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BACKGROUND

The NRC letter of December 7, 1995 to DECo (Reference 1) identified the remaining unresolved concerns/deficiencies regarding the demonstration of the structural integrity and functionality of the Fermi 2 CCHVAC duct and duct supports under the combined loading due to dead weight, maximum expected internal pressure (negative or positive) and the postulated seismic event (SSE), in accordance with the committed standards ANSI/ASME N509-1980 for ductwork (Reference 2) and AISC for duct supports (Reference 3).

Some of the NRC concerns/deficiencies involve specific errors and inconsistencies in duct and duct support structural adequacy calculations provided to the NRC, and are inherently addressed by the fact that new calculations will be generated in accordance with this design criteria. Other concerns/deficiencies involve methodology and allowables used in duct and duct support adequacy calculations; these generic items are specifically addressed in this design criteria and are summarized as follows:

- Calculation of duct cross-sectional properties will use bare metal thickness (e.g. 0.0478 inch for 18 gauge).

- Effective duct sections will be determined based on guidance from the AISI manual and industry publications. These effective duct sections will be used in calculating seismic responses, internal loads and support reaction loads.

- Seismic response loads resulting from the simultaneous application of three-directional design basis seismic effects will be used. The applicable response spectra curves are attached for both the OBE and the SSE in Appendix B. These curves are reproduced from UFSAR Section 3.7 (Reference 4).

- Damping values used will not exceed 7% and 4% in the analysis of duct/duct support systems with rectangular and round ducts, respectively, for SSE effects (4% and 2% respectively for OBE).

- Stresses in rectangular duct due to internal pressure loading will be calculated using industry guidance and finite element analysis of duct segments.

- Demonstration of adequacy of duct discontinuities, such as Tee's and Wye's, will be through detailed finite element analysis on a bounding case basis using industry guidance.

- Calculation of duct and duct support maximum stresses will be based on the combination of dead

weight, maximum pressure and three-directional design basis earthquake response loads. Both the OBE and the SSE response loads will be considered, as identified in the load combinations.

- Structural acceptance criteria for duct and duct supports will be based on minimum published yield and ultimate strengths of materials used.

- Duct maximum stresses will be limited to 0.9 F_y of the duct material for SSE (0.6 F_y for OBE) per ANSI/ASME-N509-1980 (Reference 2), and duct support member stresses shall be governed by the acceptance criteria of UFSAR Table 3.8-19 for structural steel (Reference 4). If calculated duct deflections exceed ANSI allowables, the values will be provided to the HVAC Systems Group for assessment of reduced duct cross-sectional area effect.

In addition, the NRC staff acknowledged the testing performed on the section of duct with high "reported" negative pressure of -22 in. WG and acceptability of results (the test was at -20.5 in. WG and inleakage was within Technical Specification limits). The staff reiterated their expectation that the remainder of the ductwork also be proof tested. In conclusion, the staff recommended and requested that requalification of the Fermi 2 CCHVAC duct and duct supports be performed and completed prior to restart from the next refueling outage scheduled to begin in September 1996.

In response to the NRC letter, DECo has formulated an integrated action plan to close all the unresolved NRC concerns/deficiencies identified in the December 7, 1995 letter, and meet the requested schedule (RF05 Startup). The plan includes both CCHVAC system and structural qualification aspects, and addresses all duct and duct supports included in DECo Calculations HA-05/89-686 (Reference 5) and HA-09/89-696 (Reference 6). This design criteria concentrates on the methodology, approach and acceptance limits as they pertain to the structural evaluation aspects of the plan.

1.0 SCOPE

This design criteria provides the basis for the structural adequacy evaluation of Seismic Category I CCHVAC rectangular and round duct and duct supports when subjected to the simultaneous application of dead weight, internal duct pressure (normal operating/maximum credible) and three-directional earthquake (OBE/SSE) loads. This criteria is applicable to all duct and duct supports addressed in DECo Calculations HA-05/89-686 (Reference 5) and HA-09/89-696 (Reference 6).

The criteria describes the methodology, approach and acceptance criteria used for evaluation, and considers all applicable NRC unresolved concerns/deficiencies identified in the NRC letter of December 7, 1995 (Reference 1).

This criteria is applicable to the structural adequacy evaluation of ducts, duct fittings (e.g., Tee's, Wye's and transitions), duct supports and their anchorages, and to the design of structural modifications to these components if required.

The HVAC duct and duct supports to be evaluated within this scope are listed in Appendix A. This appendix will evolve into a database summarizing duct and duct support characteristics.

2.0 ACRONYMS

AISC	-	American Institute of Steel Construction
AISI	-	American Iron and Steel Institute
ANSI	-	American National Standards Institute
ASTM	-	American Society for Testing and Materials
AWS	-	American Welding Society
CCHVAC	-	Control Center Heating, Ventilation, and Air Conditioning
GRD	-	Grilles, Registers, Diffusers
OBE	-	Operating Basis Earthquake
SRSS	-	Square Root of the Sum of the Squares
SSE	-	Safe Shutdown Earthquake

3.0 DESIGN BASIS

3.1 Functional Requirements

Seismic Category I ductwork performs a primary safety function and is essential for the safe shutdown and the maintenance of a safe shutdown condition of the plant. The ductwork must remain functional during and after dynamic events under all applicable load combinations. This requires the maintenance of a duct's overall structural integrity and

flow capacity without significant air leakage. This is achieved by supporting the ductwork to limit the stress in the spans to acceptable levels.

3.2 Applicable Specifications and Standards

Ductwork and components covered by this criteria are governed by industry standard ANSI/ASME N509-1980 (Reference 2), and duct supports are governed by AISC "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings" (Reference 3). Ducts and duct supports evaluated using this criteria are constructed in accordance with the Enrico Fermi Duct Construction Brochure (Reference 7). For the evaluation of existing duct and duct supports, and design of modifications if required, the following additional documents shall be used, as applicable.

- American Iron and Steel Institute, "Cold-Formed Steel Design Manual" (Reference 8).
- American Welding Society, AWS-A5.1 (Reference 9).
- American Welding Society, AWS-A5.6 (Reference 10).
- American Welding Society, AWS-A5.18 (Reference 11).

For sheet metal and structural steel used in HVAC duct and duct supports, the following mechanical properties shall be used:

Material Specified	Yield Strength, F_y	Tensile Strength, F_u
ASTM A526/A527 galvanized steel sheet	33 ksi	45 ksi
ASTM A575 (M1020) structural angles	32 ksi	50 ksi
ASTM A36 structural shapes	36 ksi	58 ksi

3.3 General Qualification Approach

The general qualification approach to the structural adequacy evaluation of the ductwork, duct supports and components identified in Section 1.0 shall include the following:

- Determination of forces and moments at critical duct sections and support reactions

caused by dead, seismic, and pressure loads (Section 3.5.5).

- Determination of stresses due to dead and seismic loads in ductwork including duct fittings (Section 3.4).

- Determination of pressure-induced stresses in ductwork (Section 3.6.1).

- Establishment of applicable load combinations and design allowables for ductwork and supports, and comparison of the above forces, moments and stresses against the allowables (Section 3.5.4).

This approach shall be implemented by performing the following specific activities:

For Ductwork and Duct Components

(a) Review existing duct/duct support system data to identify seismically flexible systems, systems with highest internal pressure, and largest duct systems.

(b) Perform structural evaluations of the identified rectangular duct systems, including:

  - Manual (hand) calculations to establish duct panel stresses utilizing equations in Sections 3.4.1 and 3.6.1.

  - Detailed finite element analysis of duct segments with internal duct pressure greater than 10 inch WG, since only duct segments with pressure less than or equal to 10 inch WG are covered by equations in Section 3.6.1.1. These analyses will include evaluation of duct transverse stresses due to internal pressure. The analytical model for this analysis will be as conceptually shown in Figure 3.3-1.

  - Detailed finite element type analysis of selected duct fittings (e.g. Wye's, Tee's, elbows).

  - Generic calculations to address structural adequacy of duct seams, companion angles and stiffeners utilizing equations in Section 3.6.2.

(c) Establish that the size, gage and qualification of round ductwork in the scope identified in Section 1.0 is bounded by the rectangular ductwork evaluated. Evaluation of round duct seam welds, if required, shall be performed.

(d) Evaluate selected duct transition pieces between rectangular and round duct segments.

(e) Design duct hardware modifications, if required.

In performing the above, bare duct metal thickness shall be used in calculating duct section properties.

For Duct Supports

(a) Review existing duct/duct support system data to identify seismically flexible systems, systems with highest internal pressure, and largest duct systems.

(b) For the identified flexible, highest pressure, and largest duct systems, determine the specific support configurations and establish allowable support capacities. These shall be established by review and validation of existing DECo calculations (DCxxxx series calculations).

(c) Prepare coupled duct/duct support system "string" analysis models of the identified duct systems, with supports represented by spring elements and appropriate equivalent support masses (or by three-dimensional support models), and the duct segments represented by beam type elements with "effective" duct section properties. The configuration of the model shall be based on the original stress report generated by Robert Irsay Company/Fluor Pioneer, Inc. which is an attachment to the DECo DCxxxx series calculations.

(d) Perform dynamic response spectra type analysis of the identified systems for the simultaneous application of three-directional seismic loads (OBE/SSE), in combination with dead weight effects.

(e) Compare the resulting duct support reaction loads to the established allowable support capacities and establish support adequacy or determine capacity exceedance.

(f) Design hardware modifications, if required, and establish modified system adequacy. Modifications shall be designed based on total structural system behavior to facilitate constructibility.

(g) Establish adequacy of the identified rigid systems (remaining population) based on comparison with flexible system results, including an Extent of Condition review for modifications.

3.4 Calculation of Duct Properties and Stresses

The methodology for calculation of duct properties and stresses presented in this section has been generally developed based on the information contained in Reference 12. Reference 12 provides test-based and analysis-based information for ductwork in nuclear power plants, and has been widely used in several operating nuclear power plants as well as plants under construction.

Figures 3.4-1 and 3.4-2 illustrate the modeling of a rectangular and round HVAC duct considered as a beam. For seismic and dead load evaluation, it is required to determine the longitudinal membrane stress f_m and the shear stress f_v. These stresses are calculated from the overall response of the duct to dead and seismic loads.

The section properties to be used to calculate stresses at a given duct cross-section are described in Sections 3.4.1 and 3.4.2 for rectangular and round ducts respectively (see Reference 12 for the basis of the equations in these sections).

3.4.1 Rectangular Ducts

(a) Effective Section Moduli - Figure 3.4-3 shows a W x H rectangular duct and the effective sections that shall be used to compute the bending stresses.

Only the four duct corner angles are assumed to be effective in resisting bending moment. The size of the corner angle on each duct wall depends on whether the wall is acting as a web or a flange for the particular axis of bending being considered. Each axis of bending is treated separately.

If 0.5 h_{ey} and 0.5 h_{ez} are sizes of the corner angle on the duct dimension H for each axis of bending, the values of h_{ey} and h_{ez} are calculated from the following equations:

$$h_{ei} = \rho_i H \qquad (3.4.1\text{-}1)$$

$$\rho_i = \begin{cases} 1.0, \; for \; \alpha_i \le 0.673 \\ \dfrac{1}{\alpha_i}(1.358 - \dfrac{0.461}{\alpha_i}), \; for \; 0.673 < \alpha_i < \alpha_c \\ \dfrac{1}{\alpha_i}[0.41 + 0.59 (\dfrac{F_y}{f_n})^{½} - \dfrac{0.22}{\alpha_i}], \; for \; \alpha_i \ge \alpha_c \end{cases} \qquad (3.4.1\text{-}2a)$$

where:

i = y or z

$$\alpha_i = \frac{1.052}{(k_i)^{1/2}} \left(\frac{H}{t}\right) \left(\frac{f_a}{E}\right)^{1/2} \qquad (3.4.1\text{-}2b)$$

$$\alpha_c = 0.256 + 0.328 \left(\frac{H}{t}\right) \left(\frac{F_y}{E}\right)^{1/2} \qquad (3.4.1\text{-}2c)$$

k_i = plate buckling coefficient = maximum value of 40 for webs
= value of 4 for flanges

Note: A value of 24 will be used for webs in the design adequacy evaluations. If there is a need to use higher values, not to exceed 40, these cases will be documented and assessed on a case by case basis.

t = duct wall thickness (bare sheet metal)

F_y = duct plate yield stress

E = duct plate modulus of elasticity

f_a = $0.6F_y$, for OBE load combination
f_a = $0.9F_y$, for SSE load combination

Similarly for the duct dimension W, the values of W_{ey} and W_{ez} are calculated by substituting W for H and W_{ei} for h_{ei}.

(b) Axial Area - The axial area for tension is the gross area. For compression, the areas of corner angles in Figure 3.4-4 are used to determine the effective area

$$A_x = A_e = 2\,(W_e + h_e)t \qquad (3.4.1\text{-}3)$$

where h_e and W_e are computed from equation (3.4.1-1) using k_i = 4.0 and

$$f_a = \left[\begin{array}{l} F_{ac}, \textit{ for OBE Load Combination} \\ 1.5\ F_{ac}, \textit{ for SSE Load Combination} \end{array} \right. \qquad (3.4.1\text{-}4)$$

The stress F_{ac} is defined as follows:

$$F_{ac} = \frac{F_n}{1.92} \qquad (3.4.1\text{-}5)$$

where F_n is as defined below:

$$F_n = \left\{ \begin{array}{l} F_y \left(1 - \frac{F_y}{4\ F_e}\right), \textit{ for } F_e > \frac{F_y}{2} \\ F_e \textit{ for } F_e \le \frac{F_y}{2} \end{array} \right\} \qquad (3.4.1\text{-}6)$$

where F_e is the critical buckling load defined as:

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2_{max}} \qquad (3.4.1\text{-}7)$$

and where:

K = effective length factor taken equal to 1.0 for continuous spans and 2.0 for cantilever spans

$$\left(\frac{KL}{r}\right)_{max} = \textit{maximum of } \left(\frac{KL_y}{r_y}\right) \textit{ and } \left(\frac{KL_z}{r_z}\right)$$

L_y = duct length between supports for bending in the y-direction for continuous spans and duct length for cantilevers

L_z = duct length between supports for bending in the z-direction for continuous spans and duct length for cantilevers

(c) Radius of Gyration, r - The radius of gyration used for both y and z-directions are those of gross cross-section

$$r_y = (I_y/A_g)^{1/2} \tag{3.4.1-8}$$

$$r_z = (I_z/A_g)^{1/2} \tag{3.4.1-9}$$

I_y = full moment of inertia about y-axis
I_z = full moment of inertia about z-axis

(d) Shear Area - The shear areas used for calculation of shear stresses along y and z-axis directions in Figure 3.4-3 are those of full flanges and full webs, respectively.

(e) Torsional Sectional Properties - The torsional moment of inertia and section modulus shall be calculated using full cross-section as follows:

$$I_x = \frac{2tW^2H^2}{W+H} \tag{3.4.1-10}$$

$$S_x = 2tWH \tag{3.4.1-11}$$

3.4.2 Round Ducts

Moments of inertia, section moduli, radius of gyration and axial area are calculated on the basis of full, unreduced cross-section. The shear areas used to

calculate shear stresses along the y and z-directions are taken as half of the full cross-sectional area.

$$A_x = \frac{\pi}{4}\,(D_o^2 - D_i^2) \qquad (3.4.2\text{-}1)$$

$$A_y = A_z = 0.5A_x \qquad (3.4.2\text{-}2)$$

$$S_x = \frac{\pi}{16D_o}(D_o^4 - D_i^4) \qquad (3.4.2\text{-}3)$$

$$S_y = S_z = 0.5S_x \qquad (3.4.2\text{-}4)$$

$$r_y = r_z = \left(\frac{D_o S_y}{2A_z}\right)^{1/2} \qquad (3.4.2\text{-}5)$$

where:

D_o = outside diameter of the duct, in.
D_i = inside diameter of the duct, in.

3.5 Duct and Duct Support Qualification

3.5.1 Seismic Component Combination

For both OBE and SSE, the resultant effects (resultant stresses) of both horizontal and vertical earthquake components shall be determined by combining the individual effects by the Square Root of the Sum of the Squares (SRSS).

3.5.2 Design Loads

Supports must be qualified for dead load and seismic loads. In addition to these loads, ducts must be qualified for the Operational and Design Basis Accident maximum internal pressure loads. Load combinations are defined in Section 3.5.4. Specifically, the following loads must be considered:

DL - Dead Loads. The dead load shall include self-weight of the support and the duct, including coatings, insulation, other accessories and attachments.

OBE - Operating Basis Earthquake loads based on UFSAR Design Basis OBE Spectra.

SSE - Safe Shutdown Earthquake loads based on UFSAR Design Basis SSE Spectra (i.e. SSE=DBE).

P_o* - Operating pressure in the duct system (measured in inches of water).

P_a* - Maximum pressure in the duct system (measured in inches of water) resulting from a credible single active failure during a Design Basis Accident.

*The duct internal pressures are being re-calculated and will be provided by the HVAC Systems Group.

3.5.3 Guidelines for Design Load Application

The following sections provide guidance on specific aspects of duct and duct support loads determination.

3.5.3.1 Seismic Load Application

The damping value to be used for evaluation of duct and duct supports depends on duct configuration and earthquake level as follows:

Duct Configuration	Earthquake	Damping
Rectangular Ducts and their Supports	OBE SSE	4% 7%
Round Ducts and their Supports	OBE SSE	2% 4%

Accelerations shall be taken from the appropriate, damped design response spectra of the floor to which the supports are attached. In the case of supports attached to the wall, the adjacent floor design response spectra with the highest magnitude responses shall be used. For duct/duct support analysis strings which contain both round and rectangular ducts, the damping values corresponding to round duct shall conservatively be used. As an alternative when technically justified, damping values and response accelerations corresponding to the duct segments with predominant modes may be used. Applicable design response spectra curves are provided in Appendix B. For damping ratios not included in the curves in Appendix B, a linear interpolation should be used, as permitted in Regulatory Guide 1.60, Positions C1 and C2 (Reference 13).

3.5.3.2 Pressure Load Application

Internal duct pressure does not produce significant stresses in round ducts; for rectangular ducts, however, pressure stresses may be significant. The determination of resulting stresses in rectangular ducts is described in Section 3.6.1.

3.5.4 Load Combinations and Allowables

The following load combinations shall be considered:

For Ductwork	For Supports
(1) $DL + P_o + OBE$	(1) DL + OBE
(2) $DL + P_s + SSE$	(2) DL + SSE

The allowables for evaluation of ductwork are shown in Section 3.5.4.1 and for duct supports in Section 3.5.4.2.

3.5.4.1 Overall Stress Criteria for Ducts

1. Combined axial tension and bending stresses in the duct plate shall not exceed the appropriate allowable values of F_m.

   Where F_m = 0.6 F_y, for Load Combination 1
   F_m = 0.9 F_y, for Load Combination 2

   The axial tensile stresses shall be based on full area.

2. Combined axial compression and bending interaction coefficient in the duct plate shall not exceed unity using the allowable values described below.

   The axial compressive stresses shall be based on effective area defined by Equation (3.4.1-3).

   F_a, the axial compressive stress allowable, is defined by f_a in Equation (3.4.1-4). The allowable bending stresses are calculated as follows:

$$\textit{For } \frac{F_{xc}}{F_a} \le 0.15, \; F_{by} = F_{bz} = F_m$$

$$\textit{and for } \frac{F_{xc}}{F_a} > 0.15:$$

$$F_{by} = F_m \left(1 - \frac{F_{xc}}{F_{ey}}\right)$$

$$F_{bz} = F_m \left(1 - \frac{F_{xc}}{F_{ez}}\right)$$

where:

F_{xc} = axial compressive stress computed using effective area from Eq. 3.4.1-3

F_{xg} = axial compressive stress computed using full area

F_{by} = bending stress allowable about y-axis

F_{bz} = bending stress allowable about z-axis

$F_m = 0.6\ F_y$ for Load Combination 1

$F_m = 0.9\ F_y$ for Load Combination 2

$$F_{ei} = \frac{12\ \pi^2\ E}{23\ (\frac{KL_i}{r_i})^2}, \textit{ for Load Combination } 1$$

$$F_{ei} = 1.5\ x\ \frac{12}{23}\ \frac{\pi^2\ E}{(\frac{KL_i}{r_i})^2}, \textit{ for Load Combination } 2$$

in which:

i = y or z

K = effective length factor taken as 1.0 for continuous spans and 2.0 for cantilevers.

L_i = duct length between supports in i direction for continuous spans and duct length for cantilevers.

r_i = radius of gyration for bending about i - axis as defined by Equations (3.4.1-8) and (3.4.1-9), respectively.

(Note: The type of increase in F_{ei} included for Load Combination 2 is also permitted in Section 1.6.1 of Reference 3 for seismic and wind loads).

3. The combined in-plane shear stresses shall not exceed the allowable value F_v for OBE; and 1.5 x F_v, but less than 0.52 F_y, for SSE.

(a) For ducts with Pittsburgh lock longitudinal seams

$$F_v = 0.6\ [24000\ K_v\ (\frac{t}{h})^2 + 0.1\ (F_y - f_{xpl})] \leq 0.4F_y \qquad (3.5\text{-}1)$$

where:

K_v = Shear buckling coefficient for unreinforced webs = 5.34

h = Depth of web (rectangular duct dimension W or H as appropriate), in.

f_{xpl} = Pressure induced longitudinal tensile stress, ksi, from Section 3.6.1.

Equation (3.5-1) is the minimum strength recommended in Reference 14 for webs of ducts in which duct corners are not reinforced for longitudinal stress, as is the case for ducts discussed here.

(b) For round duct with Acme lock longitudinal seams

$$F_v = 13955\ [\frac{t}{R}]^{1.25}\ [\frac{R}{L}]^{1/2} \leq 0.4\ F_y \qquad (3.5\text{-}2)$$

where:

R = duct radius, in.

L = duct length, in.

t = duct thickness, in. (bare sheet metal)

Equation (3.5-2) is based on Reference 15.

3.5.4.2 The allowables for various support elements are as follows:

Elements	Load Combination	Allowables
Steel Structural Members and Connecting Welds	(1)	AISC allowables
	(2)	1.6 x AISC allowables but less than F_y*

*But less than 0.58 F_y for shear stresses, and less than F_{cr} for critical buckling stresses.

The allowables for existing support anchorages are specified in DECo Calculation DC No. 2935, Rev. 0, "Design Methods - QAI Ductwork Supports" (Reference 16). For modifications, the requirements in DECo Specification 3071-226, Rev. J, "Purchase and Installation of Concrete Anchors" (Reference 17) will be followed.

3.5.5 Duct/Duct Support System "String" Analysis

A duct and duct support system, from termination point to termination point, shall be idealized into an analysis system. An example is shown in Figures 3.5.5-1 and 3.5.5-2.

The system shall be analyzed by using the response spectrum analysis method with the appropriate floor design response spectra in Appendix B. The analysis shall include dead load including accessories, and vertical and two horizontal seismic loads. The forces at critical sections resulting from these analyses shall be used to determine stresses in the ductwork (see Section 3.4).

The method for combining the three seismic directional components shall be the SRSS approach described in Section 3.5.1.

Duct Modeling

The ducts shall be idealized as three dimensional (3-D) beam elements. For rectangular ducts, the two shear areas shall be based on two full web depths. The torsional moment of inertia shall be based on gross cross-section. The axial area shall be based on:

$$A_{ave} = \frac{1}{2}(A_e + A_g) \qquad (3.5.5\text{-}1)$$

where:

A_g = gross cross-sectional area

A_e = effective axial cross-sectional area (in compression) determined from Equation (3.4.1-3) using a stress f_a equal to the SSE load condition.

The analysis moment of inertia (I_e^*) shall be calculated as follows:

$$I_e^* = \lambda \, I_e \qquad (3.5.5\text{-}2)$$

where:

I_e = Moment of inertia based on effective cross-section (Section 3.4) using a flange stress = 0.90 x yield stress.

λ = 0.85 for rectangular companion angle ducts (Reference 12)

λ = 1.00 for round ducts

For round ducts, the axial area and the three moments of inertia shall be based on gross cross-section. The shear areas shall each be one-half the gross area.

Support Modeling

The supports shall be modeled in the system analysis or shall be idealized as linear springs.

3.6 Cases Requiring Special Consideration

3.6.1 Stresses Due to Internal Pressure and Panel Vibration

3.6.1.1 Pressure Stresses

In a rectangular duct with companion angle transverse joints, internal pressure produces longitudinal stresses that are significant for companion angle,stiffener and duct evaluation. For round ducts, longitudinal membrane stresses caused by pressure are negligible.

Studies of rectangular ducts using a large displacement finite element analysis show that for the same companion angle size, spacing, and duct plate thickness, the stresses in a rectangular duct are less than the stresses produced in a square duct of size equal to the larger dimension of the rectangular duct (Reference 12).

The tensile stress due to pressure in the duct plate near the companion angles and stiffeners shall be obtained from the following equation:

$$f_{xpl} = C_1 \left(\frac{E}{24}\right)^{1/3} \left(P \ x \ \frac{62.4}{1728000} \ x \ \frac{\ell}{t}\right)^{2/3} \qquad (3.6.1\text{-}1)$$

where:

f_{xpl}	=	longitudinal tensile stress in duct plate near companion angles/stiffeners, ksi
E	=	modulus of elasticity of duct plate, ksi
ℓ	=	stiffener spacing, inches
P	=	internal pressure, inches of WG
t	=	duct plate thickness (bare sheet metal), inches
C_1	=	correlation factor, see Table 3.6.1-1.

The compressive stress at mid-distance between the companion angles/stiffeners at duct corner shall be calculated from the following equation:

$$f_{xpc} = C_2 \left(\frac{E}{24}\right)^{1/3} \left(P\ x\ \frac{62.4}{1728000}\ x\ \frac{\ell}{t}\right)^{2/3} \qquad (3.6.1\text{-}2)$$

where:

f_{xpc} = compressive stress due to pressure at duct corner at mid-distance between companion angles/stiffeners

C_2 = correlation factor, see Table 3.6.1-1.

3.6.1.2 Panel Vibration Stresses

The out-of-plane inertia forces acting on the duct walls cause stresses similar to pressure-induced stresses.

Using a peak floor spectral acceleration, for convenience, the resulting tensile stress, near the companion angles and stiffeners, shall be calculated from the following equation:

$$f_{xst} = C_1 \left(\frac{E}{24}\right)^{1/3} \left(\frac{aw}{144000}\ \frac{\ell}{t}\right)^{2/3} \qquad (3.6.1\text{-}3)$$

where:

f_{xst} = longitudinal tensile stress in duct plate near companion angles/stiffeners, ksi

C_1 = the same as in Equation (3.6.1-1)

a = 1.5 x the maximum floor spectral acceleration (envelope of horizontal and vertical components) at applicable damping, g units

w = dead weight of duct wall including insulation, pounds per square foot

The compressive stress due to panel vibration shall be computed as

$$f_{xsc} = C_2 \left(\frac{E}{24}\right)^{1/3} \left(\frac{aw}{144000} \frac{\ell}{t}\right)^{2/3} \qquad (3.6.1\text{-}4)$$

where:

f_{xsc} = compressive stress due to panel vibration at duct corner at mid-distance between companion angles/stiffeners

C_2 = the same as in Equation (3.6.1-2)

Because panel vibration is considered as a separate modal response, when combining these stresses with seismic beam response of the duct, they shall be combined on an SRSS basis.

3.6.2 Stiffener and Companion Angle Design

The stiffeners and companion angles on rectangular ducts shall be evaluated for load combinations of Section 3.5.4. In addition to the loads presented in these combinations, the following additional loads shall be appropriately added to these combinations:

1. The contributory effects of a GRD, if present in the adjoining panel, on the stiffener/companion angle (Figure 3.6.2-1).

2. Additional compressive axial forces resulting from the plate tension field action.

This is necessary because the allowable panel shear stresses are based on tension field action. These axial forces may result from duct dead load and seismic loads.

The distribution of plate self-weight, seismic, pressure and GRD loads on stiffeners/companion angles shall be in accordance with Figure 3.6.2-1.

The axial force in the stiffener/companion angle due to panel tension field action shall be calculated by the following equation:

$$F_c = V\left(\frac{a}{h}\right) \left[\left[1 + \left(\frac{a}{h}\right)^2 \right]^{1/2} - \frac{a}{h} \right] \tag{3.6.2-1}$$

where:

V = duct dead load shear in the panel, or
= vertical seismic shear (OBE or SSE), or
= horizontal 1 seismic shear, or
= horizontal 2 seismic shear
a = stiffener/companion angle spacing
h = stiffener/companion angle length

This load shall be appropriately added to the load combinations.

For the loads and load combinations described above, the stiffener/companion angle rectangular frame shall be analyzed using appropriate boundary conditions at the corners. The resulting stresses shall be limited to the AISC allowable (Reference 3).

For round ducts, stiffener/companion angle design is not necessary.

TABLE 3.6.1-1

CORRELATION FACTORS C_1 AND C_2 FOR PRESSURE STRESS IN RECTANGULAR DUCTS*

Duct or Fitting	C_1 Eqs. (3.6.1-1) (3.6.1-3)	C_2 Eqs. (3.6.1-2) (3.6.1-4)
1. Straight ducts, rectangular-to-rectangular transitions and offsets	0.84	0.47
2. Wye fittings:		
a. All straight branches	0.79	0.16
b. Curved branches with crotch at companion angle (Figure 3.6.1-1a)	0.50	1.27
c. Curved branches with crotch away from companion angle (Figure 3.6.1-1b)	0.91	1.24
3. Elbows	0.84	1.27
4. Rectangular-to-round fittings:		
a. 22 gauge	0.61	0.38
b. 20 gauge	0.71	0.42
c. 18 gauge	0.92	0.61
d. 16 gauge	1.13	0.84

*Factors given are applicable up to a pressure of 10 inches of water gauge (See Reference 12).

4.0 REFERENCES

1. NRC Letter entitled "Fermi 2 Control Center Heating, Ventilation and Air-Conditioning (CCHVAC) System (TAC No. M89596)" dated December 7, 1995 from Mr. T. Colburn to Mr. D. Gipson.

2. "Nuclear Power Plant Air Cleaning Units and Components", ANSI/ASME N509-1980.

3. "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings", American Institute of Steel Construction, 7th Edition and 8th Edition as noted.

4. Fermi 2 Updated Final Safety Analysis Report.

5. Hopper and Associates, "Structural Evaluation of Ducting Systems 2848-3, 4316-1, 4326-6, and 4316-7, "Report No. HA-05/89-686, May 31, 1989.

6. Hopper and Associates, "Structural Evaluation of CCHVAC and SGTS Ducting Systems Calculations," Report No. HA-09/89-696, September 29, 1989.

7. "Duct Construction Brochure", Enrico Fermi Atomic P.P. Unit #2 3071-104-Type 1.

8. "Cold-Formed Steel Design Manual", American Iron and Steel Institute, 1986.

9. ~~"Structural Welding Code",~~ American Welding Society, AWS-A5.1. (DELETE) Rev A

10. American Welding Society, AWS-A5.6.

11. American Welding Society, AWS-A5.18.

12. Amin, M. et al., "Seismic Qualification of HVAC Ducts: Criteria and Application Experience." Proceeding of the Fourth Symposium on Current Issues Related to Nuclear Plant Structures, Equipment and Piping, Orlando, Florida, 1992.

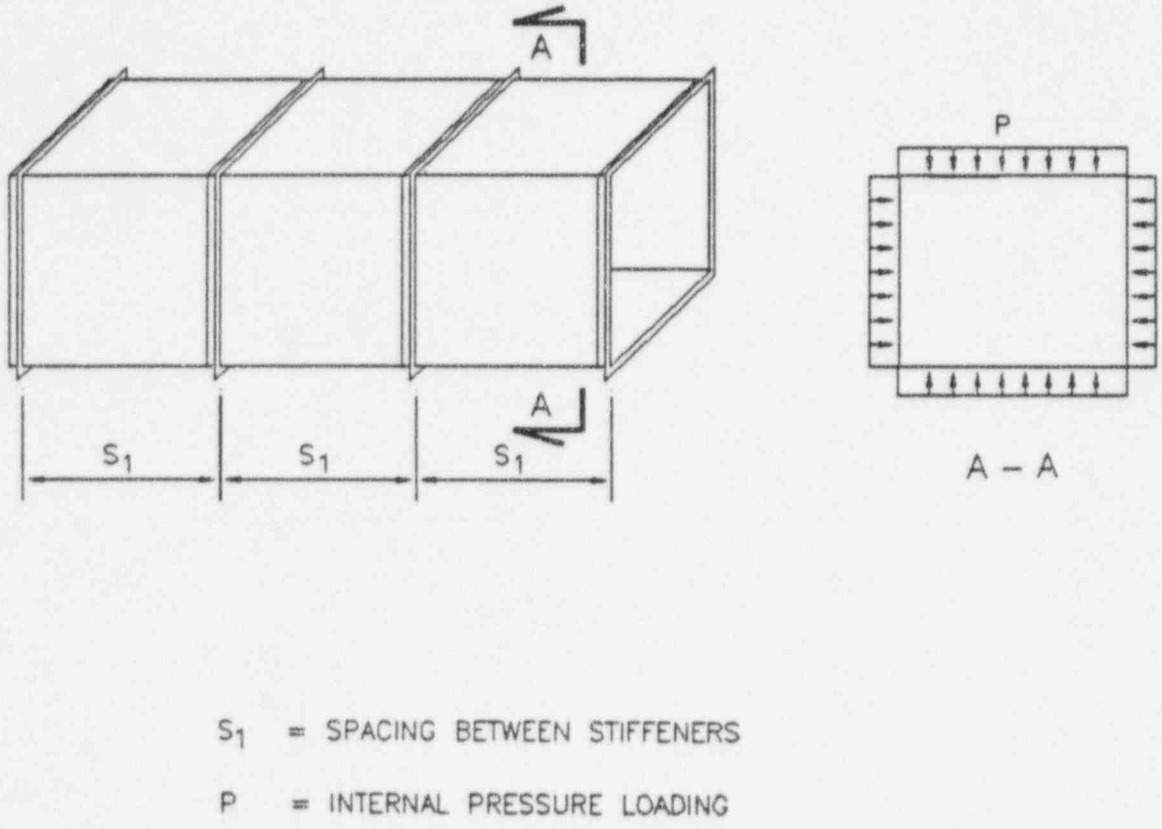
13. NRC Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants".

14. Sherbourne, A.N., and Haydl, H.M., "Ultimate Web Shear Capacity in Large Rectangular Ducts", Canadian Journal of Civil Engineering, Vol. 7, 1980, pp. 125-132.

15. Schilling, C.G., "Buckling Strength of Circular Tubes", Journal of Structural Division, Proceedings of ASCE, Vol. 91, ST5, October 1965, pp. 325-348.

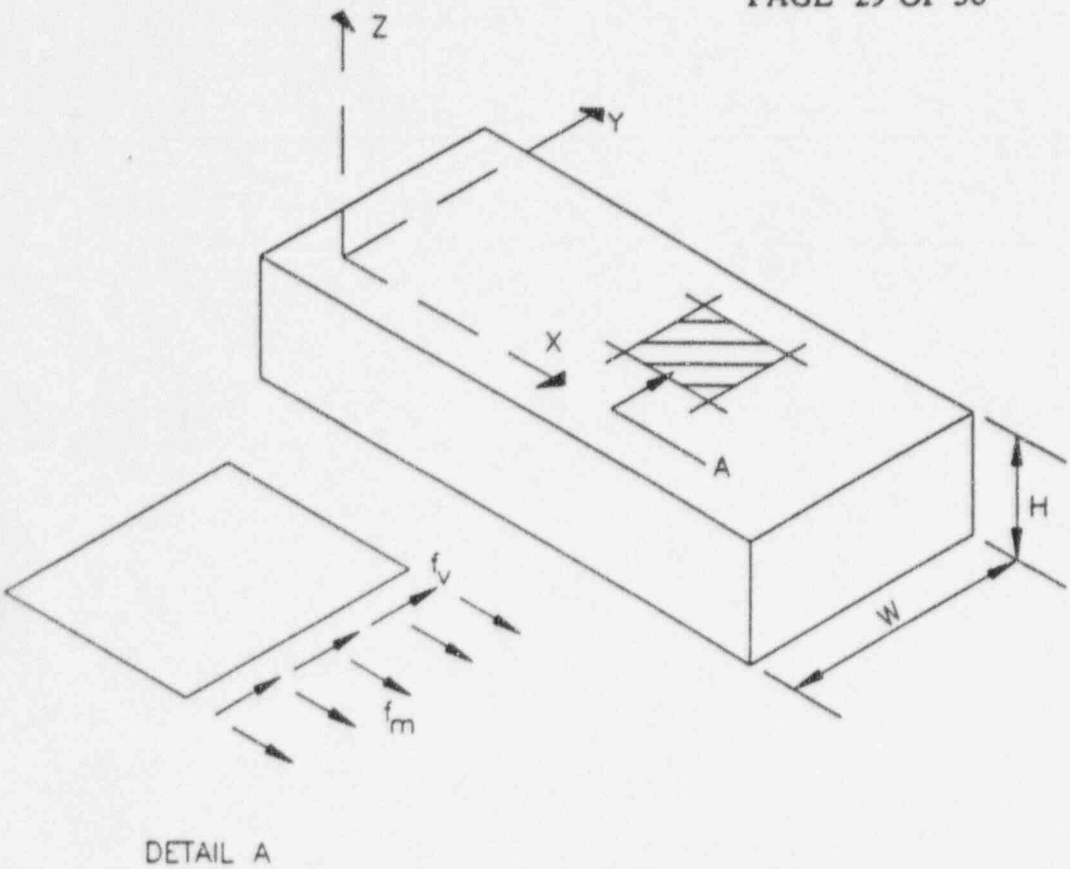
16. DECo Calculation DC No. 2935, Rev. 0, "Design Methods - QAI Ductwork Supports".

17. DECo Specification 3071-226, Rev. J, "Purchase and Installation of Concrete Anchors".

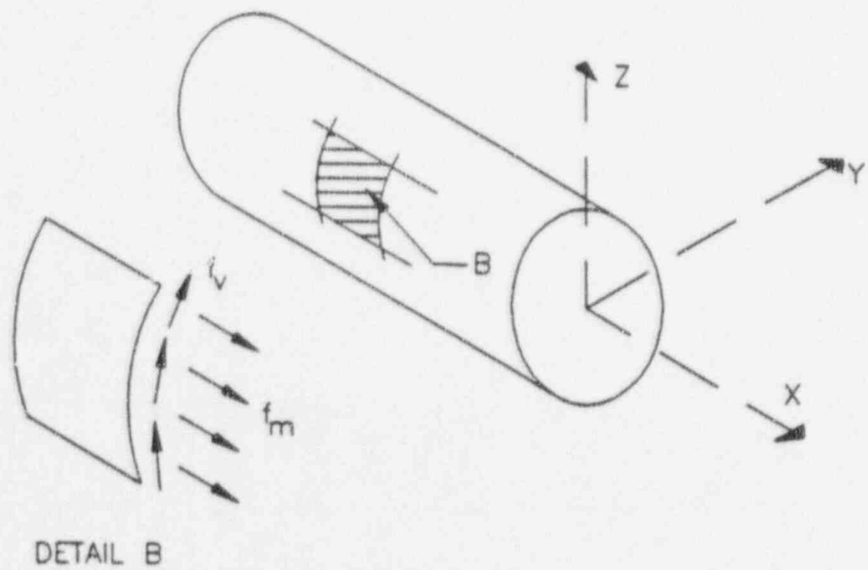


3-D SEGMENT FOR FEM ANALYSIS OF RECTANGULAR DUCT UNDER INTERNAL PRESSURE

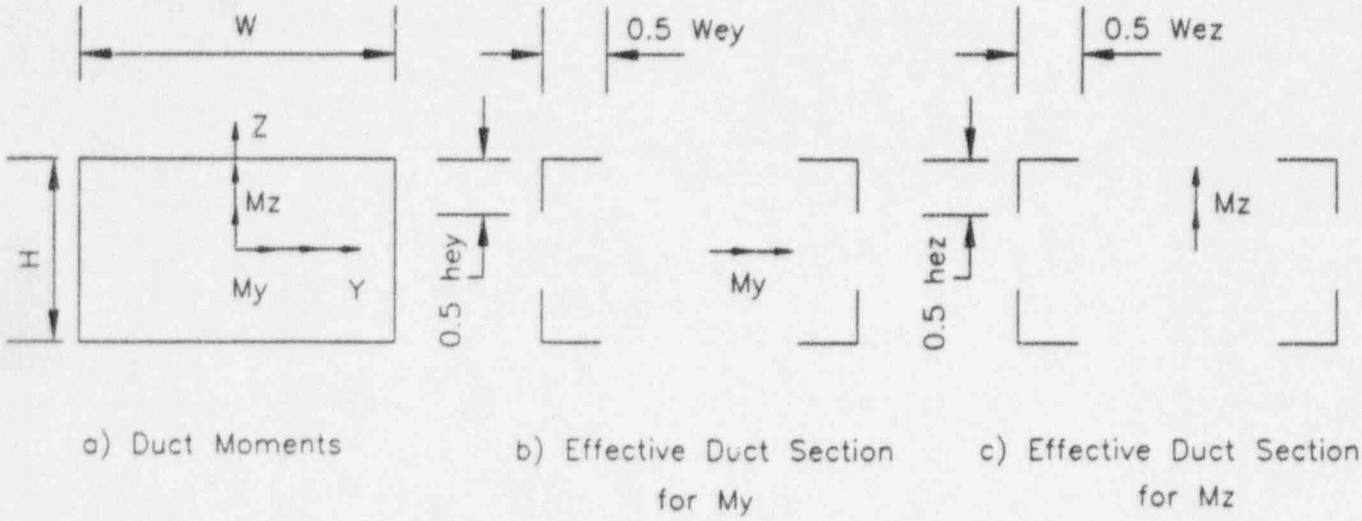
FIGURE 3.3-1



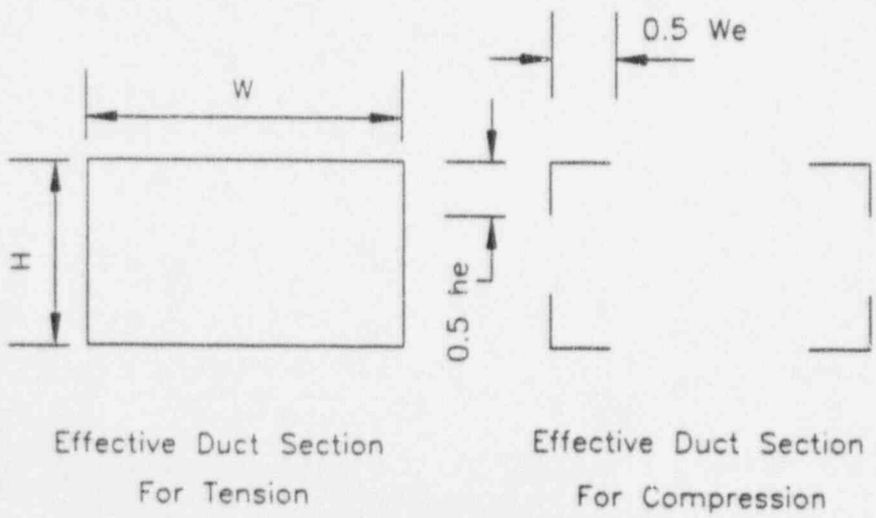
MEMBRANE STRESS IN THE RECTANGULAR DUCT PLATE
FIGURE 3.4-1



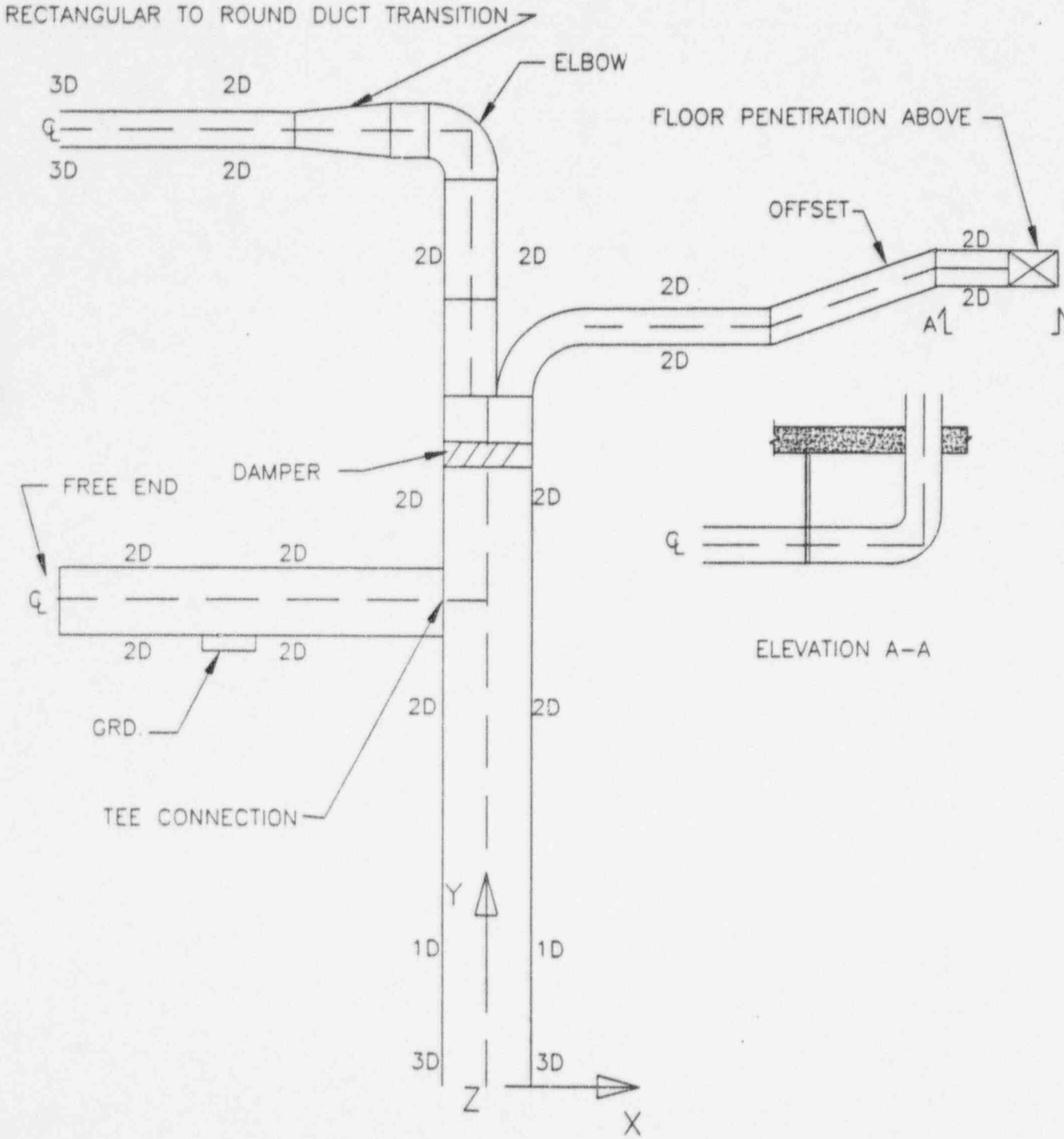
MEMBRANE STRESSES IN THE ROUND DUCT PLATE
FIGURE 3.4-2



EFFECTIVE DUCT CROSS-SECTIONS USED TO CALCULATE SECTION MODULI
S_y AND S_z FOR RECTANGULAR DUCTS
FIGURE 3.4-3

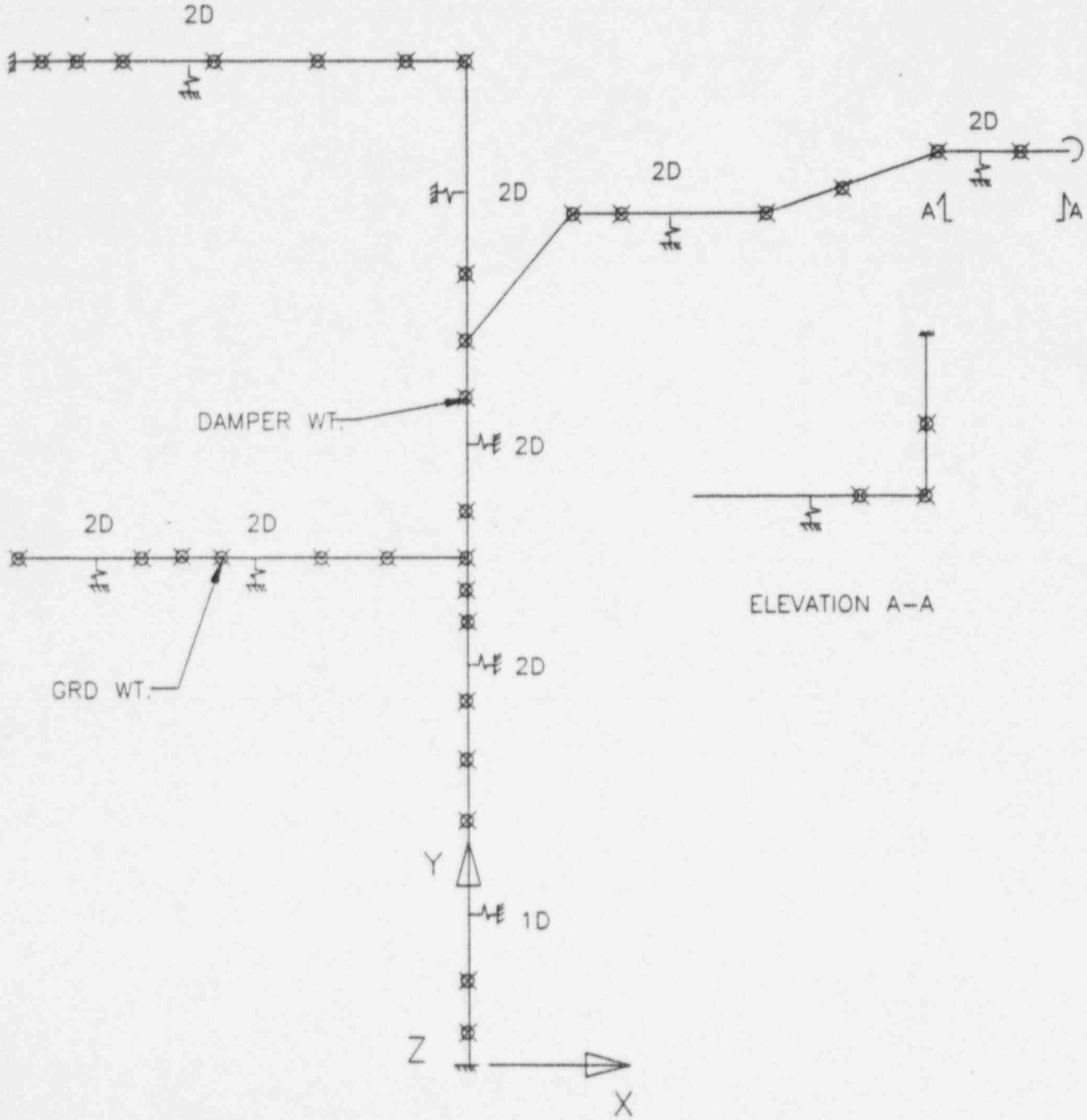


EFFECTIVE CROSS-SECTIONS FOR RECTANGULAR DUCTS
FOR AXIAL LOADING
FIGURE 3.4-4



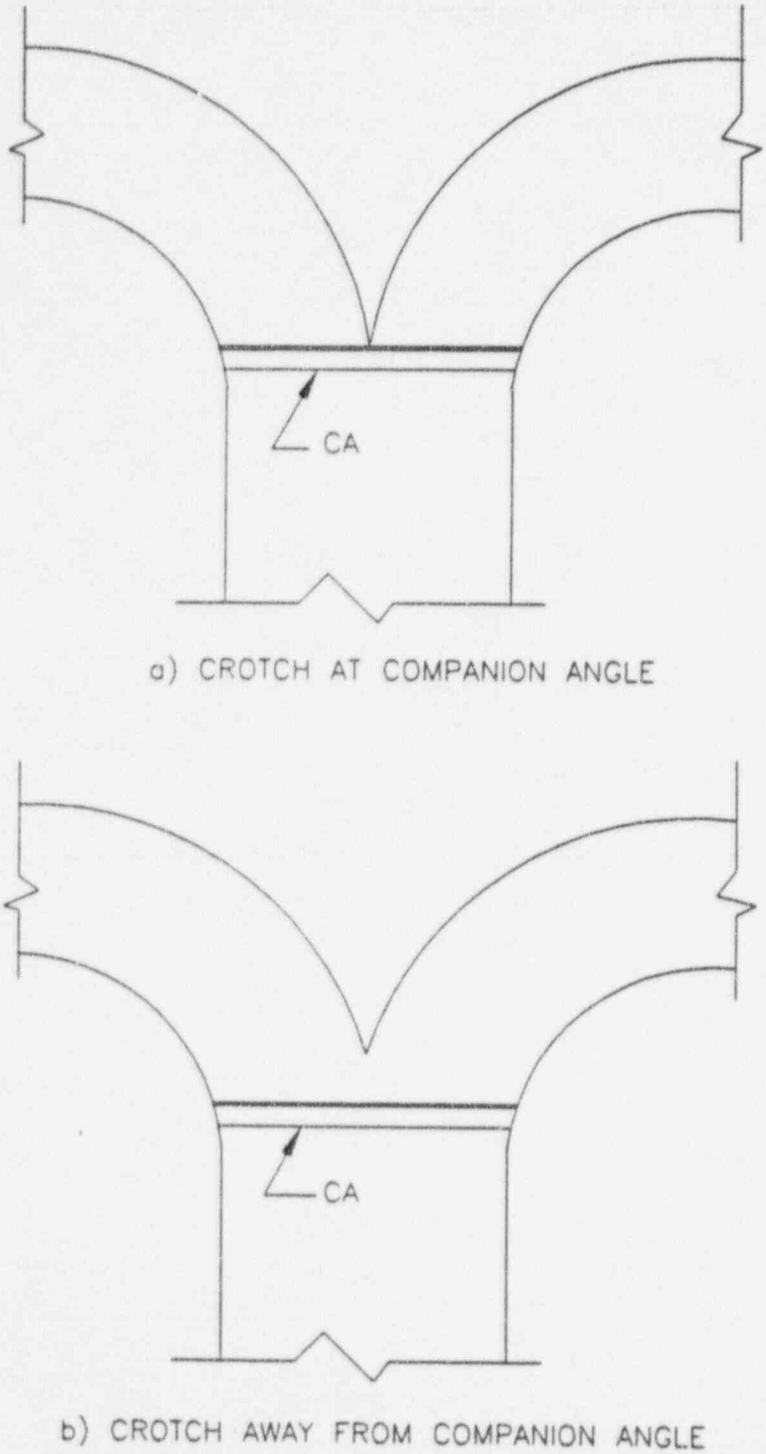
PLAN VIEW OF TYPICAL DUCTWORK AND SUPPORTS

FIGURE 3.5.5-1



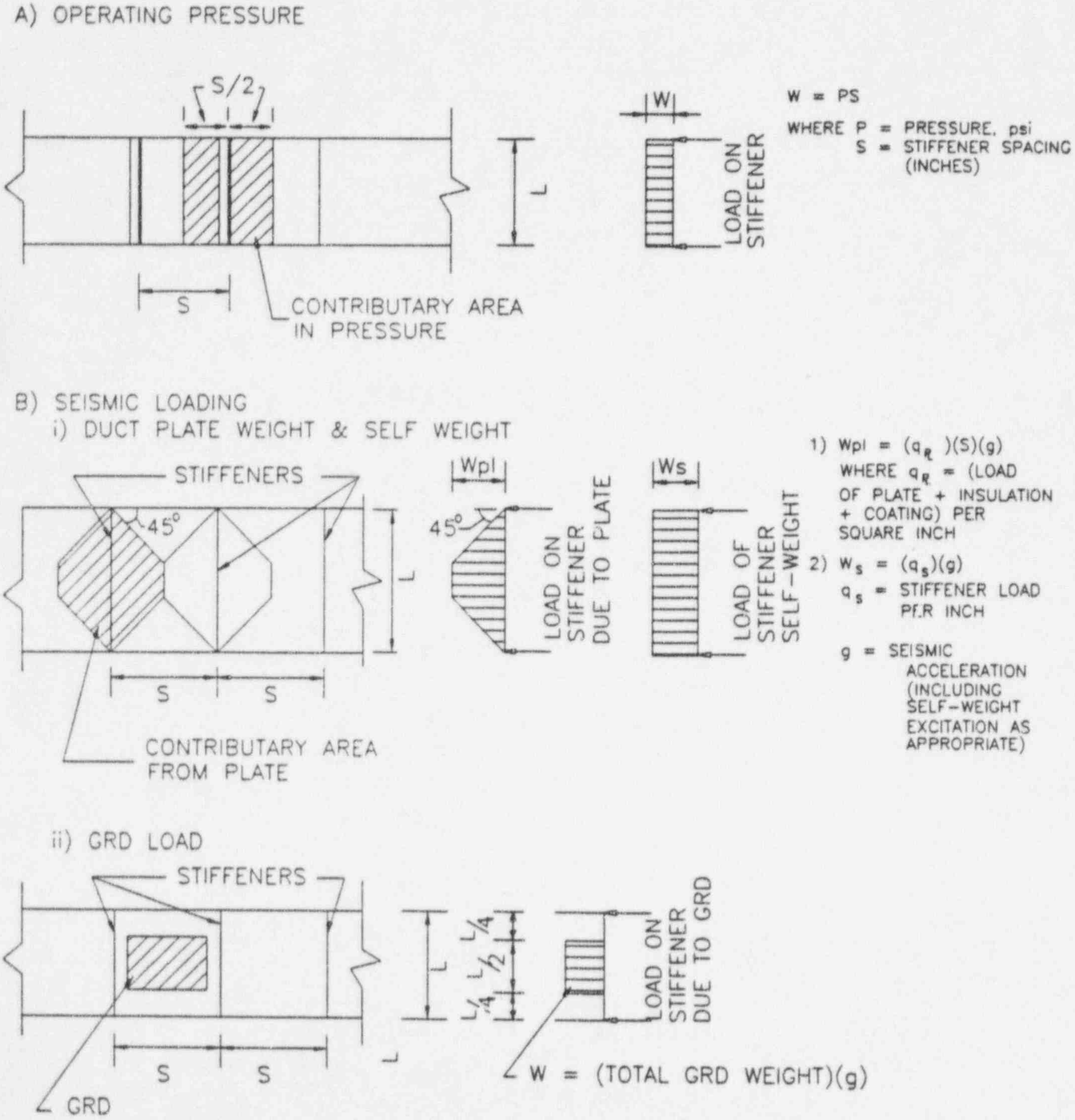
IDEALIZED COMPUTER MODEL OF DUCTWORK SUPPORT SYSTEM

FIGURE 3.5.5-2



WYE CONFIGURATIONS IN TABLE 3.6.1-1

FIGURE 3.6.1-1



LOADING ON STIFFENER/COMPANION ANGLES

FIGURE 3.6.2-1

APPENDIX A - CCHVAC DUCT AND DUCT SUPPORT DATABASE

(Sheet A-1 through A-9)

LEGENDS

System No.	Unique number of each duct/support system which is the same as RICO part number (or RICO Stress Report number).
Support No.	Unique number for each support.
Support Rev.	Revision number of support drawing.
DC No.	Existing calculation number which qualified the support.
Other Documents	Other design or change documents affecting the support.
Rigid/Flex.	R and F denotes whether the system was considered to be Rigid or Flexible in existing documents.

REV. A

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REV. A

CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2268-2A	6M-2268-H- 5	0	2785	ABN4296-1	R
2268-2A	6M-2268-H- 6	0	2785		R
2268-2A	6M-2268-H- 7	0	2785		R
2268-2A	6M-2268-H- 8	0	2785		R
2268-2A	6M-2268-H- 9	0	2785		R
2268-2A	6M-2268-H-10	0	2785		R
2268-2A	6M-2268-H-30	A	2785	DCN10906B	R
2268-2B	6M-2268-H-31	0	2786	DCN10902	R
2268-2C	6M-2268-H-18	0	2785		R
2268-2C	6M-2268-H-19	0	2785		R
2268-2C	6M-2268-H-20	0	2785		R
2268-2C	6M-2268-H-21	0	2785	DCN10899	R
2268-2C	6M-2268-H-22	0	2785		R
2268-2C	6M-2268-H-23	0	2785		R
2268-2C	6M-2268-H-34	A	2785		R
2268-2D	6M-2268-H-33	A	2788	DCN10913	R
2268-3A	6M-2268-H-11	0	2789		F
2268-3A	6M-2268-H-12	0	2789		F
2268-3A	6M-2268-H-13	0	2789		F
2268-3A	6M-2268-H-14	0	2789		F
2268-3A	6M-2268-H-15	0	2789		F
2268-3A	6M-2268-H-16	0	2789		F
2268-3B	6M-2268-H-32	0	2790	DCN10901	R
2268-3C	6M-2268-H-24	0	2791	ABN4296-1	F
2268-3C	6M-2268-H-25	0	2791		F
2268-3C	6M-2268-H-26	0	2791		F
2268-3C	6M-2268-H-27	0	2791		F
2268-3C	6M-2268-H-28	0	2791	ABN4296-1	F
2268-3D	6M-2268-H-35	0	2792	DCN10905C	R
2268-4A	6M-2268-H-17	A	2793		R
2268-4B	6M-2268-H-29	A	2793	DCN10906A	R
2848-1	6M-2848-H- 2	C	2794	DCN10908A	F
2848-1	6M-2848-H- 3	C	2794	DCN10935A	F
2848-1	6M-2848-H- 4	B	2794	DCN10915A	F
2848-1	6M-2848-H- 5	B	2794	DCN10941A	F
2848-1	6M-2848-H- 6	C	2794		F
2848-1	6M-2848-H- 7	C	2794	DCN10948A,ABN4296-1	F
2848-1	6M-2848-H- 8	A	2794	DCN10945A	F
2848-1	6M-2848-H-15	B	2794		F
2848-1	6M-2849-H-21	B	2794		F
2848-1	6M-4316-H-26	C	2794		F
2848-1-1A	6M-2848-1-H- 5	B	2795		R
2848-1-1A	6M-2848-1-H- 6	A	2795		R
2848-1-1A	6M-2848-1-H-14	A	2795		R
2848-1-1A	6M-2848-1-H-15	A	2795		R
2848-1-1A	6M-2848-1-H-16	A	2795		R
2848-1-1A	6M-2850-H-48	B	2840		R
2848-1-1B	6M-2848-1-H- 5	B	2796		R
2848-1-1B	6M-2848-1-H- 6	A	2796		R
2848-1-1B	6M-2848-1-H-17	A	2796		R
2848-1-1B	6M-2850-H-48	B	2796		R
2848-1-1C	6M-2848-1-H- 1	A	2797	DCN10909B	R
2848-1-1C	6M-2848-1-H- 5	B	2797		R
2848-1-1C	6M-2848-1-H- 6	A	2797		R
2848-1-1C	6M-2848-1-H-18	A	2797		R
2848-1-1C	6M-2848-1-H-19	A	2797		R
2848-1-1C	6M-2850-H-48	B	2797		R

REV. A

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REV. A

CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2848-1-2A	6M-2848-1-H- 4	A	2798		F
2848-1-2A	6M-2848-1-H- 5	B	2798		F
2848-1-2A	6M-2848-1-H- 6	A	2798		F
2848-1-2A	6M-2848-1-H- 8	A	2798	DCN10940	F
2848-1-2A	6M-2848-1-H- 9	A	2798	DCN10950	F
2848-1-2A	6M-2850-H-48	B	2798		F
2848-1-2B	6M-2848-1-H- 3	A	2799		F
2848-1-2B	6M-2848-1-H- 5	B	2799		F
2848-1-2B	6M-2848-1-H- 6	A	2799		F
2848-1-2B	6M-2848-1-H-12	A	2799		F
2848-1-2B	6M-2848-1-H-13	A	2799	DCN10949	F
2848-1-2B	6M-2850-H-48	B	2799		F
2848-1-2C	6M-2848-1-H- 2	0	2800		F
2848-1-2C	6M-2848-1-H- 5	B	2800	DCN10892C	F
2848-1-2C	6M-2848-1-H- 6	A	2800		F
2848-1-2C	6M-2848-1-H-10	A	2800	DCN10954A	F
2848-1-2C	6M-2848-1-H-11	A	2800		F
2848-1-2C	6M-2850-H-48	B	2800		F
2848-1-2D	6M-2848-1-H- 5	B	2801		R
2848-1-2D	6M-2848-1-H- 6	A	2801		R
2848-1-2D	6M-2848-1-H- 7	0	2801		R
2848-1-2D	6M-2848-1-H- 9	A	2801		R
2848-1-2E	6M-2848-1-H- 6	A	2801	DCN10892C	F
2848-2A	6M-2848-H-10	A	2802		R
2848-2A	6M-2848-H-11	A	2802		R
2848-2A	6M-2848-H-20	A	2802	EDP26868	R
2848-2B	6M-2849-H-17	B	2802	DC-2827,DC-2069	R
2848-3	6M-2848-H-21	B	2803	DCN10867B	F
2848-3	6M-2848-H-22	B	2803	DCN10867B	F
2848-3	6M-2848-H-23	B	2803	DCN10867B	F
2848-3	6M-2848-H-24	A	2803		F
2848-3	6M-2848-H-25	A	2803		F
2848-3	6M-2848-H-26	A	2803		F
2848-3	6M-2848-H-27	A	2803		F
2848-3	6M-2848-H-28	A	2803		F
2848-3	6M-2848-H-29	A	2803		F
2848-3	6M-2848-H-30	A	2803		F
2848-3	6M-2848-H-31	A	2803	DCN10934B	F
2848-3	6M-2848-H-32	A	2803		F
2848-3	6M-2848-H-33	A	2803		F
2848-3	6M-2848-H-34	A	2803		F
2848-3	6M-2848-H-35	A	2803		F
2848-3	6M-2848-H-36	A	2803	DCN10929,TSR-28204	F
2848-3	6M-2848-H-38	D	2803	DCN10910,TSR-28204	F
2848-3	6M-4316-H-37	A	2803		F
2848-4A,B,C	6M-2848-H-12	C	2804		R
2848-4A,B,C	6M-2848-H-13	0	2804	ABN4296-1	R
2848-4A,B,C	6M-2848-H-14	0	2804		R
2848-4A,B,C	6M-2848-H-17	0	2804		R
2848-4A,B,C	6M-2848-H-18	A	2804		R
2848-4A,B,C	6M-2848-H-19	A	2804		R
2848-5	6M-2848-H-40	B	2805		R
2848-5	6M-2848-H-41	0	2805		R
2848-5	6M-2848-H-42	B	2805		R
2849-1	6M-2849-H- 42	A	2806		F
2849-1	6M-2849-H- 43	A	2806		F
2849-1	6M-2849-H- 44	B	2806		F

REV. A

CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2849-1	6M-2849-H- 45	B	2806		F
2849-1	6M-2849-H- 46	A	2806		F
2849-1	6M-2849-H- 47	A	2806		F
2849-1	6M-2849-H- 48	B	2806		F
2849-1	6M-2849-H- 49	B	2806		F
2849-1	6M-2849-H- 50	B	2806	DCPT4102-M02	F
2849-1	6M-2849-H- 51	B	2806	DCPT4102-M02	F
2849-1	6M-2850-1-H- 6	B	2806		F
2849-1	6M-2850-1-H- 7	B	2806		F
2849-1	6M-2850-H- 8	A	2806		F
2849-1	6M-2850-H- 9	A	2806		F
2849-1	6M-2850-H-10	A	2806		F
2849-1	6M-2850-H-12	C	2806		F
2849-1	6M-2850-H-26	B	2806		F
2849-1	6M-2850-H-27	A	2806		F
2849-1	6M-2850-H-30	A	2806		F
2849-1	6M-2850-H-31	A	2806		F
2849-10	6M-2849-H- 25	B	2832	DCPT4102-M04,DC-2069	R
2849-10	6M-2849-H- 26	C	2832	DCPT4102-M04,DC-2069	R
2849-10	6M-2849-H- 27	B	2832	DCN10930	R
2849-10	6M-2849-H- 28	B	2832		R
2849-10	6M-2849-H- 29	A	2832		R
2849-2	6M-2848-H- 1	C	2825		F
2849-2	6M-2848-H- 3	C	2825		F
2849-2	6M-2848-H- 4	B	2825		F
2849-2	6M-2848-H- 5	B	2825		F
2849-2	6M-2848-H- 6	C	2825		F
2849-2	6M-2848-H- 7	C	2825		F
2849-2	6M-2848-H- 9	A	2825		F
2849-2	6M-2848-H-37	A	2825		F
2849-2	6M-2848-H-39	B	2825	DCN10926RA	F
2849-2	6M-2849-H-13	B	2825		F
2849-2	6M-2849-H-14	B	2825		F
2849-2	6M-2849-H-20	B	2825		F
2849-2	6M-2849-H-21	B	2825		F
2849-2	6M-4316-H-26	C	2825		F
2849-3	6M-2849-H- 52	A	2826	DCPT4102-M05,EDP26868	F
2849-3	6M-2849-H- 53	A	2826		F
2849-3	6M-2849-H- 54	A	2826		F
2849-3	6M-2849-H- 55	O	2826		F
2849-3	6M-2849-H- 56	A	2826	DCN10874A	F
2849-3	6M-2849-H- 57	A	2826	DCN10881A	F
2849-3	6M-2849-H- 58	O	2826		F
2849-3	6M-2849-H- 59	O	2826		F
2849-3	6M-2849-H- 60	O	2826		F
2849-3	6M-2849-H- 61	A	2826		F
2849-3	6M-2849-H- 62	A	2826		F
2849-3	6M-2849-H- 63	O	2826		F
2849-3	6M-2849-H- 64	O	2826	DCN10873A	F
2849-3	6M-2849-H-152	O	2826	DCPT4102-M05,DC-2069	F
2849-3	6M-2850-H- 47	A	2826		F
2849-4	6M-2849-H- 33	A	2828		R
2849-4	6M-2849-H- 34	A	2828		R
2849-4	6M-2849-H- 35	A	2828		R
2849-4	6M-2849-H- 36	A	2828		R
2849-5	6M-2849-H- 1	A	2827		F
2849-5	6M-2849-H- 2	O	2827		F

REV. A

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CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2849-5	6M-2849-H- 3	0	2827		F
2849-5	6M-2849-H- 4	0	2827		F
2849-5	6M-2849-H- 5	B	2827		F
2849-5	6M-2849-H- 6	A	2827		F
2849-5	6M-2849-H- 12	B	2827		F
2849-5	6M-2849-H- 13	B	2827		F
2849-5	6M-2849-H- 14	B	2827		F
2849-5	6M-2849-H- 15	0	2827		F
2849-5	6M-2849-H- 16	A	2827		F
2849-5	6M-2849-H- 17	B	2827	EDP26868	F
2849-5	6M-2849-H- 18	0	2827		F
2849-5	6M-2849-H- 19	A	2827		F
2849-5	6M-2849-H- 22	B	2827		F
2849-5	6M-2849-H- 23	0	2827		F
2849-5	6M-2849-H- 24	A	2827		F
2849-5	6M-2849-H- 69	A	2827		F
2849-5	6M-2849-H- 70	A	2827		F
2849-5	6M-2849-H- 71	0	2827		F
2849-6	6M-2849-H- 33	A	2828		R
2849-6	6M-2849-H- 34	A	2828		R
2849-6	6M-2849-H- 35	A	2828		R
2849-6	6M-2849-H- 36	A	2828		R
2849-6	6M-2849-H- 65	A	2828		R
2849-6	6M-2849-H- 66	0	2828		R
2849-7	6M-2848-H- 31	A	2829		R
2849-7	6M-2849-H- 37	0	2829		R
2849-7	6M-2849-H- 38	A	2829		R
2849-7	6M-2849-H- 65	A	2829	DCPT4102-M04	R
2849-7	6M-2849-H- 68	0	2829	DCN10872A	R
2849-8	6M-2849-H- 31	A	2830		R
2849-8	6M-2849-H- 37	0	2830		R
2849-8	6M-2849-H- 38	A	2830		R
2849-8	6M-2849-H- 68	0	2830	DCN10872A	R
2849-9	6M-2849-H- 6	A	2831		F
2849-9	6M-2849-H- 7	A	2831		F
2849-9	6M-2849-H- 8	B	2831		F
2849-9	6M-2849-H- 9	0	2831		F
2849-9	6M-2849-H- 10	A	2831		F
2849-9	6M-2849-H- 11	0	2831		F
2849-9	6M-2849-H- 40	A	2831		F
2849-9	6M-2849-H- 41	A	2831		F
2849-9	6M-2849-H- 72	A	2831		F
2849-9	6M-4126-H- 1	A	2831		F
2849-9	6M-4126-H- 2	A	2831		F
2849-9	6M-4126-H-18	A	2831		F
2849-9	6M-4126-H-19	A	2831		F
2850-1	6M-2849-H- 57	A	2833		F
2850-1	6M-2849-H- 58	0	2833		F
2850-1	6M-2849-H- 61	A	2833		F
2850-1	6M-2849-H- 62	A	2833		F
2850-1	6M-2850-1-H- 3	0	2833		F
2850-1	6M-2850-1-H-11	A	2833		F
2850-1	6M-2850-H-57	B	2833		F
2850-1	6M-2850-H-73	A	2833		F
2850-1	6M-2850-H-74	A	2833	DCN10938	F
2850-1	6M-2850-H-75	0	2833		F
2850-1	6M-2850-H-76	0	2833		F

REV. A

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REV. A

CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2850-1	6M-2850-H-77	B	2833		F
2850-1	6M-2850-H-78	0	2833		F
2850-1	6M-2850-H-79	B	2833		F
2850-1	6M-2850-H-80	0	2833		F
2850-1	6M-2850-H-81	A	2833		F
2850-1	6M-2850-H-82	0	2833		F
2850-1	6M-2850-H-83	0	2833		F
2850-1	6M-2850-H-84	0	2833		F
2850-1	6M-2850-H-85	A	2833		F
2850-1	6M-2850-H-86	B	2833		F
2850-1	6M-2850-H-87	B	2833	DCN10939A	F
2850-1	6M-2850-H-88	0	2833		F
2850-10	6M-2849-H-32	A	2841		R
2850-10	6M-2850-1-H- 6	B	2841		R
2850-10	6M-2850-1-H- 7	B	2841		R
2850-10	6M-2850-H- 8	A	2841		R
2850-10	6M-2850-H-10	A	2841	DCN10871	R
2850-10	6M-2850-H-11	B	2841		R
2850-10	6M-2850-H-13	0	2841		R
2850-10	6M-2850-H-14	A	2841		R
2850-10	6M-2850-H-15	A	2841		R
2850-2	6M-2850-H-48	B	2834		F
2850-2	6M-2850-H-49	0	2834		F
2850-2	6M-2850-H-54	A	2834		F
2850-2	6M-2850-H-55	0	2834		F
2850-2	6M-2850-H-56	0	2834		F
2850-2	6M-2850-H-58	A	2834		F
2850-2	6M-2850-H-59	A	2834		F
2850-2	6M-2850-H-60	0	2834		F
2850-2	6M-2850-H-61	0	2834		F
2850-2	6M-2850-H-62	0	2834		F
2850-2	6M-2850-H-63	0	2834		F
2850-2	6M-2850-H-64	A	2834		F
2850-2	6M-2850-H-65	A	2834		F
2850-2	6M-2850-H-66	A	2834		F
2850-2	6M-2850-H-67	A	2834		F
2850-2	6M-2850-H-68	A	2834		F
2850-2	6M-2850-H-69	A	2834		F
2850-2	6M-2850-H-70	A	2834		F
2850-2	6M-2850-H-71	A	2834		F
2850-2	6M-2850-H-72	A	2834		F
2850-3	6M-2850-1-H- 1	A	2835		R
2850-3	6M-2850-1-H- 2	0	2835		R
2850-3	6M-2850-1-H- 3	0	2835		R
2850-3	6M-2850-1-H- 4	0	2835		R
2850-3	6M-2850-1-H- 5	0	2835		R
2850-3	6M-2850-H-44	0	2835		R
2850-3	6M-2850-H-45	0	2835		R
2850-3	6M-2850-H-46	A	2835		R
2850-3	6M-2850-H-47	A	2835		R
2850-4	6M-2849-H- 3	0	2836		F
2850-4	6M-2849-H- 4	0	2836		F
2850-4	6M-2849-H- 6	A	2836		F
2850-4	6M-2849-H- 7	A	2836		F
2850-4	6M-2849-H- 31	A	2836		F
2850-4	6M-2850-H-28	A	2836		F
2850-4	6M-2850-H-48	B	2836		F

REV. A

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REV. A

CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2850-4	6M-2850-H-49	0	2836		F
2850-4	6M-2850-H-50	0	2836		F
2850-4	6M-2850-H-51	0	2836		F
2850-5	6M-2850-1-H- 6	B	2837		R
2850-5	6M-2850-1-H- 7	B	2837		R
2850-5	6M-2850-H-19	A	2837		R
2850-5	6M-2850-H-20	A	2837		R
2850-5	6M-2850-H-21	0	2837		R
2850-5	6M-2850-H-22	0	2837		R
2850-5	6M-2850-H-23	0	2837		R
2850-5	6M-2850-H-24	A	2837		R
2850-5	6M-2850-H-25	0	2837		R
2850-5	6M-2850-H-28	A	2837		R
2850-5	6M-2850-H-29	0	2837		R
2850-5	6M-2850-H-48	B	2837		R
2850-6	6M-2849-H-31	A	2838		R
2850-6	6M-2850-1-H- 6	B	2838		R
2850-6	6M-2850-1-H- 7	B	2838		R
2850-6	6M-2850-H-16	A	2838		R
2850-6	6M-2850-H-17	0	2838		R
2850-6	6M-2850-H-18	0	2838		R
2850-6	6M-2850-H-24	A	2838		R
2850-6	6M-2850-H-25	0	2838		R
2850-6	6M-2850-H-28	A	2838		R
2850-6	6M-2850-H-29	0	2838		R
2850-6	6M-2850-H-48	B	2838		R
2850-7	6M-2849-H- 7	A	2840		R
2850-7	6M-2849-H- 8	B	2840		R
2850-7	6M-2850-H-33	0	2840		R
2850-7	6M-2850-H-34	0	2840		R
2850-7	6M-2850-H-35	B	2840		R
2850-7	6M-2850-H-36	A	2840		R
2850-7	6M-2850-H-37	0	2840		R
2850-7	6M-2850-H-38	0	2840		R
2850-7	6M-2850-H-39	0	2840		R
2850-7	6M-2850-H-48	B	2840		R
2850-8	6M-2849-H-31	A	2839		R
2850-8	6M-2850-1-H- 6	B	2839		R
2850-8	6M-2850-1-H- 7	B	2839		R
2850-8	6M-2850-H- 1	B	2839		R
2850-8	6M-2850-H- 2	B	2839		R
2850-8	6M-2850-H- 3	0	2839		R
2850-8	6M-2850-H- 4	A	2839		R
2850-8	6M-2850-H- 5	0	2839		R
2850-8	6M-2850-H- 6	B	2839		R
2850-8	6M-2850-H- 7	0	2839		R
2850-9	6M-2849-H- 7	A	2840		R
2850-9	6M-2849-H- 8	B	2840		R
2850-9	6M-2850-H-32	0	2840		R
2850-9	6M-2850-H-33	0	2840		R
2850-9	6M-2850-H-34	0	2840		R
2850-9	6M-2850-H-35	B	2840		R
2850-9	6M-2850-H-36	A	2840		R
2850-9	6M-2850-H-37	0	2840		R
2850-9	6M-2850-H-38	0	2840		R
2850-9	6M-2850-H-39	0	2840		R
2850-9	6M-2850-H-48	B	2840		R

REV. A

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REV. A

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2853-1	6M-2850-1-H- 8	A	2842		R
2853-1	6M-2850-1-H- 9	A	2842		R
2853-1	6M-2850-H-39	0	2842		R
2853-1	6M-2853-H- 1	0	2842		R
2853-1	6M-2853-H- 2	0	2342		R
2853-1	6M-2853-H- 3	0	2842		R
2853-1	6M-2853-H- 4	0	2842		R
2853-1	6M-2853-H- 5	0	2842		R
2853-1	6M-2853-H- 6	0	2842		R
2853-1	6M-2853-H- 7	0	2842		R
2853-1	6M-2853-H- 8	0	2842		R
2853-1	6M-2853-H- 9	0	2842		R
2853-1	6M-2853-H-10	A	2842		R
2853-1	6M-2853-H-11	0	2842		R
2853-1	6M-2853-H-12	A	2842		R
2853-1	6M-2853-H-13	0	2842		R
2853-1	6M-2853-H-14	A	2842		R
2853-1	6M-2853-H-23	A	2842		R
2853-2	6M-2850-1-H- 8	A	2807		R
2853-2	6M-2850-1-H- 9	A	2807		R
2853-2	6M-2850-H-40	0	2807		R
2853-2	6M-2853-H-14	A	2807		R
2853-2	6M-2854-H- 1	A	2807		R
2853-3	6M-2850-1-H- 1	A	2808		R
2853-3	6M-2850-1-H- 8	A	2808		R
2853-3	6M-2850-1-H-10	A	2808		R
2853-3	6M-2850-H-41	A	2808		R
2853-3	6M-2853-H-14	A	2808		R
2853-3	6M-2853-H-15	A	2808	DCN9395	R
2853-3	6M-2853-H-16	A	2808		R
2853-3	6M-2853-H-17	A	2808		R
2853-3	6M-2853-H-18	A	2808		R
2853-3	6M-2853-H-19	A	2808		R
2853-3	6M-2853-H-20	A	2808		R
2853-3	6M-2853-H-21	A	2808		R
2853-3	6M-2854-H- 1	A	2808		R
2854-1	6M-2854-H- 1	A	2809		R
2854-1	6M-2854-H- 2	A	2809		R
2854-1	6M-2854-H- 3	B	2809		R
2854-1	6M-2854-H- 4	0	2809		R
2854-1	6M-2854-H-17	0	2809		R
2854-1	6M-2854-H-18	0	2809		R
2854-1	6M-2854-H-19	A	2809		R
2854-1	6M-2854-H-20	A	2809		R
2854-1	6M-2854-H-21	0	2809		R
2854-1	6M-2854-H-22	0	2809		R
2854-1	6M-2854-H-23	A	2809		R
2854-1	6M-2854-H-24	A	2809		R
2854-1	6M-2854-H-25	A	2809		R
2854-1	6M-2854-H-26	A	2809		R
2854-1	6M-2854-H-27	A	2809		R
2854-1	6M-2854-H-28	A	2809		R
2854-1	6M-2854-H-57	A	2809		R
2854-1	6M-2854-H-58	0	2809		R
2854-2	6M-2854-H- 4	0	2810		R
2854-2	6M-2854-H- 5	A	2810		R
2854-2	6M-2854-H- 6	A	2810		R

REV. A

CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
2854-2	6M-2854-H- 7	0	2810		R
2854-2	6M-2854-H- 8	0	2810		R
2854-2	6M-2854-H- 9	0	2810		R
2854-2	6M-2854-H-10	0	2810		R
2854-2	6M-2854-H-11	A	2810		R
2854-2	6M-2854-H-12	A	2810		R
2854-2	6M-2854-H-13	0	2810		R
2854-2	6M-2854-H-14	0	2810		R
2854-2	6M-2854-H-15	0	2810		R
2854-2	6M-2854-H-16	0	2810		R
2854-2	6M-2854-H-51	0	2810		R
2854-2	6M-2854-H-52	0	2810		R
2854-2	6M-2854-H-53	0	2810		R
2854-2	6M-2854-H-54	0	2810		R
2854-2	6M-2854-H-55	0	2810		R
2854-2	6M-2854-H-56	0	2810		R
2854-3	6M-2854-H- 1	A	2811	DCN10932	R
2854-3	6M-2854-H-29	A	2811		R
2854-3	6M-2854-H-30	A	2811		R
2854-3	6M-2854-H-31	A	2811		R
2854-3	6M-2854-H-32	A	2811		R
2854-3	6M-2854-H-33	A	2811		R
2854-3	6M-2854-H-34	A	2811		R
2854-3	6M-2854-H-35	A	2811	DCN10965	R
2854-3	6M-2854-H-36	0	2811		R
2854-3	6M-2854-H-37	0	2811		R
2854-3	6M-2854-H-38	A	2811		R
2854-3	6M-2854-H-39	A	2811	DCN10964	R
2854-4	6M-2854-H-40	0	2812		R
2854-4	6M-2854-H-40	0	2812		R
2854-4	6M-2854-H-41	0	2812		R
2854-4	6M-2854-H-42	0	2812		R
2854-4	6M-2854-H-43	0	2812		R
2854-4	6M-2854-H-44	0	2812		R
2854-4	6M-2854-H-46	0	2812		R
2854-4	6M-2854-H-47	0	2812		R
2854-4	6M-2854-H-48	0	2812		R
2854-4	6M-2854-H-49	0	2812		R
2854-4	6M-2854-H-50	0	2812		R
4126-1	6M-2849-H-40	A	2813		F
4126-1	6M-2849-H-41	A	2813		F
4126-1	6M-4126-H- 1	A	2813		F
4126-1	6M-4126-H- 2	A	2813		F
4126-1	6M-4126-H-18	A	2813		F
4126-1	6M-4126-H-19	A	2813		F
4316-1	6M-4316-H-16	A	2816		F
4316-1	6M-4316-H-17	A	2816	TSR28204	F
4316-1	6M-4316-H-18	A	2816	TSR28204	F
4316-1	6M-4316-H-19	A	2816	TSR28204	F
4316-1	6M-4316-H-20	A	2816	TSR28204	F
4316-1	6M-4316-H-21	A	2816	TSR28204	F
4316-1	6M-4316-H-22	B	2816		F
4316-1	6M-4316-H-23	A	2816		F
4316-1	6M-4316-H-24	B	2816		F
4316-1	6M-4316-H-25	A	2816		F
4316-1	6M-4316-H-26	C	2816		F
4316-2	6M-2848-H-37	A	2817		F

REV. A

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REV. A

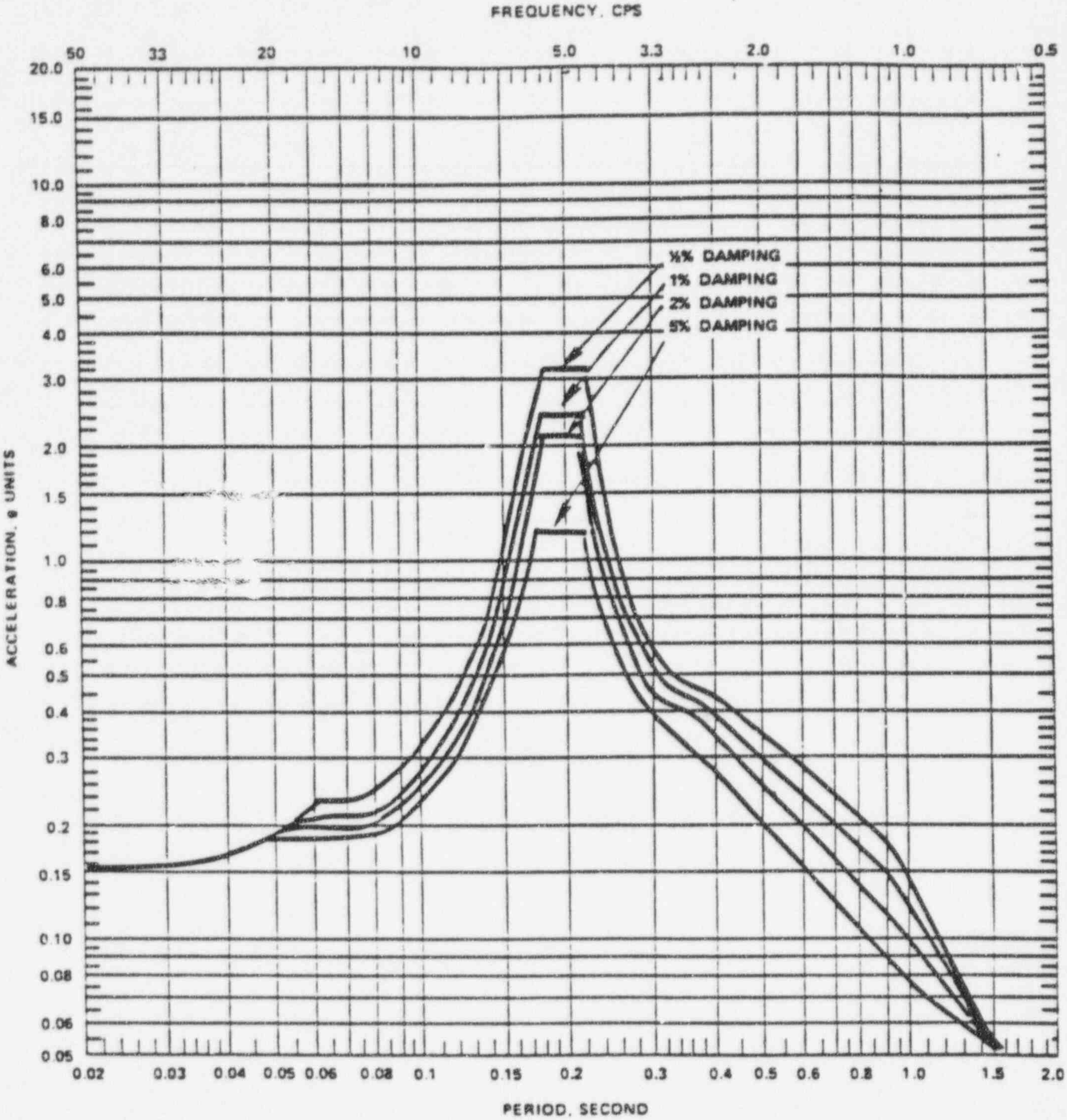
CCHVAC DUCT AND DUCT SUPPORT DATABASE

SYSTEM NO.	SUPPORT NO.	SUPP REV.	DC NO.	OTHER DOCUMENTS	RIGID/ FLEX.
4316-2	6M-4316-H-18	A	2817		F
4316-2	6M-4316-H-19	A	2817		F
4316-2	6M-4316-H-20	A	2817		F
4316-2	6M-4316-H-21	A	2817		F
4316-2	6M-4316-H-22	B	2817		F
4316-2	6M-4316-H-23	A	2817		F
4316-2	6M-4316-H-24	B	2817		F
4316-2	6M-4316-H-25	A	2817		F
4316-2	6M-4316-H-26	C	2817		F
4316-3	6M-4316-H-23	A	2818		F
4316-3	6M-4316-H-24	B	2818		F
4316-3	6M-4316-H-31	B	2818		F
4316-3	6M-4316-H-32	0	2818		F
4316-3	6M-4316-H-36	0	2818		F
4316-6	6M-4316-H-11	0	2821		F
4316-6	6M-4316-H-12	0	2821		F
4316-6	6M-4316-H-13	0	2821		F
4316-6	6M-4316-H-14	0	2821		F
4316-6	6M-4316-H-33	A	2821		F
4316-6	6M-4316-H-35	A	2821		F
4316-7	6M-4316-H-37	A	2822		F
4316-7	6M-4316-H-38	A	2822	TSR28204	F
4316-7	6M-4316-H-39	A	2822	TSR28204	F
4316-7	6M-4316-H-40	A	2822	TSR28204	F
4316-7	6M-4316-H-41	A	2822	TSR28204	F
4316-7	6M-4316-H-42	A	2822	TSR28204	F
4316-7	6M-4316-H-43	A	2822	TSR28204	F
4316-7	6M-4316-H-44	A	2822	ABN4296-1	F
4316-7	6M-4316-H-45	A	2822	TSR28204	F
4316-7	6M-4316-H-46	A	2822	TSR28204	F
4316-7	6M-4316-H-47	A	2822	DCN10898C,TSR28204	F
4316-7	6M-4316-H-47	A	2822	ABN4296-1	F
4316-7	6M-4316-H-48	A	2822	DCN10898C	F
4316-7	6M-4316-H-49	A	2822	DCN10898C	F
4316-7	6M-4316-H-50	A	2822	DCN10898C	F
4316-7	6M-4316-H-51	A	2822		F
4316-7	6M-4316-H-52	A	2822		F

REV. A

APPENDIX B - OBE & SSE DESIGN RESPONSE SPECTRA

(Figures B-1 through B-20)



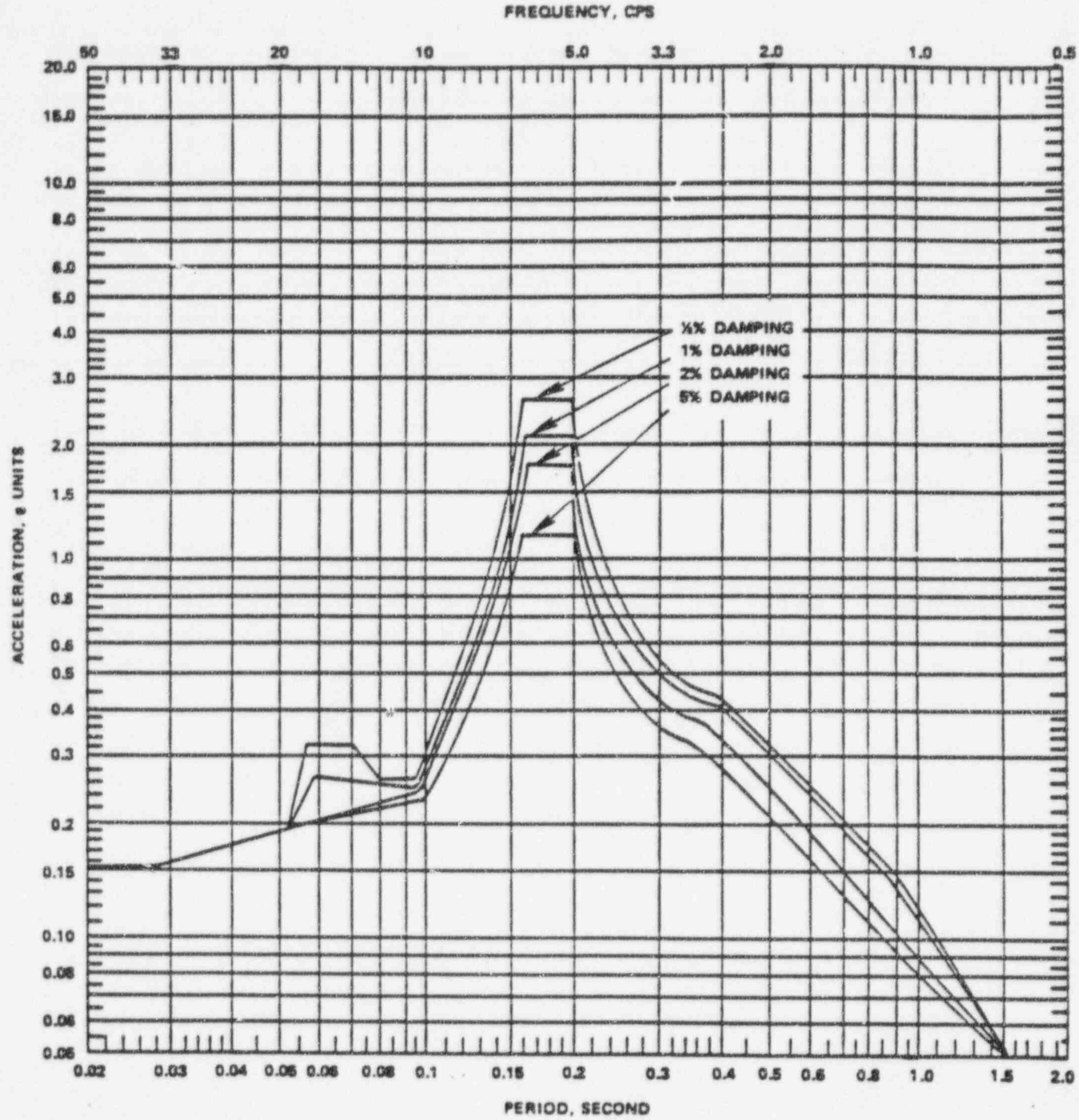
Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 3.7-36

HORIZONTAL FLOOR RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
ELEVATION 641.5 FT – SLAB 3
REACTOR/AUXILIARY BUILDING NORTH-SOUTH COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682



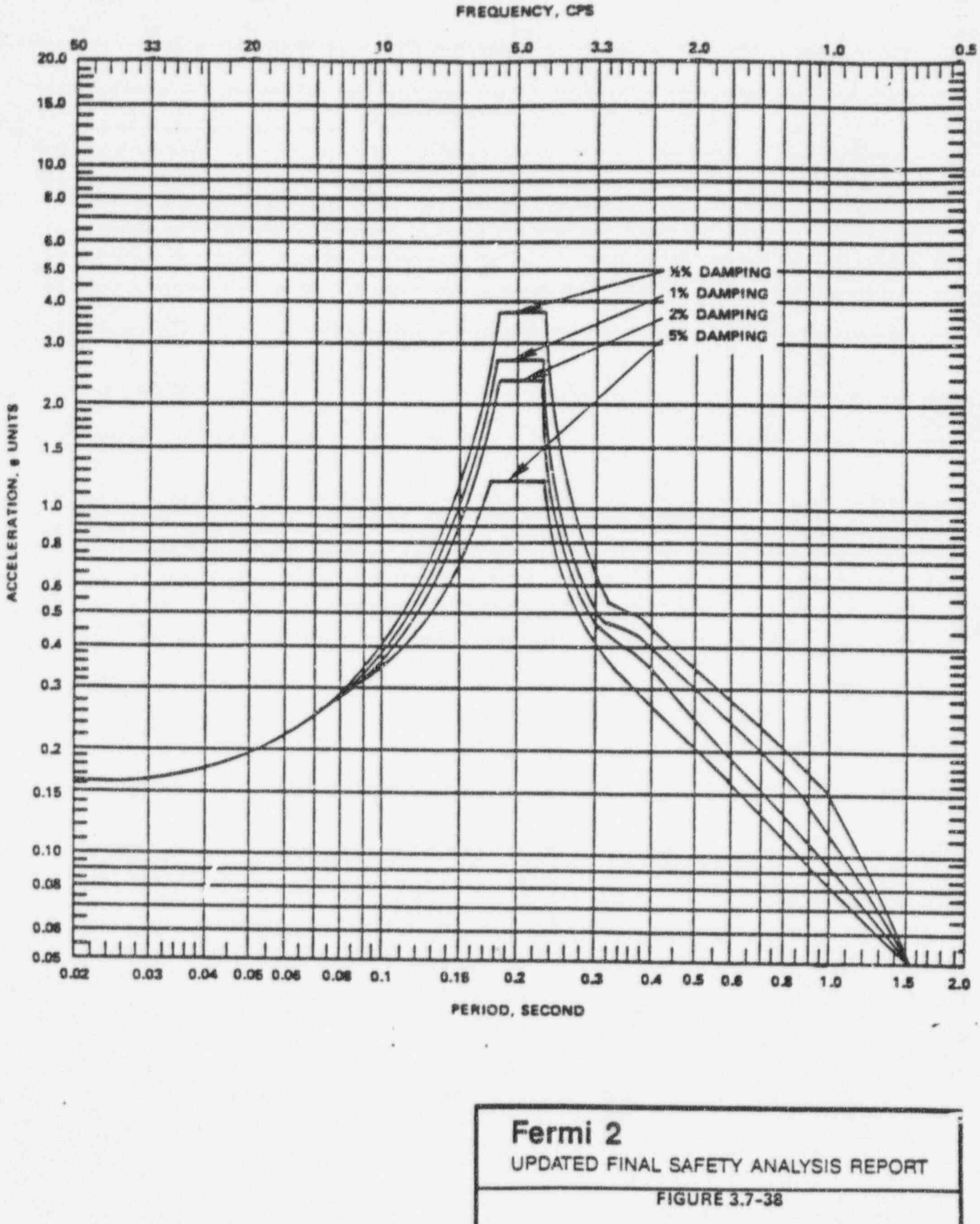
Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 3.7-37

HORIZONTAL FLOOR RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
ELEVATION 641.5 FT – SLAB 3
REACTOR/AUXILIARY BUILDING EAST-WEST
COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682



Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 3.7-38

HORIZONTAL FLOOR RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
ELEVATION 659.0 FT – SLAB 4
REACTOR/AUXILIARY BUILDING NORTH-SOUTH COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

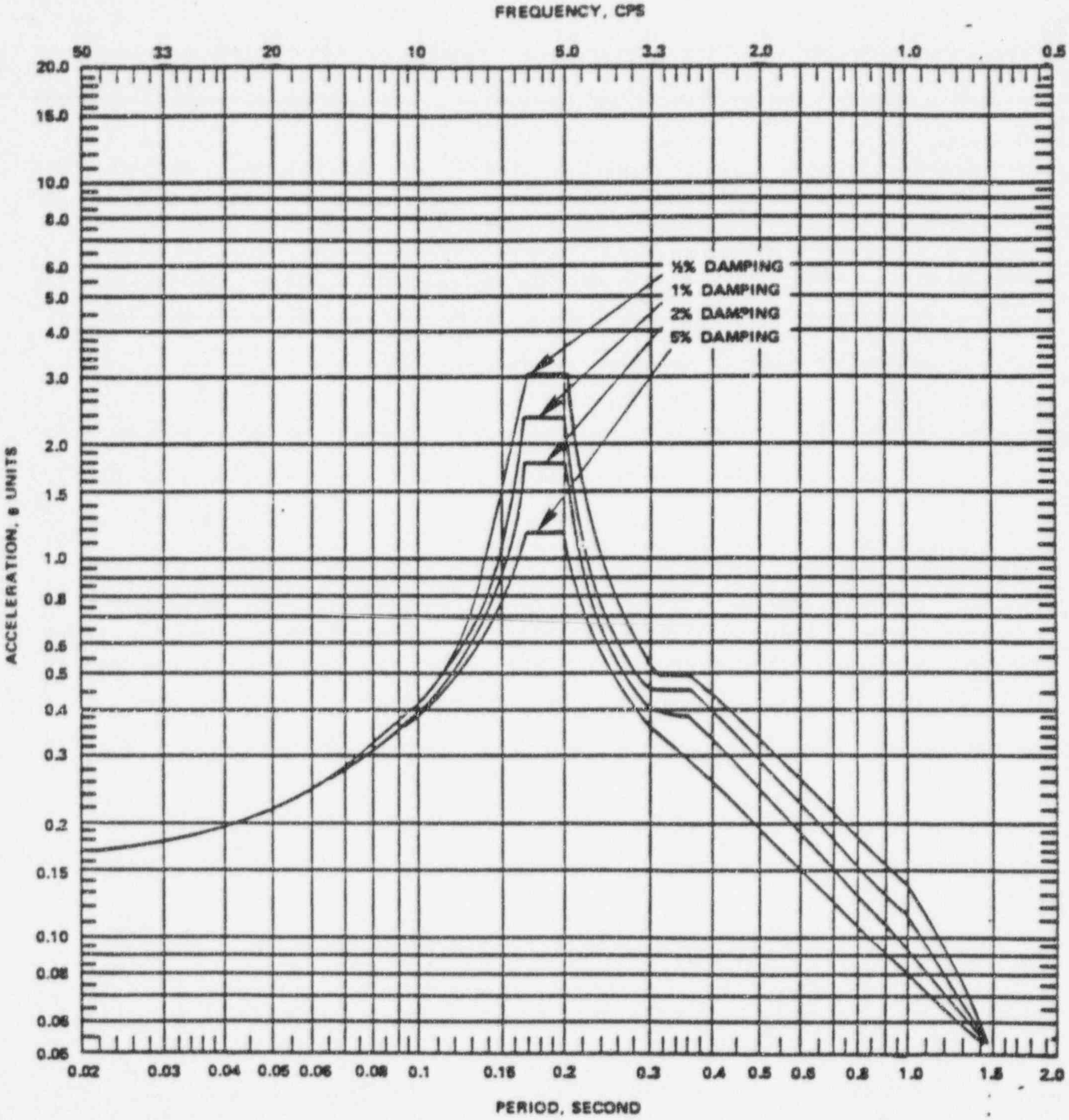


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FIGURE 3.7-39

HORIZONTAL FLOOR RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
ELEVATION 659.0 FT – SLAB 4
REACTOR/AUXILIARY BUILDING EAST-WEST COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

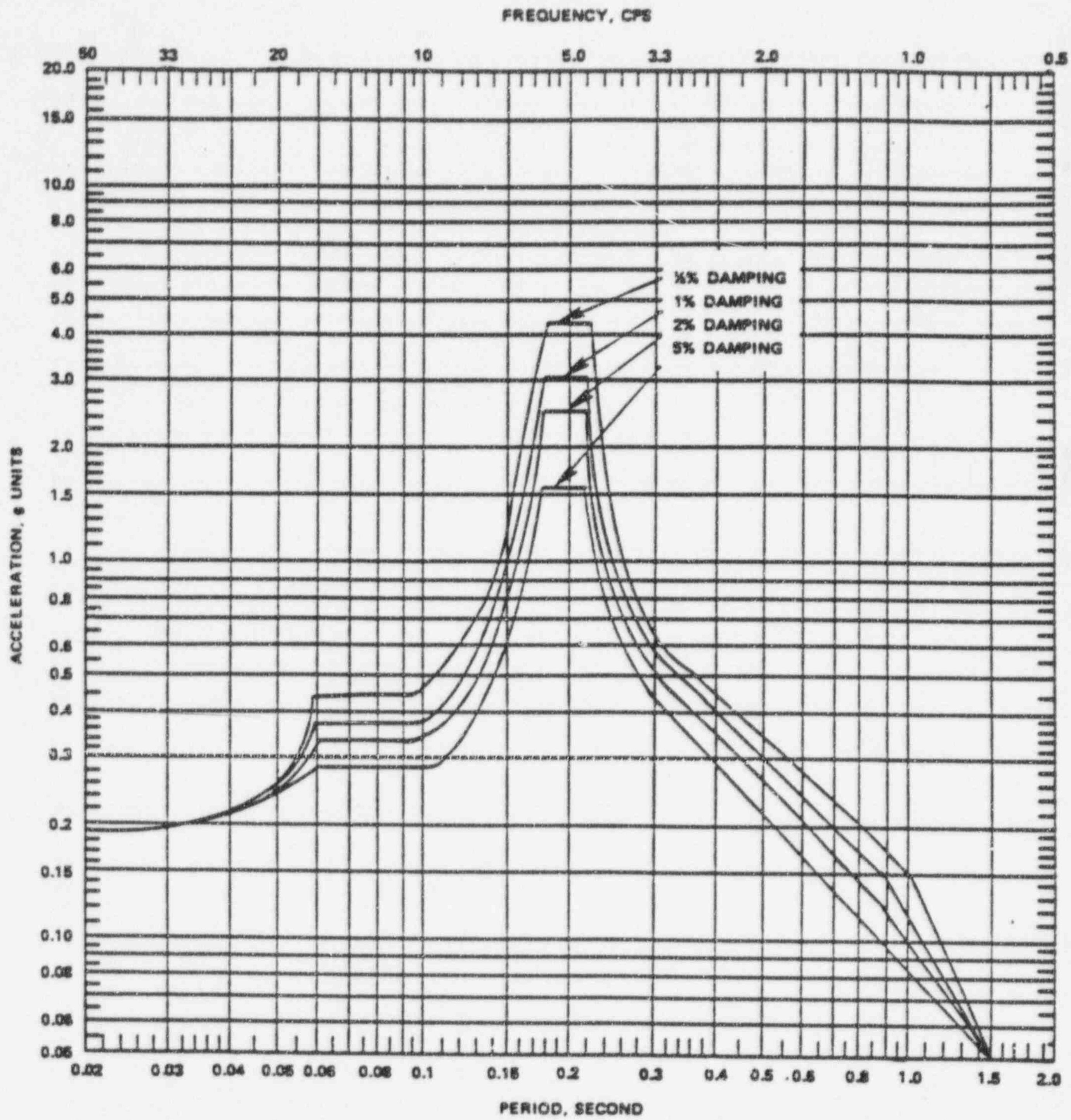

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FIGURE 3.7-40

HORIZONTAL FLOOR RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
ELEVATION 684.5 FT – SLAB 5
REACTOR/AUXILIARY BUILDING NORTH-SOUTH
COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

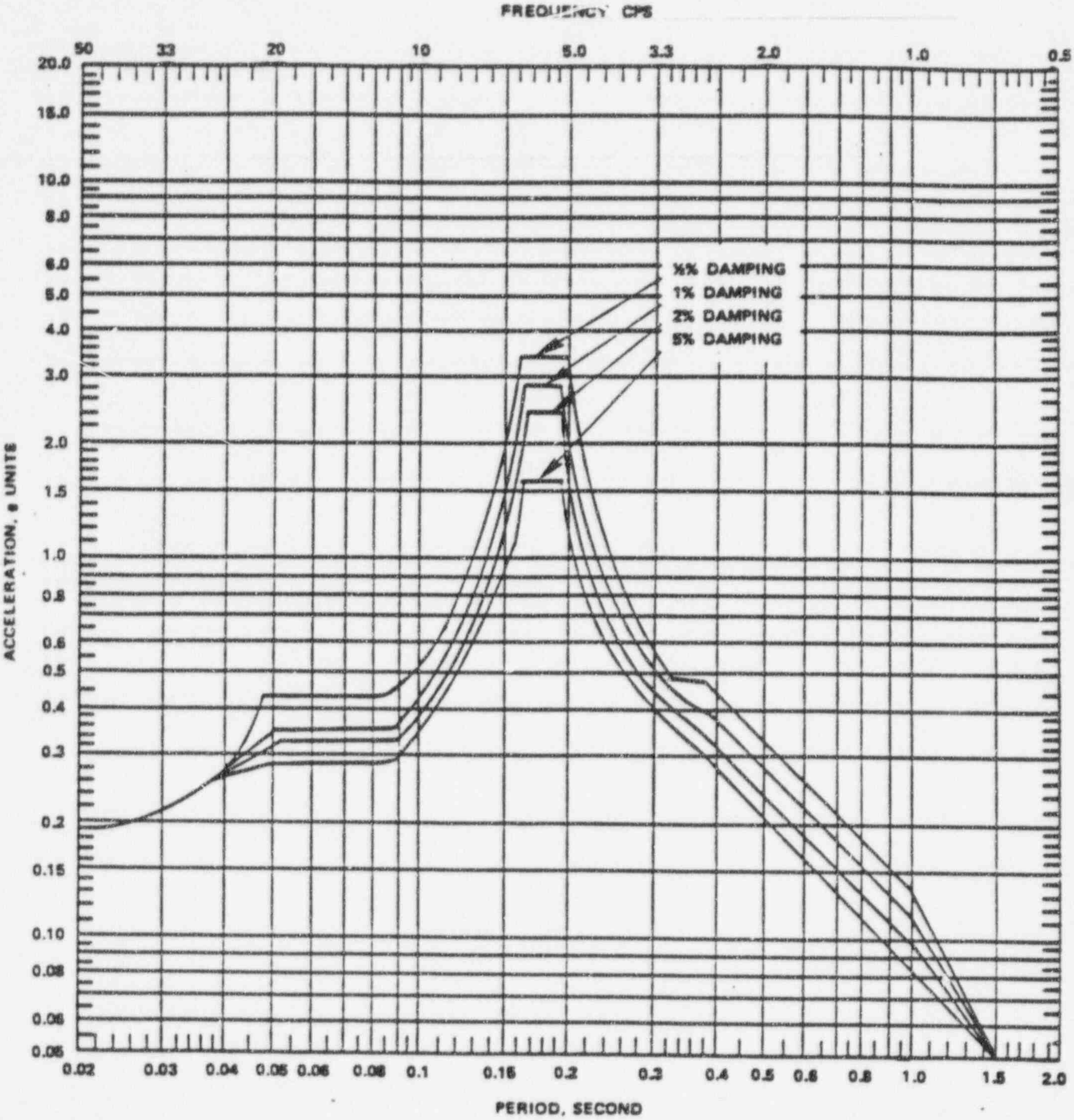

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FIGURE 3.7-41

HORIZONTAL FLOOR RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
ELEVATION 684.5 FT – SLAB 5
REACTOR/AUXILIARY BUILDING EAST-WEST COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

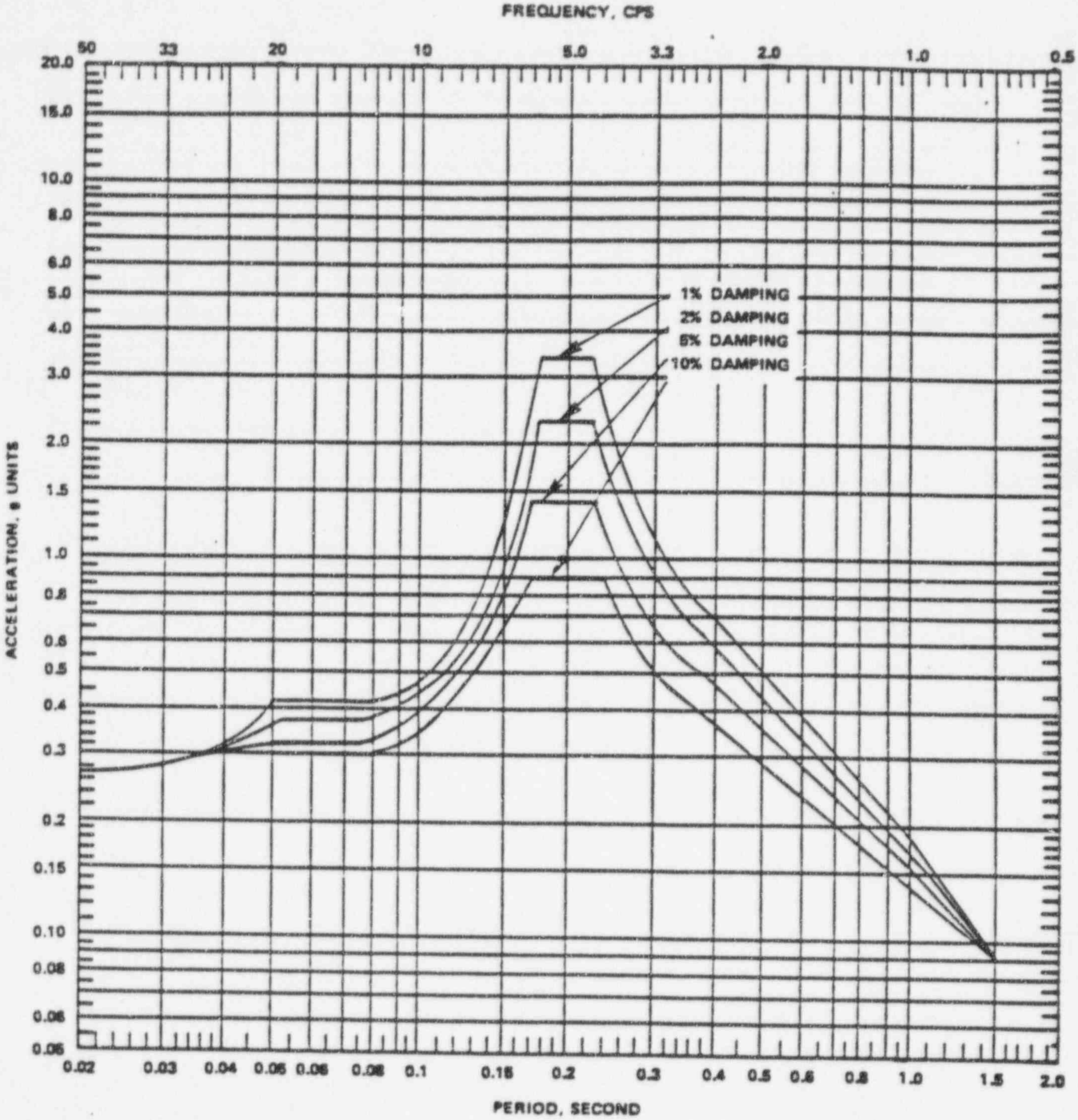

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FIGURE 3.7-60

HORIZONTAL FLOOR RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
ELEVATION 641.5 FT -- SLAB 3
REACTOR/AUXILIARY BUILDING NORTH-SOUTH COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

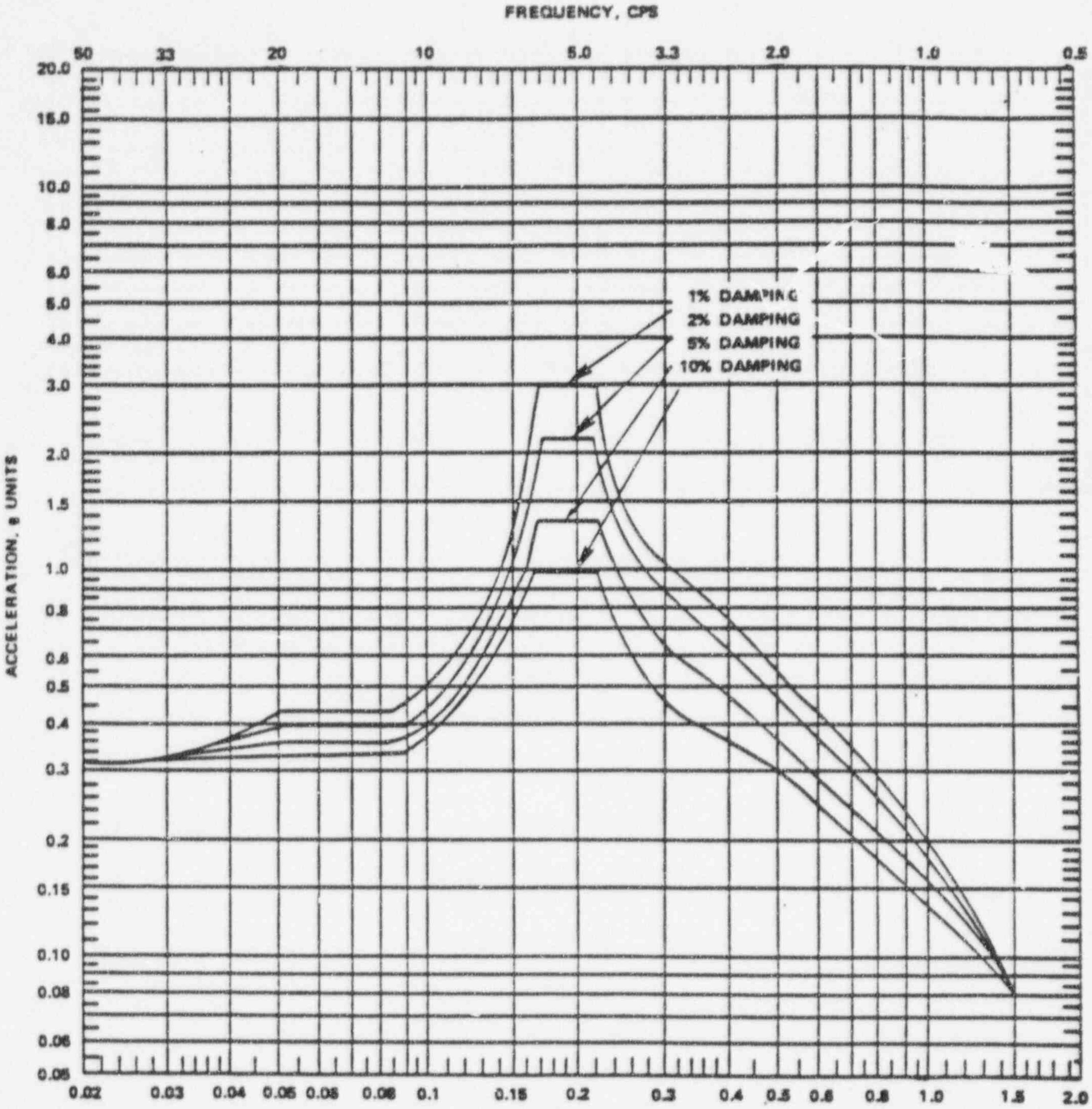

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FIGURE 3.7-61

HORIZONTAL FLOOR RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
ELEVATION 641.5 FT – SLAB 3
REACTOR/AUXILIARY BUILDING EAST-WEST
COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

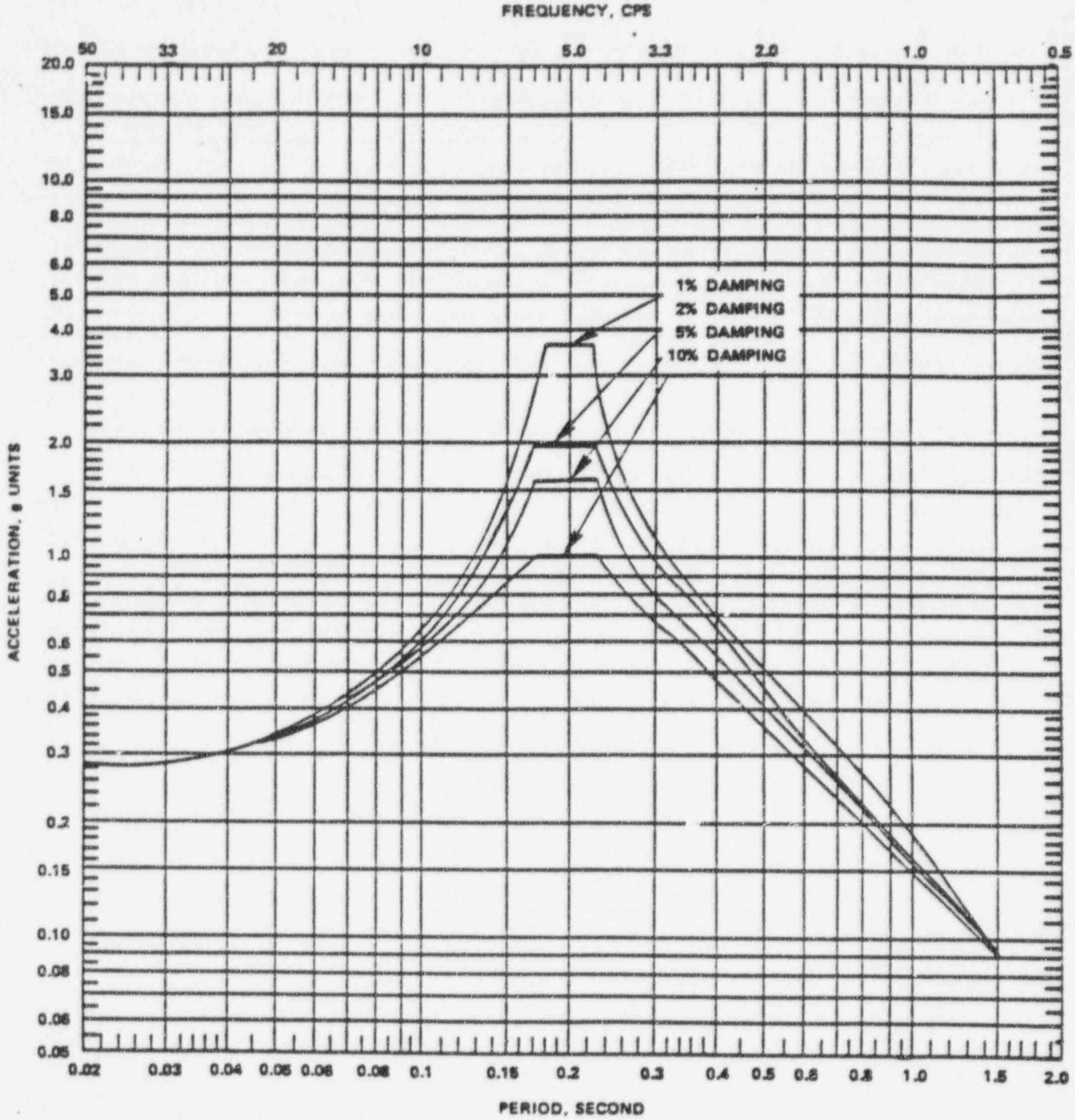

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FIGURE 3.7-62

HORIZONTAL FLOOR RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
ELEVATION 659.0 FT – SLAB 4
REACTOR/AUXILIARY BUILDING NORTH-SOUTH COMPONENT

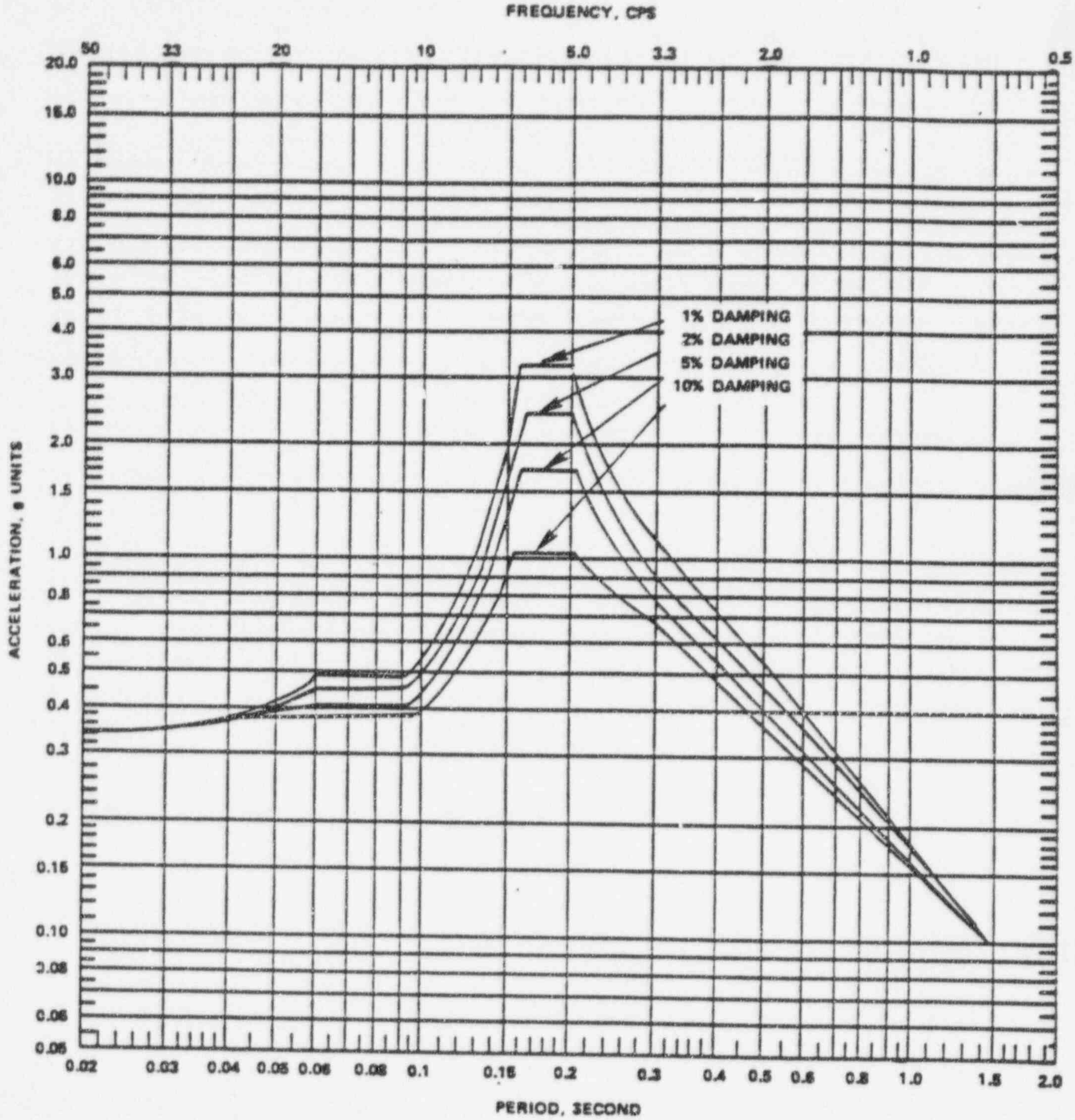

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FIGURE 3.7-63

HORIZONTAL FLOOR RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
ELEVATION 659.0 FT – SLAB 4
REACTOR/AUXILIARY BUILDING EAST-WEST
COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

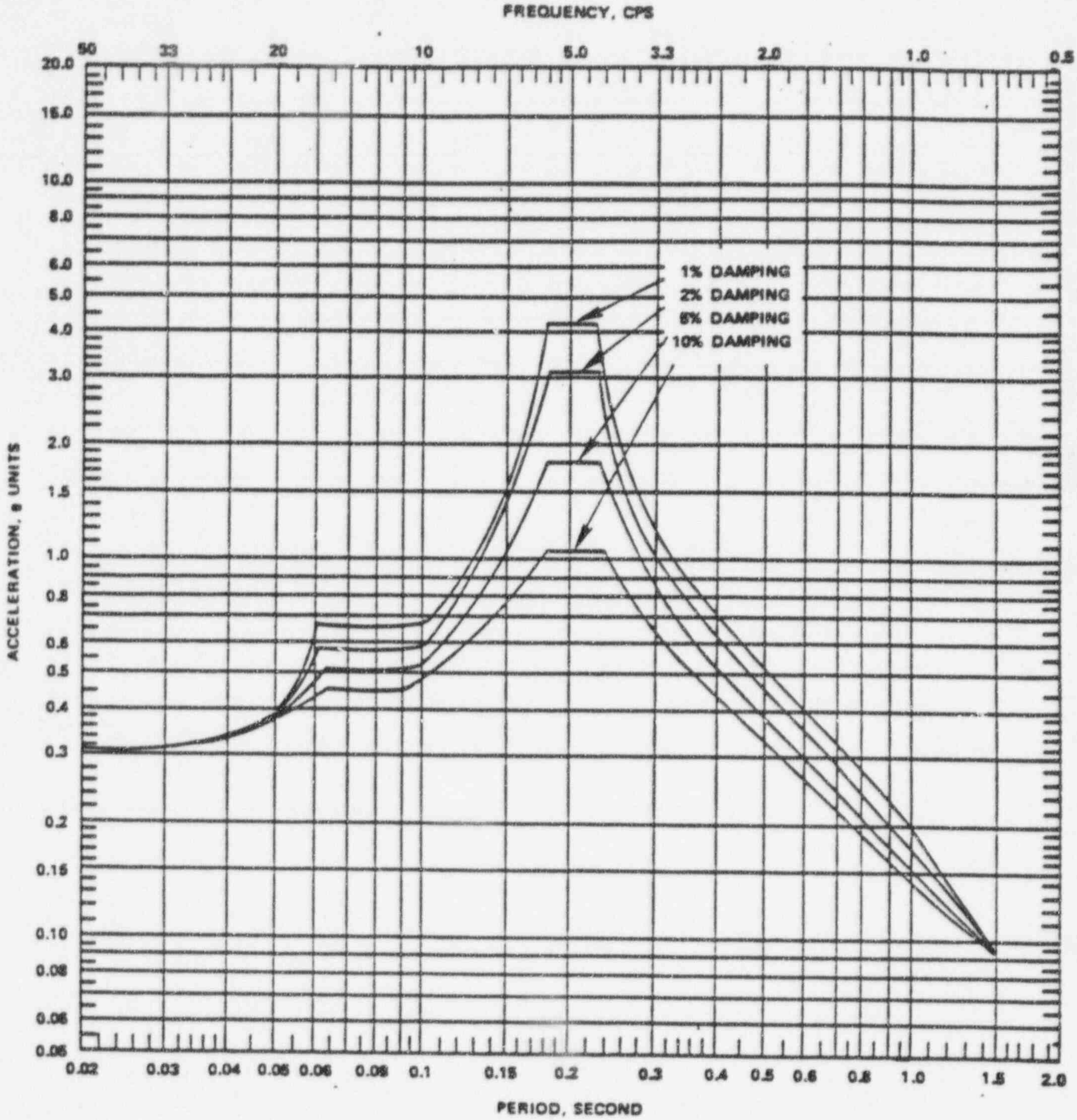

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FIGURE 3.7-64

HORIZONTAL FLOOR RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
ELEVATION 684.5 FT – SLAB 5
REACTOR/AUXILIARY BUILDING NORTH-SOUTH COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

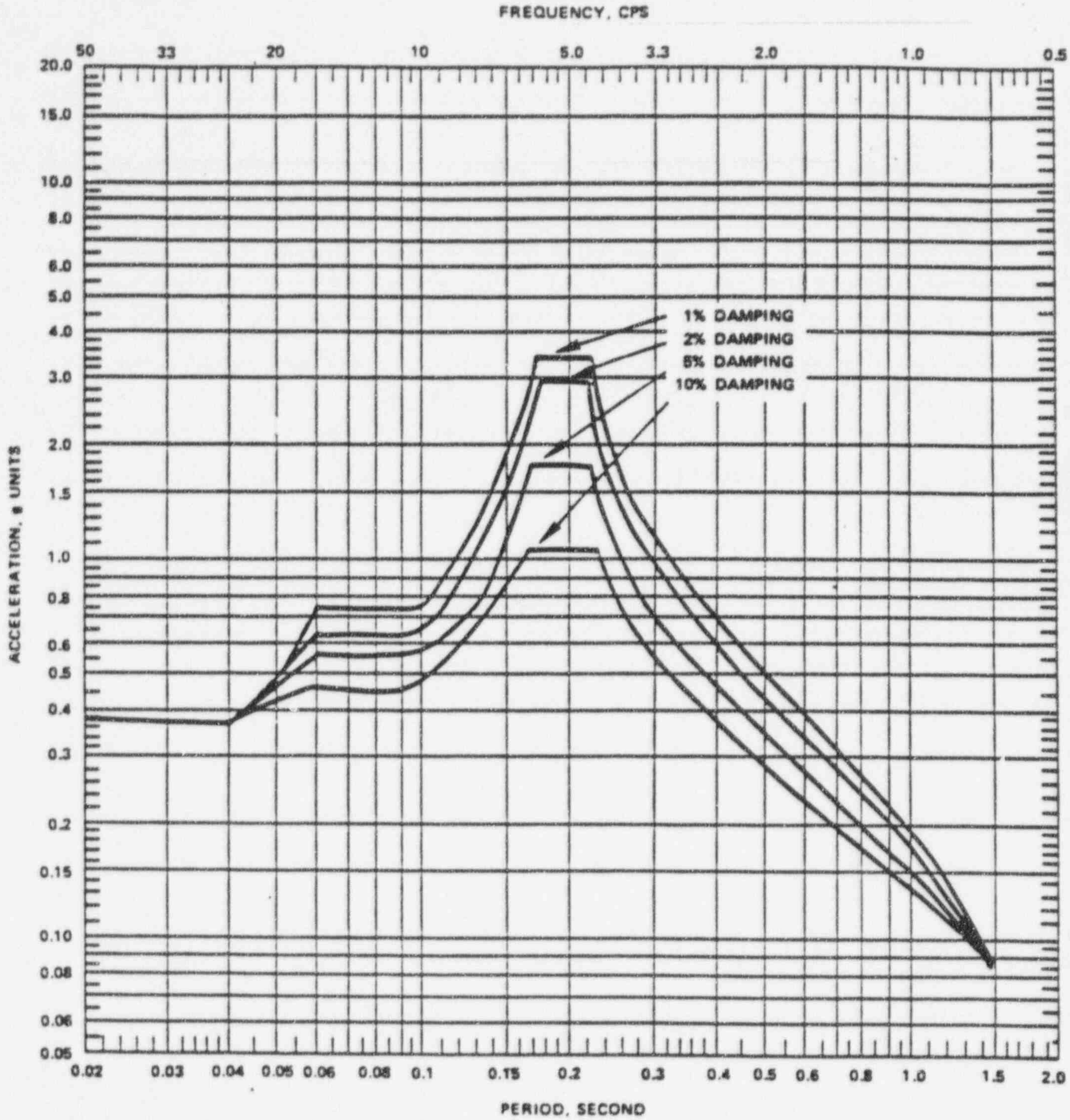

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FIGURE 3.7-65

HORIZONTAL FLOOR RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
ELEVATION 684.5 FT – SLAB 5
REACTOR/AUXILIARY BUILDING EAST-WEST COMPONENT

SARGENT & LUNDY REPORT NO. SL-2682

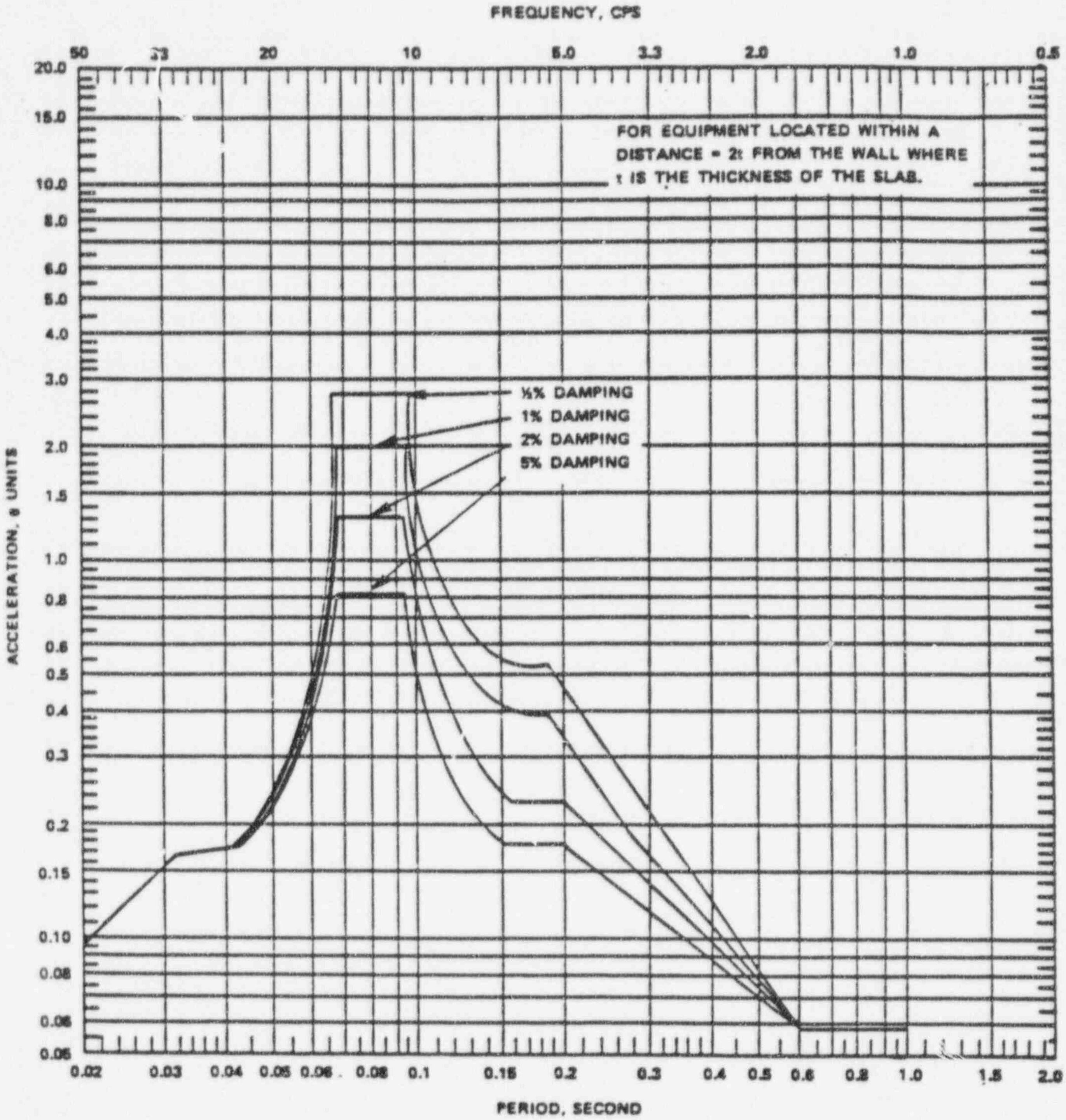

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FIGURE 3.7-83

VERTICAL RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
REACTOR/AUXILIARY BUILDING WALL
ELEVATIONS 641.5 FT, 659.5 FT, AND 684.5 FT

SARGENT & LUNDY REPORT NO. SL-2682

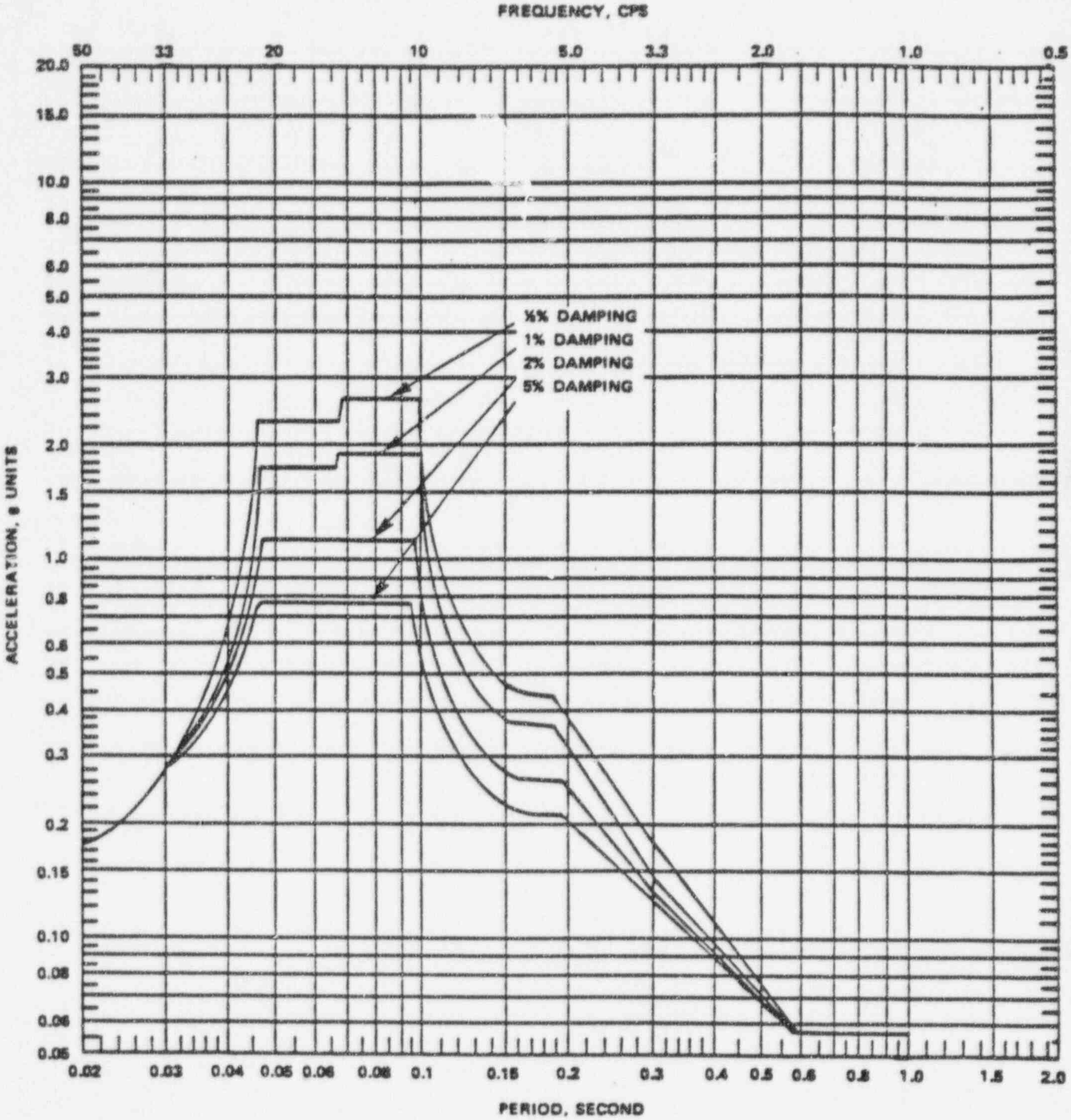

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FIGURE 3.7-65

VERTICAL RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
REACTOR BUILDING SLAB
ELEVATIONS 641.5 FT, 659.5 FT, AND 684.5 FT

SARGENT & LUNDY REPORT NO. SL-2682

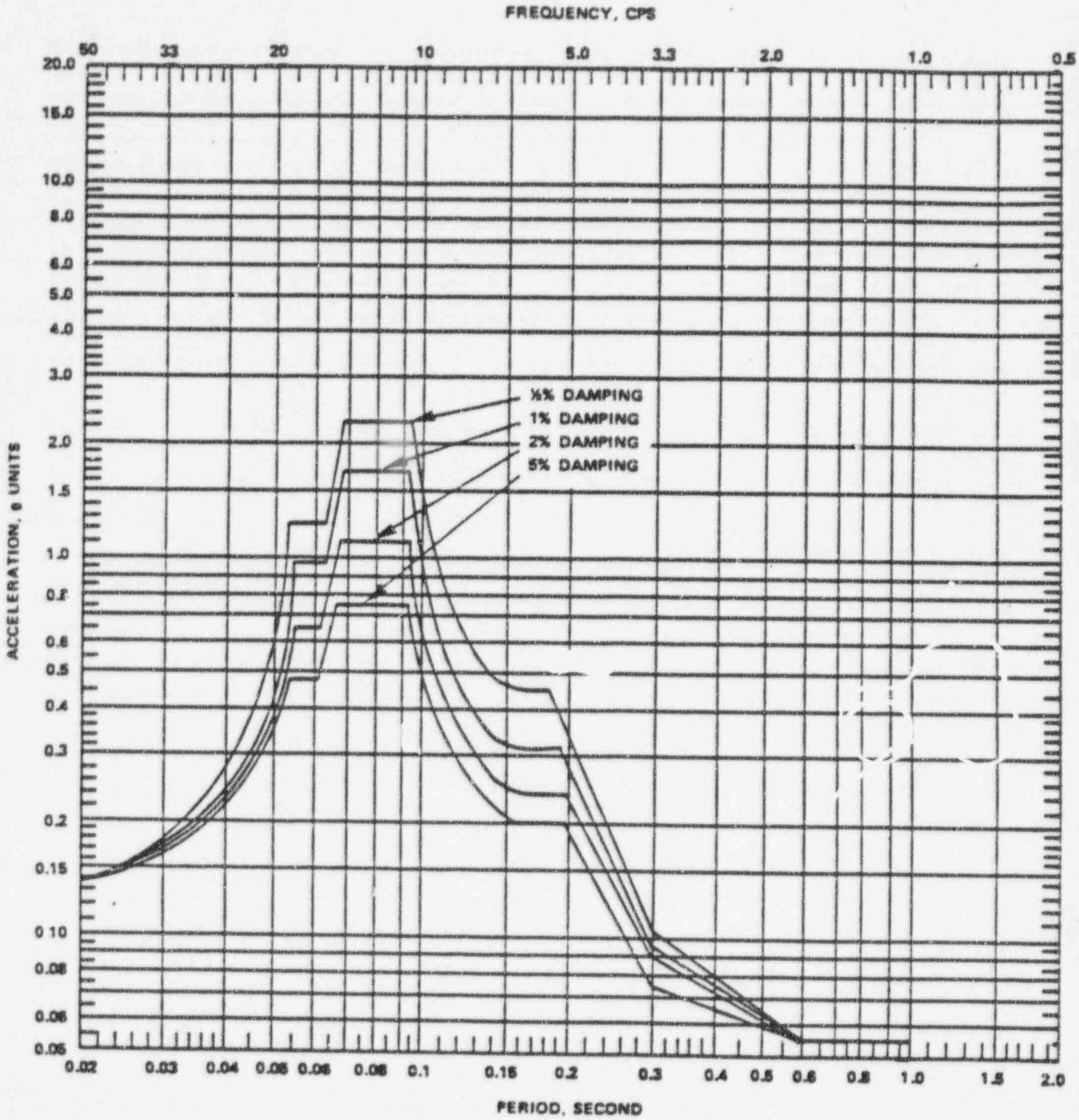

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FIGURE 3.7-86

VERTICAL RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
AUXILIARY BUILDING SLAB
ELEVATIONS 583.5 FT, 613.5 FT, AND 659.5 FT

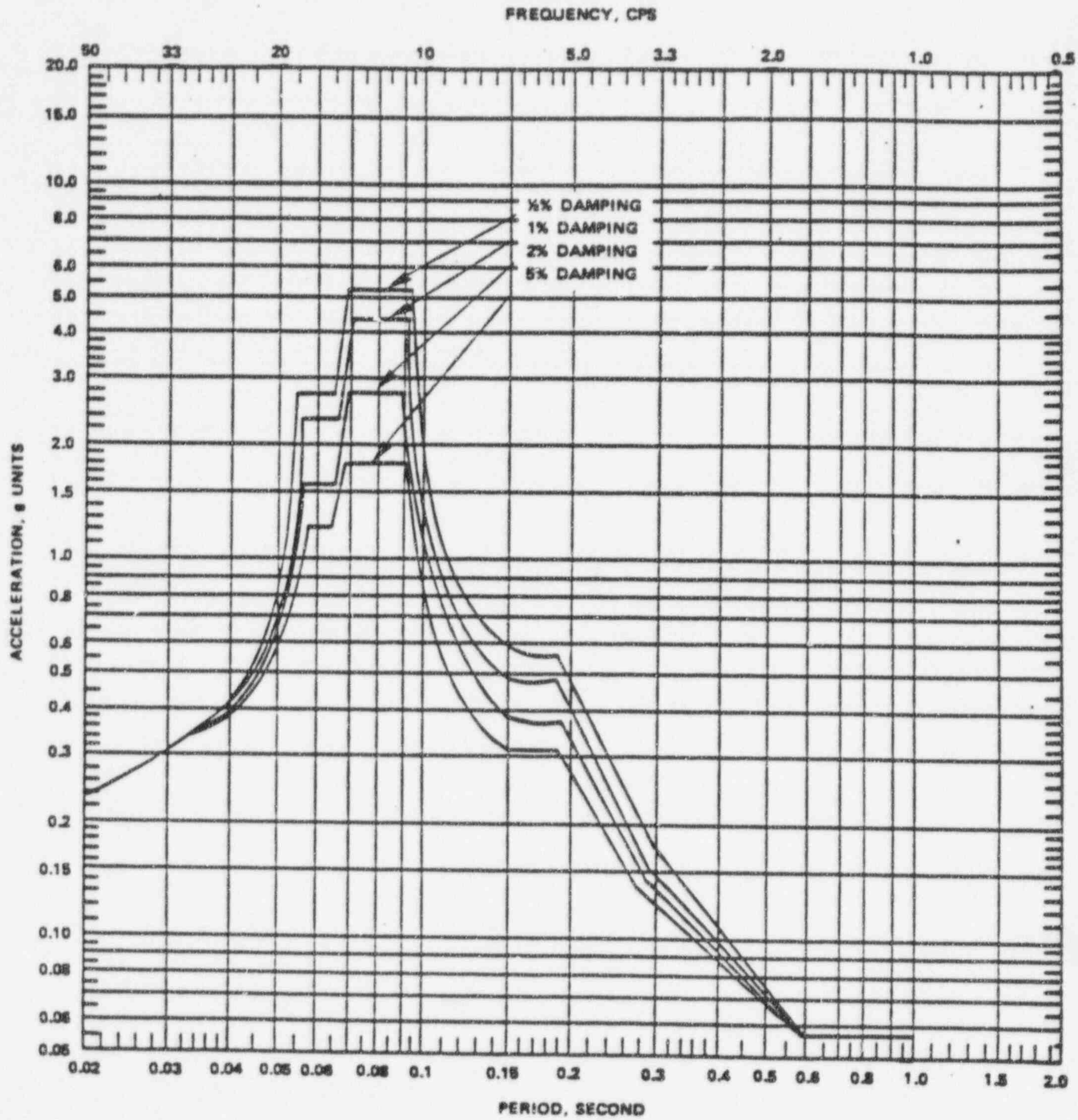

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FIGURE 3.7-87

VERTICAL RESPONSE SPECTRA
OPERATING-BASIS EARTHQUAKE
AUXILIARY BUILDING SLAB
ELEVATIONS 643.5 FT AND 677.5 FT

SARGENT & LUNDY REPORT NO. SL-2682

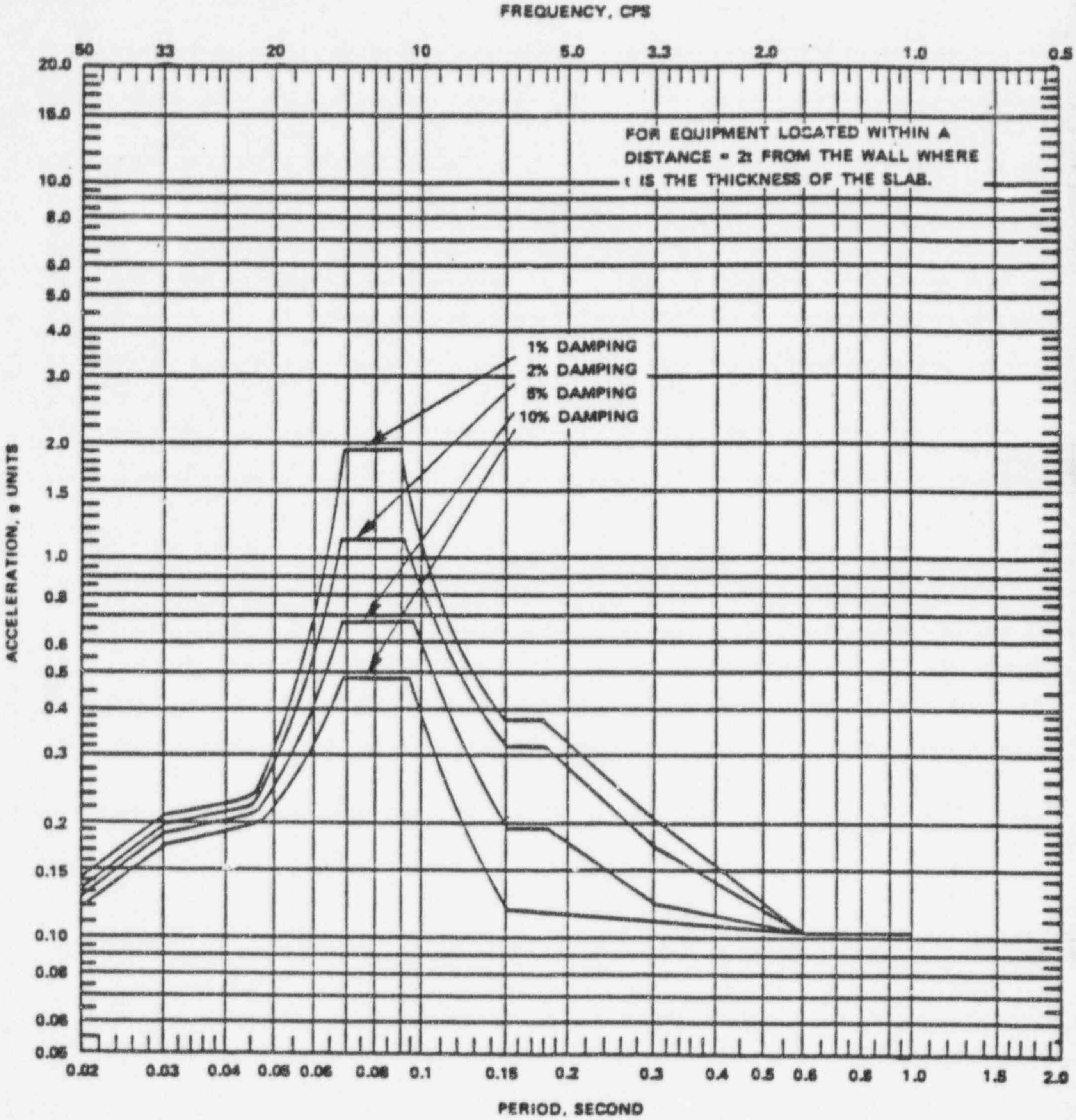

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FIGURE 3.7-92

VERTICAL RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
REACTOR/AUXILIARY BUILDING WALL
ELEVATIONS 641.5 FT, 659.5 FT, AND 684.5 FT

SARGENT & LUNDY REPORT NO. SL-2682

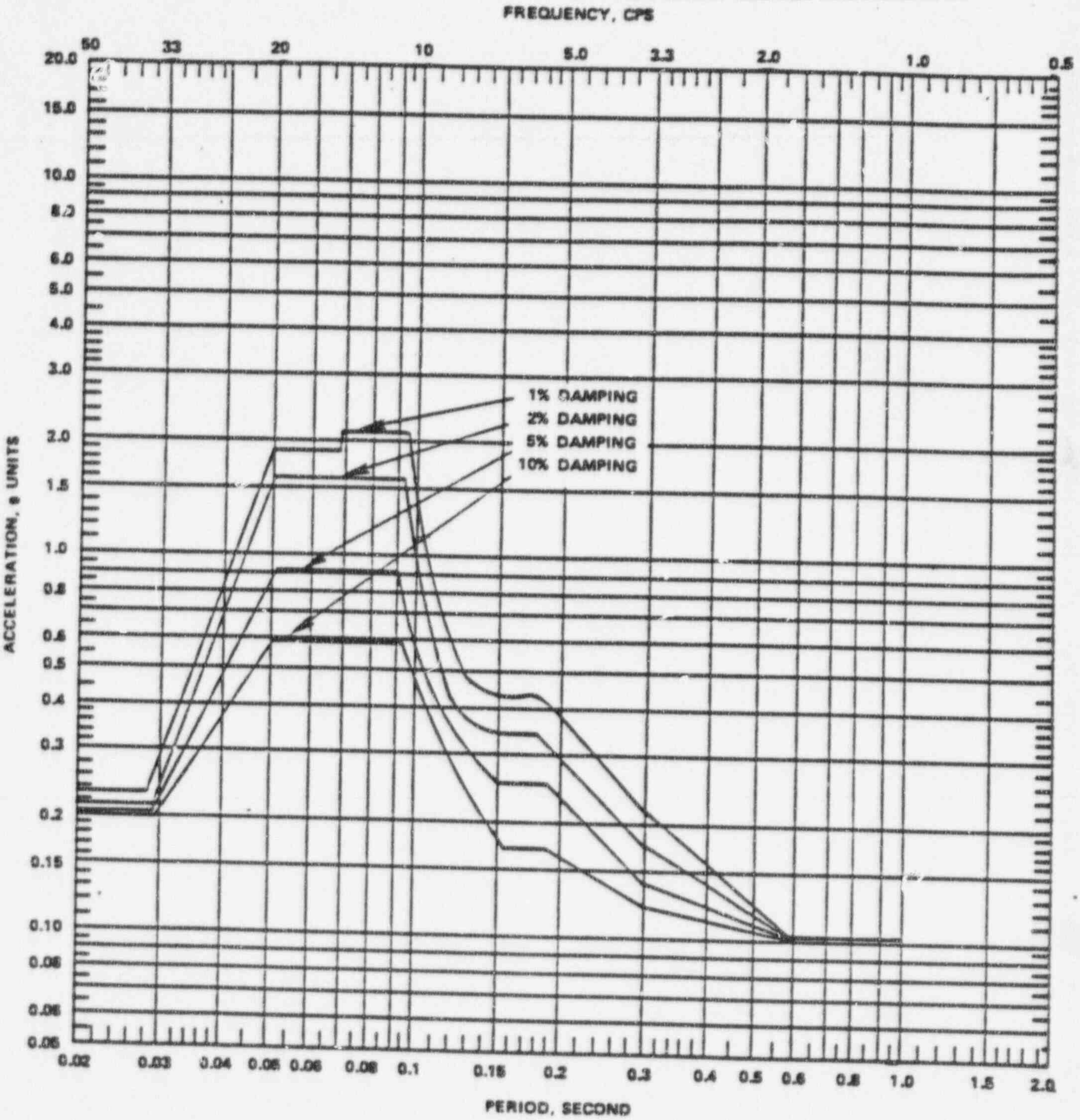

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FIGURE 3.7-94

VERTICAL RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
REACTOR BUILDING SLAB
ELEVATIONS 641.5 FT, 659.5 FT, AND 684.5 FT

SARGENT & LUNDY REPORT NO. SL-2682

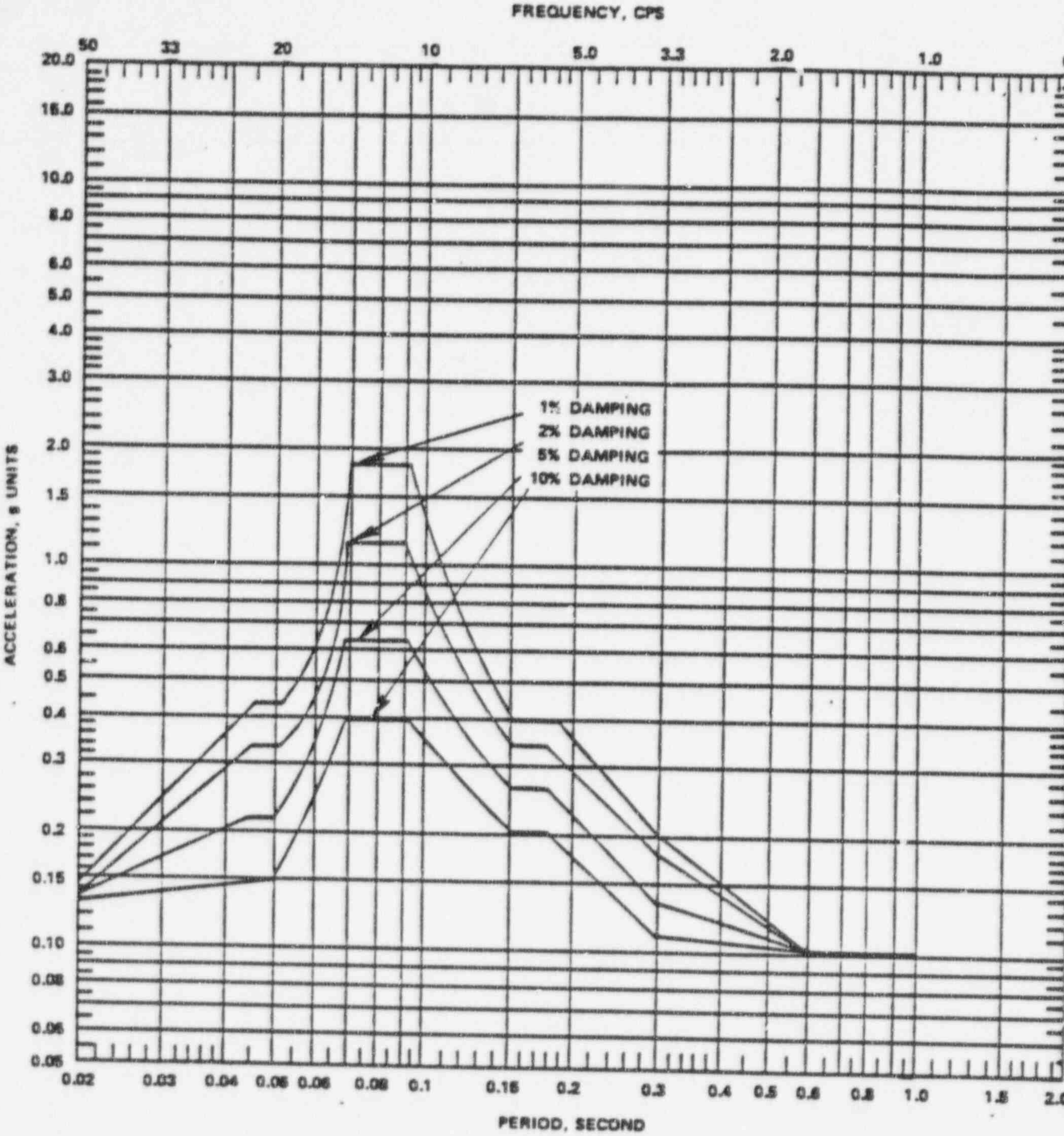

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FIGURE 3.7-95

VERTICAL RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
AUXILIARY BUILDING SLAB
ELEVATIONS 583.5 FT, 613.5 FT, AND 659.5 FT

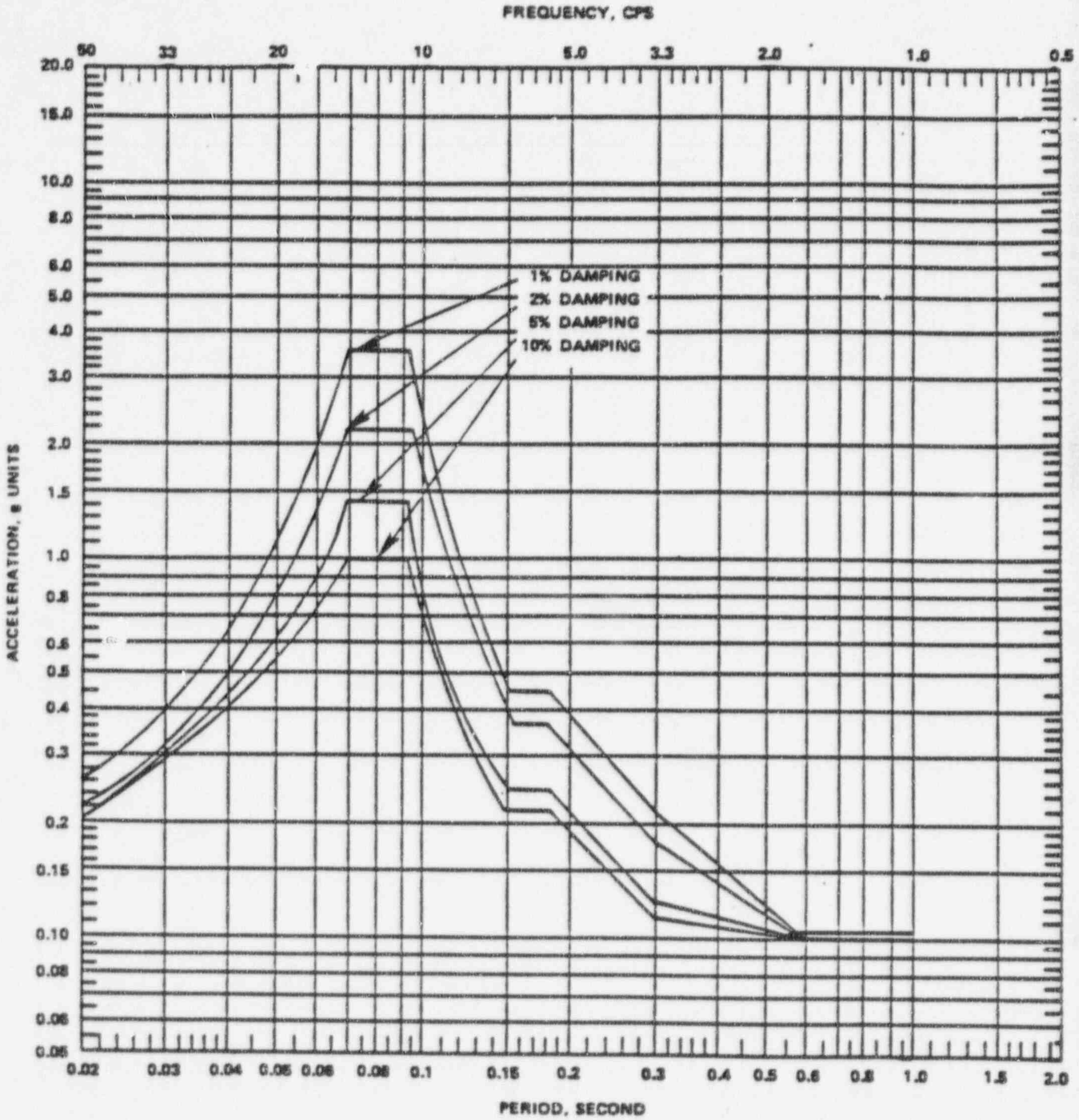

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FIGURE 3.7-96

VERTICAL RESPONSE SPECTRA
SAFE-SHUTDOWN EARTHQUAKE
AUXILIARY BUILDING SLAB
ELEVATIONS 643.5 FT AND 677.5 FT

SARGENT & LUNDY REPORT NO. SL-2682