SDC-4.1

STANDARD ARCH-CIVIL DESIGN CRITERIA

DESIGN LOADS FOR FACILITIES

This section consists
of 26 pages.

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REVISION 11
COMMENTARY

Revision 11 incorporates the guidance stipulated in DOE Order 6430.1A and its primary reference UCRL-15910 in order to upgrade the natural phenomena loading requirements for non-reactor structures. The previous requirements for the design and evaluation of reactor structures have been maintained.

The probabilistic hazards exposure identified in UCRL-15910 for the Hanford Site from both seismic and wind phenomena have been verified by independent study. This effort is documented in WHC-SD-MP-DP-001. Structure categories have been revised to reflect the Facility Use Category in UCRL-15910. Structures, systems, and components will be classified according to Safety Class as given in DOE-RL 4700.1.

The design basis wind velocity is a function of the Safety Class of the structures. The tornado criteria has been corrected to the criteria defined in the Final Safety Analysis Report (FSAR) and N-Reactor Updated Safety Analysis Report (NUSAR) for the onsite reactor facilities. The controlling wind velocities for non-reactor structures at the Hanford site is now based on the probabilistic extreme wind values identified in UCRL-15910.

The 0.25"g" site specific safe shutdown earthquake (SSE) has been maintained for the reactor structures. The seismic exposure for the non-reactor facilities is dependent on the safety classification of the structure. An additional small magnitude, high frequency, low energy earthquake has been imposed on Safety Class 1 equipment qualification to address this most probable seismic event at the Hanford Site. Studies have determined that this type of event does not result in significant ground motion that would affect buildings, but the influence on equipment, especially that mounted on ground elevation base slabs, needs to be addressed.

Revision 11 also modifies the ashfall loading requirements for the design of Safety Class 1 structures to be consistent with the latest data generated by WPPSS. It includes figures of the new spectra for non-reactor facilities along with tabular data which can be used to construct spectra for the analytical evaluation of reactor and non-reactor facilities.

This standard is effective upon issue with the following exception: Projects which have started Title I or Title II Design prior to the issue date of this revision may continue to use design criteria in effect at the time Title I/II Design commenced. DOE organizations with first-line responsibilities may invoke Revision 11 criteria to projects already in Title I/II Design, but must determine to what extent these design criteria should be applied, based on safety, cost, and schedule effect.

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STANDARD DESIGN CRITERIA
DESIGN LOADS FOR FACILITIES

A. GENERAL DESIGN REQUIREMENTS

1. These criteria establish the design loads and acceptance criteria for all facilities and new additions or for modifications of existing facilities at Hanford. Deviations from the natural phenomena design loads shall be approved by DOE prior to implementation. All deviations shall be justified in the design report.

2. Except as modified or amended by these criteria, the following guidelines, codes and standards shall apply.

   a. General design criteria for facilities, exclusive of reactor facilities safety systems, shall conform to the "Department of Energy General Design Criteria Manual" (DOE Order 6430.1A), "Uniform Building Code" (UBC), and ANSI A58.1. American National Standards Institute (ANSI), "Minimum Design Loads for Buildings and Other Structures."

   b. General design criteria for reactor facilities and their safety systems shall conform to that specified in the appropriate SAR (PSAR, FSAR). New reactor facilities must be designed according to DOE Order 5480.6 and 10CFR100.

   c. Concrete members and assemblies shall be designed according to the American Concrete Institute (ACI), "Building Code Requirements for Reinforced Concrete" (ACI-318), "Code Requirements for Nuclear Safety Related Concrete Structures" (ACI-349), and UBC, Chapter 26.

   d. Structural steel members and connections shall be designed in accordance with the American Institute of Steel Construction (AISC), "Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings," the American Welding Society (AWS), Standard D1.1, "Structural Welding Code," ANSI N690 "Nuclear Facilities - Steel Safety-related Structures for Design Fabrication and Erection," and UBC, Chapter 27.

   e. Wood members shall be designed according to the National Forest Products Association, "National Design Specification for Stress-Grade Lumber and Its Fastenings," and UBC, Chapter 25.

f. Masonry design shall be in accordance with ACI-531, "Building Code Requirements for Concrete masonry Structures," and UBC, Chapter 24.

g. "Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards," UCRL-15910: As specified by DOE Order 6430.1A this document shall be used for natural phenomena hazards loadings for non-reactor facilities.

3. For design purposes and the application of these criteria, four safety classifications of structures, systems, and components are defined. The correlation between Safety Class designation in DOE-RL 4700.1 and the Facility Use Category designation in UCRL-15910 for non-reactor facilities is as follows.

   Safety Class 1 = High Hazard
   Safety Class 2 = Moderate Hazard
   Safety Class 3 = Low Hazard/Important
   Safety Class 4 = General Use

   Facility Use Category may be upgraded by DOE direction to provide additional conservatism as outlined in UCRL-15910, Section 2.1. Specific criteria for wind loads and earthquake ground motions are stipulated for each safety class. Structures, systems, and components of any safety class need not be subjected simultaneously to tornado, earthquake ground motions and design basis accidents. The rules for combining loads are given in the codes and standards cited in Section H or elsewhere in these criteria.

B. SAFETY CLASS 1 STRUCTURES, SYSTEMS AND COMPONENTS

Safety Class 1 structures, systems and components, (DOE Order 6430.1A Safety Class), are those that perform a function required for nuclear criticality safety or whose failure might result in a significant release of radioactive, hazardous, or toxic materials as defined by DOE Order 6430.1A, Division 13, as it relates to non-reactor nuclear facilities. Included in this category are those systems and components vital for safe shutdown. Safety Class 1 structures shall be designed for normal loads, as well as wind loads and roof loads. Load combinations and allowable stresses for these loads shall be as noted in Section H. Additionally, these Class 1 structures must meet the following natural phenomena loading. The loadings are differentiated between reactor and non-reactor facilities.

Reactor Safety Class 1 structures, systems and components shall be designed for the effects of extreme environmental loads, including Safe Shutdown Earthquake (SSE), Operating Basis Earthquake (OBE), Design Basis Tornado (DBT), Design Basis Ashfall, and Probable Maximum Flood (PMF). Where applicable, other abnormal loads specified by the SAR (PSAR, FSAR) such as those generated by a postulated high energy pipe break shall also be considered.

Non-Reactor Safety Class 1 structures, systems and components are to withstand the effects cited above for reactor facilities with the exceptions: 1) SSE is identified as the Design Basis Earthquake (DBE); 2) OBE is not required; 3) Design Basis Tornado is replaced by Design Basis Wind, and 4) Other abnormal loads considered on a case by case basis.

1. **Design Basis Tornado** (Reactor Safety Class 1 Facilities Only)

   a. Reactor Safety Class 1 structures, systems and components shall be designed to withstand the effects of a tornado having a maximum tangential wind speed of 150 miles per hour (mph) plus a 25 mph translational wind speed (or a resultant wind speed of 175 mph) over the full height of the structure without loss of capability to contain any radioactive material or to perform their safety function. Wall and roof pressure coefficients shall be in accordance with ANSI A58.1.

   b. Reactor Safety Class 1 structures, systems and components shall be designed to withstand the differential pressure loading which results from a 0.75 psi ambient pressure decrease in three seconds, held for one second, and return to ambient at the same rate. Suitable allowances for venting and for structural components shielded from such ambient pressure changes may be made.

   c. The effects of the following tornado-generated missiles on Reactor Safety Class 1 structures, systems and components shall be analyzed. Protection from penetration and secondary effects of scabbing shall be provided. Investigation of the surrounding region for possible missile materials should be made. The following objects traveling end-on at any height could result from a 175 mph tornado.

      (1) 2" X 12" wood plank, 12 ft long, at 100 mph

      (2) 4′ x 8′ plywood sheet, 3/4" thick, at 150 mph

      (3) 26" X 20′ sheet of 20 gauge corrugated steel siding, at 150 mph.

Vertical missile velocity is 2/3 missile horizontal velocity. The horizontal and vertical velocities should not be vectorially combined.

These requirements are applicable in all cases except where adjacent structures or high ground create a potential for more damaging missiles or missile impacts at higher elevations.

Automobiles, railroad flatcars, and similar heavy compact objects would not become air-borne.

2. <u>Design Basis Wind (DBW)</u> (Non-Reactor Safety Class 1 Facilities Only)

Non-reactor Safety Class 1 (UCRL 15910 High Hazard) structures, systems and components shall be designed in accordance with ANSI A58.1 using the following design basis wind value. High Hazard Facilities as defined in UCRL 15910 are designed to a wind having a probability of 1 X 10^{-4}.

Fastest-Mile Speed @Height (H) = 33 Feet (10 Meters)	90 mph
Importance Factor	1.0
Exposure Class	C
Missile (horizontal)	2 X 4 Timber Plank 15 lb @ 50 mph (73.5 fps) maximum trajectory height = 50 ft.

Vertical missile velocity is 2/3 missile horizontal velocity. The horizontal and vertical velocities should not be vectorially combined.

Protection from missile penetration and the secondary effects of scabbing shall be provided.

These requirements are applicable in all cases except where adjacent structures or high ground create a potential for more damaging missiles or missile impacts at higher elevations.

These Design Basis Wind Tornado criteria values were established by DOE document UCRL-53526, "Natural Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites," prepared by Lawrence Livermore National Laboratory, February, 1984.

3. Earthquake Loads for Safety Class 1 Structures

a. Seismic Input

(1) Safe Shutdown Earthquake (SSE) for Reactor Structures

Response spectra for the design ground motion of the Safe Shutdown Earthquake (SSE) for existing reactor facilities are specified in Figure 1. These design response spectra are applied for the horizontal directions in the free field. For vertical motion, the design response spectra shall be taken as two-thirds the response spectra for the horizontal motion over the entire range of the frequencies. Combined directional loading shall conform to Regulatory Guideline 1.92.

(2) Operational Basis Earthquake (OBE) for Reactor Structures

Reactor Safety Class 1 structures shall have the additional requirement to be designed to withstand an Operating Basis Earthquake and remain operational, unless otherwise justified. The OBE shall have a maximum free field horizontal ground acceleration of 0.05 g (Figure 2), and a simultaneous maximum vertical ground acceleration equal to 2/3 of the horizontal. Simplified and generic design procedures may be used with proper analytical justification in the design documents, if they conservatively account for the dynamic behavior of the structure and members during the postulated earthquake.

(3) Design Basis Earthquake (DBE) for Non-Reactor Structures

Response spectra for the design ground motion for the Design Basis Earthquake Non-reactor Safety Class 1 Structures are specified in Figure 3. These design response spectra are applied for the horizontal directions in the free field. For vertical motion, the design response spectra shall be taken as 2/3 of the horizontal spectra over the entire range of frequencies. Existing structures may be evaluated using methods defined in UCRL-15910, Section 4.4.1. An Operational Basis Earthquake (OBE) is not required for non-reactor structures.

b. Damping

The percentage of critical damping used in the design and analysis of reactor Safety Class 1 facilities shall conform with NRC Regulatory Guide 1.61 for reactor facilities, unless otherwise justified in the design report. The percentage of critical damping used for the design, and analysis of non-reactor facilities shall conform to the values in UCRL-15910, unless otherwise justified in the design documentation.

c. Analytical Requirements

The earthquake analysis for Safety Class 1 Facilities shall address the following considerations:

- Soil-structure interaction
- Development of floor response spectra
- Three components of earthquake motion
- Combination of model responses
- Interaction of non-Safety Class 1 items with Safety Class 1 items
- Effects of soil parameter variations on floor response spectra
- Natural frequencies and response loads
- Procedures used for analytical modeling
- Account for torsional effects

Further guidance may be found in NRC SRP 3.7.2 and UCRL-15910.

4. Earthquake Loads for Safety Class 1 Systems, Components, Equipment and Supports - Reactor and Non-Reactor

a. Seismic Input

For both reactor and non-reactor Safety Class 1 systems, components, equipment and supports, the floor response spectra at the mounting points are used as seismic input. The floor response spectra are derived from the seismic time history analyses of the structure containing Safety Class 1 items. Additionally, those components that require proven operability during a seismic event, must be evaluated with floor response spectra which also accommodates the small magnitude earthquake spectra provided in Figures 4b and 4c, unless alternate techniques can be justified.

b. Damping

The percentage of critical damping used for the design and analysis of Safety Class 1 systems, components, equipment and supports shall conform with the recommended damping values in Section 3.b. If different damping values are used, technical justification must be provided in the design documentation.

c. Seismic Analysis Methods

Accepted methods of seismic analysis for Safety Class 1 reactor systems and equipment are contained in NRC Standard Review Plan No. 3.7.3 and No. 3.9.2 Section II. Alternately for non-reactor Safety Class 1 systems and components, UCRL-15910 may be used. A dynamic analysis shall be performed unless justification for the conservatism of alternative methods is provided in the design documentation.

d. Testing

Testing is required to prove operability where operability is necessary to perform a safety function, unless operability is proven by analysis.

e. Electrical Equipment

Safety Class 1 electrical equipment shall meet the criteria for qualification of IEEE 344 (ANSI N41.7) "Recommended Practices for Seismic Qualification of Class 1E Equipment of Nuclear Power Generating Stations." Additionally, those components that require proven operability during and after a seismic event, must be evaluated with floor or equipment spectra accommodating the small magnitude earthquake spectra provided in Figures 4b and 4c, unless alternate techniques can be justified. These spectra shall be utilized in lieu of the OBE event in application of IEEE 344.

5. Design Basis Ashfall

A volcanic ashfall is considered to be a potentially occurring natural phenomenon in the category of tornado and earthquake. All new Safety Class 1 structures, systems and components are required to meet the design basis ashfall criteria as follows:

Thickness of ashfall:

4.5 inches uncompacted
3 inches compacted

Duration and rate of ashfall:

Duration of ashfall	20 hours
Maximum ashfall rate	0.45 inches per hour for 6 hours
Average ashfall rate	0.15 inches per hour

Design ashfall loading:

24 psf dry, compacted

Density of ash:

Dry, loose	72 pcf
Dry, compacted	96 pcf
Wet, compacted	101 pcf

Ashfall loading is to be combined with snow load. Ashfall in combination with snow loading will normally produce the highest loading for design. Ashfall loading is not to be combined with earthquake.

6. Probable Maximum Flood (PMF)

Safety Class 1 facilities, if located in the flood-affected zone of the Columbia River, are required to be designed for Probable Maximum Flood (PMF). The PMF for locations on the Columbia River within the Hanford reservation is 1,440,000 cubic feet per second (cfs) of river flow. The water surface elevation at the PMF is shown on Figure 6. Wave action should be considered where applicable.

C. SAFETY CLASS 2, 3, AND 4 STRUCTURES, SYSTEMS AND COMPONENTS

Safety Class 2, 3, and 4 structures, systems, and components are those that are not Safety Class 1 and are respectively specified as onsite safety related, occupational safety related or non-safety items.

1. Wind Loads

a. Design shall be in accordance with ANSI A58.1, Section 6, using the following criteria:

	Safety Class		
	2	3	4
Fastest Mile Windspeed	80	70	70
Importance Factor	1.0	1.07	1.0
Exposure Category	C	C	C

b. Design for higher wind pressures shall be considered for locations subject to unusual wind velocity such as the top of Rattlesnake Mountain where winds of approximately 160 mph have been estimated.

c. The Hanford Area is subject to prolonged, straight and gusting winds prevalent from the west and southwest. Particular attention shall be given to adequate fastening of roof to walls and to details such as flashings, ventilators, access openings, louvers, etc.

2. <u>Earthquake Loads</u>

Earthquake loads shall be calculated in accordance with UCRL-15910, Section 4. The correlation between Safety Class Designation, and the Facility Use Category in UCRL-15910 is shown in Section A.3. The combination of multi-directional earthquake loads is defined in UCRL-15910, Section 4.4.3. System and component loading shall be consistent with UCRL-15910, Section 4.4.4.

The following values shall be used for seismic evaluation:

	Safety Class		
	2	3	4
Free Field Hor. Accel. (g)	.12	.12	.09
Critical Damping	UCRL-15910	5%	5%
Importance Factor	2.0	1.25	1.0

Additionally, Safety Class 2 structures must have a dynamic analysis performed consistent with UCRL-15910 utilizing the seismic spectra in Figure 5 and direction in Section B.3.a of this document, unless otherwise justified in the design documentation.

3. <u>Roof Loads</u>

a. Roof live loads shall be in accordance with ANSI A58.1, Section 4.

b. Snow loads shall be in accordance with ANSI A58.1, Section 7. Fifteen pounds per square foot (psf) shall be used as the ground snow load, Pg, but in no case shall roofs be designed for less than 20 psf snow load.

c. Additional load for ashfall is not required for Safety Class 2, 3 or 4. Ashfall loading is covered by and not combined with snow load.

D. **ELEVATED STEEL WATER TANKS, STANDPIPES, AND RESERVOIRS**

The design requirements of National Fire Protection Association and the American Water Works Association, shall be used as the basis of design for elevated steel water tanks, standpipes, and reservoirs, unless otherwise justified in the design documentation.

E. **CHIMNEYS AND STACKS**

Design of concrete chimneys and stacks shall conform to ACI-307, "Specification for the Design and Construction of Reinforced Concrete Chimneys," unless otherwise justified in the design documentation. Masonry and steel chimney design is also addressed in UBC Chapter 37.

F. **FOUNDATIONS AND RETAINING WALLS**

1. Design of foundations and retaining walls shall, in general, be in accordance with the UBC. Concrete design shall be according to UBC and ACI-318. Masonry design shall comply with UBC and ACI-531.

2. The minimum depth to the bottom of foundations of permanent structures (except elevated tanks and stacks) shall be 2'-6" below finished grade, except that footings shall bear on undisturbed earth, whichever is the greater depth.

3. The minimum depth to the bottom of foundations supporting elevated tanks and stacks shall be 4'-0" below finished grade, except that footings shall bear on undisturbed earth, whichever is the greater depth.

4. If it is not possible or practicable to place footings on undisturbed earth, footings and foundations may be placed on properly compacted backfill that has bearing capacity sufficient to meet design requirements.

G. **SOIL PRESSURES**

1. The allowable soil pressure from Chapter 29 of the UBC may be used for design of facilities where precise soil bearing information is not available. These values are considered to be for undisturbed earth.

2. For permanent facilities, the subsurface soil and ground water conditions at the building site shall be determined by means of borings, test-pits, triaxial shear tests, or other approved field and laboratory methods.

3. <u>Dynamic Earth Pressures</u>

The effect of dynamic earth pressures shall be considered in the design of Safety Class 1 and 2 below grade structures.

4. <u>Lateral Earth Pressure - Static Case</u>

For sites where the specific soil properties have not been determined by subsurface soils investigations, the following lateral earth pressures shall be used for design:

a. Cantilever or other flexible walls exposed to earth fill shall be designed for a static equivalent fluid pressure of 30 pounds per square foot (psf), based on an active earth pressure coefficient, K_a, of 0.27 and soil density of 110 pounds per cubic foot (pcf).

b. Basement or other rigid walls exposed to ordinary compacted backfill shall be designed for a static equivalent fluid pressure of 55 psf, based on at-rest earth pressure coefficient, K_o, of 0.50 and a soil density of 110 pcf.

c. Rigid walls exposed to backfill compacted to at least 75% of relative density shall be designed for 77 psf, based on a k_o of 0.70.

d. Superimposed lateral pressures due to uniform surcharge loadings shall be calculated using appropriate earth pressure coefficients as shown in a, b, and c. Resultant forces due to point and line loads shall be added.

e. Where walls will be subject to ground water head, the hydrostatic head shall be added to the equivalent fluid pressure of retained earth.

f. Consideration shall be given to passive soil loading produced by thermal growth of sub-grade structures.

H. **<u>LOAD COMBINATIONS AND ALLOWABLE STRESSES</u>**

1. Load combinations and allowable stresses for all structures, systems and components shall be in accordance with standard codes, including the following:

- American Concrete Institute "Building Code Requirements for Reinforced Concrete" (ACI-318) and "Code Requirements for Nuclear Safety Related Concrete Structure" (ACI-349).

- American Institute of Steel Construction, "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings".
- American Concrete Institute, "Building Code Requirements for Concrete Masonry Structures" (ACI-531).
- International Conference of Building Officials, "Uniform Building Code" (UBC).

2. Load combinations and allowable stresses for Safety Class 1 and 2 non-reactor structures, systems, and components shall be in accordance with UCRL-15910 for Moderate and High Hazard Facilities, ACI-349, ANSI/AISC N690-1984 and 6430.1A, as applicable.

3. Load combinations and allowable stresses for masonry walls in Safety Class 1 structures shall be in accordance with NRC SRP Section 3.8.4, Appendix A.

4. Load combinations and allowable stresses for Safety Class 1 reactor structures, systems, and components shall be in accordance with the Reactor Safety Analysis Report (SAR) requirements of SRP 3.8.3 and 3.8.4.

I. MOBILE OFFICES (TRAILERS) AND TEMPORARY STRUCTURES

Mobile offices, trailers and other temporary structures shall be supported by a system designed to Safety Class 4/General Use criteria. Anchors and supporting piers can be individual units and must resist all lateral and vertical loads defined in these criteria.

FIGURES AND TABLES

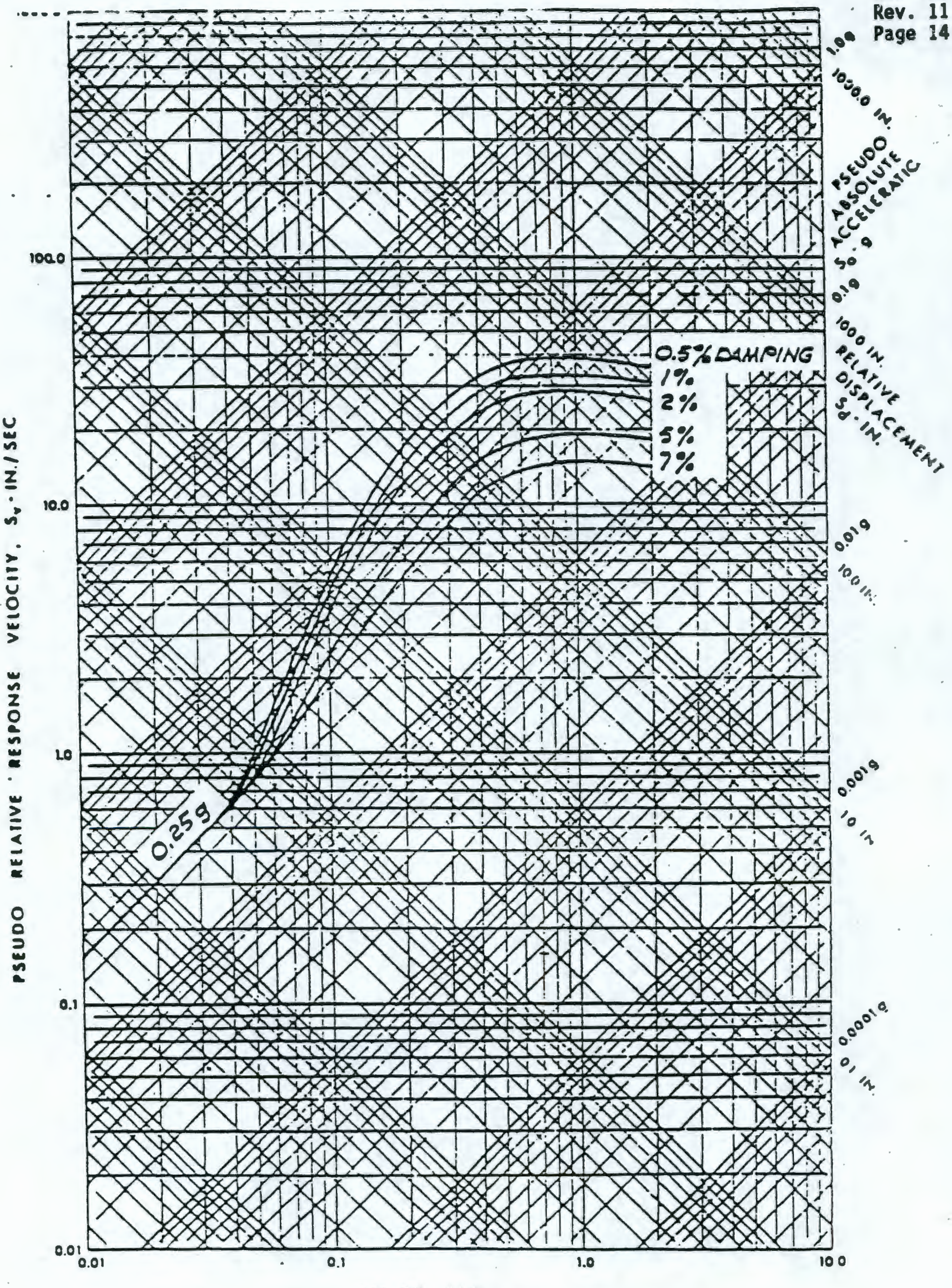

FIGURE 1 RESPONSE SPECTRA, SAFE SHUTDOWN EARTHQUAKE FOR EXISTING REACTORS

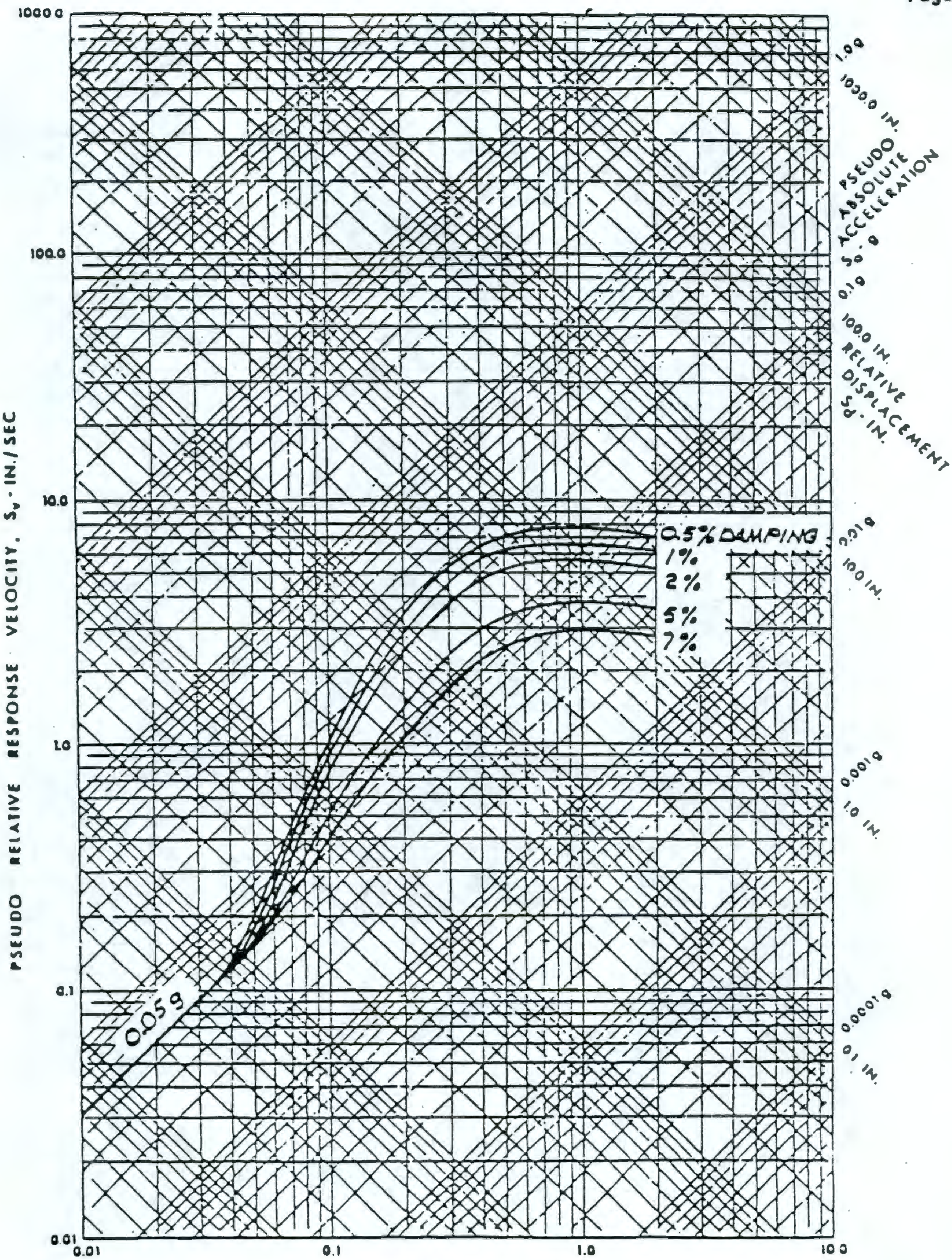

FIGURE 2 RESPONSE SPECTRA, OPERATING BASIS EARTHQUAKE FOR EXISTING REACTORS

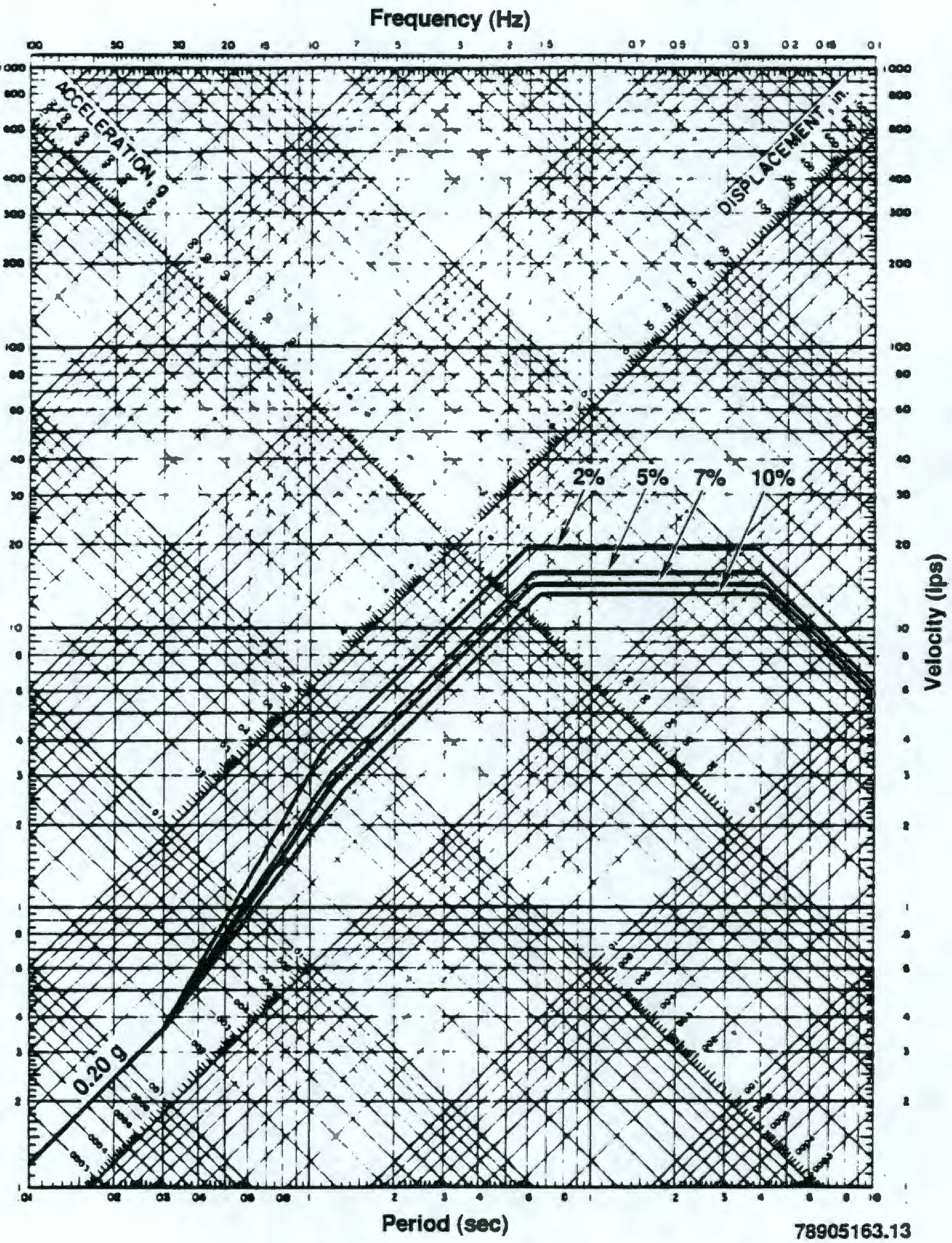

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FIGURE 3 RESPONSE SPECTRA - NON-REACTOR SAFETY CLASS 1 for 2, 5, 7, AND 10% CRITICAL DAMPING, 0.20g

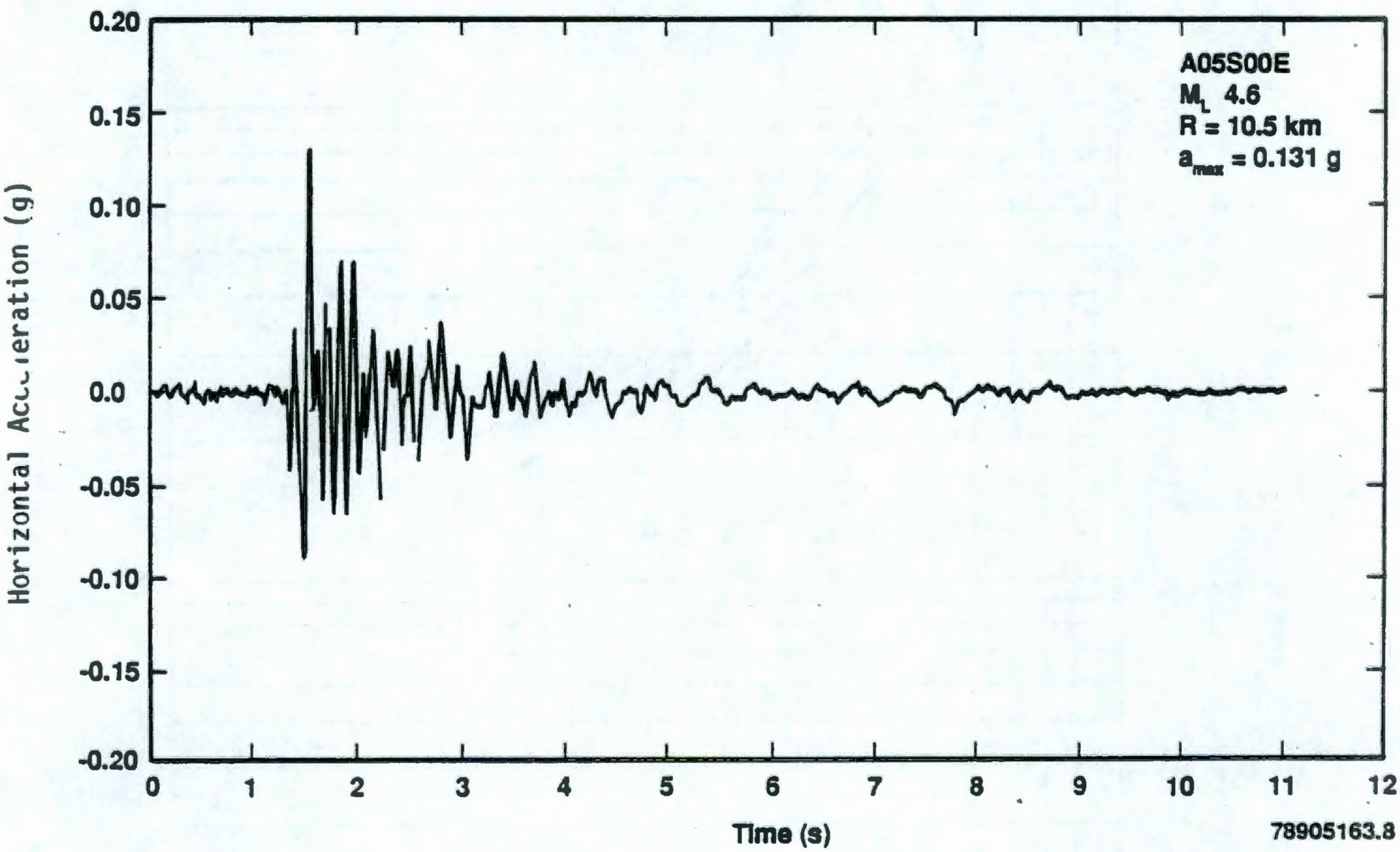


FIGURE 4a TYPICAL TIME HISTORY FOR SMALL-MAGNITUDE EARTHQUAKE

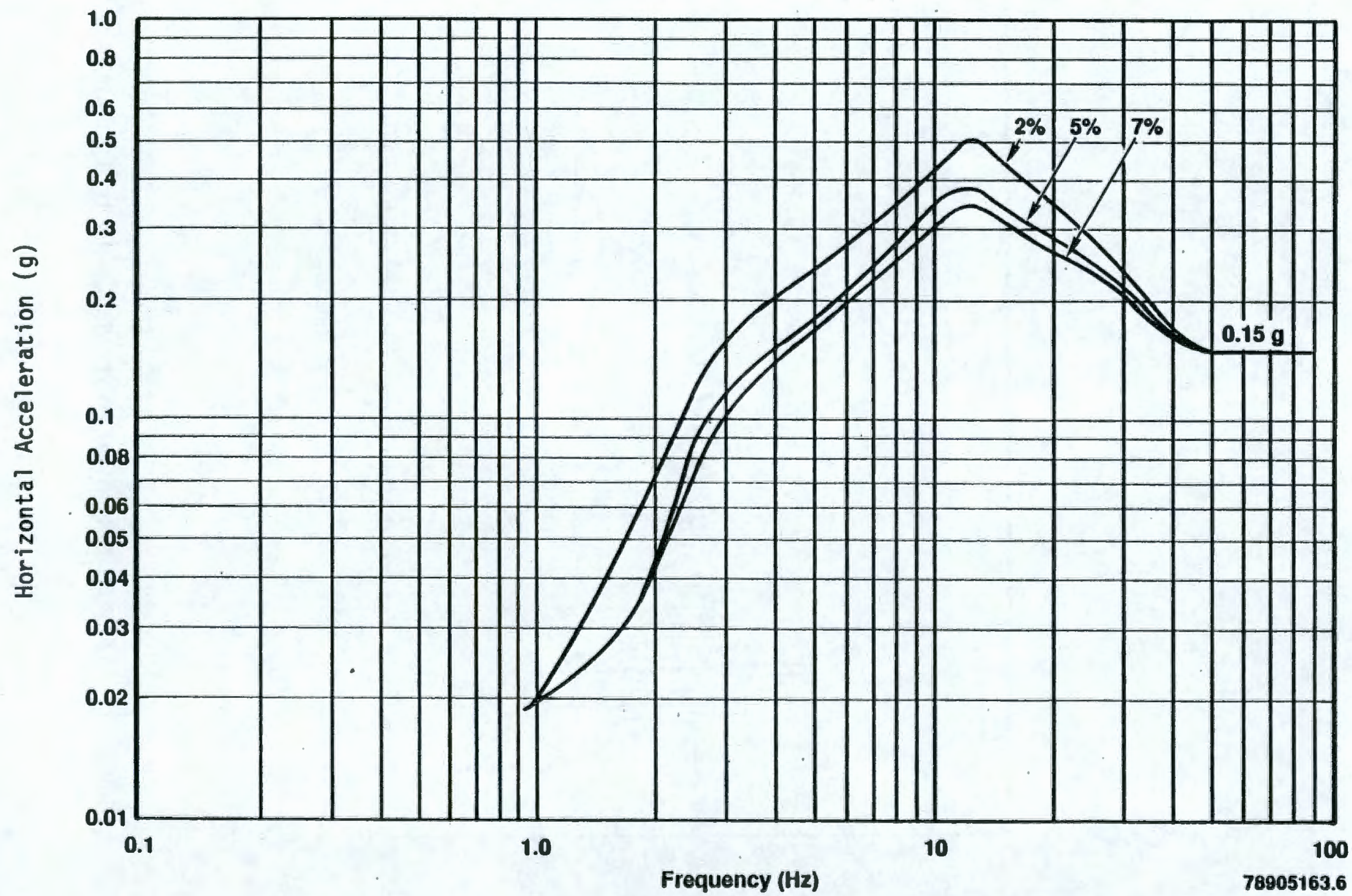


FIGURE 4b RESPONSE SPECTRA FOR SMALL-MAGNITUDE, NEAR-FIELD EARTHQUAKE, 0.15g
(ALL AREAS EXCEPT 100 AND 200 AREAS)

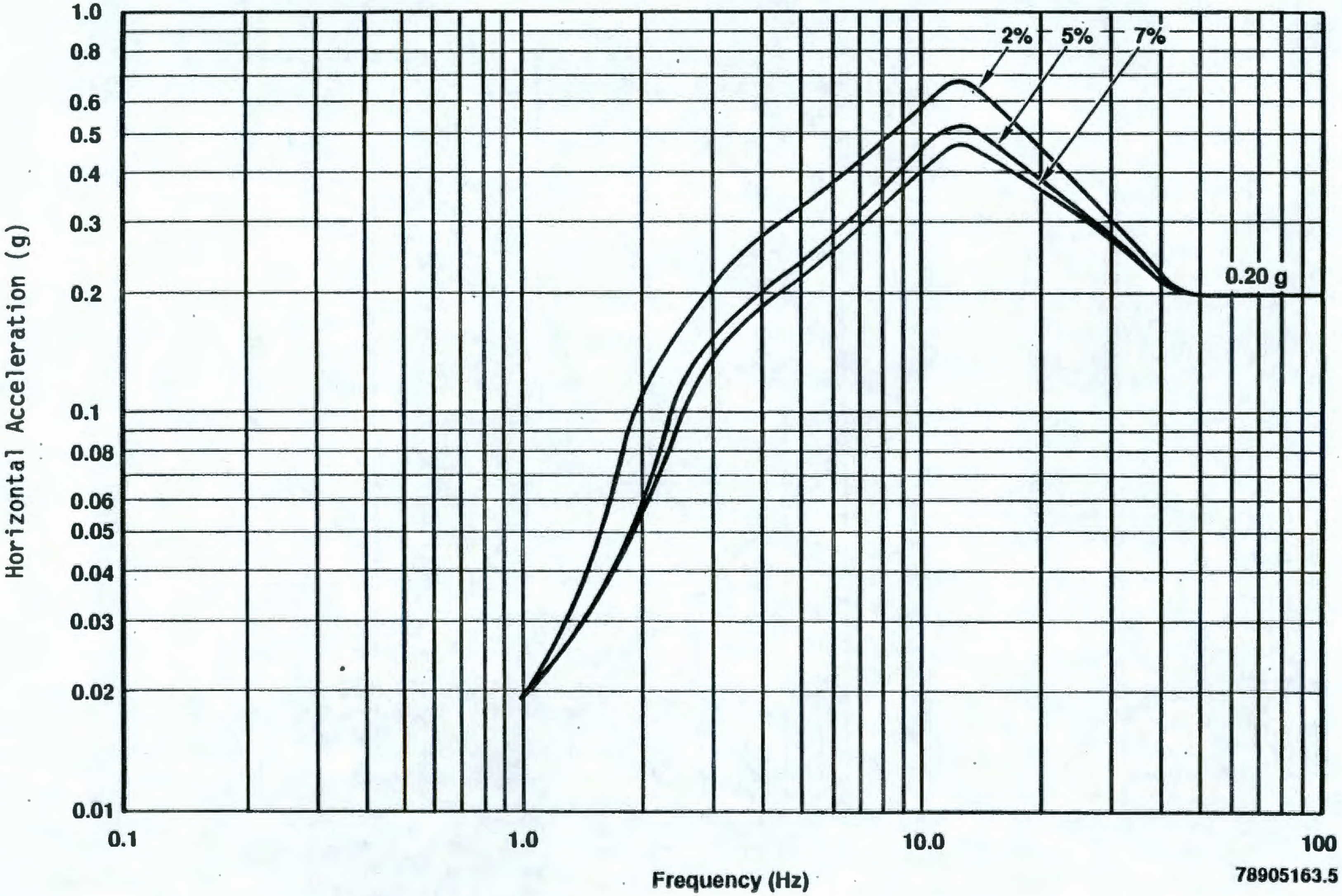


FIGURE 4c RESPONSE SPECTRA FOR SMALL-MAGNITUDE, NEAR-FIELD EARTHQUAKE, 0.20g (100 AND 200 AREAS ONLY)

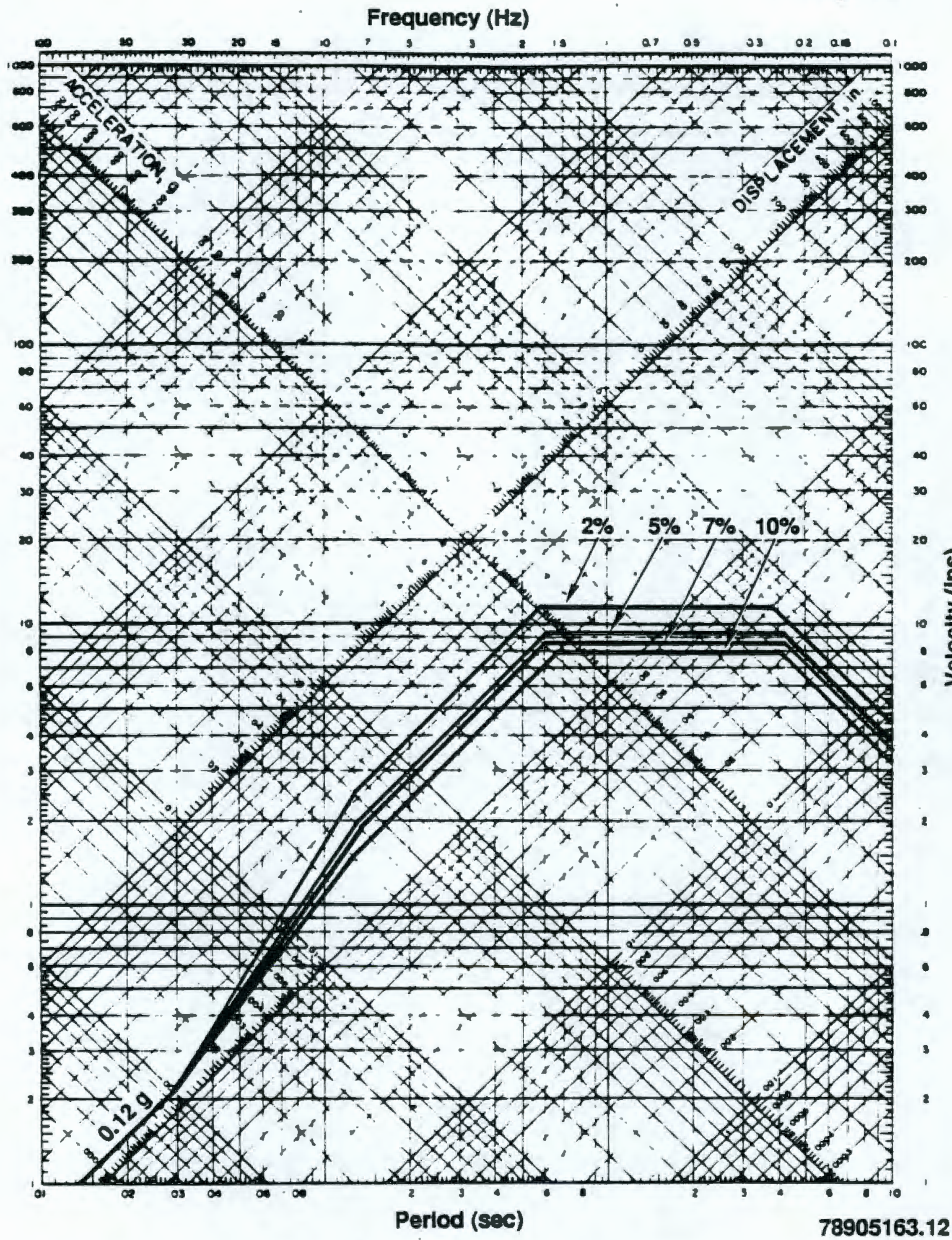
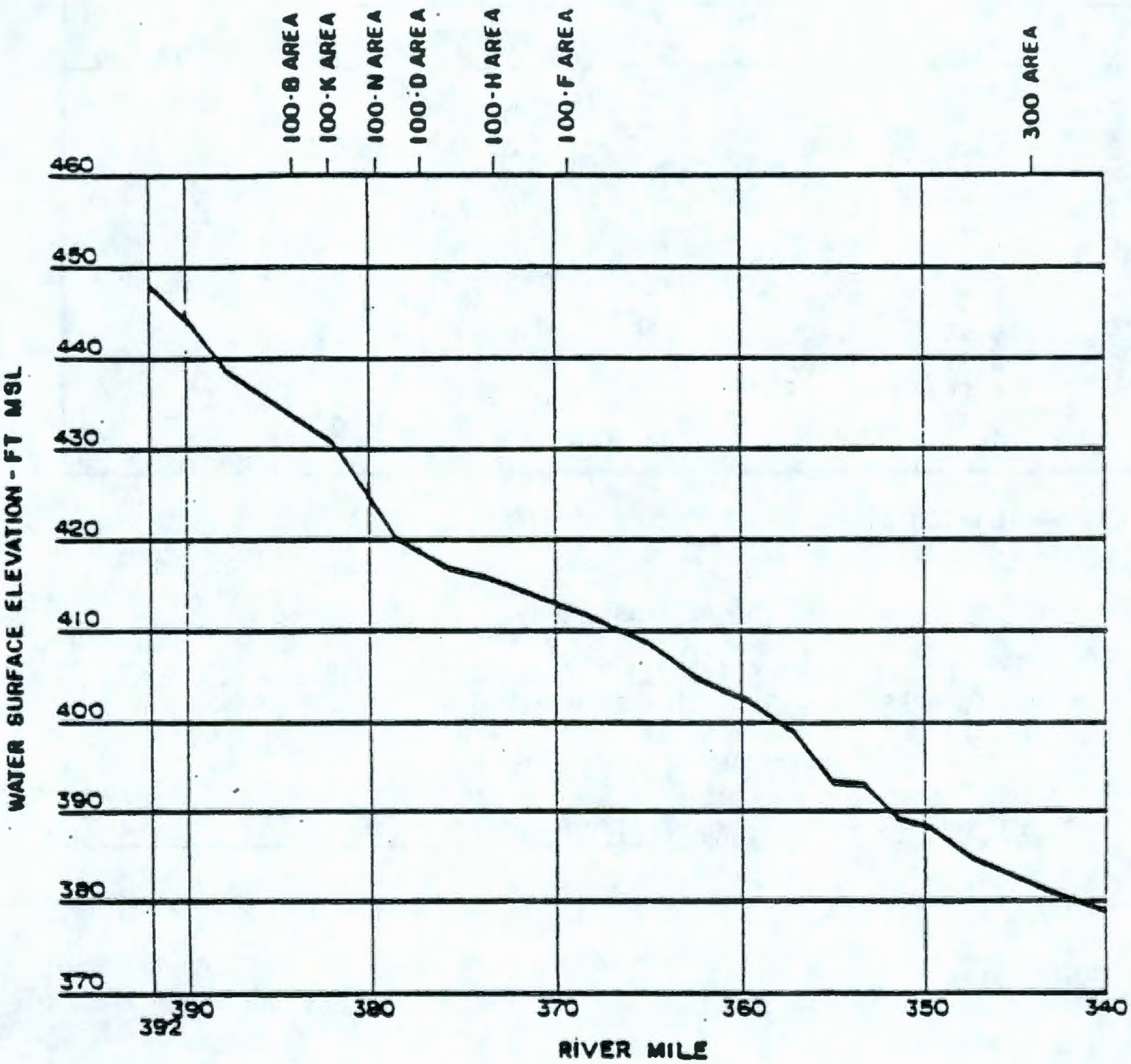


FIGURE 5 RESPONSE SPECTRA - NON-REACTOR SAFETY CLASS 2, FOR 2, 5, 7, AND 10% CRITICAL DAMPING, 0.12g



COLUMBIA RIVER MILE 340 TO RIVER MILE 392 PROBABLE MAXIMUM FLOOD (PMF)
1,440,000 CFS MEAN SEA LEVEL (MSL) WATER SURFACE ELEVATION

FIGURE 6

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TABLE 1

SAFE SHUTDOWN EARTHQUAKE ACCELERATIONS FOR EXISTING REACTORS (CORRESPONDS TO FIGURE 1, HORIZONTAL ZPA = 0.25g)

FREQUENCY VERSUS ACCELERATION

	ACCELERATION (g's)					
Frequency (Hz)	0.5%	1%	2%	5%	7%	% Damping
0.5	0.30	0.26	0.21	0.16	0.11	
1.0	0.66	0.55	0.46	0.31	0.24	
1.5	0.96	0.82	0.70	0.46	0.36	
2.0	1.2	1.0	0.85	0.55	0.41	
3.0	1.4	1.2	1.0	0.61	0.46	
5.0	1.4	1.2	1.0	0.60	0.41	
8.0	1.0	0.90	0.72	0.46	0.37	
15.0	0.48	0.40	0.36	0.30	0.27	
20.0	0.32	0.30	0.25	0.25	0.25	
33.0	0.25	0.25	0.25	0.25	0.25	
100.0	0.25	0.25	0.25	0.25	0.25	

Interpolate on log-log plots.

TABLE 2

OPERATING BASIS EARTHQUAKE ACCELERATIONS FOR EXISTING REACTORS (CORRESPONDS TO FIGURE 2, HORIZONTAL ZPA = 0.05g)

FREQUENCY VERSUS ACCELERATION

	ACCELERATION (g's)					
Frequency (Hz)	0.5%	1%	2%	5%	7%	% Damping
0.5	0.06	0.05	0.04	0.03	0.02	
1.0	0.11	0.11	0.09	0.06	0.05	
1.5	0.19	0.16	0.14	0.09	0.07	
2.0	0.24	0.20	0.17	0.11	0.08	
3.0	0.28	0.24	0.20	0.12	0.09	
5.0	0.28	0.24	0.20	0.12	0.08	
8.0	0.20	0.18	0.14	0.09	0.07	
15.0	0.10	0.08	0.07	0.06	0.05	
20.0	0.06	0.06	0.05	0.05	0.05	
33.0	0.05	0.05	0.05	0.05	0.05	
100.0	0.05	0.05	0.05	0.05	0.05	

Interpolate on log-log plots.

TABLE 3

0.2g HORIZONTAL RESPONSE SPECTRA CONTROL POINTS

MEDIAN CENTERED NEWMARK-HALL
(CORRESPONDS TO FIGURE 3)

PER CENT DAMPING	2%		5%		7%		10%		12%	
Control Points	f(Hz)	a(g)	f(Hz)	a(g)	f(Hz)	a(g)	f(Hz)	a(g)	f(Hz)	a(g)
a=0.20										
E	0.1	0.012	0.1	0.010	0.1	0.010	0.1	0.009	0.1	0.008
D	0.26	0.084	0.25	0.065	0.25	0.059	0.24	0.052	0.24	0.048
C	1.73	0.55	1.64	0.42	1.60	0.38	1.53	0.33	1.50	0.30
B	8.0	0.55	8.0	0.42	8.0	0.38	8.0	0.33	8.0	0.30
A	33.0	0.20	33.0	0.20	33.0	0.20	33.0	0.20	33.0	0.20
A′	100.0	0.20	100.0	0.20	100.0	0.20	100.0	0.20	100.0	0.20

TABLE 4

0.12g HORIZONTAL RESPONSE SPECTRA CONTROL POINTS
(CORRESPONDS TO FIGURE 5)

PERCENT DAMPING	2%		5%		7%		10%		12%	
Control Points	f(Hz)	a(g)	f(Hz)	a(g)	f(Hz)	a(g)	f(Hz)	a(g)	f(Hz)	a(g)
a=0.12										
E	0.1	0.007	0.1	0.006	0.1	0.006	0.1	0.005	0.1	0.005
D	0.26	0.050	0.25	0.039	0.25	0.035	0.24	0.031	0.24	0.029
C	1.73	0.33	1.64	0.25	1.60	0.23	1.53	0.20	1.50	0.18
B	8.0	0.33	8.0	0.25	8.0	0.23	8.0	0.20	8.0	0.18
A	33.0	0.12	33.0	0.12	33.0	0.12	33.0	0.12	33.0	0.12
A	100.0	0.12	100.0	0.12	100.0	0.12	100.0	0.12	100.0	0.12

Interpolation between control points on log-log plots only.
See Figure 7 for example plot.

TABLE 5

0.15g, HORZONTAL SMALL MAGNITUDE EARTHQUAKE
(ALL AREAS EXCEPT 100 AND 200 AREAS)
(CORRESPONDS TO FIGURE 4b)

	ACCELERATION (g)			
Frequency	2%	5%	7%	Damping
33.0	0.21	0.20	0.19	
25.0	0.29	0.25	0.24	
20.0	0.35	0.29	0.27	
12.5	0.51	0.39	0.35	
10.0	0.44	0.35	0.31	
5.0	0.24	0.18	0.17	
3.3	0.18	0.13	0.12	
2.5	0.12	0.09	0.08	
1.7	0.05	0.03	0.03	
1.0	0.02	0.02	0.02	
0.33	0	0	0	

TABLE 6

0.20g, HORIZONTAL SMALL MAGNITUDE EARTHQUAKE
(100 AND 200 AREAS ONLY)
(CORRESPONDS TO FIGURE 4c)

	ACCELERATION (g)			
Frequency	2%	5%	7%	Damping
33.0	0.28	0.26	0.26	
25.0	0.38	0.33	0.31	
20.0	0.46	0.39	0.36	
12.5	0.68	0.52	0.47	
10.0	0.58	0.46	0.41	
5.0	0.32	0.24	0.22	
3.3	0.24	0.17	0.16	
2.5	0.16	0.12	0.1	
1.7	0.07	0.04	0.04	
1.0	0.02	0.02	0.02	
0.33	0	0	0	

TABLE 7

FORMULAS FOR DETERMINATION OF CONTROL POINTS FOR MEDIAN CENTERED NEWMARK-HALL SPECTRA

1. Competent soil V_s < 3500 ft/sec

a = PGA (g)

$v_g = 48\ a_g$ (in/sec)

$d_g = 36\ a_g$ (in)

Where: a = Peak horizontal free-field ground acceleration
v_g = Peak horizontal free-field ground velocity
d_g = Peak horizontal free-field ground displacement
V_s = Shear wave velocity of soil at site

2. Spectrum Amplification Factors

Damping	A	V	D
2%	2.74	2.03	1.63
5%	2.12	1.65	1.39
7%	1.89	1.51	1.29
10%	1.64	1.37	1.20
12%	1.50	1.28	1.13

Where: A = Acceleration Amplification; V = Velocity Amplification and D = Displacement Amplification

3. Control Point Determination

Control Point	Frequency (Hz)	Spectral Acceleration (g)
E	0.1	$\frac{0.395\ d_{max}}{g}$
D	$\frac{v_{max}}{2\ \ d_{max}}$	$\frac{v^2_{max}}{g\ d_{max}}$
C	$\frac{g\ a_{max}}{2\ \ v_{max}}$	a_{max}
B	8.0	a_{max}
A	33.0	a_g
A′	100.0	a_g

Where: g = acceleration of gravity (386 in/sec)
$a_{max} = a_g \cdot A$
$v_{max} = v_g \cdot V$
$d_{max} = d_g \cdot D$

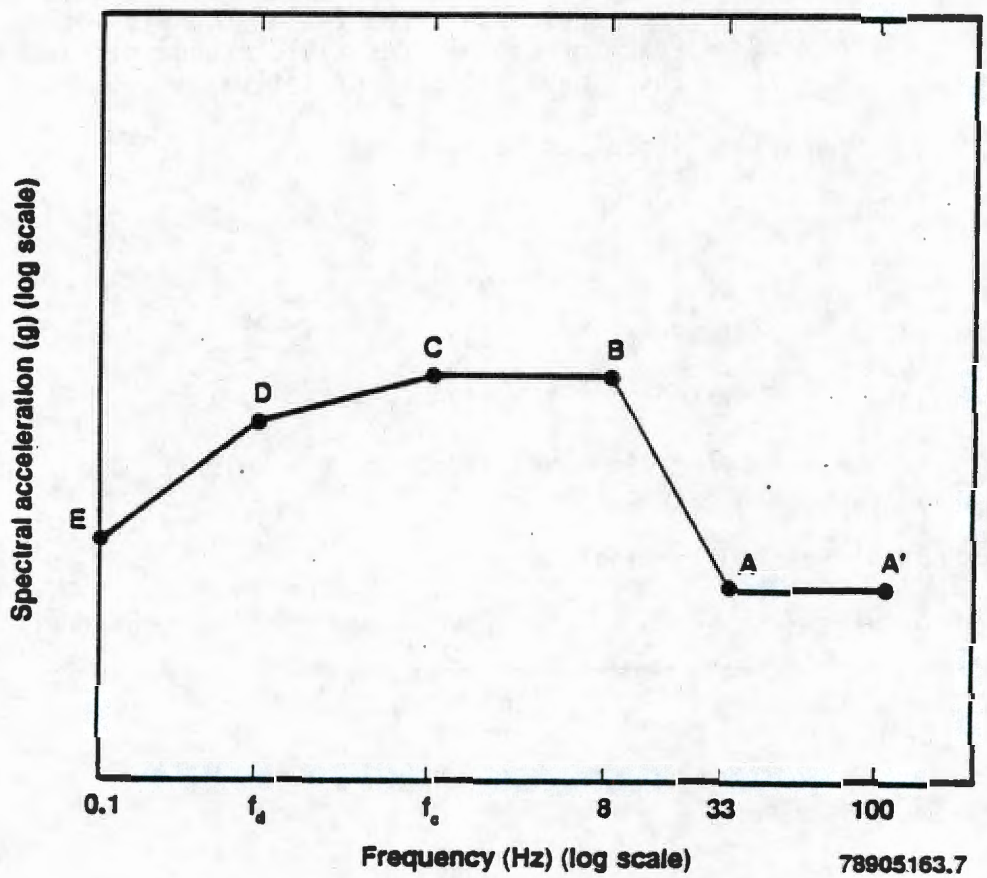

FIGURE 7 CONTROL POINTS FOR MEDIAN CENTERED NEWMARK HALL SPECTRA
SEE TABLES 3 AND 4

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5. Phone: 6-7642

6. MSIN: H5-55

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