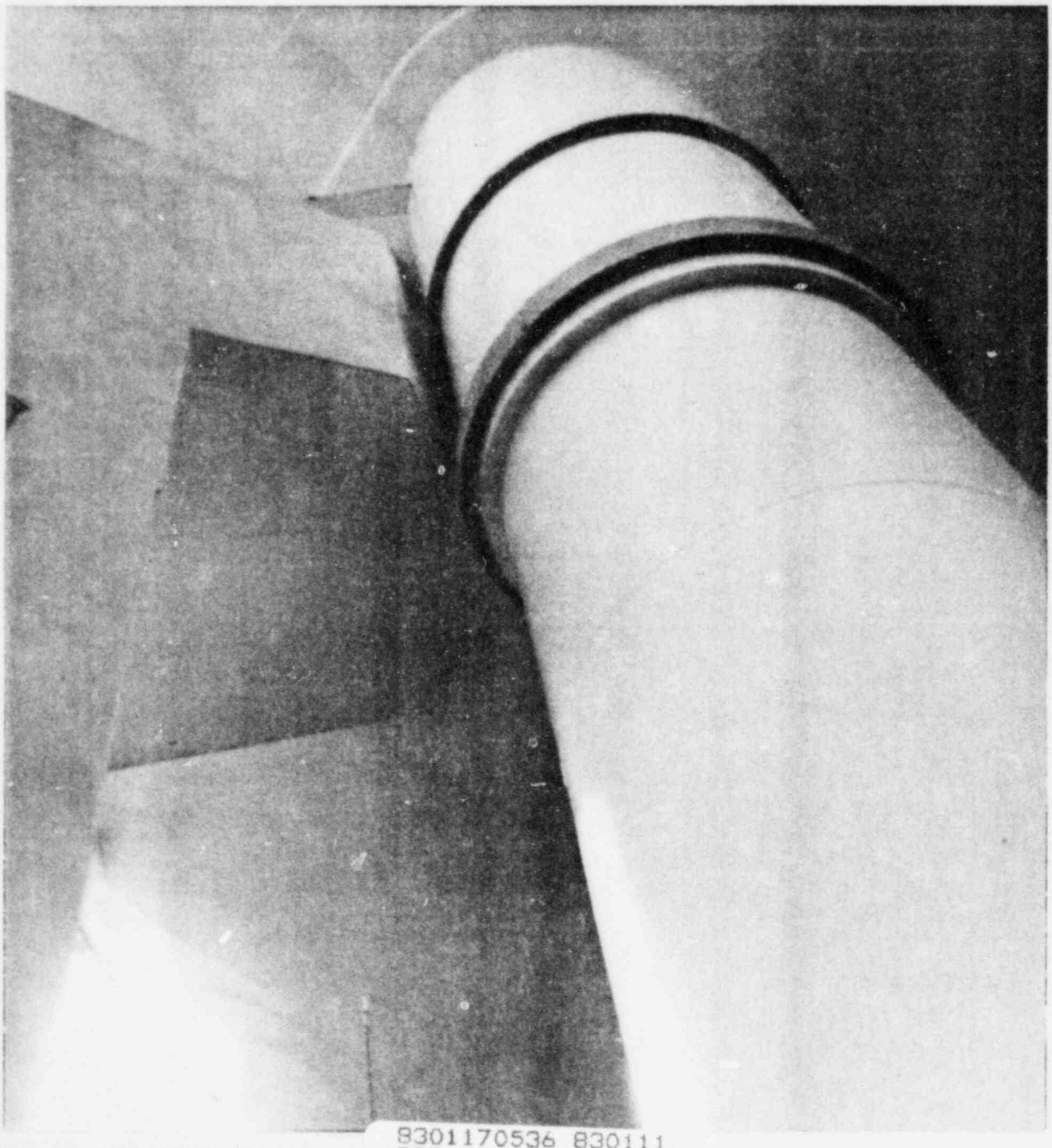
Spent Fuel Pool and Chute

Yankee Nuclear Power Station
Structural Analysis Report

For: Yankee Atomic Electric Company
By: Cygna Energy Services



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December, 1982
Rev. 2

Spent Fuel Pool and Chute

Yankee Nuclear Power Station

Structural Analysis Report

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Eric van Stijgeren

CYGNA

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APPENDICES

I. EXECUTIVE SUMMARY

I.1. Purpose:

This report summarizes results of the structural analyses performed by Cygna Energy Services* (Cygna) for Yankee Atomic Electric Company (YAEC). The results described in this report pertain to the Spent Fuel Pool and Chute at the Yankee Nuclear Power Station (YNPS) at Rowe, Massachusetts.

I.2. Scope:

As requested by YAEC, Cygna performed detailed structural analyses based on the following input data for YNPS:

Structural drawings - See Appendix A
Design Criteria - See Section III
Seismic ground motion by the Nuclear Regulatory Commission Spectrum (NRC), which envelopes the Yankee Composite Spectrum (YCS) - See Appendix C

I.3. Conclusions:

The Pool and Chute comply with Section III criteria, and therefore are capable of supporting static loads combined with simultaneous three-component motion represented by the YCS and NRC spectra.

*Cygna Energy Services is the new name for EES, Inc.
Ownership, philosophy and staffing of the firm remains the same.

II. DESCRIPTION OF STRUCTURE

Pool

The fuel pool is a reinforced concrete structure used to contain spent fuel and its cooling water. It is of open box form with doubly reinforced walls and basemat. As listed in Table B.2,* sections generally range in thickness from 3 to 6 feet.

Plan dimensions are approximately 50 feet by 30 feet, as shown in the structural drawings of Appendix A. The pool is more or less bounded by column lines C, E, 1, and 2. Its height is approximately 40 feet.

The pool is attached to the fuel storage vault to the east, ion exchange structure to the south, and to the chute near the northwest corner.

The inside of the pool is lined with a watertight stainless steel plate.

Chute (including shield)

The spent fuel chute transports spent fuel from the vapor container to the spent fuel pool. It is approximately 50 feet long, subtending an angle of about 45° to the horizontal.

Structural drawings are in Appendix A. Table B.3 tabulates the structural properties for various reinforced concrete sections along the chute length.

*Letter designations of Tables refer to Appendices.

The chute is fixed to the northwest corner of the pool. At the other end of the chute, the bellows connection at the vapor container offers essentially no structural interaction. Between these points, the chute is supported by a reinforced concrete post. The post is fixed to a spread footing approximately 10 feet below grade.

In the vicinity of this support post, removable shielding blocks provide access to the chute interior. The blocks are not considered in the analysis except for the effect of their mass.

III. PERFORMANCE CRITERIA

III.1. Materials

CONCRETE: f'_c = 3000 psi @ 28 days

REINFORCEMENT: ASTM A15 & A305
Grade 40

III.2. Loads

Earthquake

The pool and chute were analyzed using the NRC spectrum (Peak Ground Acceleration = 0.19 g) with 7% of critical damping. The same spectrum was applied to both horizontal directions and scaled to two-thirds of its original magnitude for the vertical direction. Due to the shape of the pool, the vertical spectrum is not a significant pool load.

Thermal

For the pool, thermal loads are by far the most significant due to the pool's thick, highly constrained walls. From a base temperature of 70° F for weather protected surfaces or -20° F for outside locations, the linear thermal gradient reaches 150° F for spent fuel cooling water.

At the chute, thermal stresses are insignificant due to the minor thermal restraints on the chute.

Dead loads, hydrostatic pressure, active soil pressure

Live loads

Live loads are insignificant for the spent fuel chute and pool.

Table B.1 summarizes the loads explicitly calculated (i.e., the significant loads).

Earthquake and thermal are not considered to act concurrently.

III.3 Function

For both pool and chute, the principal criterion is that no design loads cause gross structural failure.

IV. ANALYSIS PROCEDURES

IV.1. Genera.

Pool

For the reinforced sections listed in Table B.2, RCCOLA (see Section IV.2) calculated the cracked section properties and allowable moments for the cracked sections. Using the cracked moments of inertia, Cygna then determined by hand analyses the new reduced thermal moments. These moments were algebraically combined with the moments from all other loads. Engineers then checked the combined moments against the allowable moments, after accounting for moment redistribution.

Cracked moments of inertia were used because the rigidity of uncracked sections produced thermal moments well in excess of allowable moments.

Seismic loads included the effects of both: wall inertial forces, and water sloshing inside the pool. The method, by Housner, for computing water sloshing loads is given in Reference 3. Sloshing and thermal effects are assumed to be nonconcurrent.

For the liner plate, the analysis assumed that the relatively flexible 1/4" thick plate deformed to the deflected shape of the pool walls. Engineers then checked stresses due to these imposed displacements.

Chute

Cygna modeled the chute as a simple finite element stick model (see Fig. C.1). The computer program ANSYS (See Section IV.2) was used for static, modal, and spectral analyses.

IV.2. Computer Programs (See Appendix F)

The structural analyses of the pool and chute used the following programs:

Pool

RCCOLA - A public domain program (Reference 1) to evaluate flexural properties of reinforced concrete cross-sections subjected to axial forces and uniaxial bending moments. Concrete cracking is allowed by using an iterative solution to find equilibrium.

Chute

ANSYS - A general purpose public domain program (Reference 2) for static and dynamic finite element analyses.

IV.3. Assumptions

General

Refer to References 1 and 2 for assumptions inherent in the computer software.

As previously determined for this site, soil-structure interaction is considered negligible. In addition, there is no significant interaction between the chute and Steel Vapor Container.

Pool

The stainless steel liner plate is ignored for structural purposes.

Chute

The chute is assumed fixed at its connection to the pool, and free at the vapor container. The chute support post is considered fixed at the chute.

V. ANALYSIS RESULTS

V.1. Structural Characteristics

Pool

The pool, with its massive structural sections, is fully capable of carrying its primary* loads. These stiff sections, however, induce relatively high thermal moments. As permitted by Section III, Division 2 of the ASME B&PV Code, the strain relief for secondary** thermal loads reduces the associated moments.

Chute

The chute behaves with relatively simple beam response. As a planar structure, the north/south direction is uncoupled from the east/west and vertical directions.

Plots of mode shapes for the first four modes are shown in Appendix C. Other dynamic characteristics are shown in Appendix D.

V.2. Results

The pool and chute are capable of withstanding all primary and secondary loads. The liner plate is acceptable for thermal and seismic loads.

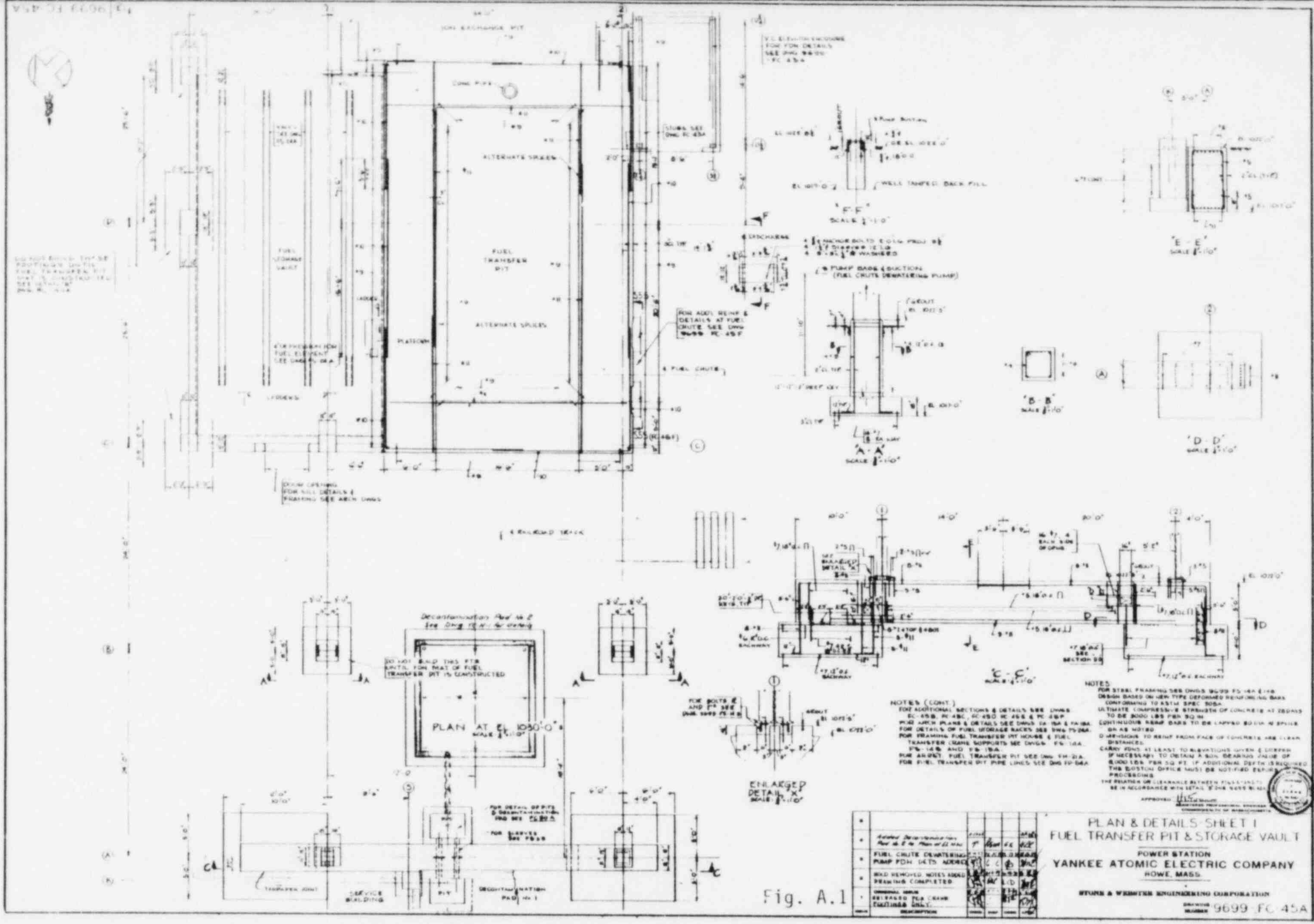
Chute displacements and element stresses are insignificant as shown in Appendix E.

*Primary loads are those which are independent of strain.

**Secondary loads are self-relieving as strain/displacement occurs.

APPENDIX A

BUILDING PLANS



PLAN & DETAILS-SHEET 1
FUEL TRANSFER PIT & STORAGE VAULT
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-45A
PLAN AT EL. 1030-0"
FUEL TRANSFER PIT

Fig. A.1

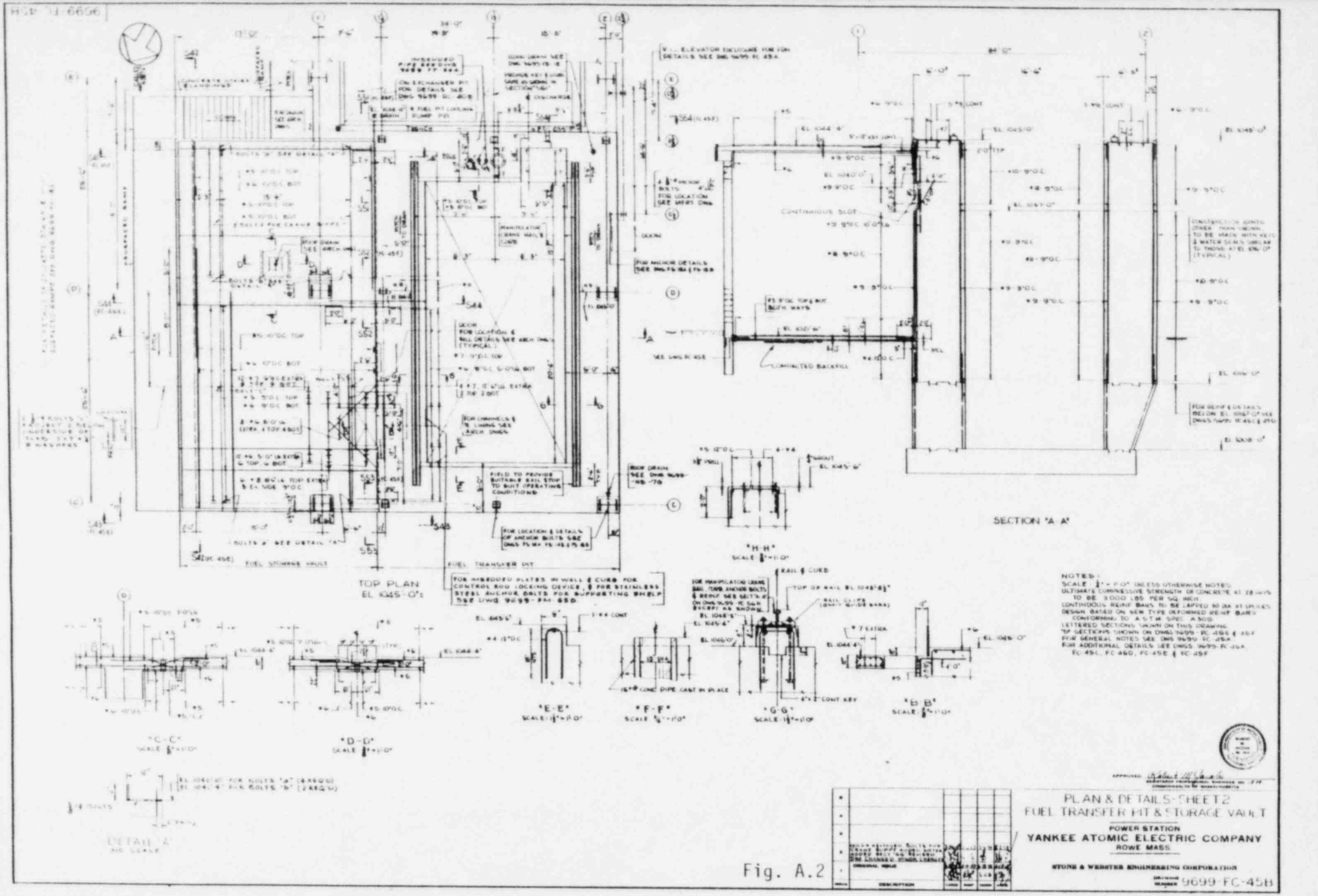

TOP PLAN
EL 1045'-0"
FUEL STORAGE VAULT
FUEL TRANSFER PIT
SECTION "A-A"
"H-H"
"E-E"
"F-F"
"G-G"
"B-B"
"C-C"
"D-D"
DETAIL "A"
NO SCALE
NOTES:
PLAN & DETAILS-SHEET 2
FUEL TRANSFER PIT & STORAGE VAULT
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-45B

Fig. A.2

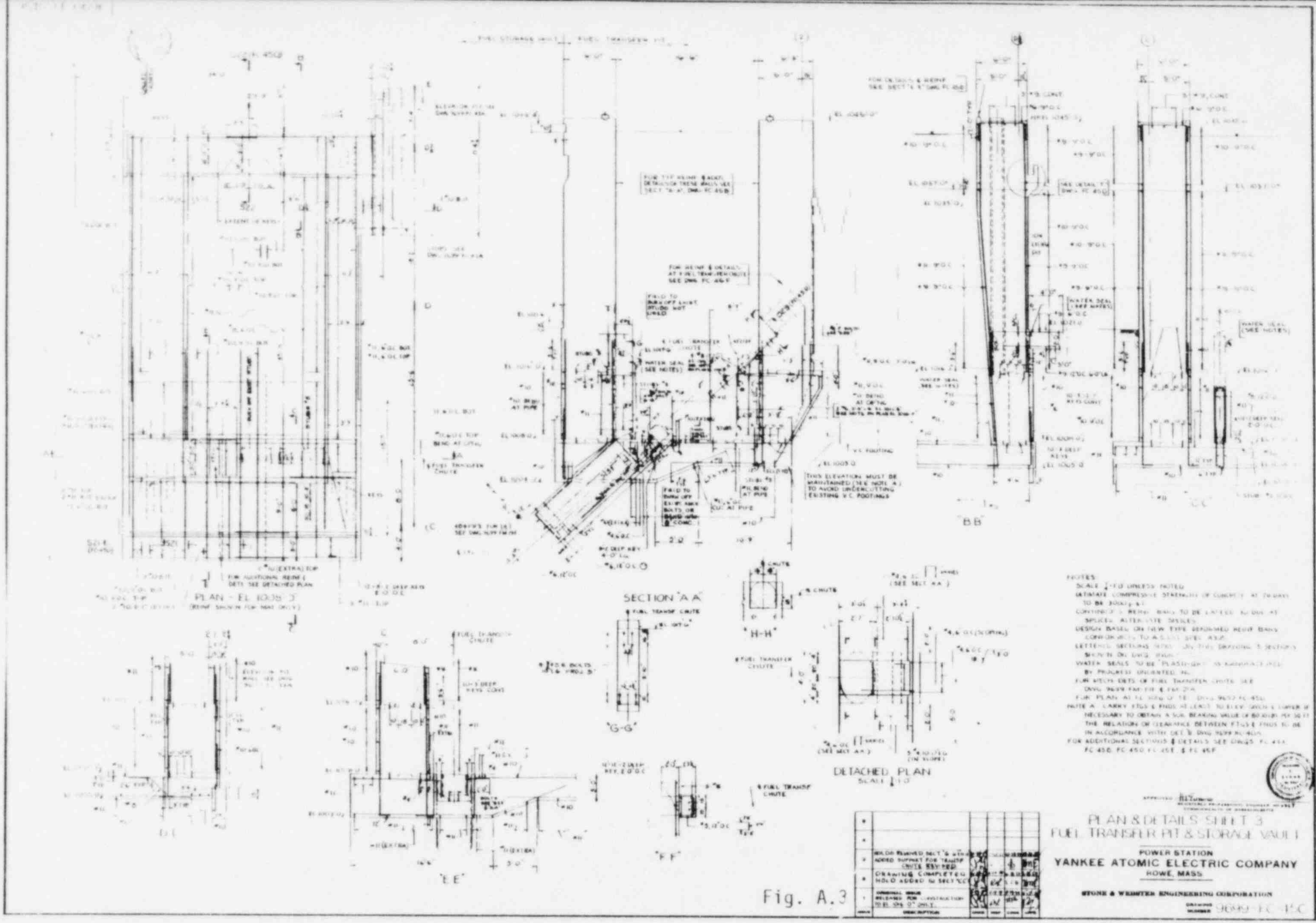
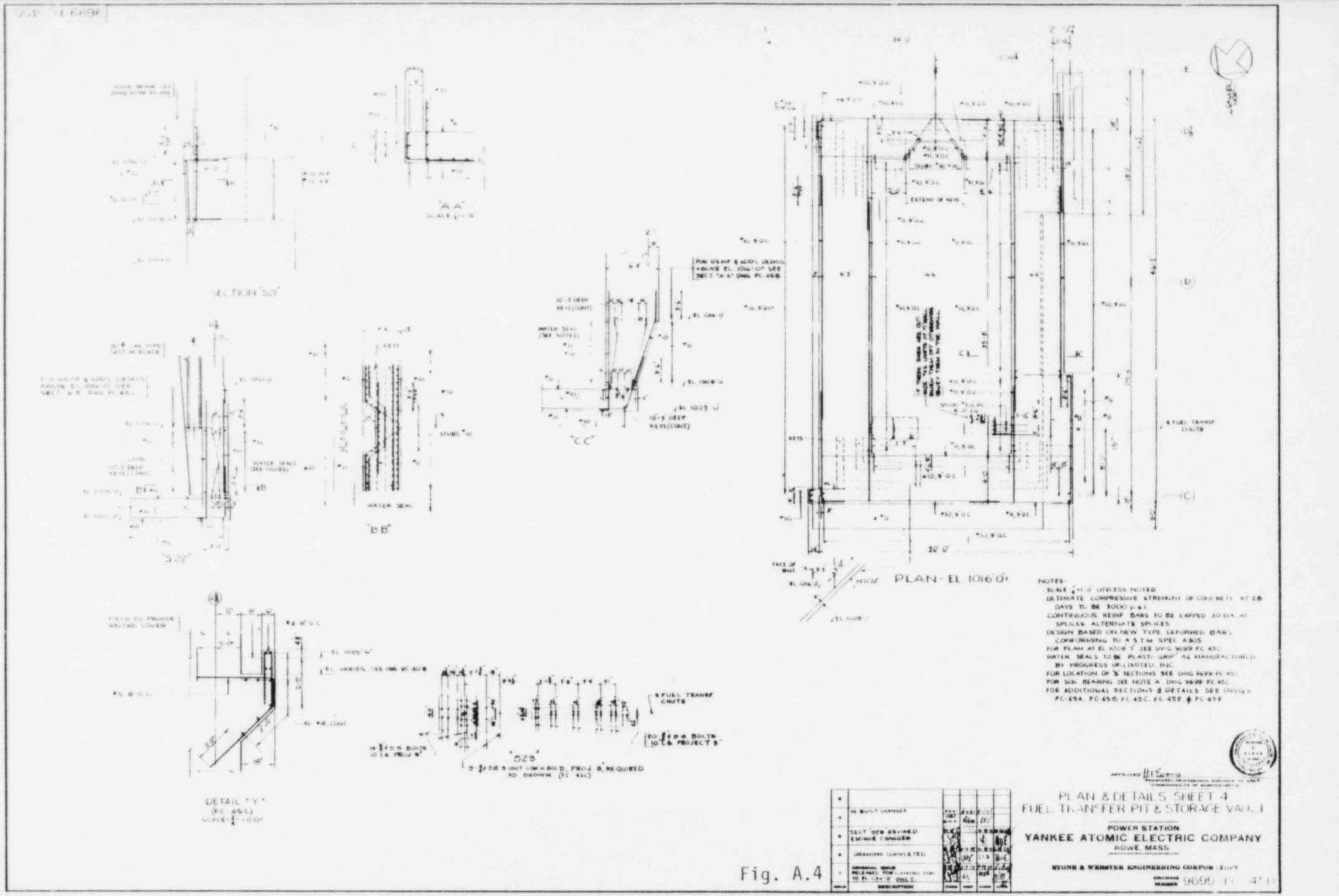
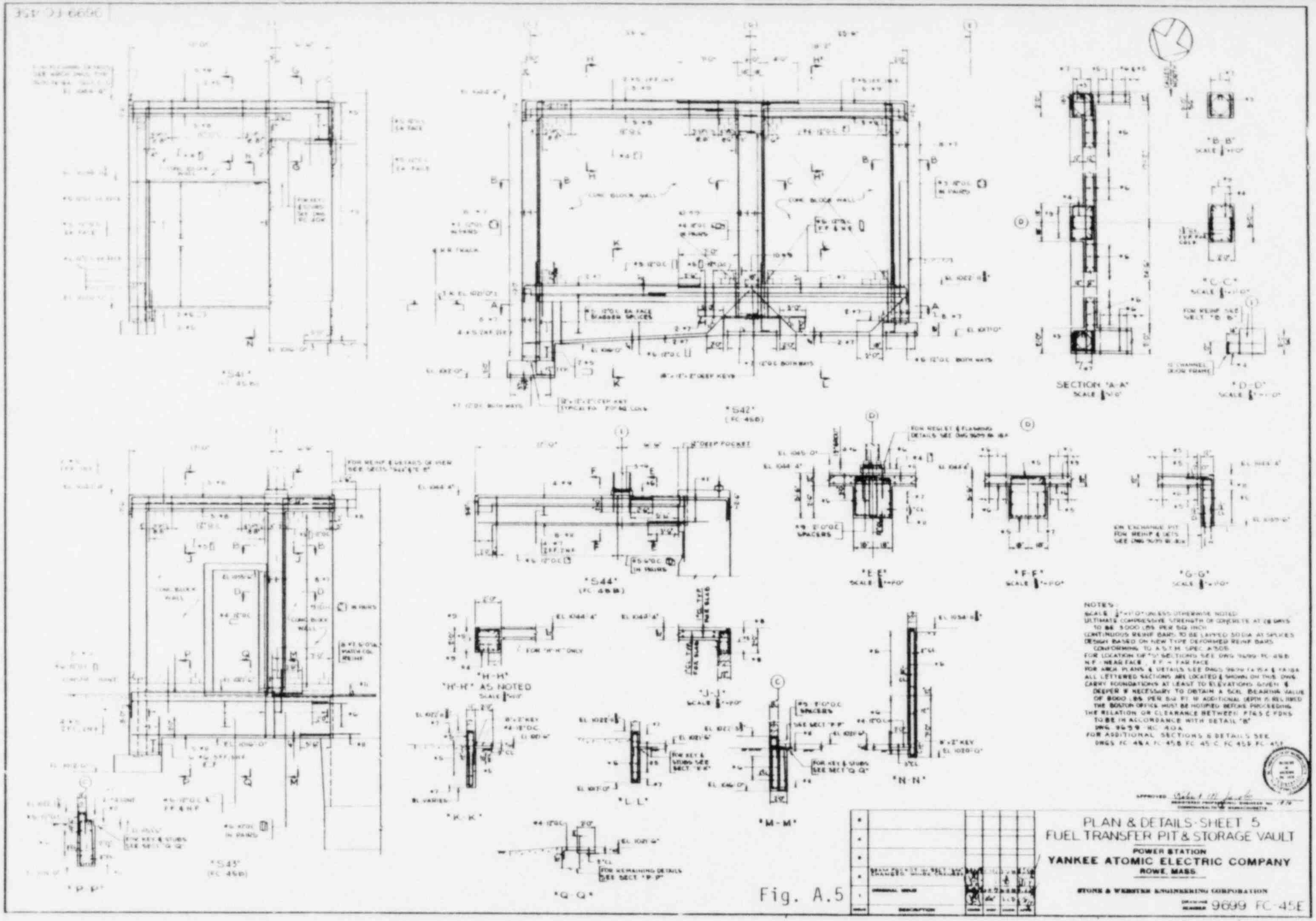

SECTION "A-A"
"H-H"
"G-G"
"F-F"
"E-E"
"B-B"
"C-C"
DETACHED PLAN
PLAN - EL 1008'-3"
PLAN & DETAILS SHEET 3
FUEL TRANSFER PIT & STORAGE VAULT
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-45C

Fig. A.3



SECTION "S21"
"A-A"
"B-B"
"C-C"
"S22"
"S23"
DETAIL "Y"
PLAN - EL 1016'-0"
WATER SEAL
FUEL TRANSF. CHUTE
NOTES:
SCALE 1/4" = 1'-0" UNLESS NOTED
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE AT 28 DAYS TO BE 3000 p.s.i.
CONTINUOUS REINF. BARS TO BE LAPPED 30 DIA. AT SPLICES. ALTERNATE SPLICES.
DESIGN BASED ON NEW TYPE DEFORMED BARS CONFORMING TO A.S.T.M. SPEC. A305
WATER SEALS TO BE "PLASTI-GRIP" AS MANUFACTURED BY PROGRESS UNLIMITED, INC.
PLAN & DETAILS SHEET 4
FUEL TRANSFER PIT & STORAGE VAULT
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
AS BUILT CHANGES
DRAWING COMPLETED
DESCRIPTION

Fig. A.4



PLAN & DETAILS-SHEET 5
FUEL TRANSFER PIT & STORAGE VAULT
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699 FC-45E
SECTION "A-A"
"B-B"
"C-C"
"D-D"
"E-E"
"F-F"
"G-G"
"H-H"
"J-J"
"K-K"
"L-L"
"M-M"
"N-N"
"P-P"
"Q-Q"
"S41"
"S42"
"S43"
"S44"
NOTES

Fig. A.5

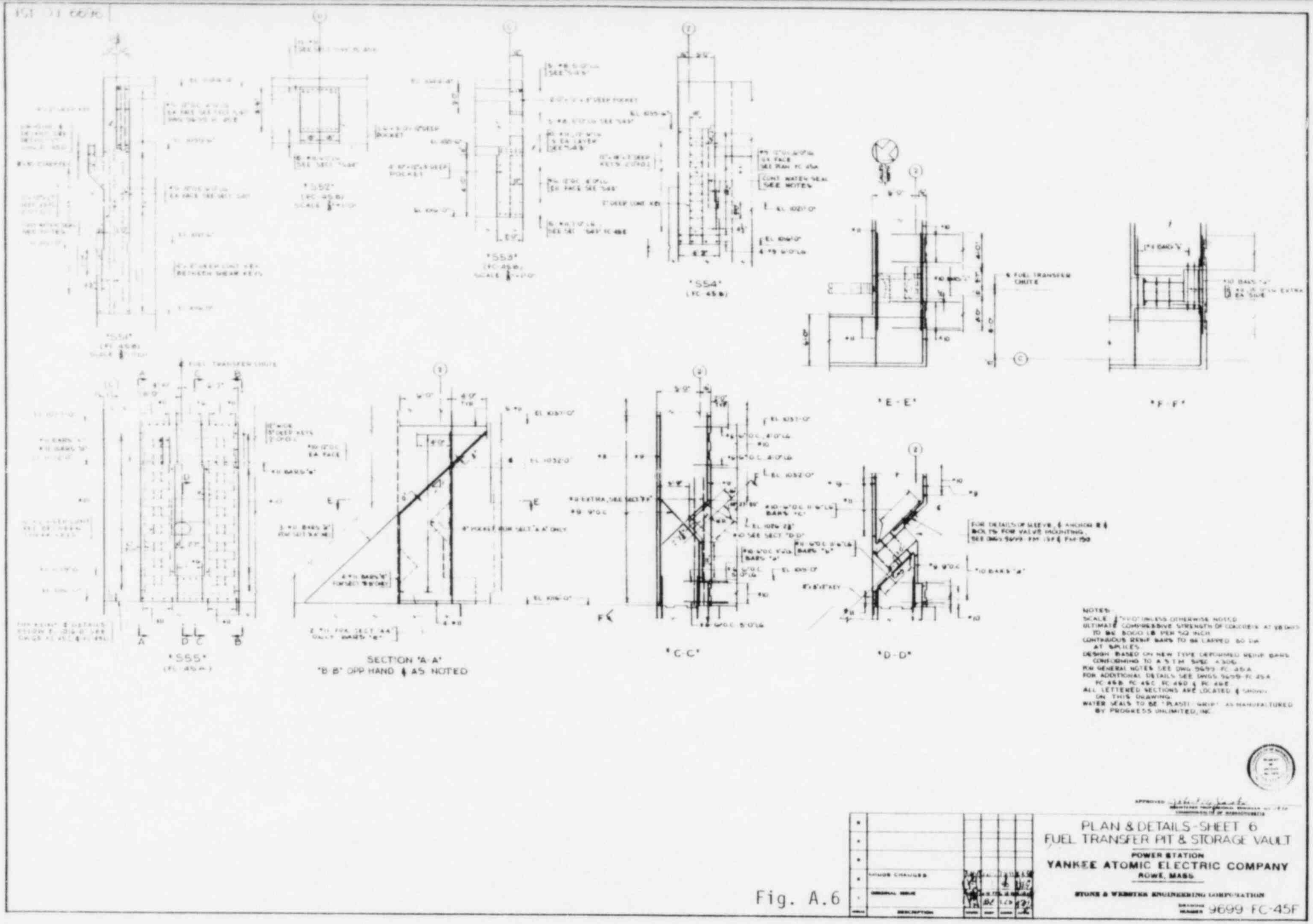

"S51"
"S52"
"S53"
"S54"
"S55"
"E-E"
"F-F"
SECTION "A-A"
"B-B" OPP HAND & AS NOTED
"C-C"
"D-D"
FOR DETAILS OF SLEEVE & ANCHOR R & BOLTS FOR VALVE MOUNTING, SEE DWGS 5699-FM-15F & FM-150
NOTES:
SCALE ½"=1'-0" UNLESS OTHERWISE NOTED
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE AT 28 DAYS TO BE 3000 LB PER SQ INCH
CONTINUOUS REINF BARS TO BE LAPPED 30 DIA AT SPLICES
DESIGN BASED ON NEW TYPE DEFORMED REINF BARS CONFORMING TO A.S.T.M. SPEC A305
FOR GENERAL NOTES SEE DWG 9699-FC-45A
FOR ADDITIONAL DETAILS SEE DWGS 9699-FC-45A FC-45B, FC-45C, FC-45D & FC-45E
ALL LETTERED SECTIONS ARE LOCATED & SHOWN ON THIS DRAWING
WATER SEALS TO BE "PLASTI-GRIP" AS MANUFACTURED BY PROGRESS UNLIMITED, INC.
PLAN & DETAILS-SHEET 6
FUEL TRANSFER PIT & STORAGE VAULT
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-45F

Fig. A.6

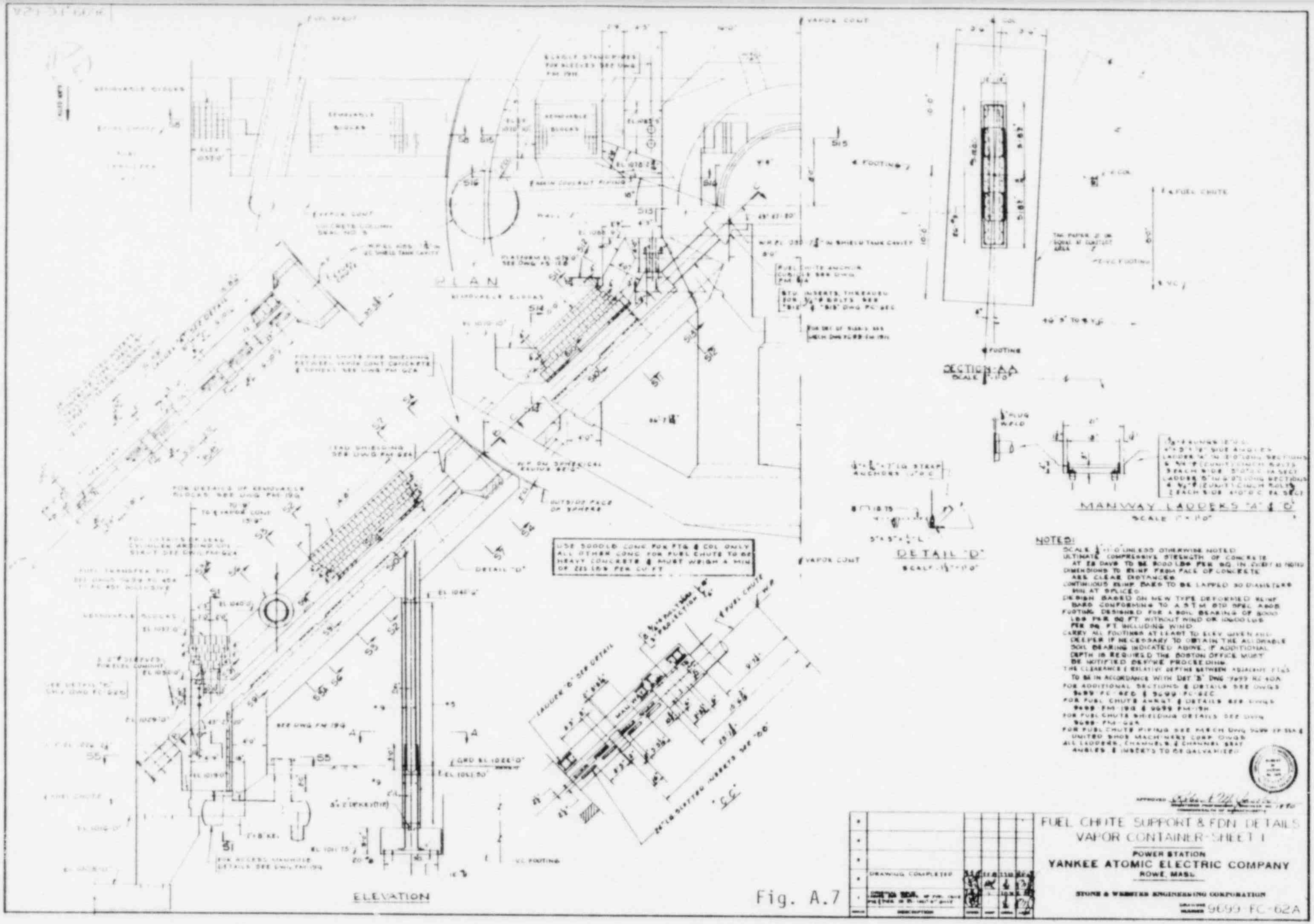
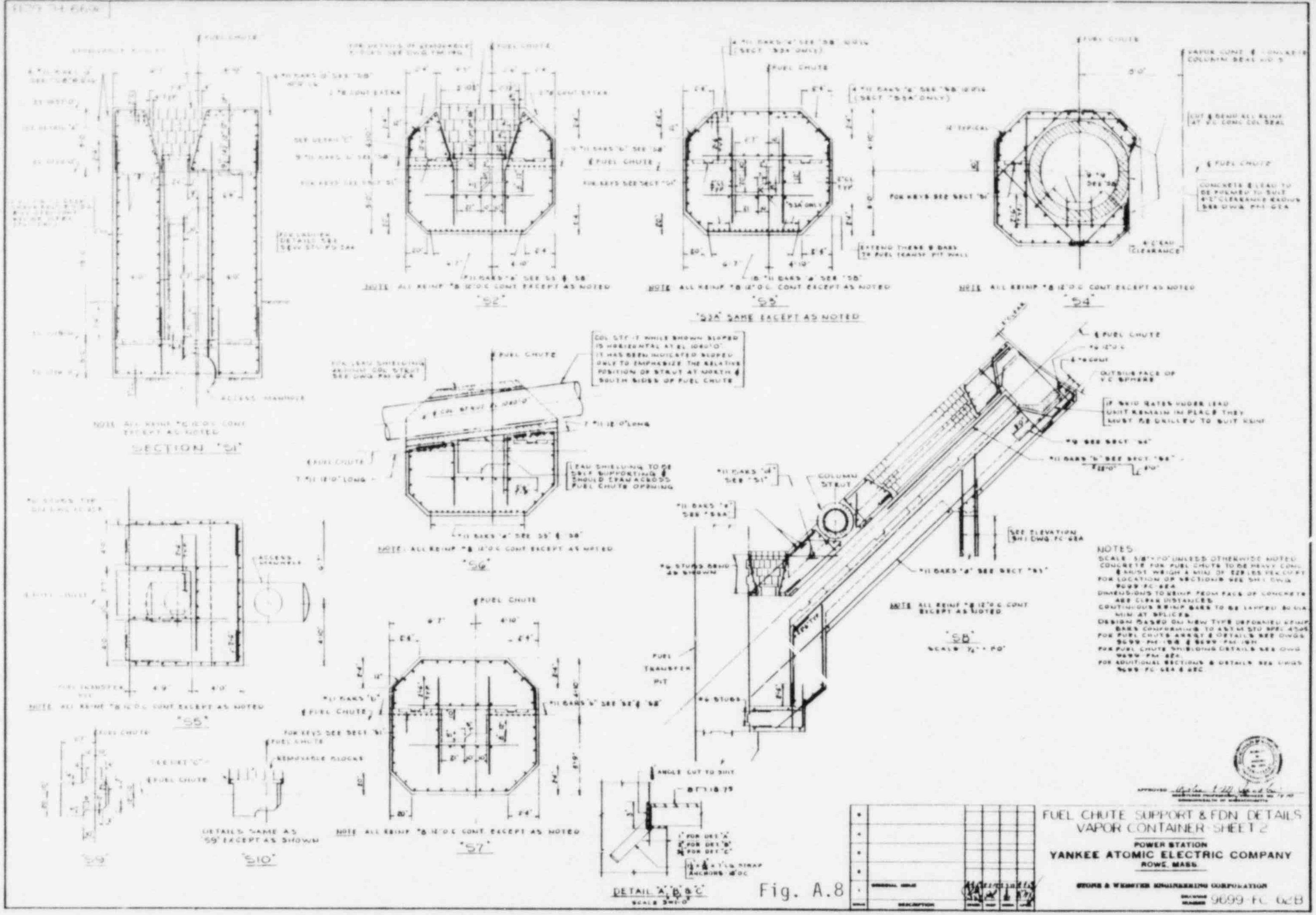

PLAN
ELEVATION
SECTION-AA
DETAIL "D"
MANWAY LADDERS "A" & "D"
USE 5000LB CONC FOR FTG & COL ONLY. ALL OTHER CONC FOR FUEL CHUTE TO BE HEAVY CONCRETE & MUST WEIGH A MIN OF 225 LBS PER CU FT
NOTES:
FUEL CHUTE SUPPORT & FDN DETAILS
VAPOR CONTAINER-SHEET 1
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-62A

Fig. A.7


SECTION "S1"
"S2"
"S3"
"S3A" SAME EXCEPT AS NOTED
"S4"
"S5"
"S6"
"S7"
"S8"
"S9"
"S10"
DETAIL "A", "B" & "C"
NOTE: ALL REINF #8 @ 12" O.C. CONT EXCEPT AS NOTED
FUEL CHUTE
FUEL TRANSFER PIT
COLUMN STRUT
NOTES:
FUEL CHUTE SUPPORT & FDN DETAILS
VAPOR CONTAINER-SHEET 2
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-62B
Fig. A.8

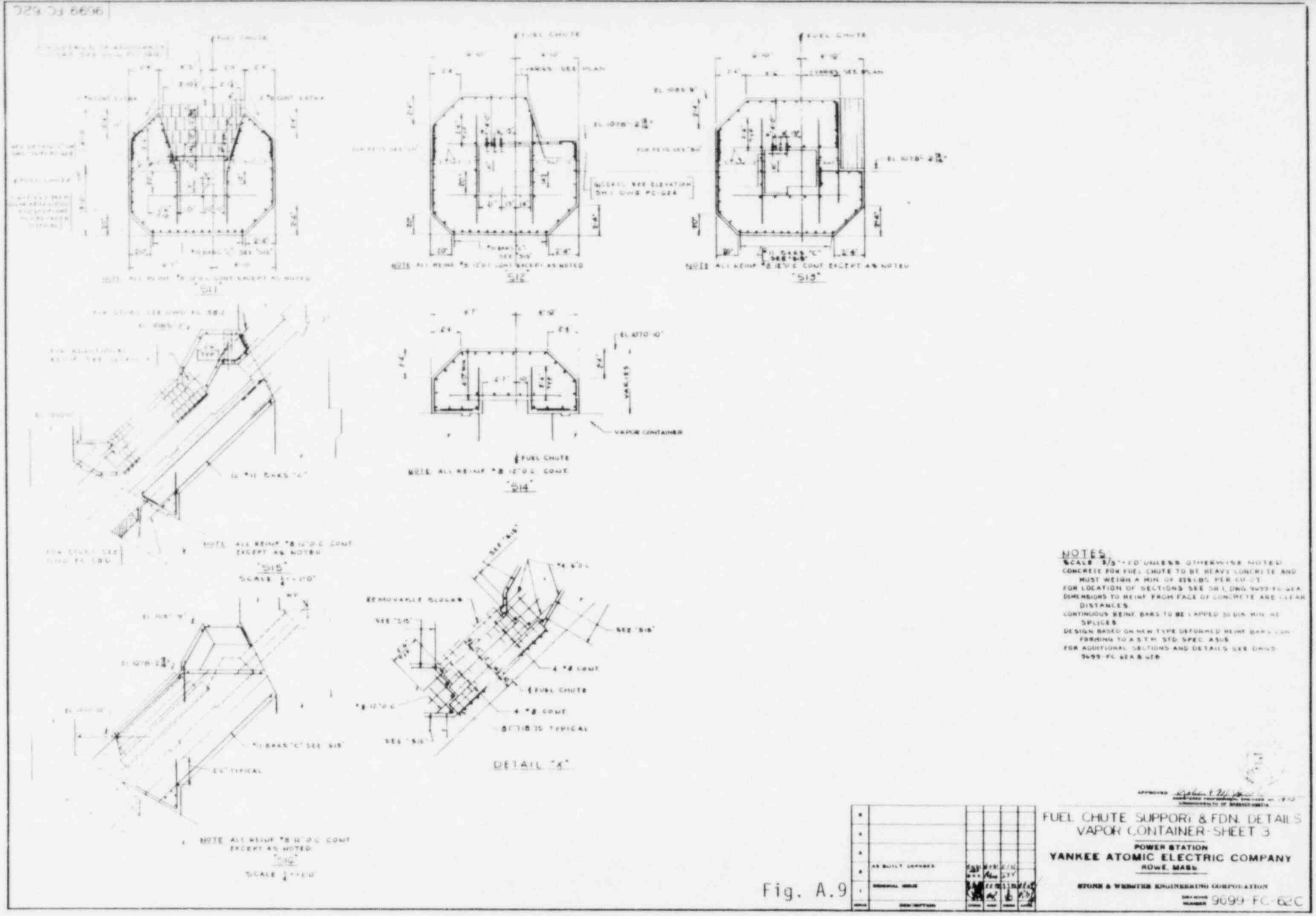

NOTES:
SCALE 3/8"=1'0" UNLESS OTHERWISE NOTED
CONCRETE FOR FUEL CHUTE TO BE HEAVY CONCRETE AND MUST WEIGH A MIN OF 225 LBS PER CU FT
FOR LOCATION OF SECTIONS SEE SH 1, DWG 9699-FC-62A
DIMENSIONS TO REINF FROM FACE OF CONCRETE ARE CLEAR DISTANCES
CONTINUOUS REINF BARS TO BE LAPPED 30 DIA MIN AT SPLICES
DESIGN BASED ON NEW TYPE DEFORMED REINF BARS CONFORMING TO A.S.T.M. STD SPEC A305
FOR ADDITIONAL SECTIONS AND DETAILS SEE DWGS 9699-FC-62A & 62B
DETAIL "A"
FUEL CHUTE SUPPORT & FDN. DETAILS
VAPOR CONTAINER-SHEET 3
POWER STATION
YANKEE ATOMIC ELECTRIC COMPANY
ROWE, MASS.
STONE & WEBSTER ENGINEERING CORPORATION
9699-FC-62C

Fig. A.9

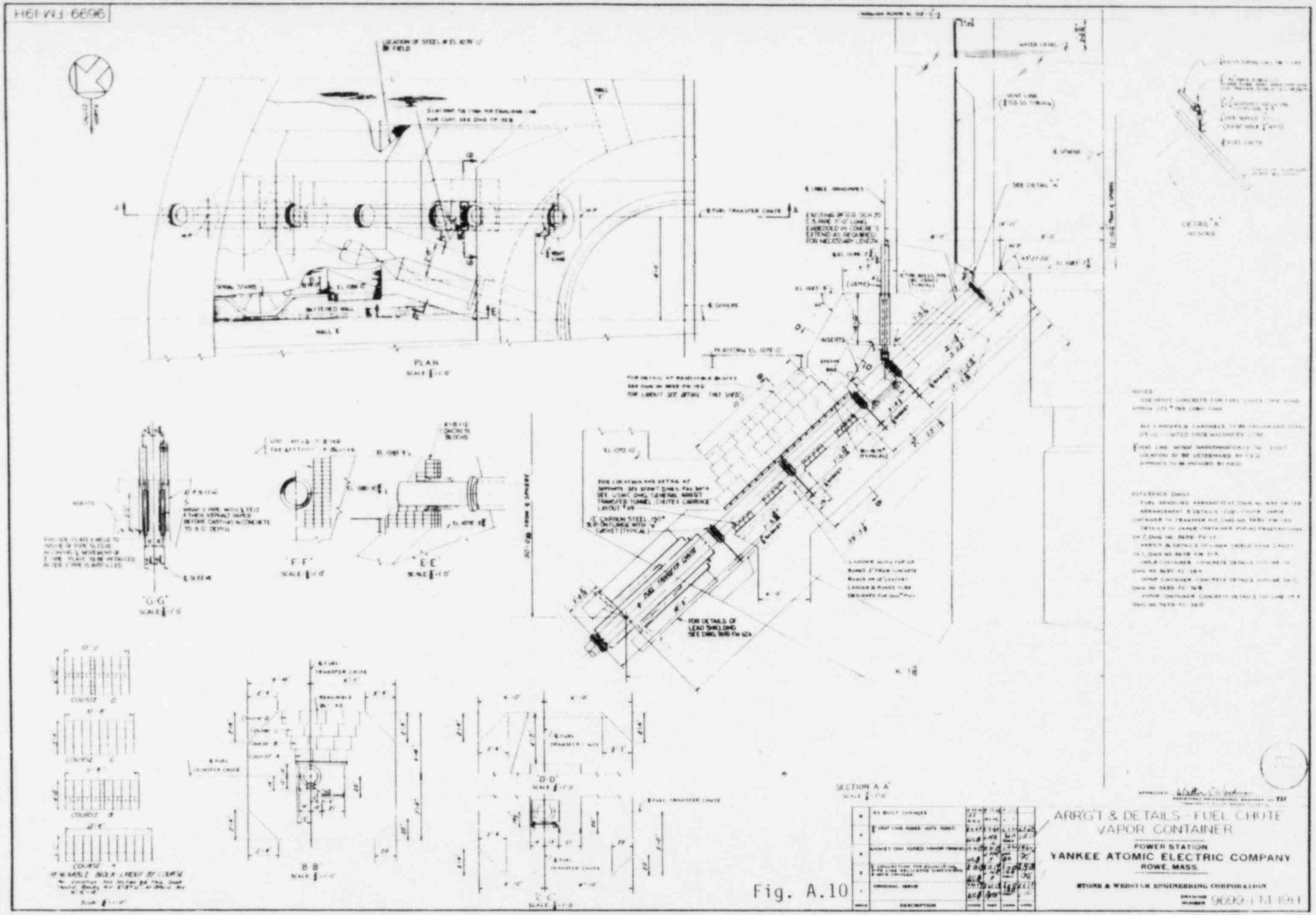


Fig. A.10

Yankee Atomic Electric Company
Spent Fuel Pool and Chute
80023; Report No. EY-YR-80023-10; Rev. 2

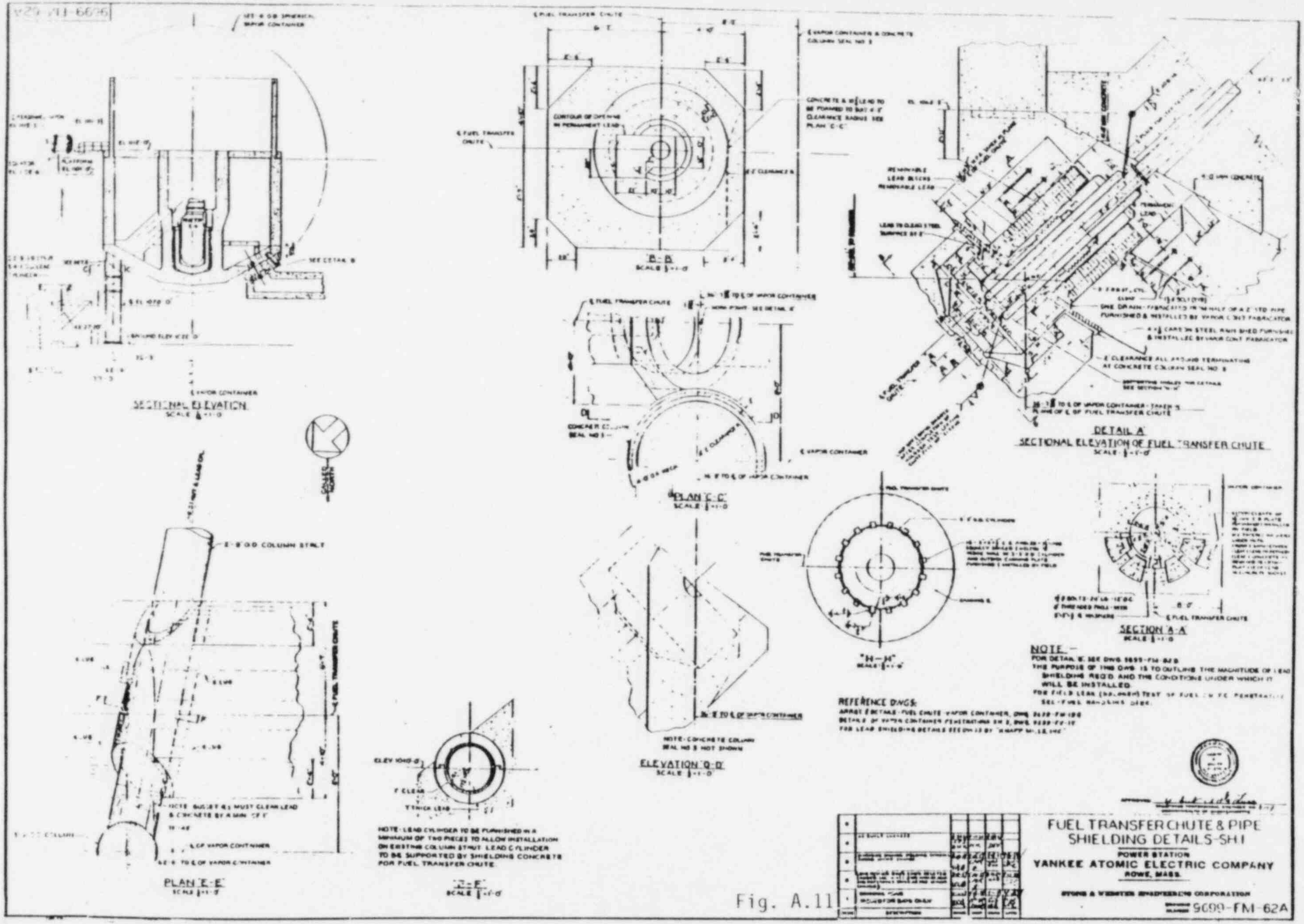


Fig. A.11

Yankee Atomic Electric Company
Spent Fuel Pool and Chute
80023; Report No. EY-YR-80023-10; Rev. 2

APPENDIX B

LOADS
SECTION PROPERTIES

TABLE B.1

LOADS

	Dead	Hydrostatic	Soil	Live	Thermal	Earthquake
Pool	-	x	x	-	x	x
Chute	x	-	-	-	-	x

Legend:

x = Considered

\- = Negligible

TABLE B.2

SECTION PROPERTIES - SPENT FUEL POOL

Section No.	Location	Thickness (inches)	Area of Tension Steel (in2/ft)	Total Moments (K-in/ft)	Allowable Moments (k-in/ft)
1	East Wall	75	1.69	1540	2200
2	West Wall	75	1.69	1540	2200
3	North Wall	72	1.69	860	2100
4	South Wall	54	1.69	640	1550
5	South Wall	36	1.69	430	960
6	West Wall	42	2.08	440	1410
7	South Wall	36	1.69	350	960
8	East, West Wall	75	1.33	1080	1740
9	North, South Wall	72	1.33	580	1640
10	North Wall	72	1.69	720	2090
11	South Wall	69	1.69	540	2000
12	Mat	54	1.69	510	1550
13	Mat	60	1.69	570	1720
14	Mat	36	1.69	2070	9130
15	Mat	60	3.12	990	3120
16	Mat	36	3.12	500	1750

TABLE B.3

SECTION PROPERTIES

SPENT FUEL CHUTE

Section	Location	I_{major} (ft^4)	I_{minor} (ft^4)	Area (ft^2)
1	Entire chute except as noted below	950	710	93
2	Chute at removable blocks	420	130	73
3	Chute near Vapor Container	650	600	65
4	Support Column near center of chute	250	7.6	22

APPENDIX C

COMPUTER MODEL (CHUTE),
MODE SHAPES (CHUTE)
EARTHQUAKE SPECTRA

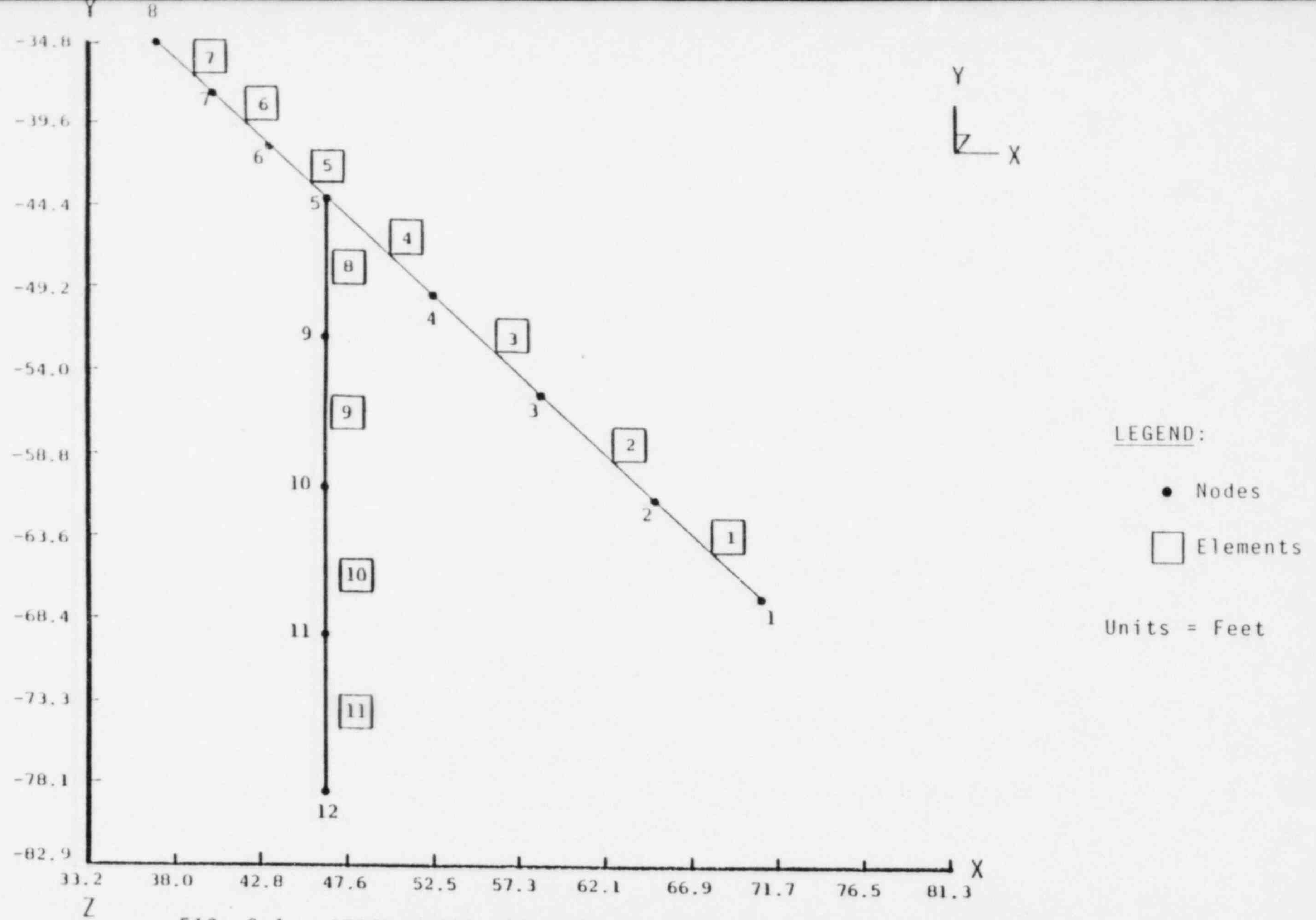


FIG. C.1 STICK MODEL FOR THE SPENT FUEL CHUTE SPECTRAL ANALYSIS

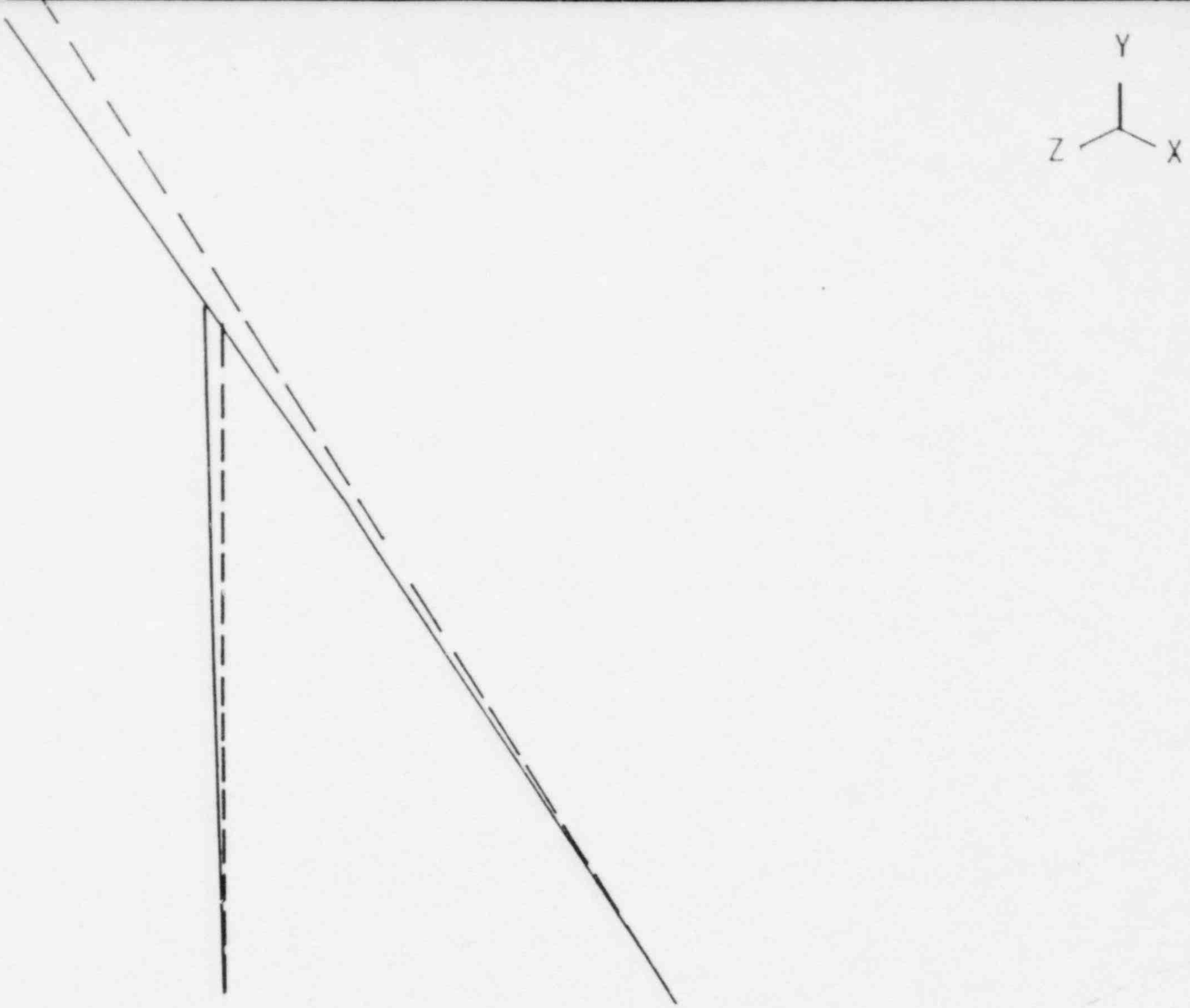


FIG. C.2 PLOT OF MODE SHAPE #1 - SPENT FUEL CHUTE

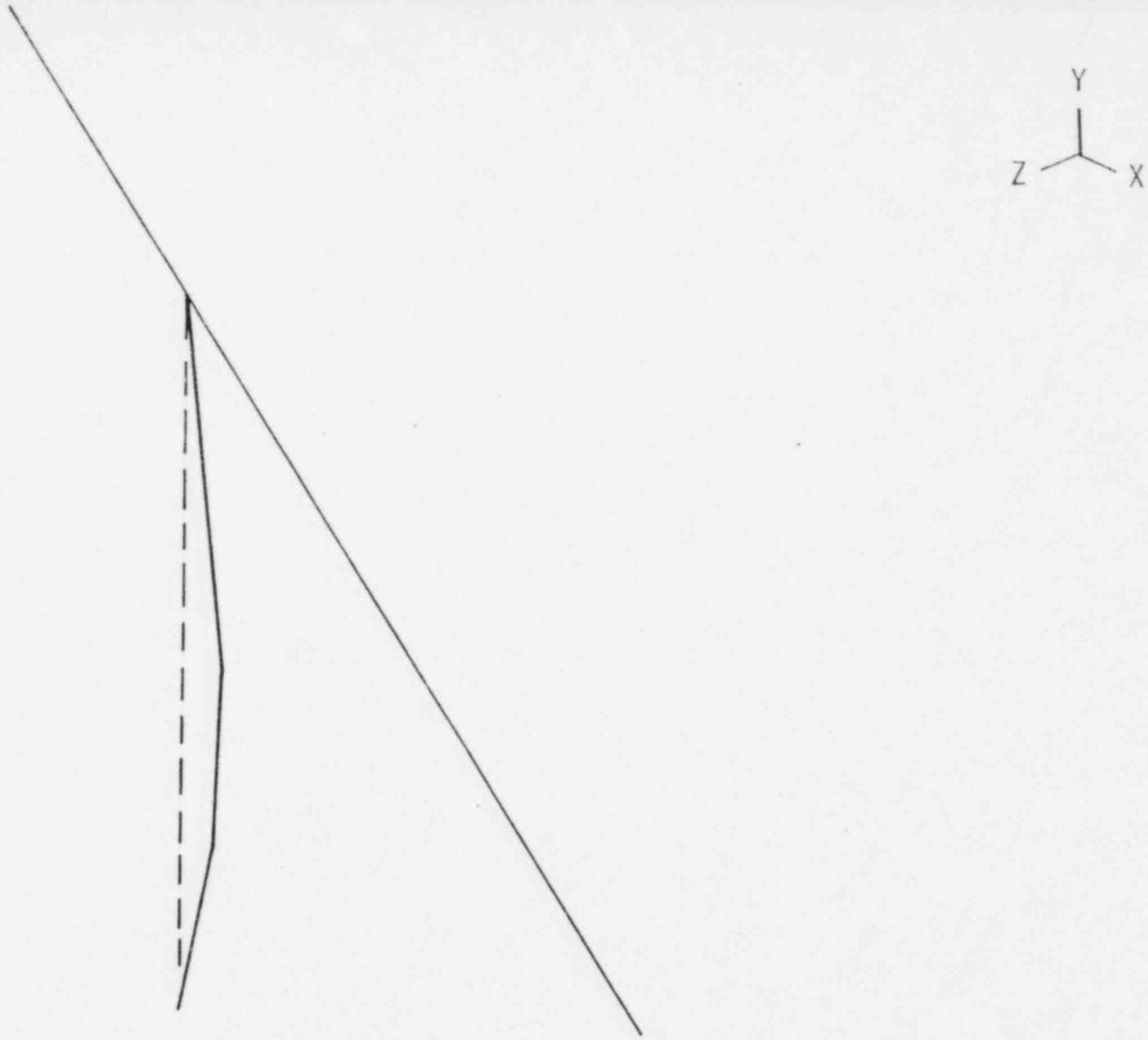


FIG. C.3 PLOT OF MODE SHAPE # 2 - SPENT FUEL CHUTE

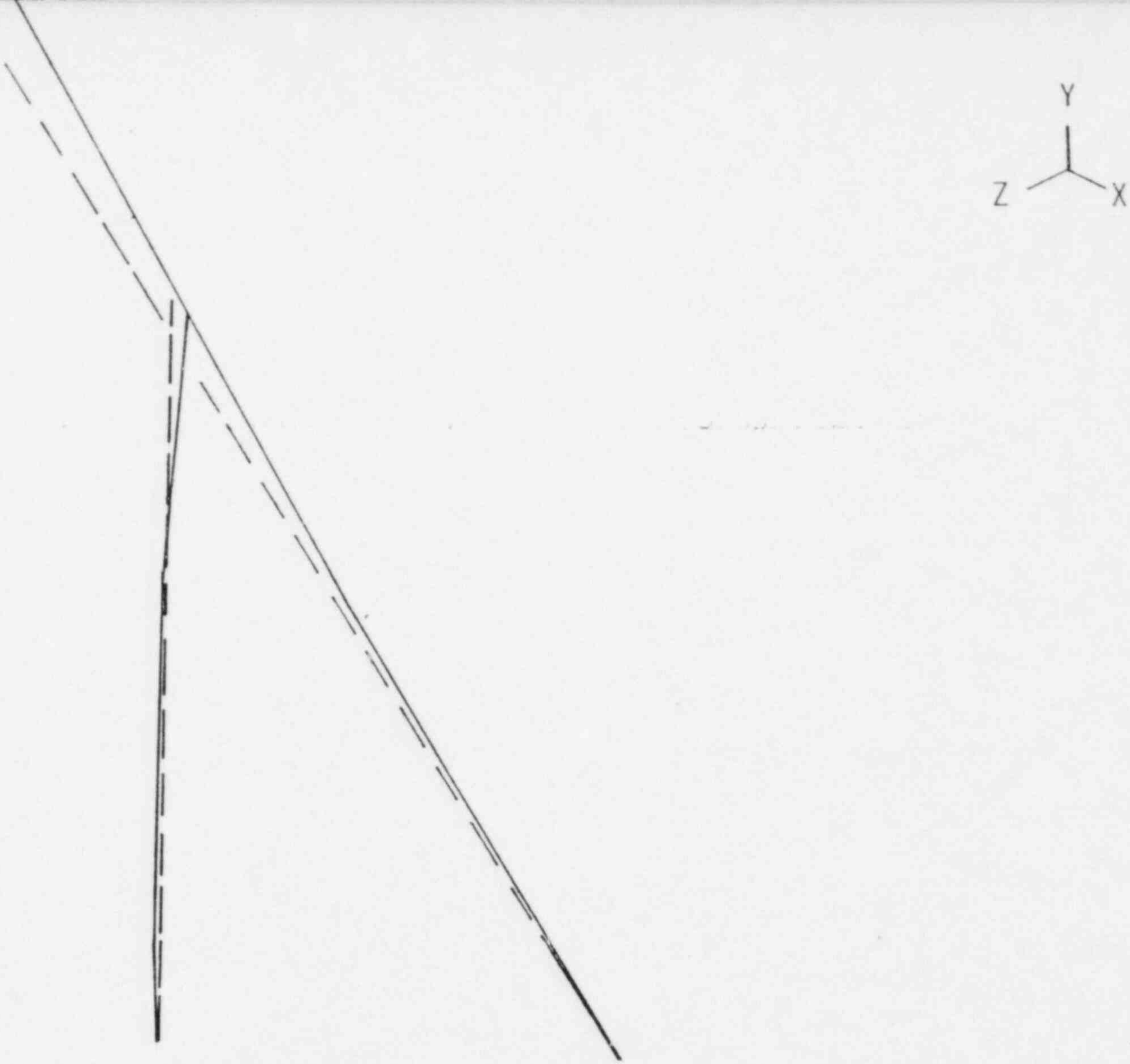


FIG. C.4 PLOT OF MODE SHAPE #3 - SPENT FUEL CHUTE

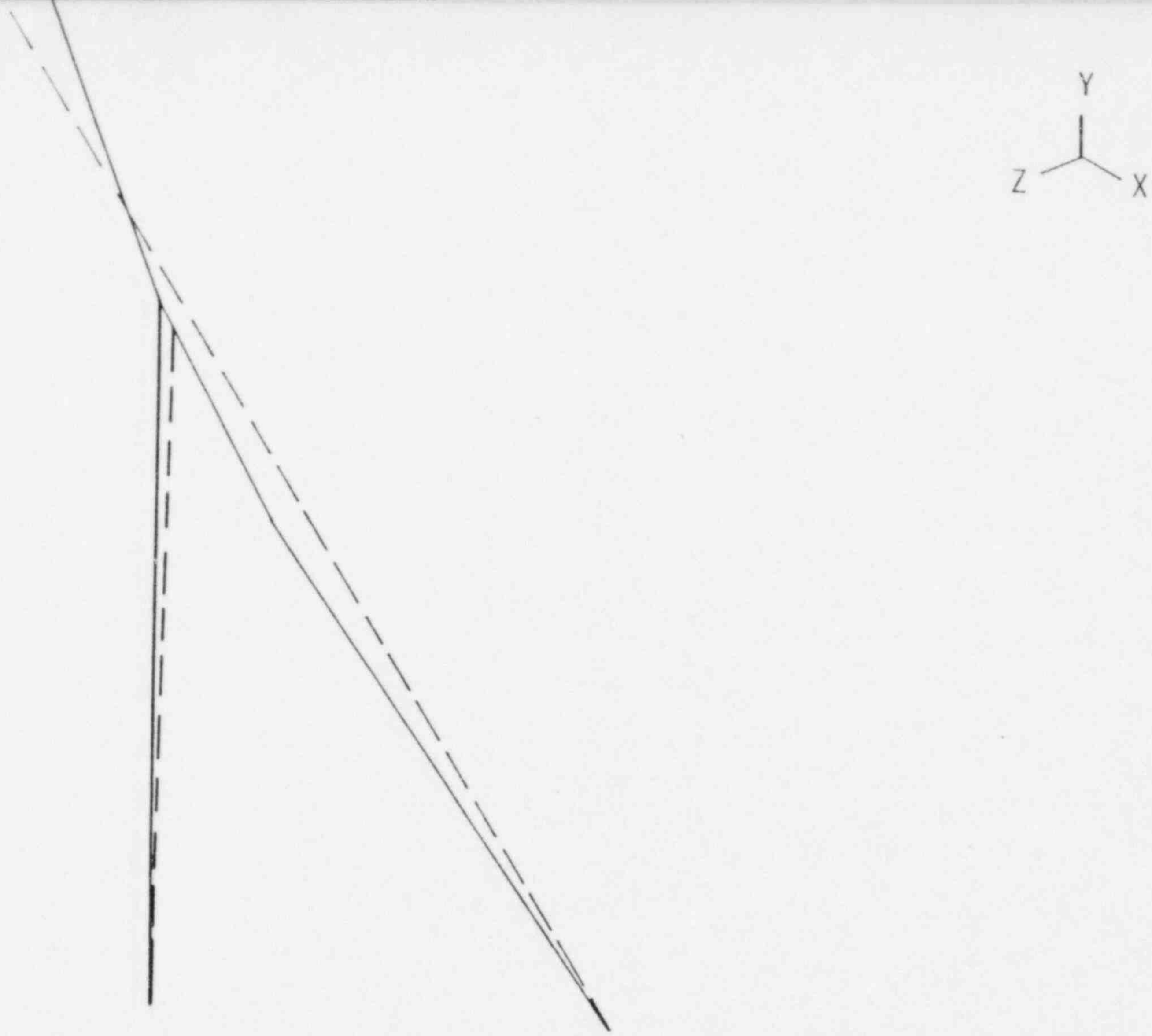


FIG. C.5 PLOT OF MODE SHAPE #4 - SPENT FUEL CHUTE

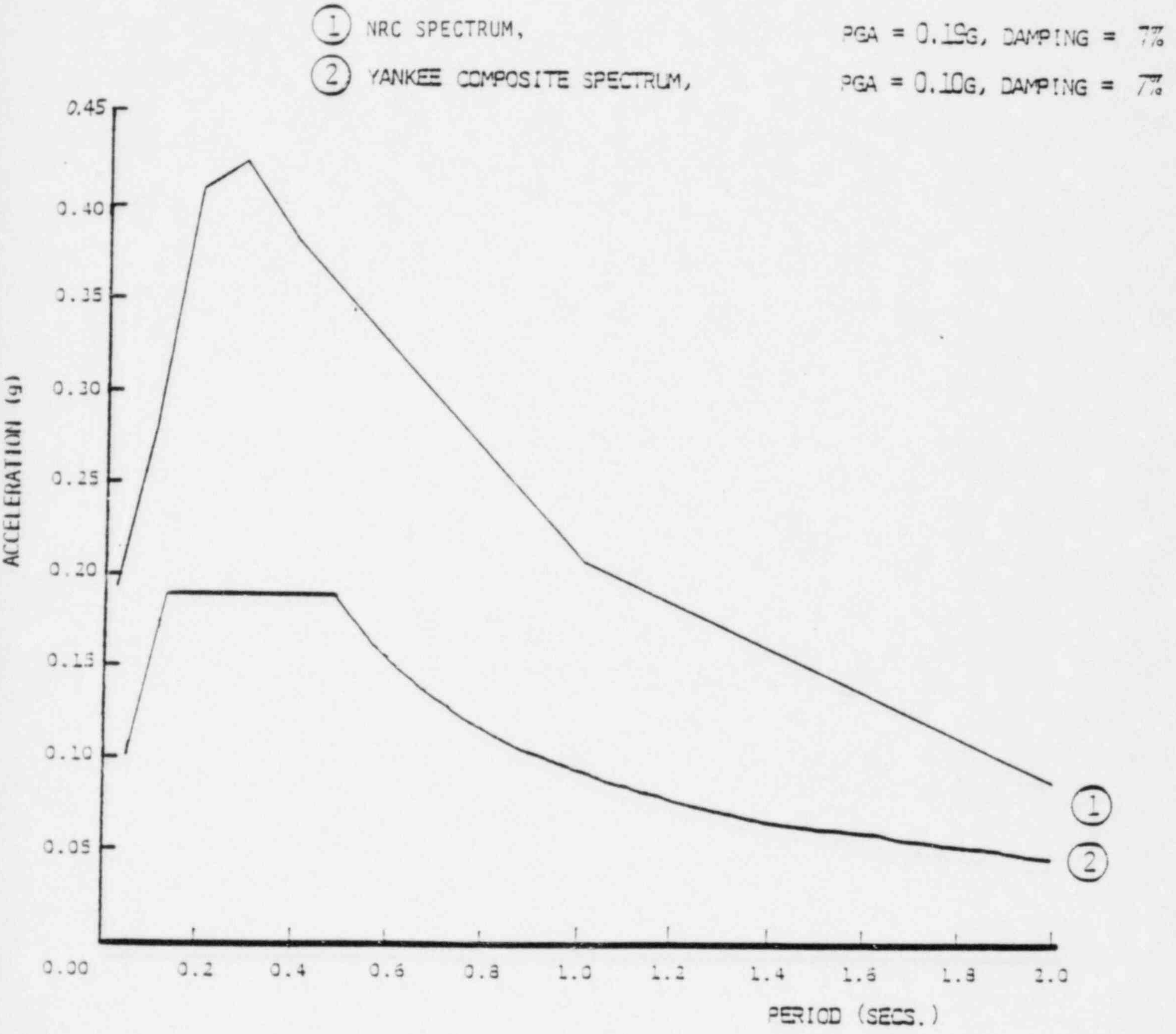


FIG. C.6 EARTHQUAKE SPECTRA

APPENDIX D

FUNDAMENTAL PERIODS AND MASS DISTRIBUTIONS

TABLE D.1

FUNDAMENTAL PERIODS AND MASS DISTRIBUTION
OF SPENT FUEL CHUTE

Excitation Direction	L2	Period (sec)	Frequency (Hz)	Mode
East-West	3.47	.0855	11.7	2
	8.16	.0662	15.1	3
	1.95	.0274	36.5	5
	1.54	.0243	41.2	6
Vertical	7.59	.0662	15.1	3
	2.88	.0243	41.2	6
	12.5	.0184	54.4	8
North-South	16.9	.1250	8.03	1
	5.70	.0332	30.2	4
	1.08	0.194	51.5	7

Legend:

L = Participation Factor

$L2 = \frac{K.Sec.^2}{ft.}$

APPENDIX E

RESULTS (CHUTE)

TABLE E.1

CHUTE DISPLACEMENTS - FEET X 10^{-3}

Node	Dead	SSE (1)
2	.27	.48
3	.86	1.75
4	1.55	3.57
5	2.34	6.49
6	2.83	8.44
7	3.34	10.4
8	3.85	12.4
9	1.56	4.44
10	.99	4.35
11	.49	3.27

(1) SRSS of Modes and Directions

TABLE E.2

ELEMENT STRESSES (CHUTE)
(PSI)

ELEMENT	AXIAL(1)	BENDING(1)
1	74	90*
4	25	85
11	460*	25

* Maximum

(1) SRSS of modes plus D. L., minor and major axes added absolutely.

NOTE: See Fig. C.1 for element locations.

APPENDIX F

REFERENCES

APPENDIX F

REFERENCES

1. Mahin, S. A. and V. V. Bertero, "RCCOLA User's Manual and Documentation," University of California, Berkeley, 1977

2. Swanson Analysis Systems, Inc., "ANSYS Engineering Analysis Systems User's Manual," Rev. 3

3. U.S.A.E.C., "Nuclear Reactors and Earthquakes," 1963, Chapter 6, (Dynamic Pressure on Fluid Containers)