GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

May 19, 1993

Docket No. STN 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Review Schedule - **Revision of Appendix 3A**

Dear Chet:

Enclosed are the revised pages to Appendix 3A, Seismic Soil-Structure Interaction Analysis. The summary of the changes is provided on the first page of the enclosure.

Please provide a copy of this transmittal to Tom Cheng.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Gary Ehlert (GE)
Norman Fletcher (DOE)
Ting-Yu Lo (LLNL)

JF93-165

ABWR SEISMIC SOIL-STRUCTURE INTERACTION ANALYSIS REPORT, REV. 2, APRIL 1993

SUMMARY OF CHANGES OF THIS REVISION:

1. Text:

Page No.	Paragraph	Comments
3A-10	1	Revised
3A-60	1	Revised
3A-63	1	Added
3A-80	-	Added

In addition, the equations in sub-section 3.A.3 through 3.A.5 are re-numbered to be compatible with each sub-section.

The shear modulus and material damping of soil are strain dependent. Figure 3A.3-3 shows the variation of shear modulus and damping ratio with shear strain for various soil profiles considered. The soil curves shown correspond to average curves of Reference 6. On the basis of the recommendations made in Ref. 3 the soil material damping of a hysteretic nature is limited to a maximum of 15% of critical. In addition to use of average soil curves, a parametric study was performed in which the upper bound shear modulus soil degradation curve of Ref. 6 is used. This curve is the same as the shear modulus degradation curve reported in Ref. 7 for sands. The results of this case are presented in Section 9. Variation of shear modulus and damping for rock profiles (VP5 and VP7) are shown in Figure 3A.3-4. The shear modulus reduction factors and damping ratios at various strain levels are shown in Tables 3A.3-3 and 3A.3-4. For VP7 profile, the free-field site response analysis results has shown that the strain-compatible shear modulus and material damping are essentially unchanged from their initial values. The SSI analysis for R profile is performed using uniform velocity of 6098 m/sec (20,000 ft/sec). 2

3A.3.3 Ground Water Table

The effect of ground water on the soil properties is considered using the following procedure:

(a) Perform one dimensional convolution or deconvolution analysis for the horizontal excitation component to obtain strain compatible shear modulus, G, corresponding to the induced strain level. The corresponding shear wave velocity, V_s, is then computed as

$$V_S = \sqrt{G/\rho} \qquad \text{(3A.3-3)}$$

3A.9.5 Effects of Change in Soil Degradation Curve

For all SSI soil cases, strain-compatible soil properties were obtained using free-field SHAKE analysis results as discussed in Section 3A.6. For the free-field analysis, the strain-dependent soil properties were obtained from the generic Seed and Idriss soil curves (Ref 6) using the mean curves. Recent data indicate that the amount of soil degradation due to shaking can be less than the mean values of the generic curves and is closer to the upper bound of the 1970 soil curves (Ref 6). The soil shear modulus degradation curves (mean and upper bound) are shown in Figure 3A.9-5.1. The upper bound of the 1970 soil shear modulus curve is the same as the curve reported for sand in Ref. 7.

2

In order to evaluate the effect of change in soil degradation curves on SSI responses, the soil case with velocity profile VP3 and soil column depth of 150 ft. was re-analyzed using the upper bound soil degradation curve. The results of the analysis in the horizontal X- direction for this case (SSI case VP3D1AX) are compared with the respective SSI case results using the mean curve (SSI case VP3D1X) and the very rigid soil case results (R1UX) for both the reactor and control buildings in Figures 3A.9-5.2 through 3A.9-5.7. As shown in these results, the effect of change in soil degradation curve on the spectral values is insignificant. The effect on the seismic forces is shown in Table 3A.9-5.1. The effect on seismic forces is also insignificant.

Based on these results, variation of soil degradation for other soil cases was not considered warranted. The results based on mean soil degradation curve were used to obtain the enveloping responses.

The results in terms of seismic soil pressure were also computed. As expected, seismic soil pressure in between the reactor building and control building increased due to structure-to-structure interaction effect. The seismic soil pressure results obtained from analysis of individual buildings as well as multiple buildings were enveloped and used in the design of respective walls of each building. The enveloping seismic soil pressure results are shown in Table 3.9.7.4. 2

Based on these results, except for seismic soil pressure, consideration to structure-to-structure interaction effect is not warranted for the purpose of obtaining enveloping seismic forces and floor acceleration response spectra. Consequently, the enveloping results presented in Section 3A.10 are based on the analysis of each individual building.

7. Idriss, I.M.--*Response of Soft Soil Sites During Earthquakes*, H. Bolton Seed Memorial Symposium Proceedings, Volume 2, Bi Tech Publishers, May 1990.

2

ABWR SEISMIC SOIL-STRUCTURE INTERACTION ANALYSIS REPORT, REV. 2, APRIL 1993

SUMMARY OF CHANGES OF THIS REVISION:

2. Tables:

Table No.	Comments
3A.6-2	Revised
3A.9-7.4	Added
3A.10-1.3d	Deleted
3A.10-4.1a,b,c & d	Revised
3A.10-4.3c	Revised

In addition, unit conversion scale factors are added as a note for each table.

Table 3A.6-2

SSE Free-Field Site Response Results
for All Soil Profiles (Average Properties)

SOIL PROFILE ID	AVERAGE SHEAR WAVE VELOCITY m/sec (ft/sec)	SOIL COLUMN FREQUENCY (CPS)
UB1D85a	283 (927)	2.73
VP3D85a	499 (1638)	4.82
UB1D150	320 (1050)	1.75
UB2D150	320 (1050)	1.75
UB3D150	320 (1050)	1.75
VP3D150	487 (1599)	2.67
VP4D150	659 (2161)	3.60
VP5D150	877 (2877)	4.80
UB1D200	345 (1131)	1.41
VP3D200	483 (1585)	1.98
UB1D300	431 (1415)	1.18
VP3D300	486 (1595)	1.33
VP7D300	1486 (4876)	4.06
R Cases	6097 (20000)	> 33

2

TABLE 3A.9-7.4

Effect of Adjacent Buildings
Enveloping Seismic Soil Pressures

Elevation (m)	R/B (tsm)	C/B (tsm)
12.0 to 9.9	94	94
9.9 to 7.9	44	44
7.9 to 6.3	22	26
6.3 to 4.8	16	14
4.8 to 3.5	15	22
3.5 to 0.90	12	14
0.90 to -1.7	17	17
-1.7 to -3.8	24	24
-3.8 to -5.9	16	34
-5.9 to -8.2	40	40

TABLE 3A.10-4.1a

ABWR REACTOR BUILDING
SUMMARY OF ENVELOPING MAXIMUM RELATIVE DISPLACEMENTS

REACTOR BUILDING: BUILDING WALLS AND FLOORS

Reference Motion: Displacement at Free-Field Grade Level

NODE NO.	ELEV. TMSL(m)	LOCATION	MAX. REL. DISPLACEMENT (mm)	
			HORIZONTAL	VERTICAL
95	49.70	R/B	28.5	7.4
96	38.20	R/B	22.3	6.7
98	31.70	R/B	18.7	6.8
100	23.50	R/B	13.7	5.8
102	18.10	R/B	10.1	5.6
103	12.30	R/B	7.5	5.4
104	4.80	R/B	8.2	5.0
105	-1.70	R/B	8.8	4.7
88	-8.20	R/B	12.0	4.3

NOTE: (1) Horizontal displacements are the envelopes of X and Y direction responses
(2) The results represent the maximum responses at the respective floor elevation
(3) 1 mm = 0.0394 inches

TABLE 3A.10-4.1b

ABWR REACTOR BUILDING
SUMMARY OF ENVELOPING MAXIMUM RELATIVE DISPLACEMENTS

REACTOR BUILDING: RCCV

Reference Motion: Displacement at Free-Field Grade Level

NODE NO.	ELEV. TMSL(m)	LOCATION	MAX. REL. DISPLACEMENT (mm)	
			HORIZONTAL	VERTICAL
89	31.70	RCCV	18.7	4.1
90	23.50	RCCV	13.7	6.6
91	18.10	RCCV	10.1	6.4
92	12.30	RCCV	7.5	5.6
93	4.80	RCCV	8.2	3.9
94	-1.70	RCCV	8.8	3.3
88	-8.20	RCCV	12.0	4.3

NOTE: (1) Horizontal displacements are the envelopes of X and Y direction responses
(2) The results represent the maximum responses at the respective floor elevation
(3) 1 mm = 0.0394 inches

TABLE 3A.10-4.1c

ABWR REACTOR BUILDING
SUMMARY OF ENVELOPING MAXIMUM RELATIVE DISPLACEMENTS

REACTOR BUILDING: RSW/PED

Reference Motion: Displacement at Free-Field Grade Level

NODE NO.	ELEV. TMSL(m)	LOCATION	MAX. REL. DISPLACEMENT (mm)	
			HORIZONTAL	VERTICAL
70	21.20	RSW/PED	11.1	2.2
78	18.44	RSW/PED	9.5	2.2
79	17.02	RSW/PED	8.9	2.2
80	15.60	RSW/PED	8.1	2.2
81	13.95	RSW/PED	7.6	2.2
82	12.30	RSW/PED	7.6	2.7
71	8.20	RSW/PED	8.0	2.6
83	7.00	RSW/PED	8.1	2.6
72	4.50	RSW/PED	8.3	2.5
84	3.50	RSW/PED	8.4	2.4
73	1.70	RSW/PED	8.6	2.4
85	-0.18	RSW/PED	8.9	2.4
86	-2.10	RSW/PED	9.8	2.2
87	-4.70	RSW/PED	10.8	2.2
88	-8.20	RSW/PED	12.0	4.3

NOTE: (1) Horizontal displacements are the envelopes of X and Y direction responses
(2) The results represent the maximum responses at the respective floor elevation
(3) 1 mm = 0.0394 inches

2

TABLE 3A.10-4.1d

ABWR REACTOR BUILDING
SUMMARY OF ENVELOPING MAXIMUM RELATIVE DISPLACEMENTS

REACTOR BUILDING: RPV/INTERNALS

Reference Motion: Displacement at Free-Field Grade Level

NODE NO.	ELEV. TMSL(m)	LOCATION	MAX. REL. DISPLACEMENT (mm)	
			HORIZONTAL	VERTICAL
17	16.48	RPV	10.8	1.6
18	15.68	RPV	10.3	1.6
25	9.65	RPV	7.7	1.6
27	6.75	RPV	8.0	1.6
28	26.06	RPV	14.9	1.6
33	20.49	RPV	11.0	3.2
36	17.18	RPV	9.0	2.8
38	15.68	RPV	8.5	2.8
46	9.29	RPV	7.9	2.8
50	5.95	RPV	8.1	1.6
51	5.49	RPV	8.2	1.6
52	4.82	RPV	8.2	1.6
60	1.65	RPV	8.4	1.6
66	1.65	RPV	10.6	1.6

NOTE: (1) Horizontal displacements are the envelopes of X and Y direction responses
(2) 1 mm = 0.0394 inches

TABLE 3A.10-4.3c

ABWR REACTOR BUILDING
SUMMARY OF ENVELOPING MAXIMUM RELATIVE DISPLACEMENTS

REACTOR BUILDING: RSW/PED

Reference Motion: Displacement at Node 88

NODE NO.	ELEV. TMSL(m)	LOCATION	MAX. REL. DISPLACEMENT (mm)	
			HORIZONTAL	VERTICAL
70	21.20	RSW/PED	8.8	2.2
78	18.44	RSW/PED	8.0	2.2
79	17.02	RSW/PED	7.4	2.2
80	15.60	RSW/PED	6.9	2.2
81	13.95	RSW/PED	6.3	2.7
82	12.30	RSW/PED	5.8	2.7
71	8.20	RSW/PED	4.6	2.6
83	7.00	RSW/PED	4.2	2.6
72	4.50	RSW/PED	3.4	2.4
84	3.50	RSW/PED	3.1	2.3
73	1.70	RSW/PED	2.5	2.0
85	-0.18	RSW/PED	2.7	2.0
86	-2.10	RSW/PED	1.6	1.4
87	-4.70	RSW/PED	1.3	1.4
88	-8.20	RSW/PED	0.0	4.0

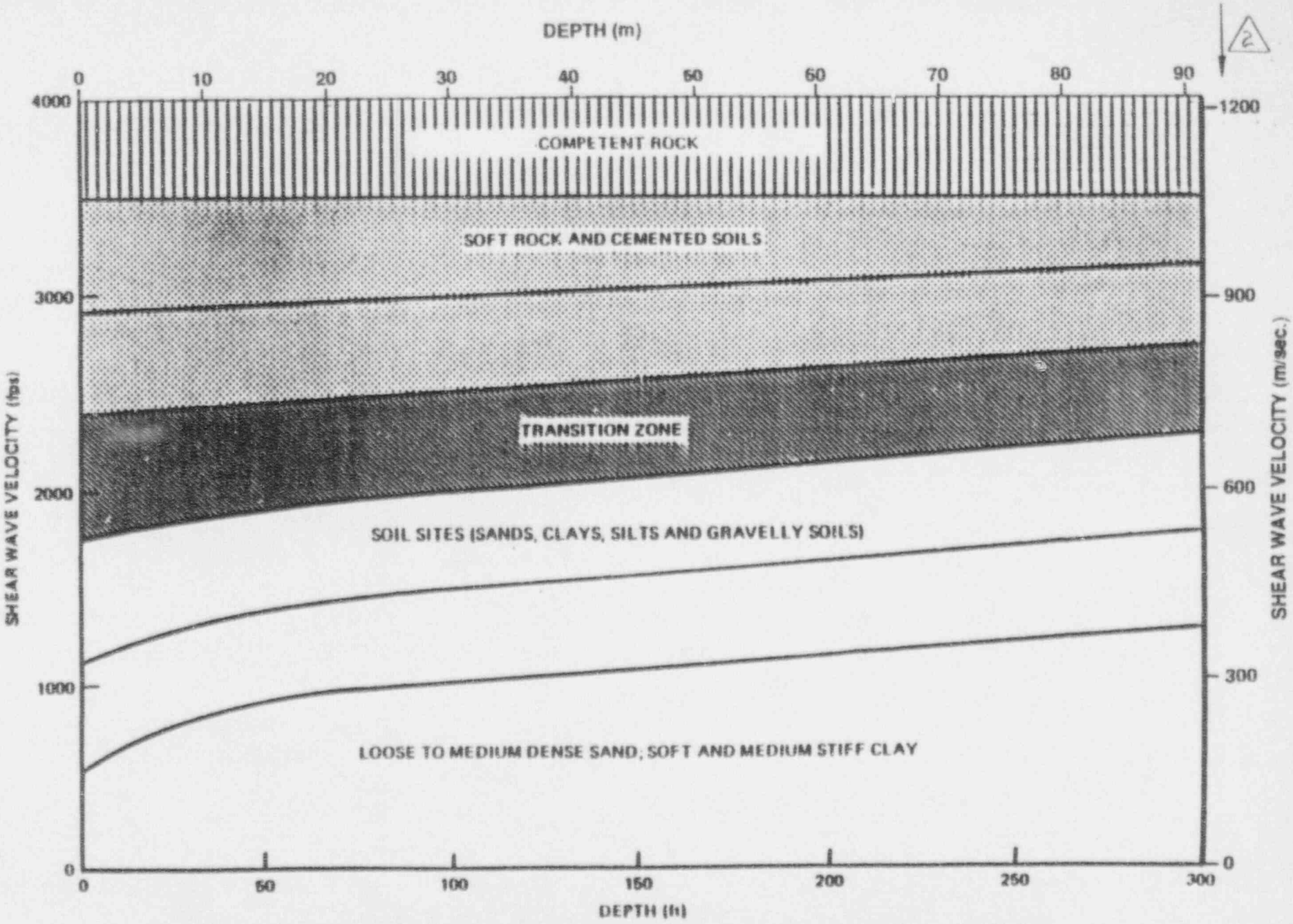
NOTE: (1) Horizontal displacements are the envelopes of X and Y direction responses
(2) The results represent the maximum responses at the respective floor elevation
(3) 1 mm = 0.0394 inches

ABWR SEISMIC SOIL-STRUCTURE INTERACTION ANALYSIS REPORT, REV. 2, APRIL 1993

SUMMARY OF CHANGES OF THIS REVISION:

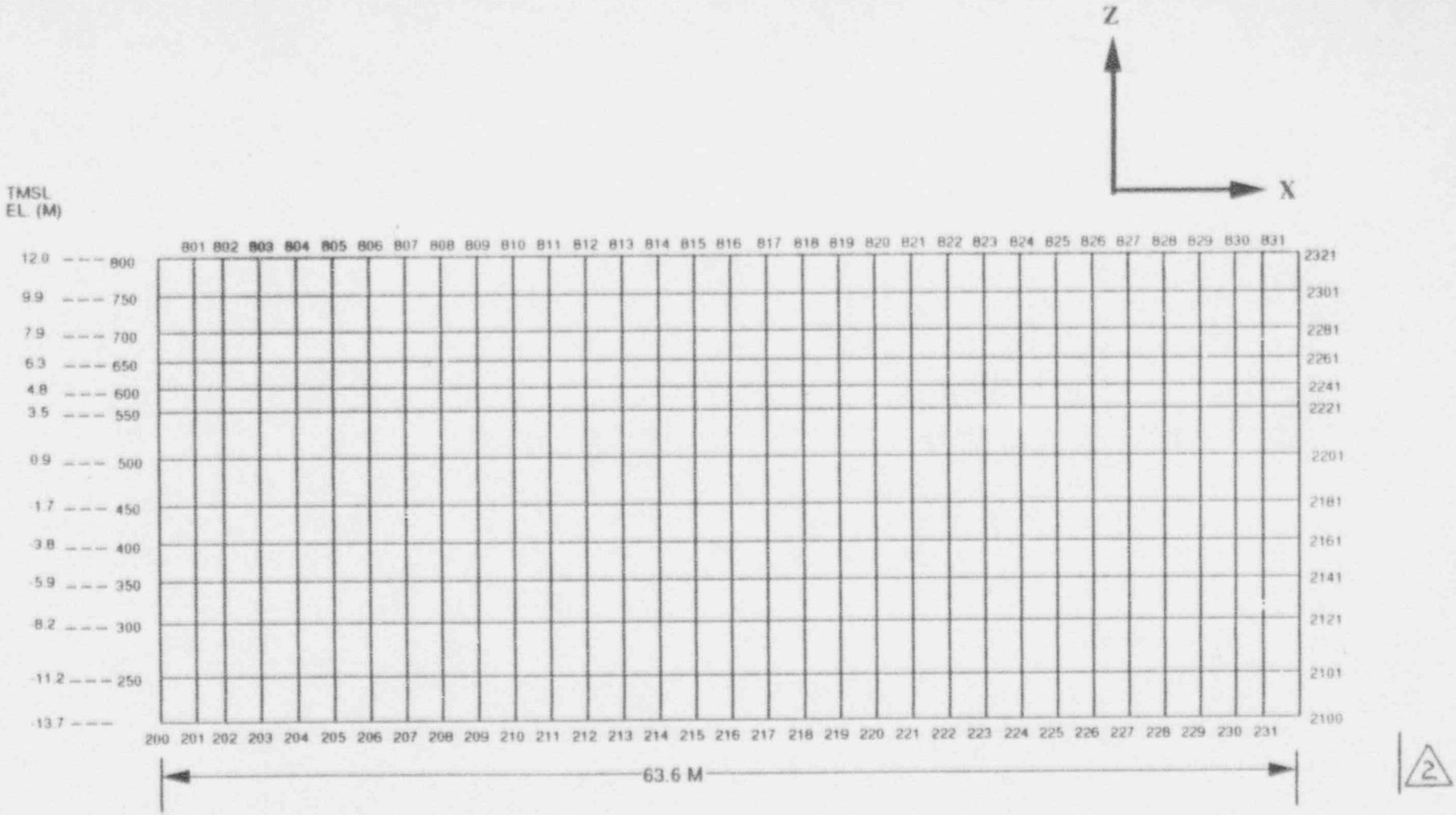
3. Figures:

Figure No.	Comments
3A.3 -2	Replaced
3A.8 -2.2	Revised
-2.5	Revised
-2.7	Revised
-2.9	Revised
-2.11	Revised
-2.13	Revised
-2.15	Revised
3A.8 -4.5	Revised
-4.6	Revised
-4.9	Revised
-4.11	Revised
-4.13	Revised
-4.15	Revised
3A.10-2.23 & 24	Replaced
-2.37 & 38	Replaced



RANGE OF SHEAR WAVE VELOCITIES FOR NUCLEAR POWER PLANT SITES IN HIGH SEISMIC AREAS

FIGURE 3A.3-2



The Excavated Soil Elements of Reactor Building
2D Model

FIGURE 3A.8-2.2

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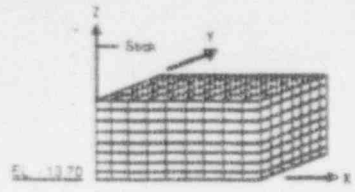
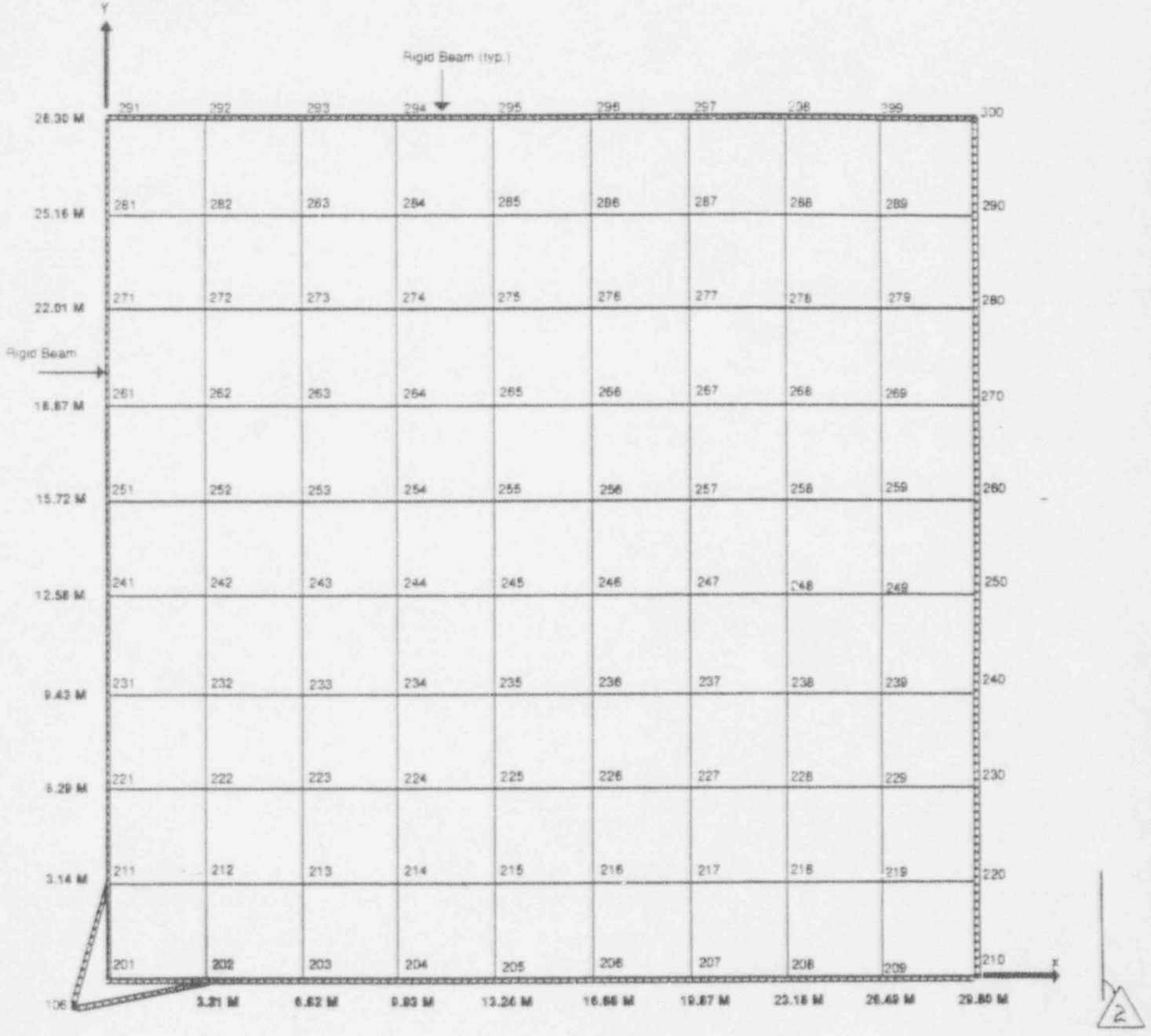
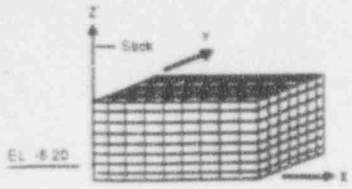
1021mf 12/21/92 19b

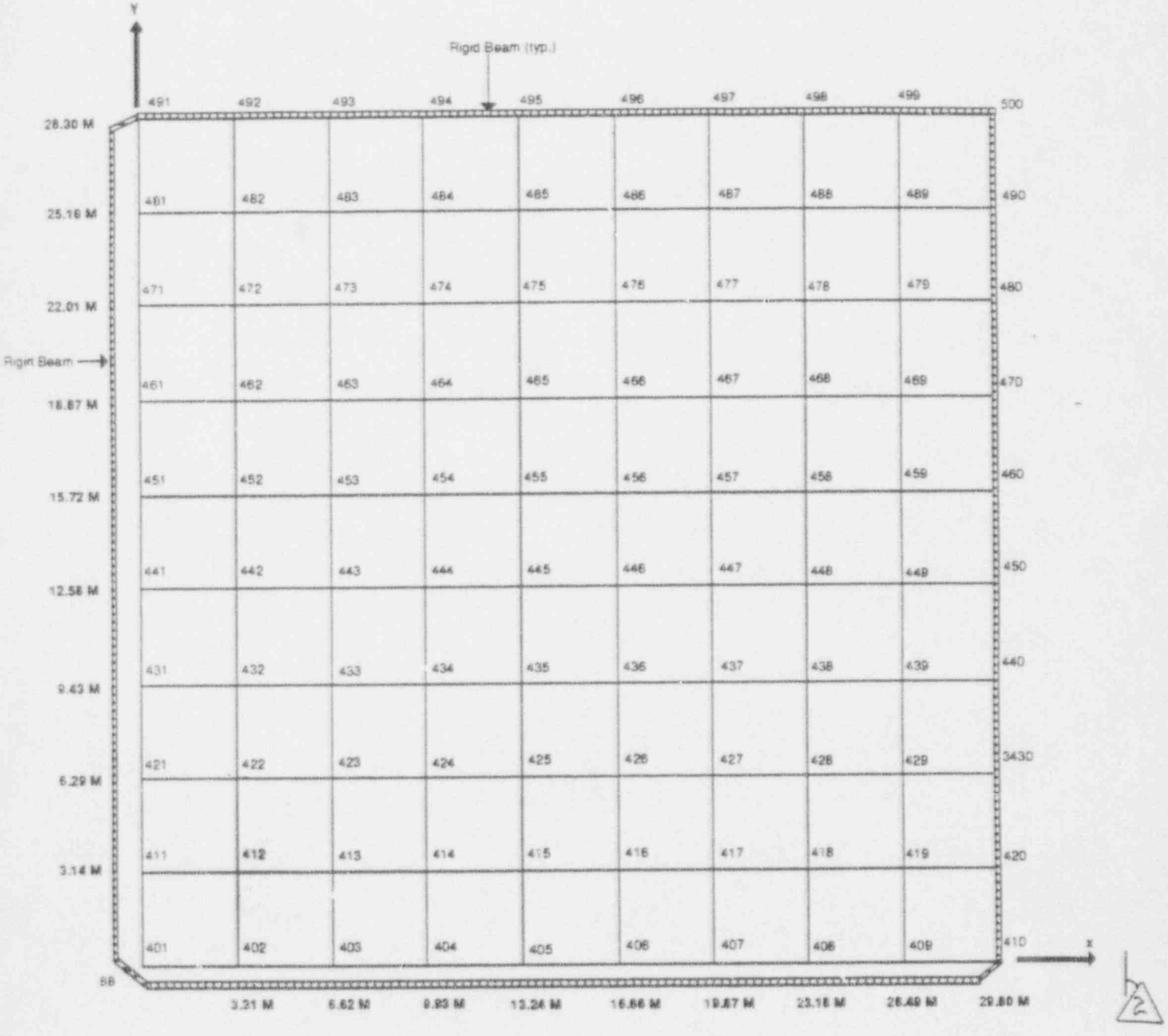




UB Case: Nodal Points @ El. -13.70 M

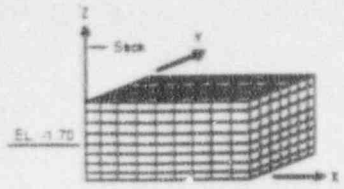
FIGURE 3A.8-2.5

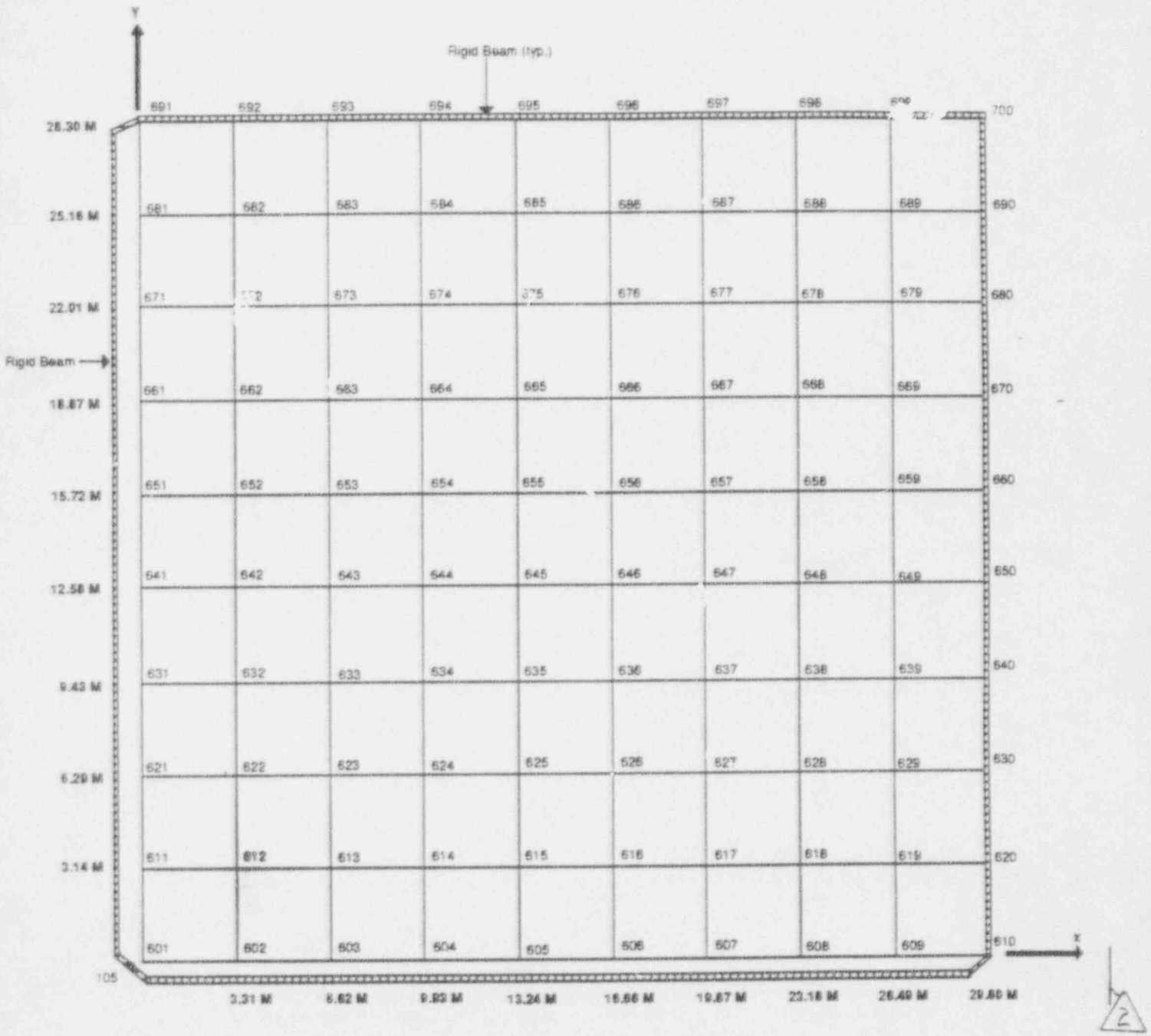




UB Case: Nodal Points @ El. -8.20 M

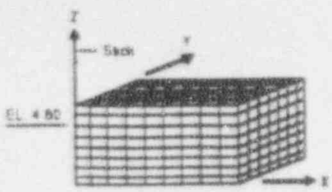
FIGURE 3A.8-2.7

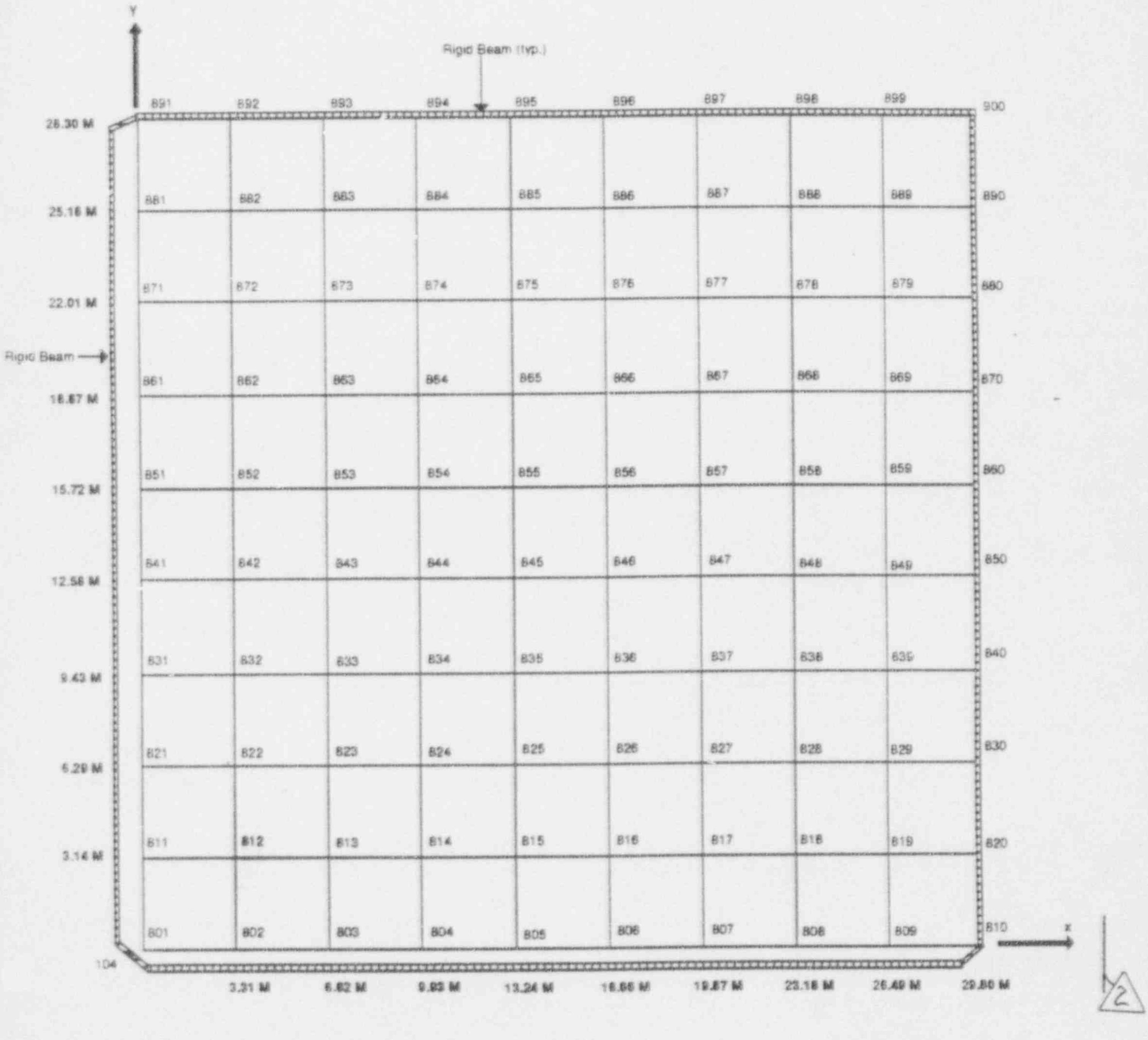




UB Case: Nodal Points @ El. -1.70 M

FIGURE 3A.8-2.9





UB Case: Nodal Points @ El. 4.80 M

FIGURE 3A.8-2.11

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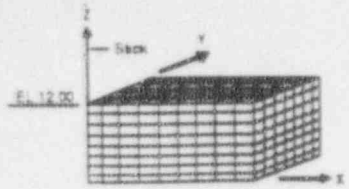
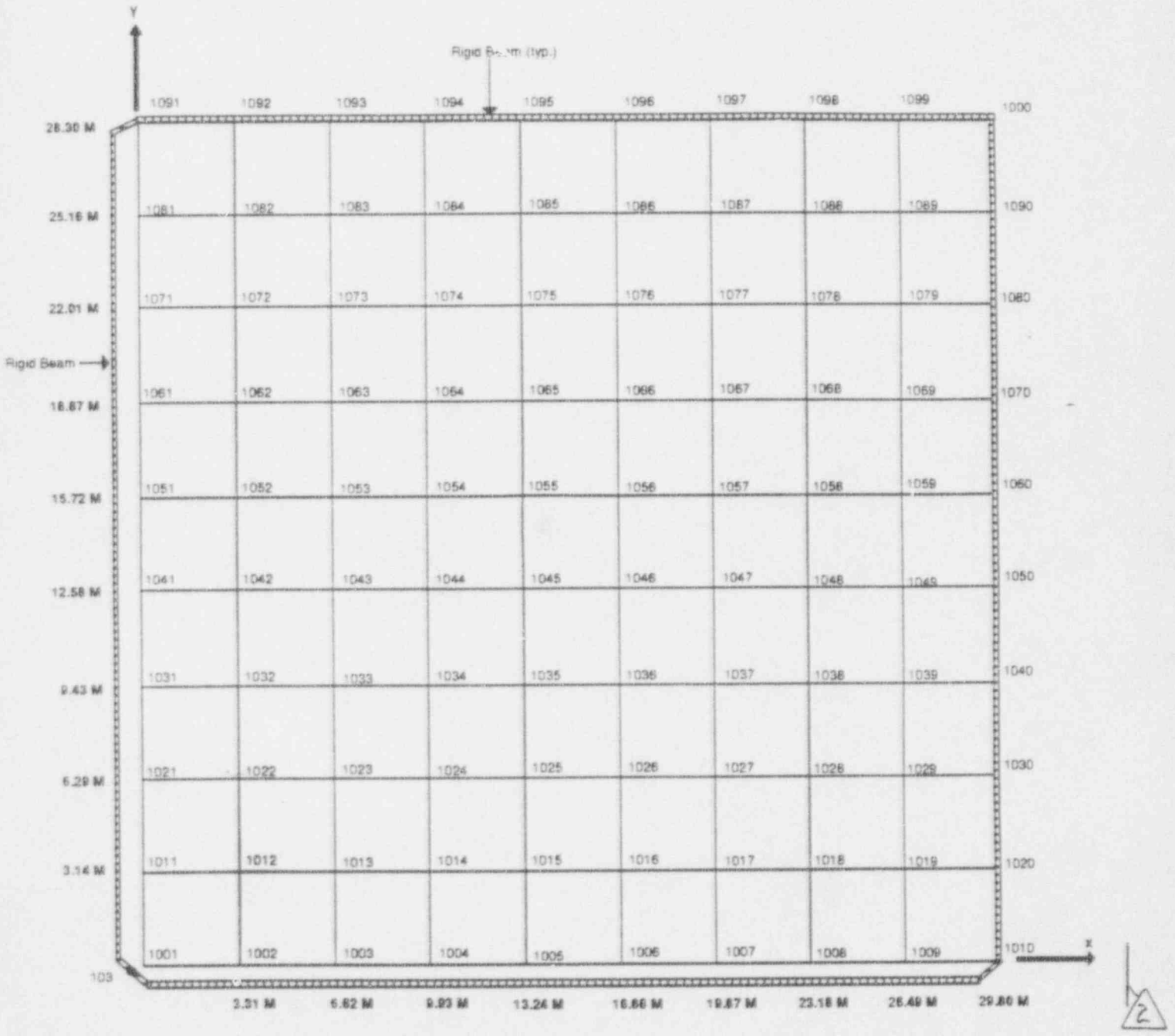
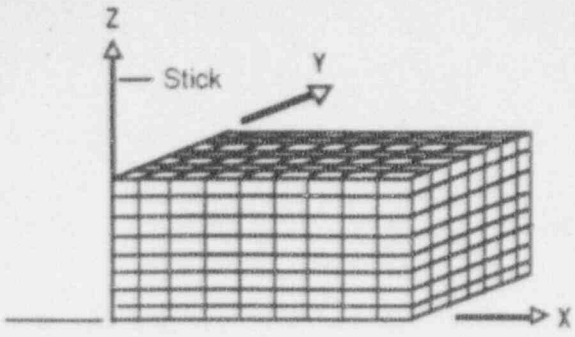
1022ml 11/9/92 (186)





UB Case: Nodal Points @ El. 12.00 M

FIGURE 3A.8-2.13



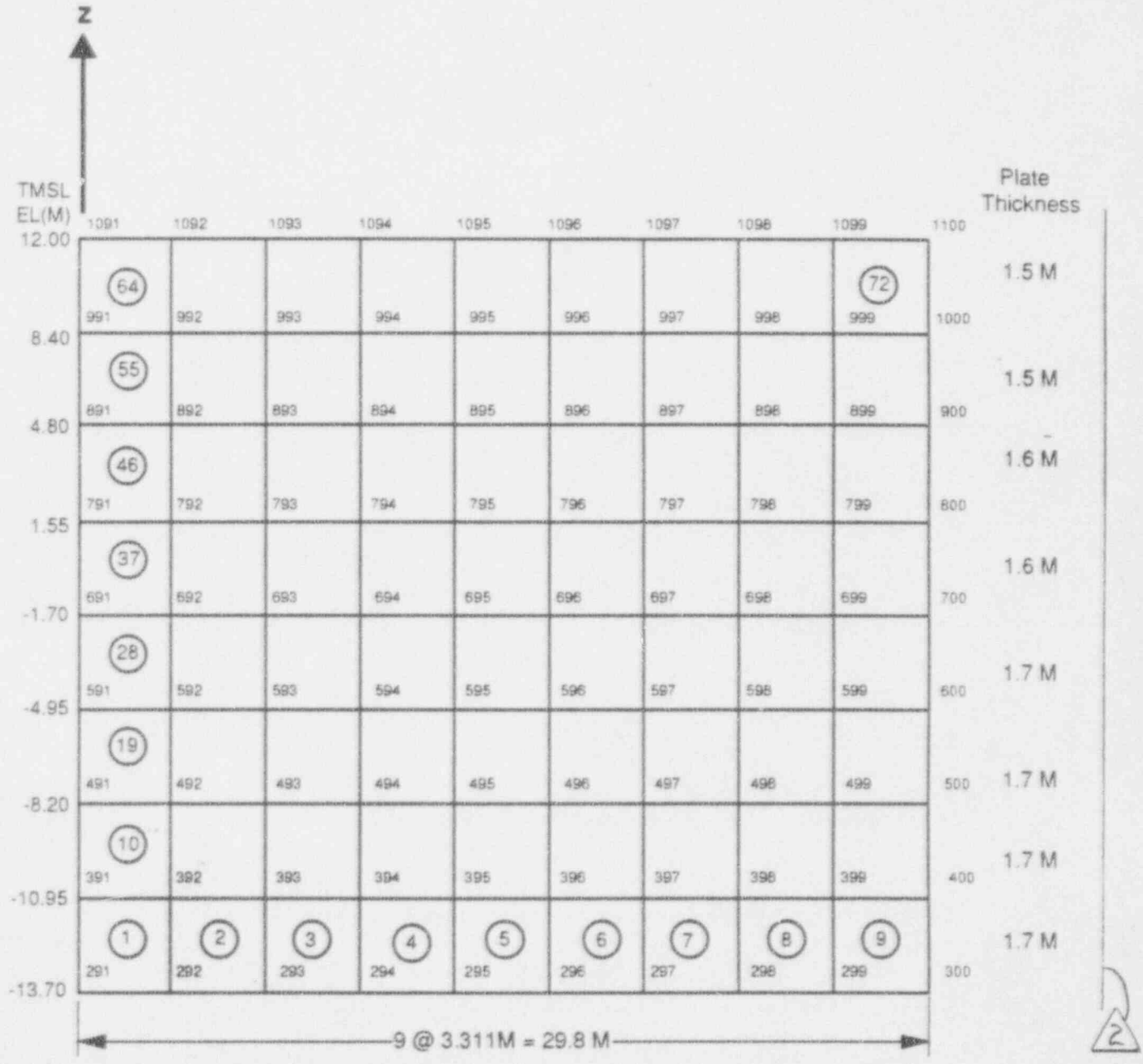
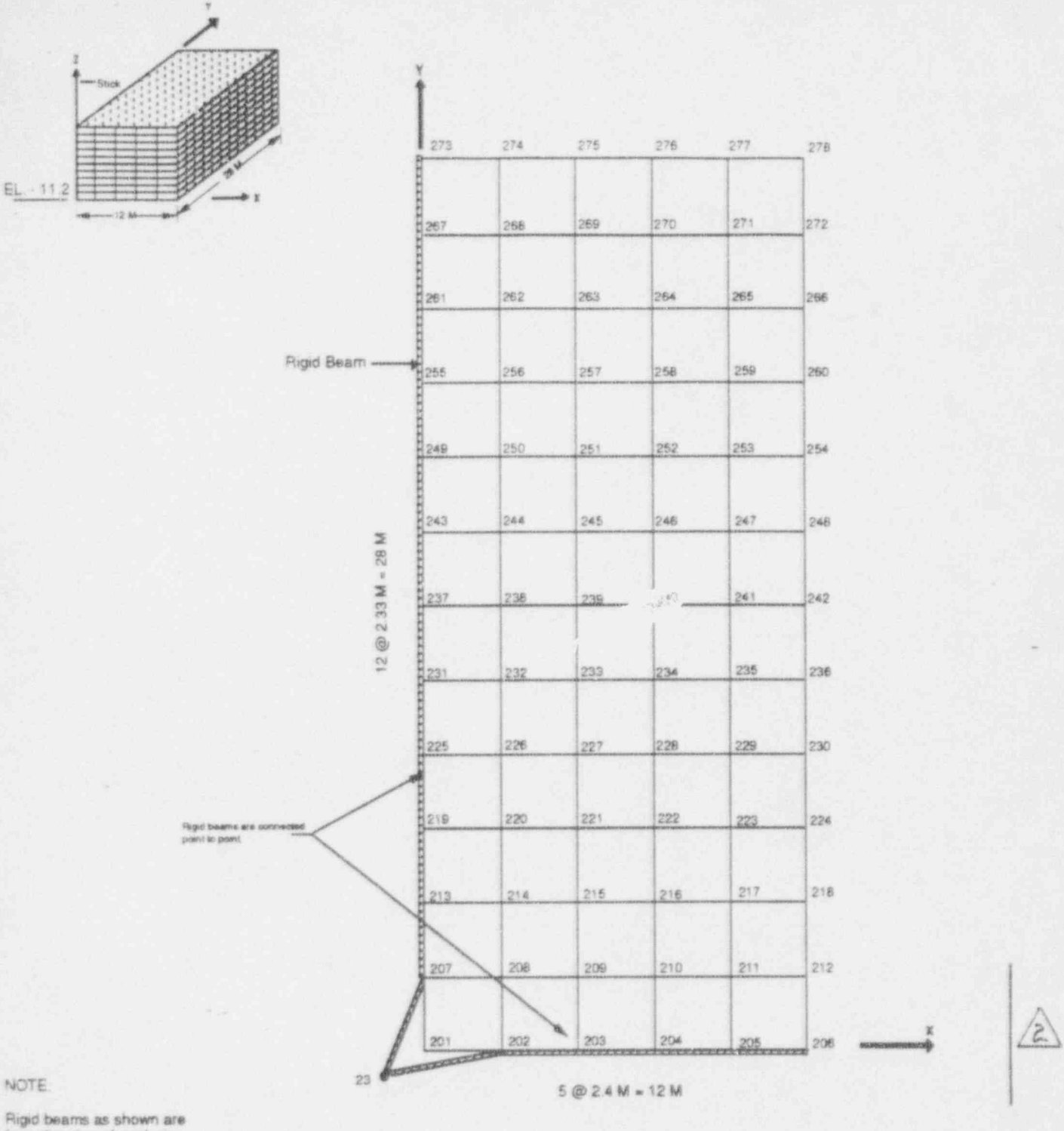


Plate Elements of the Side Wall (Y = 28.30 M)

FIGURE 3A.8-2.15

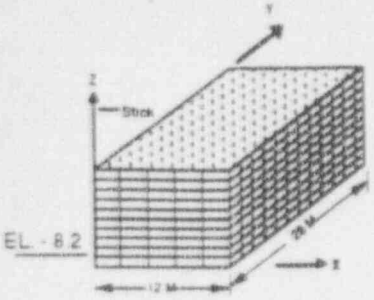


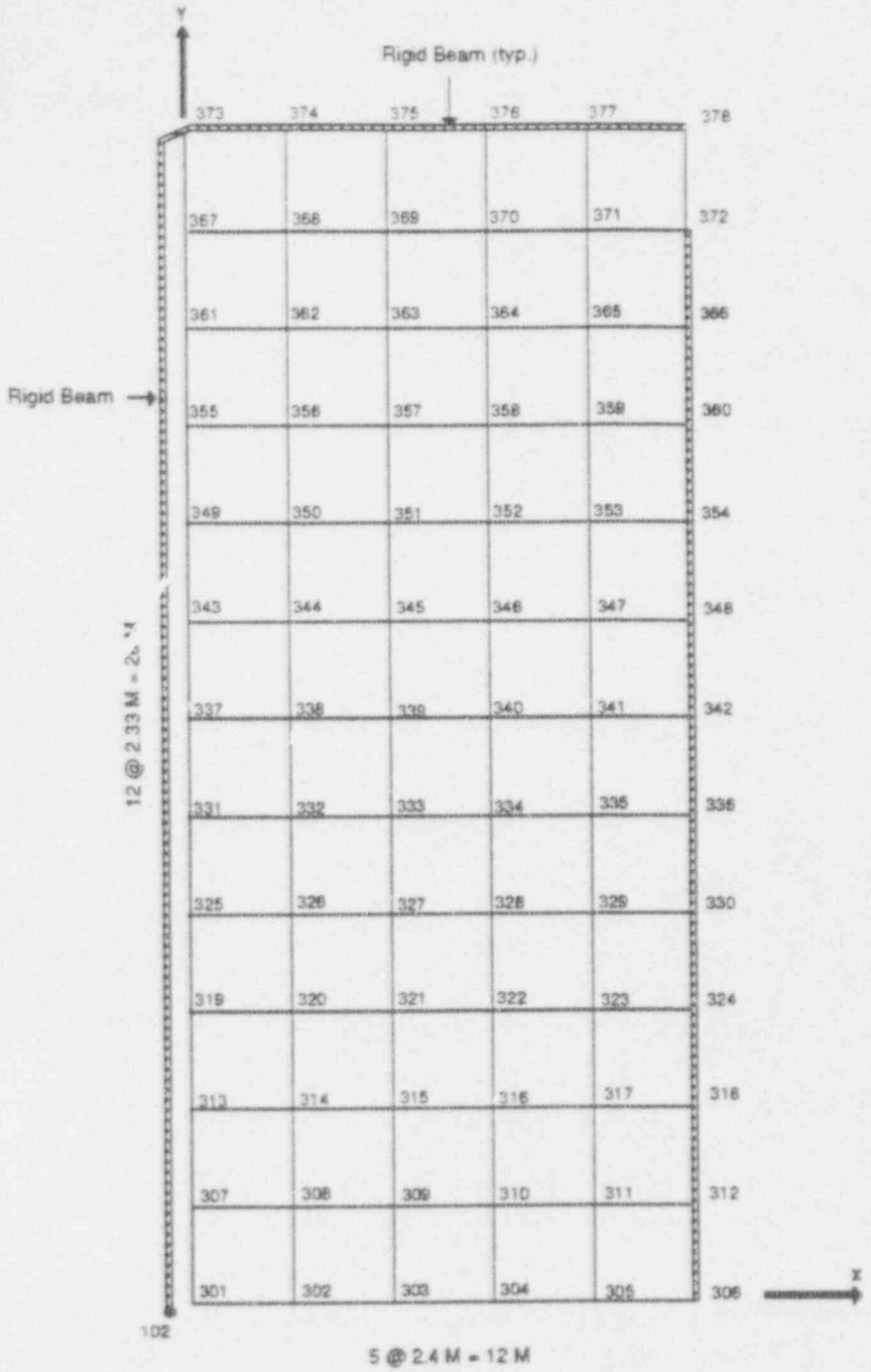
NOTE:

Rigid beams as shown are for x-direction of analysis.

UB Case: Nodal Points @ El. -11.2 M

FIGURE 3A.8-4.5



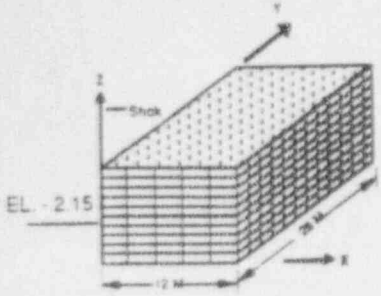


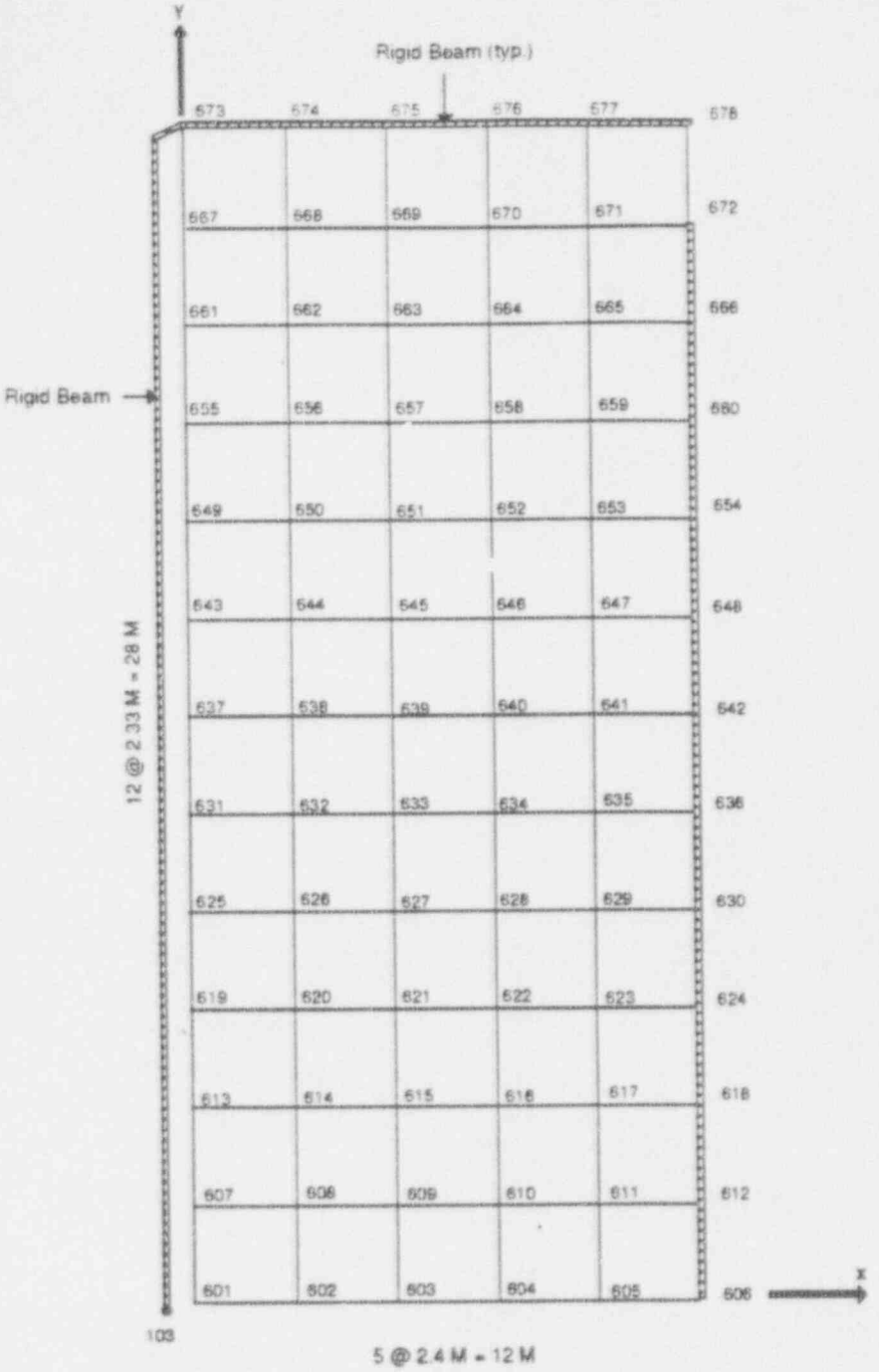
NOTE:

Rigid beams as shown are for x-direction of analysis.

UB Case: Nodal Points @ El. -8.2 M

FIGURE 3A.8-4.6



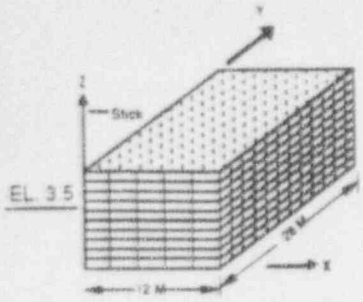


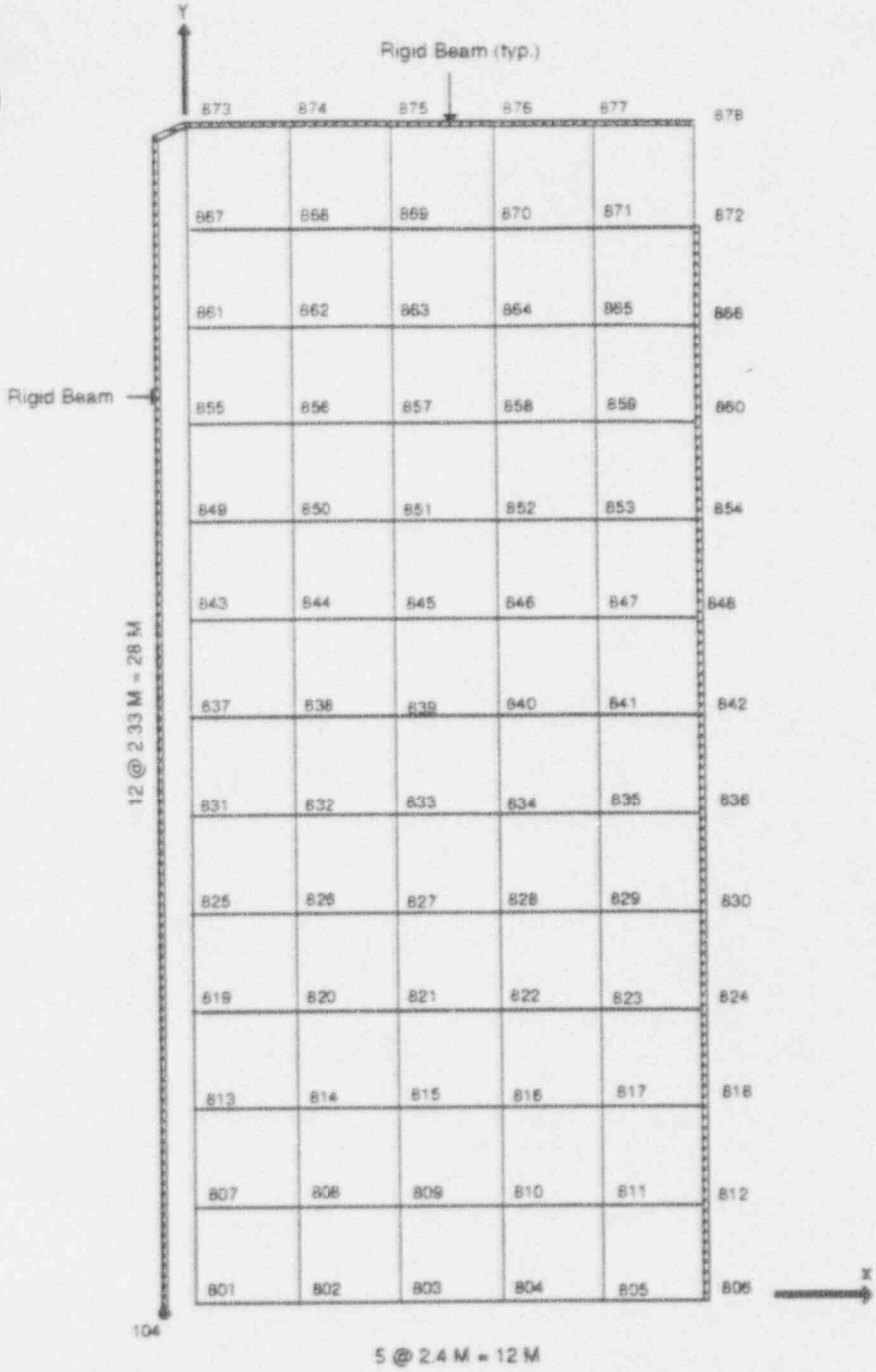
NOTE:

Rigid beams as shown are for x-direction of analysis.

UB Case: Nodal Points @ El. -2.15 M

FIGURE 3A.8-4.9



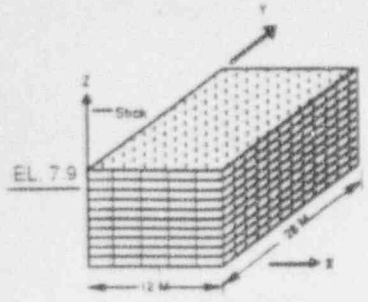


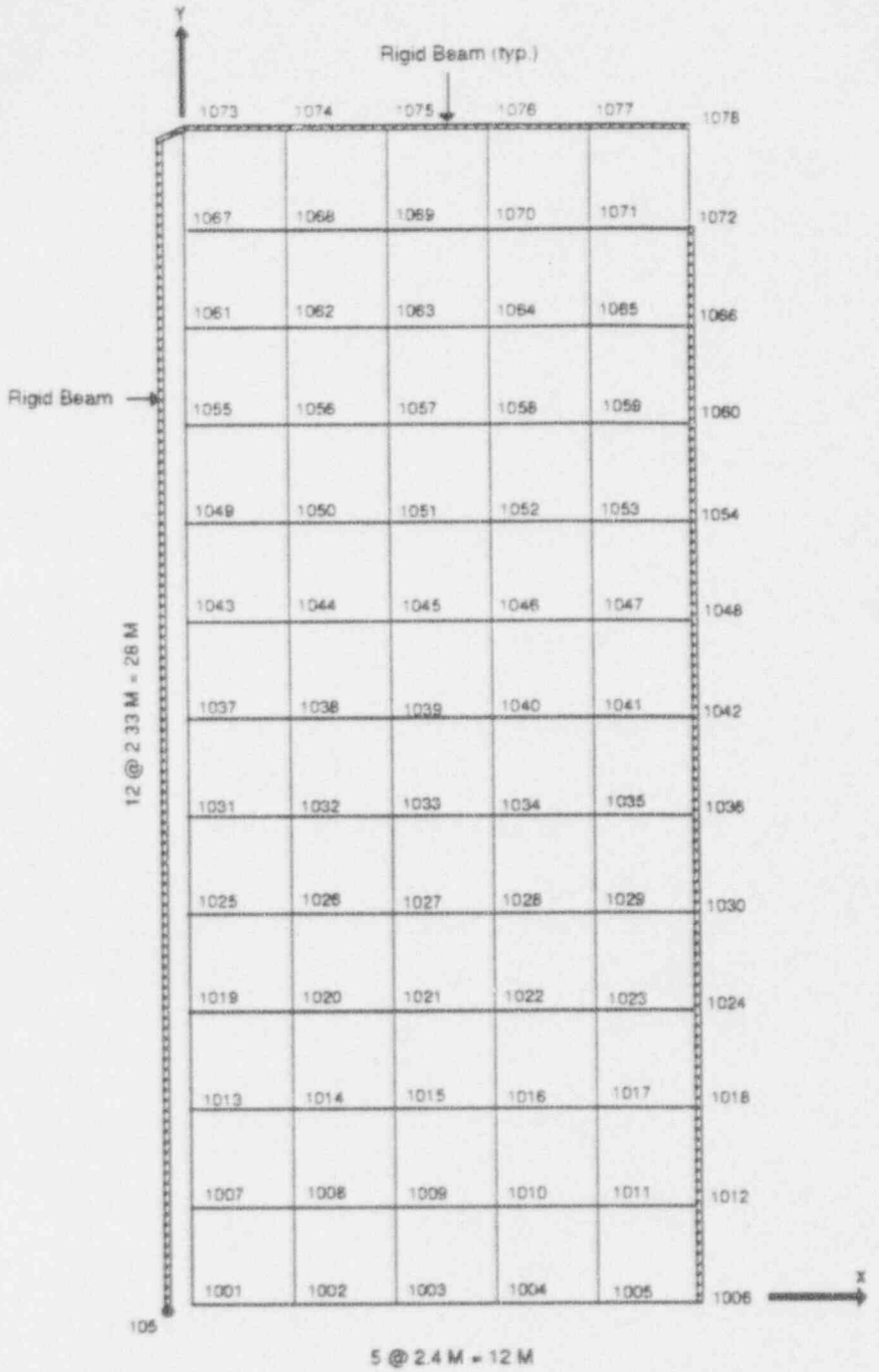
NOTE:

Rigid beams as shown are for x-direction of analysis.

UB Case: Nodal Points @ El. 3.5 M

FIGURE 3A.8-4.11



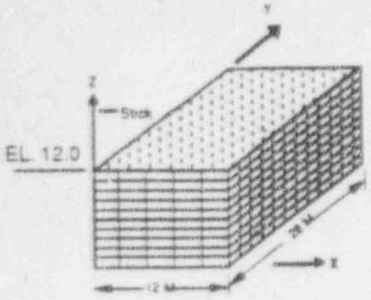


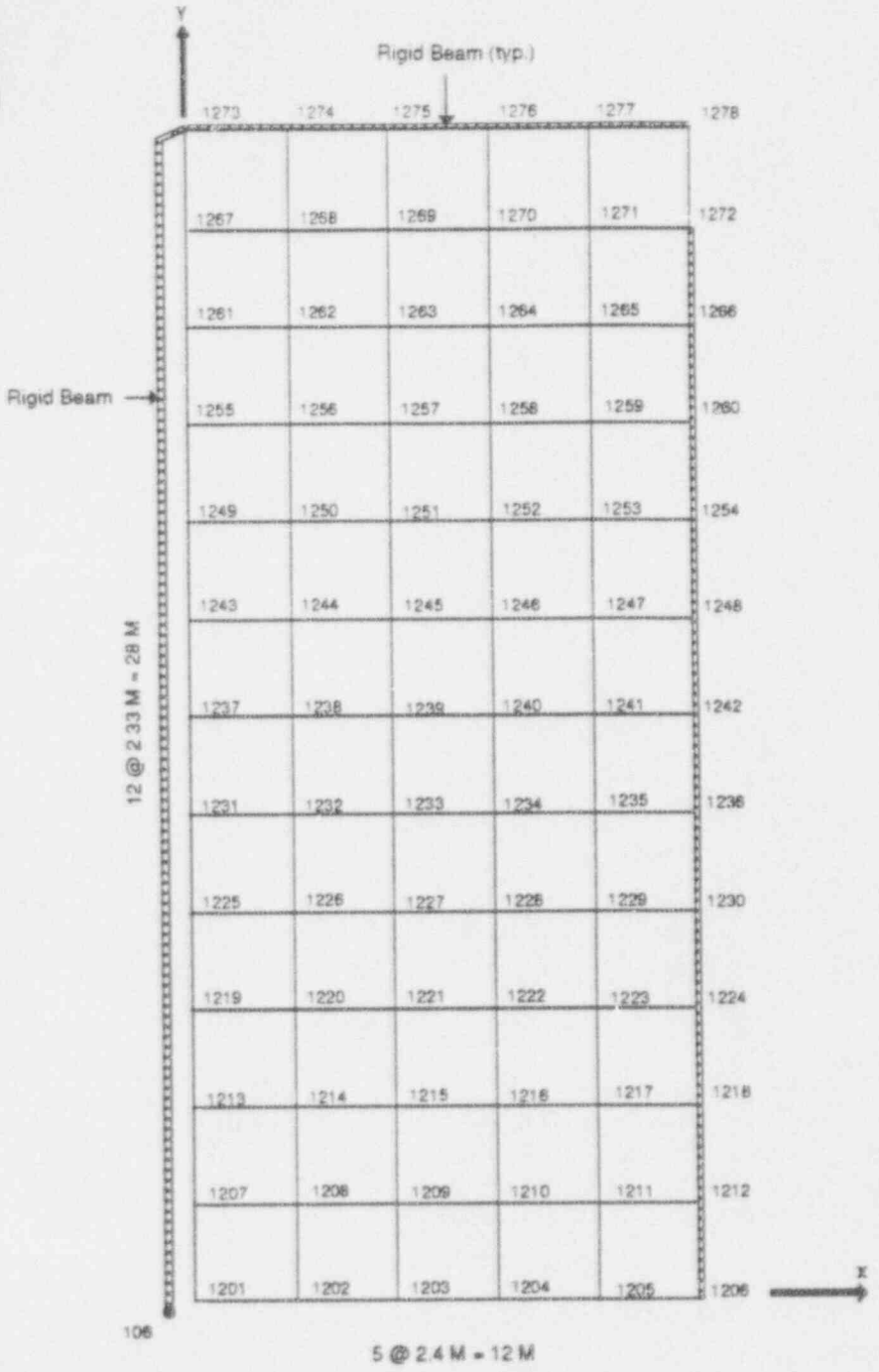
NOTE:

Rigid beams as shown are for x-direction of analysis.

UB Case: Nodal Points @ El. 7.9 M

FIGURE 3A.8-4.13





NOTE:

Rigid beams as shown are for x-direction of analysis.

UB Case: Nodal Points @ El. 12.0 M

FIGURE 3A.8-4.15

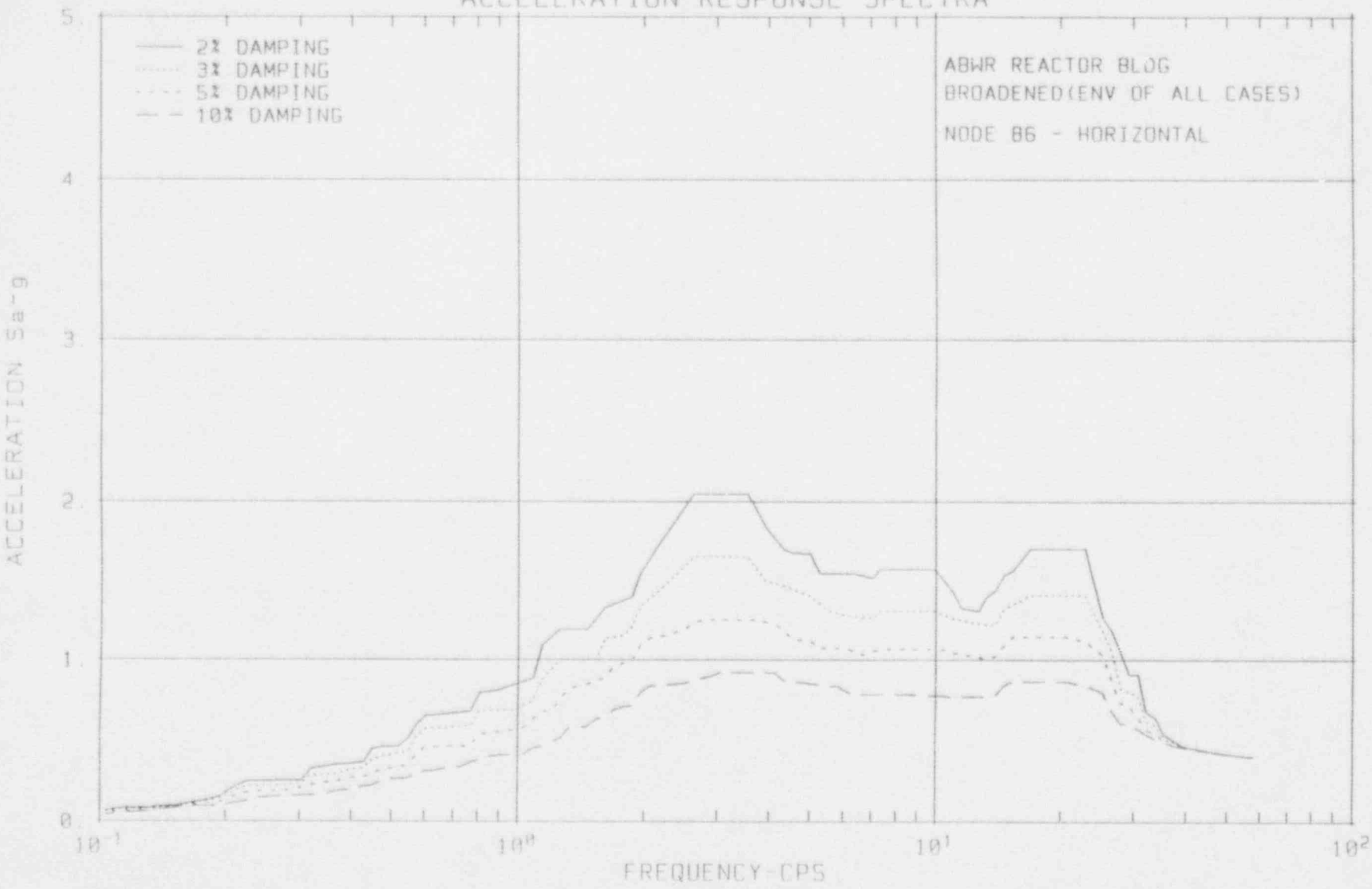


FIGURE 3A.10-2.23

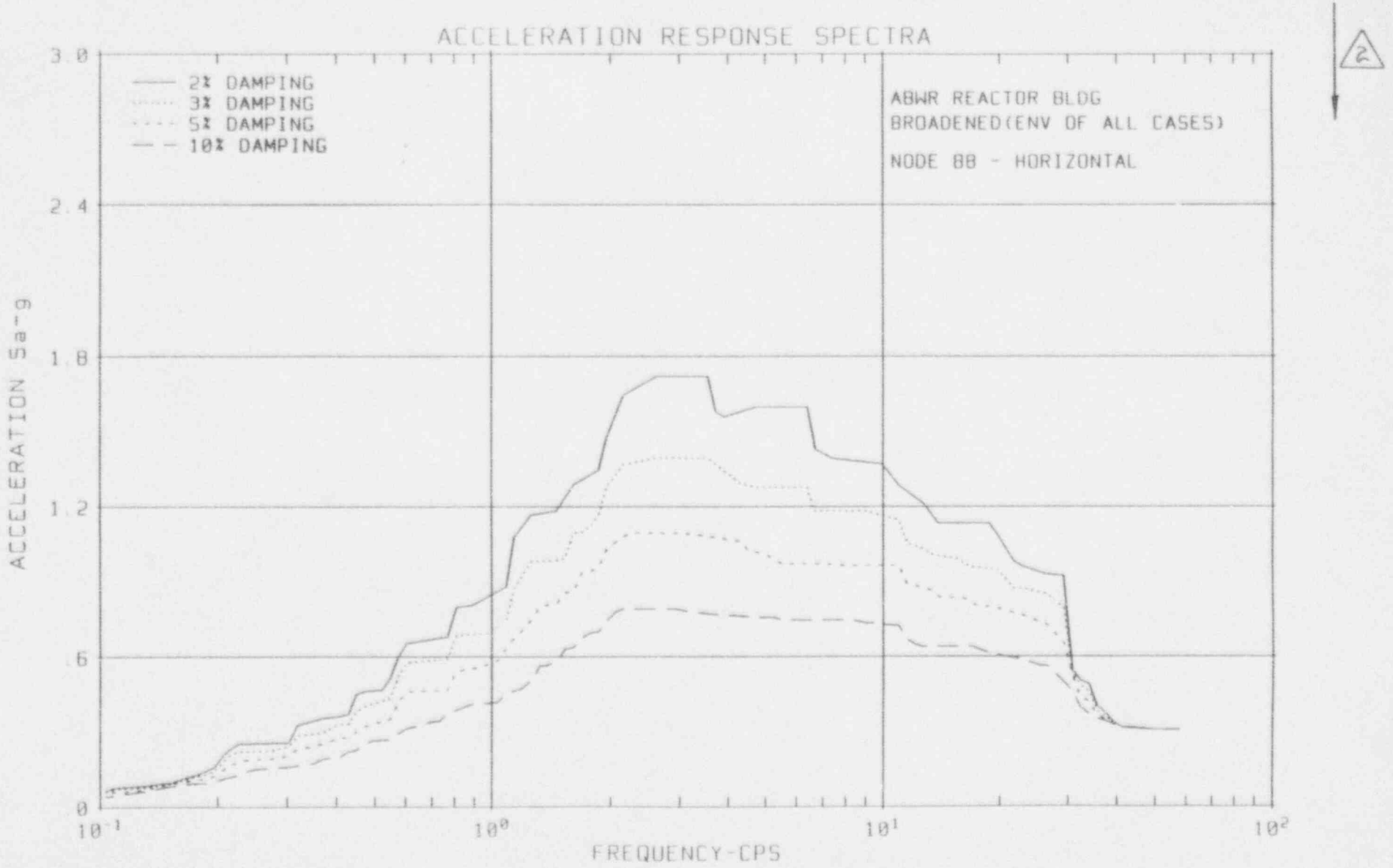


FIGURE 3A.10-2.24

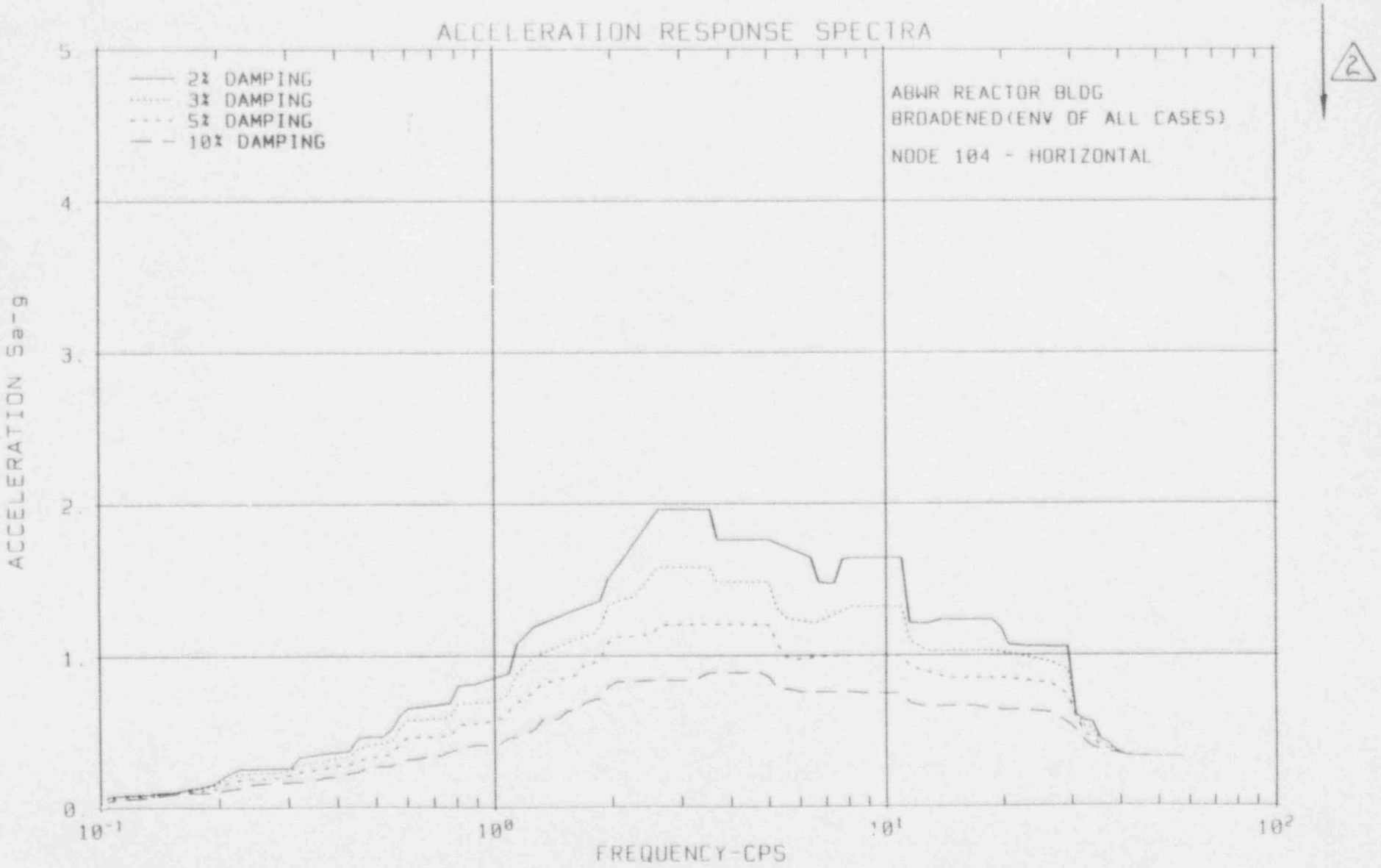


FIGURE 3A.10-2.37

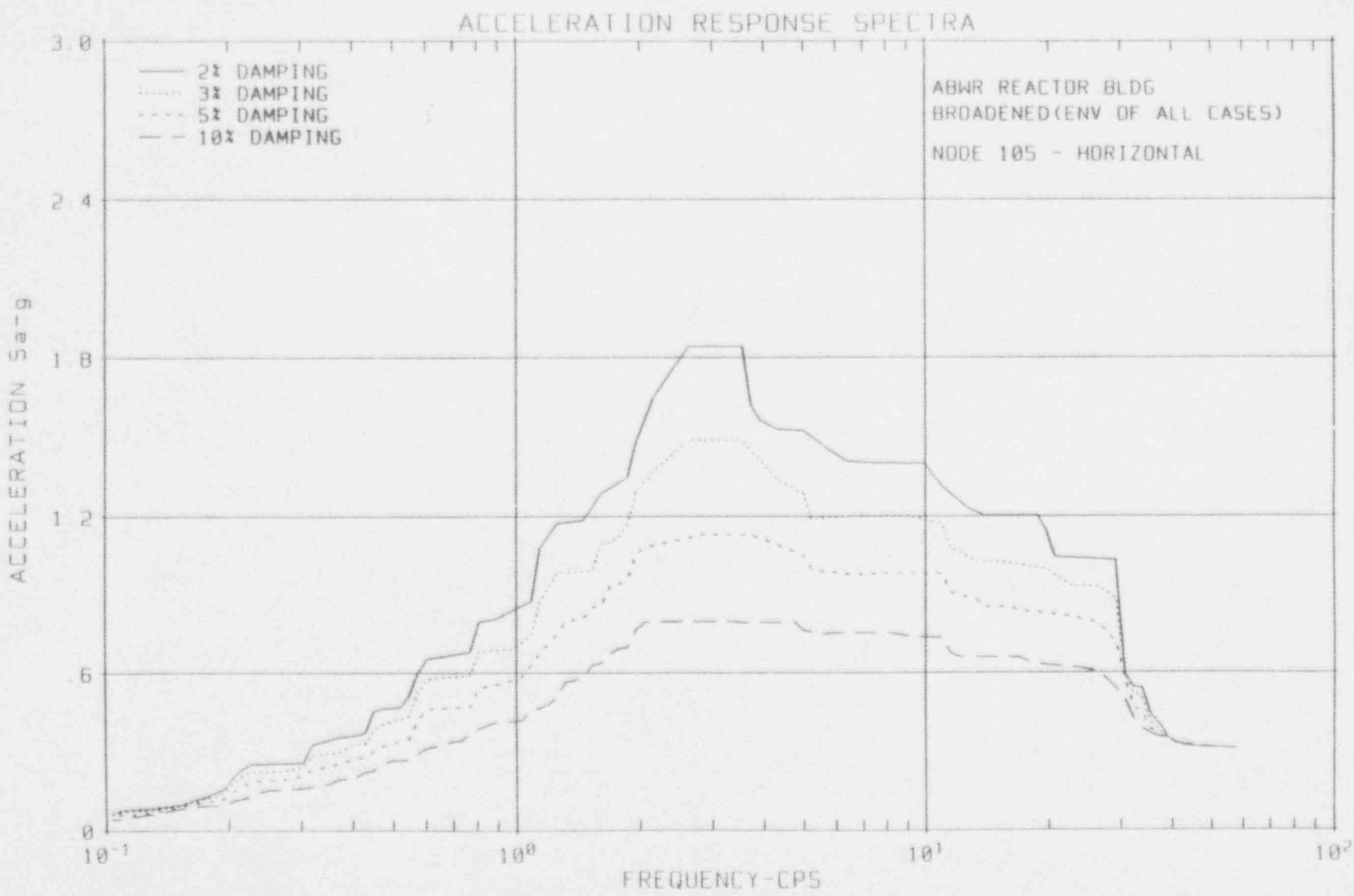


FIGURE 3A.10-2.38