GENERATION OF IN-EQUIPMENT RESPONSE SPECTRA FOR SEISMIC QUALIFICATION OF MSFIS SYSTEM

Prepared for

WOLF CREEK NUCLEAR OPERATING CORPORATION
Purchase Order No. 736522
ARES Calculation No.: 0620514.01-C-003

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Wolf Creek Project No. 0620514.01

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CALCULATION COVER SHEET

Calculation No: 0620514.01-C-003

Project No.	Project Title:	Client:
0620514.01	Modification of Main Control Panels at WCNOC	Wolf Creek Nuclear Operating Corporation

Title:
Generation of In-Equipment Response Spectra For Seismic Qualification of MSFIS System

Purpose and Objective:
The purpose of this calculation is to generate In-Equipment Response Spectra for seismic qualification of replacement components inside the MSFIS cabinets.

Rev. No.	Total Pages	Revision Description (Add Continuation Sheet If Required)	Prepared By Name/Date	Checked By Name/Date	PM/TL Approval/Date
0	25	Original Issue	Mohsin R Khan, PhD, P.E. Mohsin Khan 1/09/07	L. T. Nicholson 1/09/07	M. R. Khan, PhD, P.E. Mohsin Khan 1/09/07

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CALCULATION REVIEW CHECKLIST

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ITEMS CHECKED	ACCEPT Y	ACCEPT N	ACCEPT N/A	INITIAL/DATE
1. Cover sheets properly completed.	X			
2. Calc sheet headers complete with calc no, rev, etc.	X			
3. Calc sheet contents complete per format.	X			
4. Listed attachments included.	X			
5. Calc objective clearly described.	X			
6. Criteria are suitable and properly referenced to task specific documents.	X			
7. Assumptions and input data described and attached or referenced to task documents.	X			
8. Calc method identified and appropriate for the design activity.	X			
9. Calc results reasonable and correctly described in results and conclusions.	X			
10. Computer program identified with version and revision.			X	
11. Computer input/output provided or referenced.			X	
12. Computer run traceable to calculation (file #, etc.).			X	
13. Computer input data within permissible design input range.			X	
14. Computer program validation/verification addressed.			X	

Discrepancies / Comments:

Checker (Print Name and Sign):	Date:
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Originator (Print Name and Sign):	Date:
Mohsin R. Khan	1/09/07

Signatures obtained only after discrepancies are corrected and comments are resolved.

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1.0 INTRODUCTION

The purpose of this calculation is to generate In-Equipment Response Spectra for seismic qualification of replacement components inside the Main Steam and Feedwater Isolation Actuation System (MSFIS) cabinets.

The MSFIS cabinets are installed in the Main Control Room at elevation 2047'-6" at WCNOC.

2.0 INPUT

The seismic qualification of the MSFIS cabinet was performed by shake table testing per Reference 1. Resonance searches in the side-to-side, front-to-back, and in the vertical direction were performed to obtain the dynamic amplification factors at each input frequency. After the resonance search was completed, several bi-axial tests were performed in the side-to-side with vertical, and front-to-back with vertical direction of input motion. The testing demonstrated that the test response spectra conservatively enveloped the required response spectra.

Reference 2 documents the seismic qualification for the components installed inside the Engineered Safety Features Actuation System (ESFAS), Load Shedding and Emergency Load Sequencing System (LSFLS) and, MSFIS cabinets by shake table testing. The information provided in Reference 1 and 2 will be used to generate more realistic in-equipment response spectra for the seismic qualification of replacement components to be performed per Reference 3 and 4.

3.0 GENERATION OF IN-EQUIPMENT SPECTRA

3.1 WCNOC Floor Response Spectra

WCNOC As-Built Response Spectra are provided in Calculation 10-19-F (Reference 5). Figures 3-1 to 3-3 show the As-Built 3% SSE for 3 SNUPPS site envelope Floor Response Spectra for the North South, East West and Vertical direction respectively. The digitized values of the response spectra are provided in Tables 3-1 to 3-3.

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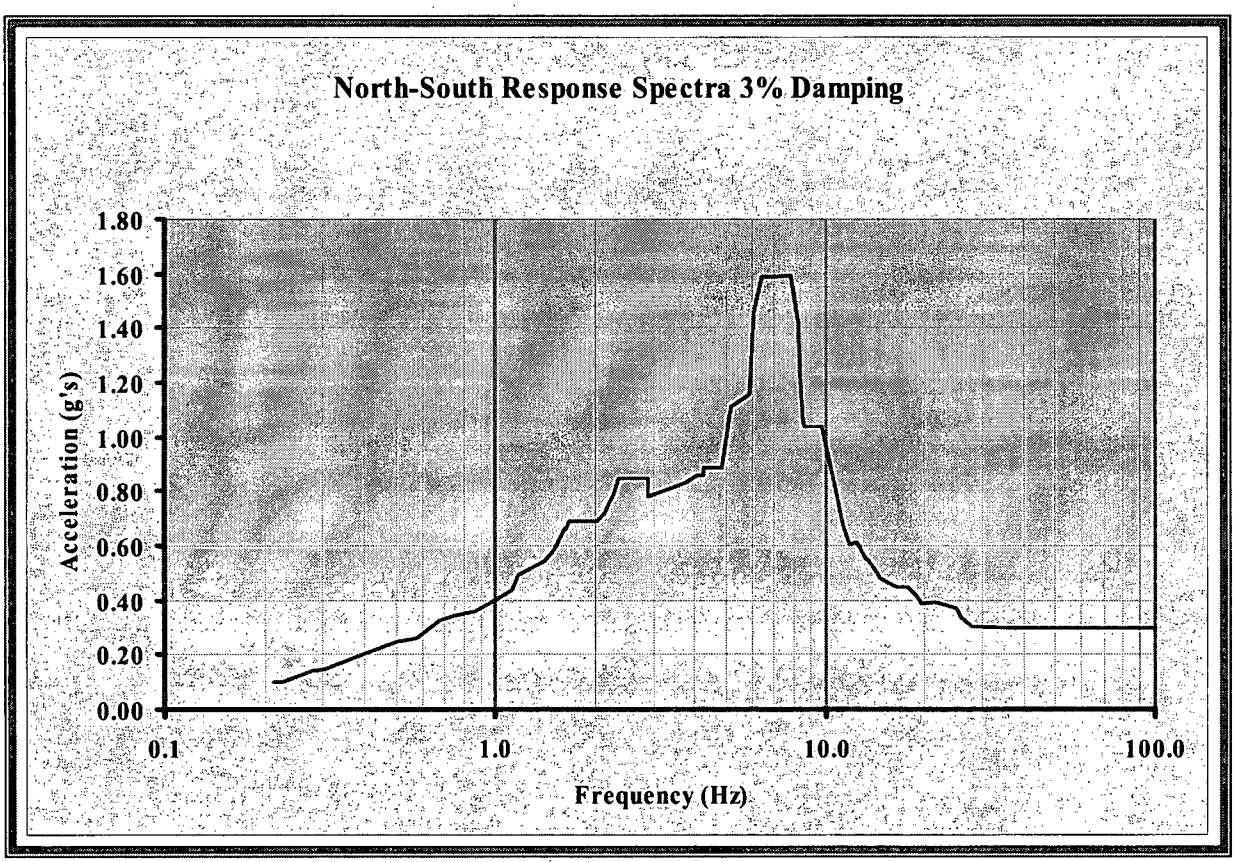

Figure 3-1. 3% SSE North South Response Spectra for 3 SNUPPS Sites at Elevation 2047'-6" in the AUX/CONTROL Building.

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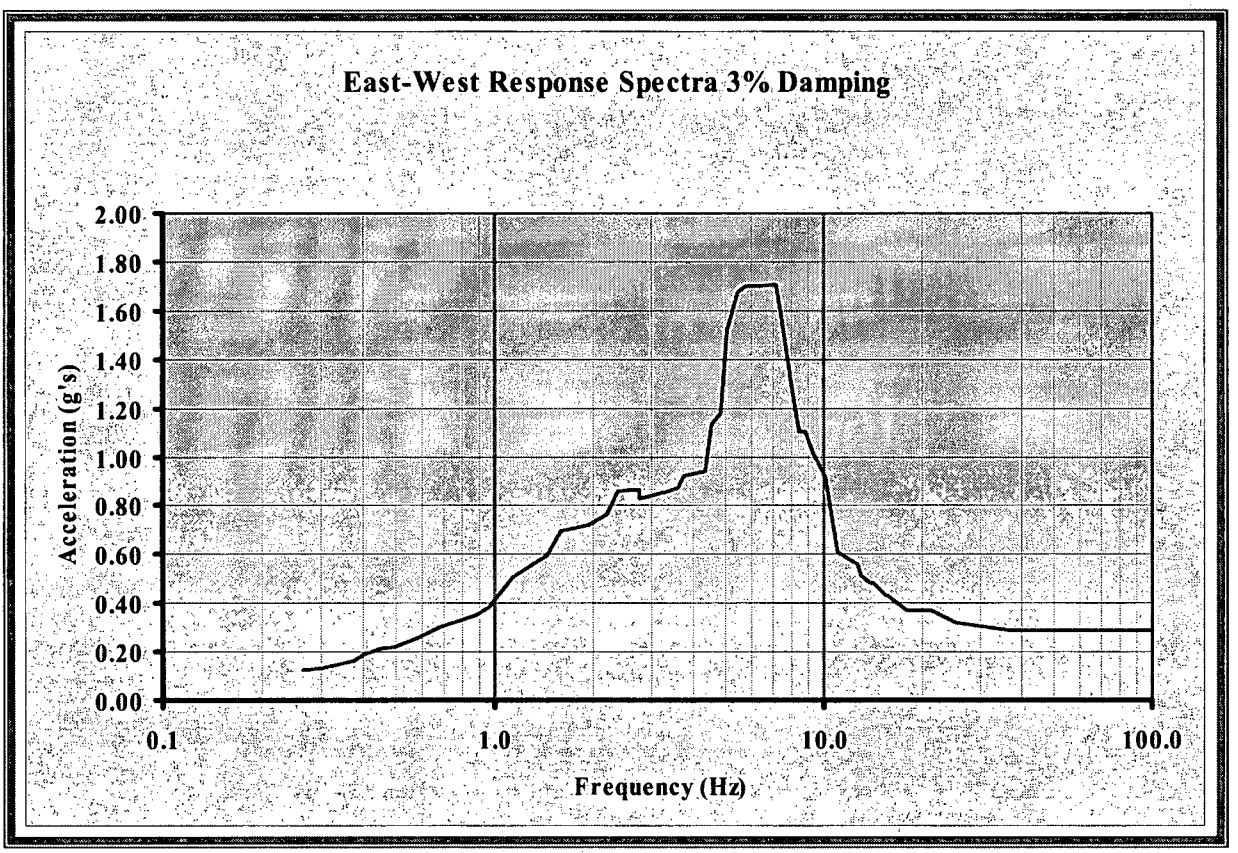

Figure 3-2. SSE 3% East West Response Spectra for 3 SNUPPS Sites at Elevation 2047'-6" in the AUX/CONTROL Building.

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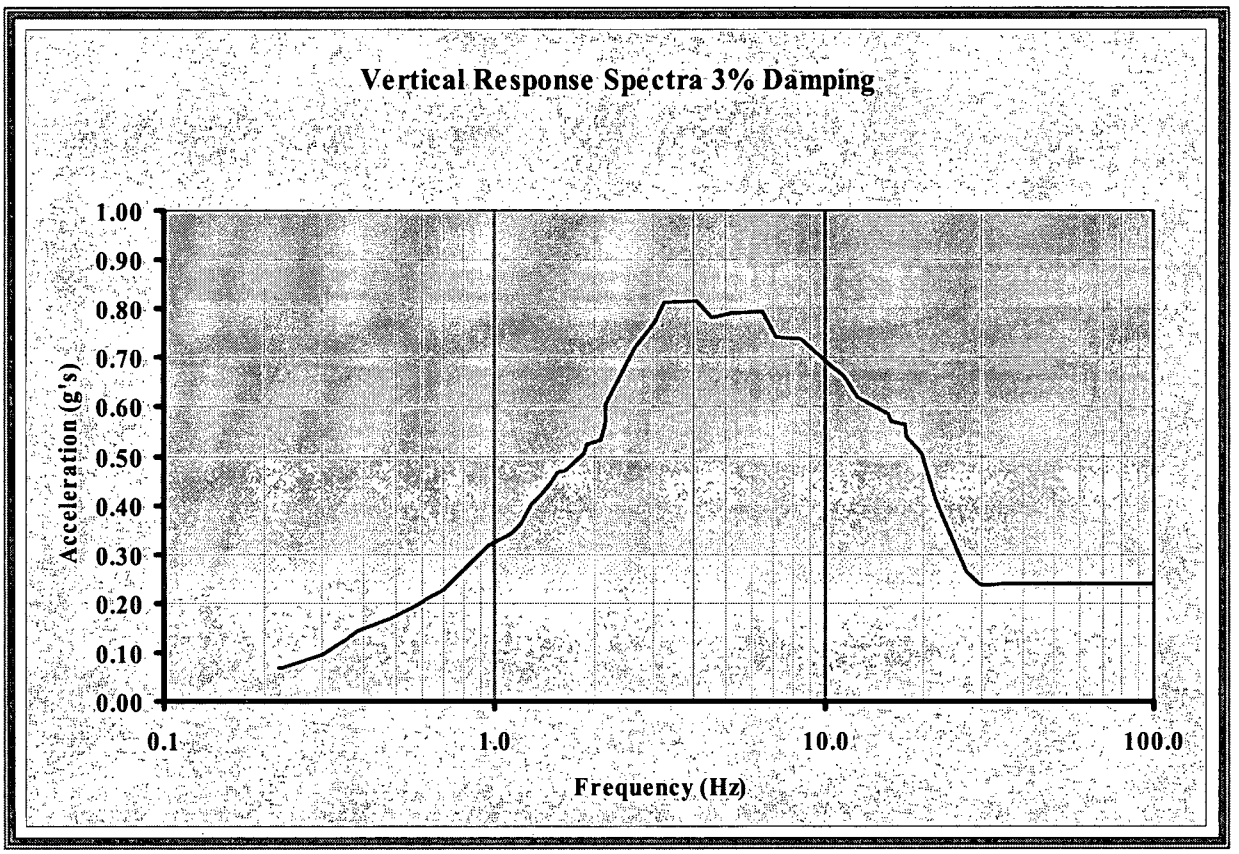

Figure 3-3. SSE 3% Vertical Response Spectra for 3 SNUPPS Sites at Elevation 2047'-6" in the AUX/CONTROL Building.

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Table 3-1. 3% SSE East West Response Spectra for 3 SNUPPS Sites at Elevation 2047'-6" in the AUX/CONTROL Building.

Frequency Hz	Acceleration g's
0.263	0.123
0.268	0.123
0.299	0.13
0.375	0.163
0.401	0.186
0.45	0.215
0.498	0.222
0.587	0.258
0.682	0.304
0.798	0.33
0.875	0.3517
0.954	0.381
1.14	0.507
1.447	0.598
1.583	0.698
1.929	0.724
2.189	0.764
2.369	0.862
2.746	0.865
2.759	0.828
3.368	0.862
3.588	0.87
3.763	0.919
4.3453	0.9409
4.348	0.944
4.571	1.137

Frequency Hz	Acceleration g's
4.888	1.179
5.076	1.518
5.45	1.677
5.764	1.699
7.145	1.704
7.394	1.59
7.947	1.292
8.4285	1.1024
8.762	1.105
9.318	1.018
10.114	0.914
10.985	0.607
12.674	0.56
12.967	0.515
13.7573	0.4836
14.147	0.483
15.3383	0.433
15.586	0.433
17.943	0.372
21.221	0.372
25.16	0.321
36.915	0.289
37.244	0.289
100	0.289

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Table 3-2. 3% SSE Vertical Response Spectra for 3 SNUPPS Sites at Elevation 2047'-6" in the AUX/CONTROL Building.

Frequency Hz	Acceleration g's
0.222	0.069
0.226	0.069
0.302	0.096
0.333	0.1143
0.352	0.126
0.385	0.144
0.481	0.169
0.5356	0.1832
0.5837	0.1975
0.599	0.204
0.6194	0.2077
0.696	0.228
0.95	0.318
1.124	0.343
1.199	0.361
1.287	0.403
1.3705	0.4208
1.4604	0.4429
1.55	0.468
1.625	0.4689
1.8514	0.5057
1.9	0.523
2.094	0.532
2.1403	0.5553
2.1581	0.5692
2.16	0.605

Frequency Hz	Acceleration g's
2.647	0.719
3.041	0.774
3.257	0.812
4.064	0.817
4.546	0.782
5.219	0.79
6.468	0.795
7.119	0.74
8.49	0.738
10.486	0.683
11.446	0.663
12.517	0.619
15.536	0.587
15.957	0.569
17.464	0.565
17.653	0.539
19.704	0.505
21.818	0.411
26.955	0.264
29.4994	0.2409
30.235	0.237
35.657	0.24
37.619	0.24
100	0.24

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Table 3-3. 3% SSE North South Response Spectra for 3 SNUPPS Sites at Elevation 2047'-6" in the AUX/CONTROL Building.

Frequency Hz	Acceleration g's
0.211	0.1
0.2267	0.1
0.277	0.139
0.303	0.147
0.387	0.196
0.503	0.244
0.5694	0.2598
0.581	0.264
0.674	0.323
0.748	0.343
0.862	0.36
1.011	0.401
1.12	0.436
1.173	0.494
1.398	0.5438
1.401	0.545
1.4024	0.5453
1.502	0.581
1.621	0.663
1.6307	0.6627
1.671	0.691
1.914	0.69
2.021	0.69
2.091	0.708
2.1451	0.7161
2.195	0.757
2.2747	0.7911
2.352	0.845
2.878	0.846
2.891	0.777
3.718	0.829
4.052	0.857
4.2463	0.8579
4.264	0.884
4.823	0.884
5.155	1.112
5.865	1.154

Frequency Hz	Acceleration g's
6.045	1.46
6.397	1.586
7.808	1.59
8.239	1.414
8.381	1.228
8.568	1.052
8.622	1.038
9.761	1.038
10.311	0.888
10.892	0.751
11.274	0.6717
11.761	0.607
12.447	0.611
13.3175	0.5519
13.426	0.552
14.21	0.511
14.67	0.485
15.386	0.468
16.47	0.447
17.669	0.446
18.364	0.434
18.871	0.414
19.349	0.398
19.526	0.389
21.623	0.39
22.575	0.385
24.944	0.371
25.927	0.337
27.9553	0.3038
37.188	0.296
100	0.296

3.2 Amplification Factors

In Reference 1, the MSFIS cabinet was tested to obtain the resonant frequencies and amplification factors, and for a conservative 4-site envelope SNUPPS input floor response spectra. Figure 3-4 shows the location of accelerometers that were instrumented in the cabinet. Figure 3-5 illustrates the corresponding channels that collected the data for the resonance searches. Figure 3-6 provides the output accelerations from the resonance search tests. As it can be seen that the highest response in the side-to-side direction is around 8 Hz. Therefore, the amplification factors around this frequency would be the greatest.

In Reference 2, the components to be mounted inside the MSFIS cabinet were separately tested using a generic response spectra. In this test report, the amplification factors for the floor response spectra to obtain in-equipment response spectra were based on the results of the bi-axial tests performed in Reference 1 and no resonance search data was used. These amplification factors used are as shown in column 5 of Figure 3-7. The amplification factor around 8 Hz is close to 1, thus indicating that there was no resonance around 8 Hz. Figure 3-8 shows a comparison of the envelope of the North-South and East-West floor response spectra times the square root of two and amplified floor response spectra using the factors in Figure 3-7. Figure 3-8 also shows a modified amplified floor spectra where the acceleration between 6 and 9 Hz is multiplied by an average amplification factor of 2.8 to account for the resonance frequency observed around 8 Hz. The modified amplified spectra is increased by 10% and plotted in Figure 3-9 and the corresponding digitized values are given in Table 3-4.

From Reference 1, there are no resonant frequencies in vertical direction and thus the floor spectra can be used. Figure 3-10 is the vertical floor spectra from Section 3.1 increased by 10%. The corresponding digitized values are given in Table 3-5.

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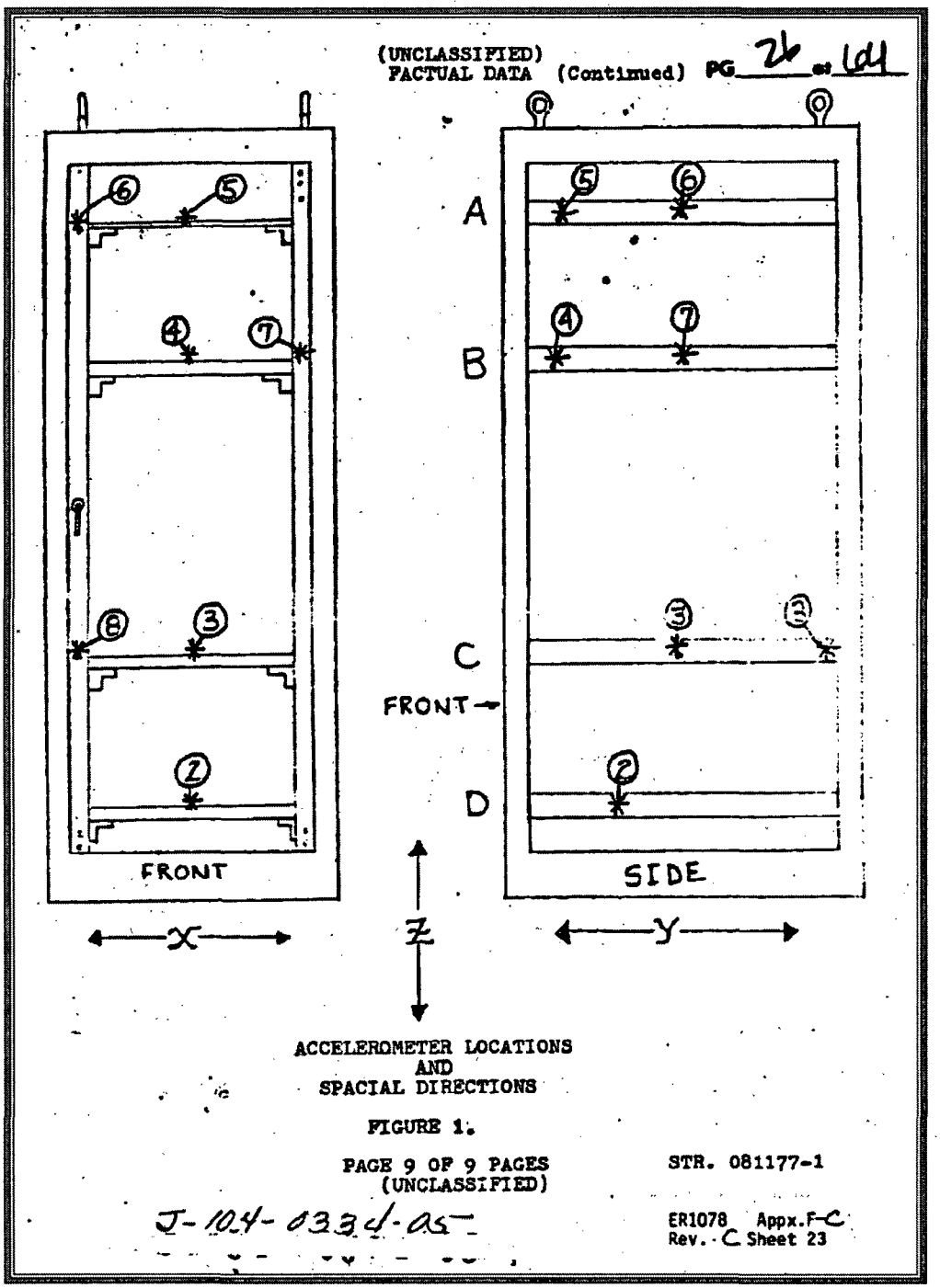

Figure 3-4. Location of Accelerometers in MSFIS Cabinet (Reference 1).

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FACTUAL DATA (Continued)

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1.0 RESONANT FREQUENCY SEARCH:
(Horizontal, side to side)

ACCELEROMETER LOCATIONS (See figure 1)

	CHANNEL	LOCATION
INPUT:	1	X - Base of cabinet
OUTPUTS:	3	X - 5
	4	Z - 5
	5	X - 4
	6	Z - 4
	7	X - 3
	8	Z - 3
	9	X - 2
	10	Z - 2

Figure 3-5. Channel assignments for Accelerometers MSFIS Cabinet (Reference 1).

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FACTUAL DATA (Continued)

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Frequency (Hz)	Input (g-peak) 1	Outputs (g-peak) 3	4	5	6	7	8	9	10
1	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
3	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
4	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
5	0.2	0.24	0.1	0.2	0.1	0.2	0.1	0.2	0.1
6	0.2	0.42	0.1	0.2	0.1	0.22	0.1	0.2	0.1
7	0.2	0.86	0.18	0.36	0.16	0.32	0.16	0.22	0.13
*8	0.2	1.1	0.28	0.56	0.24	0.42	0.22	0.24	0.21
9	0.2	0.66	0.14	0.4	0.14	0.32	0.12	0.2	0.1
10	0.2	0.38	0.1	0.26	0.1	0.22	0.1	0.2	0.1
11	0.2	0.24	0.1	0.22	0.1	0.2	0.1	0.2	0.1
12	0.2	0.21	0.1	0.2	0.1	0.2	0.1	0.2	0.1
13	0.2	0.22	0.1	0.2	0.1	0.2	0.1	0.2	0.1
14	0.2	0.22	0.1	0.2	0.1	0.2	0.1	0.2	0.1
15	0.2	0.28	0.1	0.2	0.1	0.2	0.1	0.2	0.1
16	0.2	0.43	0.1	0.26	0.1	0.24	0.1	0.2	0.1
*17	0.2	0.64	0.14	0.38	0.12	0.28	0.1	0.22	0.1
18	0.2	0.56	0.1	0.29	0.1	0.26	0.1	0.2	0.1
19	0.2	0.4	0.1	0.24	0.1	0.22	0.1	0.2	0.1
20	0.2	0.26	0.1	0.2	0.1	0.2	0.1	0.2	0.1
21	0.2	0.22	0.1	0.2	0.1	0.2	0.1	0.2	0.1
22	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
23	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
24	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
25	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
26	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
27	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
28	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
29	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
30	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
31	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
32	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
33	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
34	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
35	0.2	0.38	0.1	0.28	0.1	0.2	0.1	0.2	0.1

* Significant resonances observed.

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DATA SECTION 2

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Figure 3-6. Results from Resonance Search (Reference 1).

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FIGURE 12 J-1041-0351-04

OCTAVES ABOVE 1 Hz	FREQUENCY (Hz)	CABINET TOP ACCELERATIONS	COMPOSITE RRS ACCELERATIONS (g)	AMPLIFICATION FACTORS	CURVE D: 3 SITES RRS ACCELERATIONS (g)	CURVE C: ANTICIPATED COMPONENT ACCELERATIONS (g)
0	1	1.2	0.6	2	0.42	0.84
1/3	1.26	1.35	0.9	1.5	0.60	0.90
2/3	1.59	1.9	1.0	1.9	0.75	1.43
1	2	1.9	1.0	1.9	0.84	1.60
1 1/3	2.52	2.1	1.3	1.62	0.92	1.49
1 2/3	3.17	2.15	1.4	1.54	0.96	1.48
2	4	2.25	1.6	1.41	0.99	1.40
2 1/3	5.04	3.2	3.3	1.45	1.36	1.97
2 2/3	6.35	4.15	3.6	1.15	1.90	2.19
3	8	4.85	4.3	1.13	1.90	2.15
3 1/3	10.08	4.95	3.5	1.41	1.51	2.13
3 2/3	12.7	4.9	3.1	1.58	0.82	1.30
4	16	4.55	1.5	3.03	0.78	2.36
4 1/3	20.16	4.15	1.8	2.31	0.66	1.52
4 2/3	25.40	3.15	1.5	2.1	0.60	1.26
5	32	2.9	0.9	3.22	0.46	1.48
5 1/3	40.3	3.15	0.9	3.5	0.45	1.58

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Figure 3-7. Calculated Amplification Factors from Reference 2.

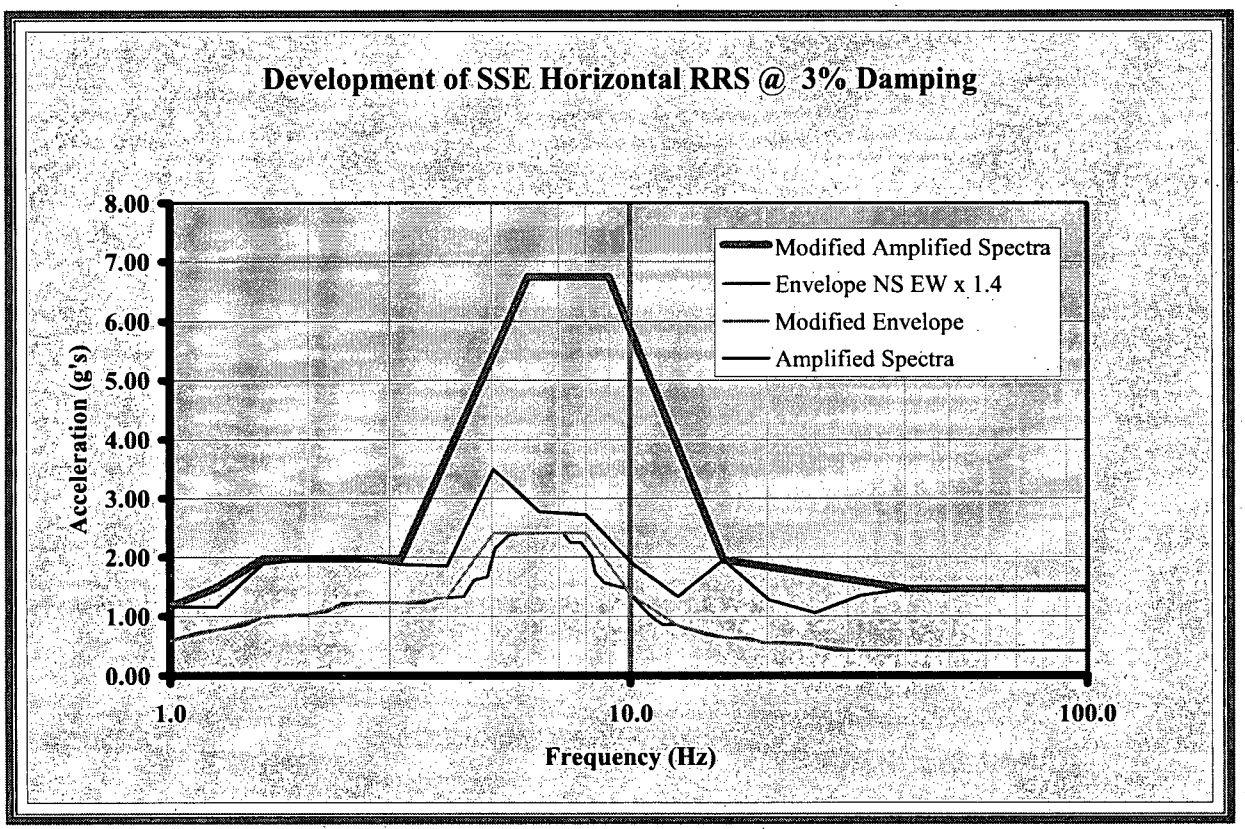

Figure 3-8. Comparison of Floor Spectra and Amplified Spectra.

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Title: Generation of In-Equipment Response Spectra For Seismic Qualification of MSFIS System

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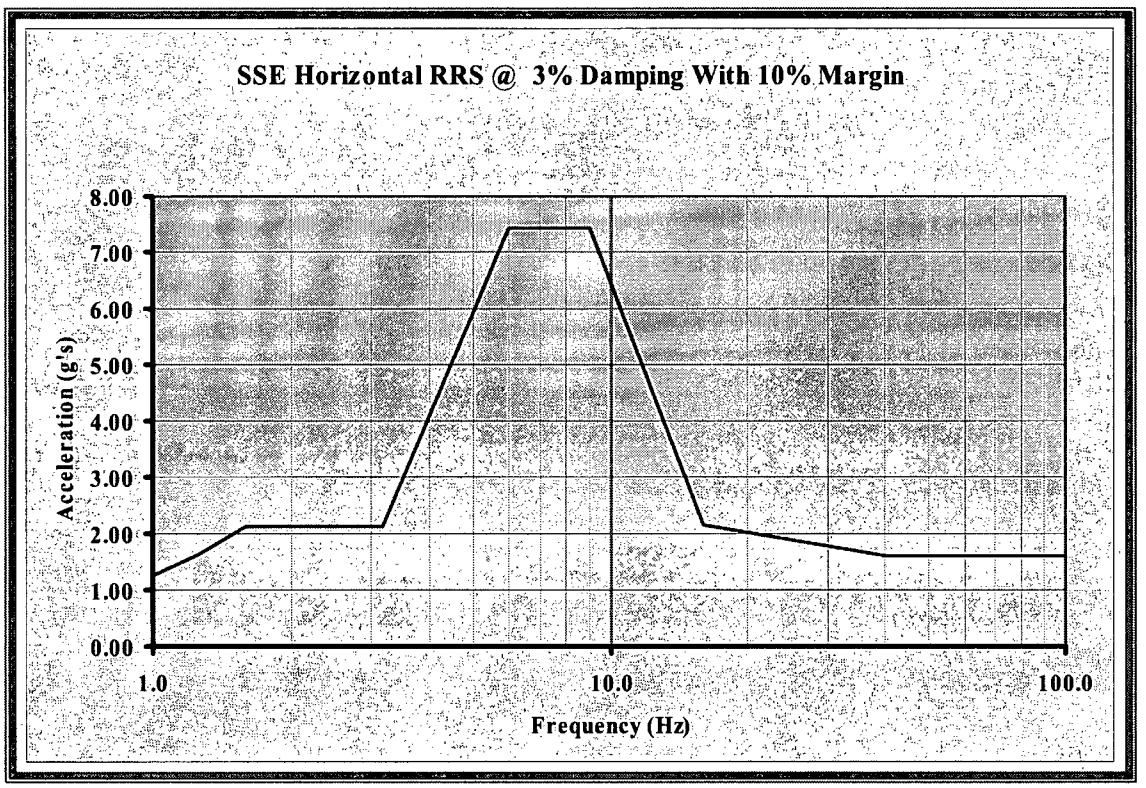

Figure 3-9. Final SSE Horizontal RRS @ 3% Damping With 10% Margin.

ARES CORPORATION

CALCULATION SHEET

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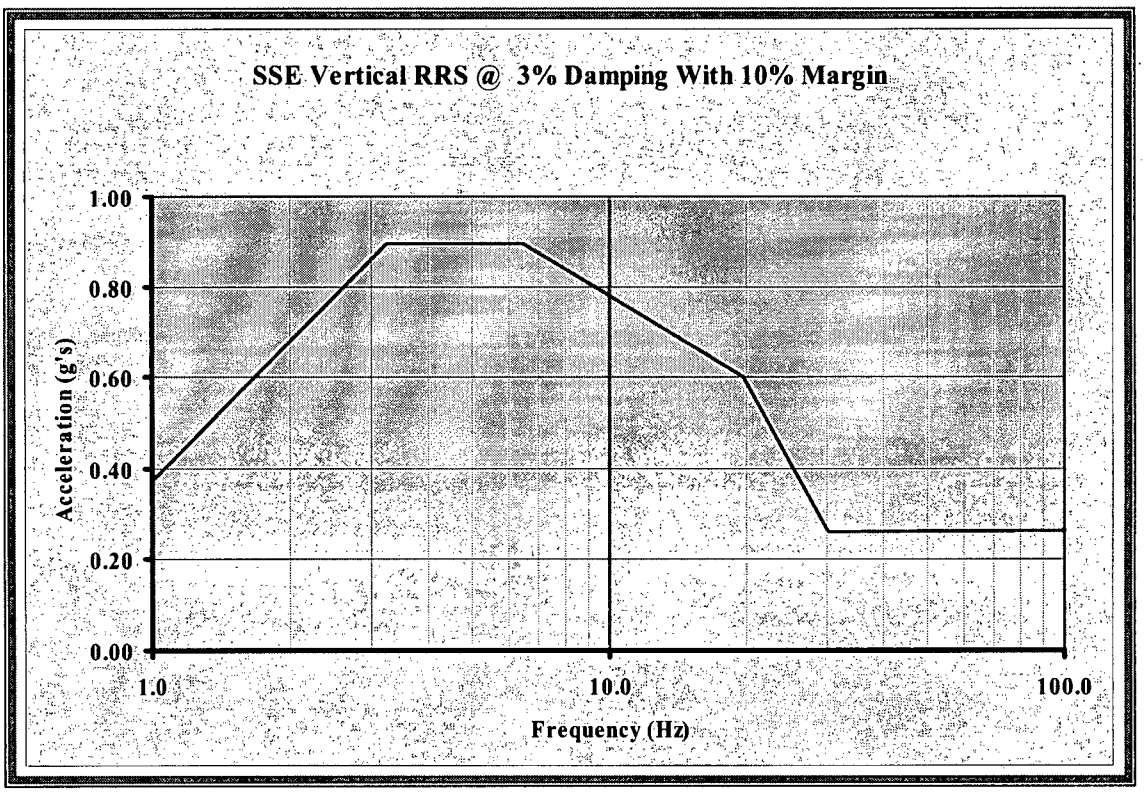

Figure 3-10. Final Vertical RRS @ 3% Damping With 10% Margin.

Table 3-4. 3% Final SSE Horizontal RRS @ 3% Damping With 10% Margin (Figure 3-9).

Frequency Hz	Acceleration g's	Accel (g) + 10%
1	1.13	1.24
1.26	1.48	1.63
1.59	1.94	2.13
2	1.94	2.13
2.52	1.94	2.13
3.17	1.94	2.13
6	6.75	7.42
9	6.75	7.42
16	1.95	2.15
40.3	1.47	1.61
100	1.47	1.61

Table 3-5. 3% Final SSE Vertical RRS @ 3% Damping With 10% Margin (Figure 3-10).

Frequency Hz	Acceleration g's	Accel (g) + 10%
0.950	0.32	0.35
3.257	0.81	0.89
6.468	0.81	0.89
19.704	0.55	0.60
30.235	0.24	0.26
100.000	0.24	0.26

4.0 CONCLUSION

ARES has developed composite In-Equipment response spectra for the North-South and East-West direction. The vertical spectra was developed separately, which is much lower than the North-South and East-West response spectra. All spectra are at 3% structural damping. The In-Equipment response spectra are provided in Figure 3-9 and 3-10 for the seismic qualification of components installed inside the MSFIS cabinets.

5.0 REFERENCES

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3. Specification J-105A(Q), Rev. 2, "Technical Specification for Replacement MSFIS System Wolf Creek Generating Station (WCGS)", Dated October 3, 2006.
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