4/15/92

SELECTION OF CONTROL MOTION
FOR THE
ABB-CE SYSTEM 80+ STANDARD DESIGN

Prepared By:

ABB Combustion Engineering

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report was prepared for the purpose of demonstrating that the control motions that are used in the seismic design of the ABB Combustion Engineering System 80+ Standard Plant meet or exceed current USNRC regulatory guidance and provide an appropriate basis for the design of a standard plant to be built on a large majority of sites in the United States.

For the System 80+ seismic design, ABB-CE developed three control motions which, when combined cover the majority of potential sites in the U.S. Sites near major active faults such as those in California are excluded. In addition, to cover a broad range of sites, twelve generic soil sites and one rock site are included in the seismic evaluations, for each of the control motions.

To cover sites with deep soil deposits, a control motion with a Regulatory Guide 1.60 (Reference 1) spectral shape is used as the input motion to the ground surface of each site. To cover shallow soil sites, two rock motions applied at a hypothetical rock outcrop are used. The selection of the two rock outcrop motions was performed using low frequency content consistent with industry-wide accepted response spectra, and high frequency content that exceeds the current industry practice. The enrichment of the rock outcrop motions with high frequency content is consistent with recent studies on Eastern North America seismicity and is a proactive measure of the System 80+ design in anticipation of future trends in the industry regarding seismic motions.

The control motions described in this report are intended to provide future owners of System 80+ design with ***high confidence*** that the design is suitable for most sites in the United States and to obtain NRC certification of the System 80+ design.

1.0 OBJECTIVE

This report provides a summary of the development process for the earthquake control motion for use in the seismic design of the ABB Combustion Engineering System 80+ Advanced Light Water Reactor. This is in support of the Certification process for this standard design.

The overall objective of ABB Combustion Engineering under this program is to have a standard design, certified by the NRC, which is suitable to be built on most sites in the United States with the exception of sites near major active faults in the states such as those in California. For any future potential site, a site-specific response spectrum will have to be developed in accordance with the requirements of the Standard Review Plan (SRP) Section 2.5.2.6 (Reference 2) and shown that it would fall below the design control motion for the standard plant. It is expected that this site-specific check will also qualify a good number of sites within states with major active faults as acceptable. It is also feasible that the site specific check might disqualify certain sites in some of the other states.

However, the overall objective is to devise a control motion that will provide the owners of System 80+ design with ***high confidence*** that the design is suitable for most sites in all of the United States with the exception of the locations described above. With this objective in mind, and knowing the current state of practice in seismic engineering as well as the upcoming trends in this field, the ABB Combustion Engineering seismic design team developed the control motion as described in this report for use in seismic design. This control motion is in full compliance with the SRP guidance as well as the EPRI recommendations for design of ALWRs.

The goal is to obtain NRC certification of the System 80+ design having satisfied the objective stated above.

2.0 SELECTION PROCESS

To cover a maximum range of possible site conditions where System 80+ design may be constructed, a range of generic site conditions was selected. In total, 13 cases were developed corresponding to 12 soil cases and one rock case. These generic cases are described in detail in CESSAR Section 2.5 (Reference 3).

The Control Motion design response spectra are anchored to a 0.3g peak ground acceleration. They were developed with the objective of being in full compliance with the SRP guidance as well as the EPRI ALWR Utility Requirements Document. Again, to cover a maximum range of possible sites where the System 80+ standard design may be constructed, three separate control motion spectra were developed. These are:

1. Control Motion Spectrum 1 (CMS1): This spectrum is a soil spectrum, it is identical to Regulatory Guide 1.60 (R.G. 1.60) spectrum and it is considered in order to cover sites with deep soil deposits.

2. Control Motion Spectrum 2 (CMS2): This is a rock outcrop spectrum and is developed to cover sites typical of Eastern North America which could be subjected to earthquakes with high frequency content.

3. Control Motion Spectrum 3 (CMS3): This is a rock outcrop spectrum and is developed based on recommendations of the NUREG/CR-0098 (Reference 4) primarily to cover lower frequency motions which may not be covered by CMS2. In addition, it is in full compliance with SRP Section 2.5.2.6, Item 3 for "scaling the acceleration, velocity and displacement values by appropriate amplification factors". It is also enhanced with respect to NUREG/CR-0098 in the high frequency range to cover earthquakes with high frequency content. The maximum spectral acceleration range is extended to 15 Hz, as opposed to 8 Hz which is used in NUREG/CR-0098 motions.

All of the above Control Motion Spectra are shown in Figure 2.1. CMS2 and CMS3 are applied at the rock outcrop, and CMS1 is applied at the free-field ground surface. All three motions are applied to each of the 13 sites to conservatively cover all combinations.

The logic for selection process of each of these control motion spectra is described in more detail below:

2.1 Selection Process for CMS1

The spectrum shape corresponding to this control motion is as per the requirements of R.G. 1.60. This spectrum shape is chosen in order to be in full compliance with the SRP Section 2.5 guidance as well as the EPRI ALWR recommendations, and is intended to cover deep soil sites. The control motion is anchored to a peak ground acceleration for 0.3g for the two horizontal directions and the vertical direction.

2.2 Selection Process for CMS2

The spectrum shape corresponding to this control motion is for application at the rock outcrop surface, is an 84 percentile curve, and is developed considering NUREG/CR-0098 recommendations as well as ground motions deemed appropriate for the Eastern North American continent. The intent of this spectral shape is to cover various soil sites overlaying a competent material as well as having rock outcrop motion characteristics typical of Eastern North America. The construction of this spectrum shape is shown in Figure 2.2. As can be noted from this figure, the spectral ordinates were kept equal to those obtained using NUREG/CR-0098 for frequencies lower than 3.3 Hz, with maximum ground velocity of 24 in/sec/g, which again is typical of expected earthquakes for the Eastern United States. For higher frequencies, particularly above 10 Hz, the selected spectral ordinates are based upon ground motion estimates appropriate for Eastern North America and, as can be seen, are significantly higher than those obtained using the NUREG/CR-0098.

This control motion is anchored to a peak ground acceleration of 0.3g and peak ground velocity of 7.2 in/sec for the two horizontal directions. In the vertical direction,t he control motion is anchored to a peak ground acceleration of 0.2g and peak ground velocity of 4.8 in/sec. The selection of 0.2g at the rock outcrop for the vertical direction leads to vertical spectra at the ground surface that equal or exceed the horizontal spectra at the ground surface over a significant range of frequencies for most of the soil cases.

2.3 Selection Process for CMS2

The spectrum shape corresponding to this control motion is developed for application to rock outcrop surface, is in 84 percentile curve, and is in full compliance with the recommendations of NUREG/CR-0098 with maximum ground velocity of 36 in/sec/g representing typical sites in Western North America. CMS3 is enriched in the high frequency end of the spectrum to cover earthquakes with high frequency content. The maximum spectral acceleration range extends from 2.2 Hz to 15 Hz. Again, this control motion is anchored to a peak ground acceleration of 0.3g for the two horizontal directions and 0.2g for the vertical direction.

2.4 Chronological Order of Selection

The System 80+ Standard Plant was originally designed for CMS2 applied at a hypothetical rock outcrop for the 12 soil cases and at the foundation level for the one rock case. Comparison of the envelope of amplified free-field surface and foundation level spectra with the R.G. 1.60 spectrum confirmed the technical soundness of the seismic design basis for both deep and shallow soil sites and for rock sites. It was subsequently decided to evaluate the System 80+ design for CMS1 and CMS3 to address concerns regarding possible low frequency (less than 0.7 Hz) deficiencies in CMS2 and also to demonstrate full design conformance for a R.G. 1.60 spectrum defined at the free-field ground surface.

Two rock outcrop spectra (CMS2 and CMS3) as described above are design such that they would cover a maximum range of possible earthquake spectral shapes as predicted by attenuation relationships currently used and accepted in the industry. Table 2.1 summarizes various earthquake magnitude/distance combinations that are covered by the design control motions for the System 80+ standard design. Figures 2.3 through 2.7 show this comparison for each earthquake scenario as listed in Table 2.1, versus CMS2 and CMS3. Each of these comparisons was done using three different attenuation relationships. These are Campbell, Geomatrix, and Idriss.

TABLE 2.1
Various Upper Bound Earthquake Scenarios Covered by the System 80+ Design Control Motions

Magnitude	Distance (km)
6.0	15
6.75	25
7.0	30
7.25	40
7.5	50

Note: All earthquakes of either lower magnitude or at higher fault distances than the above five scenarios are also covered by the System 80+ design control motions.

3.0 APPLICATION OF CONTROL MOTION TO SEISMIC SSI ANALYSES

The analysis methodology which is used in the seismic evaluation of the System 80+ is shown in the schematic diagrams of Figures 3.1 and 3.2. There are two basic tasks involved in the seismic computation:

- Computation of site response
- Soil-structure interaction analysis

A description of each of these tasks follows below.

The site response analyses consist of the computation of the soil motion and the strain iterated soil properties. When the CMS2 and CMS3 motions are used, they are applied as input motions at a rock outcrop of the soil profile (defined as motion (R) in Figures 3.1 and 3.2). The response at the soil ground surface (defined as (S) in Figure 3.1) and the strain iterated soil properties are then computed using the equivalent linear response analysis methodology of the computer program SHAKE. For each of the selected soil cases, the computed surface motion (S) is the result of the amplification of the rock motion through the soil profile , i.e., the motion is convolved from the bedrock to the ground surface. From the site response analyses performed for CMS2, it is observed that the envelope of all the horizontal spectra at the ground surface significantly exceeds the rock outcrop spectra CMS2 and also significantly exceeds the CMS1 motion at all frequencies above 0.7 Hz (Figure 3.3). In addition, as shown in Figure 3.4, the envelope of the computed motions at the foundation level (defined as (F) in Figure 3.1) exceed 60% of CMS1 and CMS2.

The computed strain iterated soil properties of the twelve soil cases using the CMS2 motion are used in all the SSI analyses in order to retain these properties as standard for the soil media. The computation of the ground surface motions using the CMS3 motion as rock outcrop motion is performed using these standard strain iterated properties.

The SSI analyses are performed using the methodology of the computer program SASSI. The structural model of the System 80+ is combined with the soil model taking into account the proper foundation embedment configuration. The input motions to SASSI are applied at the ground surface in the free field, as shown in Figures 3.1 and 3.2.

For the analysis cases involving CMS2 and CMS3, the input motion to the SASSI SSI model is the surface motion (S) derived from the site response analyses. Therefore, the input motion to the SASSI SSI model contains the site amplification. Since the control motion CMS1 is specified at the ground surface, the input motion is applied directly to the SASSI SSI model.

In addition to the SSI analyses described above, fixed-base analyses of the System 80+ structural model are also performed using as input motion at the fixed base each of the three control motions, CMS1, CMS2 and CMS3. In the fixed-base analyses the foundation embedment is conservatively neglected.

4.0 CONCLUSION

The seismic control motions that are utilized in the System 80+ design were developed to qualify the plant for the majority of the sites in the United States. In particular, three different motions are used, CMS1, CMS2 and CMS3, to cover all the site categories on which the plant may be built. The control motions and their use in SSI analysis are in full compliance with the Standard Review Plan Sections 2.5 and 3.7. Furthermore, the control motions provide an extra level of conservatism beyond the SRP requirements, since for shallow and rock sites, they are rich in high frequency content, which is a characteristic of Eastern North America earthquakes not reflected in the R. G. 1.60 spectral shape.

CMS1, which is a R. G. 1.60 spectrum anchored at 0.3g, is applicable to every site except shallow soil sites. Shall sites are covered by the use of reasonable rock outcrop spectra such as CMS2 and CMS3, which are enriched with high frequency content and also contain adequate low frequency content.

The control motions allow all future owners of the System 80+ design to qualify their site provided that site specific spectra developed for the owner's site are enveloped by one or more of the System 80+ control motion spectra and the envelope of site conditions.

5.0 REFERENCES

1. U.S. Nuclear Regulatory Commission Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants", Revision 1, December 1973.

2. U.S. Nuclear Regulatory Commission, "Standard Review Plan", NUREG-0800, Section 2.5 Revision 2 and Section 3.7, Revision 2.

3. CESSAR Design Certification, Amendment I, December 21, 1990.

4. Newmark N.M., Hall, W. J., "Development of Criteria For Seismic Review of Selected Nuclear Power Plants", NUREG/CR-0098, prepared for U.S. NRC, May, 1978.

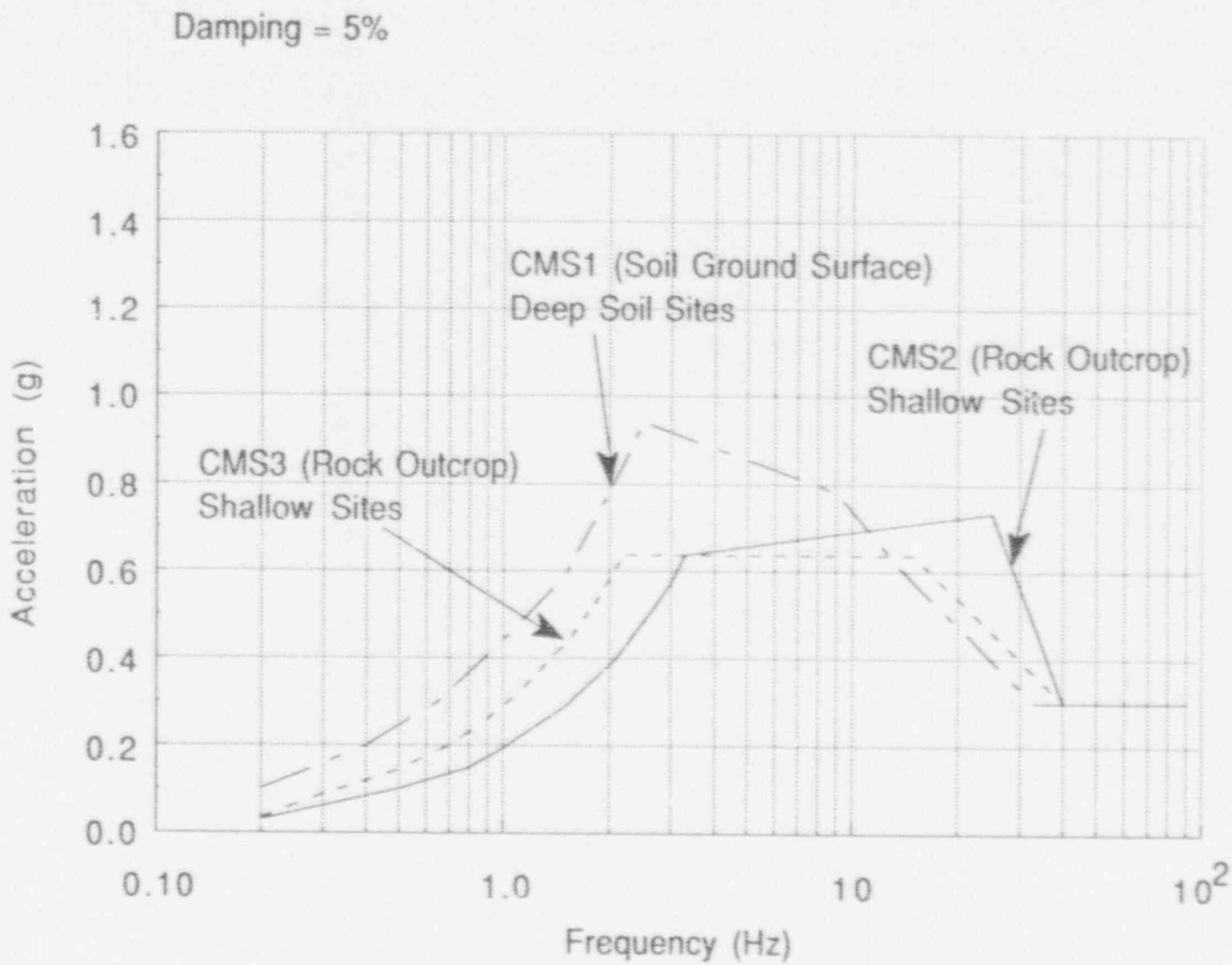

Figure 2.1 - CMS1, CMS2 and CMS3
(5% Damping)

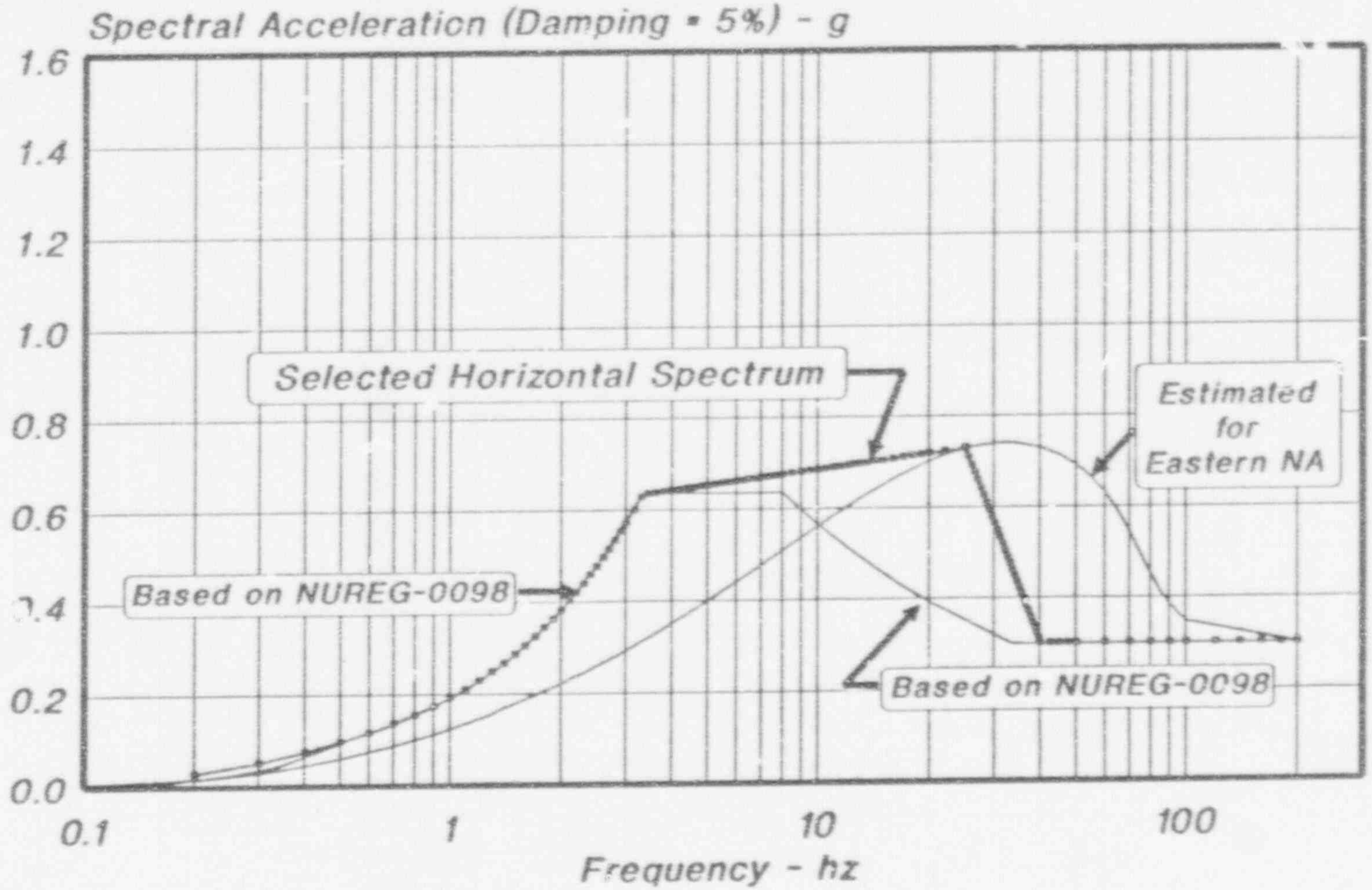

Figure 2.2 - Derivation of CMS2

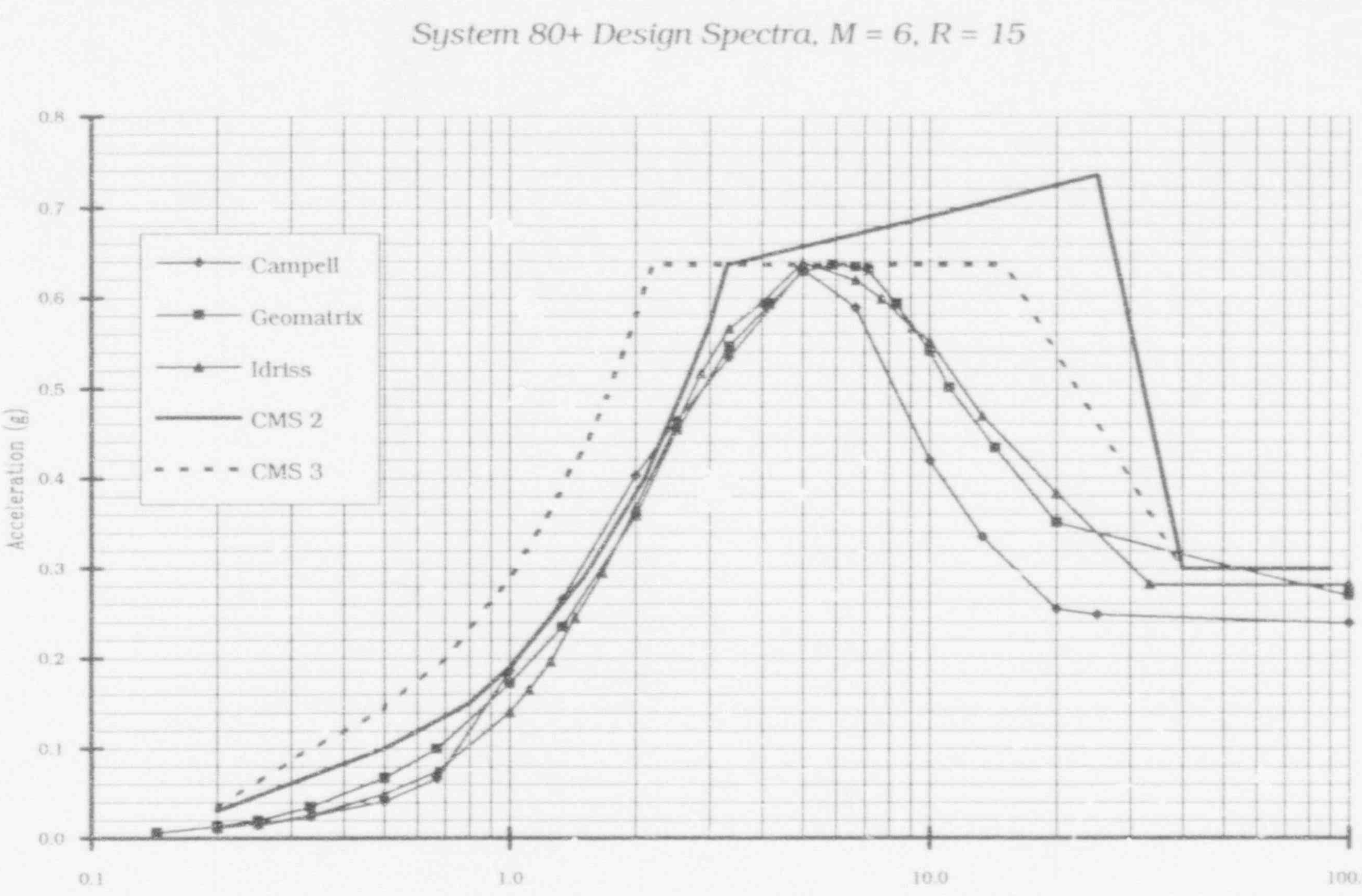

Figure 2.3 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=6, R=15 km)

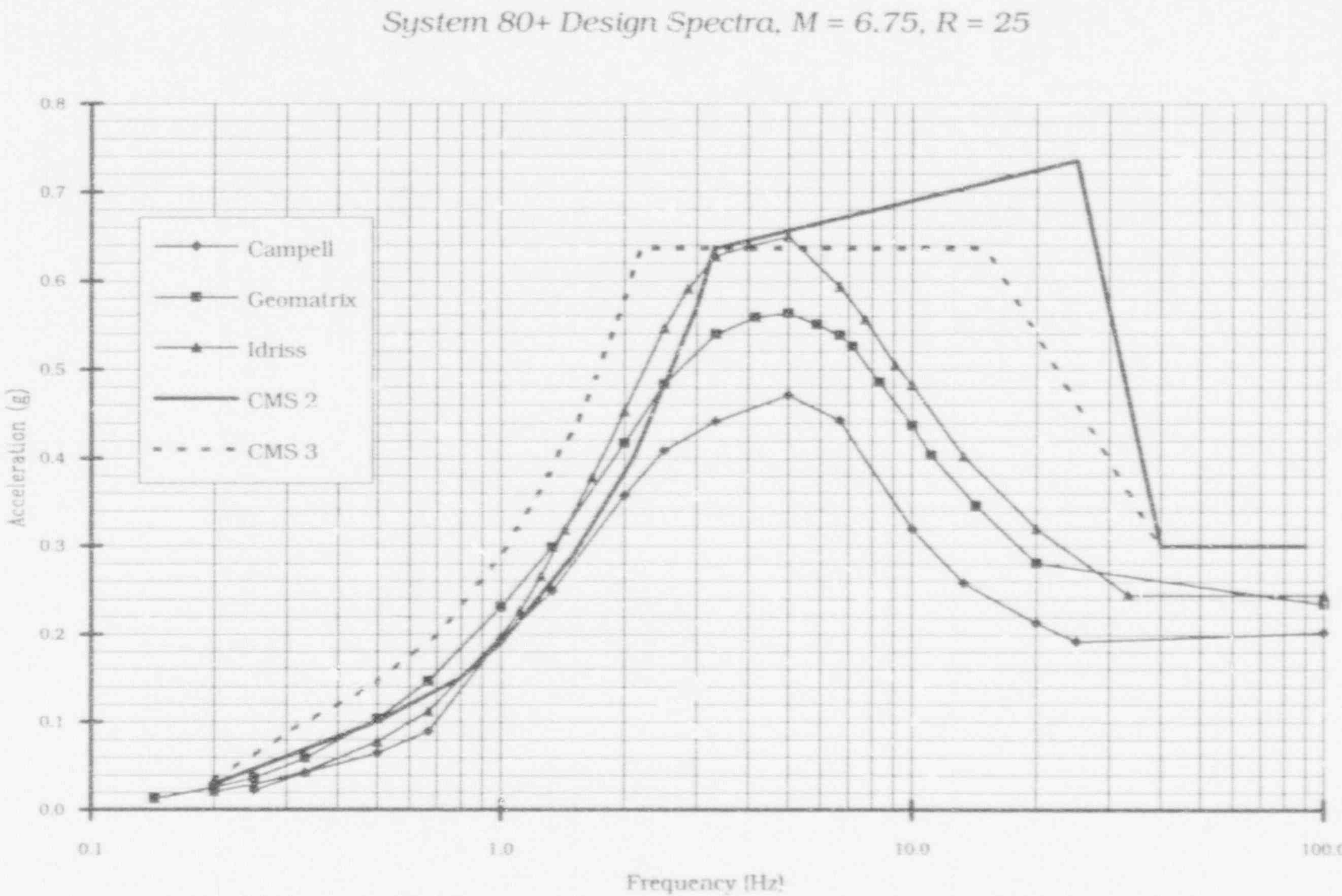

Figure 2.4 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=6.75, R=25 km)

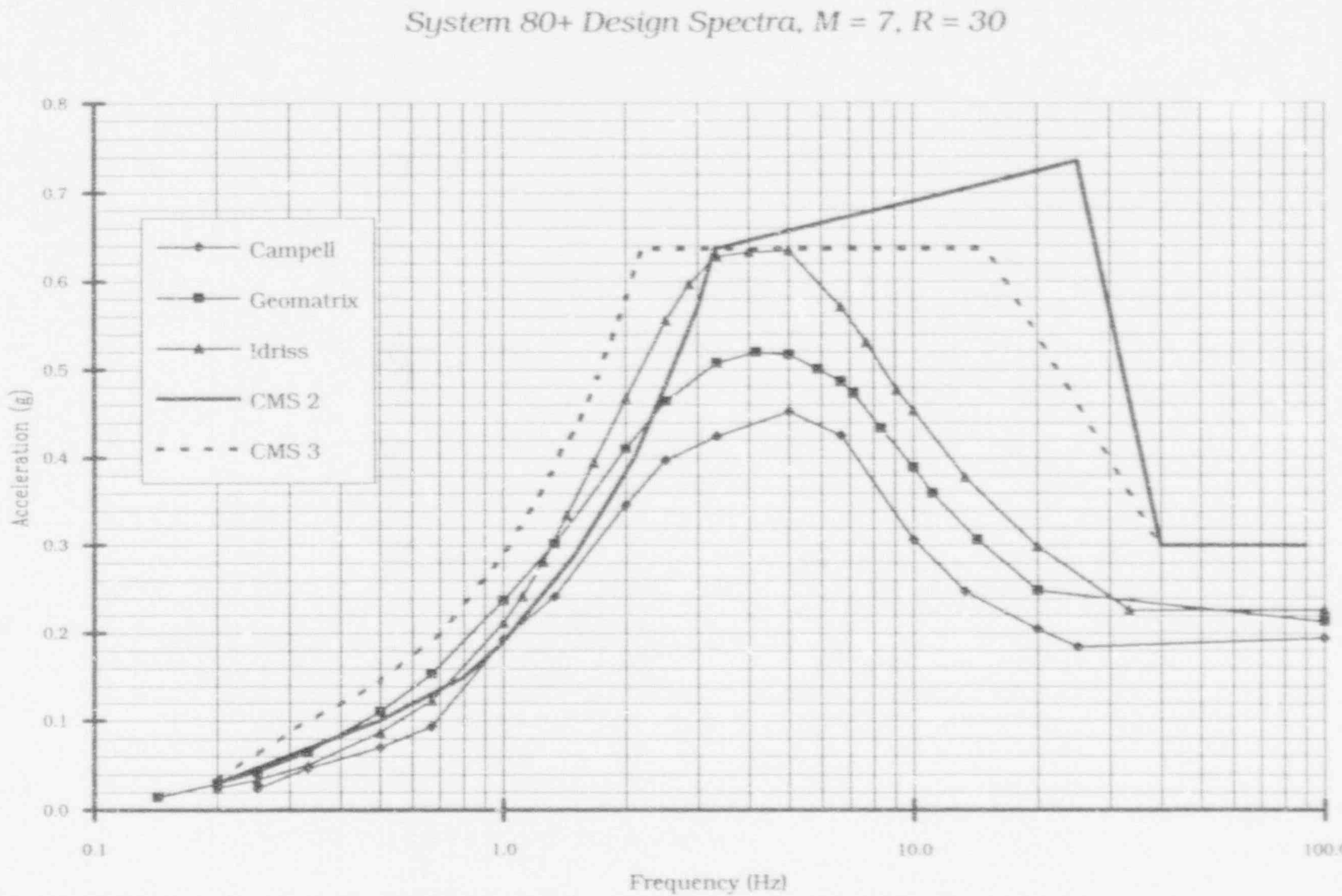

Figure 2.5 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=7, R=30 km)

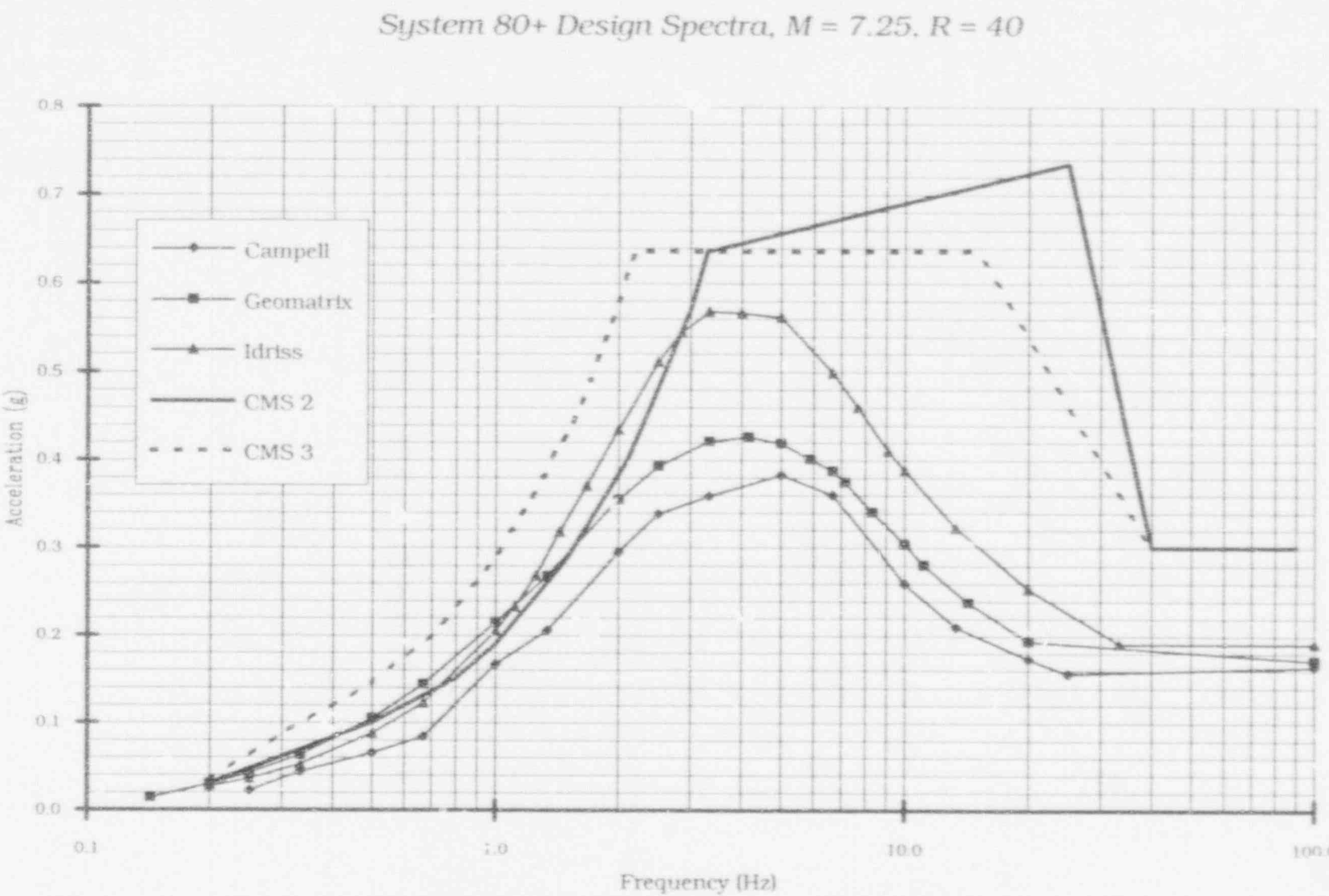

Figure 2.6 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=7.25, R=40 km)

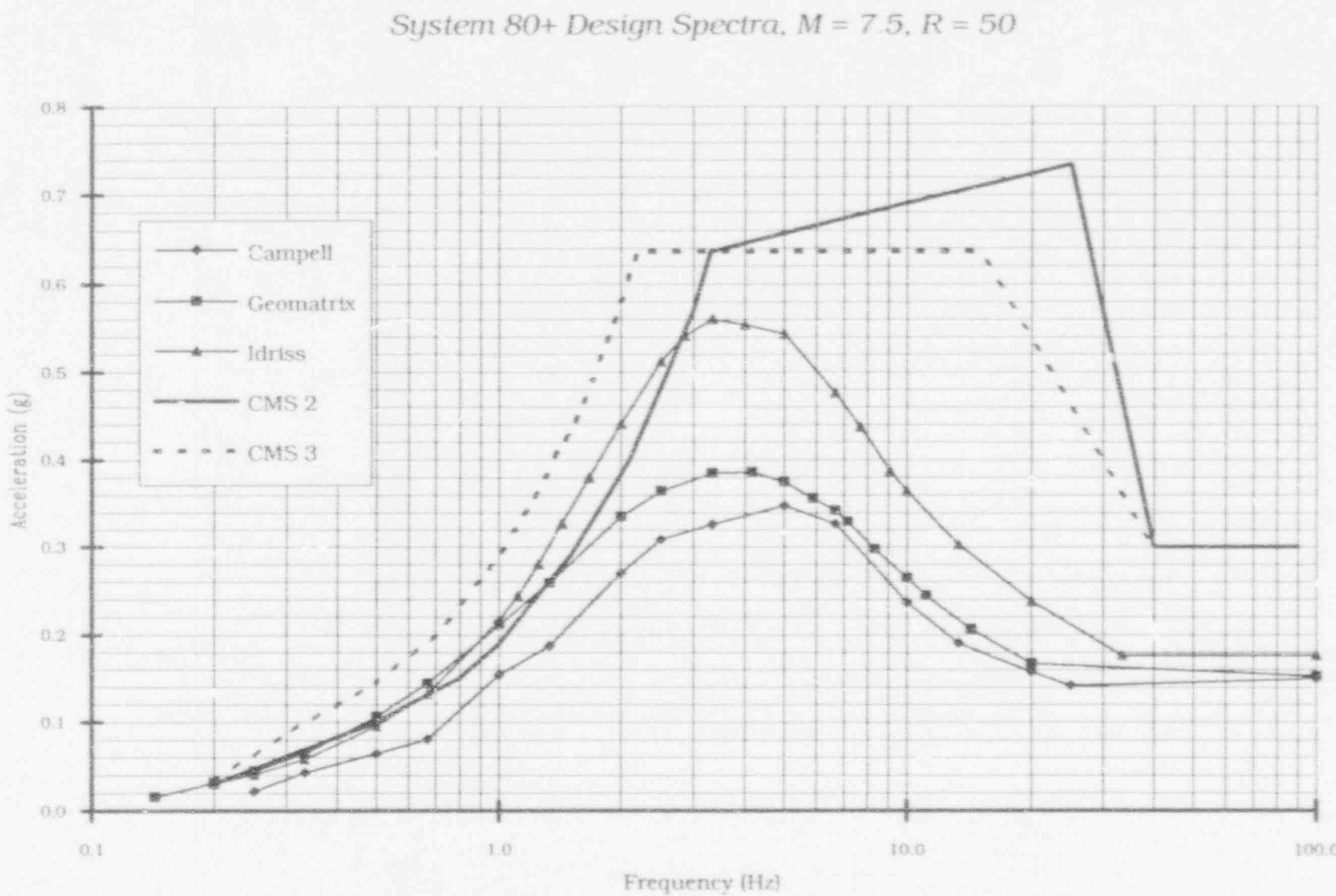

Figure 2.7 - Comparison of CMS2 and CMS3 with Attenuation Relationships by Campbell, Geomatrix and Idriss (M=7.5, R=50 km)

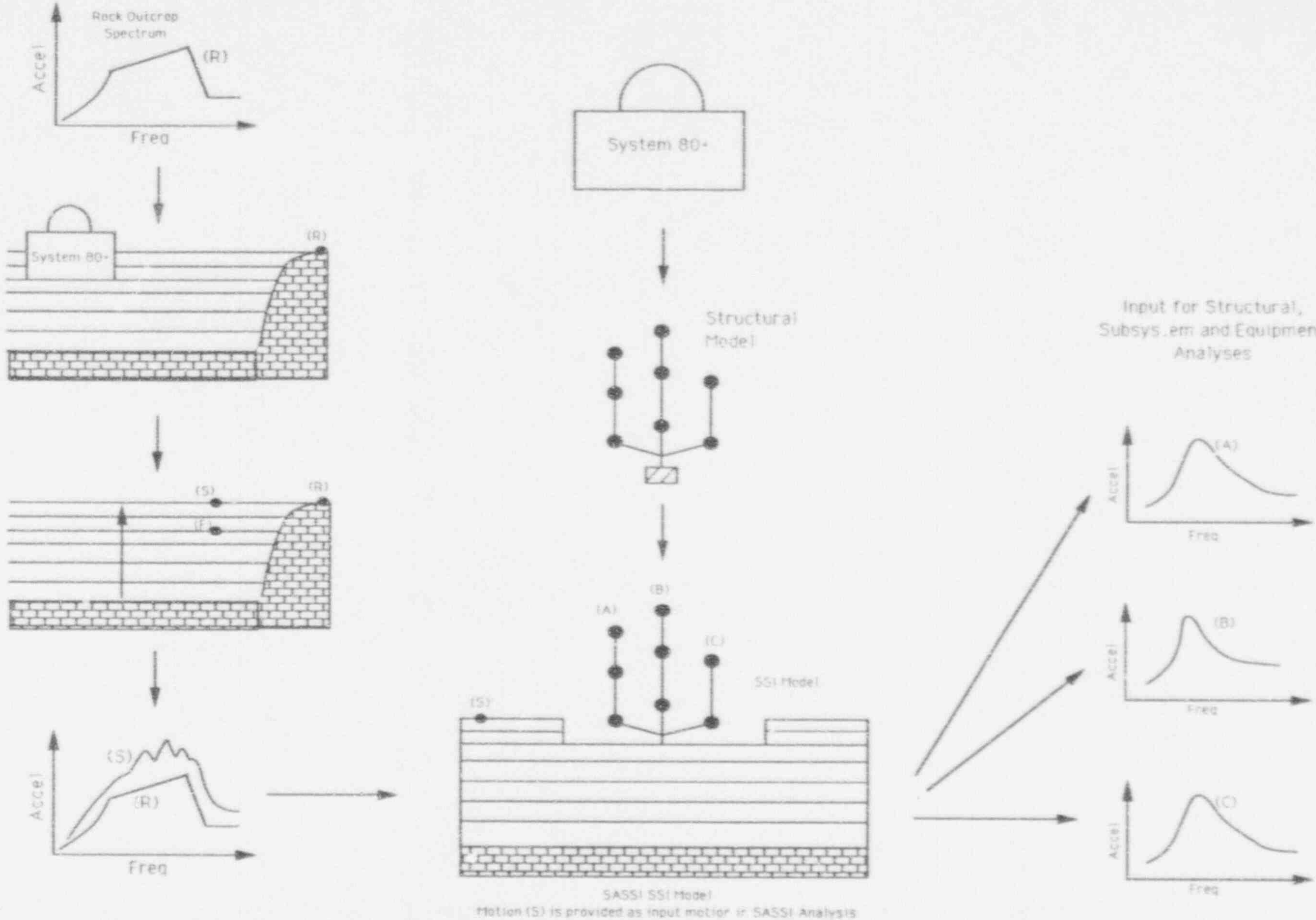

Figure 3.1 - Outline of Application of Control Motions CMS2 and CMS3 in SSI Analyses

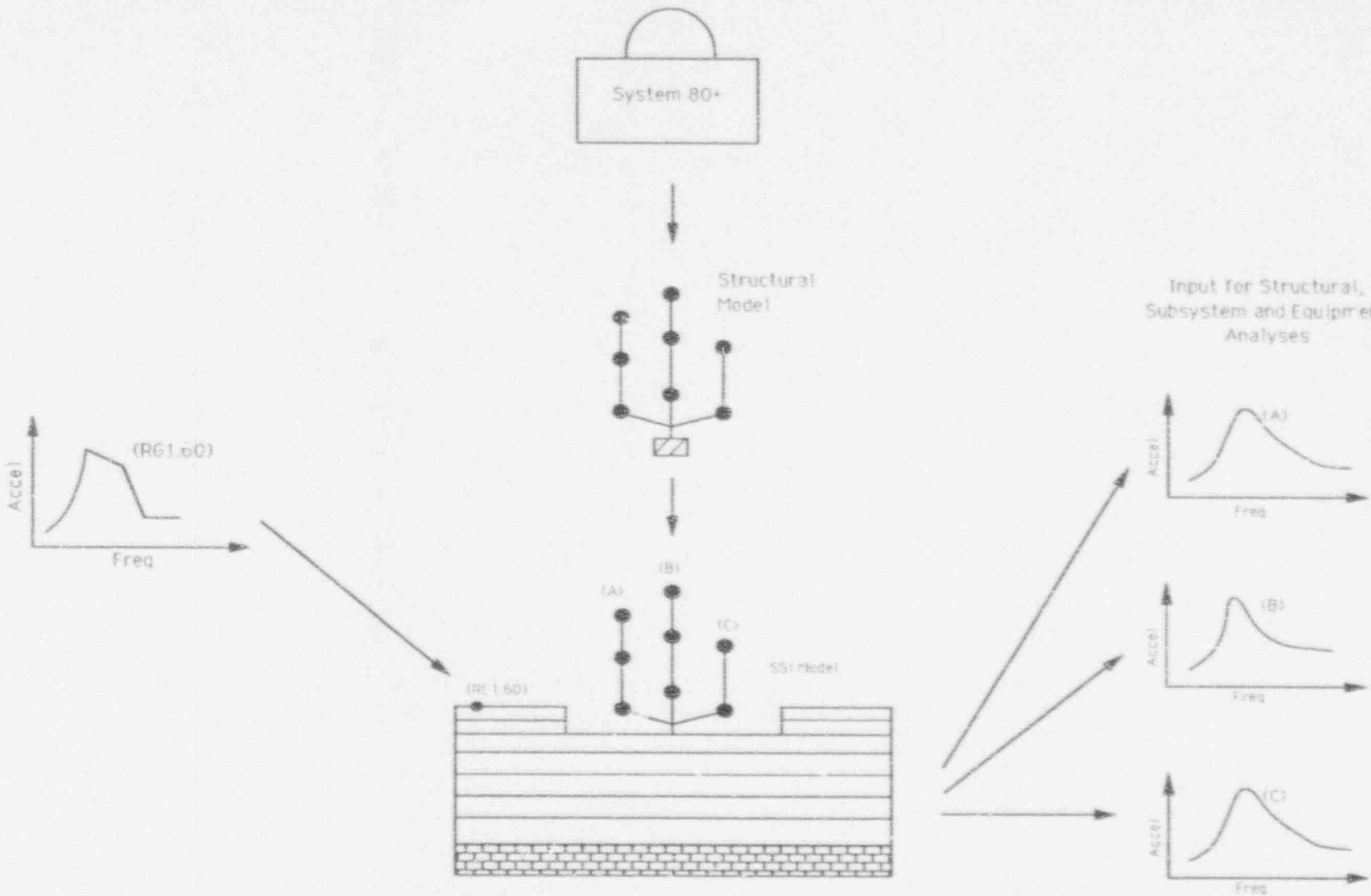

Figure 3.2 - Outline of Application of Control Motion CMS1 in SSI Analyses

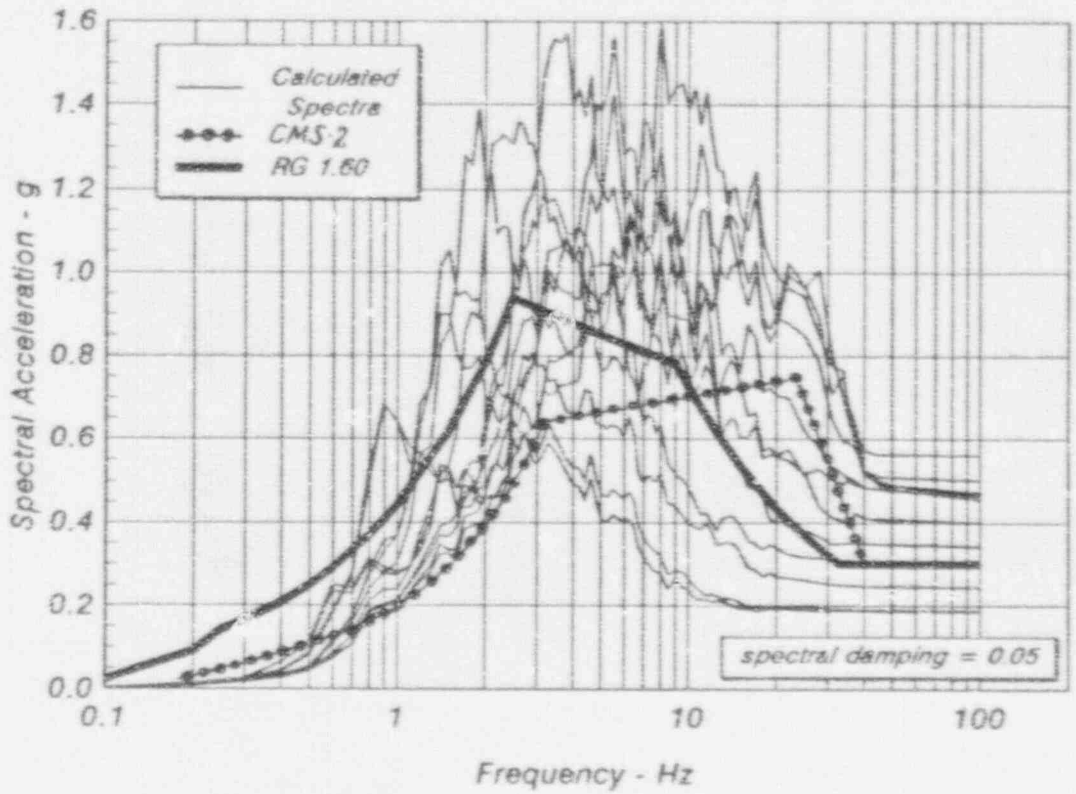

Figure 3.3 - Comparison of CMS1 with Horizontal Ground Surface Motions Computed from Application of CMS2 at the Rock Outcrop

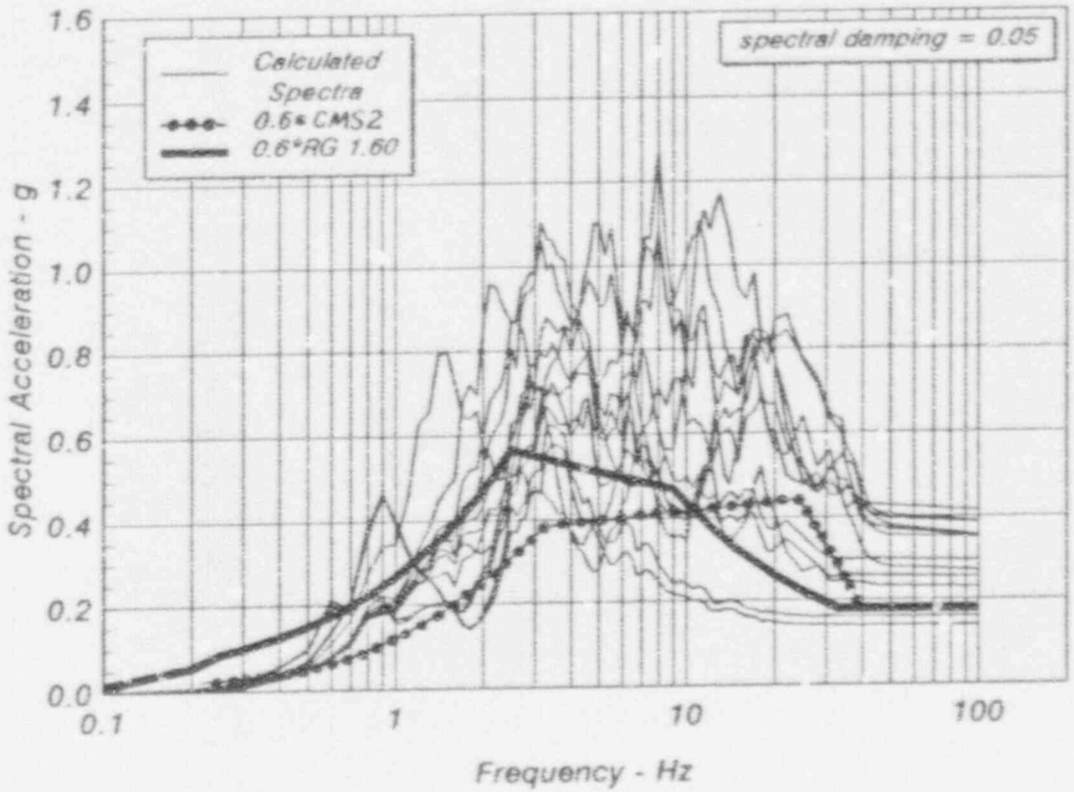

Figure 5.4 - Comparison of 60% of CMS1 with Horizontal Motions at Foundation Level Computed from Application of CMS2 at Rock Outcrop