

SEISMIC CONSIDERATIONS IN NUCLEAR POWER PLANT SITING AND DESIGN

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Three factors are considered in this evaluation of seismic effects in nuclear power plant siting and design: 1) an estimate of the maximum ground motions which are likely to occur at any site, 2) an estimate of the spectral response of elastic systems to this ground motion, and 3) an estimate of the spectral capacity of various components of typical nuclear power systems. Comparisons of the spectral response envelope to the spectral capacity for families of typical components provide criteria for preliminary site selection or for evaluation of typical designs. The current design process includes an extensive analysis of the seismicity of each proposed site and of the dynamic characteristics of a proposed system. In such considerations of specific sites and systems, the broad concepts of design of such systems can be overlooked. Herein, parametric studies based on approximate analyses provide general guidelines which could be used in preliminary site selection or initial conceptualization of a design. Maximum ground motions and failure conditions are utilized to establish criteria based on public safety. For continued operation during small earthquakes, which is required for economic operation of the plant, other criteria must be developed.

The vibratory ground motions which will result at various locations relative to a potential earthquake source must be estimated. Ideally, one would model the source mechanism for each anticipated source, the transmission path between these sources and each potential site, and the local site conditions. Then the surface motion resulting from hypothesized earthquakes could be determined for each event which is likely to occur. Since that approach is not practicable at this time, for this study, the magnitude of potential events was estimated based on tectonic and seismic evidence of the size of possible source regions and on simple attenuation curves believed to be appropriate for the region under consideration. Such curves include estimates of the attenuation of maximum vibratory ground displacement, velocity, and acceleration. For example, curves for the attenuation of maximum acceleration for various magnitudes of event are shown in Figure 1. From such curves, spectral envelopes of maximum expected ground motion may be drawn which will include the effects of all potential sources of damaging ground motion. An example is shown in Figure 2 which might be typical for some sites in southern California. For this hypothetical site, the maximum ground motions are caused by the intermediate or small event close to the site.

Assuming that a spectral envelope of maximum ground motion can be estimated for any potential site, the response of elastic systems to this ground motion can be summarized in terms of typical amplification factors by which the values of the spectral envelope of maximum ground motion must be multiplied to obtain a spectral response envelope for single degree-of-freedom systems. This can then be extended to

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multi-degree-of-freedom systems by introducing modal participation factors. A spectral response envelope for first mode response of containment structures is shown in Figure 3.

Approximate analyses were used to establish the spectral capacity of families of steel and concrete cylindrical containment structures. For both cases, the internal volume was maintained constant to maintain a constant internal design pressure. The wall thickness was varied as required to maintain a constant membrane stress under this design pressure, and a stress-concentration factor of 3 was used to represent the effect of penetrations. Two lines in Figure 3 indicate the elastic capacity of steel and concrete containments. As the height-diameter ratio decreases, the seismic capacity of the containment structures increases significantly.

The most likely source of initiation of a "loss of coolant" incident is the rupture of the piping connecting the reactor vessel to the steam generators and coolant pumps. The vibration of the piping itself is not likely to lead to rupture, but large displacements of the steam generators or pumps could cause excessive bending of the pipes, pipe flanges, or nozzels. Figure 4 illustrates the results of the analyses of the capacity of two types of internal equipment and piping. The failure criteria for the cantilevered equipment was based on general yielding of the support skirt which would lead to excessive bending of the piping. Increasing the skirt thickness is most effective in increasing the dynamic capacity. Increases in the skirt length do not significantly alter capacity since natural frequency is decreasing while the distortion to elastic limit is increasing. The suspended equipment was considered to be large rigid masses interconnected by the flexible piping. Increasing the pipe thickness is the most effective design change. This is the result of decreasing the initial stresses due to internal pressure within the piping. Increases in the pipe lengths has an adverse effect since the natural frequency decreased more rapidly than the distortional capacity increased. Increasing the pipe diameter becomes adverse largely due to the effect of internal pressure. The generally low capacity of suspended equipment dictates that restraints must be added to prevent excessive motion. This will introduce large local stresses.

Additional design studies for the many remaining components of nuclear power plants must be made. When completed, comparisons of the type outlined could be used in preliminary site selection or in initial design studies. For example, comparison of Figure 1 to Figures 3 and 4 implies that containments and internal equipment could be designed for the most severe ground motions to be expected and that sites which are 100 km from any potential source require a minimum of seismic design. A bibliography is given in Reference 1.

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Public Health Risks of Thermal Power Plants; Appendix IV, "Seismic Safety of Power Plants," R. B. Matthiesen, G. Howard, and C. B. Smith, Schl. Engr. Appl. Sci., UCLA, Los Angeles, May 1972. (To appear in Nuclear Engineering and Design, Spring 1973)

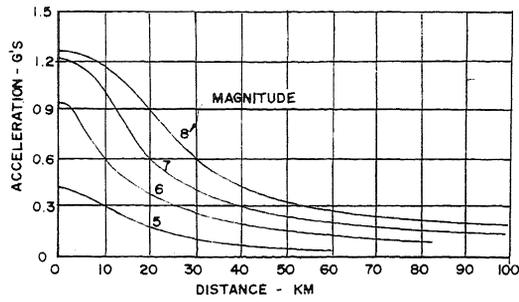


Fig 1 ATTENUATION OF MAXIMUM ACCELERATION

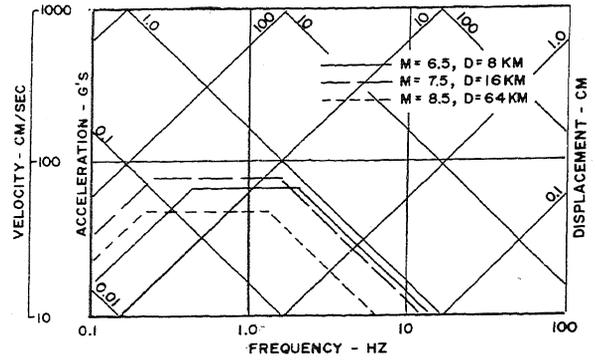


Fig 2 SPECTRAL ENVELOPE OF MAXIMUM GROUND MOTION

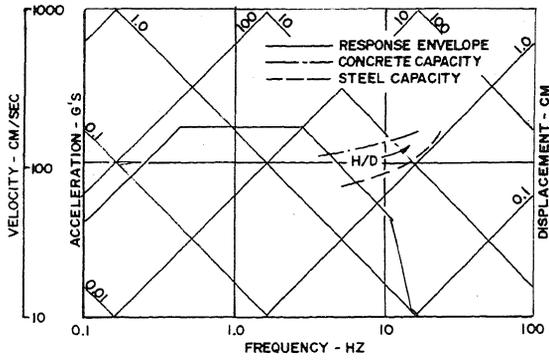


Fig 3 SPECTRAL COMPARISON FOR CONTAINMENTS

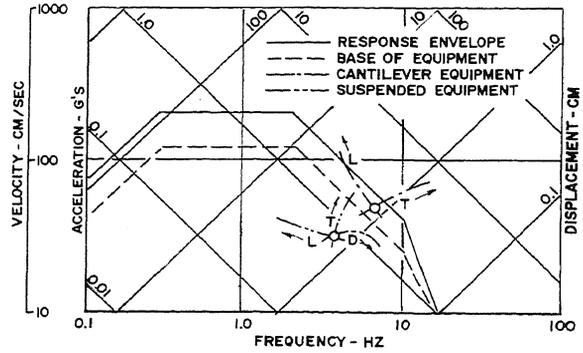


Fig 4 SPECTRAL COMPARISONS FOR EQUIPMENT