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Docket 50-289

Zwetzig 27435

July 21, 1977

Mr. Gerald B. Zwetzig
Project Manager
Three Mile Island Unit 1
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Zwetzig:

Enclosed please find information concerning the spent fuel pool structural analysis which was informally requested by the Engineering Branch, Operating Reactors Division, U.S. Nuclear Regulatory Commission. This information serves to clarify the information in our response to question No. 1 of our May 24, 1977 submittal.

Very truly yours,

C. R. Montgomery
Project Manager

CRM/DHR/ab
Enclosure

POOR ORIGINAL

1491 081

MISC 4

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THREE MILE ISLAND NUCLEAR STATION UNIT 1
SPENT FUEL POOL MODIFICATION
REQUEST FOR ADDITIONAL INFORMATION

Preface

The letter of May 24, 1977 (GQL 0703) to R. W. Reid of the USNRC from J. G. Herbein of Metropolitan Edison Co. (Met Ed) provided a response to a USNRC request for additional information related to the TMI-1 spent fuel pools. The response to "Question #1" identified four (4) local regions of the spent fuel pool complex (pools A and B, see Figures 1 and 2) which were designated as "Critical Sections 1, 2, 3 and 4." The overall evaluation of the spent fuel pool complex was based on a general linear elastic uncracked analysis as reported in the May 24, 1977 submittal. Subsequent to that submittal, discussions with USNRC personnel resulted in an informal request for additional information. As evidenced by the responses contained herein, this additional information focuses on "Critical Sections 1, 2, 3 and 4."

Question 1a

For Critical Section 1, verify that the pool slab can withstand load combinations a, b, c & f, assuming one way slab action in the East-West direction.

Response

The basic loads and load combinations applied to the slab of Pool A are tabulated below:

Load	Vertical Pressure on Pool Slab	Comment
D	5.21 psi	5' thick concrete
F	22.29 psi	hydrostatic
L	0	negligible
$E_{(1)}$	1.61 psi	hydrodynamic seismic inertial pressure
$E_{(2)}$	0.79 psi	concrete and fuel rack seismic inertial load

Load Combination	D	F	[illegible]	E	Loading (psi)
a	1.4	1.4	1.7		38.5
b	1.4	1.4	1.7	1.9	43.1
e	1.2	1.2		1.9	37.6
f	0.9	1.4			35.9

As illustrated by the above tabulation, load combination (b) is the controlling combination (43.1 psi).

Considering a unit strip in the East-West direction, conservative upper bounds can be estimated for both the negative and positive bending moments. Considering first the negative moment and referring to Figure 3, the maximum negative moment is -563 ft-k based on a center to center fixed span of 33 feet. With reference to Figure 4 the maximum positive moment is +608 ft-k based on a clear simple span of 28 feet.

In addition to the bending moments, the maximum in-plane axial forces conservatively based on the linear elastic uncracked analyses are as follows:

Combined Load	Maximum Force k/ft
a	56
b	66
e	57
f	56

These axial force estimates are conservative since the local cracking in section 1 would have negligible effect on the axial forces (based on elastic analysis) in the East-West direction.

The combination of maximum negative moment (-563 ft-kips) and maximum axial tension (66 kips) is plotted on Figure 5 (interaction curve #22). The combination of maximum positive moment (608 ft-kips) and maximum axial tension (66 kips) is plotted on Figure 6 (interaction curve #23). In both cases the required capacities are within the available capacities as represented by the interaction curves. Therefore, even disregarding the substantial benefit of two-way action, the slab of Pool A is satisfactory for load combinations a, b, e and f.

The region identified in the May 24, 1977 submittal as "Critical Section 1" is shown in Figure 7. The internal forces and moments predicted by the elastic analysis indicate that nominal cracking and redistribution will take place locally in the vicinity of Critical Section 1. Such localized effects will have

a negligible effect on the overall response of the spent fuel pool complex as predicted by the elastic analyses. The integrity of the liner in this region as affected by cracking is discussed in response to Question 1b.

Question 1b

Verify that the crack width at Critical Section 1 will not result in damage to the pool liner.

Response

The maximum tensile strain in the liner of Pool A has been estimated to be 0.0016 in/in. with no credit given to compressive strains created by the thermal conditions in the pool. Although not applicable, this value can be compared with liner strain allowables defined in the ASME, Section III, Division 2 concrete containment code. For example, the lowest allowable tensile strain specified by the ASME Code is 0.002 in./in. for membrane conditions due to service load categories.

Since the maximum pool liner strain is within the most stringent containment liner allowable strain, the integrity of the Pool A liner is not a concern. This comparison is not intended to imply that the stringent allowable strains for containment liners are appropriate for spent fuel pool liners.

Question 2a

With regard to Critical Sections 2, 3 and 4, verify that the required section capacity does not exceed existing section capacity for load combinations c, d, g and h, neglecting thermal loads.

Response

The regions identified in the May 24, 1977 submittal as "Critical Sections 2, 3 and 4" are shown in Figures 8, 9 and 10. Tables 1, 2 and 3 provide required capacities for load combinations c, d, g and h (neglecting thermal loads) for Critical Sections 2, 3 and 4, respectively. Comparison of the required capacities to the available capacities given in Figures 11, 12 and 13 indicates that all available capacities exceed required capacities.

TABLE 1 - CRITICAL SECTION 2

CALCULATION FOR: REQUIRED CAPACITIES

ORIGINATOR T.H. Chen DATE 7/18/77
REVIEWER L.A. Lecheski DATE 7/20/77
RESULTS

Section 2

Load	D		F		L		E'		I_a	
T EL	F_x	M_x	F_x	M_x	F_x	M_x	F_x	M_x	F_x	M_x
486	+1.1	+1.6	+3.0	+2.1	0	0	+2.4	-1.5	-1.3	+1.0
489	-7.4	+1.1	+3.4	+3.6	-0.6	-0.4	+7.8	-1.6	-7.8	+0.7
492	-3.5	+0.5	+3.9	+3.3	-0.4	0	+7.2	-1.8	-4.8	+0.3
495	-9.3	-0.9	+4.9	+4.5	-0.8	0	+13.7	-1.9	-8.9	-0.7
Sum	-19.1	+2.1	+15.2	+13.5	-1.8	-0.4	+31.1	-6.8	-22.8	+1.3
Avg	-4.8	+0.5	+3.8	+3.4	-0.5	-0.1	+7.8	-1.7	-5.7	+0.3

Combination c, d, g and h with no thermal load.

c. $U = 0.75\ (1.4D + 1.4F + 1.7L)$

$F_x = -1.7$ K/ft
$M_x = +5.3$ K-ft/ft

d. $U = 0.75\ (1.4D + 1.4F + 1.7L \pm 1.9E)$

$F_x = +3.9,\ -7.3$ K/ft
$M_x = +4.1,\ +6.5$ K-ft/ft

g. $U = D + L \pm E' + F$

$F_x = +6.3,\ 9.3$ K/ft
$M_x = +2.1,\ 5.5$ K-ft/ft

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POOR ORIGINAL

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DIVISION

TABLE 1 (CONTINUED)

CALCULATION FOR

ORIGINATOR T.H. W.
DATE 7/1
REVIEWER L.A. ...
DATE 7/20/77
RESULTS

Section 2

h. $U = D + L + I_a + F$

$F_x = -7.2$ K/ft

$M_x = +4.1$ K-ft/ft

SYSTEM: TABLE 2 - CRITICAL SECTION 3

CALCULATION FOR: REQUIRED CAPACITIES

ORIGINATOR: T. H. Chen
DATE: 7/18/77
REVIEWER: C. B. Luckabaugh
DATE: 7/20/77
RESULTS

Section 3

Load D (BL1)			F (BL3)		L (BL2)		E'		I_a (Bl. 19)	
T PL	F_x	M_x	F_x	M_x	F_x	M_x	F_x	M_x	F_x	M_x
1144	-1.7	-7.1	+9.7	-9.1	-0.4	-0.8	+32.9	-29.8	-3.0	-37.8
1145	-0.4	-11.9	+10.2	-3.8	-0.8	-1.9	+47.7	+38.0	-4.7	-50.5
1159	+0.9	-11.4	+4.8	-8.6	-0.3	-2.1	+39.1	-20.9	-4.3	-12.1
1160	+4.0	-26.1	+5.9	-8.2	-0.6	-3.8	+54.9	+41.1	-6.3	-45.4
1174	+2.6	-10.5	+6.9	-8.8	-0.3	-1.7	+42.5	-23.7	-6.0	-26.4
1175	+4.7	-25.7	+6.0	-8.4	-0.6	-3.4	+56.3	+37.5	-7.6	-57.1
1189	+8.7	-13.1	+0.4	-9.1	+0.3	-3.0	+63.3	-14.3	-21.8	+7.3
1190	+14.0	-28.5	+2.0	-10.9	+0.4	-3.8	+72.8	+36.3	-20.0	-29.4
Sum	+32.8	-134.3	+43.9	-66.9	-2.3	-20.5	+409.5	+64.2	-73.6	-261.6
Avg	+4.1	-16.8	+5.5	-8.4	- .3	-2.6	+51.2	+8.0	-9.2	-32.7

Combination c, d, g and h with no thermal load.

c. $U = 0.75\ (1.4D + 1.4F + 1.7L)$

$F_x = +9.7$ K/ft
$M_x = -29.7$ K-ft/ft

POOR ORIGINAL

1491 087

Section 3

d. $U = 0.75\ (1.4D + 1.4F + 1.7L \pm 1.9E)$

F_x = 58.3, 38.9 K/ft
M_x = -22.1, -37.3 K-ft/ft

g. $U = D + L \pm E'F$

F_x = 60.5, -41.9 K/ft
M_x = -19.8, -27.8 K-ft/ft

h. $U = D + L + 1_a + F$

F_x = +0.1 K/ft
M_x = -60.5 K-ft/ft

POOR ORIGINAL

SUBJECT: TABLE 3 - CRITICAL SECTION 4

CALCULATION FOR: REQUIRED CAPACITIES

ORIGINATOR T.H. Chu DATE 7/15/77
REVIEWER L.A. Sachdeva DATE 7/20/77
RESULTS

Section 4

Load	D		F		L		E'		T_a	
T FL	F_y	M_y	F_y	M_y	F_y	M_y	F_y	M_y	F_y	M_y
216	-28.5	-1.6	-3.8	+4.7	-1.7	0	+36.8	-7.1	+8.0	+0.1
235	-28.8	-4.1	-1.7	+6.5	-1.7	0	+38.1	-6.9	+8.4	-0.1
236	-28.7	-1.2	-3.7	+0.4	-1.7	0	+37.2	-8.8	+8.0	+0.1
217	-27.5	+1.1	-3.9	-0.5	-1.7	+0.2	+34.6	-9.7	+7.6	+0.1
218	-24.7	-0.5	+0.6	+6.9	-1.4	+0.1	+35.1	-9.7	+7.4	-1.0
237	-27.8	+0.4	-3.8	-1.8	-1.7	+0.1	+34.9	-9.1	+7.7	-0.8
Sum	-166	-5.9	-16.3	+16.2	-9.9	+0.4	+216.7	-48.3	+47.1	-1.6
Avg	-27.7	-1.0	-2.7	+2.7	-1.7	+0.1	+36.1	-8.2	+6.9	-0.3

Combination c, d, g and h with no thermal load.

c. $U = 0.75\ (1.4D + 1.4F + 1.7L)$

$F_y = -34.1$ K/ft
$M_y = +1.9$ K-ft/ft

d. $U = 0.75\ (1.4D + 1.4F + 1.7L \pm 1.9E)$

$F_y = +0.2,\ -68.4$ K/ft
$M_y = -5.9,\ +9.7$ K-ft/ft

1491 089

READING, PA.	PROJECT Three Mile Island Nuclear Station Unit 1	6 of 6
SUBJECT TABLE 3 (CONTINUED)		ORIGINATOR T. A. Chen DATE 7/18/77
CALCULATION FOR		REVIEWER L. A. Laudenslager DATE 7/20/77
		RESULTS

Section 4

g. U = D + L ± E' + F

F_y = +4.0, -68.2 K/ft
M_y = -6.4, +10.0 K-ft/ft

h. U = D + L + T_a + F

F_y = -24.2 K/ft
M_y = +1.5 K-ft/ft

POOR ORIGINAL

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Question 7b

When considering thermal loads due to T_o, verify that load combinations c and d are satisfied. When considering the effects of T_o' demonstrate that at the critical sections the concrete stresses do not exceed 0.85 f_c', and the rebar steel strains do not exceed twice the yield strain. Demonstrate that the crack width at these critical sections will not damage the liner. Discuss the effects of redistribution of the forces and moments in the structure at these critical sections where the cracks occur.

Response

When considering the internal effects due to the T_o thermal "load" based on linear elastic uncracked analyses, load combinations c and d are not satisfied at the localized sections 2, 3 and 4. The internal forces in those regions which would try to develop in response to the thermal "load" (either T_o or T_o') will result in cracking of the concrete. A description of the cracking for the three (3) local regions is as follows:

A. Section 2 - Vertical cracking of the wall below Pool B is produced by bending and axial tension. Since the region in which cracking occurs is remote from the pool, the cracking does not affect the integrity of the Pool B liner.

B. Section 3 - Vertical cracking of the wall is produced by bending and axial tension. The liner is in compression as a result of the combined effect of thermal and mechanical loads and, thus, there is no danger of over-straining the liner in tension.

C. Section 4 - Horizontal cracking of the concrete of Pool A is produced by combined bending and axial tension. Again, both pool liners are in compression and there is no danger to the liners.

An estimate of the average strains in the walls due to T_o for sections 2, 3 and 4 can be obtained using the axial tensions predicted by the elastic analyses.

Section	Axial Force	ε
2	+284	0.000090
3	+ 77	0.000025
4	+150	0.000048

Where $\varepsilon = F/AE$

ε - Axial Strain

F = Force in Kips

A - Axial area = 5' x 1'

$E_c = 6.2 \times 10^5$ ksf or 4.3×10^6 psi

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POOR ORIGINAL

Although the concrete in regions 2, 3 and 4 cannot sustain the above strains and cracking will occur, the resulting strains in the reinforcement subsequent to concrete cracking are the same order of magnitude due to the physical constraint of the local regions by surrounding structure.

Furthermore, as can be seen in Figures 8, 9 and 10, the redistribution of internal forces as a result of cracking will be confined to the localized areas shown. Hence, the thermal loads are dissipated at very small strain values and the structural integrity of the pool complex is adequate.

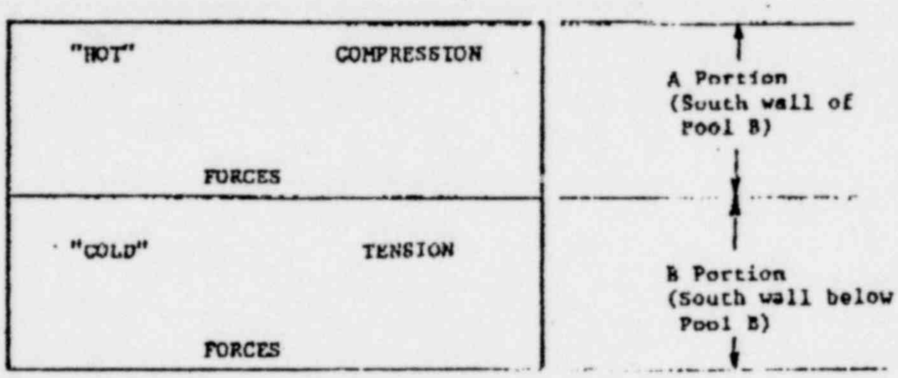
Specifically considering T_o' combinations for sections 2, 3 and 4, the axial force response is tension in combination with bending. Concrete cracking is through the thickness with the liner in compression due to the direct thermal "load". Hence, concrete compressive stresses (or strains) are not a concern in the local sections 2, 3 and 4.

Although the reinforcing steel strains would be difficult to calculate accurately, an upper bound thermal axial strain calculation indicates that:

$$\epsilon = \Delta t \times \alpha = (199^o - 67^o) \times 6 \times 10^{-6} = 0.0008 \text{ in/in}$$

which is small in comparison with the rebar steel yield strain.

With regard to a discussion of the redistribution of internal forces and moments due to thermal "loads", a schematic representation of section 2 is illustrated below:



In this case, because of the temperature distribution, the B Portion restrains the A Portion. When vertical cracking occurs in the B Portion, the tensile forces of the B Portion are reduced and also relieve the compressive forces of the A Portion. Because of equilibrium requirements between the two portions, Portion A will never go into tension, and the tensile strains in the B Portion reinforcement will not exceed the previously calculated upper bound thermal axial strain.

The above discussion of section 2 is directly applicable to section 4. In section 4 the common wall between the two pools is "hotter" than the west wall of the two pools. The middle wall is analogous to the A Portion above and the west wall analogous to the B Portion.

Section 3 is similar but more complex. Adjacent structures abutting the north end of Pool A below section 3 creates a compressive axial condition below section 3 (analogous to A Portion described above) with section 3 in tension (analogous to B Portion described above).

POOR ORIGINAL

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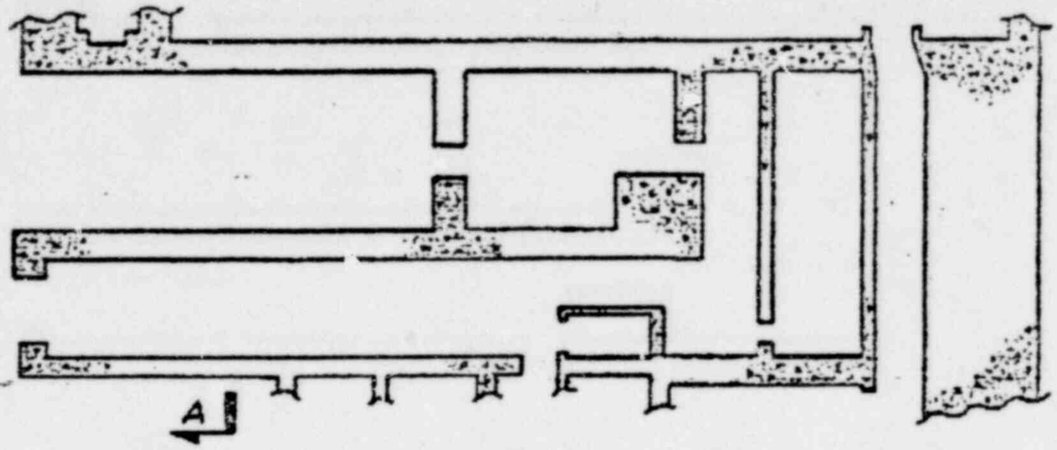
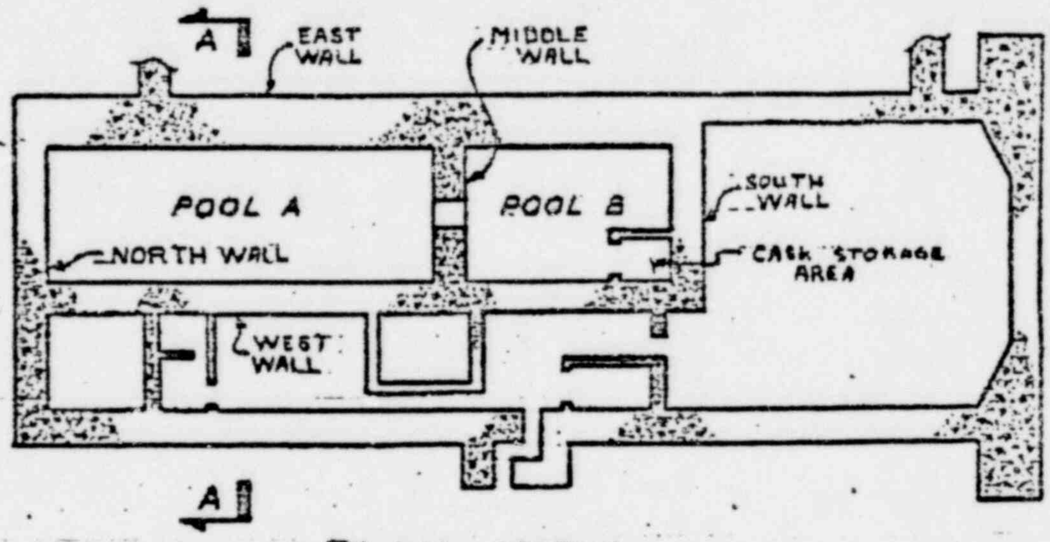


FUEL HANDLING BUILDING COMPLEX

WALLS BELOW ELEV. 305'-0"



PLAN VIEW
FUEL HANDLING BUILDING COMPLEX

TYPICAL WALLS AT INTERMEDIATE FLOOR LEVELS
(ELEV. 305'-0", 329'-0", 348'-0")

POOR ORIGINAL

FIGURE 1

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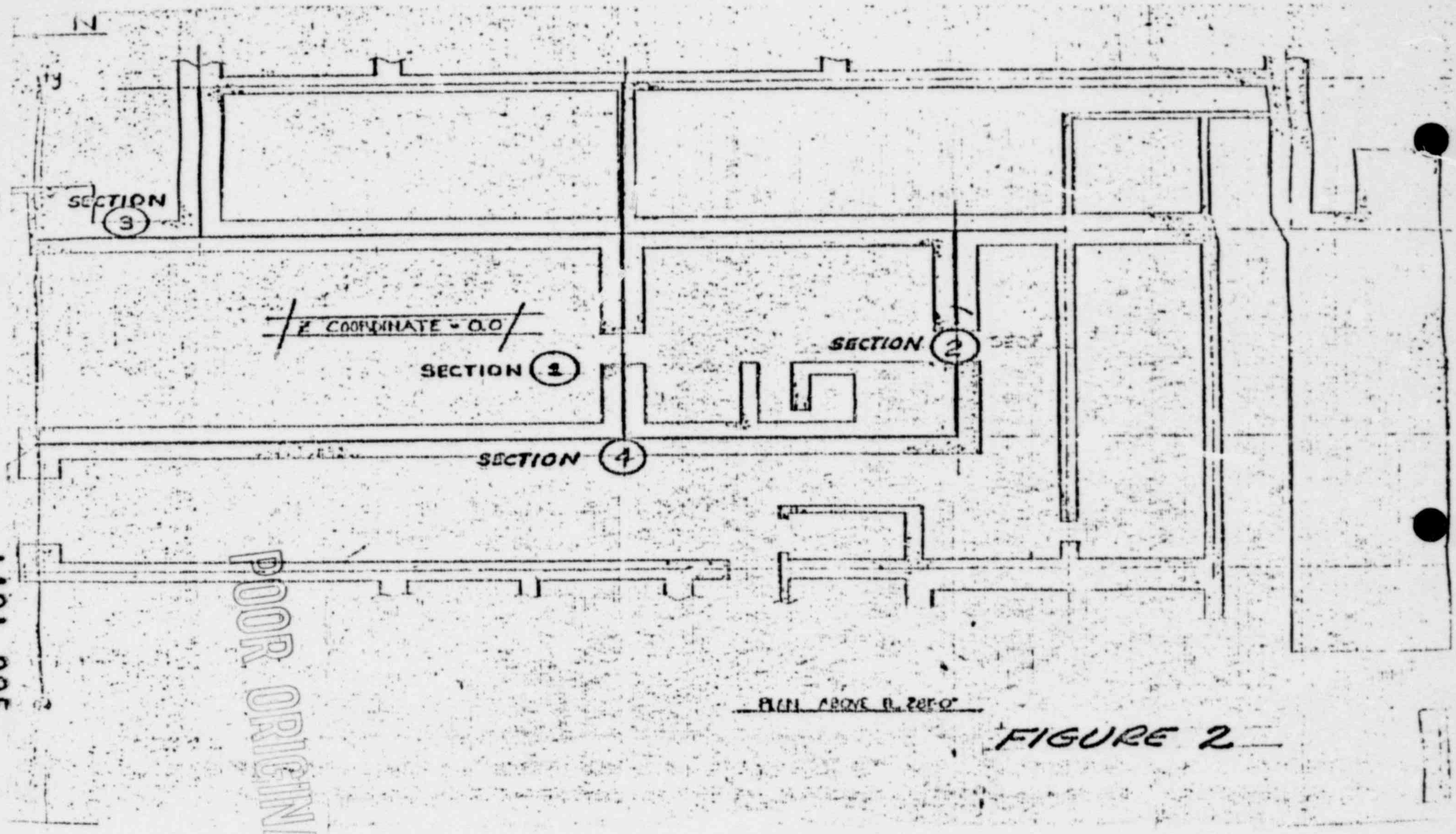

PLAN ABOVE EL. 280'-0"

FIGURE 2

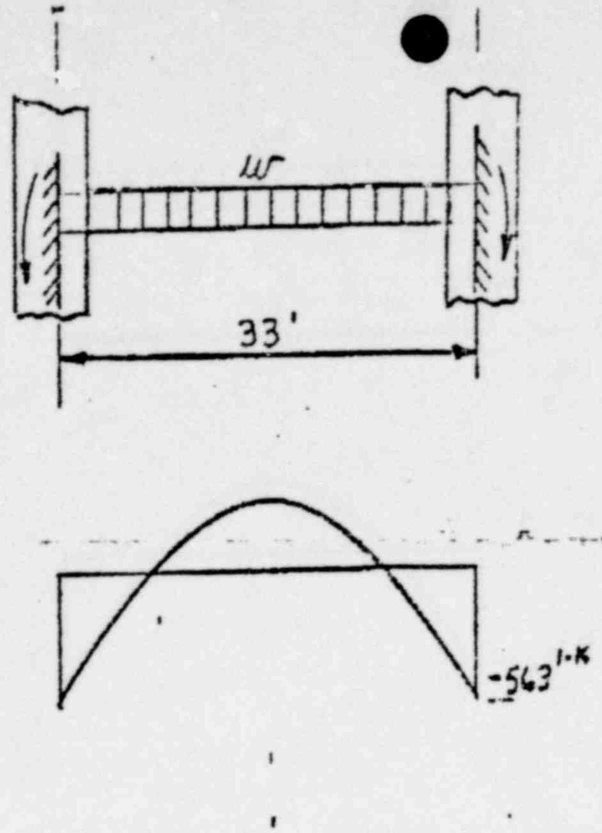

FIGURE - 3 - MAXIMUM NEGATIVE MOMENT

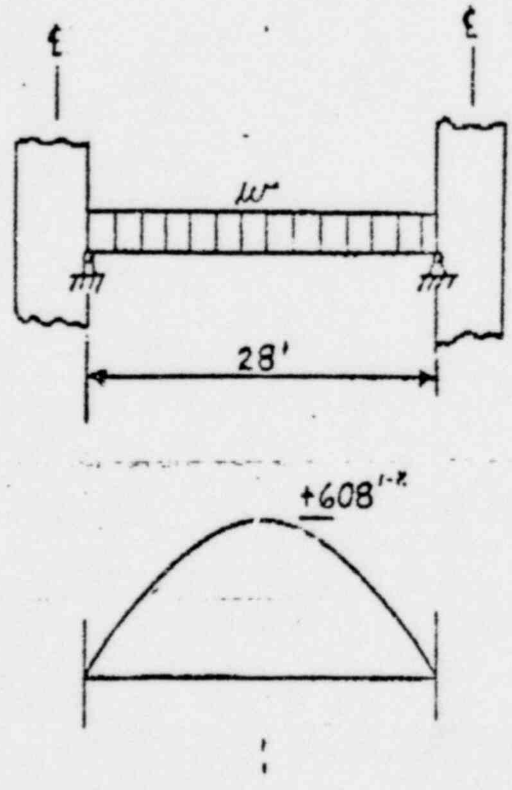

FIGURE - 4 - MAXIMUM POSITIVE MOMENT

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READING, PA.	TMI UNIT #1		OF

SYSTEM SPENT FUEL POOL REANALYSIS	ORIGINATOR DATE
CALCULATION FOR INTERACTION DIAGRAMS	REVIEWER L.A. [illegible] DATE 7/
	RESULTS

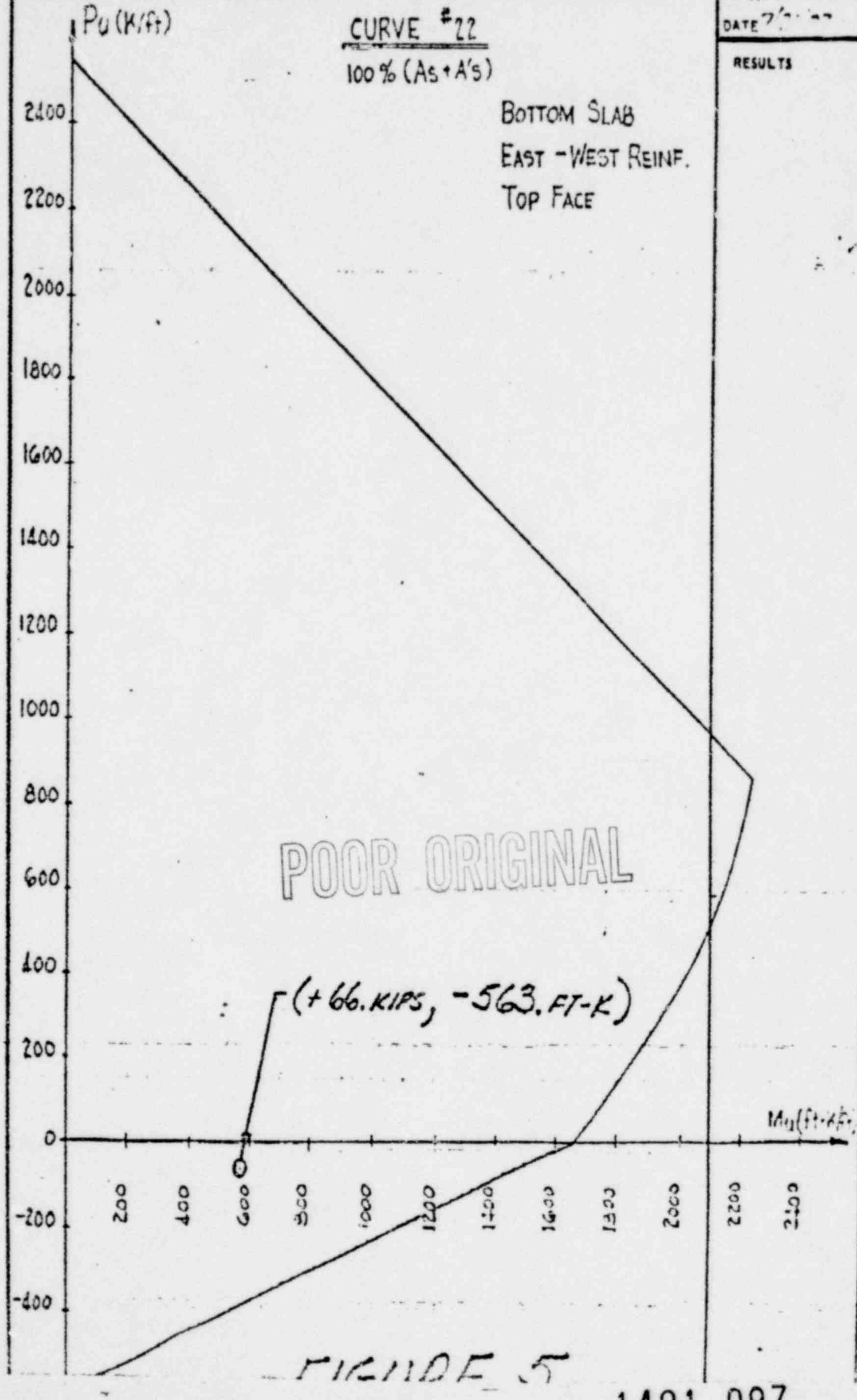

FIGURE 5

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SYSTEM

SPENT FUEL POOL REANALYSIS

CALCULATION FOR

INTERACTION DIAGRAMS

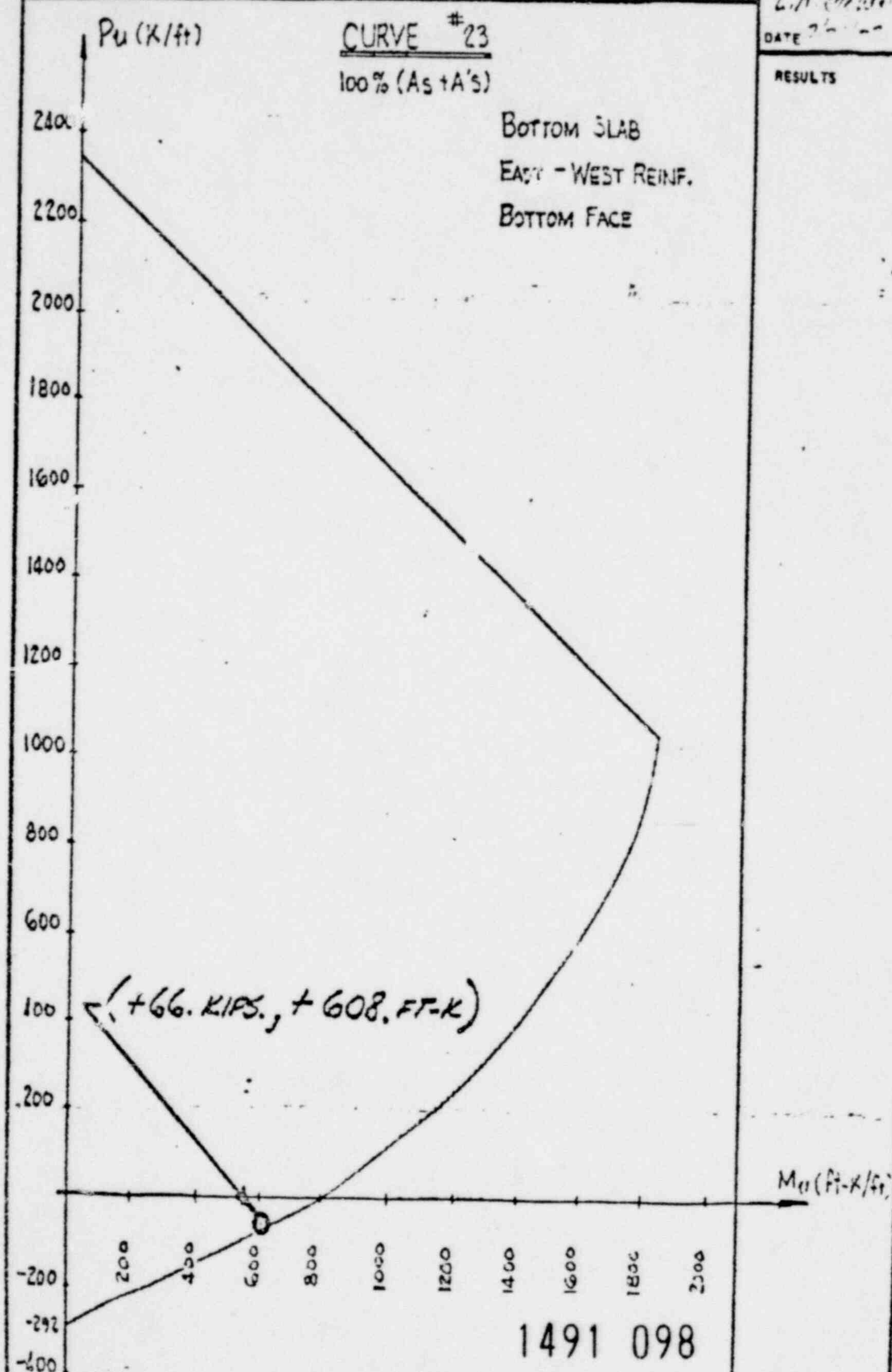
ORIGINATOR

DATE

REVIEWER

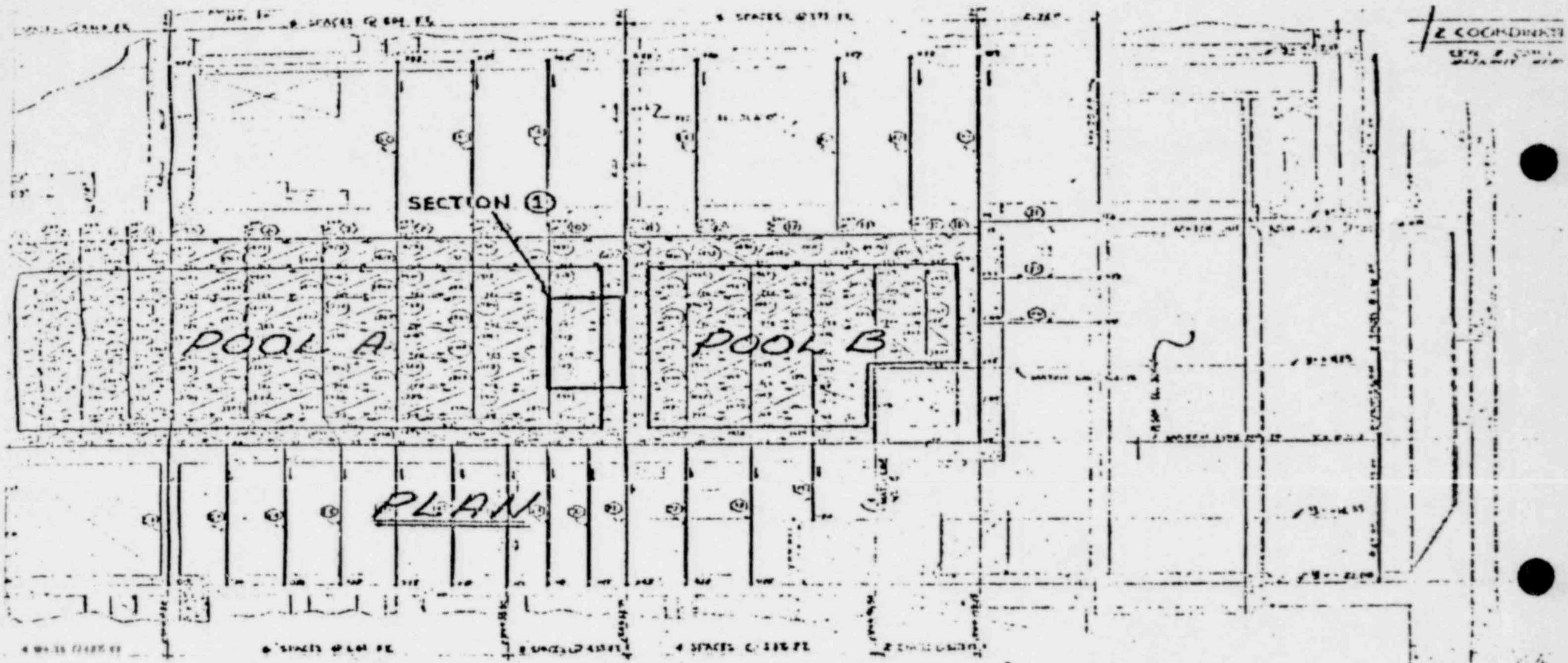
DATE

RESULTS



1491 098

FIGURE 6



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	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
CURVE	17,23,24,26		21,23,24,26		28,25,24,26		22,23,25,26		21,23,24,[illegible]		28,29,24,26	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOP	[illegible]	[illegible]	3.12	[illegible]	7.28	0.11	[illegible]	1.12	3.12	[illegible]	7.28	[illegible]
BOT.	4.33	0.11	4.33	[illegible]	4.34	[illegible]	4.33	[illegible]	[illegible]	[illegible]	5.12	[illegible]
TOT.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PLAN

FIGURE 7

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1491 099

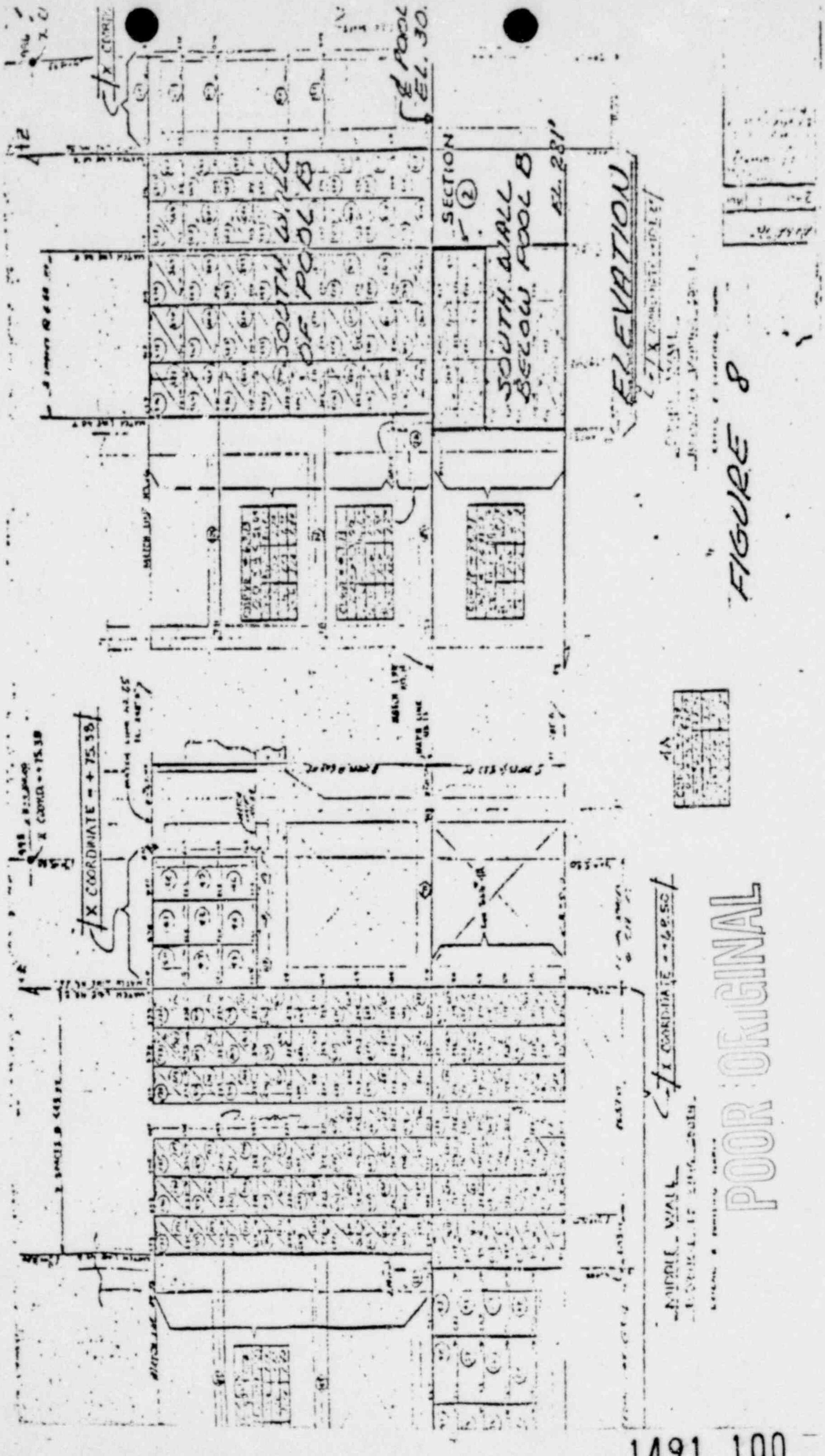

SOUTH WALL OF POOL B
SECTION 2
SOUTH WALL BELOW POOL B
EL. 281'
ELEVATION
X COORDINATE = +75.38
MIDDLE WALL
POOR ORIGINAL

FIGURE 8

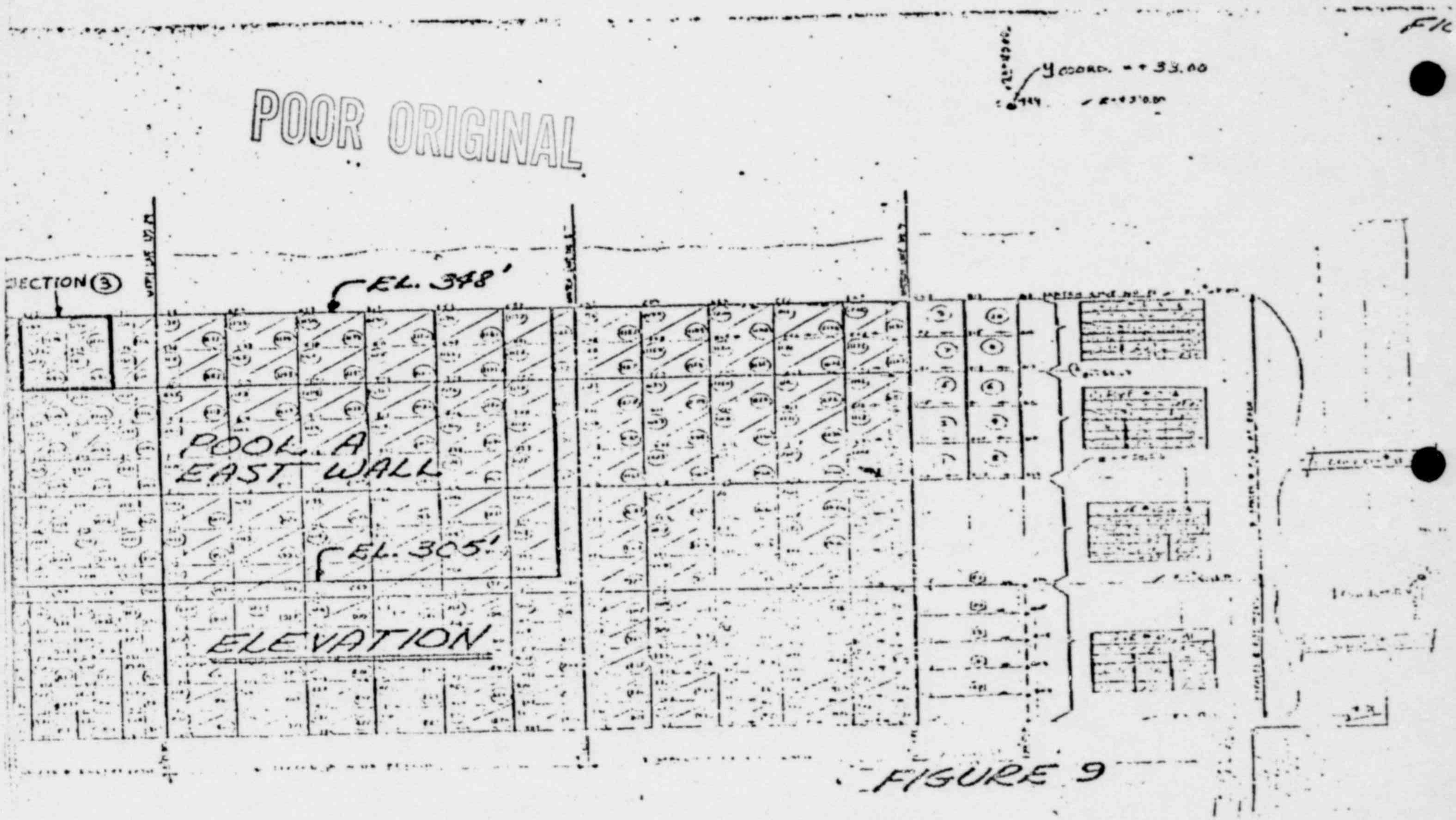
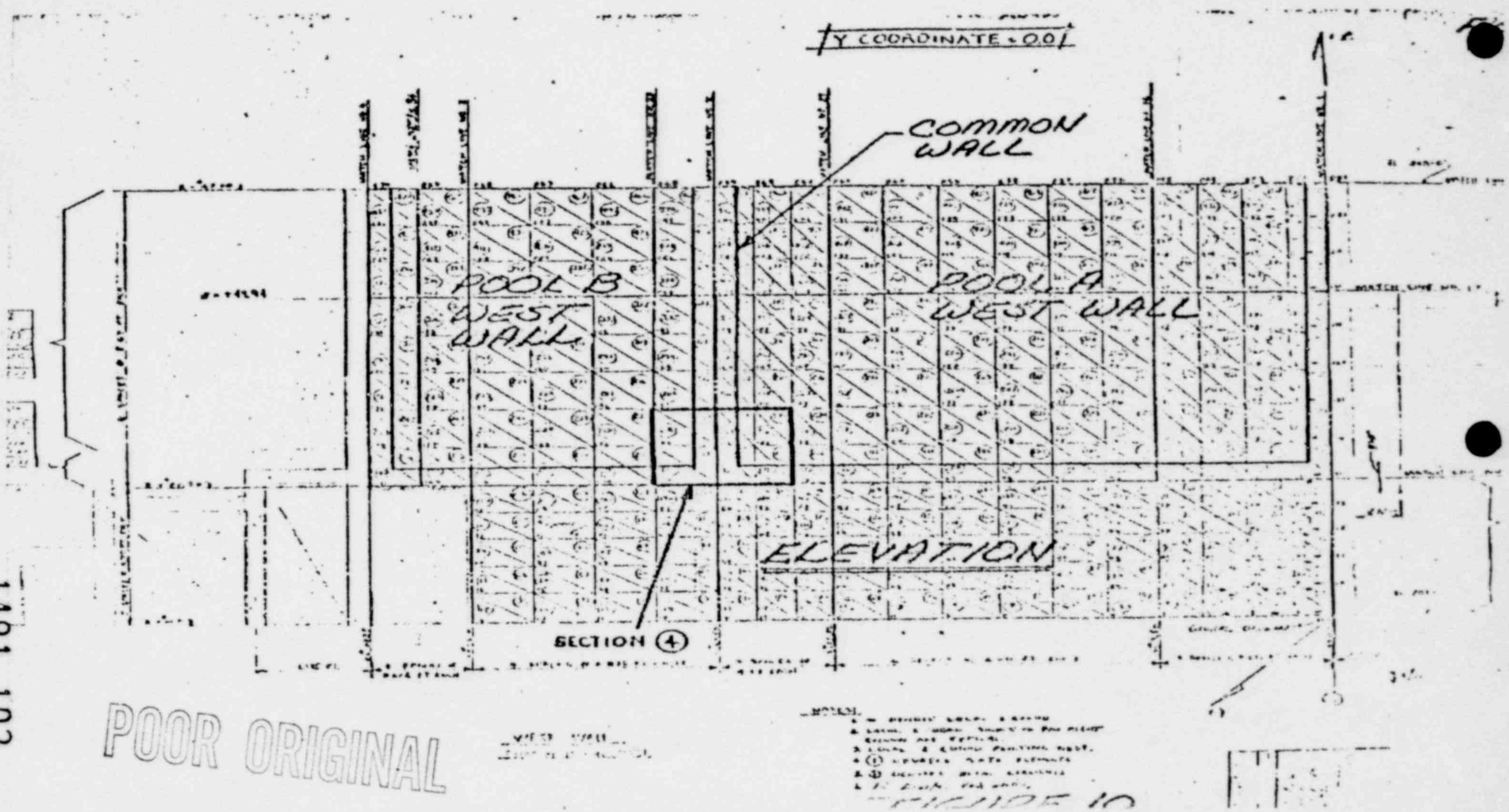
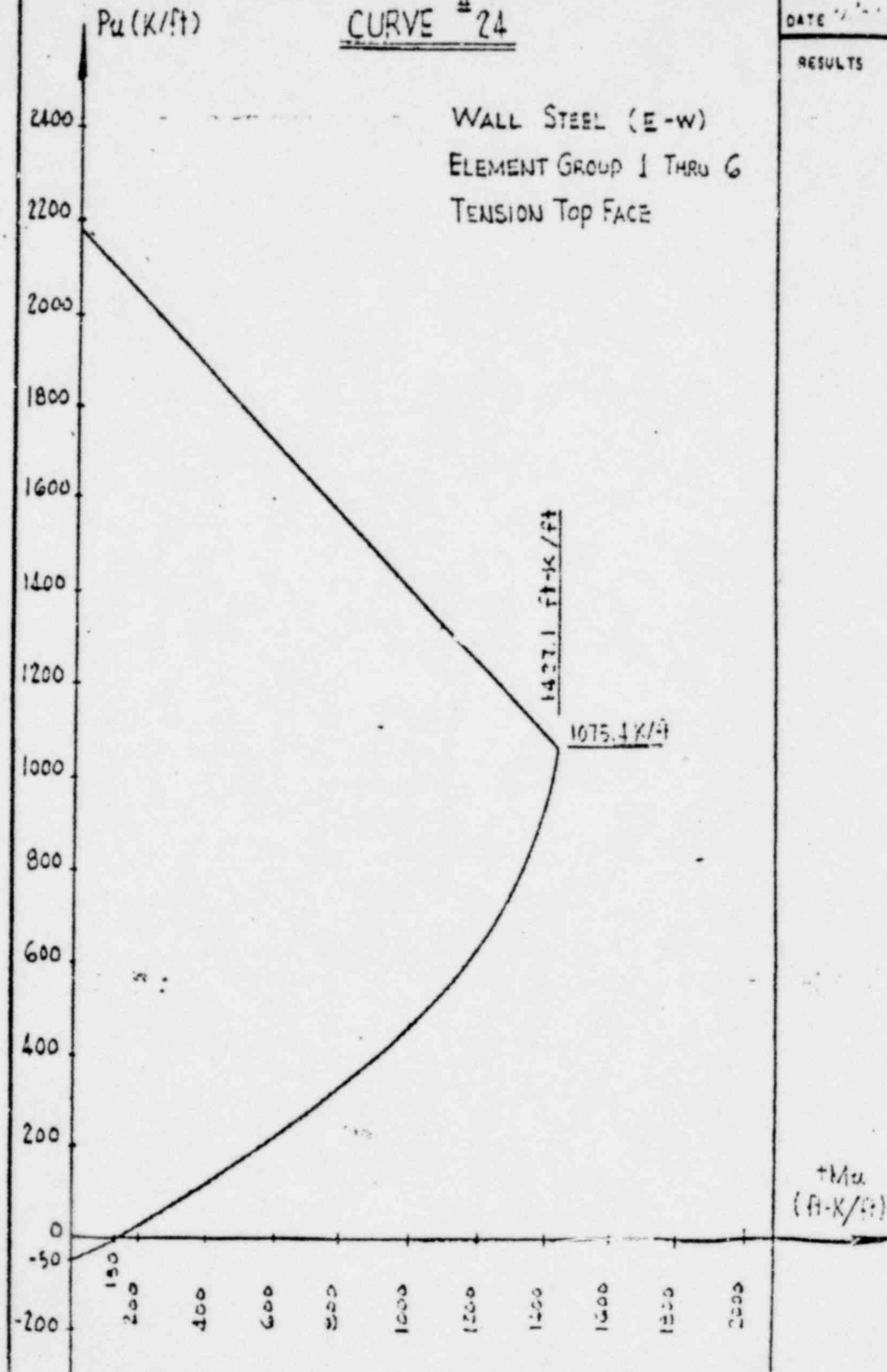

Y COORD. = + 33.00
SECTION 3
EL. 348'
POOL A
EAST WALL
EL. 305'
ELEVATION

FIGURE 9


Y COORDINATE = 0.0
COMMON WALL
POOL B WEST WALL
POOL A WEST WALL
ELEVATION
SECTION 4
FIGURE 10

GILBERT ASSOCIATES INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT METROPOLITAN EDISON CO.	FILING CODE	
	PROJECT TMI UNIT #1	W.O.	PAGE OF
SYSTEM SPENT FUEL POOL REANALYSIS		ORIGINATOR DATE	
CALCULATION FOR SECTION CAPACITY · CRITICAL SECTION 2		REVIEWER L.R. [illegible] DATE	

RESULTS



GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: METROPOLITAN EDISON CO.

PROJECT: TMI UNIT #1

FILING CODE

W.O. | PAGE | OF

ORIGINATOR

DATE

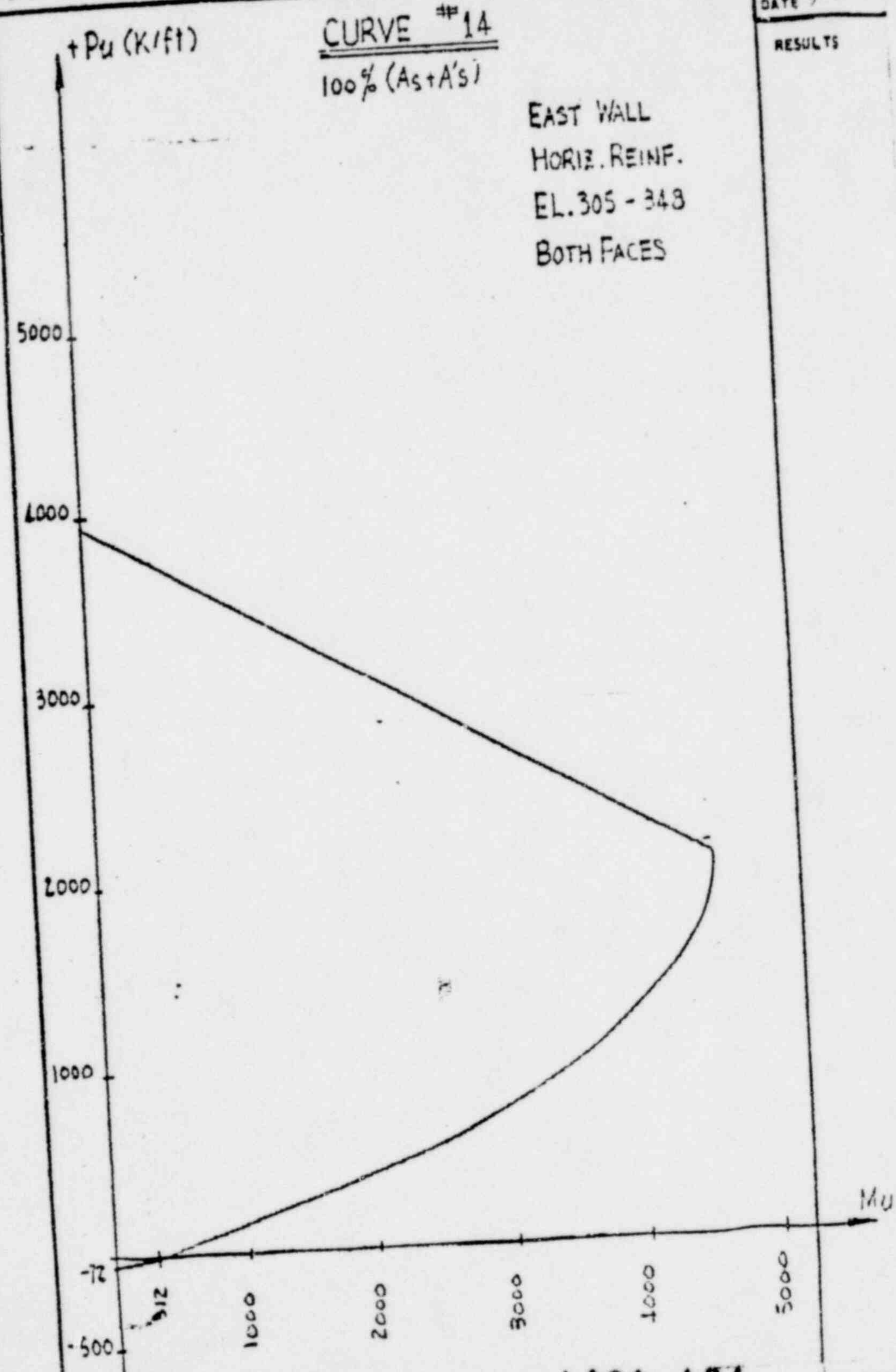
SYSTEM: SPENT FUEL POOL REANALYSIS

CALCULATION FOR: INTERACTION DIAGRAMS - CRITICAL SECTION 3

REVIEWER

DATE 7/...

RESULTS



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ENGINEERS AND CONSULTANTS READING, PA.	PROJECT TMI UNIT #1	W.O.	PAGE OF
SYSTEM SPENT FUEL POOL REANALYSIS		ORIGINATOR	DATE
CALCULATION FOR SECTION CAPACITIES - CRITICAL SECTION 1		REVIEWER L.B.	DATE
		RESULTS	

CURVE #9

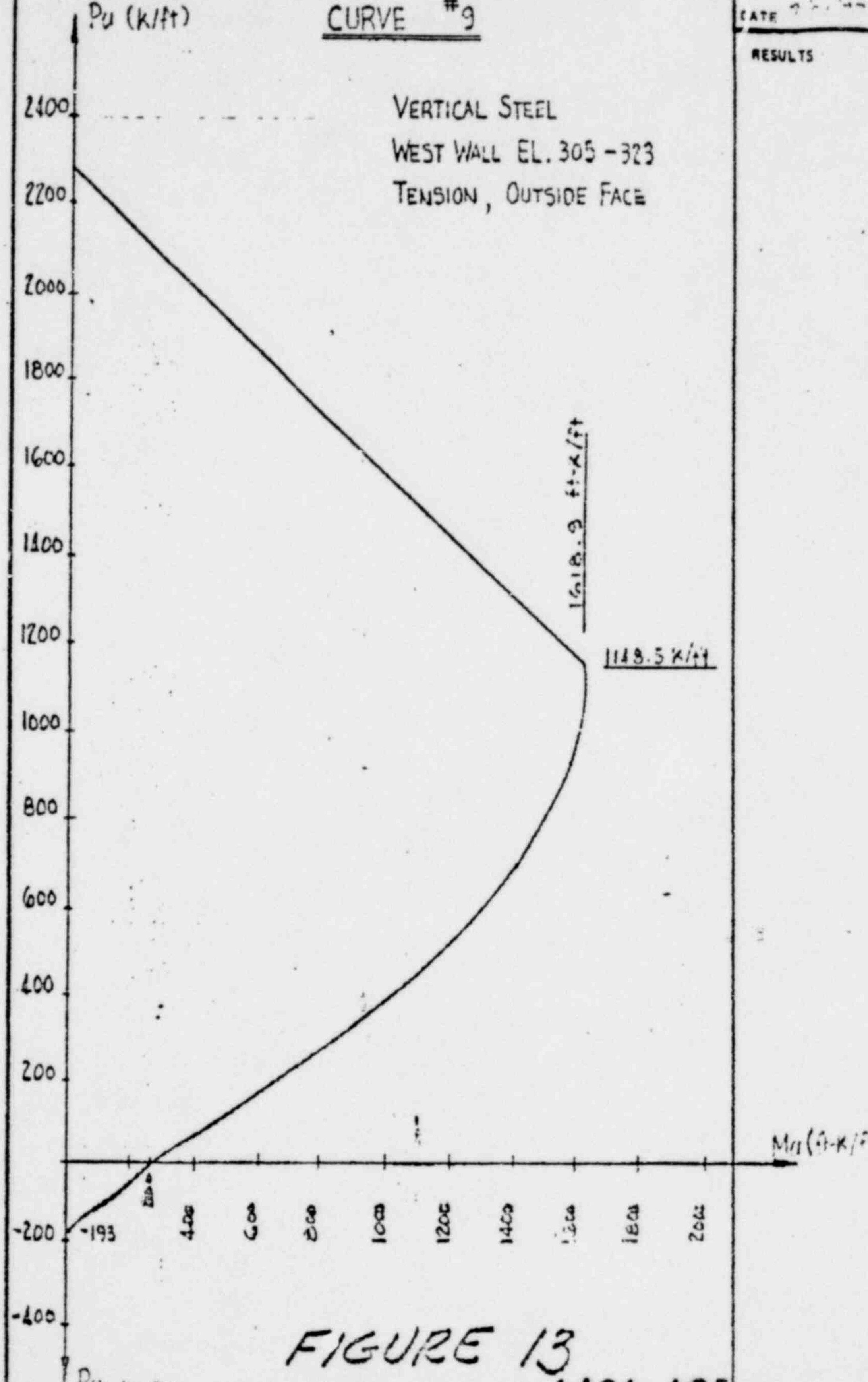

FIGURE 13

1491-105