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Informal Report

Modified Floor Response Spectra for the Brookhaven National Laboratory High Flux Beam Reactor (HFBR)

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1.0 INTRODUCTION

This report documents the modified floor response spectra that will be used for future seismic evaluations of structures, systems, and components (SSC's) within the HFBR and the technical basis for the modified floor response spectra. When used within this report, the term "current spectra" refers to the 1978 spectra developed in BNL Informal Report BNL-26019 (Ref. 1). The following introduction provides a brief description of the issues which formed the bases for the development of this report.

The current horizontal floor response spectra used for the evaluation of SSC's within the HFBR were developed in 1978 and documented in BNL Informal Report BNL-26019 (Ref. 1). Although the 1978 spectra are conservative, they are inappropriate in view of the current state-of-the art methodology. First, the time history does not match the design response spectra in the high frequency range (the peak ground acceleration (PGA) of the time history is significantly greater than the target value, i.e., .33 vs. .20) and, second, the technique used to model the soil did not appropriately consider soil damping behavior resulting in unrealistic amplifications at all frequencies. A more recent analysis was performed in 1992 using a free-field response spectrum developed for the HFBR PRA (Ref. 4). The methodology used in this more recent analysis provided a time history which closely matched the free field response spectrum. The soil structure interaction (SSI) analysis also appropriately modeled the soil and soil damping effects. The results from this analysis demonstrate the excessive amplification in the 1978 floor response spectra and provide a part of the technical basis for modifying the 1978 spectra. Use of the 1978 spectra results in significant engineering and installation efforts when evaluating SSC's for modification. If floor response spectra based on today's standards are used in place of the current floor response spectra, modifications of SSC's for seismic adequacy are simplified and in some instances may not be required. A meeting was held between the Reactor Division and DOE in Germantown, MD on October 28, 1993 to discuss possible approaches for developing more realistic HFBR floor response spectra. Based on consideration of cost/benefit, time constraints, etc., it was mutually agreed that the existing spectra could and would be modified instead of constructing a new analytical structural model and generating new floor response spectra. The modified response spectra would be based on sound engineering judgment and simple calculation. See Reference 3 and Appendix A of this report.

For the horizontal direction, the current floor response spectra will be modified by reducing the accelerations at frequencies above approximately 12 Hz. The acceleration reduction would be based on engineering judgment previously accepted by the DOE in the evaluation of the Control Room structure (Ref. 2). Judgments used in the development of the modified horizontal floor response spectra are discussed in Section 2.1 of this report.

For the vertical direction, the current technical approach utilizes two-thirds of the current horizontal floor spectra because no vertical spectra were previously generated for use in design. Therefore, regardless of the appropriateness, the characteristics of the horizontal floor spectra are reflected in the vertical seismic analysis. Use of the two-thirds factor was generally perceived to produce conservative estimates of vertical seismic response. The specific approach to generation of more realistic vertical response spectra for future design and evaluation efforts was not finalized at the above DOE meeting. BNL was to investigate further and propose more realistic vertical response spectra with a minimum of new analytical effort and appropriate margin of conservatism. The results of this investigation are documented in Section 2.2 of this report.

2.0 DEVELOPMENT OF MODIFIED FLOOR RESPONSE SPECTRA FOR HFBR

The current HFBR Design Basis Earthquake (DBE) is based on the 70^{th} percentile Newmark and Hall spectral shape anchored at 0.2 g (Ref. 1). In the 1978 analysis, the soil was modeled as linear springs based on the elastic half-space method. No radiation damping effect of the HFBR foundation was considered. This is a very conservative omission and considered unrealistic. Recent studies have also shown that the synthetic time history developed and used for the generation of the current floor response spectra is grossly over-conservative at frequencies above 12 Hz, causing Zero Period Acceleration (ZPA) values to be over-estimated by approximately 100 percent (Ref. 2). In addition, the building model used in the original modal analysis had no capability to determine explicit vertical floor response spectra and account for vertical floor flexibilities. As a result, the current design basis for vertical earthquake is to use the horizontal floor response spectra multiplied by 2/3 over all frequencies.

Therefore, based on today's standards, use of the current floor response spectra results in the application of seismic demands that contain a large margin of conservatism when evaluating SSC's and often leads to more complex modifications. This often increases the level of effort for both engineering and installation of modifications to SSC's. This effort could be reduced and possibly eliminated through the use of more realistic floor response spectra. The following describes the techniques used to modify the current floor response spectra and develop more realistic floor response spectra curves that incorporate an appropriate margin of conservatism.

2.1 Horizontal Floor Response Spectra

As discussed in Reference 2, the original 1978 analysis (Ref. 1), which generated the ground motion used as input to the foundation of the HFBR and resulting floor response spectra, has two major conservatisms:

(1) The Peak Ground Acceleration (PGA) of the generated input motion describing the ground Design Basis Earthquake (DBE) is 0.33 g versus the target value of 0.2 g. This can be readily seen by the plot of the synthetic time history used in the original analysis (illustrated in Appendix B, Figure B-1).

(2) The response spectrum developed from the synthetic time history shown in Appendix B significantly overshoots the DBE ground spectral shape at frequencies above approximately 12 Hz. This results in excessive seismic input energy above 12 Hz. A plot showing the generated response spectrum versus the DBE ground spectral shape is also contained in Appendix B.

Since the above conservatisms are contained within the input base motion used to generate the floor time histories within the HFBR, they are inherent in all the current floor response spectra and potentially affect the spectral accelerations at all frequencies. However, quantification of the effect on floor response spectra accelerations in the amplified region is not possible without a redefinition of the input synthetic time history and regeneration of the individual floor response spectra. Therefore, the effect that the above conservatisms have on the amplified region of the floor response spectra is retained. Only accelerations in the unamplified, rigid region of the floor response spectra are modified.

Based on review of the original HFBR modal analysis (Ref. 1) and analyses performed to support the HFBR Probabilistic Risk Assessment (PRA) studies (Ref. 4), the rigid region of the floor response spectra curves occurs around 12 Hz. This is evident by the floor response spectra generated for the operations level of the HFBR in support of Reference 4 and shown in Appendix C, which shows no amplification beyond approximately 12 Hz of the floor input motion. Since building response in the rigid region is "pseudo-static," the accelerations that would be anticipated in this region, if a redefinition of the time history was performed to eliminate the above conservatisms, can be reasonably and conservatively estimated by reducing the accelerations in this region by the ratio of the target PGA (.2 g) to the actual PGA (.33 g). Therefore, the current floor response spectra accelerations in the rigid range are reduced by multiplying the governing acceleration within this range by .2/.33=0.6. The determination of the governing acceleration is described in the paragraph below.

Plots of the current HFBR unbroadened floor response spectra (Ref. 1), show significant spectral amplifications in the vicinity of frequencies 15 and 25 Hz. Review of the original HFBR modal analysis (Ref. 1) shows no building response exists at these frequencies, indicating that the accelerations at these frequencies should mirror the input motion with no amplification. As previously discussed, the synthetic time history used to represent the input ground motion poorly matches the ground spectral shape above 12 Hz as shown in Appendix B. Further study of the input ground motion above 12 Hz reveals significant acceleration peaks near 15 and 25 Hz. Since the original modal analysis shows no building response at these two frequencies, it is concluded that the acceleration peaks in the current floor response spectra, at approximately 15 and 25 Hz, are the result of the conservative input motion and not due to any building response. Therefore, for the purposes of defining a governing acceleration for reduction, the acceleration peaks near the frequencies of 15 and 25 Hz are ignored. As a result, the governing acceleration is based on the highest acceleration above 12 Hz, ignoring the peaks near 15 and 25 Hz caused by the poorly matching input motion. This acceleration is multiplied by 0.6 to define the modified ZPA at each floor. Review of the current unbroadened floor response spectra shows the governing acceleration occurs at approximately 18 Hz.

The transition from the amplified (approximately 10 Hz) to the reduced rigid region (approximately 12 Hz) of the modified floor spectra curves is accomplished by connecting the two extreme ends (10 and 12 Hz) by a straight line. Figures C-1 to C-12 of Appendix C graphically depict the development of the governing acceleration and transition region from amplified to rigid portion of the modified floor response spectra curves. These figures also show the acceleration peaks occurring at 15 and 25 Hz in the current unbroadened spectra caused by the input ground motion poorly matching the ground spectra shape above 12 Hz.

Based on the approach described above, horizontal modified floor response spectra curves were developed as shown in Figures 2-1 to 2-4. To determine the reasonableness of this approach, the reduced rigid region acceleration values for the modified Operations Level floor response spectra are compared to the ZPA value for the same curves developed in support of the HFBR PRA (Ref. 4). Both spectra curves are based on a 0.2 g PGA. By comparing Figure 2-1 to the 1992 floor response spectra in Appendix D, the predicted ZPA values are as follows:

ZPA Accelerations(g)

Damping(%)	Modified Curves	1992 Curves
2	.55	.44
5	.49	.44
7	.48	.44

Since the modified floor response spectra accelerations compare favorably to the 1992 curves developed by a detailed, independent analysis, the modifications made to the current horizontal floor spectra are considered to be realistic and contain an appropriate margin of conservatism.

2.2 Vertical Floor Response Spectra

Vertical floor response spectra for the HFBR Reactor Building were not developed during the Reference 1 seismic analysis. Consequently, it is current practice for the HFBR to use 2/3 of the corresponding horizontal floor response spectra as the vertical floor response spectra. Therefore, in addition to redefining the horizontal spectra, as discussed in Section 2.1, a second objective was to develop reasonable vertical floor response spectra which reflect any significant vertical seismic response of the Reactor Building.

The new vertical floor response spectra developed herein are based primarily on engineering judgement, supplemented by simplified vibration analysis to identify significant vertical response modes below 33 Hz. The spectra are judged to be conservative, compared to expected results from a detailed, state-of-the-art analysis. A detailed analysis would be expected to predict lower floor ZPA's, lower peak spectral accelerations, and narrowly-banded spectral peaks. The new vertical spectra are intended to envelope the uncertainties associated with the absence of a detailed vertical analysis.

The starting point for development of the vertical floor spectra is the Design Basis Earthquake vertical ground spectra, as specified in Reference 5. The design vertical PGA is 0.133 g (2/3 of design horizontal PGA) and the design spectra are based on 70th percentile Newmark-Hall amplification factors. Appendix E shows the Design Basis vertical ground spectra for a range of damping. It is noted that the 7 percent damping spectrum is interpolated and the 15 percent damping spectrum is extrapolated based on amplification factors provided in Reference 5 for the other damping values.

Two potential contributors to amplification of vertical seismic ground motion in the HFBR Reactor Building have been identified:

(1) A deep soil layer supports the reactor building. Based on best estimate soil properties from Reference 4 and the soil spring constant formula from Table 3300-1 of Reference 6, the soil/building system has a fundamental vertical vibration mode at 4.6 Hz. Associated with this vibration mode is extremely high soil damping. Based on the soil damping formula in Table 3300-1 of Reference 6, the equivalent viscous damping is 96.5 percent of critical damping.

(2) The reinforced concrete floors at the operations, balcony, and experimental levels have fundamental out-of-plane vibration modes at around 12 Hz. Applying a ± 15 percent error band to account for calculational uncertainty, the fundamental vibration frequency range is 10 to 14 Hz.

The fundamental vertical vibration frequency of the reactor building structure (not considering floor flexibility) is high enough to consider the building rigid with respect to vertical seismic excitation.

The potential amplification effects of the two significant vertical response modes are considered separately.

2.2.1 Soil/Building Response

A reasonable value of equivalent viscous damping for a combined soft soil/reinforced concrete structure model is 15 percent. From Appendix E, the peak spectral acceleration for 15 percent damping is 0.2 g. This value is specified as the ZPA for the vertical floor spectra applicable to the equipment level (base mat) and to the reactor building walls. They are unaffected by out-of-plane floor flexibility. The increase in ZPA is intended to conservatively account for any amplification resulting from the 4.6 Hz soil/building vibration mode. The vertical floor response spectra are defined as 70th percentile Newmark Hall spectra, anchored at 0.2 g. See Figure 2-5.

The peak spectral accelerations are maintained at a constant value over the frequency range 1.5 to 8 Hz. Therefore, the effect of variations in the soil properties on the frequency of the soil/building vibration mode is adequately represented in the spectra.

2.2.2 Flexible Floor Response

A reasonable value of equivalent viscous damping for the reinforced concrete slabs with composite steel/concrete stiffeners is 7 percent. From Appendix E, the peak spectral acceleration for 7 percent damping is 0.28 g. A value of 0.3 g is specified as the ZPA for the vertical floor spectra applicable to the floor slabs at the operations, balcony, and experimental levels. The increase in ZPA is intended to conservatively account for any amplification resulting from the 10 to 14 Hz out-of-plane floor vibration modes.

The vertical floor response spectra are defined as 70th percentile Newmark-Hall spectra, modified to extend the peak acceleration out to 14 Hz and anchored at 0.3 g. See Figure 2-6. Extension of the peak acceleration out to 14 Hz is intended to conservatively envelope a second spectral peak expected in the 10 to 14 Hz range resulting from the out-of-plane floor vibration modes.

2.2.3 Comparison of DBE Vertical Ground Spectrum, 2/3 of the 1978 Horizontal Floor Spectra, and Modified Vertical Spectra

Plots comparing the DBE vertical ground spectrum, 2/3 of the 1978 horizontal floor response spectra, and the modified vertical floor spectra @ 5 percent damping are contained in Appendix F.

3.0 CONCLUSION

Based on the technical arguments presented in Section 2.0 of this report, the modified response spectra curves, as shown in Figures 2-1 to 2-6, are realistic and contain an appropriate level of conservatism and shall replace the current curves developed in 1978

(Ref. 1) and become the new seismic design basis for evaluation of SSC's within the HFBR building.

4.0 REFERENCES

[1] BNL Informal Report BNL-26019, "Determination of the Floor Response Spectra for the Brookhaven HFBR Reactor Building Structure," November 1978

[2] Seismic Evaluation of the HFBR Control Room Structure, March 1993 by ERAD/DNE

[3] Agreements From Seismic Commitments Meeting dated October 28, 1993 at DOE (Germantown)

[4] Level 1 Seismic PRA for the High Flux Beam Reactor

[5] Informal Report to P.R. Tichler, BNL from Nathan M. Newmark Consulting Engineering Services, dated November 1, 1977, Subject: Seismic Review of HFBR.

[6] ASCE Standard 4-86, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures," September 1986.

POINT	FREQ(HZ)	ACCELERATION(G) 2% DAMP	ACCELERATION(G) 5% DAMP	ACCELERATION(G) 7% DAMP	PERIOD
	0	0	0	0	
A	2.5	4	2.75	2.27	0.400
B	3.5	4	2.75	2.27	0.286
C	5	2.18	1.47	1.26	0.200
D	6	2.18	1.47	1.26	0.167
E	7.25	1.23	0.93	0.834	0.138
F	10.5	1.23	0.93	0.834	0.095
G	12	0.55	0.49	0.48	0.083
H	34	0.55	0.49	0.48	0.029

MODIFIED HFBR HORIZ FLOOR SPECTRA OPERATIONS LEVEL

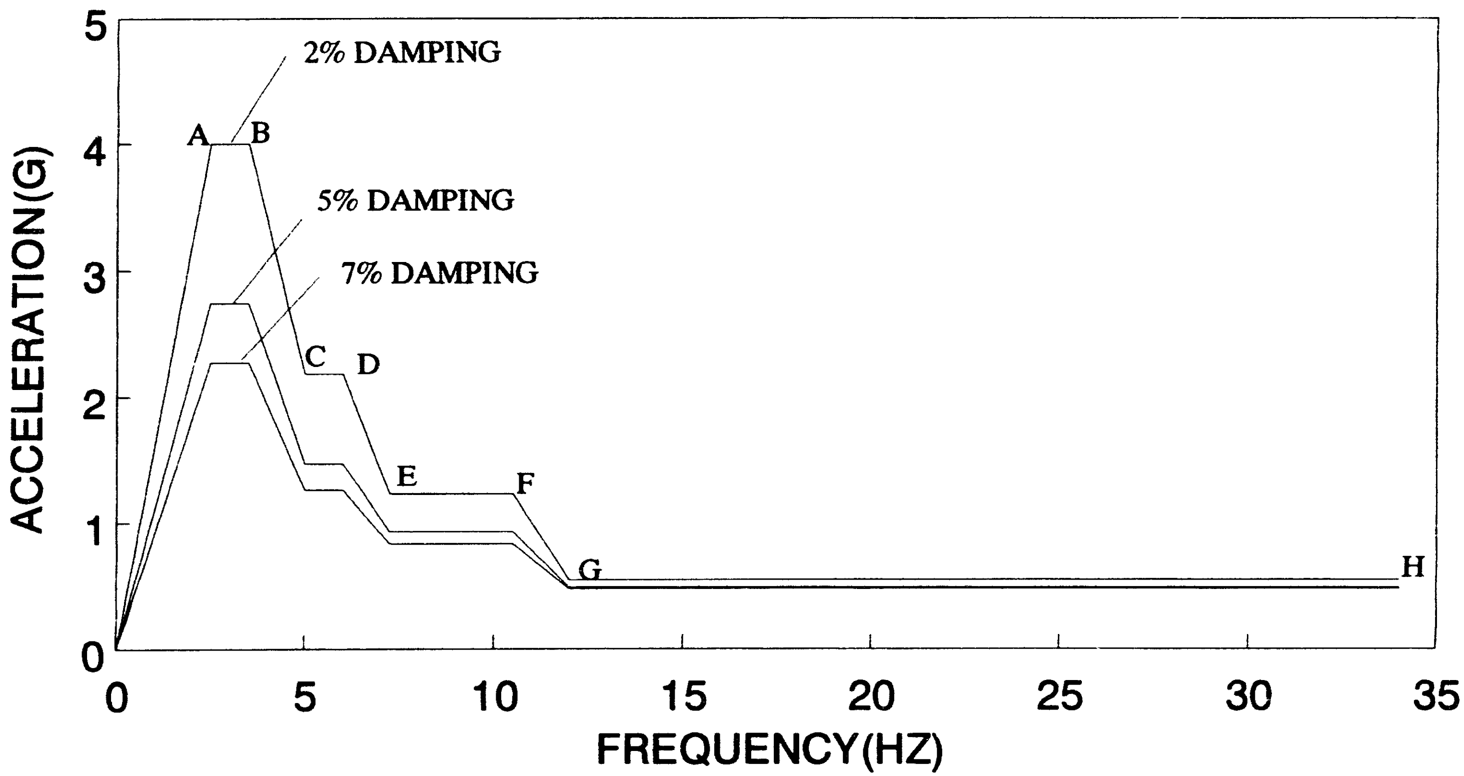


Figure 2–1

POINT	FREQ(HZ)	ACCELERATION(G) 2% DAMP	5% DAMP	7% DAMP	PERIOD
	0	0	0	0	
A	2.5	4.25	2.92	2.42	0.400
B	3.5	4.25	2.92	2.42	0.286
C	5	2.4	1.62	1.37	0.200
D	6	2.4	1.62	1.37	0.167
E	7	1.68	1.2	1.08	0.143
F	8	1.68	1.2	1.08	0.125
G	9	0.99	0.84	0.81	0.111
H	10.25	0.99	0.84	0.81	0.098
I	12	0.57	0.51	0.5	0.083
J	34	0.57	0.51	0.5	0.029

MODIFIED HFBR HORIZ FLOOR SPECTRA
BALCONY LEVEL

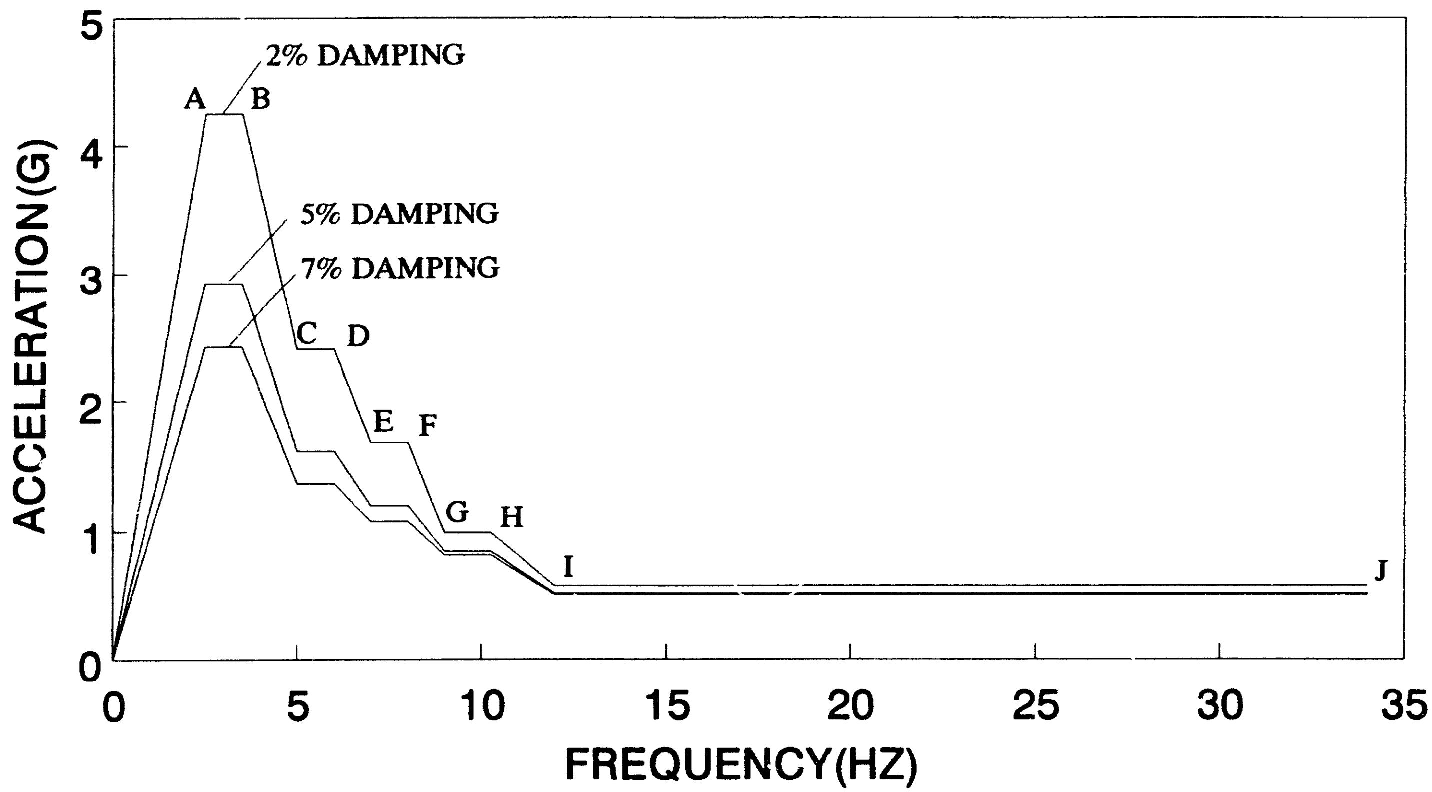


Figure 2–2

POINT	FREQ(HZ)	ACCELERATION(G) 2% DAMP	5% DAMP	7% DAMP	PERIOD
	0	0	0	0	
A	2.5	3.14	2.15	1.78	0.400
B	3.5	3.14	2.15	1.78	0.286
C	5	1.47	1.02	0.87	0.200
D	6	1.47	1.02	0.87	0.167
E	7	1.12	0.75	0.68	0.143
F	9.5	1.12	0.75	0.68	0.105
G	12	0.47	0.41	0.4	0.083
H	34	0.47	0.41	0.4	0.029

MODIFIED HFBR HORIZ FLOOR SPECTRA
EXPERIMENTAL LEVEL

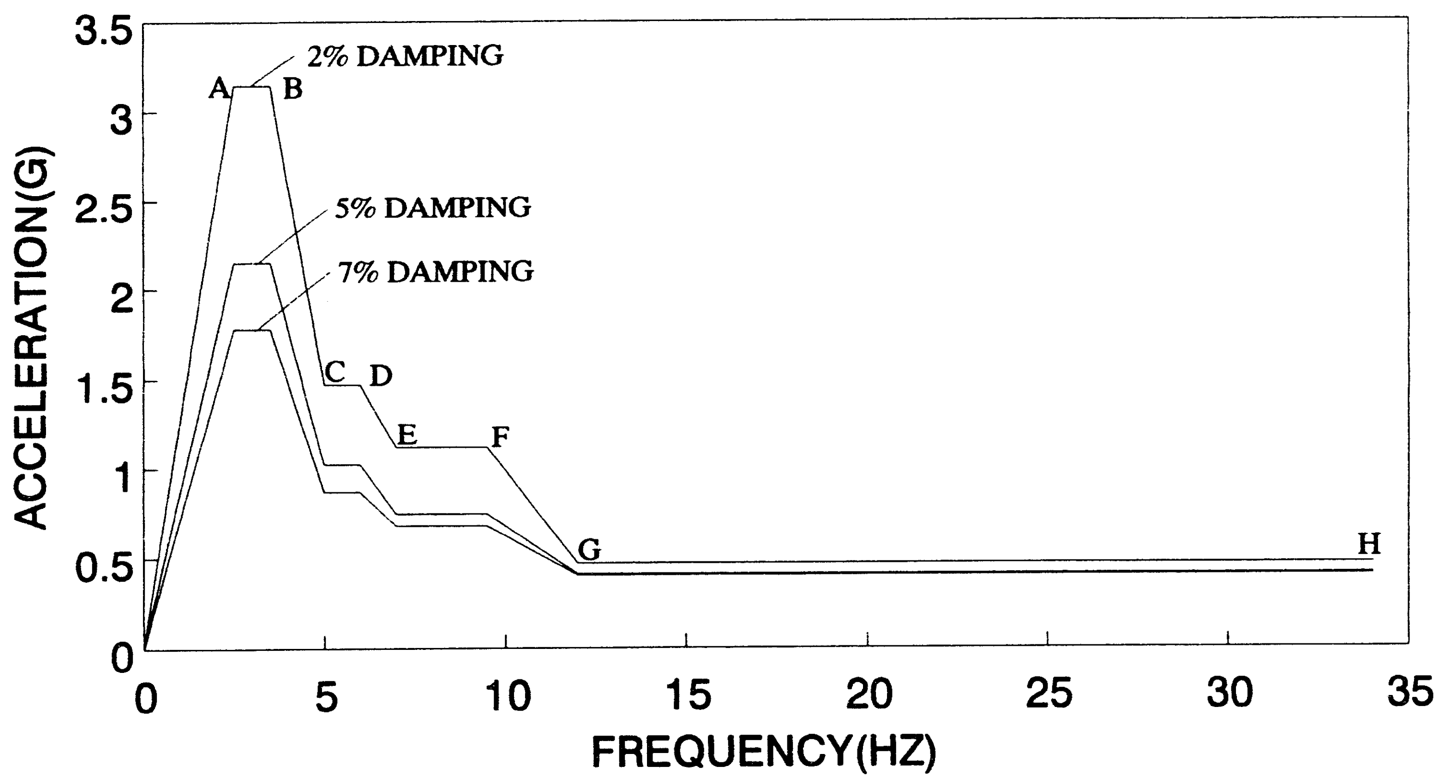


Figure 2–3

		ACCELERATION(G)			
POINT	FREQ(HZ)	2% DAMP	5% DAMP	7% DAMP	PERIOD
	0	0	0	0	
A	2.5	2.6	1.79	1.48	0.400
B	3.5	2.6	1.79	1.48	0.286
C	5	1.29	0.89	0.77	0.200
D	7	1.29	0.89	0.77	0.143
E	8.5	1.06	0.71	0.64	0.118
F	10.5	1.06	0.71	0.64	0.095
G	12	0.42	0.36	0.34	0.083
H	34	0.42	0.36	0.34	0.029

MODIFIED HFBR HORIZ FLOOR SPECTRA
EQUIPMENT LEVEL

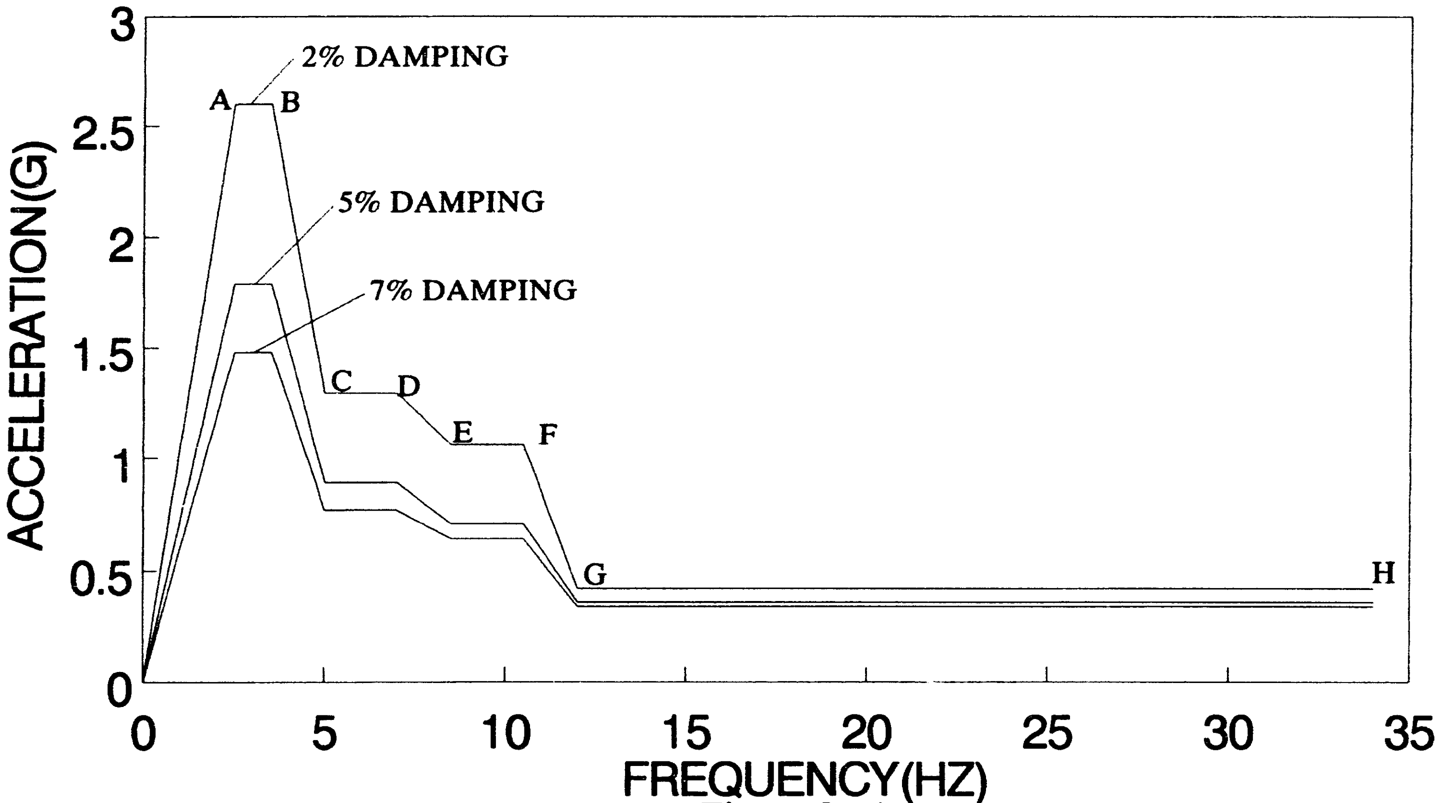
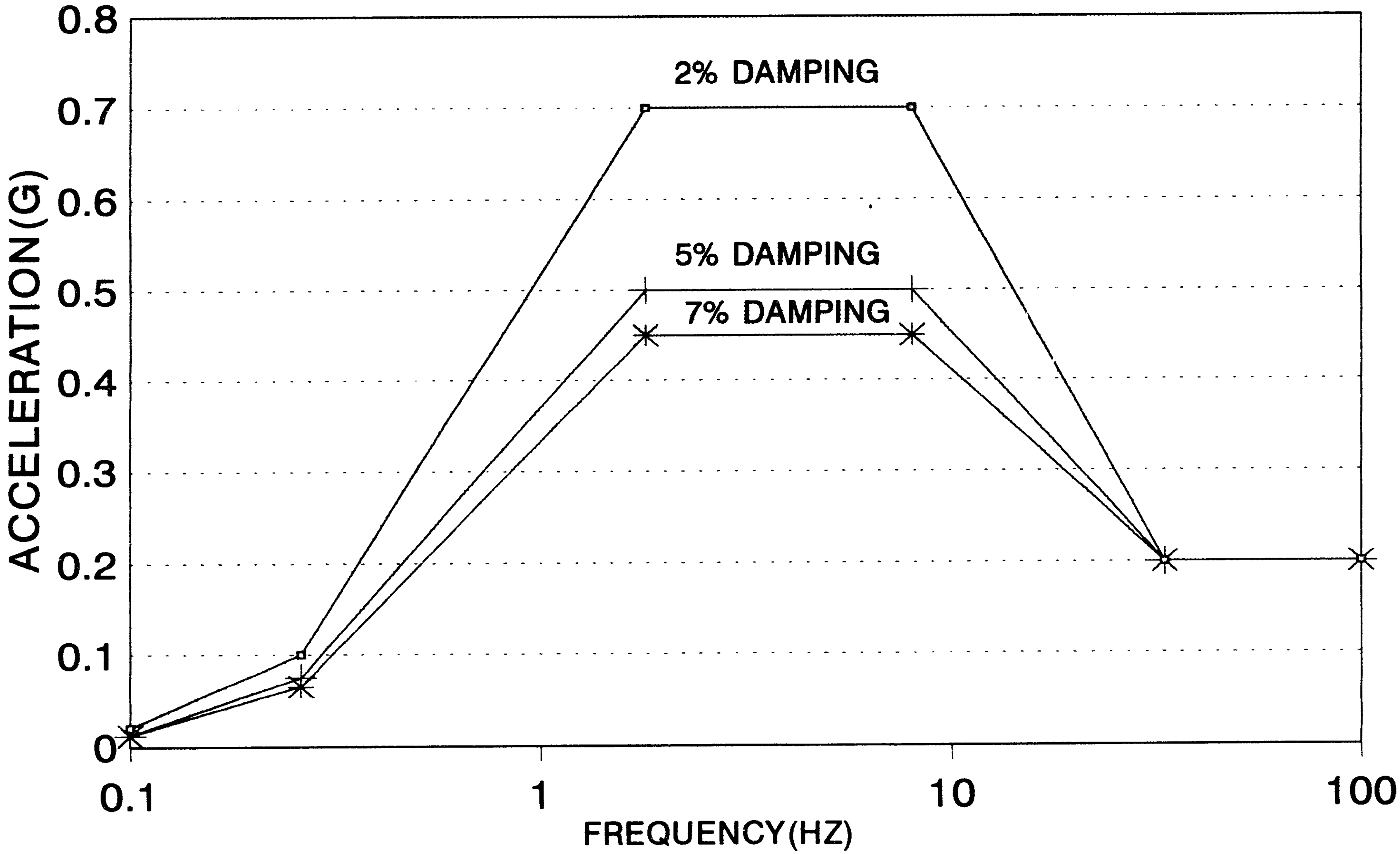


Figure 2–4

HFBR VERTICAL SPECTRA 70TH PERCENTILE ANCHORED @ 0.2g

BASED ON NEWMARK AND HALL SPECTRAL SHAPE

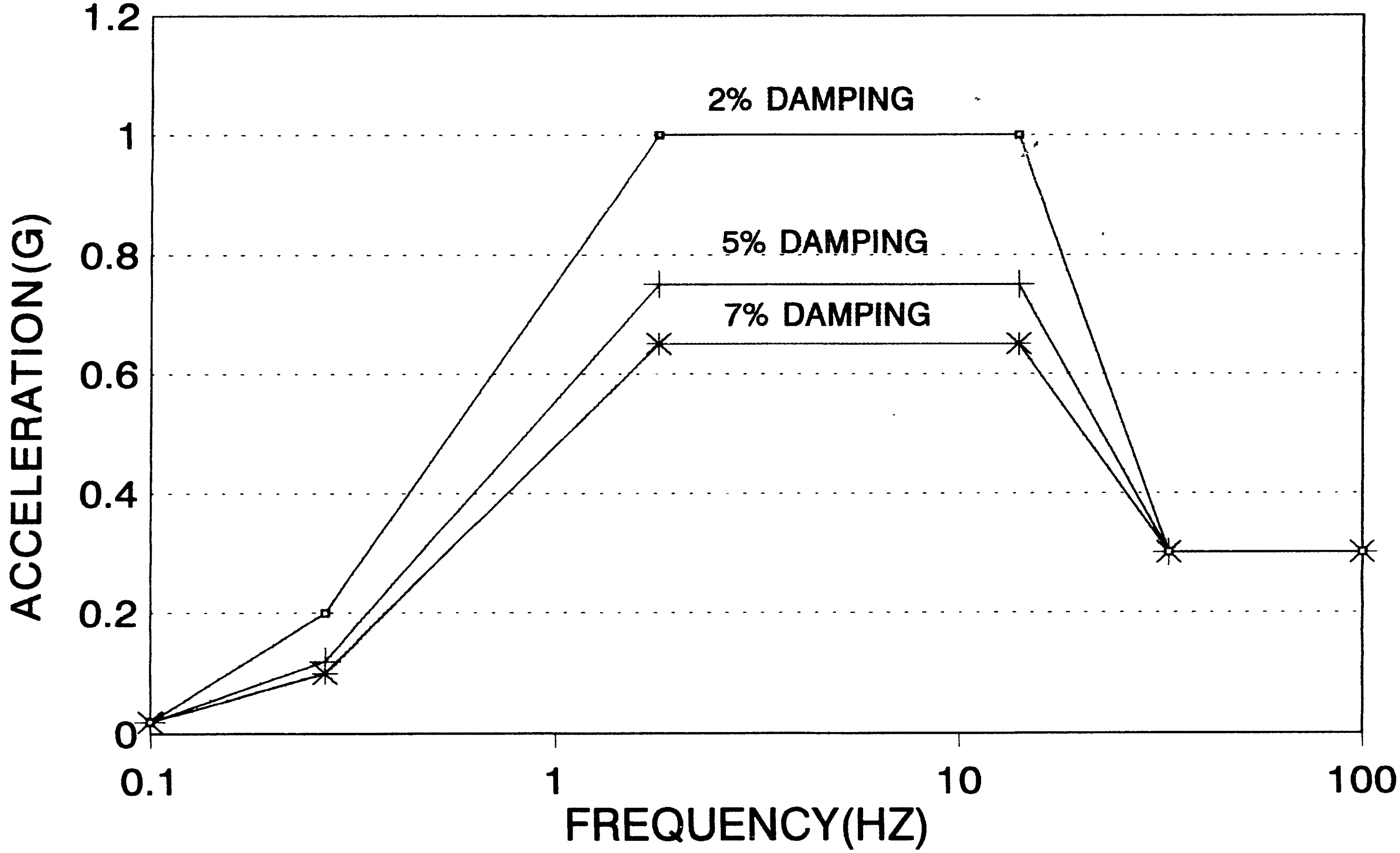


USE FOR EQUIPMENT LEVEL, CELL WALLS AND BIO-SHLD WALLS @ EXPER AND OPS LEVEL

Figure 2-5

HFBR VERTICAL SPECTRA 70TH PERCENTILE ANCHORED @ 0.30g

BASED ON NEWMARK AND HALL SPECTRAL SHAPE



USE FOR OPERATIONS, BALCONY AND EXPERIMENTAL LEVELS

Figure 2-6

APPENDIX A

Agreements from Seismic Commitments Meeting of October 25, 1993 at DOE (Germantown)

This Appendix contains a copy of the approaches agreed upon by the Reactor Division and the DOE to satisfy outstanding seismic commitments for the BNL High Flux Beam Reactor (HFBR). These agreements form the basis for the methodologies used to develop modified horizontal and vertical floor response spectra as described in Sections 2.1 and 2.2 of this report.

AGREEMENTS FROM SEISMIC COMMITMENTS MEETING-OCTOBER 28, 1993
AT DOE (GERMANTOWN)

Based on discussions at the above meeting between Department of Energy and Brookhaven National Laboratory personnel, the following lists the approach for satisfying the seismic commitments.

1. The alternate approach, as delineated in Section 5.0 of Reactor Division's response to the Department of Energy commitments, will be used to modify the existing High Flux Beam Reactor horizontal floor response spectra. The high frequency end of the spectra will be reduced based on previous engineering arguments used in the analysis of the High Flux Beam Reactor control room [Seismic Evaluation of High Flux Beam Reactor Control Room Structure, dated 03/93 by Y. J. Park (Brookhaven National Laboratory-DAT)]. Vertical accelerations will be defined based on the approach used in response to questions regarding the Control Room Analysis.

2. The Control Room is considered a Life Safety and not Nuclear Safety structure. As a result, the control room will be evaluated in accordance with the provisions of the latest Uniform Building Code.

3. M. Davister (DP-621) and a Nuclear Energy representative will travel to Brookhaven National Laboratory to finalize the technical details of the approach discussed in (1) above. This trip is tentatively scheduled for November 9-10, 1993. The proposed implementation of the Uniform Building Code with respect to the Control Room evaluation will also be reviewed.

4. The modified floor spectra curves will be used to evaluate present and future Structures, Systems, and Components at the High Flux Beam Reactor. Use of the 1978 seismic data in the evaluation of the spent fuel storage racks is an acceptable approach.

5. Based on the above agreements, Brookhaven National Laboratory will submit a revised plan to the Department of Energy for approval.

Matthew A. Hutmaker | Michael D. Holland | Michael H. Brooks

10/28/93

APPENDIX B

1978 Ground Motion Time History and Plot of DBE Ground Spectral Shape versus Generated Response Spectrum

Figures B-1 and B-2 of this Appendix represent plots of the 1978 Ground Motion Time History and DBE Ground Spectral Shape versus Generated Response Spectrum respectively. As can be seen in Figure B-1, the Peak Ground Acceleration (PGA) used in describing the 1978 or current ground motion was 0.33g. This value is obtained by converting the GAL units of acceleration to "g" units by dividing GAL by 980. Figure B-2 illustrates the very poor matching of the generated response spectrum to the ground spectral shape at frequencies above approximately 12 Hz. Both of these figures show the conservatisms inherent in the current floor response spectra used at the HFBR as discussed in Section 2.1 of this report.

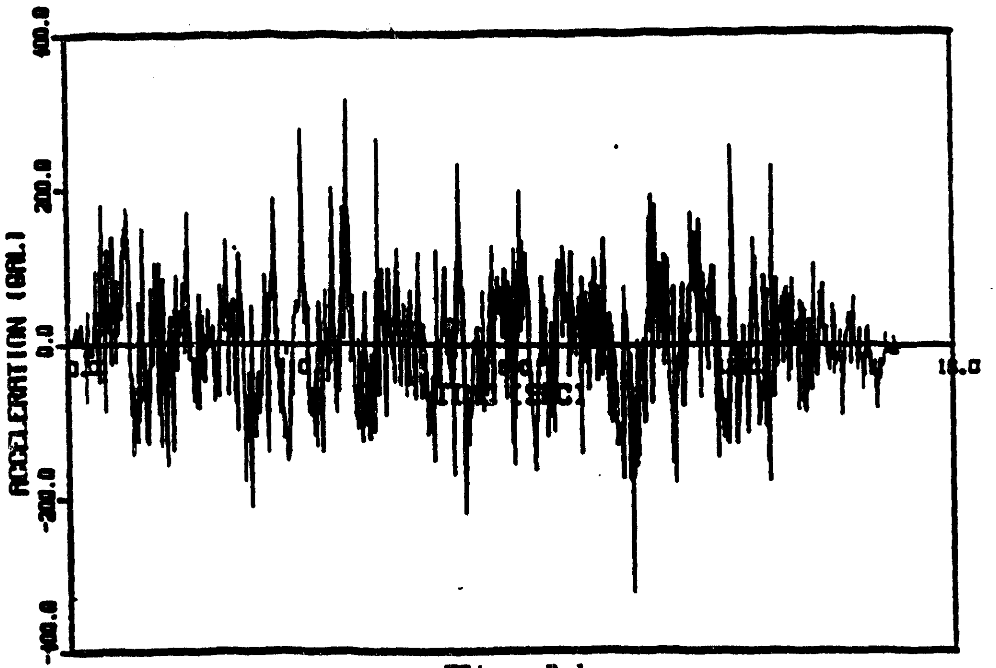


Figure B-1
1978 Ground Motion Time History

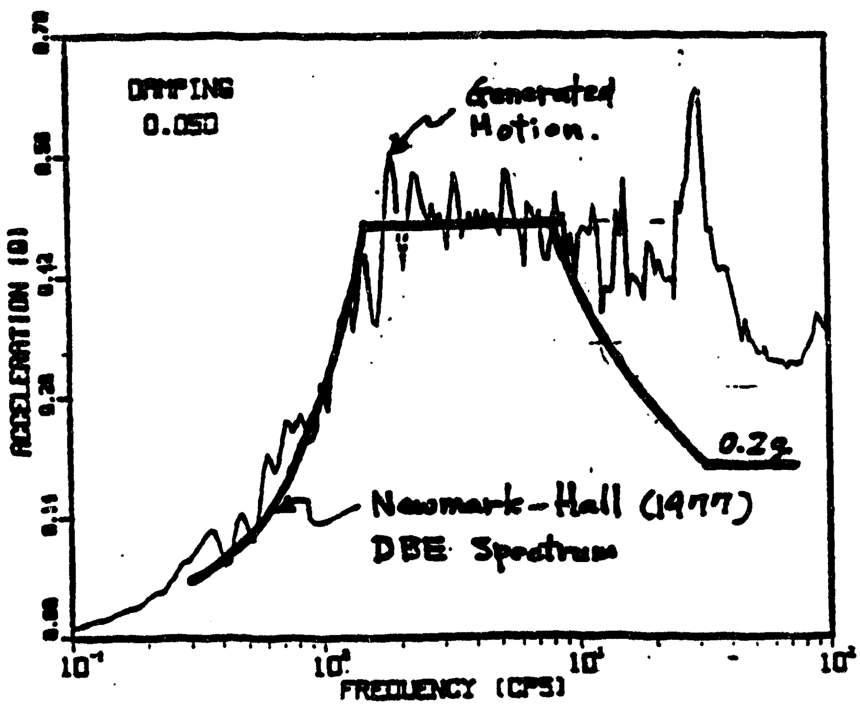


Figure B-2
1978 Ground Motion Response Spectrum versus DBE Spectral Shape

APPENDIX C

1978 HFBR Floor Response Spectra Curves (unbroadened)

This Appendix contains the 1978 unbroadened HFBR floor response spectra curves annotated to show the three primary judgments used in the development of the modified horizontal floor response spectra curves as discussed in Section 2.1 of this report. These are:

- Fictitious peak accelerations for frequencies above approximately 12 Hz.
- Governing acceleration to be used as a basis for response spectra curve modifications for frequencies above approximately 12 Hz.
- Transition region between the low frequency and high frequency portion of the modified floor response spectra curve.

HFBR FLOOR SPECTRA(OPER LEVEL) 2% DAMP
UNBROADENED

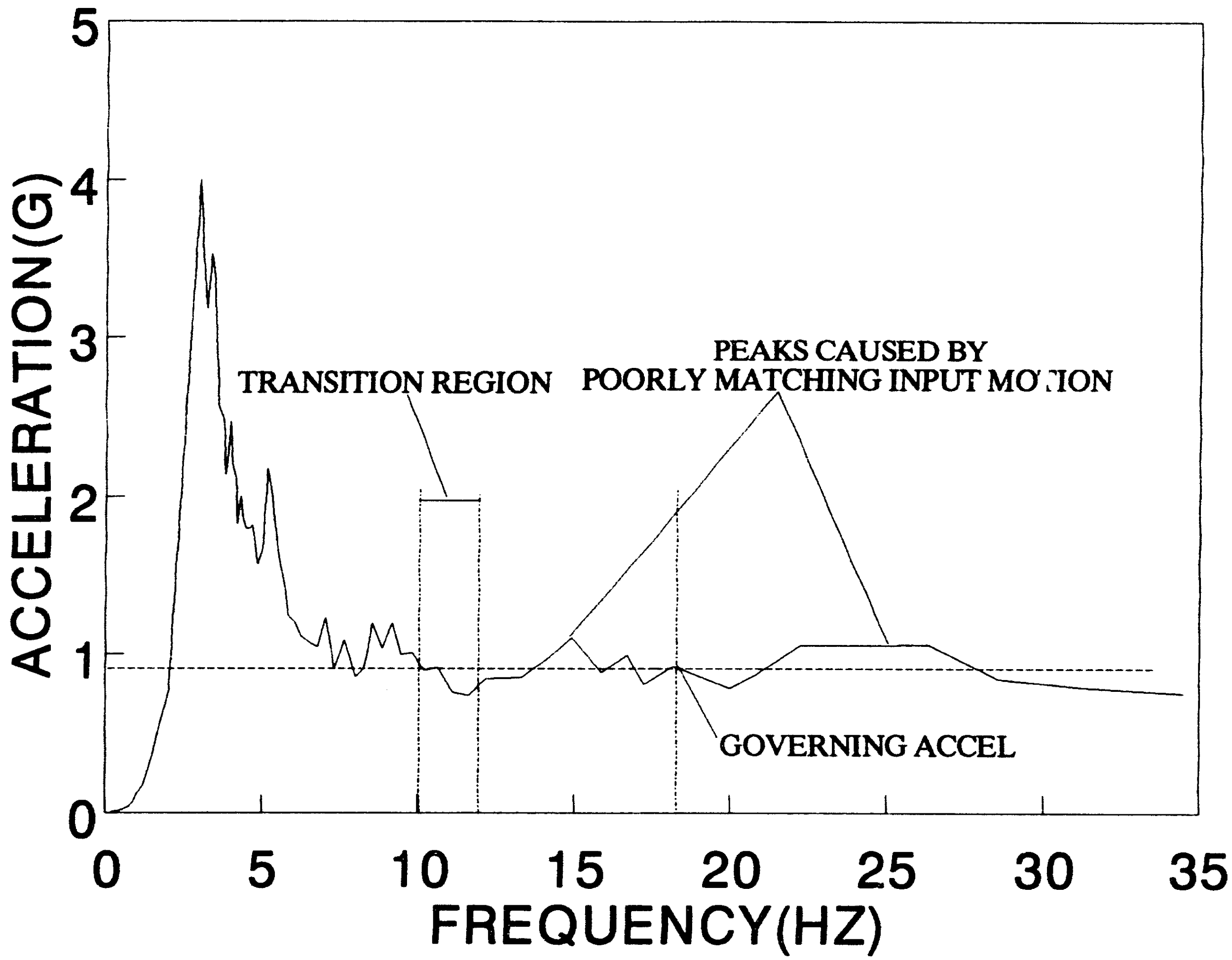


Figure C–1

OPERUN2.WK1

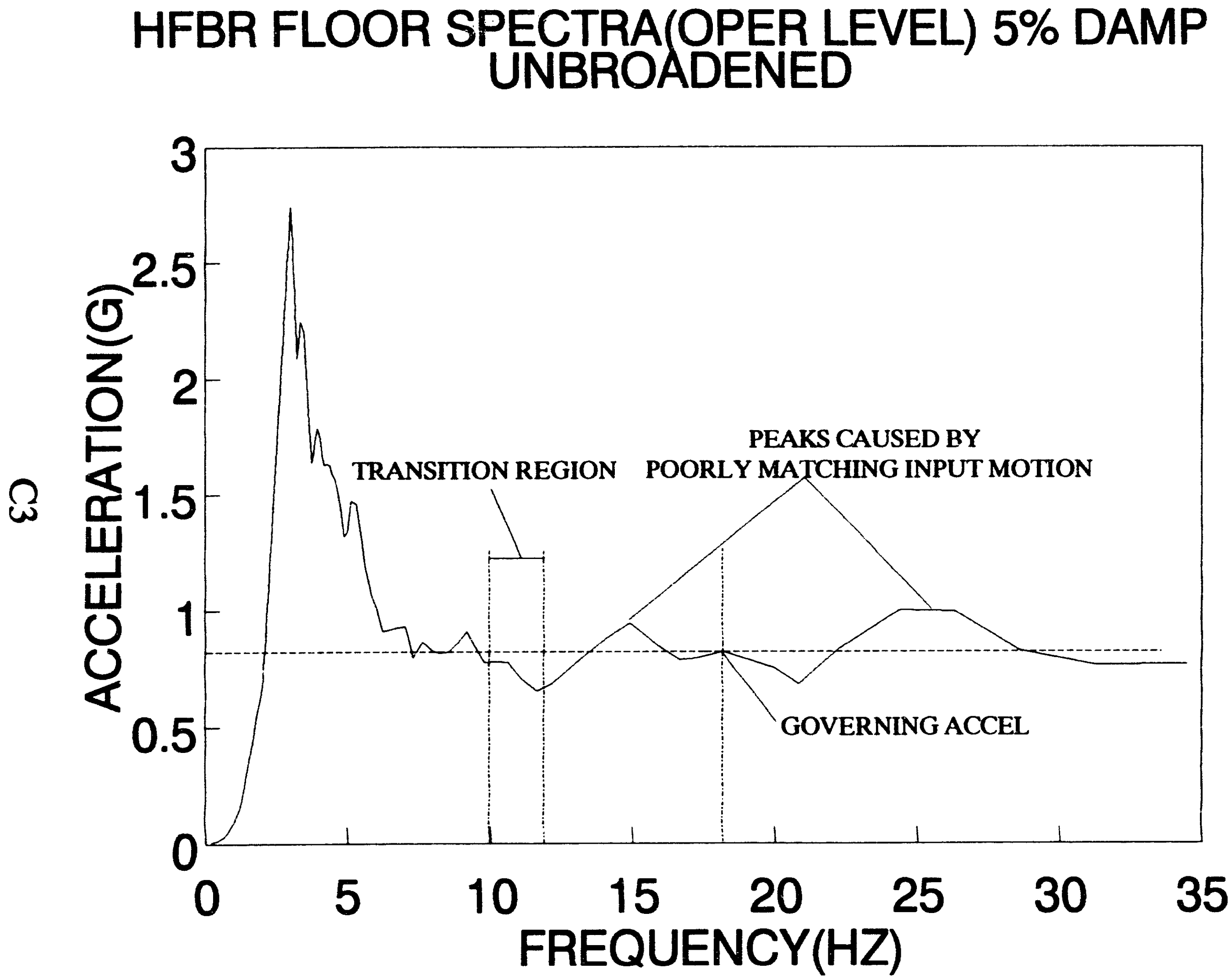


Figure C-2

OPERUN5.WK1

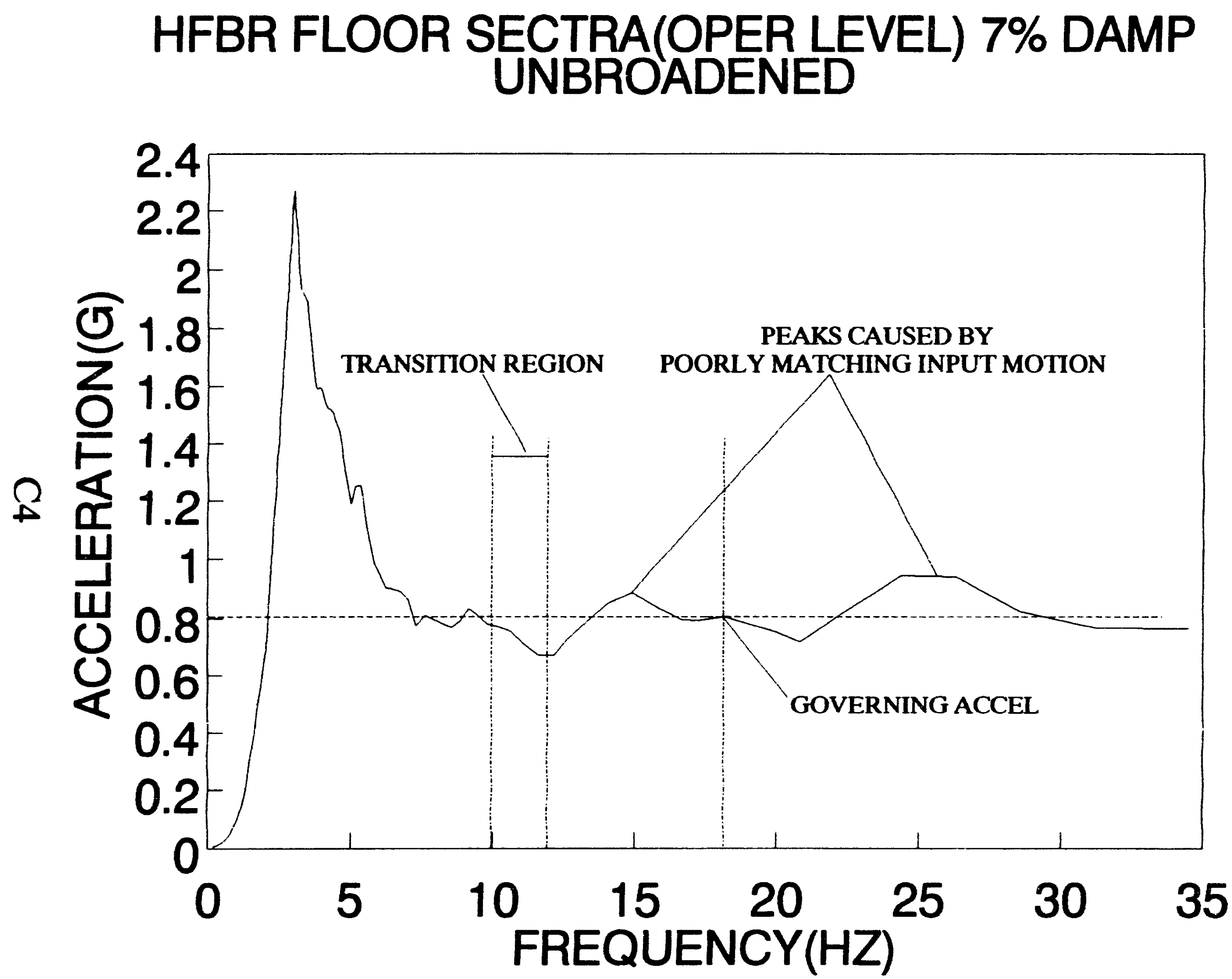


Figure C–3

OPERUN7.WK1

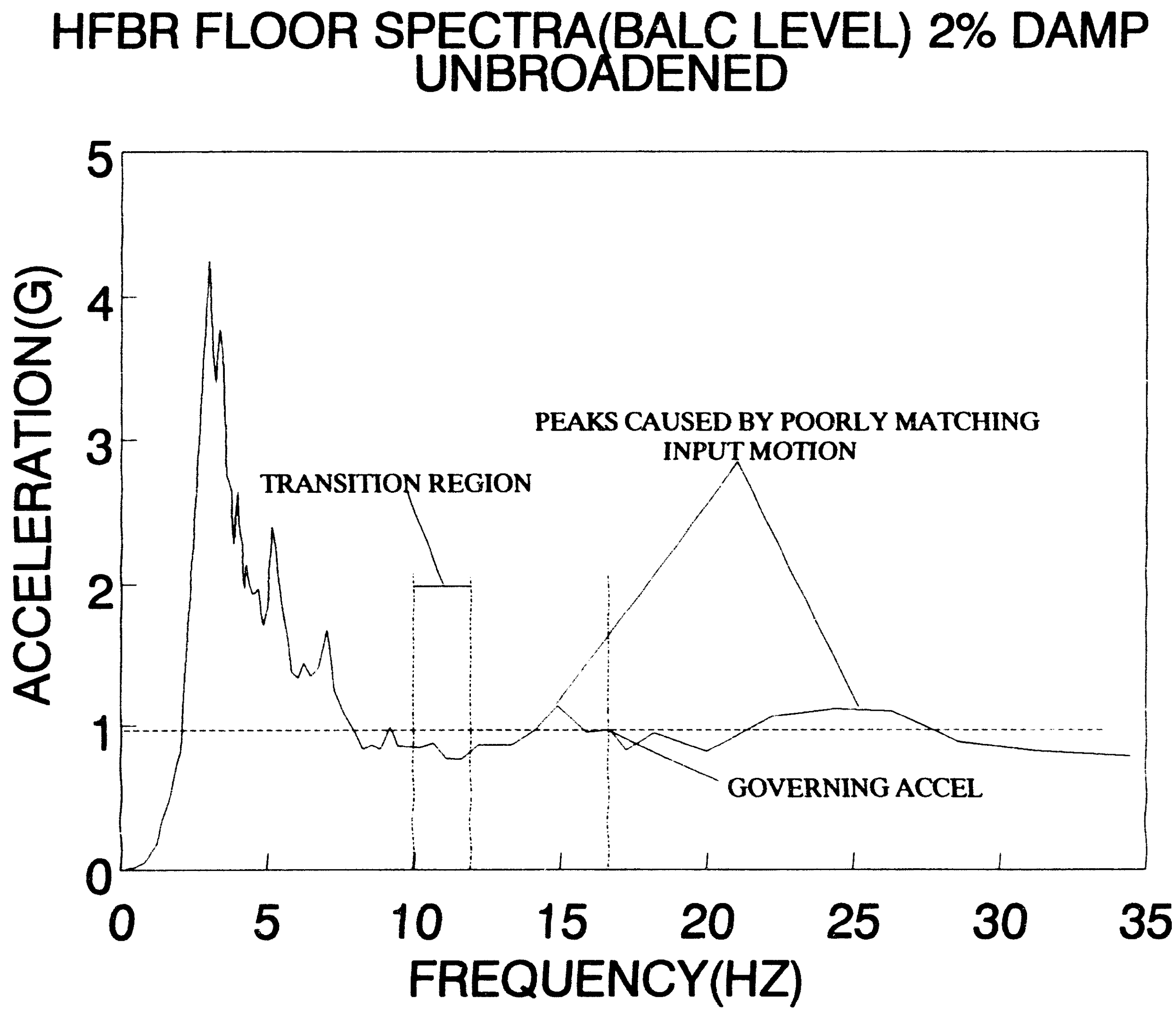


Figure C-4

BALCUN2.WK1

HFBR FLOOR SPECTRA(BALC LEVEL) 5% DAMP UNBROADENED

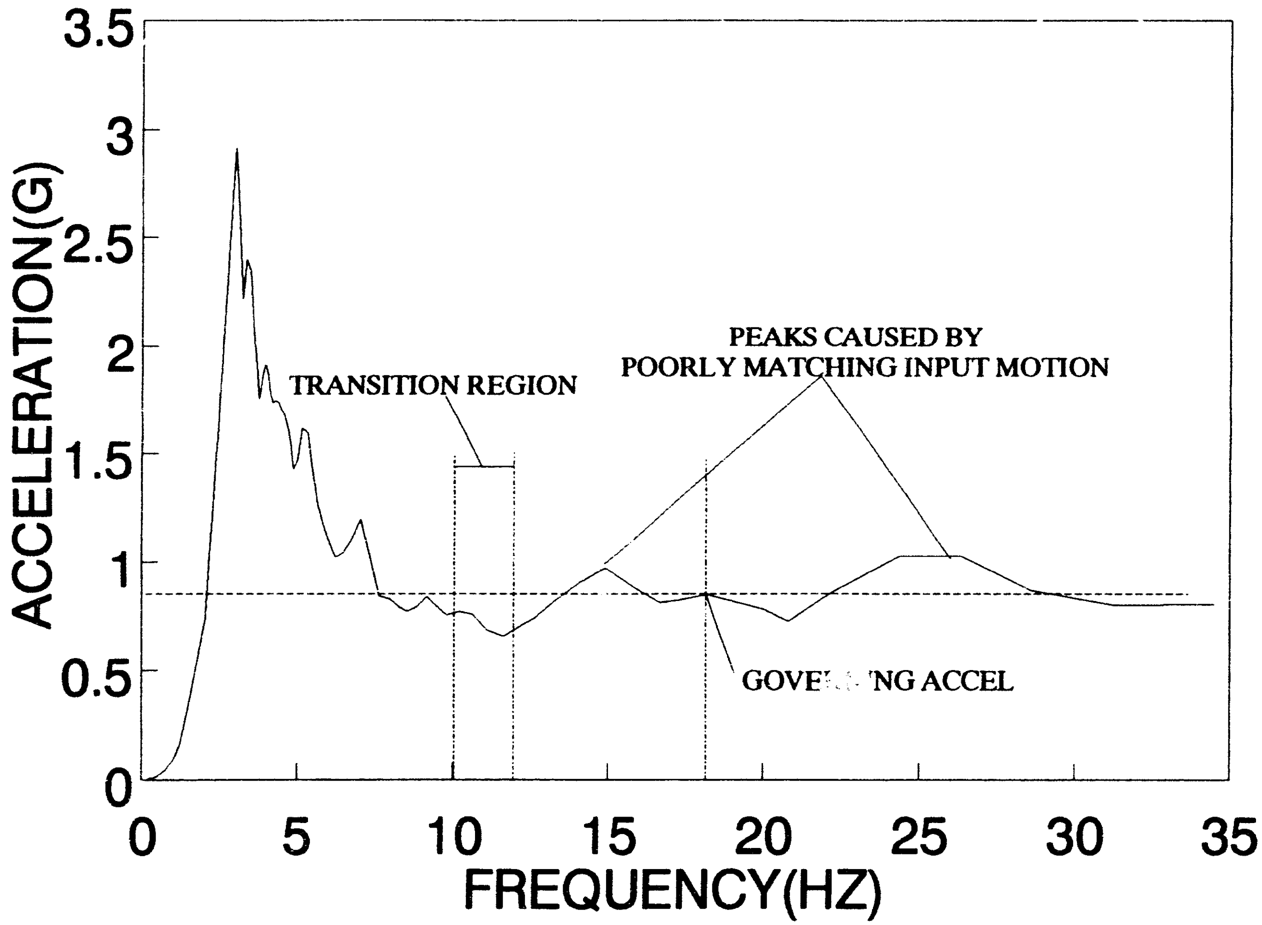


Figure C−5

BALCUN5.WK1

C6

HFBR FLOOR SECTRA(BALC LEVEL) 7% DAMP
UNBROADENED

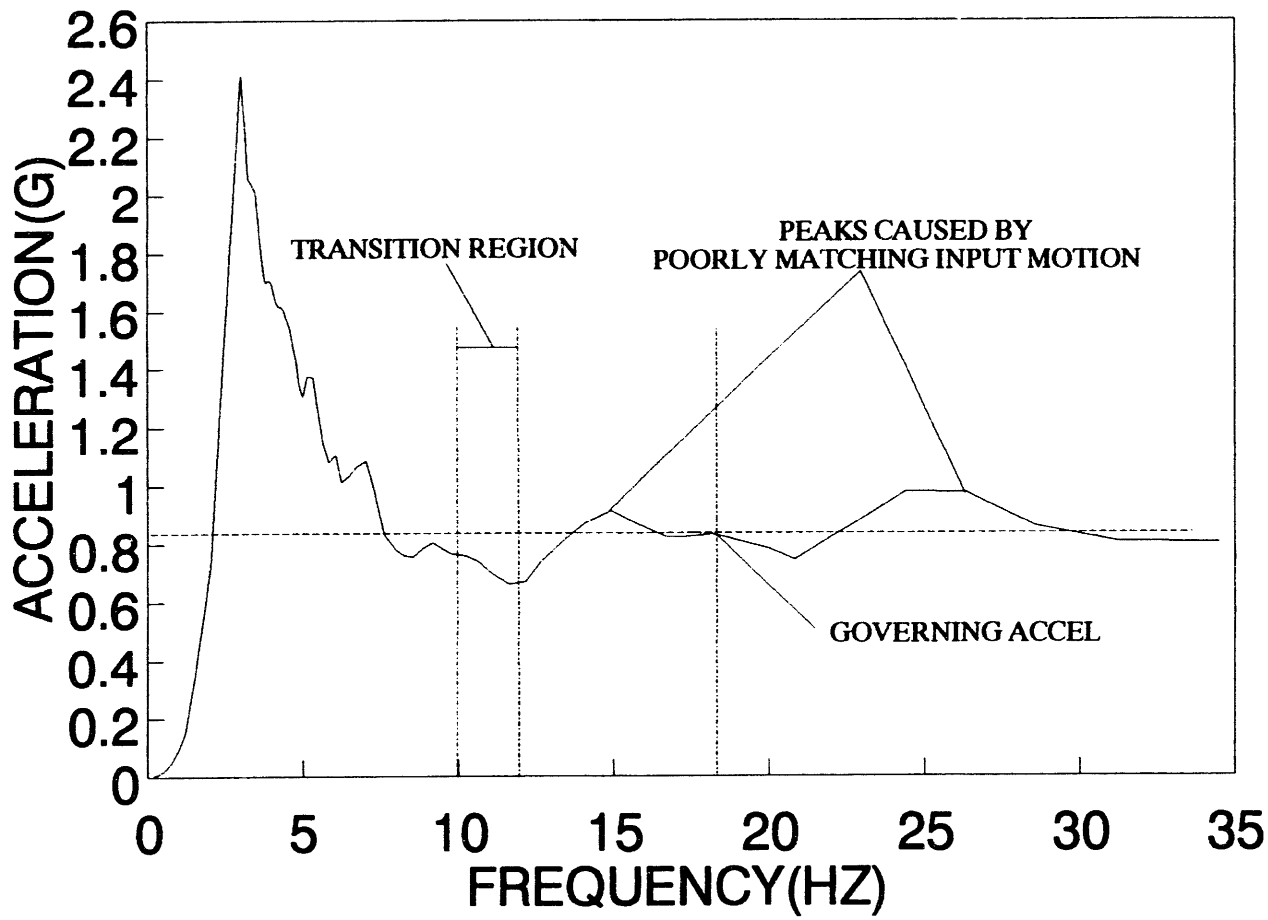


Figure C−6

BALCUN7.WK1

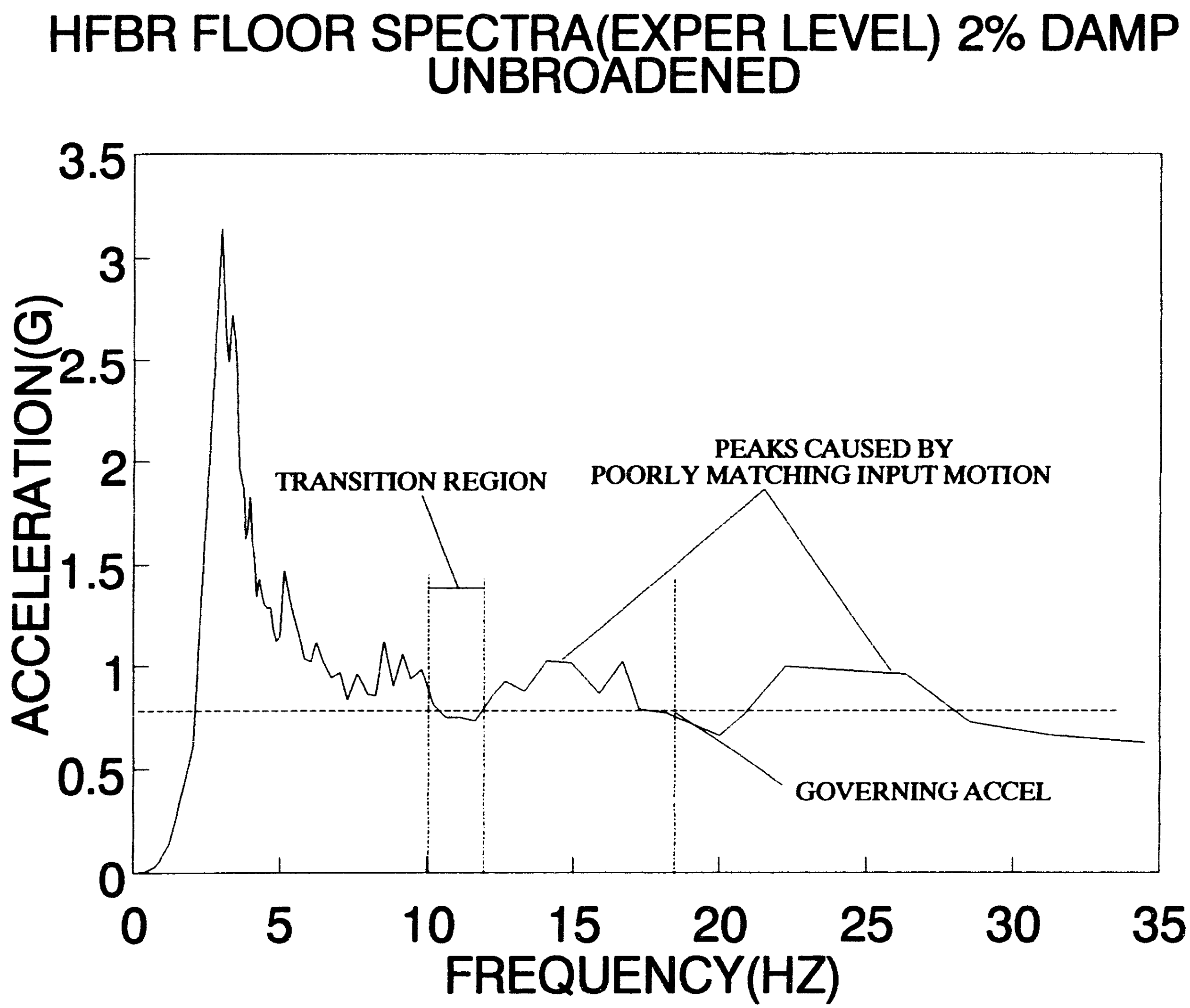


Figure C–7

EXPUN2.WK1

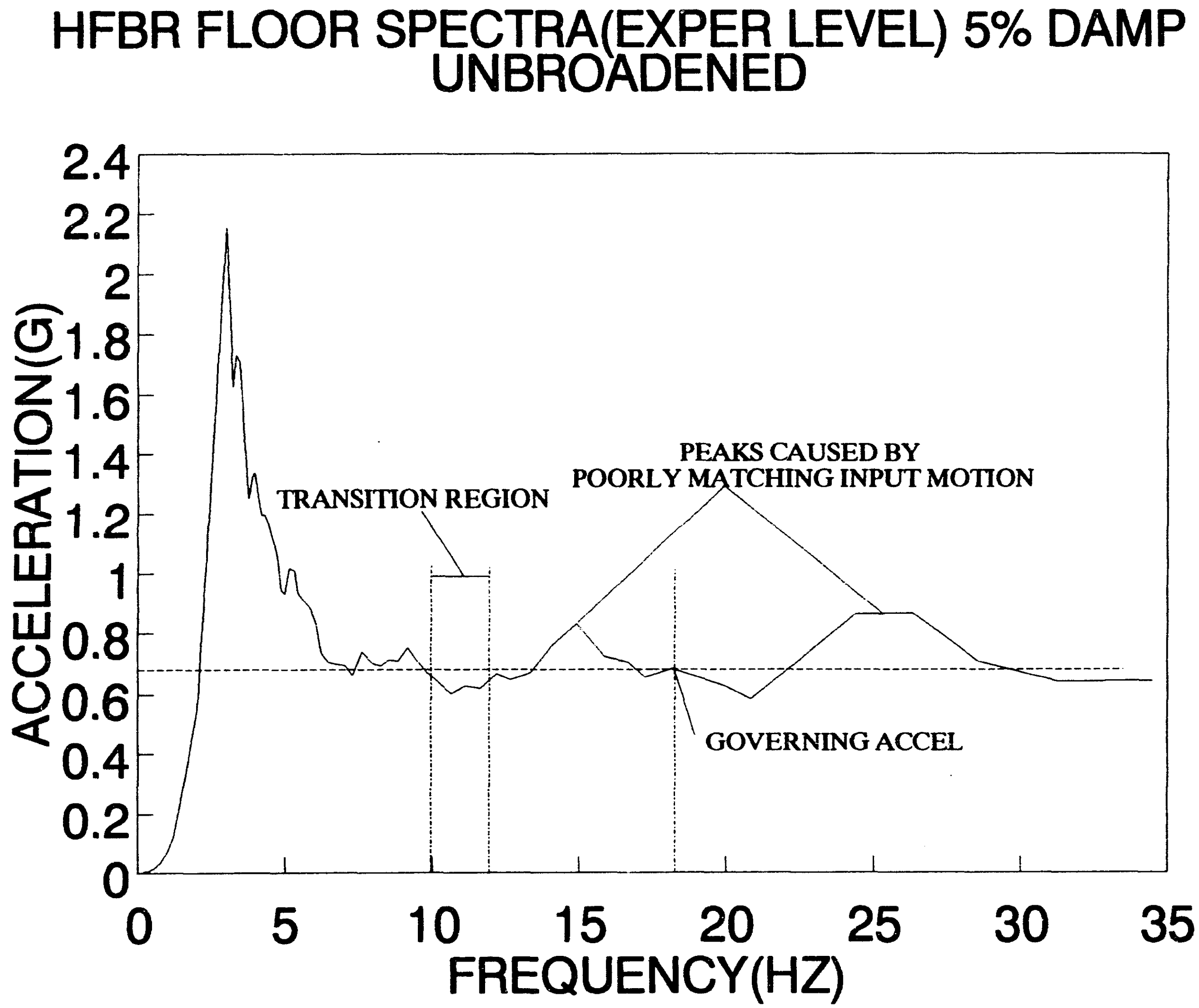


Figure C-8

EXPUN5.WK1

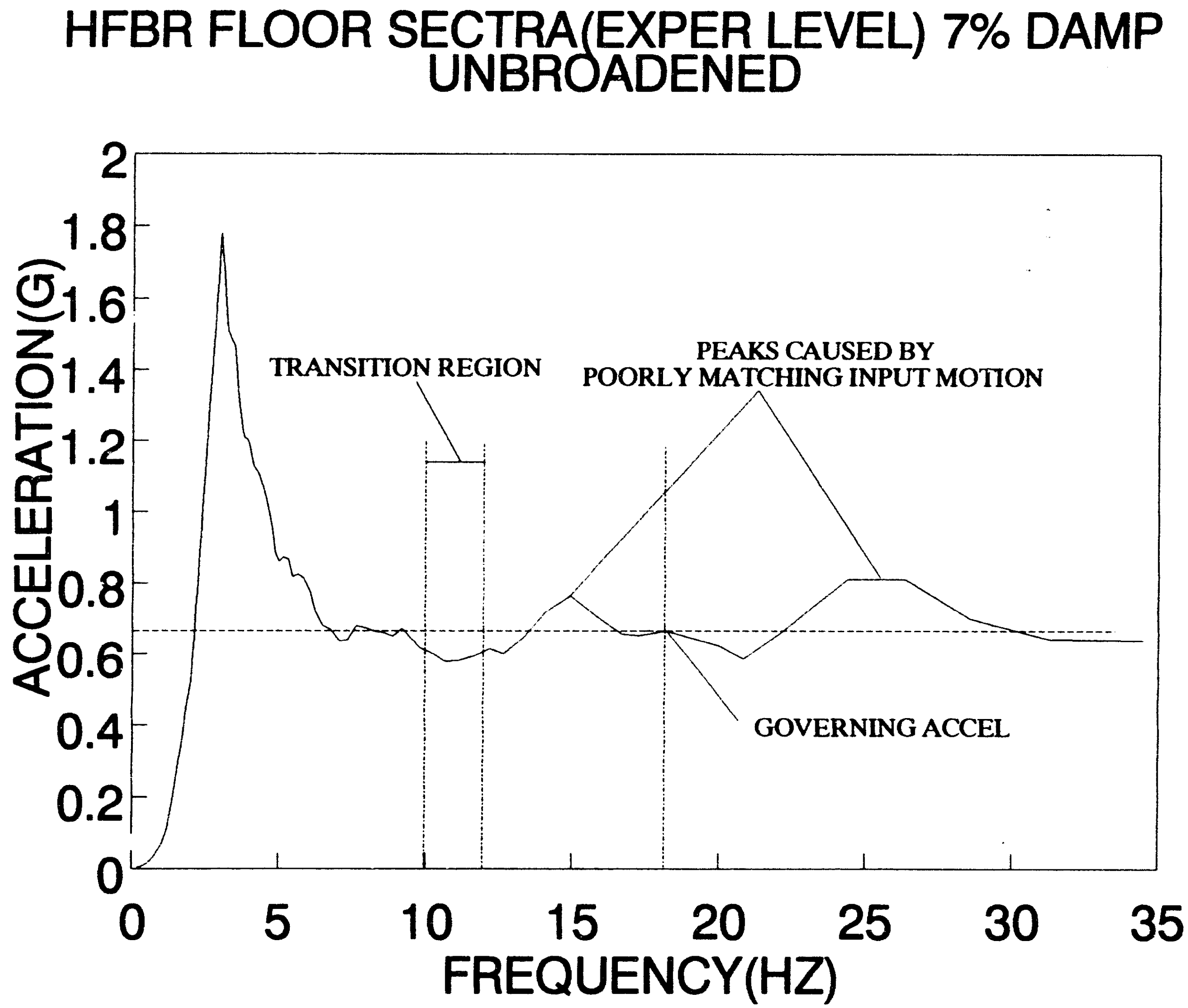


Figure C-9

EXPUN7.WK1

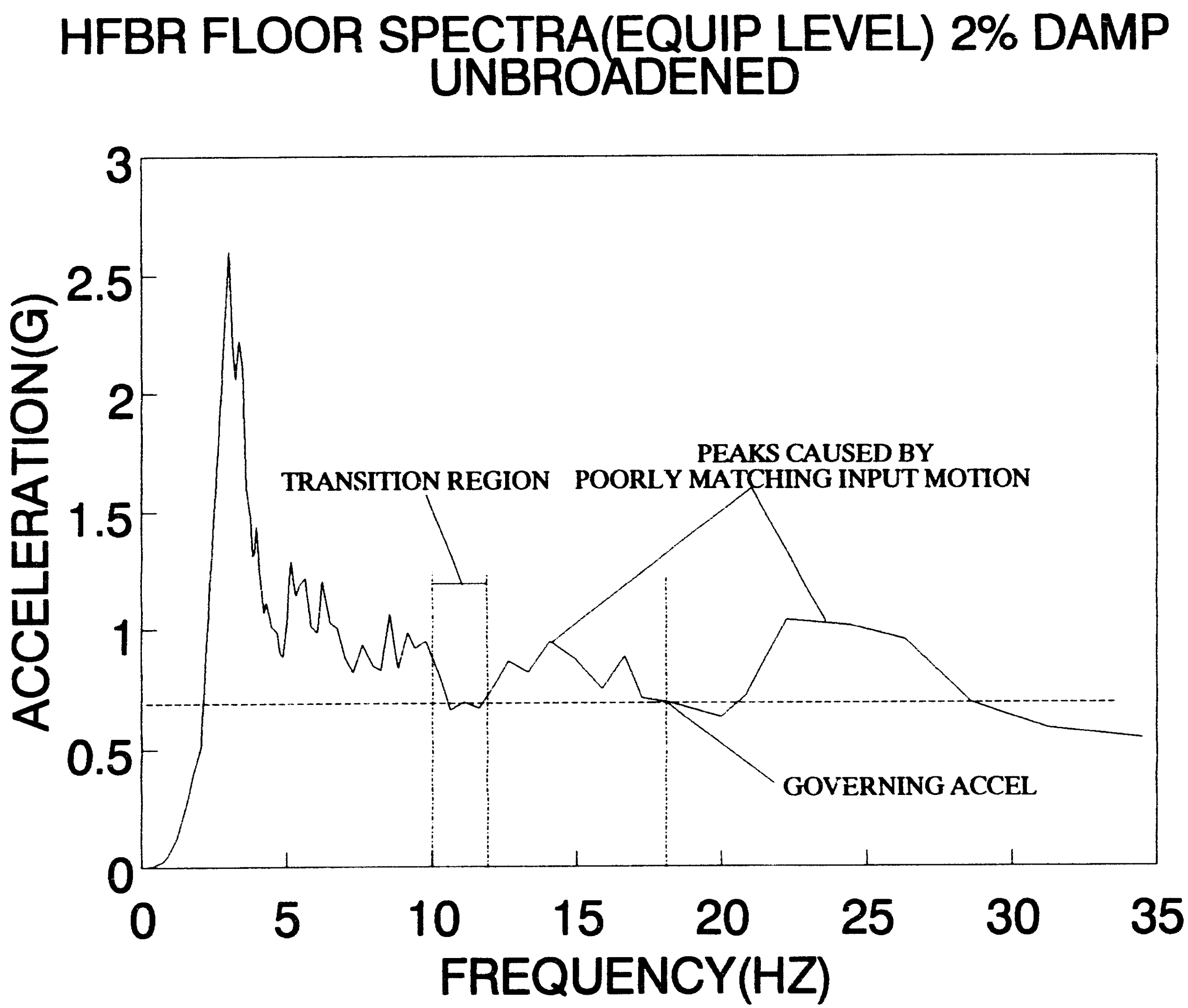


Figure C-10

EQPUN2.WK1

HFBR FLOOR SPECTRA(EQUIP LEVEL) 5% DAMP
UNBROADENED

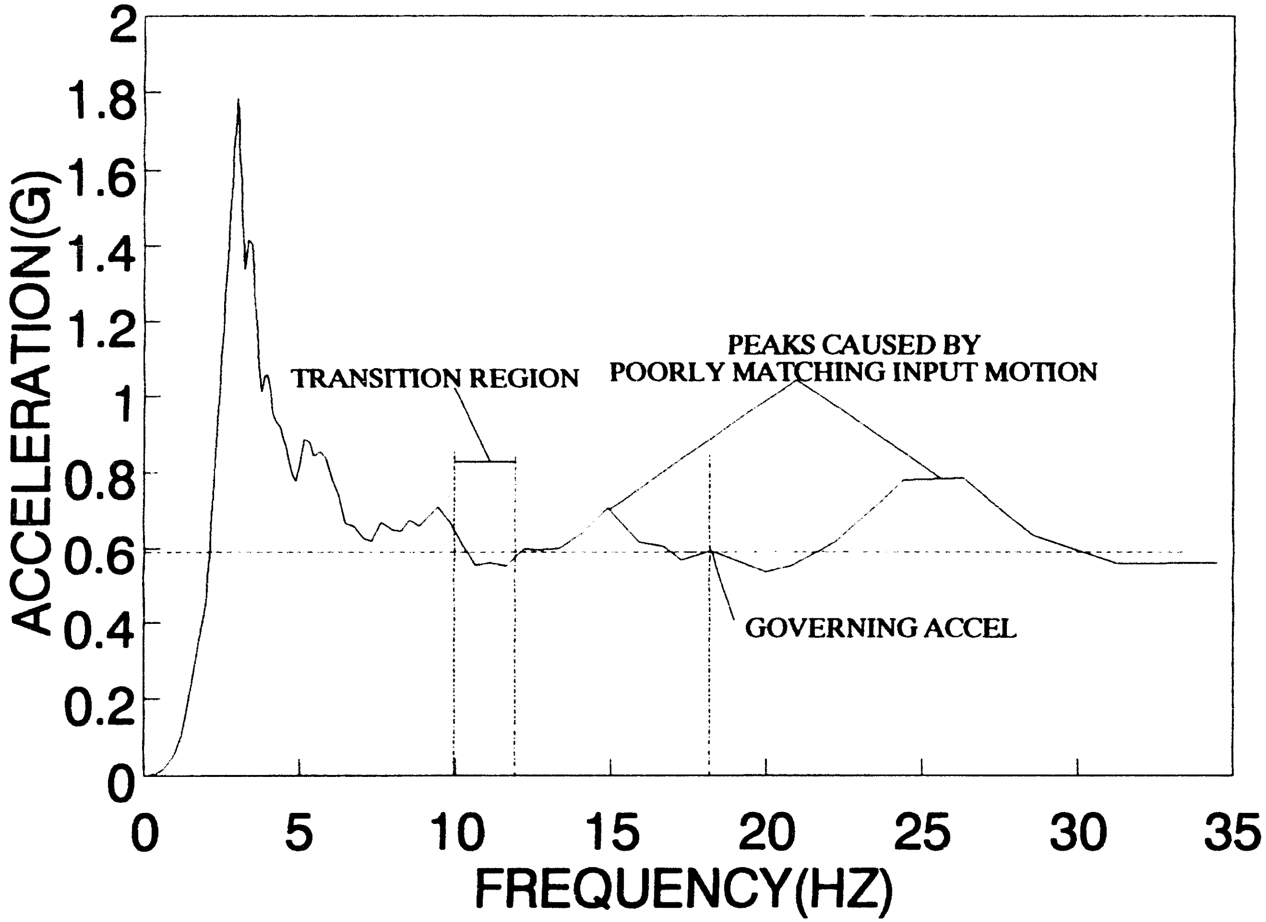


Figure C-11

EQFUNS.WK1

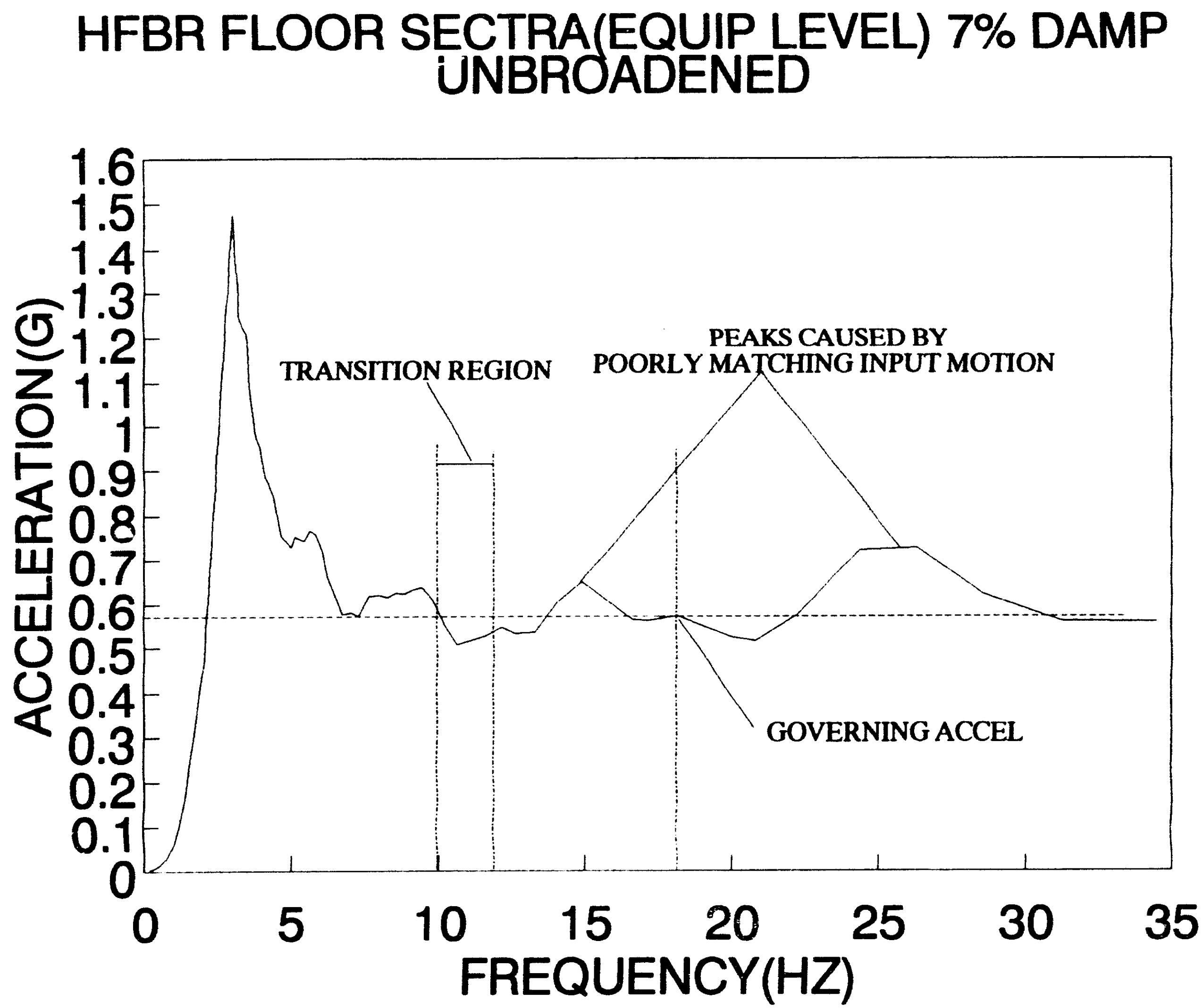


Figure C−12

EQFUN7.WK1

APPENDIX D

1992 Operations Level Time History and Associated Floor Response Spectra

Figures D-1 and D-2 of this Appendix represent the 1992 Operations Level Floor Time History and Floor Response Spectra generated in support of the HFBR PRA (Ref. 4). These curves are presented solely for comparative purposes to determine the reasonableness of the modified horizontal floor response spectra ZPA values as developed within this report. Details concerning the development of the modified horizontal floor response curves can be found in Section 2.1 of this report.

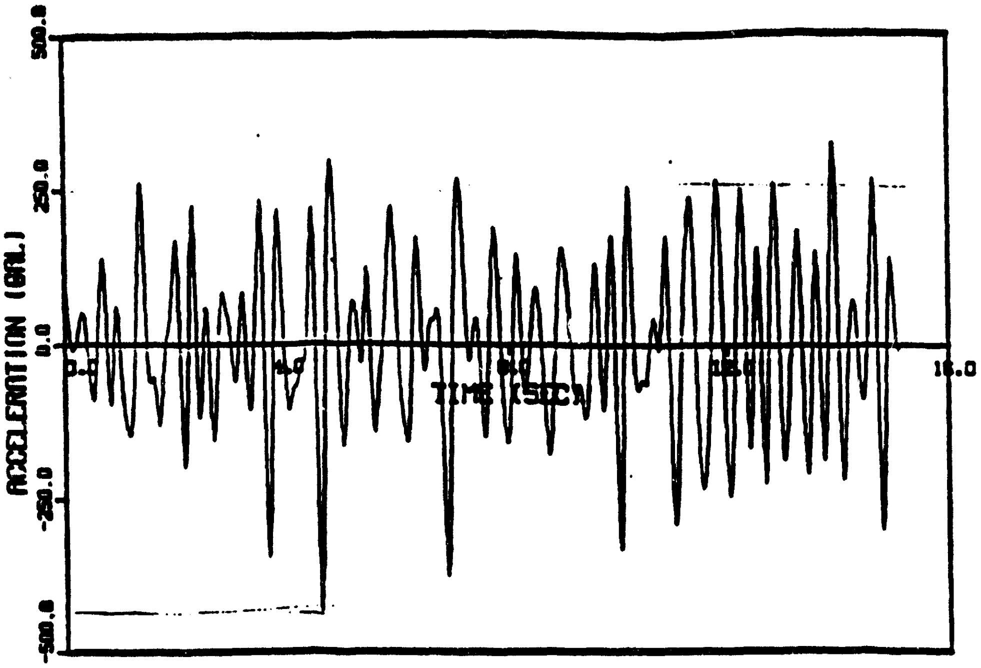


Figure D-1
1992 Operations Level Time History

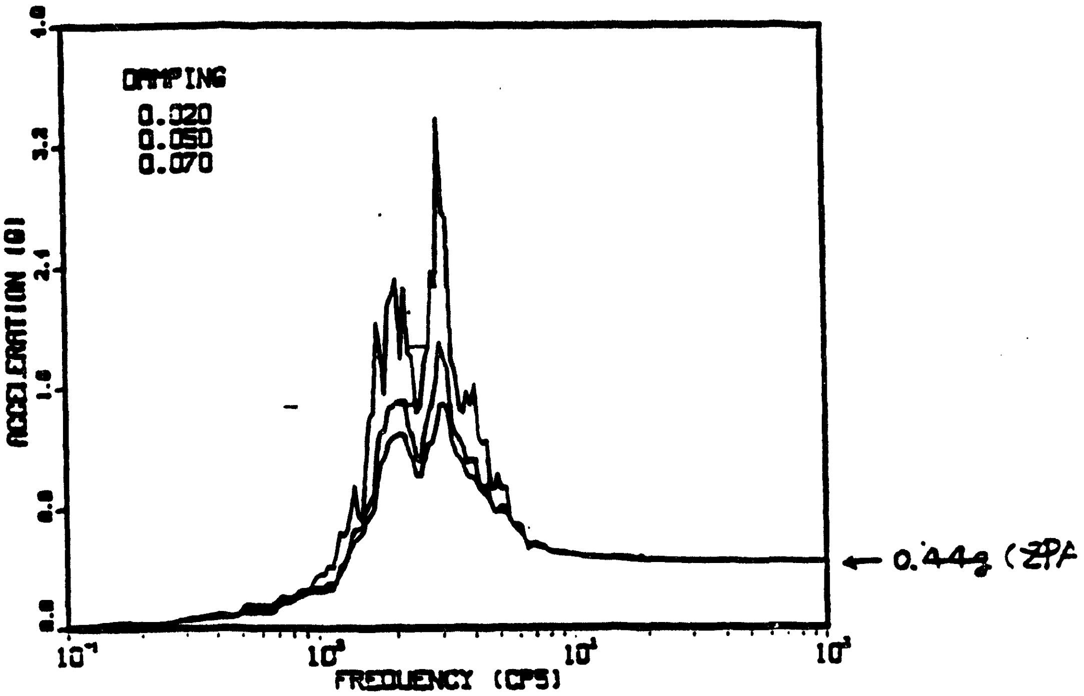


Figure D-2
1992 Operations Level Floor Response Spectra

APPENDIX E

HFBR DBE Vertical Ground Spectra

This Appendix contains plots of the HFBR vertical ground spectra at 0.5%, 2%, 5%, 7%, 10% and 15% damping. These curves form the starting point for the development of the modified vertical floor response spectra as described in Section 2.2 of this report.

HFBR DBE VERTICAL GROUND SPECTRA 70TH PERCENTILE ANCHORED @ 0.133g

BASED ON NEWMARK AND HALL SPECTRAL SHAPE

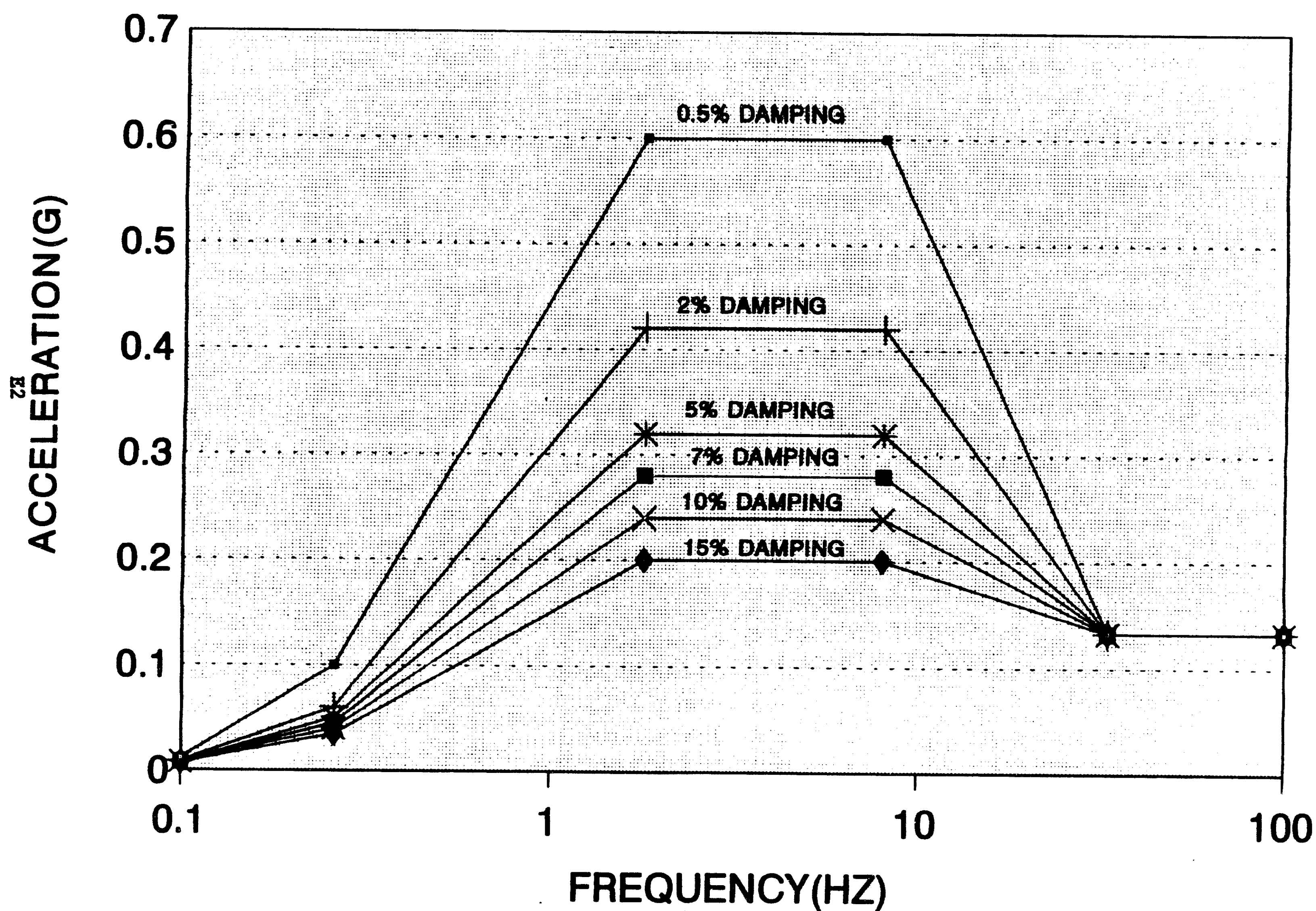


FIGURE E-1

APPENDIX F

Comparison of DBE Vertical Ground Spectrum, 2/3 of the 1978 Horizontal Floor Spectra, and Modified Vertical Floor Spectra @ 5% Damping

This Appendix contains the above mentioned curves for the Operations, Balcony, Experimental and Equipment levels.

DBE HFBR GROUND SPECTRUM & 1978 FLOOR SPECTRUM COMPARED TO MODIFIED SPECTRUM
VERTICAL DIRECTION @ 5% DAMPING

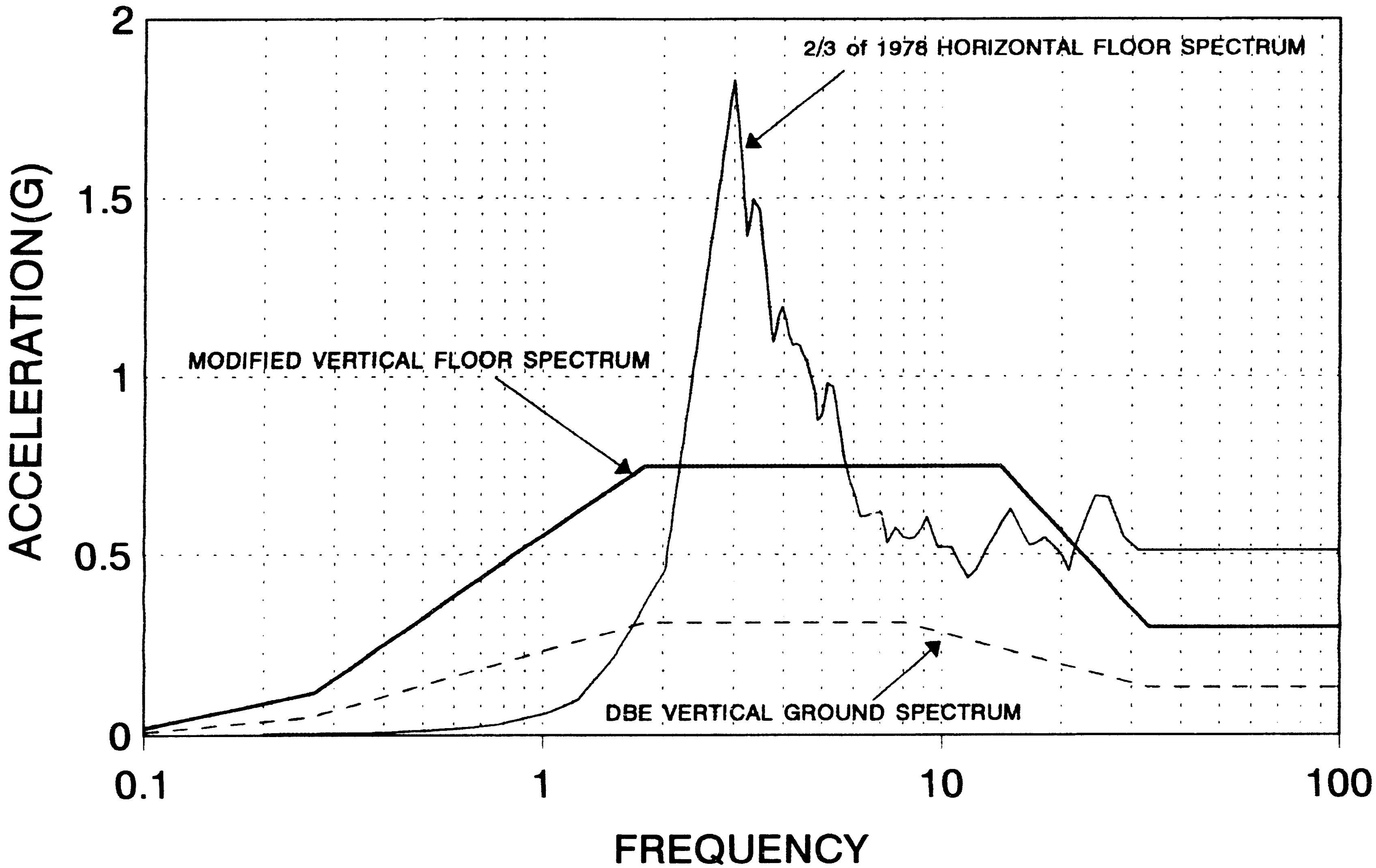


Figure F-1

OPERATIONS LEVEL

OPRV5.CH3

DBE HFBR GROUND SPECTRUM & 1978 FLOOR SPECTRUM COMPARED TO MODIFIED SPECTRUM
VERTICAL DIRECTION @ 5% DAMPING

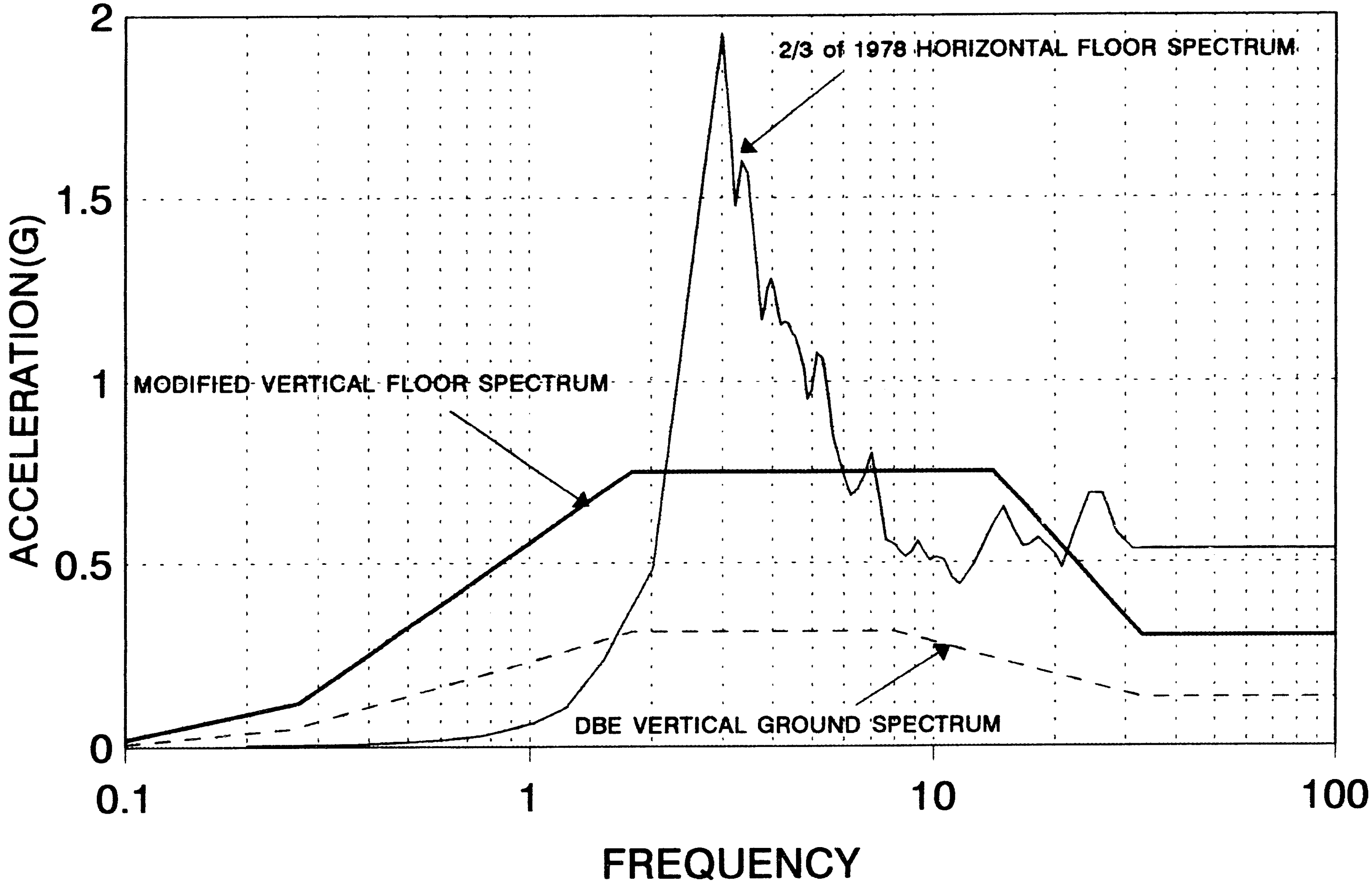


Figure F-2

BALCONY LEVEL

BALV5.CH3

DBE GROUND SPECTRUM & 1978 FLOOR SPECTRUM COMPARED TO MODIFIED SPECTRUM
VERTICAL DIRECTION @ 5% DAMPING

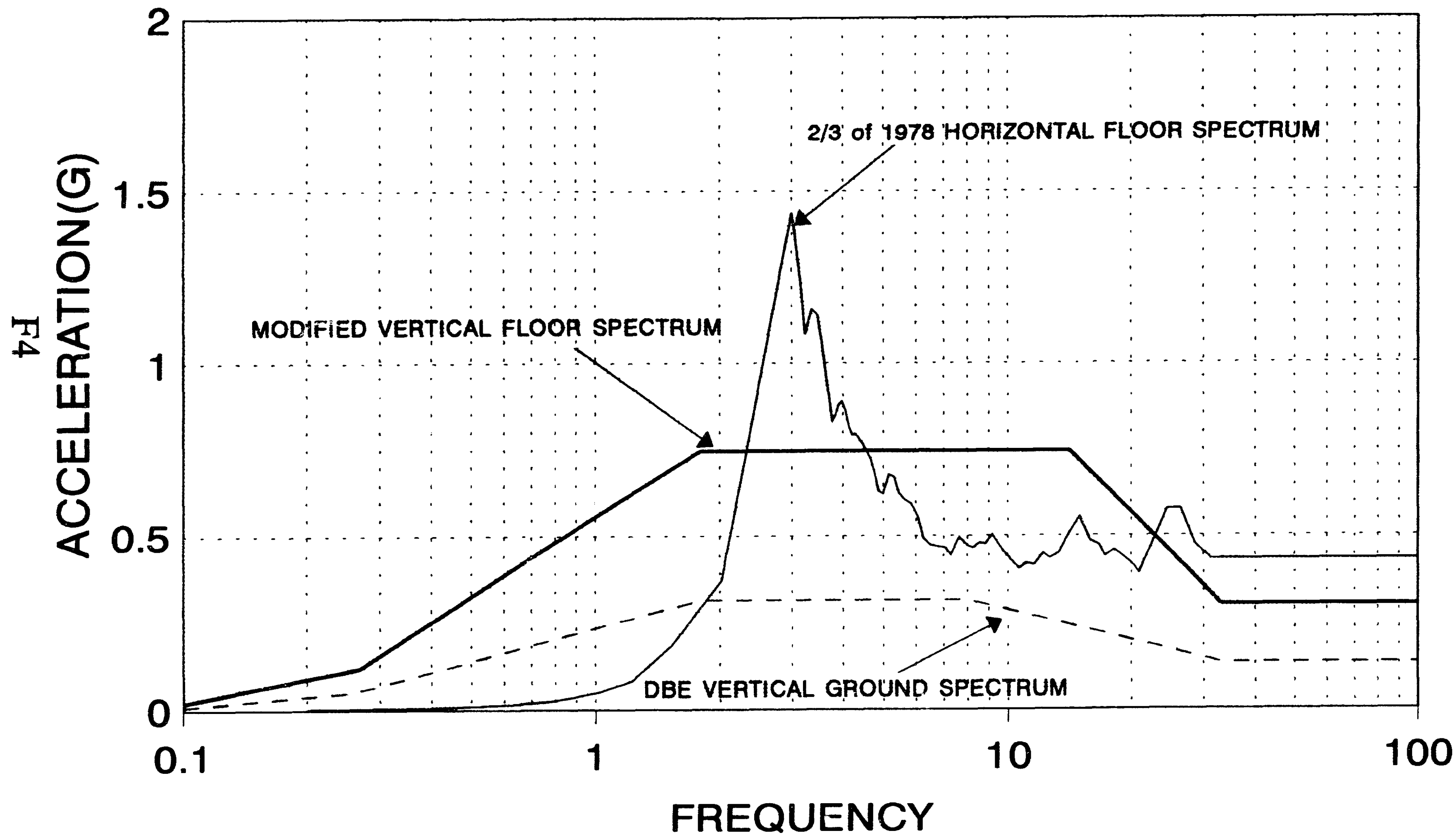


Figure F-3

EXPERIMENTAL LEVEL

EXPV5.CH3

DBE HFBR GROUND SPECTRUM & 1978 FLOOR SPECTRUM COMPARED TO MODIFIED SPECTRUM

VERTICAL DIRECTION @ 5% DAMPING

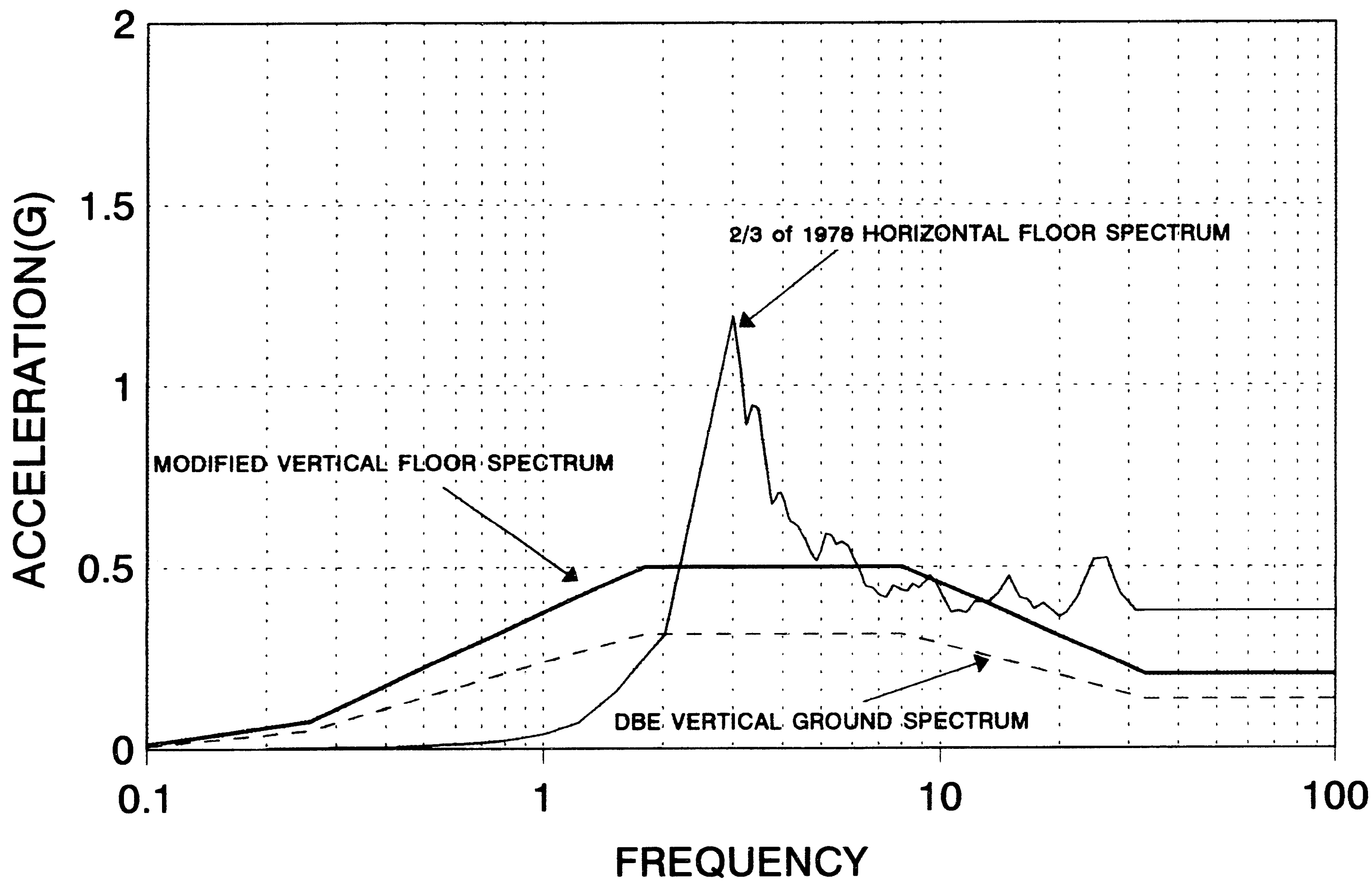


Figure F-4

EQUIPMENT LEVEL

EQPV5.CH3

F5

APPENDIX G

Modified Floor Response Spectra for the Brookhaven National Laboratory High Flux Beam Reactor (HFBR)

This Appendix contains the signed Approval Sheet for BNL informal report entitled "Modified Floor Response Spectra for the Brookhaven National Laboratory High Flux Beam Reactor (HFBR)."

Modified Floor Response Spectra for the Brookhaven National Laboratory High Flux Beam Reactor (HFBR)

Prepared By: John F. Skomorny / Richard J. Morante Date: 3/16/94

Reviewed By: [signature] / Joseph Braverman Date: 3/29/94

Approved By: [signature] / [signature] Date: 4/1/94

DATE FILMED

5/10/94

END