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SUBJECT: Provides responses to questions posed by NRC during TVA/NRC 940324 meeting in Rockville,MD re proposed approach to resolve vertical flexible floor issue at BNP.

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Gentlemen:

In the Matter of the Application of) Docket Nos. 50-438
Tennessee Valley Authority) 50-439

BELLEFONTE NUCLEAR PLANT (BLN) - RESPONSE TO NRC QUESTIONS ON THE BLN VERTICAL FLEXIBLE FLOOR STUDY

The purpose of this letter is to provide responses to the questions posed by the NRC during a TVA/NRC meeting held March 24, 1994 at the NRC office in Rockville, Maryland. The meeting was requested by TVA to discuss the proposed approach to resolve the vertical flexible floor issue at BLN. Enclosure 1 is a listing of the NRC questions identified prior to the March 24, 1994 meeting and TVA's response. Enclosure 2 contains the information requested by the NRC during the March 24, 1994 meeting. Enclosure 3 illustrates the historical development of the vertical flexible floor issue at BLN.

The information contained in this letter is being provided to supplement the information previously provided to the NRC by letter dated December 21, 1993 which was submitted to justify TVA's position for the approach used to verify the seismic design of Category I structures for BLN. TVA requests the staff include the enclosed information in the review of TVA's proposed approach. This letter contains no commitments.

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Should there be any questions regarding this matter, please contact G. D. Pierce, Nuclear Assurance and Licensing Manager at (205) 574-8058.

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ENCLOSURE 1

NRC QUESTIONS IDENTIFIED BEFORE THE MARCH 24, 1994 MEETING AND TVA'S RESPONSES

NRC Question No. 1:

Provide information (procedure, figures) related to the development of a single synthetic time-history that would meet the provisions of Standard Review Plan (SRP) 3.7.1 (i.e. enveloping design response spectra (DRS) and meeting the minimum 100% of target power spectral density (PSD)). Also provide information related to the site specific time-history records that are used in the development of flexible floor response spectra (FFRS-Vertical), specifically, the information related to the number of records (if not all thirteen) and parameters (e.g. structural damping) used for the computing the FFRS in Figure 2-3 of the report (Ref. A)

TVA Response:

The Bellefonte design basis synthetic time histories meet all applicable criteria identified in SRP 3.7.1. The BLN Task Report "Generation of Synthetic Time Histories Compatible With Design Response Spectra of Bellefonte Nuclear Plant" (Reference 1-1), demonstrates the compliance of the BLN design basis synthetic time histories to Regulatory Guide 1.60 ground response spectra and SRP 3.7.1 PSD criteria. (Please note that the SRP 3.7.1 criteria, as specified in paragraphs 3 and 4 of Appendix A to SRP Section 3.7.1, are for the one-sided PSD of the design basis synthetic time history to exceed 80% of the target PSD.) A Special Engineering Review of these synthetic time histories, performed by Dr. Robert P. Kennedy of Structural Mechanics Consulting, Inc., (Reference 1-2), concluded that the time histories "produce response spectra which provide an excellent fit to the BLN FSAR horizontal and vertical design response spectra. In addition, all NRC SRP requirements for Design Time Histories are met."

The development of the Bellefonte synthetic time-histories are based on the method originally developed by Kaul (Reference 1-3) for single damping spectrum and was later extended by Lilhanand and Tseng (Reference 1-4) for multiple damping spectra. The method is an iterative method in which a set of linear algebraic equations is solved to match a discrete set of spectral values at the prescribed spectral frequencies and damping ratios, in each iteration. The iteration will carry on until the specified accuracy is reached. The PSDs of the synthetic time-histories are then computed and compared to the target PSD as defined in SRP 3.7.1. The procedure for the development of the time histories is discussed in BLN calculation No. BLN-01 (Reference 1-5).

All thirteen site specific time histories were used in the study of flexible floor response spectrum (FFRS). The list of the thirteen time histories is shown in Table 1. The damping ratios used in the amplified response analyses are 4% for OBE and 7% for SSE; consistent with Regulatory Guide 1.61 damping criteria. The identical fixed base lumped mass linear elastic building model has been used in all studies performed to evaluate the flexible floor issue.

ENCLOSURE 1 (continued)

TABLE 1

I.D. Number	Earthquake	Date/Time	Recording Station	Instrument Orientation
1	Friuli, Italy	09-11-76 1631	S. Rocco	Vertical
2	Friuli, Italy	09-11-76 1635	S. Rocco	Vertical
3	Friuli, Italy	09-15-76 0315	S. Rocco	Vertical
4	Friuli, Italy	09-15-76 0921	S. Rocco	Vertical
5	Friuli, Italy	05-11-76 2244	Tolmezzo	Vertical
6	Friuli, Italy	05-06-76 2000	Tolmezzo	Vertical
7	Friuli, Italy	05-09-76 0053	Carroll College	Vertical
8	Helena, Montana	10-31-35 1138	Allen Ranch	Vertical
9	Lytle Creek, CA	09-12-70 0600	Devils Canyon	Vertical
10	Lytle Creek, CA	09-12-70 0600	Oroville Dam	Vertical
11	Oroville, CA	08-01-75 2020	Temblor	Vertical
12	Parkfield, CA	06-27-66 2026	Golden Gate Park	Vertical
13	San Francisco, CA	03-22-57 1144		Vertical

ENCLOSURE 1 (continued)

References:

1-1 "Task Report On Generation Of Synthetic Time Histories Compatible With Design Response Spectra of Bellefonte Nuclear Plant," dated March 8, 1991, prepared by International Civil Engineering Consultants, Inc., of Berkeley, California.

1-2 Correspondence from Dr. Robert P. Kennedy to Mr. John W. Johnston, entitled "Bellefonte Nuclear Plant - Seismic Design Assessment - Time History Generation," dated April 23, 1991.

1-3 Kaul, M. K., "Spectrum- Consistent Time-History Generation," ASCE Engineering Mechanics Division, Vol 104, No. EM4, August 1978, pp.781-788.

1-4 Lilhanand, K. and Tseng, W. S., "Development And Application Of Realistic Earthquake Time Histories Compatible With Multiple-Damping Design Spectra," Proceeding of Ninth World Conference on Earthquake Engineering, August 2-9, 1988, Tokyo-Kyoto, Japan (Vol. II).

1-5 Bellefonte Calculation No. BLN-01, Revision 0.

NRC Qnestion No. 2:

A comparison of the vertical FFRS for the Auxiliary-Control Building (ACB) shown during the presentation on September 14, 1993, and those shown in Figure F-1 through F-7 of the report indicates that the building models utilized for the two studies are significantly different. Provide information related to the ACB model together with SDOF oscillators (and their impedances) used in the development of FFRS in the report.

TVA Response:

The dynamic building model of the ACB used in the vertical floor flexibility study presented at the September 14, 1993 meeting is the same as the model that was used in the December 1993 report. The only difference between the two analyses is the input time-histories.

The floor response spectra (FRS) presented at the September 14, 1993 presentation are rigid floor spectra. The original ACB structural model (i.e., 1973) was updated to resolve identified discrepancies. The updated ACB model (i.e., 1991) has consistently been used in all seismic analyses related to confirmation of the BLN design basis and the floor flexibility issue. The approach to the development of the updated "1991" structural model has been accepted by the NRC Staff as discussed in the SERs (References 2-3, 2-4, 2-5 and 2-6).

Information related to the 1991 ACB building lumped-mass-linear-elastic stick model properties is attached (e.g., stiffness and inertia properties).

The development of the single degree of freedom (SDOF) oscillators and their impedance is based on References 2-7 and 2-8 (Task Report On Watts Bar Nuclear Plant Floor And Wall Flexibility Study). Reference 2-7 discusses the derivation of the impedance methodology presented in Appendix D of the December 1993 Bellefonte "Vertical Floor Flexibility" report. Reference 2-8 discusses the methodology of selecting the SDOF oscillators. Impedances for the SDOF oscillators are computed internally to the dynamic analysis computer code and have not been printed.

ENCLOSURE 1 (continued)

References:

2-1 Bellefonte Position Paper Regarding Seismic Design Of Category I Structures, Enclosure to TVA Letter from E.G. Wallace to U.S. Nuclear Commission dated February 14, 1991.

2-2 Bellefonte Position Paper Regarding Seismic Design Of Category I Structures, Enclosure to TVA Letter from E.G. Wallace to U.S. Nuclear Commission dated July 18, 1991.

2-3 "Safety Evaluation By the Office of Nuclear Reactor Regulation for Tennessee Valley Authority's Position Regarding Seismic Design of Category I Structures," Enclosure to USNRC letter from Mohan C. Thadani of NRC to Mr. Nauman of TVA, dated October 4, 1991.

2-4 "Safety Evaluation By the Office of Nuclear Reactor Regulation for Tennessee Valley Authority's Position Regarding Seismic Design of Category I Structures," Enclosure to USNRC letter from Mohan C. Thadani of NRC to Mr. Nauman of TVA, dated August 29, 1991.

2-5 "Safety Evaluation By the Office of Nuclear Reactor Regulation for Tennessee Valley Authority's Position Regarding Evaluation of Concrete Elastic Modulus For Reanalysis of Category I Civil Structures," Enclosure to USNRC letter from Mohan C. Thadani of NRC to Mr. Nauman of TVA, dated December 11, 1991.

2-6 "Safety Evaluation By the Office of Nuclear Reactor Regulation for Tennessee Valley Authority's Position Regarding Dynamic Properties of Foundation Bedrock," and "Safety Evaluation By the Office of Nuclear Reactor Regulation for Tennessee Valley Authority's Position Regarding The Use Of Fixed-Base Model in Seismic Reanalysis," Enclosures 1 and 2, respectively , to USNRC letter from Mohan C. Thadani of NRC to Dr. Medford of TVA, dated May 1, 1992.

2-7 "Equipment Response Spectra Including Equipment-Structure-Interaction Effects," by W.S. Tseng, Proceedings of the 1989 ASME Pressure Vessels and Piping Conference, Honolulu, Hawaii, July 23-27, 1989, ASME, PVP-Vol. 155, PP. 21-29.

2-8 "Task Report On Watts Bar Nuclear Plant Floor And Wall Flexibility Study," Revision 3, August 1990, TVA, RIMS No. B26 90 0823 155.

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1

Response Spectra Plot - 3% Equipment Damping - Vertical Acceleration Time History (SSE)

Auxiliary-Control Building - Elev 628 ft - Node 901 - Floor Freq. 6.8 Hz - West Stick

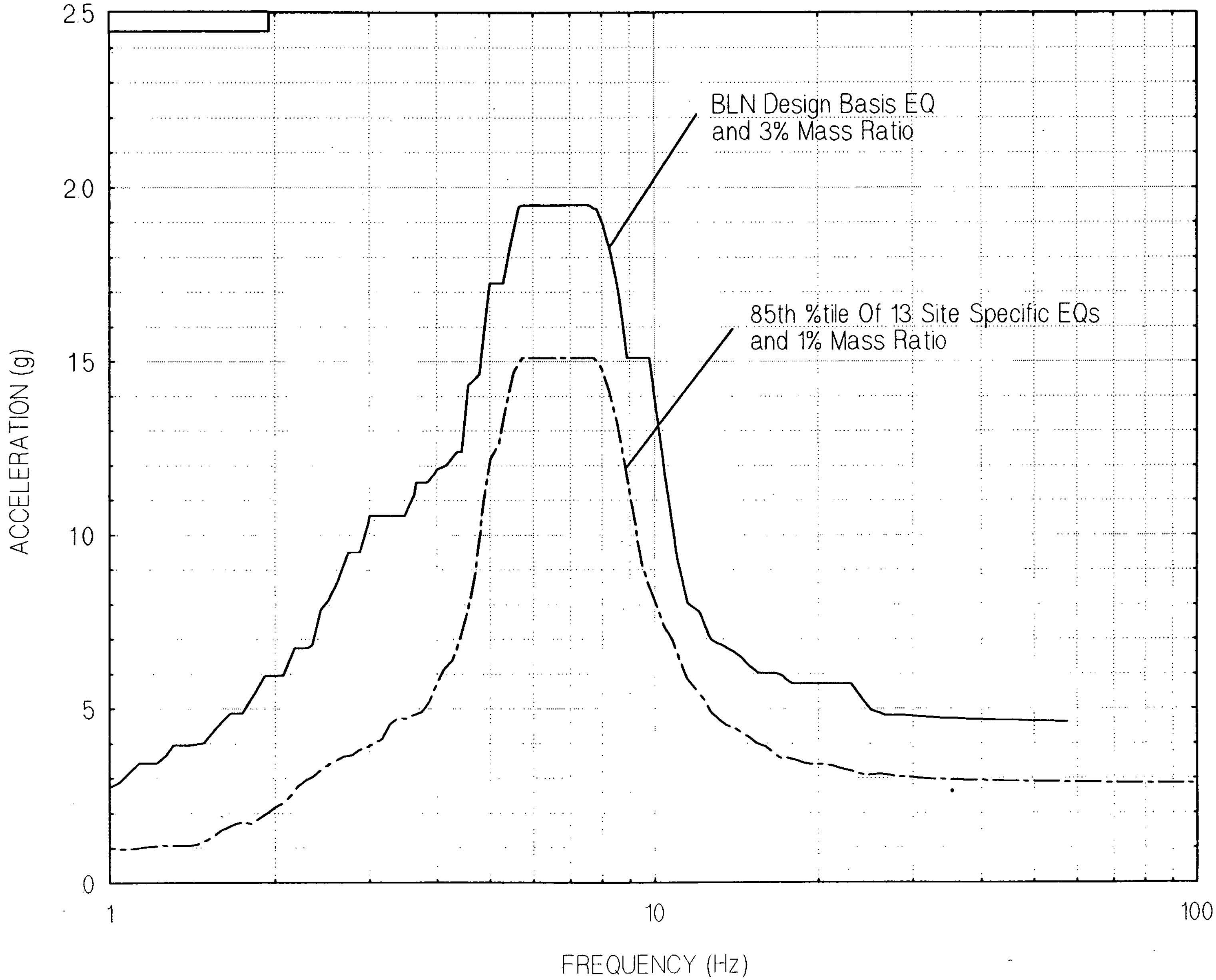


FIGURE 3-1

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equipment Damping - Vertical Acceleration Time History (SSE)
Auxiliary-Control Building - Elev. 628 ft - Node 902 - Floor Freq 9.6 Hz - West Stick

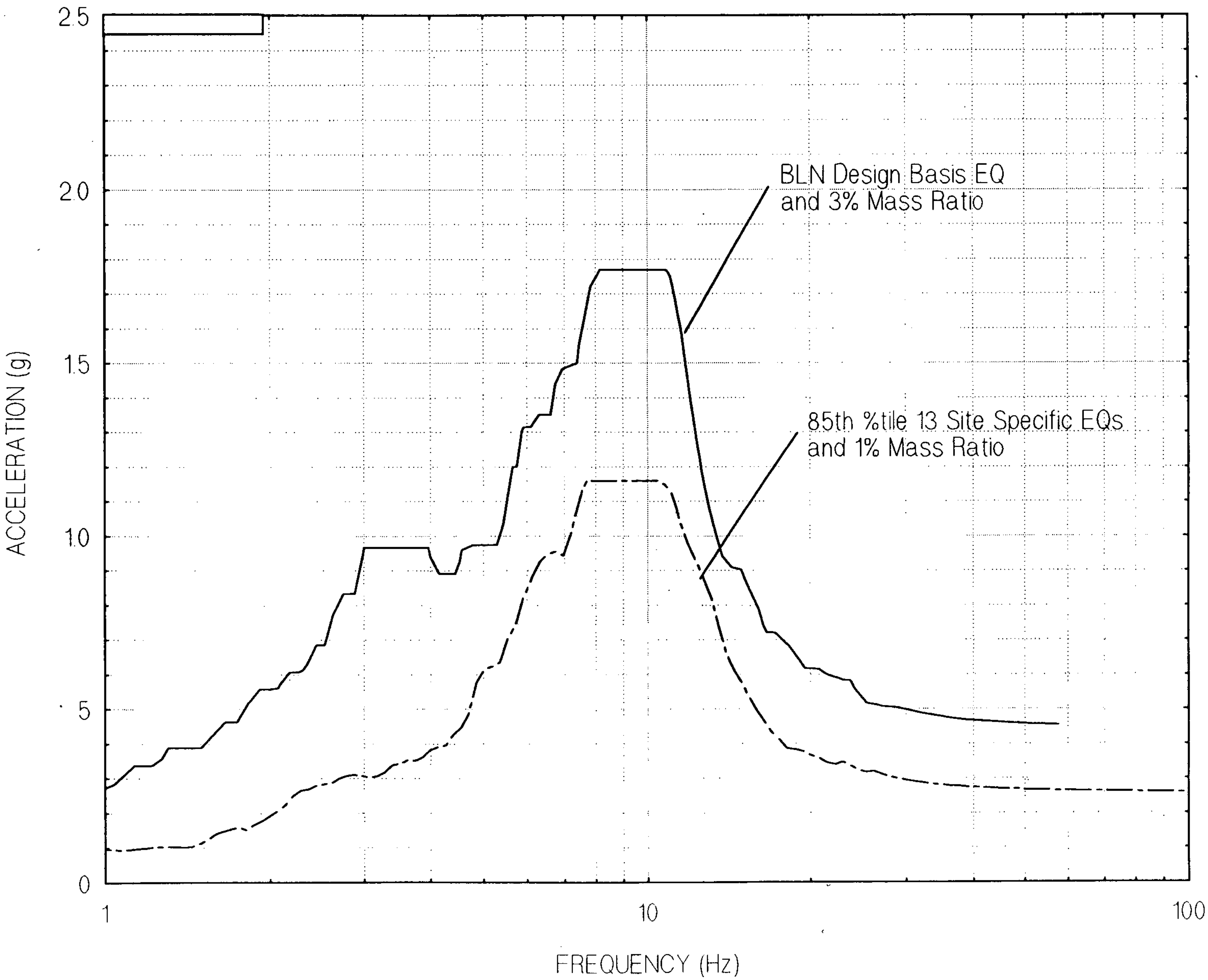


FIGURE 3-2

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equipment Damping - Vertical Acceleration Time History (SSE)
Auxiliary-Control Building - Elev 628 ft - Node 903 - Floor Freq 14 3 Hz - West Stick

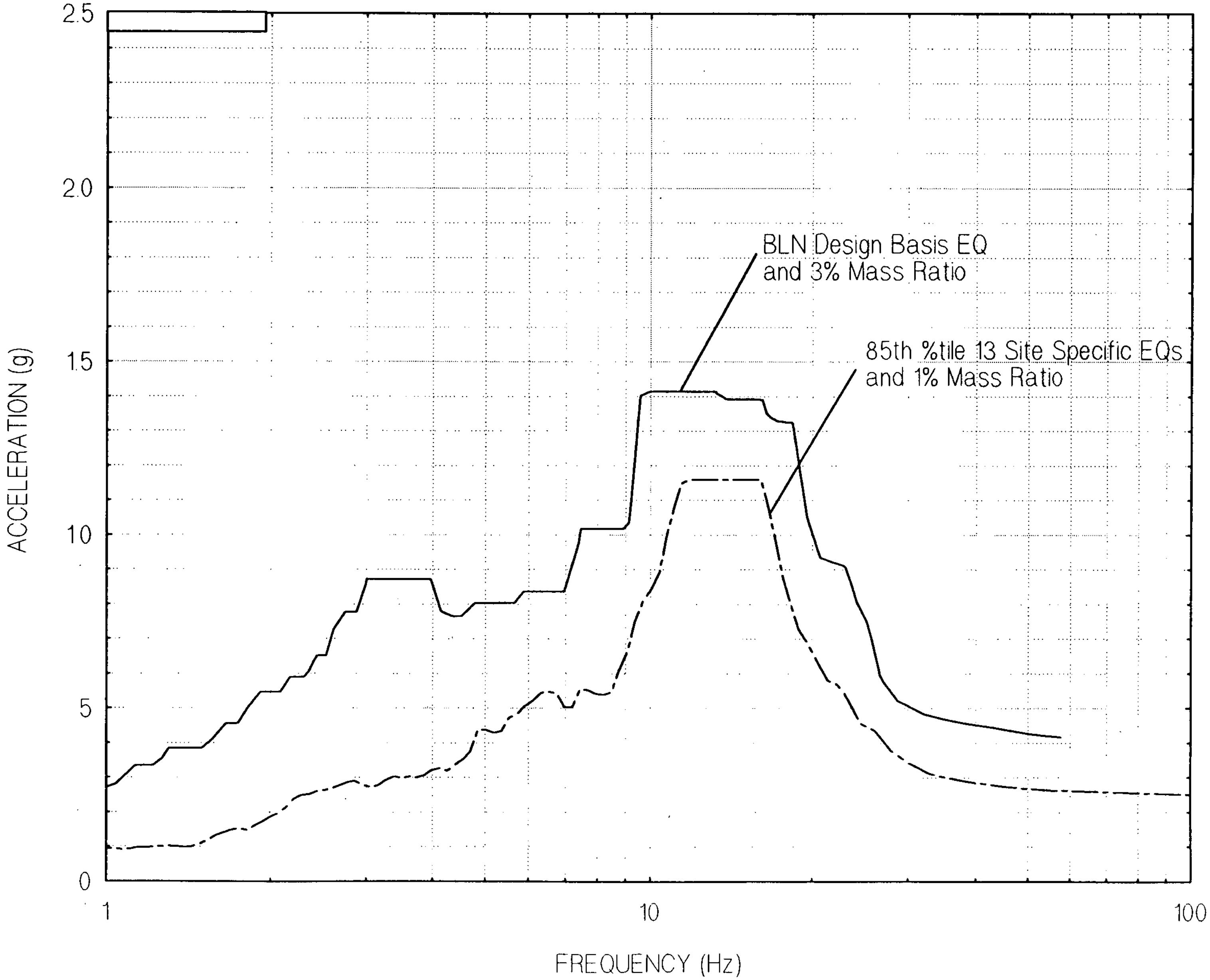


FIGURE 3-3

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equipment Damping - Vertical Acceleration Time History (SSE)
Auxiliary-Control Building - Elev. 628 ft - Node 904 - Floor Freq. 21.0 Hz - West Stick

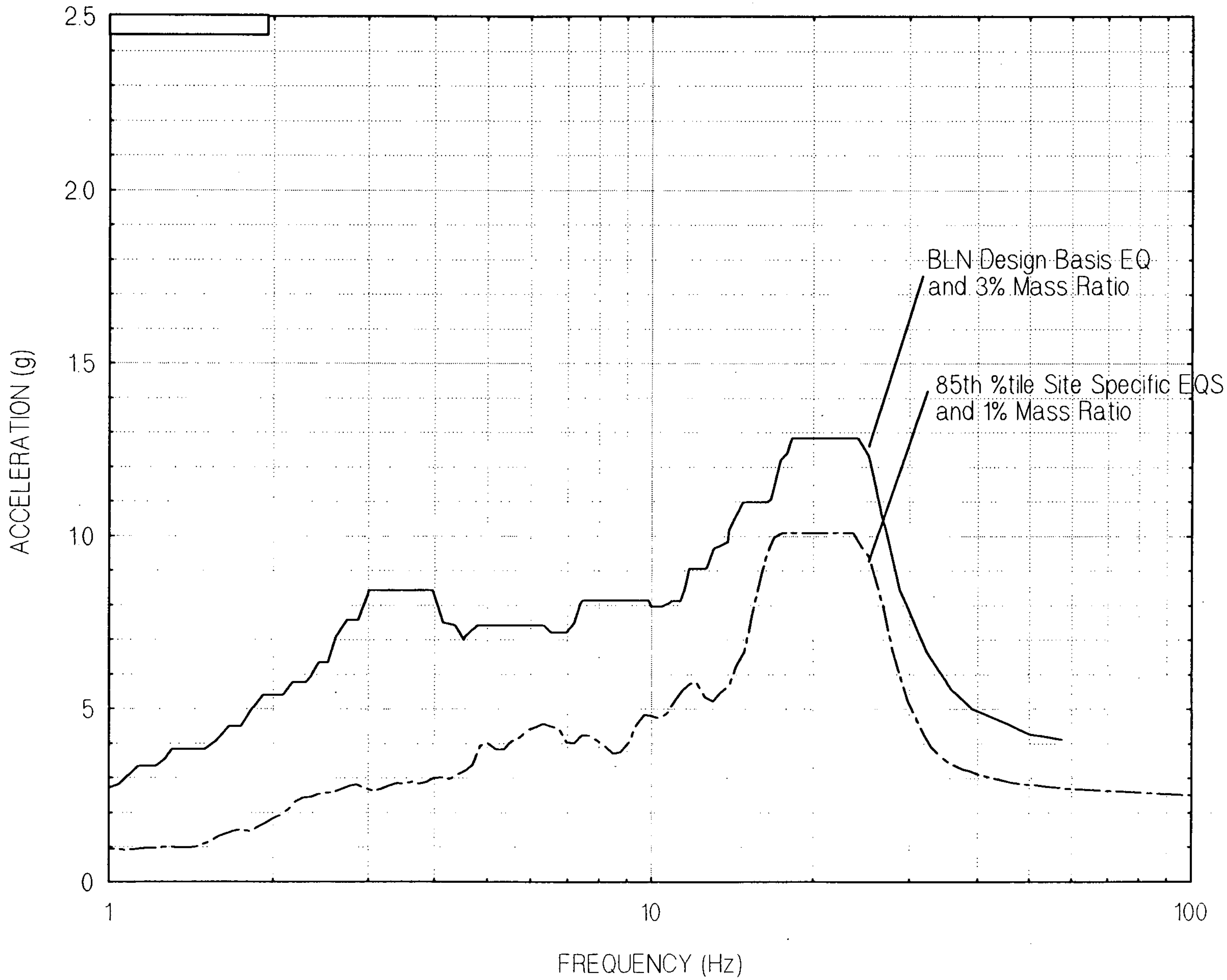


FIGURE 3-4

Lumped-Mass Model Properties
Auxiliary Control Building – West stick

Elevation	Centroid (ft)		Shear Center (ft)		Axial Areas (ft²)	Shear Areas (ft²)		Moment of Inertias *10**6 (ft**4)			Weight Center (ft)		Weight kips	Weight Moment of Inertias *10**6 (k-ft²)
(ft)	Xc	Yc	Xs	Ys	A	Ax	Ay	Ixx	Iyy	Izz	Xm	Ym	Wx=Wy=Wz	Jzz
704											0.00	123.60	27,016	415
	0.00	121.37	0.00	99.59	5,320	2,742	2,574	21.3	72.6	50.1				
699											0.10	130.00	5,989	123
	0.00	121.37	0.00	99.59	5,320	2,742	2,574	21.3	72.6	50.1				
692											1.90	102.00	6,597	173
	0.00	99.61	0.00	72.96	6,560	3,822	2,754	29.6	86.7	59.8				
685											0.70	86.30	31,653	531
	0.12	95.72	-0.33	68.60	6,930	4,161	2,772	30.8	91.8	56.5				
672											1.60	86.40	11,012	220
	-2.82	93.31	-1.52	68.59	7,070	4,184	2,890	31.1	91.3	60.3				
668											-2.70	119.40	27,241	454
	-4.29	126.44	-3.34	99.56	11,300	5,412	5,862	54.7	92.1	83.8				
658											-3.30	132.90	21,284	328
	-4.10	126.95	-2.96	100.57	11,500	5,492	5,970	54.9	92.8	84.7				
848											-0.60	121.00	41,860	847
	0.04	126.37	0.07	108.74	11,400	6,267	5,136	49.0	94.2	68.0				
636											-0.90	131.70	21,059	332
	0.73	125.93	0.67	109.59	11,860	6,343	5,492	49.6	92.1	86.0				
628											0.30	119.70	44,114	747
	0.27	123.83	0.57	103.38	12,400	5,968	6,468	52.0	96.4	109.0				
619											0.10	117.40	18,322	325
	0.39	101.67	0.72	61.14	10,400	5,030	5,366	23.5	92.7	89.6				
610														

Concrete Properties

Modulus of Elasticity =576,000 k/ft²

Poisson's Ratio = 0.15

+X = SOUTH +Y = EAST

Lumped-Mass Model Properties
Auxiliary Control Building – East stick

Elevation	Centroid (ft)		Shear Center (ft)		Axial Areas (ft²)	Shear Areas (ft²)		Moment of Inertias *10**6 (ft**4)			Weight Center (ft)		Weight kips	Weight Moment of Inertias *10**6 (k-ft²)
(ft)	Xc	Yc	Xs	Ys	A	Ax	Ay	Ixx	Iyy	Izz	Xm	Ym	Wx=Wy=Wz	Jzz
726											0.00	290.30	3,832	22
	0.00	334.52	0.00	339.33	659	384	475	0.96	0.39	1.89				
714											0.00	279.10	2,392	17
	0.00	334.52	0.00	339.33	659	384	475	0.96	0.39	1.69				
704											0.00	288.50	2,492	10
	0.00	316.22	0.00	341.26	1,510	489	1,025	4.52	1.99	2.01				
699											0.00	327.00	1,732	7
	0.00	316.22	0.00	341.26	1,510	489	1,025	4.52	1.99	2.01				
692											0.00	310.90	1,684	8
	0.00	316.22	0.00	341.26	1,510	489	1,025	4.52	1.99	2.01				
685											1.30	312.40	2,363	11
	0.00	316.22	0.00	342.94	1,510	507	1,007	4.37	2.04	2.02				
672											1.60	316.39	1,922	8
	0.00	316.83	0.00	342.94	1,490	507	979	4.37	2.04	1.96				
668											-2.00	316.70	6,247	14
	-0.10	305.78	-1.07	335.41	2,370	677	1,496	5.29	2.53	2.70				
658											-2.40	309.60	5,603	15
	-0.09	305.70	-1.07	332.53	2,460	964	1,496	5.29	2.50	2.76				
648											-3.20	317.80	9,016	21
	-0.01	301.19	0.73	315.70	2,730	1,289	1,441	5.70	3.01	2.61				
638											-1.00	300.60	4,733	12
	-0.26	301.46	-0.38	315.61	2,810	1,324	1,484	5.73	3.00	2.87				
628											-1.00	300.60	3,767	10
	-0.01	300.63	0.72	315.70	2,740	1,289	1,456	5.78	3.01	2.81				
622														

<u>Concrete Properties</u>

Modulus of Elasticity =576,000 k/ft²

Poisson's Ratio = 0.15

+X = SOUTH +Y = EAST

NRC Question No. 3:

As the reduction of equipment specific FFRS are sensitive to the relative impedances (and mass ratios), the use of one mass ratio (i.e. 3%) is not justifiable. Provide a systematic procedure which would be representative of the actual equipment impedances in arriving at the vertical seismic loads on the equipment.

TVA Response:

Systematic procedures have been developed for the walkdown of the plant to identify flexible floors and attached commodities, and for the computation of masses of the commodities.

A walkdown performed for the vertically flexible floors in the Auxiliary-Control Building was performed and the corresponding mass ratios computed (see Appendices A and E of the December 1993 report).

BLN believes that the use of a single equipment mass ratio is justified given that:

- Use of a single mass ratio greatly simplifies the analytical effort to develop production FFRS and provides a less complex process than one of using multiple mass ratio/FRS values on the same building elevation on a large production engineering project.

- Walkdown results of vertically flexible floors in the Auxiliary-Control Building (ACB) found actual mass ratios to vary between 0.1% to 5.6% with an average of 1.5%

- The magnitude of the FFRS reduce with increases in the mass ratio

- A mass ratio value of 1% is clearly conservative for 70% of the flexible floor slabs (i.e., the actual mass ratio is 1% or larger)

- Slabs with a mass ratios less than 1% are addressed by conservatively enveloping the 1% MR site specific FFRS.

- BLN design basis FFRS for 3% mass ratio conservatively envelop 1% mass ratio site specific FFRS (Refer to Figures 3-1 through 3.4).

- Based on the above, use of the single mass ratio (i.e., 3%), proposed by BLN is justified.

NRC Question No. 4:

Appendix A (Ref. A) - Use of the floor fundamental frequencies to identify flexible floors is reasonable. However, provide justification for using only the fundamental mode masses in the SDOF oscillators.

TVA Response:

A STARDYNE dynamic finite element analysis of a typical flexible floor slab (i.e., S628-02) demonstrates that use of only the first mode provides over 90% of the total response when 10 modes are considered.

NRC Question No. 5:

All floors in the ACB have some rigid floor-slabs and some flexible floor-slabs. Provide information regarding the vertical seismic input utilized (specifically, at the interface between the rigid and flexible floor-slabs) in verifying the design of the floor systems, and the rigid and flexible equipment supported by floor systems. Also, provide information related to combining the responses due to three components of the design basis earthquake in the verification of the adequacy of the floor supported equipment and commodities.

TVA Response:

For the design of the reinforced concrete rigid and flexible floor slabs is procedurally identical; the maximum vertical response of the slab being considered is used to develop design forces and moments. The maximum response corresponds to the zero period acceleration from the corresponding FRS.

Procedurally there is no difference between verifying the design of equipment and systems supported on rigid floor slab areas and those on flexible floor slab areas. The only difference is in the input motions (i.e., the floor response spectra).

When the response spectra method is used, the maximum structural response due to each of the three components of earthquake motion is combined by taking the square root of the sum of the squares (SRSS), of the maximum codirectional responses caused by each of the three components of the earthquake motion at a particular point.

NRC Question No. 6:

At a number of places in the report, it is indicated that various procedures utilized (e.g. ESI methodology) have been accepted by the staff during Watts Bar reviews. Provide information related to the differences in the structural configurations, procedures, modelling parameters, methods of utilizing the mass-ratios, etc. that are finally utilized at Watts Bar and those proposed to be used at Bellefonte.

TVA Response:

PARAMETER	WATTS BAR	BELLEFONTE
Structure Damping	Regulatory Guide 1.61 damping, i.e., concrete members used 7% for SSE.	Regulatory Guide 1.61 damping, i.e., concrete members used 4% for OBE and 7% for SSE.
Concrete Modulus Of Elasticity (E_c)	590,000 ksf	576,000 ksf
Poisson's Ratio (υ)	0.167	0.15
Design Basis Ground Response Spectra	Modified Newmark Spectrum normalized to 0.18g for horizontal motion and 0.12g for vertical motion for the SSE.	Regulatory Guide 1.60 normalized to 0.18g for the SSE.
Site Specific Ground Response Spectrum	Defined at the 84th %tile NEP level for the 13 site specific time-histories.	Same
Basis Used To Study Floor Flexibility Effects	Site specific Ground Response Spectrum	Same
Input Time Histories Used In The Study	Site Specific Synthetic Time-Histories	The 13 actual site specific vertical time histories
Shear Wave Velocity Of Supporting Media (V_s)	Approximately 6,000 fps	Approximately 10,000 fps
Method Of SSI Analysis	Used SASSI and CLASSI computer codes to determine SSI effects.	Fixed based building model. No SSI effects were accounted for.
Definition Of Flexible Floor	Floors with fundamental frequencies less than 33 Hz.	Same
Building Model	Linear Elastic Lumped Mass Stick Model	Same
Flexible Floor Models	Linear Elastic Single-Degree-of-Freedom Oscillators	Same

PARAMETER	WATTS BAR	BELLEFONTE
Flexible Floor Frequencies	Manually computed based on the fundamental mode of the slab.	Same
Attachment Of Flexible Floor Models to Building Model	Attached to their respective elevations of the building model with a rigid link to the extreme edge of the building.	Attached to the centers of mass at their respective elevations of the building model.
Equipment-Structure - Interaction	Sub-structuring technique based on the Two-Step analysis	Same
	STEP 1:	
	(A) Compute dynamic force-displacement relationship (Impedance Functions) of the supporting flexible floor slabs including the overall building model.	(A) Same
	(B) Compute vertical time-history responses at the flexible floor slab mass points (without the presence of the subsystems) due to the combined effects of Set B SSE horizontal and vertical time histories.	(B) Vertical time-history responses at the flexible floor slab mass points (without the presence of the subsystems) were computed due to the 13 vertical site specific earthquake records.
	Note: The Set B time histories correspond to the site specific response spectra.	

PARAMETER	WATTS BAR	BELLEFONTE
	STEP 2: (A) Develop a computer model of a single-degree-of-freedom (SDOF) oscillator consisting of the subsystem mass. (B) Attach the spring of the SDOF oscillator, representing the subsystem, in series with the impedance functions computed in STEP 1(A). (C) Use the vertical time-history computed in STEP 1(B) as input to the base of the combined SDOF oscillator and compute responses. Maximum acceleration responses of the subsystem are obtained based on the selected mass ratio of subsystem to flexible floor slab, subsystem damping value, and subsystem frequencies.	(A) Same (B) Same (C) Same
Floor Slab Frequencies Evaluated	Simplifying assumption was made that floor slabs with fundamental frequencies within +/- 15% would respond the same. Therefore, floor slabs were consolidated into groups within +/- 15% of each other. One SDOF oscillator was used to represent the slabs in each group.	Same
Frequency Range of Flexible Commodity Masses	8 to 33 Hz	Same

PARAMETER	WATTS BAR	BELLEFONTE
Definition "Frequency Windows"	The simplifying assumption was made that modal masses with closely spaced frequencies will interact with the flexible floor mass in the same frequency range. That modal mass within +/- 15% of a given frequency will act together to affect the subsystem response. Therefore, a series of "frequency windows" were defined over the flexible commodity frequency range (i.e., 8 to 33 Hz) with central values which will interact with the floor slab at the same frequency. Using 8 Hz as the lowest central value leads to five (5) frequency windows.	Same
Range Of Actual Mass Ratios	2.1 to 19.2	0 to 5.8
Mass Ratio To be Used For Evaluation Sub - Systems Attached to Flexible Portions Floor Slabs	ACB equipment: 5% ACB cable tray: 5% ACB piping: 5% ACB HVAC ducts: 2% ACB conduit less than 4" diam: 1% ACB conduit equal or greater than 4" diam: 2%	3%
Flexible Commodity Mass	Analogy made to the first mode of a uniformly loaded slab. That is, 65% of the total flexible commodity mass was assumed to be uniformly spread over the five frequency windows. The remaining 35% of the total commodity mass plus the equipment mass (which is generally relatively heavy and rigid), were considered to act with the slab mass.	Same

PARAMETER	WATTS BAR	BELLEFONTE
Flexible Floor Mass	The 35% of the total commodity mass plus the equipment mass that was considered to act with the slab mass (i.e. from above item) was assumed uniformly distributed over the floor slab. 65% of the combined floor dead weight and commodity/equipment is taken as the "flexible floor mass."	Same
Definition of "Mass Ratio"	The "Mass Ratio" is the ratio of flexible commodity modal mass to the effective flexible modal mass of the floor slab. Two formulations were used to compute the "mass ratio." (1) The flexible commodity mass within one "frequency window" is divided by the flexible floor mass, from above item. (2) The flexible commodity mass within one "frequency window" is divided by sum of the flexible floor mass and the flexible commodity mass from the over four :frequency windows."	Same Same
Peak Broadening Of FRS	+/- 15%	+/- 15%
Results of the Floor Flexibility Study	Flexible floor response spectra (FFRS) were not incorporated into the design basis. The study demonstrated that the commodities had sufficient design margin.	The final FRS will incorporate the local amplifications of the rigid FRS corresponding to FFRS for a mass ratio of 3% and the BLN design basis synthetic vertical time-history.

ENCLOSURE 2

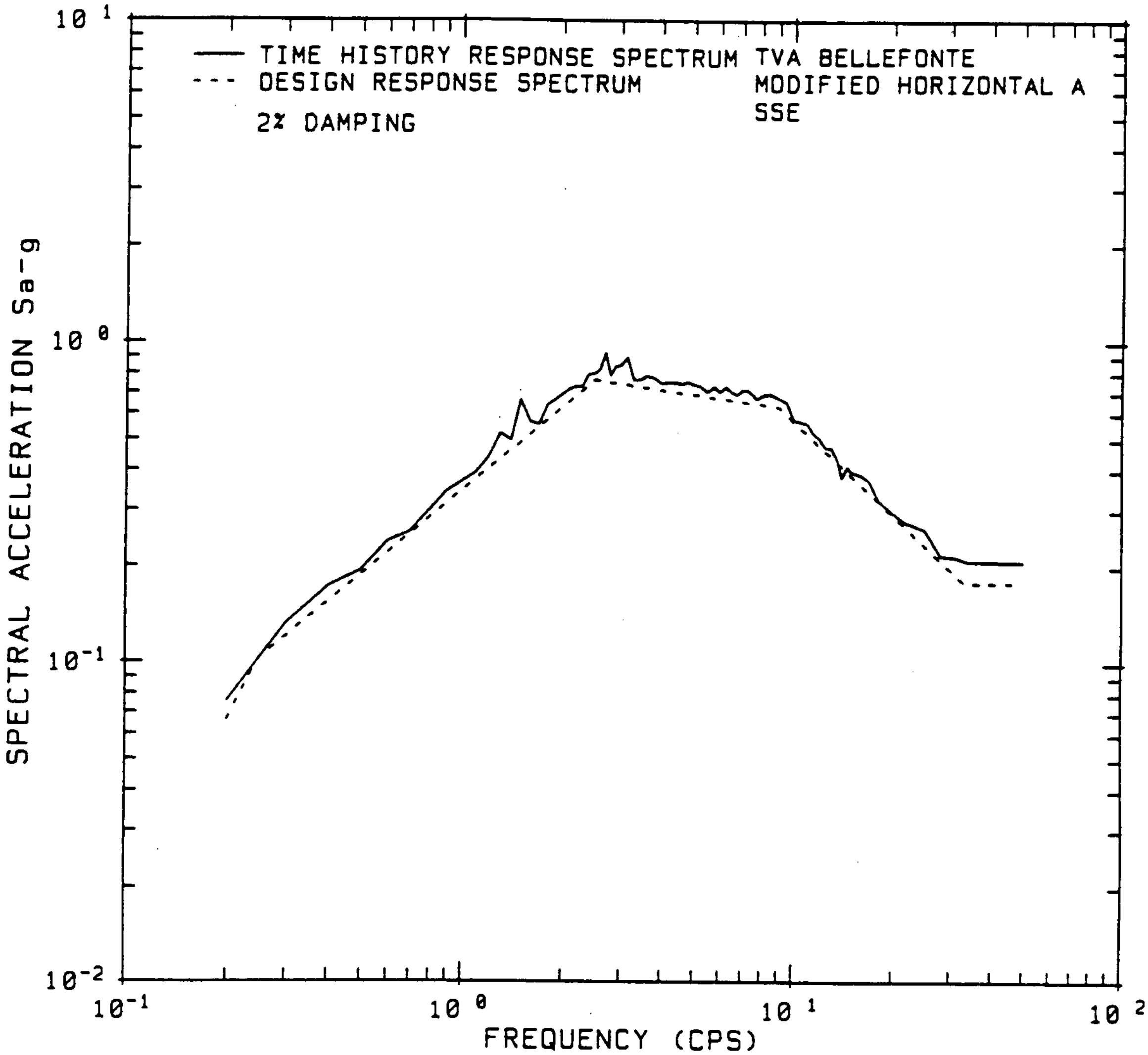
INFORMATION REQUESTED BY THE NRC DURING THE MARCH 24, 1994 MEETING

NRC Item No. 1:

Provide plots of the power spectral density functions (PSDFs), for the BLN design basis SSE synthetic acceleration time-histories to verify they meet the Standard Review Plan (SRP) 3.7.1 target PSD enveloping guidance.

TVA Response:

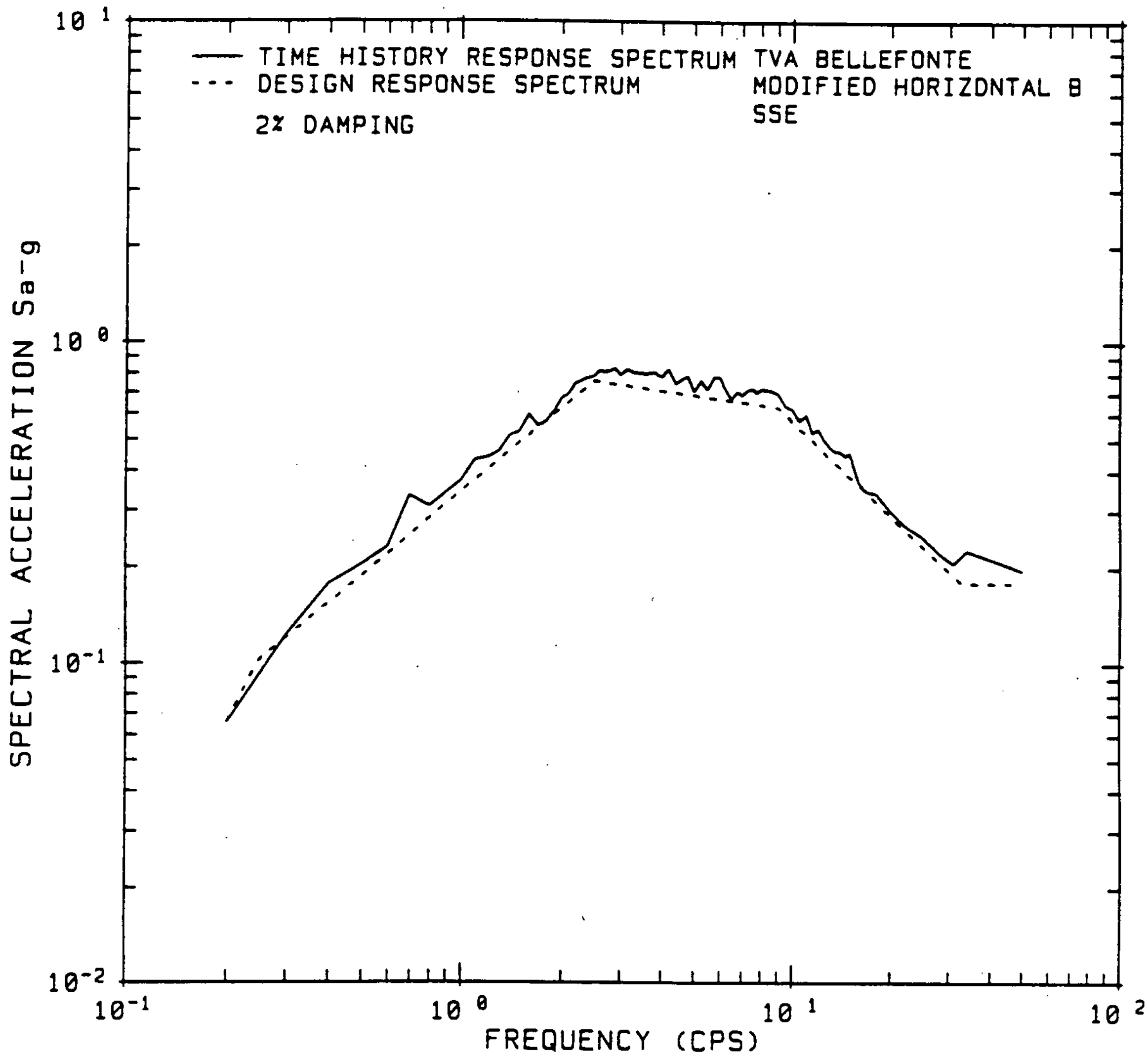
Discussion of the design basis ground response spectra (i.e., Regulatory Guide 1.60), development of the three synthetic time-histories, computation of the corresponding ground response spectra and power spectral density functions (PSDFs), and meeting of SRP 3.7.1 response spectra and PSD enveloping guidance is provided in Sections 3.7.1.1 and 3.7.1.2 of the BLN FSAR (Amendment 30). Plots of the synthetic time-histories, design response spectra, and PSDFs are provided in FSAR Figures 3.7.1-1 through 3.7.1.27. [See attached sheets for examples.]



Amendment 30

BELLEFONTE NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT

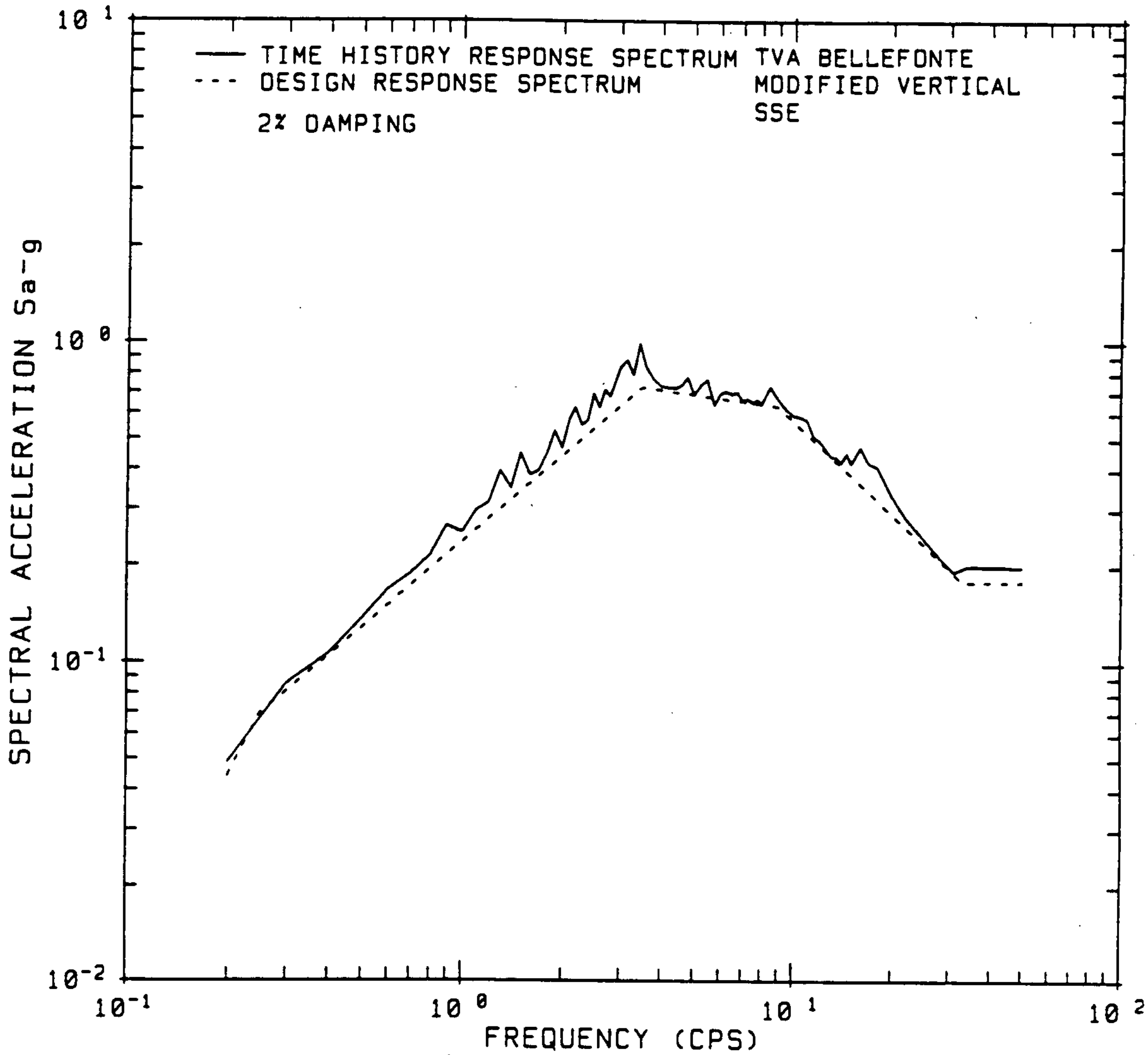
SAFE SHUTDOWN EARTHQUAKE
DESIGN RESPONSE SPECTRA
HORIZONTAL MOTION A
ROCK-SUPPORTED STRUCTURES
2% DAMPING
FIGURE 3.7.1-5



Amendment 30

BELLEFONTE NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT

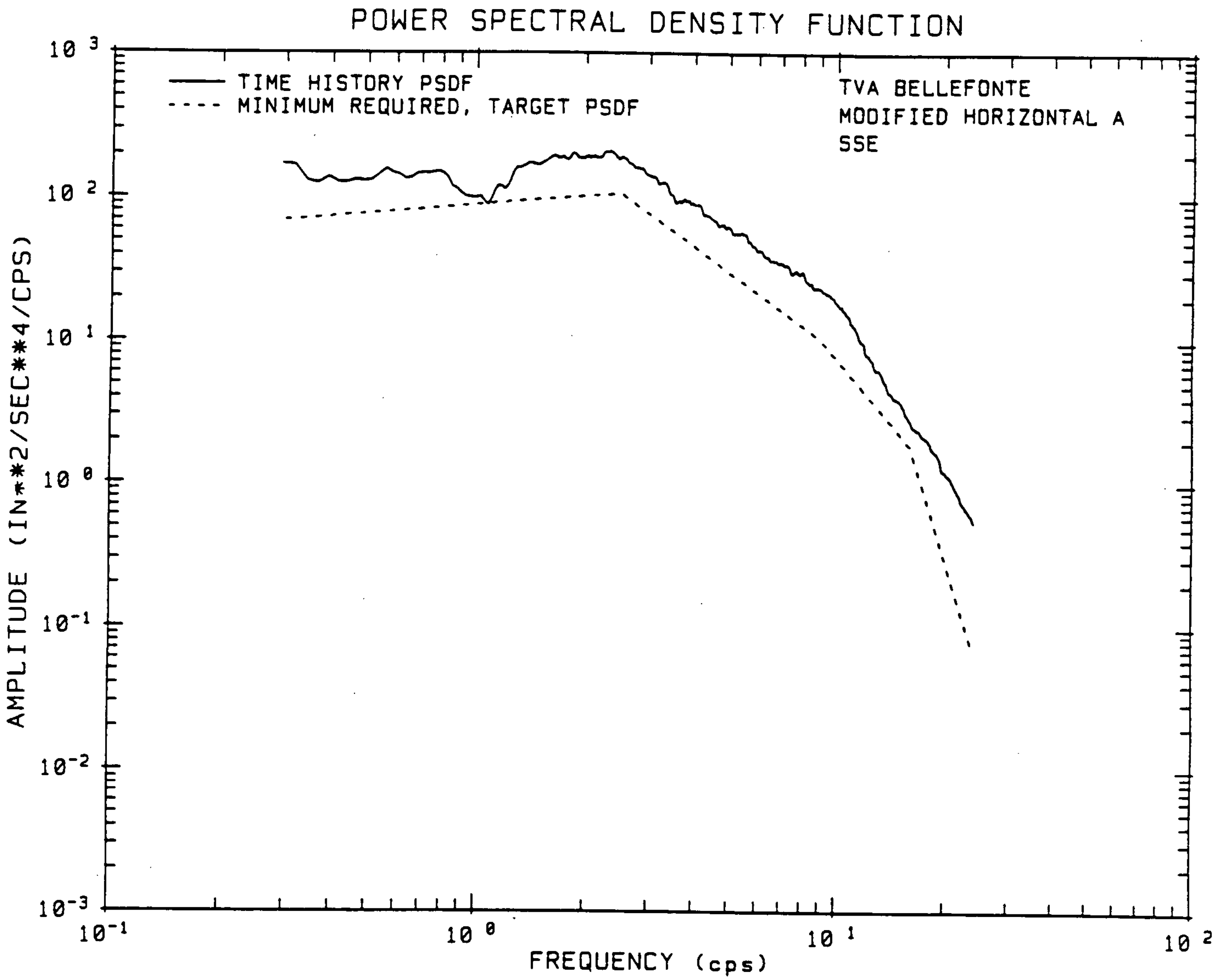
SAFE SHUTDOWN EARTHQUAKE
DESIGN RESPONSE SPECTRA
HORIZONTAL MOTION B
ROCK-SUPPORTED STRUCTURES
2% DAMPING
FIGURE 3.7.1-12



Amendment 30

BELLEFONTE NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT

SAFE SHUTDOWN EARTHQUAKE
DESIGN RESPONSE SPECTRA
VERTICAL MOTION
ROCK-SUPPORTED STRUCTURES
2% DAMPING
FIGURE 3.7.1-19

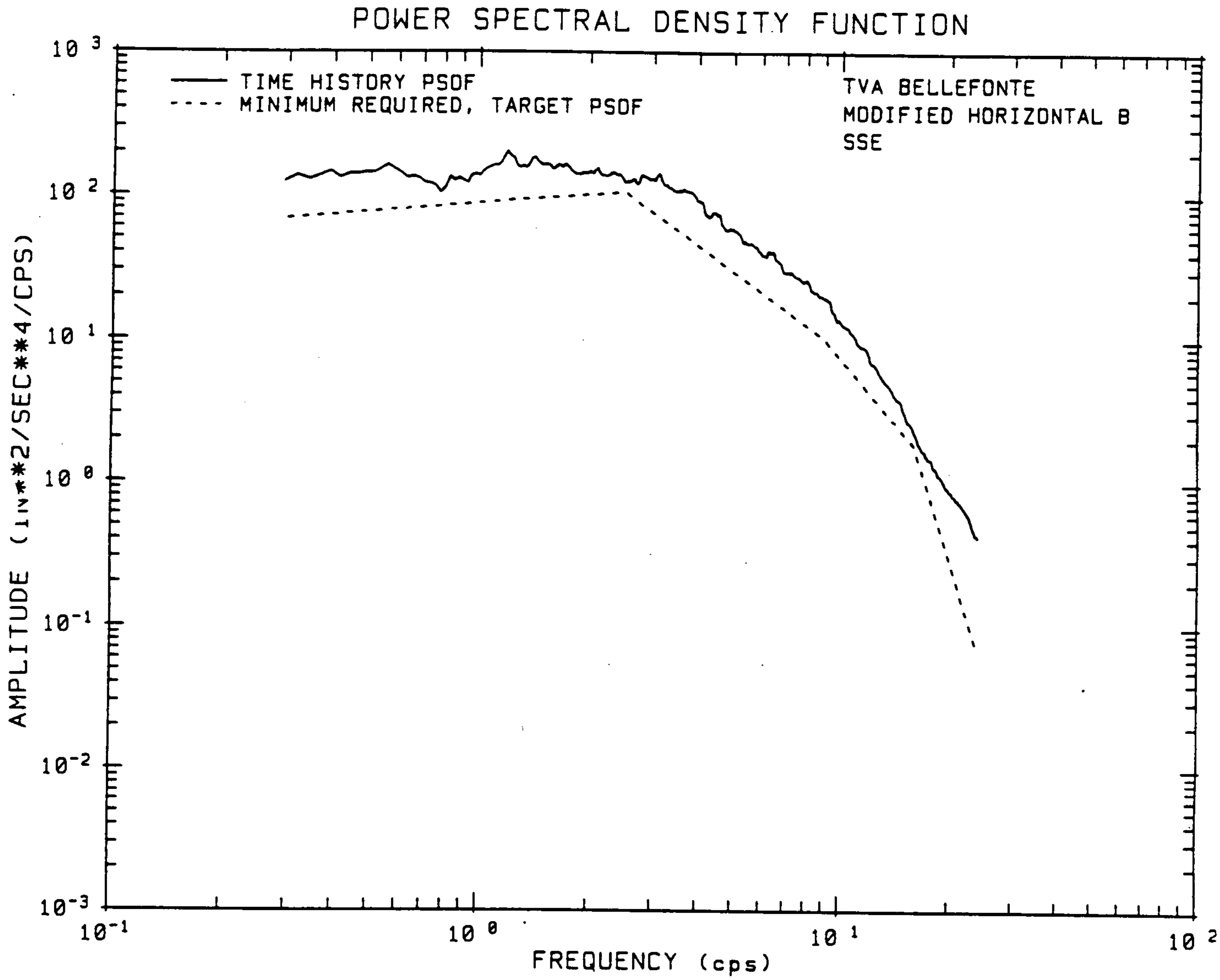


Amendment 30

BELLEFONTE NUCLEAR PLANT FINAL SAFETY ANALYSIS REPORT

SAFE SHUTDOWN EARTHQUAKE COMPARISON OF PSDFs FOR HORIZONTAL A TIME HISTORY AND MINIMUM REQUIRED PSDFs

FIGURE 3.7.1-25

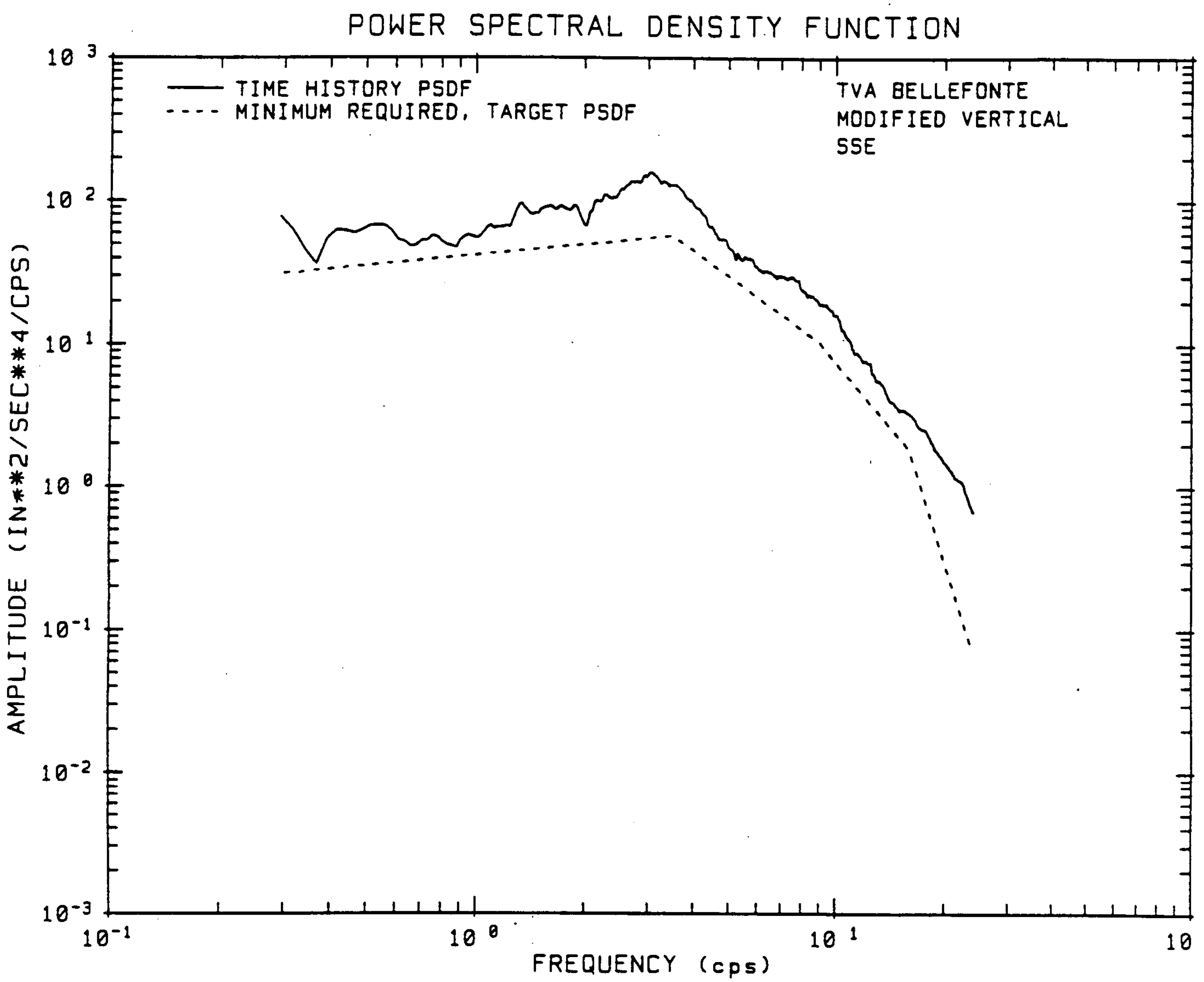


Amendment 30

BELLEFONTE NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT

SAFE SHUTDOWN EARTHQUAKE
COMPARISON OF PSDFs FOR
HORIZONTAL B TIME HISTORY
AND MINIMUM REQUIRED PSDFs

FIGURE 3.7.1-26



Amendment 30

BELLEFONTE NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT

SAFE SHUTDOWN EARTHQUAKE
COMPARISON OF VERTICAL
TIME HISTORY PSDFs
AND MINIMUM REQUIRED PSDFs

FIGURE 3.7.1-27

NRC Item No. 2:

Provide a summary of the equivalent mass and stiffness values for each of the single degree of freedom (SDOF) models used to represent the flexible floors in the Auxiliary-Control Building.

TVA Response:

ELEV. 628' Floor Oscillator Consolidation

STICK and NODE No.	FREQUENCY f(Hz)			FLOOR SLAB ID	FLOOR SLAB EFFECTIVE WT, We (kips)	SDOF WT. Σ We (kips)	SDOF SPRING, Ke (k/ft)*
	SDOF	AVERAGE RANGE	FLOOR SLAB				
WEST 901	6.8	5.8 – 7.8	6.4 6.8 7.1	S628-17 S628-06 S628-05	368 1,366 650	2,384	135,100
902	9.6	8.2 – 11.0	9.6	S628-01	1,012	1012	114,300
903	14.3	12.2 – 16.4	13.6 14.0 14.7 14.9	S628-02 S628-10 S628-13 S628-03	696 682 340 272	1,990	498,900
904	21.0	17.9 – 24.0	19.8 20.8 23.6	S628-09 S628-04 S628-15	1,006 1,280 392	2,678	1,447,900
905	28.0	24.0 – 32.2	28.3	S628-18	428	428	411,400
				TOTAL	8,492	8,492	

* $K_e = (\Sigma W_e/g)*(2\pi f)^2 = 1.226\ (\Sigma W_e)*(f)^2$

ENCLOSURE 2 (continued)

ELEV. 648' Floor Oscillator Consolidation

STICK and NODE No.	FREQUENCY f(Hz)			FLOOR SLAB ID	FLOOR SLAB EFFECTIVE WT, We (kips)	SDOF WT. Σ We (kips)	SDOF SPRING, Ke (k/ft)*
	SDOF	AVERAGE RANGE	FLOOR SLAB				
WEST 911	5.1	4.3 – 5.9	4.6 5.7 5.7	S648-06 S648-02 S648-11	1,506 852 1,153	3,511	111,900
912	6.8	5.9 – 7.8	6.8	S648-03	270	270	15,310
913	9.0	8.0 – 10.8	9.4 9.3	S648-10 S648-01	3,122 240	3,362	364,200
914	18.0	15.3 – 19.3	17.7	S648-04	190	190	75,500
915	21.0	19.3 – 24.2	22.1	S648-05	1,134	1,134	613,100
				TOTAL	8,467	8,467	

STICK and NODE No.	FREQUENCY f(Hz)			FLOOR SLAB ID	FLOOR SLAB EFFECTIVE WT, We (kips)	SDOF WT. Σ We (kips)	SDOF SPRING, Ke (k/ft)*
	SDOF	RANGE	FLOOR SLAB				
EAST 916	6.0	5.1 – 6.9	6.0	S648-14	1,915	1,915	84,500
				TOTAL	1,915	1,915	

* $K_e = (\Sigma W_e/g)*(2\pi f)^2 = 1.226\ (\Sigma W_e)*(f)^2$

ELEV. 668' Floor Oscillator Consolidation

STICK and NODE No.	FREQUENCY f(Hz) SDOF	AVERAGE RANGE	FLOOR SLAB	FLOOR SLAB ID	FLOOR SLAB EFFECTIVE WT, We (kips)	SDOF WT. Σ We (kips)	SDOF SPRING, Ke (k/ft)*
WEST 921	5.0	4.3 5.8	4.6 4.7 5.4	S668-05 S668-08 S668-06	934 675 888	2,497	76,500
922	11.5	9.8 12.6	11.5	S668-01	1,824	1,824	295,700
923	14.0	12.6 16.1	13.5	S668-07	266	266	63,900
924	21.0	17.9 23.8	22.1 22.3	S668-04 S668-12	751 134	885	478,500
925	27.5	23.8 31.6	27.5 26.8	S668-09 S668-13	602 113	715	662,900
				TOTAL	6,187	6,187	

STICK and NODE No.	FREQUENCY f(Hz) SDOF	RANGE	FLOOR SLAB	FLOOR SLAB ID	FLOOR SLAB EFFECTIVE WT, We (kips)	SDOF WT. Σ We (kips)	SDOF SPRING, Ke (k/ft)*
EAST 926	16.0	13.6 18.4	15.8	S668-11	710	710	222,800
927	31.3	26.4 35.7	31.3	S668-10	545	545	654,600
				TOTAL	1,255	1,255	

* $K_e = (\Sigma W_e/g)*(2\pi f)^2 = 1.226\ (\Sigma W_e)*(f)^2$

ENCLOSURE 2 (continued)

ELEV. 685' Floor Oscillator Consolidation

STICK and NODE No.	FREQUENCY f(Hz)			FLOOR SLAB ID	FLOOR SLAB EFFECTIVE WT, We (kips)	SDOF WT. Σ We (kips)	SDOF SPRING, Ke (k/ft)*
	SDOF	AVERAGE RANGE	FLOOR SLAB				
WEST 931	5.2	4.4 5.8	5.2	S685-07	1,024	1,024	33,910
932	6.6	5.8 7.5	6.6 6.7	S685-09 S685-08	102 1,234	1,336	71,300
933	8.6	7.5 10.1	8.6 8.6	S685-01 S685-10	3,299 142	3,441	312,000
934	12.0	10.1 13.8	11.8 13.0	S685-11 S685-06	539 171	710	125,300
935	21.0	13.8 24.0	22.2	S-685-02	186	186	100,600
936	28.0	24.0 32.2	27.9	S685-12	200	200	192,200
				TOTAL	6,897	6,897	

* $K_e = (\Sigma W_e/g)*(2\pi f)^2 = 1.226\ (\Sigma W_e)*(f)^2$

NRC Item No. 3:

Provide the basis for using 65% of the total floor mass as the effective mass representing a flexible floor.

TVA Response:

The derivation of the equivalent SDOF oscillators which represent the vertically flexible floors is addressed in Appendix-B of the December 1993 report. Tables A-1 through A-4 of the report summarize the total floor weights (W_t) and the effective flexible floor weights (W_e).

The percentage of the total floor mass used to represent the effective mass of a vertically flexible floor depends on the floor's dimensions and boundary conditions. For a rectangular floor with simple supports approximately 65% of the total slab mass is associated with the first mode; 50% for fixed supports (e.g., slab S628-02 which is 28'x34'x1'). It can be seen from comparison of W_t and W_e values for each slab in Tables A-1 through A-4 that computed effective flexible floor weights range from 48% to 80% of W_t; the average of this range is approximately 65%.

The commodities are also assumed to be uniformly distributed over the floor slabs. Therefore, a simplifying assumption is made in computing the effective flexible mass of the commodities; i.e., 65% of the total commodity mass is taken to be in the flexible range; 35% in the rigid range. Note, that this analogy is consistent with that used for Watts Bar evaluations.

TABLE A-1
FLEXIBLE FLOOR SLABS AT ELEVATION 628.0 FT.

SLAB ID	SLAB LOCATION* (COL. LINE)	APPROXIMATE SLAB DIMENSION (ft)	NO. OF SLABS	DL/LL (psf)	Wt (kip)	We (kip)	f (Hz)
S628-01	M-P-C11-C13 N-P-C3-C5	50x45x1	2	150/75	506	334	9.6
S628-02	N-P-C5-C11	28x34x1	6	150/75	214	116	13.6
S628-03	N-P-C1-C3 M-N-C1-C3	50x22.5x1	2	150/75	253	136	14.9
S628-04	P-Q-A1-A14	42x18x1	10	150/75	170	128	20.8
S628-05	Q-R-A1-A3 Q-R-A12-A14	71x34.5x1	2	150/75	551	325	7.1
S628-06	Q-R-A3-A6 Q-R-A9-A12	91x34.5x2	2	300/75	1177	683	6.8
S628-07	R-T-A1-A2 R-T-A13-A14	17.5x46x3	-	300/75	-	-	>33.3
S628-08	R-T-A1-A2 R-T-A13-A14	18.3x46x3	-	450/75	-	-	>33.0
S628-09	R-T-A2-A3 R-T-A12-A13	35.3x46x3	2	450/75	853	503	19.8
S628-10	R-T-A3-A4 R-T-A11-A12	33.5x46x2	2	300/75	578	341	14.0
S628-11	R-T-A4-A5 R-T-A10-A11	18x46x3	-	450/75	-	-	>33.0
S628-12	S-T-A4-A5 S-T-A10-A11	15.3x29.5x1	-	150/75	-	-	>33.0
S628-13	R-T-A5-A6 R-T-A9-A10	21.8x28.3x1	4	150/75	139	85	14.7
S628-14	Q-R-A8-A10	45.3x23x4	-	600/75	-	-	>33.0
S628-15	Q-S-A7-A8 Q-S-A6-A7	26x47.3x1.5	2	225/75	369	196	23.6
S628-16	R-T-A8-A9	26x40.5x3	-	450/75	-	-	>33.0
S628-17	S-U-A6-A8	52x51.5x1	1	150/75	603	368	6.4
S628-18	U-W-A6-A7 U-W-A8-A9	26x38.5x3	2	300/75	375	214	28.3
S628-19	U-W-A7-A8	26x38.5x3	-	450/75	-	-	>33.0

Notes:
DL = Dead load. LL = Live load. Wt = Floor slab weight of one slab panel. f = Fundamental vertical frequency.
We = Effective floor slab weight of one slab panel associated with the fundamental mode.
*Approximate slab location to the nearest column line.

TABLE A-2
FLEXIBLE FLOOR SLABS AT ELEVATION 648.0 FT. AND VICINITY (ELEV. 641.0 FT AND ELEV. 661.0 FT)

SLAB ID	SLAB LOCATION* (COL. LINE)	APPROXIMATE SLAB DIMENSION (ft)	NO. OF SLABS	DL/LL (psf)	Wt (kip)	We (kip)	f (Hz)
S648-01	N-P-C6-C8	56x34x1	1	150/50	381	240	9.3
S648-02	M-P-C3-C6 M-P-C8-C11	83x45x1	2	150/50	747	426	5.7
S648-03	M-P-C11-C13	50x45x1	1	150/50	450	270	6.8
S648-04	M-N-C1-C3 N-P-C1-C3	41.5x22.5x1	2	150/50	186	95	17.7
S641-04**	N-P-C1-C3	41.5x22.5x1	1	150/50	186	95	17.7
S661-04***	M-N-C11-C13 N-P-C11-C13	50x22.5x1	2	150/50	225	115	16.2
S648-05	P-Q-A1-A14	42x18x1	10	150/50	151	113.4	22.1
S648-06	Q-T-A1-A3 Q-T-A12-A14	68x80.5x1.5	2	225/50	1506	753	4.6
S648-10	Q-T-A3-A6 Q-T-A9-A12	89.5x80.5x2.2	2	330/50	2738	1561	9.4
S648-11	R-U-A6-A9	82.5x77x1.6	1	225/50	1746	1153	5.7
S648-12	U-W-A6-A7 U-W-A8-A9	25.5x38.5x3	-	450/50	-	-	>33.0
S648-13	W-X-A7-A8	26x30.8x3	-	450/50	-	-	>33.0
S648-14	X-Z-A6-A9	78x83.2x3	1	450/50	3245	1914	6.0

Notes:
DL = Dead load. LL = Live load. Wt = Floor slab weight of one slab panel.
f = Fundamental vertical frequency. We = Effective floor slab weight of one slab panel associated with the fundamental mode.
*Approximate slab location to the nearest column line.
**This slab has the same dimensions as the dimensions of slab S648-04. Therefore, SDOF 914 representing S648-04 can also be used to represent S641-04.
***This also has approximately the same dimensions as slab S648-04. Therefore, SDOF 914 representing S648-04 can also be used to represent S661-04.

TABLE A-3
FLEXIBLE FLOOR SLABS AT ELEVATION 668.0 FT.

SLAB ID	SLAB LOCATION* (COL. LINE)	APPROXIMATE SLAB DIMENSION (ft)	NO. OF SLABS	DL/LL (psf)	Wt (kip)	We (kip)	f (Hz)
S668	M-P-C1-C13		12	110/50	190	152	11.5
S668-04	P-Q-A3-A12	55.6x18x1	5	150/50	200.2	150.2	22.1
S668-05	P-R-A1-A3 P-R-A12-A14	69x41x1.5	2	225/50	778	467	4.6
S668-06	R-T-A1-A2 R-T-A13-A14 Q-R-A3-A5	33.6x67.5x1.5	3	225/50	529	296	5.4
S668-07	S-T-A4-A6	55.7x31x1.5	1	225/50	474	266	13.5
S668-08	Q-T-C9-C12	80.5x57.5x1.5	1	225/50	1274	675	4.7
S668-09	Q-W-C6-C9***	26x25x1	7	150/50	130	86	27.5
S668-10	W-X-A7-A8	28x86.8x2	1	300/50	790	545	31.3
S668-11	X-Y-A6-A8	46x57.2x3	1	450/50	1316	710	15.8
S668-12	R-S-A4-A5	26.5x33x1.5	1	225/50	240	134	22.3
S668-13	Q-R-A11-A12	23x33x1.5	1	225/50	209	113	26.8
S668-14	R-T-A2-A3 R-T-A12-A13	57.5x23x3	2	450/50	-	-	>33.0

Notes:
DL = Dead load. LL = Live load. Wt = Floor slab weight of one slab panel.
f = Fundamental vertical frequency. We = Effective floor slab weight of one slab panel associated with the fundamental mode.
*Approximate slab location to the nearest column line.
**Develop and documented in calculation of Reference No. 2.
***Locally rigid areas for this slab are marked on the corresponding sketch.

TABLE A-4
FLEXIBLE FLOOR SLABS AT ELEVATION 685.0 FT.

SLAB ID	SLAB LOCATION* (COL. LINE)	APPROXIMATE SLAB DIMENSION (ft)	NO. OF SLABS	DL/LL (psf)	Wt (kip)	We (kip)	f (Hz)
S685-01	M-P-C1-C13	26.8x45x2	12	300/30	398	274.9	8.6
S685-02	P-Q-A6-A9	39x18x1	2	150/30	126	93	22.2
S685-03	P-Q-A10-A14 P-Q-A1-A5	145.7x18x1.5	2	-	-	-	>33.0
S685-04	Q-R-A2-A3 Q-R-A12-A13	47x22.3x2	2	-	-	-	>33.0
S685-05	Q-R-A3-A5 Q-R-A10-A12	47.3x22.3x2	2	-	-	-	>33.0
S685-06	Q-R-A7-A9	84.3x30.8x1	1	150/30	356	171	13.8
S685-07	R-T-A1-A3 R-T-A12-A14	61.5x58.2x1.5	2	225/30	913	512	5.2
S685-08	R-T-A4-A6 R-T-A9-A11	58.2x54.4x2	2	300/30	1045	617	6.7
S685-09	Q-S-C5-A7	38.3x25x1	2	150/30	172	102	6.6
S685-10	V-W-C5-A7 V-W-A8-C9	26x25x1	2	150/30	118	71	8.6
S685-11	S-V-C5-C9	26x25x1	7	150/30	117	77	11.8
S685-12	Q-R-A1-A2 Q-R-A13-A14	23x30.5x1.5	2	225/30	179	100	27.9
S685-13	Q-R-A5-A6 Q-R-A9-A10	23x34x2	2	-	-	-	>33.0
S685-14	P-Q-A5-A6 P-Q-A9-A10	33.3x18x2	2	-	-	-	>33.0

Notes:
DL = Dead load. LL = Live load. Wt = Floor slab weight of one slab panel.
f = Fundamental vertical frequency. We = Effective floor slab weight of one slab panel associated with the fundamental mode.
*Approximate slab location to the nearest column line.

NRC Item No. 4:

Provide verification that the equipment/component responses (i.e., flexible floor response spectra, FFRS) computed using the equipment-structure-interaction (ESI) methodology proposed by BLN are equivalent to the responses obtained using an equivalent time domain solution. In the time domain solution a SDOF oscillator representing the equipment/component is to be incorporated into the lumped mass building/flexible floor model by attaching it directly on the flexible floor mass.

TVA Response:

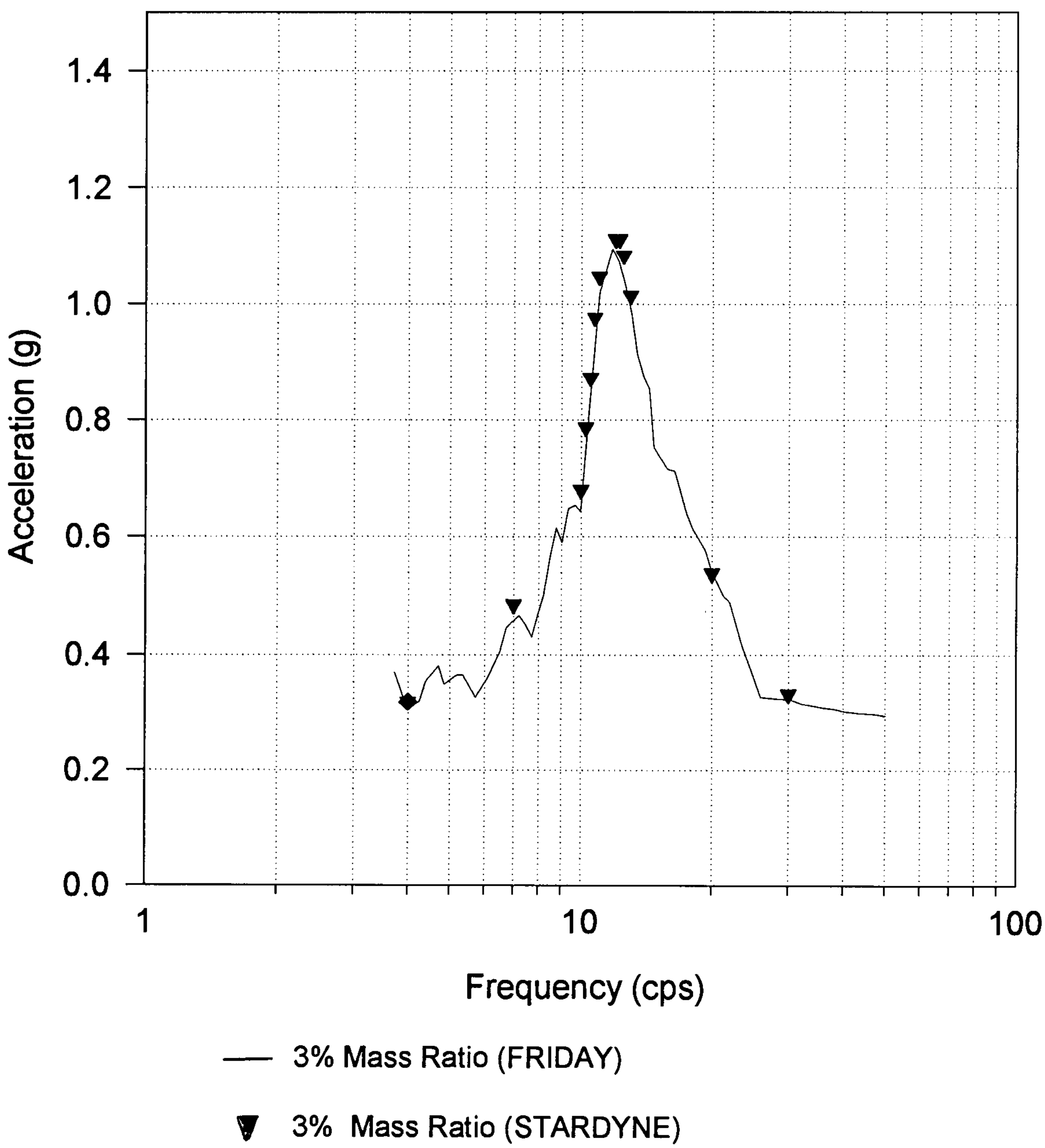
An analysis was performed for auxiliary/control building upper elevation 685' which is representative of other floors. In this analysis SDOF oscillators representing the equipment/components were incorporated into the lumped mass building/flexible floor model of the Auxiliary-Control Building by attaching them directly to the flexible floor mass. The equivalent mass of the equipment/component SDOF oscillators was taken as 3% of the flexible floor SDOF oscillator. The individual equipment/component SDOF oscillator frequencies evaluated included 4.0, 7.0, 10.0, 10.25, 10.5, 10.75, 11.0, 12.0, 12.25, 12.5, 13.0, 20.0, and 30.0 Hz. The modified lumped mass building/flexible floor/equipment model was subjected to an input motion at its base corresponding to the BLN design basis OBE vertical artificial acceleration time history. A time domain dynamic response analysis was performed utilizing the STARDYNE computer code.

The results of this time domain solution was compared to that obtained using the methodology presented in the December 1993 report using the computer code FRIDAY; see the attached figure. Review of the figure demonstrates that both methodologies provide essentially identical results.

Response Spectra Curve Comparison - Bellefonte Nuclear Plant

Auxiliary Control Building - EL. 685' - 4% Damping

Flexible Floor Frequency 12 CPS

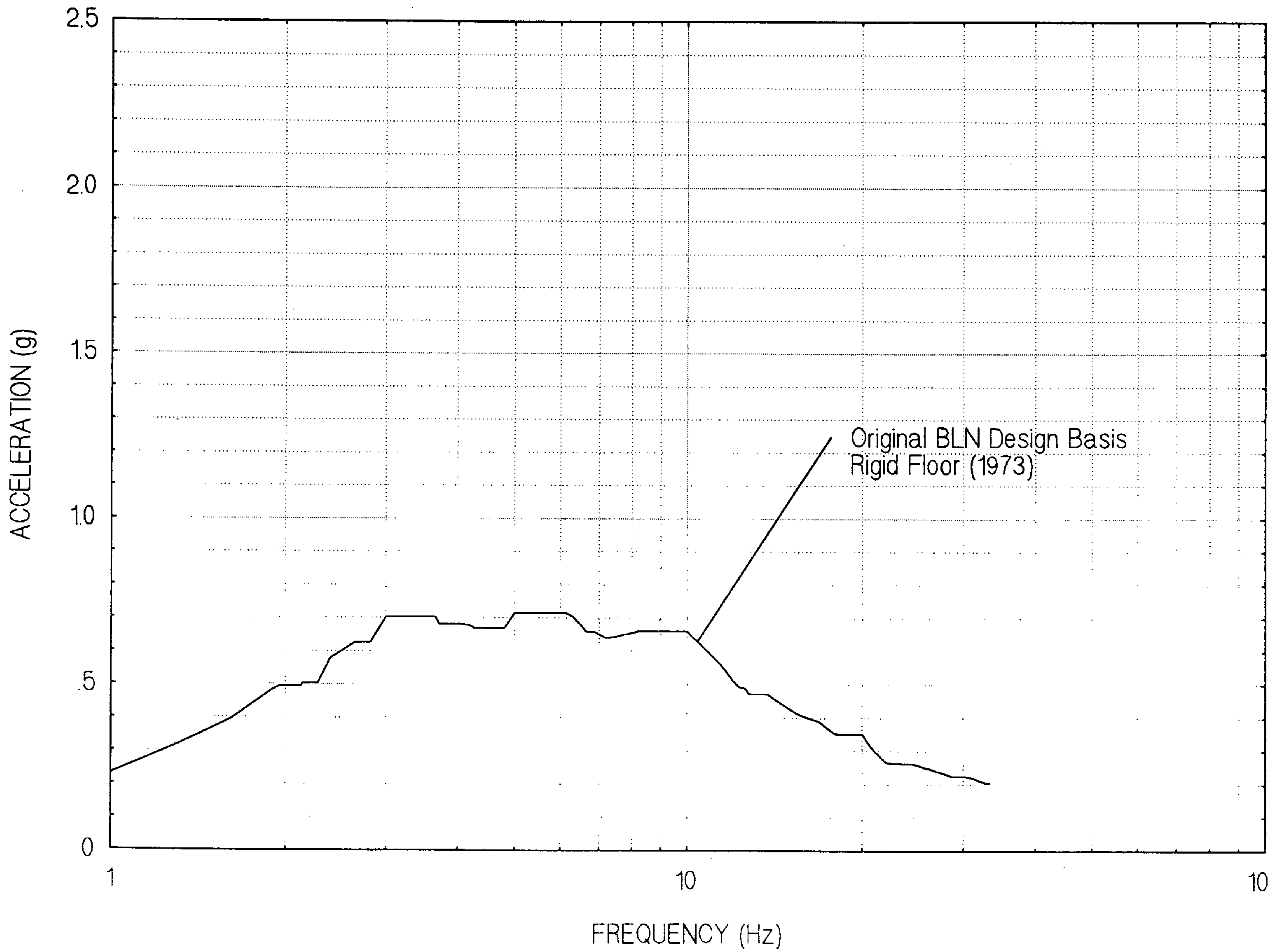


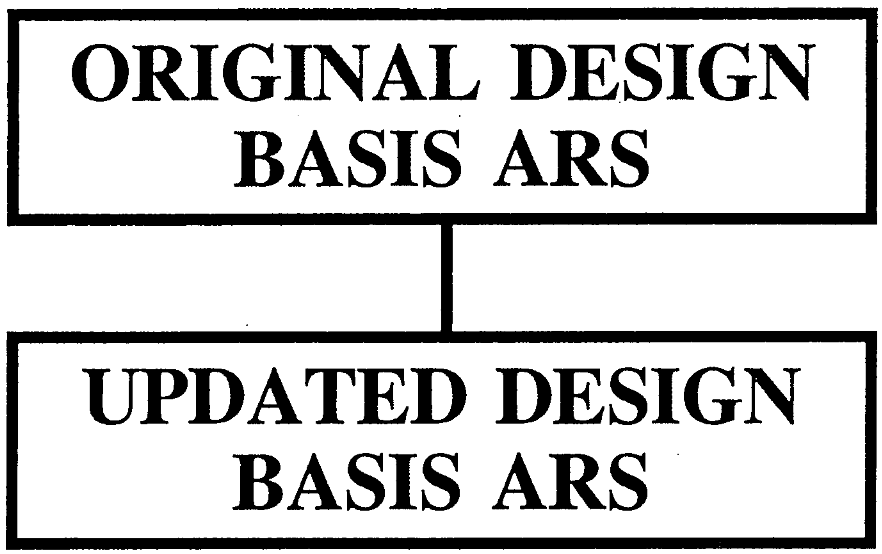
ENCLOSURE 3

HISTORICAL DEVELOPMENT OF THE VERTICAL FLEXIBLE FLOOR RESPONSE SPECTRA

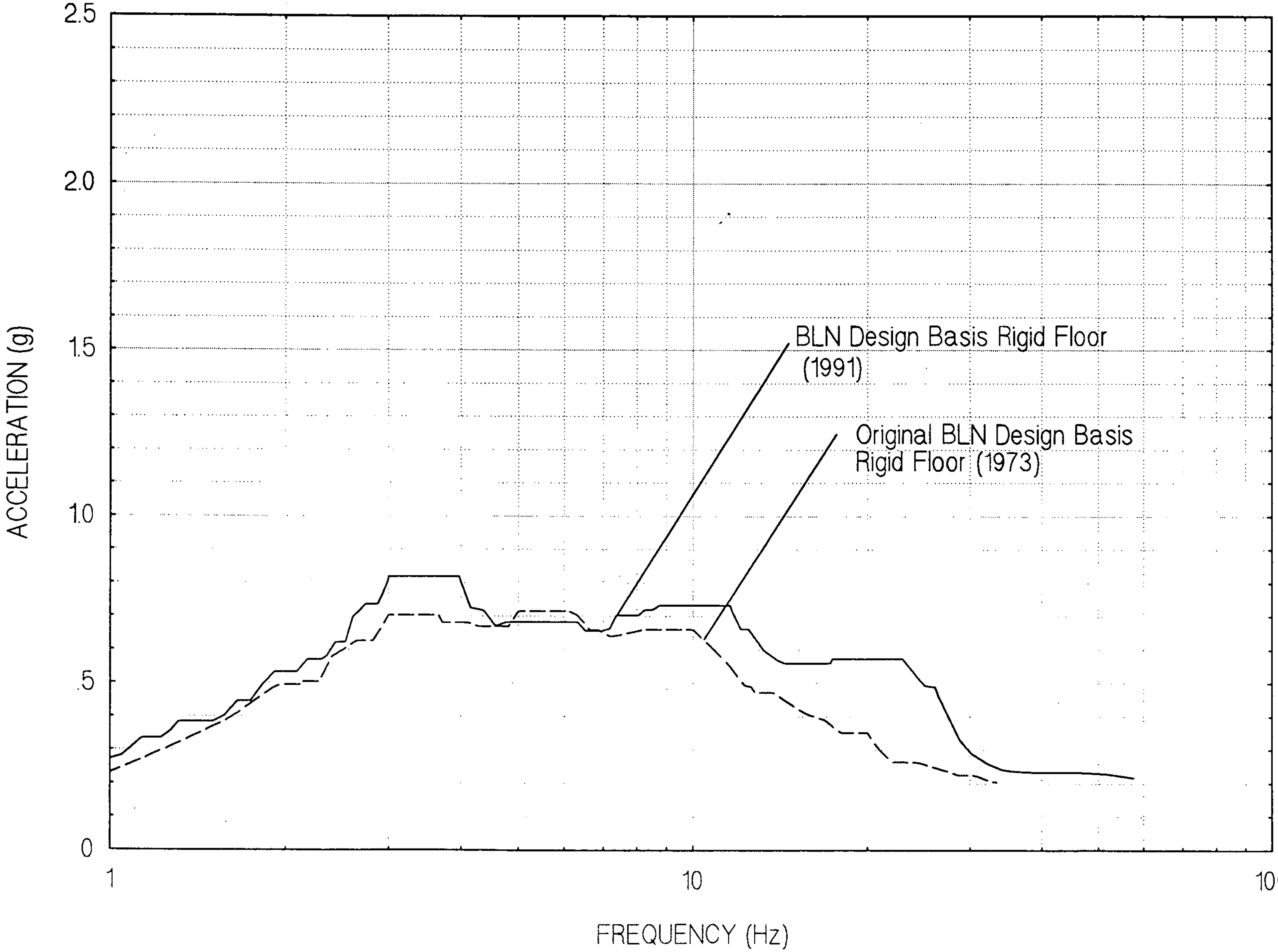
ORIGINAL DESIGN BASIS ARS

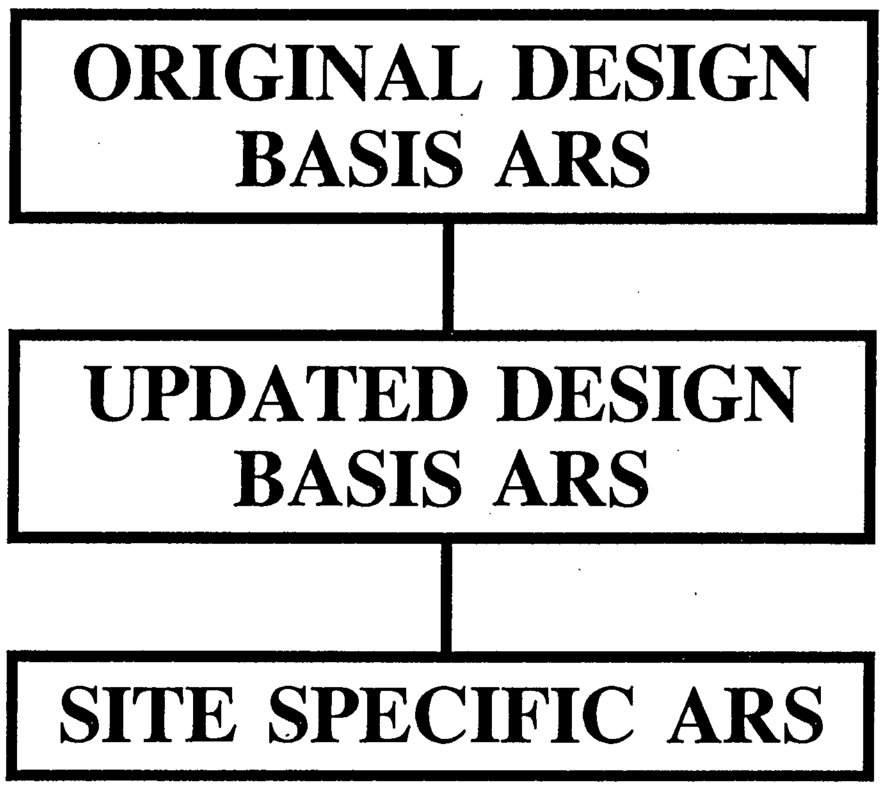
TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equip Damp - Vertical Accel Time History (SSE)
Aux-Control Building - Elev. 628 ft - Node 901 - Floor Freq 6.8 Hz - West Stick




ORIGINAL DESIGN BASIS ARS
UPDATED DESIGN BASIS ARS

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equip Damp - Vertical Accel Time History (SSE)
Aux-Control Building - Elev. 628 ft - Node 901 - Floor Freq 6.8 Hz - West Stick

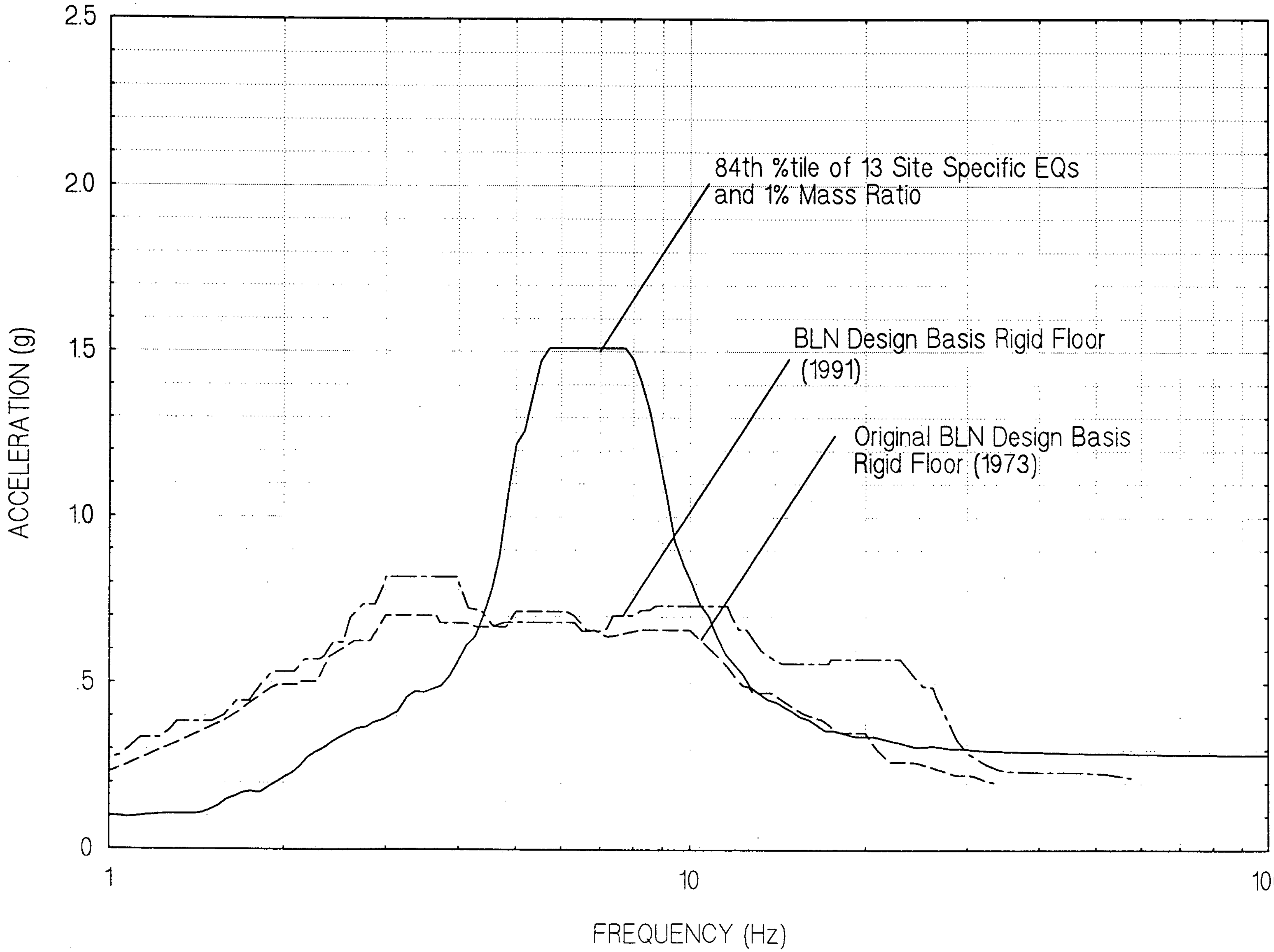


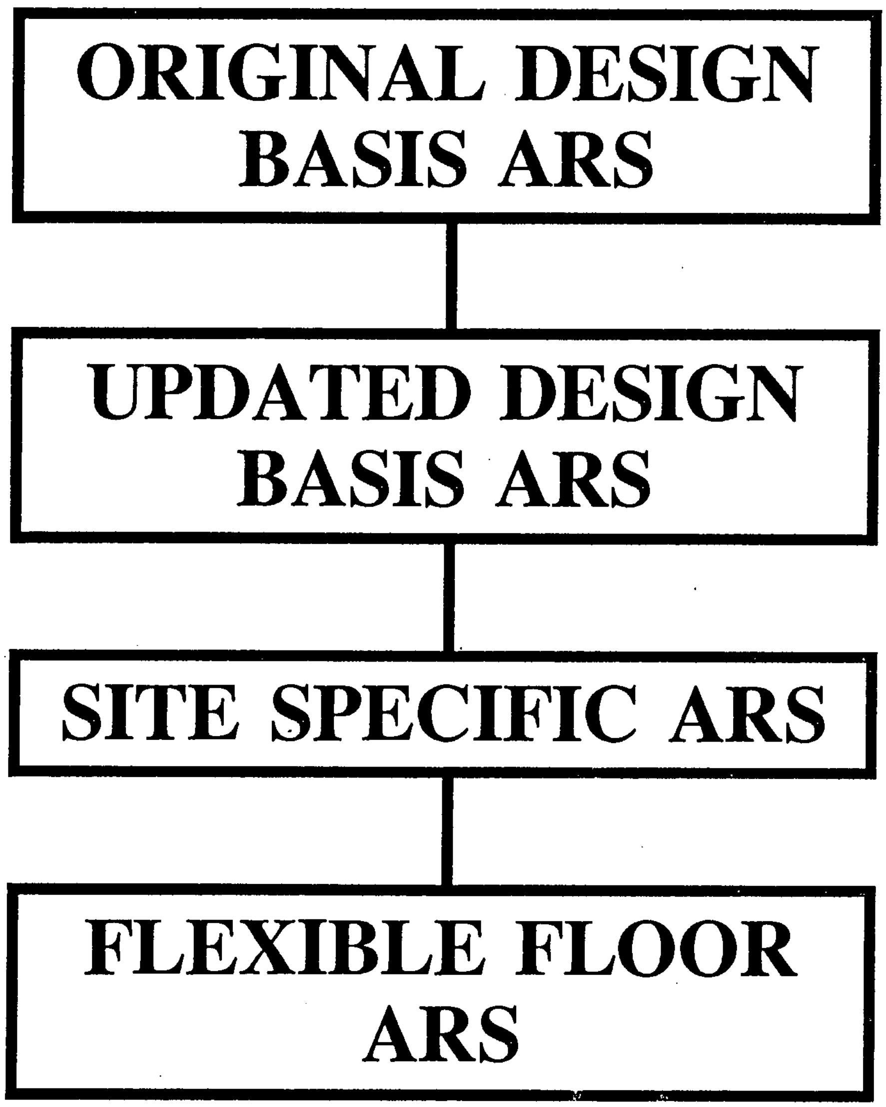

ORIGINAL DESIGN BASIS ARS
UPDATED DESIGN BASIS ARS
SITE SPECIFIC ARS

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1

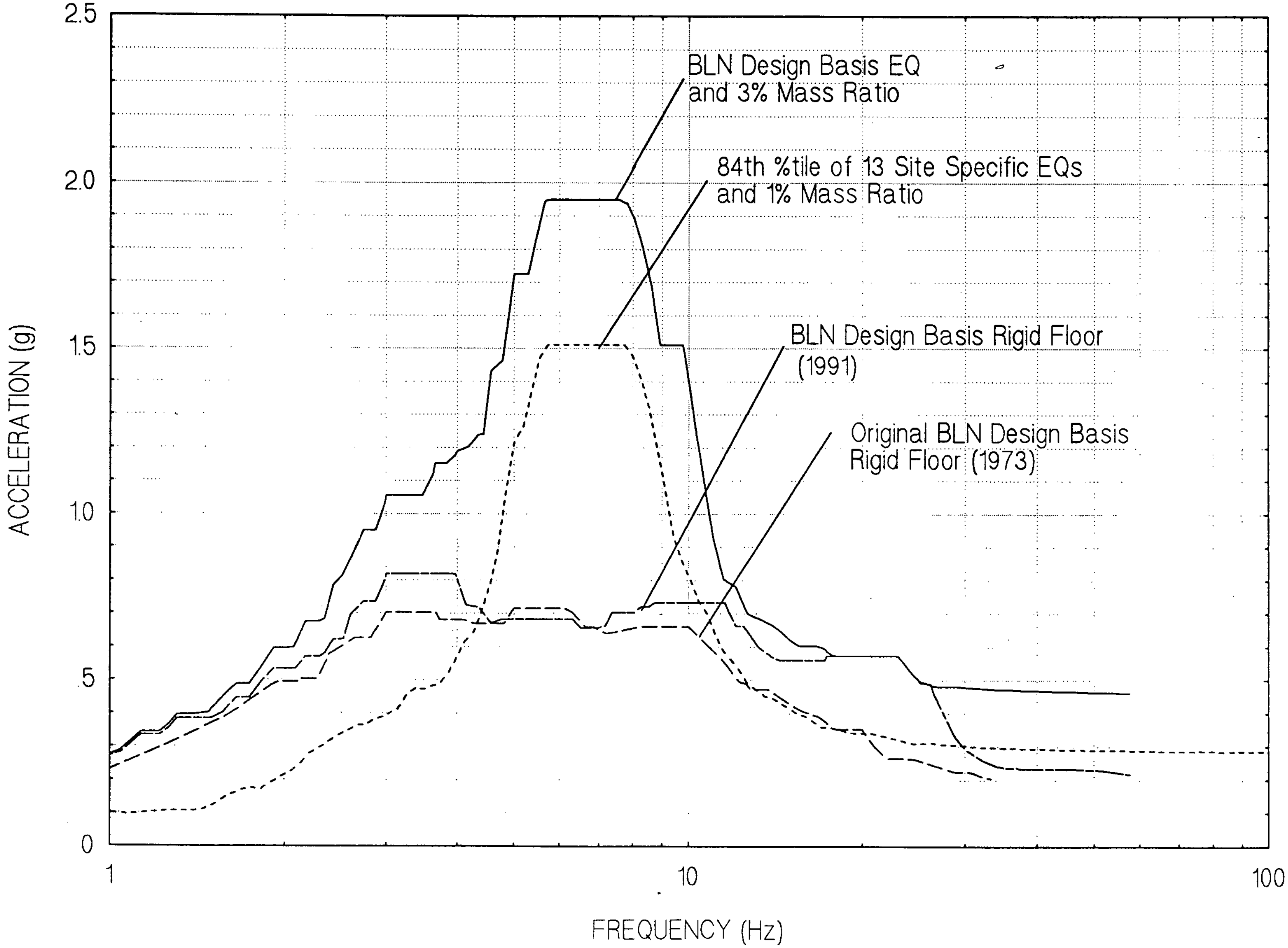
Response Spectra Plot - 3% Equip Damp - Vertical Accel Time History (SSE)

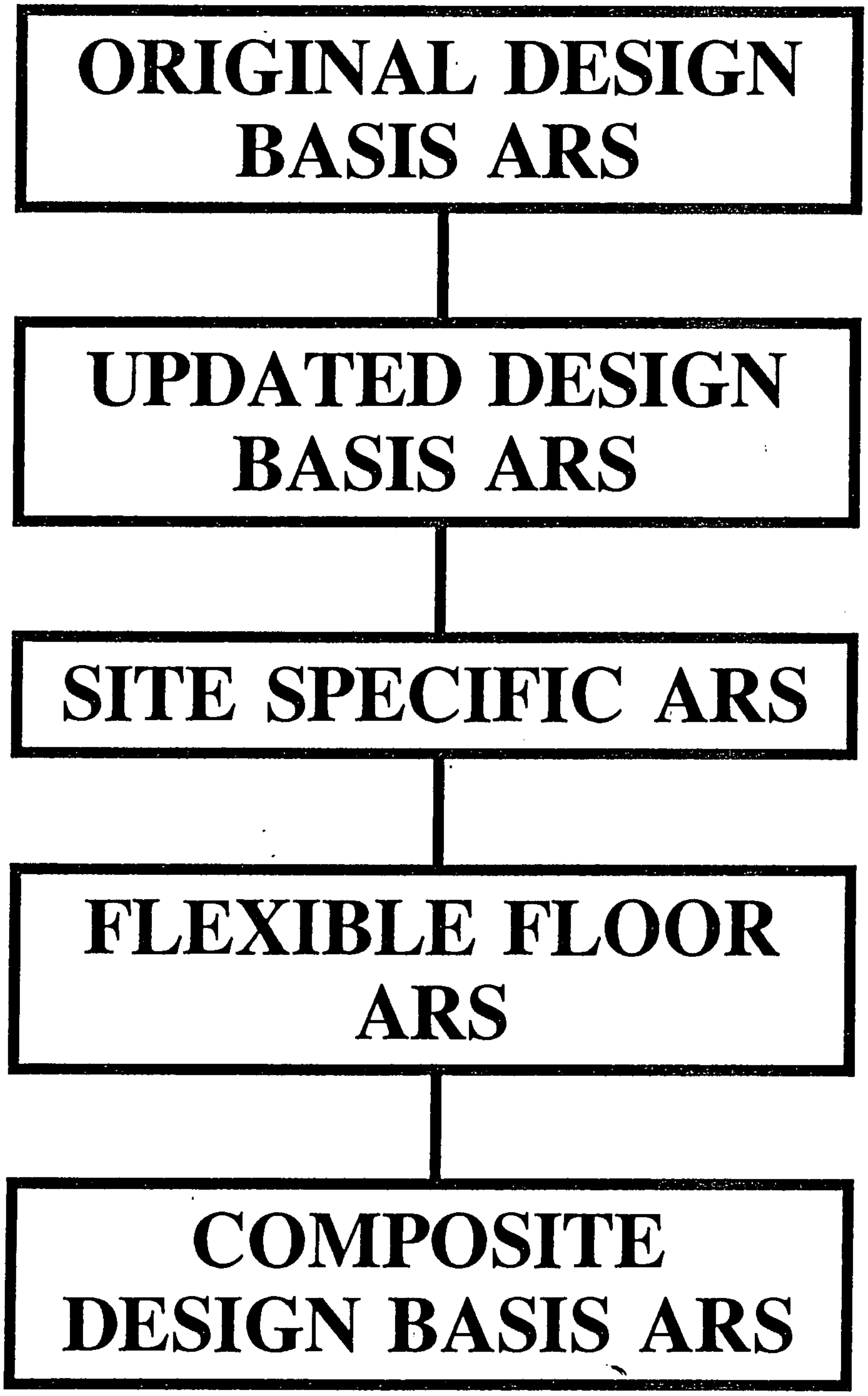
Aux-Control Building - Elev. 628 ft - Node 901 - Floor Freq 6.8 Hz - West Stick




ORIGINAL DESIGN BASIS ARS
UPDATED DESIGN BASIS ARS
SITE SPECIFIC ARS
FLEXIBLE FLOOR ARS

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equip Damp - Vertical Accel Time History (SSE)
Aux-Control Building - Elev. 628 ft - Node 901 - Floor Freq 6.8 Hz - West Stick




ORIGINAL DESIGN BASIS ARS
UPDATED DESIGN BASIS ARS
SITE SPECIFIC ARS
FLEXIBLE FLOOR ARS
COMPOSITE DESIGN BASIS ARS

TENNESSEE VALLEY AUTHORITY - BELLEFONTE NUCLEAR POWER PLANT - UNIT 1
Response Spectra Plot - 3% Equip Damp - Vertical Accel Time History (SSE)
Aux-Control Building - Elev. 628 ft - Node 901 - Floor Freq 6.8 Hz - West Stick