PACIFIC GAS AND ELECTRIC COMPANY
DEPARTMENT OF ENGINEERING

ANALYSIS OF RELATIVE RISK ASSOCIATED WITH OPERATION OF THE DIABLO CANYON NUCLEAR POWER PLANT UNIT 1 FOR AN INTERIM LICENSING PERIOD

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Introduction and Summary

On August 25, 1977, Pacific Gas and Electric Company (PGandE) submitted a motion(1) for an interim operating license for Diablo Canyon Unit 1, citing serious concerns for the adequacy of power supply in the PGandE service area in the summer of 1978. In support of this motion, PGandE submitted a summary of projections of generating capacity and energy supply and a detailed probabilistic analysis of seismic safety.(2) An analysis of this type had been previously requested by the NRC as necessary support for an interim license application.(3) The report was entitled "Analysis of the Risk to the Public From Possible Damage to the Diablo Canyon Nuclear Power Station From Seismic Events."

The report took into consideration the postulation of a 7.5M seismic event on the Hosgri fault and included the consideration of risk contributions beyond the accelerations expected from this event. The major result of the study was the conclusion that seismic risks to the Diablo Canyon Plant do not present significant risks to the health and safety of the public, with or without plant modifications. Another conclusion drawn from the study was that ma . modifications to the turbine building for the purpose of raising the seismic qualification level would not result in further significant reduction of the public health risk.

In connection with a discussion of the Diablo Canyon Interim License in Congressional Hearings,(4) Mr. Edson Case, the Acting Director of the Office of Nuclear Reactor Regulation, indicated the staff would require PGandE to show that the risk to the public during the period of the interim license was no greater than the risk to the public for the period of the full term license, using for the comparison two years for the interim license and thirty years for the full term license.

In this analysis, a number of simplified analytical functions have been postulated which cover the full range of earthquake acceleration probabilities which have been proposed by various consultants. These probability distributions have been combined analytically with a variety of assumed one-parameter plant response curves

to yield a ratio of risk for the interim license period to the risk for the full term license period. The resulting ratios of two-year risks to thirty-year risks ranged from 0.09 to 0.31 for the cases analyzed. On the basis of this analysis, it can be concluded that the calculated risk associated with the proposed interim license period would be significantly less than that calculated for the full term of plant operation. In addition, it can be concluded that this general conclusion would not be changed by the consideration of a wide variety of earthquake probability curves or plant response curves.

Calculation of Relative Risks

The values of peak acceleration used in this analysis are those developed in previous papers by various consultants, and were presented and discussed in Amendment 50 to the Diablo Canyon Final Safety Analysis Report.[5] In this analysis, acceleration probabilities developed by all consultants were included in the evaluation, although PGandE and its consultants agree that some of these values are not appropriate for this site. The probability curves used are shown in Figure I which has been reproduced directly from Reference 5. For this analysis, the curves have been approximated by enveloping straight line segments which are represented analytically as:

$$F(a) = Ka^{-p} \qquad (1)$$

where:

$F(a)$ = the rate of exceedance of acceleration "a" at the site, per year

K = Intercept constant

p = Slope constant

The various values of the constants and several particular values of the rate of exceedance (or frequency) are given in Table I. The corresponding lines have also been drawn on Figure I.

In this analysis, the plant response to accelerations has been assumed to be represented by simple one-parameter conditional distributions in an approach similar to that used in several previous studies[6,7,8,9,10] to allow an approximate examination of relative risks. The distributions used are shown in Figure II. For the cases involving step functions for plant response, the risk

ratios were taken simply from the enveloping straight line approximations to the earthquake curves. For the ramp function cases, the products of two curves were integrated in the following procedure.

As discussed in an earlier analysis,[2] the absolute value of risk can be expressed by a generalized equation having the following parts:

Probability that an individual at some location suffers a significant health effect as a result of a quake-caused accident at Diablo Canyon

equals

Probability of an earthquake — FACTOR I

times

Probability that the quake causes major damage to plant — FACTOR II

times

Probability that major damage results in a significant radiation level at the individual's location at some time — FACTOR III

times

Probability that the individual will remain in the area throughout the duration of the high radiation level — FACTOR IV

Each of these factors has many possible values, depending upon numerous parameters. Some of these variable parameters are: (a) a wide variation of earthquake accelerations and spectra; (b) many possible variables characterizing plant response to the earthquake; and (c) many types of radiation health effects, locations, population groups, times, and so on. Thus, the total risk can be represented by a generalized equation of this form:

$$R = P_I \, P_{II} \, P_{III} \, P_{IV} \qquad (2)$$

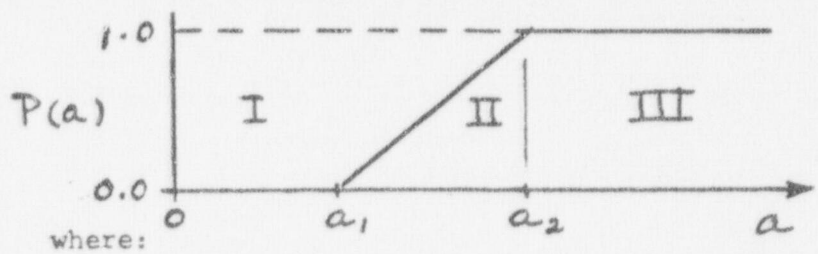
where the terms refer to the general factors above. In the previous analysis[2] the absolute values for the risk were developed and factors P_{III} and P_{IV} were included. In this analysis, an approximation of the relative risk, absolute values can be left out. Using the relationship (1) for this earthquake frequency, equation (2) reduces to:

$$R = \int \left[-\frac{dF(a)}{da}\right] \cdot P(a)\, da \qquad (3)$$

where:

P(a) = Probability of plant failure, given a peak acceleration of "a."

For the evaluation of the ramp functions shown in Figure II, the plant response was divided into three regions as follows:



where:

$P(a) = 0$ Region I

$P(a) = (a - a_1)/(a_2 - a_1)$ Region II

$P(a) = 1.0$ Region III

In the first region where P(a) = 0, the integral for R is zero, since the differential $|dF(a)|$ is bounded:

$$R_I = \int_0^{a_1} \left[-\frac{dF(a)}{da}\right](0)\, da = 0 \qquad (4)$$

In the second region, the integral is:

$$R_{II} = \int_{a_1}^{a_2} \left[K p a^{-p-1}\right] \cdot \frac{(a - a_1)}{(a_2 - a_1)}\, da \qquad (5)$$

which reduces to:

$$R_{II} = \frac{K a_1^{1-p}}{(1-p)(a_2-a_1)}\left[\left(\frac{a_1}{a_2}\right)^p \left\{p\left(\frac{a_2}{a_1} - 1\right) + 1\right\} - 1\right] \quad (6)$$

In the third region where P(a) = 1, the integral for R is just the value of the cumulative frequency of exceedance evaluated at a_2. That is:

$$R_{III} = \int_{a_2}^{\infty} \left[-\frac{dF(a)}{da}\right](1.0)\, da = F(a_2) \quad (7)$$

The total risk for the three regions is then just the sum of expressions (6) and (7). The relative risks for the interim and full term periods were calculated using these relationships with the data presented in Table I and Figures I and II. The results of the analysis are presented in Table II and show that for all cases analyzed, the ratio of risk during the interim license to the risk during the full term license is less than unity.

As discussed earlier, the study of seismic risks(2) concluded that certain modifications to qualify additional plant components for 0.75g would not result in significant reduction in the plant response curves. If the plant response is not significantly different for the plant nominally designed for 0.4g or 0.75g, the ratios of interim risk to full term risk are even lower than the values given in Table II. Other shapes of plant response using convex, concave or "s" shaped curves can also be assumed and easily represented by combinations of the straight lines used in this analysis. The use of such curves would not result in different conclusions.

TABLE 1

ENVELOPING APPROXIMATION TO VARIOUS CURVES
FOR THE ANNUAL EXCEEDANCE RATE OF SEISMIC GROUND ACCELERATION

Source Curve	Approximation Constants		Annual Rate of Exceedance			
	K	P	0.1g	0.4g	0.75g	1.0g
Blume (Effective)	1.41×10^{-5}	2.47	4.2×10^{-3}	1.4×10^{-4}	2.9×10^{-5}	1.4×10^{-5}
Blume (Instrumental)	4.08×10^{-5}	2.47	1.2×10^{-2}	3.9×10^{-4}	8.3×10^{-5}	4.1×10^{-5}
Somerville	6.29×10^{-5}	2.82	4.2×10^{-2}	8.3×10^{-4}	1.4×10^{-4}	6.3×10^{-5}
Anderson & Trifunac, #50	5.57×10^{-3}	1.37	1.3×10^{-1}	2.0×10^{-2}	8.3×10^{-3}	5.6×10^{-3}
Anderson & Trifunac, #51	3.03×10^{-3}	1.02	3.2×10^{-2}	7.7×10^{-3}	4.1×10^{-3}	3.0×10^{-3}

TABLE II

RATIO OF RISK DURING TWO YEAR INTERIM OPERATING PERIOD TO THIRTY YEAR FULL TERM OPERATING PERIOD

Earthquake Acceleration Curve	Plant Response Case			
	A	B	C	D
Blume Effective	0.31	0.23	0.13	0.15
Blume Instrumental	0.31	0.23	0.13	0.15
Anderson-Trifunac #50	0.16	0.13	0.11	0.10
Anderson-Trifunac #51	0.13	0.11	0.10	0.09

REFERENCES

1. Motion for Interim Operating License, Diablo Canyon Unit 1, Pacific Gas and Electric Company, Docket No. 50-275, August 25, 1977.

2. Final Safety Analysis Report, Diablo Canyon Site, Units 1 and 2, Amendment 52, Dockets 50-275-OL, 50-323-OL, Pacific Gas and Electric Company, August 25, 1977.

3. Summary of Meeting Held on June 2, 1977, to Discuss Diablo Canyon Seismic Design, Memorandum from Dennis P. Allison, Project Manager, Light Water Reactors Branch Number 1, Division of Project Management, U.S. Nuclear Regulatory Commission, June 29, 1977, Docket Nos. 50-275, 50-323.

4. Transcript of Proceedings of Hearings Held Before the Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs, Washington, D.C., Thursday, June 30, 1977.

5. Final Safety Analysis Report, Diablo Canyon Site, Units 1 and 2, Amendment 50, Dockets 50-275-OL, and 50-323-OL, Pacific Gas and Electric Company, particularly Item D-LL-36.

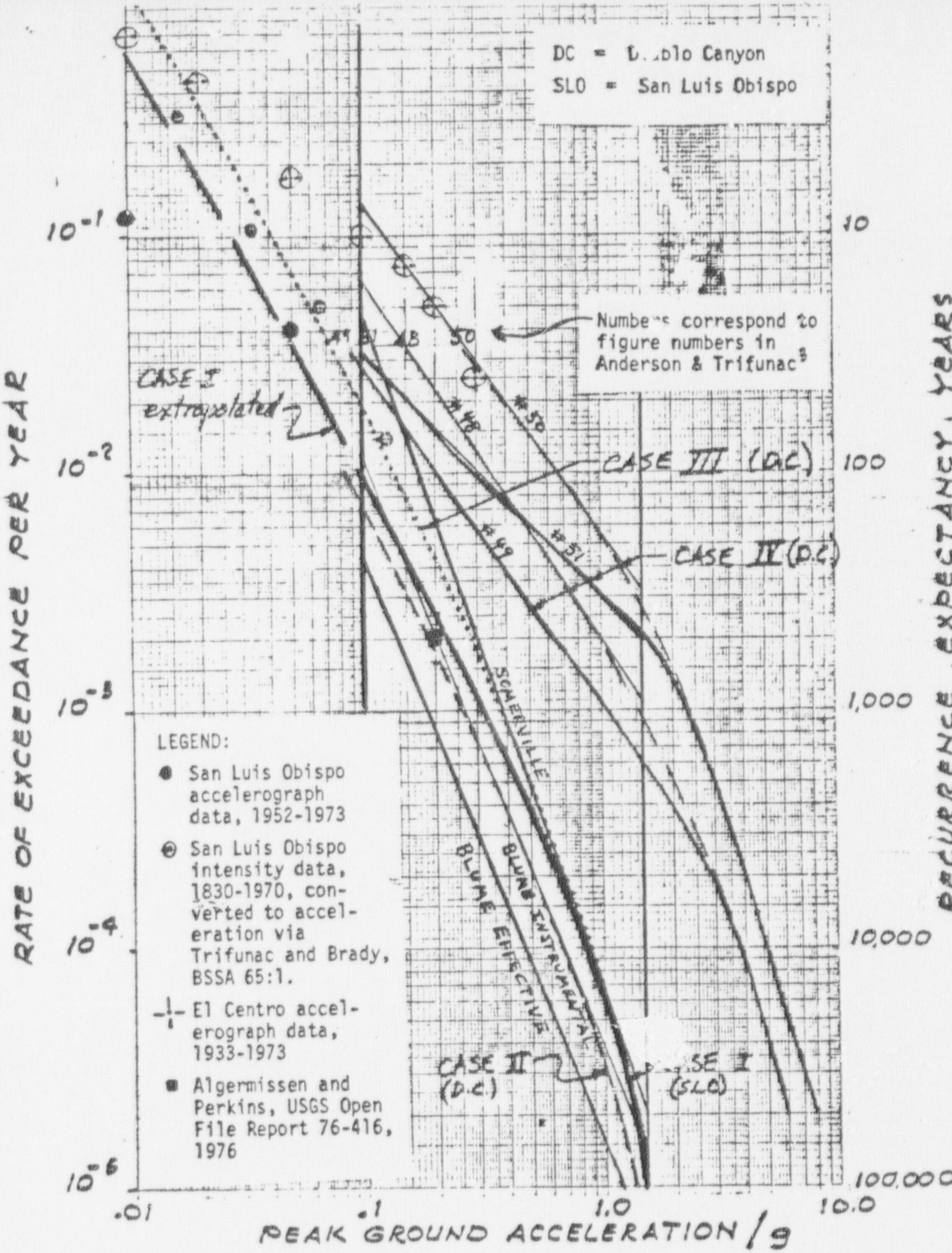
6. Reactor Safety Study, U.S. Nuclear Regulatory Commission, WASH-1400, (NUREG-75/014), October 1975.

7. N. M. Newmark, "Probability of Predicted Seismic Damage in Relation to Nuclear Reactor Facility Design"; prepared for NRC, NMN Consulting Engineering Services, Urbana, Illinois, September 30, 1975.

8. T. M. Hsieh and D. Okrent, "Some Probabilistic Aspects of the Seismic Risk of Nuclear Reactors," UCLA-ENG.-76113, U.C.L.A. School of Engineering, Los Angeles, December 1976.

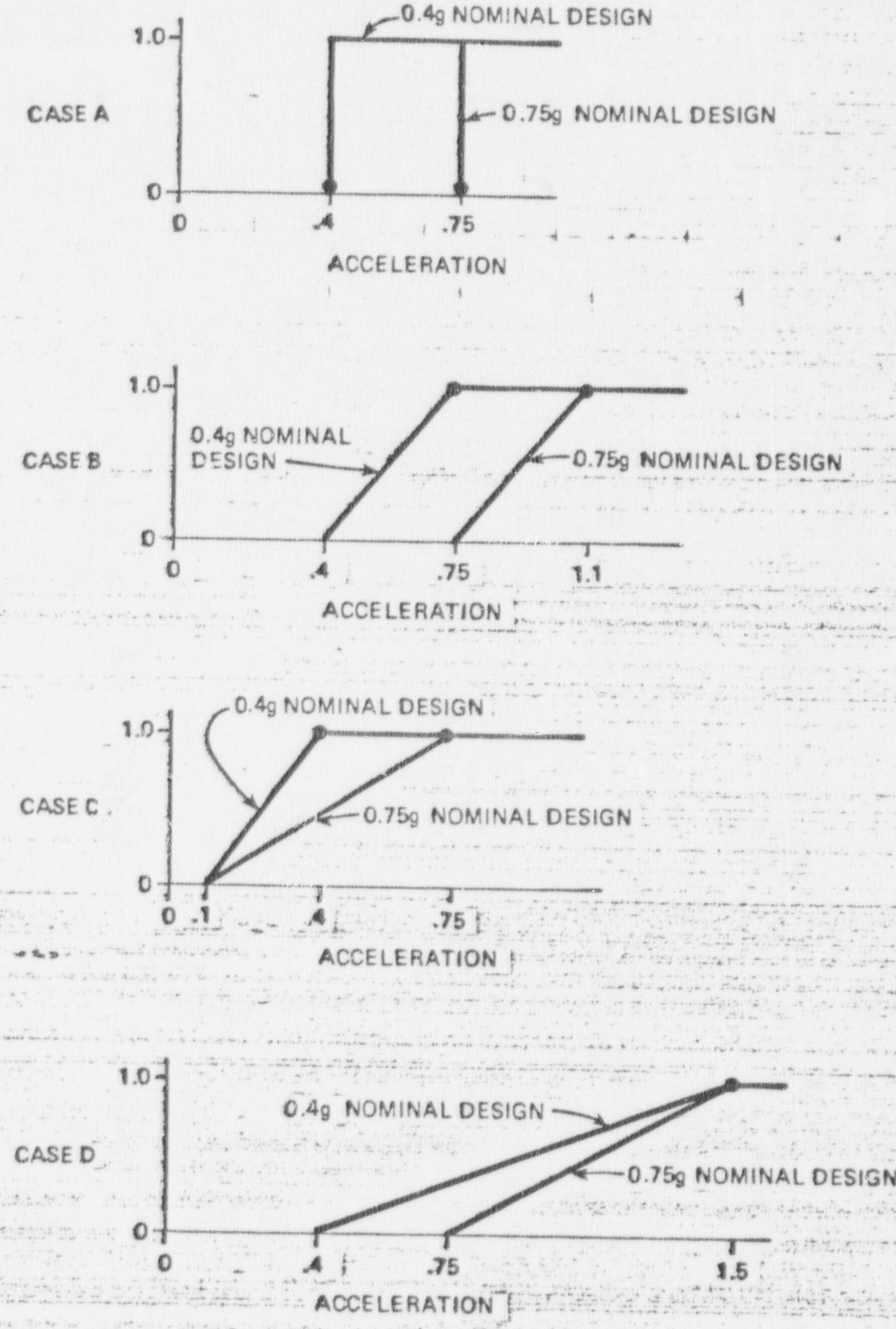
9. D. L. Anderson, R. G. Charlwood, and C. B. Chapman, "On Seismic Risk Analysis of Nuclear Plants Safety Systems," Candian Society of Civil Engineers, V.2, p. 558, 1975.

10. Same as Reference 2, Appendix A.



DIABLO CANYON
NUCLEAR POWER PLANT

FIGURE I



PLANT RESPONSE REPRESENTATIONS
FIGURE 11