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May 12, 1989

Dr. Raman Pichumani
Office of Nuclear Reactor Regulation
Mail Stop OWFN 8D-22
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Task 1, Task Assignment 17, FIN A-3841

Dear Dr. Pichumani:

As per our recent discussions over the telephone, I am enclosing the report by Professor Veletsos pertaining to the work outlined in Task 1 of Task Assignment 17, under FIN A-3841. The comments contained in this report are limited to what Professor Veletsos believes are the most important involving ground motion issues.

If you have any questions, please do not hesitate to contact me.

Very truly yours,

Morris Reich, Head
Structural Analysis Division

MR:gfs
Enclosure
cc: R. Rothman
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A. S. VELETSOS

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May 9, 1989

Dr. Morris Reich, Head
Structural Analysis Division
Brookhaven National Laboratory
Department of Nuclear Energy
Building 129
Upton, Long Island, New York 11973

Re: March 1-3, 1989 Meeting of Ground Motion Panel for Diablo Canyon Long Term Seismic Studies

Dear Morris:

Following is my report on the above-referenced meeting. My comments are limited to what I regard to be the most important unresolved ground motion issue, the appropriateness of the records employed in the deterministic evaluation of plant response. The topics addressed include:

- The choice of the ground motion records;
- The appropriateness of the adjustment factors assigned to these records;
- The appropriateness of the style of faulting considered for the site; and
- Miscellaneous other topics.

I would first like to note, however, that the March 1-3 meeting was highly productive and has helped to clarify the issues on which questions had been raised.

Choice of Ground Motion Records

The deterministic comparisons of responses presented in Chapter 7 of PG&E's Final Report (Ref. 1) are based on the 1988 site-specific, 84th percentile of non-exceedance pseudoacceleration response spectrum for systems with 5 percent of critical damping. Displayed in Figs. 2 and 7-2 of Ref. 1, this spectrum and the associated ground motions have the following characteristics:

- Its absolute maximum value is slightly less than 2.0 g;
- Its high-frequency limit is approximately 0.84 g; and
- The mean peak value of the ground accelerations is 0.67 g.

By contrast, the corresponding values for the set of ground motions considered in PG&E's fragility studies and in the studies conducted at Rice University under sponsorship of the Brookhaven National Laboratory (Ref.

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2) were 2.57 g, 1.11 g and 0.83 g, respectively. Several of the ground motions in the latter studies are for earthquake magnitudes of about 6.5, and have not been upgraded to the 7.2 magnitude event stipulated for the Hosgri fault. Had these motions been upgraded to the 7.2 event, the ordinates of the resulting spectra would, in all likelihood, have been higher.

As indicated in my November 4, 1988 report to you (Ref. 3), the differences in the two sets of results stem from the use of different sets of ground motion records in the two studies. Whereas the BNL-Rice studies and PG&E's fragility studies are based on the 12 pairs of records listed in the attached Table 1, PG&E's site-specific studies are based on the 18 pairs of records listed in Table 4.4 of Ref. 1. Of the records involved in the two sets, only 9 pairs are common. Significantly, the larger set does not include the records from the Morgan Hill, Coalinga and Parkfield earthquakes, for which the mean value of the maximum ground accelerations is 0.90 g, but does include six supplementary pairs of records from the 1979 Imperial Valley and the 1971 San Fernando earthquakes, for which the mean value of the peak ground accelerations is 0.47 g. The mean value of the peak ground accelerations for the complete set of records in the attached Table 1 is naturally 0.83 g, whereas the corresponding value for the set presented in Table 4.4 of Ref. 1 is only 0.67 g.

In the discussion of these differences at the March 1-3 meeting, it was noted that the ground motions in PG&E's fragility studies included only the more intense of the records deemed to be appropriate for the Hosgri site, whereas those for the deterministic studies included a more broadly representative set of records. While I agree that the records used in the fragility studies do tend to bias the results on the high side, I feel that those used in the deterministic studies have the opposite effect: they tend to bias the results on the low side. By deleting the Morgan Hill, Coalinga and Parkfield records and overemphasizing the effects of the Imperial Valley and San Fernando earthquakes, one effectively

- Reduces the values of both the mean maximum ground acceleration and of the spectral accelerations; and
- Suggests that the design motion at the Hosgri site would be similar to those obtained for the Imperial Valley and San Fernando earthquakes.

It is strongly recommended that the sensitivity of the critical design parameters to the selection of the ground motion records be evaluated critically. Of special interest is the sensitivity of the absolute maximum spectral pseudoacceleration.

The use of the large number of records from the Imperial Valley earthquake was justified at the March 1-3 meeting by the desire to have a reasonable number of records from strike-slip events. However, considering that the factor of 0.83 is used to convert the peak ground acceleration from a thrust to a strike-slip style of faulting, this argument is not convincing in my view. As already noted, the effect of using a large number of records from the Imperial Valley earthquake would be to reduce both the mean peak ground acceleration and the values of the associated response spectra.

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Appropriateness of Adjustment Factors

The intensities of the design ground motions and of the associated response spectra used in the deterministic studies depend importantly on the "adjustment factors" listed in Table 4.4 of Ref. 1. These are effectively scaling factors that convert the original ground motion records to the conditions deemed appropriate for the plant site. The derivation of these factors is not described in sufficient detail to permit an independent evaluation to be made of the results presented. In addition to a complete listing of all the factors provided for, it would be desirable to have an indication of the effects upon the maximum ground acceleration and the spectral accelerations of each parameter separately, not merely their combined effect. It might also be advisable to have an independent evaluation of these factors.

Appropriateness of Style of Faulting

The scaling factors 0.83 and 0.91 (p. 4-34 of Ref. 1) are used to convert the ground accelerations and spectral accelerations associated with earthquakes of thrust faulting to those of strike-slip faulting and reverse faulting, respectively. Additionally, the factors 0.65, 0.30 and 0.05 (p. 4-15 of Ref. 1) are used to express the probabilities of occurrence at the Hosgri site of strike-slip faulting, oblique faulting and thrust faulting, respectively. At the March 1-3 meeting, it became clear that these factors are applied in addition to "the adjustment factors" listed in Table 4.4 of Ref. 1. It was also clear that there continue to be substantial uncertainties regarding the style of faulting that may be appropriate for the Hosgri site. In particular, it was suggested that there was a much higher probability of a reverse faulting occuring than previously estimated.

It is significant to note in this regard that no distinction was made in Dr. K. Campbell's latest study (Ref. 4) among oblique, reverse and thrust faulting, suggesting that a reverse faulting should be treated as equivalent to a thrust faulting. This would require that the scaling factor for reverse faulting be increased from 0.91 to unity. The effect of this uncertainty on the critical design quantities remains to be assessed.

Miscellaneous Other Topics

1. The ground motion attenuation relationships used for short epicentral distances are constrained by data obtained at large distances or for small magnitude quakes. The net effect seems to be an underestimation of the peak acceleration at small distances, particularly for large magnitude events (see, for example, the plots in Figs. Q8-2, Q8-4 and Q8-5 of Ref. 5). These results seem also to be affected by how distance is defined.

2. The ratio of the peak accelerations for rock and soil sites in the PG&E studies has been taken as 1.15, although some recent studies by Idriss and Sadigh suggest that a value between 1.2 and 1.3 may be more appropriate. A clarification is requested of the impact of this difference on the design spectra.

3. In the numerical studies which have been carried out to assess the effect of site topography, the seismic waves were presumed to travel parallel to the cliff. For waves travelling perpendicular to the cliff, the topographical effect may be more substantial and deserves further examination.

Yours sincerely,

A. S. Veletsos

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REFERENCES

1. Pacific Gas & Electric Company, "Final Report of the Diablo Canyon Long Term Seismic Program," July, 1988

2. Veletsos, A. S., Tang, Y., and Prasad, A. M., "Studies of Earthquake Ground Motions and Soil-Structure Interaction for Diablo Canyon Nuclear Power Plant," Report to Brookhaven National Laboratory, Long Island, New York, December 10, 1988

3. Veletsos, A. S., "Comments on PG&E's Final Report on Long Term Seismic Program for Diablo Canyon Plant," Letter Report to Dr. M. Reich of Brookhaven National Laboratory, Long Island, New York, November 4,1988

4. Campbell, K. W., "Preliminary Report on Empirical Studies of Horizontal Ground Motion for the Diablo Canyon Site, California," U. S. Geological Survey, Report to U. S. Nuclear Regulatory Commission, October, 1988

5. Pacific Gas & Electric Company, "Response to Questions 4, 5, 6, 7, 8, 9, 10, 11, and 12," Diablo Canyon Long Term Seismic Program, January 19, 1989

TABLE 1 Maximum Values of Acceleration, Velocity and Displacement for Empirical Ground Motions Considered

Earthquake; Record Name; Date	Record No.	Component	$\ddot{x}_g$ (in g's)	$\dot{x}_g$ (in/sec)	x_g (in)
Tabas, Iran; Tabas	1	Long.	0.812	36.40	18.44
16 September 1978	2	Trans.	0.705	40.92	35.57
San Fernando; Pacoima Dam	3	S16E	1.170	44.98	13.96
9 Feb. 1971	4	S74W	1.075	22.97	7.82
San Fernando; Lake Hughes No. 12	5	N21E	0.902	15.39	2.04
9 Feb. 1971	6	N69W	0.711	12.02	3.27
San Fernando; Castaic	7	N69W	0.853	41.40	11.84
9 Feb. 1971	8	N21E	1.025	22.91	6.56
Imperial Valley; Differential Array	9	N00E	0.567	12.50	2.90
15 Oct. 1979	10	N90W	0.514	15.84	5.19
Imperial Valley; El Centro No. 4	11	S50W	0.483	17.84	11.14
15 Oct. 1979	12	S40E	0.693	15.90	3.05
Morgan Hill; Coyote Lake Dam	13	N75W	1.663	48.73	11.44
24 April 1984	14	S15W	0.886	33.77	14.26
Coalinga; Pleasant Valley Pump Plant	15	045	0.854	40.74	8.24
2 May 1983	16	135	0.738	21.79	3.33
Nahanni; Site 1	17	N10W	1.101	18.98	16.56
23 Dec. 1985	18	280	1.345	18.64	19.67
Gazli; Karakyr Point	19	East	0.699	18.97	3.96
17 May 1976	20	North	0.655	17.84	3.24
Parkfield; Temblor	21	N65N	0.550	18.89	8.65
27 June 1966	22	S25W	0.703	23.11	10.88
Tabas, Iran; Dayhook	23	Trans.	0.683	17.83	11.00
(Scaled by 1.7)	24	Long.	0.635	20.12	46.04
Mean Values			0.834	24.94	11.63
Mean plus Sigma Values			1.108	35.88	21.87

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