ENCLOSURE

Enclosure to NEI Letter dated January 14, 2008 on
Effects of High Frequency on Structures, Systems and Components

1. NRC information request: The industry recommended that structural models and analytical methods be sufficiently refined so as to provide reasonable estimates of in-structure response spectra (ISRS) up to a specified "cutoff" frequency defined as the lesser of a) twice the frequency at which the 5% damped Foundation Input Response Spectra (FIRS) spectral acceleration (SA) has dropped below 80% of its peak value, but not less than 16 Hz, or, b) 25 Hz. Spectra which meet the former frequency limit would contain very little HF content, so the more important "cutoff" frequency is the 25 Hz value. The NRC asked that industry provide the basis for the cutoff frequency when the ISRS are used to evaluate the adequacy of systems and equipment (normally qualified by analysis) for HFs beyond the cutoff frequencies.

Response: The bases for the upper limit of 25 Hz are as follows:

- EPRI report 1015108, "The Effects of High-Frequency Ground Motion on Structures, Components and Equipment in Nuclear Power Plants," summarizes a significant amount of empirical and theoretical evidence, and regulatory precedents, that support the conclusion that high-frequency (HF) seismic motions over about 10 Hz are non-damaging to typical nuclear plant structures, systems and large components (with the possible exception of HF-sensitive components). The proposed "cutoff" frequency of 25 Hz is a factor of 2.5 greater than the upper limit of about 10 Hz, above which no significant damage has been experienced by the types of systems and equipment which are normally qualified by analysis.
- Westinghouse report APP-GW-GLR-115, "Effect of High Frequency Seismic Content on SSCs," presents the results of evaluations of the effects of a generic rock site in-structure response spectra on a broad sample of AP1000 systems, structures and large components selected as being the most susceptible to HF motions. These results confirm the conclusion that HF excitations are not damaging to such SSCs.
- The response displacements associated with a seismic spectral acceleration of 2g at frequencies above the 25 Hz cutoff frequency are extremely small, amounting to less than 0.03-inch. This magnitude of displacement has virtually no damage potential for typical nuclear plant equipment and systems. Traditional equipment and piping supports typically have gaps greater than this.
- Traditional analytical methods and modeling techniques for prediction of structural response are generally accurate to the 25 Hz limit. In this regard, it should be noted that these analytical evaluations would consider higher frequency modes consistent with present practice (i.e., analyses would not be cut off at 25 Hz). However, reasonable accuracy in predicting structural response would only be expected below about 25 Hz unless the analyst demonstrates that the analytical model contains sufficient additional refinement to produce reliable results at higher frequencies.

2. NRC information request: The industry proposed that screening tests of potentially HF-sensitive components, both in the generic method described in EPRI report 1015109 and in the location-specific method proposed by Westinghouse, be conducted over a frequency range up to 50 Hz where the maximum exceedance is expected to occur. The NRC requested that the technical basis for this upper limit be provided.

Response: The purpose of the proposed screening tests is to detect components that are sensitive to high frequencies expected in plants located on hard rock sites so that adverse HF vulnerabilities

can be avoided. The frequency of 50 Hz is considered to be a reasonable upper limit on the seismic frequency range of concern for potentially HF-sensitive components in new nuclear plants. It should also be noted that the peak displacement response associated with a frequency of 50 Hz at 2g spectral acceleration is extremely small (i.e., less than 0.01-inch) which supports the selection of 50 Hz as an acceptable upper limit for the HF screening evaluation.

3. NRC information request: The NRC asked that information be provided that explains why the 50 Hz upper limit frequency is sufficient for newer vintage I&C components such as solid-state/digital electronics.

Response: Solid-state and other modern electronics are not new to nuclear power applications and have been used successfully in digital protection and control systems and post-accident monitoring systems (PAMS) applications for the last 20 years. Such devices are inherently non-sensitive to HF excitations as has been demonstrated by their qualification and use in military, aerospace, construction and industrial applications. As an example, digital systems used for years in military and NASA applications are typically qualified to MIL-STD-202 (Test Method Standard, Electronic and Electrical Component Parts). This standard specifies a number of very high-frequency vibration and shock test regimes (e.g., Method 204) which far exceed the frequency ranges and accelerations of concern in nuclear plant applications. Such tests demonstrate the inherent high-frequency ruggedness and lack of high-frequency functional sensitivity of solid-state and digital equipment; therefore, as stated in EPRI 1015109, the only potential concerns with digital or solid-state components are component mountings and connections. Issues with the component mountings or connections would be detected during IEEE Std 344 qualification testing of the certified design component and result in redesign and re-qualification.

4. NRC information request: The generic screening tests recommended by industry in EPRI report 1015109 calls for vibration testing over a frequency range of 25 to 50 Hz at a 5% damped spectral acceleration across this entire frequency range of 5g for floor-mounted components and 15g for enclosure/rack-mounted components. The NRC requested justifications for:

a) the lower frequency of 25 Hz,
b) the upper frequency of 50 Hz (as discussed in item 2, above), and
c) the proposed test acceleration values.

Response: The generic HF screening test frequency range of 25 to 50 Hz was chosen because it is the expected bounding high frequency peak region for the generic rock response spectrum (GRRS). The lower value of 25 Hz provides a reasonable overlap of the frequencies normally included in traditional IEEE Std 344 testing (minimum range of 1 to 33 Hz). The proposed upper limit of 50 Hz is discussed in item 2, above. The recommended screening amplitudes of 5g for floor/wall mounted equipment and 15g for cabinet/enclosure/rack-mounted components were selected very conservatively to assure that the screening test would have sufficient amplitude and energy content across the entire 25 to 50 Hz range to identify any HF resonances or other vulnerabilities. The spectral acceleration of 5g is more than five times the expected peak response of the GRRS. The 15g recommended in-cabinet screening level is the same generic acceleration as the Seismic Qualification Reporting and Testing Standardization (SQURTS) organization determined to be the worst case in-cabinet spectral acceleration level for their generic qualification tests.

The 5g for floor/wall mounted equipment and 15g for cabinet/enclosure/rack-mounted components are considered sufficient to screen out from use those components which are high frequency sensitive. In addition, while the proposed screening test is not intended as a plant-specific qualification test, we are not aware of any in-structure or in-cabinet response spectra for currently

planned hard rock sites that exceed these values. Finally, seismic test experience through programs such as SQURTS indicate that these values are achievable in practical seismic shake table testing.

As discussed in the recent NRC/industry meeting, it was pointed out that most of the failure modes observed historically in HF-sensitive components would be detected during the traditional IEEE qualification tests which contain far more energy content and higher dynamic forces.

5. NRC information request: The industry indicated that existing seismic qualification test data may be used to verify the adequacy of potentially HF-sensitive components if the seismic test excitation contains sufficient HF content. The NRC requested that industry describe the criteria that will be used to assure that the high frequency portion of existing test data has sufficient energy content, considering that past qualification testing generally required testing only up to 33 Hz.

Response: The industry agrees that existing seismic qualification test data when used must be evaluated to assure that they encompass adequate frequency range, e.g., up to 50 Hz or the upper limit of location-specific generic rock in-structure response spectra (GRISRS), and that the test response spectra possess adequate energy content in the HF range. To this end, the industry recommends that the existing seismic qualification test data be evaluated over the required frequency range of interest in accordance with IEEE Std 344-87, Appendix B, "Frequency Content and Stationarity," to determine acceptability of high frequency content.