TERA

April 18, 1984

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Mr. D. G. Eisenhut
Director, Division of Licensing
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U.S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Docket Nos. 50-329 OM, OL and 50-330 OM, OL
Midland Nuclear Plant - Units 1 and 2
Independent Design and Construction Verification (IDCV) Program
Meeting Summary

Gentlemen:

A meeting was held in Chicago, Illinois on April 17, 1984 to discuss details of the SMA Seismic Margins Evaluation (SME) of the Midland plant and its potential applicability to the disposition of outstanding items in the IDCVP civil/structural review area. Attachment 1 identifies participants which included representatives of TERA, CPC, and NRC. Attachment 2 includes viewgraphs presented by SMA at the meeting.

TERA indicated that elements of the SME were being reviewed to assist in the independent design verification of Bechtel's seismic analysis and design with emphasis on modeling assumptions and inputs used in the design evaluations as well as the significance of various discrepancies noted by the IDCVP.

SMA presented an overview of their work and a detailed discussion in areas of particular interest to TERA. Concentration was given to the areas such as soil-structure interaction, floor flexibility, equipment qualification, parameter variation, sampling criteria, and differences between the SME and FSAR seismic

D021
1/1

TERA CORPORATION
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evaluations. SMA provided TERA with necessary clarification to understand information presented in their series of SME reports as well as the level of detail and parametric evaluation actually applied during the course of their study.

Sincerely,

Howard A. Levin
Project Manager
Midland IDCV Program

Enclosure

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J. Karr, S&W (site)
IDCV Program Service List

HAL/djb

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AND CONSTRUCTION VERIFICATION PROGRAM

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ATTACHMENT I

PARTICIPANTS

MIDLAND INDEPENDENT DESIGN AND
CONSTRUCTION VERIFICATION PROGRAM MEETING

CHICAGO, ILLINOIS

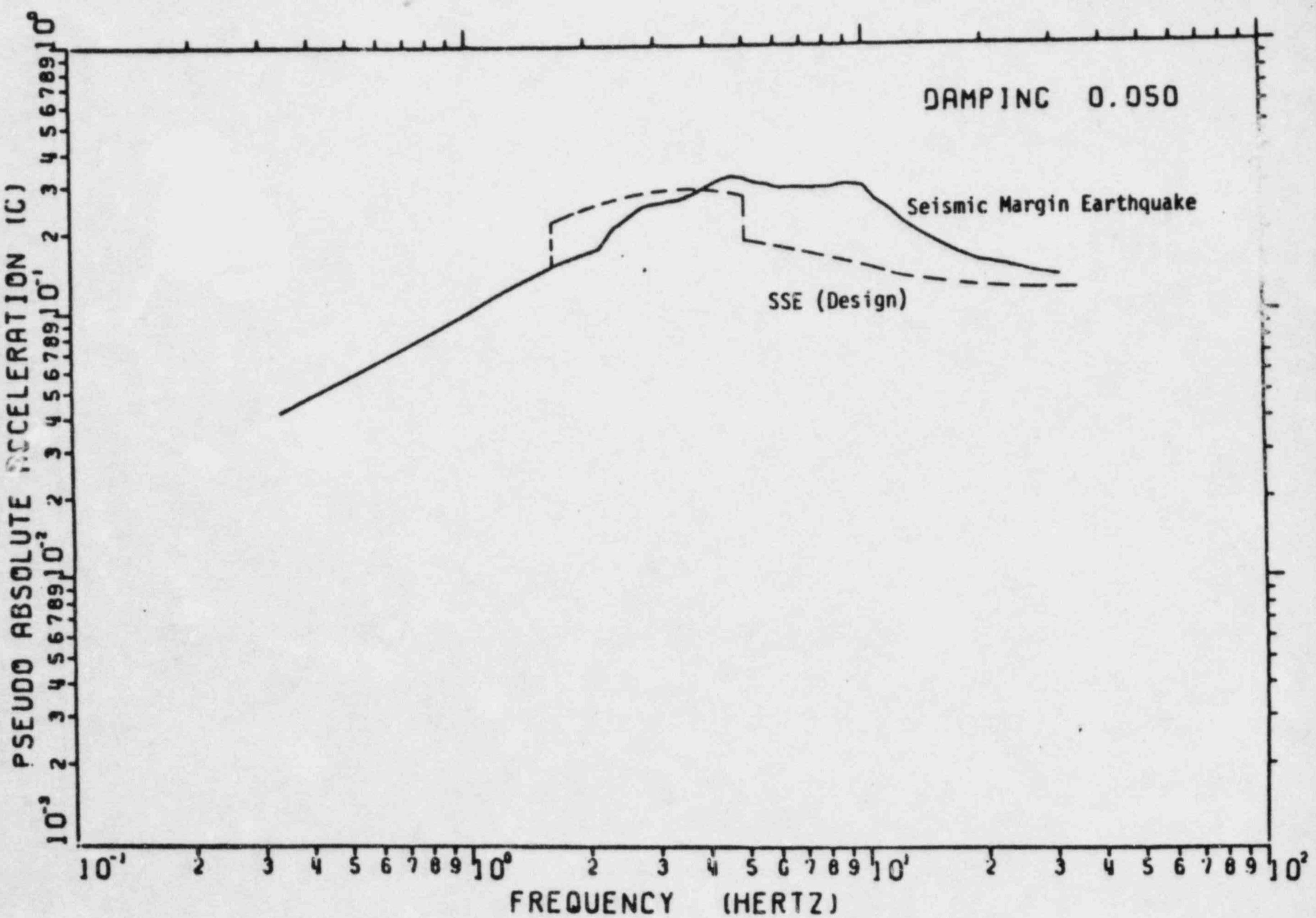
APRIL 17, 1984

Name	Affiliation
H. Levin	TERA
J. Martore	TERA
C. Mortgat	TERA
W. Hall	TERA Consultant, Univ. of Illinois
D. Wesley	SMA
R. Campbell	SMA
L. Gibson	CPC
T. Thiruvengadam	CPC
H. Wang	NRC
F. Rinaldi	NRC

ATTACHMENT 2

SEISMIC MARGIN EARTHQUAKE (SME)

- BASED ON SITE SPECIFIC EARTHQUAKE
- INCLUDES STRUCTURES AND EQUIPMENT
- SCREENING PROCESS USED TO IDENTIFY CRITICAL ELEMENTS AND COMPONENTS FOR REVIEW FOR SEISMIC ADEQUACY
- ALLOWS FOR DEVIATIONS FROM STANDARD REVIEW PLAN FOR FAILURE CAPACITY EVALUATION



MIDLAND - ORIGINAL GROUND SURFACE ENVELOPE RESPONSE SPECTRA

DIFFERENCES BETWEEN SME REVIEW AND FSAR DESIGN

- SEISMIC INPUT
- WIDER RANGE OF SOIL PARAMETERS
- PARAMETRIC VARIATION OF RELATIVE SOIL STIFFNESS UNDER AUXILIARY PENETRATION WINGS
- DAMPING

STRUCTURES EVALUATION

- USE BECHTEL STRUCTURES MODELS FOR:
  - CONTROL/AUXILIARY BUILDING*
  - SERVICE WATER PUMP STRUCTURE*
  - REACTOR BUILDINGS
  - DIESEL GENERATOR BUILDINGS
- DEVELOP NEW MODEL FOR BORATED WATER STORAGE TANK*
- DEVELOP NEW SOIL COMPLIANCE FUNCTIONS FOR A WIDER RANGE OF SOIL PROPERTIES THAN CONSIDERED IN DESIGN
- GENERATE NEW STRUCTURE LOADS AND IN-STRUCTURE RESPONSE SPECTRA
- CALCULATE SEISMIC MARGIN AGAINST CODE STRENGTH FOR SELECTED ELEMENTS
- CALCULATE SEISMIC MARGIN AGAINST FAILURE (IF REQUIRED)

* INCLUDES SOILS REMEDIAL DESIGN EFFECTS

DAMPING

- REG. GUIDE 1.61 SSE DAMPING USED FOR THE CODE MARGIN EVALUATION FOR BOTH STRUCTURES AND EQUIPMENT

- INCREASED DAMPING FOR FAILURE MARGIN EVALUATION FOR EQUIPMENT TO REFLECT HIGH STRESSES AT FAILURE

- GEOMETRIC (RADIATION) DAMPING FOR SOIL-STRUCTURE INTERACTION LIMITED TO EITHER 75% OF THEORETICAL ELASTIC HALF SPACE VALUES OR 100% OF ANALYTICALLY DETERMINED VALUES FOR LAYERED SOIL PROFILES WHICH-EVER IS <u>LOWER</u>

SOIL PROPERTIES

- WIDE PARAMETRIC RANGE OF SOIL PROFILES WERE DEVELOPED TO ACCOUNT FOR UNCERTAINTIES IN SITE CONDITIONS

THREE PROFILES DEVELOPED:

- SOIL LAYERING PROFILE REPRESENTATIVE OF SOFT SITE CONDITIONS
- SOIL LAYERING PROFILE REPRESENTATIVE OF STIFF SITE CONDITIONS
- INTERMEDIATE SOIL PROFILE

Elevation

634 — Top of Grade

603 — Original Ground Sur

Glacial Till

W_s = 135 pcf G_{max} = $7 \cdot 10^6$ psf
ν = 0.47 G_{SME} = $2 \cdot 10^6$ psf
V_s = 1290 fps

550

Glacial Till

W_s = 135 pcf G_{max} = $12 \cdot 10^6$ psf
ν = 0.47 G_{SME} = $4.2 \cdot 10^6$ psf
V_s = 1690 fps

410

Dense Cohesionless Material

W_s = 135 pcf V_s = 2540 fps G_{max} = $27 \cdot 10^6$ psf, G_{SME} = $17.8 \cdot 10^6$ psf (Elevat 410)
ν = 0.34

V_s = 2970 fps G_{max} = $37 \cdot 10^6$ psf, G_{SME} = $25.2 \cdot 10^6$ psf (Elevati 260)

260

Bedrock

W_s = 150 pcf V_s = 5000 fps
ν = 0.33

Soft Site Soil Profile

Elevation

634 — Top of Grade

603 — Original Ground Sur

Glacial Till

W_s = 120 pcf

ν = 0.49

V_s = 1400 fps

G_{max} = $7.3 \cdot 10^6$ psf

G_{SME} = $3.65 \cdot 10^6$ psf

Aux. Bldg.- 570

Reactor Bldg.- 568

Glacial Till

W_s = 135 pcf

ν = 0.42

V_s = 2300 fps

G_{max} = $22.2 \cdot 10^6$ psf

G_{SME} = $13.3 \cdot 10^6$ psf

463

Glacial Till

W_s = 135 pcf

ν = 0.42

V_s = 3000 fps

G_{max} = $37.8 \cdot 10^6$ psf

G_{SME} = $25.0 \cdot 10^6$ psf

363

Dense Cohesionless Material

W_s = 135 pcf

ν = 0.34

V_s = 3000 fps

G_{max} = $37.8 \cdot 10^6$ psf

G_{SME} = $31.0 \cdot 10^6$ psf

263

Bedrock

W_s = 150 pcf

ν = 0.33

V_s = 5000 fps

Stiff Site Soil Profile

Elevation

634 — Top of Grade

603 — Original Ground Sur

Glacial Till

W_s = 110 pcf — G_{max} = $7.7 \cdot 10^6$ psf

ν = 0.49 — G_{SME} = $4.08 \cdot 10^6$ psf

V_s = 1500 fps

553

Glacial Till

W_s = 135 pcf — G_{max} = $15 \cdot 10^6$ psf

ν = 0.42 — G_{SME} = $7.95 \cdot 10^6$ psf

V_s = 1890 fps

463

Dense Cohesionless Material

W_s = 135 pcf — G_{max} = $25.6 \cdot 10^6$ psf

ν = 0.34 — G_{SME} = $13.6 \cdot 10^6$ psf

V_s = 2468 fps

263

Bedrock

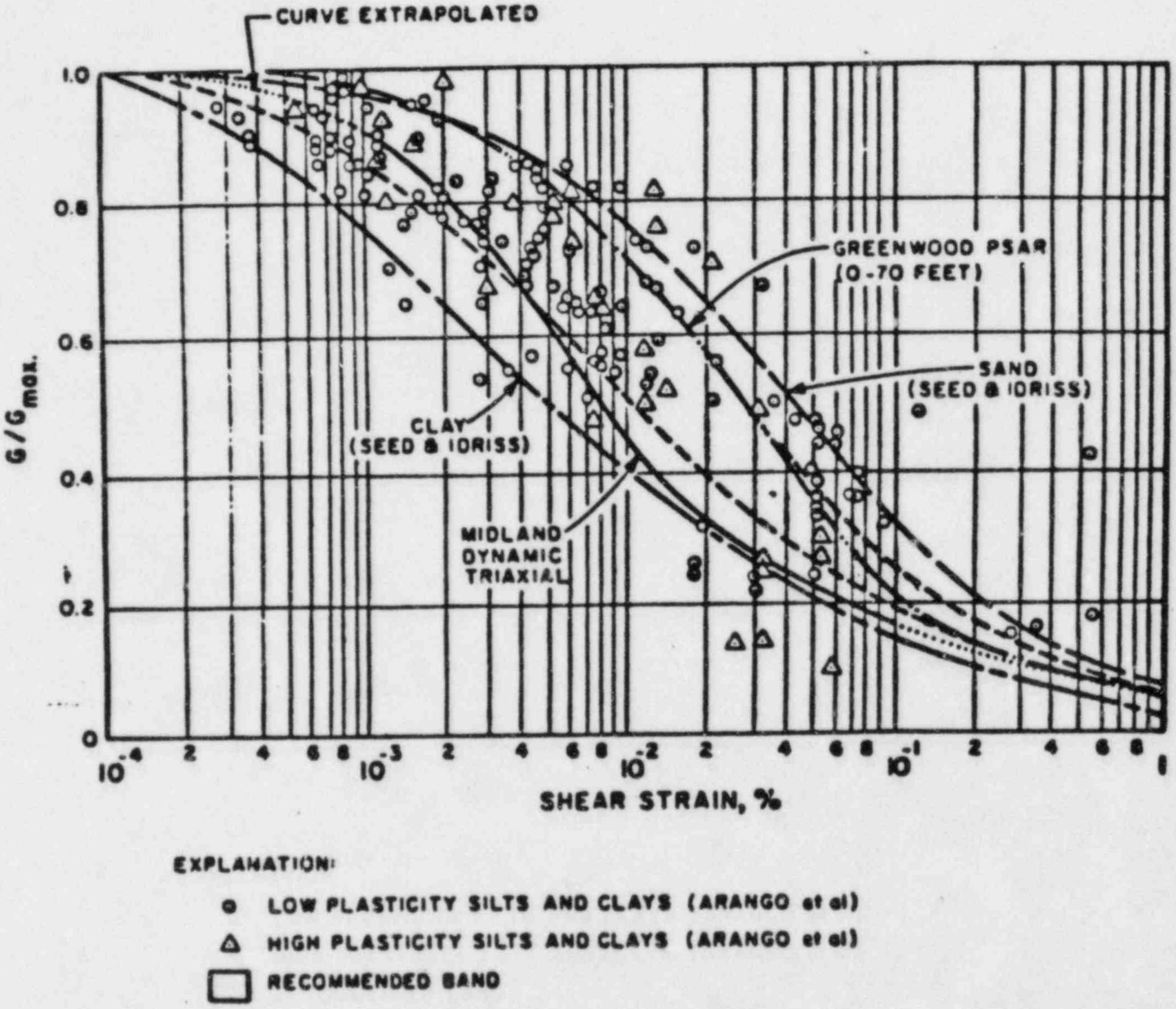
W_s = 145 pcf — V_s = 5000 fps

ν = 0.33

INTERMEDIATE SOIL PROFILE

STRAIN DEGRADATION EFFECTS

- SOIL PROFILES BASED ON LOW STRAIN SHEAR MODULI, G_{MAX}
- EQUIVALENT LINEAR HIGH STRAIN SOIL SHEAR MODULI, G_{SME}, ACCOUNT FOR EFFECT OF EARTHQUAKE INDUCED SHEAR STRAINS ON SOIL MATERIAL PROPERTIES
- STRAIN DEGRADATION RELATIONSHIPS APPROPRIATE FOR SME GROUND MOTION LEVELS WERE DEVELOPED BY DAMES & MOORE



STRAIN DEGRADATION RELATIONSHIPS

LAYERED SITE SOIL IMPEDANCE

SOIL IMPEDANCE DEVELOPMENT:

- PROGRAM CLASSI USED
- FIVE PERCENT SOIL MATERIAL DAMPING

REASONS FOR CLASSI APPROACH:

- LAYERED SOIL PROFILES MAY ENTRAP ENERGY NORMALLY DISSIPATED BY GEOMETRIC DAMPING
- PROCEDURE WITH THEORETICAL BASIS FOR EVALUATING EFFECTIVE STIFFNESS OF LAYERED SOIL PROFILE

EFFECTIVE SOIL SHEAR MODULUS

- AN EFFECTIVE SOIL SHEAR MODULUS, G_{EFF}, WAS DEVELOPED BASED ON CLASSI RESULTS

ADVANTAGES OF THIS APPROACH:

1. CHECK ON CLASSI RESULTS
   - COMPARE G_{EFF} TO LAYERED SOIL PROFILE CHARACTERISTICS
2. ALLOWS FOR MODIFICATION OF SOIL SPRINGS AND DASHPOTS TO ACCOUNT FOR:
   - NON-STANDARD FOUNDATION SHAPES
   - EMBEDMENT EFFECTS

UNCERTAINTY RANGE ON SHEAR MODULUS

CONSIDERATIONS:

- UNCERTAINTY IN LOW STRAIN SHEAR MODULUS, G_{MAX}
- UNCERTAINTY IN STRAIN DEGRADATION EFFECTS
- UNCERTAINTY IN LAYERING EFFECTS
- UNCERTAINTY IN MODELING USED TO OBTAIN SOIL COMPLIANCES

PARAMETRIC RANGES USED:

- LOWER BOUND SOIL CASE
    - 0.6 G_{EFF} (SOFT SITE PROFILE)
- UPPER BOUND SOIL CASE
    - 1.3 G_{EFF} (STIFF SITE PROFILE)
- INTERMEDIATE SOIL CASE
    - REMAINS THE SAME

ENERGY ENTRAPMENT DUE TO LAYERING

TWO TYPES OF DAMPING:

1. HYSTERETIC (MATERIAL) DAMPING
   - ESTIMATED AS 5 PERCENT OF CRITICAL DAMPING
   - NOT STRONGLY AFFECTED BY LAYERING

2. GEOMETRIC (RADIATION) DAMPING
   - WAVE PROPOGATION OF ENERGY THROUGH THE SOIL
   - LAYERED SOIL PROFILE MAY ENTRAP ENERGY EFFECTIVELY REDUCING GEOMETRIC DAMPING
   - EFFECT IS EVALUATED BY A KNOCKDOWN FACTOR

$$F_{LAYER} = \frac{C(\text{CLASSI LAYERED SITE ANALYSIS})}{C(\text{THEORETICAL ELASTIC HALF-SPACE})}$$

   - LIMITED TO EITHER 75 PERCENT OF THEORETICAL ELASTIC HALF-SPACE VALUES OR 100 PERCENT OF ANALYTICALLY DETERMINED VALUES FOR SOIL PROFILE WHICH EVER IS LOWER

DEVELOPMENT OF IN-STRUCTURE RESPONSE SPECTRA

CONSIDERATIONS:

- THREE SOIL CASES (LOWER, INTERMEDIATE, UPPER)
- EFFECTS OF MULTIDIRECTIONAL EXCITATION
- TORSIONAL RESPONSE
- BROADENING AND ENVELOPING TECHNIQUES
- FLOOR SLAB VERTICAL AMPLIFICATION

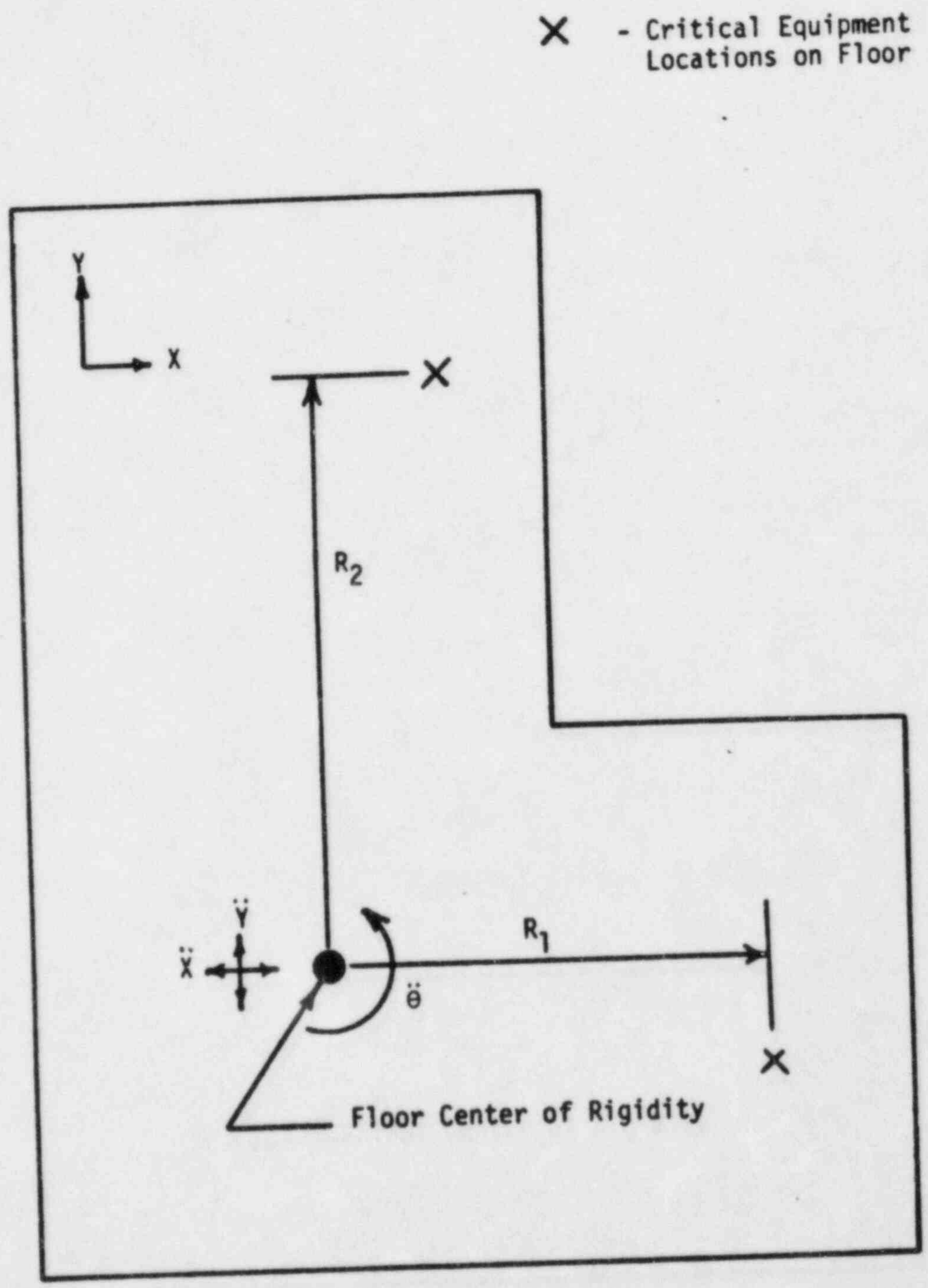
DETERMINATION OF SME IN-STRUCTURE RESPONSE SPECTRA

- TRANSLATIONAL AND ROTATIONAL SPECTRA AT THE FLOOR CENTER OF RIGIDITY FOR EACH RESPONSE DIRECTION WERE DETERMINED BY TAKING THE SQUARE-ROOT-SUM-OF THE-SQUARES OF CONTRIBUTIONS TO THE SPECTRAL ORDINATES FROM THE VERTICAL AND THE TWO HORIZONTAL GROUND MOTIONS

- TORSIONAL RESPONSE CONTRIBUTION TO TRANSLATIONAL RESPONSE WAS INCLUDED:

  - IMPORTANT FOR EQUIPMENT NOT AT THE CENTER OF RIGIDITY

  - TRANSLATIONAL COMPONENT DUE TO TORSION WAS CONSERVATIVELY INCLUDED BY ADDING IN THE ABSOLUTE SUM OF A MOMENT ARM R_1 TIMES THE ROTATIONAL SPECTRA AT THE FLOOR CENTER OF RIGIDITY TO THE APPROPRIATE TRANSLATIONAL COMPONENT

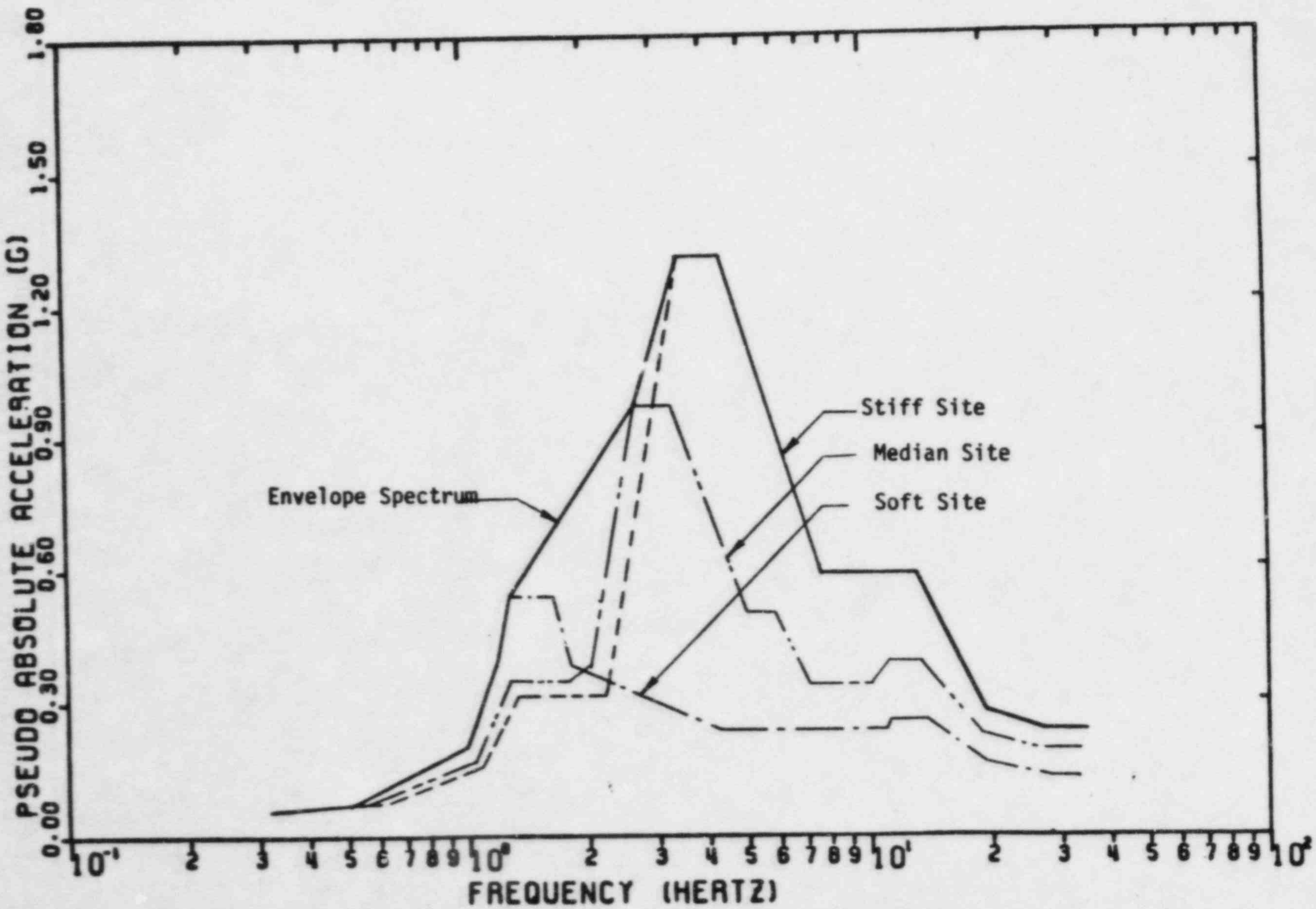


SCHEMATIC REPRESENTATION OF TYPICAL FLOOR SHOWING CRITICAL EQUIPMENT LOCATIONS RELATIVE TO THE FLOOR CENTER OF RIGIDITY

IN-STRUCTURE RESPONSE SPECTRA SMOOTHING AND BROADENING

- PEAKS OF THE SPECTRA WERE BROADENED AN ADDITIONAL ± 10%
- ACCOUNTS FOR VARIABILITIES IN-STRUCTURE FREQUENCIES DUE TO UNCERTAINTIES IN:
  - A) MATERIAL PROPERTIES
  - B) STRUCTURAL MODELING ASSUMPTIONS
- UNCERTAINTY IN SITE SOIL CHARACTERISTICS IS COVERED BY BROAD RANGE OF SOIL SHEAR MODULI USED IN SME

- FINAL SME IN-STRUCTURE RESPONSE SPECTRA WERE DEVELOPED AS AN ENVELOPE OF THE BROADENED SPECTRA FOR THE THREE SOIL CASES
  - CONSIDERED POSSIBLE SHIFTING OF STRUCTURE FREQUENCIES
  - SPECTRA WERE SMOOTHED TO REMOVE MINOR VOLLEYS



DEVELOPMENT OF ENVELOPE IN-STRUCTURE RESPONSE SPECTRA

FLOOR SLAB VERTICAL AMPLIFICATION

- SEISMIC DESIGN MODELS DEVELOPED TO COMPUTE OVERALL BUILDING RESPONSE AND DID NOT INCLUDE FLOOR FLEXIBILITY.

- FLOOR SLAB AMPLIFICATION MAY BE SIGNIFICANT FOR SLABS WITH RELATIVELY LOW FREQUENCIES.

- SLABS WITH LOWEST EXPECTED FREQUENCIES WERE SELECTED FOR ANALYSIS FROM:

    - AUXILIARY BUILDING
    - DIESEL GENERATOR BUILDING (DGB)
    - SERVICE WATER PUMP STRUCTURE (SWPS)

- SLAB FLEXIBILITY INCLUDED IN THE REACTOR BUILDING EQUIPMENT QUALIFICATION ANALYSIS.

BUILDING FLOOR SLABS EVALUATED

- AUXILIARY BUILDING FLOORS SELECTED FROM:

  MAIN AUXILIARY BUILDING
  CONTROL TOWER
  ELECTRICAL PENETRATION AREA (EPA)

  EL. 584'-0" MAIN AUX. BLDG. (LOW, HEAVILY LOADED SLAB)
  EL. 614'-0" MAIN AUX. BLDG. (HIGH, FLEXIBLE SLAB)
  EL. 646'-0" CONTROL TOWER (LOW, FLEXIBLE SLAB)
  EL. 685'-0" CONTROL TOWER (HIGH, MOST FLEXIBLE SLAB)
  EL. 642'-7" EPA (MOST FLEXIBLE, HIGH MASS)

- DGB FLOOR

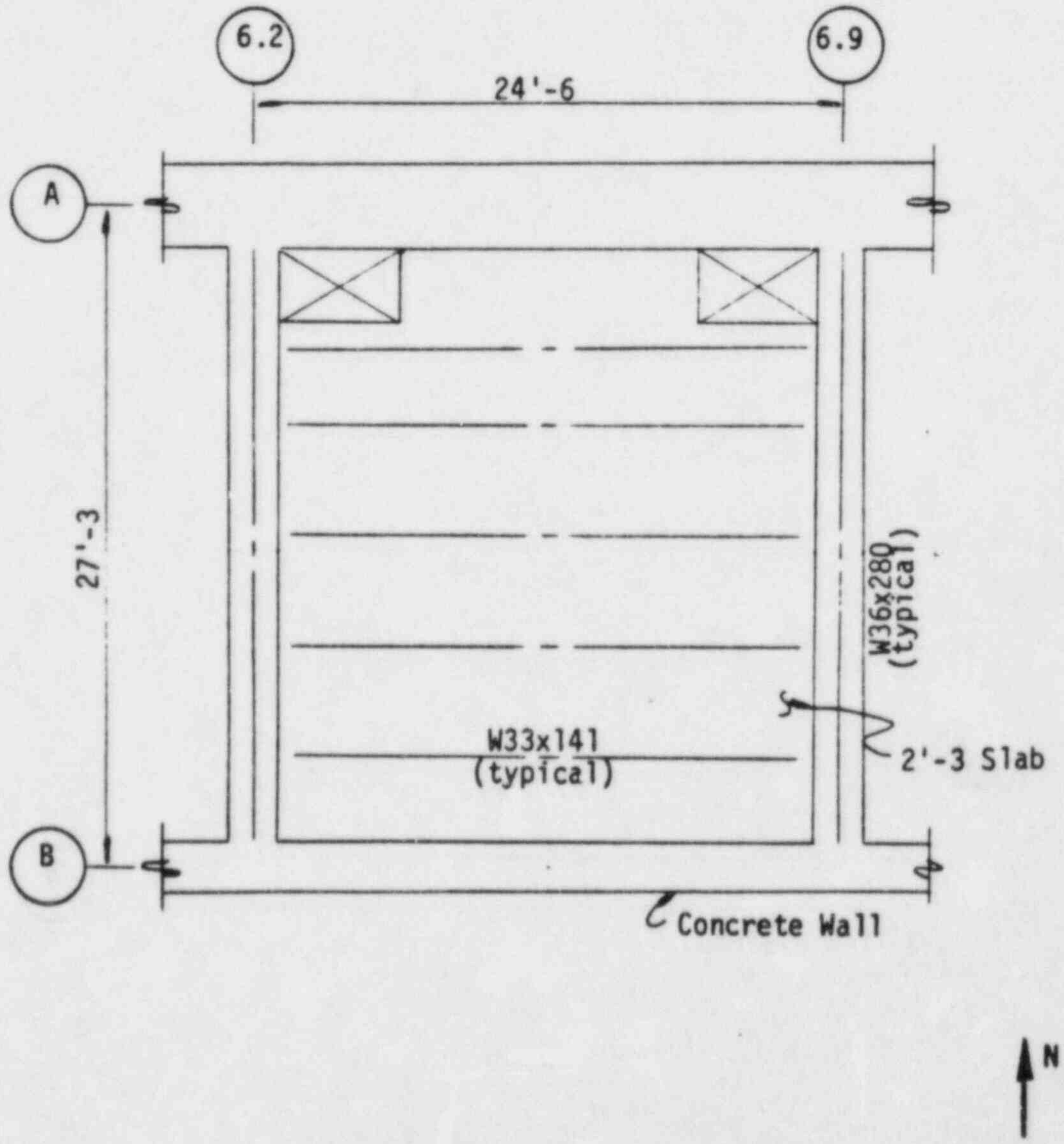
  EL. 664'-0" (INCLUDES SOME CAT.I EQUIPMENT)

- SWPS FLOOR

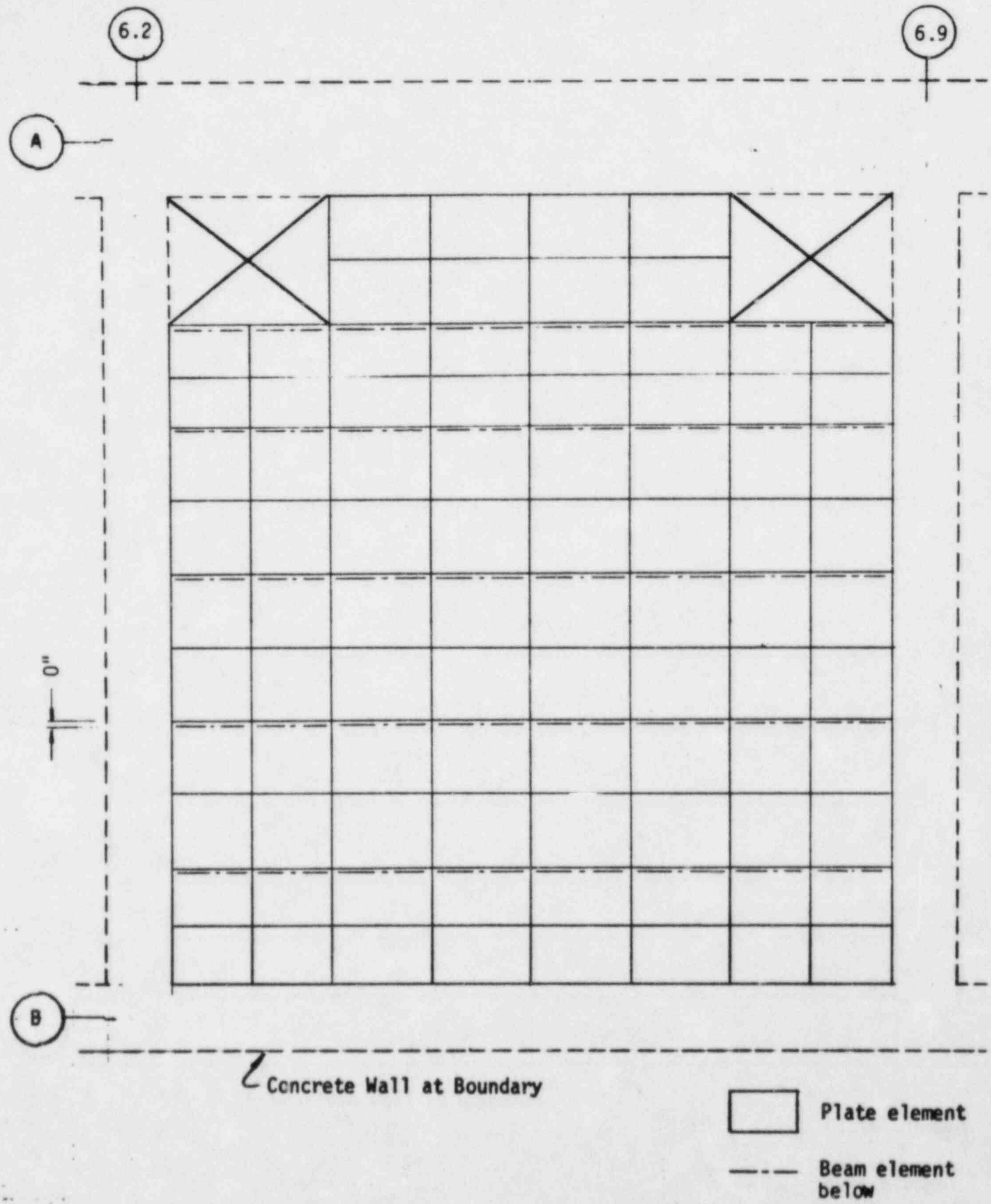
  EL. 634'-6" (INCLUDES MOST CAT. I EQUIPMENT)

FLOOR SLAB ANALYSIS

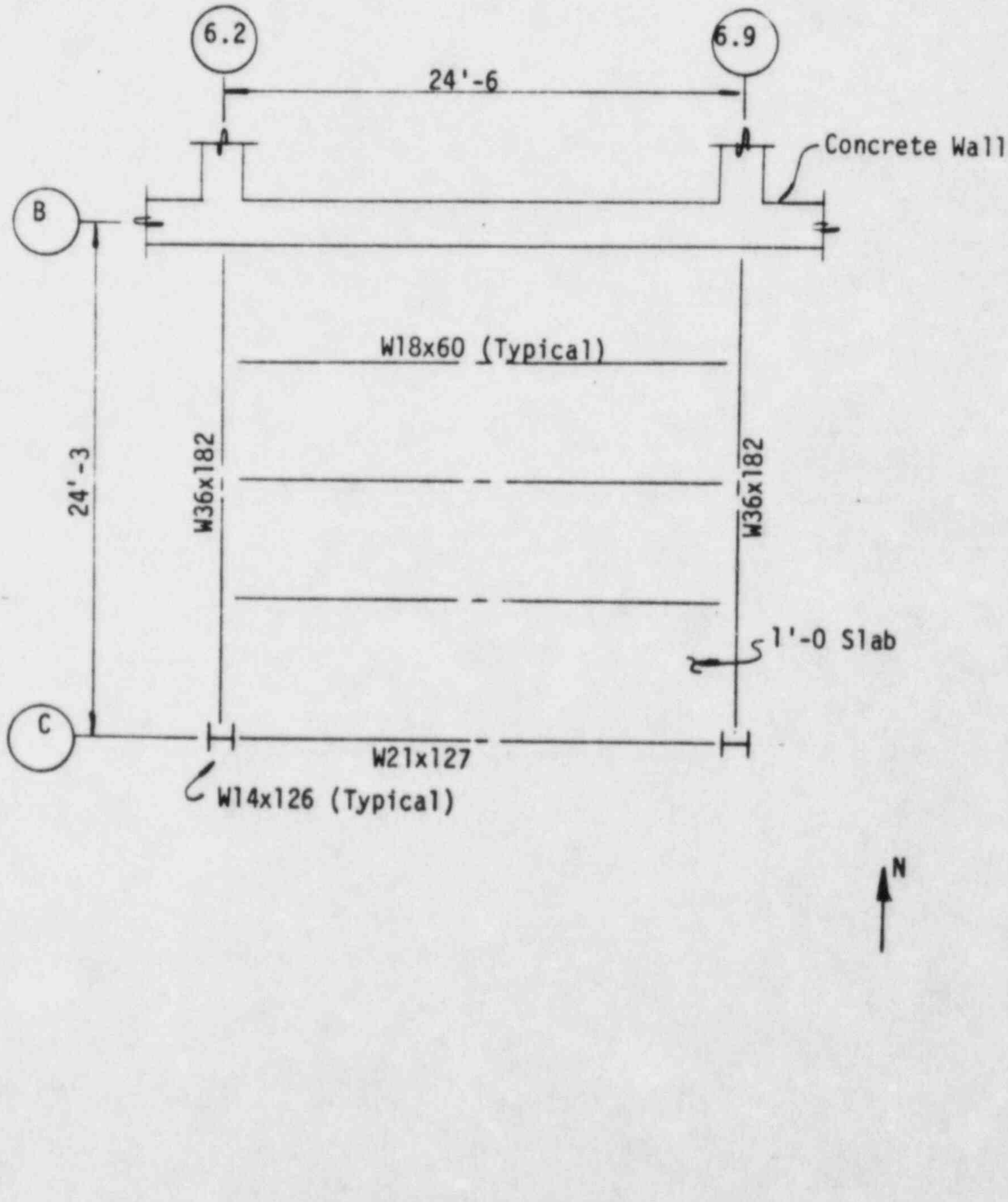
- FLOORS SELECTED ARE SINGLE BAYS BOUNDED BY VERTICAL SUPPORTS.
- FINITE ELEMENT MODELS DEVELOPED TO CONSERVATIVELY REFLECT APPROPRIATE GEOMETRY AND BOUNDARY CONDITIONS.
- MODELS CONSIST OF PLATE AND BEAM ELEMENTS.
- MASS REPRESENTING STRUCTURAL ELEMENTS AND NON-LOAD BEARING WALLS AND EQUIPMENT INCLUDED.
- FLOOR STRESSES SUBSEQUENTLY CHECKED TO ESTIMATE DAMPING.



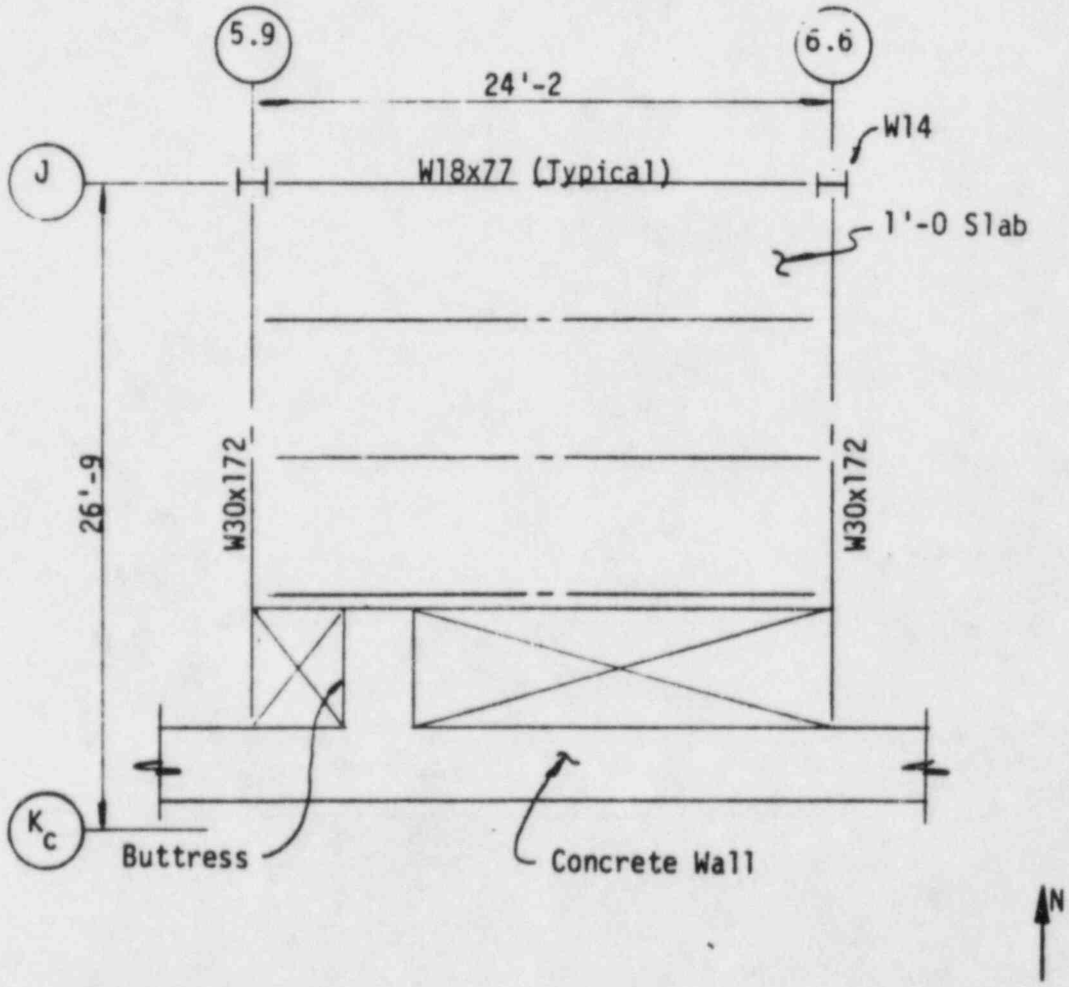
AUXILIARY BUILDING FLOOR AT ELEVATION 584'-0



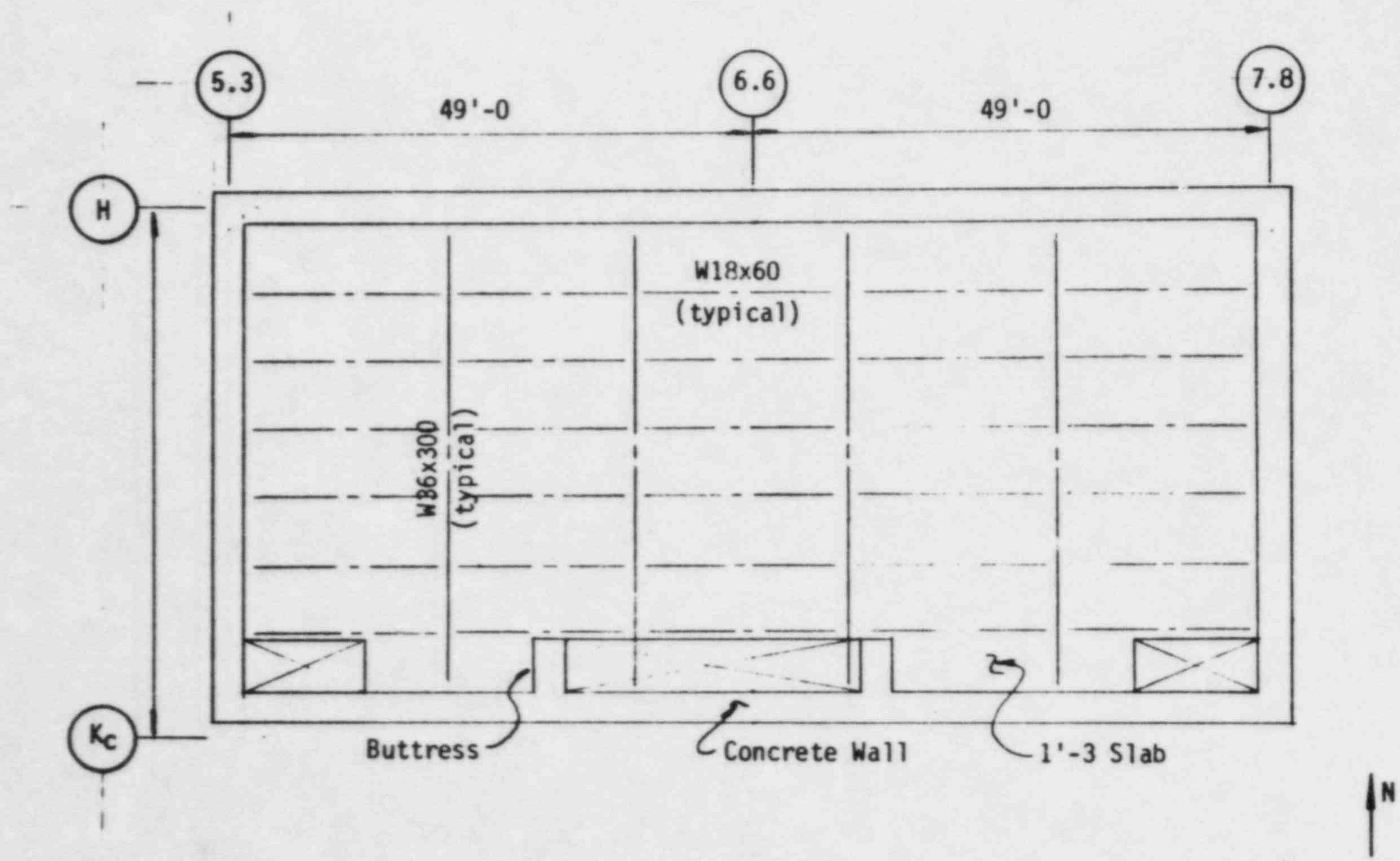
FINITE ELEMENT MESH OF AUXILIARY BUILDING FLOOR AT ELEVATION 584'-0"



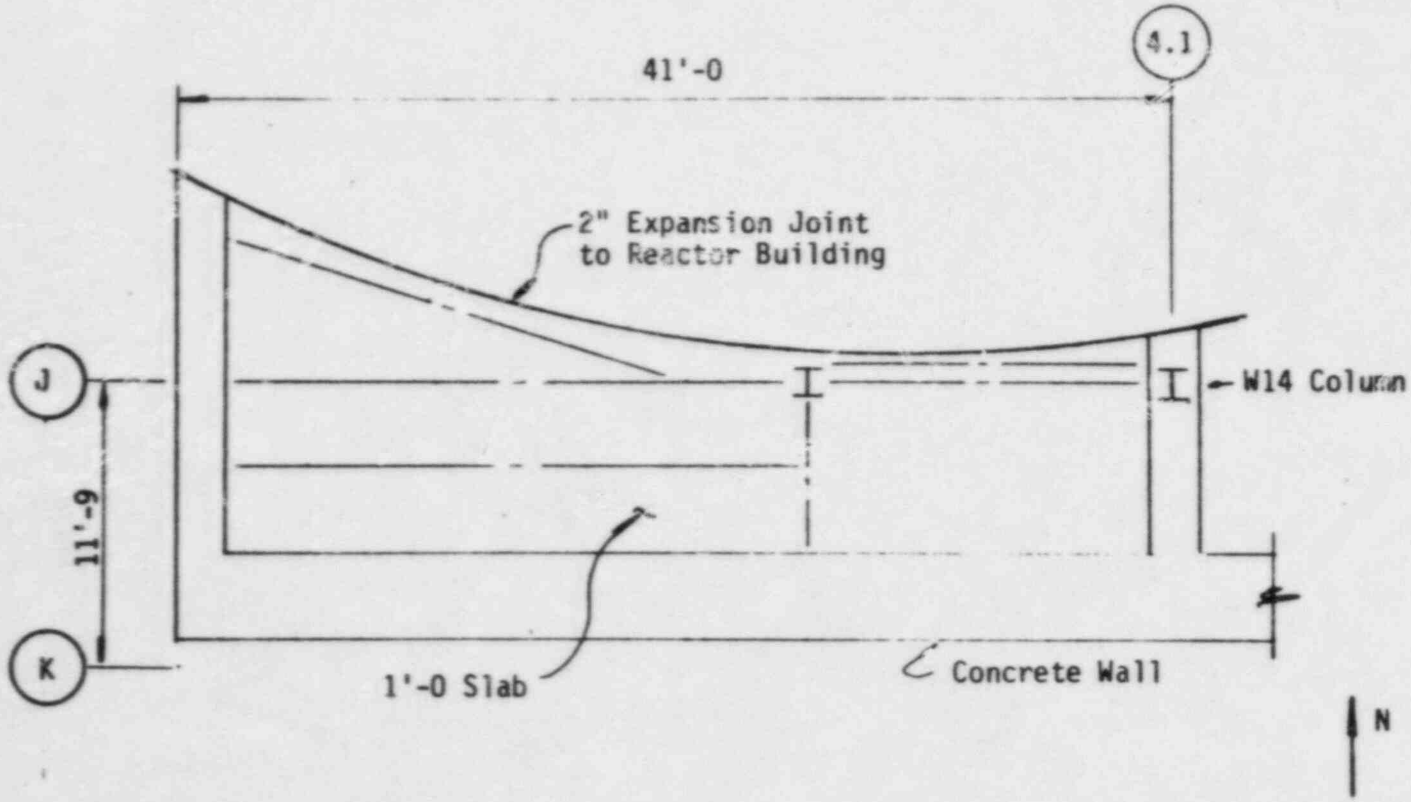
AUXILIARY BUILDING FLOOR AT ELEVATION 614'-0



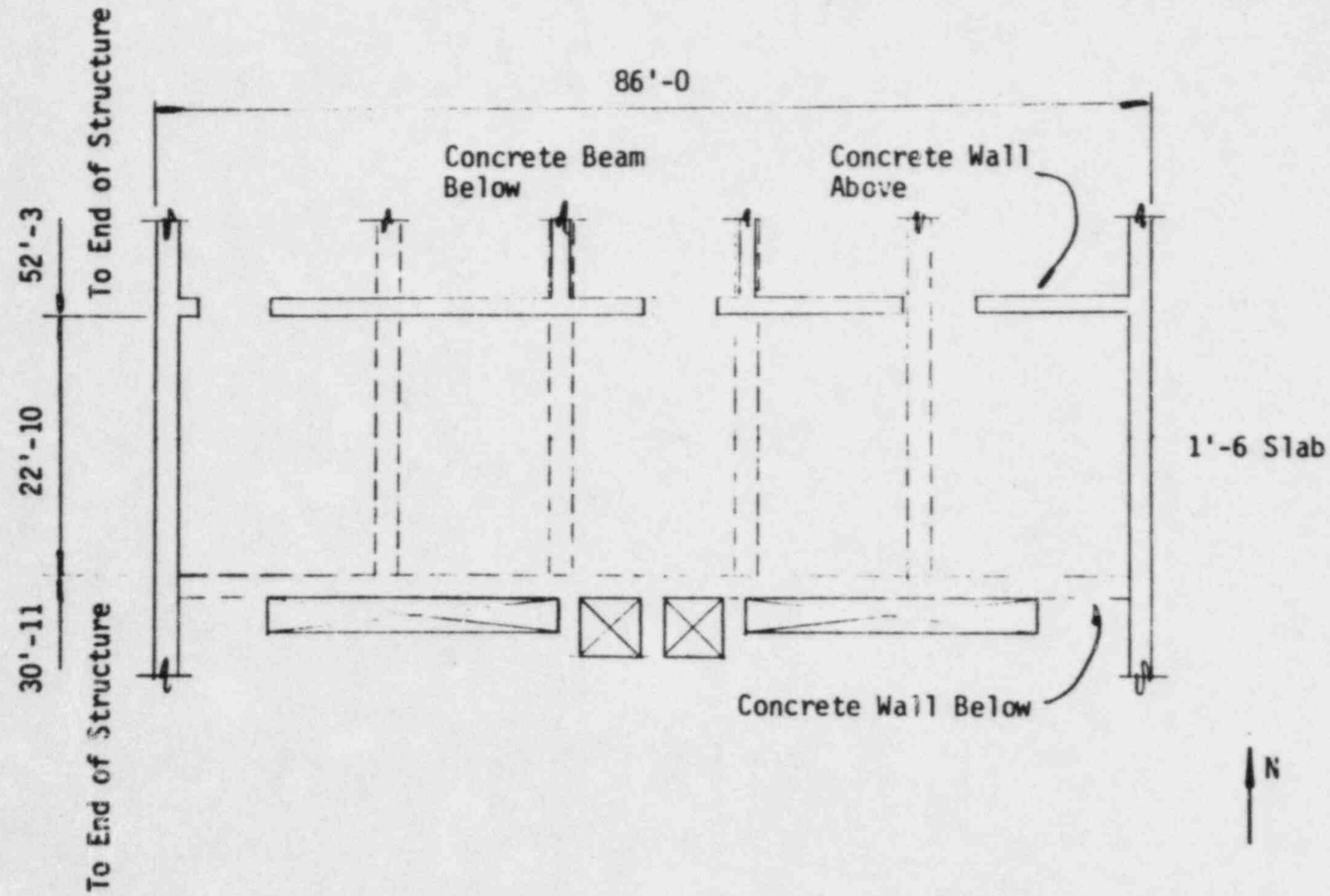
AUXILIARY BUILDING FLOOR AT ELEVATION 646'-0"



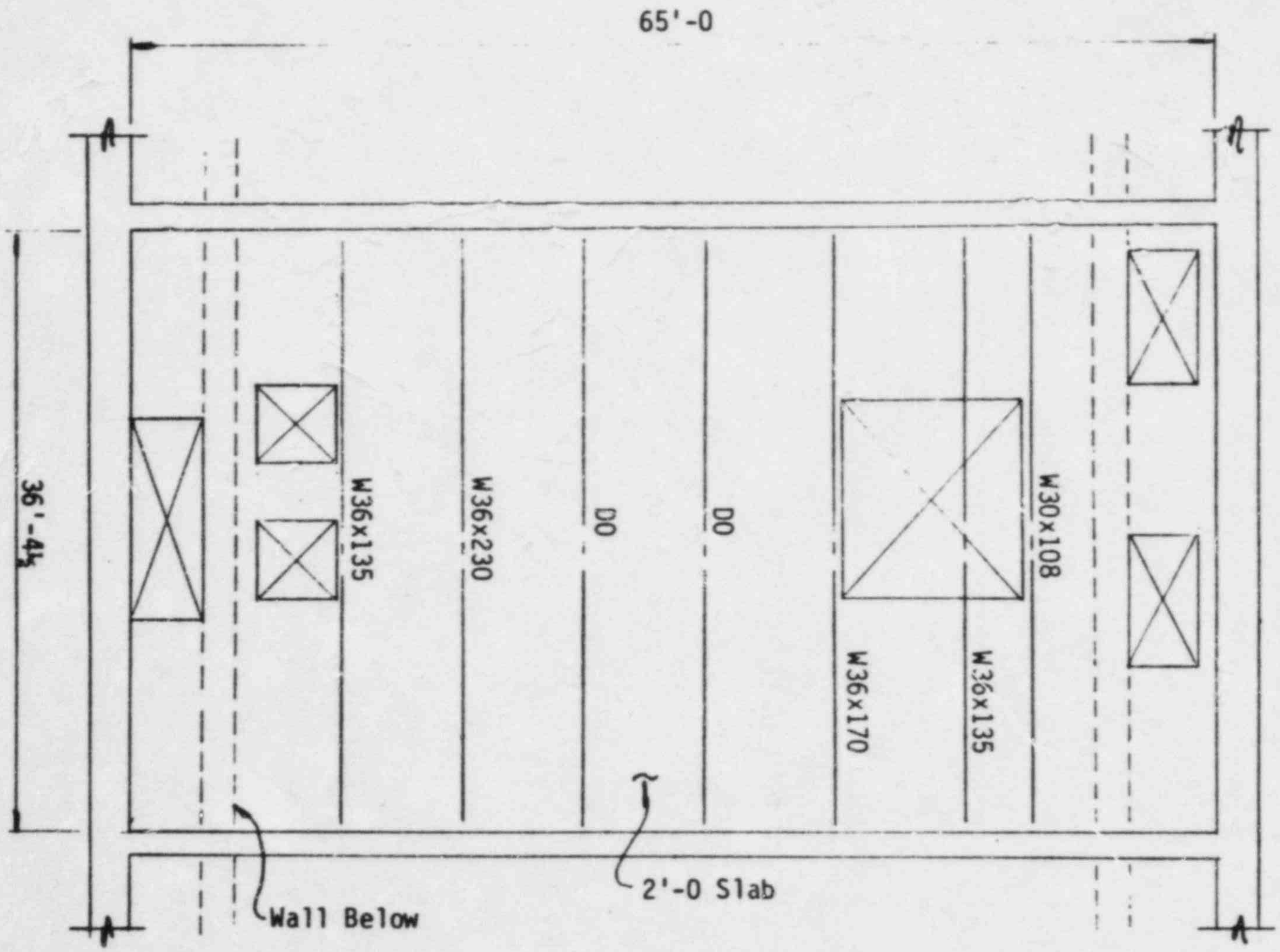
AUXILIARY BUILDING FLOOR AT ELEVATION 685'-0



AUXILIARY BUILDING FLOOR AT ELEVATION 642'-7
(WEST ELECTRICAL PENETRATION WING)



SERVICE WATER PUMP STRUCTURE FLOOR
AT ELEVATION 634'-6



Note: Some walls and framing not shown for clarity.

DIESEL GENERATOR BUILDING FLOOR AT ELEVATION 664'-0

VERTICAL INPUT TO EQUIPMENT

- IN-STRUCTURE RESPONSE SPECTRA DEVELOPED FROM SINGLE DEGREE OF FREEDOM MODELS WITH FREQUENCIES EQUAL TO FEM FUNDAMENTALS.
- DAMPING FOR UNCRACKED CONCRETE (4% OF CRITICAL) USED FOR ALL SLABS.
- FOR AUXILIARY BUILDING: VERTICAL TIME HISTORIES FROM BUILDING STRUCTURAL MODEL USED TO DEVELOP IN-STRUCTURE RESPONSE SPECTRA.
- FOR DGB AND SWPS: SDOF MODELS ADDED TO OVERALL BUILDING MODELS.
- VERTICAL IN-STRUCTURE RESPONSE SPECTRA WITHOUT FLOOR FLEXIBILITY INCREASED BY VERTICAL AMPLIFICATION FACTOR (VAF) IN AUXILIARY BUILDING.

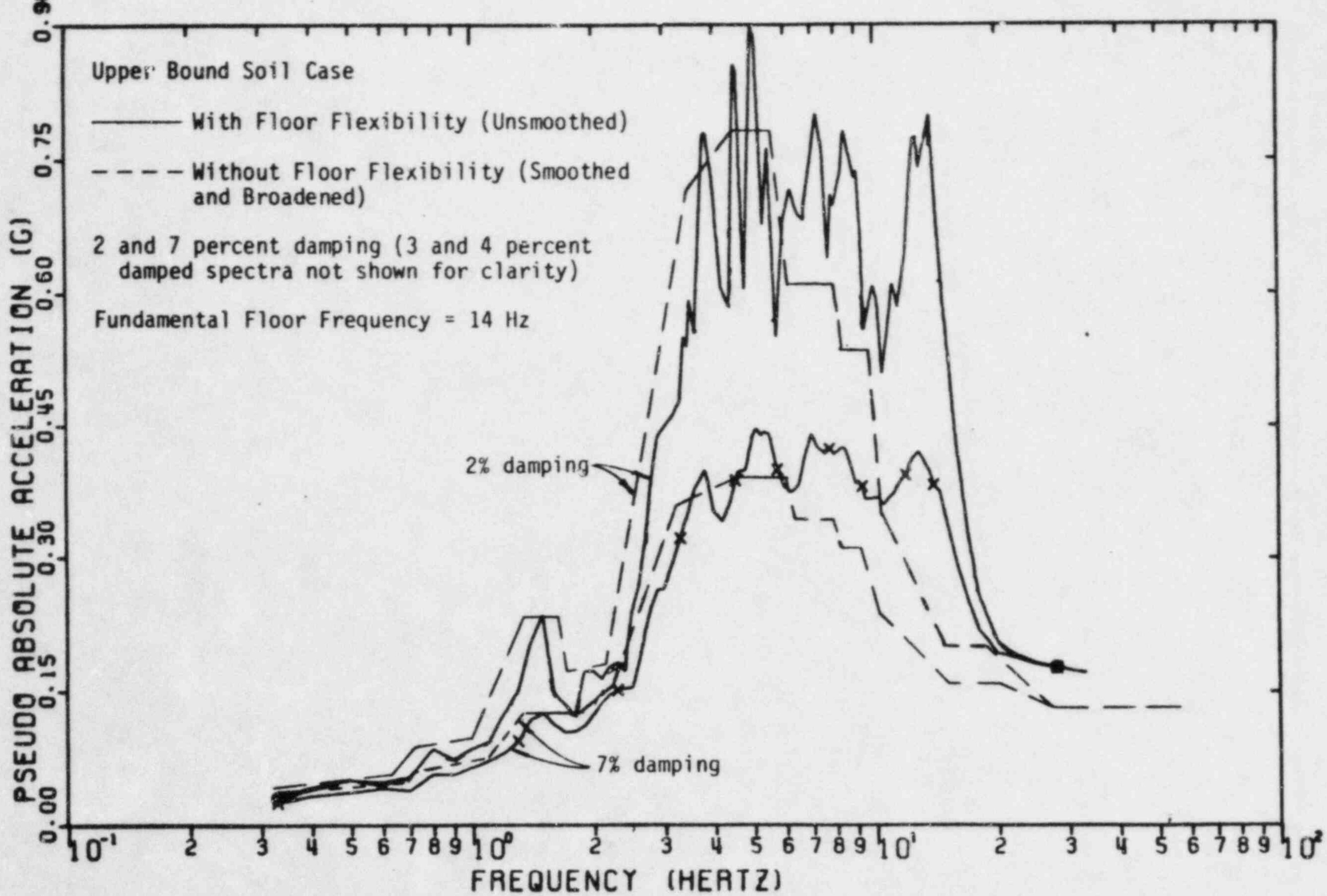
VERTICAL AMPLIFICATION FACTOR (VAF)

- $$\text{VAF} = \frac{\text{(UNBROADENED SPECTRAL ACCELERATION AT FREQUENCY F INCLUDING FLOOR FLEXIBILITY}}{\text{(BROADENED SPECTRAL ACCELERATION AT FREQUENCY F NOT INCLUDING FLOOR FLEXIBILITY}}$$

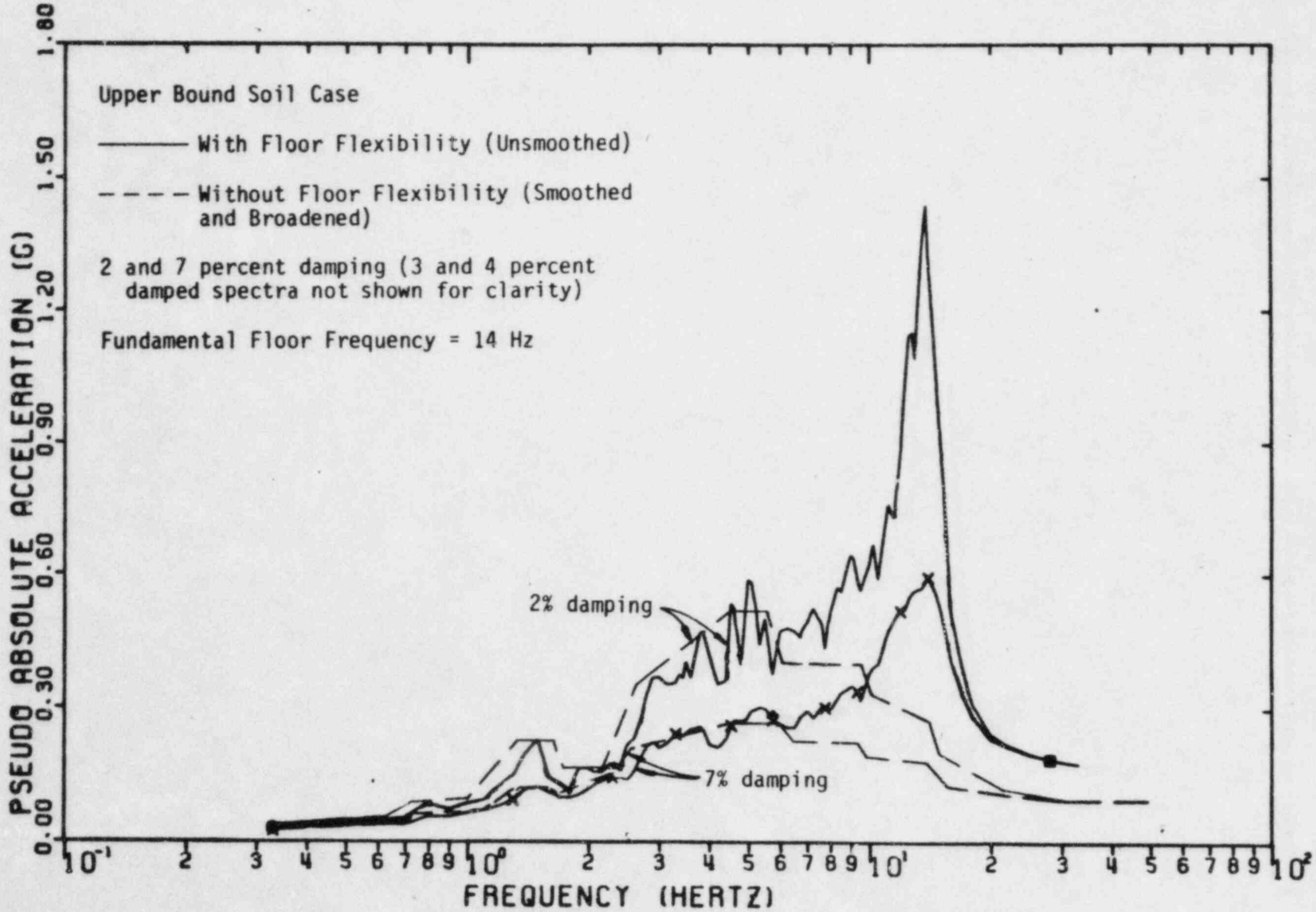
- OVERALL VAF DEVELOPED FROM ENVELOPE OF ALL FLOORS AS A FUNCTION OF EQUIPMENT FREQUENCY AND DAMPING.

- VAF BROADENED $\pm$ 10%.

- VAF FOR EQUIPMENT LOCATED AWAY FROM SLAB CENTER ASSUMED FOLLOW SINE WAVE.



COMPARISON OF VERTICAL SPECTRA
WITH AND WITHOUT FLOOR FLEXIBILITY AT
ELEVATION 646'-0", CONTROL TOWER

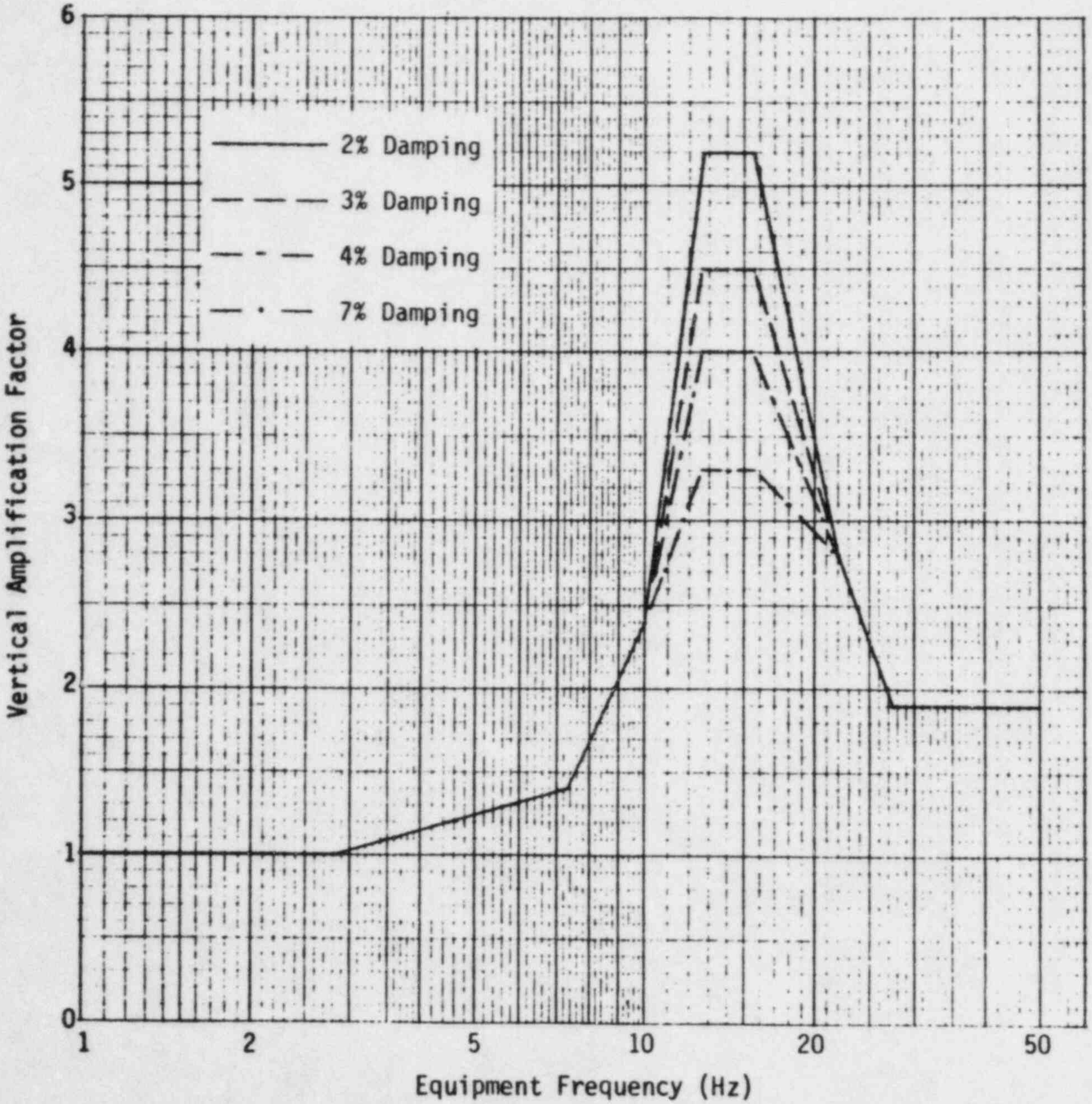


COMPARISON OF VERTICAL SPECTRA
WITH AND WITHOUT FLOOR FLEXIBILITY AT
ELEVATION 614'-0", MAIN AUXILIARY BUILDING

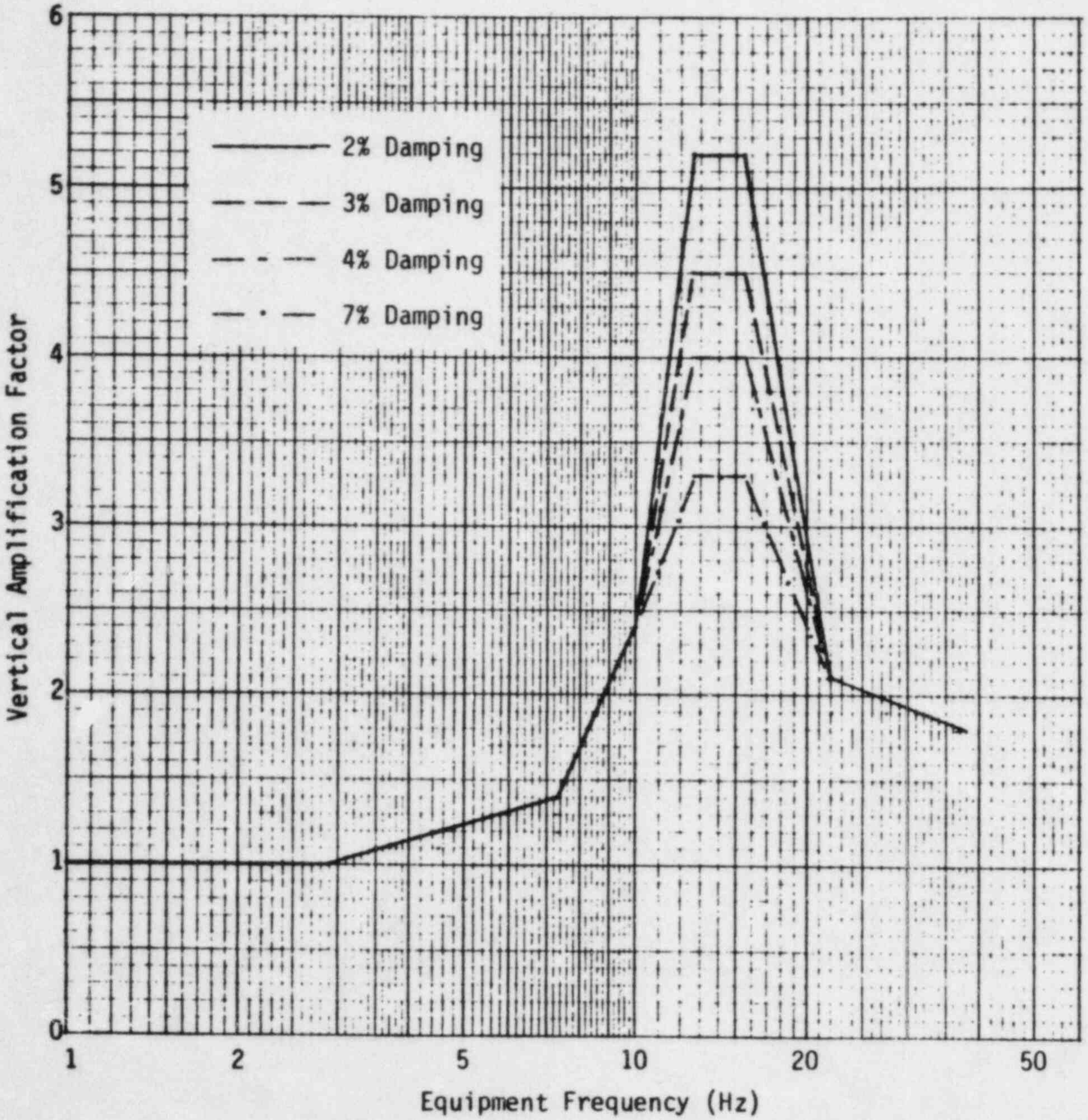
AUXILIARY BUILDING VERTICAL AMPLIFICATION FACTORS

2% Equipment Damping

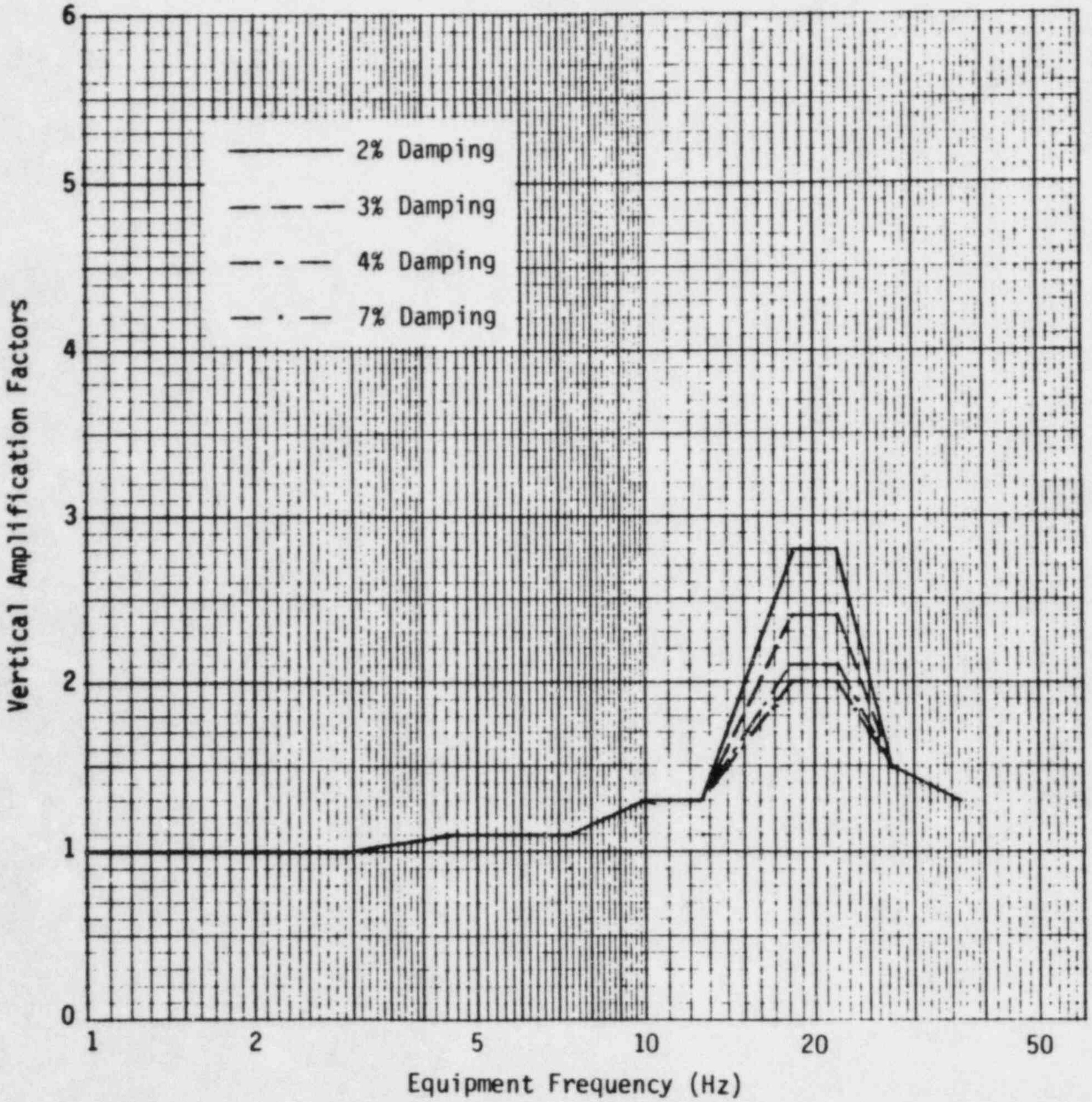
Location	Floor Frequency (Hz)	Equipment Frequency							
		5 Hz	8 Hz	11 Hz	14 Hz	20 Hz	25 Hz	29 Hz	33 Hz
El. 584'-0", Main Auxiliary Bldg.	35	1.0	0.89	0.96	0.79	0.95	1.1	1.3	1.6
El. 614'-0", Main Auxiliary Bldg.	14	1.1	1.3	2.3	5.2	1.9	1.8	1.9	1.8
El. 646'-0", Control Tower	14	1.2	1.1	1.8	3.4	1.1	1.3	1.4	1.4
El. 685'-0", Control Tower	11	1.3	1.7	5.0	2.1	1.6	2.0	2.0	2.0
El. 642'-7", West Penetration Wing	29	1.0	0.96	0.87	1.1	0.98	1.1	1.3	1.1



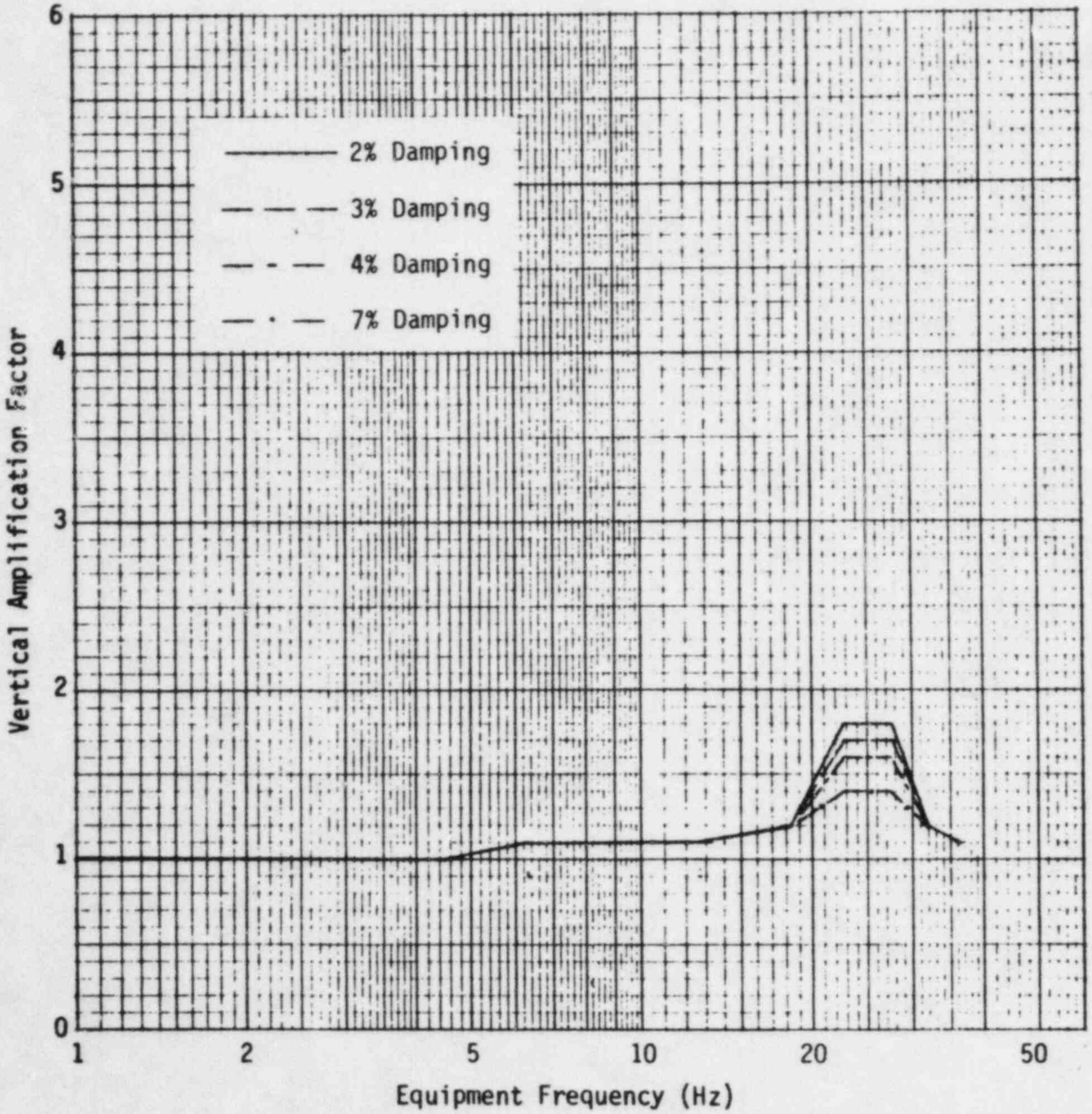
ENVELOPE VERTICAL AMPLIFICATION FACTORS
FOR AUXILIARY BUILDING



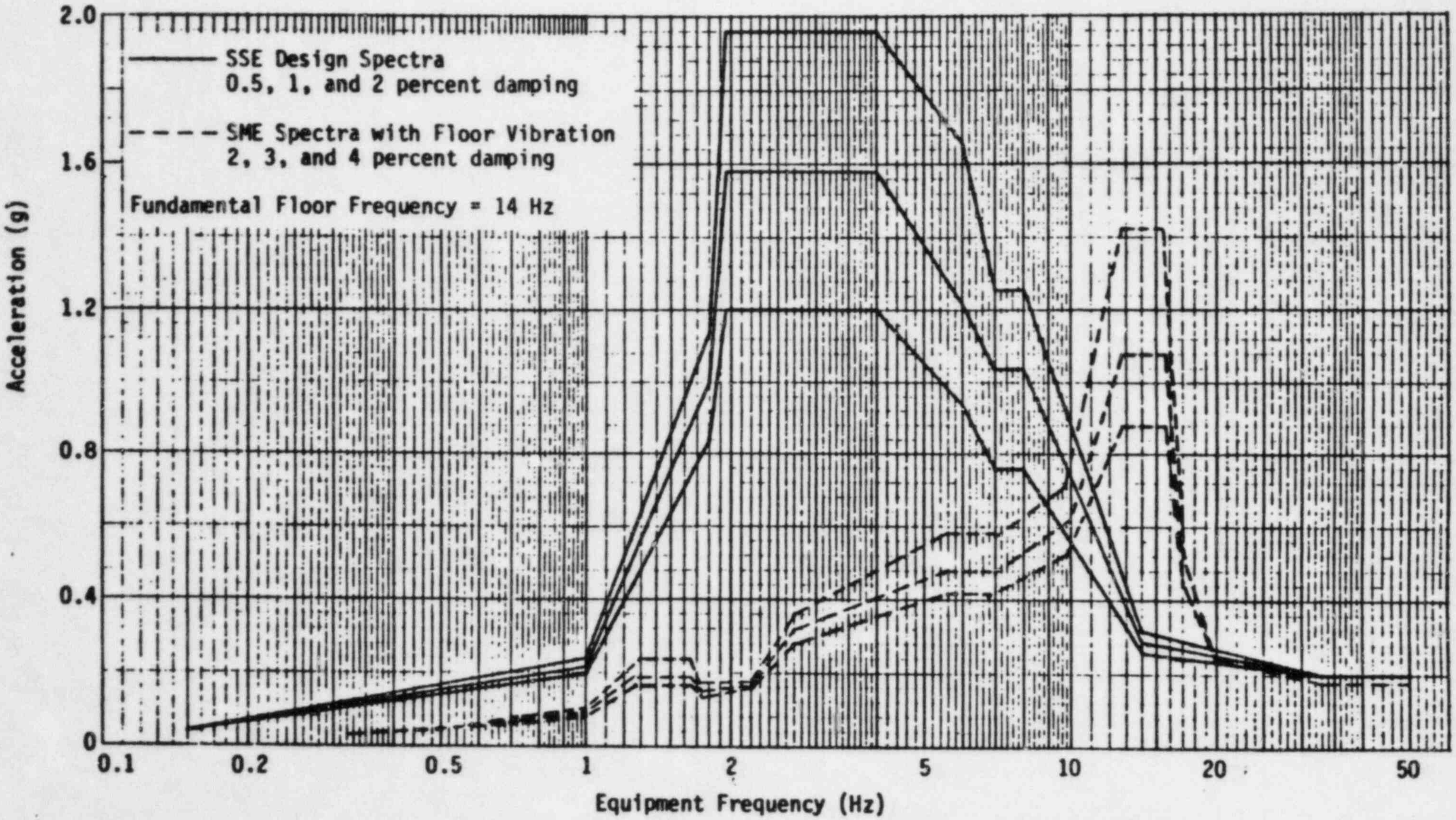
VERTICAL AMPLIFICATION FACTOR FUNCTIONS
FOR 14 Hz FUNDAMENTAL FREQUENCY FLOORS
FOR AUXILIARY BUILDING



VERTICAL AMPLIFICATION FACTOR FUNCTIONS
FOR 20 Hz FUNDAMENTAL FREQUENCY FLOORS
FOR AUXILIARY BUILDING



VERTICAL AMPLIFICATION FACTOR FUNCTIONS
FOR 25 Hz FUNDAMENTAL FREQUENCY FLOORS
FOR AUXILIARY BUILDING



COMPARISON OF SSE DESIGN AND SME VERTICAL SPECTRA
AT ELEVATION 614'-0", MAIN AUXILIARY BUILDING

SEISMIC MARGINS

FOR

MECHANICAL, ELECTRICAL, CONTROL AND

INSTRUMENTATION EQUIPMENT

PRESENTATION TO

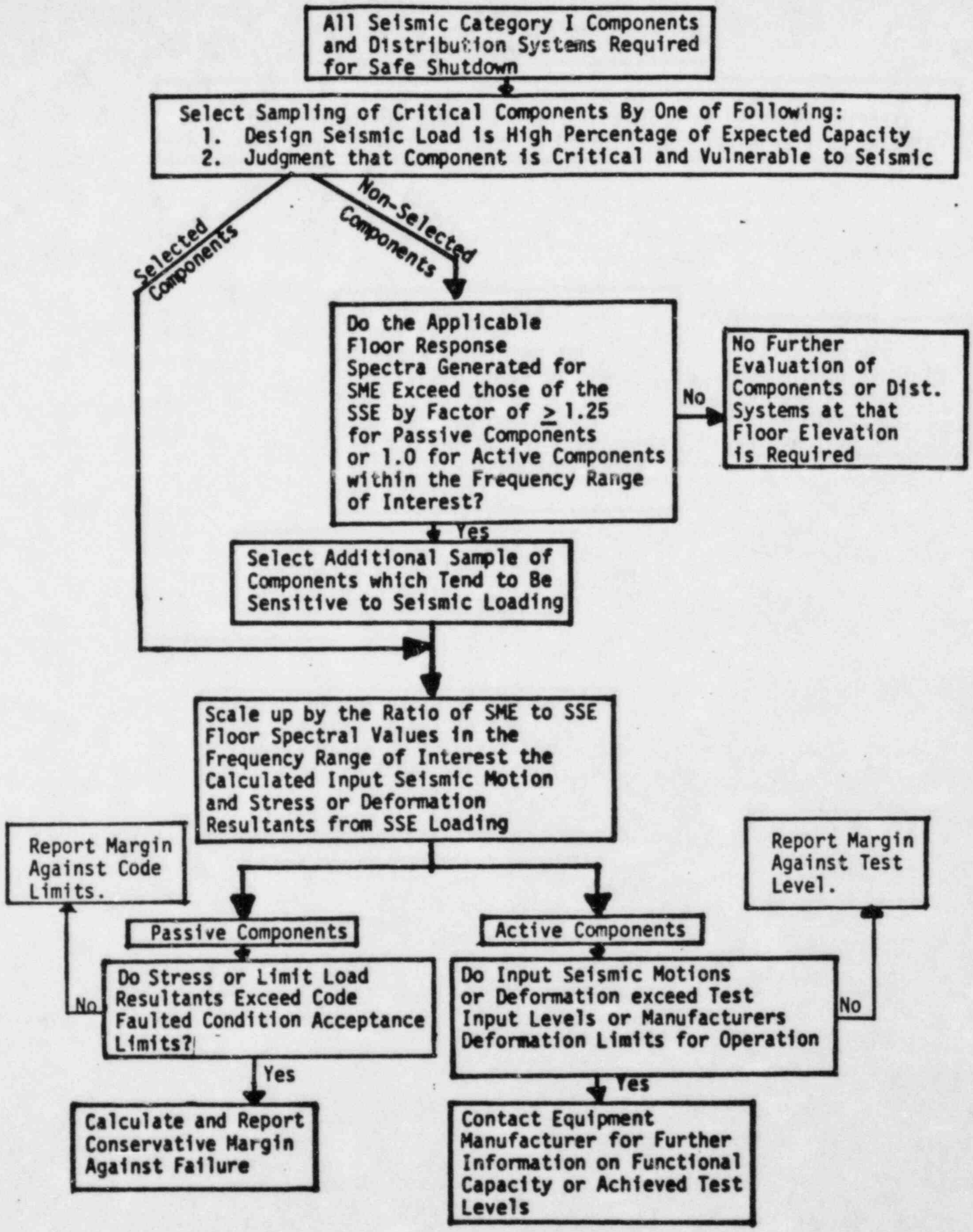
USNRC/CONSUMERS POWER CO.

APRIL 1984

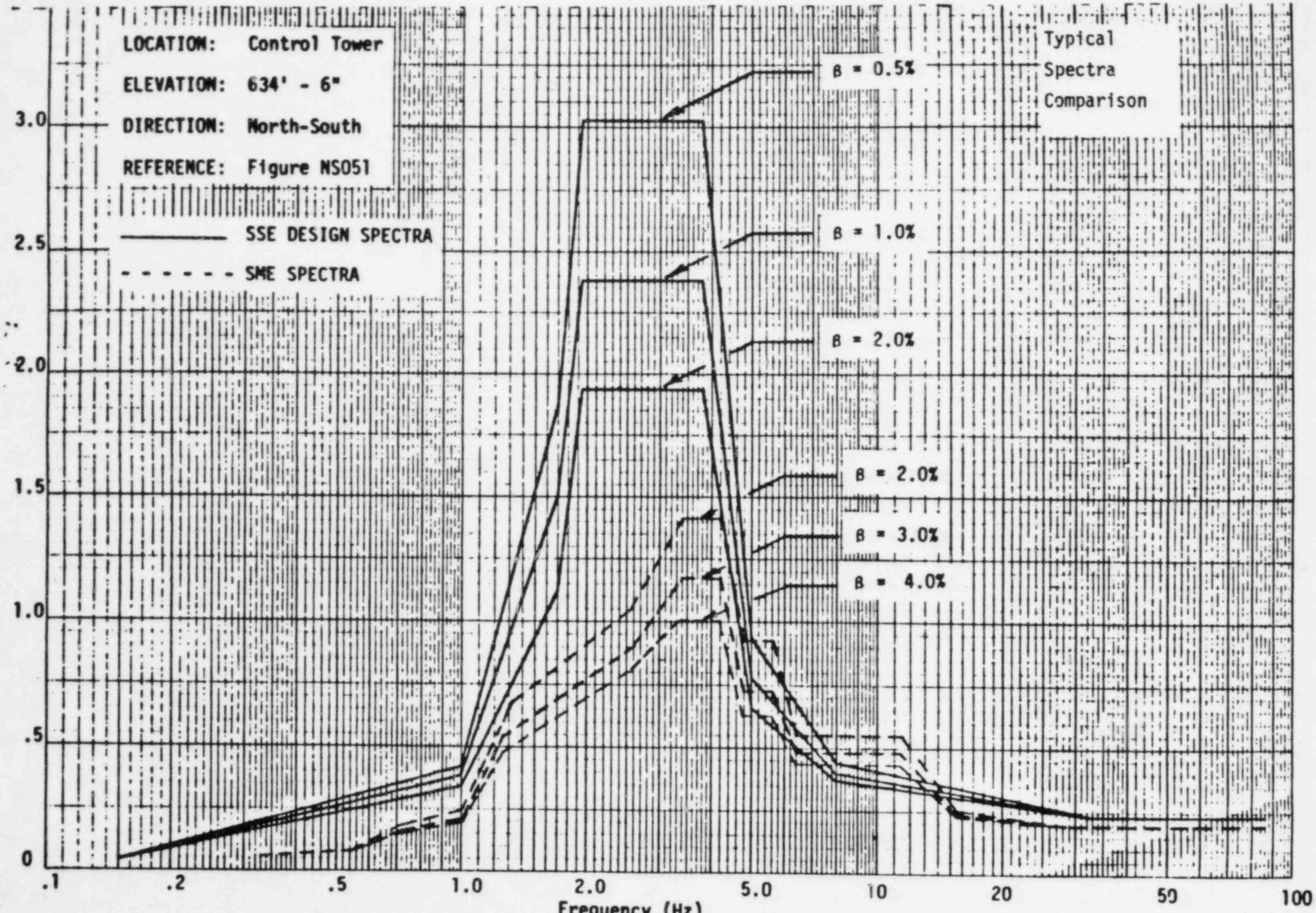
SCOPE OF STUDY

- CONSIDER ALL EQUIPMEMT AND SUPPORTING SYSTEMS REQUIRED FOR SAFE SHUTDOWN
- SELECT REPRESENTATIVE SAMPLES FROM TOTAL INVENTORY
- EVALUATE SAMPLES FOR SEISMIC MARGIN EARTHQUAKE PLUS NORMAL OPERATING LOADS
- DETERMINE MARGIN AGAINST:

  CODE ALLOWABLE OR
  FUNCTIONAL ALLOWABLE OR
  FAILURE



PROCESS TO SELECT COMPONENTS AND DISTRIBUTION SYSTEMS
FOR SEISMIC SAFETY MARGIN EVALUATION AND DEVELOP MARGINS



Comparison of SSE Design and Enveloped SME Spectra
Control Tower, Elevation 634'-6"
North-South Direction

SYSTEMS REQUIRED FOR SAFE SHUTDOWN

- REACTOR COOLANT & PRESSURE CONTROL
- MAKEUP & PURIFICATION
- DECAY HEAT REMOVAL (COLD SHUTDOWN ONLY)
- COMPONENT COOLING WATER
- SERVICE WATER
- SAFEGUARDS CHILLED WATER
- EMERGENCY DIESEL GENERATOR FUEL OIL STORAGE AND TRANSFER
- HVAC
- MAIN STEAM
- CONDENSATE AND FEEDWATER (AUX. F.W.)
- EMERGENCY DIESEL POWER GENERATION
- STATION BATTERIES
- ELECTRICAL POWER DISTRIBUTION, CONTROL AND INSTRUMENTATION SYSTEMS

NSSS SUBSYSTEMS AND COMPONENTS

- REACTOR VESSEL AND SUPPORTS
- REACTOR VESSEL INTERNALS
- CONTROL ROD DRIVES AND HOUSINGS
- STEAM GENERATORS AND SUPPORTS
- REACTOR COOLANT PUMPS AND SUPPORTS
- PRESSURIZER AND SUPPORTS
- REACTOR COOLANT LOOP PIPING
- PRESSURIZER SURGE LINE

AE DESIGNED SUBSYSTEMS

- o BOP PIPING
- o HVAC DUCTING AND SUPPORTS
- o CABLE TRAYS AND SUPPORTS
- o ELECTRICAL CONDUIT AND SUPPORTS

VENDOR SUPPLIED BOP EQUIPMENT PURCHED BY A/E AND NSSS SUPPLIER

ELECTRICAL POWER DISTRIBUTION

SWITCHGEAR, MCC'S, TRANSFORMERS, BUSSES

ELECTRICAL POWER SUPPLY

AC - DIESEL GENERATOR UNITS
DC - 125 V STATION BATTERIES

INSTRUMENTATION AND CONTROL

CONTROL PANELS, CABINETS,
INSTRUMENTATION PANELS, CABINETS

MECHANICAL EQUIPMENT

ACTIVE - PUMPS, FANS, COMPRESSORS
PASSIVE - TANKS, HEAT EXCHANGERS, FILTERS

VALVES

ACTIVE MOV, AOV

SAMPLING CRITERIA

- MAJOR COMPONENTS AND SUBSYSTEMS ESSENTIAL FOR SAFE SHUTDOWN
- COMPONENTS AND SUBSYSTEMS DEEMED MUST SENSITIVE TO SEISMIC LOADING (EXPERIENCE FROM PRA)
- COMPONENTS AND SUBSYSTEMS LOCATED IN AREAS OF GREATEST SEISMIC RESPONSE
- REPRESENTATION OF EQUIPMENT IN ALL CATEGORY 1 BUILDINGS (RB, AUX. BLDG, DGB, SWPS)

SELECTIONS BASED UPON CRITICALITY

- ALL PUMPS AND HEAT EXCHANGERS IN SERVICE WATER, COMPONENT COOLING WATER, AUXILIARY FEED WATER, MAKEUP AND DECAY HEAT REMOVAL SYSTEMS.

- ALL AC AND DC EMERGENCY POWER SUPPLIES, SWITCHGEAR AND MOTOR CONTROL CENTERS.

- ALL OF NSSS SYSTEM.

SENSITIVITY TO SEISMIC RESPONSE

- CONTROL AND INSTRUMENTATION CABINETS IN CONTROL STRUCTURE AND ELECTRICAL PENETRATION AREAS.

HIGH SEISMIC RESPONSE AREAS

- CONTROL ROOM HVAC HIGH IN CONTROL BUILDING.

- DUCTING FOR CONTROL ROOM HVAC

- CABLE TRAYS IN SPREADING ROOM AND ELECTRICAL PENETRATION AREAS.

REPRESENTATION IN ALL STRUCTURES

- PIPING, PIPE SUPPORTS AND VALVES

- CABLE TRAYS AND SUPPORTS

- CONDUIT AND SUPPORTS

- MISCELLANEOUS ELECTRICAL AND MECHANICAL EQUIPMENT AND SUPPORTS.

FRACTION OF COMPONENTS SELECTED

BOTH UNITS AND REDUNDANT COMPONENTS INCLUDED IN QUANTITY STATED.

ELECTRICAL POWER DISTRIBUTION	34 OF 93
ELECTRIC POWER SUPPLY	
AC - DIESEL GEN. & GRD. REST.	8 OF 8
DC - STA. BATTERIES & CHGS.	4 OF 12
INSTRUMENTATION & CONTROL CABINENTS	23 OF 77
MECHANICAL EQUIPMENT	
ACTIVE COMPONENTS	27 OF 61
PASSIVE COMPONENTS	61 OF 69
VALVES	
ACTIVE VALVES INCLUDED IN PIPING SYSTEMS INDEPENDENTLY EVALUATED	19 OF 290

SAMPLE SIZE FOR BOP EQUIPMENT

157 OF 320 COMPONENTS = 49%

19 OF 290 ACTIVE VALVES = 7%

NOTE: ALL VALVES WERE INCLUDED IN GENERIC PROBABILISTIC STUDY TO DEMONSTRATE EXTREMCY HIGH NON-EXCEEDENCE PROBABILITY OF EXCEEDING 3 G DESIGN CRITERIA.

METHODOLOGY

QUALIFICATION BY ANALYSIS

VENDOR COMPUTED RESPONSE FOR SSE IS SCALED BY RATIO OF SME/SSE AT EQUIPMENT NATURAL FREQUENCY

CASE 1 - SEISMIC & NORMAL STRESSES ARE SEPARATED

$$F_{SME} = \frac{\sigma_A - \sigma_N}{\sigma_{SME}}$$

CASE 2 - SEISMIC & NORMAL STRESSES NOT SEPARATED
SME EXCEEDS SSE

$$F_{SME} > \frac{\sigma_A}{\sigma_T}$$

$$\text{WHERE} \quad \sigma_T = \frac{S_{a_{SME}}}{S_{a_{SSE}}} (\sigma_{SSE} + \sigma_N)$$

CASE 3 - SEISMIC & NORMAL STRESSES NOT SEPARATED
SSE EXCEEDS SME

$$F_{SME} > \frac{\sigma_A}{\sigma_D}$$

$$\text{WHERE} \quad \sigma_D = (\sigma_{SSE} + \sigma_N)$$

FOR FUNCTIONAL FAILURE MODES, ABOVE EQUATIONS APPLY SUBSTITUTING δ FOR σ

METHODOLOGY (CONT)

QUALIFICATION BY TEST

$$F_{SME} = \left(\frac{TRS}{RRS}\right)_{MIN}$$

- COMPARISON OF TRS AND RRS MADE AT EQUIPMENT FUNDAMENTAL FREQUENCY FOR EACH DIRECTION

- MIN. MARGIN REPORTED FOR GOVERNING DIRECTION

- IF TESTS ARE SINGLE AXIS OR SINGLE FREQUENCY, APPROPRIATE ADJUSTMENTS ARE MADE TO TRS TO EQUATE TO MULTIAXIS RANDOM MOTION INPUT

NSSS

- B & W CONDUCTED ANALYSIS OF NSSS USING SME BASEMAT INPUT FROM SMA.

- B & W PROVIDED TO SMA:

  SME RESPONSES
  SSE RESPONSES
  FAULTED CONDITION DESIGN LOADS
  SELECTED STRESS ANALYSIS RESULTS

- SMA DEVELOPED SEISMIC MARGINS BY COMPARING LOAD RATIOS AND SCALING STRESSES.

- RESULTS - ALL NSSS PIPING, VESSELS, SUPPORTS & INTERNALS MEET ACCEPTANCE CRITERIA

CLASS 1, 2 & 3
BOP PIPING AND SUPPORTS

- PIPING SYSTEMS SELECTED FOR INDEPENDENT ANALYSIS ON BASIS OF STRESS RESPONSE COMPUTED FOR SSE PLUS NORMAL LOADING. ONLY THE HIGHEST STRESSED LINES WITH THE MAJOR LOADING CONTRIBUTION COMING FROM SEISMIC WERE SELECTED.

- ALL RESULTS ARE POSITIVE. CODE ALLOWABLES ARE MET.

CLASS 1, 2 & 3 BOP EQUIPMENT AND SUPPORTS

- VENDOR REPORTS REVIEWED.
- SSE RESPONSE SCALED BY RATIO OF SPECTRAL ACCELERATION OF SME/SSE AT EQUIPMENT FUNDAMENTAL FREQUENCY.
- FOR COMPONENTS QUALIFIED BY TEST, TRS WAS SHOWN TO EXCEED RRS FOR SME AT FUNDAMENTAL FREQUENCY OF EQUIPMENT.

LOADING COMBINATION AND STRESS LIMITS
FOR CLASS 1 VESSELS, PUMPS AND VALVES

Loading Combination	Stress Limit[1,2,3,4]	
$P_N + D + OML + SME$	$P_m \le \begin{matrix} 2.4\ S_m \\ 0.7\ S_u \end{matrix}$	For Materials in Table I-1.2
	$P_L + P_b \le \begin{matrix} 3.6\ S_m \\ 1.05\ S_u \end{matrix}$	
	$P_m \le 0.7\ S_u$	For Materials in Table I-1.1
	$P_L + P_b \le 1.05\ S_u$	
	$P_L + P_b \le S_y$ (5)	

Where:

P_N = Normal operating pressure

D = Deadweight

OML = Operating mechanical loads from connecting piping including earthquake anchor motion and restraint of free end thermal displacement

SME = Seismic Margin Earthquake Inertial Loading

S_m = Allowable stress value from ASME Code, 1974 edition with Addenda through Winter 1976, Table I-1

P_m = General membrane stress intensity produced by pressure and other mechanical loads

P_L = Local membrane stress intensity produced by pressure and other mechanical loads

P_b = Primary bending stress intensity produced by pressure and other mechanical loads

S_y = Specified Yield Strength

Notes:

1. Stress limits apply to extended support structures for valves.

   For active valves, the extended operator support structure primary stress is limited to S_y.

2. Faulted condition stress criteria per 1974 ASME Code, Section III, with Winter 76 Addenda.

3. Use lesser of limits specified.

4. Valve operator acceleration is limited to 3g in any direction.

5. Functional limit for active components.

LOADING COMBINATIONS AND STRESS LIMITS FOR ASME CLASS 1 COMPONENT SUPPORTS

Loading Combination	Linear Type Support Limits[1,2,3,7]	Component Standard Linear Supports Designed by Load Rating	Plate and Shell[3] Support Limit
D + OML + SME	Within Lesser of: $\frac{1.2\ S_y}{F_t}$ or $\frac{0.7\ S_u}{F_t}$ Times Normal Operating Stress Limit, F_{all}.	$0.8\ L_t$	$P_m \leq \begin{cases} 1.5\ S_m \\ 1.2\ S_y \end{cases}$ [4,5] $P_m + P_b \leq \begin{cases} 2.25\ S_m \\ 1.8\ S_y \end{cases}$ [4,6]

where:

- D = Deadweight
- OML = Operating Mechanical Loads
- SME = Seismic Margin Earthquake Loading
- S_y = Material yield strength at temperature
- S_u = Material ultimate strength at temperature
- F_t = Allowable tensile stress per ASME Section III, Appendix XVII at temperature
- F_{all} = Allowable stress value from ASME Code, Appendix XVII, XVII-1100
- L_t = Ultimate Collapse Load as defined in ASME Code, Appendix F, F1370(d)
- P_m = Primary membrane stress intensity produced by mechanical loads
- P_b = Primary bending stress intensity produced by mechanical loads
- S_m = Allowable stress intensity from ASME Code, Appendix I

Notes:

1. Compressive axial member loads should be kept to less than 0.67 times the critical buckling load.
2. Includes Component Standard Supports designed by analysis.
3. Component support analyses and material allowables per ASME Code, Section III, 1974 edition with Winter 1976 Addenda.
4. Use greater of values specified.
5. Not to exceed $0.7\ S_u$.
6. Not to exceed $1.05\ S_u$.

LOADING COMBINATION AND STRESS LIMITS FOR NSSS COMPONENT SUPPORTS DESIGNED TO THE AISC CODE

Loading Combination	Stress Limit[1]
D + OML + SME	..6 f_s

where:

D = Dead Load

OML = Operating Mechanical Loads

SME = Seismic Margin Earthquake Loading

f_s = Allowable stress from Part 1 of the AISC Specification for Design, Fabrication and Erection of Structural Steel for Buildings, 7th Edition

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Notes:

1. Shear Stress is limited to 0.5 Fy where Fy is the specified yield strength of the material

LOADING COMBINATIONS AND STRESS LIMITS FOR CLASS 1 PIPING

Loading Combinations for Faulted Conditions:

Operating Pressure + Deadweight + Seismic Margin Earthquake Loads (SME)

Code Stress Acceptance Criteria

$$B_1 \frac{P D_o}{2t} + B_2 \frac{D_o}{2I} M_i \leq 3.0 S_m \quad (1)$$

Where:

B_1, B_2 = primary stress indices for the specific product under investigation (NB-3680)

P = Design Pressure, psi

D_o = outside diameter of pipe, in (NB-3683)

t = nominal wall thickness of product, in. (NB-3683)

I = moment of inertia, $in.^4$ (NB-3683)

M_i = resultant moment due to a combination of Design Mechanical Loads (Dead Wt.+SME)

S_m = allowable design stress intensity value, psi (Tables I-1.0)

Notes:

1. Faulted condition criteria per 1974 ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, with no addenda.

LOADING COMBINATIONS AND STRESS LIMITS FOR CLASS 2 AND 3 COMPONENT SUPPORTS

Loading Combination	Linear Type Support Limits[1,2,3]	Component Standard Linear Supports Designed by Load Rating	Plate and Shell[3] Support Limit
D + OML + SME	Within Lesser of: $\frac{1.2\ S_y}{F_t}$ or $\frac{0.7\ S_u}{F_t}$ Times Normal Operating Stress Limit, F_{all}.	$0.8\ L_t$	$\sigma_1 \leq 1.5\ S$[4] $\sigma_1 + \sigma_2 \leq 2.25\ S$[5] $\sigma_3 \leq 0.5\ S$

where:

- D = Deadweight
- OML = Operating Mechanical Loads
- SME = Seismic Margin Earthquake Loading
- S_y = Material yield strength at temperature
- S_u = Material ultimate strength at temperature
- F_t = Allowable tensile stress per ASME Section III, Appendix XVII at temperature
- F_{all} = Allowable stress value from ASME Code, Appendix XVII, XVII-1100
- L_t = Ultimate Collapse Load as defined in ASME Code, Appendix F, F1370(d)
- σ_1 = Average membrane stress produced by mechanical loads
- σ_2 = Primary bending stress produced by mechanical loads
- σ_3 = Maximum tensile stress at contact surface of welds in through thickness direction of plates and rolled sections
- S = Allowable stress from ASME Code, Appendix I

Notes:

1. Compressive axial member loads should be kept to less than 0.67 times the critical buckling load.
2. Includes Component Standard Support designed by analysis.
3. Component support analyses and material allowables per ASME Code, Section III, 1974 edition with Winter 1976 Addenda.
4. Not to exceed $0.4\ S_u$.
5. Not to exceed $0.6\ S_u$.

LOADING COMBINATIONS AND STRESS LIMITS FOR CLASS 2 & 3 PIPING

Loading Combination for
Faulted Conditions:

Operating Pressure + Deadweight + Seismic
Margin Earthquake Loads (SME)

Stress Acceptance Criteria

$$\frac{P_{max} D_o}{4t_n} + 0.75i\left(\frac{M_A + M_B}{Z}\right) \leq 2.4\ S_h \qquad (1)$$

Where:

- P_{max} = peak pressure, psi
- D_o = outside diameter of pipe, in.
- t_n = nominal wall thickness, in.
- M_A = resultant moment loading on cross section due to weight and other sustained loads, in.lb.
- M_B = resultant moment loading on cross section due to earthquake inertial loads.
- Z = section modulus of pipe, $in.^3$ (NC-3652.4)
- i = stress intensification factor [NC-3673.2(b)]. The product of 0.75i shall never be taken as less than 1.0.
- S_h = basic material allowable stress at operating temperture, psi

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Note:

1. Faulted condition stress criteria per 1974 ASME Code, Section III, with Winter 1976 Addenda.

LOADING COMBINATIONS AND STRESS LIMITS FOR CLASS 2 & 3 VESSELS, PUMPS AND VALVES

Loading Combination	Stress Limit[1,2]
$P_N + D + OML + SME$	$\sigma_m \leq 2.0\ S$
	$\sigma_L + \sigma_b \leq 2.4\ S$
	$\sigma_L + \sigma_b \leq S_y$ (4)

Where:

P_N = Normal operating pressure

D = Deadweight

OML = Operating mechanical loads including earthquake anchor motion and restraint of free-end thermal displacement loading from connecting pi

SME = Seismic Margin Earthquake Inertial Loading

S = Allowable stress value from ASME Code, 1974 edition with Addenda through Winter 1976, Tables I-7 or I-8

σ_m = General membrane stress produced by pressure and and other mechanical loads

σ_L = Local membrane stress produced by pressure and other mechanical loads

σ_b = Primary bending stress produced by pressure and other mechanical loads

S_y = Specified Yield Stress

Notes:

1. Stress limits apply to extended support structures for valves. For active valves, the extended operator support structure primary stress is limited to S_y.
2. Faulted condition stress criteria per 1974 ASME Code, Section III, with Winter 76 Addenda.
3. Valve operator acceleration is limited to 3.0g in any direction.
4. Stress limit for function of active components.

HVAC DUCTING AND SUPPORTS

- CRITICAL DUCTING SYSTEMS SELECTED AS REPRESENTATIVE OF MIDLAND DUCTING.
- INDEPENDENT ANALYSES CONDUCTED.
- RESULTS ARE ALL POSITIVE FOR DUCTING AND SUPPORTS.

LOADING COMBINATION AND STRESS LIMITS FOR HVAC DUCTING

Loading Combination	Stress Limit
P + D + SME	0.5 σ_{cr}

where:

P = Design pressure acting externally on duct

D = Dead Weight

SME = Seismic Margin Earthquake

σ_{cr} = Critical bucklin- stress computed for thin sheet simply supported on all edges and subjected to biaxial compressive stresses resulting from P, D and SME

CABLE TRAYS AND SUPPORTS

- TYPICAL RUNS OF CABLE TRAYS WERE SELECTED IN REGIONS OF HIGH SEISMIC RESPONSE.

- INDEPENDENT ANALYSES WERE CONDUCTED.

- RESULTS ARE ALL POSITIVE FOR TRAYS AND SUPPORTS.

LOADING COMBINATION AND ACCEPTANCE CRITERIA FOR CABLE TRAYS

Load Combination	Acceptance Criteria[1,2]
D + SME	$\frac{M_D}{M_{UV}} + \left[\left(\frac{M_V}{M_{UV}}\right)^2 + \left(\frac{M_T}{M_{UT}}\right)^2 + \left(\frac{E_L}{Y_L}\right)^2\right]^{1/2} \leq 1$

where:

- D = Dead Weight of Tray and Contents
- SME = Seismic Margin Earthquake Inertial Loading
- M_D = Bending Moment due to Dead Weight
- M_V = Bending Moment in the Vertical Plane from the SME
- M_T = Bending Moment in the Transverse Plane from the SME
- M_{UV} = Allowable Moment in the Vertical Plane
- M_{UT} = Allowable Moment in the Transverse Plane
- E_L = Axial Load in Tray from the SME
- Y_L = Allowable Axial Load in Tray

Note:

1. M_{UV} and M_{UT} are derived from ultimate load tests and are based on the lessor of 2/3 the maximum collapse moment or the moment at a displacement equal to 1/2 the ultimate load displacement.

2. Y_L is 2/3 of the ultimate load capacity.

LOADING COMBINATION AND ACCEPTANCE CRITERIA FOR HVAC AND CABLE TRAY SUPPORTS

Load Combination	Allowable Stress*
D + L + To + SME	1.6 S or Y

Where:

D = Dead Load

L = Live Load

To = Loading from Restraint of Free-End Thermal Displacement

SME = Loading from Seismic Margin Earthquake Including Inertial Effects and Differential Anchor Motion

S = Working Stress Allowable from AISC Code, 8th Edition, 1980

Y = Section Strength Required to Resist Design Loads and Based on Plastic Design Methods Described in Part 2 of the AISC Code

*Allowable Stress Based upon AISC Code, 8th Edition, Part 2, Plastic Design and NUREG-0800

LOADING COMBINATIONS AND STRESS LIMITS FOR COMPONENT SUPPORT ANCHORAGE[1,2]

Loading Combination (1)	Embedded Anchors (2,3,4)	Grouted Anchors	Expansion Anchors
D+L+To+Ro+SME	Lesser of U or 1.6S	Allowable loads per Bechtel Specification 7220-C-306Q	Allowable loads per Bechtel Specification 7220-C-305Q

where:

D = Dead loads from attached equipment or piping

L = Live loads from attached equipment or piping

To= Restraint of free-end thermal displacement of attached equipment or piping

Ro= Pipe and equipment reactions during normal operating or shutdown conditions not already included in D+L+To (i.e., piping reactions on vessel which are transmitted to vessel anchors)

SME= Load effects of Seismic Margin Earthquake including effects of differential anchor movement.

U= Ultimate pullout strength per ACI 349-80, Appendix B

S= Allowable working stress per AISC Code, 8th edition, 1980.

NOTES:

1. Load combinations are consistent with NUREG-0800 Standard Review Plan, Section 3.8.4; ACI 349-1980, Section 9.2, and Regulatory Guide 1.142
2. Strength criteria are consistent with NUREG-0800, Standard Review Plan, Section 3.8.4; ACI 349-1980, Appendix B and AISC Part 2, eighth edition, 1980.
3. The faulted stress limit for the reactor vessel anchor studs is 75 ksi (See Reference 43)
4. The faulted stress limits for LAQT bolts will be provided later.

ELECTRICAL CONDUIT

- GENERIC EVALUATION OF CONDUIT AND SUPPORT DESIGN CRITERIA WAS CONDUCTED FOR THE SEISMIC MARGIN EARTHQUAKE.

- SPAN SPACING AND SUPPORT CRITERIA USED IN DESIGN WERE DEMONSTRATED TO BE ACCEPTABLE FOR THE SME.

ACCEPTANCE CRITERIA FOR ELECTRICAL CONDUIT AND SUPPORTS

- CLASS 3 THREADED PIPING CRITERIA USED FOR CONDUIT.
- CONDUIT CLAMP STRENGTH DETERMINED BY TEST.
- INTERACTION EQUATION FOR CLAMPS.

$$\left[\left(\frac{Q_P}{P}\right)^2 + \left(\frac{Q_S}{S}\right)^2 + \left(\frac{Q_L}{L}\right)^2\right]^{1/2} + \frac{|Q_{PST}|}{P} + \frac{|Q_{SST}|}{S} + \frac{|Q_{LST}|}{L} \leq 1.0$$

Q_P = Clamp or strap force in the pull direction due to earthquake in the vertical, East-West or North-South direction

Q_S = Clamp or strap force in the slip direction due to earthquake in the vertical, East-West or North-South direction

Q_L = Clamp or strap force in the longitudinal direction due to earthquake in the vertical East-West or North-South direction

$Q_{PST}, Q_{SST}, Q_{LST}$ = Clamp or strap force in the pull, slip, and longitudinal directions due to the weight of the conduits and cables, i.e., 1g

P, S, L = Clamp or strap allowable loads in the pull, slip, and longitudinal directions, respectively

RESULTS

- ALL COMPONENTS COMPLETED MEET CODE OR FUNTIONAL LIMIT

- COMPUTATION OF MARGINS AGAINST FAILURE NOT REQUIRED

SUMMARY OF SEISMIC MARGINS FOR SELECTED NSSS PIPING AND EQUIPMENT SUPPORTS

Description		Minimum Margin F_{SME}
1. RPV Support Skirt/Base Interface	(Vessel Skirt)	>8.10
	(RPV Anchor Studs)	31.0
2. RPV Upper Support		3.54*
3. OTSG Support Skirt/Base Mat Interface	(Skirt)	6.43
	(OTSG Anchor Studs)	>4.65
4. OTSG Upper Support		>4.75
5. Pressurizer Lug/Support Structure Interface		8.26
6. Pressurizer Upper Support		>3.82
7. RPV 36" Hot Leg Outlet Nozzle		9.98
8. RPV 28" Cold Leg Inlet Nozzle		5.83
9. OTSG 36" Hot Leg Inlet Nozzle		12.99
10. OTSG 28" Cold Leg Outlet Nozzle		9.87
11. RCP 28" Cold Leg Inlet Nozzle		>4.51
12. RCP 28" Cold Leg Outlet Nozzle		>6.65
13. CRD Housing/RPV Interface		8.94
14. RCP Snubbers (P1A1 Upper Horizontal Support)		>2.34

* Margin Against Gap Closure

SUMMARY OF SEISMIC MARGINS FOR SELECTED REACTOR VESSEL INTERNALS

Description	Minimum Margin F_{SME}
1. Plenum Cover	26.2
2. Upper Grid Assembly - Rib Section	25.0
3. Upper Grid Pad Joint	14.4
4. Core Support Shield - Lower End	37.7
5. Core Support Shield - Upper Flange	22.7
6. Thermal Shield - Upper End	107.3
7. Thermal Shield/Lower Grid Shell Bolted Joint	63.1
8. Thermal Shield Upper Restraint Flange	67.9
9. Core Barrel Assembly - Upper End	31.5
10. Core Barrel/Former Bolted Joint	21.7
11. Lower Grid Assembly - Top Rib Section	73.9
12. Lower Grid Assembly - Top Rib Section/Shell Forging Bolted Joint	101.8
13. Lower Grid Assembly - Support Post/Support Forging Welded Joint	145.5
14. Control Rod Guide Tubes - Slotted Region	203.5
15. Plenum Cylinder - Upper End	80.8

SUMMARY OF SEISMIC MARGINS FOR BOP EQUIPMENT

Equipment	Qualification (1) Method	Governing Critical Area (2)	Minimum F_{SME} Margin (3)	Notes
Main Switchgear 1A05, 2A05	Test,(Random Input)	N/A	6.10	
Main Switchgear 1A06, 2A06	Test,(Random Input)	N/A	6.10	
Motor Control Centers 1B23, 2B23	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B24, 2B24	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B43, 2B43	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B44, 2B44	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 0B45, 0B46	Test,(Sine Beat)	N/A	6.3	
Motor Control Centers 1B53, 2B53	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B54, 2B54	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B55, 2B55	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B56, 2B56	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B63, 2B63	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B64, 2B64	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 0B65, 0B66	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 0B68, 0B69	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B79, 2B79	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B80, 2B80	Test,(Random Input)	N/A	>3.25	
Motor Control Centers 1B89, 2B89	Test,(Random Input)	N/A	>3.25	(7)
Motor Control Centers 1B90, 2B90	Test,(Random Input)	N/A	>3.25	(7)
125V DC Batteries and Racks 1D1, 2D1, 1D2, 2D2	Anal. & Test (Random Input)	Battery Rack Structures	2.24	

SUMMARY OF SEISMIC MARGINS FOR BOP EQUIPMENT (cont.)

Equipment	Qualification Method (1)	Governing Critical Area(2)	Minimum SME Margin (3)	Notes
Diesel Generator, Engine and Appendages	Anal. & Test (Random Input)	Engine Appendages	>3.49	
Diesel Generator, Neutral Grounding Cabinet 1G-11X, 2G-11X, 1G-12X, 2G-12X	Test,(Random Input)	N/A	3.83	
Diesel Generator, Generator Control Panel 1C-231, 2C-231, 1C-232, 2C-232	Test,(Random Input)	N/A	3.55	
Diesel Generator, Engine Control Panel 1C-111, 2C-111, 1C-112, 2C-112	Test,(Random Input)	N/A	1.5	
Diesel Generator, Generator Unit 1G-11, 2G-11, 1G-12, 2G-12	Analysis	Stator, beam adjacent to foot pad	1.70	
Diesel Generator, Exhaust Air Silencer 1M-101 A&B, 2M-101 A&B	Analysis	Shell	>1.24	(5)
Diesel Generator Intake Air Filter 1F-19 A-D, 2F-19 A-D	Analysis	Shell	>1.86	(5)
Diesel Generator Jacket Water Standpipe	Analysis	Anchor Bolting to pedestal	>2.06	(6)
Diesel Generator Skid and Building Mounted Auxiliaries Qualified by Testing	Testing (Random Input)	N/A	>5.0	
Other Diesel Generator Building Mounted Equipment	Analysis	Misc.	>2.06	(8)
Auxiliary Shutdown Panel 1C-114, 2C-114	Analysis	Support Angle (Struct.) Devices	1.52 Incomplete	(4)(10)
HVAC Control Cabinet 1C-175A-B, 2C-175A-B	Analysis & Test (Random Input)	Angle Frame (Struct.) Devices	25.2 Incomplete	(4)(10)

SUMMARY OF SEISMIC MARGINS FOR BOP EQUIPMENT (cont.)

Equipment	Qualification Method (1)	Governing Critical Area (2)	Minimum SME Margin(3)	Notes
HVAC Control Panel OC-151	Analysis & Test (Random Input)	Roof Bar (Structural Devices	1.48 Incomplete	(4,10)
ESFAS 1C-44, 2C-44	Test, (Random Input)	N/A	1.33	
Balance of Plant Logic Cabinet 1C-166, 2C-166	Test, (Sine Beat)	N/A	1.49	
Safeguards Chiller, IVM-59A&B,2VM-59A&B	Analysis & Testing	Compressor Wobble Foot Bolts	>1.07	(4,6)
Control Room HVAC, OVM-01 A&B	Analysis & Test (Sine Sweep)	Finned Coils	1.42	
Component Cooling Water Surge Tank 1T-173 A&B, 2P-73 A&B	Analysis	Tank Legs	1.31	
Service Water Pumps OP-75 A-E	Analysis	Nozzle	1.43	(9)
Component Cooling Water Pumps 1P-73 A&B, 2P-73 A&B	Analysis	Suction Nozzle Flange	1.0	(9)
Component Cooling Water Heat Exchanger 1E-73 A&B, 2E-73 A&B	Analysis	Anchor Bolts	1.20	
Auxiliary Feed Pump (Electric) 1P-05A, 2P-05A	Analysis	Discharge Flange	2.10	(9)
Auxiliary Feed Pump (Turbine) 1P-05B, 2P-05B	Analysis	Discharge Flange	>2.10	(9)
Air Filtration Unit OVM-79 A&B	Analysis	Door Frame	>1.50	(6,7)
Decay Heat Removal Pump 1P-60 A&B, 2P-60 A&B	Analysis	Discharge Flange	1.76	(9)

SUMMARY OF SEISMIC MARGINS FOR BOP EQUIPMENT (cont.)

Equipment	Qualification Method (1)	Governing Critical Area (2)	Minimum SME Margin (3)	Notes
Decay Heat Exchanger 1E-60 A&B, 2E-60 A&B	Analysis	Shell at Support	1.23	
Makeup Pump 1P-58 A,B&C, 2P-58 A,B,&C	Analysis	Suction Flange	4.2	(9)
Service Water Strainer OF75-A-E	Analysis	Base Plate Gusset Weld	>1.62	

Notes:

1. For designs governed by allowable stresses, the margin against code allowable is (code allowable/applied SME stress). For equipment qualified by test, the margin is defined as (test response/required response).
2. Qualification test method is described in Section 5 through 8 and in Appendix A.
3. Critical area is local region or component within a subsystem with the governing minimum margin.
4. Structural portion qualified by analysis. Devices qualified by test.
5. Margin calculation was very conservative. Stresses in vendor report were scaled upward by the maximum ratio of the SME to the SSE in effect at the time of equipment qualification.
6. Margin based upon original design load since seismic and normal portion of design load could not be separated out from information in design report. Safe shutdown earthquake load exceeded SME load.
7. These units are not required for safe shutdown to cold condition.
8. Detailed margins not computed. Equipment less critically stressed than other items evaluated for SME.
9. Minimum margin quoted is for function. Structural margins are greater.
10. Completion of SSE qualification of all devices is pending.

MINIMUM SEISMIC MARGINS FOR BOP PIPING

Piping System	Critical Element	Node	Maximum Stress (psi)	Allowable Stress (psi)	Code Margin (CM)	Seismic Factor (F_{SME})
1. DHR and Core Flooding	Reducing Tee	495	19,895	49,800	2.50	5.25
2. DHR Suction	Taper Transition	480	12,046	39,600	3.29	7.20
3. DHR Suction and Reactor Building Spray	Tee	240	4,173	41,856	10.03	49.2
4. Makeup and Purification Discharge	Taper Transition	631	21,761	45,120	2.07	2.67
5. High Pressure Injection (Part 1)	Branch	190	20,570	49,800	2.42	4.52
6. High Pressure Injection (Part 2)	Pipe (Anchor)	250	18,457	45,120	2.44	2.52
7. Reactor Coolant and Pressure Control	Socket Weld	400	17,637	40,080	3.07	3.82
8. SWS - Reactor Building Return Header	Elbow	459	5,892	36,000	6.11	8.51
9. SWS - Pump Structure Header	Tee	60	26,724	42,000	1.57	2.66

MINIMUM SEISMIC MARGINS BASED UPON PIPE SUPPORT CAPACITY

Piping System	Support No.	Restraint Type and Direction	Node	Calculated Code Margin (CM)	Calculated Seismic Factor (F_{SME})[1]	Minimum Seismic Factor (F_{SME})[2]
1. DHR and Core Flooding	FSK-2CCA-66H3	Restraint (x)	514	22.0	34.9	≥2.24
2. DHR Suction	1-610-3-4	Strut (z)	139	1.14	1.26	≥1.03
3. DHR Suction and Reactor Building Spray	1-610-3-37	Anchor	185	1.35	1.60	≥1.33
4. Makeup and Purification Discharge	2-604-9-33	Strut (x)	667	1.81	1.90	≥1.22
5. High Pressure Injection (Part 1)	2-604-1-101	Restraint (z)	620	*	*	≥2.91
6. High Pressure Injection (Part 2)	2-604-1-1	Strut (x)	142	*	*	≥1.66
7. Reactor Coolant and Pressure Control	2-602-2-32	Restraint (z)	500	*	*	≥3.06
8. SWS - Reactor Building Return Header	2-619-2-511	Strut (x)	720	4.66	8.78	≥1.07
9. SWS - Pump Structure Header	0-618-1-17	Snubber (z)	428	1.15	1.40	1.17

* Support design load always exceeds seismic margin load
1 Based upon a detailed stress analysis of supports where SMR load exceed design load
2 Based upon a ratio of design load to SMR load when SMR load is less than the design load assuming the design load stresses the support to the Code allowable limit

MINIMUM SEISMIC MARGINS BASED UPON VALVE ACCELERATIONS

Piping System	Valve Type	Node	Maximum Combined Acceleration (g)	Qualification Margin	Seismic Factor (F_{SME})
1. DHR and Core Flooding	3/4" Angle Relief	460	1.516	1.98	2.88
2. DHR Suction	2-1/2" HO Globe	480	1.407	2.13	3.94
3. DHR Suction and Reactor Building Spray	12" Butterfly	518	1.235	2.43	6.48
4. Makeup and Purification Discharge	2-1/2" MO Globe	660	1.700	1.76	2.20
5. High Pressure Injection (Part 1)	1" Globe	646	1.448	2.07	4.04
6. High Pressure Injection (Part 2)	1" Globe	221	1.481	2.03	2.76
7. Reactor Coolant and Pressure Control	1/2" Globe	445	1.610	1.86	2.40
8. SWS - Reactor Building Return Header	6" MO Butterfly	625	1.824	1.64	2.30
9. SWS - Pump Structure Header	6" MO Gate	570	2.228	1.35	1.56

SUMMARY OF SEISMIC MARGINS - HVAC SYSTEMS

HVAC System	System Element	Maximum Stress Ratio	Minimum Code Margin CM	Minimum Seismic Factor F_{SME}
Aux. Building	Duct	0.25 < 1.0	4.0	15.8
	Support Angle	0.054 < 1.0	18.5	19.5
Diesel Gen. Bldg.	Duct	0.28 < 1.0	3.6	17.2
	Support Anchor Bolts	0.39 < 1.0	2.6	8.6

SUMMARY OF SEISMIC MARGINS - CABLE TRAYS

Cable Tray System	Critical Area	Maximum Combined Stress Ratio	Minimum Seismic Factor, F_{SME}
Upper Cable Spreading Room:			
36" Cable Tray	Element #38	0.63	2.14
Cable Tray Support	3/4" Expansion Anchor Bolt Element #64	0.89	1.21
Auxiliary Building East-West Wing:			
24" Cable Tray	Element #98	0.331	5.34
12" Cable Tray	Element #210	0.168	10.14
Cable Tray Support	Elements #53,54	0.714	1.73
Containment Building Internal Structure:			
24" Cable Tray	Element #27	0.17	9.66
Cable Tray Support	3/16" Fillet Weld Element #16	0.46	2.62
Auxiliary Building East-West Wing:			
24" Cable Tray (2BJQ)	Element #4	0.33	3.50
Cable Tray Support	1/2" ϕ Expansion Anchor Bolt Element #6	0.59	2.29
Service Water Pump Structure:			
18" Cable Tray	8' Maximum Span	0.498	2.68
Cable Tray Support	1/2" ϕ Expansion Anchor Bolt Element #9	0.71	1.42

MINIMUM SEISMIC MARGIN FOR ELECTRICAL

CONDUIT AND SUPPORTS

Element	Code Margin CM	Seismic Factor F_{SME}
Conduit	2.78	3.32
Conduit Strap	1.32	1.57
Conduit Clamp	1.10	1.13
Conduit Support	1.36	1.56

UNRESOLVED ITEMS

- AUXILIARY SHUTDOWN PANEL -DEVICES
- CONTROL ROOM HVAC CONTROL PANEL -DEVICES
- DIESEL GENERATOR HVAC CONTROL PANEL-DEVICES
- UNRESOLVED ISSUES STEM FROM INCOMPLETE VENDOR QUALIFICATION