Docket File

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

June 3, 1992

Docket No. 52-002

APPLICANT: Combustion Engineering, Inc. (ABB-CE)

PROJECT: CE System 80+

SUBJECT: PUBLIC MEETING APRIL 27-30, 1992, REGARDING SEISMIC AND STRUCTURAL DESIGN ISSUES

A public meeting was held between representatives of ABB-CE and the Nuclear Regulatory Commission (NRC) staff from April 27 through 30, 1992, at the Phillips Building in Bethesda, Maryland, regarding seismic ground motion issues for input to the seismic design of System 80+ and the structural design issues for System 80+. A list of attendees for each day is provided in Enclosure 1. The agenda for each day is provided in Enclosure 2. The summary for the orientation session on the morning of April 28, 1992, was published separately May 4, 1992. The material presented to the staff is provided in Enclosure 3.

ABB-CE presented the Control Motion Spectra (CMS) used for input to the seismic analysis, including two new spectra (CMS-1 and CMS-3). The Combustion Engineering Standard Safety Analysis Report-Design Certification (CESSAR-DC) will be revised later, not in time for the draft safety evaluation report (DSER), to incorporate these new inputs. ABB-CE stated that the System 80+ civil structures design is standardized for all applicable sites. ABB-CE believed that they had been designed for the most severe loads resulting from the generic site categories considered, since soil profiles were selected to produce soil column frequencies which correspond to the principle structural frequencies. They also clarified the use of the term "84th percentile spectrum" by stating that the enveloping spectrum will be compared to the 84th percentile seismic design response spectrum for the specific site being considered. Piping and components, however, may be designed to conditions that envelope a subgroup of generic sites.

ABB-CE stated that some structural modifications had been made and these modifications are being incorporated into the Soil Structure Interaction (SSI) analysis. The CESSAR-DC contains the preliminary SSI. Results of a final SSI analysis will not be available for the DSER but will be added to CESSAR-DC prior to the final safety evaluation report (FSER). During the four days of meetings, commitments were made by ABB-CE to provide responses to staff questions. These are listed below.

1. ABB-CE is to provide a sensitivity study on the effects of variations in soil properties, using Case B-3.5 which demonstrates that bounding

conditions are used. ABB-CE is also to provide data to support this position on soil depths greater than 300 feet.

2. To support NRC confirmatory SSI analysis, ABB-CE will provide the following input: stick model of the structures including the containment shell, dimensions of basemat, input data for soil Cases B-3.5 and B-4, low strain soil properties, unit weights, Poisson's ratio, constrained modulus and Young's modulus (E) for P-wave, digitized values of G/Gmax vs. ϵ and damping vs. ϵ.

3. Provide site acceptance criteria to be added to CESSAR-DC. Consider near field earthquake (< 25 km) for vertical motion vs. horizontal motion. Also, consider that vertical motion may be the same as or greater than the horizontal motion in the near field earthquakes.

4. Recheck case B-1 vs. B-2 using a shear wave velocity of 11,000 fps for rock. Determine the peak frequency shift with the change in shear wave velocity.

5. List all COL action items to demonstrate that the site can meet the envelope. Clearly describe definitions of input ground motions and how they are to be applied at specific sites.

6. Provide the cut-off frequency for the SHAKE calculations.

7. Perform an SSI analysis for Case A-1 to compare to fixed base case. Confirm that fixed base case is to be used for embedment up to 52 feet.

8. Specific soil properties should be defined clearly in CESSAR-DC.

9. Specify input for analysis and acceptance criteria for buried piping.

10. How was the equipment hatch modeled for the structural analysis? In the final analysis, will it be modeled as an axisymmetric mass or lumped mass at actual location?

11. Address how the variability of structural elements (parameters such as the effects of concrete cracking) are accounted for.

12. Provide support for statement in CESSAR-DC on page 3.7-15 regarding broadened spectrum.

13. Address the treatment of common walls, i.e., half to each adjacent area, in the stick models.

14. Address bending or flexural shear of wall intersections.

15. Revised CESSAR-DC must better address design analysis of the non-seismic Category I structures which may cause damage to seismic Category I structures.

16. Define the fragility level of the containment shell structure beyond the SSE.

17. References must be placed in CESSAR-DC for eastern North America CMS-2 spectra.

18. Revised CESSAR-DC, especially Sections 2.5 and 3.7, must incorporate appropriate responses to RAI's.

19. Assess the effects of sticks connected to sidewalls vs. not connected.

20. Define criteria for evaluating containment performance (Service Level C with pressure-temperature profile, fragility curve with conditional containment failure probability, CCFP).

21. Submit summary report with additional information to augment response to RAI 220.55.

22. Provide the basis for the spring constant used for the compressible material between the containment shell sphere and the concrete support dish. The specifications for this material must account for a 60-year design life.

23. Identify the documentation of the ANSYS verification problem(s) for elastic-plastic analysis.

24. How are localized strains around reinforced areas for penetrations and around the transition region between the containment shell and the concrete support dish evaluated? SANDIA strain criteria should be considered for localized effects at penetrations and the transition region.

25. Rerun the buckling analysis with model refinements and new seismic design requirements. Address the anomaly of present results showing buckling at the top of the containment shell sphere and provide a basis for reasonableness of results (e.g., obtain results that are physically realistic on the location where buckling occurs).

26. Transmit to NRC the pre-buckling stresses after ABB-CE is satisfied with results for the Level B and Level D performance.

27. Detailed design criteria for penetrations must be established. Provide evaluation of ultimate capacity on the basis of the code and the "severe accident" criteria. ITAAC should address confirmation after designs of as-purchased penetration assemblies are available.

28. Provide justification of the factor of safety of 2 used for level C.

Finally, NRC requested copies of the following documents to be made available for audit at the ABB-CE office at Rockville, Maryland:

1. Fixed Base Analysis Calculation/Design No. FB-01 Title: ALWR System 80+ FB Analysis (Job No. 8503-003-1355)

2. SSI Analysis-Calculation/Design No. ALWR-I (Job No. 8503-003)

3. Report No.: 01-8503-1784 Rev. 0, August 1990, Title: Seismic Analysis of Reactor Building of System 80+ certified design by ABB Impell.

ABB-CE stated that a schedule for submittal of all of the above items would be provided.

Thomas V. Wambach

Thomas V. Wambach, Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of Nuclear Reactor Regulation

Enclosures:
1. List of attendees
2. NRC Meeting/Audit Agenda
3. ABB-CE Presentations

cc w/enclosures:
See next page

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Original Signed By:

Thomas V. Wambach, Project Manager
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Associate Directorate for Advanced Reactors
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Office of Nuclear Reactor Regulation

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Enclosure 1

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TODD OSWALD	DUKE ENGINEER
FRANK SNIPES	DUKE ENGINEER
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DELWNY BLUHM	AMES LAB
LOWEL GREIMANN	AMES LAB
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LYLE GERDES	ABB-CE

NRC MEETING/AUDIT AGENDA

APRIL 27-30, 1992

WASHINGTON, D.C.

APRIL 27

9:00 A.M.	INTRODUCTIONS
	CONTROL MOTION SELECTION AND APPLICATION
12:00 NOON	LUNCH
1:00 P.M.	SEISMOLOGICAL REVIEW
	SEISMIC DESIGN BASIS
	SSE MOTIONS
	INPUT MOTION
	METHODS OF ANALYSIS
	FOUNDATION MATERIAL PROPERTIES
	DEGRADATION RELATIONSHIPS
	VARIATION OF SOIL

NRC MEETING / AUDIT AGENDA

APRIL 27-30, 1992

WASHINGTON, D.C.

APRIL 28

9:00 A.M.	ORIENTATION OF NEW STAFF REVIEWERS TO THE SYSTEM 80+ DESIGN
	GENERAL LAYOUT
	SYSTEM OVERVIEW
12:00 NOON	LUNCH
1:00 P.M.	STRUCTURAL REVIEW
	DYNAMIC MODEL
	ANALYSIS METHODS
	SPECTRA
	CODES AND STANDARDS
	FORCES IN DESIGN
	DESIGN DETAILS
	SITE ACCEPTANCE
	EFFECTS OF OBE = 1/3 SSE

NRC MEETING / AUDIT AGENDA

APRIL 27-30, 1992

WASHINGTON, D.C.

APRIL 29

9:00 A. M.	DISCUSSIONS ON SEISMOLOGICAL AND STRUCTURAL DESIGN
	MATERIAL AUDIT / REVIEW
12:00 NOON	LUNCH
1:00 P. M.	CONTAINMENT BUCKLING
	CONTAINMENT MODEL
	SEISMIC INPUT
	CRITICAL LOAD COMBINATIONS
	LOCATION OF BUCKLING
	FACTOR OF SAFETY
	MARGIN FOR BEYOND DESIGN BASIS
	CONTAINMENT PERFORMANCE
	PRESSURE_TEMPERATURE PROFILES
	CONTAINMENT INTEGRITY
	PENETRATIONS

NRC MEETING / AUDIT AGENDA

APRIL 27-30,1992

WASHINGTON, D.C.

APRIL 30

9:00 A.M. DISCUSSIONS ON CONTAINMENT PERFORMANCE AND BUCKLING

MATERIAL AUDIT / REVIEW

11:00 A.M. WRAP-UP

Enclosure 3

SELECTION OF CONTROL MOTION FOR THE SYSTEM 80+ STANDARD DESIGN

Prepared by:

ABB COMBUSTION ENGINEERING

April 27, 1992

AGENDA

- OBJECTIVES
- SELECTION PROCESS
- SITE ACCEPTANCE CRITERIA FOR CONTROL MOTION
- APPLICATION OF CONTROL MOTION TO SEISMIC SSI ANALYSES
- CONCLUSIONS

OBJECTIVES

- Develop a control motion that provides potential for a safe standardized seismic design.

- Develop a control motion that provides the owners of the System 80+ design with high confidence that the design is suitable for most sites in the U.S.

  Exception: Sites near major active faults, as for example certain sites in California.

- Develop a control motion in full compliance with:

  - SRP, Sections 2.5, Rev.2 and 3.7, Rev.2
  - EPRI URD

- Develop a control motion which exceeds SRP guidance for added safety

SELECTION PROCESS

- Control Motion Spectra are anchored to 0.3 g horizontal Peak Ground Acceleration (84th percentile PGA).

- Control Motion Spectra are applied to 13 generic site conditions, 12 soil cases and one rock case.

SELECTION PROCESS

- Chronological Order of Selection:

  - *Originally, CMS2 was developed for application to a hypothetical rock outcrop for the 12 soil cases, and direct application to the foundation level for the rock case.*

  - *These soil cases were chosen such that application of CMS2 at the rock outcrop would result in surface motions which would envelop the expected surface motion covering both shallow and deep soil sites as well as rock sites.*

  - *CMS2 is anchored to 0.3 g in the horizontal directions and 0.2 g in the vertical direction.*

  - *84th percentile spectrum*

  - *Combination of NUREG/CR-0098 and typical Eastern North America spectra for rock, with maximum ground velocity of 24 in/sec/g (therefore, maximum ground velocity is 7.2 in/sec in the horizontal direction and 4.8 in/sec in the vertical direction).*

SELECTION PROCESS

- *To address NRC concerns regarding possible low frequency deficiencies in CMS2 and to demonstrate full design conformance for a RG 1.60 spectrum defined at the free-field ground surface, the System 80+ is also designed for CMS1 and CMS3 as additional control motions.*

- *CMS1 (RG 1.60 spectrum) is used to envelop conditions for deep soil sites. It is anchored to 0.3 g in all directions (horizontal and vertical).*

- *CMS3 is developed for application at the rock outcrop of shallow sites.*

  84th percentile spectrum

  CMS3 is anchored to 0.3 g in the horizontal directions and 0.2 g in the vertical direction.

  In full compliance with NUREG/CR-0098 spectra with 36 in/sec/g ground velocity.

  Enriched with high frequency content up to 15 Hz (NUREG/CR-0098 has cutoff frequency of 8 Hz)

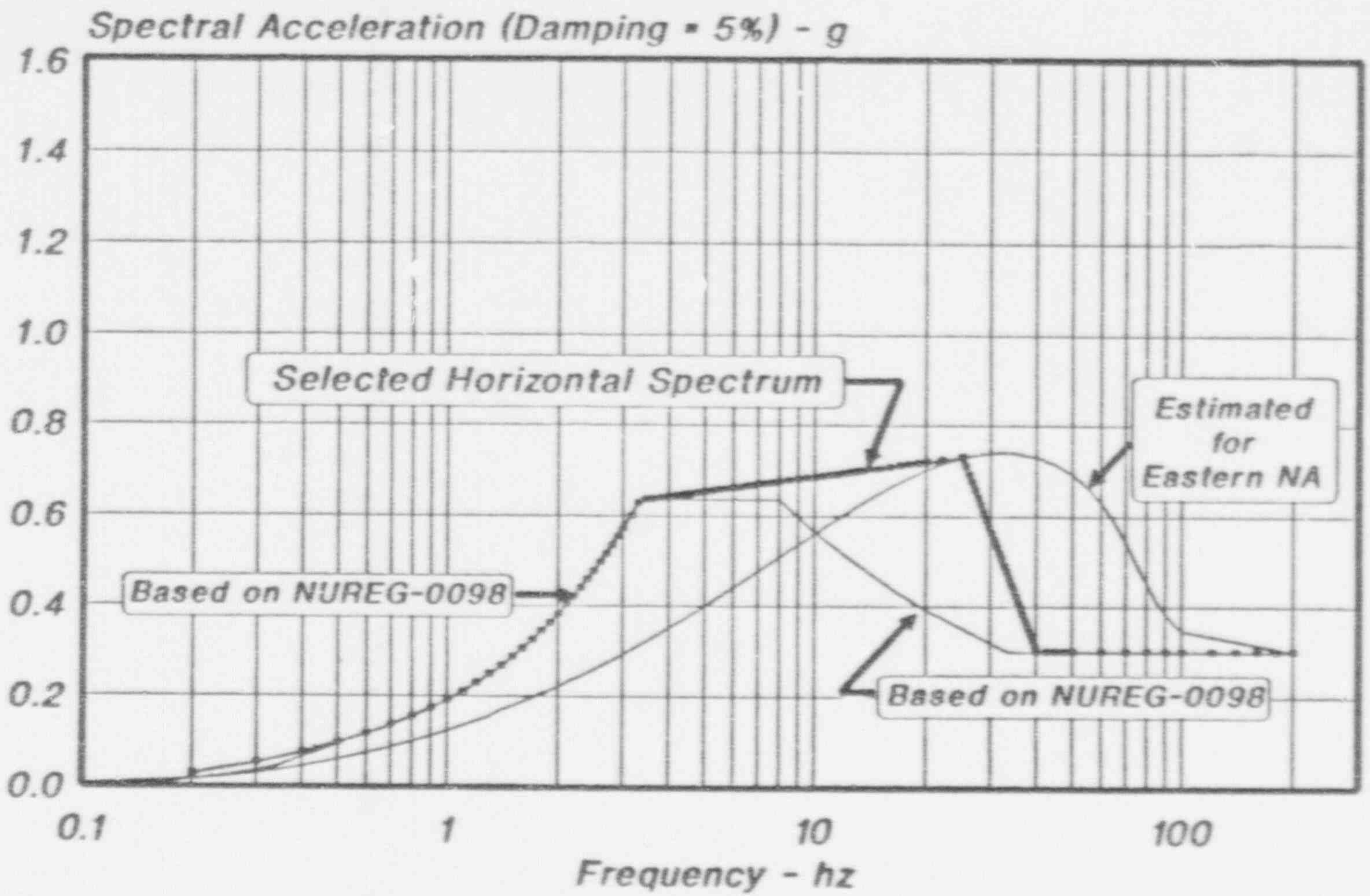


Figure 2.2 - Derivation of CMS2

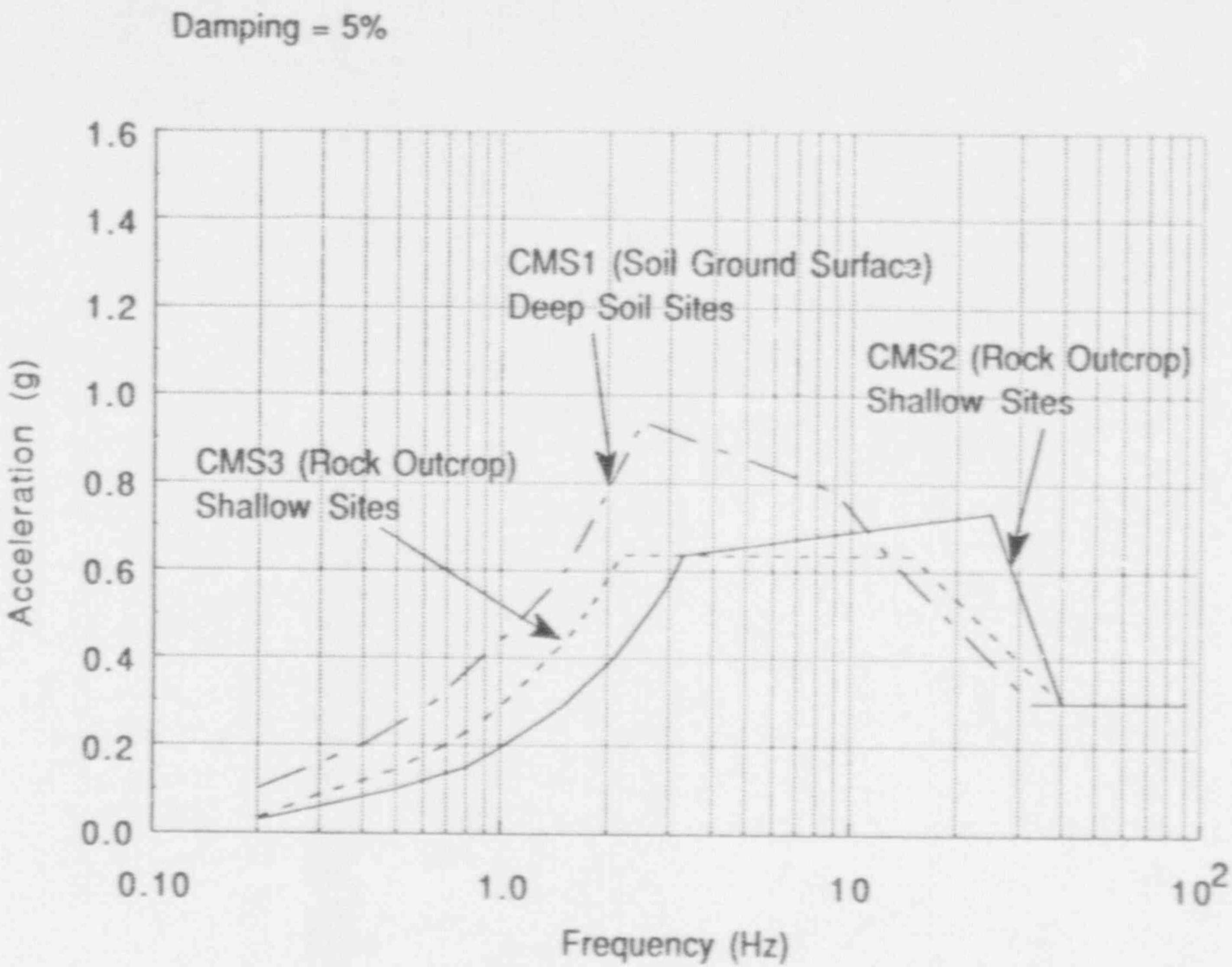


Figure 2.1 - CMS1, CMS2 and CMS3
(5% Damping)

SELECTION PROCESS

- *The envelope of the amplified free-field surface motions resulting from the application of CMS2 at the rock outcrop significantly exceeds a RG 1.60 spectrum. This provides a technically sound seismic design basis for shallow and deep soil sites as well as for rock sites.*

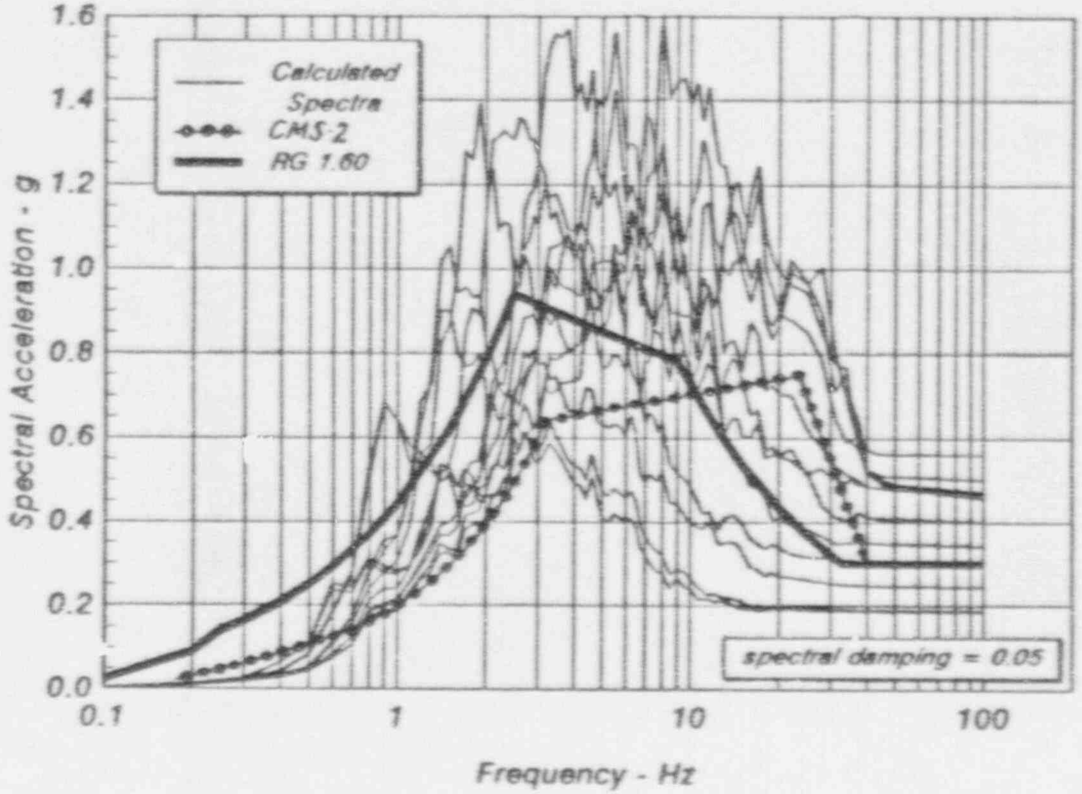


Figure 3.3 - Comparison of CMS1 with Horizontal Ground Surface Motions Computed from Application of CMS2 at the Rock Outcrop

SELECTION PROCESS

- *The envelope of the amplified free-field motions at the foundation level resulting from the application of CMS2 at the rock outcrop significantly exceeds 60% of CMS2 and 60% of the RG 1.60 spectrum. Note that it also exceeds 100% of RG 1.60 over the frequency range of interest for structural response.*

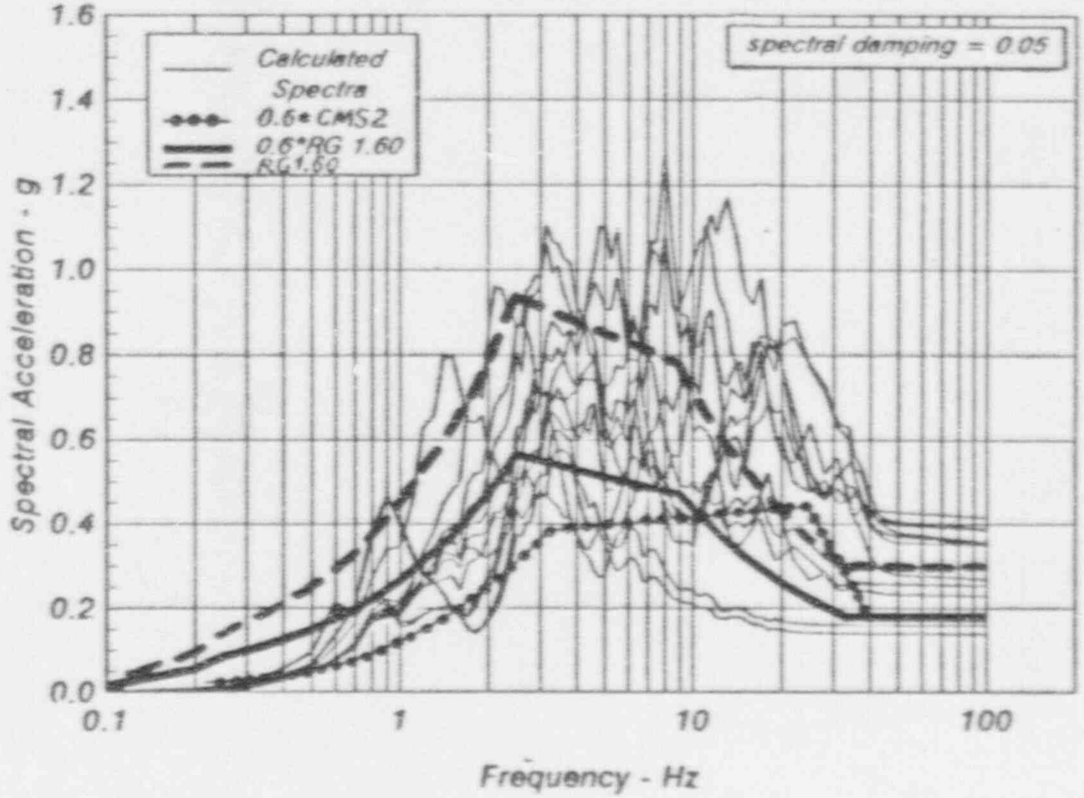


Figure 3.4 - Comparison of 60% of CMS1 with Horizontal Motions at Foundation Level Computed from Application of CMS2 at Rock Outcrop

SELECTION PROCESS

- Various Upper Bound Earthquake Scenarios Covered by the System 80+ Design Control Motions

Magnitude	Distance (km)
6.0	15
6.75	25
7.0	30
7.25	40
7.5	50

All earthquakes of either lower magnitude or at higher fault distances than the above five scenarios are also covered by the System 80+ design control motions.

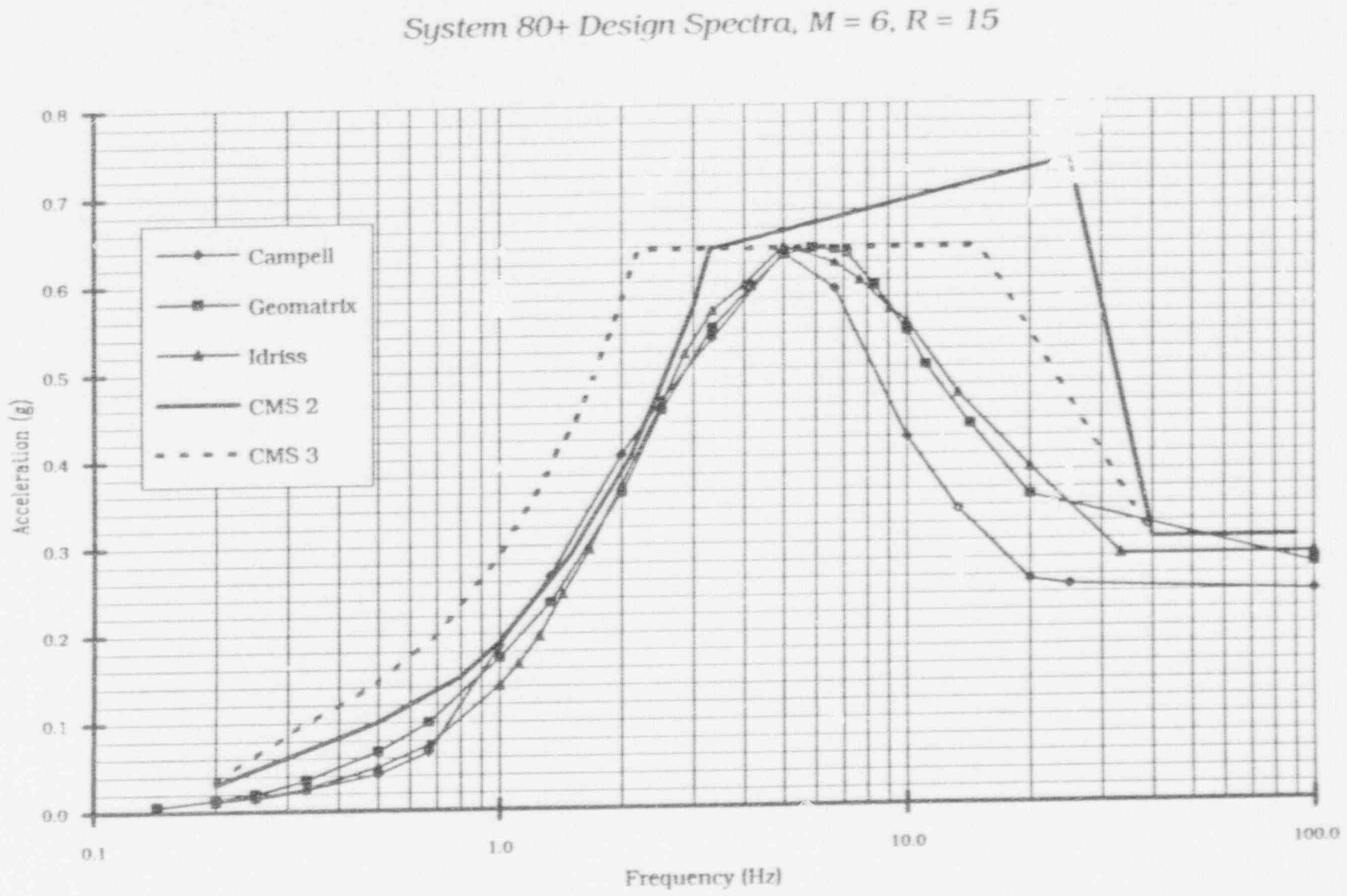


Figure 2.3 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=6, R=15 km)

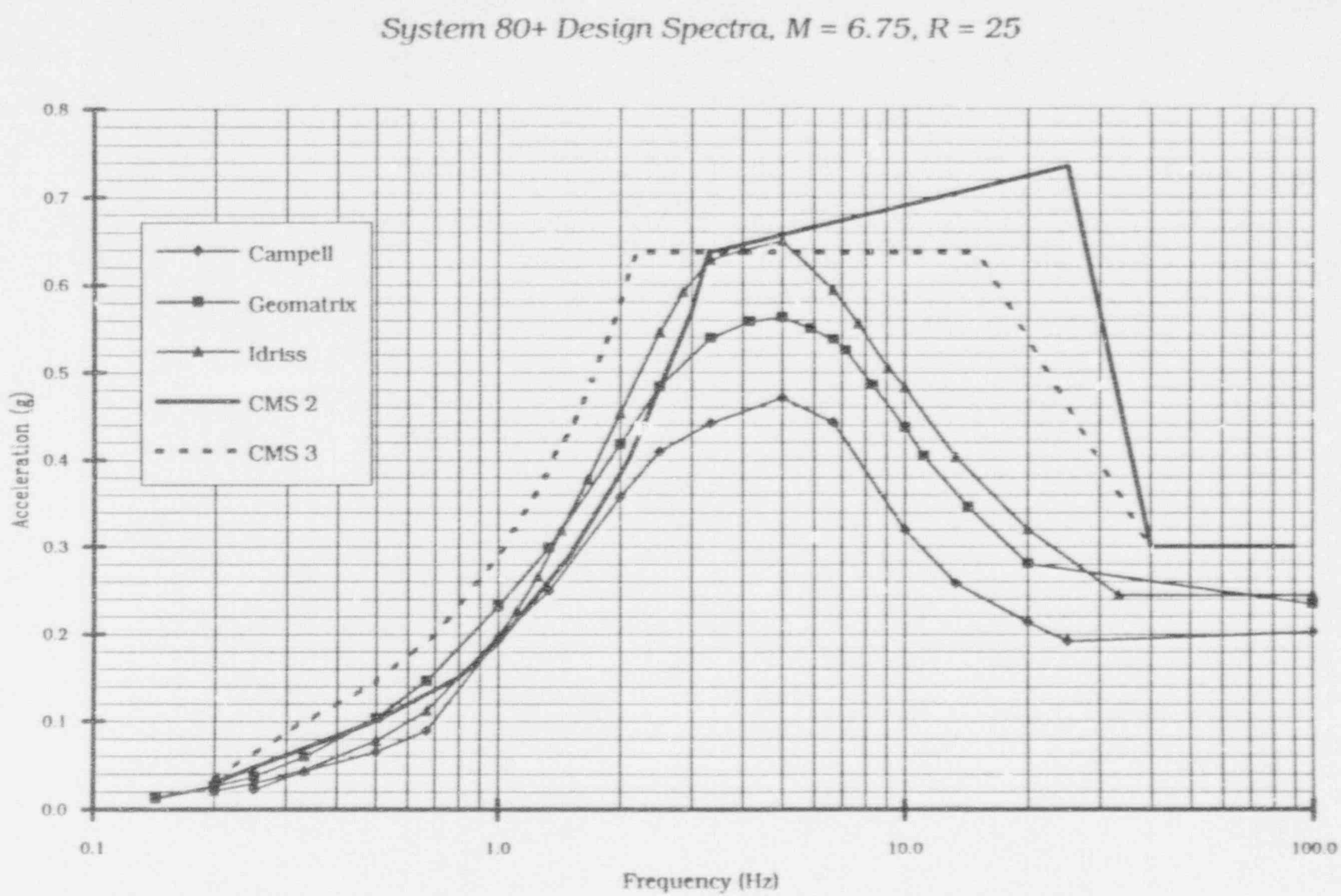


Figure 2.4 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=6.75, R=25 km)

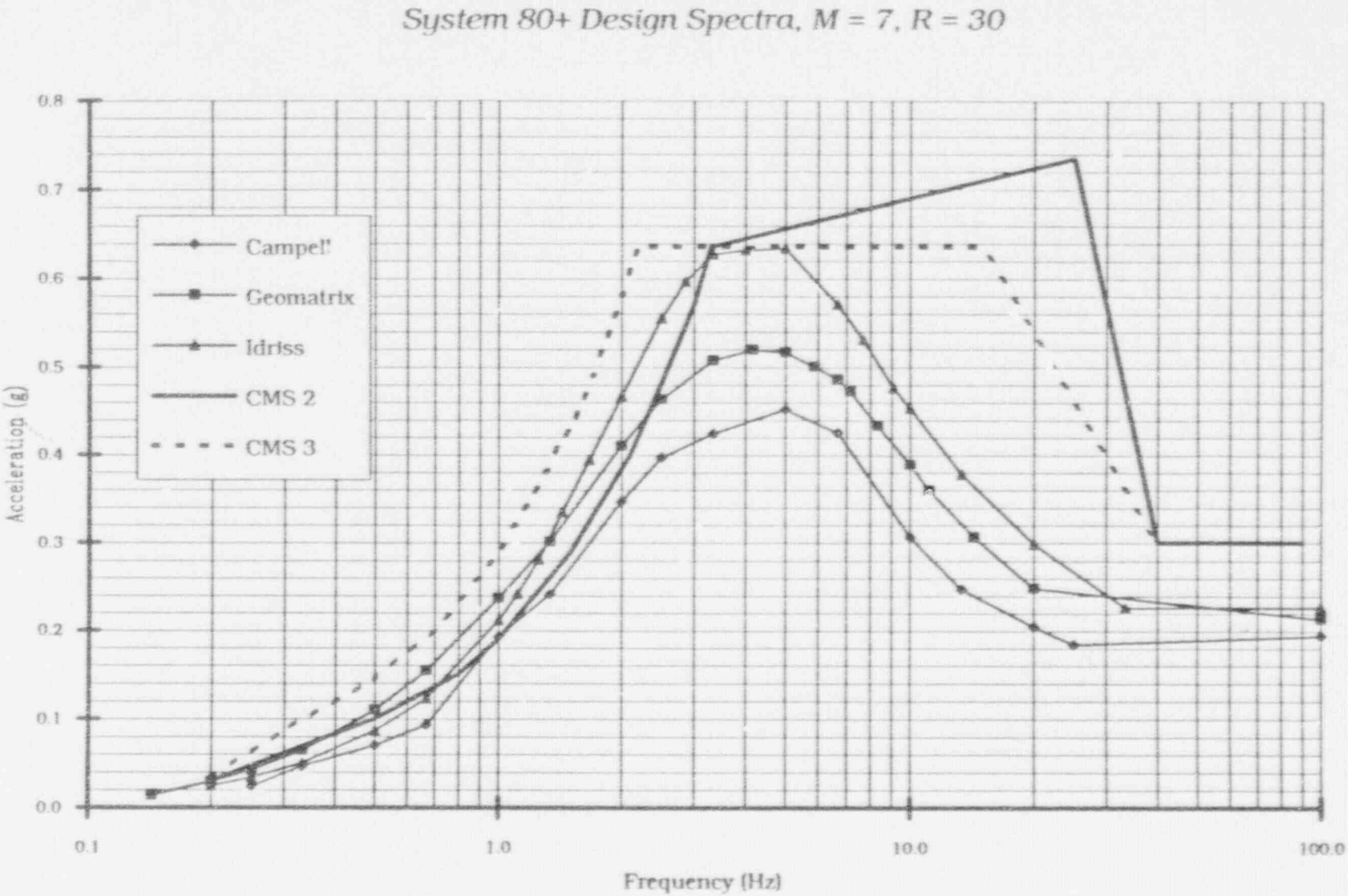


Figure 2.5 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=7, R=30 km)

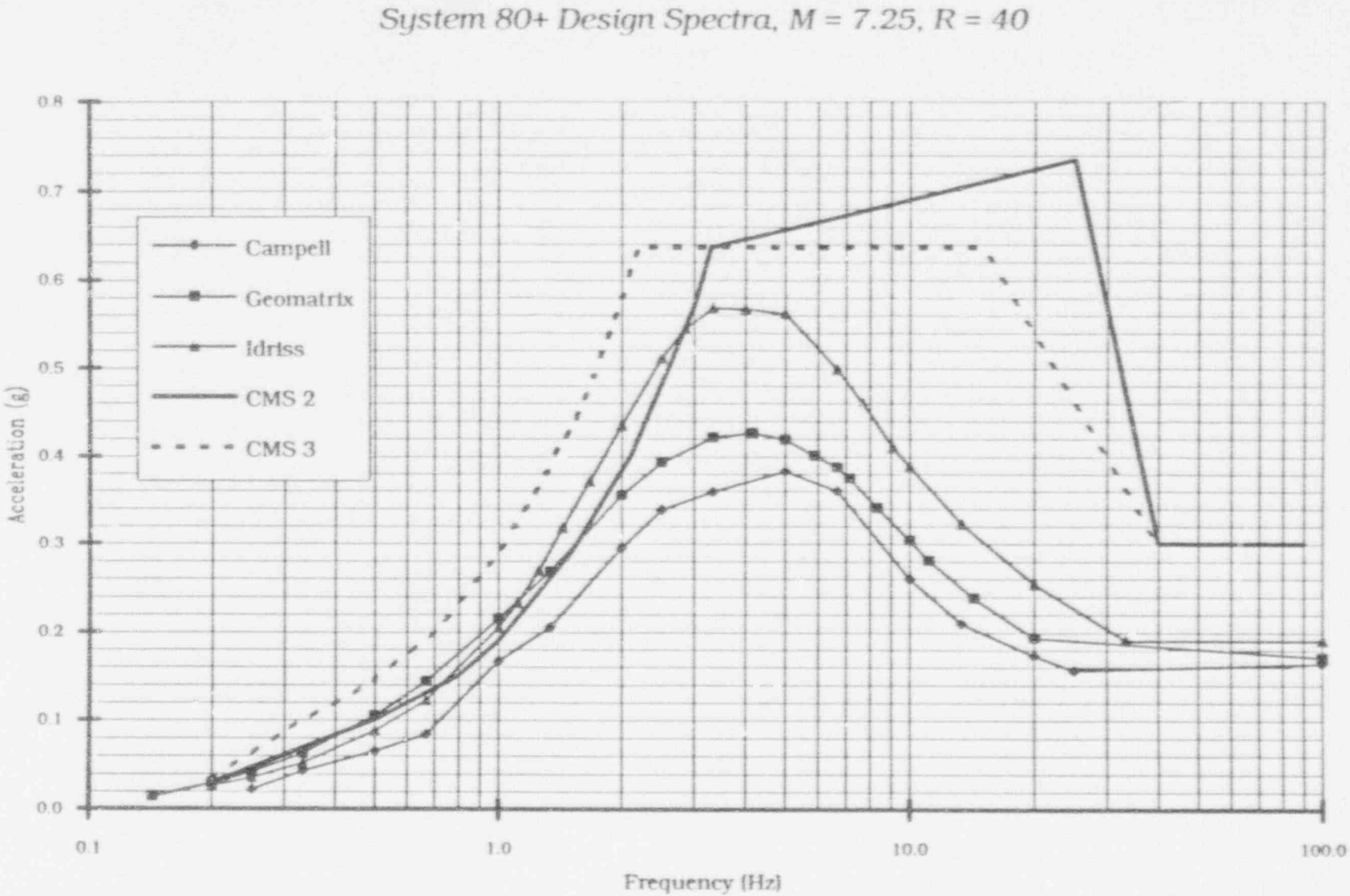


Figure 2.6 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=7.25, R=40 km)

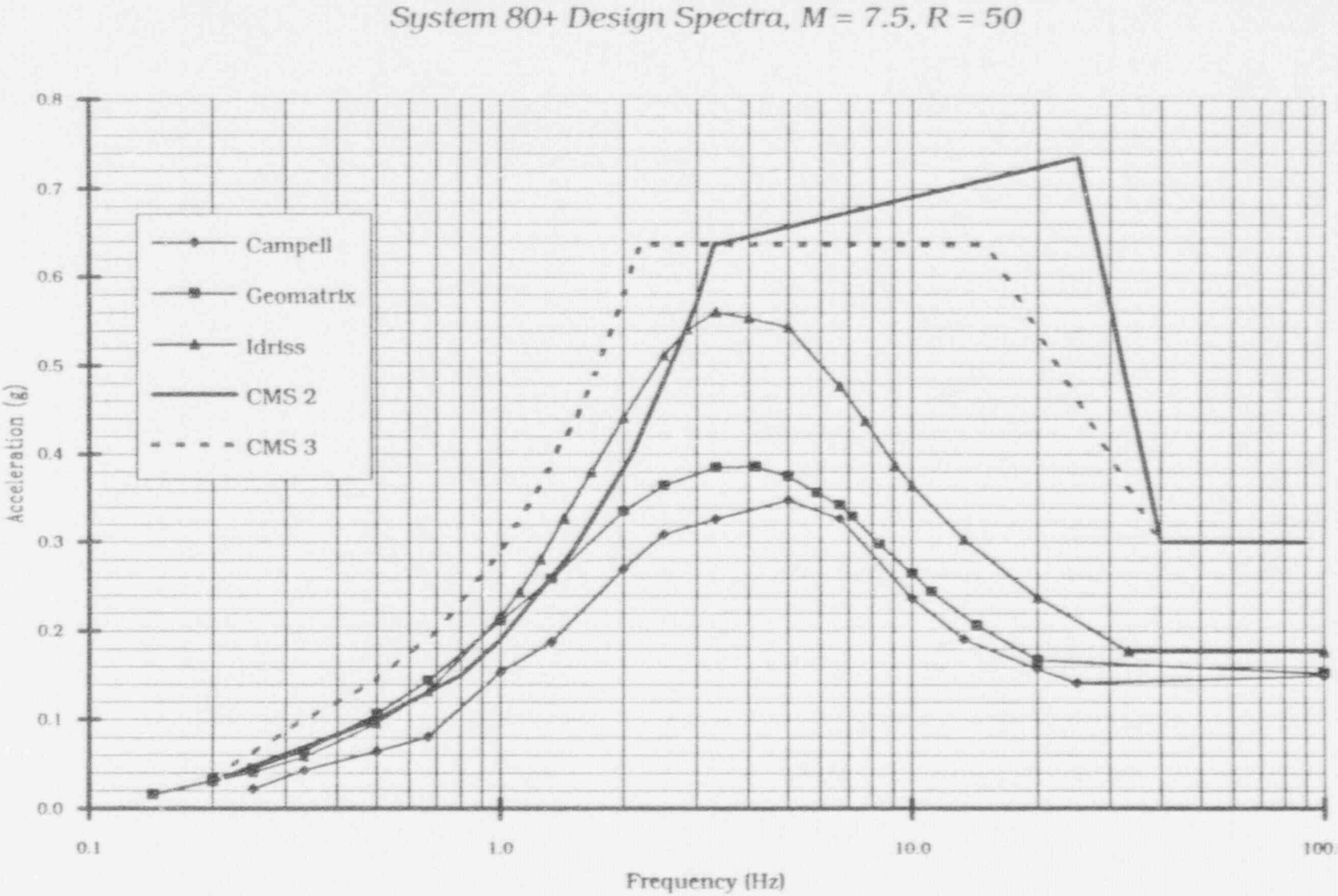


Figure 2.7 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=7.5, R=50 km)

SITE ACCEPTANCE CRITERIA FOR CONTROL MOTION

- Site-specific response spectra to fall below one or more of the three control motions of the System 80+ standard design.

  - *CMS1 to be used for deep soil sites or rock sites. Compare site-specific free-field surface spectra with CMS1.*

  - *If site-specific spectra exceed CMS1, compare site-specific surface spectra to the System 80+ envelope surface spectra.*

  - *CMS2 or CMS3 to be used for all soil sites (shallow and deep) as well as rock sites. Compare site-specific rock outcrop spectra with CMS2 or CMS3.*

  - *If site-specific rock outcrop spectra exceed CMS2 and CMS3, then site specific spectra should be developed at the surface elevation and compared to the System 80+ envelope of surface spectra.*

SITE ACCEPTANCE CRITERIA FOR CONTROL MOTION

- Compliance with SRP (Section 2.5.2.6, Rev. 2)
  - *CMS1 complies with 2.5.2.6 Item 3b.*

    'Where only estimates of peak ground acceleration are available, it is acceptable to select a peak ground acceleration and use this acceleration as the high frequency asymptote to standardized response spectra such as described in Regulatory Guide 1.60'.

  - *CMS2 amd CMS3 comply with 2.5.2.6 Item 1:*

    'Both horizontal and vertical component site-specific spectra should be developed statistically from response spectra or recorded strong motion records..."

    "An 84th percentile response spectrum for the records should be presented for each damping value of interest and compared to the SSE free-field and design response spectrum."

  - *CMS2 and CMS3 also comply with 2.5.2.6 Item 3a.*

    'If strong motion records are not available, site specific peak ground acceleration, velocity, and displacement (if necessary) should be determined for appropriate magnitude, distance, and foundation conditions. Then response spectra may be determined by scaling the acceleration, velocity and displacement values by appropriate amplification factors (NUREG/CR-0098)."

APPLICATION OF CONTROL MOTION TO SEISMIC SSI ANALYSES

- Computation of Site Response

  - *CMS2 is applied at the rock outcrop for each soil case*
    Motion (S) at the ground surface is obtained through convolution.
    Strain-iterated properties are computed for each soil case and used as standard in all SSI analyses

  - *CMS3 is applied at the rock outc. op for each case*
    Motion (S) at the ground surface is obtained through convolution.
    Use standard strain-iterated properties from CMS2 analysis.

- Soil-Structure Interaction Analysis

  - *Use SASSI methodology*

  - *Input motion is applied at ground surface*
    For CMS2 and CMS3, surface motion (S) is provided as input motion
    CMS1 is directly applied at the free-field ground surface

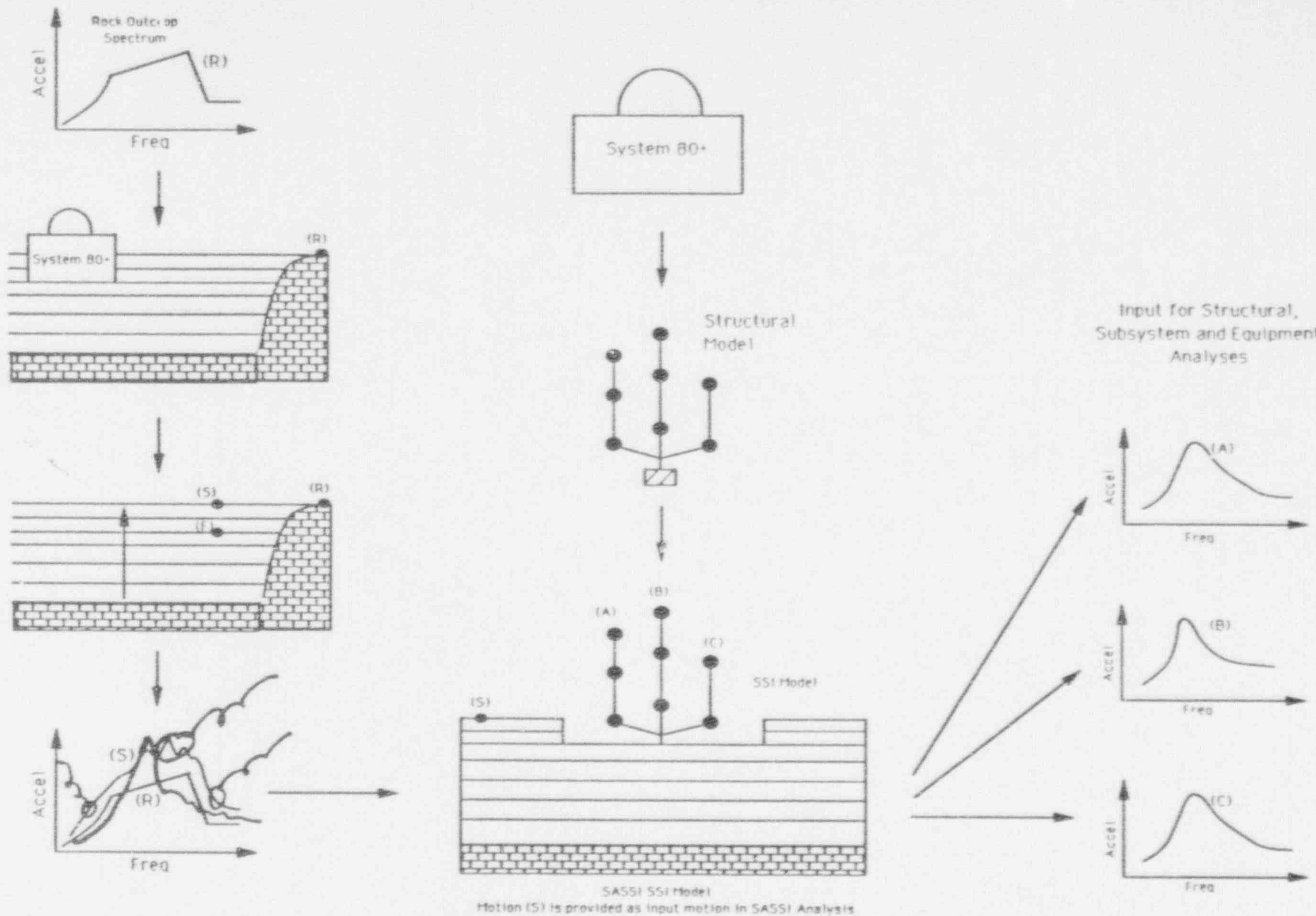


Figure 3.1 - Outline of Application of Control Motions CMS2 and CMS3 in SSI Analyses

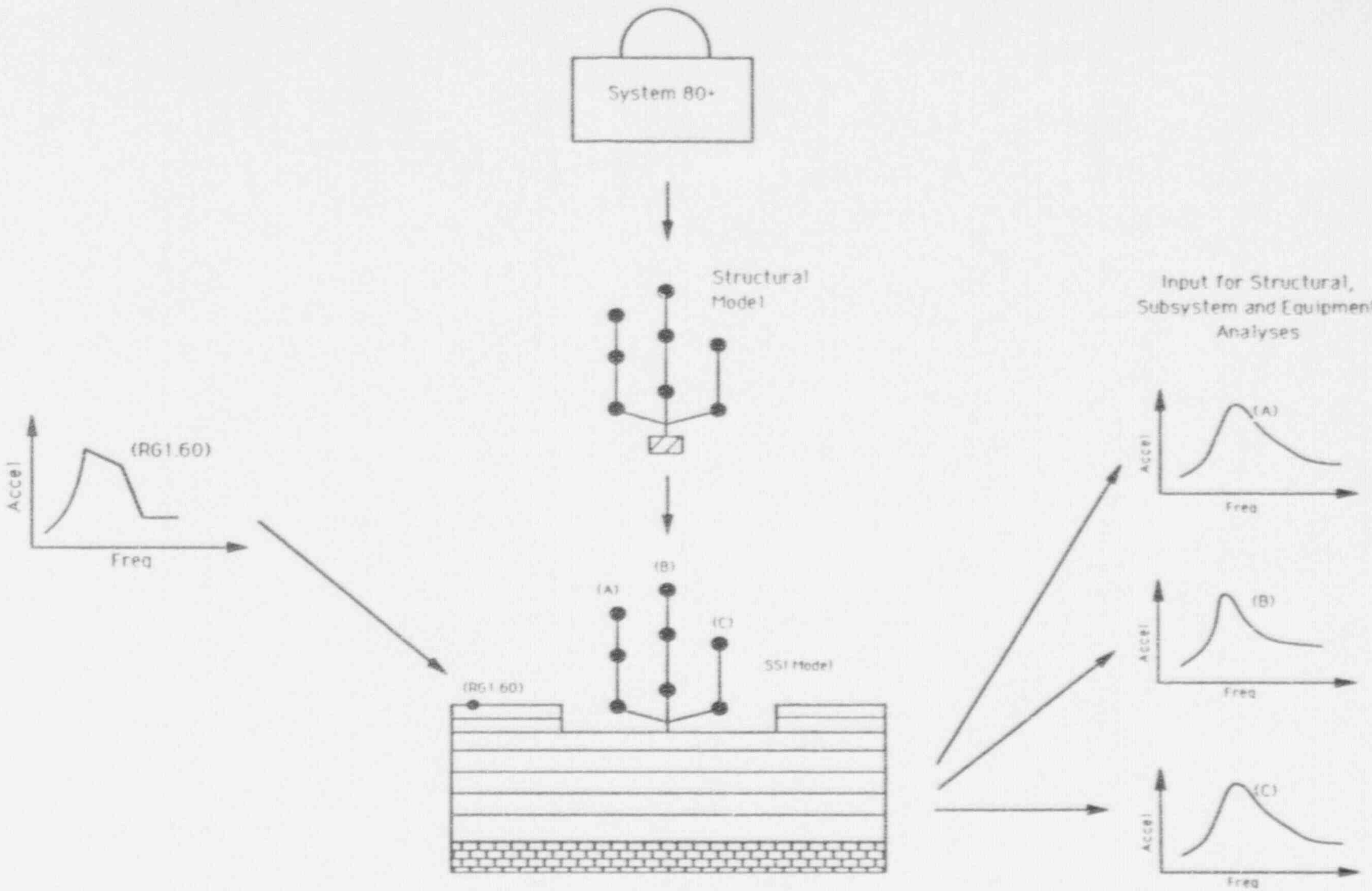
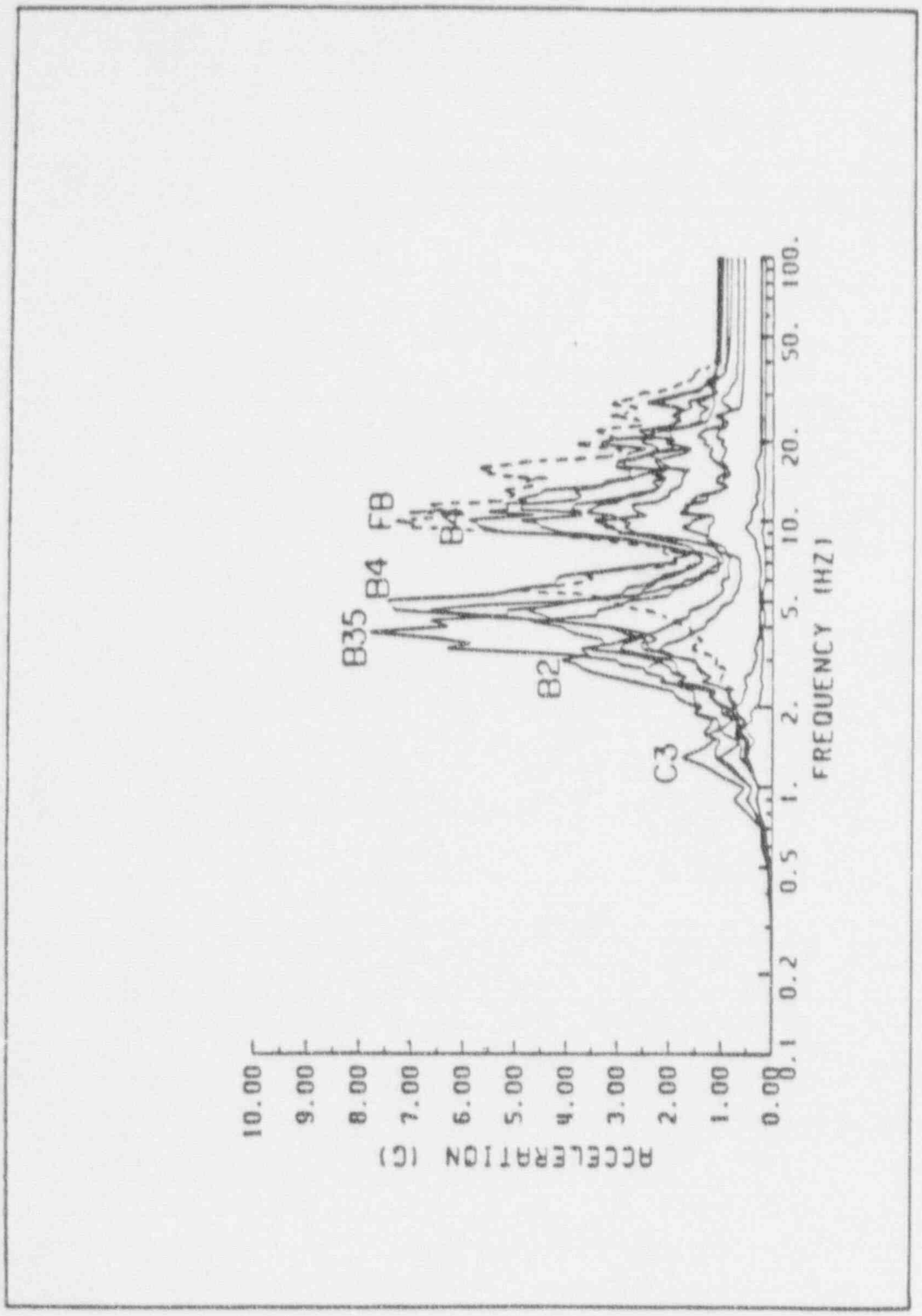


Figure 3.2 - Outline of Application of Control Motion CMS1 in SSI Analyses



Amendment I
December 21, 1990

SYSTEM 80+™	COMPARISON OF 2% H+V RESPONSE SPECTRA (SSE, IIS, NODE 210, 0-180 DIRECTION)	Figure 3.7B-7

CONCLUSIONS

- Control motions developed qualify the System 80+ standard plant for the majority of sites in the U.S.

- Control motions and use in SSI analyses are in full compliance with SRP

- Control motions provide conservatism beyond minimum SRP guidance since for shallow and rock sites, they are rich in high frequency content (characteristic of Eastern North America motions).

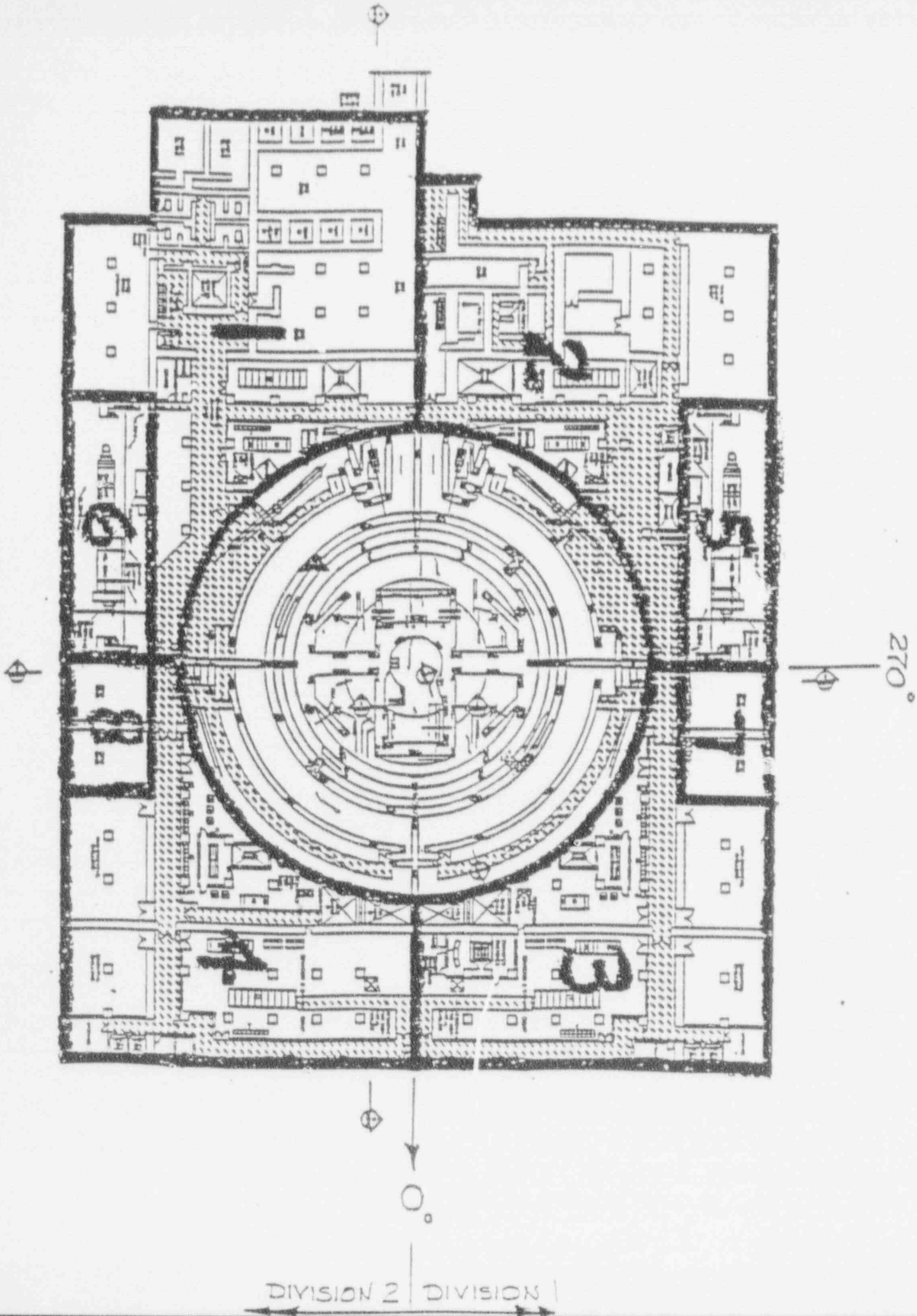
Mass Model

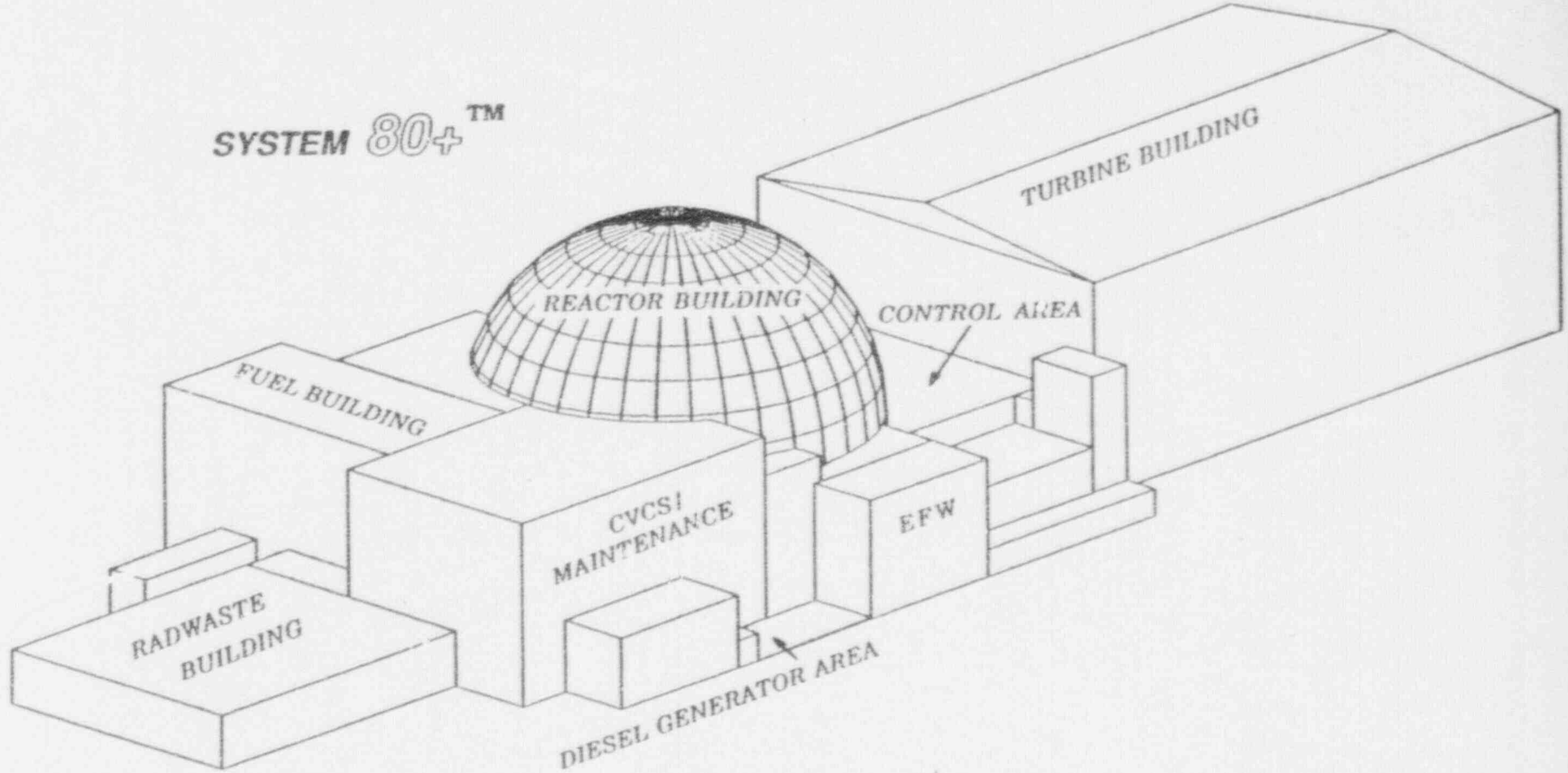
Translational Masses

- building structure
- equipment
- piping

Center of Mass

Mass Moment of Inertia


270°
0°
DIVISION 2
DIVISION 1


SYSTEM 80+™
TURBINE BUILDING
REACTOR BUILDING
CONTROL AREA
FUEL BUILDING
CVCS/
MAINTENANCE
EFW
RADWASTE
BUILDING
DIESEL GENERATOR AREA

Stiffness Properties

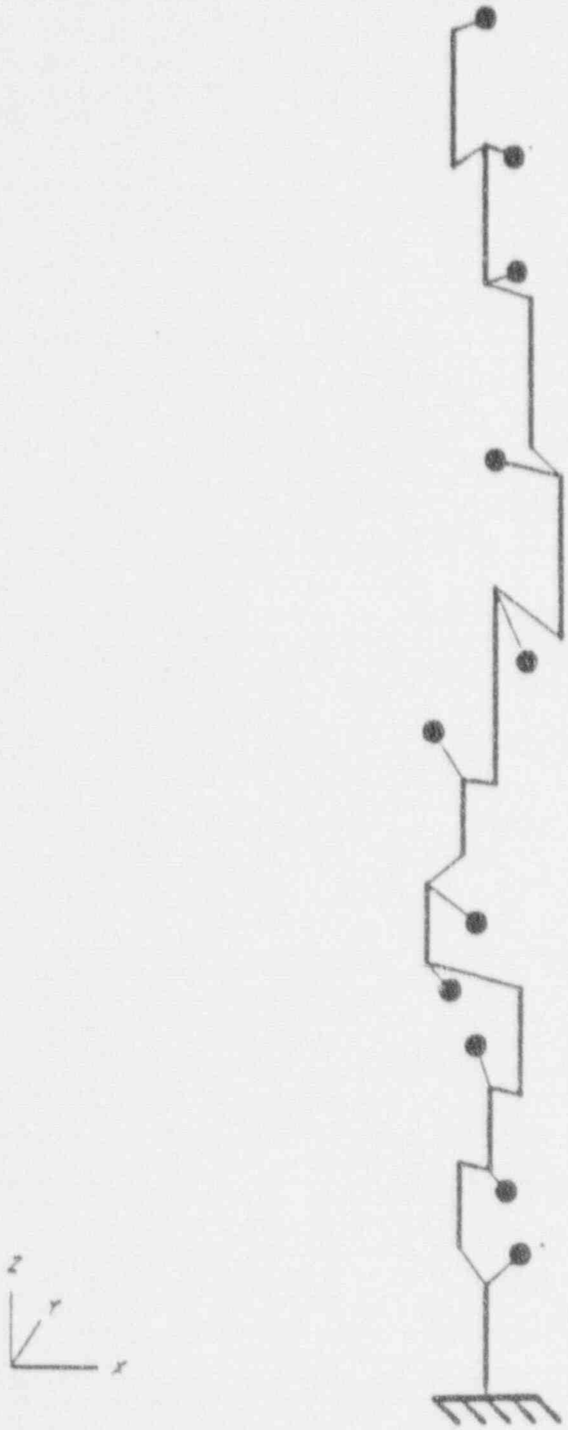
Axial Area and Centroid

Moment of Inertia

Shear Center

Shear Area

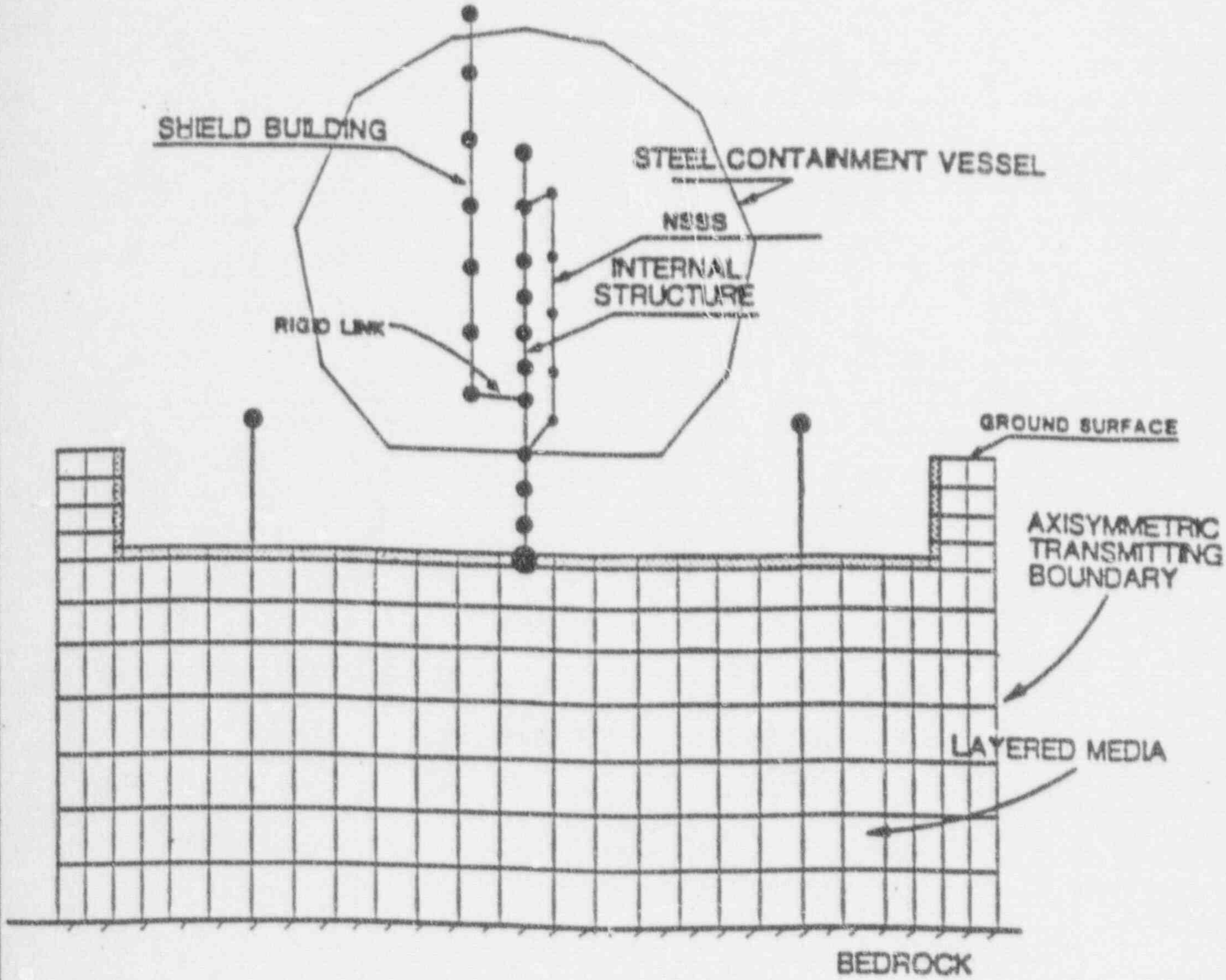
Torsional Constant



STICK MODEL OF INTERNAL STRUCTURE

ANSYS Axisymmetric Containment Model

SYSTEM 80+™


SHIELD BUILDING
STEEL CONTAINMENT VESSEL
NSSS
INTERNAL STRUCTURE
RIGID LINK
GROUND SURFACE
AXISYMMETRIC TRANSMITTING BOUNDARY
LAYERED MEDIA
BEDROCK

SEISMIC DESIGN AND ANALYSIS
OF THE
SYSTEM 80+ CATEGORY I STRUCTURES

Prepared by:

ABB COMBUSTION ENGINEERING

April 28, 1992

AGENDA

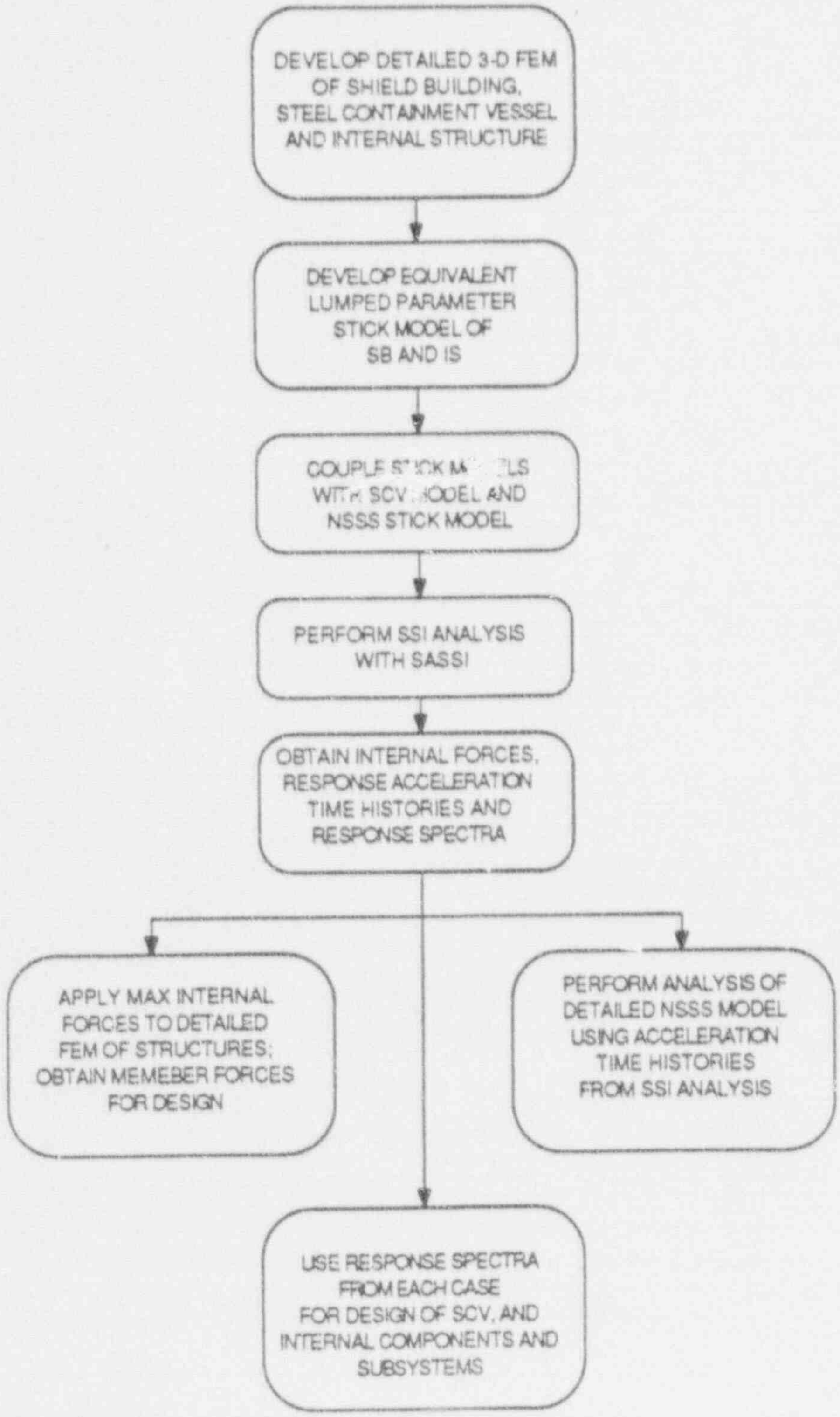
- DEVELOPMENT OF DYNAMIC MODEL
- ANALYSIS METHOD AND
  GENERATION OF FLOOR RESPONSE SPECTRA

DEVELOPMENT OF DYNAMIC MODEL

- Methodology and Assumptions
- Preliminary Model
- Final Model

METHODOLOGY AND ASSUMPTIONS

GENERAL ANALYSIS APPROACH

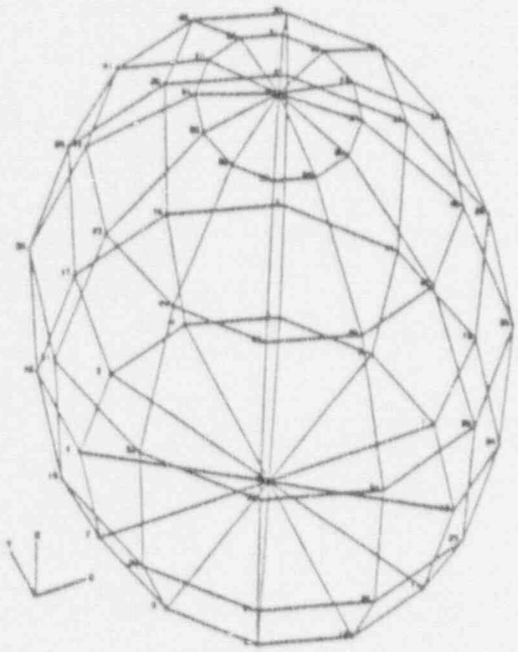


STRUCTURAL MODEL DEVELOPMENT

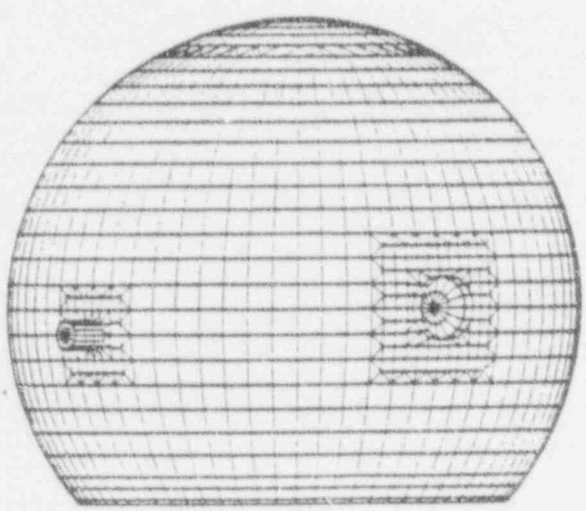
- DEVELOPMENT OF 3-D FEM
  - STEEL CONTAINMENT VESSEL (SCV)
  - CONCRETE SHIELD BUILDING (SB)
  - INTERNAL STRUCTURE (IS)
  - MASSES
  - MODAL ANALYSIS
- DEVELOPMENT OF EQUIVALENT 3-D STICK MODEL
  - COMPUTATION OF TORSIONAL CONSTANT AND CENTER
  - COMPUTATION OF SHEAR AREAS AND MOMENTS OF INERTIA
- FIXED-BASE NATURAL FREQUENCIES
- EVALUATION OF MEMBER FORCES IN FEM

DEVELOPMENT OF 3-D FEM

- STEEL CONTAINMENT VESSEL
  - SSI SEISMIC ANALYSIS



  - DETAILED CONTAINMENT ANALYSIS



DEVELOPMENT OF 3-D FEM

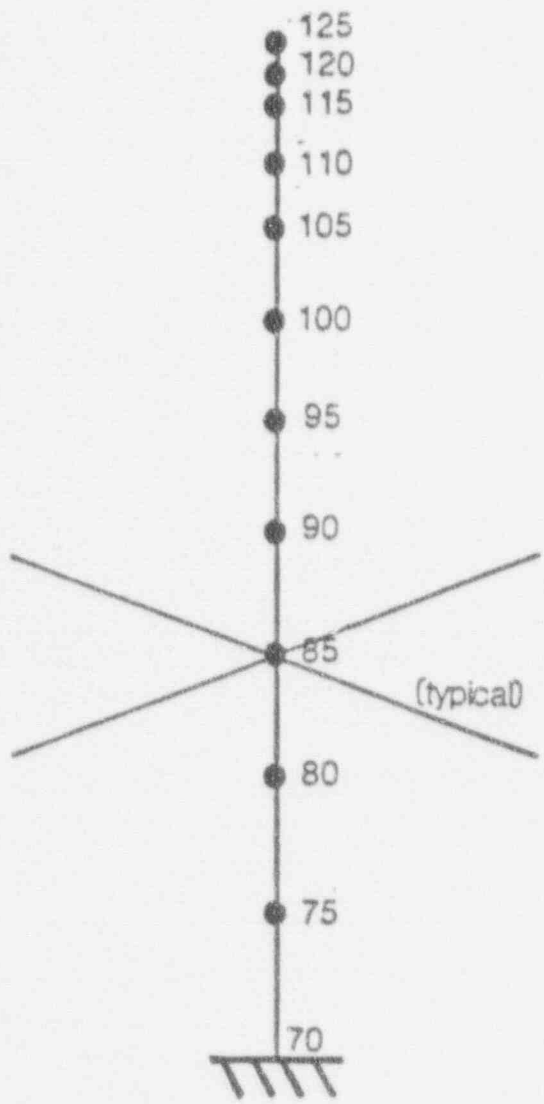
- **SHIELD BUILDING**
  - AXISYMMETRIC SHELL ELEMENTS

- **INTERNAL STRUCTURE**
  - SELECT MAJOR ELEVATIONS BASED ON:
    - FLOORS
    - SIGNIFICANT STIFFNESS DISCONTINUITIES ALONG HEIGHT
  - EACH FLOOR ASSUMED RIGID IN ITS OWN PLANE
  - LOAD RESISTING ELEMENTS (**STIFFNESS**):
    - CONCRETE WALLS
      (INCLUDE OUTSIDE WALLS FROM GROUND LEVEL TO BASEMAT)
      USE QUALIDRATERAL SHELL ELEMENTS
    - MASSIVE CONCRETE WALLS NEAR REACTOR CAVITY
      USE 8-NODE SOLID ELEMENTS
    - NARROW WALLS, WALLS WITH LARGE OPENINGS
      USE 3-D BEAM ELEMENTS
    - SLABS OF SIGNIFICANT THICKNESS
      USE QUADRILATERAL SHELL ELEMENTS
  - BASEMAT MODELED RIGID (10 ft. THICK)

DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

SHIELD BUILDING

- LUMP MASSES AT NODAL POINTS ALONG HEIGHT OF STICK
- DETERMINE I_{xx}, I_{yy}, J, A_x, A_y, A_z, BASED ON MODAL ANALYSIS



Stick Model of Shield Building

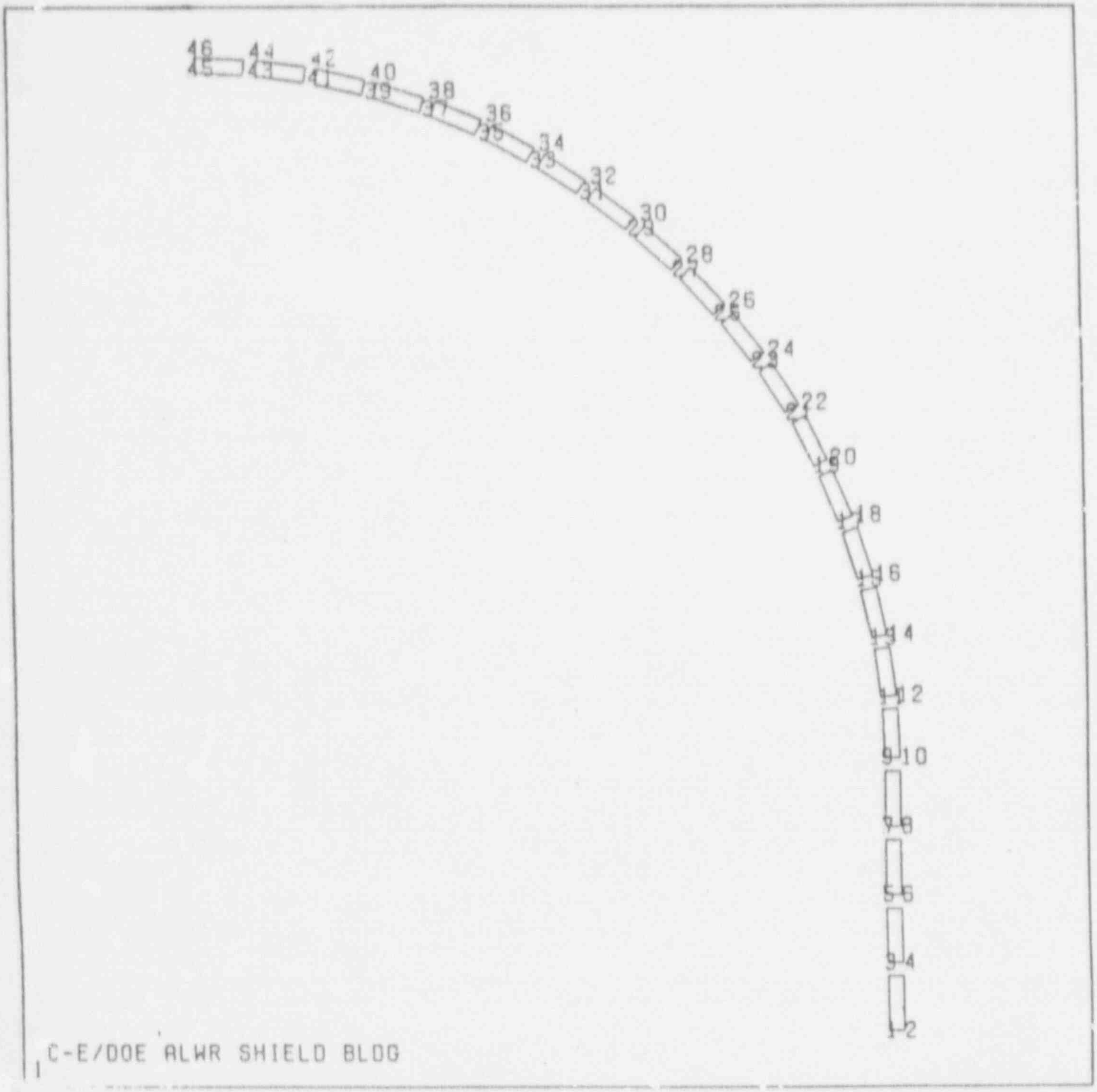


Figure 220.16-1 - Detailed Axisymmetric Model of Shield Building

DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

INTERNAL STRUCTURE

COMPUTE TORSIONAL CONSTANT J
AND TORSIONAL CENTER (e_x, e_y)

- ISOLATE EACH SECTION OF FEM MODEL
- CONSTRAIN TOP AND BOTTOM BOUNDARIES IN-PLANE (X, Y, ZZ); ALLOW SECTION TO WARP (XX, YY, Z FREE)
- APPLY TORQUE; MEASURE TORSIONAL ROTATIONS
- COMPUTE J
- DETERMINE TORSIONAL CENTER e_x, e_y

DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

- COMPUTE SHEAR AREAS A_x, A_y, AND MOMENTS OF INERTIA I_{xx}, I_{yy}
  - DEVELOP SEPARATE CANTILEVER MODEL FOR EACH FLOOR OF THE FEM
  - MULTIPLE SUPERIMPOSED SECTIONS OF A SINGLE FLOOR
  - CHOOSE LONG CANTILEVER (MAXIMIZING BENDING DEFORMATION) TO COMPUTE MOMENTS OF INERTIA I_{xx}, I_{yy}
  - CHOOSE SHORT CANTILEVER (MAXIMIZING SHEAR DEFORMATION) TO COMPUTE SHEAR AREAS A_x, A_y
  - FREE END OF CANTILEVER CONSTRAINED IN ALL 6 DOF
  - APPLY MOMENTS M_x, M_y AT FREE END

    COMPUTE I_{xx}, I_{yy} BASED ON TOP LATERAL DISPLACEMENT

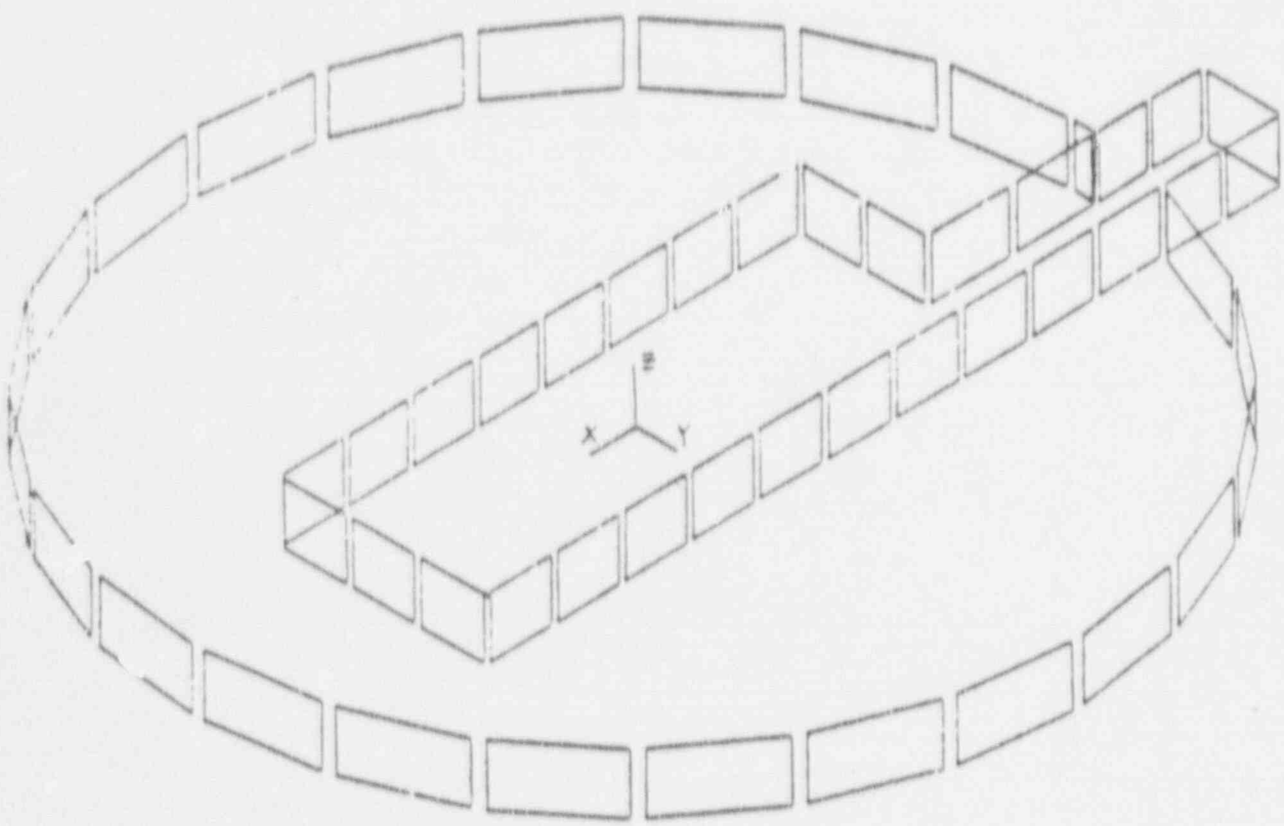
    COMPUTE CENTROID OF AXIAL AREA (d_x, d_y) BASED ON VERTICAL EDGE DISPLACEMENTS AT TOP
  - APPLY FORCES P_x, P_y AT TORSIONAL CENTER (e_x, e_y)

    COMPUTE A_x, A_y BASED ON LATERAL DISPLACEMENT AT TOP;
    SUBTRACT DISPLACEMENT DUE TO BENDING DEFORMATION

DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

EXAMPLE

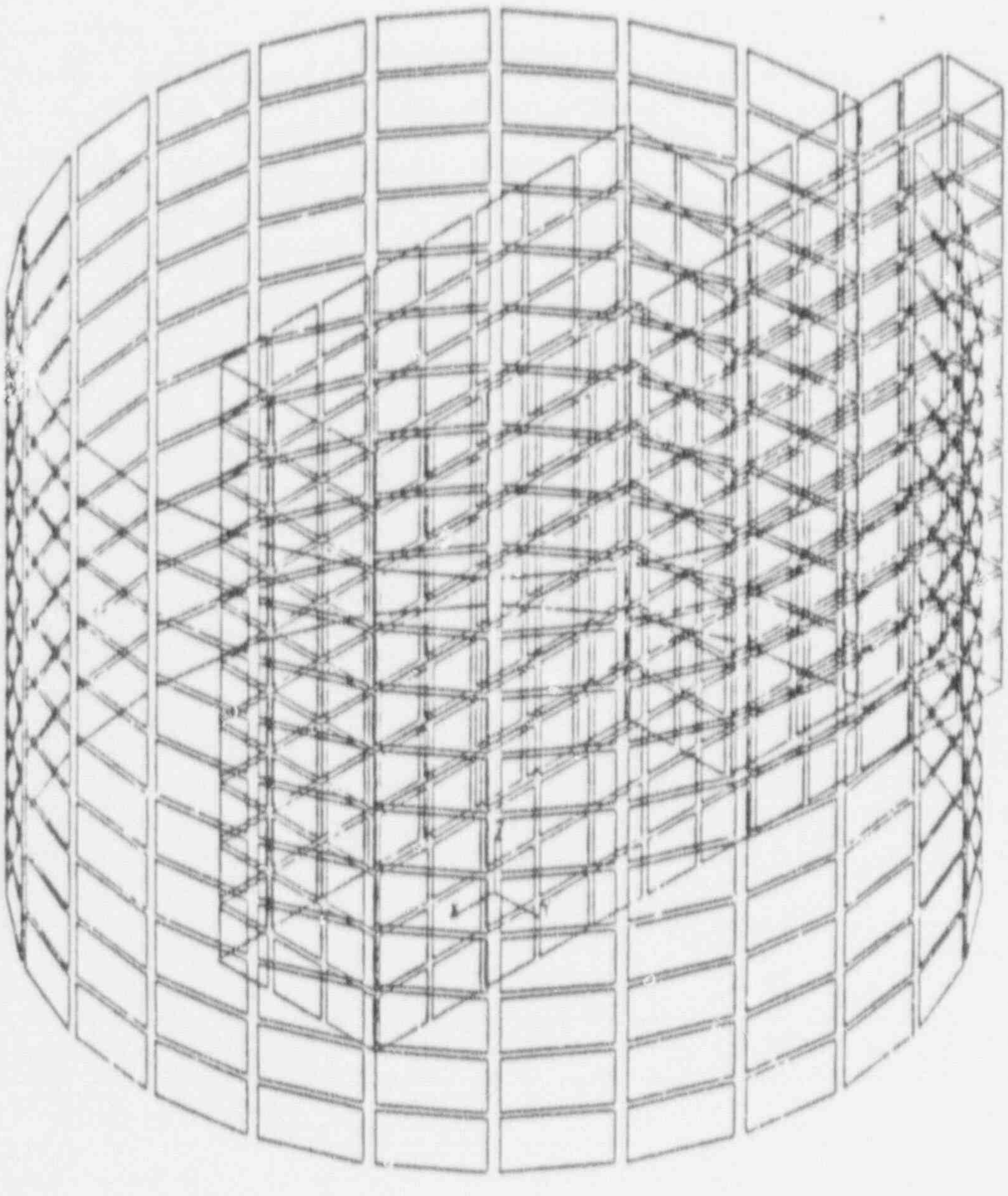
ISOLATED SECTION OF FEM



DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

EXAMPLE

UNIFORM-SECTION "LONG" FEM CANTILEVER



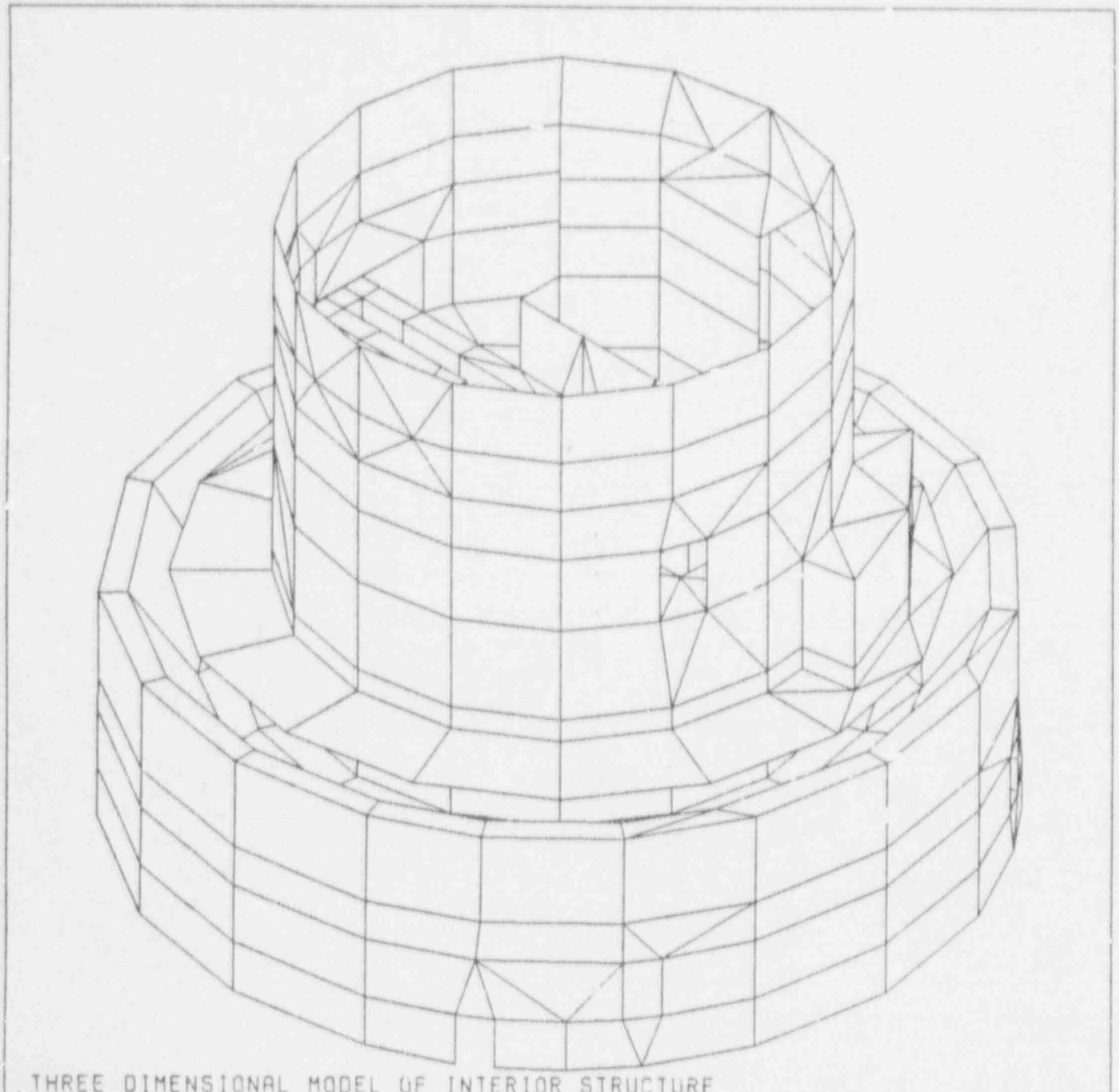
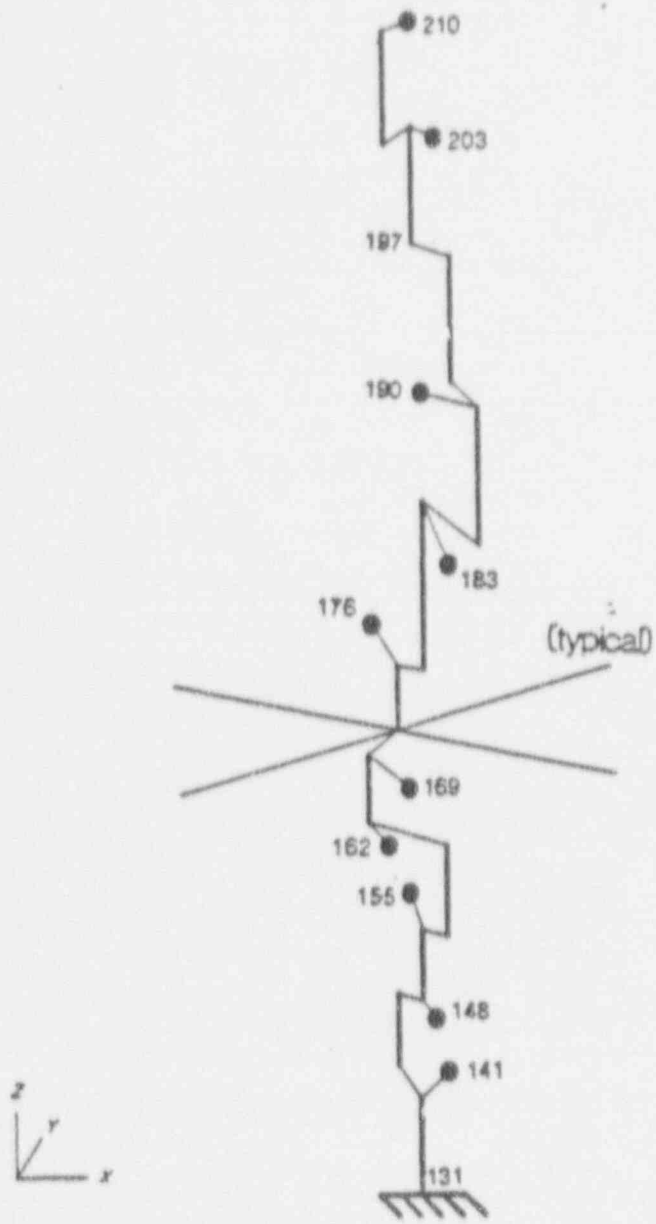


Figure 220.16-1 - Detailed 3D Finite Element Model of Internal Structure

DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

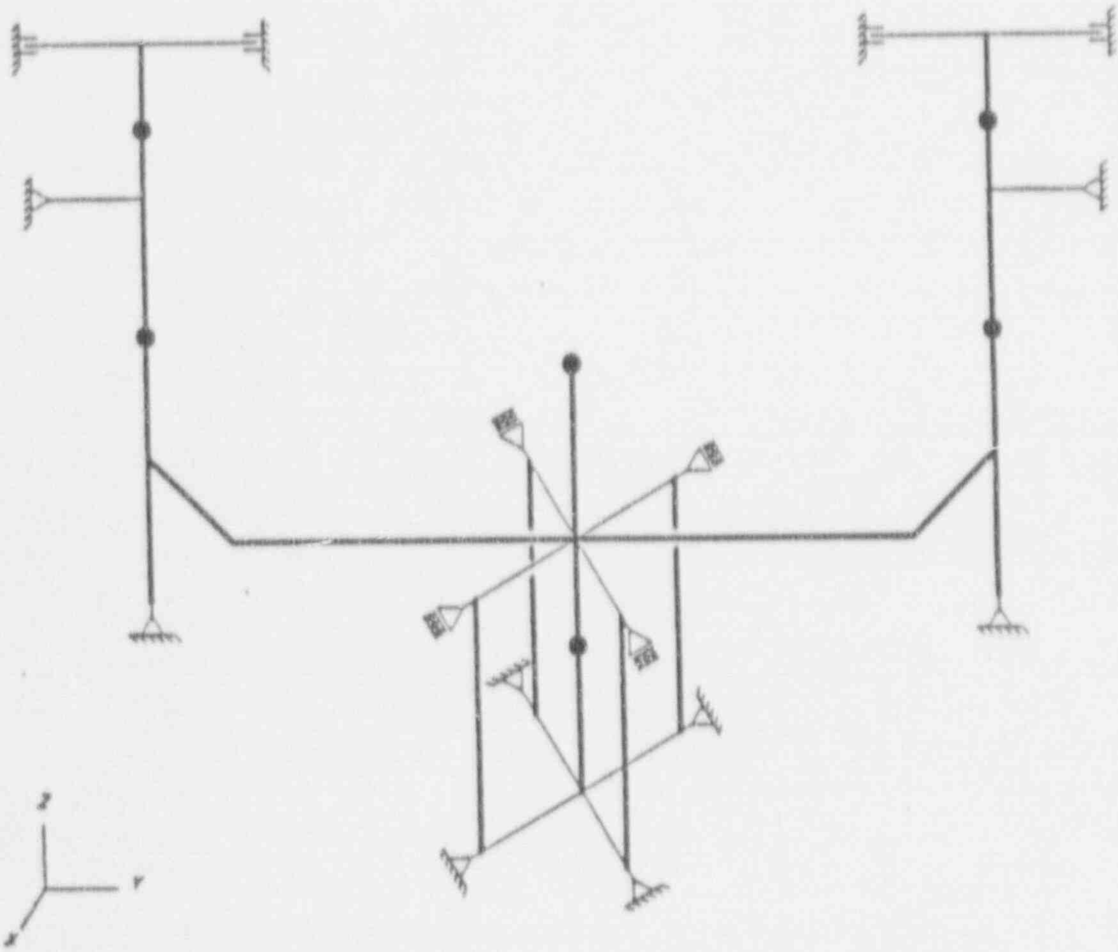
INTERNAL STRUCTURE STICK MODEL



Stick Model of Internal Structure
(for Horizontal Analysis)

DEVELOPMENT OF EQUIVALENT 3-D BEAM STICK MODEL

NSSS MODEL

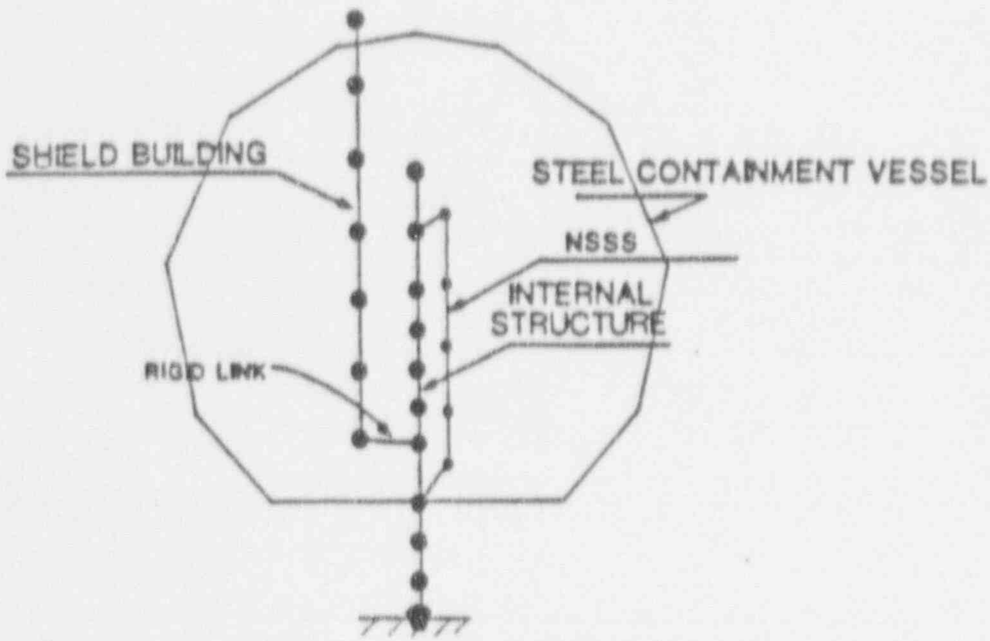


EVALUATION OF MEMBER FORCES IN FEM

- OBTAIN MAXIMUM INTERNAL FORCES OF EACH FLOOR FROM SSI ANALYSIS OF STICK MODEL
- APPLY MAXIMUM FORCES STATICALLY TO EACH ISOLATED FLOOR SECTION OF THE FEM
- COMPUTE INDIVIDUAL MEMBER FORCES

PRELIMINARY MODEL

FIXED-BASE NATURAL FREQUENCIES

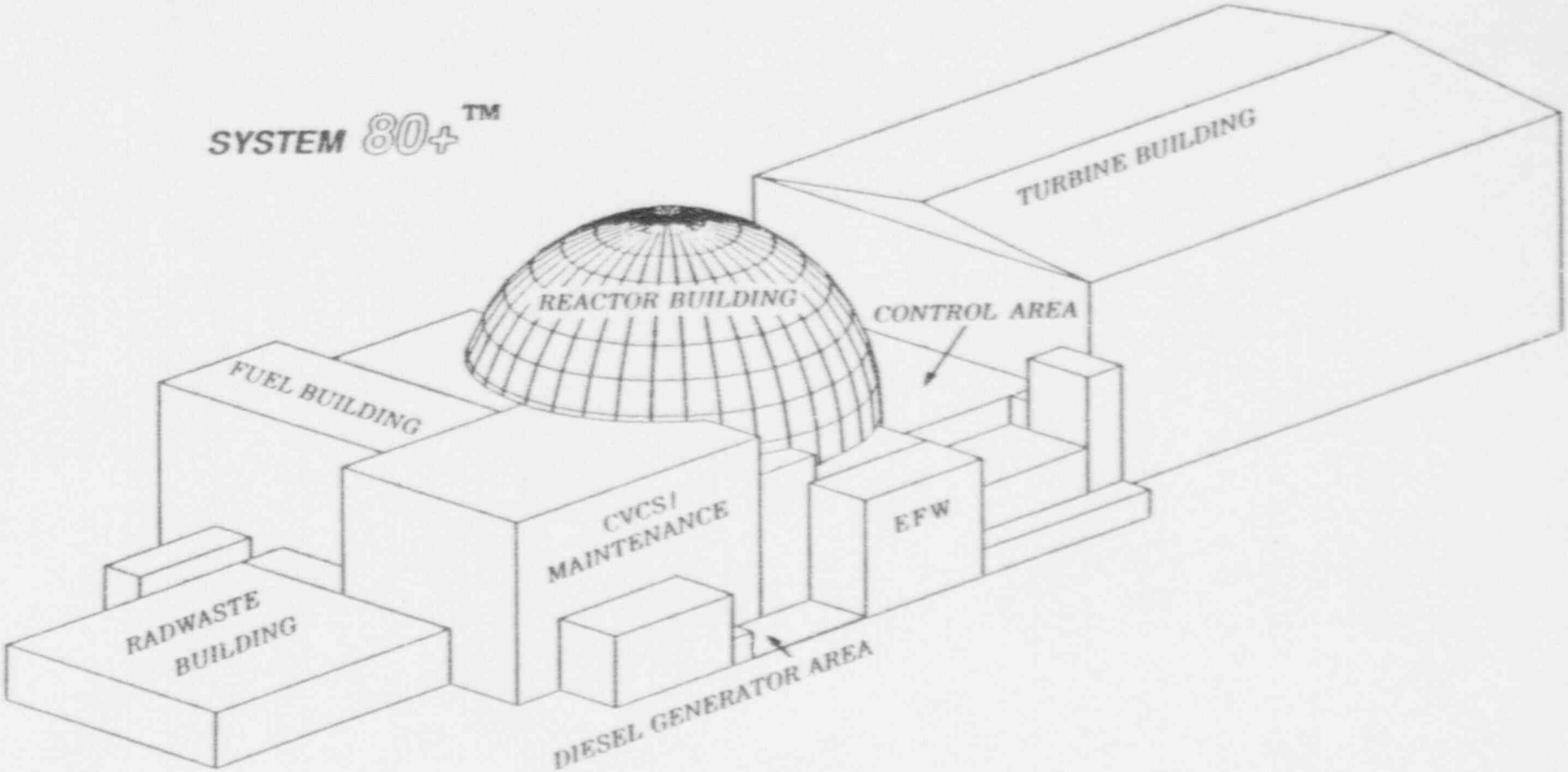


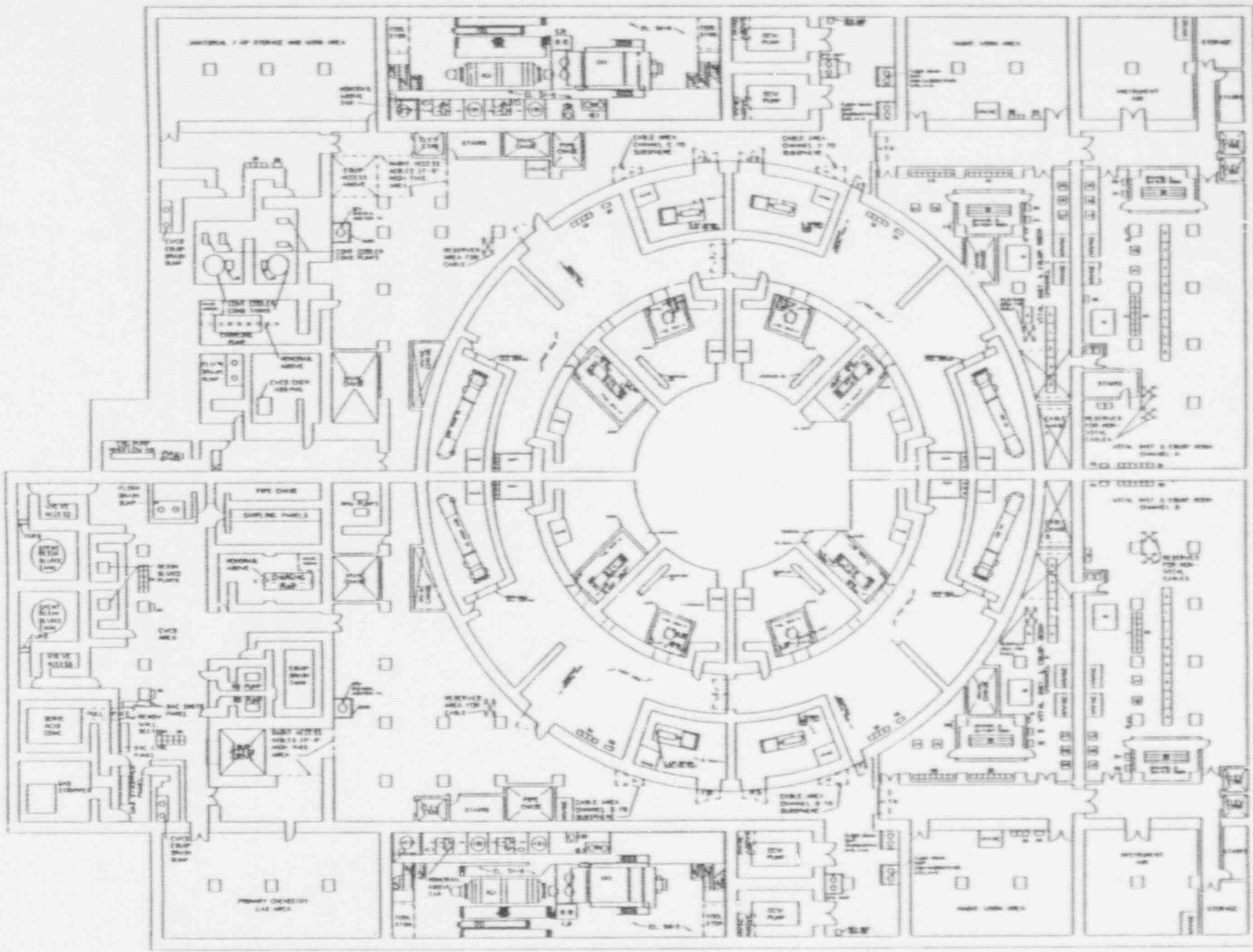
FUNDAMENTAL FREQUENCIES (FIXED BASE; HORIZONTAL DIR.)

INDIVIDUAL STICKS (STAND ALONE)

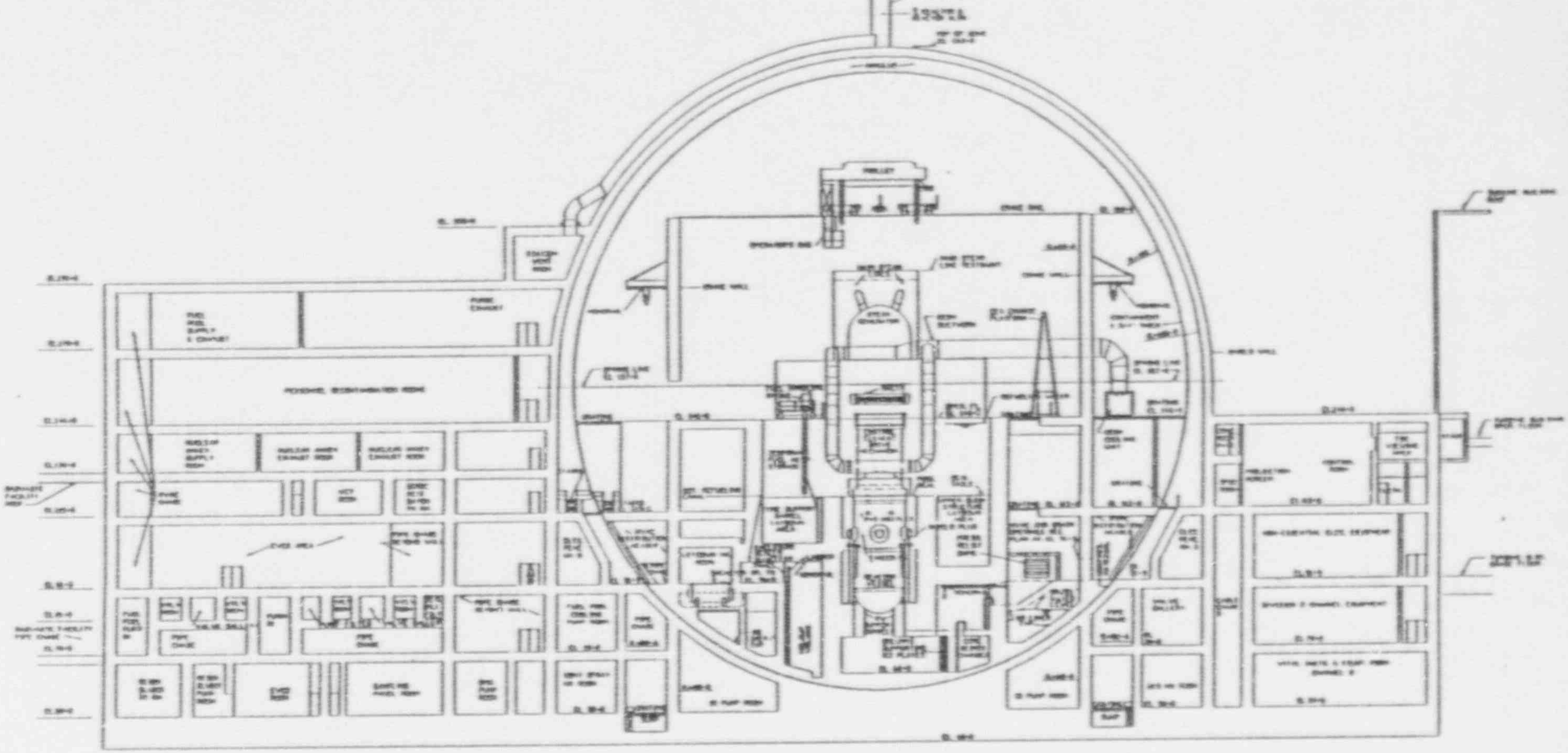
SHIELD BUILDING:	7.4 Hz
STEEL CONTAINMENT VESSEL:	5.5 Hz
INTERNAL STRUCTURE:	8.0 Hz
NSSS:	12.5 Hz
COMBINED RB MODEL:	5.6 Hz

FINAL MODEL

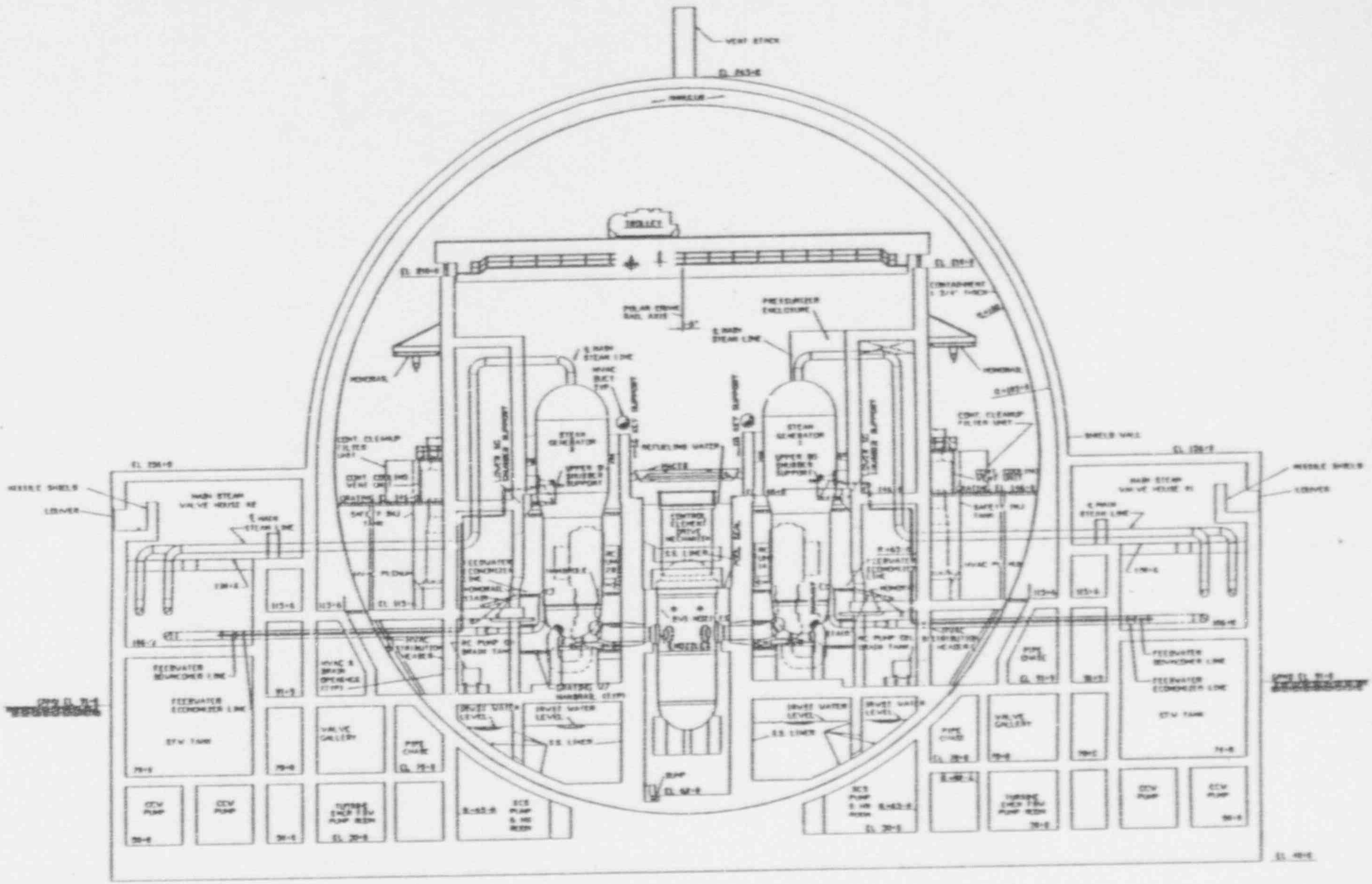

SYSTEM 80+™
TURBINE BUILDING
REACTOR BUILDING
CONTROL AREA
FUEL BUILDING
CVCS/
MAINTENANCE
EFW
RADWASTE
BUILDING
DIESEL GENERATOR AREA



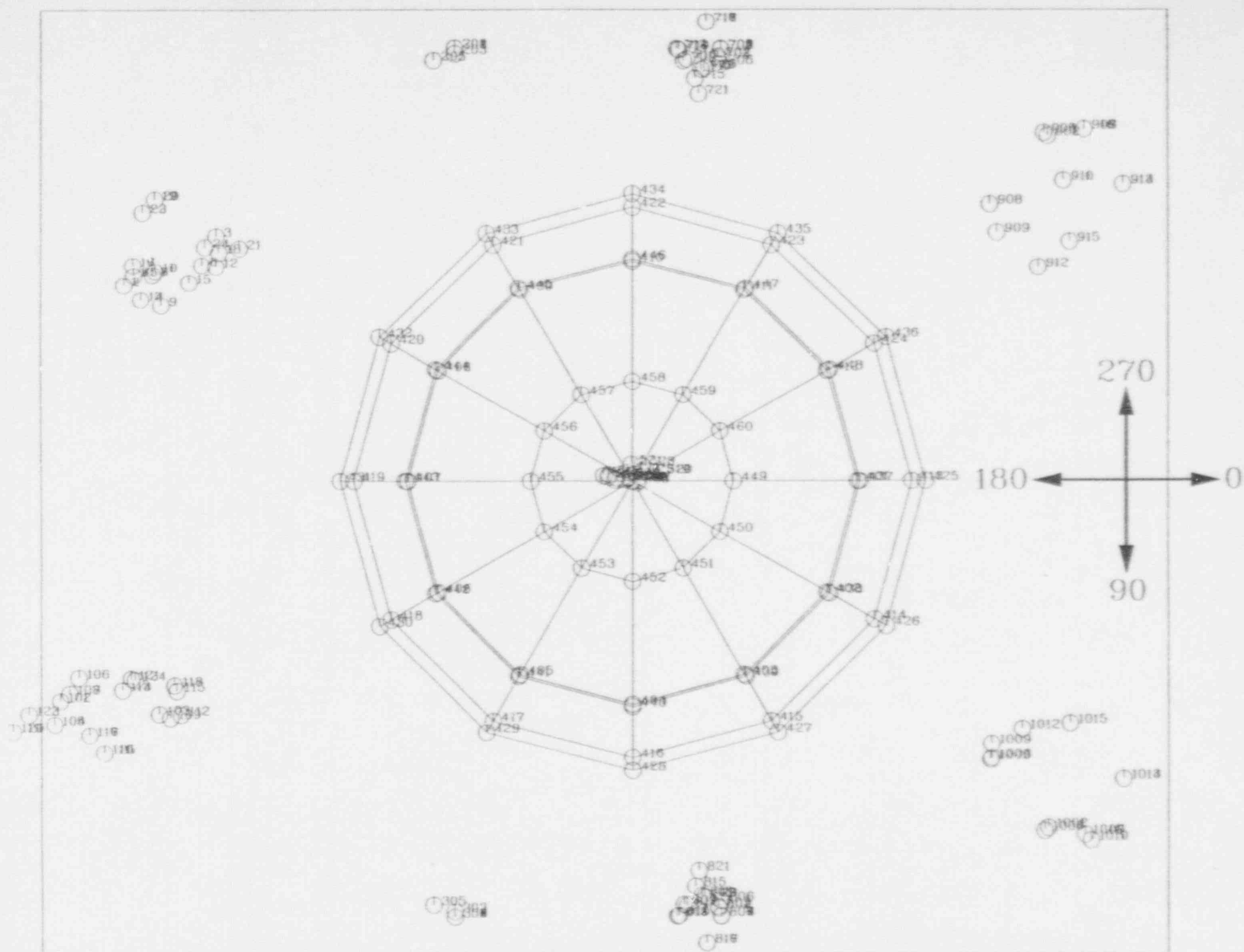
ELEVATION 50+0 BASEMAT



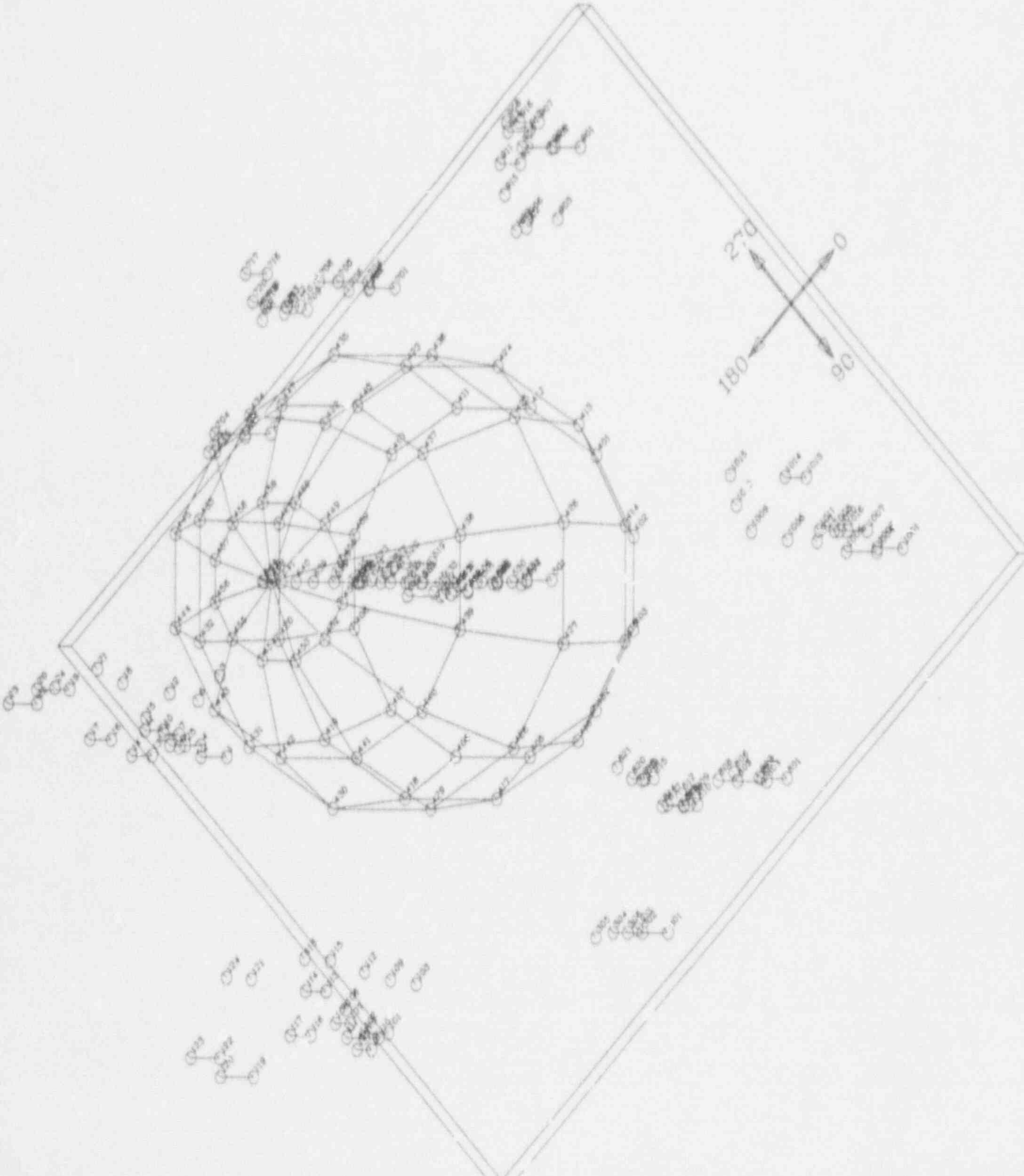
SECTION A
0 - 180

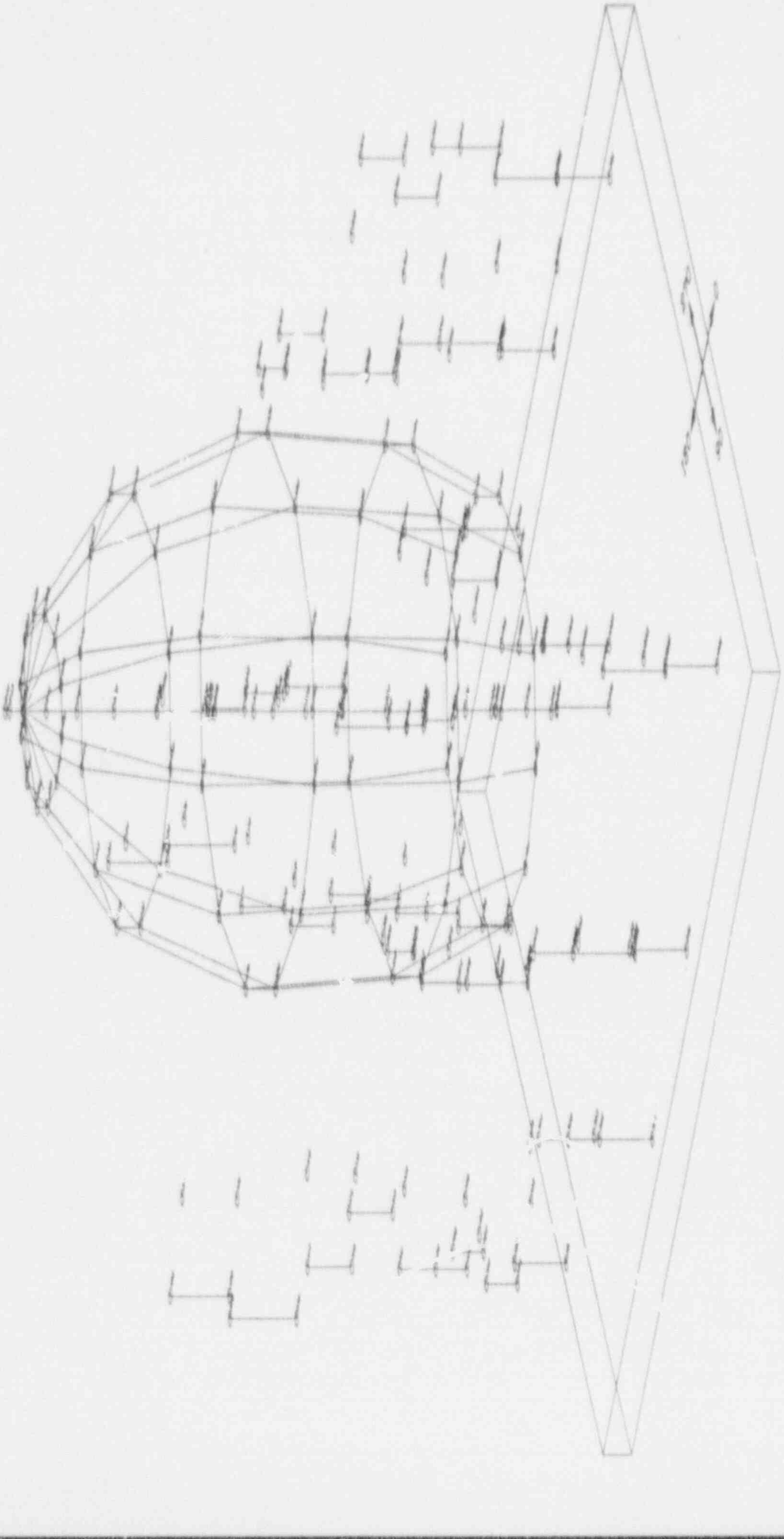


SECTION B
90 - 270



0
90
180
270


270
0
180
90



ANALYSIS METHOD AND GENERATION OF FLOOR RESPONSE SPECTRA

- PRELIMINARY SEISMIC SSI ANALYSIS

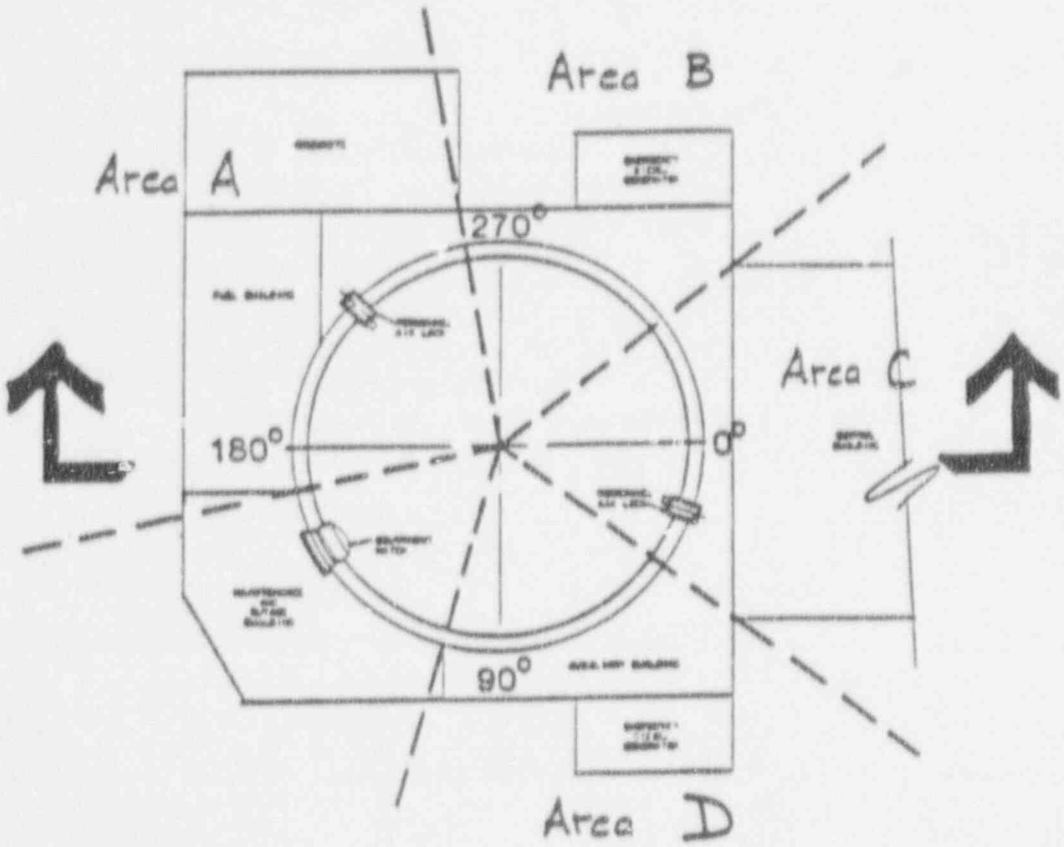
- FINAL SEISMIC SSI ANALYSIS

PRELIMINARY SEISMIC SSI ANALYSIS

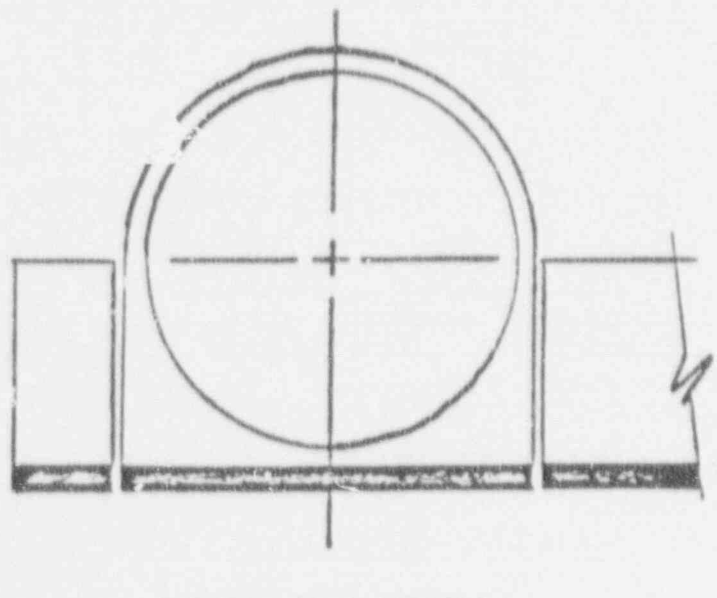
SEISMIC SSI ANALYSIS

- SITE PLAN AND ELEVATION
- ANALYSIS FEATURES
- SASSI METHODOLOGY
  - SITE RESPONSE
  - COMPUTATION OF FOUNDATION IMPEDANCES
  - STRUCTURAL MODEL
  - COMPUTATION OF STRUCTURAL RESPONSE AND GENERATION OF RESPONSE SPECTRA
- ANALYSES CASES
- SSE RESULTS
- OBE RESULTS
- COMMON BASEMAT ANALYSIS
- CORRELATION OF SHAKE WITH SASSI
- UTILIZATION OF SSI RESULTS

SITE PLAN AND ELEVATION



PLAN



TYP. SECTION

ANALYSIS FEATURES

DESIRED FEATURES:

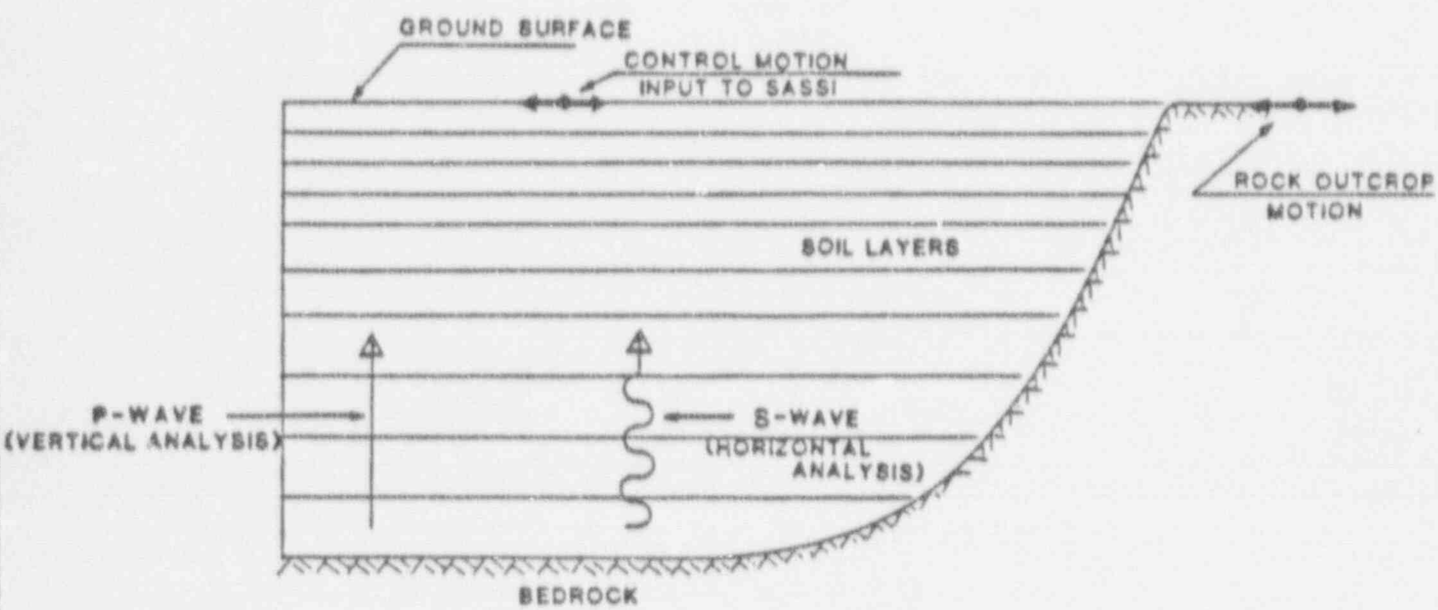
- THREE-DIMENSIONAL ANALYSIS
- EMBEDMENT EFFECTS
- MULTIPLE FOUNDATIONS; EFFECT OF ADJACENT STRUCTURES
- WAVE SCATTERING AND RADIATION DAMPING

SASSI METHODOLOGY

SITE RESPONSE

- SITE CONSISTS OF HORIZONTAL SOIL LAYERS OVERLYING BEDROCK
- HORIZONTAL ANALYSIS: VERTICALLY PROPAGATING S -WAVES

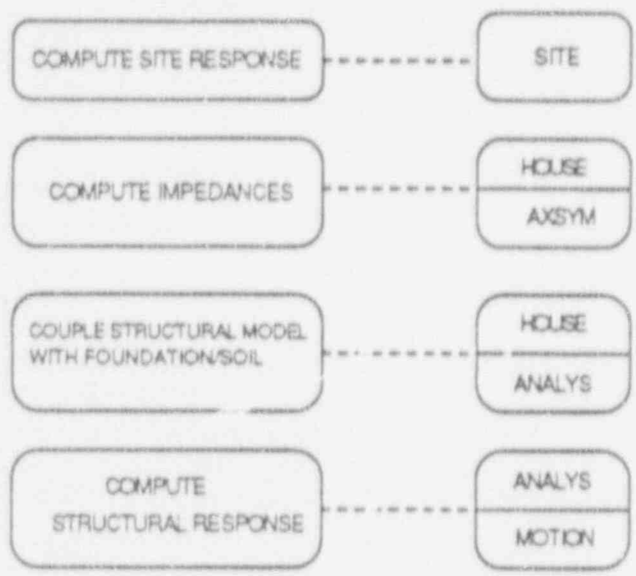
  VERTICAL ANALYSIS: VERTICALLY PROPAGATING P-WAVES
- CONTROL MOTION SPECIFIED AT GROUND SURFACE
- MODULE SITE

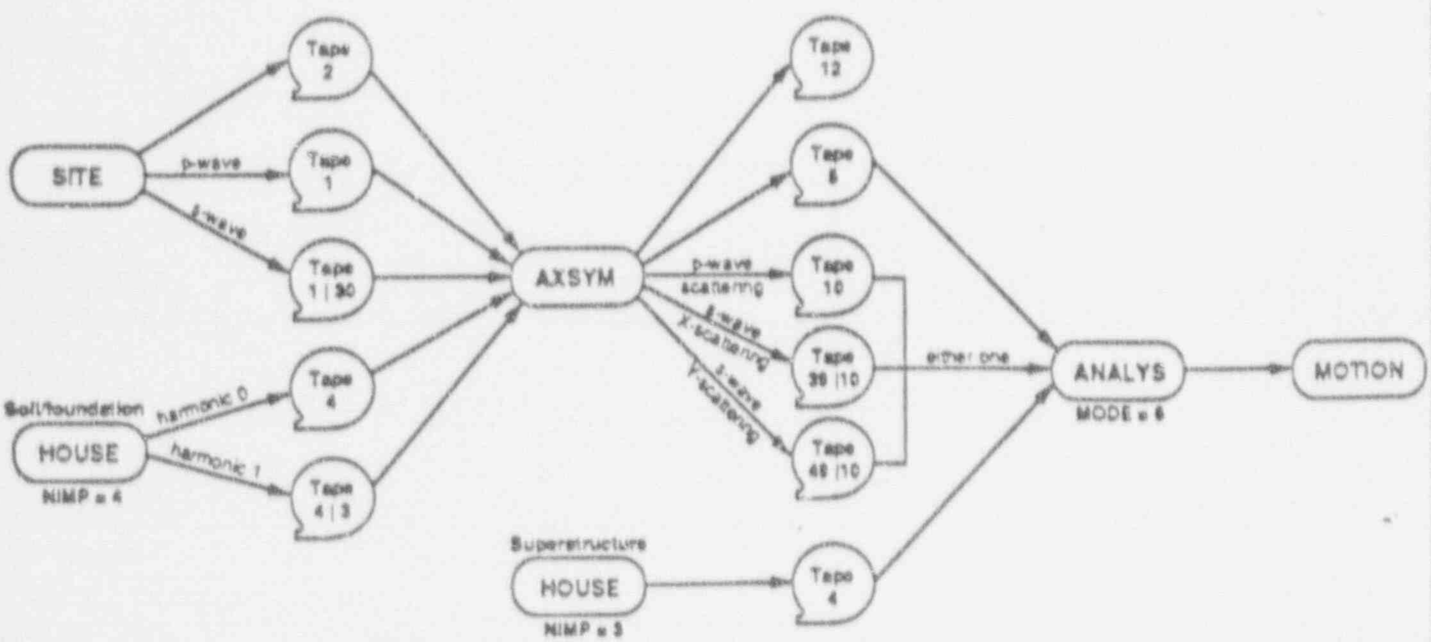


SASSI METHODOLOGY

GENERAL SUBSTRUCTURING APPROACH FORMULATED IN THE FREQUENCY DOMAIN USING COMPLEX RESPONSE AND FINITE ELEMENT METHOD.

AXISYMMETRIC CAPABILITIES FOR COMPUTATION OF FOUNDATION IMPEDANCES





SASSI METHODOLOGY

COMPUTATION OF FOUNDATION IMPEDANCES

- AXISYMMETRIC MODEL OF REACTOR BUILDING FOUNDATION, FOUNDATION OF ADJACENT BUILDINGS AND NEAR-FIELD SOIL
- AXISYMMETRIC SOLID ELEMENTS CONNECTED TO SEMI-INFINITE LAYERED ZONES REPRESENTED BY AXISYMMETRIC TRANSMITTING BOUNDARIES
- MODULE HOUSE:

  -FORMS STIFFNESS AND MASS MATRICES OF FOUNDATIONS, NEAR-FIELD SOIL

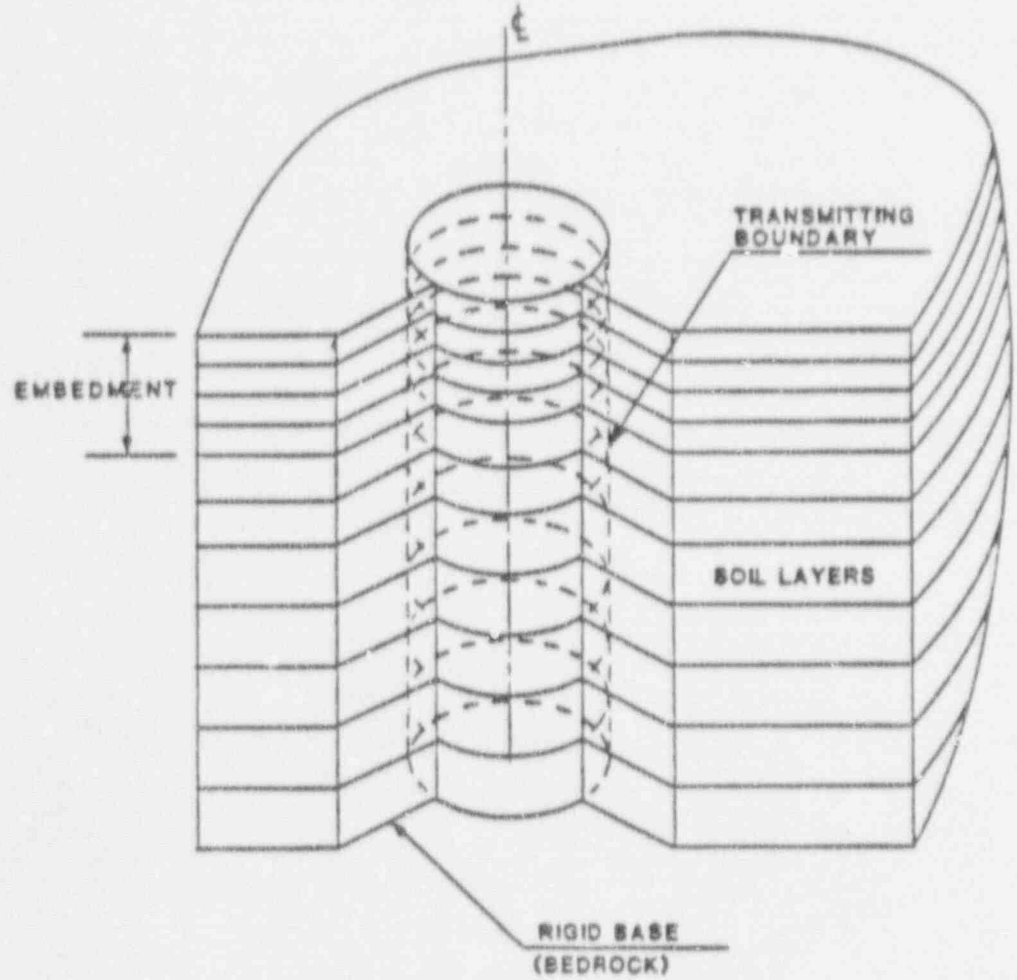
- MODULE AXSYS:

  -FORMS TOTAL STIFFNESS OF COMPLETE FOUNDATION/SOIL SYSTEM

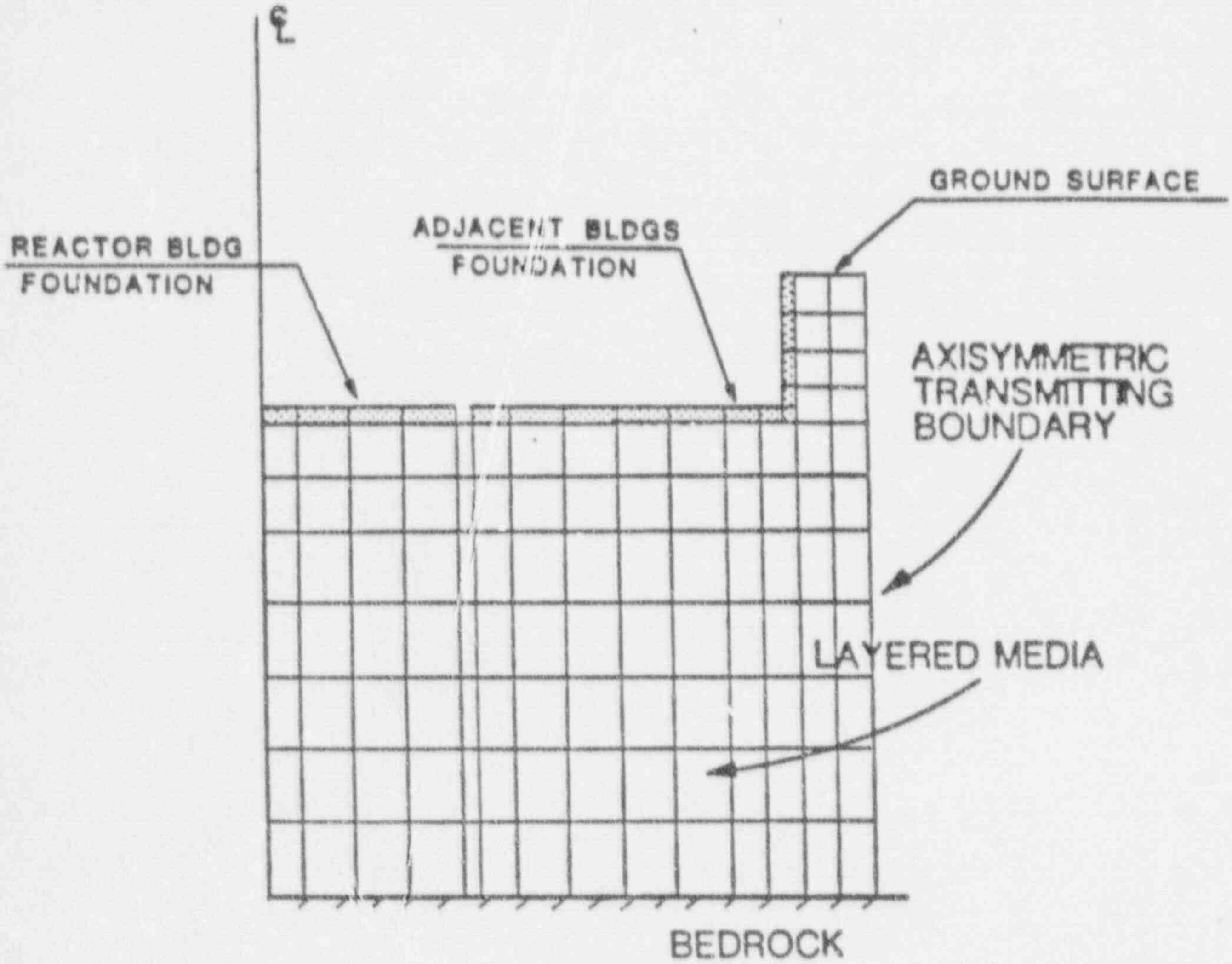
  -COMPUTES DYNAMIC FLEXIBILITY MATRIX AND SCATTERING PROPERTIES

  -INVERTS DYNAMIC FLEXIBILITY MATRIX TO OBTAIN IMPEDANCES

  -TRANSFORMS IMPEDANCES TO CARTESIAN COORDINATES



Axisymmetric Transmitting Boundaries for Impedance Analysis

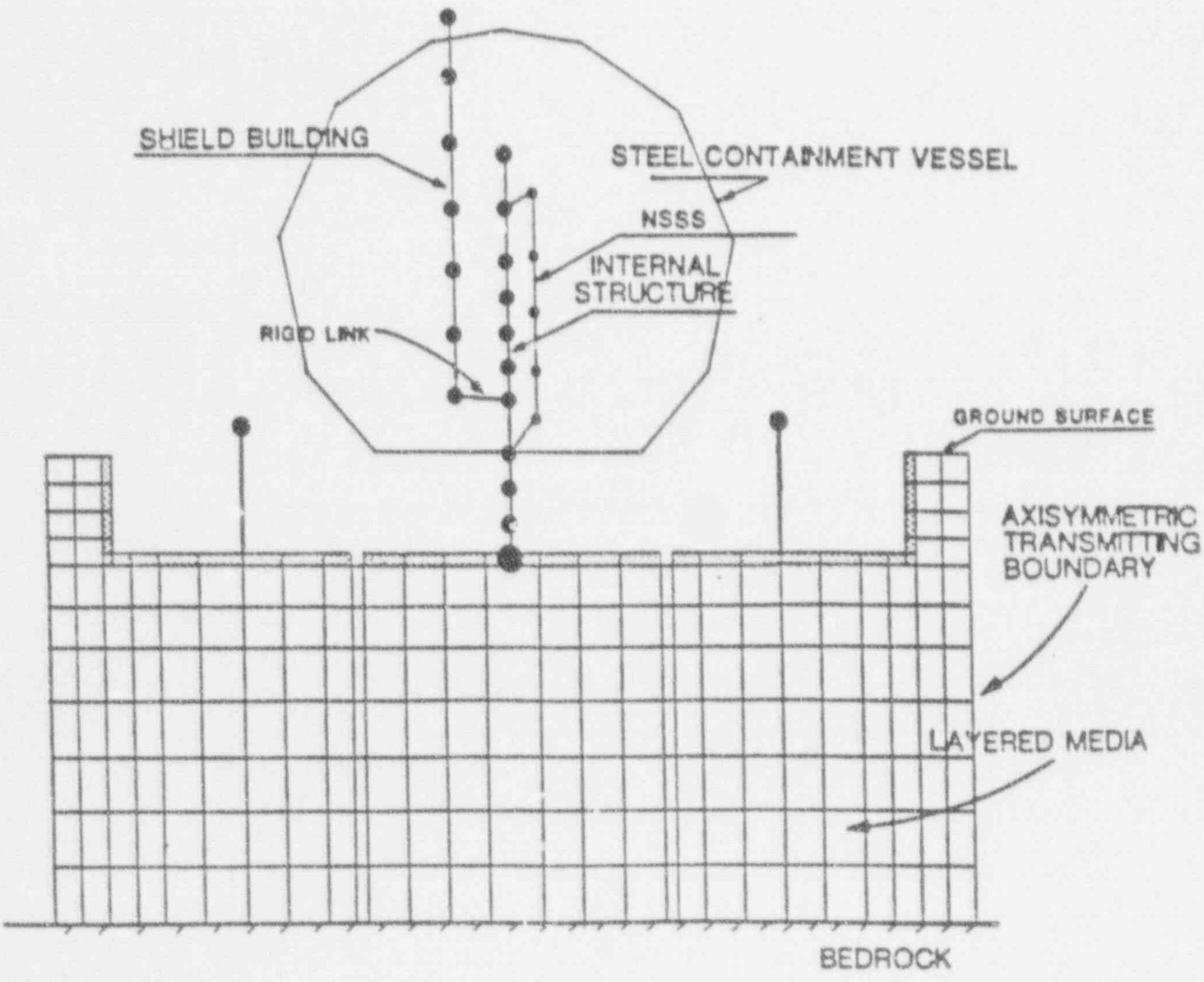


Axisymmetric Finite Element Mesh for the Near-Field Soil and Foundations

SASSI METHODOLOGY

STRUCTURAL MODEL

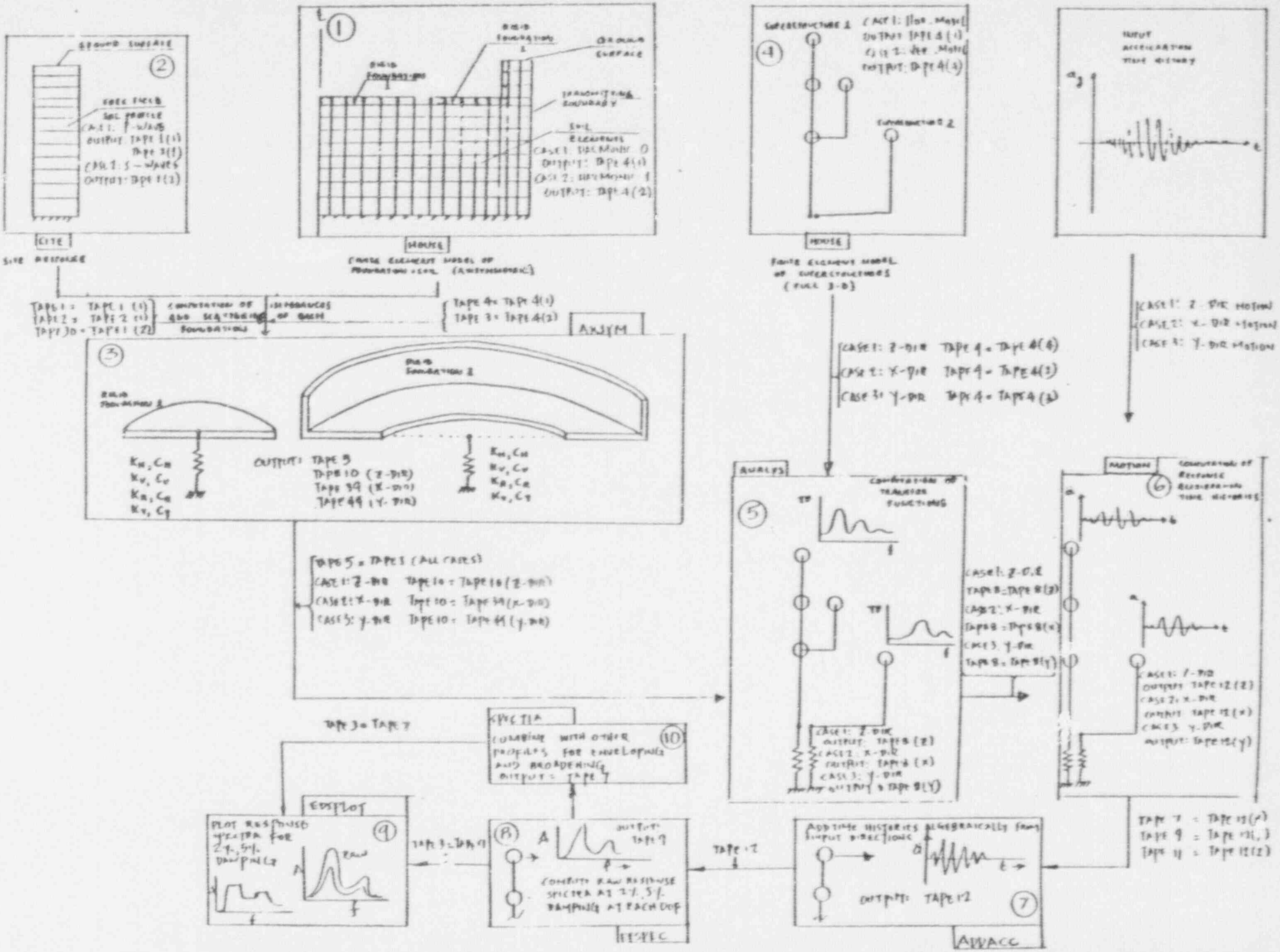
- STICK MODEL OF SCV, SB, IS AND NSSS MODEL
- STICK MODEL OF ADJACENT BUILDINGS
- NSSS MODEL ATTACHED TC STICK MODEL OF INTERNAL STRUCTURE
- MODULE HOUSE FORMS STIFFNESS AND MASS MATRICES OF BUILDING STICK MODELS AND NSSS MODEL



SASSI METHODOLOGY

COMPUTATION OF STRUCTURAL RESPONSE

- USE SOIL IMPEDANCES, MASS AND STIFFNESS MATRICES OF STICK & NSSS MODELS
- GENERATE TRANSFER FUNCTIONS AT SELECTED LOCATIONS
- PERFORM INTERPOLATION OF TRANSFER FUNCTIONS OVER FREQUENCY RANGE OF ANALYSIS.
- COMPUTE FFT OF CONTROL MOTION. MULTIPLY FFT OF CONTROL MOTION WITH TRANSFER FUNCTION. RETURN TO TIME DOMAIN THROUGH INVERSE FFT.
- GENERATE RESPONSE ACCELERATION TIME HISTORIES
- COMPUTE RESPONSE SPECTRA.



GROUND SURFACE
SITE
HOUSE
SUPERSTRUCTURE 1
SUPERSTRUCTURE 2
INPUT ACCELERATION TIME HISTORY
TRANSMITTING BOUNDARY
SOIL ELEMENTS
CASE 1: HARMONIC 0
CASE 2: HARMONIC 1
OUTPUT: TAPE 4 (2)
AXSYM
OUTPUT: TAPE 3
TAPE 10 (Z-DIR)
CASE 1: Z-DIR MOTION
CASE 2: X-DIR MOTION
CASE 3: Y-DIR MOTION
CASE 1: Z-DIR TAPE 4 = TAPE 4 (1)
CASE 2: X-DIR TAPE 4 = TAPE 4 (2)
CASE 3: Y-DIR TAPE 4 = TAPE 4 (3)
TAPE 5 = TAPE 3 (ALL CASES)
ANALYS
MOTION
TAPE 3 = TAPE 7
SPECTRA
COMBINE WITH OTHER PROFILES FOR ENVELOPING AND BROADENING
OUTPUT: TAPE 7
EDSPLOT
PLOT RESPONSE SPECTRA FOR 2%, 5% DAMPING
COMPUTE RAW RESPONSE SPECTRA AT 2%, 5% DAMPING AT EACH DOF
RESPEC
ADD TIME HISTORIES ALGEBRAICALLY FROM INPUT DIRECTIONS
OUTPUT: TAPE 12
ADDACC

ANALYSIS CASES

SEISMIC SSI ANALYSIS CASES

CASE	SSE	OBE
Fixed-Base	Yes	Yes
B1	Yes	No
B1.5	Yes	No
B2	Yes	No
B3.5	Yes	Yes
B4	Yes	Yes
C1	Yes	No
C1.5	Yes	No
C2	Yes	No
C3	Yes	No

SSE RESULTS

STRUCTURE	ELEV. (ft.)	NODE NO.	LOCATION	DIRECTIONS (X=0-180, Y=90-270, Z=Vert)
RB FDTN	50.00	131	Center of foundation	X, Y, Z
SCV	174.37	25	Midheight, 0-180 dir.	X, Y, Z
SCV	174.37	34	Midheight, 90-270 dir.	X, Y, Z
SCV	257.00	61	Top of SCV shell	X, Y, Z
SB	261.88	125	Top of SB shell	X, Y, Z
IS	64.73	141	Second Floor (C.M.)	X, Y, Z
IS	90.25	150	Third Floor (C.M.)	X, Y, Z
IS	91.82	155	SCV Support (C.M.)	X, Y, Z
IS	114.06	169	Fourth Floor (C.M.)	X, Y, Z
IS	142.92	183	Operating Floor (C.M.)	X, Y, Z
IS	207.48	210	Top of Crane Wall (C.M.)	X, Y, Z

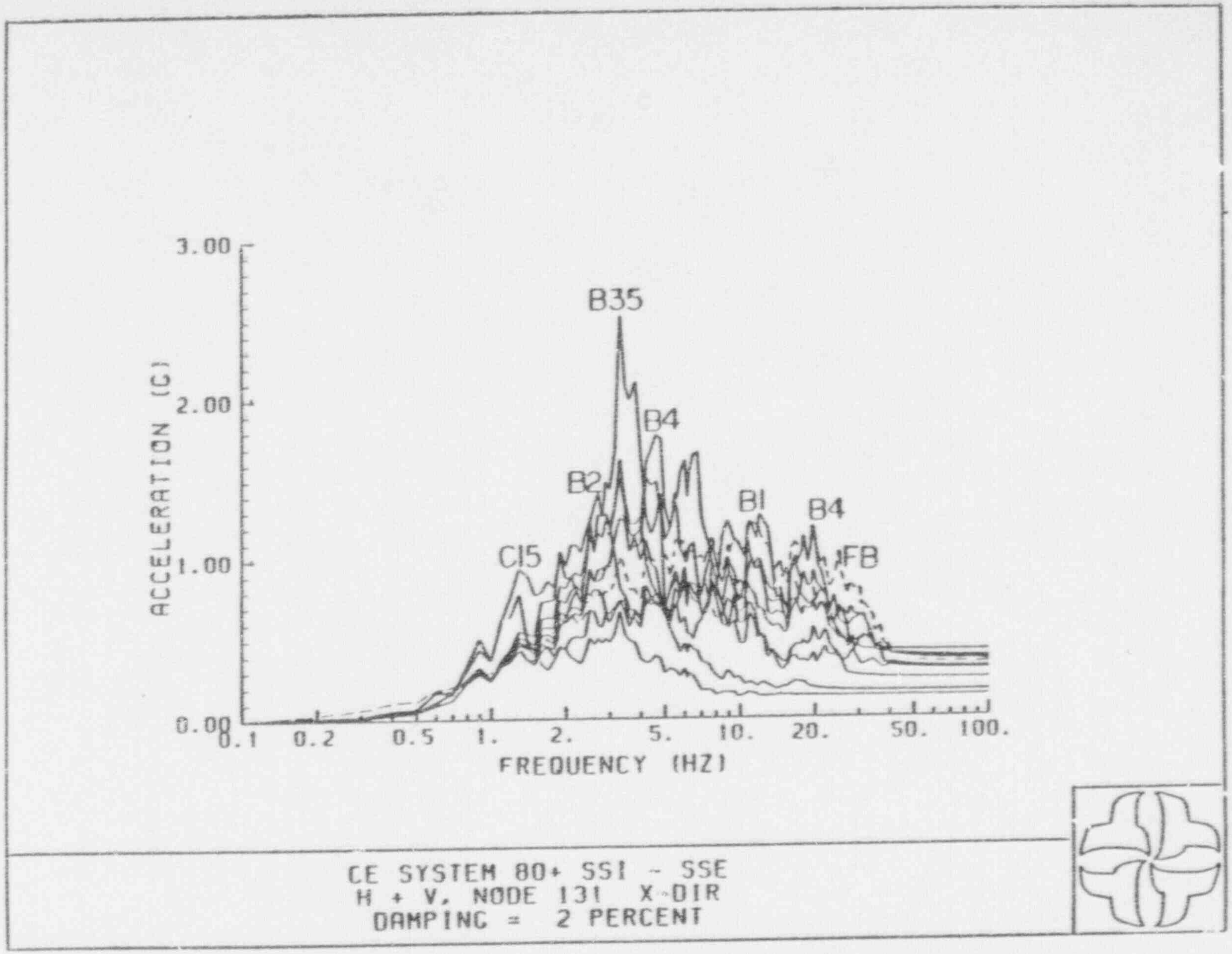


Figure 4.1 - Comparison of 2% Response Spectra
(SSE, RB Fdtn, Node 131, 0-180 Direction)

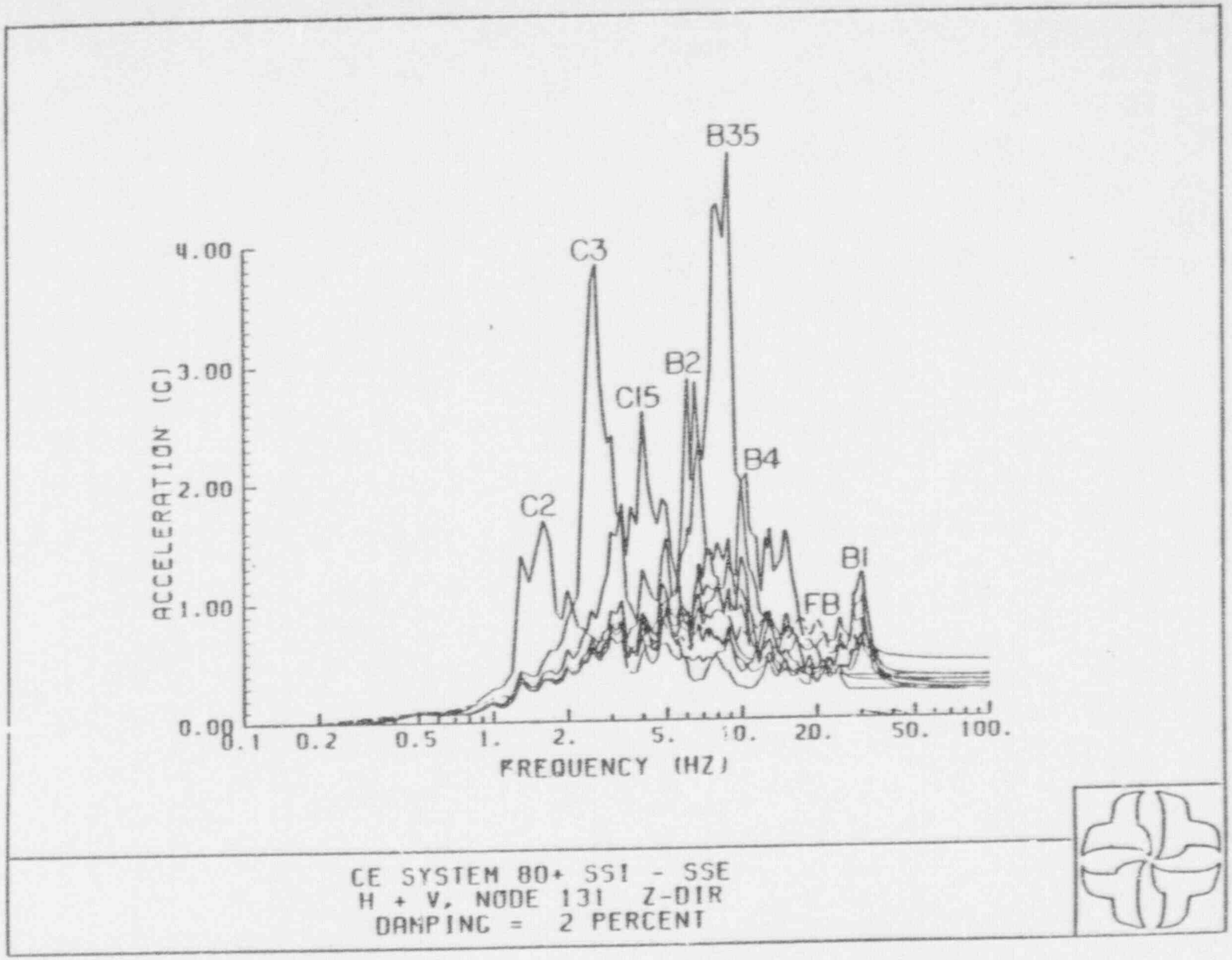


Figure 4.2 - Comparison of 2% Response Spectra
(SSE, RB Fdtn, Node 131, Vertical Direction)

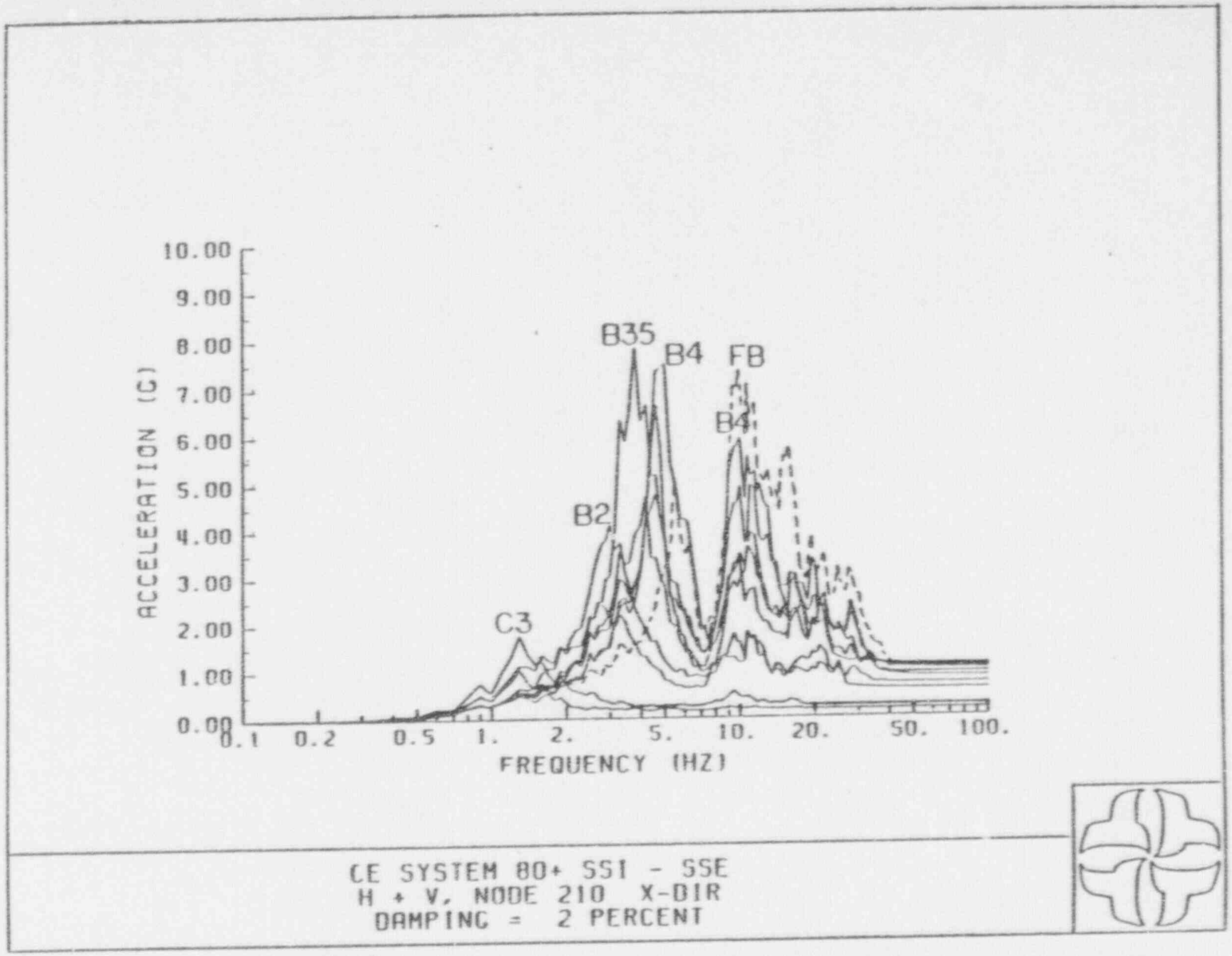


Figure 4.3 - Comparison of 2% Response Spectra
(SSE, IS, Node 210, 0-180 Direction)

SYSTEM 80+™

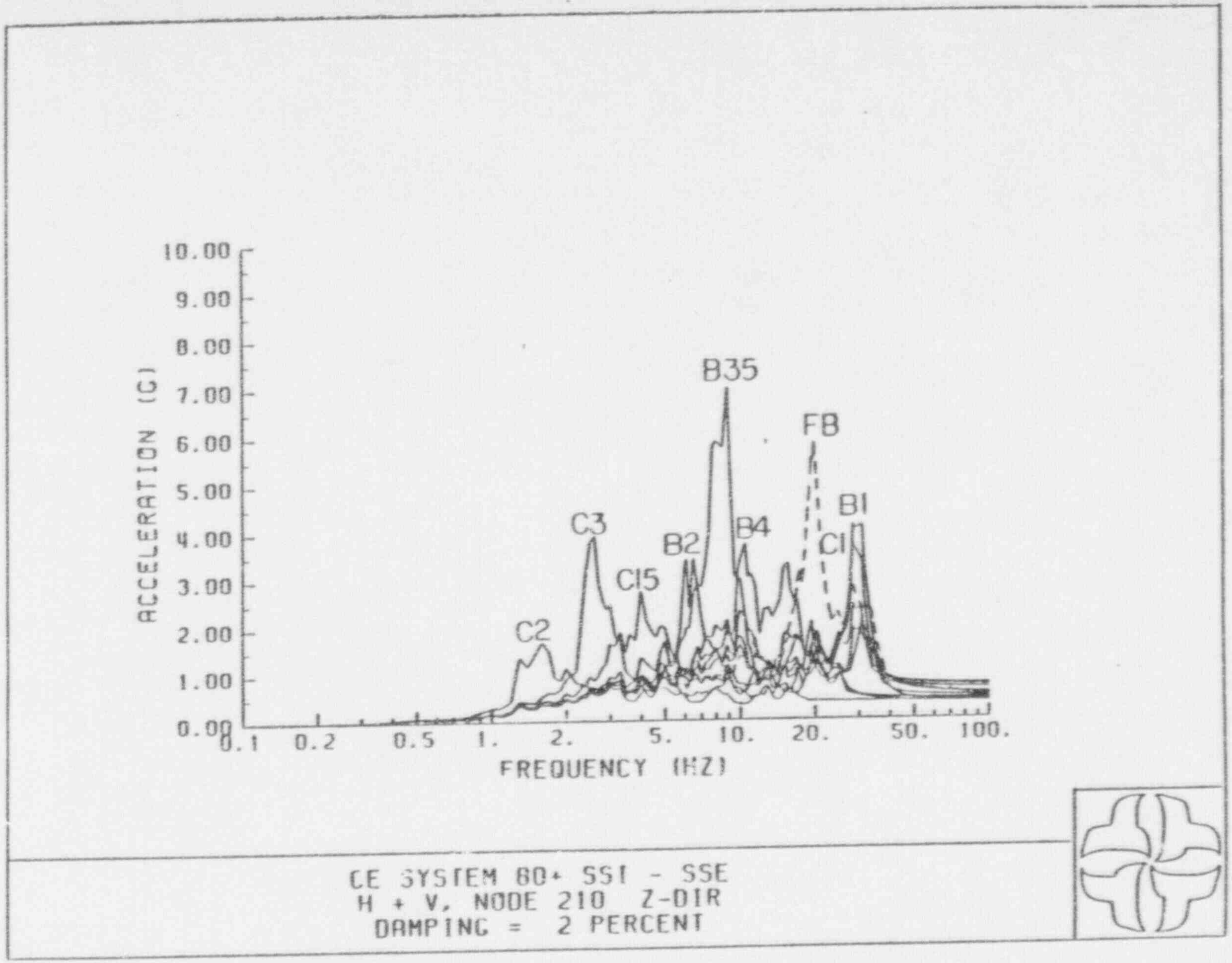


Figure 4.4 - Comparison of 2% Response Spectra
(SSE, IS, Node 210, Vertical Direction)

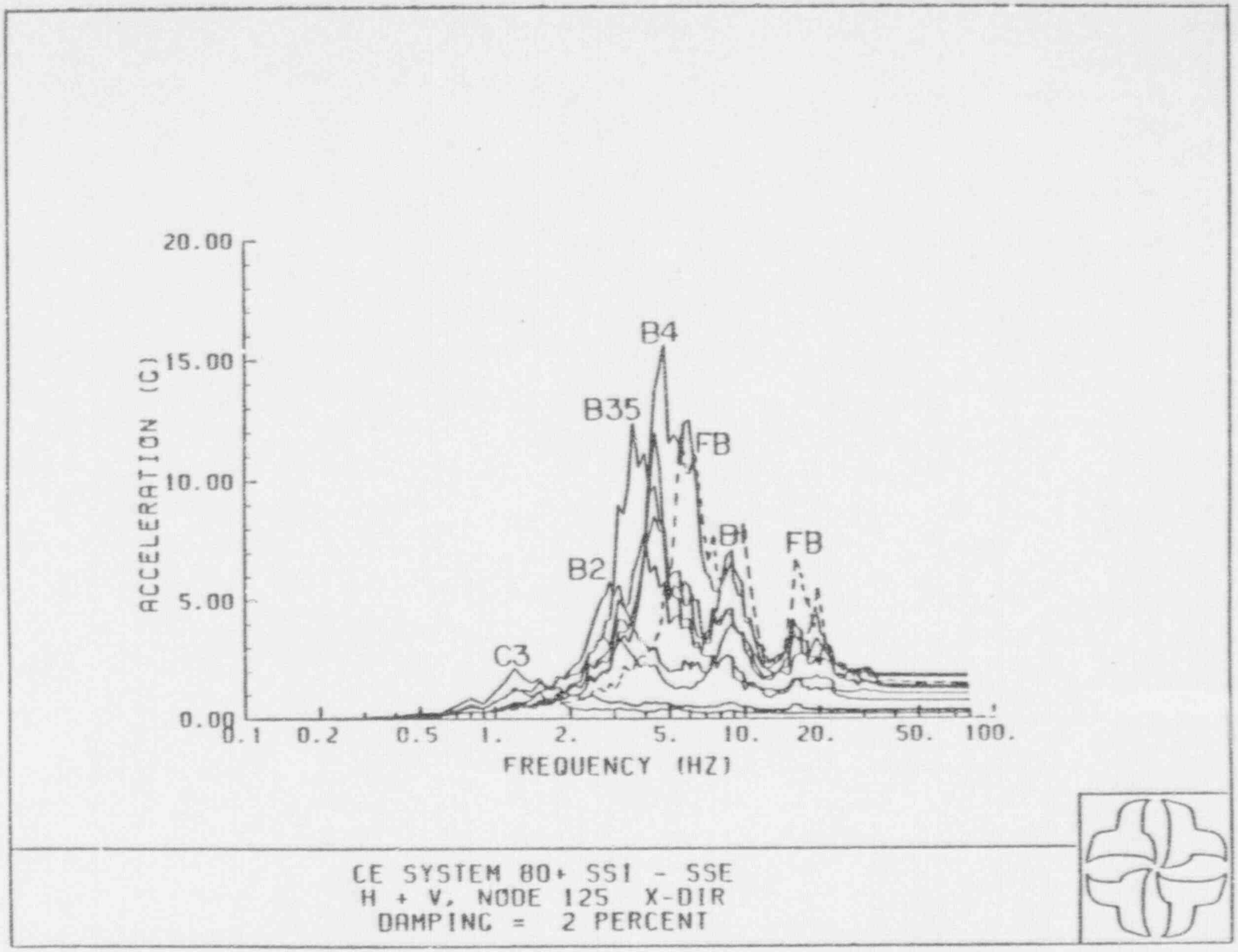


Figure 4.5 - Comparison of 2% Response Spectra
(SSE, SB, Node 125, 0-180 Direction)

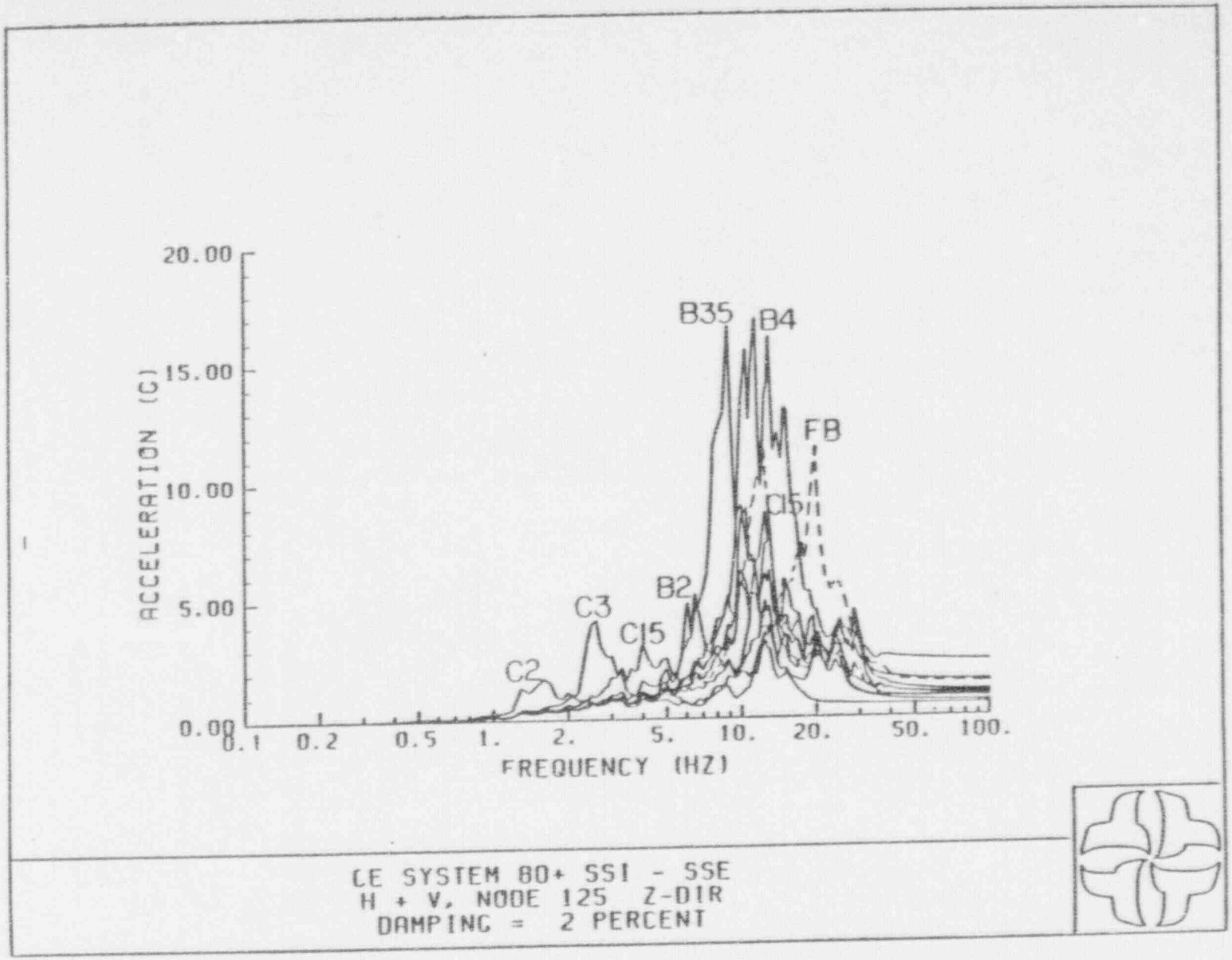


Figure 4.6 - Comparison of 2% Response Spectra
(SSE, SB, Node 125, Vertical Direction)

SYSTEM 80+™

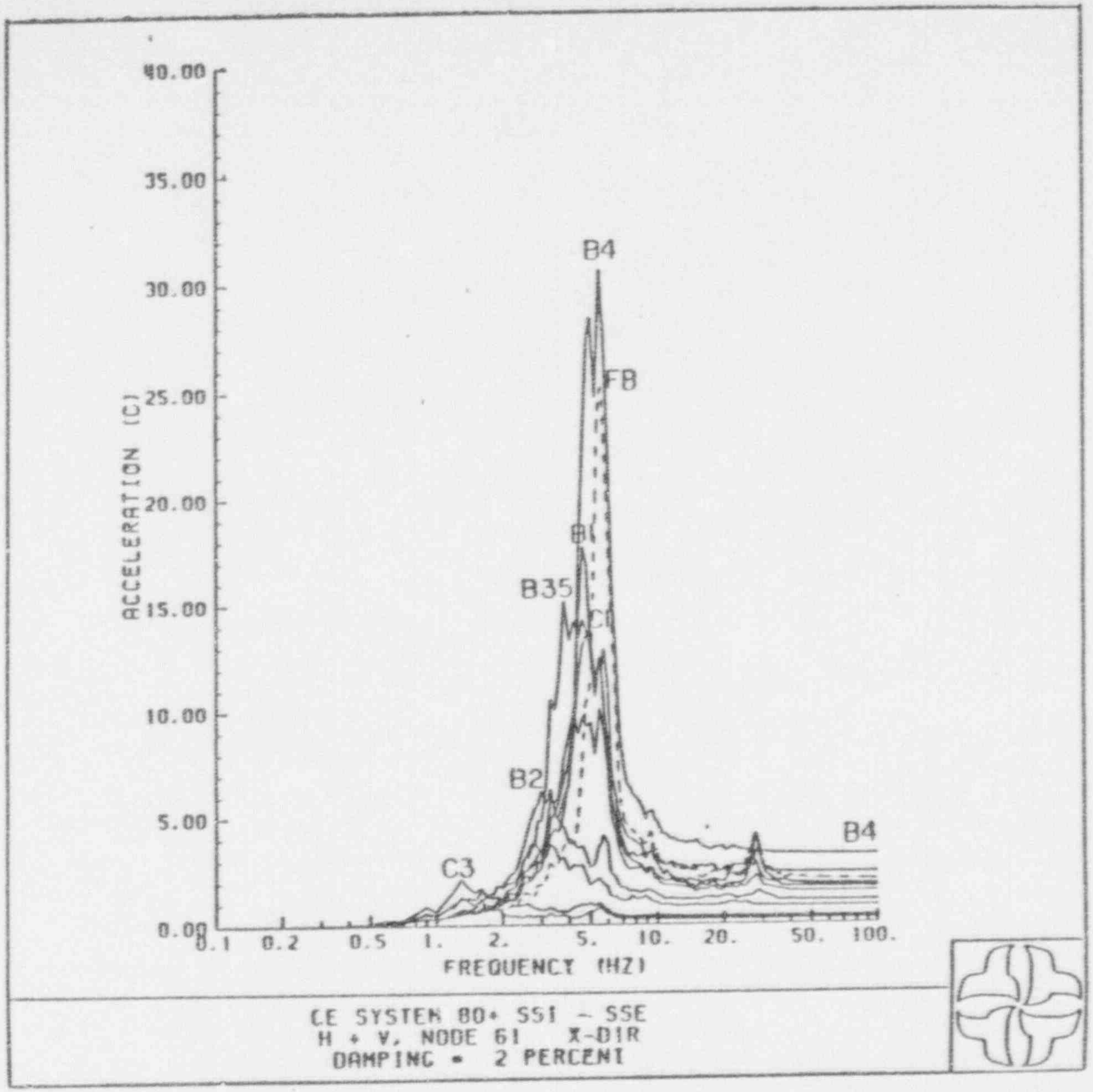


Figure 4.7 - Comparison of 2% Response Spectra
(SSE, SCV, Node 61, 0-180 Direction)

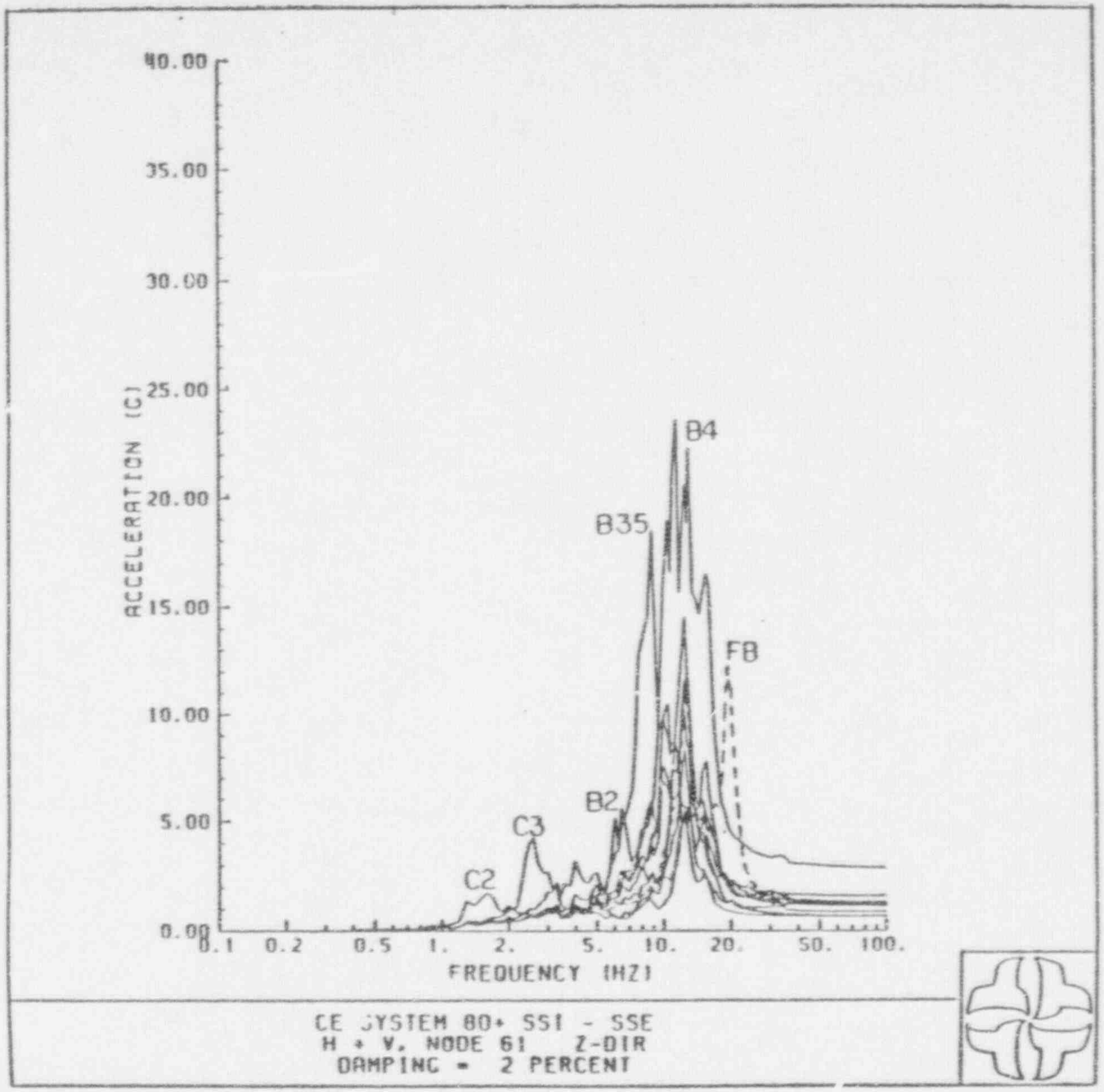


Figure 4.8 - Comparison of 2% Response Spectra
(SSE, SCV, Node 61, Vertical Direction)

OBE RESULTS

APPROACH USED:

- PERFORM OBE ANALYSIS FOR B3.5, B4 AND FIXED-BASE CASES
- COMPUTE RATIOS OF SPECTRA FOR B3.5, B4 AND FB
- SELECT GENERIC SCALING FACTORS TO SCALE SSE SPECTRA

SCALING FACTORS:

Structure	Direction	Factor(s)
PGC Foundation	X, Y, Z	0.4 (all frequencies)
IS (all elevations)	X, Y, Z	0.45 (all frequencies)
SB (all elevations)	X, Y, Z	0.45 (all frequencies)
SCV (all elevations)	X, Y	0.40 for frequencies $\leq$ 5 Hz 0.45 for frequencies > 5 Hz
SCV (all elevations)	Z	0.40 for frequencies $\leq$ 10 Hz 0.65 for frequencies > 10 Hz

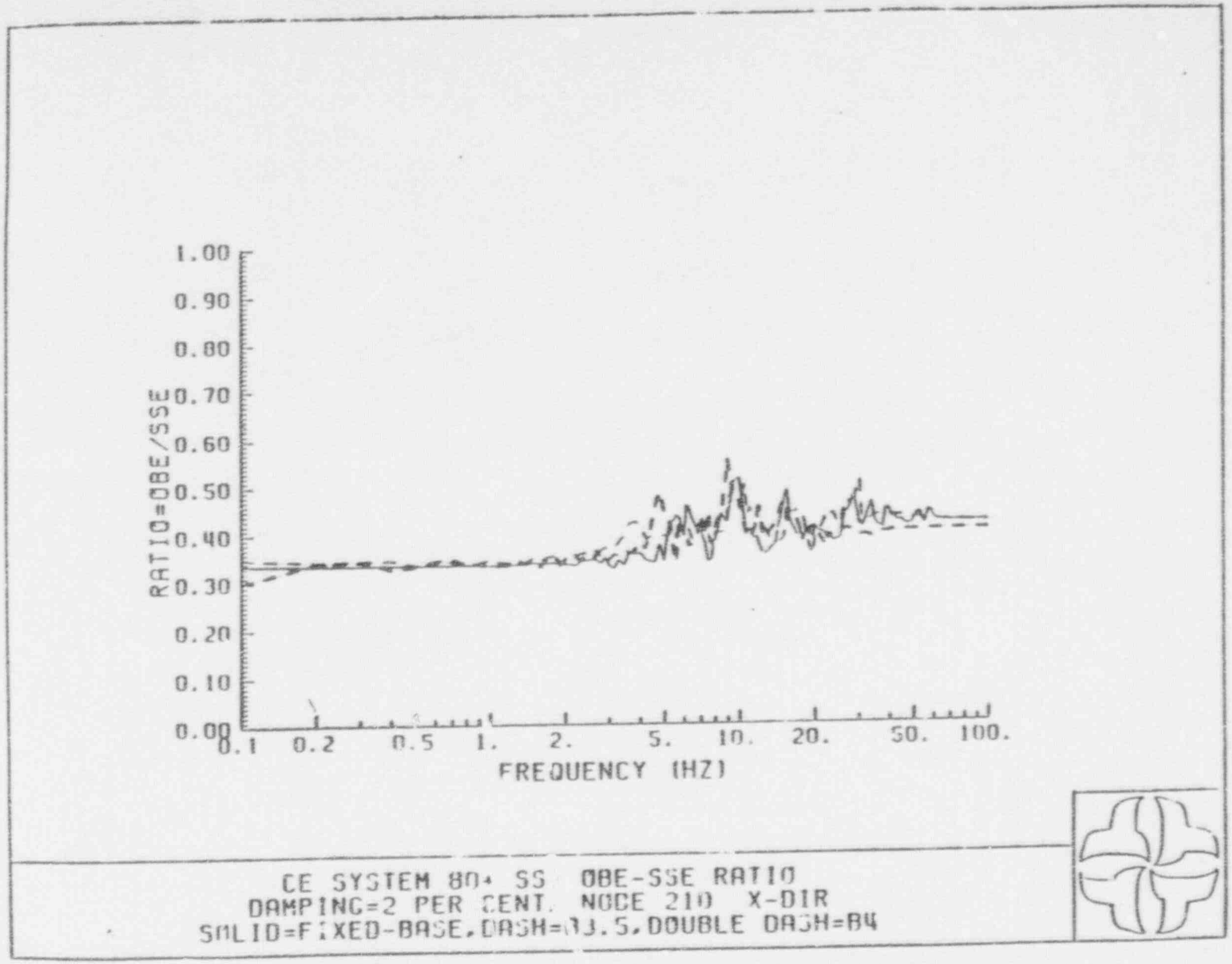
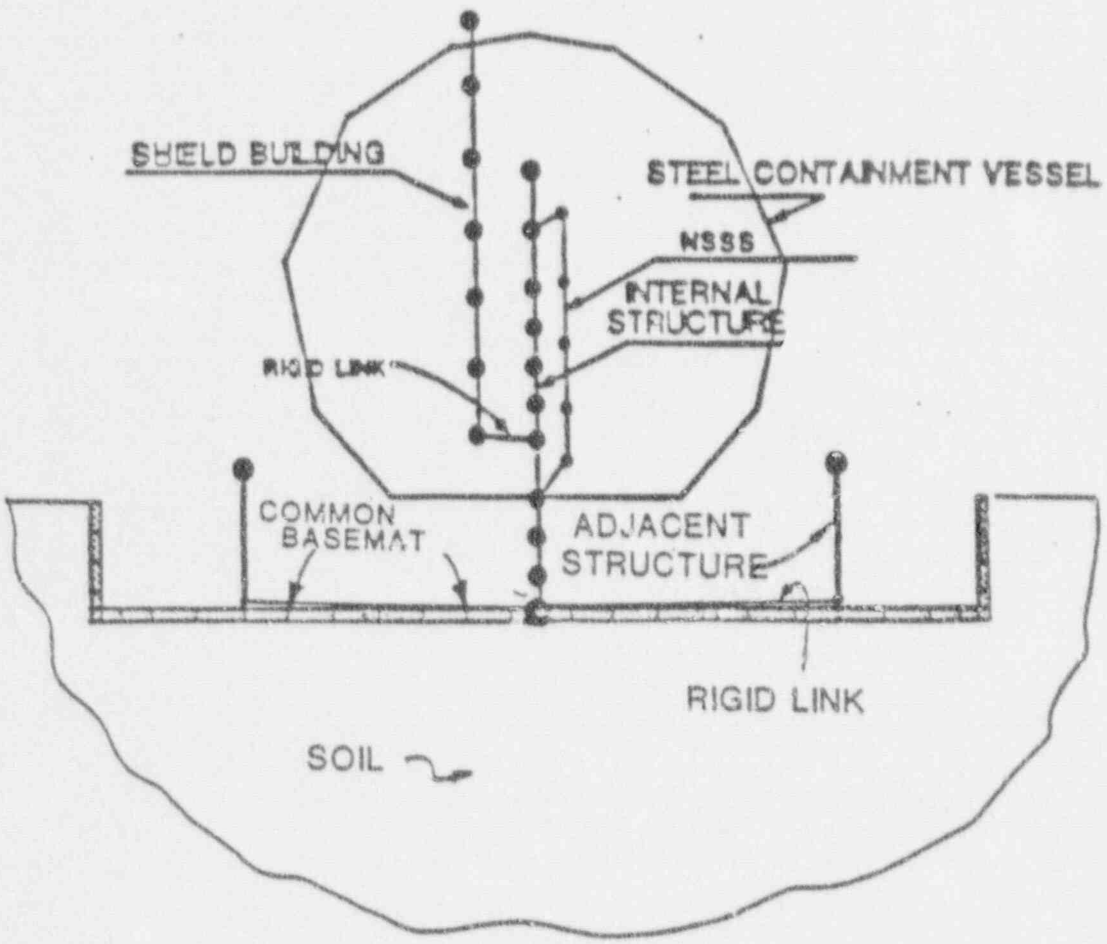
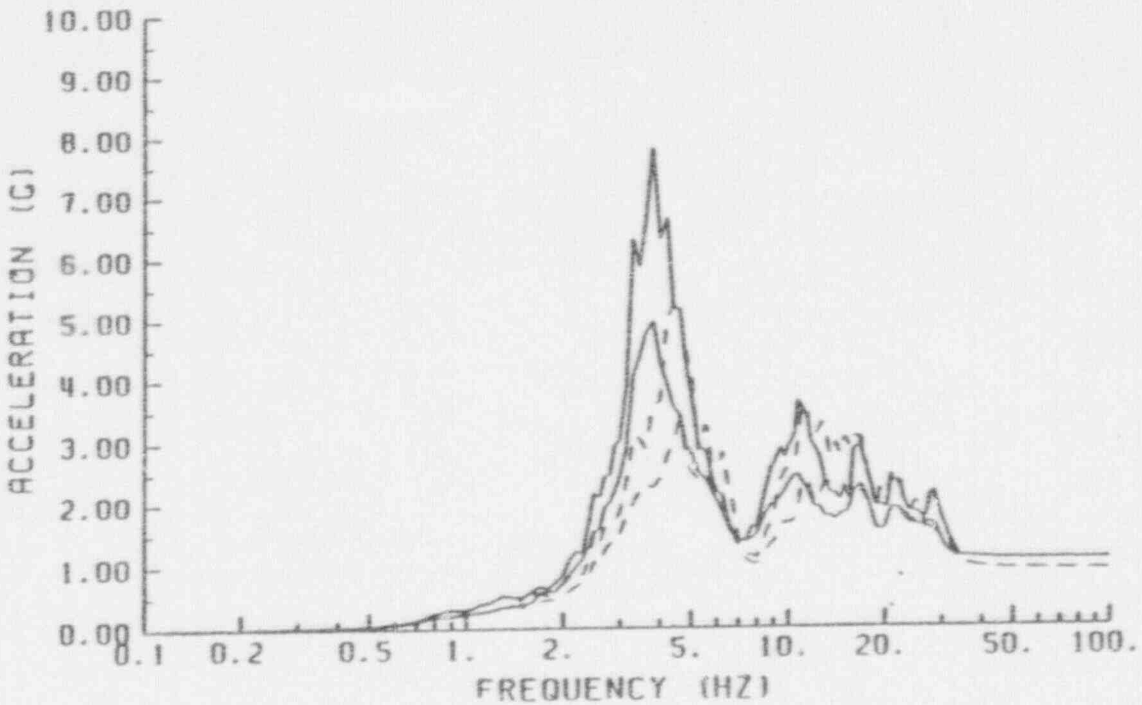


Figure 4.12 - OBE/SSE Spectral Ratio for 2% damping
(IS, Node 210, 0-180 Direction)

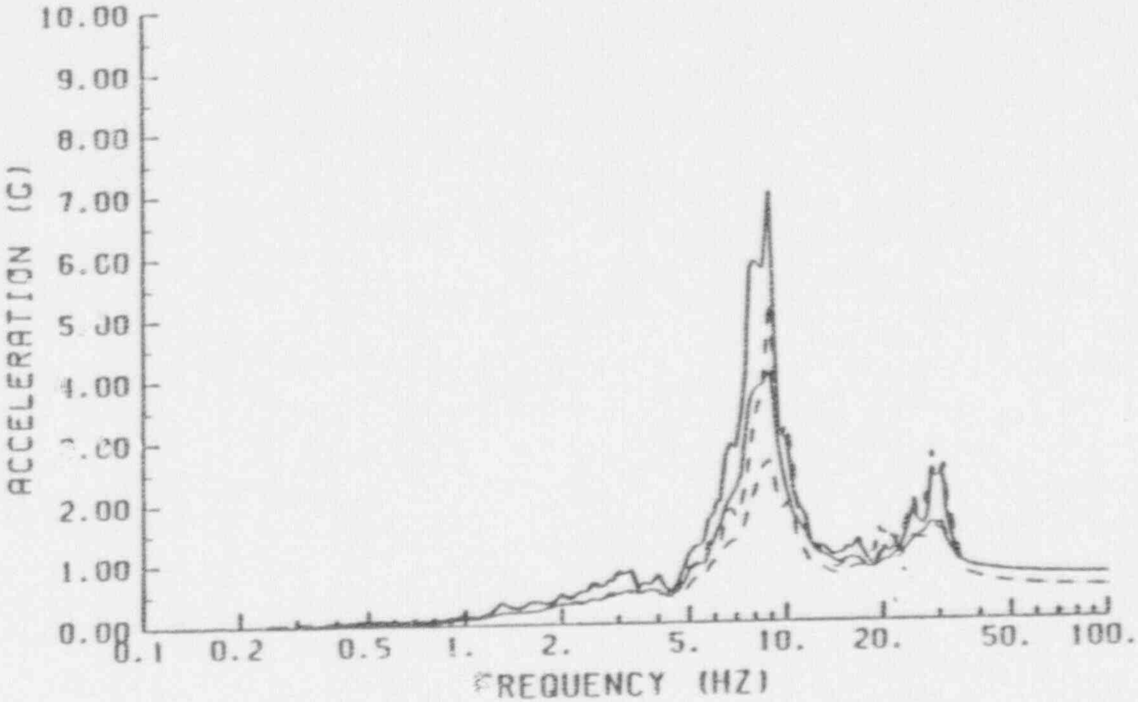
COMMON BASEMAT ANALYSIS



Schematic Representation of PGC Model with Common Basemat

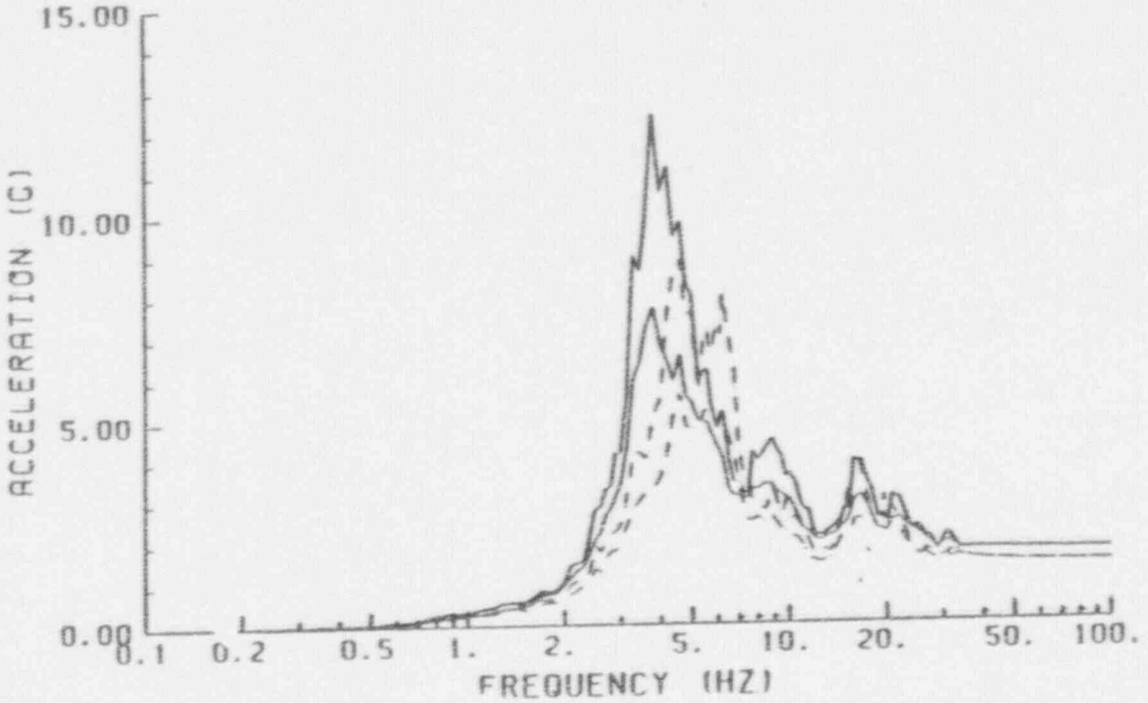


CE SYSTEM 80+ SSI B35 SOIL - SSE
NODE 210 X-DIR, DAMP. = 2 AND 5 PERCENT
DASHED=COM. BSMT., SOLID=DUAL FNDTN.

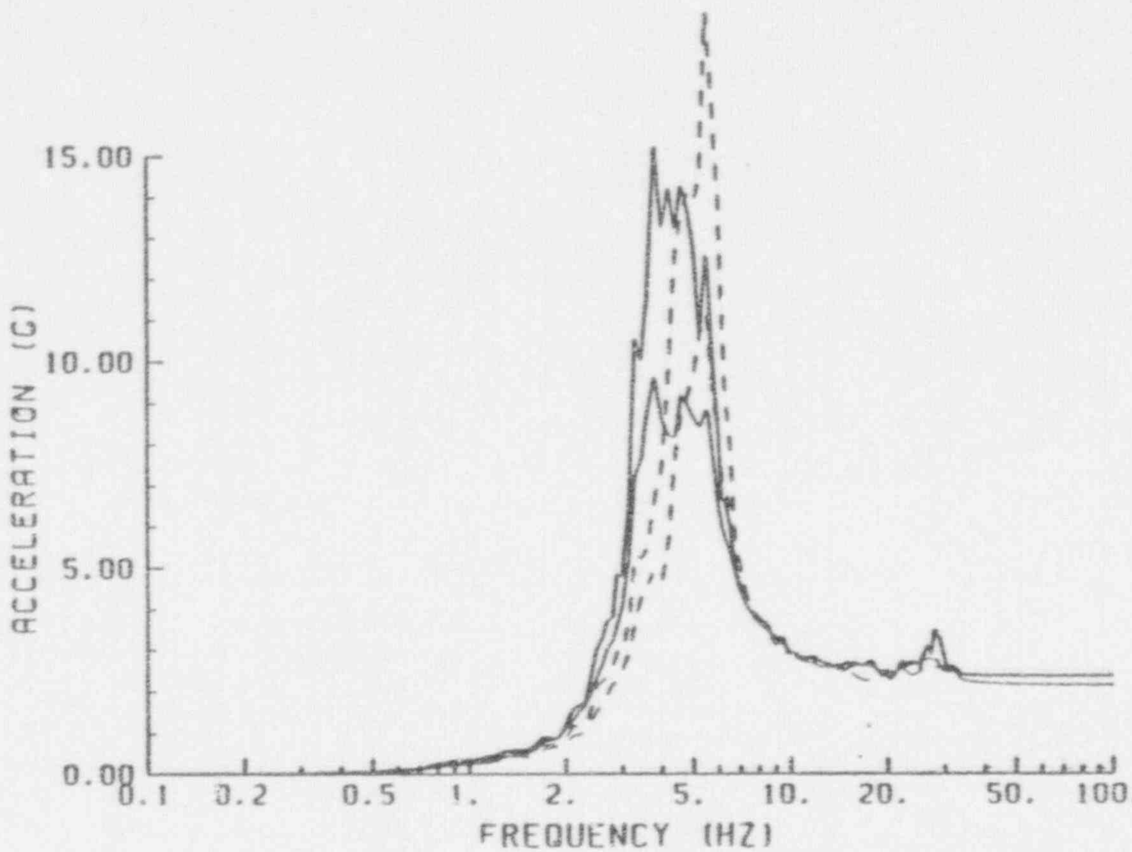


CE SYSTEM 80+ SSI B35 SOIL - SSE
NODE 210 Z-DIR. DAMP. = 2 AND 5 PERCENT
DASHED=COM. BSMT., SOLID=DUAL FNDTN.

SYSTEM 80+™



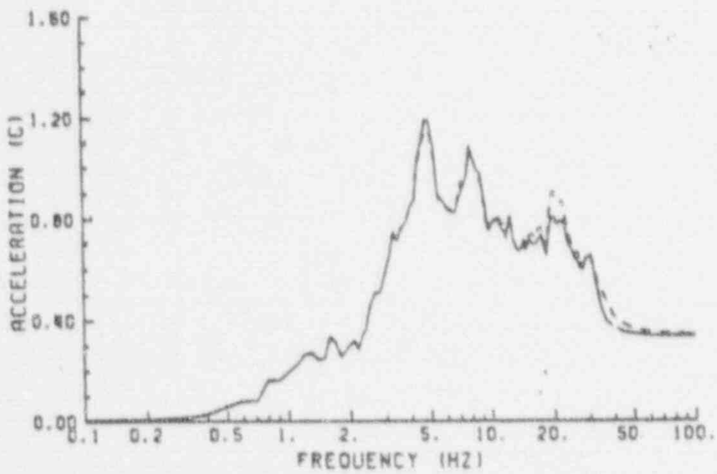
CE SYSTEM 80+ SSI B35 SOIL - SSE
NODE 125 X-DIR. DAMP.= 2 AND 5 PERCENT
DASHED=COM. BSMT., SOLID=DUAL FNDTN.



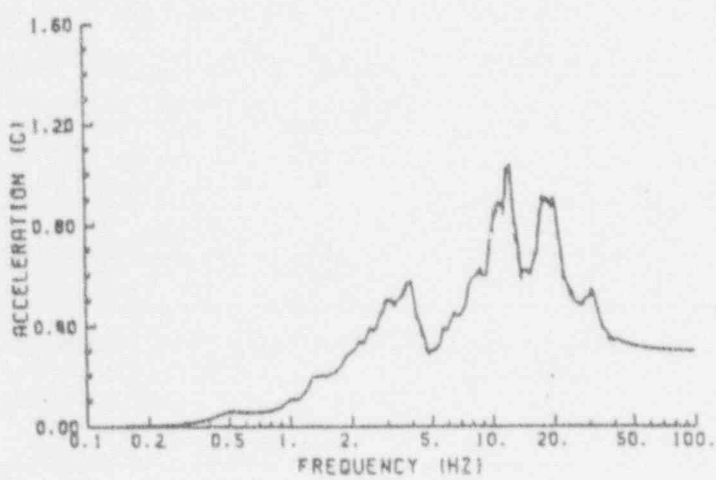
CE SYSTEM 80+ SSI B35 SOIL - SSE
NODE 61 X-DIR, DAMP.= 2 AND 5 PERCENT
DASHED=COM. BSMT., SOLID=DUAL FNDTN.

CORRELATION OF SHAKE WITH SASSI

FREE FIELD RESPONSE



CE SYSTEM 80+ SSI B35 SOIL MODEL - SSE
FOUNDATION MOTION AT ELEV 40 FT - Y DIR, 5 P.C. DAMPING
SOLID=SASSI, DASH=SHAKE



CE SYSTEM 80+ SSI B35 SOIL MODEL - SSE
FOUNDATION MOTION AT ELEV 40 FT - Z DIR, 5 P.C. DAMPING
SOLID=SASSI, DASH=SHAKE

UTILIZATION OF SSI RESULTS

- OBTAIN MAXIMUM INTERNAL FORCES OF EACH BEAM ELEMENT IN THE STICK MODEL.

  APPLY MAXIMUM FORCES TO CORRESPONDING ISOLATED FLOOR SECTION OF DETAILED FINITE ELEMENT MODEL. COMPUTE INDIVIDUAL MEMBER FORCES.

- USE SPECTRA FROM EACH CASE TO DESIGN SCV AND INTERNAL REACTOR BUILDING COMPONENTS.

- NSSS ANALYSIS: OBTAIN RESPONSE ACCELERATION TIME HISTORIES AT ATTACHMENT POINTS OF NSSS ON REACTOR BUILDING.

  PERFORM TIME-HISTORY ANALYSES OF DETAILED NSSS MODEL (USE THREE BOUNDING CASES FROM SSI ANALYSES).

FINAL SEISMIC SSI ANALYSIS

- SITE RESPONSE

  (same as in preliminary SSI analysis)

- COMPUTATION OF FOUNDATION IMPEDANCES

  - Single embedded rigid foundation with final geometrical configuration (rectangular in shape)

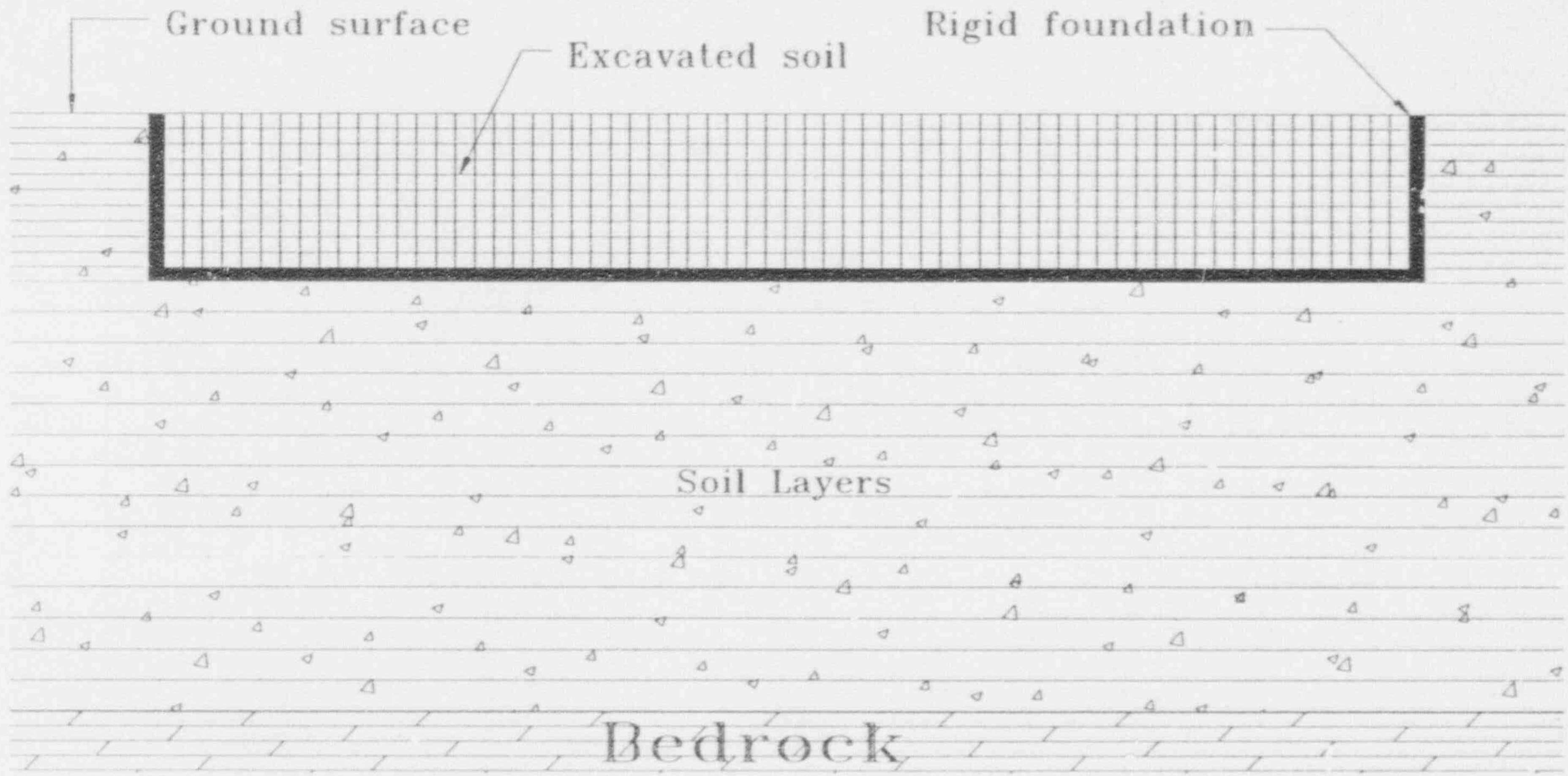
  - SASSI methodology

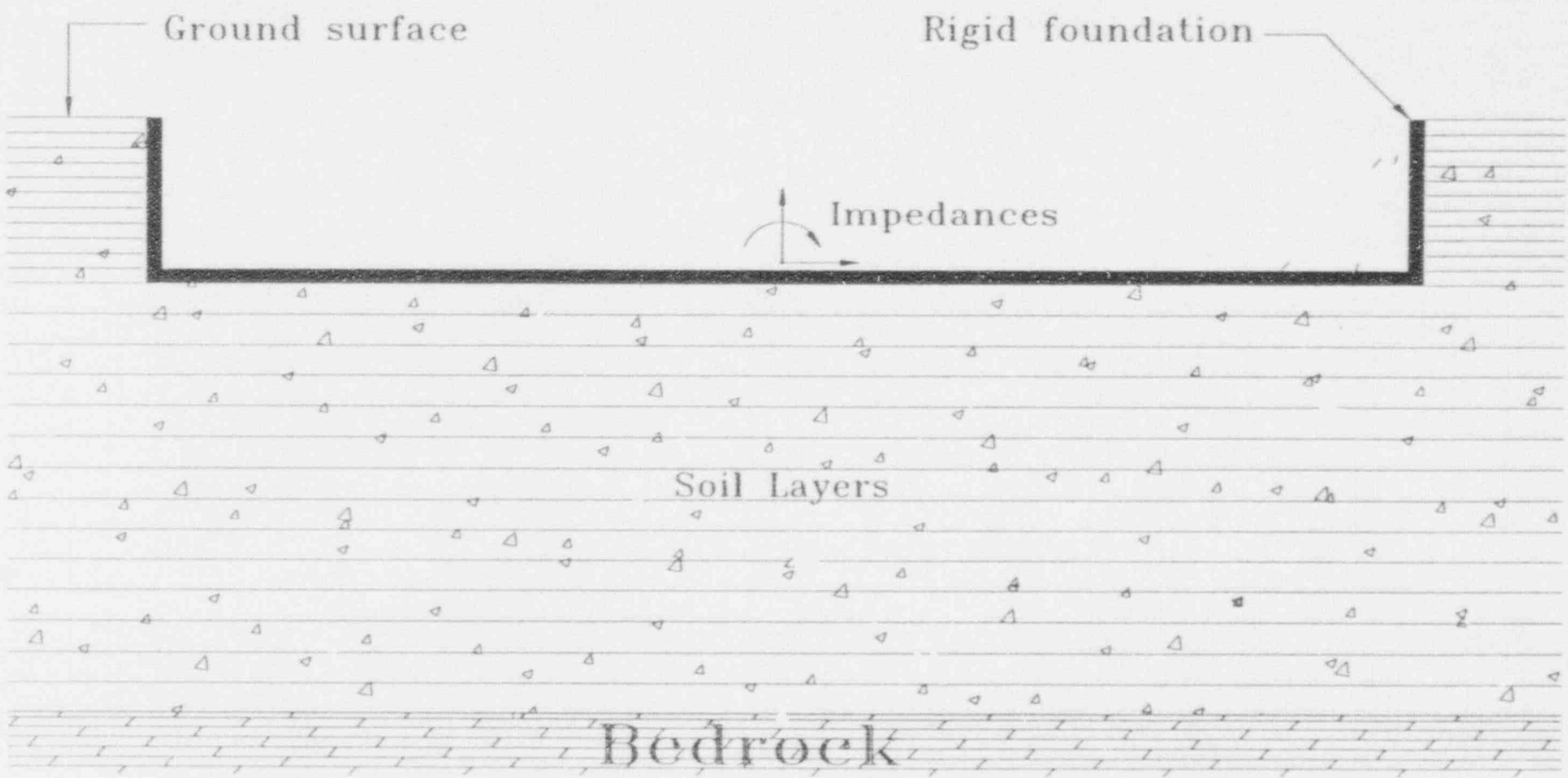
- STRUCTURAL MODEL

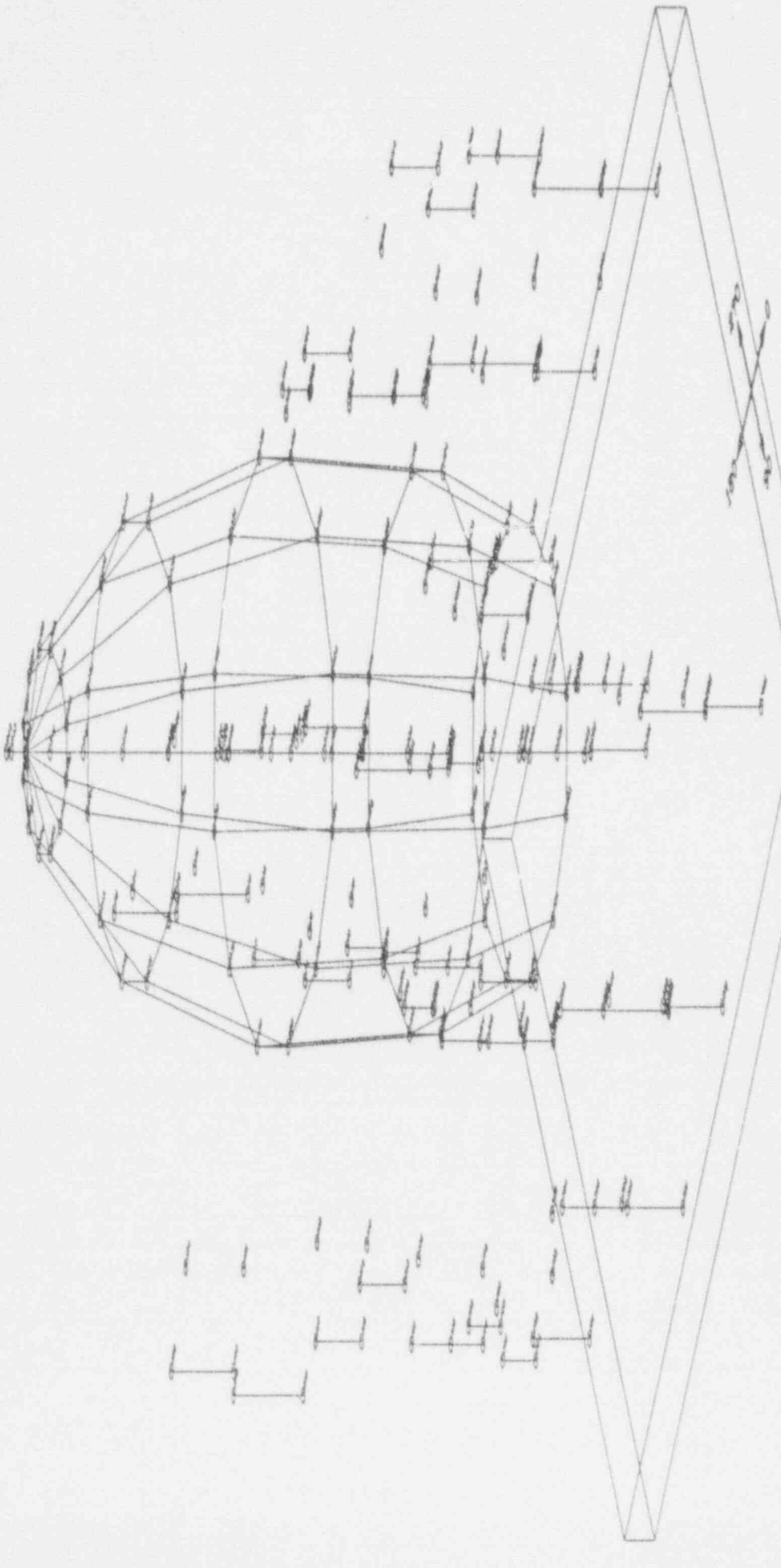
  - Final dynamic model of Nuclear Island and Annex Structures

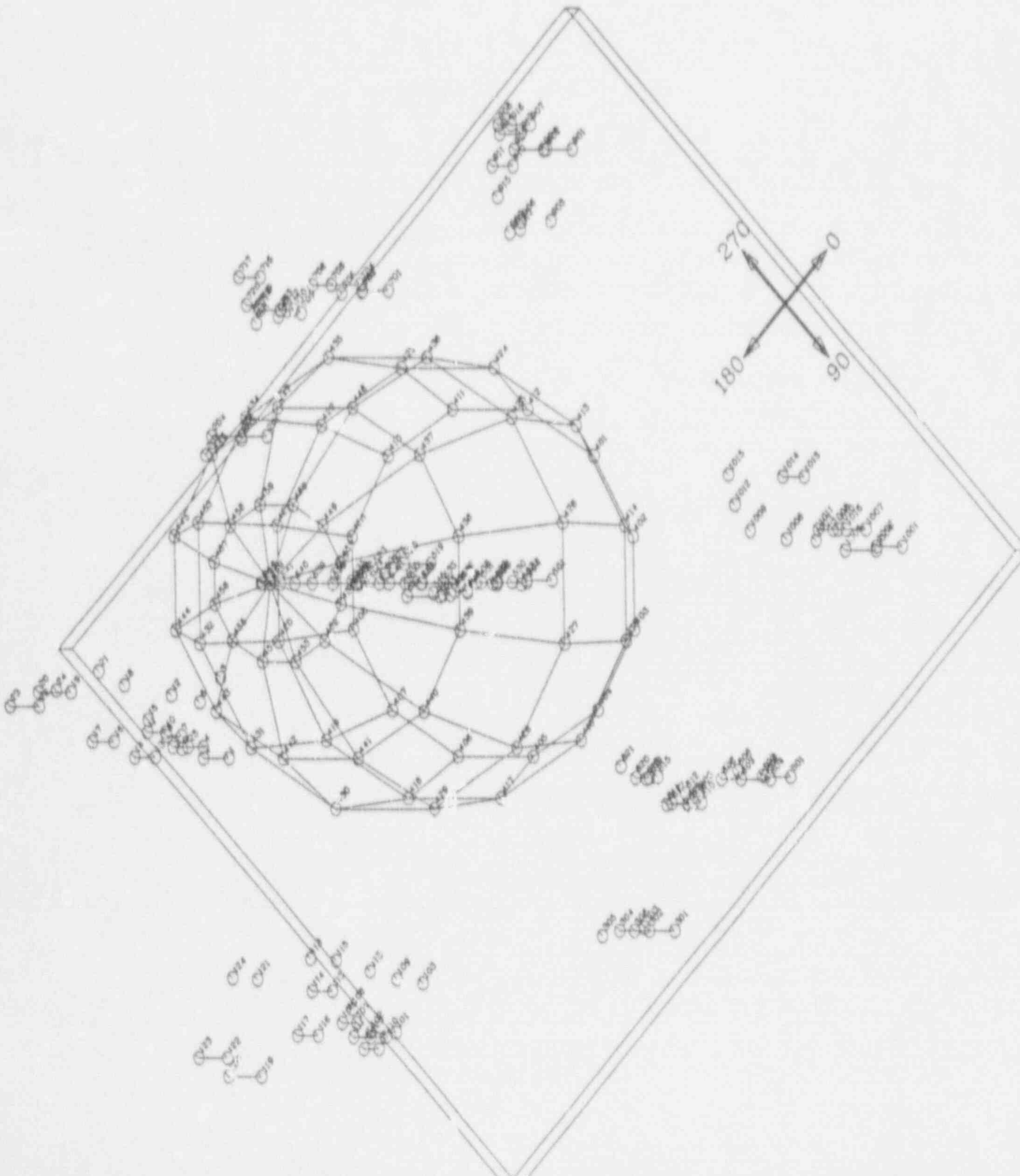
- COMPUTATION OF STRUCTURAL RESPONSE AND GENERATION OF RESPONSE SPECTRA

  (same as in preliminary SSI analysis)


Ground surface
Excavated soil
Rigid foundation
Soil Layers
Bedrock


Ground surface
Rigid foundation
Impedances
Soil Layers
Bedrock




270
0
180
90

System 80+™

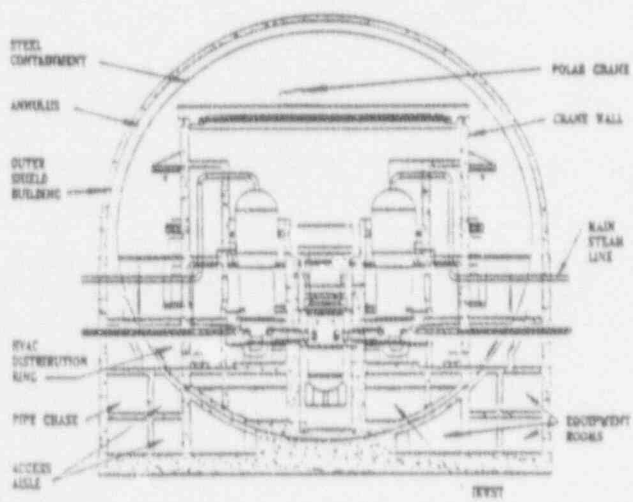
Steel Containment Vessel

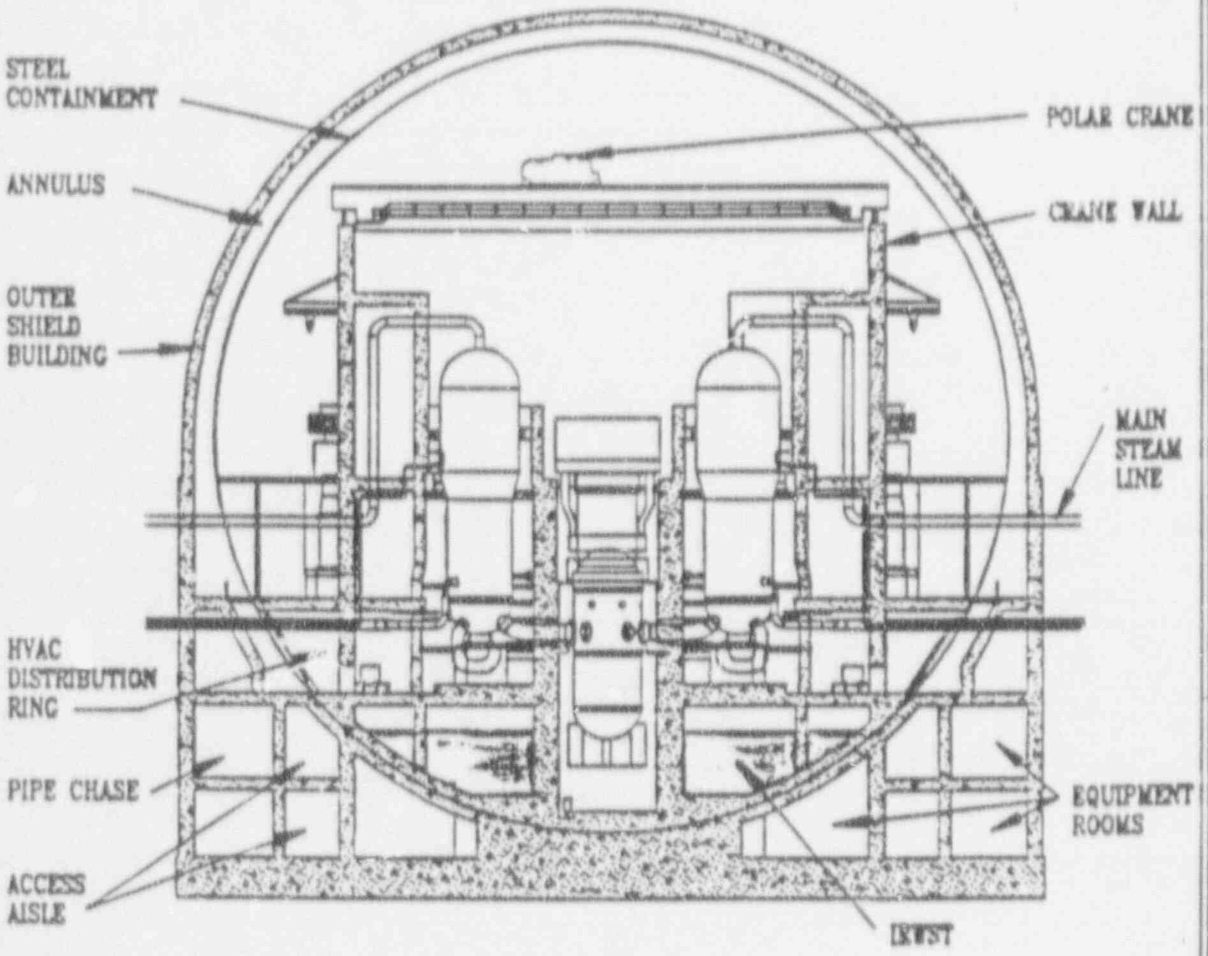
Code Design Activities

Containment Description

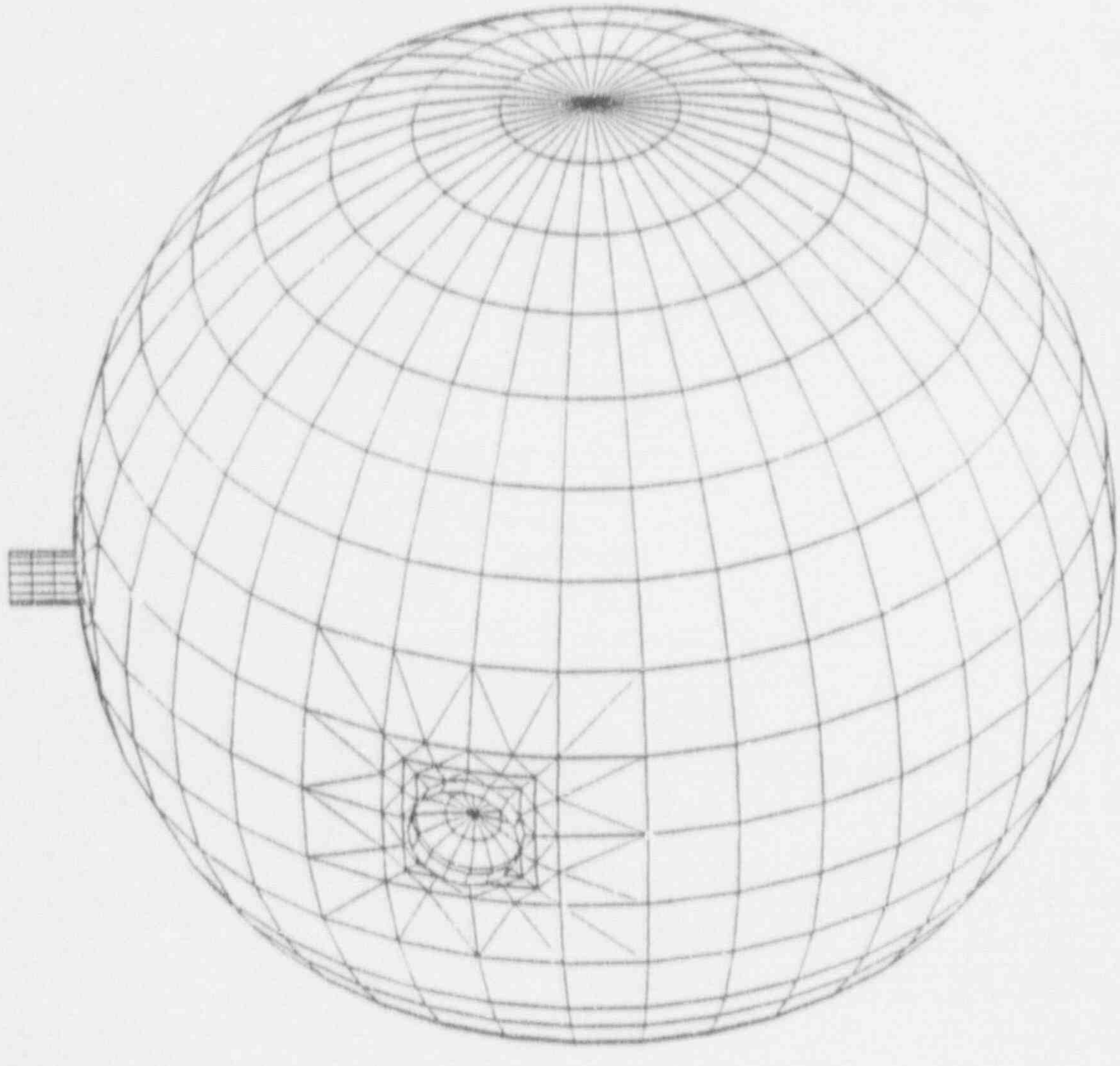
Spherical Steel Containment Vessel (SSCV)

- Free-Standing 200 Ft. Diameter
- Welded Steel Plate Construction - 1 3/4" Thick
- Bottom of Sphere Concrete Encased
- No Structural Connection Between Steel Containment and Concrete
- ASME Section III, Division I, Subsection NE
- Enclosed In a Cylindrically Shaped Concrete Shield Building with Hemispherical Dome
- Large Lower Subsphere Area In Shield Building

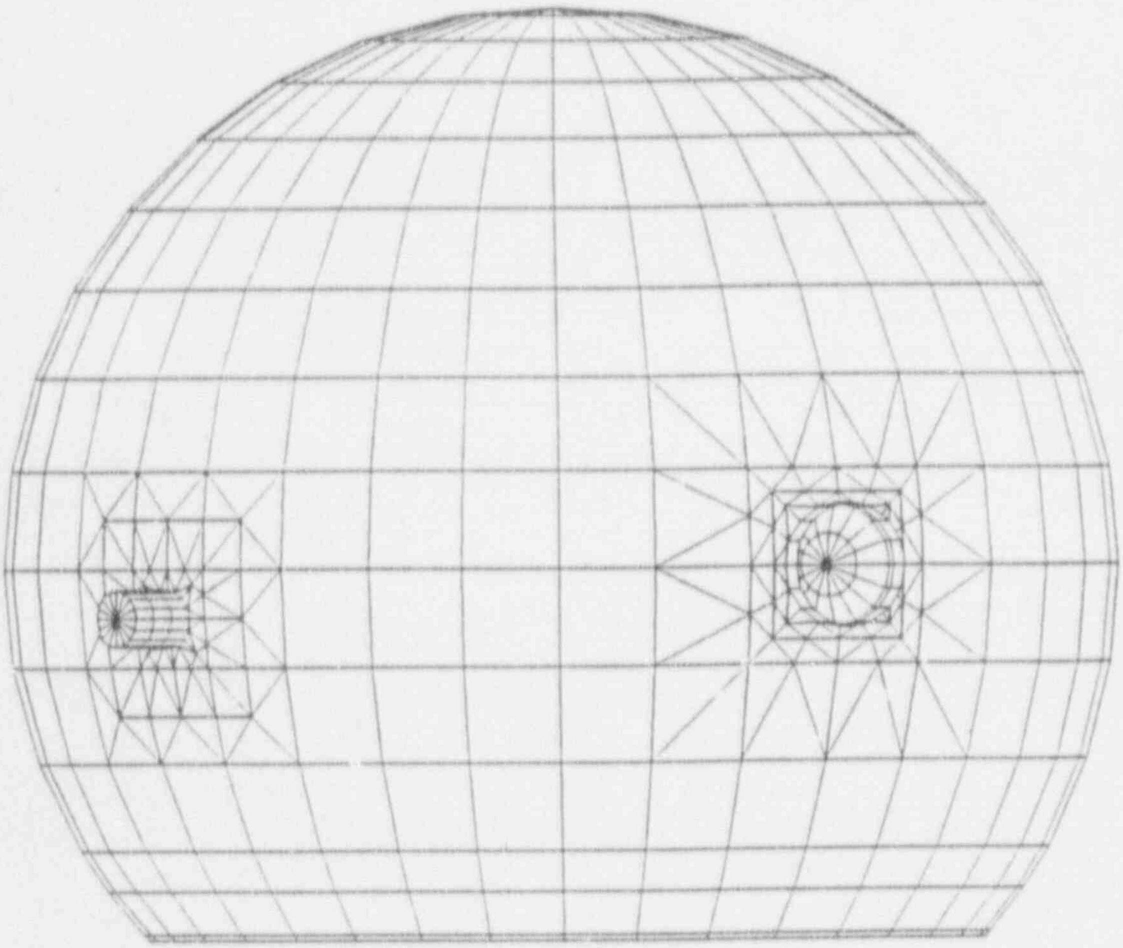



STEEL
CONTAINMENT
ANNULUS
OUTER
SHIELD
BUILDING
HVAC
DISTRIBUTION
RING
PIPE CHASE
ACCESS
AISLE
POLAR CRANE
CRANE WALL
MAIN
STEAM
LINE
EQUIPMENT
ROOMS
IRWST

SYSTEM 80+ ™



THREE DIMENSIONAL MODEL
OF
STEEL CONTAINMENT



THREE DIMENSIONAL MODEL
OF
STEEL CONTAINMENT

SYSTEM 80+™

Containment Technical Data

- Containment

– Containment Type	Steel Sphere
– Steel Type	SA-537 CL. 2
– Internal Diameter	200 Feet
– Wall Thickness	1.75 In.
– Free Volume	3.34×10^6 Cu.Ft.
– Design Pressure	49 psig

- Shield Building

– Type	Concrete
– Internal Diameter	210 Feet
– Wall Thickness	3 Ft.

Design Conditions

1) Normal Operating
   - Temperature: 110° F
   - Pressure: 0 psig
2) Inadvertent Spray Actuation
   - Temperature: 110°F
   - Pressure: 2.0 psig (vacuum)
3) Design Basis Accident
   - Temperature: 290°F
   - Pressure: 49 psig

SA-537 Class 2 Properties

- E 28,350,000 psi
- S_{mc} 22,000 psi
- S_{m1} 26,700 psi
- S_y 52,480 psi
- S_u 80,000 psi

All values are calculated at the Design Temperature

Codes and Standards

- 1989 ASME Boiler & Pressure Vessel Code
  Section III, Division I, Subsection NE
  "Class MC Vessels"
- Standard Review Plan (NUREG-0800)
- Regulatory Guide 1.57
  (Steel Containment)
- Regulatory Guide 1.61
  (Damping)
- Regulatory Guide 1.84
  (Code Cases)
- Regulatory Guide 1.92
  (Modal Combinations)
- 10 CFR50 (General Design Criteria)

Containment Analysis

Analysis Performed for:

- Service Loads
- Stability (Buckling), Considering Vacuum Pressures
- Ultimate Capacity (Hydrogen Burn)
- ASME Code Calculation for Penetration Area Replacement
- Attachments
- Construction Loading

Containment Design Bases

Design Conditions Consider the Effects of :

- Dead/Live Loads
- Pressure/Temperature
- Mechanical/Electrical/Attachment Loads
- Natural Phenomena Loads (earthquake, tornado, etc.)
- Pipe Whip/Jet Impingement/Missiles
- Hydrodynamic Loads
- Construction

Design Loadings

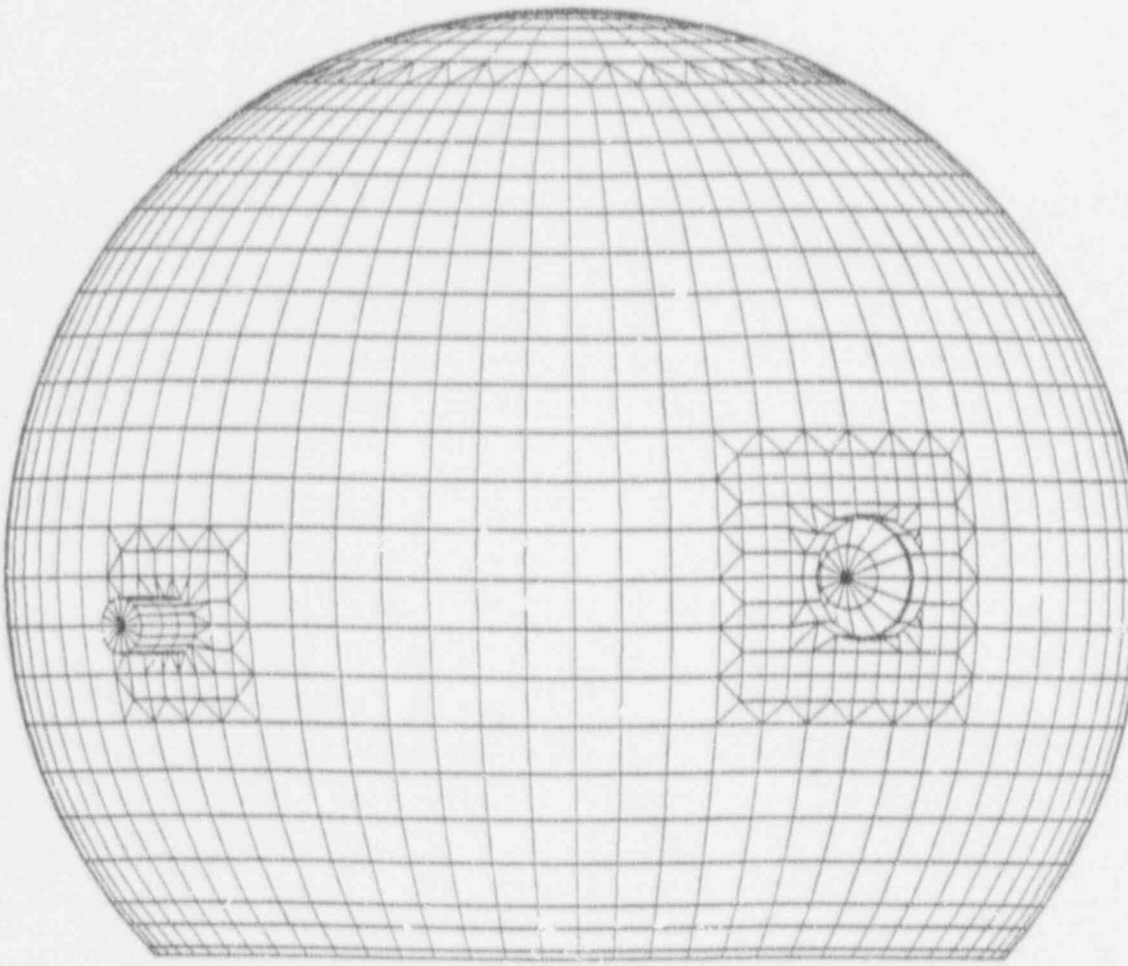
- D - dead loads
- L - live loads
- P_t - test pressure loads
- T_t - test thermal loads
- P_o - normal operating pressure loads
- R_o - normal operating piping loads
- T_o - normal operating thermal loads
- P_e - vacuum pressure loads
- R_e - vacuum piping loads
- T_e - vacuum thermal loads
- E - operating basis earthquake loads
- E' - safe shutdown earthquake loads
- P_a - accident pressure loads
- R_a - accident piping loads
- T_a - accident thermal loads
- Y_r - pipe rupture loads
- Y_j - jet impingement loads
- Y_m - missile loads

Detailed Loading Combinations:

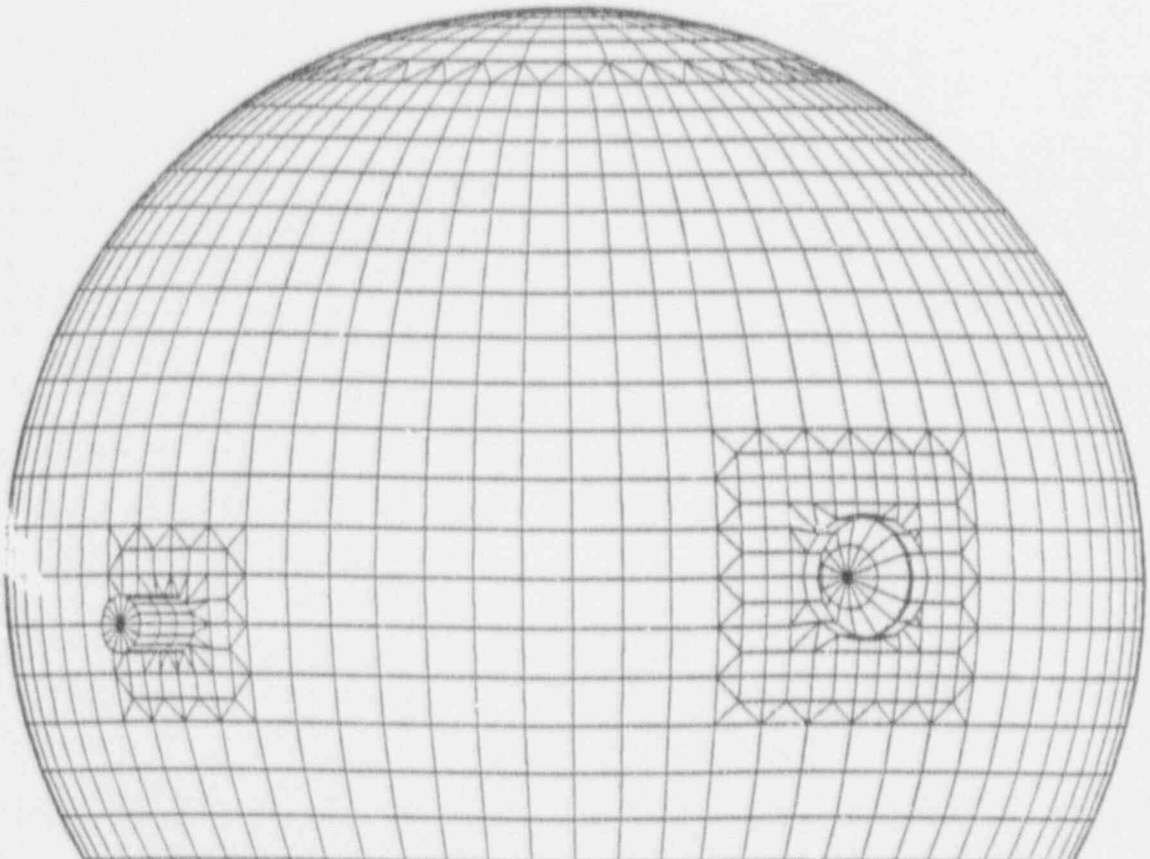
- Testing Conditions
  $D + L + P_t + T_t$
- Design Conditions
  $D + L + P_a + T_a + R_a$
- Level A Service Limits
  $D + L + P_a + T_a + R_a$
- Level B Service Limits
  $D + L + P_a + T_a + R_a + E$
- Level C Service Limits
  $D + L + P_a + T_a + R_a + E'$
- Level D Service Limits
  $D + L + P_a + T_a + R_a + Y_r + Y_j + Y_m + E'$
- Stability Considerations
  $D + L + P_e + T_e + R_e + E$
  $D + L + P_e + T_e + R_e + E'$

Service Load Analysis

- Finite Element Method
- Thin Shell Theory
- Linear Elastic
- Three Dimensional Analysis
- ANSYS Computer Code



SYSTEM 80+™
THREE DIMENSIONAL MODEL
OF STEEL CONTAINMENT



SYSTEM 80+™
THREE DIMENSIONAL MODEL
OF STEEL CONTAINMENT

Table 3.8.2-3

<u>Stress Intensity Limits for Steel Containments</u>

Load Categories		Primary Stresses Gen. Mem. P_m	Primary Stresses Local Mem. P_L	Bending & Local Mem. $P_b + P_L$ (6)	Primary & Secondary $P_L + P_b + Q$	Peak Stresses $P_L + P_b + Q + F$	Buckling
Testing Condition	Pneumatic	$0.75S_y$	$1.15S_y$	$1.15S_y$	N/A (2)	Consider for (5) fatigue evaluation	See (9)
Design Condition		$1.0S_{mc}$	$1.5S_{mc}$	$1.5S_{mc}$	N/A	N/A	See (9)
Level A Service Limit (1)		$1.0S_{mc}$	$1.5S_{mc}$	$1.5S_{mc}$	$3.0S_{mi}$	Consider for fatigue evaluation	See (9)
vel B Service Limit		$1.0S_{mc}$	$1.5S_{mc}$	$1.5S_{mc}$	$3.0S_{mi}$	Consider for fatigue evaluation	See (9)
Level C Service Limit	Not Integral and Continuous	$1.0S_{mc}$	$1.5S_{mc}$	$1.5S_{mc}$	$3.0S_{mi}$	N/A	See (9)
	Integral and Continuous (4) (7)	$1.2S_{mc}$ or * $1.0S_y$	$1.8S_{mc}$ or * $1.5S_y$	$1.8S_{mc}$ or * $1.5S_y$ (8)	N/A	N/A	See (9)
Level D Service Limit	Not Integral and Continuous	$1.2S_{mc}$ or * $1.0S_y$	$1.8S_{mc}$ or * $1.5S_y$	$1.8S_{mc}$ or * $1.5S_y$ (8)	N/A	N/A	See (9)
	Integ. & Cont. — Elas. An. (3)	S_f	$1.5S_f$	$1.5S_f$	N/A	N/A	See (9)
	Integ. & Cont. — Inel. An. (3)	S_f	S_f	S_f			
Post-Flooding		$1.2S_{mc}$ or * $1.0S_y$	$1.8S_{mc}$ or * $1.5S_y$	$1.8S_{mc}$ or * $1.5S_y$	$3.0S_{mi}$	N/A (2)	See (9)

NOTES:

(1) The allowable stress intensity S_{mi} shall be the S_m listed in Tables I-1.0 and the allowable stress intensity S_{mc} shall be the S_m listed in Tables I-10.0 of Appendix I of the ASME Code.

(2) N/A = No evaluation required.

(3) S_f is 85% of the general primary membrane allowable permitted in Appendix I. In the application of the rules of Appendix F, S_{mi}, if applicable, shall be as specified in Tables I-1.0.

(4) Those limits identified by the asterisk (*) indicate a choice of the larger of the two limits.

(5) The number of test sequences shall not exceed 10 unless a fatigue evaluation is considered.

(6) Values shown are for a solid rectangular section. See NE-3220 for other than a solid rectangular section.

(7) These stress intensity limits apply to the partial penetration welds also.

(8) Values shown are applicable when $P_L < 0.67S_y$. When $P_L > 0.67S_y$, use the larger of the two limits, $[2.5-1.5(P_L/S_y)]1.2S_{mc}$ or $[2.5 - 1.5(P_L/S_y)]S_y$.

(9) It must be demonstrated that any axisymmetric techniques proposed are applicable to a vessel having large asymmetric openings, and that the overall margin of safety to prevent buckling is adequate.

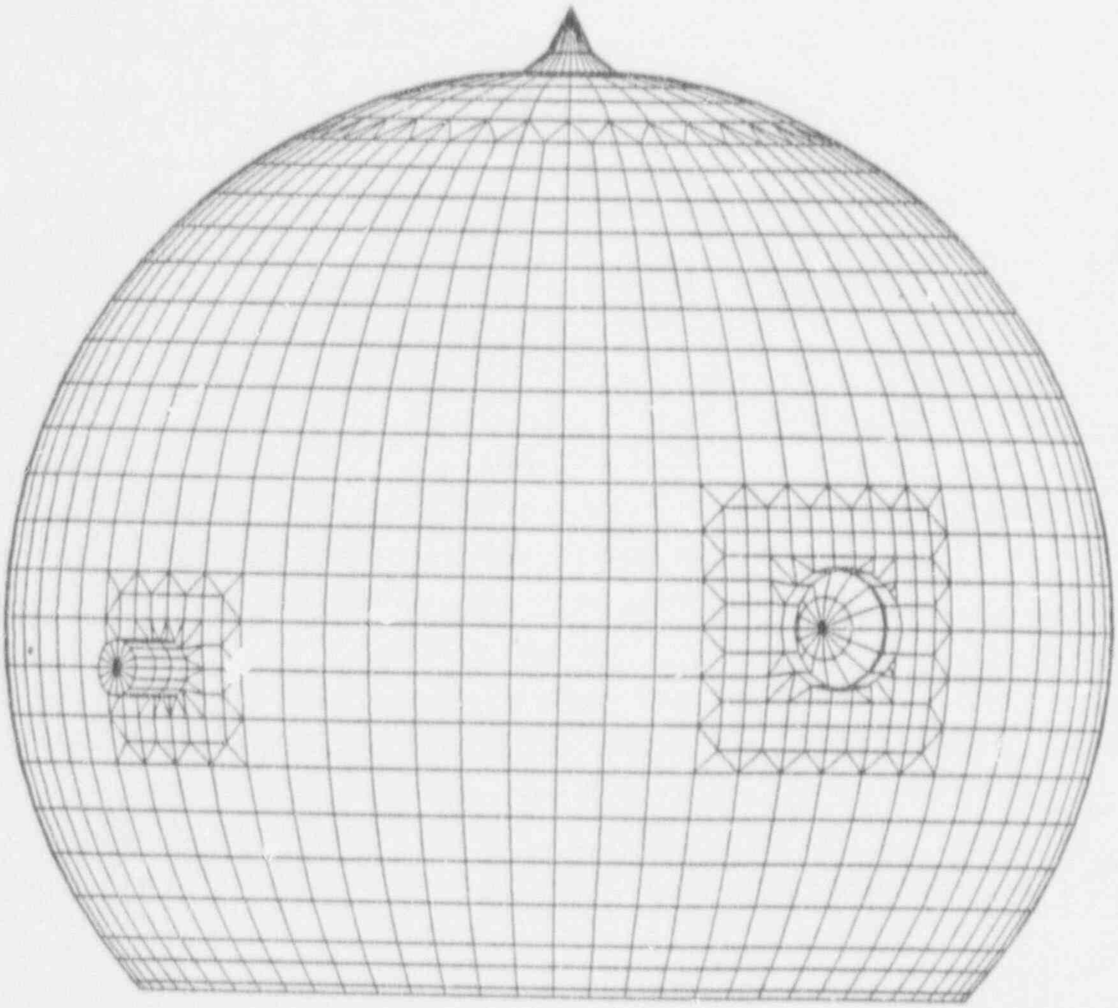
Containment Allowable Stress Intensities for SA537 Class 2 Steel

Load Categories		Primary Stresses Gen. Mem. P_m	Primary Stresses Local Mem. P_L	Bending & Local Mem. $P_b + P_L$	Primary & Secondary $P_L + P_b + Q$
Testing Condition	Pneumatic	44250	67850	67850	N/A
Design Condition		22000	33000	33000	N/A
Level A Service Limit		22000	33000	33000	90100
Level B Service Limit		22000	33000	33000	80100
Level C Service Limit	Not Integral and Continuous	22000	33000	33000	80100
	Integral and Continuous	52480	78720	78720	N/A
Level D Service Limit	Not Integral and Continuous	52480	78720	78720	N/A
	Integral & Cont. Elastic An.	47600	71400	71400	
	Inelastic An.	47600	47600	47600	

NOTE: All values are given in pounds per square inch.

Stability Analysis

- ASME Code Article NE-3222
- ASME Code Case N-284
- Linear Elastic Bifurcation Analysis
- Capacity Reduction Factors
- Three Dimensional Analysis
- ANSYS Computer Code



SYSTEM 80+™ STEEL CONTAINMENT STABILITY ANALYSIS

SYSTEM 80+ CONTAINMENT STABILITY SAFETY FACTORS

Stability Safety Factor = Capacity Reduction Factor X Load Factor

<u>Minimum</u>

Normal Operating - 3.0

Design Bases Accidents - 2.0

<u>Actual</u>

Normal Operating - 3.039

Design Bases Accidents - 2.385

CONTAINMENT STABILITY SAFETY FACTORS

ASME NE-3222

Design, Level A and B - 3.0

Level C - 2.5

Level D - 2.0

ASME Code Case N-284 With Capacity Reduction Factor

Design, Level A and B - 2.0

Level C - 1.67

Level D - 1.34

ASME NE-3131 And Standard Review Plan 3.8.2

Refers To NE-3200

Regulatory Guide 1.57

All Stability Design Loads - 2.0

Capacity Reduction Factors

- Code Case N-284
  - External Pressure: 0.124
- Funahashi, Mieda, Oyamada, Nagashima and Freiman[1]
  - Lateral Force: 0.47
  - Vertical Compressive Force: 0.40
  - Vertical Tensile Force: 0.52

[1] "Study of Spherical Steel Shell Buckling," 10th SMIRT, Los Angeles, CA, August 1989.

CAPACITY REDUCTION FACTOR LITERATURE SEARCH

Early investigators quickly realized experimental critical buckling stress values were considerably lower than the theoretical values. "They found that the measured buckling pressure was approximately one-fourth of the theoretical value and in addition that buckling was confined to a small dimple, whereas the theory predicted that it would extend all over the shell."

Kaplan, A., "Buckling Of Spherical Shells," in Thin-Shell Structures, Theory, Experiment, and Design, Edited By Y. C. Fung and E. E. Sechler, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1974, Pg. 248.

"When tests were carried out on thin shell structures in the early 1900's, the classical theory became suspect because then actual buckling loads were frequently found to be as little as one-quarter of the classical load."

Hutchison, J. W., Koiter, W. T., 1971. "Postbuckling Theory," in Applied Mechanics Reviews, 23:1354.

Other References:

Danielson, D. A., "Theory of Shell Stability," Thin Shell Structures, Fung, Y. C. , and Sechler, E. E. (Editors), Prentice Hall, 1974.

Seide, P., "A Reexamination of Koiter's Theory of Initial Postbuckling Behavior and Imperfection Sensitivity of Structures," Thin Shell Structures, Fung, Y. C. and Sechler, E. E. (Editors), Prentice Hall, 1974.

Bushnell, D., "Bifurcation Phenomena in Spherical Shells under Concentrated and Ring Loads," AIAA J., 5:11, November 1967, pp. 2034-2040.

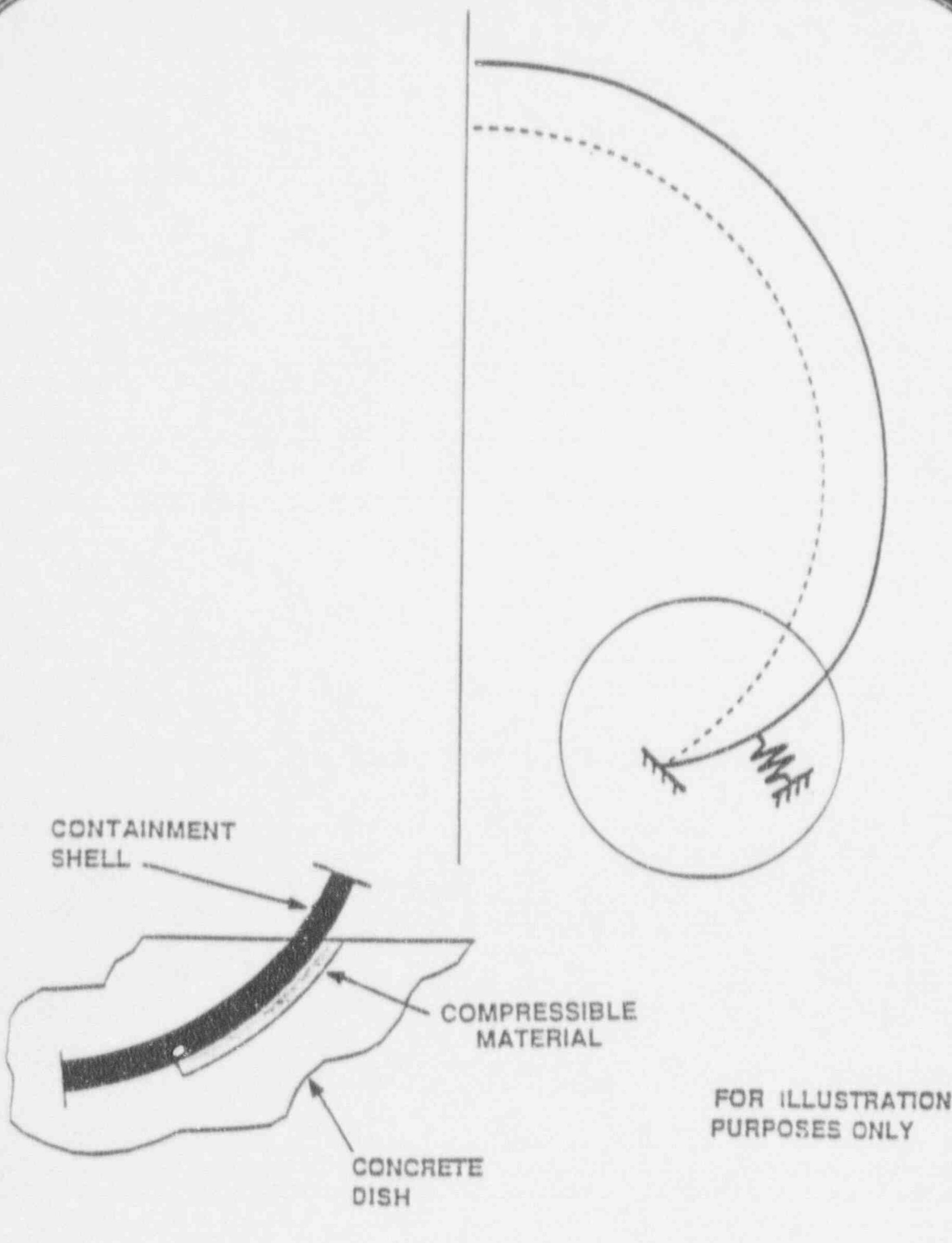
Sechler, E. E., "The Historical Development of Shell Research and Design," in Thin-Shell Structures, Theory, Experiment, and Design, edited by Y.C. Fung and E. E. Sechler, Prentice-Hall, Englewood Cliffs, N.J., 1974, pp. 3-25.

Seide, P., Weingarten, V., Masri, S., "Buckling Criteria and Application of Criteria To Design of Steel Containment Shell," NUREG/CR-0793

Funahashi, Naruse, Mieu , Oyamada, Kume, Nagashima, Freiman, "Study of Spherical Steel Shell Buckling," from Transactions of the 10th International Conference on Structural Mechanics in Reactor Technology, 1989, Volume J, pp. 79-84.

Ultimate Capacity Analysis

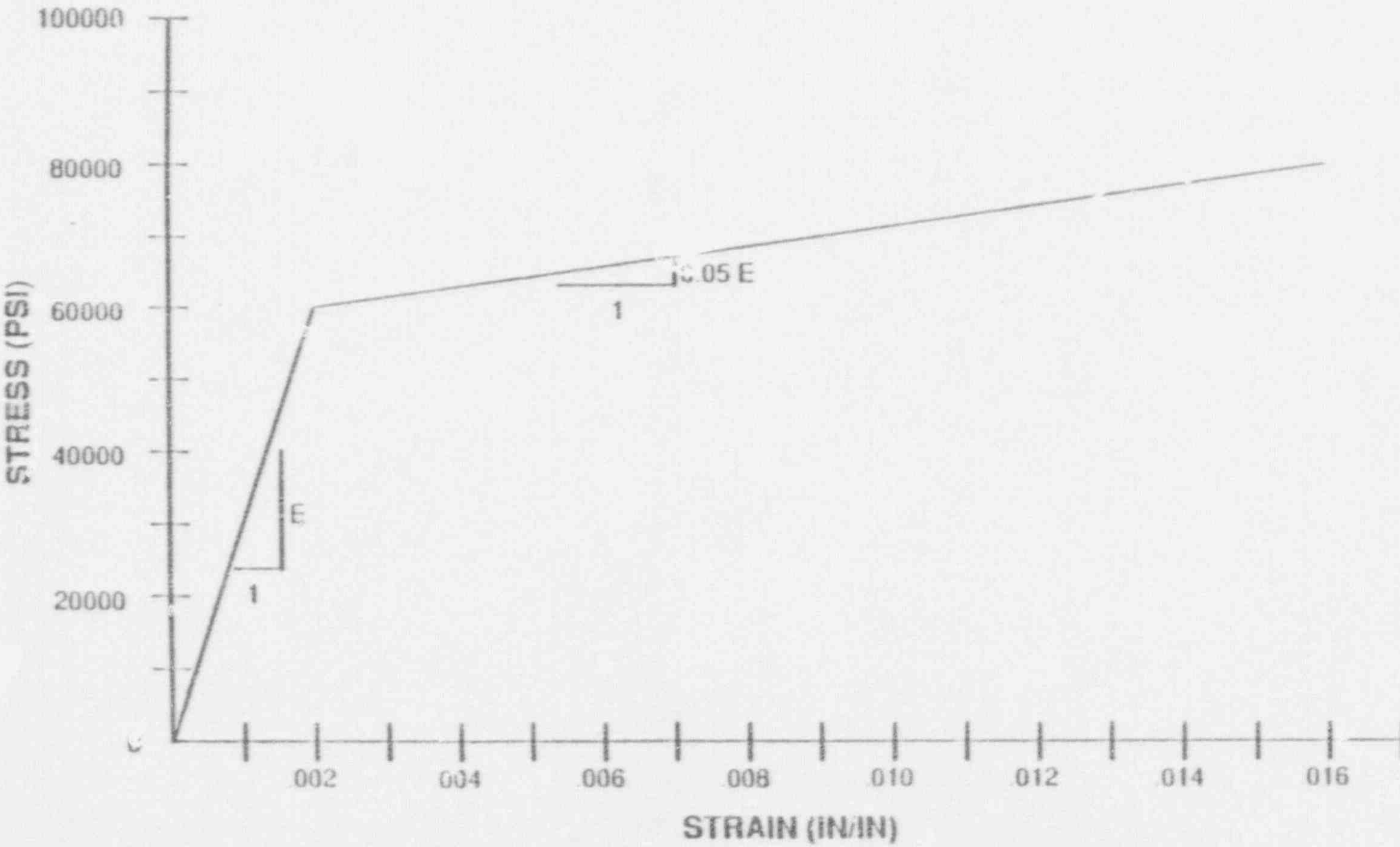
- Nonlinear Elastic-Plastic
- Large Displacements
- Small Strains
- Bi-Linear Stress-Strain Curve
- Axisymmetric Analysis
- ANSYS Computer Code

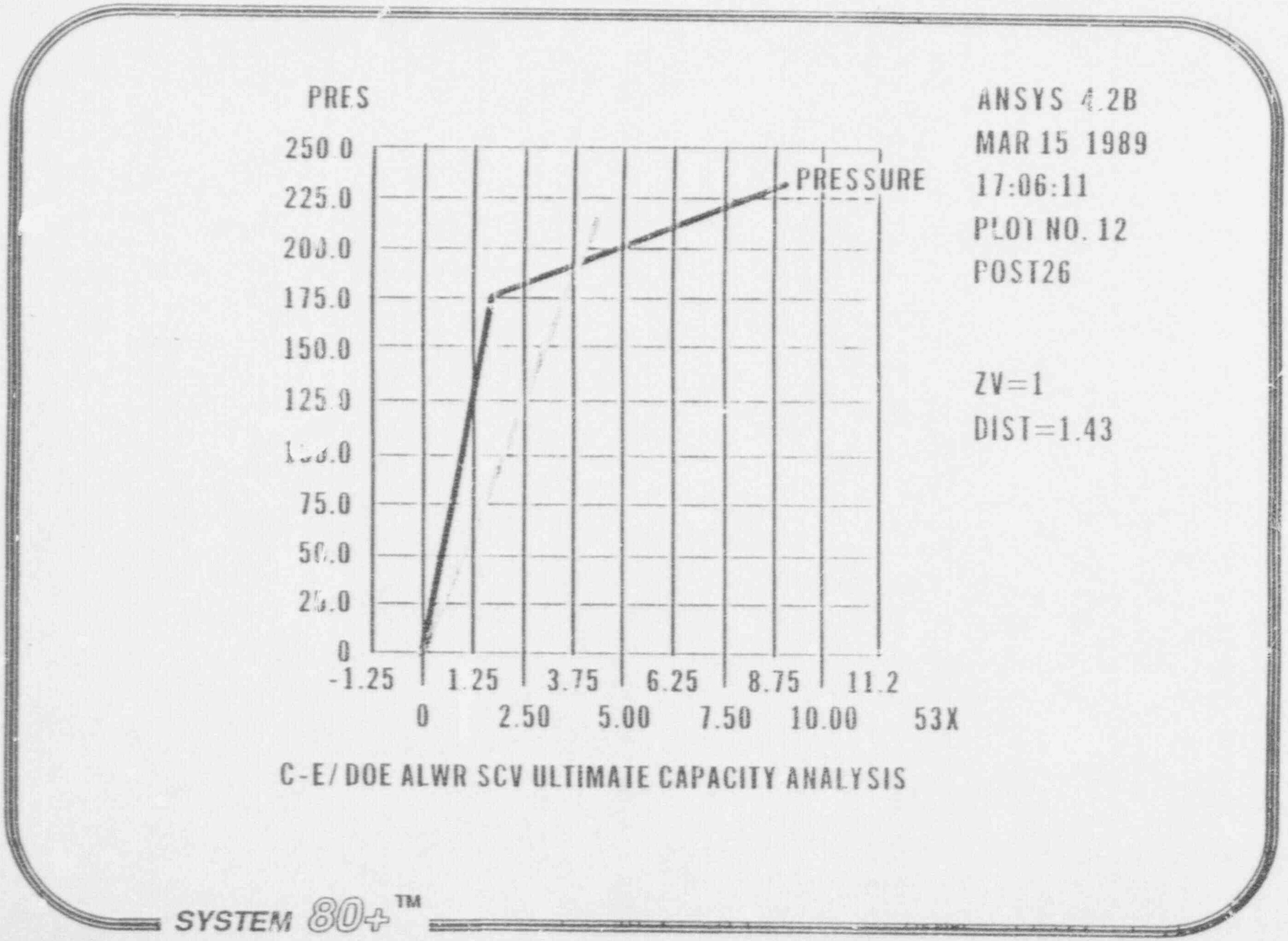


ULTIMATE CAPACITY MODEL

ANSYS Axisymmetric Containment Model

SA-537 Cl. 2 Stress-Strain Curve for ANSYS





PRES
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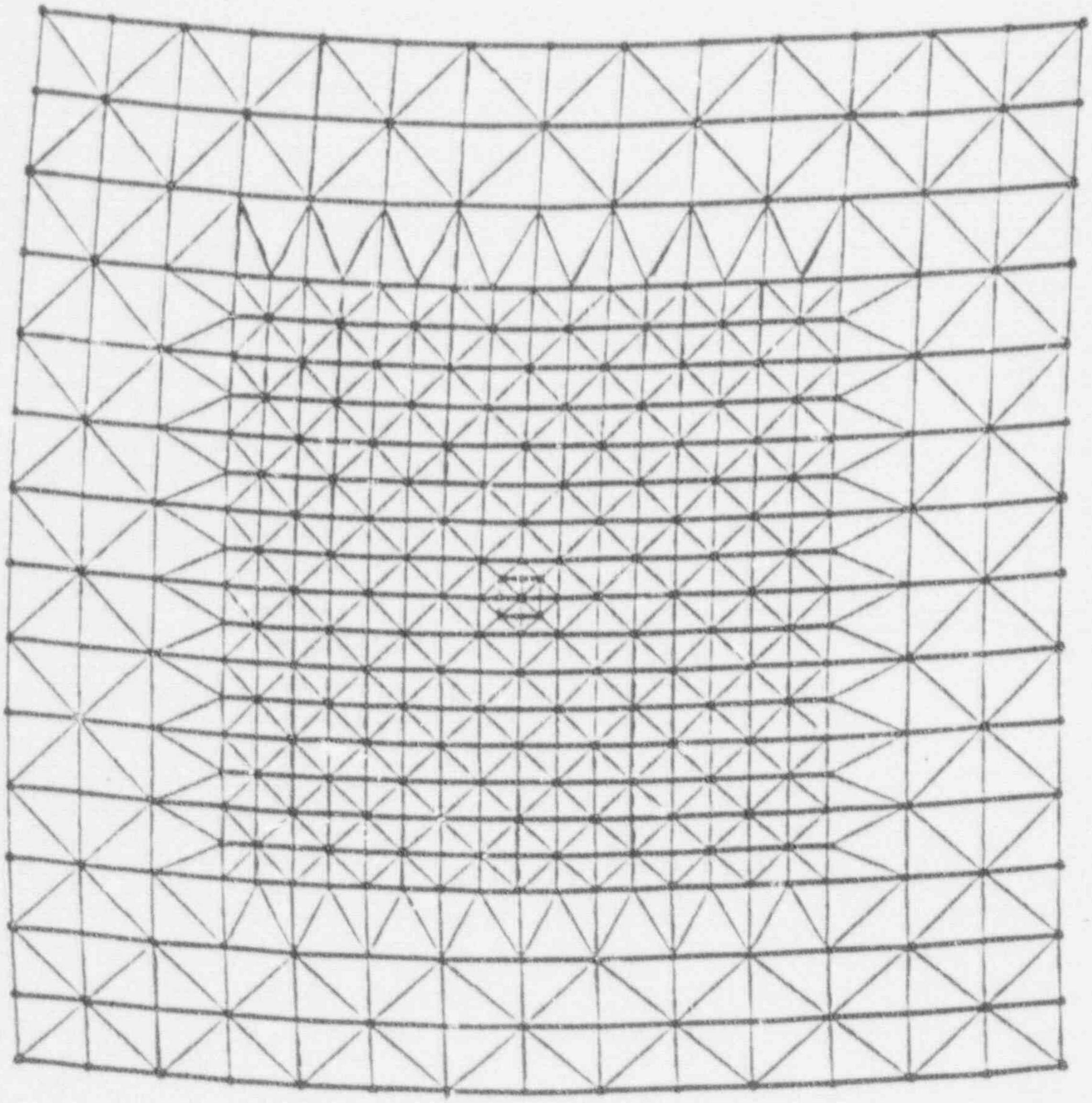
225.0
200.0
175.0
150.0
125.0
100.0
75.0
50.0
25.0
0
-1.25
1.25
3.75
6.25
8.75
11.2
0
2.50
5.00
7.50
10.00
53X
PRESSURE
ANSYS 4.2B
MAR 15 1989
17:06:11
PLOT NO. 12
POST26
ZV=1
DIST=1.43
C-E/DOE ALWR SCV ULTIMATE CAPACITY ANALYSIS
SYSTEM 80+™

ASME Code Calculations for Penetration Area Replacement

- Meets requirements of Section III, Subsection NE
- 12" - 54" diameter sleeves for mechanical and electrical penetrations
- Equipment hatch and personnel airlocks

Attachment Analysis

- S/R for piping, HVAC or cable tray
- Applied force and moment unit loads
- Stress intensity for any combination of forces and moments calculated and compared to allowable margin



FINITE ELEMENT MODEL
ATTACHMENT ANALYSIS

SYSTEM 80+™

Construction Loading Analysis

- Lifting / supporting pre-assembled sections of steel containment vessel
- Dead weight of vessel
- 110 MPH Wind Load on partially erected vessel
- Support of Shield Building formwork and concrete

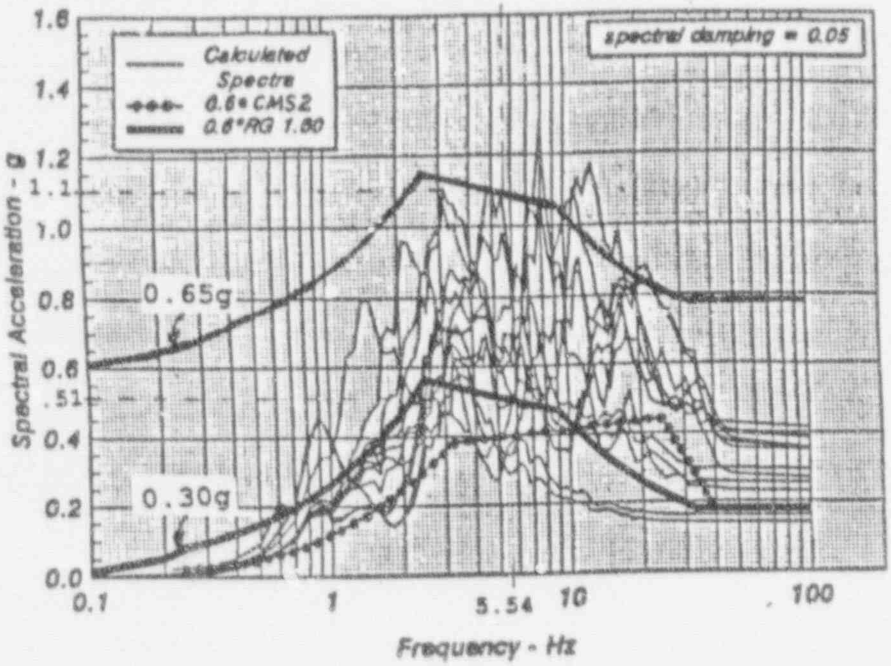
Considerations for Physical Testing

- Choice of Model Scale
- Construction Tolerances (geometric imperfections)
- Material Flaws (non-linearities)
- Loading Method and Path Affects Results
- Expensive

SYSTEM 80+™ CONTAINMENT

MARGIN BEYOND DESIGN BASES

COMPARISON OF CALCULATED SPECTRA (CMS2) TO R.G. 1.60



HORIZONTAL MOTIONS AT FOUNDATION LEVEL

Spectral Acceleration @ Containment Fundamental Frequency - 5.54 Hz

0.6 R.G. 1.60 (0.3g)	- 0.51g
CMS2 (0.3g)	- 1.1g

Equivalent R.G. 1.60 Required to Produce 1.1g Motion at Foundation Level

$$\frac{1.1g}{0.51g} \times 0.3g = 0.65g$$

SYSTEM 80+™ CONTAINMENT

MARGIN BEYOND DESIGN BASES

COMPARISON TO YIELD STRESS

Additional Capacity Available

$$S_y - (S_{DW} + S_{P(49)} + S_{THERMAL})$$

SSE Stress per g at Foundation

$$S_{SSE}$$

Foundation Input to Reach Yield

$$\frac{S_y - (S_{DW} + S_{P(49)} + S_{THERMAL})}{S_{SSE}} \times g \text{ @ foundation}$$

Most Highly Stressed Element Determined From CMS2 Input Value of 1.1 g

$$\frac{S_y - (S_{DW} + S_{P(49)} + S_{THERMAL})}{S_{SSE}} \times 1.1\ g = 2.07\ g$$

Rock Outcrop Input Required to Reach Yield with CMS2

$$2.07\ g \times \frac{0.3\ g \text{ @ rock outcrop}}{1.1\ g \text{ @ foundation}} = 0.57\ g$$

Free Field Input Required to Reach Yield with RG 1.60

$$2.07\ g \times \frac{0.3\ g \text{ @ free field}}{0.51\ g \text{ @ foundation}} = 1.22\ g$$