INTERIM REPORT

Accession No. LTR 1111-65

Contract Program or Project Title: LOFT PROGRAM

Subject of this Document: (Title) "LOFT Fuel Bundle Structural Response to Mechanical Loads During Subcooled LOCE"

Type of Document: Analysis

Author(s): J. S. Martinell

Date of Document: April 1980

Responsible NRC Individual and NRC Office or Division: G. D. McPherson

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Prepared for
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

INTERIM REPORT

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(LTR) Report No. 1111-65, Rev. 1

Date: April 2, 1980

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Report No. RE-A-79-120 Rev. 1

USNRC-P-394

INTERNAL TECHNICAL REPORT

Title: LOFT FUEL BUNDLE STRUCTURAL RESPONSE TO MECHANICAL LOADS DURING SUBCOOLED LOCE

Organization: Applied Mechanics Branch

Author: J. S. Martinell/ J S Martinell by RGR

THIS REVISION COMPLETELY SUPERSEDES ALL PREVIOUS ISSUES OF LTR 1111-65

Checked By: R. G. Rahl/ R G Rahl

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EG&G Idaho, Inc.

FORM EG&G-229
(Rev. 01-80)

LOFT TECHNICAL REPORT

Title: LOFT FUEL BUNDLE STRUCTURAL RESPONSE TO MECHANICAL LOADS DURING SUBCOOLED LOCE	LTR No. 1111-65 Rev. 1 RE-A-79-120 Rev. 1
Author: J. S. Martinell	Released By LOFT CDCS
Performing Organization: Applied Mechanics	Date April 2, 1980
LOFT Review and Approval	Project System Engineer: M. L. Russell

LTSD FE&OB Mgr. FD&AB Mgr. LEPD Mgr. RSB Mgr. See incorporated DRR-L-4063

ABSTRACT

A structural analysis of the LOFT type 'A', 'D', and 'E' fuel bundle assemblies was conducted to predict the response to combined axial and lateral loads experienced during the subcooled portion of a 5-inch, 15-msec loss-of-coolant experiment (LOCE). The fuel bundle assemblies were modeled with a linear elastic finite element technique. Dynamic loads predicted in previous dynamic analyses were applied. Worst case misalignment of the upper and lower end boxes were assumed due to allowable tolerances within the flow skirt. This analysis yields maximum axial deflection, internal loads, and subsequent stress intensities in the fuel bundle structural components.

Results indicate that stresses in the fuel bundle structural components, with the exception of the grid spacer intersection welds, are within ASME Section III allowable limits for reaction of mechanical dynamic loads. Over-conservative assumptions at the spacer grid to fuel rod and guide tube interfaces causes the predicted spacer gird intersection weld stresses to exceed allowable limits. The conservative modeling at the spacer grid to fuel rod and guide tube interfaces does not adversely affect the results for the remainder of the structure.

DISPOSITION OF RECOMMENDATIONS

No disposition required. RGR/SH per telecon 4-2-80

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1.0 INTRODUCTION

This analysis was performed to demonstrate the structural integrity of the LOFT fuel bundles during loss-of-coolant experiments (LOCE's) as recommended in resolution of comments concerning a previous analyses[1]. The analysis includes prediction of the axial displacement and internal loads and stresses for type 'A', 'D', and 'E' fuel bundles subjected to LOCE loads which are calculated in previous analyses[2,3]. The mechanical response is predicted using the SAP IV[4] computer code with finite element models of the fuel bundles, as described in Section 2.0. Evaluation of the fuel bundles for mechanical loads is done in accordance with ASME Section III, Subsection NG, of the Boiler and Pressure Vessel Code[5]. Results are presented in Section 3.0 and conclusions are included in Section 4.0.

Detailed illustrations of the models are included in Appendices A and B. Equations used for determining maximum stresses and loads, and allowable stresses and loads are summarized in Appendix C. Finally, computer output for the finite element analysis is included in entirety in Appendix D.

2.0 ANALYSIS

Analysis for prediction of the response of the type 'A', 'D', and 'E' fuel bundles, to maximum loads occuring during subcooled blowdown involved the following:

(1) development of finite element models of the bundles.

(2) development of maximum loads and boundary conditions as a result of dynamic loads occuring during a 5"-1 msec cold leg LOCE (subcooled portion only).

(3) application of loads and boundary conditions to finite element models using the SAP IV computer code to predict displacement response and distribution of loads within the fuel bundle structure.

(4) reduction of internal loads to stresses and combining stresses to determine stress intensities in fuel bundle structural members.

(5) evaluation of fuel bundle structural members using allowable stress intensities and loads calculated from ASME Section III, Subsection NG.

Model development is discussed in Subsection 2.1, and details are presented in Appendices A and B. Development of loads and boundary conditions is presented in Subsection 2.2. The finite element analysis is presented as computer output in Appendix D. Procedures for calculating maximum stress intensities, loads, allowable stress intensities and allowable loads are discussed in Subsection 2.3, with supporting information in Appendix C.

2.1 Model Development

A cross section of the LOFT reactor core is shown in Figure 1. This analysis concerns response of the type 'A', 'D', and 'E' fuel bundles, as illustrated in Figures 2-7. For detailed discussion of the fuel bundle assemblies, and structural components (guide tubes, fuel rods, etc.), refer to MPR-509[6], a previous dynamic analysis of the fuel.

The procedures for construction of finite element models of the fuel bundles include:

(1) node placement - nodes are placed at every guide tube to spacer grid interface and every fuel rod to spacer grid interface as well as at the fuel rod ends, and junction of guide tubes to upper and lower tie plates.

Vertical node spacing (along fuel bundle axes) is equal to the distance between grid spacers, and grid spacers to tie plates. Horizontal node spacing (in a cross section at the grid spacers) is equal to the distance between grid strips. Nodes defining the top and bottom of the guide tubes, and the top of the instrumented fuel rods are fixed (i.e., no motion allowed). All other nodes are allowed to move vertically, horizontally in a direction parallel to the minor principal axis of the fuel bundle cross section, and to rotate about the major principal axis of the cross section.

(2) element definition - the structural members of the LOFT fuel bundles are modeled using linear elastic beams. Material and section properties are developed in Appendices A and B. Beam properties for the elements representing guide tubes, instrumented guide tubes, instrumentation tubes, fuel rods, instrumented fuel rods, and dummy half rods are based on cross-sectional properties of single rods or tubes. Beam properties for the elements representing the grid spacer

strips, springs, and dimples are developed using parallel and/or series linear springs. In addition, a parametric study of the effect of bending stiffness of the modeled grid structure on overall lateral stiffness of a type 'D' assembly was performed. The results, as shown in Figure 8, allowed evaluation of the model's lateral response compared to experimentally determined lateral response[7]. The bending stiffness (about both horizontal axes) of the elements representing the fuel rod to fuel rod interfaces in the model are based on the results of the lateral response comparison, which showed excellent agreement between predicted and experimentally determined lateral response.

(3) boundary conditions - boundary conditions on the models include the node fixities discussed above as well as provisions for applying lateral and axial loads. Axial loads are applied at the top of the guide tubes in a vertical direction. 'Effective' lateral loads are applied by imposing lateral deflections at the spacer grid and lower end box locations with boundary elements. These elements lie in horizontal planes at the spacer grids and lower end box, and define the lateral displacements of the guide tubes in a direction parallel to the minor principal axes of the fuel bundle cross section.

A summary of the type 'A', 'D', and 'E' model characteristics is given in Table 1. A complete model for each type is presented in Appendices A and B.

2.2 Force and Imposed Displacement Development

Loads applied to the finite element models consist of maximum forces predicted for dynamic response of the fuel[2,3]. These loads are applied simultaneously and statically to the models in an attempt to predict the most severe state of stress which could occur during the dynamic transient. No attempt was made to perform a detailed time history stress analysis accounting for response to less severe loads at varying frequencies. Loads used include:

(1) axial - axial loads are applied vertically downward at the top of the guide tubes. Values are summarized in Tabl^ 2,

(2) lateral - 'effective' lateral loads on the fuel bundle are imposed by using boundary elements to force the guide tubes into a predetermined shape. This shape is predicted by combining results of lateral dynamic analysis[3] with lateral displacements calculated by assuming the fuel bundles are installed so that the upper and lower end boxes are misaligned by maximum clearance values within the flow skirts. The lateral deflections due to dynamic reponse are taken at a time when moments in the fuel bundle are at a maximum. The lateral deflections due to misalignment are calculated from clearance values on fuel and flow skirt drawings. The combined lateral deflections are summarized in Table 2. Note that two cases exist since values due to dynamic response can be either added or subtracted from the misaligned lateral deflection values. Both cases were examined in this analysis.

2.3 Stress Analysis

Stress analysis of the fuel bundle structural elements involves reducing element axial, shear, and moment loads to stresses and stress intensities for comparison to Section III allowables. For the case of the grid strip intersection welds, allowables consist of both code material allowables, and test load[8] allowables. Equations for stress analysis and evaluation are summarized in Appendix C.

(7) Results for the 'D' and 'E' type assemblies are representative of the response of the 'B' and 'C' type assemblies as well.

The above constraints provide the means for a conservative approach to predict the response of the fuel assemblies to the worst case mechanical loads associated with a 5"-15 msec cold leg LOCE. Internal loads and stresses within the fuel bundle will be conservative estimates of the actual response.

Predicted axial end box to end box deformations are;

(1) type 'A' - 0.0097 inch

(2) type 'D' - 0.0079 inch

(3) type 'E' - 0.0053 inch

Maximum loads in the guide tubes, instrumented guide tubes, and instrumentation tubes give rise to stress intensities within Section III code allowables Maximum stresses in the fuel rods, instrumented fuel rods and dummy half rods are also within the allowable limits. However, due to linear modeling of the fuel rod to fuel rod interfaces (i.e., no slippage of rods), and conservative values for shear area and bending stiffness of grid spacer structure, loads transmitted from guide tubes through grid structure to fuel rods are conservatively high. This conservatism leads to prediction of stresses and loads which exceed allowable limits in the grid strip intersection welds. This is judged to be a modeling problem since the predicted loads transferred from the spacer grid to the fuel rods exceed the maximum friction loads which can be carried at the spacer grid spring to fuel rod interfaces. The problem results from modeling the interfaces with single, linear type beam elements used in SAP IV. Adjusting section properties of these beam elements (i.e., shear area and moment of inertia) may lead to less conservative results for the grid spacer strip welds. This is not deemed advisable with these models since results may still be overconservative, and/or the change in lateral stiffness of the fuel bundle may be reflected in a poor comparison between predicted and experimentally determined response to lateral loads.

Reanalysis of the spacer grid strip intersection welds using a more refined model and/or review of existing analysis would be necessary in order to demonstrate structural integrity of the welds. Spacer grid welds will be examined as part of the fuel bundle posttest examination program.

3.0 RESULTS

The results of this analysis include predicted maximum axial displacements, loads, and stress levels in the fuel bundle structural elements for worst case LOFT L1-5 LOCE conditions. The results are summarized in Tables 3-7 as reduced from the SAP IV finite element analysis output included in Appendix D.

Constraints imposed on the fuel bundle models for this analysis include the following:

(1) response is predicted for the worst combination of dynamic loads, and is assumed to be linear elastic (no permanent deformation is allowed).

(2) response is predicted assuming lateral motion parallel to the minor principal axes of the fuel cross sections only.

(3) the upper and lower tie plates and end boxes are assumed rigid and are not allowed to rotate, thus providing a clamped type support for the guide tubes and instrumented fuel rods.

(4) the interface between the fuel rods and grid spacer structure is modeled using a linear spring, and fuel rods are not allowed to slip vertically.

(5) loads and stresses are predicted for guide tubes, instrumented guide tubes, instrumentation tubes, fuel rods, instrumented fuel rods, dummy half rods, and grid spacer structure and strip intersection welds for mechanical loads arising from reaction to the worst case dynamic load condition.

(6) internal loads in the upper and lower tie plates and end boxes are not addressed in this analysis.

4.0 CONCLUSIONS

The following conclusions are drawn based on the analysis presented herein:

(1) axial deformations presented in Section 3.0 should be the maximum response to axial dynamic mechanical loads arising during the subcooled portion of a 5"-15 msec LOCE,

(2) stresses due to combined axial and lateral dynamic mechanical loads are within ASME Section III allowables for the guide tubes, instrumented guide tubes, instrumentation tubes, fuel rods, instrumented fuel rods and dummy half rods in the type 'A', 'D', and 'E' assemblies,

(3) predicted stresses and loads in the grid spacer strip intersection welds exceed allowables, however, this is due to overconservative model limitations in the grid spacer to fuel rod and guide tube interfaces,

(4) conservative modeling of the grid spacer to fuel rod and guide tube interfaces does not adversely affect the results for the remainder of the fuel bundle structure. This is because maximum guide tube loads occur at the ends near the upper and lower end boxes, and maximum fuel rod loads occur near the center of the rods. The predicted stress levels are within allowable limits for these components.

(5) with the exception of the spacer grid welds, the components in the LOFT fuel bundles addressed in this report are structurally adequate to withstand mechanical LOCE loads.

(6) further analysis of LOFT fuel using the models presented herein is subject to the same limitations at the grid spacer to rod and tube interfaces as discussed above.

TABLE 1

FINITE ELEMENT MODEL CHARACTERISTICS

Model Type	Nodes	Degrees of Freedom	Beam Elements	Boundary Elements	Specific Data
'A'	1575	4607	3450	120	Bandwidth = 318, includes instrumented guide tubes and fuel rods
'D'	1575	4645	3450	120	Bandwidth = 318, no instrumented guide tubes or fuel rods
'E'	623	1837	1354	48	Bandwidth = 255, no instrumented guide tubes or fuel rods

GENERAL DATA

Guide tubes fixed in rotation about all axes at each end of models

Motion allowed vertically, horizontally in a direction parallel to the minor principal axis of the cross section, and about the major principal axis of the cross section

Upper and lower tie plates and end boxes are assumed rigid (i.e., provide clamped type support of guide tubes).

TABLE 2

AXIAL LOADS AND LATERAL DEFLECTIONS IMPOSED ON MODELS

Model Type	Axial Load[a] (lb)	Guide Tubes Loaded	Position Along Fuel Axis[b]	Lateral Deflection[c] (inch)			
				Clearance Available[d]	Dynamic Response[e]		
				δc	δd	$\delta c - \delta d$	$\delta c + \delta d$[f]
'A'	235	18	6	0.0002	-0.0001	0.0003	0.0001
			5	0.0056	0.0003	0.0053	0.0059
			4	0.0114	0.0010	0.0104	0.0124
			3	0.0163	0.0014	0.0149	0.0177
			2	0.0195	0.0011	0.0184	0.0195
			1	0.0195	0.0011	0.0184	0.0195
'D'	191	20	6	0.0003	-0.0002	0.0005	0.0001
			5	0.0082	0.0003	0.0079	0.0085
			4	0.0168	0.0011	0.0157	0.0179
			3	0.0244	0.0015	0.0229	0.0259
			2	0.0293	0.0012	0.0281	0.0293
			1	0.0293	0.0011	0.0282	0.0293
'E'	198	8	6	0.0003	-0.0002	0.0005	0.0001
			5	0.0097	0.0003	0.0094	0.0100
			4	0.0202	0.0010	0.0192	0.0212
			3	0.0311	0.0014	0.0297	0.0325
			2	0.0417	0.0010	0.0407	0.0426
			1	0.0426	0.0009	0.0417	0.0426

a From axial dynamic analysis (LTR 1111-31), per Guide Tube.

b 6 - Top grid spacer; 5, 4, 3 - Intermediate grid spacers; 2 - bottom grid spacer; 1 - lower end box.

c Relative to upper end box.

d Calculated from fuel and flow skirt drawings.

e From Lateral Dynamic Analysis (LTR 1115-34).

f $\delta c + \delta d \leq \delta c$ due to contact with the flow skirt.

TABLE 3

MAXIMUM AXIAL DISPLACEMENTS AND ELEMENT LOADS

Model Type	Max. Axial Disp. (inch)	Load Type	Guide Tube			Instrumented Guide Tube			Instrumentation Tube		
			El. No.	Run[a] No.	Load	El. No.	Run No.	Load	El. No.	Run No.	Load
'A'	0.0097	Axial (lb)	193	2	239	697	1	233	676	2	24.4
		Shear (lb)	198	2	7.03	697	1	50.7	674	2	1.32
		Moment (in-lb)	198	2	9.64	697	1	50.7	674	2	10.8
'D'	0.0079	Axial (lb)	193	2	196	None	/	/	676	2	0.9
		Shear (lb)	240	2	10.3	None	/	/	676	2	0.2
		Moment (in-lb)	240	2	15.2	None	/	/	676	2	1.7
"E'	0.0053	Axial (lb)	199	1	382	None	/	/	None	/	/
		Shear (lb)	199	1	62.5	None	/	/	None	/	/
		Moment (in-lb)	199	1	56.0	None	/	/	None	/	/

a Run No. 1 uses lateral deflection calculated by subtracting lateral dynamic response from clearance values (Table 2).

Run No. 2 uses lateral deflection calculated by adding lateral dynamic response to clearance values (Table 2).

TABLE 4

MAXIMUM ELEMENT LOADS

Model Type	Load Type	Fuel Rod			Instrumented Fuel Rod			Dummy Half Rod			Grid Spacer Structure		
		El. No.	Run[(a)] No.	Load	El. No.	Run No	Load	El. No.	Run No.	Load	El. No.	Run No.	Load
'A'	Axial (lb)	207	2	58.8	878	1	42.4	None	/	/	2299	2	4.6
	Shear (lb)	522	2	9.94	330	1	14.9	None	/	/	2299	2	95.8
	Moment (in-lb)	522	2	9.94	330	1	17.8	None	/	/	2299	2	62.6
'D'	Axial (lb)	188	2	48.8	None	/	/	None	/	/	2119	2	0.18
	Shear (lb)	689	2	0.20	None	/	/	None	/	/	1520	2	54.5
	Moment (in-lb)	689	2	1.97	None	/	/	None	/	/	1520	2	32.4
'E'	Axial (lb)	182	2	32.7	None	/	/	266	1	70.8	985	1	0.34
	Shear (lb)	194	2	0.19	None	/	/	320	1	1.24	993	1	175
	Moment (in-lb)	194	2	1.54	None	/	/	320	1	9.59	993	1	84.3

(a) See Table 2 footnotes.

TABLE 5

MAXIMUM AND ALLOWABLE STRESS INTENSITIES FOR
REACTION OF MECHANICAL LOADS
BY GUIDE TUBES

Model Type	Guide Tubes			Instrumented Guide Tubes			Instrumentation Tube		
	P_m (psi) $S_a^{(a)} = 23,300$	$P_m + P_b$ (psi) $S_a^{(b)} = 34,950$	$P_m = P_b + F$ (psi) $S_a^{(c)} = 300,000$	P_m (psi) $S_a = 23,300$	$P_m + P_b$ (psi) $S_a = 34,950$	$P_m + P_b + F$ (psi) $S_a = 300,000$	P_m (psi) $S_a = 23,300$	$P_m + P_b$ (psi) $S_a = 34,950$	$P_m + P_b + F$ (psi) $S_a = 300,000$
'A'	8,330	11,000	44,000	8,830	30,100	120,400	865	3,550	14,200
'D'	6,950	11,000	44,000	None	None	None	31.0	512	2,050
'E'	13,550	29,110	116,400	None	None	None	None	None	None

(a) $S_a = S_m$.

(b) $S_a = 1.5 \times S_m$.

(c) $S_a = 2$ Salt for 200 cycles.

Refer to Section III, ASME Code for Definition of Terms.

TABLE 6

MAXIMUM AND ALLOWABLE STRESS INTENSITIES FOR REACTION OF MECHANICAL LOADS BY FUEL RODS

Model Type	Fuel Rods		Instrumented Fuel Rods		Dummy Half Rods	
	P_m (psi) (a) S_a = 10,000	$P_m + P_b$ (psi) (b) S_a 15,000	P_m (psi) S_a = 10,000	$P_m + P_b$ (psi) S_a = 15,000	P_m (psi) S_a = 13,400	$P_m + P_b$ (psi) S_a = 20,100
'A'	1,960	3,470	1,410	6,230	None	None
'D'	1,630	1,700	None	None	None	None
'E'	1,090	1,340	None	None	770	2,980

a) $S_a = S_m$.

b) $S_a = 1.5 \times S_m$.

TABLE 7

MAXIMUM AND ALLOWABLE STRESS INTENSITIES AND LOADS FOR REACTION OF MECHANICAL LOADS BY SPACER GRID STRUCTURES

Model Type	Spacer Grid Structure		Spacer Grid Strip Intersection Welds	
	P_m (psi) (a) $S_a + 61,700$	$P_m + P_b$ (psi) (b) $S_a = 92,550$	Q (psi) (c) $S_a = 185,000$	F_v (lb) (d) $F_{va} = 108$
'A'	153	9,680	953,000	111
'D'	6.0	5,500	520,000	63.0
'E'	11.3	17,680	1,200,000	203

(a) $S_a = S_m$.

(b) $S_a = 1.5 \times S_m$.

(c) $S_a = 3.0 \times S_m$.

(d) F_{va} Based on Exxon Analysis (JN-72-9).

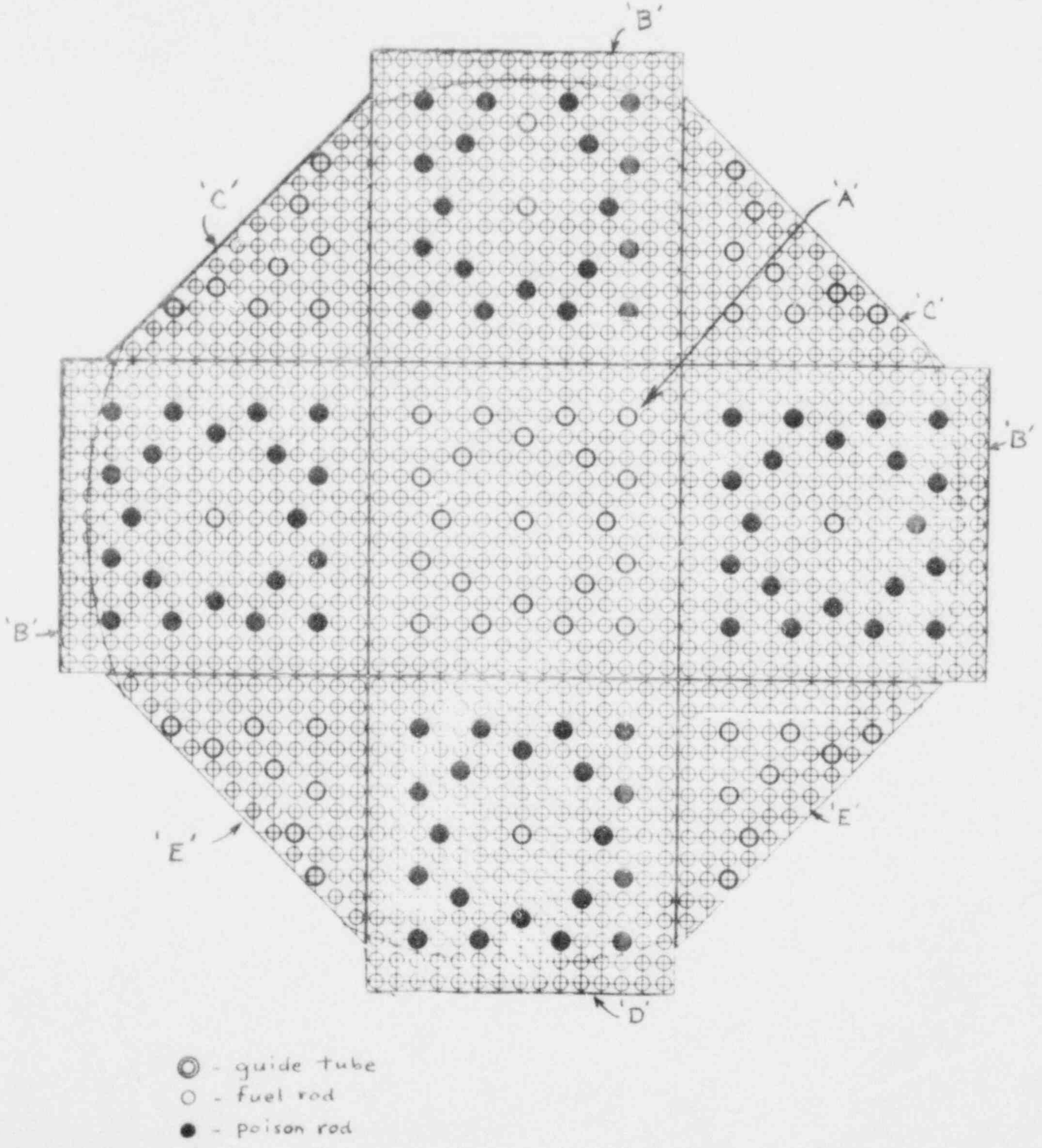


FIGURE 1 LOFT REACTOR CORE
CROSS SECTION

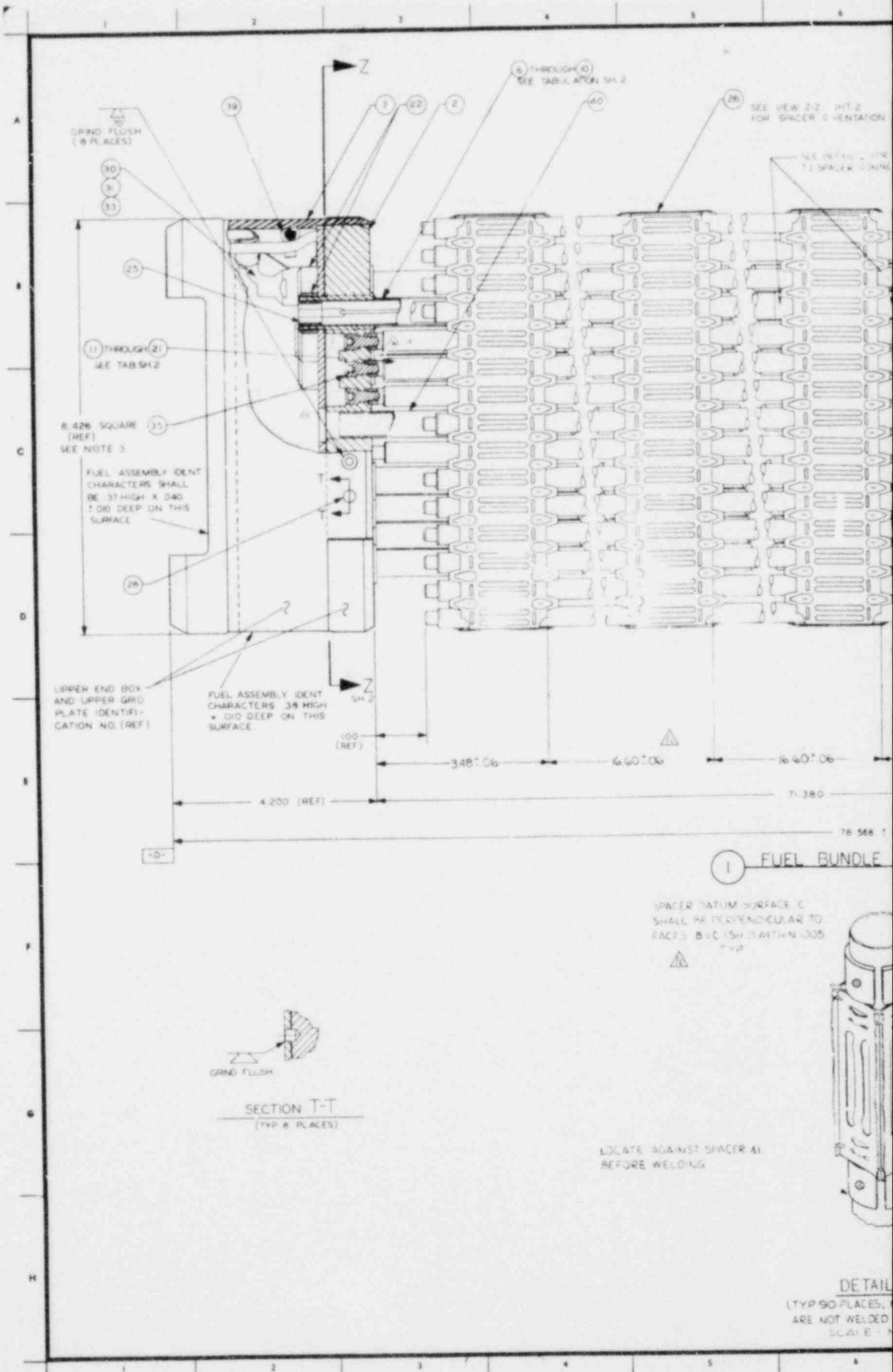
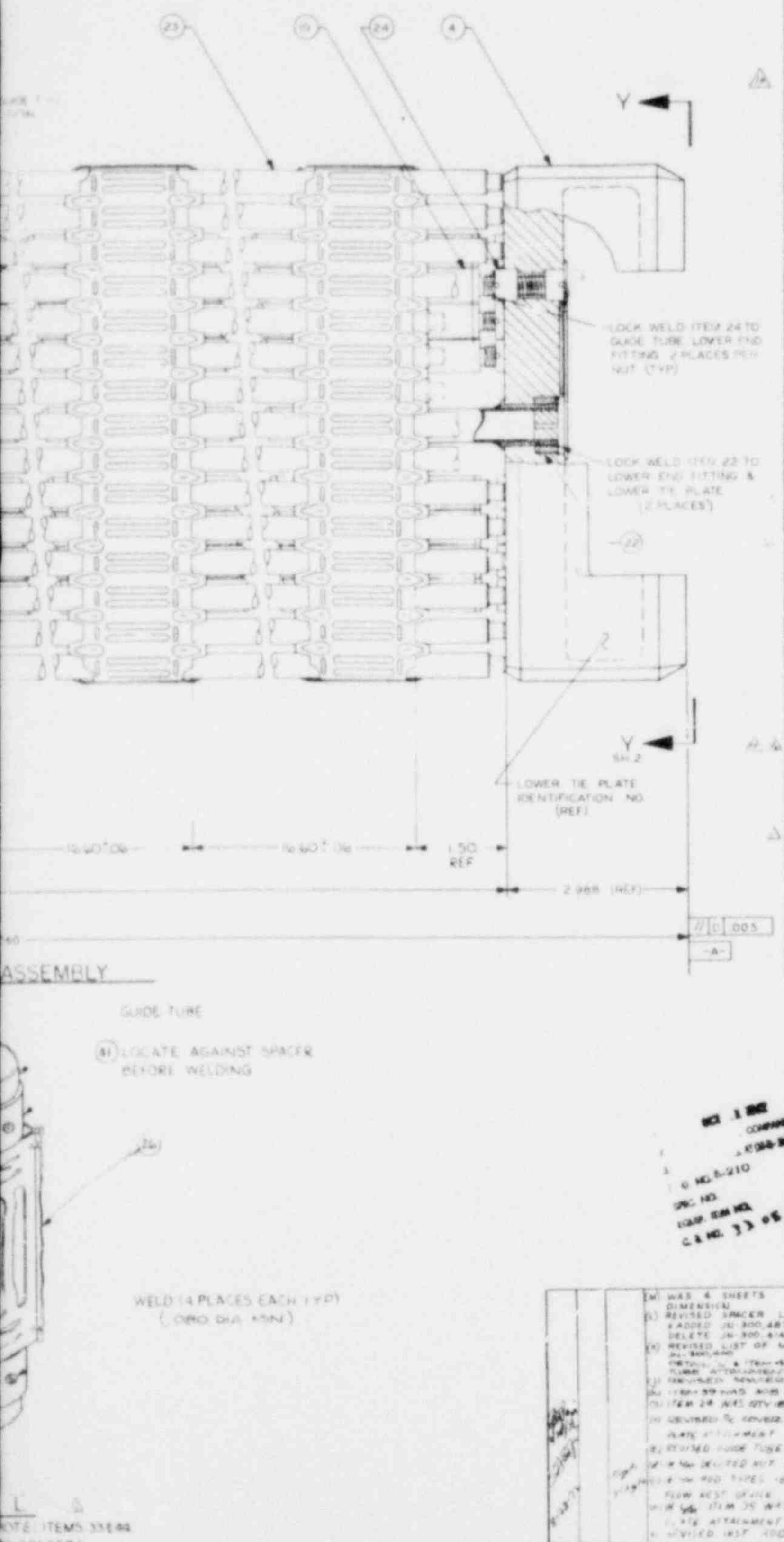


FIGURE 2 TYPE



QTY	PT NO.	DESCRIPTION	REMARKS
X	1	FUEL BUNDLE ASSY TYPE A	
1	2	UPPER GRID PLATE ASSY	JN-300.395
1	3	UPPER BOX ASSY	JN-300.396
1	4	LOWER TIE PLATE	[illegible]-300.383
11	5	GUIDE TUBE ASSY ASSY 1	JN-300.345
3	6	INSTRUMENTED GUIDE TUBE ASSY 1	JN-300.487
1	7	INSTRUMENTED GUIDE TUBE ASSY 2	JN-300.487
1	8	INSTRUMENTED GUIDE TUBE ASSY 3	JN-300.487
1	9	INSTRUMENTED GUIDE TUBE ASSY 4	JN-300.487
1	10	FIXED FLUXED SCAN GUIDE TUBE ASSY	JN-300.489
2	11	INSTRUMENTED ROD ASSY TYPE 1A	JN-300.466
2	12	INSTRUMENTED ROD ASSY TYPE 2A	JN-300.466
2	13	INSTRUMENTED ROD ASSY TYPE 3A	JN-300.466
2	14	INSTRUMENTED ROD ASSY TYPE 4A	JN-300.466
2	15	INSTRUMENTED ROD ASSY TYPE 5A	JN-300.466
1	16	INSTRUMENTED ROD ASSY TYPE 1B	JN-300.466
1	17	INSTRUMENTED ROD ASSY TYPE 2B	JN-300.466
1	18	INSTRUMENTED ROD ASSY TYPE 3B	JN-300.466
1	19	INSTRUMENTED ROD ASSY TYPE 4B	JN-300.466
1	20	INSTRUMENTED ROD ASSY TYPE 5B	JN-300.466
4	21	INSTRUMENTED ROD ASSY TYPE 11	JN-300.466
19	22	NUT UPPER GUIDE TUBE (OPTION 1)	JN-300.[illegible]
185	23	STANDARD ROD	JN-300.468
36	24	NUT LOWER GUIDE TUBE	JN-300.356
7	25	SUPPORT GUIDE TUBE (OPTION 1)	JN-300.415
5	26	SPACER ASSEMBLY	JN-300.410
1	27	THERMOCOUPLE COVER PLATE (OPTION 2)	JN-300.387
8	28	DOWEL	JN-300.399
1	29	ROUTING FIXTURE	JN-300.416
1	30	ROUTING FIXTURE	JN-300.417
1	31	SLEEVE OPTION 1	JN-300.419
1	32	SLEEVE OPTION 2	JN-300.419
2	33	LIQUID LEVEL DETECTOR	SUPPLIED BY CUSTOMER
8	34	UPPER COOLANT THERMOCOUPLE	SUPPLIED BY CUSTOMER
19	35	CAP SCREW INSTRUMENTED ROD	[illegible]-300.437
1	36	CABLE SLEEVE (OPTION 1)	[illegible]
1	37	CABLE SLEEVE (OPTION 2)	JN-300.418
1	38	CLIP THERMOCOUPLE COVER PLATE	JN-300.439
A.R.	39	CABLE CLAMP .125 DIA.	MATL 308 ST ST
1	40	INSTRUMENTATION TUBE ASSY ASSY 1	JN-300.351
180	41	LOCKING RING (OPTION 1)	JN-300.428
	42		
	43		
	44		

NOTES (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONAL TOLERANCES (UNLESS OTHERWISE STATED) XX ± .015, .XXX ± .005 ANGLES ± 2°.
2. DIMENSIONING AND TOLERANCING ARE IN ACCORDANCE WITH ANSI Y14.5 1966.
3. THE ASSEMBLED BUNDLE IN THE VERTICAL POSITION SHALL FIT WITHIN AN ENVELOPE OF PARALLEL BOUNDARY PLANES WITH AN 8.449 MAX SQUARE CROSS SECTION PERPENDICULAR TO A LOCATING PLANE DESCRIBED BY SURFACE A. ALL FOUR SIDES OF THE LOWER TIE PLATE MUST BE CENTERED INSIDE THIS ENVELOPE BY A MINIMUM OF .005.
4. CONSULT PRODUCT SPEC FOR BUNDLE ASSEMBLY SEQUENCE & WELD REQUIREMENTS.

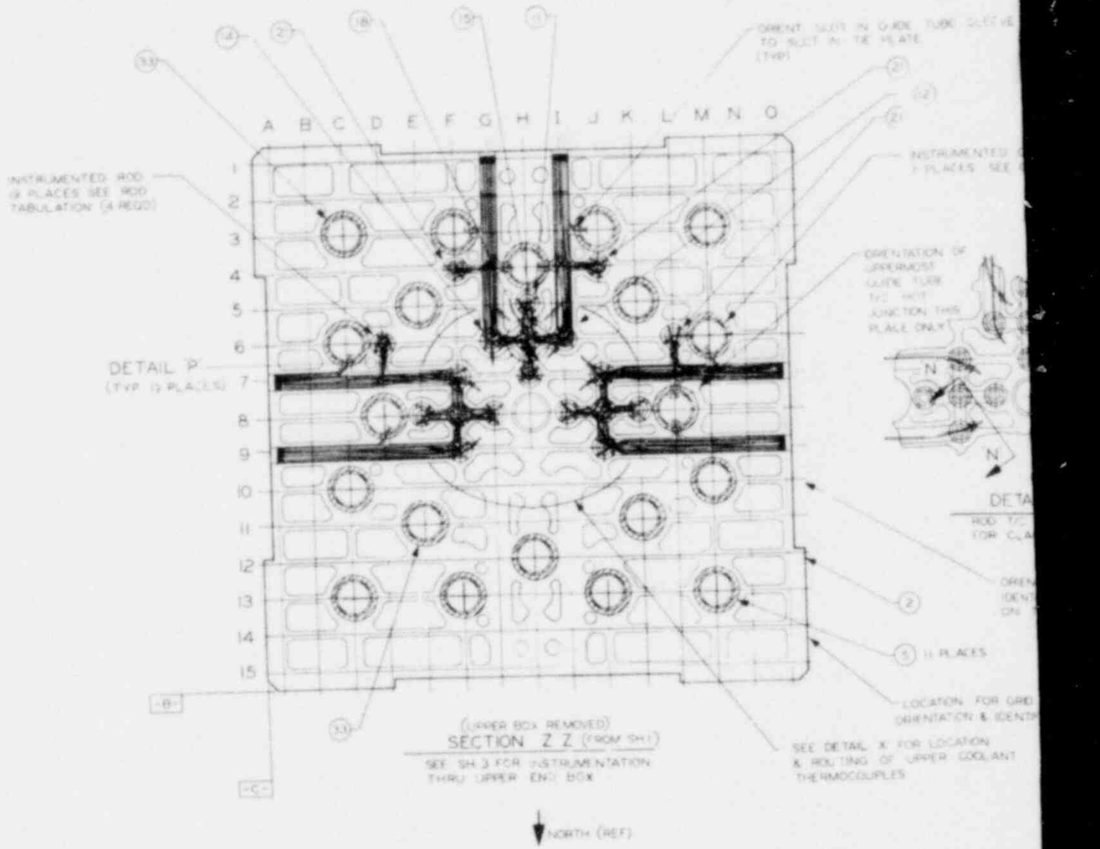
REFERENCE DRAWINGS

Jersey Nuclear Company

FUEL BUNDLE ASSEMBLY (TYPE A)

JN-300.329

A' FUEL BUNDLE ASSEMBLY



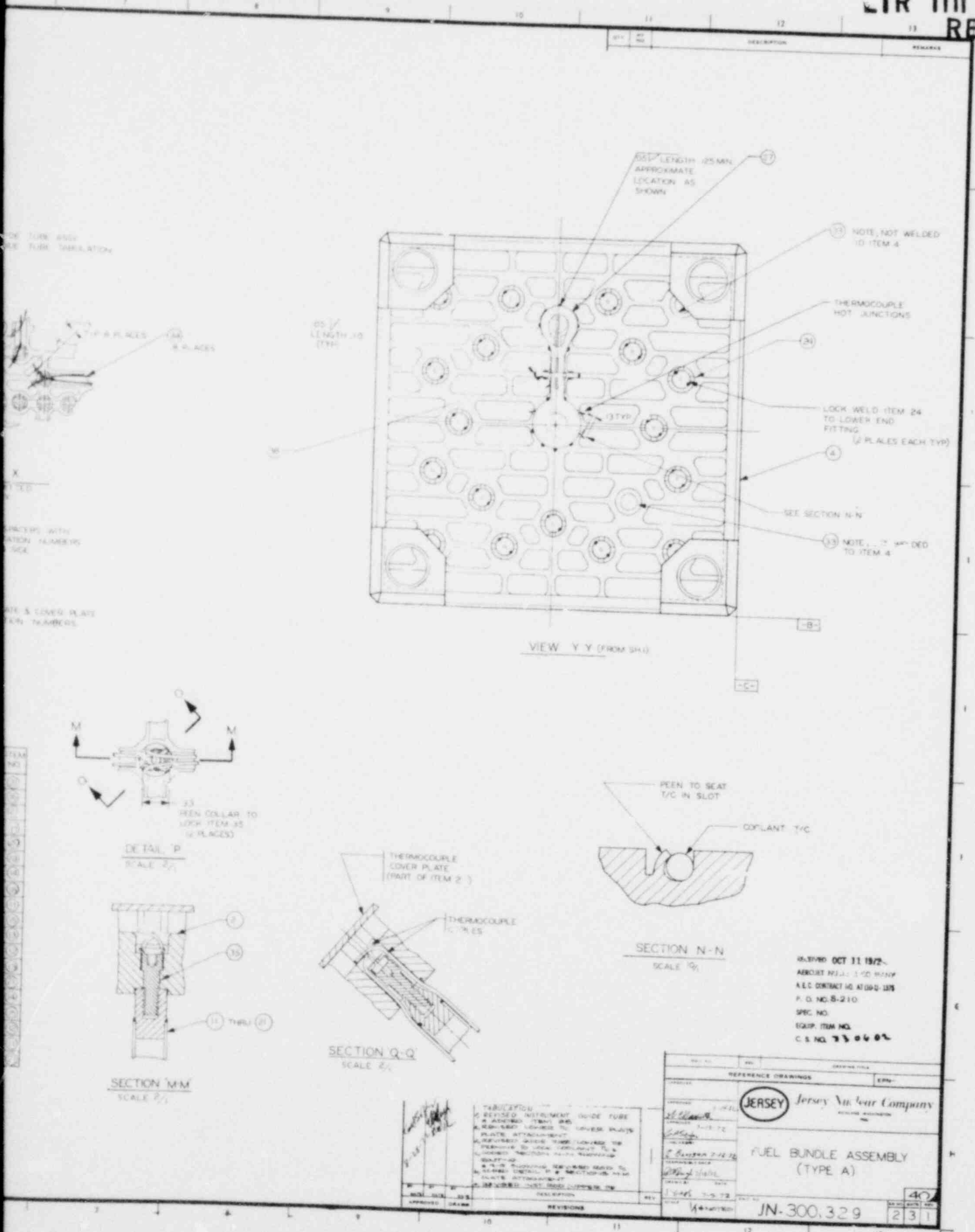
INSTRUMENTED GUIDE TUBE TABULATION

GRID LOCATION	GUIDE TUBE INST. ASSY	ITEM NO.
C6	JN-300,487 ASSY 1	(5)
D8	JN-300,489	(10)
F3	JN-300,487 ASSY 1	(6)
H4	JN-300,487 ASSY 3	(8)
J3	JN-300,487 ASSY 1	(6)
L8	JN-300,487 ASSY 4	(9)
M6	JN-300,487 ASSY 2	(7)

INSTRUMENTED ROD TABULA

GRID LOCATION	INSTRUMENTED FU ROD ASSY
D6	JN-300,466 ASSY
E8	JN-300,466 ASSY
F4	JN-300,466 ASSY
F7	JN-300,466 ASSY
F8	JN-300,466 ASSY
F9	JN-300,466 ASSY
G6	JN-300,466 ASSY
G8	JN-300,466 ASSY
H5	JN-300,466 ASSY
H6	JN-300,466 ASSY
H7	JN-300,466 ASSY
I6	JN-300,466 ASSY
I8	JN-300,466 ASSY
J4	JN-300,466 ASSY
J7	JN-300,466 ASSY
J8	JN-300,466 ASSY
J9	JN-300,466 ASSY
K8	JN-300,466 ASSY
L6	JN-300,466 ASSY

FIGURE 3 TYPE



FUEL BUNDLE CROSS SECTION

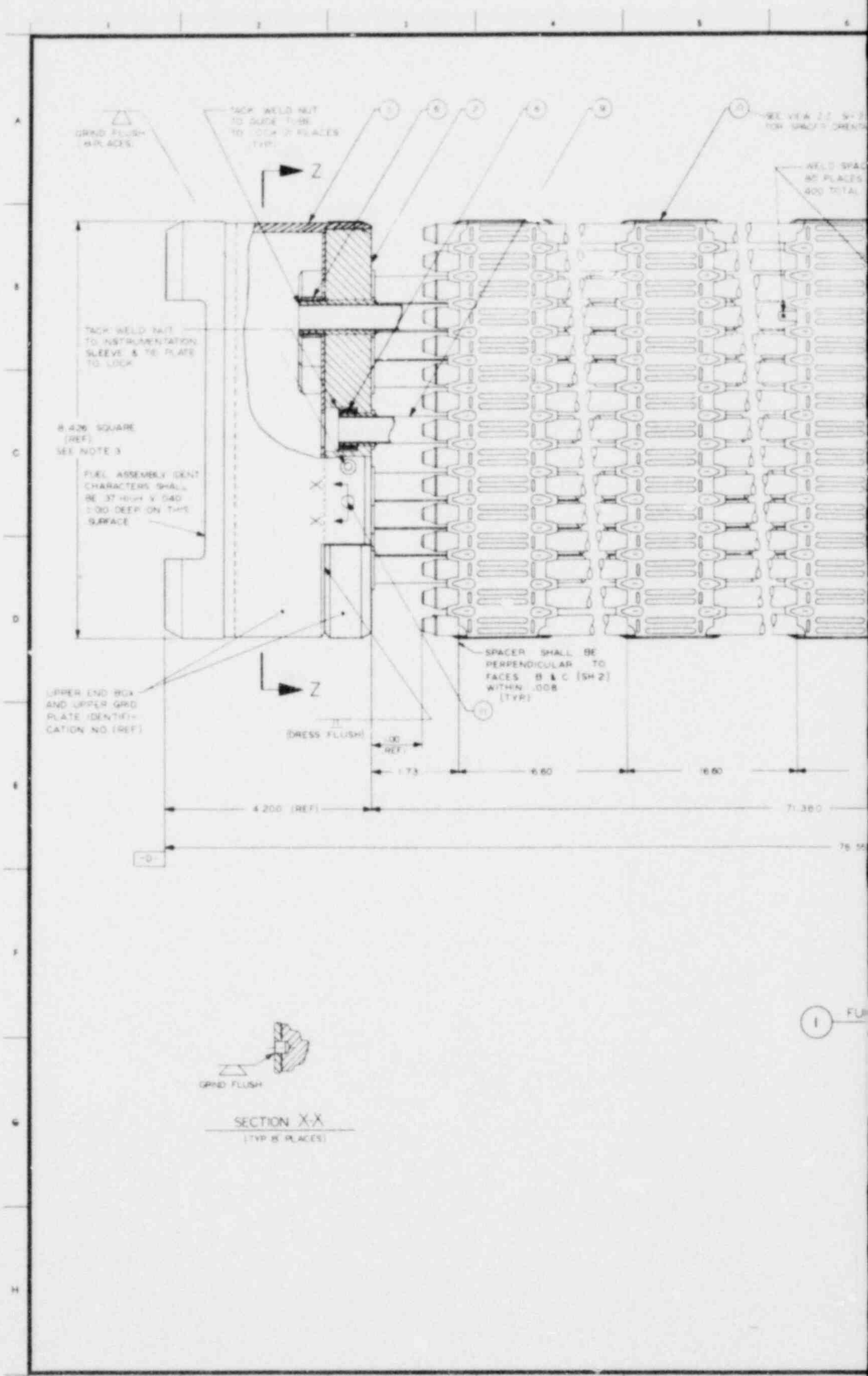
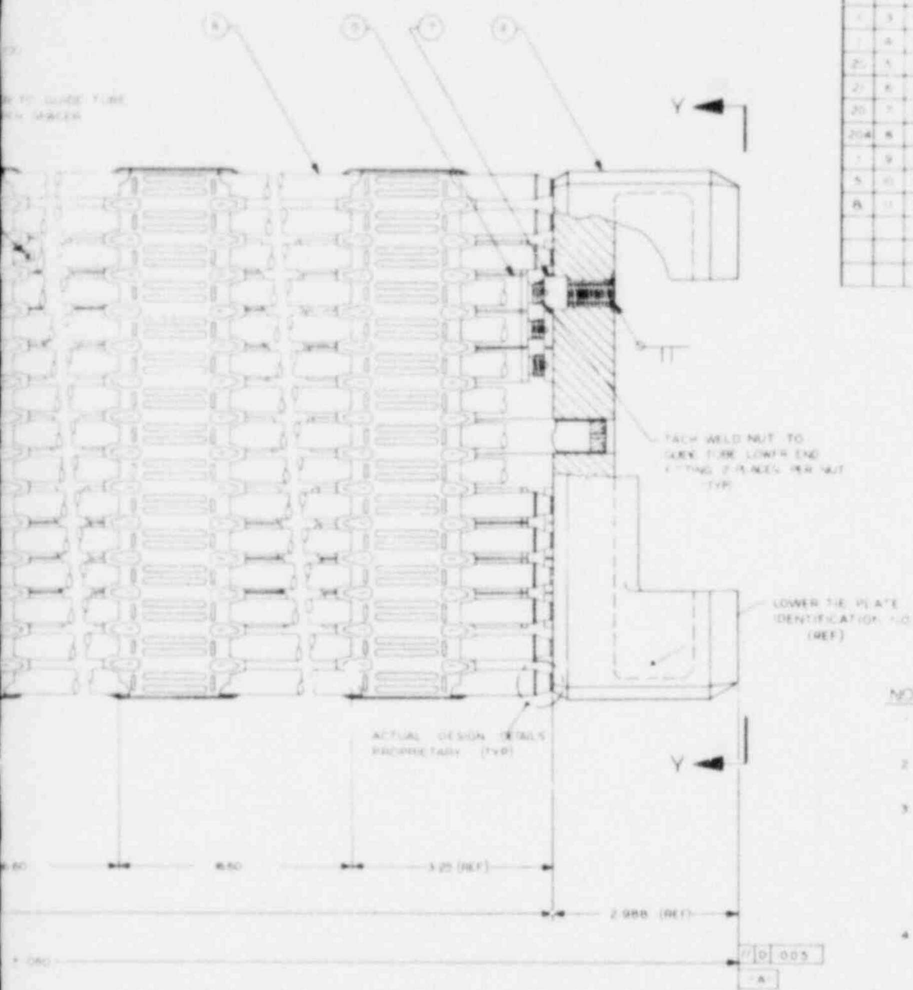


FIGURE 4 TYPE '

QTY	PT NO	DESCRIPTION	REMARKS
X	1	FUEL BUNDLE ASSY (TYPE D)	
1	2	UPPER GRID PLATE ASSY	JN-300.378 (ASSY 1)
1	3	UPPER BOX ASSY	JN-300.379
1	4	LOWER TIE PLATE ASSY	JN-300.382
20	5	GUIDE TUBE ASSY	JN-300.345 (ASSY 1)
21	6	NUT UPPER GUIDE TUBE	JN-300.341
20	7	NUT LOWER GUIDE TUBE	JN-300.356
204	8	STANDARD ROD ASSY	JN-300.463
1	9	INSTRUMENTATION TUBE ASSY	JN-300.35 (OPTION 2)
5	10	SPACER ASSY	JN-300.400
8	11	DOWEL PIN	JN-300.398



NOTES

1. DIMENSIONAL TOLERANCES (UNLESS OTHERWISE STATED) XX ±.05, XXX ±.005 ANGLES ±2°
2. DIMENSIONING AND TOLERANCING ARE IN ACCORDANCE WITH ANSI Y14.5 1966
3. THE ASSEMBLED BUNDLE IN THE VERTICAL POSITION SHALL FIT WITHIN AN ENVELOPE OF PARALLEL BOUNDARY PLANES WITH AN 8.449 MAX SQUARE CROSS SECTION PERPENDICULAR TO A LOCATING PLANE DESCRIBED BY SURFACE A. ALL FOUR SIDES OF THE LOWER TIE PLATE MUST BE CENTERED INSIDE THIS ENVELOPE BY A MINIMUM OF .005
4. CONSULT PRODUCT SPEC FOR BUNDLE ASSEMBLY SEQUENCE & WELD REQUIREMENTS

L BUNDLE ASSEMBLY

REFERENCE DRAWINGS

JERSEY Jersey Nuclear Company

40

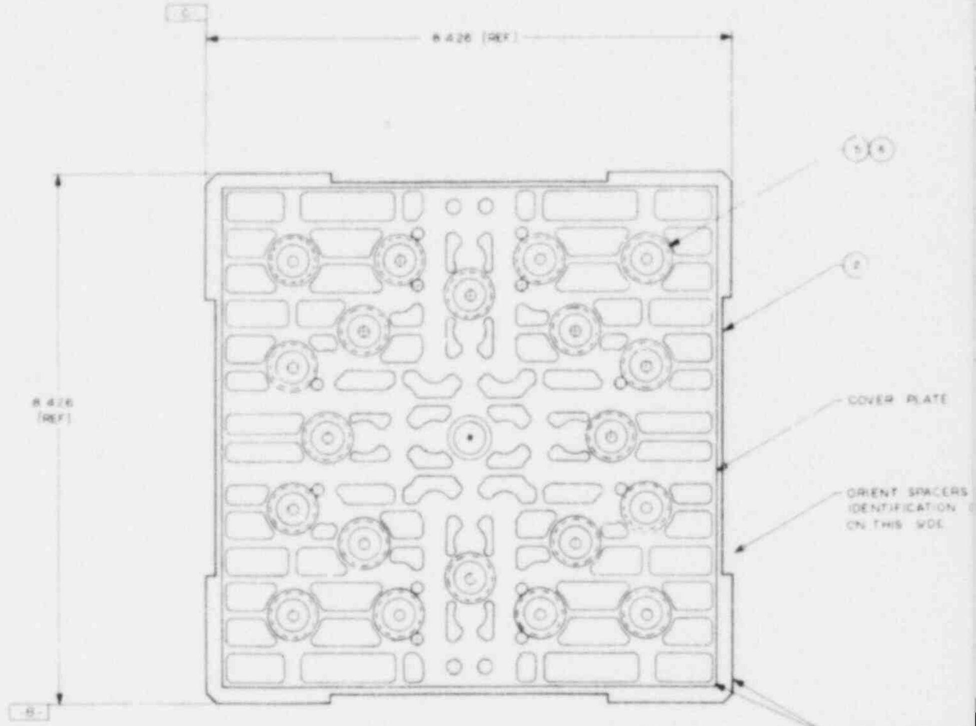
FUEL BUNDLE ASSEMBLY
(TYPE D)

SCALE 1/1

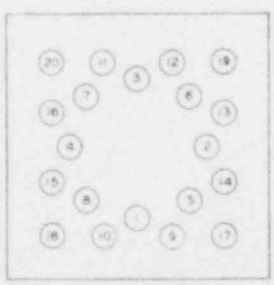
JN 300.470

1 | 2 | 0

D' FUEL BUNDLE ASSEMBLY



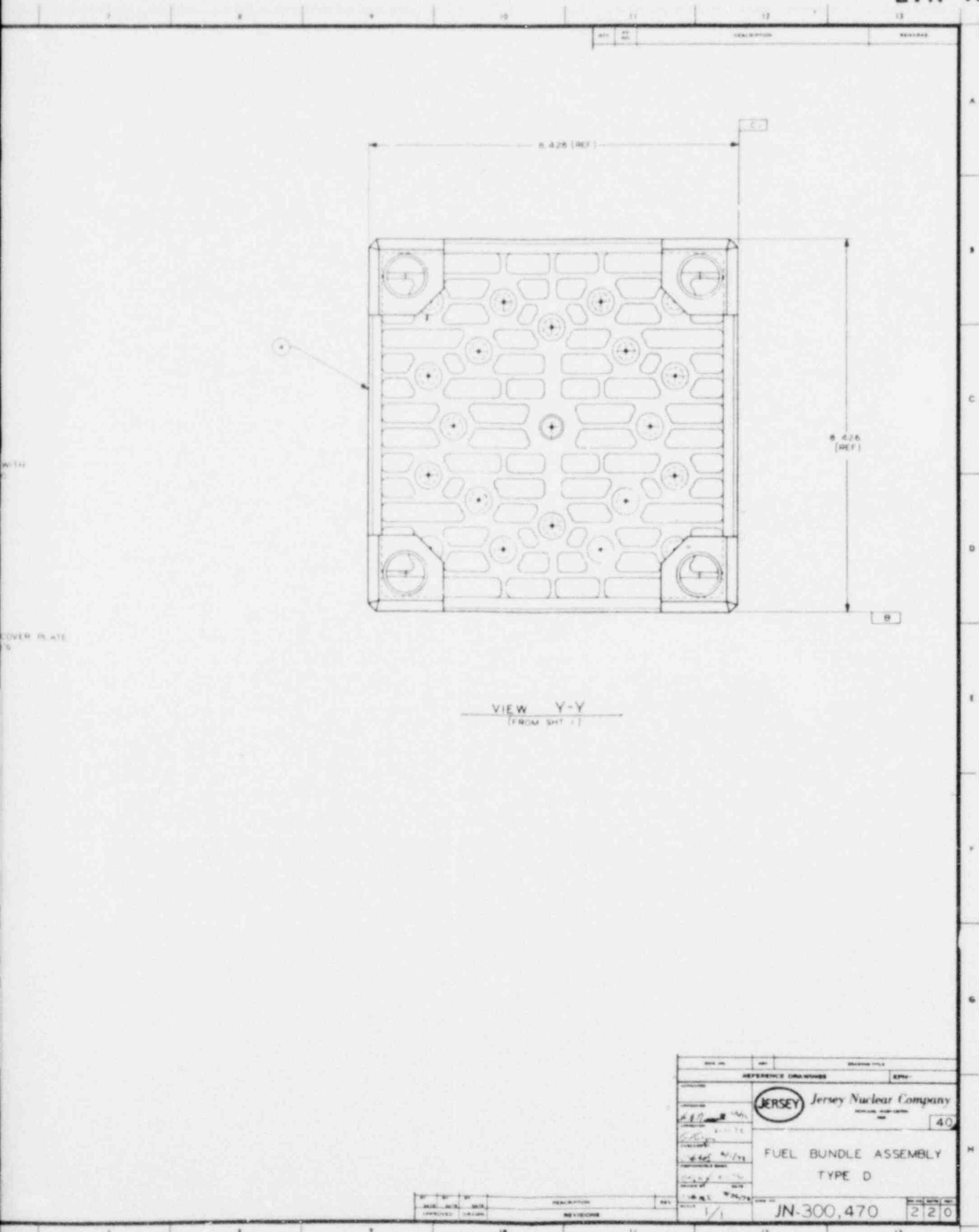
VIEW Z-Z
(FROM SHT 1)
UPPER END BOX -ITEM 3- REMOVED FOR CLARITY



GUIDE TUBE INSTALLATION SEQUENCE DIAGRAM

FIGURE 5 TYPE 'D'

LTR 1111.65
REV 1



FUEL BUNDLE CROSS SECTION

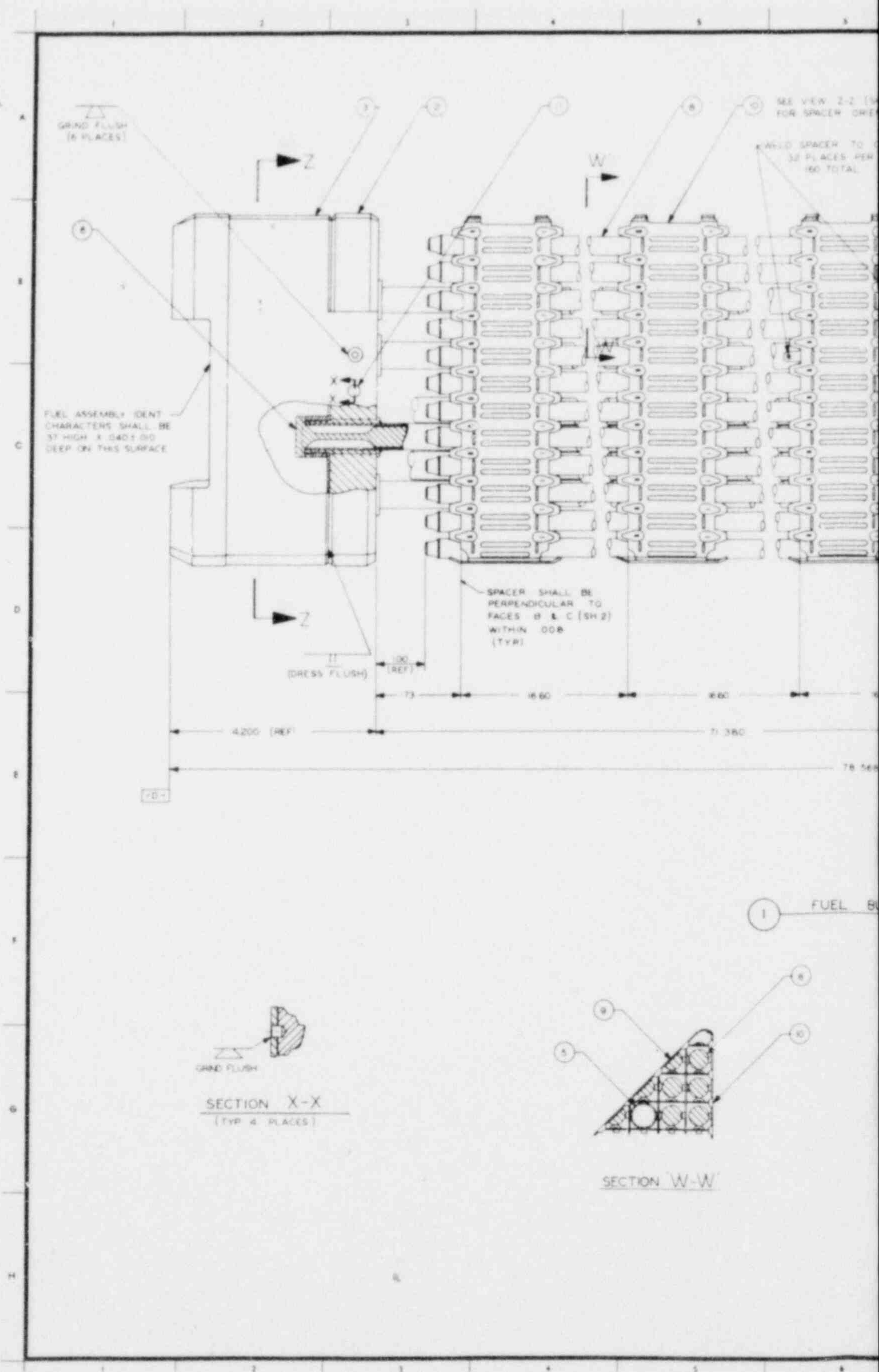
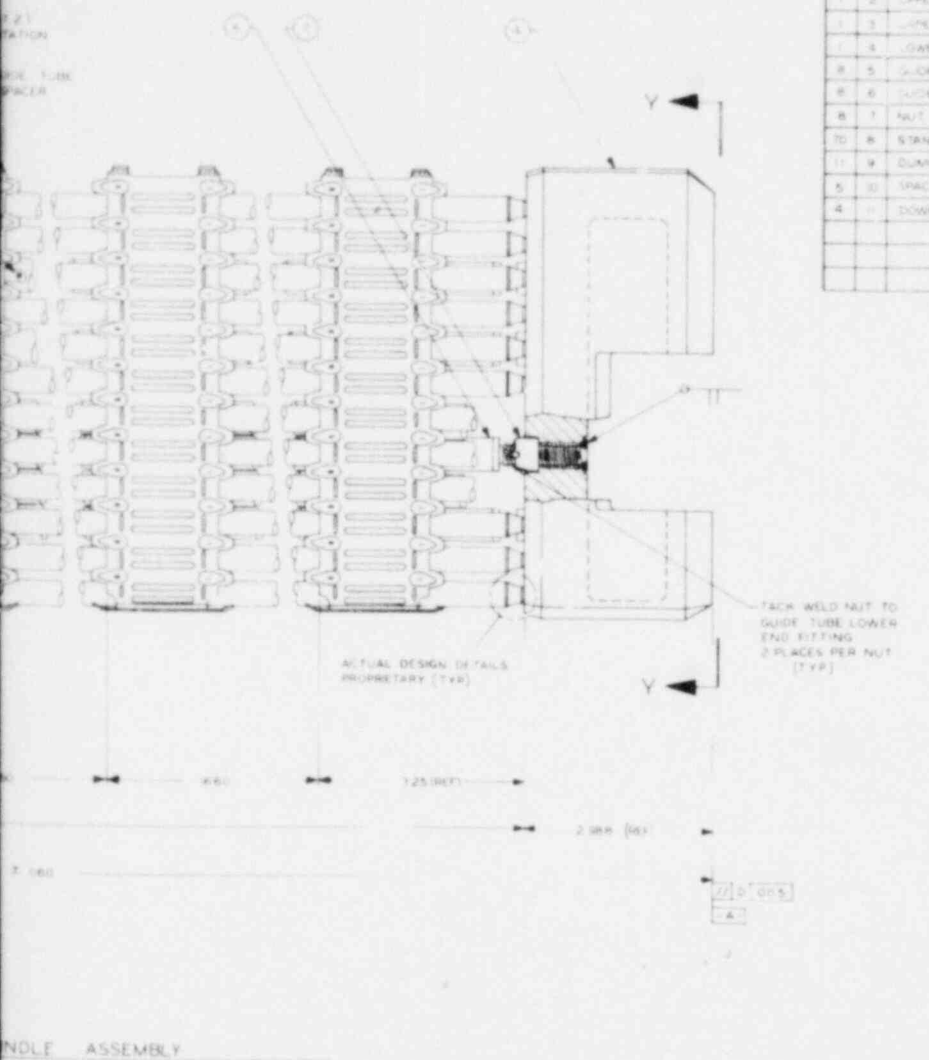


FIGURE 6 TYPE 'E



		DESCRIPTION	REMARKS
X	1	FUEL BUNDLE ASSY (TYPE E)	————
1	2	UPPER GRID PLATE ASSY	JN-300.389
1	3	UPPER BOX ASSY	JN-300.390
1	4	LOWER TIE PLATE ASSY	JN-300.388
8	5	GUIDE TUBE ASSY	JN-300.345 ASSY
8	6	GUIDE TUBE FLOW RESTRICTION DEVICE	JN-300.566
8	7	NUT LOWER GUIDE TUBE	JN-300.356
70	8	STANDARD ROD ASSY	JN-300.483
11	9	DUMMY HALF ROD	JN-300.398
5	10	SPACER ASSY	JN-300.406
4	11	DOWEL PIN	JN-300.399

NOTES

1. DIMENSIONAL TOLERANCES (UNLESS OTHERWISE STATED) .XX ± .015, .XXX ± .005 ANGLES ± 2°
2. DIMENSIONING AND TOLERANCING ARE IN ACCORDANCE WITH ANSI Y14.5 1968
3. THE ASSEMBLED BUNDLE IN THE VERTICAL POSITION SHALL FIT WITHIN A TRIANGULAR ENVELOPE BOUNDED BY TWO SIDES OF 7.429 AND ONE SIDE OF 10.506, ALL PERPENDICULAR TO A LOCATING PLANE DESCRIBED BY PLANE A. ALL THREE SIDES OF THE LOWER TIE PLATE MUST BE CENTERED INSIDE THIS ENVELOPE BY A MINIMUM OF .005
4. CONSULT PRODUCT SPEC FOR BUNDLE ASSEMBLY SEQUENCE & WELD REQUIREMENTS

REFERENCE DRAWINGS

JERSEY Jersey Nuclear Company

FUEL BUNDLE ASSEMBLY (TYPE E)

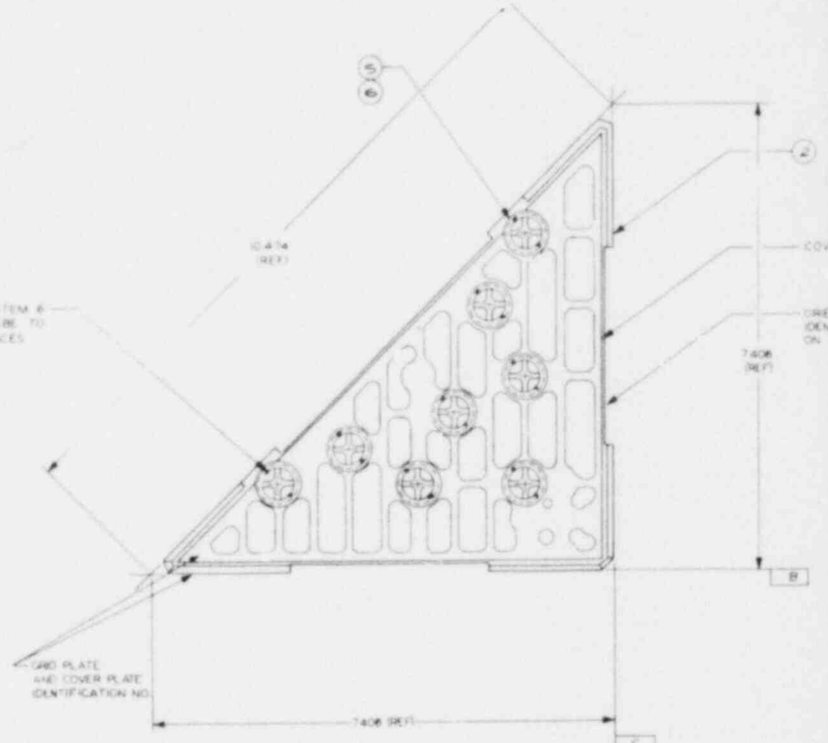
SCALE 1/1

JN-300.471

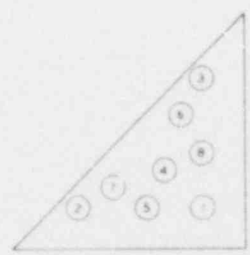
40

1	2	0

FUEL BUNDLE ASSEMBLY



VIEW Z-Z
(FROM SHEET 1)
UPPER END BOX - ITEM 3 REMOVED FOR CLARITY

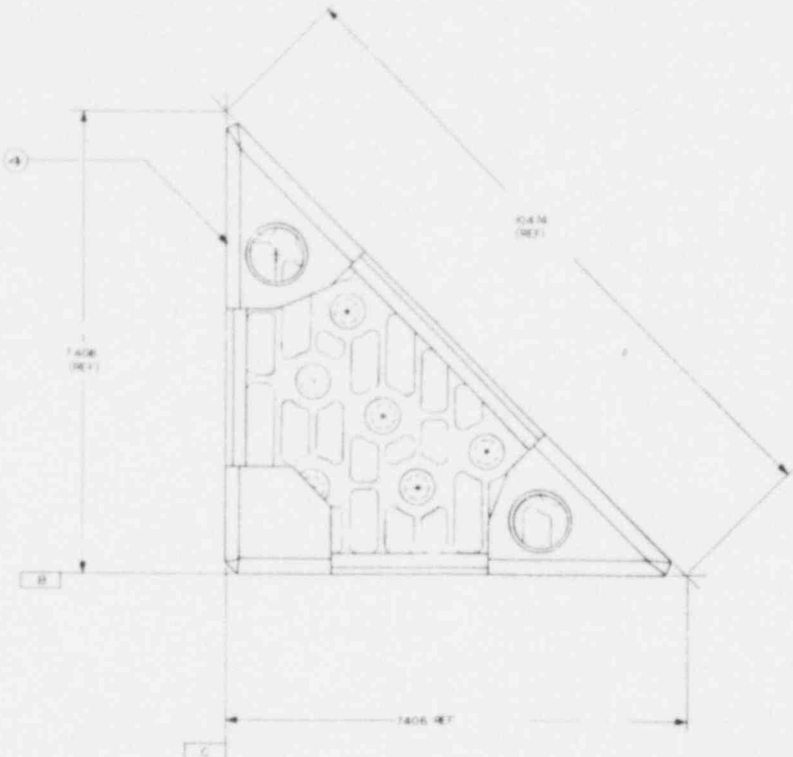


GUIDE TUBE INSTALLATION
SEQUENCE DIAGRAM

FIGURE 7 TYPE 'E'

LTR 1111 65

REV 1



VIEW Y-Y
(FROM SHEET 1)

REFERENCE DRAWINGS

JERSEY Jersey Nuclear Company

40

FUEL BUNDLE ASSEMBLY
TYPE E

JN-300.471

2 2 0

FUEL BUNDLE CROSS SECTION

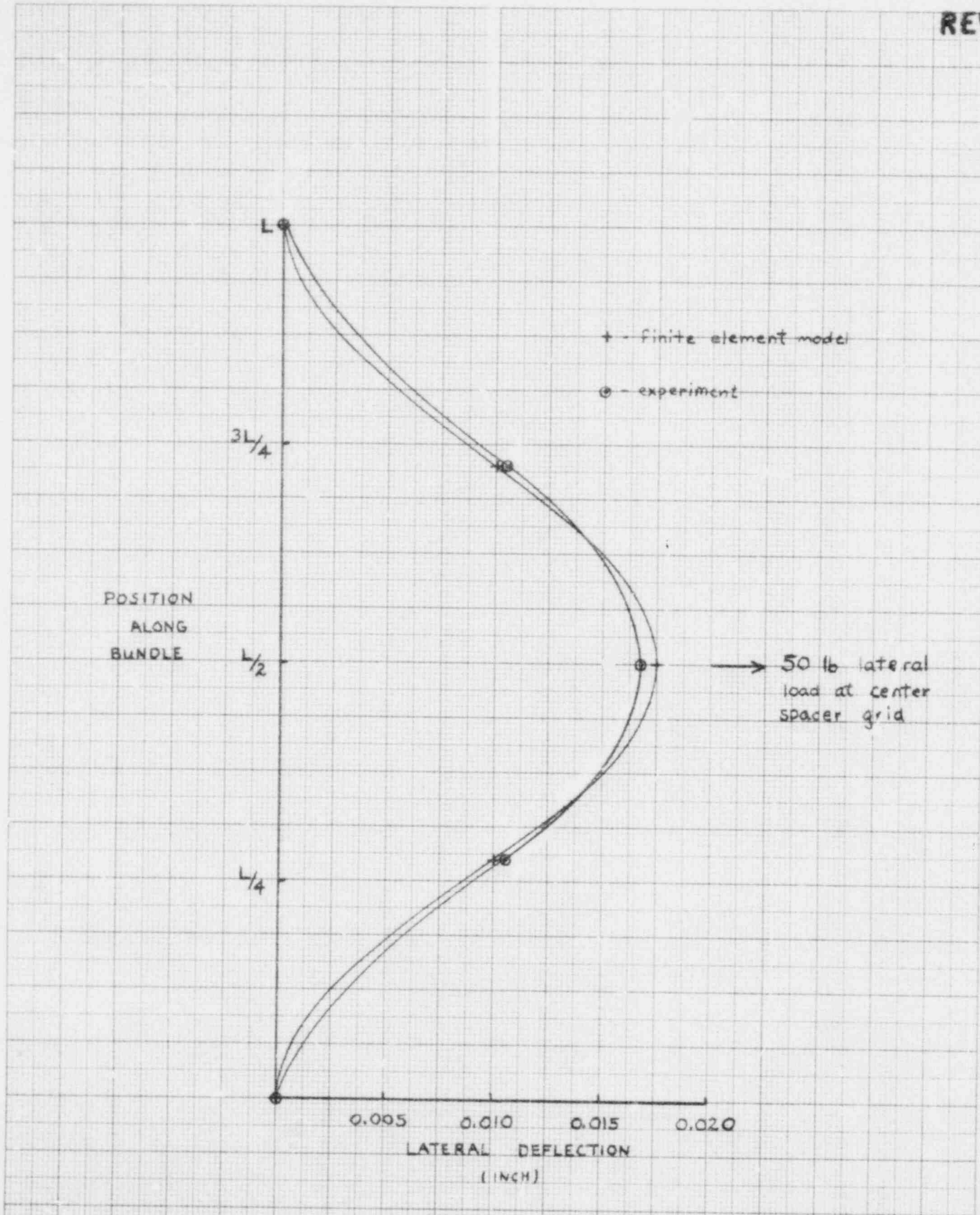


FIGURE 8 LATERAL DEFLECTION OF 'D' TYPE FUEL BUNDLE

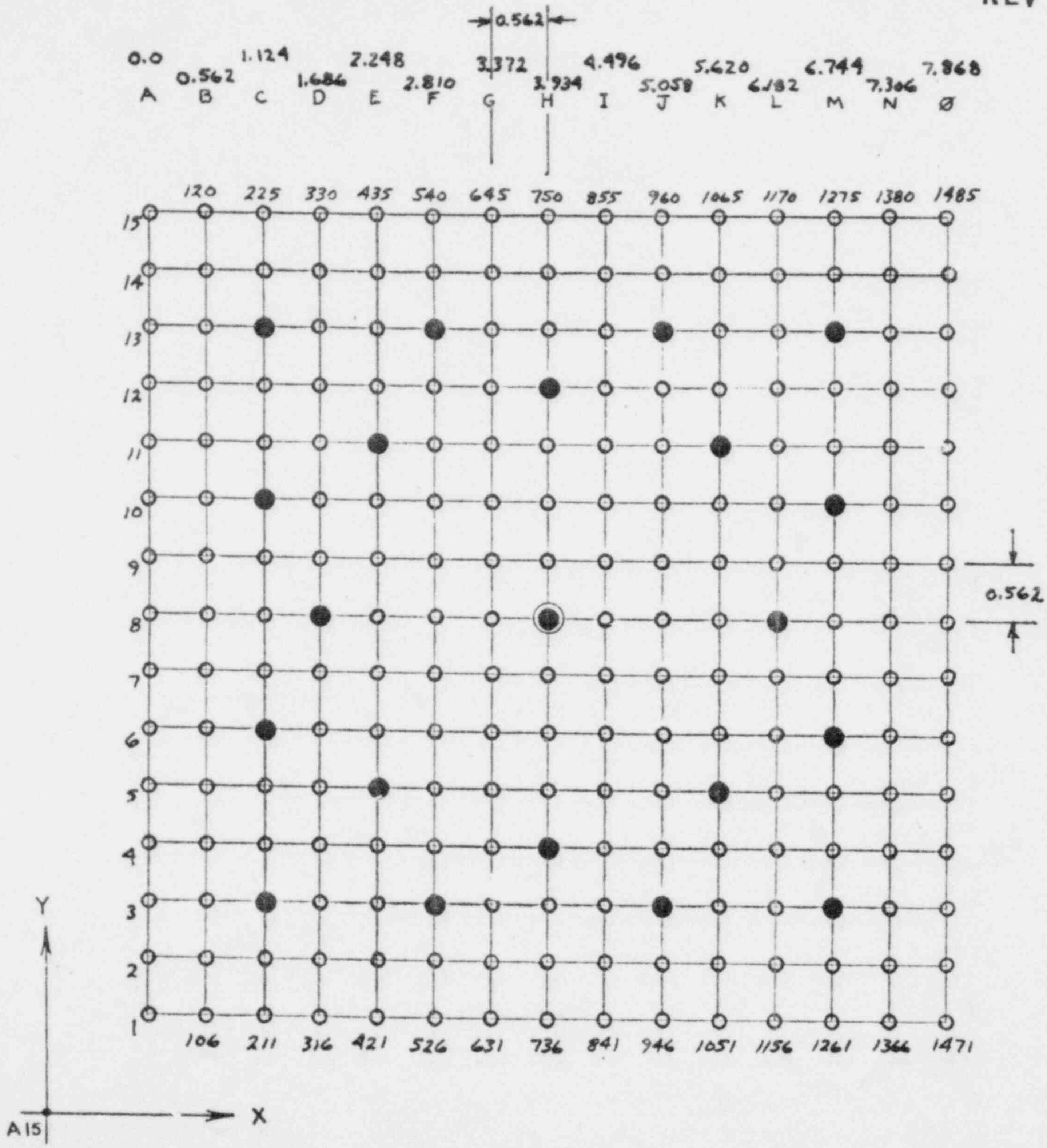


FIGURE 9 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 0.0

LTR IIII-65

REV 1

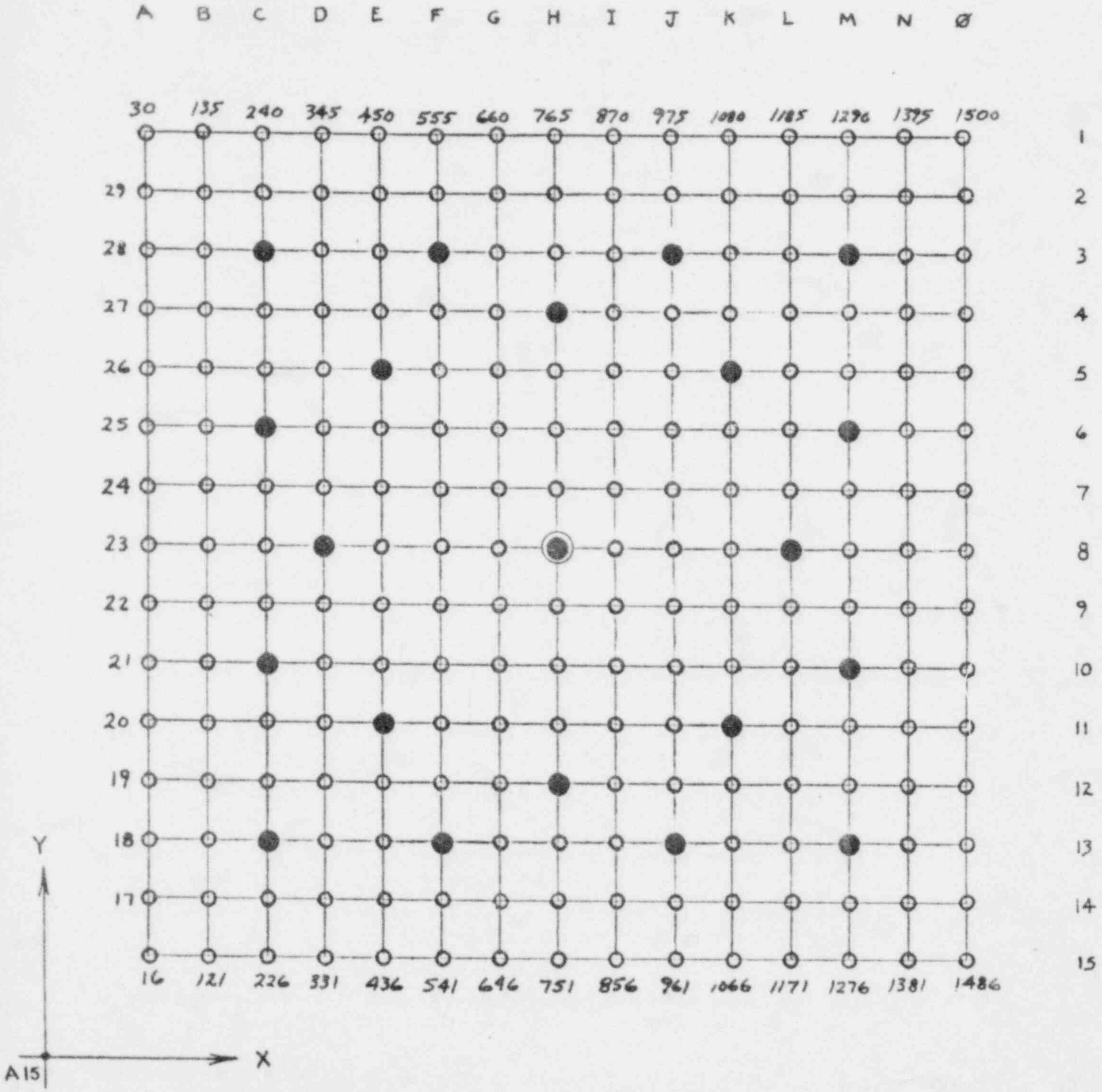


FIGURE 10 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 1.50

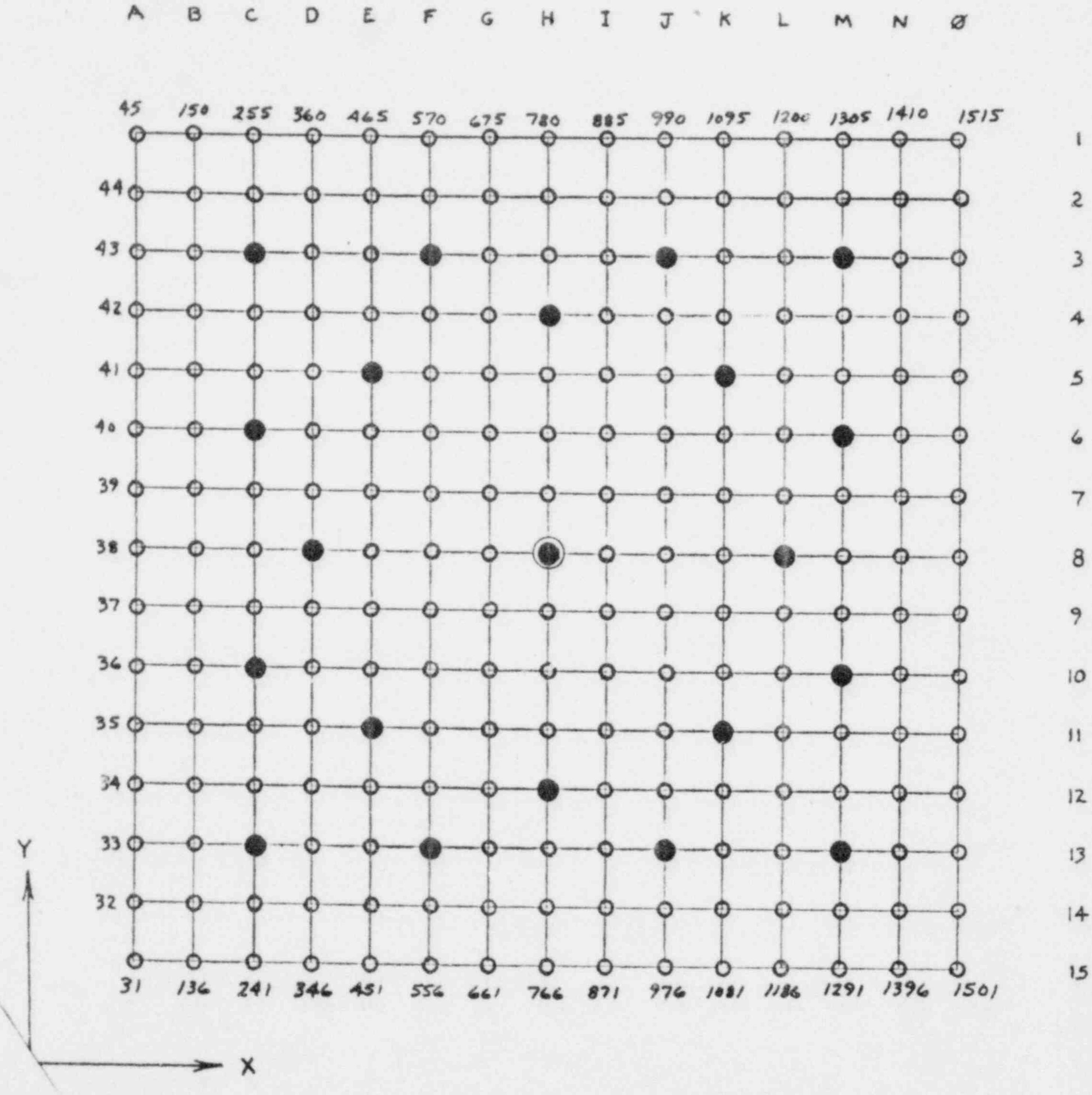


FIGURE 11 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 16.35

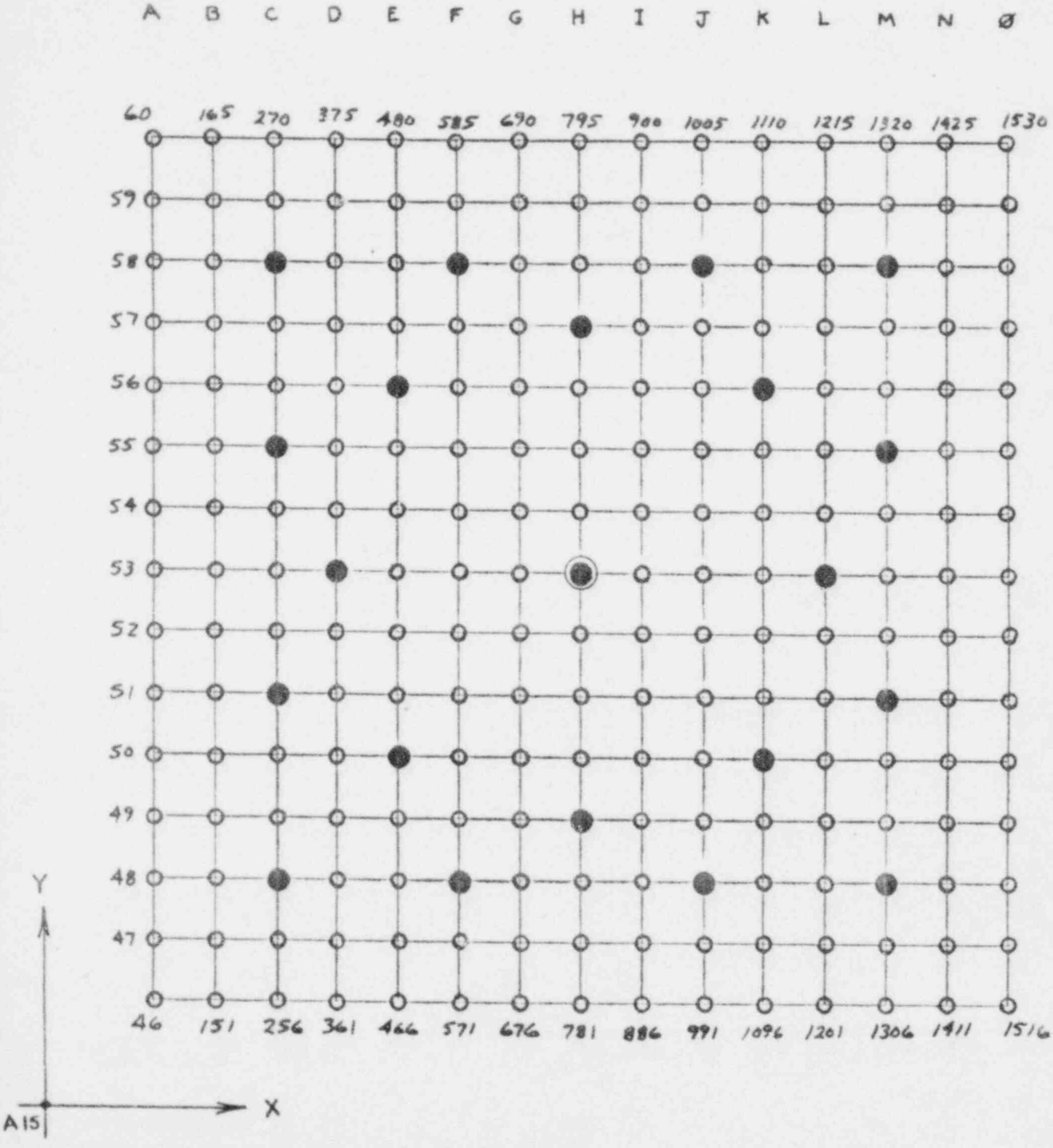


FIGURE 12 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 31.20

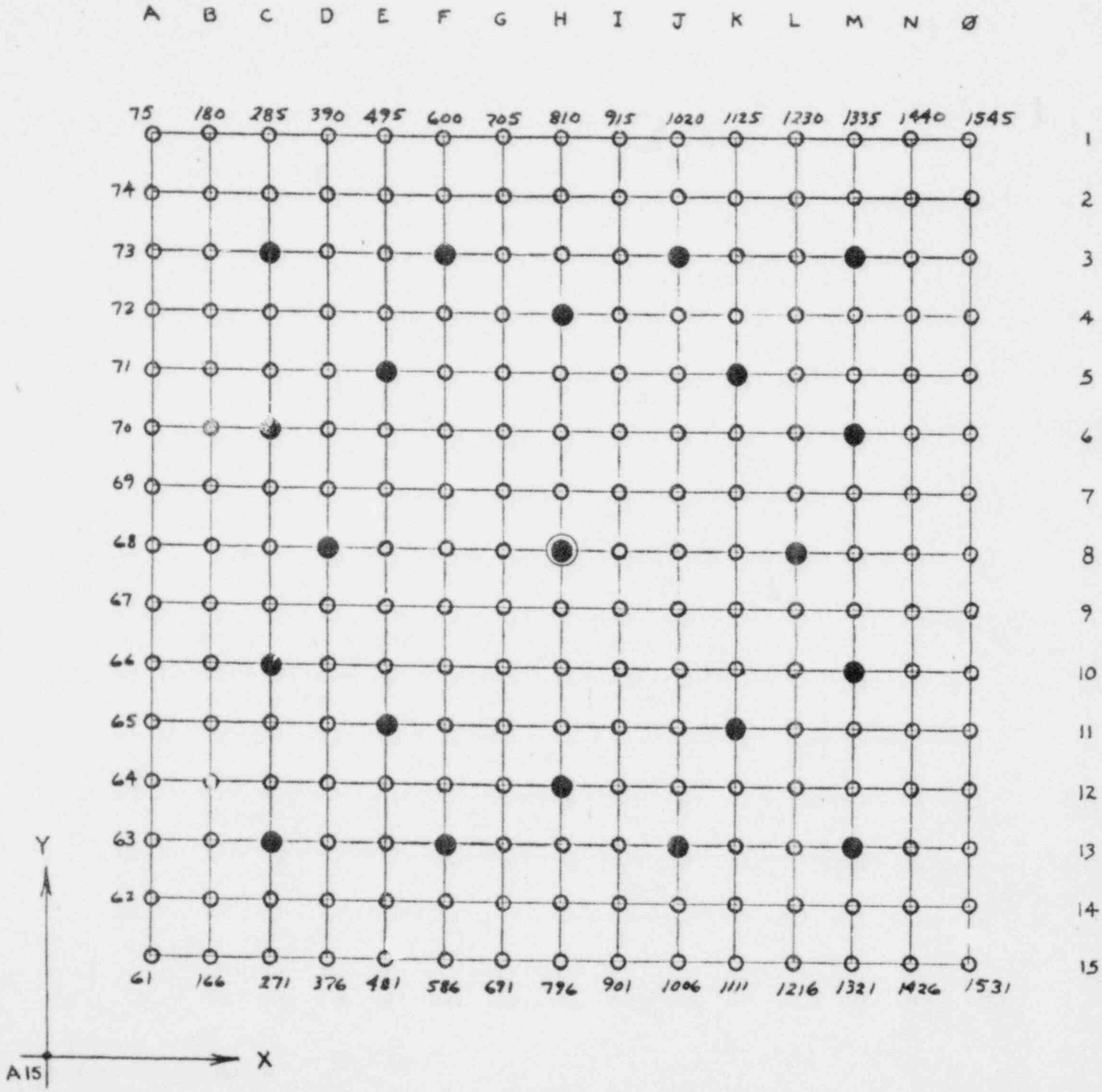


FIGURE 13 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 46.05

LTR 1111-65
REV 1

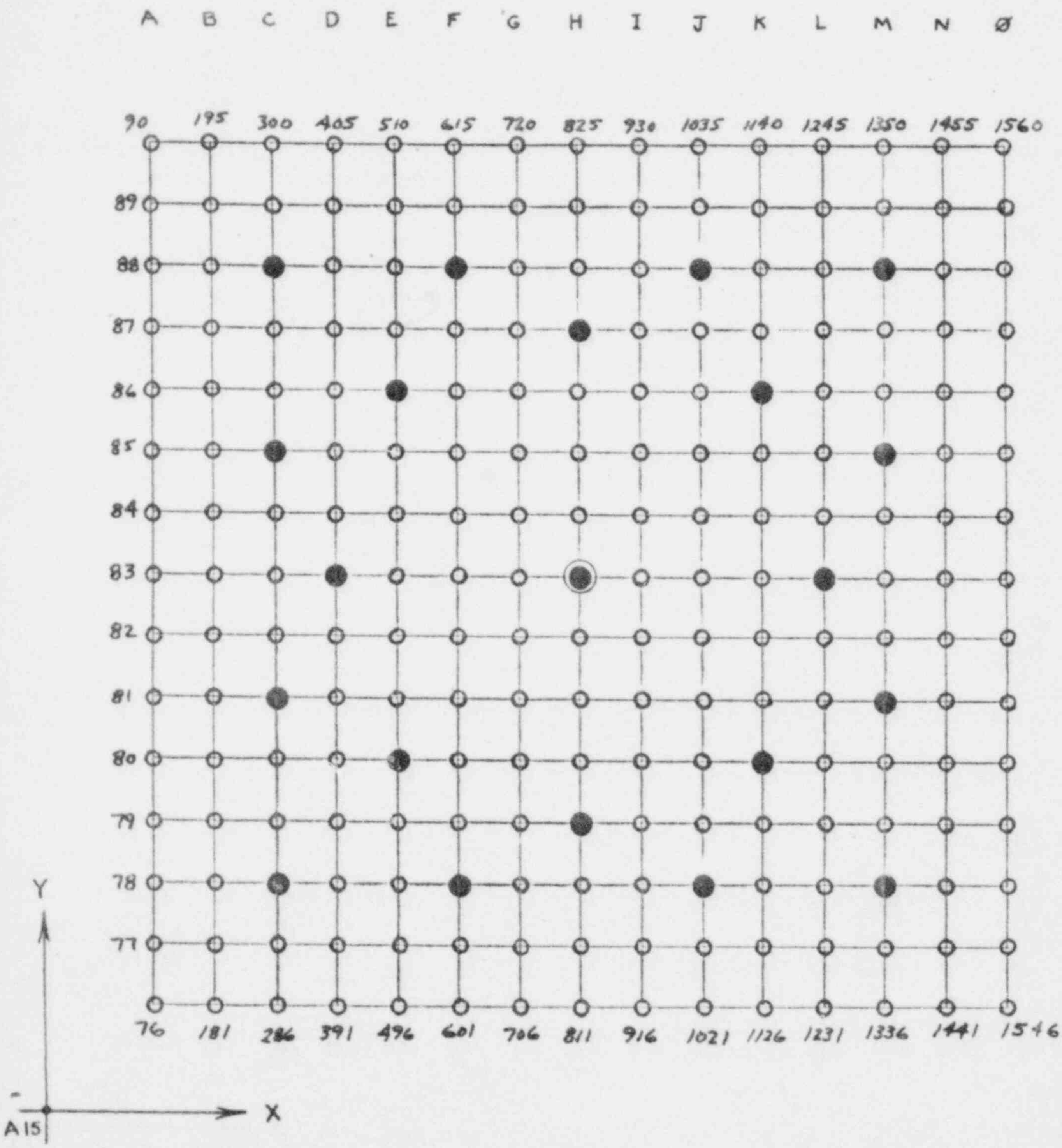


FIGURE 14 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 60.90

LTR 1111 65
REV 1

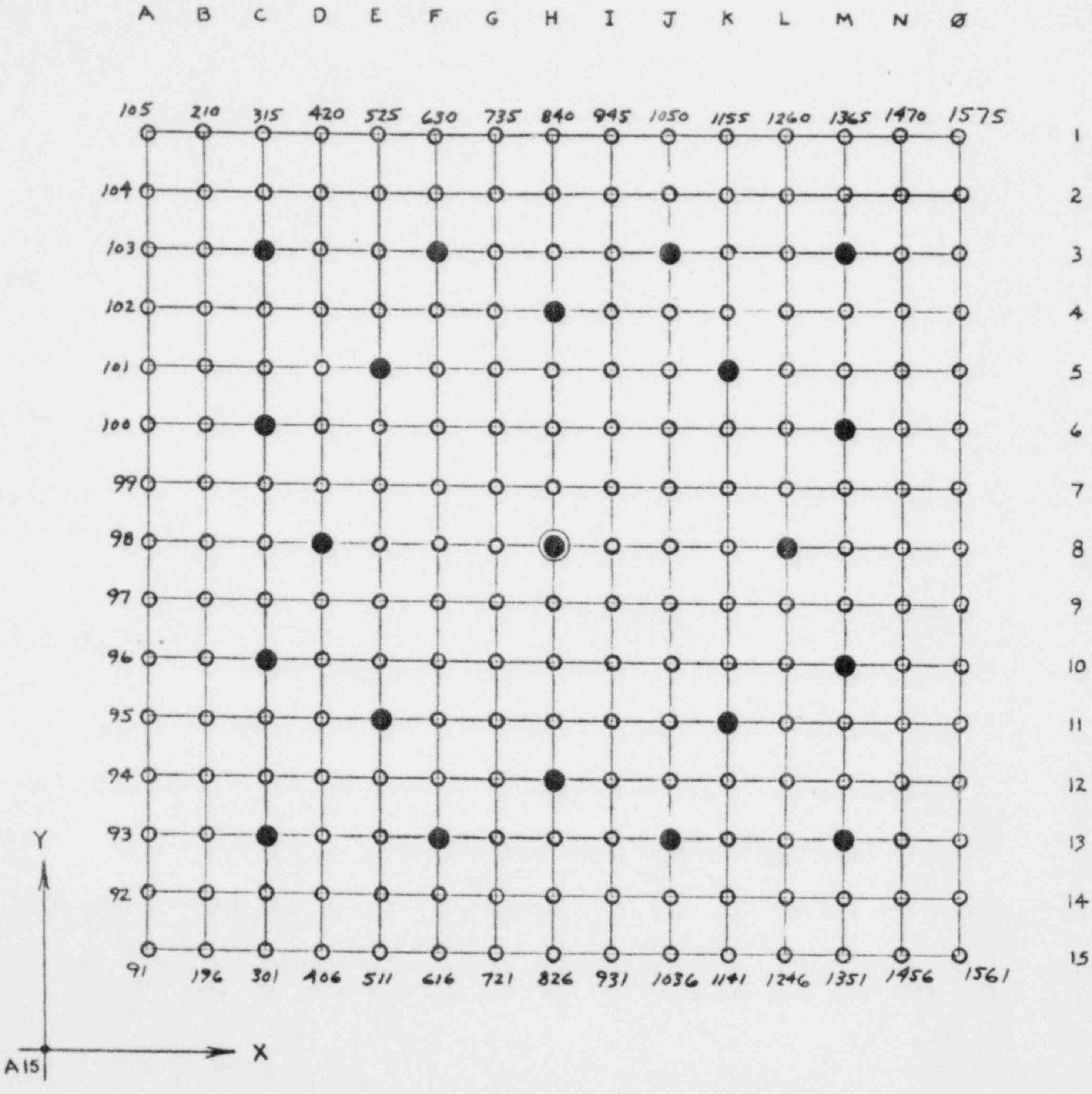


FIGURE 15 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE NUMBERS, Z = 62.63

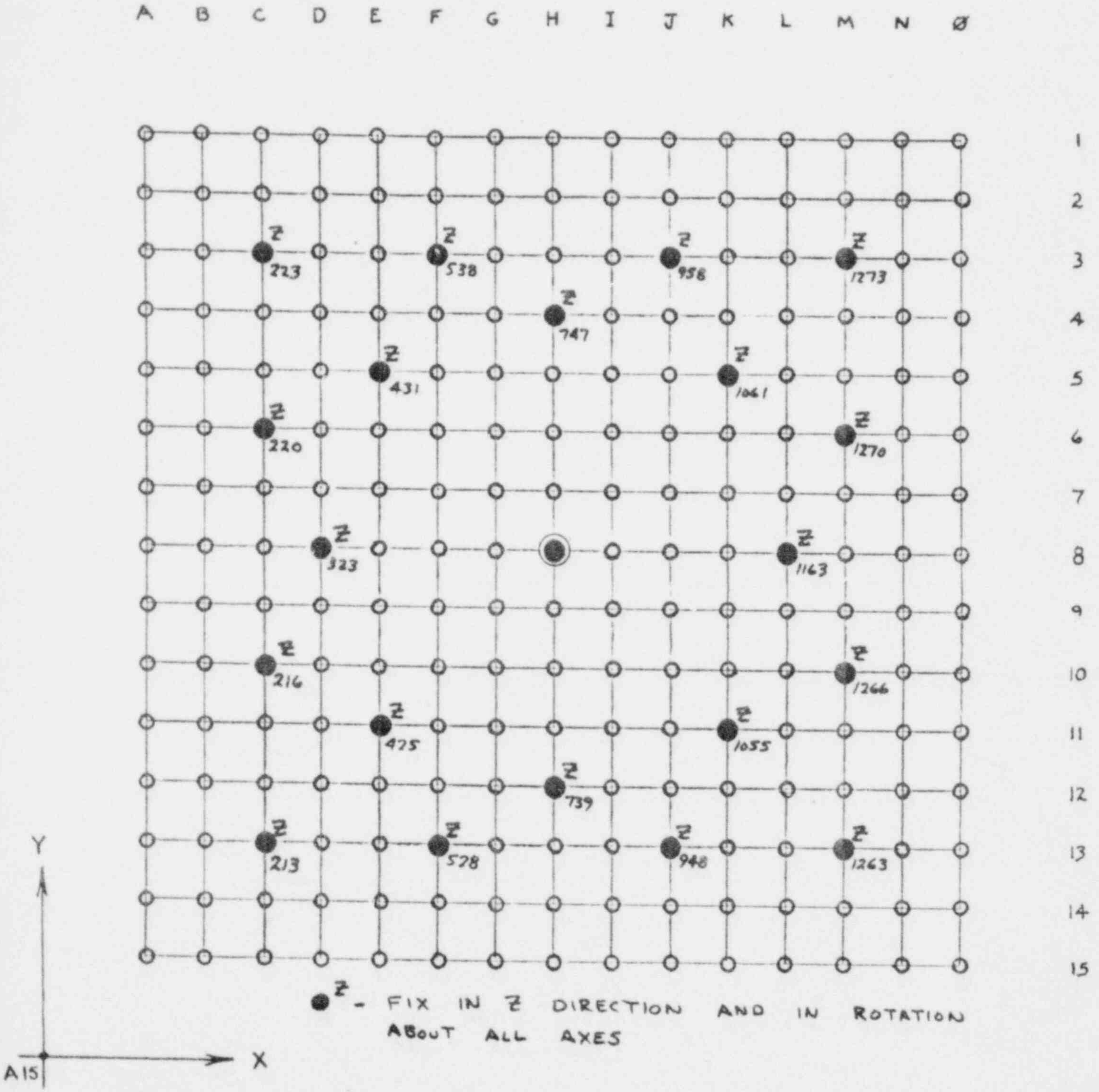


FIGURE 16 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

NODE FIXITIES, Z = 0.0

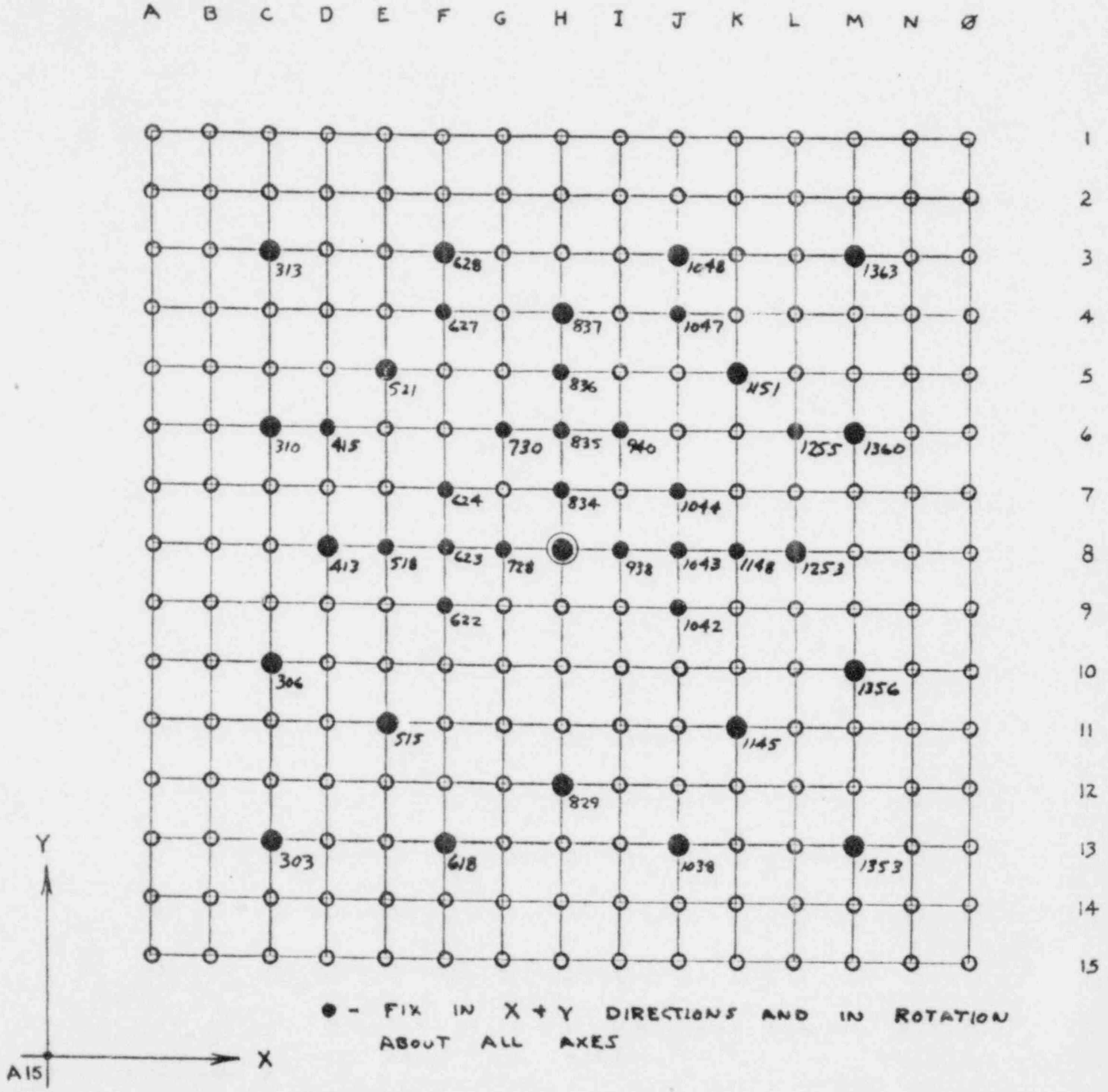


FIGURE 17 LOFT 'A' TYPE FUEL BUNDLE MODEL

NODE FIXITIES , Z = 62.63

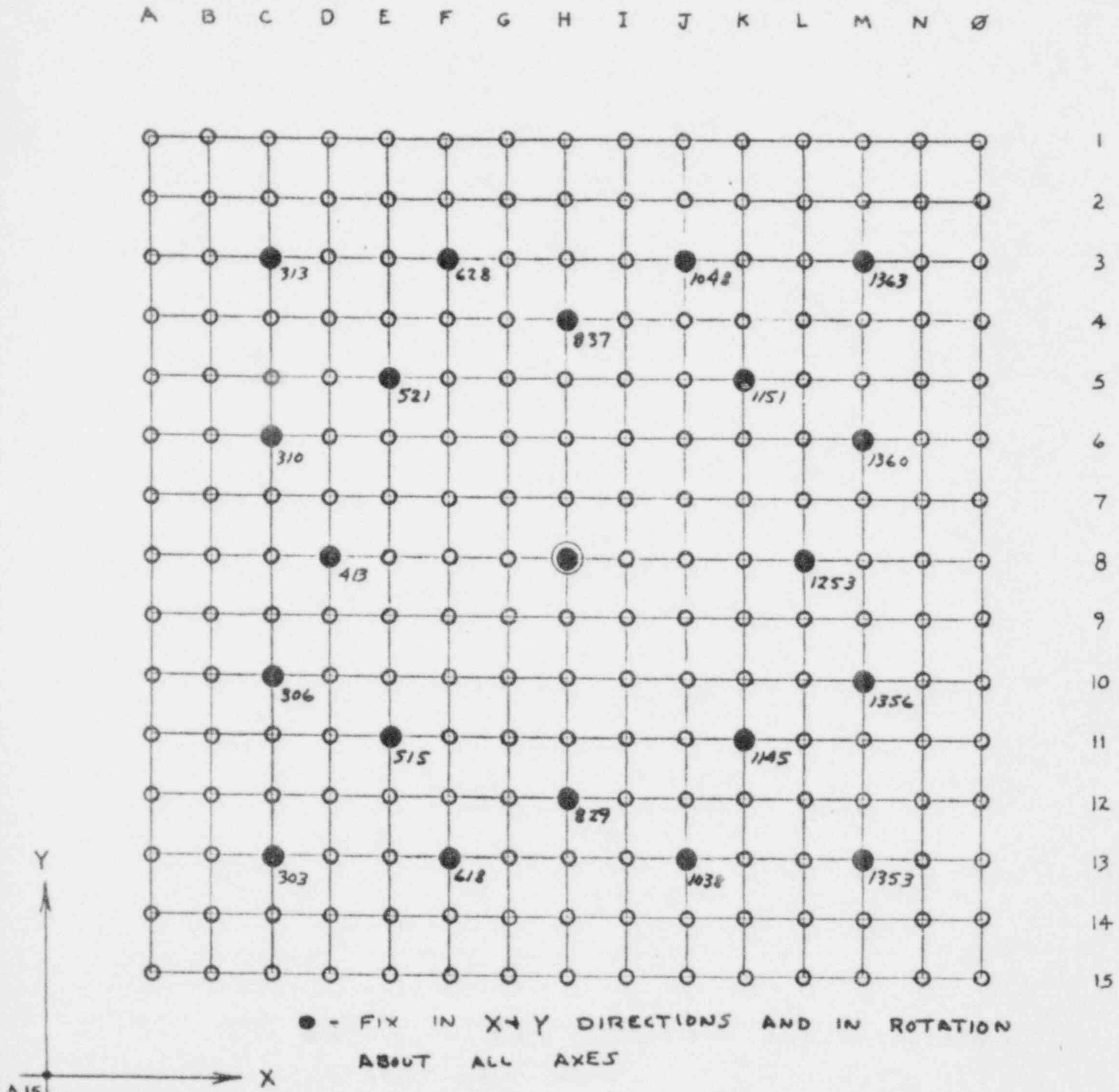


FIGURE 18 LOFT 'D' TYPE FUEL BUNDLE MODEL

NODE FIXITIES, Z = 62.63

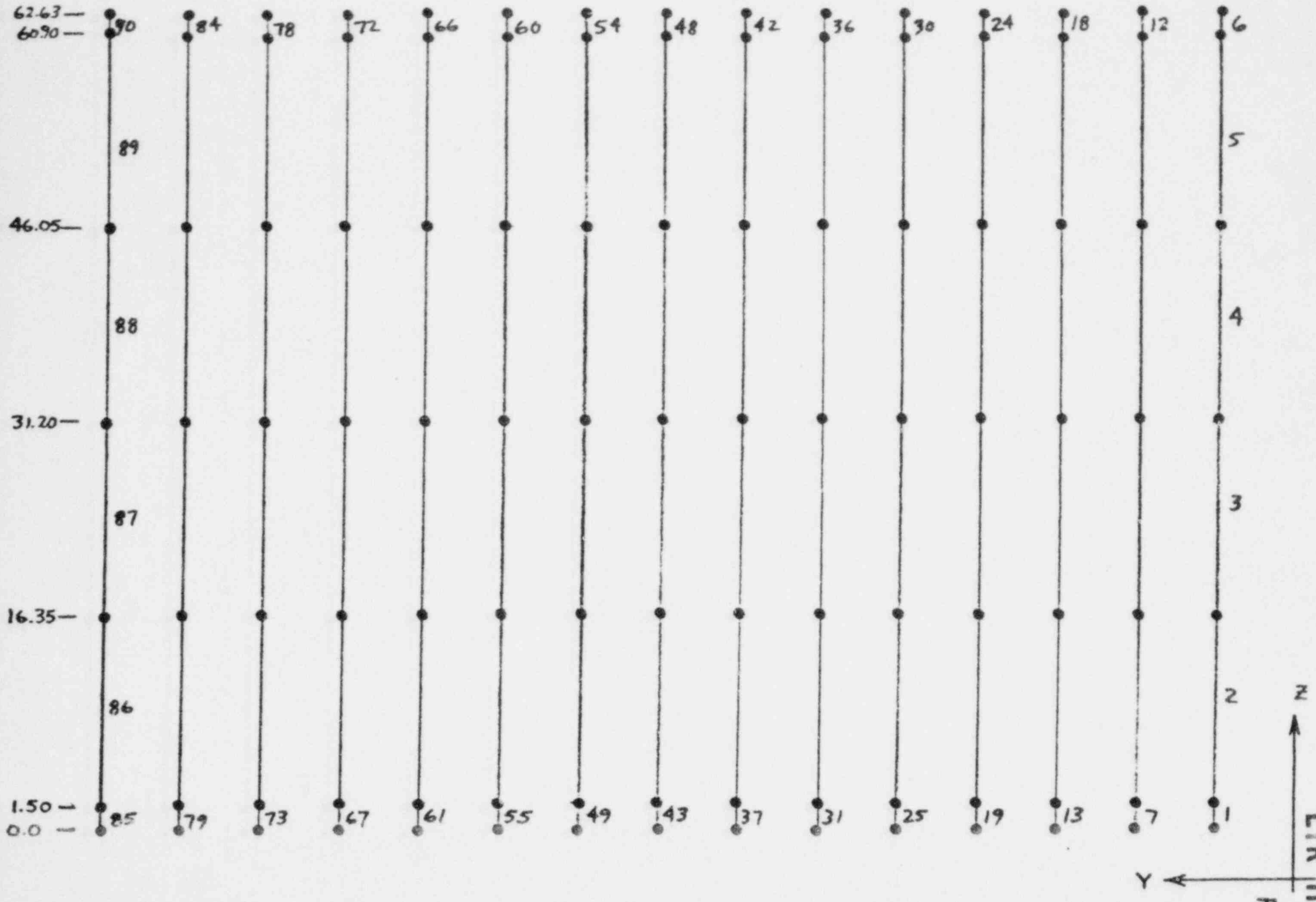


FIGURE 19 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 0.0

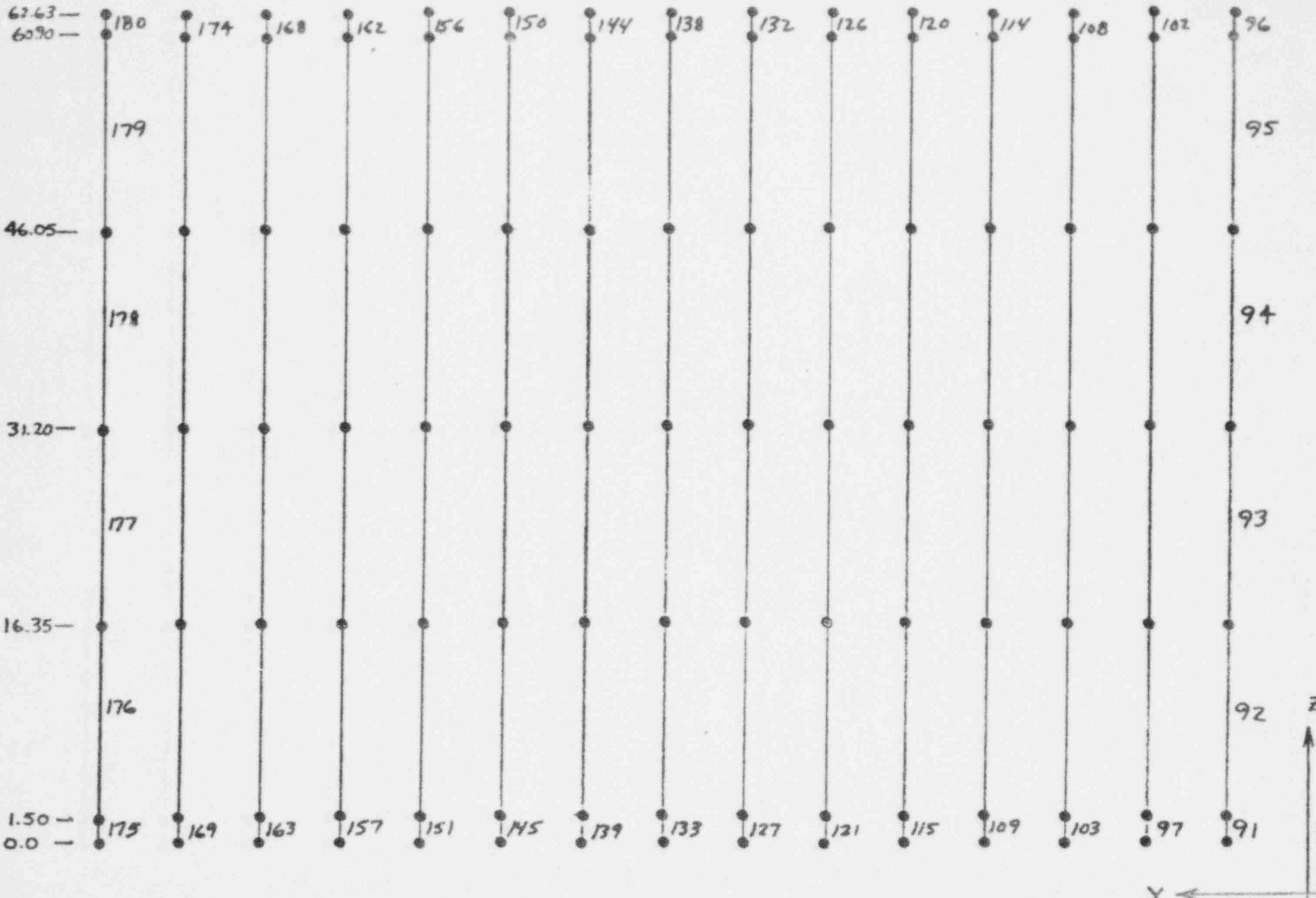


FIGURE 20 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 0.562

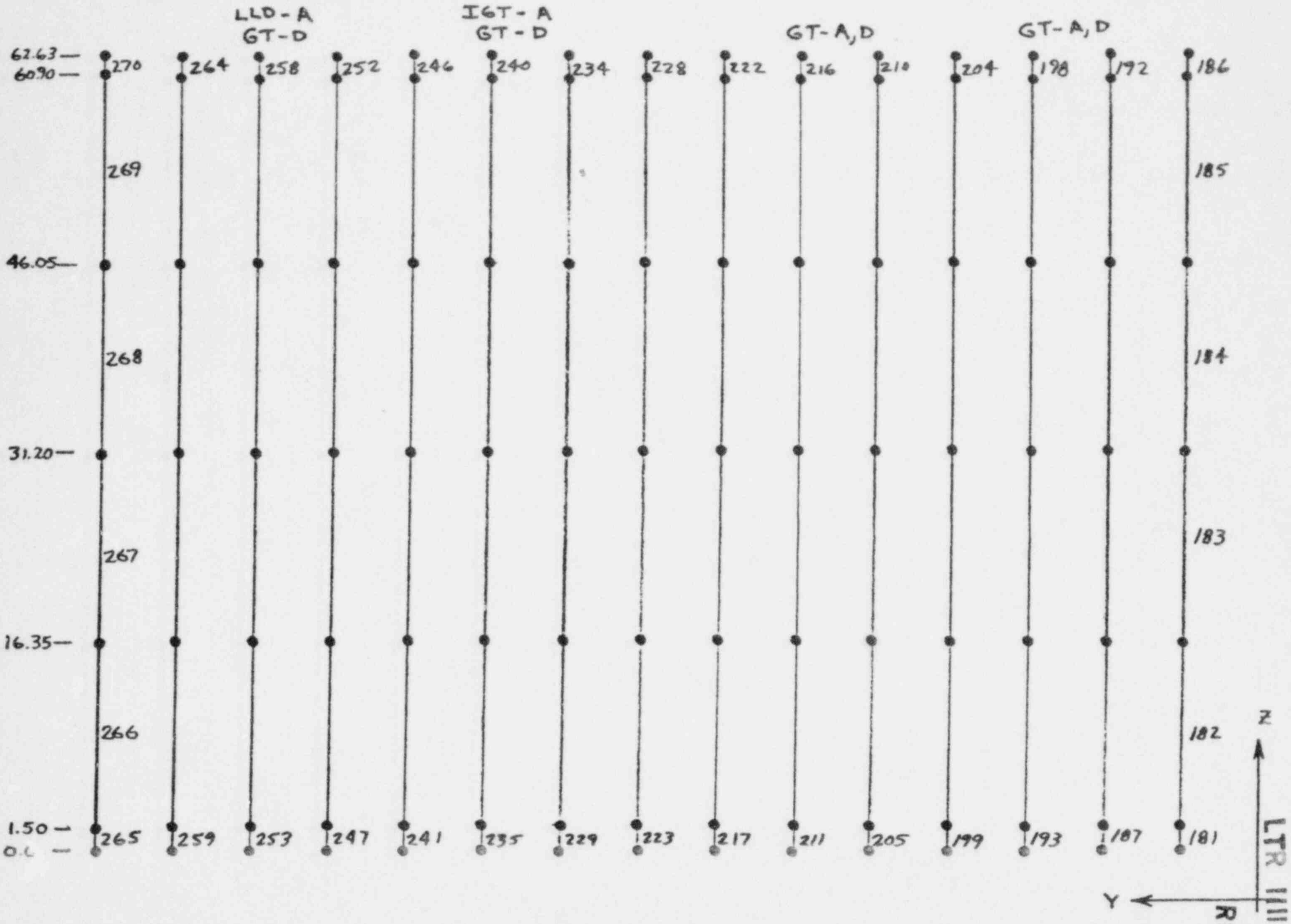


FIGURE 21 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 1.124

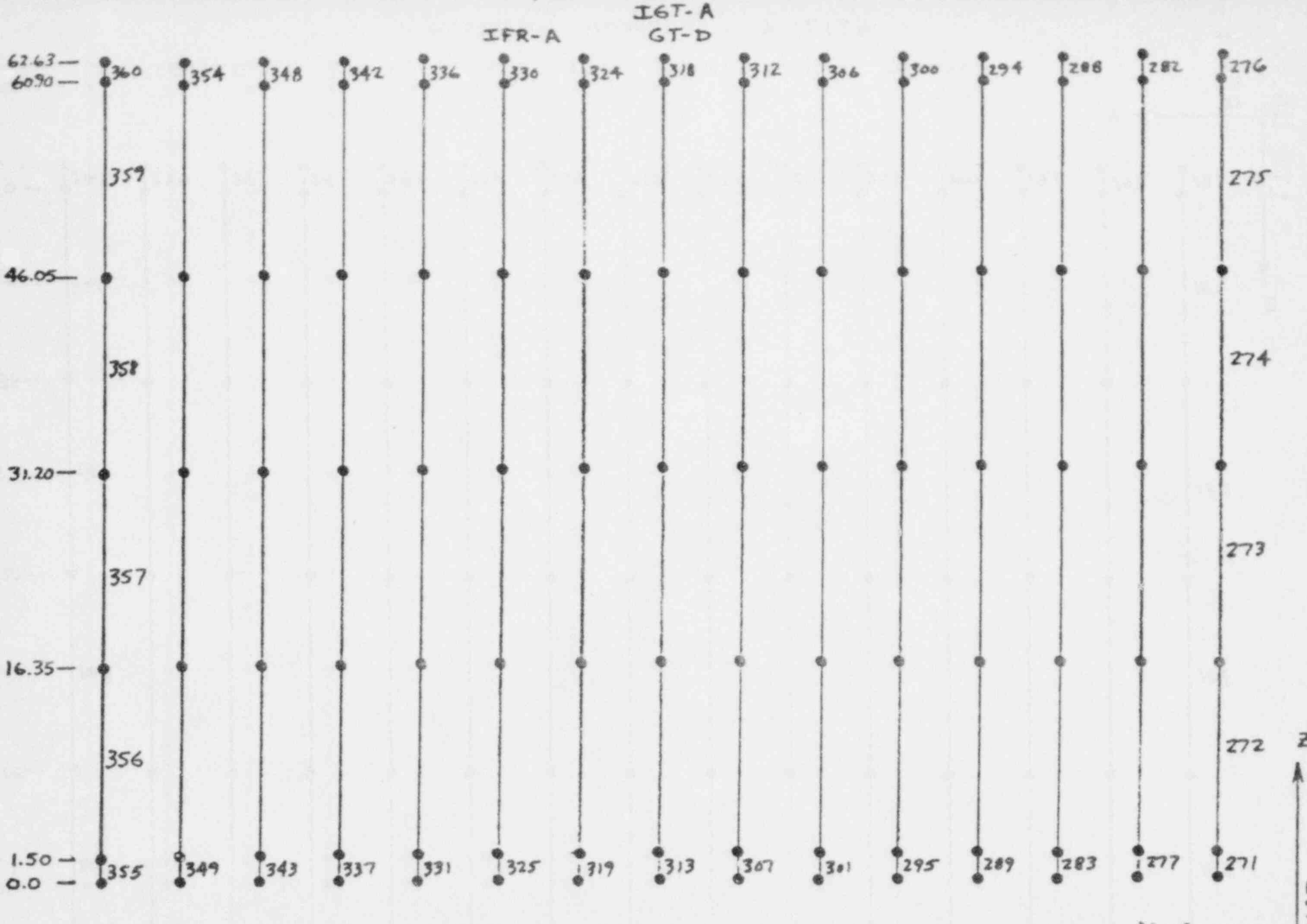


FIGURE 22 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS
ELEMENT NUMBERS, X = 1.686

LTR 44 IIII-65
REV 1

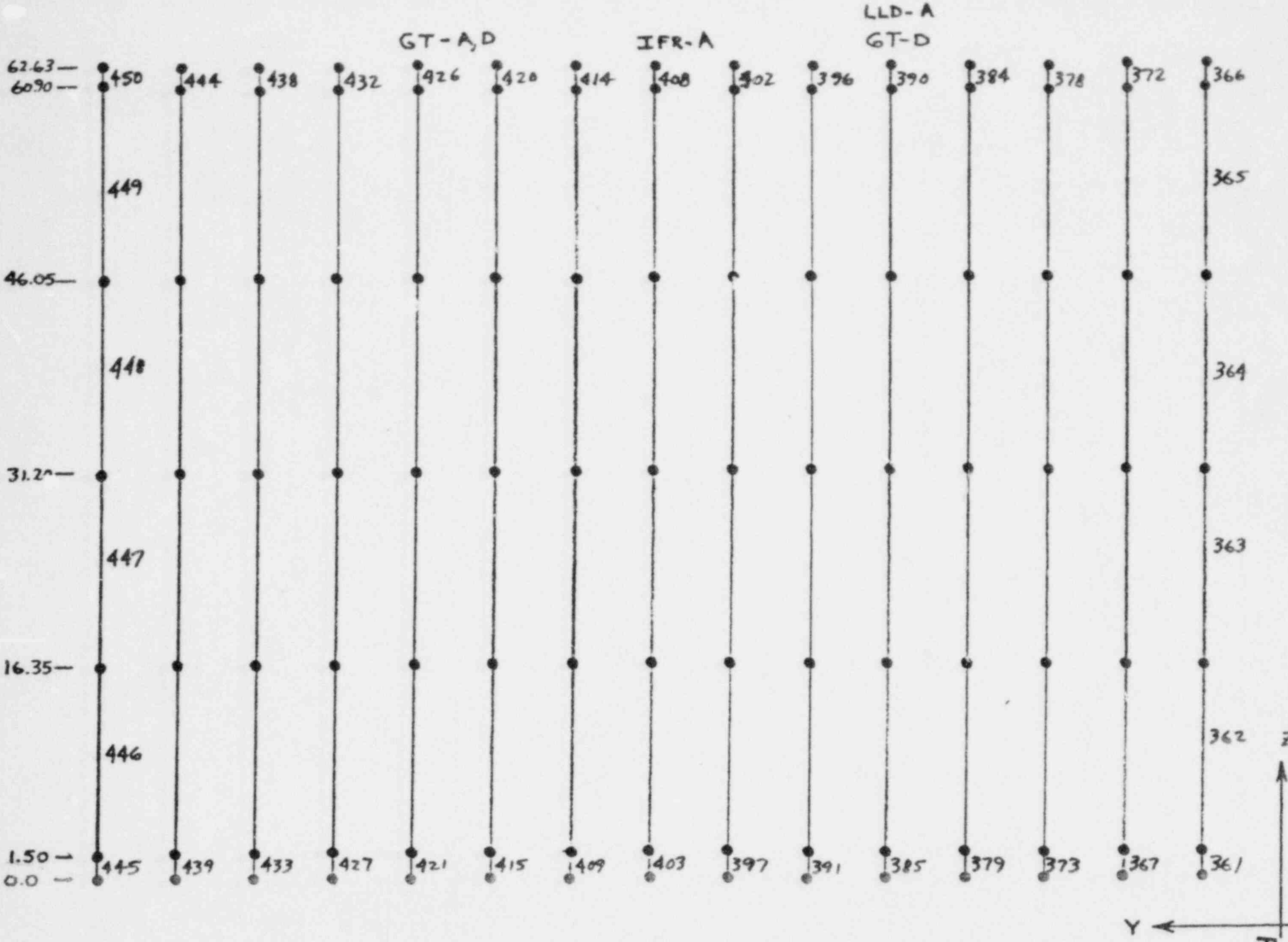


FIGURE 23 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 2.248

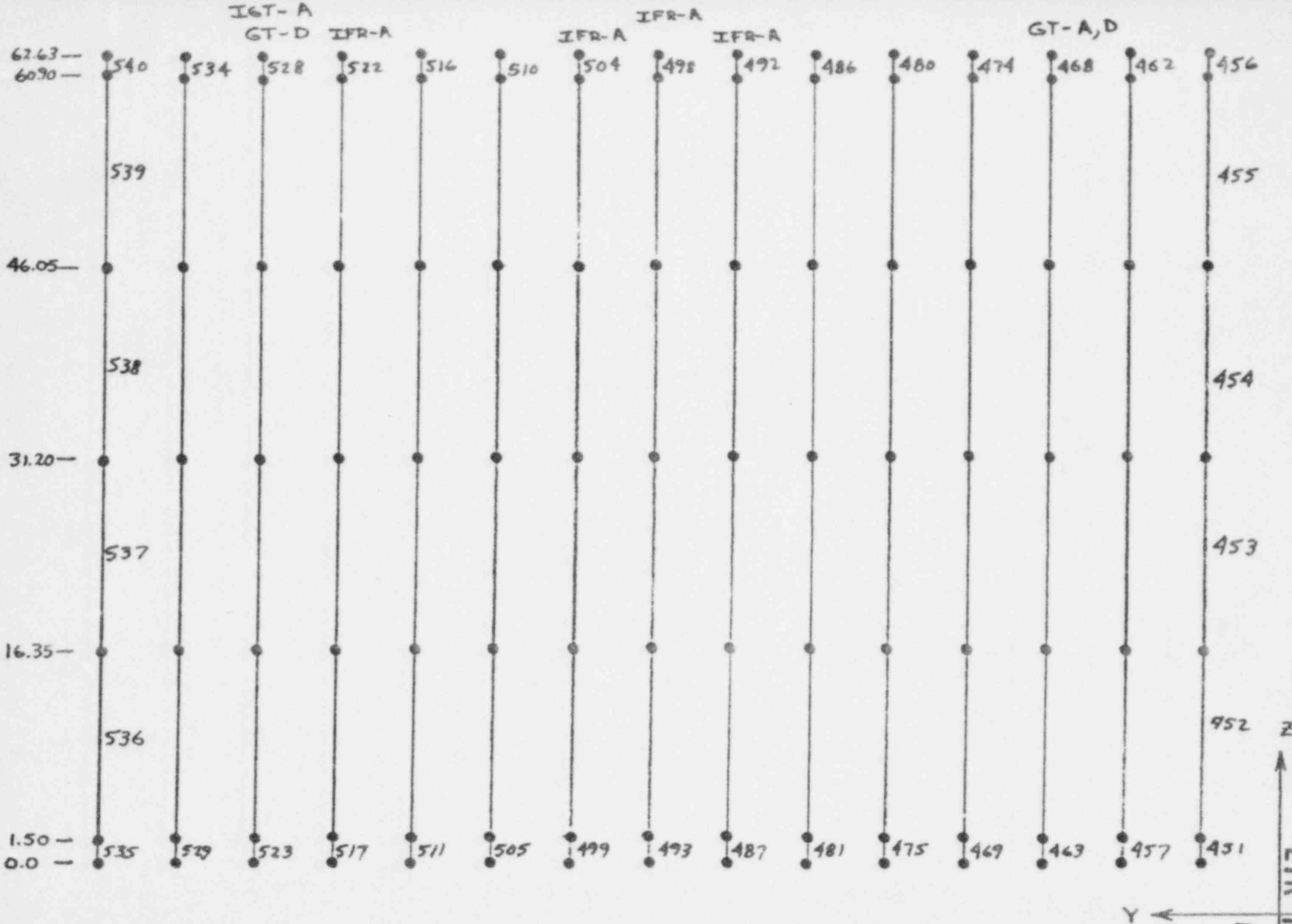


FIGURE 24 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 2.810

LTR 11111.65
REV 1

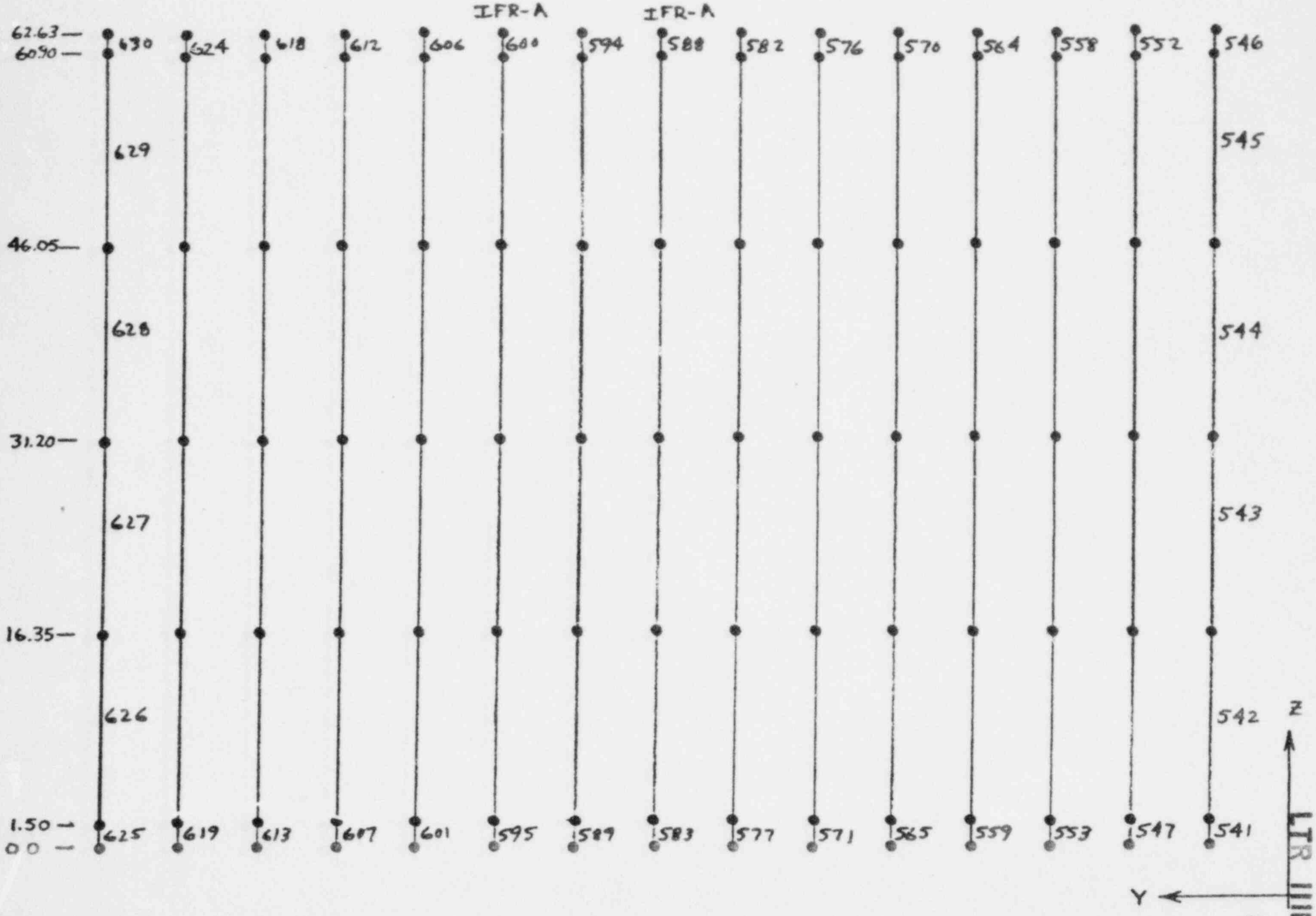


FIGURE 25 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 3.372

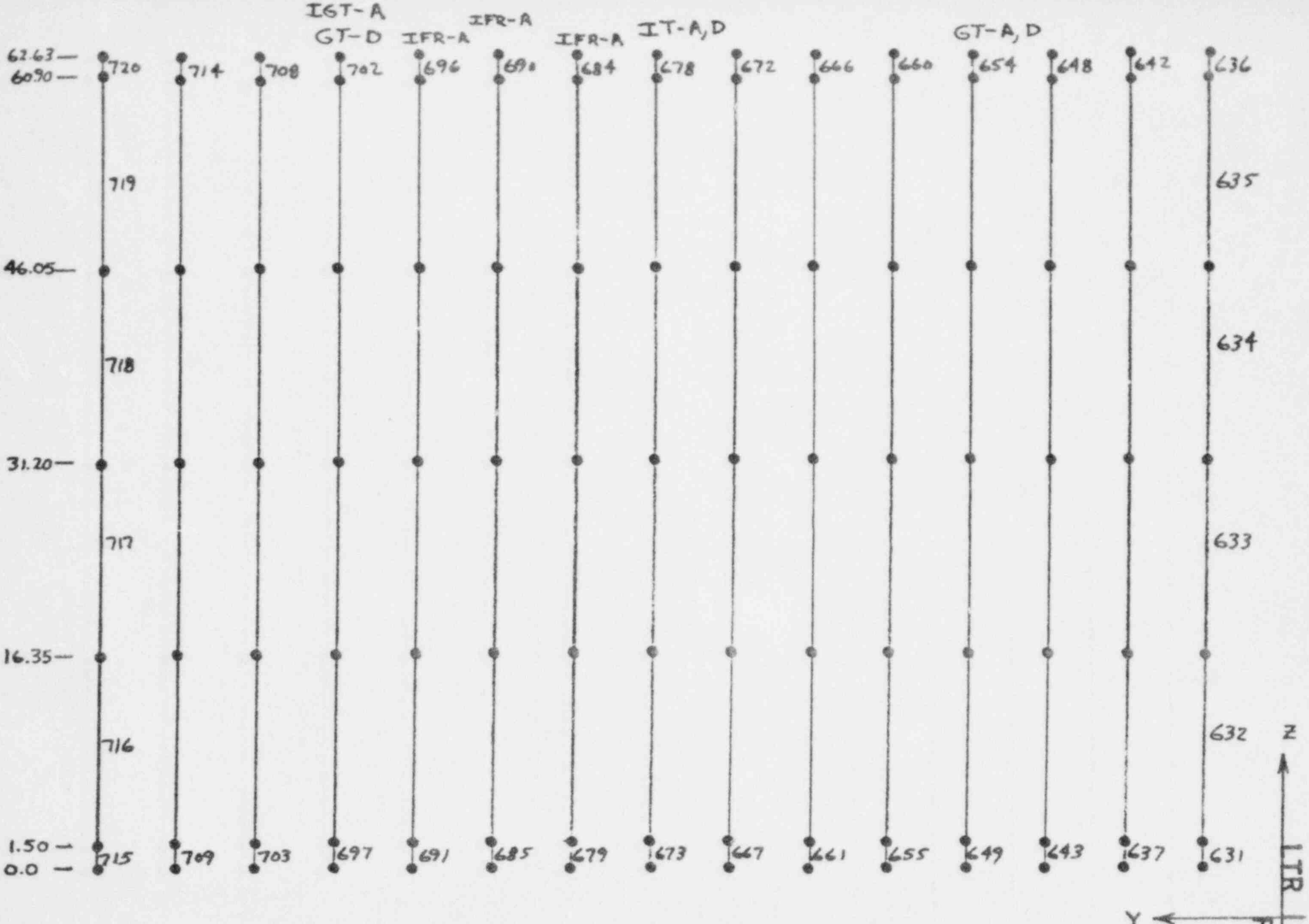


FIGURE 26 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 3.934

LTR IIII 65
REV 1

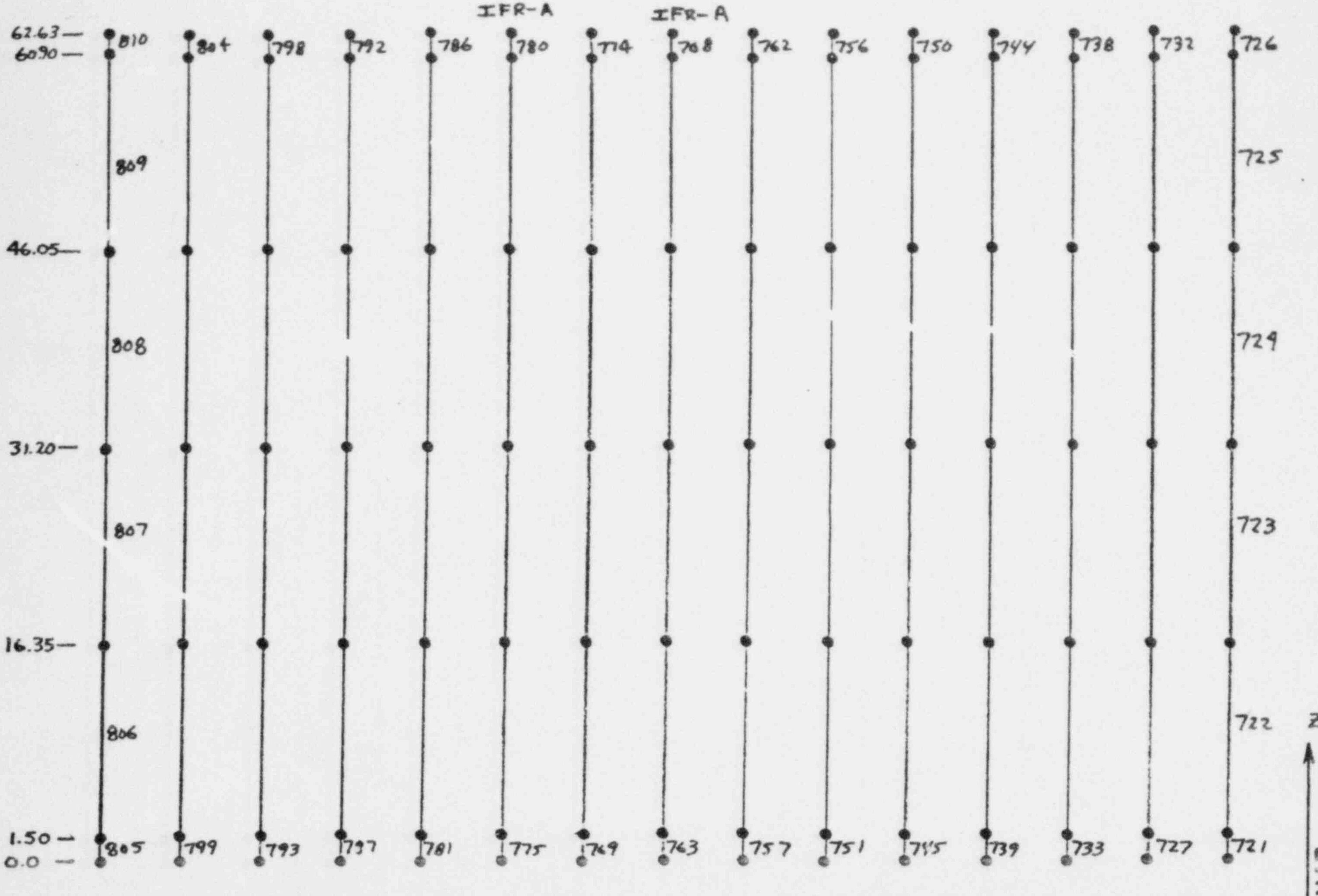


FIGURE 27 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 4.496

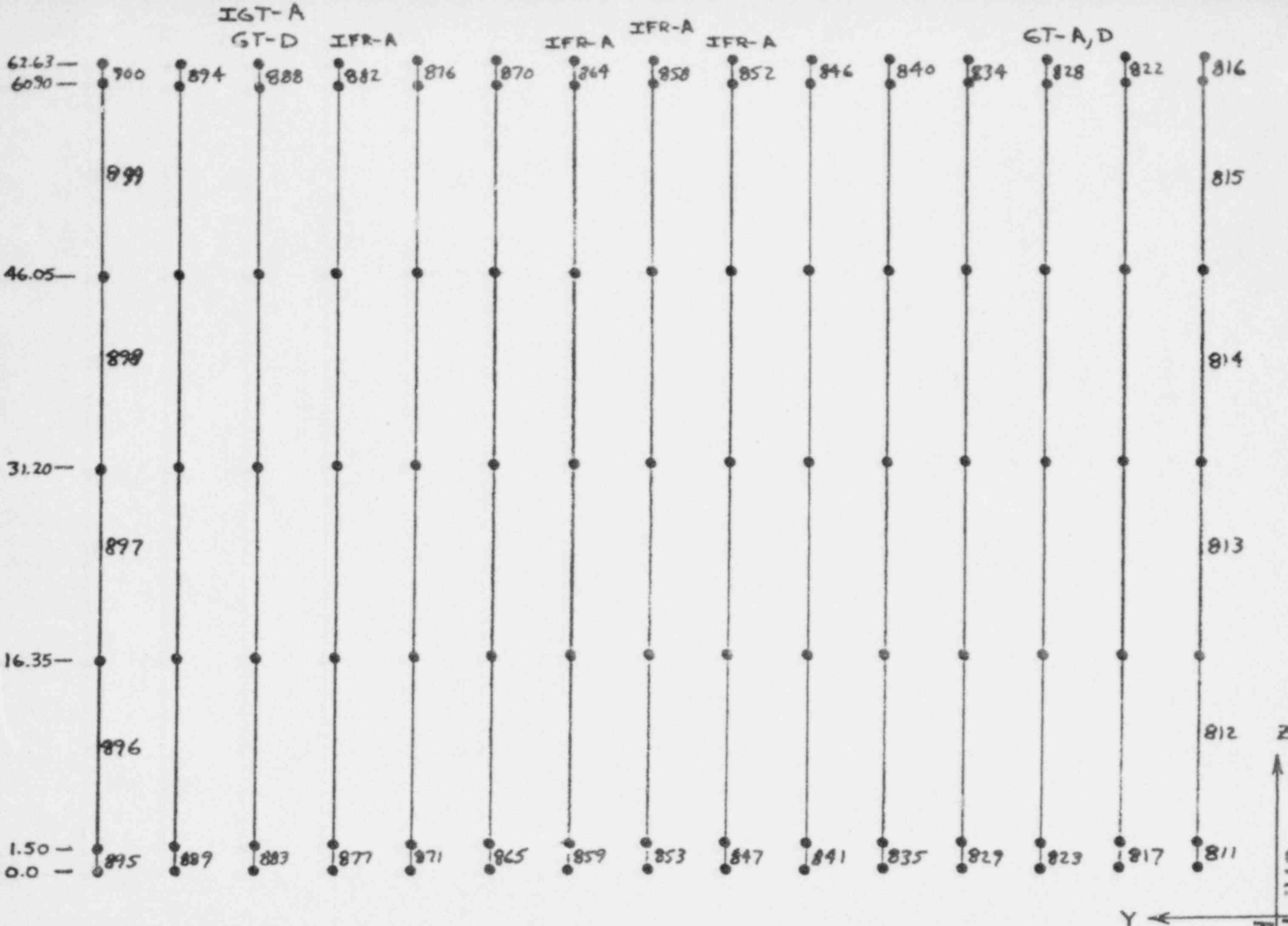


FIGURE 28 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS
ELEMENT NUMBERS, X=5.058

LTR 11111-65
REV 1

50

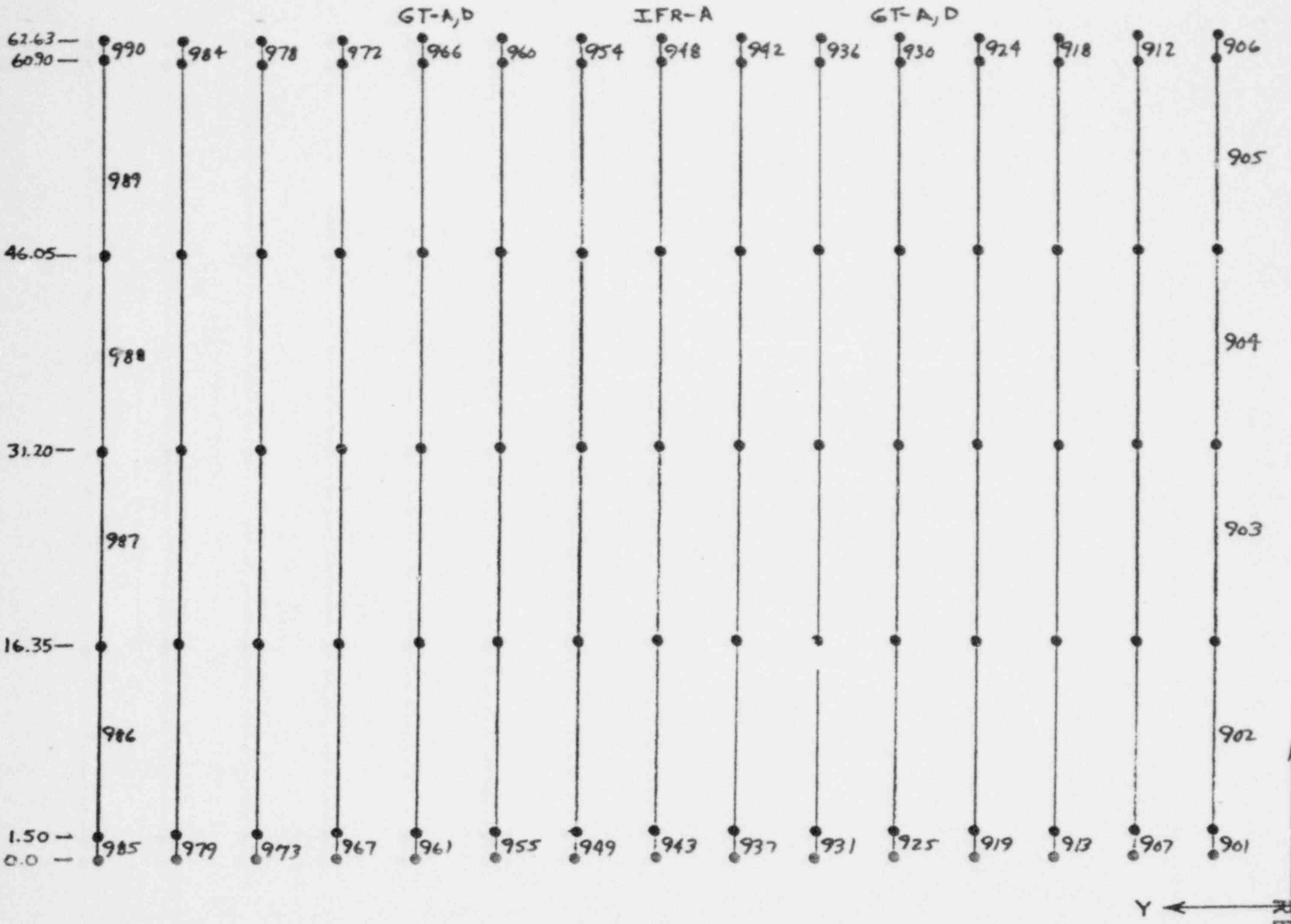


FIGURE 29 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 5.620

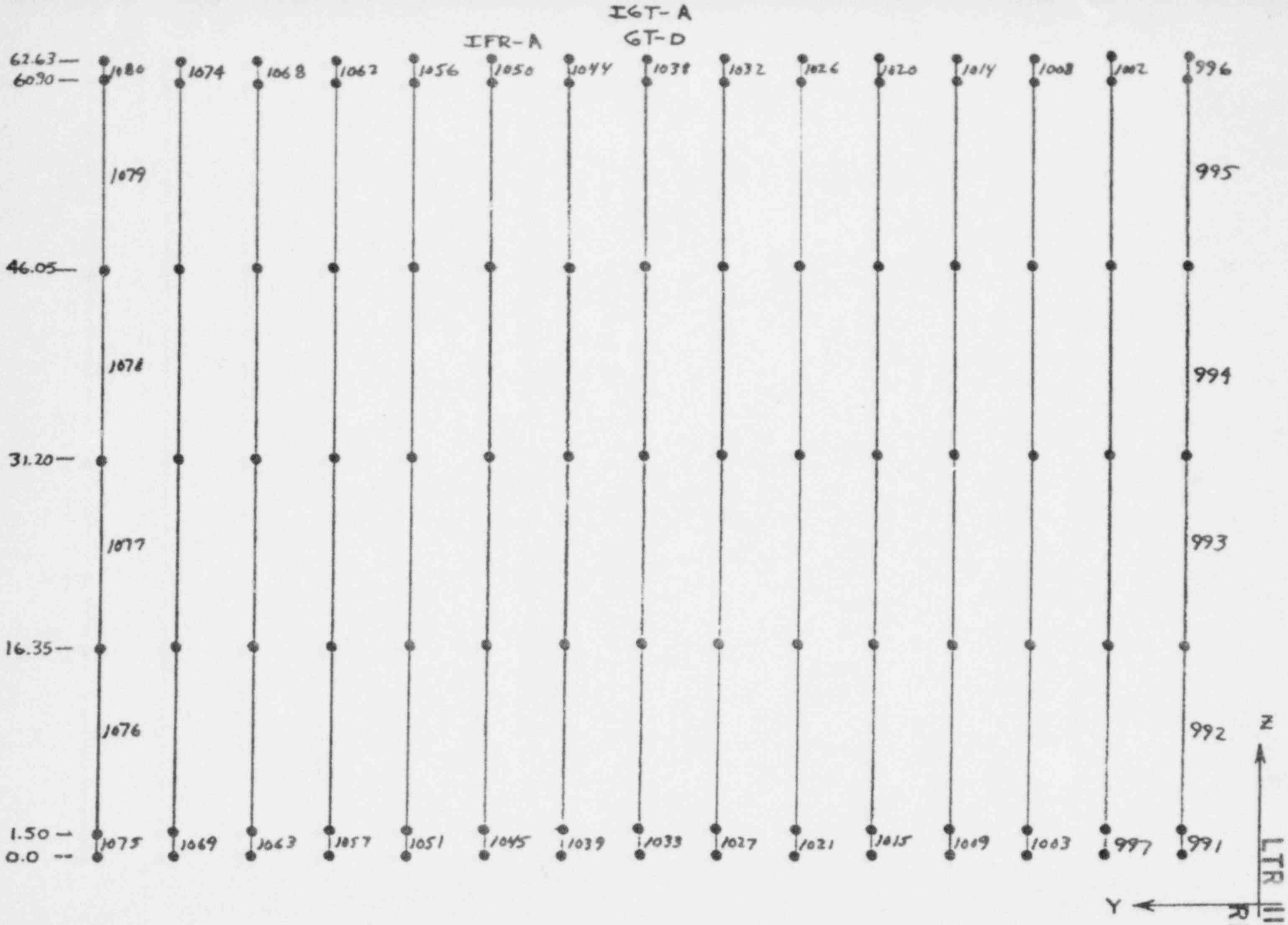


FIGURE 30 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS
ELEMENT NUMBERS, X = 6.182

LTR IIIII-65
REV 1

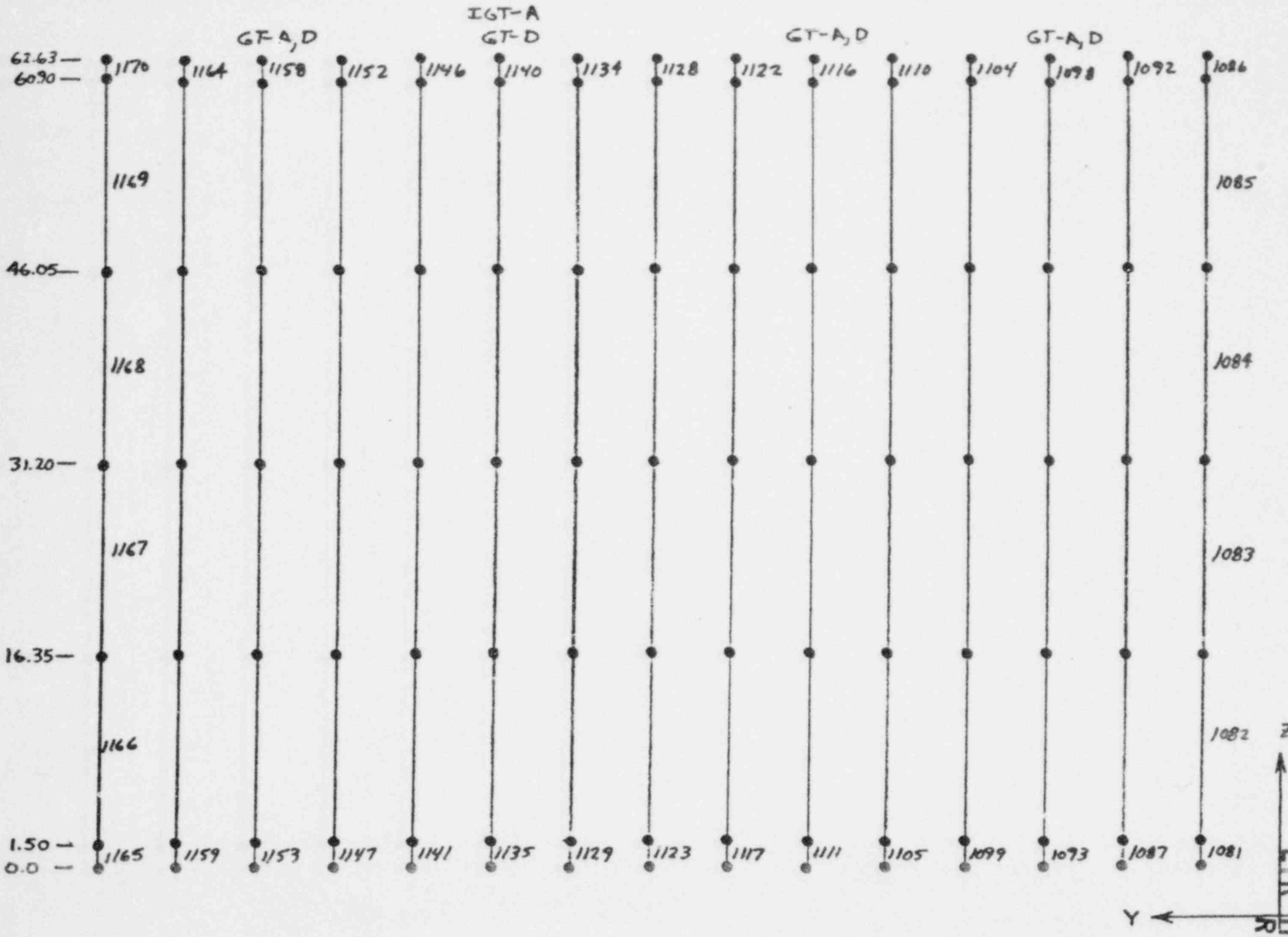


FIGURE 31 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, X = 6.744

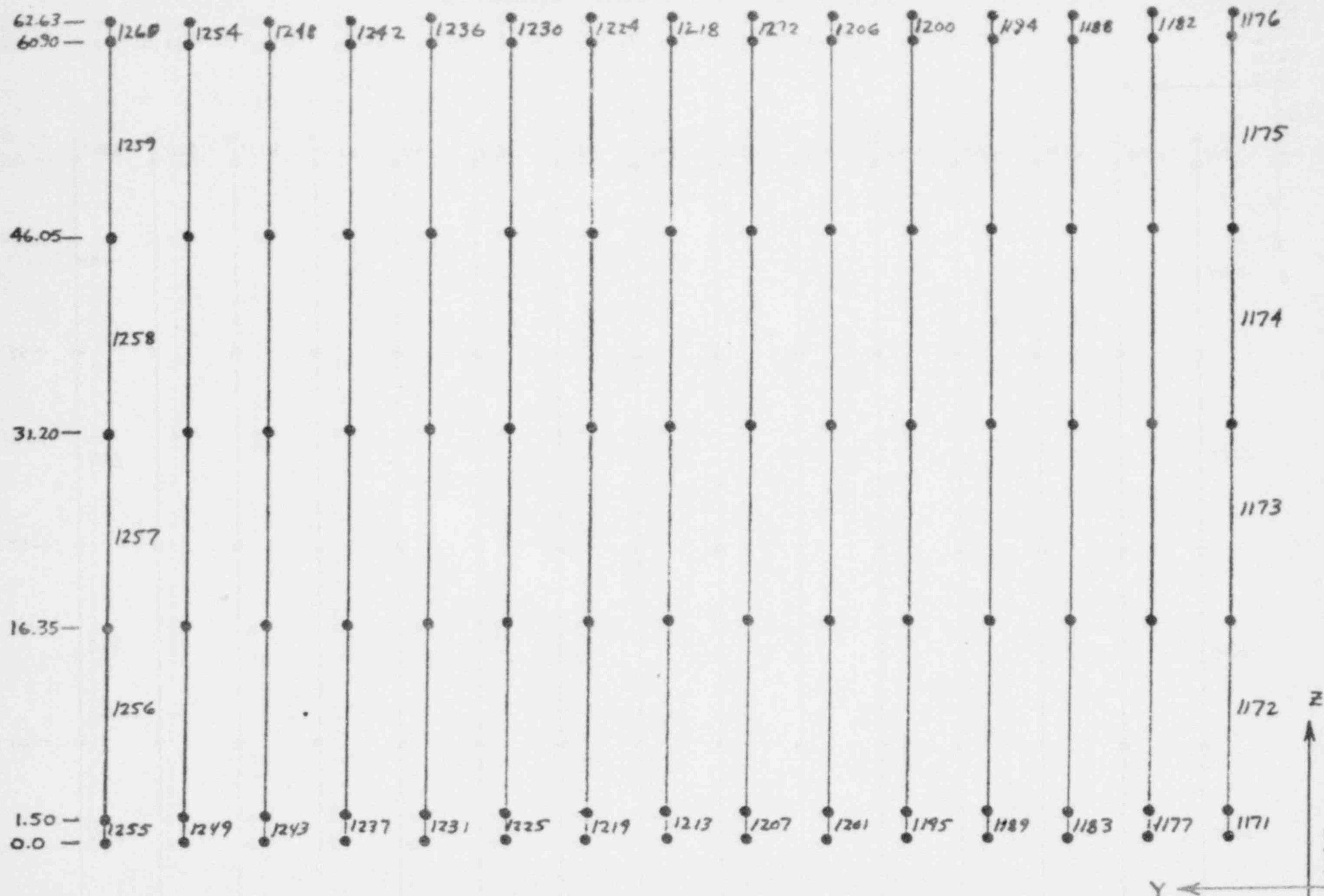


FIGURE 32 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS ELEMENT NUMBERS, X = 7.306

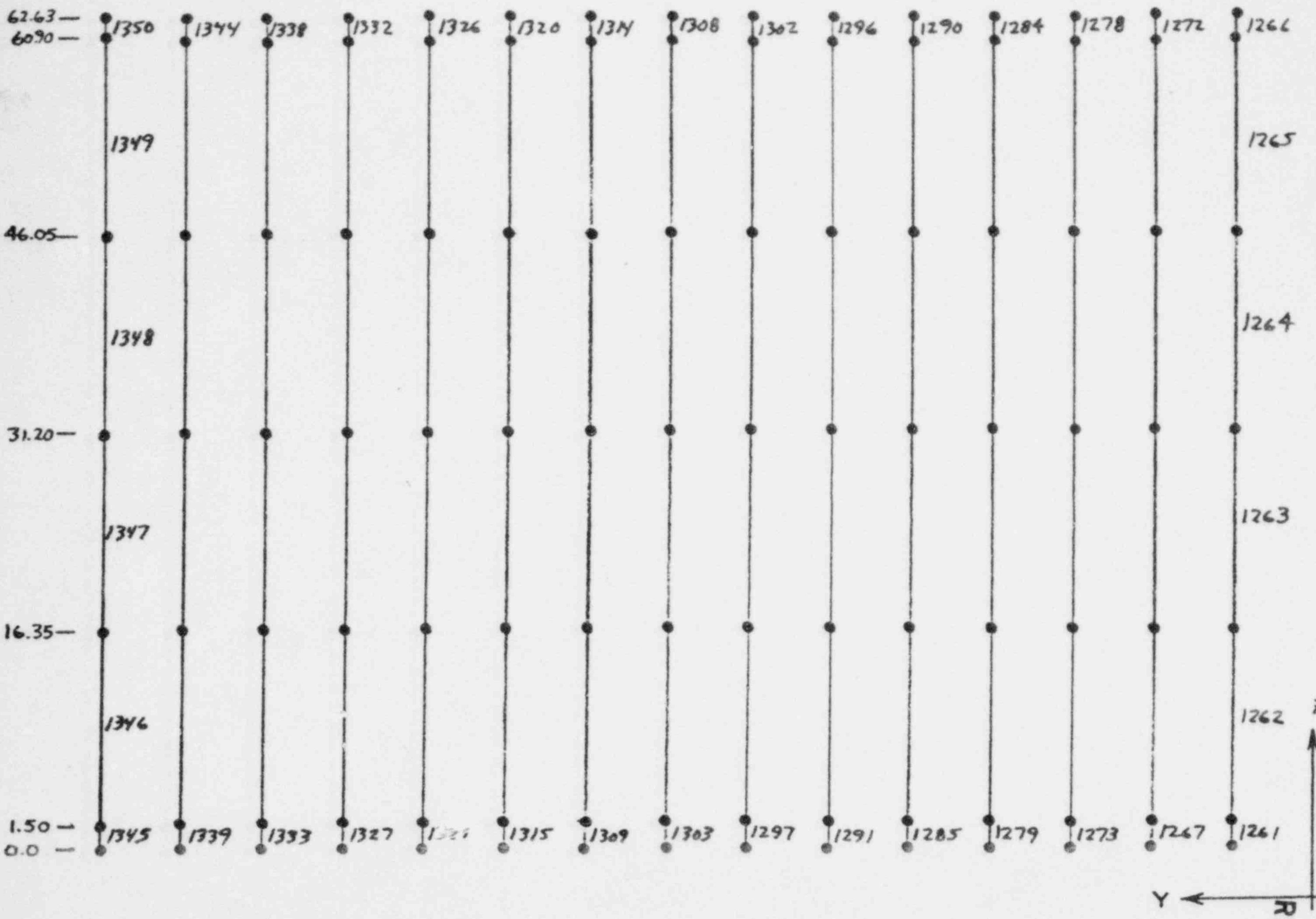


FIGURE 33 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS
ELEMENT NUMBERS, X = 7.868

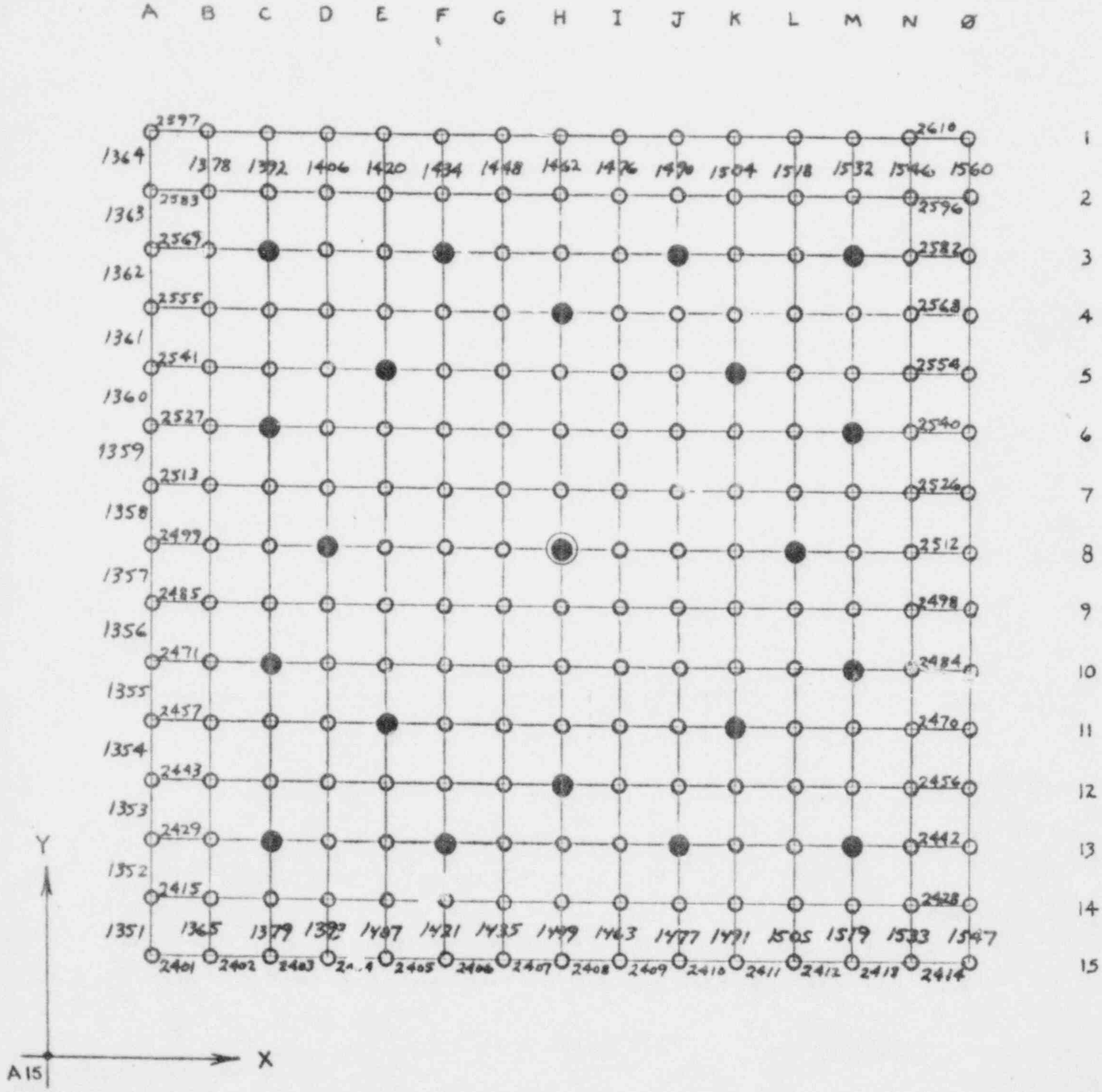


FIGURE 34 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 1.50

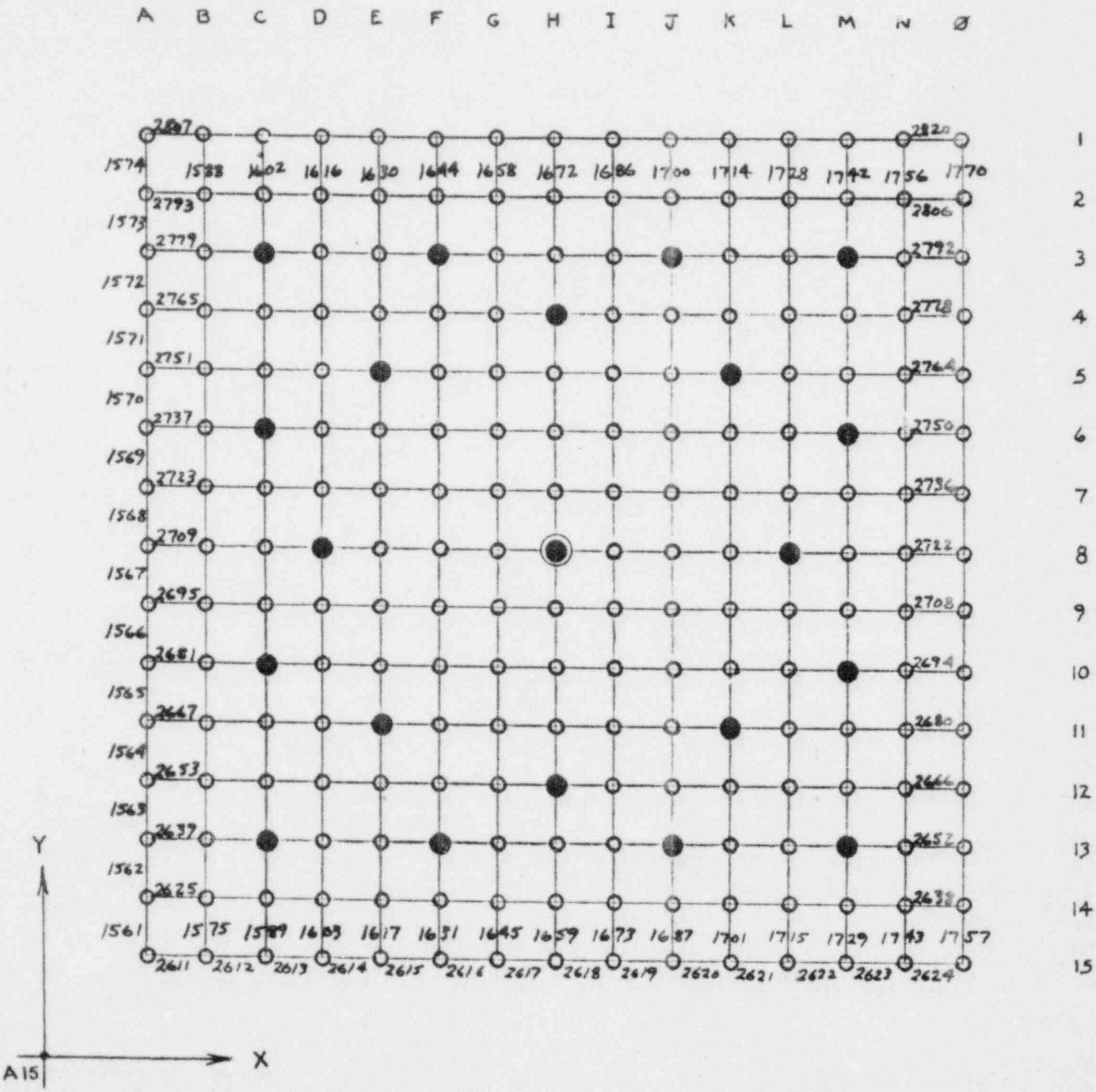


FIGURE 35 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 16.35

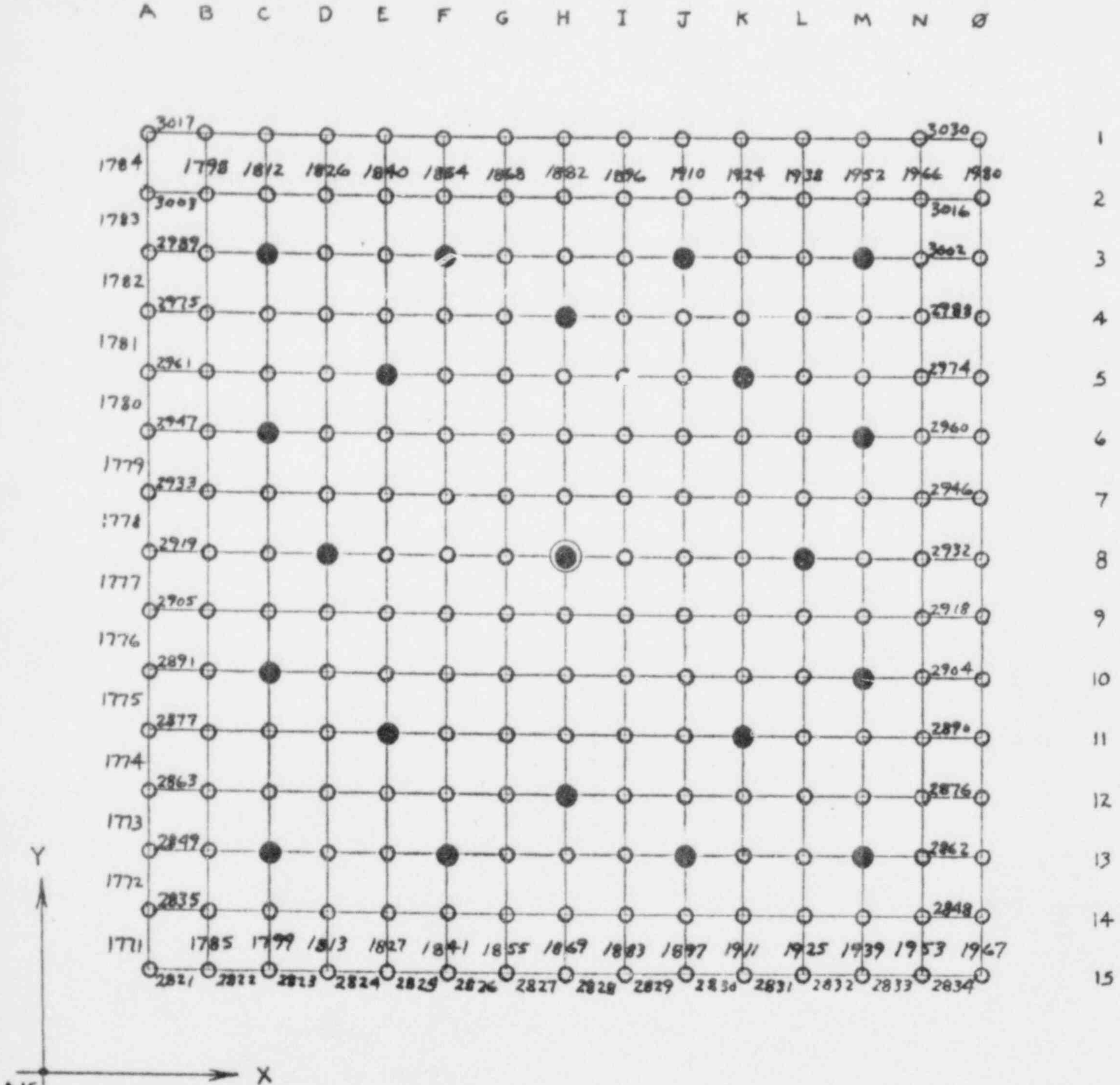


FIGURE 36 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 31.20

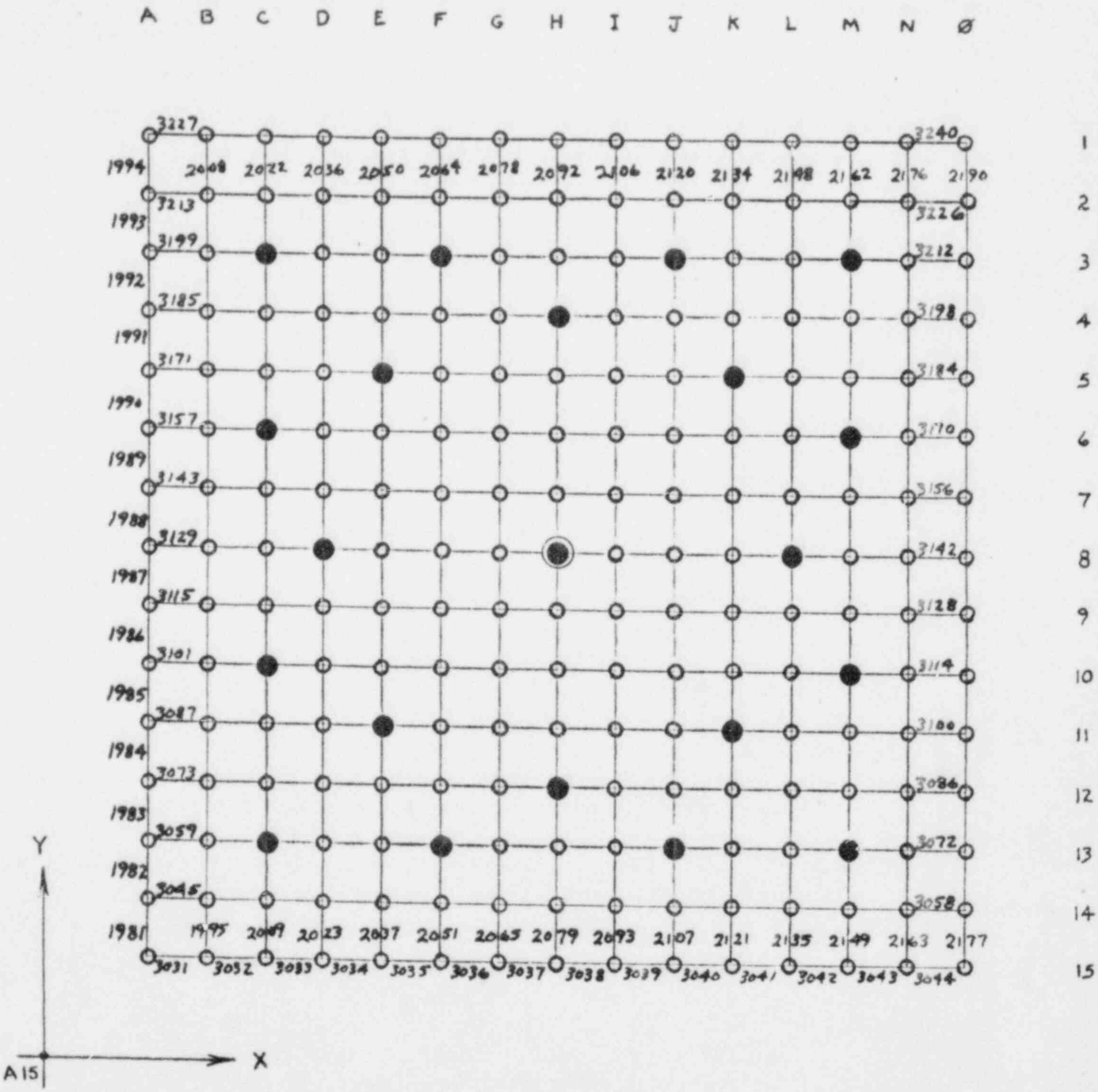


FIGURE 37 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 46.05

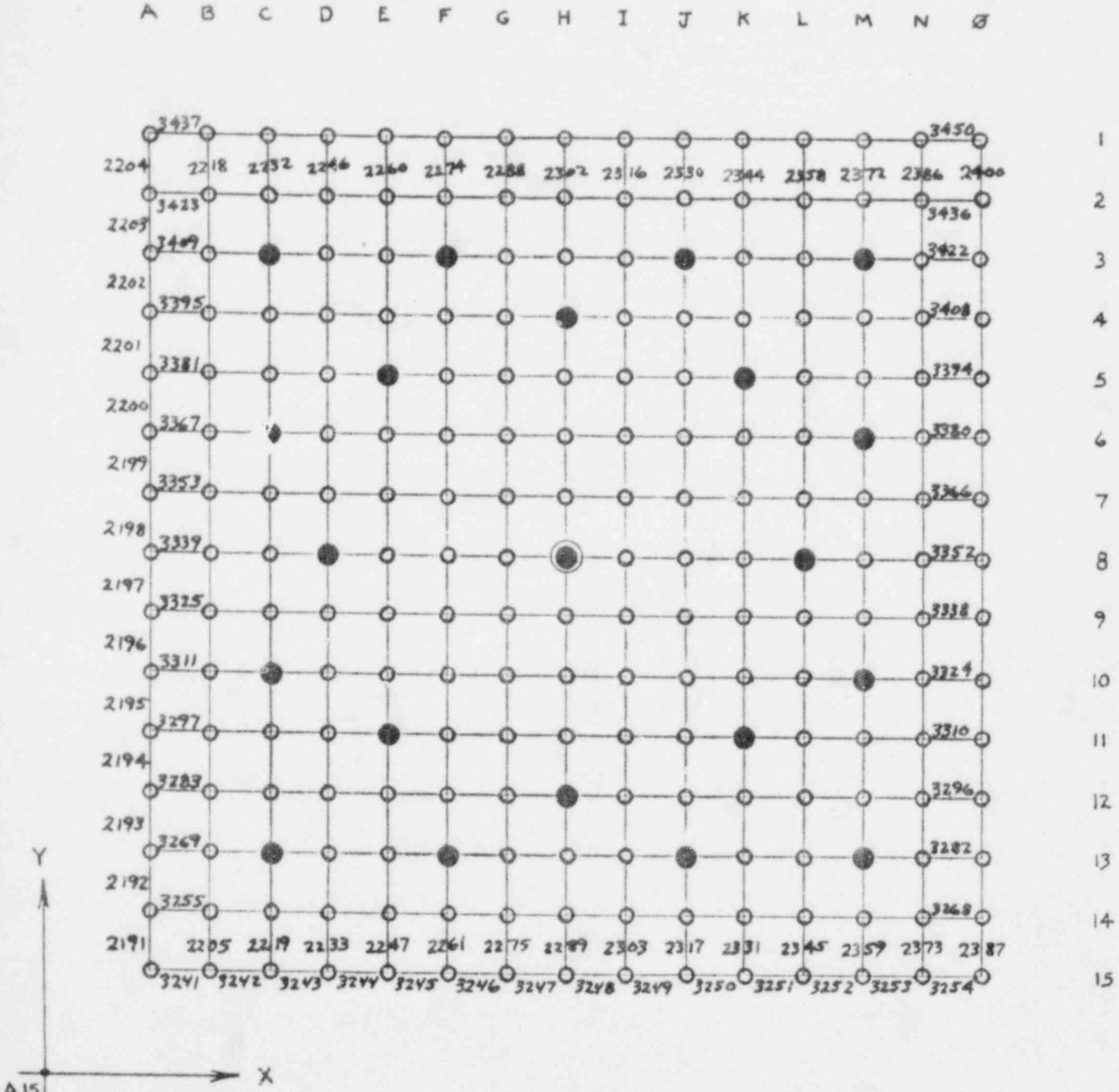


FIGURE 38 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 60.90

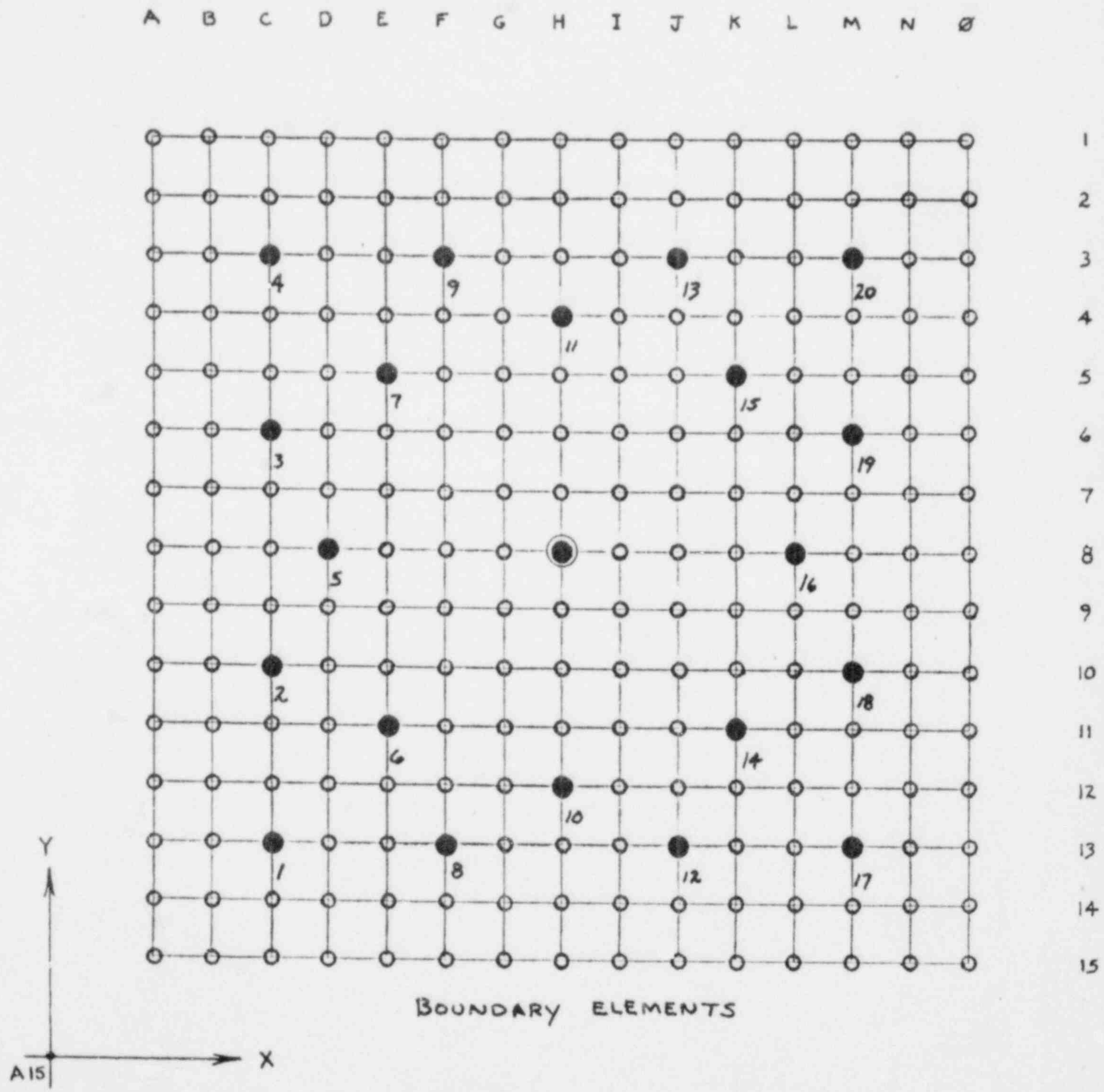


FIGURE 39 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 0.0

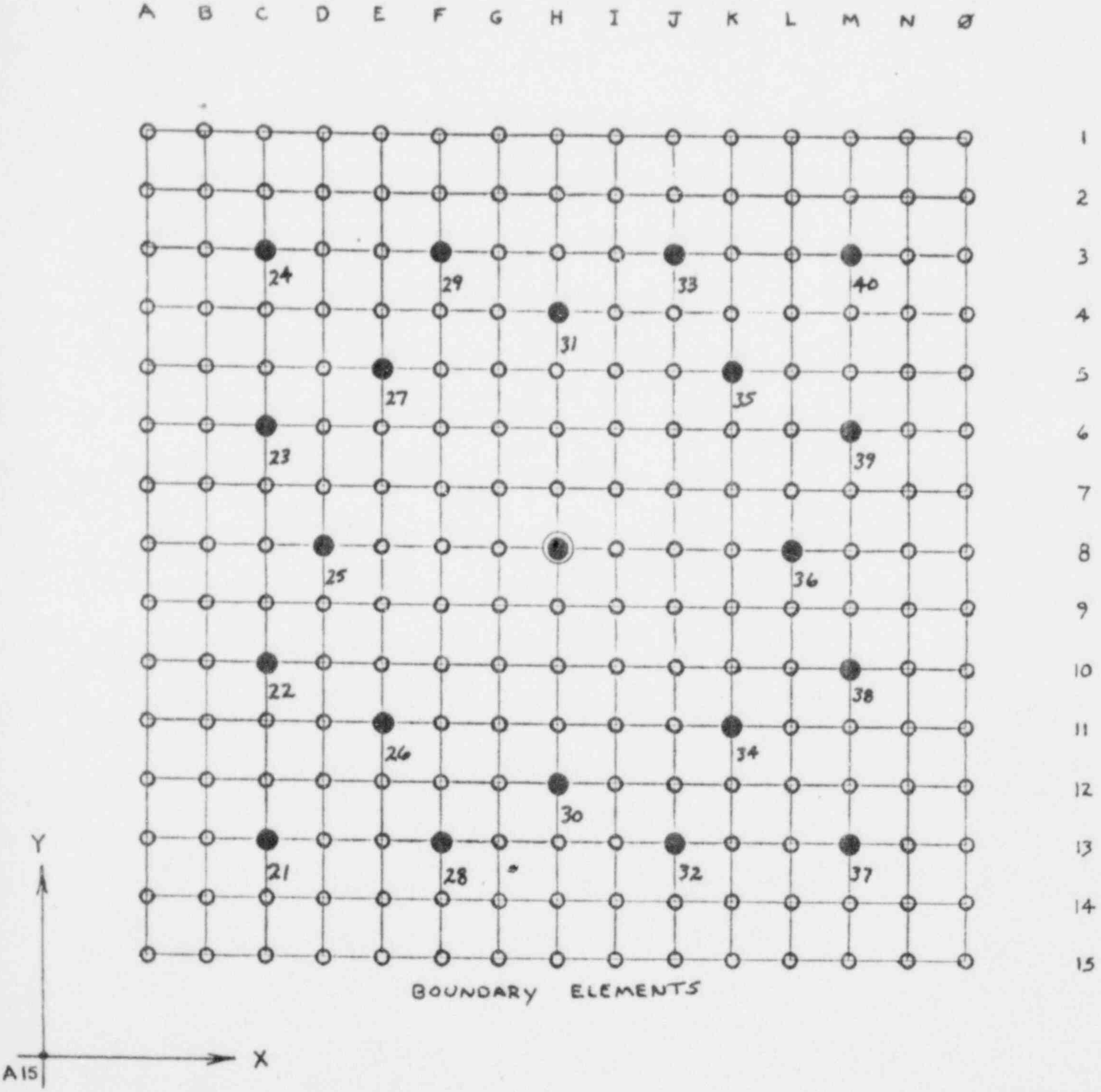


FIGURE 40 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 1.50

LTR 1111-65
REV 1

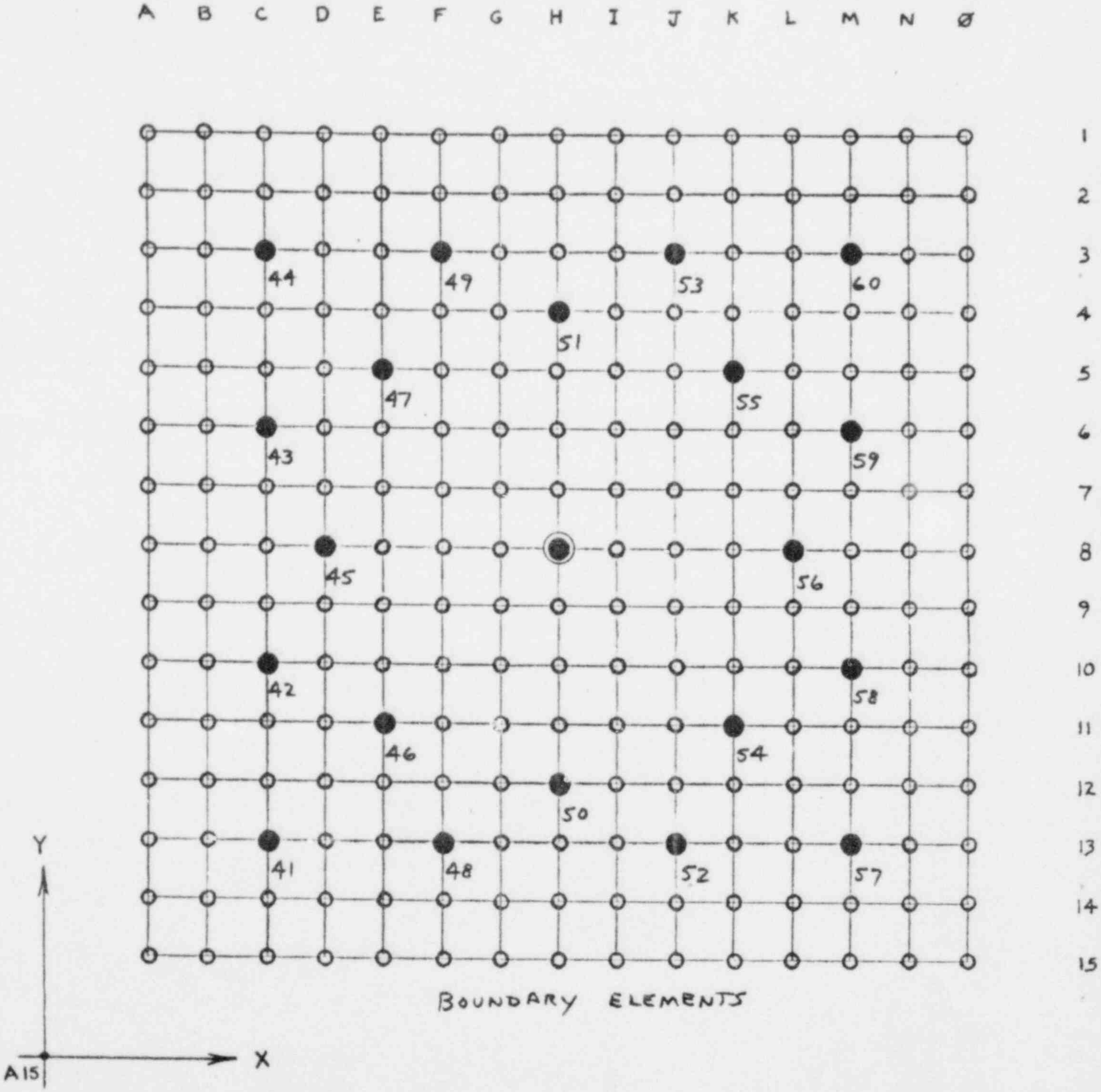


FIGURE 41 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 16.35

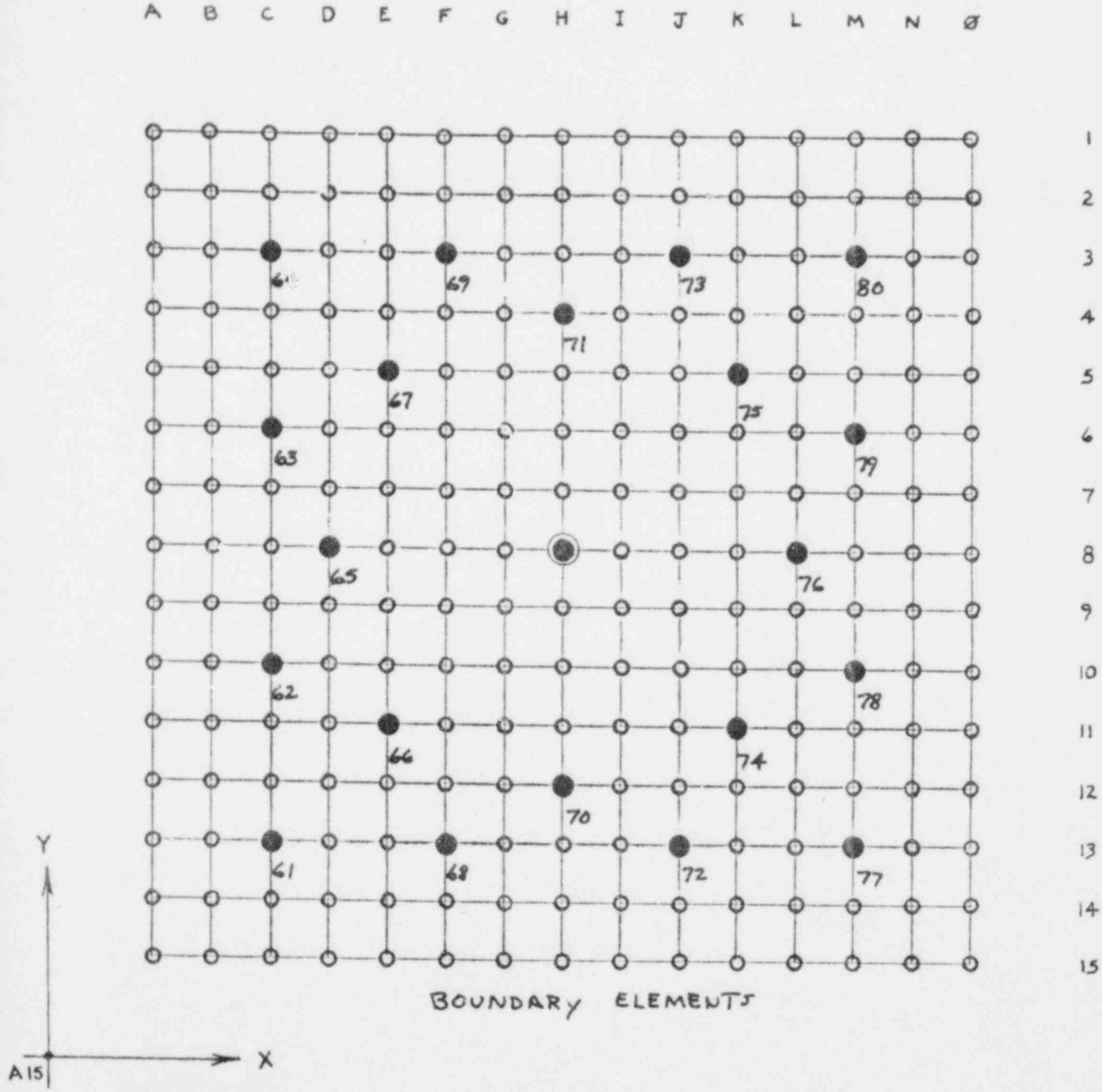


FIGURE 42 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 31.20

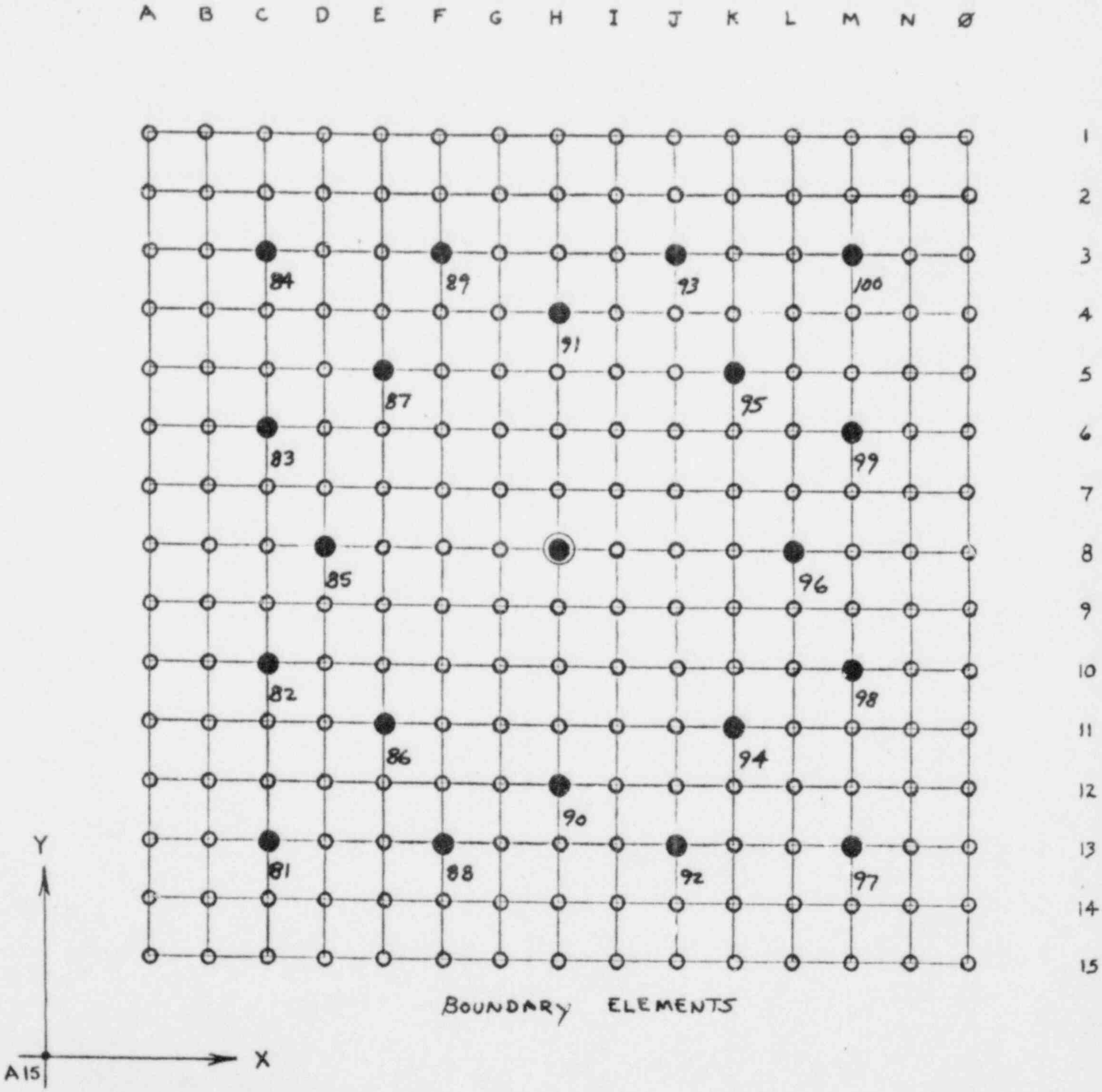


FIGURE 43 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 46.05

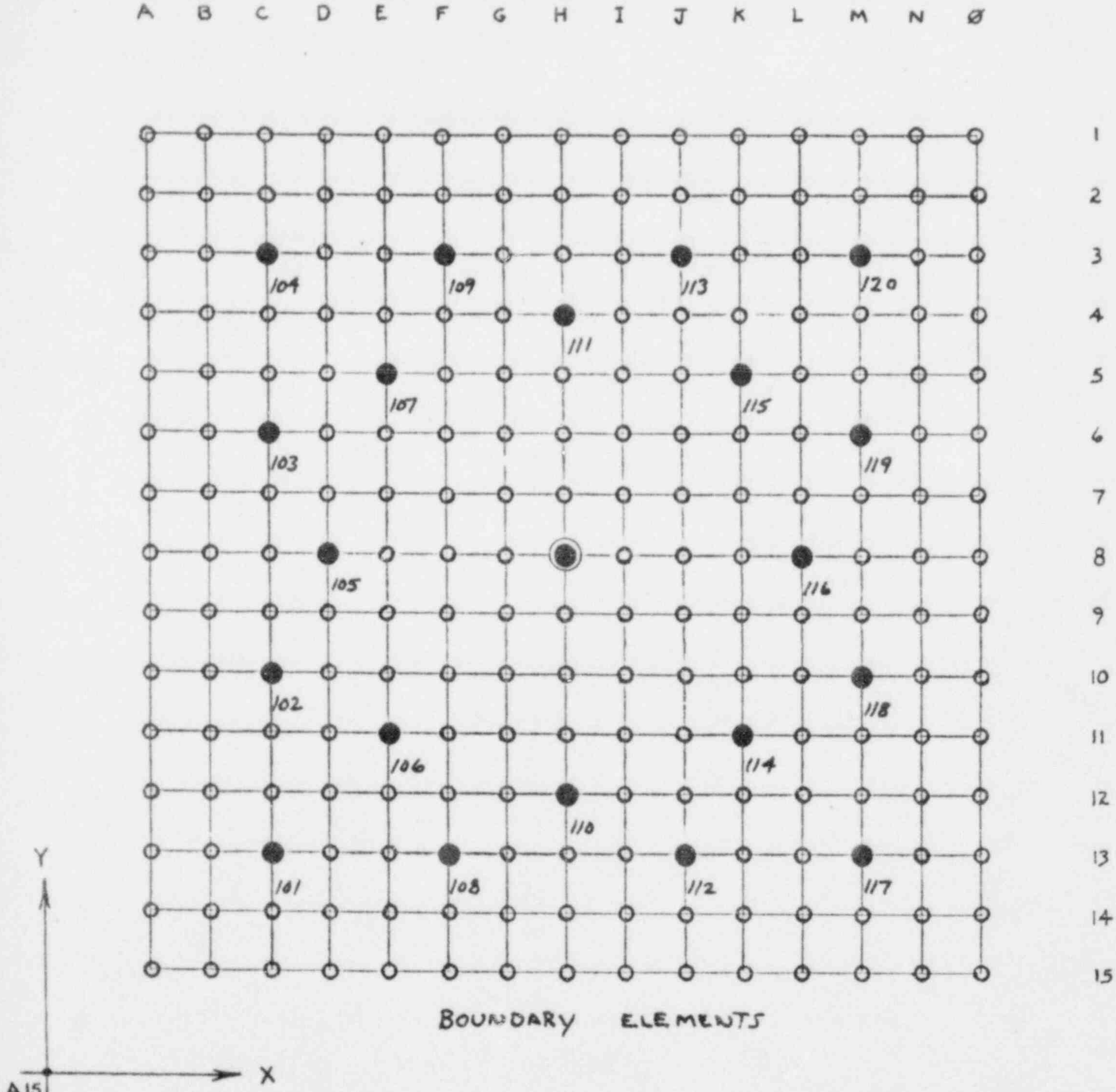


FIGURE 44 LOFT 'A' + 'D' TYPE FUEL BUNDLE MODELS

ELEMENT NUMBERS, Z = 60.90

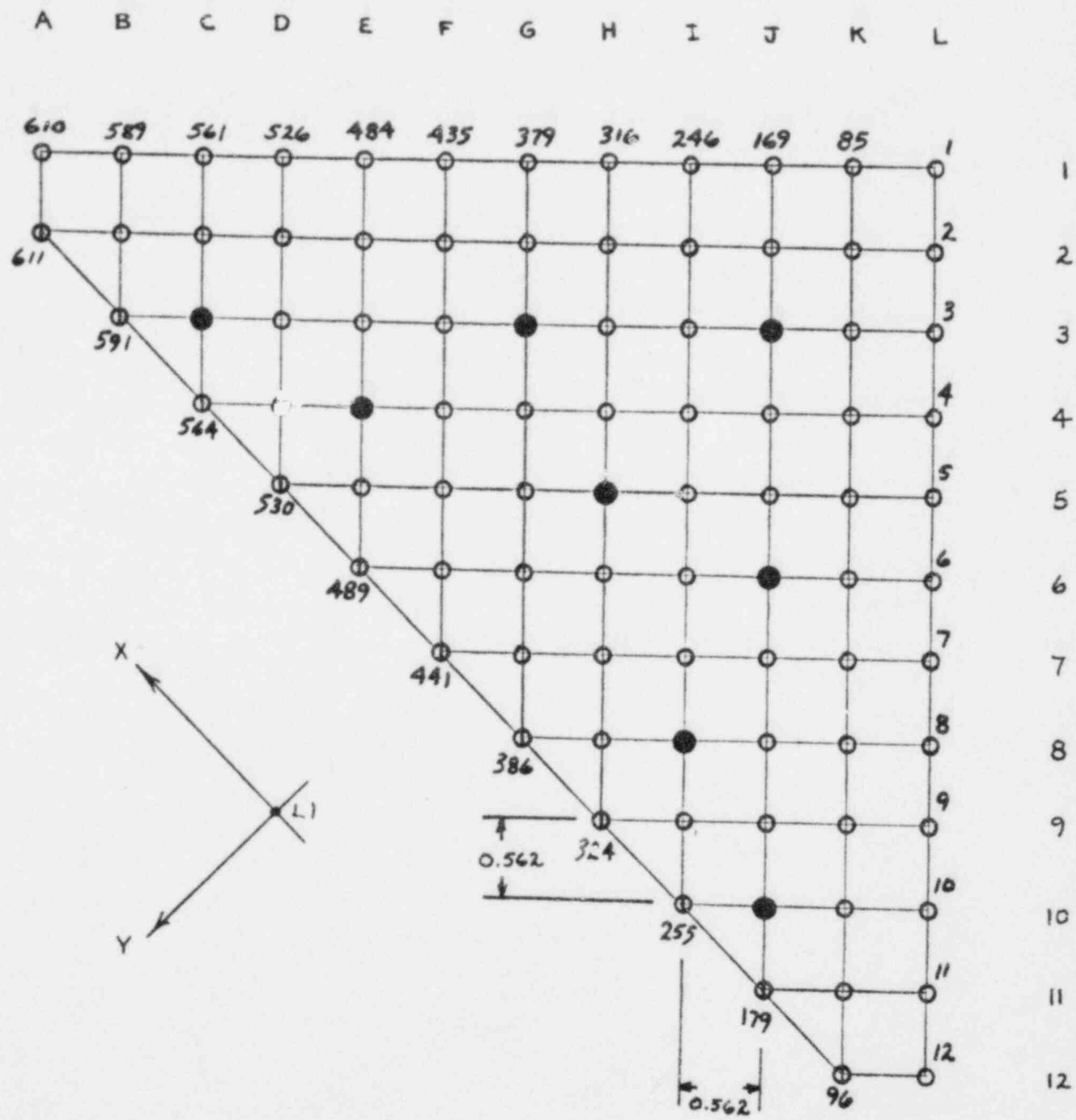


FIGURE 45 LOFT 'E' TYPE FUEL BUNDLE MODEL
NODE NUMBERS, Z = 0.0

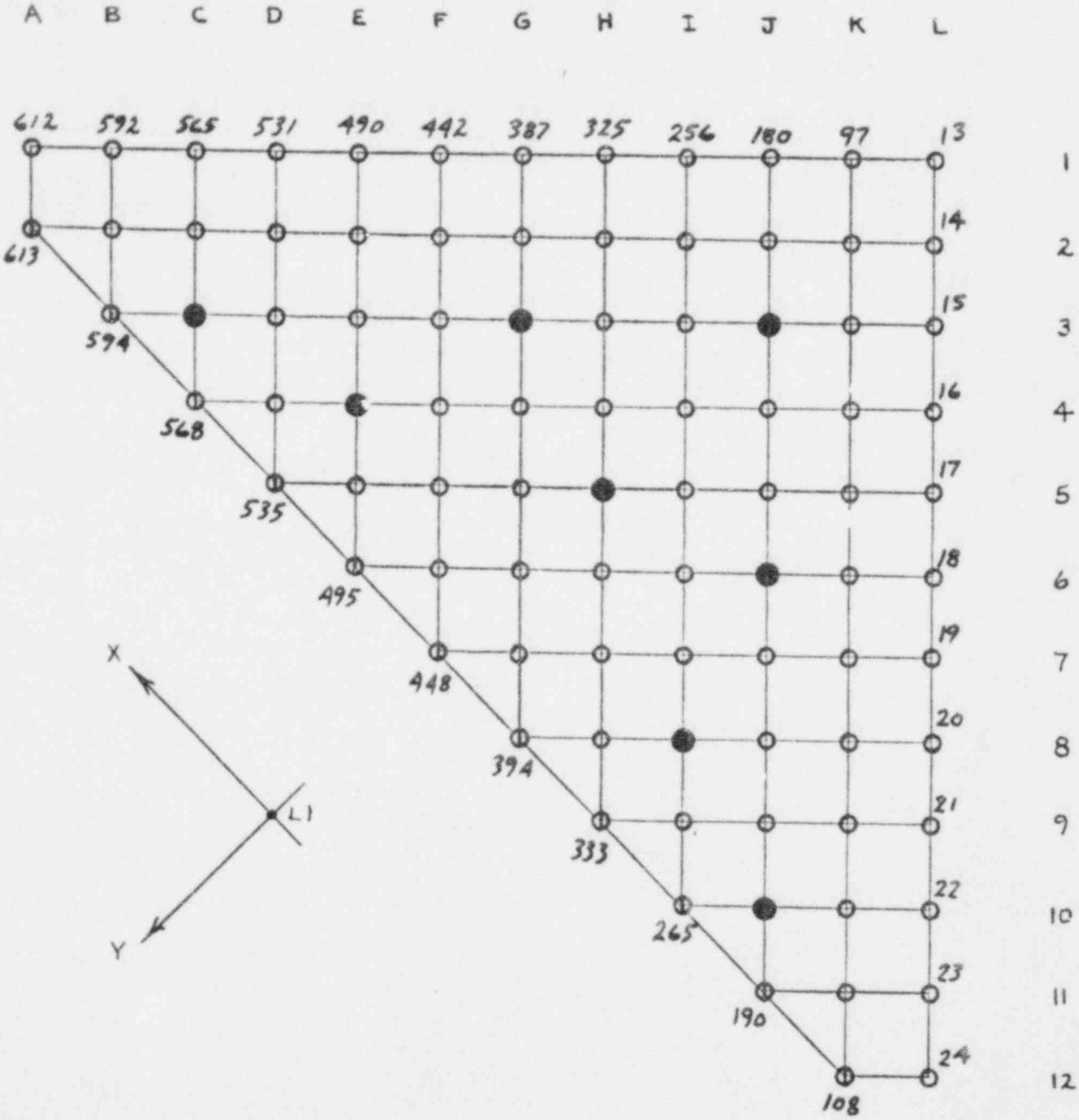


FIGURE 46 LOFT 'E' TYPE FUEL BUNDLE MODEL NODE NUMBERS, Z = 1.50

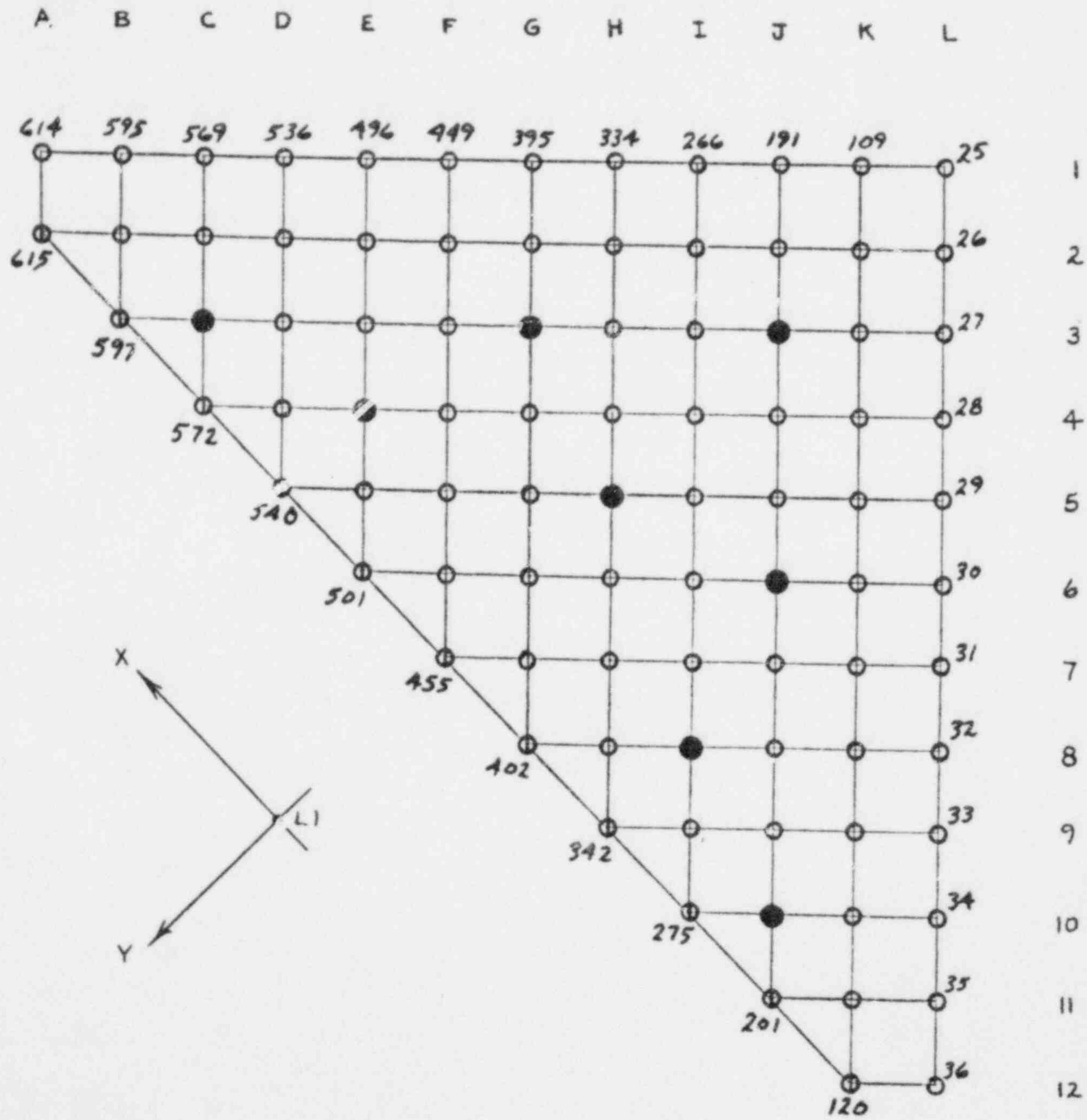


FIGURE 47 LOFT 'E' TYPE FUEL BUNDLE MODEL
NODE NUMBERS, Z = 16.35

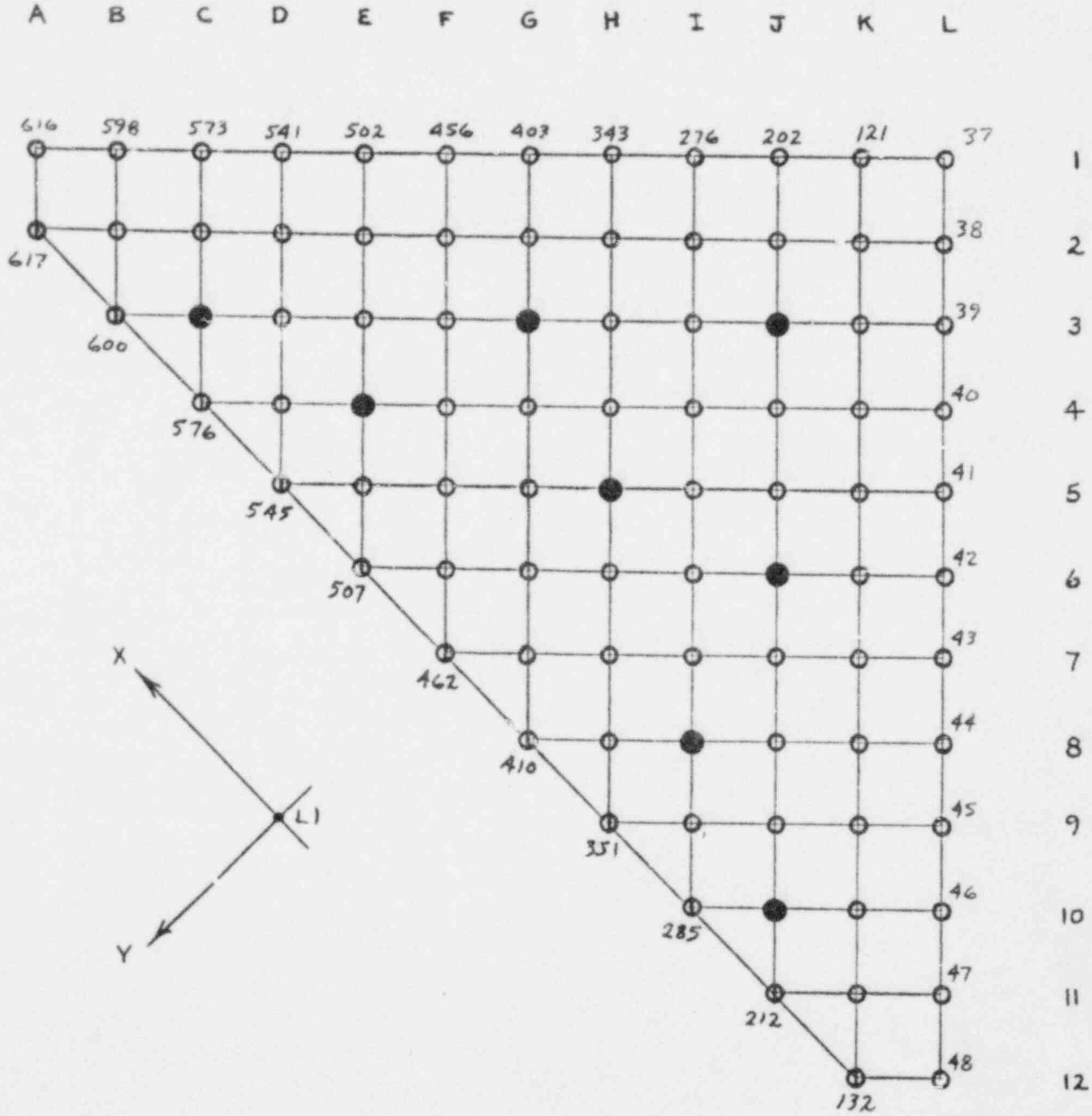


FIGURE 48 LOFT 'E' TYPE FUEL BUNDLE MODEL

NODE NUMBERS, Z = 31.20

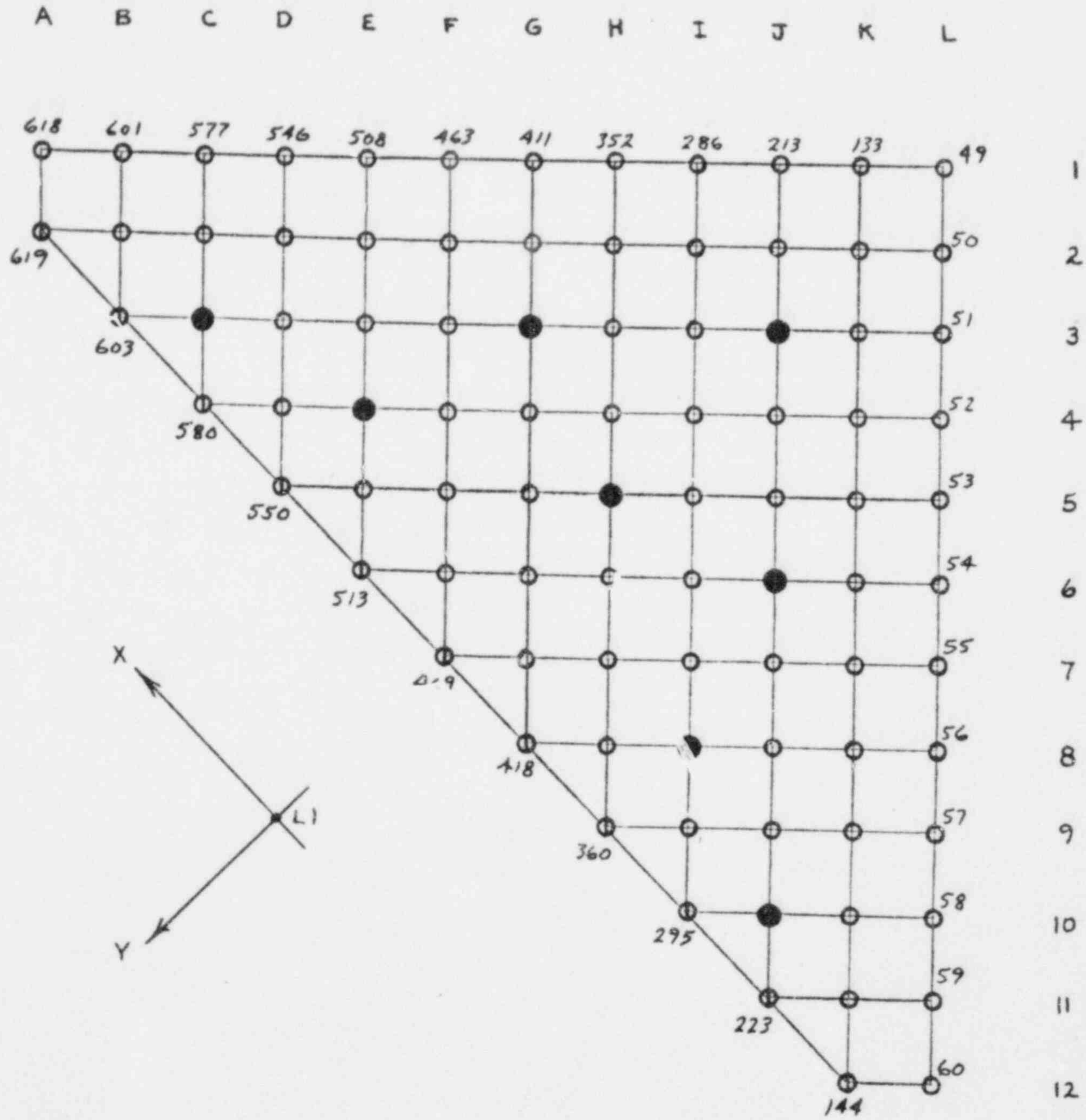


FIGURE 49 LOFT 'E' TYPE FUEL BUNDLE MODEL NODE NUMBERS, Z = 46.05

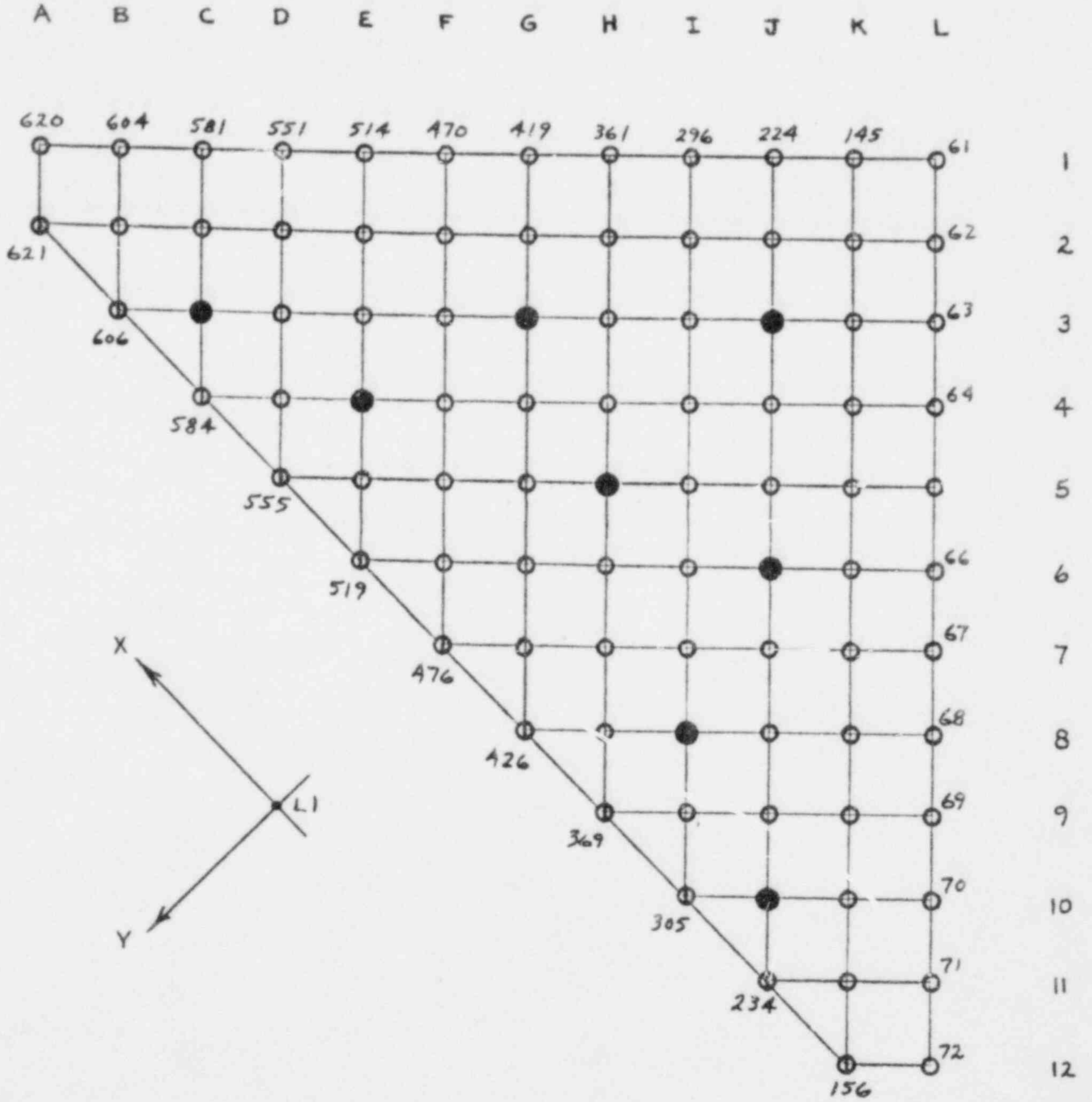


FIGURE 50 LOFT 'E' TYPE FUEL BUNDLE MODEL

NODE NUMBERS, Z = 60.90

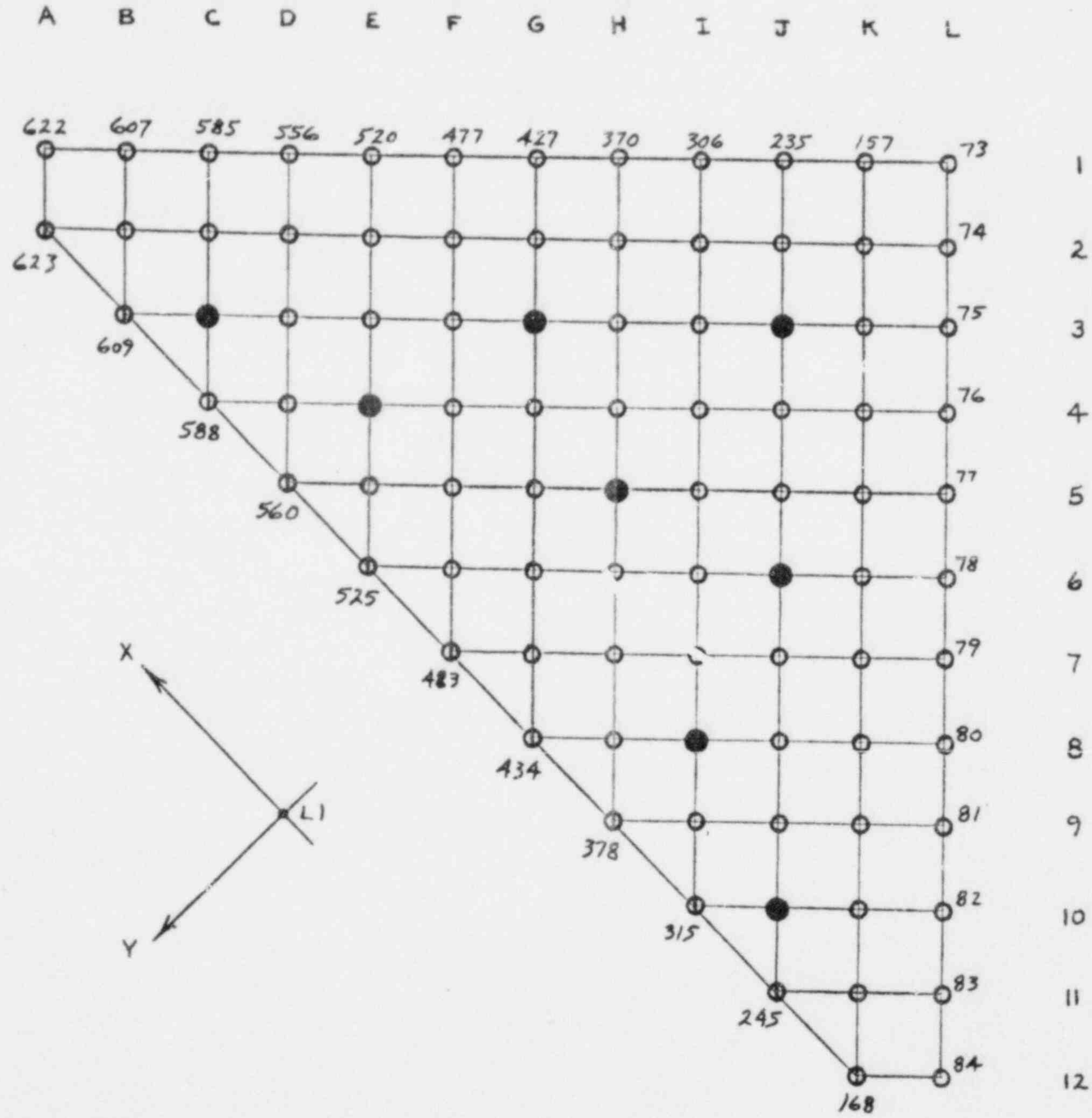


FIGURE 51 LOFT 'E' TYPE FUEL BUNDLE MODEL
NODE NUMBERS, Z = 62.63

LTR 1111-65
REV 1

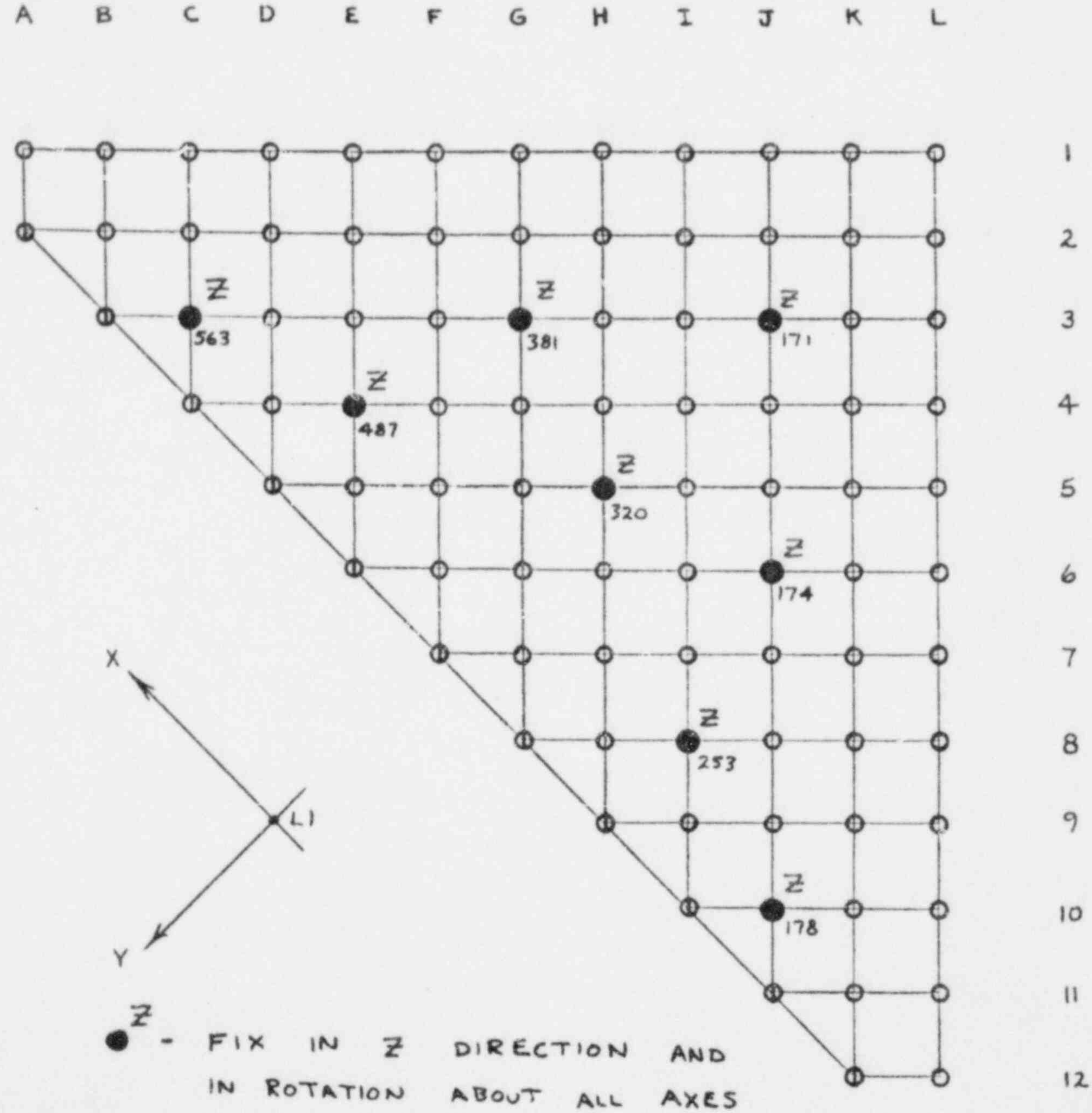


FIGURE 5?: LOFT 'E' TYPE FUEL BUNDLE MODEL NODE FIXITIES , Z = 0.0

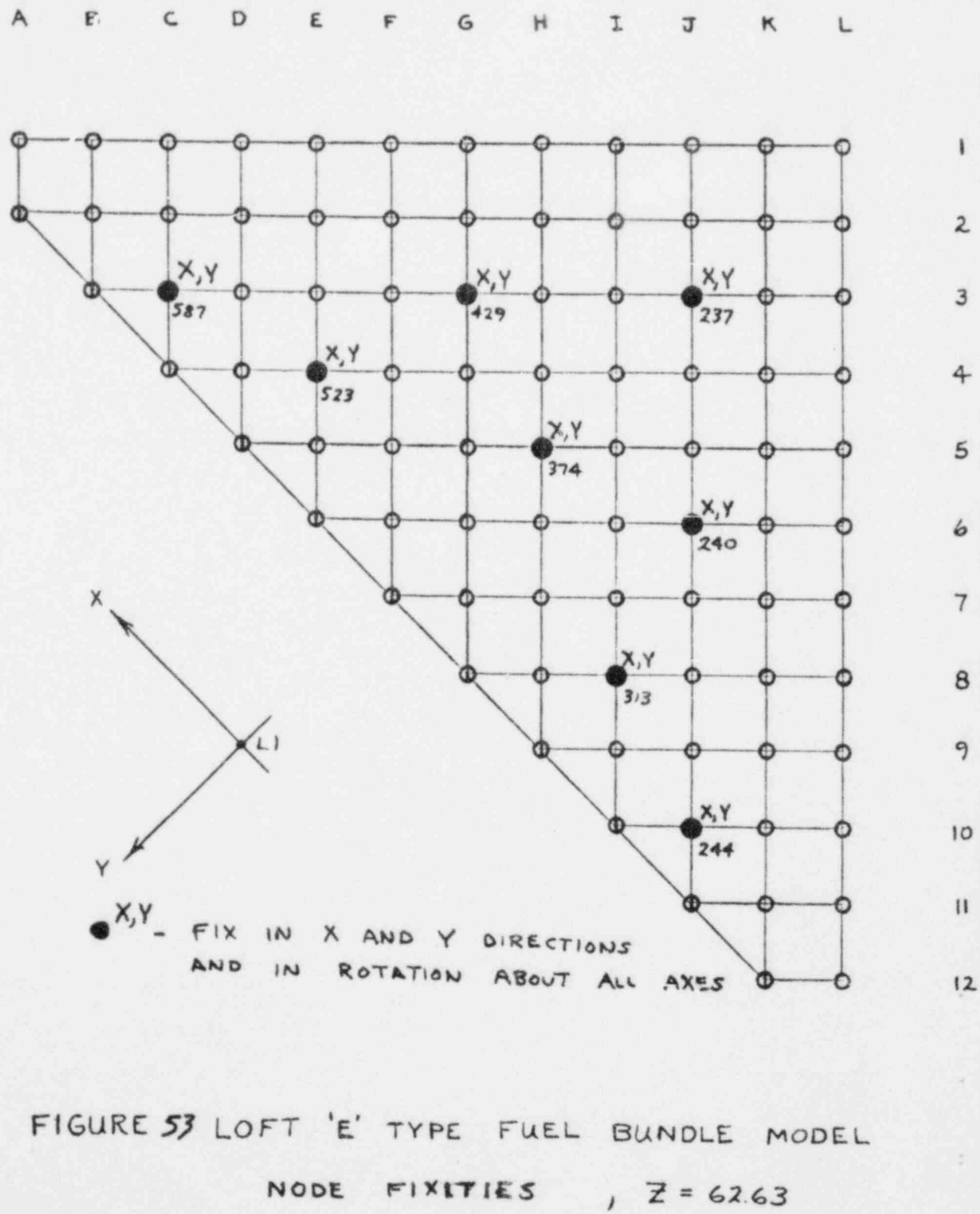


FIGURE 53 LOFT 'E' TYPE FUEL BUNDLE MODEL

NODE FIXITIES , Z = 62.63

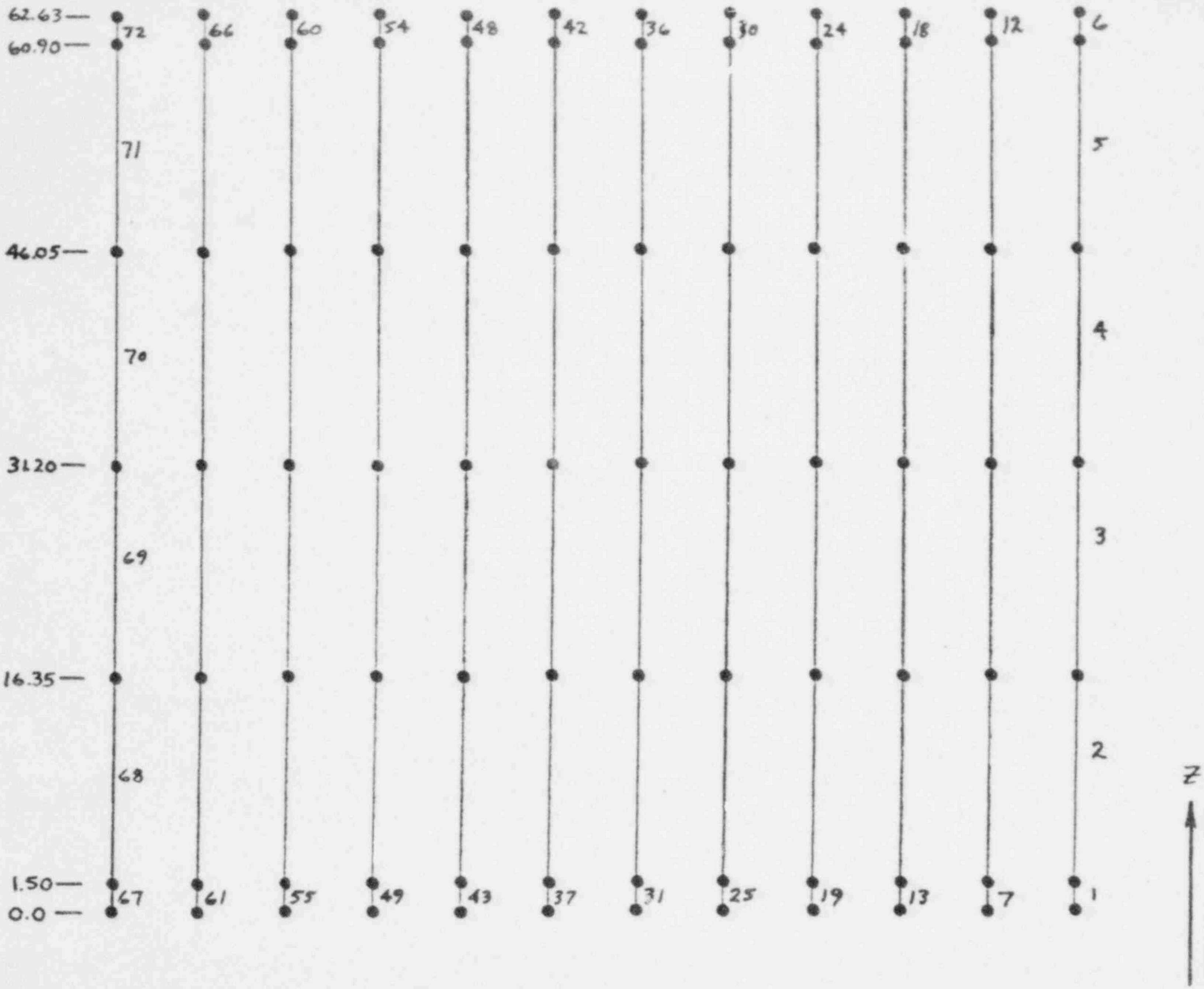


FIGURE 54 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN L

LTR 1111 65
REV 1

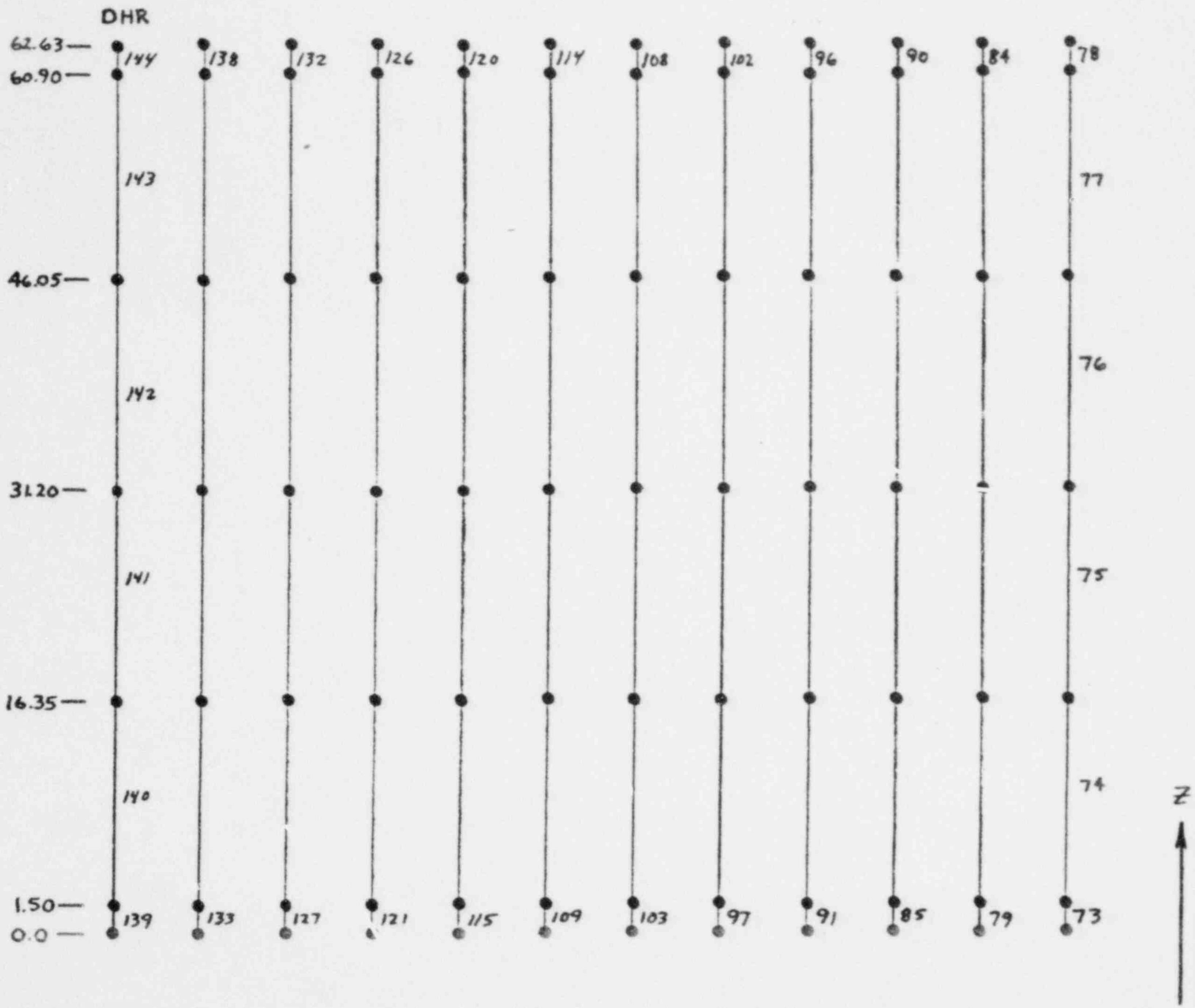


FIGURE 55 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN K

LTR 1111 65
REV 1

77

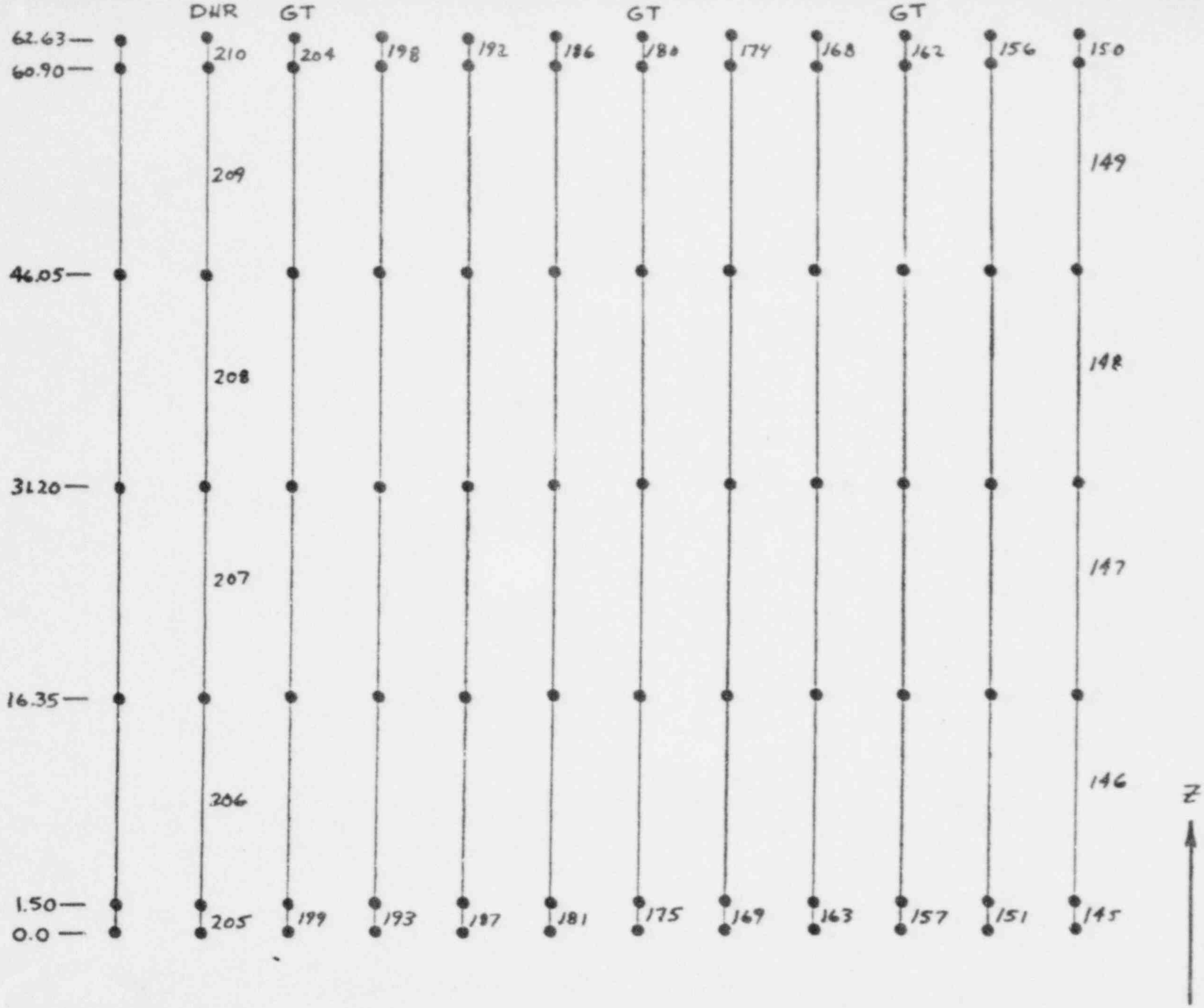


FIGURE 56 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN J

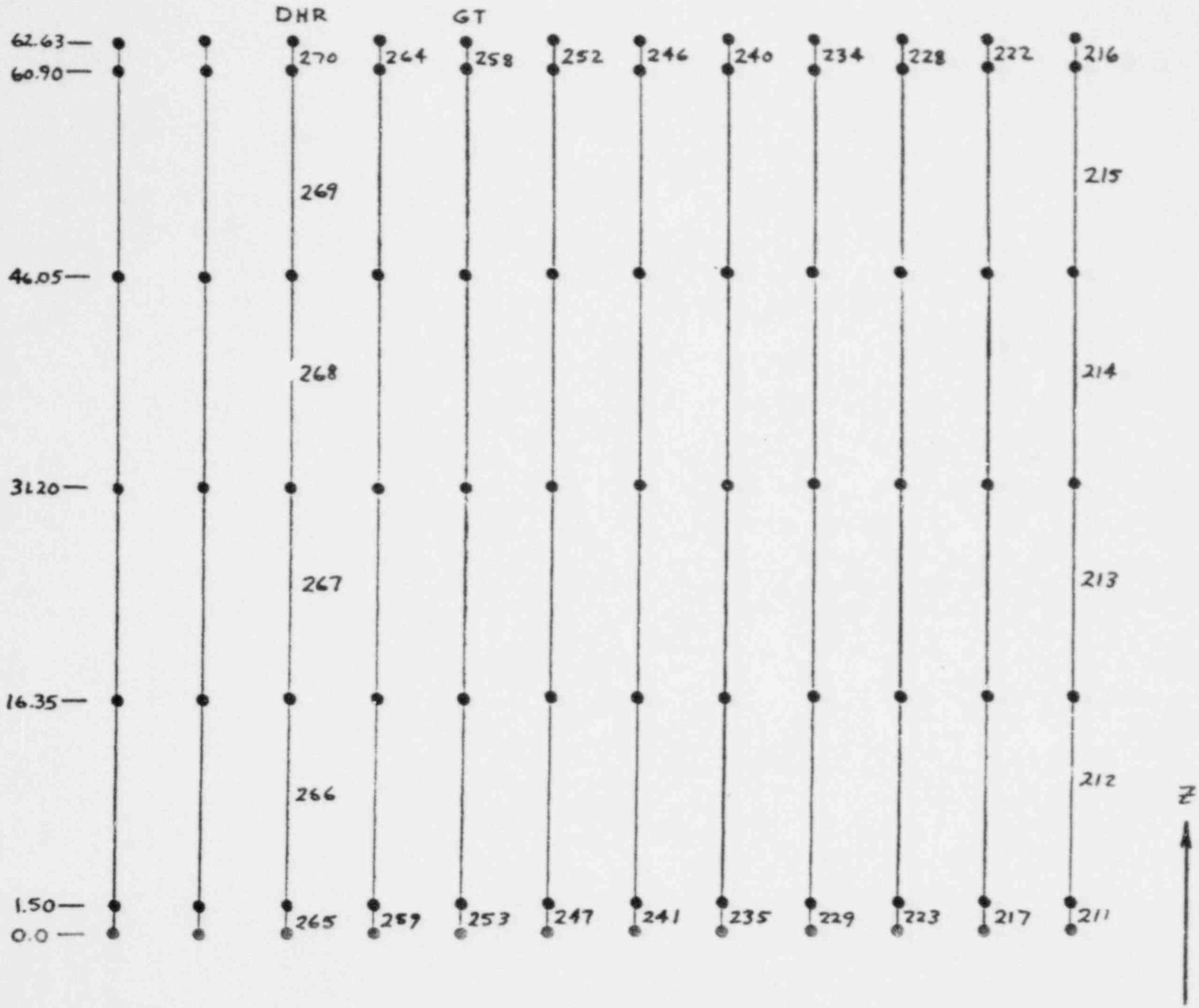


FIGURE 57 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN I

LTR 1111 65
REV 1

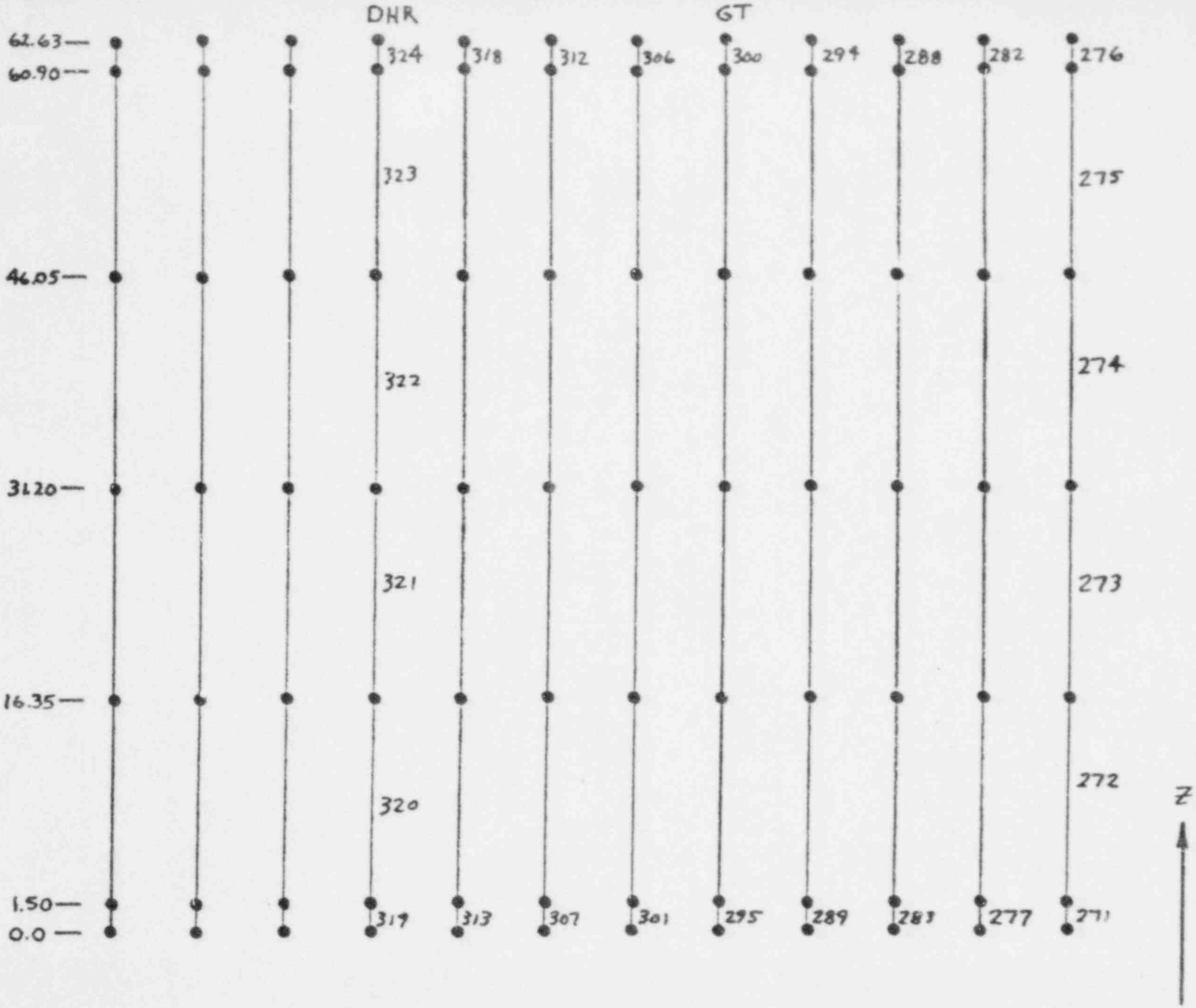


FIGURE 58 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN H

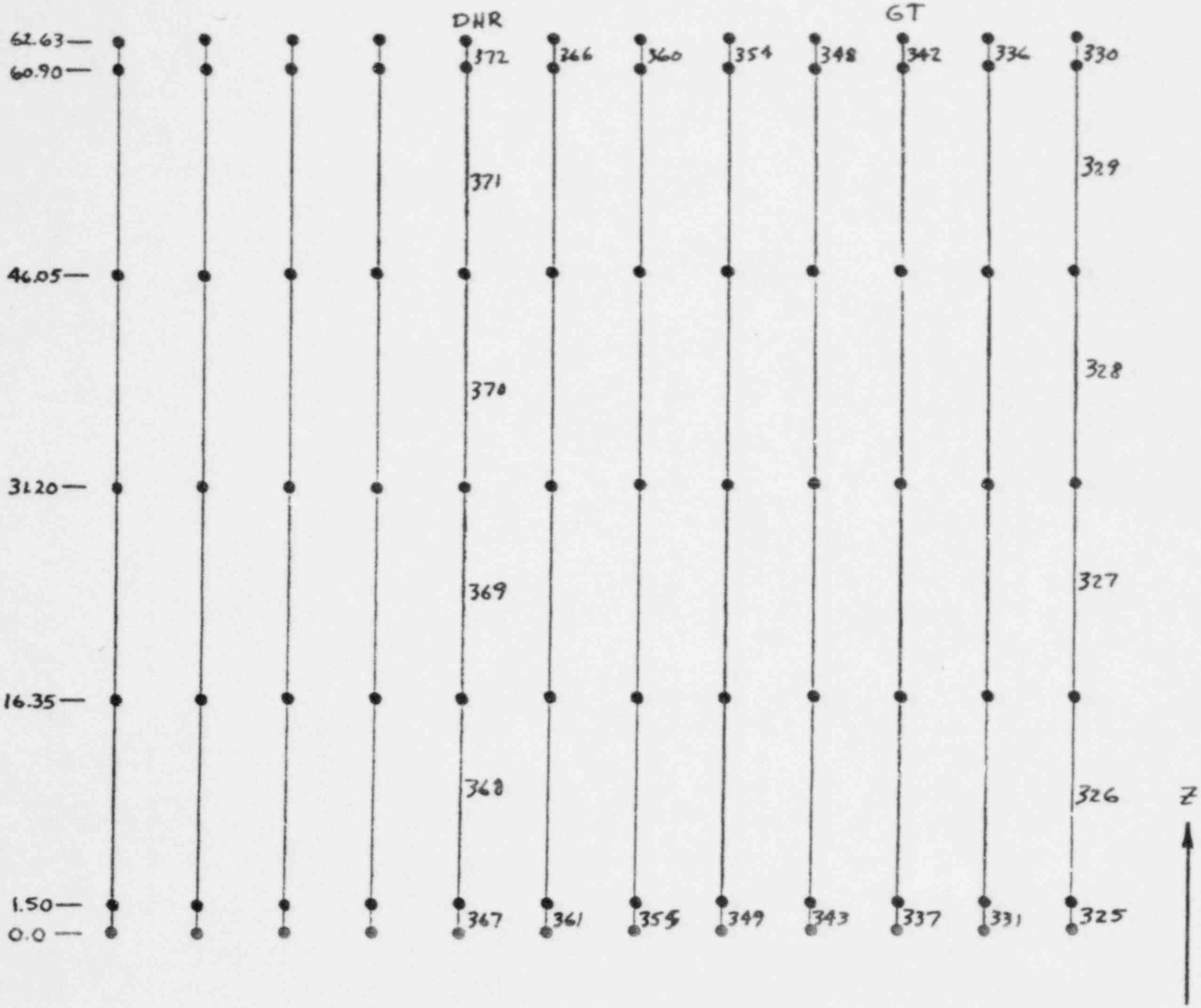


FIGURE 59 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN G

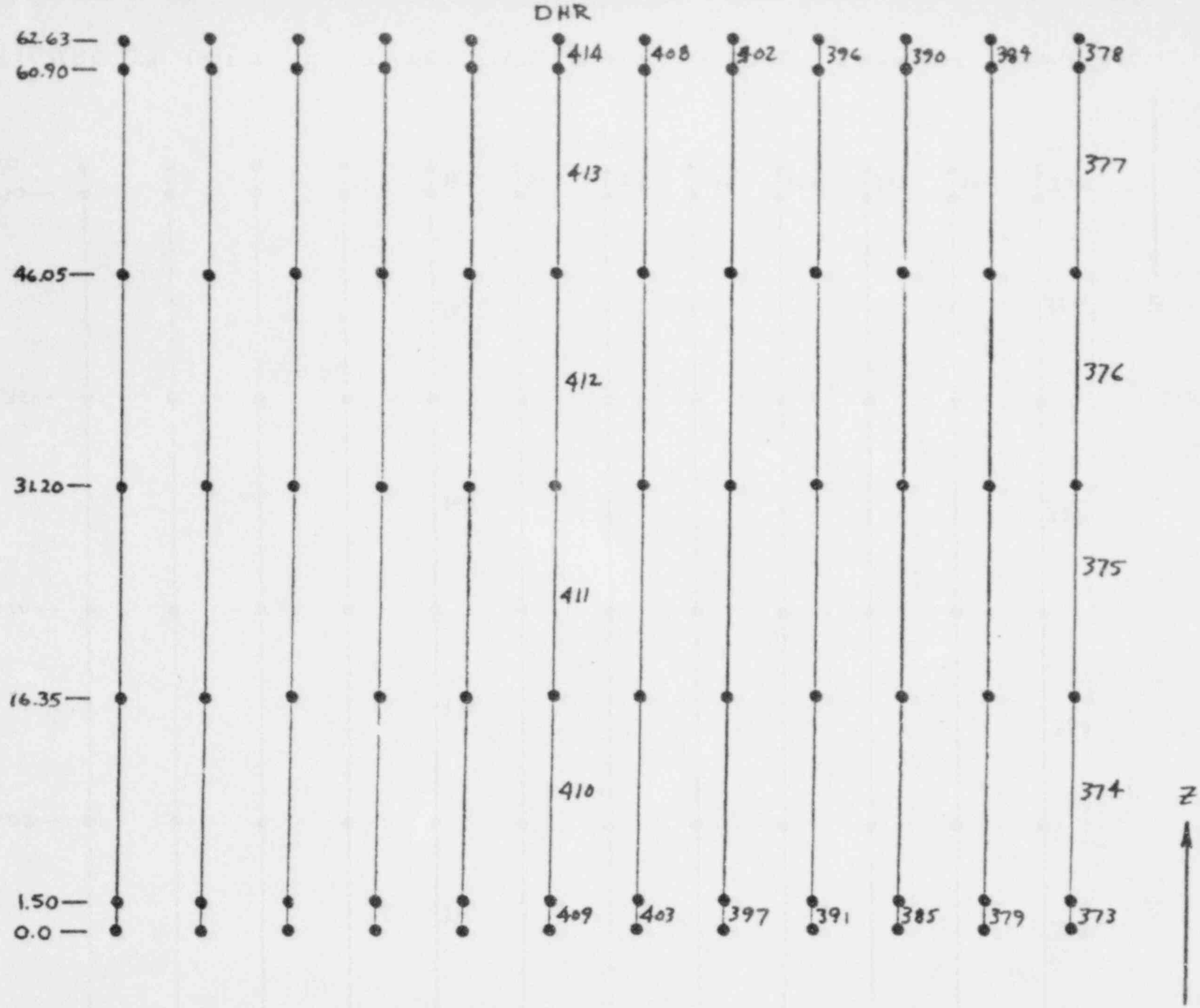


FIGURE 60 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN F

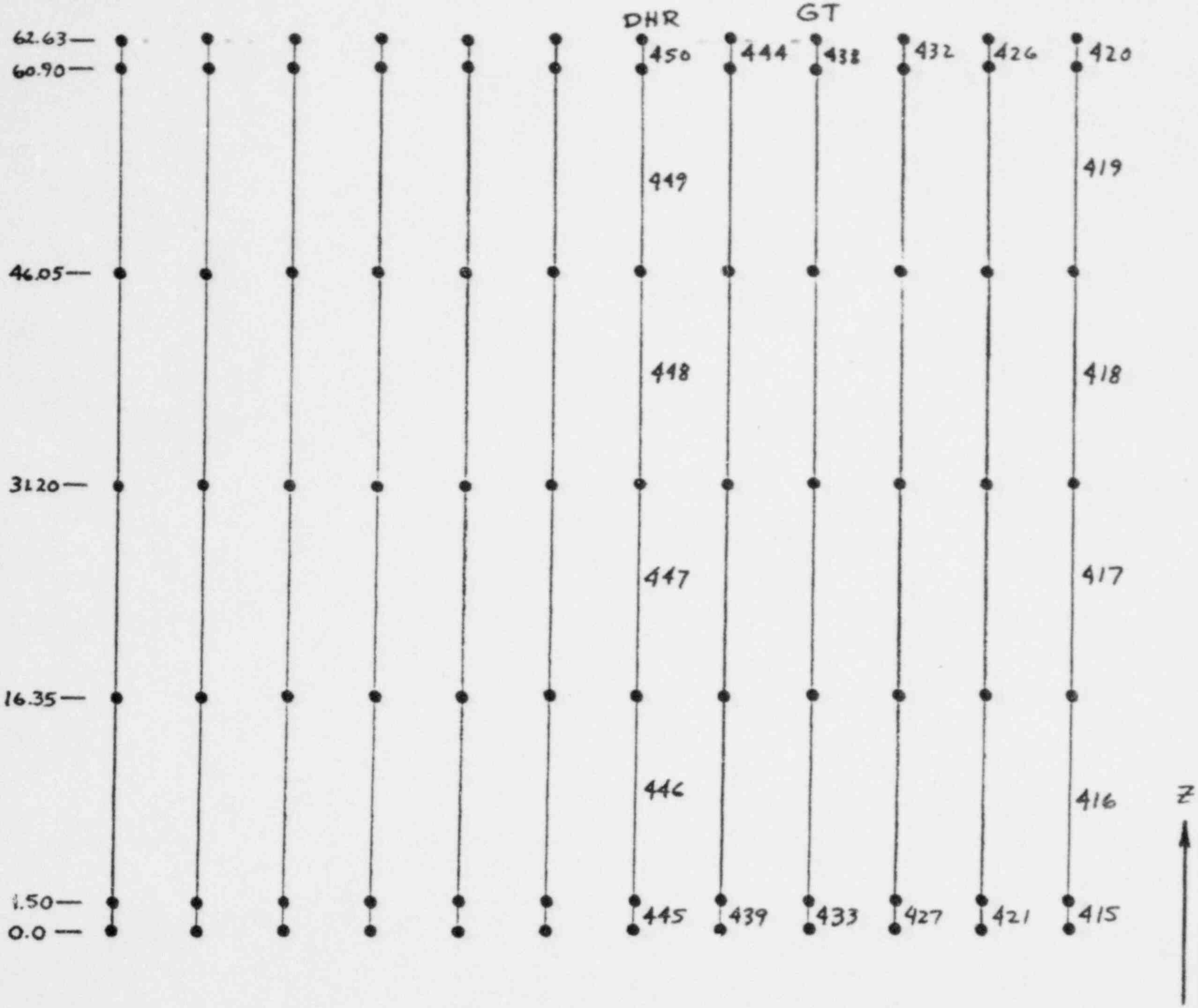


FIGURE 61 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN E

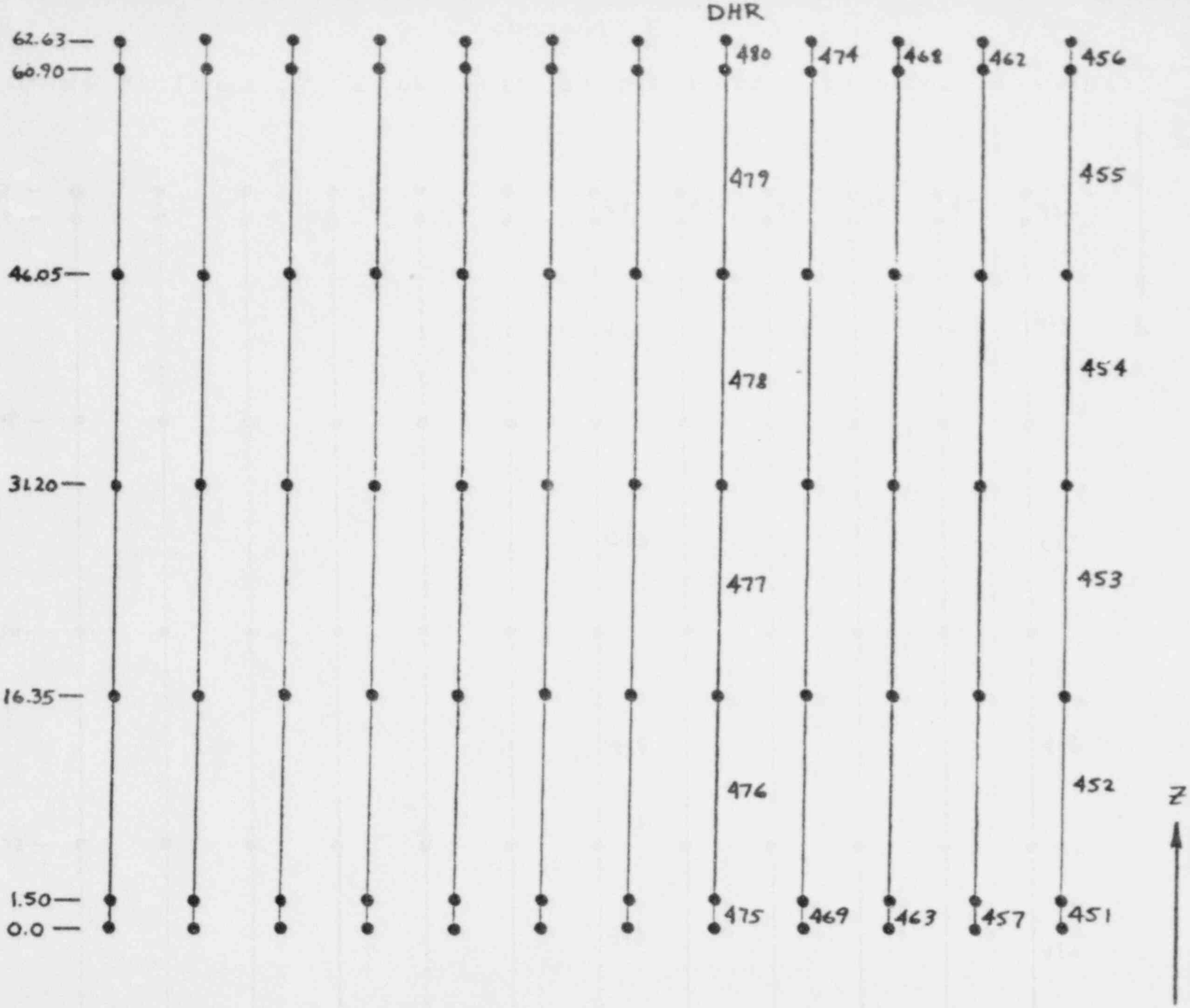


FIGURE 62 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN D

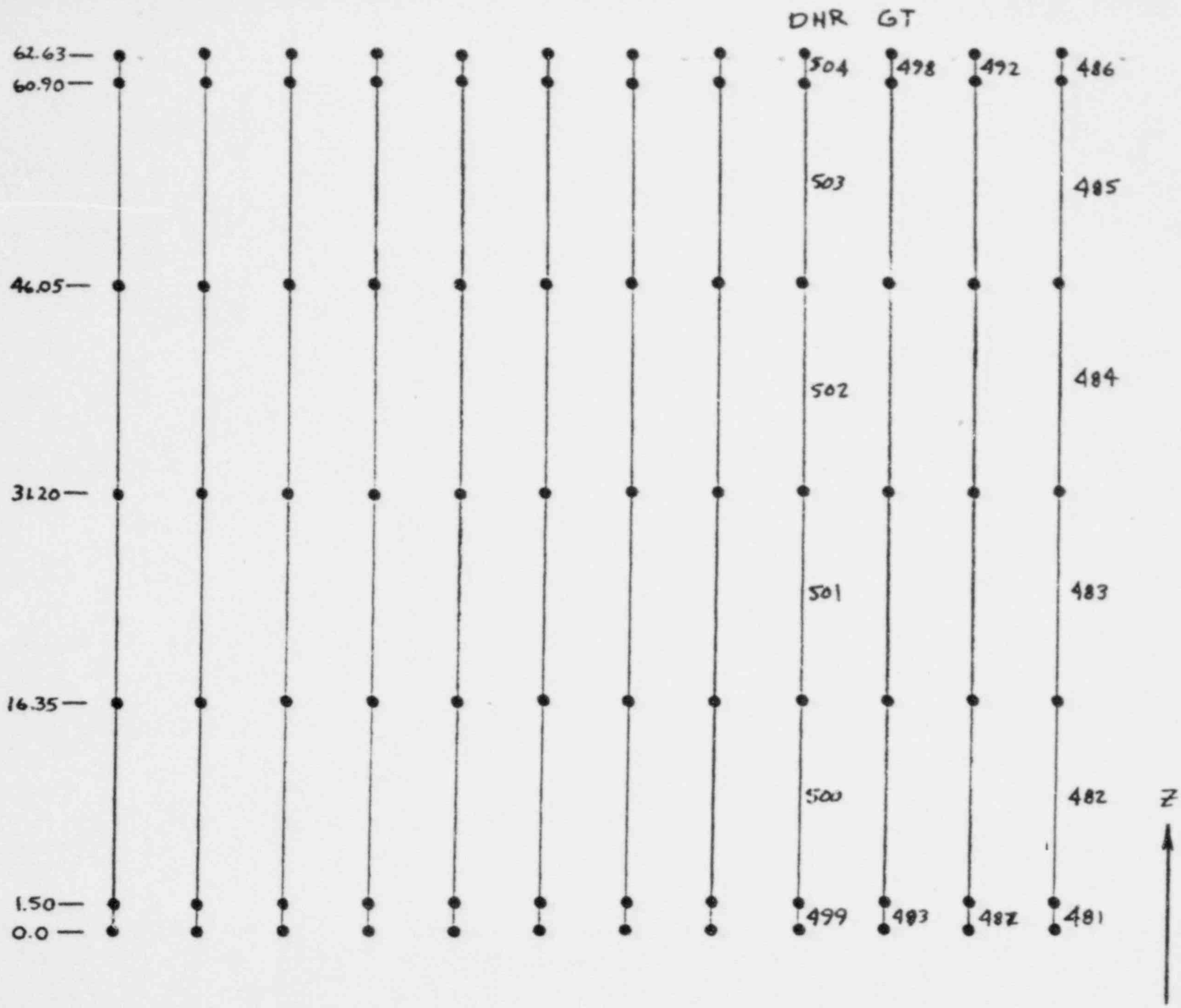


FIGURE 63 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN C

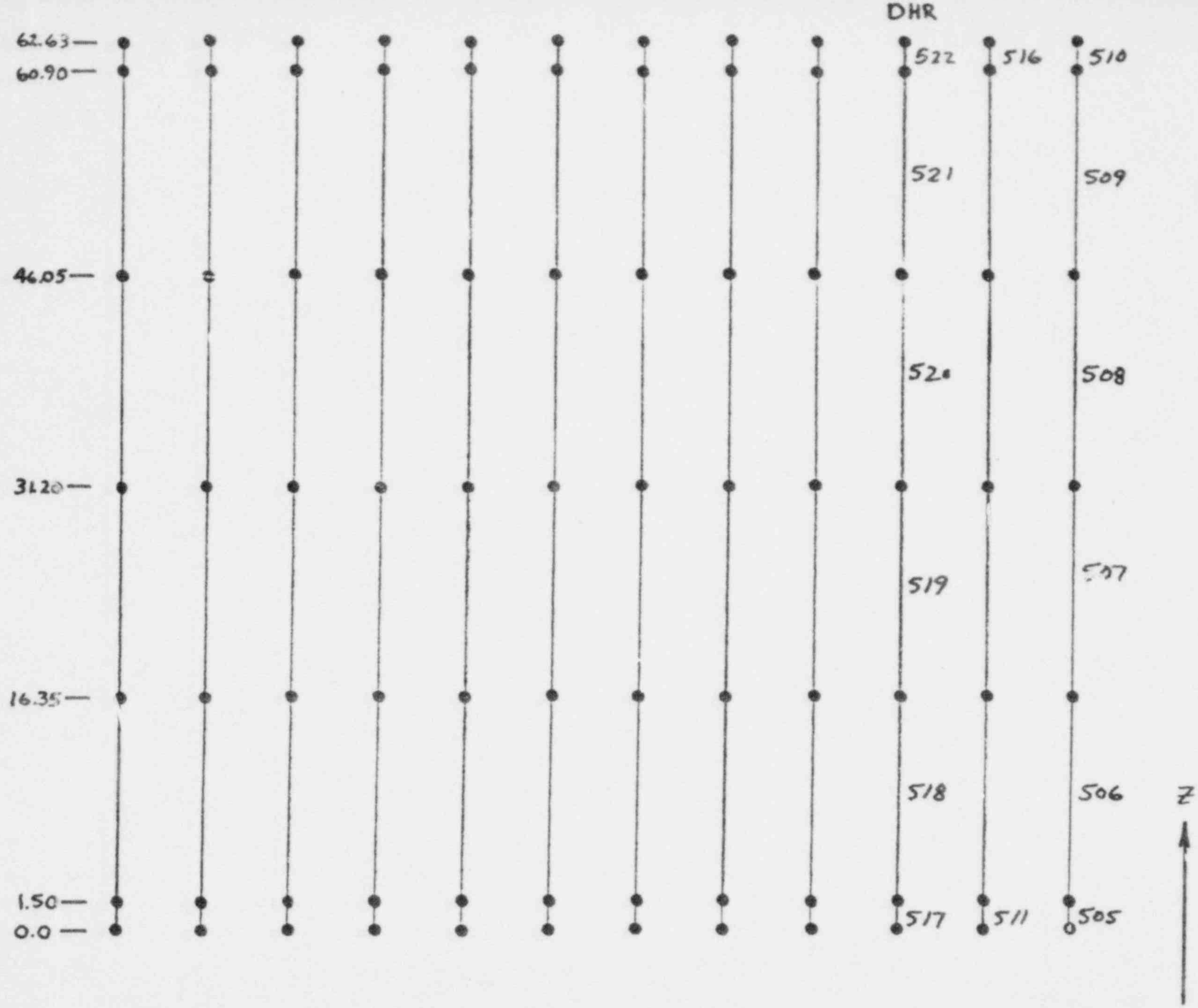


FIGURE 64 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN B

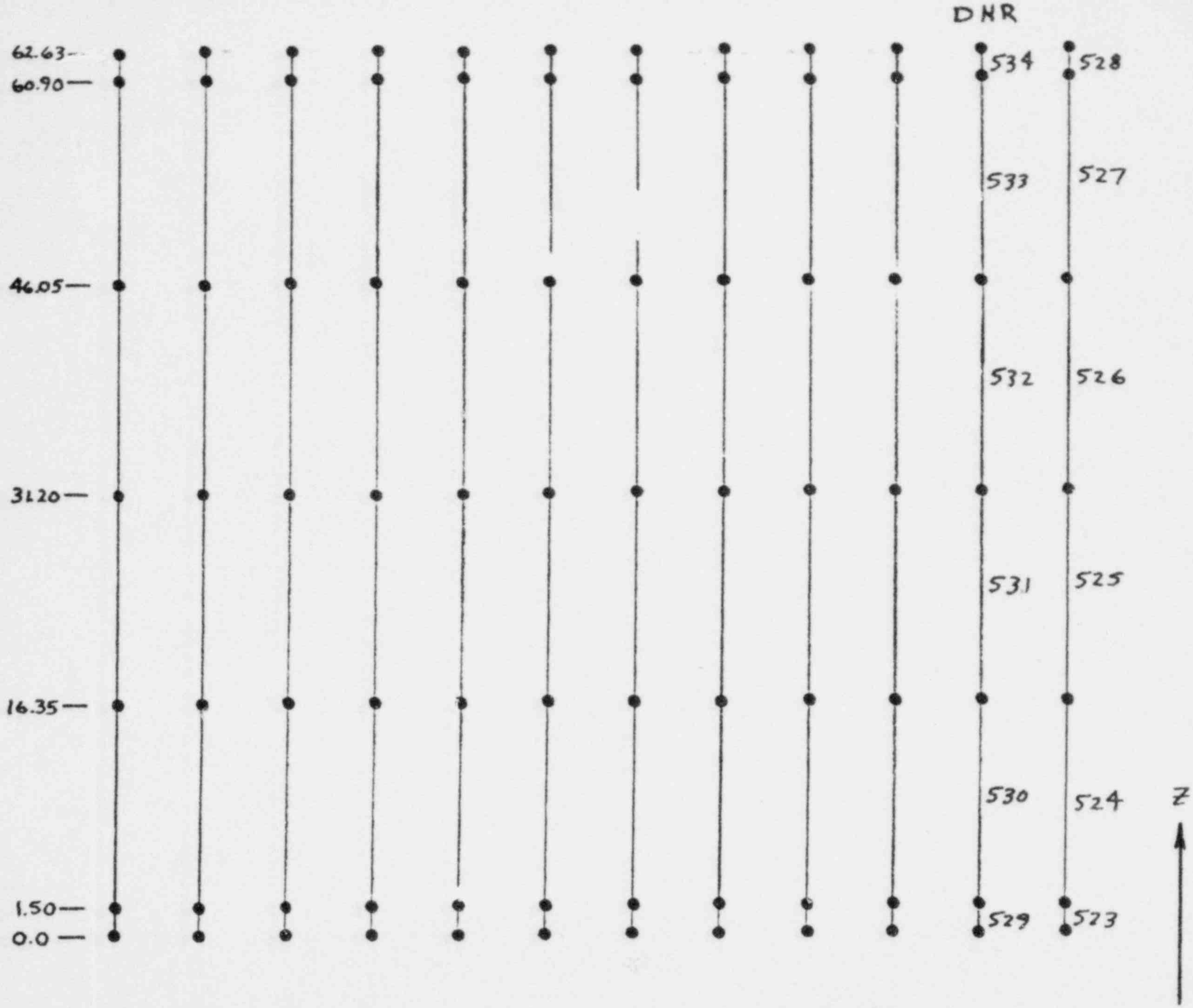


FIGURE 65 LOFT 'E' TYPE FUEL BUNDLE MODEL ELEMENT NUMBERS, COLUMN A

LTR 1111-65
REV 1

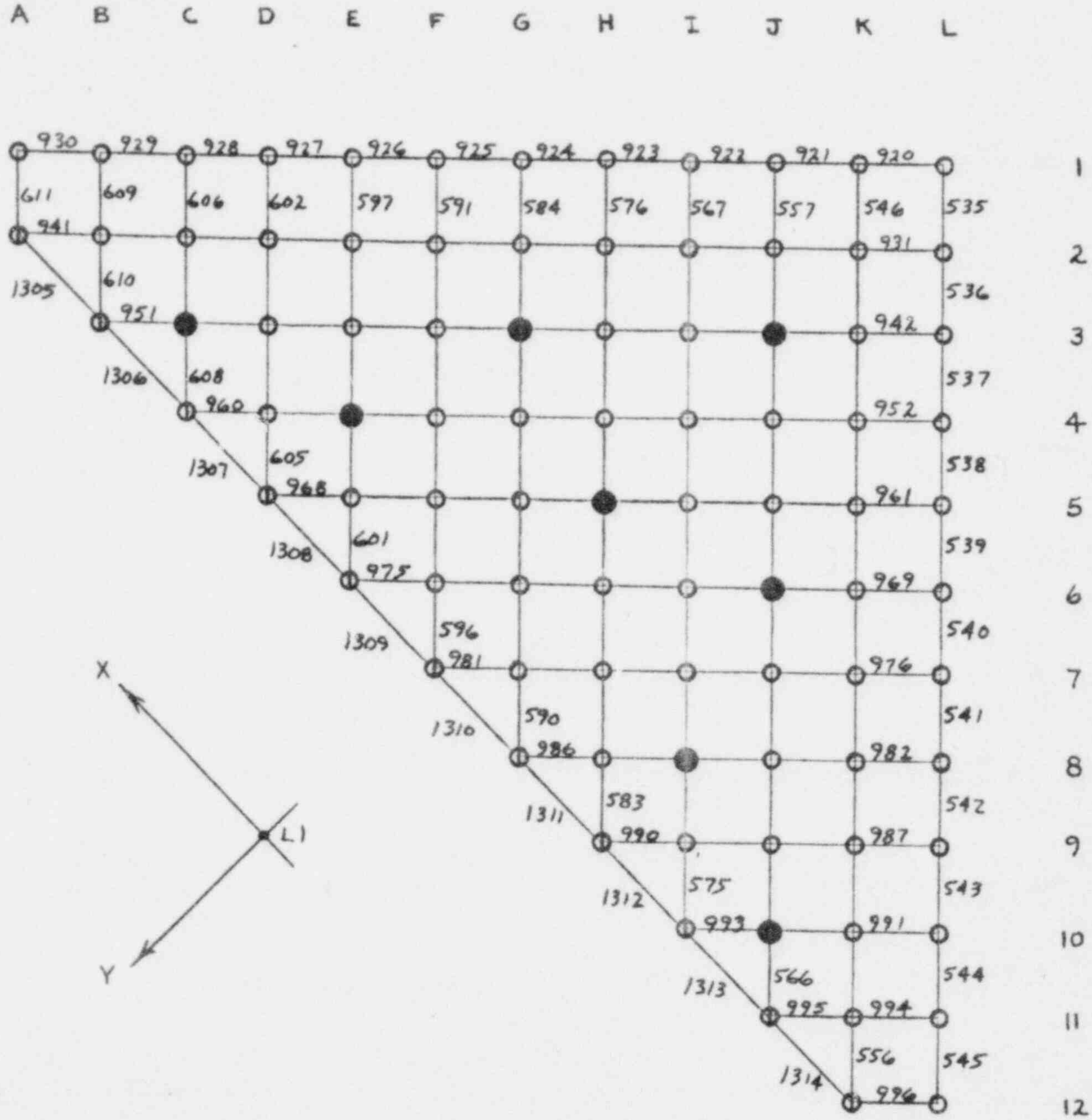


FIGURE 66 LOFT 'E' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 1.50

LTR 1111-65
REV 1

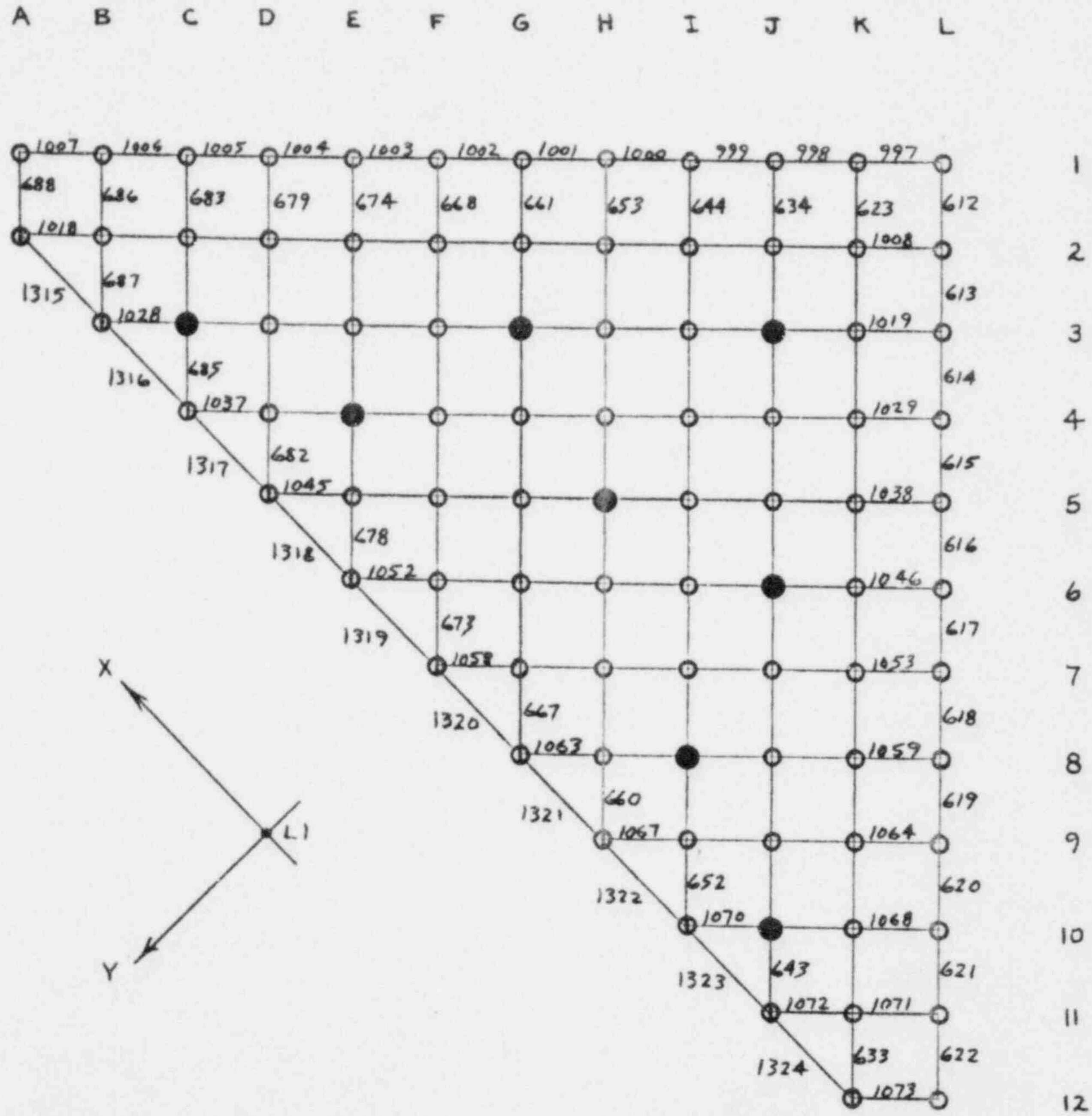


FIGURE 67 LOFT 'E' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 16.35

LTR 1111-65
REV 1

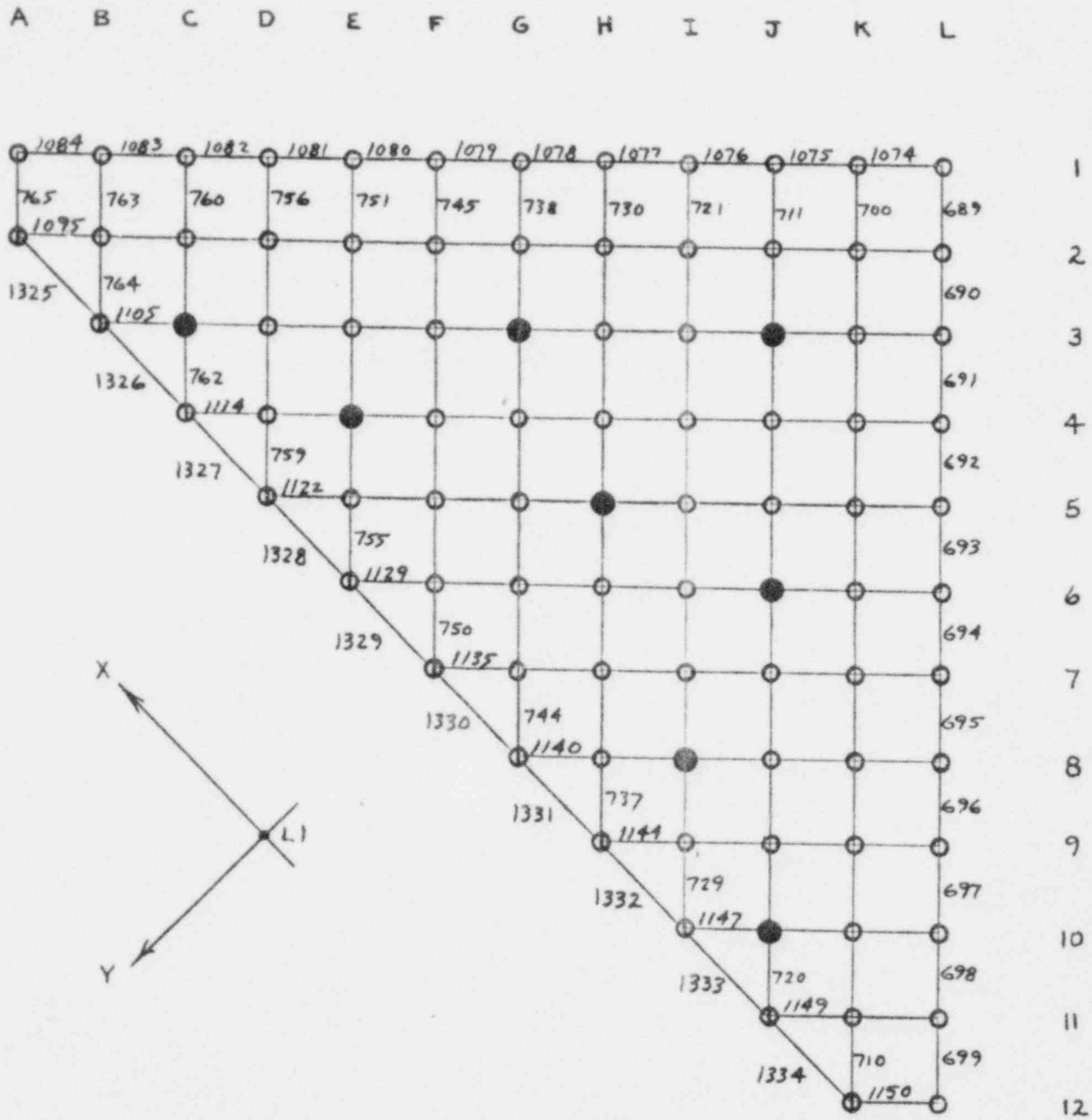


FIGURE 68 LOFT 'E' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 31.20

LTR 1111-65
REV 1

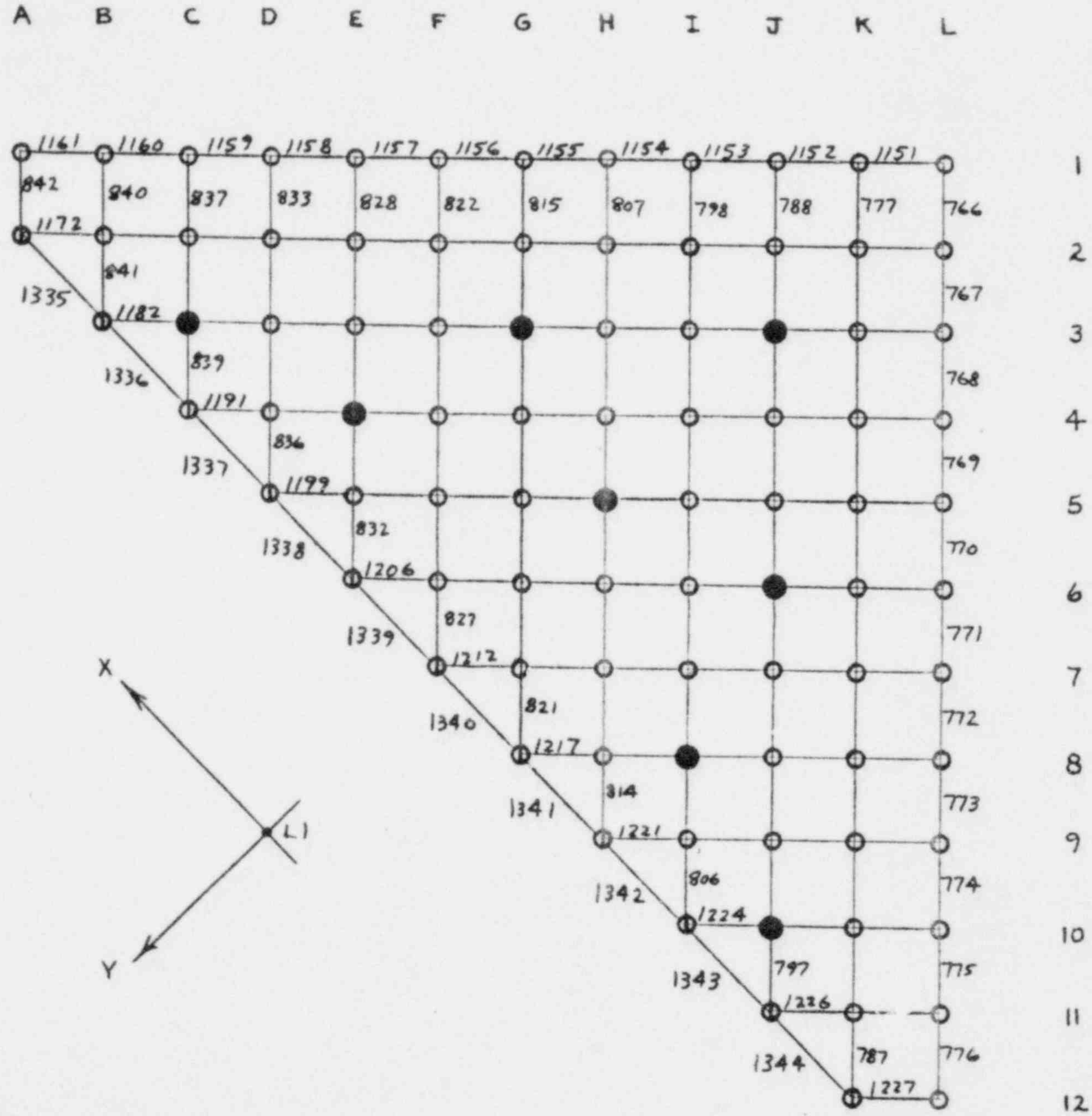


FIGURE 69 LOFT 'F' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 46.05

LTR 1111-65
REV 1

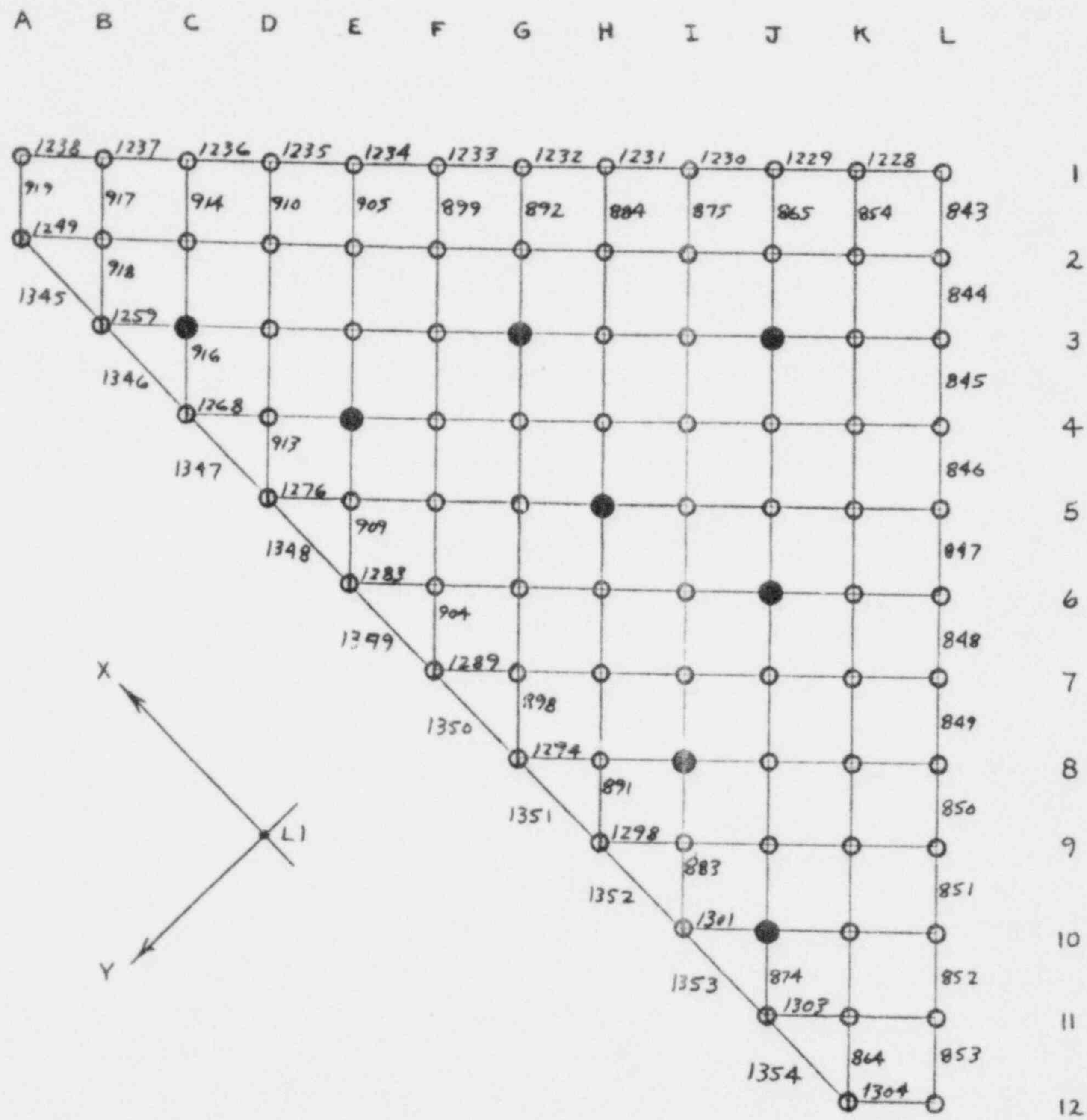


FIGURE 70 LOFT 'E' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 60.90

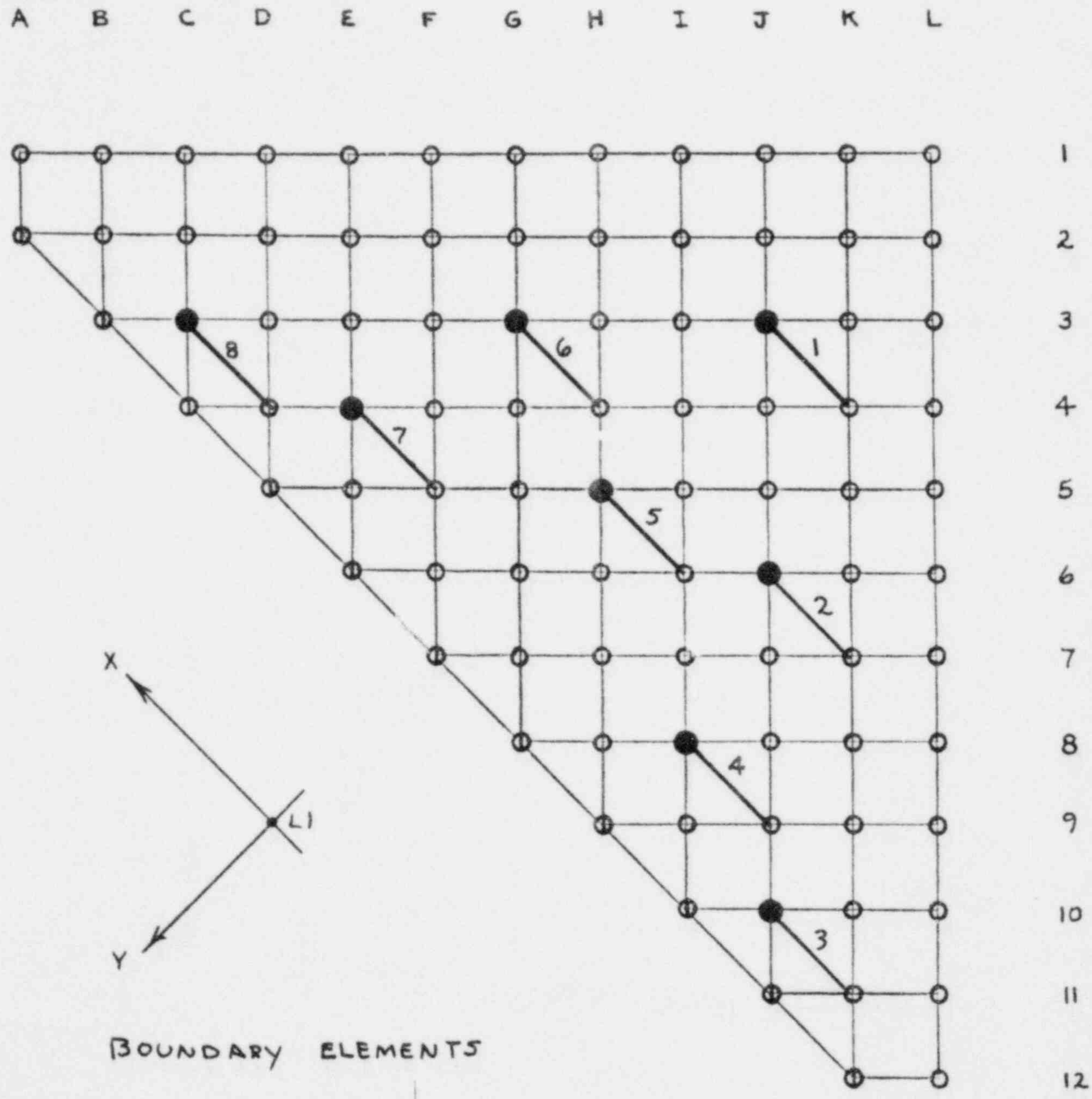


FIGURE 71 LOFT 'E' TYPE FUEL BUNDLE MODEL
ELEMENT NUMBERS, Z = 0.0

LTR 1111-65
REV 1

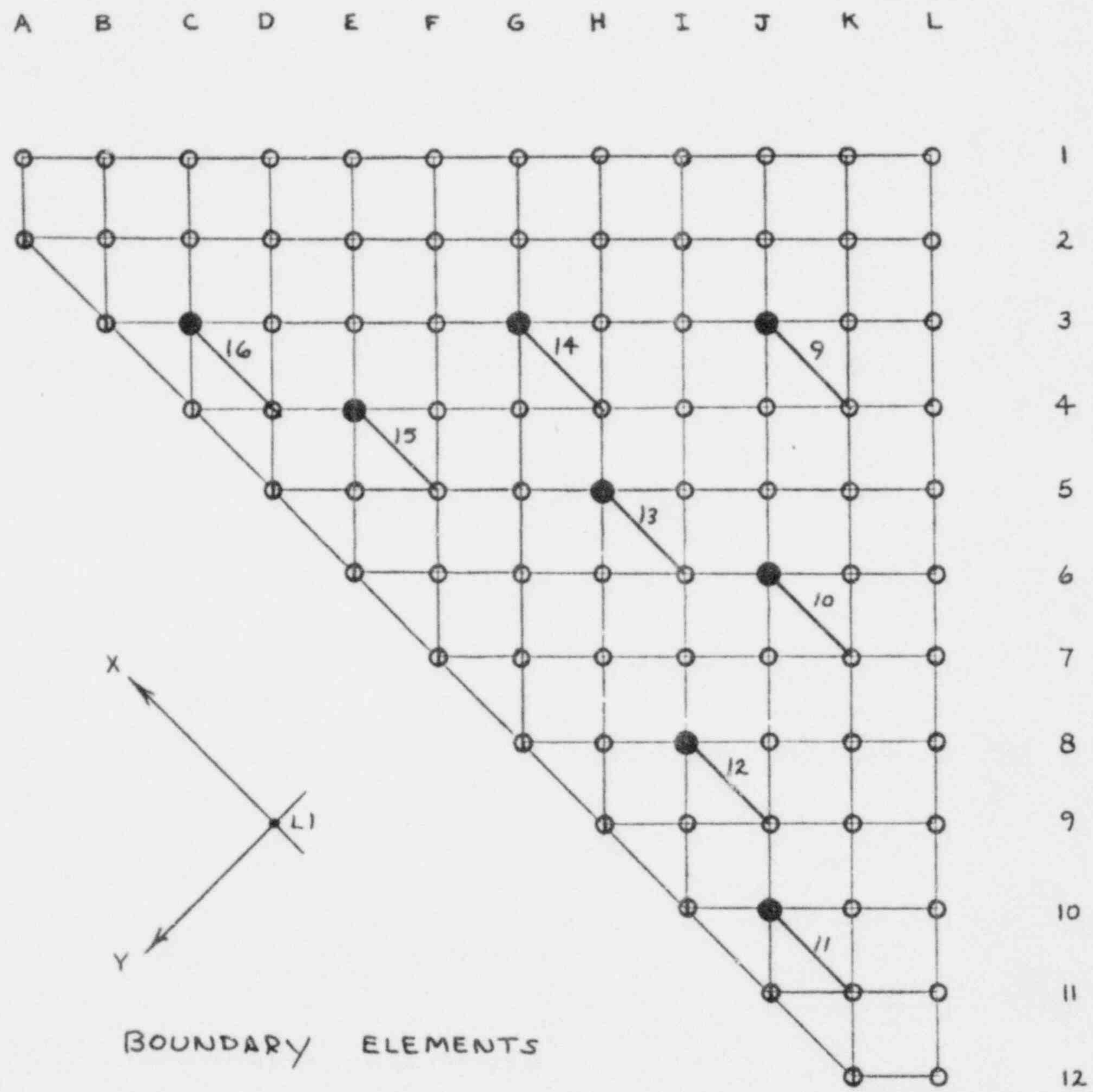


FIGURE 72 LOFT 'E' TYPE FUEL BUNDLE MODEL
ELEMENT NUMBERS, Z = 1.50

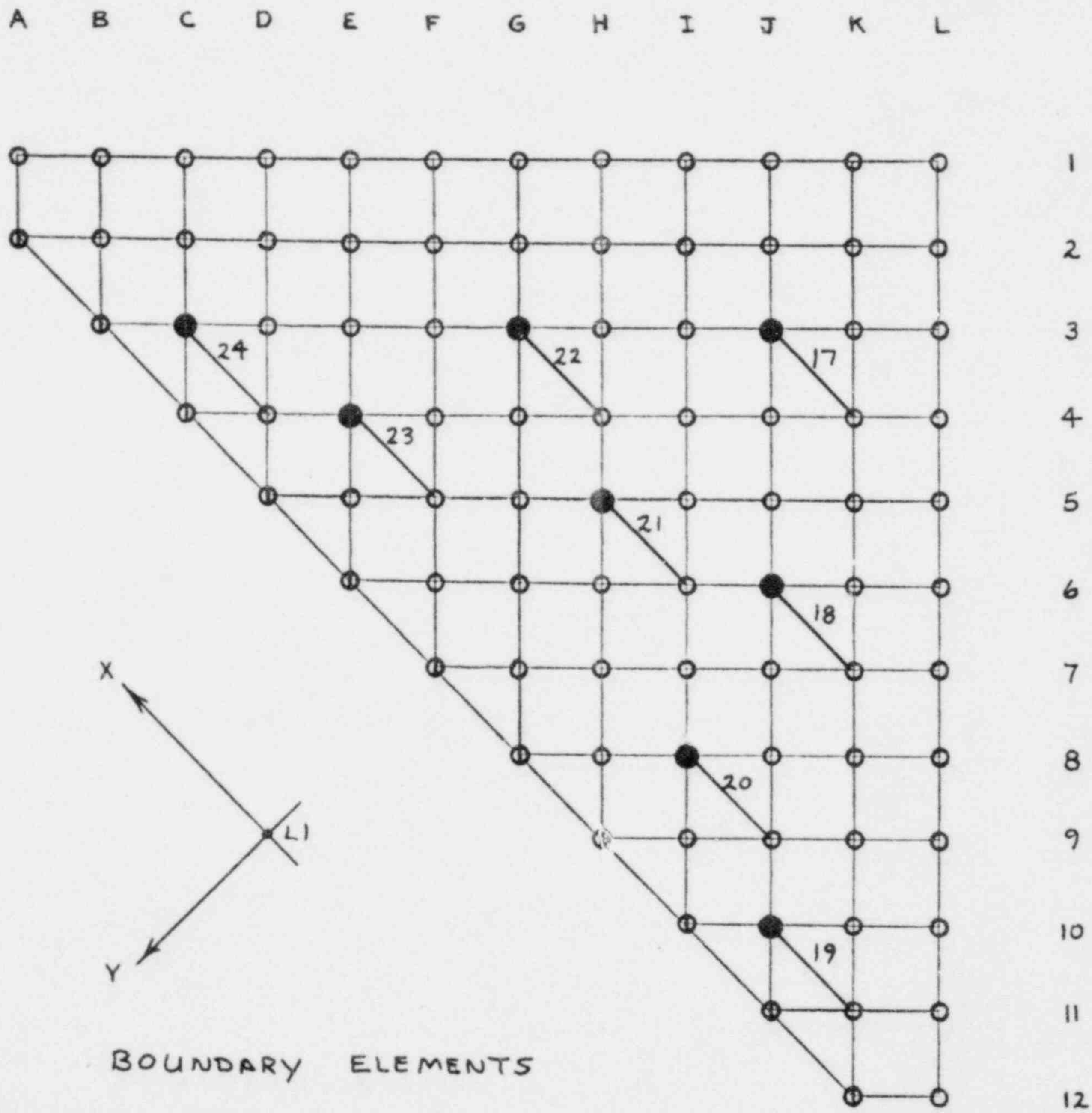


FIGURE 73 LOFT 'E' TYPE FUEL BUNDLE MODEL
ELEMENT NUMBERS, Z = 16.35

LTR 1111-65
REV 1

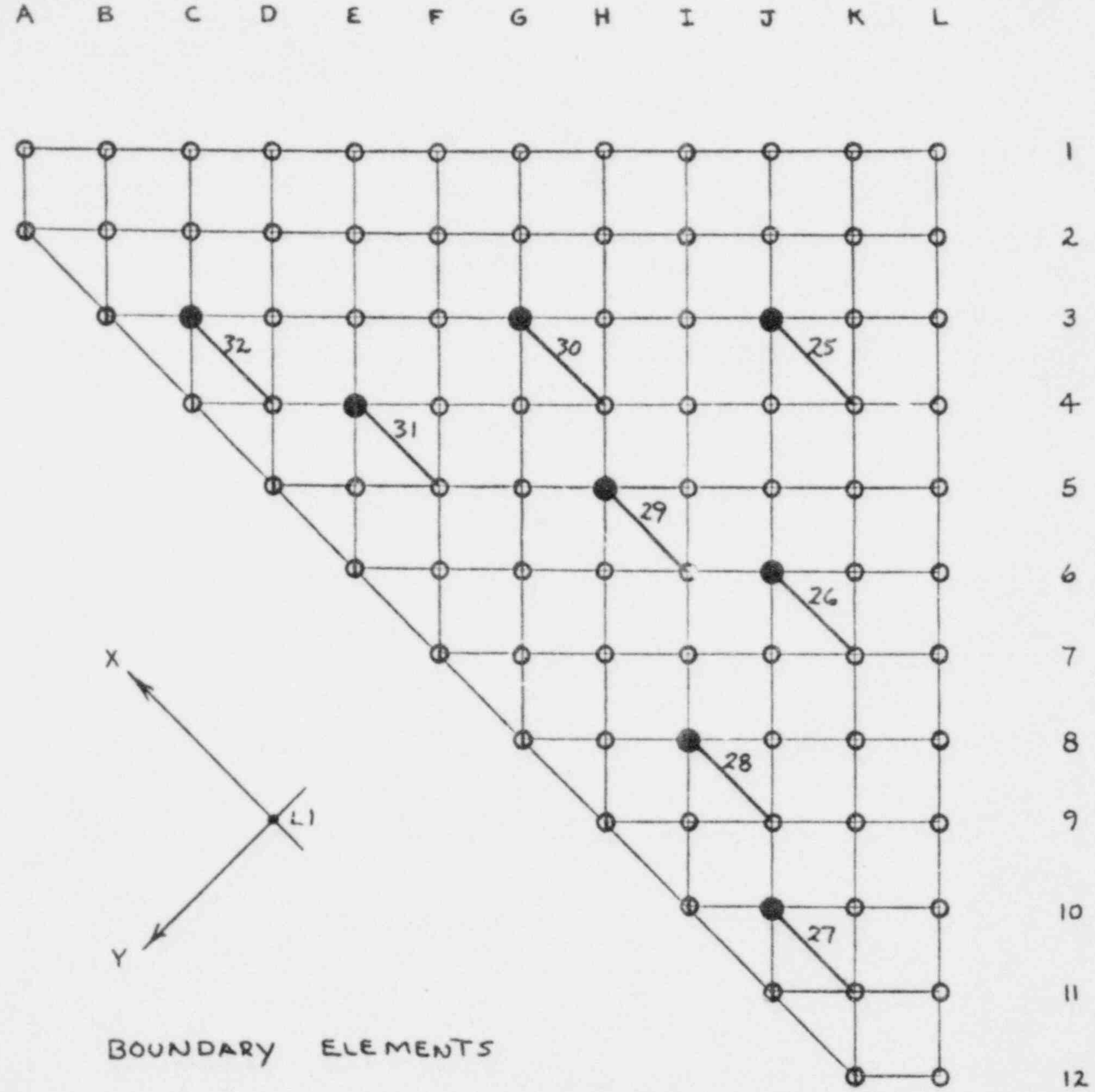


FIGURE 74 LOFT 'E' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 31.20

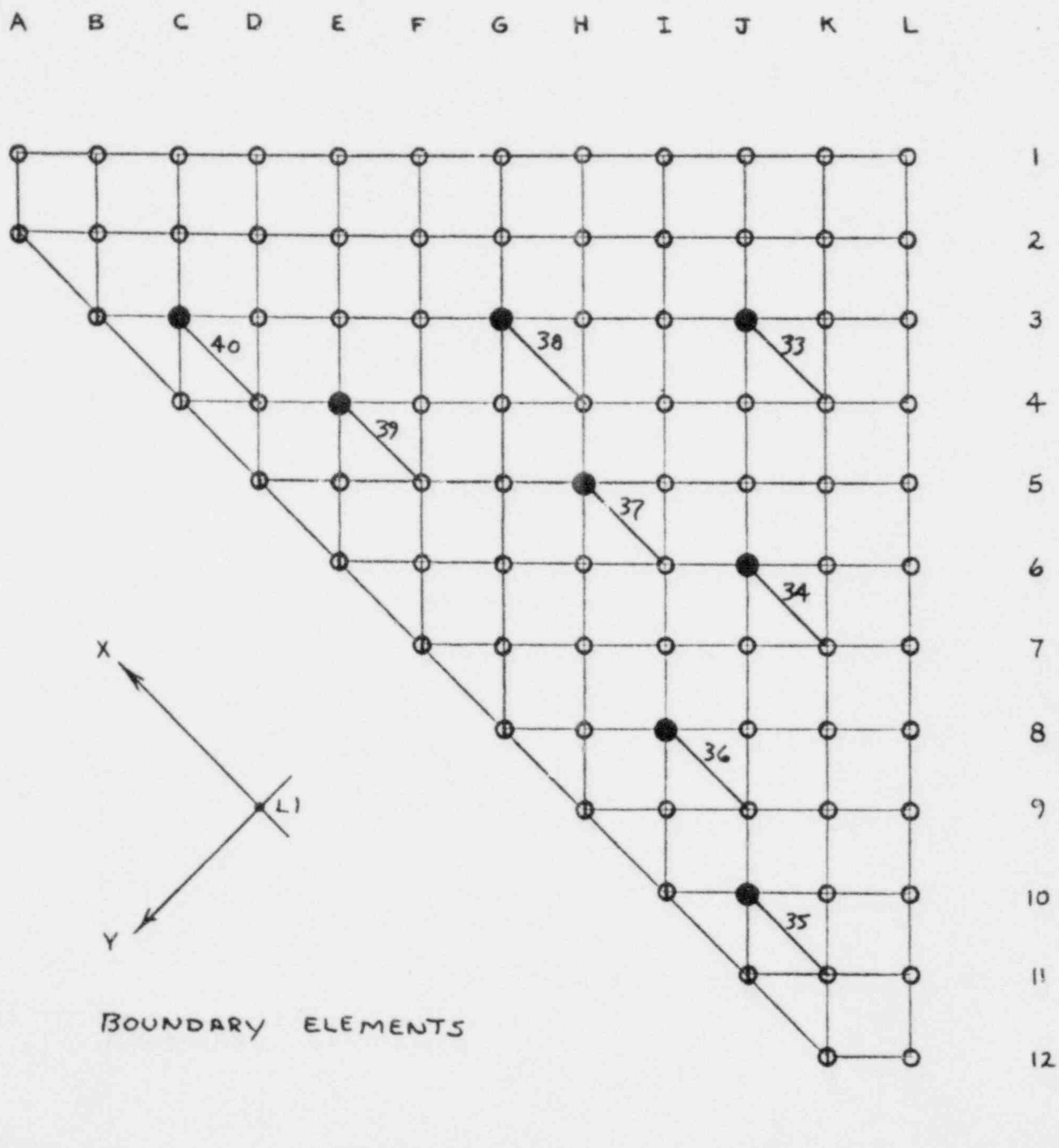


FIGURE 75 LOFT 'E' TYPE FUEL BUNDLE MODEL
ELEMENT NUMBERS, Z = 46.05

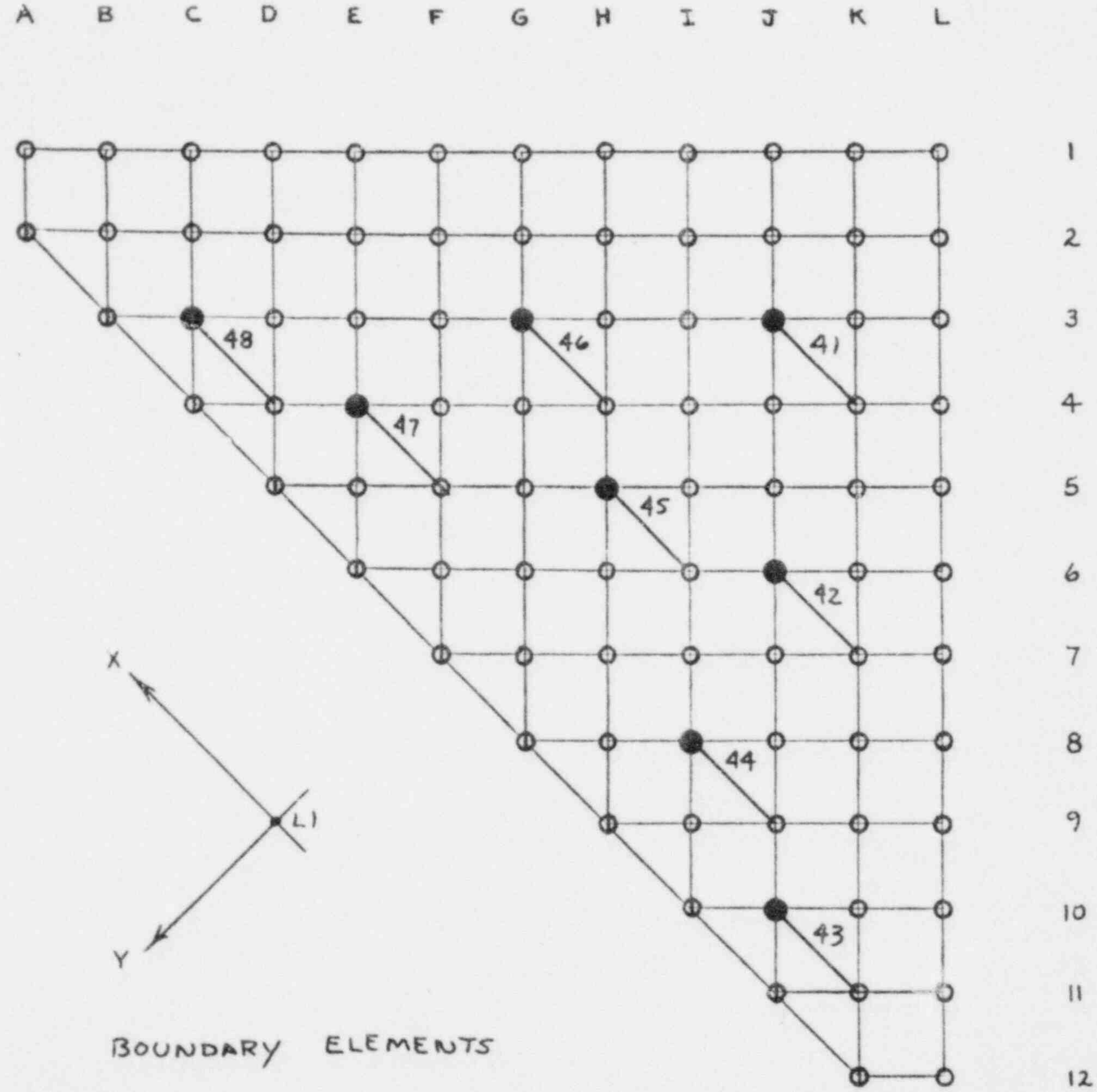


FIGURE 76 LOFT 'E' TYPE FUEL BUNDLE MODEL

ELEMENT NUMBERS, Z = 60.90

5.0 REFERENCES

1. B. F. Saffell, Jr., Letter to File, SAFF-37-76, Resolution of Comments on MPR-509, November 8, 1976.

2. B. F. Saffell, Jr., Dynamic Analysis of the LOFT Reactor Fuel Modules for Subcooled Blowdown Loads, LTR 1111-31, December 21, 1976.

3. T. R. Thompson, Mechanical Analysis of LOFT Reactor Internals Due to Loss-of-Coolant Experiments, LTR 1115-34, April 28, 1977.

4. K. J. Bathe, E. L. Wilson, F. E. Peterson, SAP IV, a Structural Analysis Program for Static and Dynamic Response of Linear Systems, EERC 73-11, Earthquake Engineering Research Center, University of California, Berkely, California, June 1973.

5. ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, 1974.

6. Report of LOFT Fuel Module Dynamic Analysis, Vol. I and Vol. II, MPR-509 (March 1976).

7. LOFT Fuel Assembly Strength Test, Test Report, XN-74-28, Exxon Nuclear Company, Inc., July 15, 1974.

8. "Aerospace Structural Metals Handbook, Vol. IIA, Non-Ferrous Heat Resistant Alloys," Alloy Code 4103 (Inconel 718).

APPENDIX A

FINITE ELEMENT MODELS OF TYPE 'A' AND 'D' FUEL BUNDLES

APPENDIX A

FINITE ELEMENT MODELS OF TYPE 'A' AND 'D' FUEL BUNDLES

Included in this Appendix is a summary of material and section properties for beam elements in the type 'A' and 'D' fuel bundle models as well as complete summary of models in Figures 9-44.

(1) Guide tubes, instrumented guide tubes, instrumentation tube (304 L stainless)

E	$= 28.3 \times 10^6$ psi	(modulus of elasticity)
ν	$= 0.3$	(Poisson's ratio)
ρ	$= 0.295$ lb/in^3	(density)
A	$= 0.0282$ in^2	(neglects slots) (cross-sectional area)
A_{shear}	$= 0.0$ in^2	(shear area)
J*	$= 1.967 \times 10^{-3}$ in^4	(polar moment of inertia)
I_2*	$= 9.837 \times 10^{-4}$ in^4	(moment of inertia about element axis 2)
I_3*	$=9.837 \times 10^{-4}$ in^4	(moment of inertia about element axis 3)

* calculated from mean dimensions, neglects slots

(2) Fuel rods, instrumented fuel rods (Zr - 4)

$E = 13 \times 10^6$ psi

$\nu = 0.3$

$\rho = 1.618$ lb/in^3 (includes fuel weight)

$A = 0.0306$ in^2

$A_{shear} = 0.0$ in^2

$J = 1.204 \times 10^{-3}$ in^4

$I_2 = 6.02 \times 10^{-4}$ in^4

$I_3 = 6.02 \times 10^{-4}$ in^4

(J, I_2, I_3: calculated from mean dimensions)

(3) Grid spacer structure (fuel to fuel interface) parallel to lateral deflection

$E = 29.6 \times 10^6$

$\nu = 0.3$

$\rho = 0349$ lb/in^3 (distributes weight of grid structure evenly in elements)

$A = 0.0298$ in^2

$A_{S2} = 0.0248 \text{ in}^2 = \frac{A}{1.2}$

$A_{S3} = 0.0$ in^2

$J = 1.0 \times 10^{-8}$ in^4 — beam not loaded in these directions

$I_2 = 1.0 \times 10^{-8}$ in^4 — beam not loaded in these directions

$I_3 = 1.0 \times 10^{-6}$ in^4 — from overlay of analytical model and experimental response to 50 lb lateral load (XN-74-28)

(4) Grid spacer structure (guide tube and instrumented fuel rod to fuel interface) parallel to lateral deflection (Inconel 718)

$E = 29.6 \times 10^6$ psi

$\nu = 0.3$

$\rho = 0.349$ lb/in^3 (distributes weight of grid structure evenly in elements)

$A = 0.0298$ in^2

$A_{S2} = 0.0248$ in^2 $= \frac{A}{1.2}$

$A_{S3} = 0.0$ in^2

$J = 1.0 \times 10^{-8}$ in^4 — beam not loaded in these directions

$I_2 = 1.0 \times 10^{-8}$ in^4 — beam not loaded in these directions

I_3	$= 2.16 \times 10^{-3}$ in^4	based on load being carried in grid structure between welded tubes with at most three fuel rods between

(5) Grid spacer structure (all locations) direction normal to lateral deflection (Inconel 718)

E	$= 29.6 \times 10^6$ psi	
ν	$= 0.3$	
ρ	$= 0.349$ lb/in^3	(distributes weight of grid structure evenly in elements)
A	$= 0.0298$ in^2	
A_{S2}	$= 0.0248$ in^2 $= \frac{A}{1.2}$	
A_{S3}	$= 0.0$ in^2	
J	$= 1.0 \times 10^{-8}$ in^4	(no load)
I_2	$= 2.35 \times 10^{-3}$ in^4	(based on $I = \Sigma I_o + \Sigma Ad^2$)
I_3	$= 2.16 \times 10^{-3}$ in^4	(same as I_3 for previous case)

APPENDIX B

FINITE ELEMENT MODEL OF TYPE 'E' FUEL BUNDLE

APPENDIX B

FINITE ELEMENT MODEL OF TYPE 'E' FUEL BUNDLE

This Appendix includes a summary of material and section properties for beam elements, and a complete summary of the type 'E' model in Figures 45-76.

(1) Guide tubes (304 L stainless)

$E = 28.3 \times 10^6$ psi

$\nu = 0.3$

$\rho = 0.295$ lb/in^3

$A = 0.0282$ in^2

$A_{shear} = 0.0$ in^2

$J = 1.967 \times 10^{-3}$ in^4

$I_2 = 9.84 \times 10^{-4}$ in^4

$I_3 = 9.84 \times 10^{-4}$ in^4

(J, I_2, I_3 calculated from mean dimensions)

(2) Fuel rods (Zr - 4)

$E = 13. \times 10^6$ psi

$\nu = 0.3$

$\rho = 1.618$ lb/in^3 (includes fuel weight)

$A = 0.0306$ in^2

A_{shear} = 0.0 in^2

J	= 1.204×10^{-3} in^4	calculated from mean dimensions
I_2	= 6.02×10^{-4} in^4	
I_3	= 6.02×10^{-4} in^4	

(3) Dummy half rods (304 L stainless)

E = 28.3×10^6 psi

ν = 0.3

ρ = 0.331 lb/in^3

A = 0.0917 in^2

J	= 1.9×10^{-3} in^4	calculated from mean dimensions
I_2	= 8.3×10^{-4}	
I_3	= 1.07×10^{-3} in^4	

(4) Grid structure (fuel to fuel locations) (Inconel 718)

E = 29.6×10^6 psi

ν = 0.3

ρ = 0.349 lb/in^3 (distributes grid structure weight evenly)

A = 0.0298 in^2

A_{S2} = 0.0248 in2 = $\frac{A_2}{1.2}$

A_{S3} = 0.0 in^2

J = 1.0×10^{-8} in^4 (not loaded in this direction)

I_2 = 2.35×10^{-3} in^4 (based on $I = \Sigma I_o + \Sigma Ad^2$)

I_3 = 1.0×10^{-6} in^4 (see fuel to fuel location in Appendix A)

(5) Grid structure (guide tube to fuel rod locations) (Inconel 718)

E = 29.6×10^6 psi

ν = 0.3

ρ = 0.349 lb/in^3 (distributes grid structure weight evenly)

A = 0.0298 in^2

A_{S2} = 0.0248 $in^2 = \frac{A}{1.2}$

A_{S3} = 0.0 in^2

J = 1.0×10^{-8} in^4 (not loaded in this direction)

I_2 = 0.00235 in^4 (based on $I = \Sigma I_o + \Sigma Ad^2$)

I_3 = 2.16×10^{-3} in^4 (see guide tube to fuel rod location in Appendix A)

(6) Grid structure (dummy half rod to dummy half rod)
(Inconel 718)

E	$= 29.6 \times 10^6$ psi	
ν	$= 0.3$	
ρ	$= 0.349$ lb/in^3	(distributes grid structure weight evenly in elements)
A	$= 0.0298$ in^2	
A_{S2}	$= 0.0$ in^2	
A_{S3}	0.0248 in^2 $= \frac{A}{1.2}$	
J	$= 1.0 \times 10^{-8}$ in^4	(no load)
I_2	$= 0.0076$ in^4	($\frac{bh^3}{12}$ for grid)
I_3	$= 1.0 \times 10^{-8}$ in 4	(no load)

APPENDIX C

CALCULATIONS FOR MAXIMUM STRESS INTENSITIES, LOADS, AND ALLOWABLES

APPENDIX C

CALCULATIONS FOR MAXIMUM STRESS INTENSITIES, LOADS, AND ALLOWABLES

This Appendix summarizes the equations used for predicting stresses and loads, as well as allowables for the fuel bundle structural components. (Refer to MPR-509 for calculations.)

(1) Guide Tubes (304 L stainless, 20% cold worked)

$$P_m = \frac{\text{Axial load}}{\text{Area}} = \frac{F_A}{0.0282} \quad \text{(primary membrane stress)}$$

$$P_b = \frac{\text{Moment}}{\text{Section Modulus}} = \frac{M}{0.0036} \quad \text{(primary bending stress)}$$

$$\tau = \frac{\text{Shear Load}}{\text{Section Shear Modulus}} = \frac{F_V}{0.00706} \quad \text{(shear stress)}$$

S_m = 23,300 psi @ 650°F (design stress intensity)

Salt = 150,000 psi (200 cycles) (alternating stress intensity)

(2) Instrumented Guide Tubes (304 L stainless, 20% cold worked)

$$P_m = \frac{F_A}{0.0264}$$

$$P_b = \frac{M}{0.0032}$$

$$\tau = \frac{F_V}{0.00352}$$

S_m = 23,300 psi @ 650°F

Salt = 150,000 psi (200 cycles)

(3) Instrumentation Tubes (304 L stainless, 20% cold worked)

$$P_m = \frac{F_A}{0.0282}$$

$$P_b = \frac{M}{0.0036}$$

$$\tau = \frac{F_V}{0.00706}$$

S_m = 23,300 psi @ 650^{o}F

Salt = 150,000 psi (200 cycles)

(4) Fuel Rod (standard and instrumented) (Zr - 4)

$$P_m = \frac{F_A}{0.030}$$

$$P_b = \frac{M}{0.00285}$$

$$\tau = \frac{F_V}{0.0076}$$

S_m = 20,000 psi @ 720^{o}F (cold worked)

S_m = 10,000 psi @ 720^{o}F (annealed)

(5) Dummy Half Rod (304 L stainless, annealed)

$$P_m = \frac{F_A}{0.0917}$$

$$P_b = \frac{M}{0.00393}$$

$$\tau = \frac{F_V}{0.0175}$$

P_m = 13,400 psi @ 700^{o}F

(6) Grid Spacer Structure (Inconel 718)

$$P_m = \frac{F_A}{0.030}$$

$$P_b = \frac{M}{0.0087}$$

$$\tau = \frac{F_V}{0.0198}$$

S_m = 61,700 psi @ 700°F

(7) Grid Strip Intersection Welds

$$F_A = \frac{F_A}{2}$$ (internal load due to axial force)

Assumes axial load and moment equally carried at guide tube interfaces with top and bottom of grid spacer strip

$$F_M = \frac{M}{1.75}$$ (internal load due to moment)

$$F_T = F_A + F_M$$

$$\sigma = 75{,}000 \left(\frac{F_T}{3}\right)$$ (stress in weld)

$$\sigma_A = 3Sm = 185{,}000 \text{ psi @ } 700^{\circ} \text{ F}$$ (allowable stress)

(8) Grid Strip Intersection Welds (shear load in model)

$$F_{eq} = \frac{F_V}{12} \times 13.9$$ (equivalent load in weld)

F_{eqA} = 108 lb @ 600^{o}F (allowable equivalent load in weld)

APPENDIX D

COMPUTER LISTINGS OF FINITE ELEMENT ANALYSIS RESULTS

APPENDIX D

COMPUTER LISTINGS OF FINITE ELEMENT ANALYSIS RESULTS

Included in this Appendix are microfiche copies of the finite element analysis results for use in determining axial displacement and maximum loads and stresses in the type 'A', 'D', and 'E' fuel bundle assemblies.

LOFT A Assembly, Run 1 (JZMAB17)*

LOFT D Assembly, Run 1 (JZMDB2M)

LOFT E Assembly, Run 1 (JZMEB6D)

LOFT A Assembly, Run 2 (JZMABQ2)

LOFT D Assembly, Run 2 (JZMDBRB)

LOFT E Assembly, Run 2 (JZMEBQW)

NOTES: (1) Run 1 includes lateral displacement formed by subtracting dynamic response values from clearance values at maximum end box misalignment.

Run 2 includes lateral displacements formed by adding the dynamic response values to the clearance values at maximum end box misalignment.

(2) These runs were made on the CDC 7600 on a module called SAP4LCM. The FORTRAN source copy for this module is attached.

* Job name on microfiche.

TABLE 1

FINITE ELEMENT MODEL CHARACTERISTICS

Model Type	Nodes	Degrees of Freedom	Beam Elements	Boundary Elements	Specific Data
'A'	1575	4607	3450	120	Bandwidth = 318, includes instrumented guide tubes and fuel rods
'D'	1575	4645	3450	120	Bandwidth = 318, no instrumented guide tubes or fuel rods
'E'	623	1837	1354	48	Bandwidth = 255, no instrumented guide tubes or fuel rods

GENERAL DATA

Guide tubes fixed in rotation about all axes at each end of models

Motion allowed vertically, horizontally in a direction parallel to the minor principal axis of the cross section, and about the major principal axis of the cross section

Upper and lower tie plates and end boxes are assumed rigid (i.e., provide clamped type support of guide tubes).

COMPUTER OUTPUT

RUN 1

COMPUTER OUTPUT

RUN 2

SOURCE LISTING

SAP4