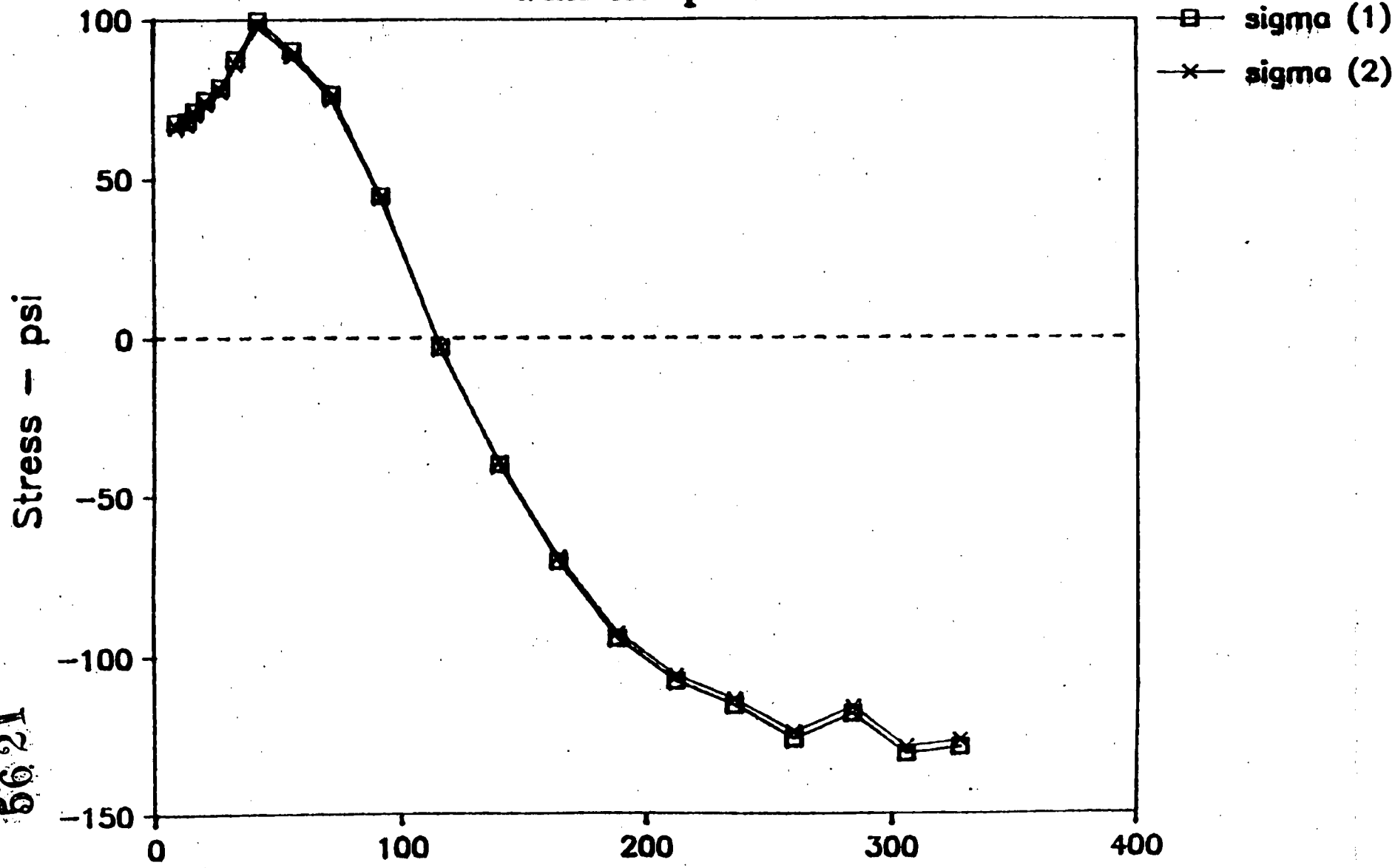
4

000077

B 21

South silo at 6.1 sec.

Wall hoop stresses



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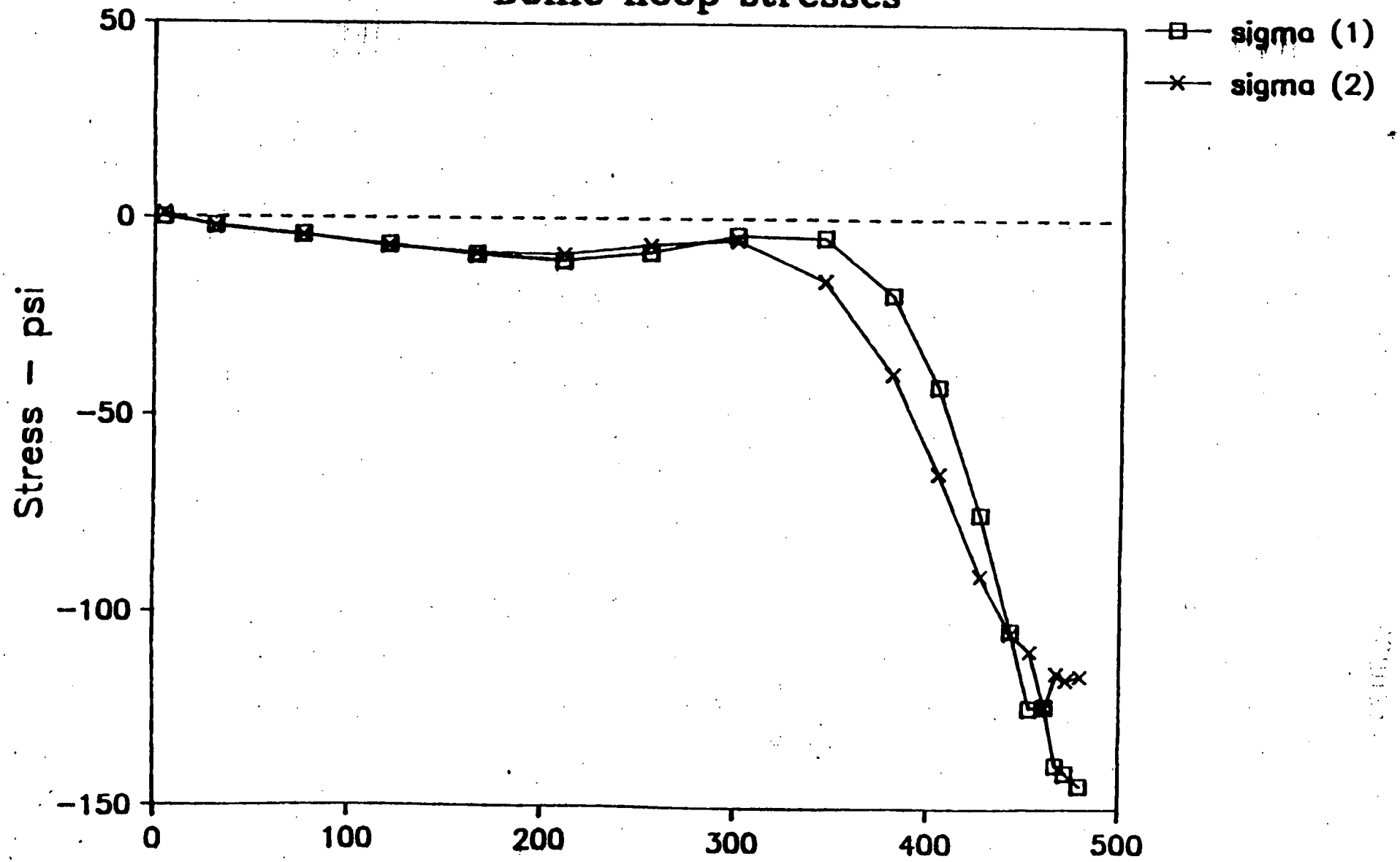
B-22

South silo at 6.1 sec.

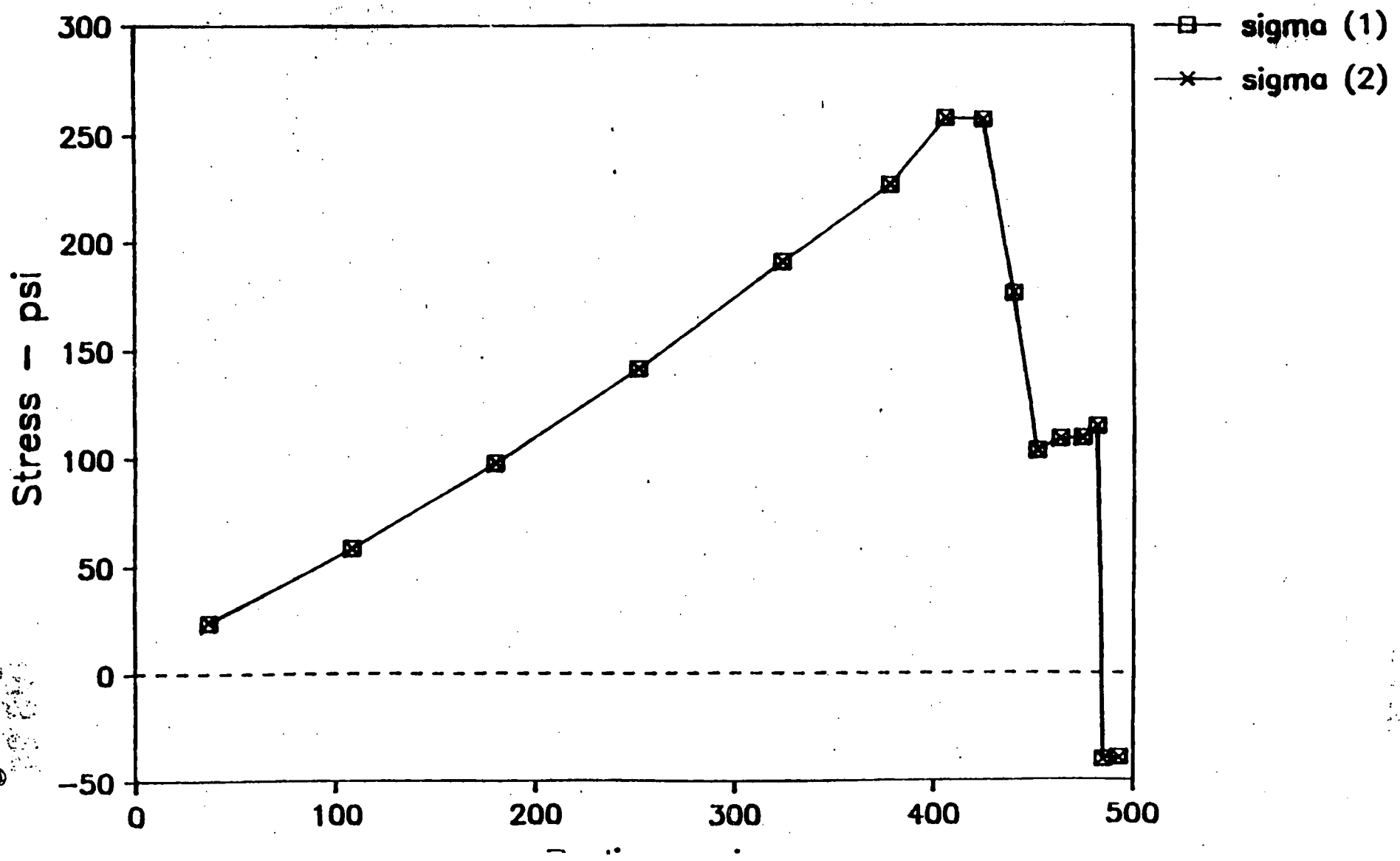
Dome hoop stresses



South Silo at 6.8 sec.

Base slab long. stresses

B-23



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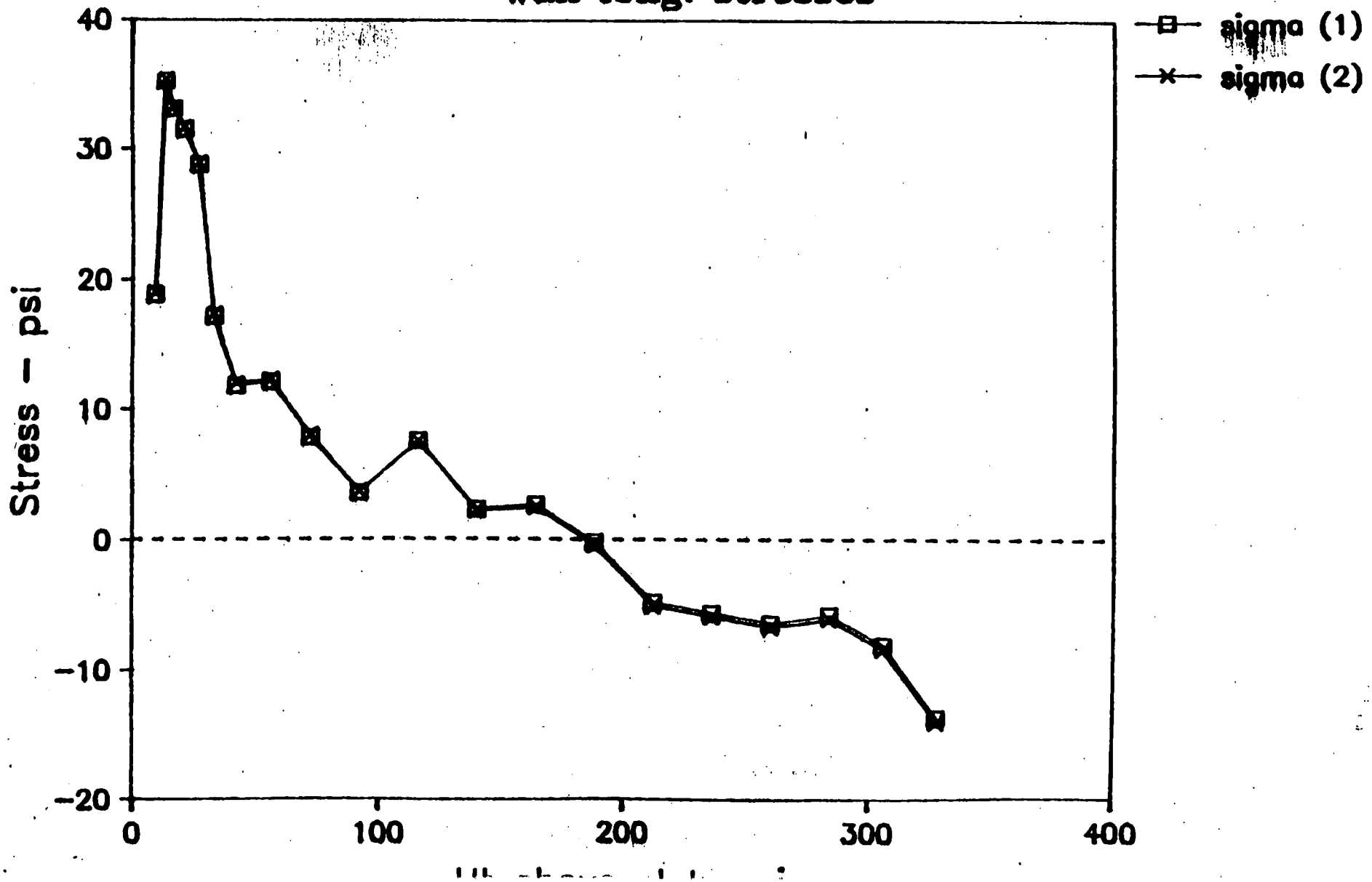
South Silo at 6.8 sec.

B 24

Wall long. stresses

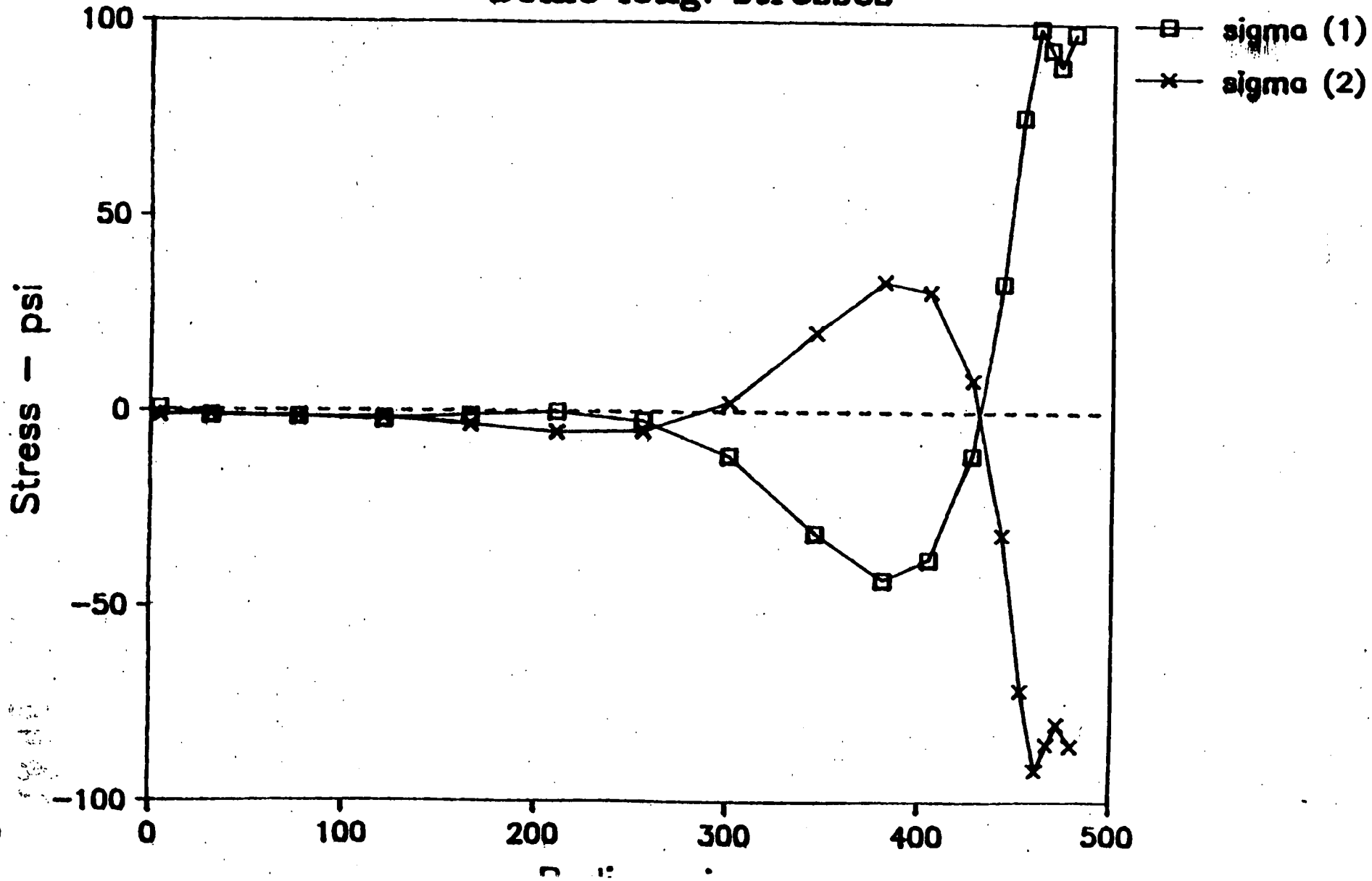


South Silo at 6.8 sec.

B-25

180000

Dome long. stresses



1269

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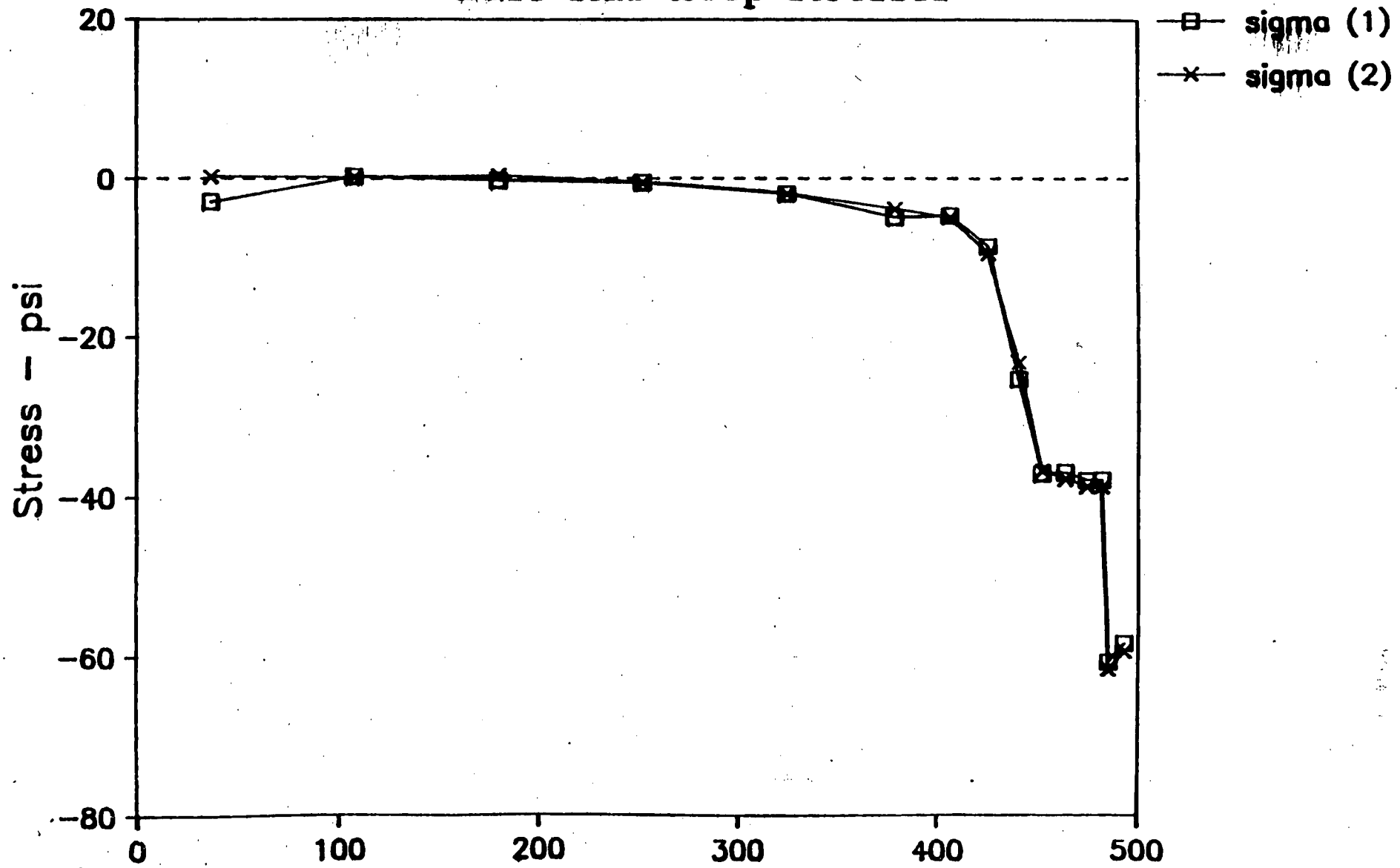
South Silo at 6.8 sec.

B26

Base slab hoop stresses



4

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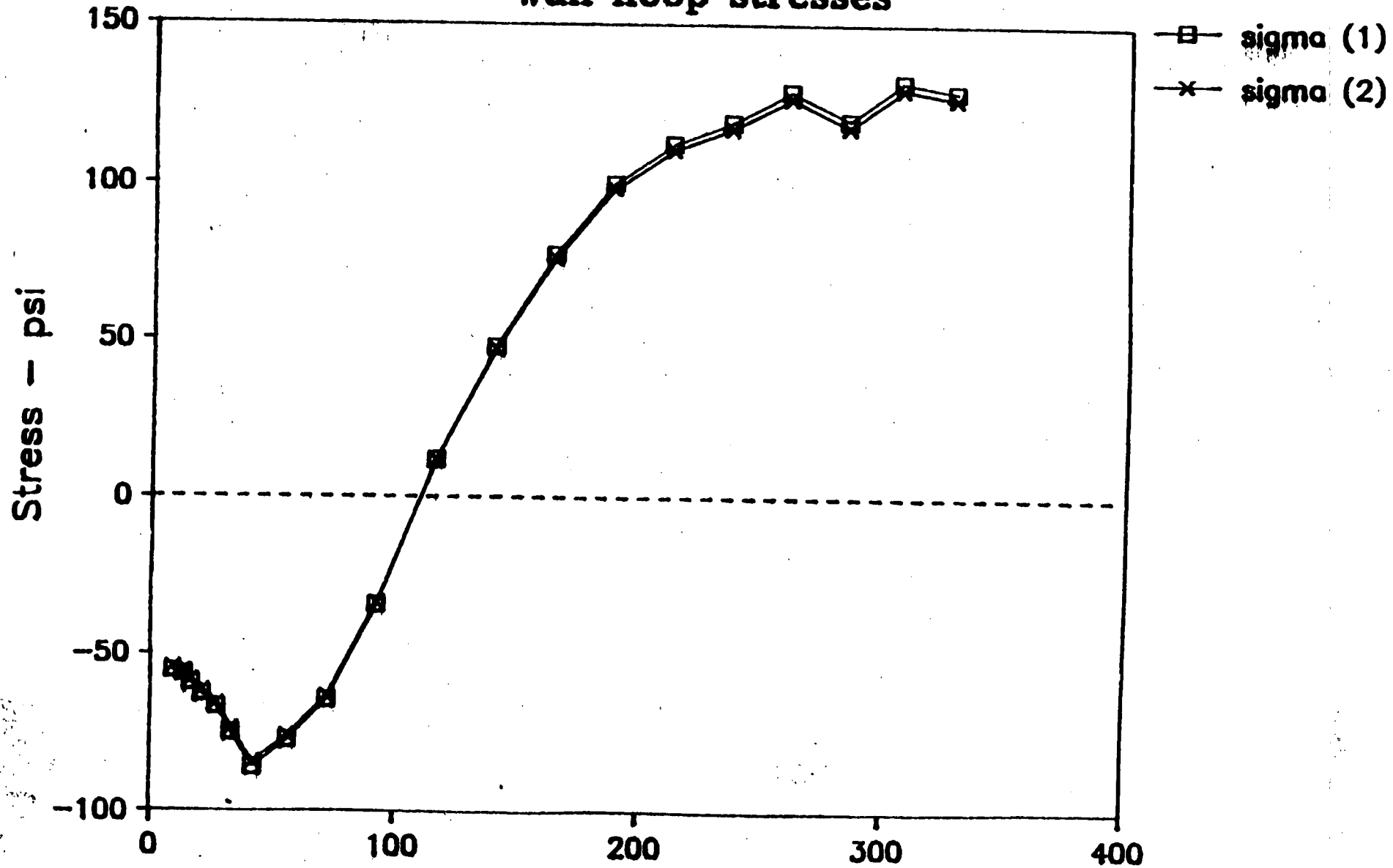
B27

South Silo at 6.8 sec.

Wall hoop stresses



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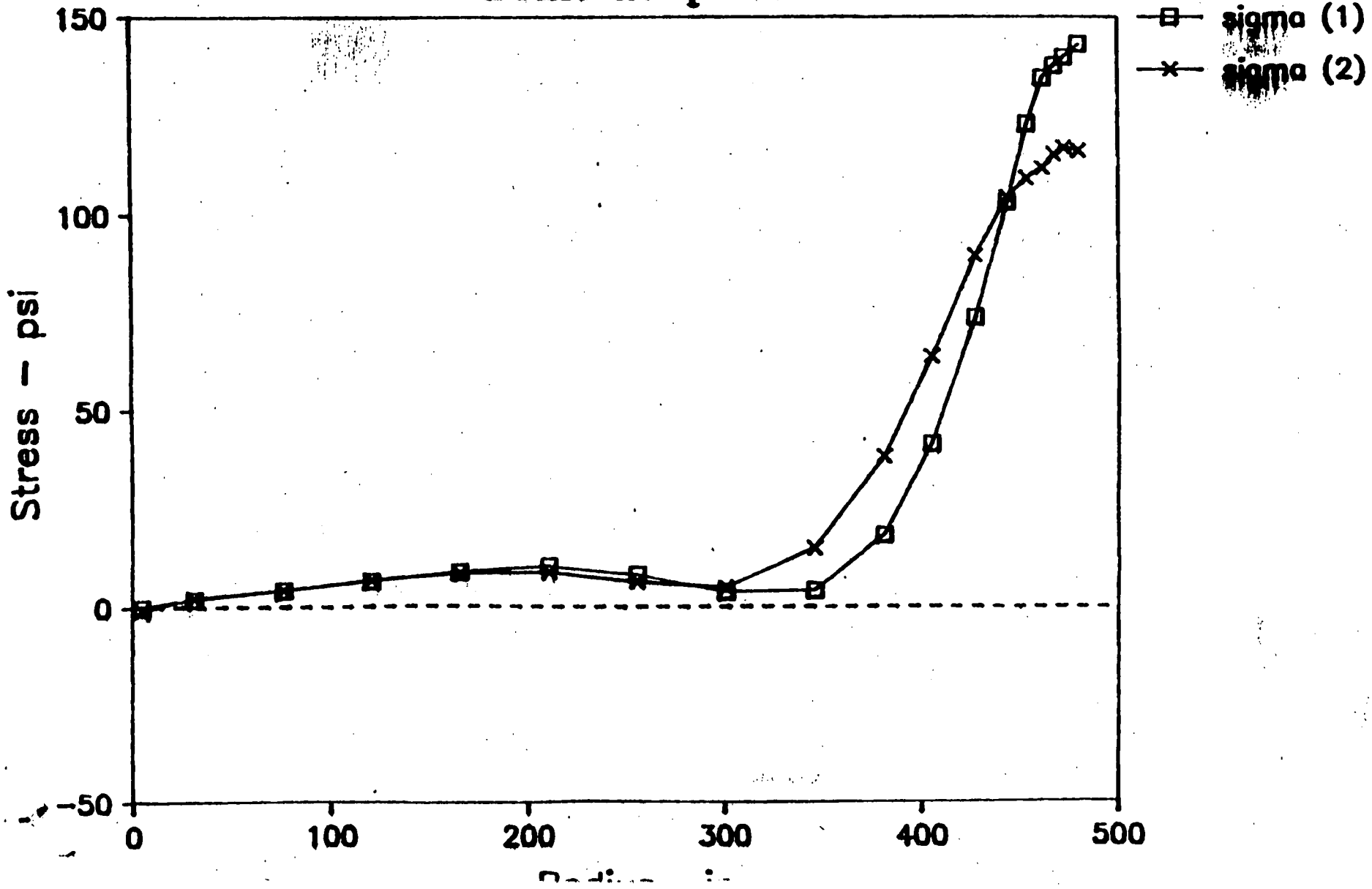
B-28

South Silo at 6.8 sec.

Dome hoop stresses