APPENDIX X

EFFECTS OF NEAR-FIELD EARTHQUAKE GROUND MOTION ON STRUCTURE AND EQUIPMENT DESIGN

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EFFECTS OF NEAR-FIELD EARTHQUAKE GROUND MOTION ON STRUCTURE AND EQUIPMENT DESIGN

The extensive body of site-specific observational evidence presented elsewhere in this report shows that in this highly heterogeneous environment there is a limit of approximately one kilometer to the maximum fault dimension for any single earthquake occurrence. This corresponds to a limiting magnitude of $M_L = 4.0$. The calculations of ground motion presented in this Appendix were carried out both for this limiting magnitude event and for a larger assumed magnitude of M_L = 4.5 which provides a conservative assessment of ground motion effects on the Virgil C. Summer Nuclear Station.

The $M_L = 4.0$, stress drop of 25 bars, and R = 2.0 km case gives a zero period acceleration (ZPA) value of 0.14 g, which is less than the Virgil C. Summer SSE ZPA value of 0.15g for structures on rock. Therefore, this maximum induced seismic event has no effect on structures or equipment.

The $M_L = 4.5$, stress drop of 25 bars, and R = 2.0 km case gives a ZPA value of 0.22 g, which is higher than the Virgil C. Summer SSE ZPA values of 0.15 g for structures on rock and is lower than the SSE ZPA value of 0.25 g for structures on soil. In the original seismic analysis, a very conservative 2 percent damping value was used. NRC Regulatory Guide 1.61 allows a 5 percent damping value for prestressed concrete and 7 percent damping value for reinforced concrete structures in the SSE analysis. Thus, the Virgil C. Summer (0.15 g) SSE spectrum at 2 percent damping is compared with the $M_L = 4.5$ (mean value plus one standard deviation) event spectra at 5 percent and 7 percent damping in Figure 1. As shown in the comparison, the $M_L = 4.5$ event exceeds the Virgil C. Summer (0.15 g) SSE spectrum only in the frequency region higher than about 9 Hertz. The dominant frequencies of all Seismic Category I structures are lower than 9 Hertz except for the interior concrete structures of the Reactor Building. However, since the original seismic analysis used the artificial time history (ATH) as input and the the ATH's response spectrum always exceeds or equals the Virgil C. Summer SSE spectrum, additional conservatism of the ATH method can be used to justify the original seismic design of the interior concrete structures and the equipment contained therein.

To remove the conservatism of the ATH method, the Oroville accelerograms were used in statistical studies. Four horizontal components of two M_L = 4.0 aftershocks of the 1975 Oroville, California earthquake, recorded at rock sites, were modified to match the 5 percent damping target spectrum in the mean as shown in Figures 2 to 5. Four Oroville aftershocks were extended into 36 components by adjusting the time increment, which achieves the effect of shifting the frequency content of the accelerogram (Tsai, 1969). The original Oroville aftershock accelerograms have time increments of 0.005 second. Each component was extended into 9 components by using time increments of 0.0038, 0.0041, 0.0044, 0.0047, 0.005, 0.0053, 0.0056, 0.0059, and 0.0062 second. The 36 accelerograms were used as input to the Reactor Building seismic analysis. The mean values of the 2 percent floor response spectra were compared with the original Virgil C. Summer floor response spectra used in design (Figures 6 to 20). As shown in the comparison, the Virgil C. Summer spectra envelop the M_L = 4.5 mean value spectra in the resonance peak region and almost all other frequency regions. Thus, it is concluded that the original Virgil C. Summer seismic design is not exceeded by this M_L = 4.5 event.

Some NSSS equipment are designed to floor response spectra generated at 5 percent structural damping, for loading combinations containing SSE and LOCA. This set of Virgil C. Summer floor response spectra is also compared with the M_L = 4.5 mean value floor response spectra (Figures 21 to 35). As shown in the comparison, the original Virgil C. Summer seismic design is not exceeded by the M_L = 4.5 event and continues to be valid and adequate.

As shown in Figures 6 through 35, the Virgil C. Summer SSE floor response spectra envelop the M_L=4.5 event floor response spectra in the resonance peak region and in almost all other frequency regions. The 1

only exception is in the frequency region of 20 to 30 Hz, where the Virgil C. Summer response spectra are exceeded by a very small amount. For piping systems and other multiple degree of freedom systems, the frequencies of dominant modes are always lower than 20 Hz. Higher modes have smaller participation factors. Thus, the combined stresses of multiple modes due to the Virgil C. Summer response spectra will always be higher than those due to the M_L=4.5 event spectra. There are a few relatively rigid systems and equipment with frequencies of fundamental modes in the region of 20 to 30 Hz. These systems and equipment all have high moments of inertia and large section sizes in order to reach high frequencies, and are originally over-designed. 1
Therefore, the slight exceedance of the Virgil C. Summer floor response spectra in the frequency region of 20 to 30 Hz will not cause any overstress problems.

To demonstrate the additional margins available in systems design, the seismic stress, design stress, and allowable stress are shown in Table 1 for the emergency feedwater and residual heat removal systems. The margins between the required input and the actual input values of equipment seismic qualification are also shown in Table 1. As shown in the table, ample margins are available in the original design to accommodate the reservoir induced seismicity.

TABLE 1

V. C. SUMMER NUCLEAR PLANT

SEISMIC BUILT-IN DESIGN MARGINS

COMPONENT	DESIGN STRESSES OR REQUIRED INPUT G VALUES	SEISMIC STRESS	ALLOWABLE STRESSES OR ACTUAL INPUT G VALUES
EMERGENCY FEEDWATER PIPING (TO DATE)	19,000 PSI	12,000 PSI	36,000 PSI
RHR PIPING (CLASS 2) (TO DATE)	18,000 PSI	11,640 PSI	39,360 PSI
TURBINE DRIVEN EFW TURBINE	.36G/.36G/.21G TEST		.5G/.5G/.4G
TURBINE DRIVEN EFW PUMP APPURTENANCES	.36G/.36G/.21G TEST		.48G/.48G/0.4G
RHR PUMP & MOTOR	.21G/.31G/.17G ANALYSIS		2.0G/1.5G/1.5G
SAFETY INJECTION CHARGING PUMP	.29G/.24G/.19G ANALYSIS		3.0G/3.0G/2.0G

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REFERENCES

Tsai, N.C., 1969. Transformation of Time Axes of Accelerograms. ASCE Proceedings, Engineering Mechanics Division, vol. 95, no. EM3.