UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of PACIFIC GAS AND ELECTRIC COMPANY (Diablo Canyon Nuclear Power Plant, Units 1 and 2)	Docket Nos. 50-275 OL 50-323 OL

Prepared Direct Testimony of George A. Young

on Behalf of Governor Edmund G. Brown, Jr.

Regarding

APPEAL BOARD QUESTIONS 1-6

August 8, 1980

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PREPARED DIRECT TESTIMONY
OF GEORGE A. YOUNG

Q 1 Please state your name.

A 1 My name is George A. Young.

Q 2 Where are you employed?

A 2 I am self-employed.

Q 3 What is your professional background?

A 3 A statement of my qualifications and professional background is attached.

Q 4 What is the purpose of your testimony?

A 4 This testimony is to respond to Questions 1-6 set forth in the Appendix to ALAB-598, as set forth below.

Q 5 Item 1 of the Appendix of ALAB-598 requests the parties to compare the horizontal peak acceleration values recorded in the near field during the October 15, 1979 Imperial County, California, earthquake (IV-79) for various instrument positions with earlier predictions and compilations of such motions, e.g., those contained in the Final Safety Analysis Report (FSAR) on the Diablo Canyon Nuclear Power Plant, Amendment 50, Appendix D LL 11B, Figures 2, 3, and 4; and United States Geological Survey (USGS) Circular 795, Figures 4, 24, 47, and 48. The comparisons were to address whether there is magnitude independence or a saturation effect for ground motion intensity in the near

field of earthquakes. Have you made these comparisons and addressed this question?

A 5 Yes, I have made both comparisons and have studied the question of whether there is magnitude independence or a saturation effect for ground motion intensity in the near field of earthquakes.

Q 6 Would you summarize your results and state your conclusions?

A 6 I have consolidated Figures 4, 24, 47, and 48 from Circular 795 into the enclosed Figure 1. Upon each figure, I have plotted the two peak horizontal ground accelerations reported for each station listed in Table 1 for the IV-79 event. This includes all USGS stations closer than 18 km to the fault except Brawley Airport and the Parachute Test Facility. I have excluded these two stations because they are located well beyond the horizontal extent of the fault. The plot includes El Centro Stations 2 through 12, Holtsville, Calexico, and Bond's Corner. I have also plotted the mean SAM IV attenuation curve for magnitude 6.5 on Circular 795 Figure 47, and the mean SAM V attenuation curve for magnitude 7 on Circular 795 Figure 48 so that I would not need to repeat Figures 2, 3, and 4 from Appendix D LL 11B of Amendment 50 of the Diablo Canyon FSAR.

The IV-79 data plotted on Circular 795 Figure 4 between 13 and 18 km are consistent with the magnitude 6.0 to 6.4 70% prediction intervals from Circular 795 data. Between 5 and 13 km, the IV-79 data plots above the mean of the magnitude 5.0 to 5.7 70% prediction interval. This would indicate

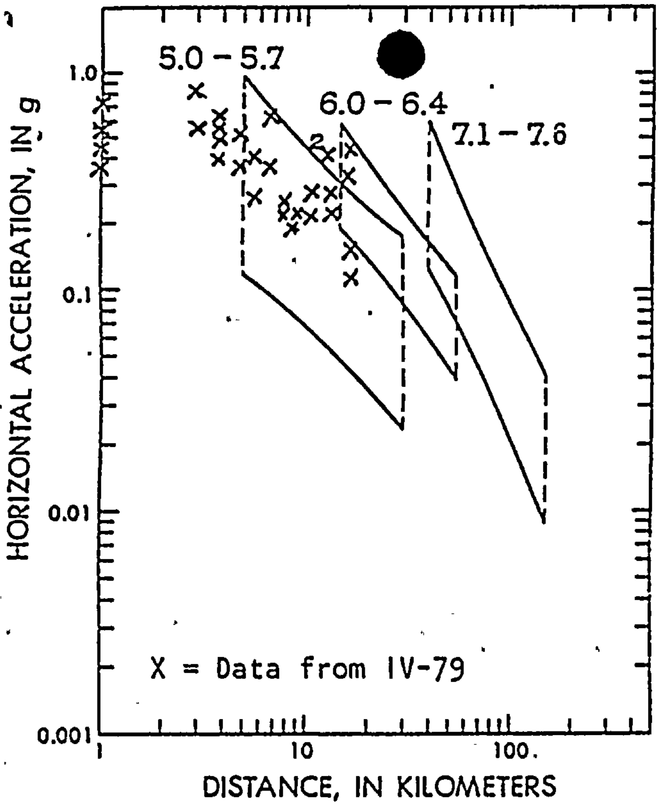


Figure 4. Comparison of 70 percent prediction intervals for peak horizontal acceleration recorded at base of small structures for magnitude classes 5.0-5.7, 6.0-6.4, 7.1-7.6.

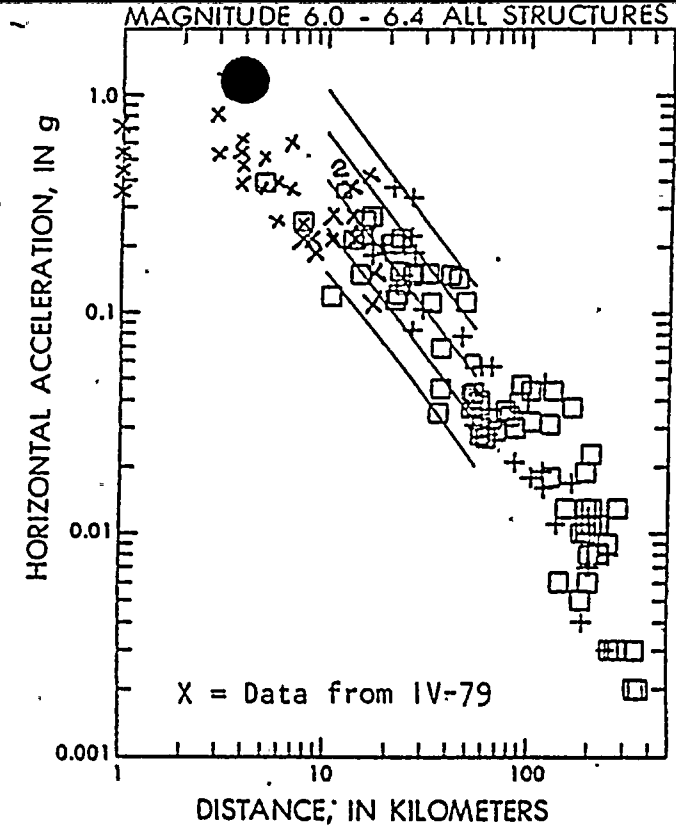


Figure 24. Peak horizontal acceleration versus distance to slipped fault for magnitude range 6.0-6.4 including data from both large and small structures.

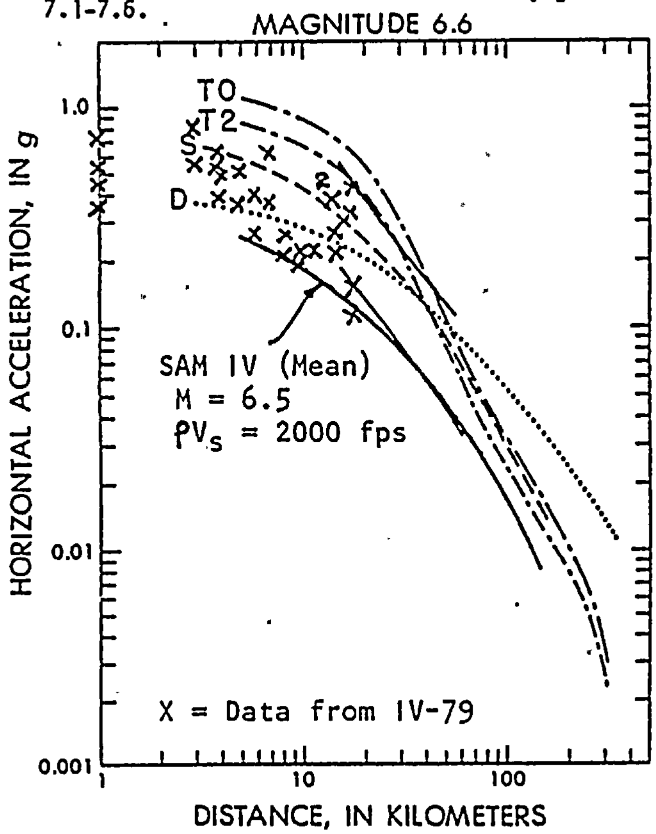


Figure 47. Proposed relations of peak horizontal acceleration to distance from slipped fault for magnitude 6.6 earthquake.

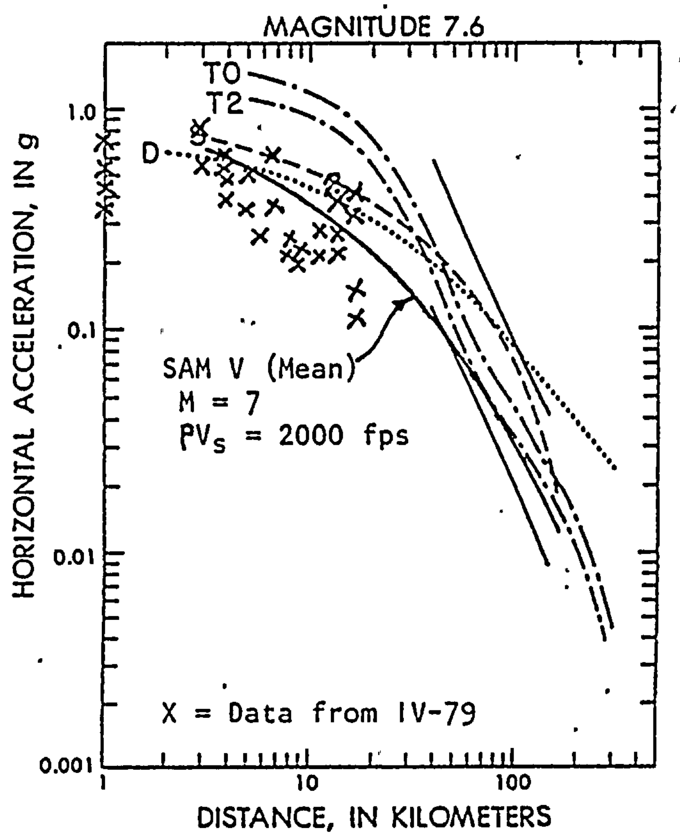


Figure 48. Proposed relations of peak horizontal acceleration to distance from slipped fault for magnitude 7.6 earthquake.

FIGURE 1 - COMPARISON OF IV-79 NEAR FIELD PEAK HORIZONTAL GROUND ACCELERATIONS WITH USGS CIRCULAR 795, AND SAM IV AND V MEAN ATTENUATION CURVES (Basic figures from Circular 795)

TABLE 1 - PEAK HORIZONTAL GROUND ACCELERATIONS PLOTTED IN FIGURE 1 FROM IV-79 EVENT

STATION	FAULT DISTANCE (Km)	EPICENTRAL DISTANCE (Km)	PEAK HORIZONTAL GROUND ACCELERATION (G)
EL CENTRO 7	1	26	0.52 0.36
EL CENTRO 6	1	27	0.45 0.72
BOND'S CORNER	3	6	0.81 0.66
EL CENTRO 8	4	27	0.50 0.64
EL CENTRO 5	4	28	0.40 0.56
EC DIFF ARRAY	5	26	0.51 0.37
EL CENTRO 9	6	26	0.40 0.27
EL CENTRO 4	7	26	0.38 0.61
HOLTSVILLE	8	19	0.22 0.26
EL CENTRO 10	9	27	0.20 0.23
CALEXICO	11	15	0.22 0.28
EL CENTRO 11	13	27	0.38 0.38
EL CENTRO 3	13	28	0.22 0.27
EL CENTRO 2	16	31	0.43 0.33
EL CENTRO 12	18	30	0.11 0.15

that the peak horizontal ground accelerations are consistent with Circular 795 data, and that the peak horizontal ground accelerations are magnitude dependent. Furthermore, peak horizontal ground acceleration-magnitude-fault distance curves should be approaching a horizontal asymptote at a fault distance of 1 km. I find that the IV-79 data are consistent with this relationship in Figure 1.

In Circular 795 Figure 24 the IV-79 data are again consistent with Circular 795 data between 13 and 18 km, in general, falling within the one standard deviation limits and having a mean that approximates the mean of the Circular 795 data. The IV-79 data plotted in Circular 795 Figure 47 plots above the SAM IV mean curve for M = 6.5. The IV-79 data are generally above the Donovan (D) mean curve, below the Trifunac (T0; T2) curves, and scatters almost equally above and below the Schnabel and Seed (S) curve. The (S) curve is an approximate mean of the IV-79 data. In Circular 795 Figure 48 the SAM V mean attenuation curve for a magnitude 7 earthquake is an approximate mean to the IV-79 (magnitude 6.5) data, the (D) curve for magnitude 7.6 is higher than the mean of the IV-79 data, and the (S) and (T0; T2) curves for magnitude 7.6 fall well above the IV-79 data. The curves in Circular 795 Figures 47 and 48 lead to the following conclusions when compared to IV-79 data:

a. The SAM IV and V, and the Donovan (D) curves are low.

b. The Trifunac (T0; T2) curves are high.

c. The Schnabel and Seed (S) curve for magnitude 6.6 plots as an approximate mean curve to the IV-79 data. However, magnitude 7.6 near field data are needed to confirm the (S) curve at magnitude 7.6.

d. Peak ground accelerations are magnitude dependent in the near field.

I would like to further state that in interpreting the IV-79 data, I do not agree with the general interpretation given in Testimony Tr. 8597; 10,105; 5889-90 by Dr. Newmark* relative to stress drop relationships. It is true that studies such as those by Brune (1970), Trifunac (1976), Hanks and Johnson (1976), and Bernreuter (1977) have expressed peak ground acceleration in the near field as a function of tectonic stress drop ($\Delta\sigma$) and fault dimension (r) with magnitude (M) not appearing in the relationships. However, $\Delta\sigma$ and r are both a function of magnitude, and peak ground acceleration is therefore magnitude dependent. This has been demonstrated by Ts'ao (1980), who has provided a regression equation based on near field data compiled by Trifunac (1972, 1976) from the 1940 El Centro (Imperial County) and 1971 San Fernando earthquakes and aftershocks, and from the near field data reported for the Friuli, Italy, 1976 earthquake aftershocks. The correlation equation developed by Ts'ao for peak horizontal ground acceleration for California earthquake data is as follows.

*Referenced in ALAB-598 at Footnote 34.

$$\ln A' = 3.05 - 9.24/M - 1.60 \ln (R + 1) + 0.58 \ln (\Delta\sigma) + 0.91 \ln (r) \quad (1)$$

where

$\ln A'$ = The natural logarithm of peak horizontal ground acceleration in units of 0.1 g

M = Local magnitude

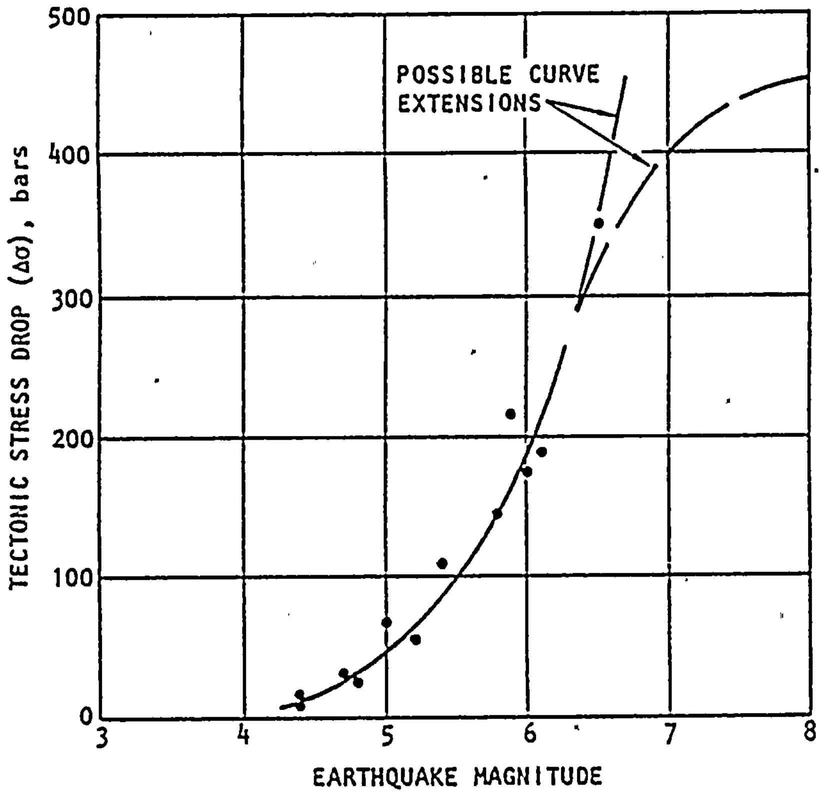
R = Hypocentral distance in km

$\Delta\sigma$ = Tectonic stress drop in bars

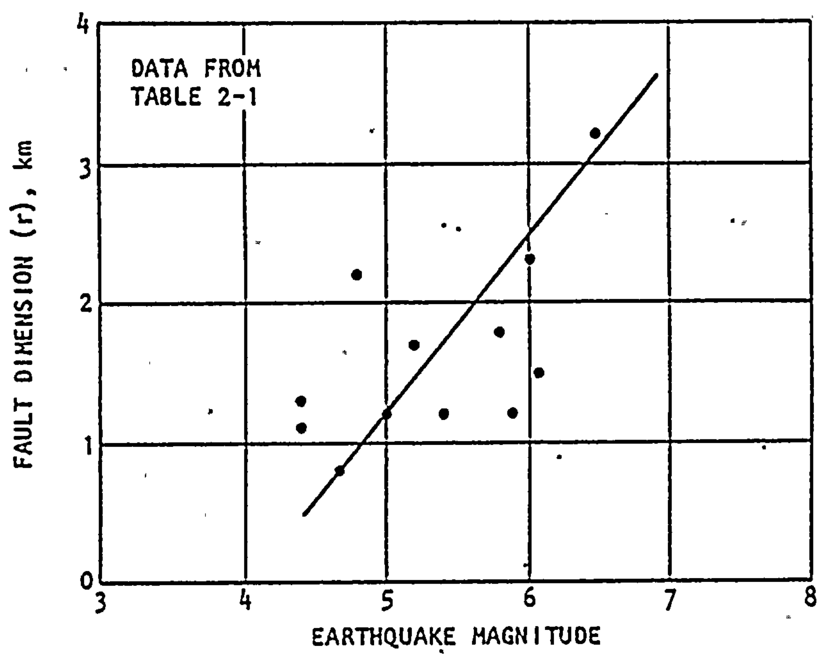
r = Radius of equivalent circular dislocation (fault dimension) in km

Ts'ao found magnitude (M), stress drop ($\Delta\sigma$), and fault dimension (r) all to be significant statistically, and since M is determined independent of $\Delta\sigma$ and r, all three terms were included in the correlation relationship. This gave a more stable relationship than was obtained when M was omitted.

The fact that $\Delta\sigma$ and r are a function of M is also indicated in Figure 2 which has been constructed from the data used by Ts'ao from the 1940 El Centro earthquake. It is possible that the stress drop curve in Figure 2 may become horizontal (i.e., independent of magnitude) at some higher magnitude, as has been indicated in the figure, but we have no data to indicate this and I don't recommend that we assume this to be true below magnitude 8 (see Fig. 2a).



(a) Relationship between magnitude and stress drop



(b) Relationship between magnitude and fault dimension

FIGURE 2. RELATIONSHIPS BETWEEN EARTHQUAKE MAGNITUDE AND STRESS DROP AND FAULT DIMENSION BASED ON 1940 EL CENTRO EARTHQUAKE DATA COMPUTED BY TRIFUNAC (1972) (From SAN/1011-125)

As proof of the validity of the Ts'ao relationship, which was developed before the IV-79 event, Equation 1 is compared with IV-79 recorded horizontal peak ground accelerations in Figure 3. The locations of the data stations are given in Figure 4. The correlation equation was evaluated and plotted in Figure 3 for a magnitude of 6.5, a fault dimension of 3.2 km, and for stress drops of 350, 200, and 100 bars, respectively. The fault dimension of 3.2 km and the stress drop of 350 bars represent plotted points taken from Figure 1 that were derived from the 1940 El Centro 6.5 magnitude event. The 200 and 100 bars were selected to bracket the IV-79 data since the stress drop obviously varies along the fault, as has been noted by Bernreuter (1977).

In contrast to the IV-79 event, the 1971 San Fernando earthquake was a reverse fault of almost the same magnitude (6.5), but had a higher calculated stress drop and shorter fault length. However, the stress drop and fault dimension derived from the 1971 San Fernando data were also found to be magnitude dependent. Therefore, while stress drop equations can be used to explain why the same peak accelerations may occur at the same source distance from earthquakes of two different magnitudes, these equations do not imply that peak ground acceleration in the near field is independent of magnitude.

In summary, I conclude that the IV-79 data comparisons indicate that in the near field the SAM IV and V attenuation curves used by Blume and the Donovan ground motion attenuation curve used by Newmark are low, the Trifunac curves are high, and the Schnabel and Seed curve is in agreement with

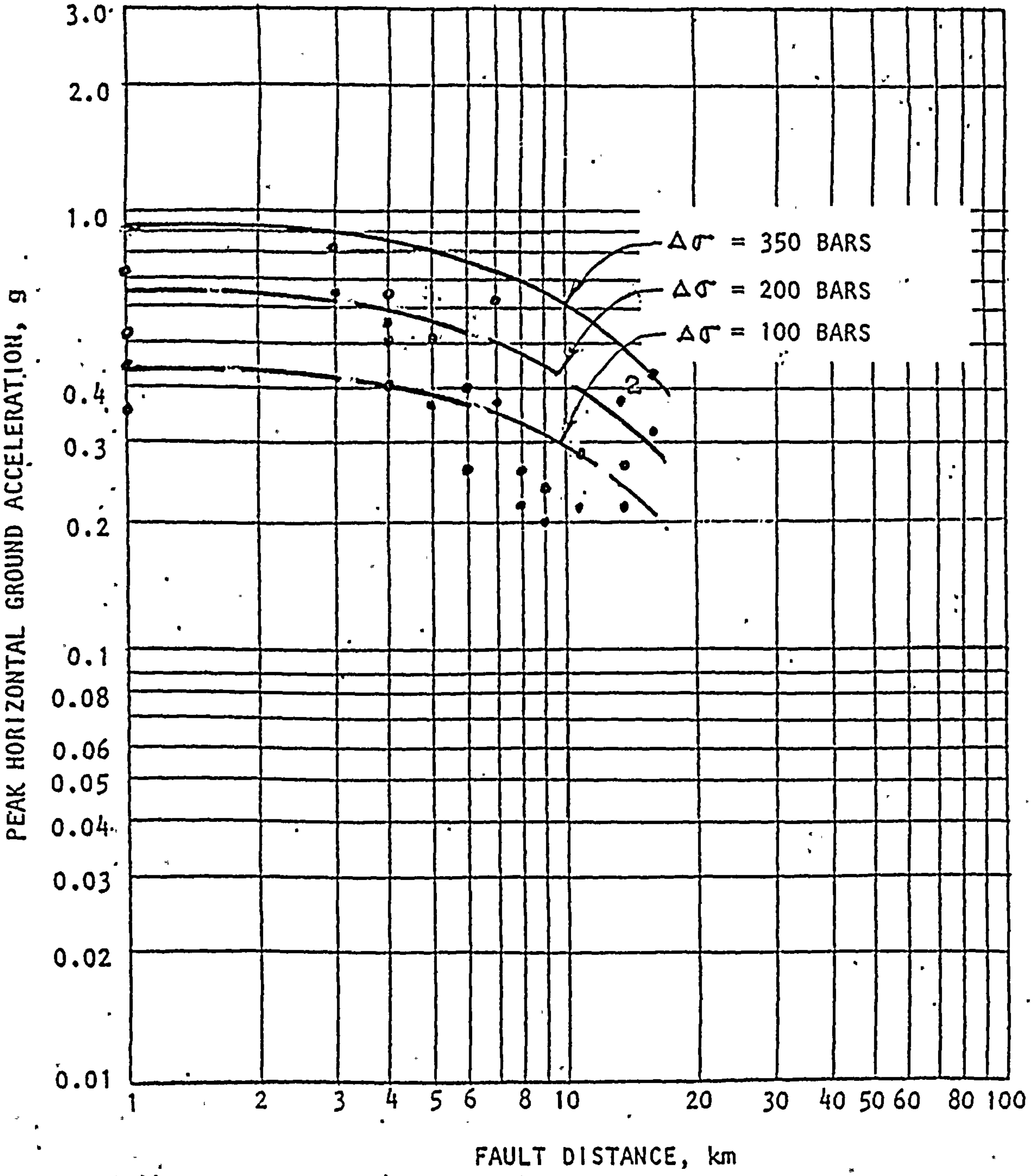


FIGURE 3. COMPARISON OF EQUATION 1 WITH PEAK HORIZONTAL GROUND ACCELERATIONS RECORDED AT BOND'S CORNER AND EL CENTRO ARRAY STATIONS FOR IV-79 EVENT

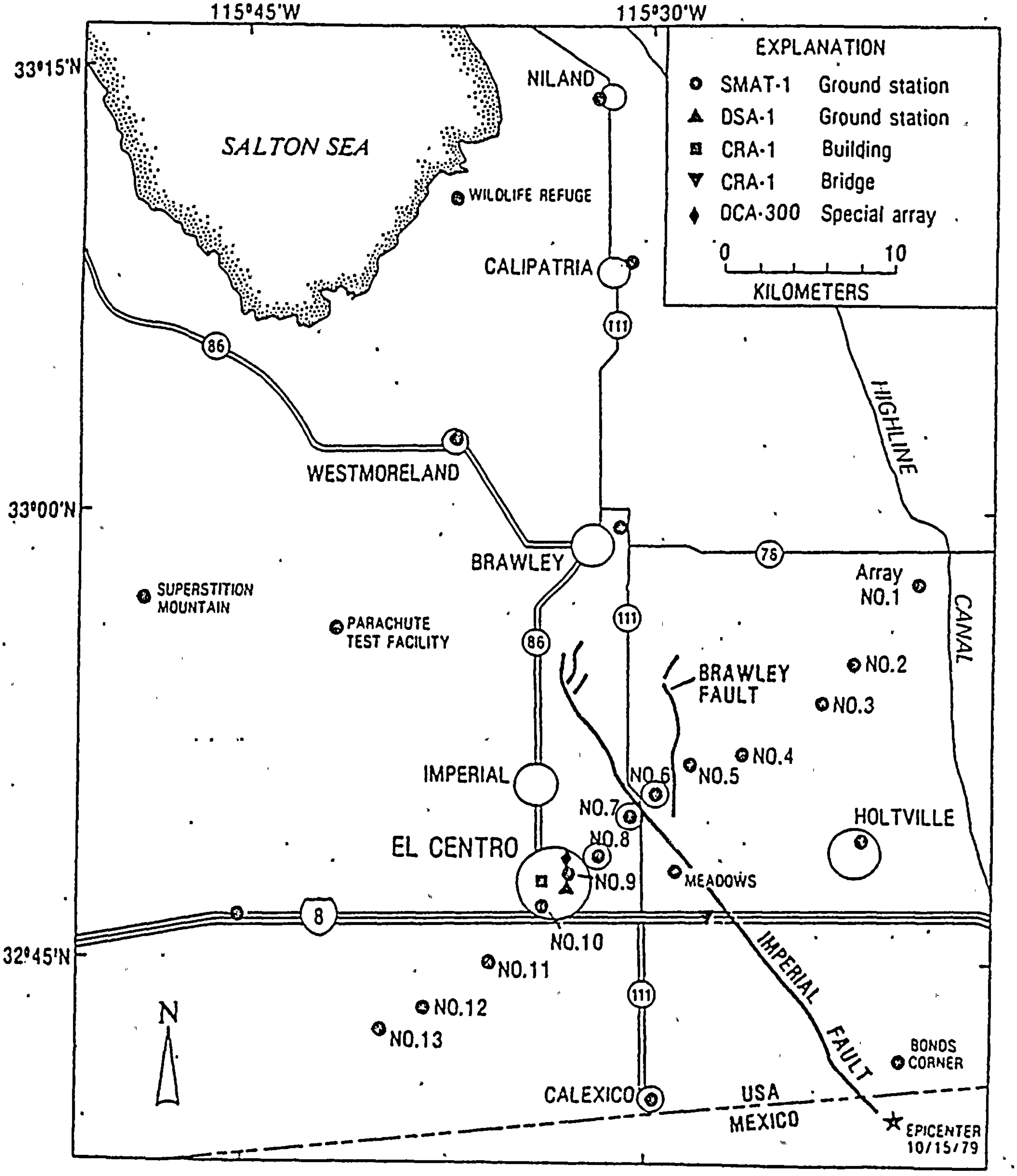


FIGURE 4. MAP SHOWING LOCATION OF STRONG MOTION RECORDERS AND FAULT OF OCTOBER 15, 1979 IMPERIAL COUNTY, CALIFORNIA, EARTHQUAKE (From EERI, 1979)

the IV-79 data for a magnitude 6.6 earthquake. I further conclude that the peak ground accelerations in the near field are magnitude dependent. I would like to add that these conclusions are not new discoveries to me as I have conducted a broader comparison of peak ground motion attenuation relationships during the past two years and reached substantially the same conclusions relative to the Donovan, Trifunac, and Schnabel and Seed attenuation relationships. I also directed the study by Ts'ao (1980) which demonstrates that peak ground acceleration is magnitude dependent.

Q 7 Would you recommend Equation 1 as a relationship that could be used to predict the peak horizontal ground accelerations that would result at the Diablo Canyon nuclear power plant site from a magnitude 7.5 earthquake located on the Hosgri fault at an epicentral distance of 6 km?

A 7 Yes, if we could predict appropriate values for the stress drop and fault dimension terms. However, these values are a function of the type of faulting and have been estimated for the faulting associated with relatively few large earthquakes (i.e., 1940 El Centro, 1971 San Fernando, and 1976 Friuli earthquakes). I would therefore recommend a less complex relationship. I find the Schnabel and Seed (1973) relationship gives reasonable estimates of mean peak ground acceleration *at the ground surface* up to magnitude 6.5. Above magnitude 6.5, I have greater confidence in the regression equations developed by Werner, Ts'ao, and Rothman (1979) which have been recently published as NUREG/CR-1175. Their regression equations were expressed as a function of epicentral distance since practically all strong motion data available to them had been recorded at epicentral distances greater than 20 km. The

difference between their epicentral distance term (D+1) and the hypocentral distance at fault distances greater than 30 km for a focal depth of 10 km is 2%, or less. However, the error grows progressively larger for epicentral distances less than 30 km. In order to extrapolate their relationship to near field distances, their equations should be adjusted by substituting hypocentral distance R for the term (D+1). The Werner, Ts'ao, and Rothman adjusted regression equation for peak horizontal ground acceleration is as follows:

$$\ell n\ a' = 12.38 - \frac{32.85}{M} - 1.01\ \ell n\ R + 1.72\ E - 0.38\ (\ell n\ R) E \qquad (2)$$

Here

$\ell n\ a'$ = Natural logarithm of the peak horizontal ground acceleration in in./sec^2

M = Richter magnitude

R = Hypocentral distance in km

E = A constant based on earthquake data sample

where

E = 1 for 1971 San Fernando earthquake data

E = 0 for earthquake data based on 56 other earthquakes

E = 0.545 for data based on all 57 earthquakes

I have compared Equations 1 and 2 in Figure 5 using the stress drops computed for the Imperial County fault for Equation 1. It will be noted that good agreement is obtained in the near field with E = 1 and $\Delta\sigma$ = 350 bars,

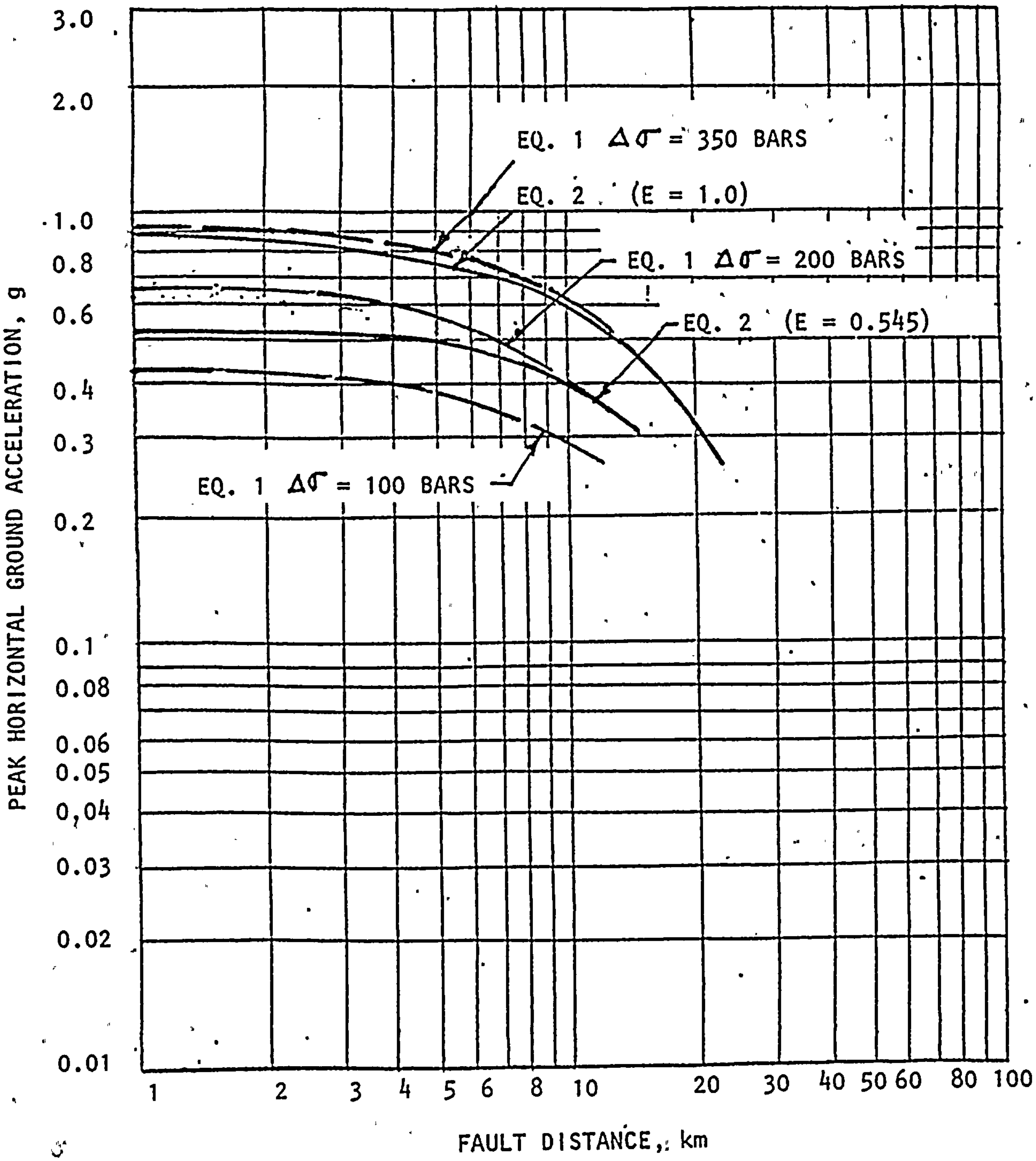


FIGURE 5 - COMPARISON OF EQUATIONS 1 AND 2 FOR 6.5 MAGNITUDE AND FOCAL DEPTH OF 10 Km

and for E = 0.545 and $\Delta\sigma$ = 200 bars. I would recommend Equation 2 for the Diablo Canyon site with E set equal to 0.545 to 1.0. If E is set equal to 1.0 you will be correlating with the 1971 San Fernando data. With E = 0.545 you will be correlating with data from 57 earthquakes including the 1971 San Fernando earthquake. I would be unwilling to accept a value of E less than 0.545 for the Diablo Canyon site.

Q 8 What peak horizontal ground acceleration would you predict at the Diablo Canyon site for a magnitude 7.5 earthquake located on the Hosgri fault at an epicentral distance of 6 km, and having a focal depth of 10 km, with Equation 2 using E = 0.545?

A 8 Equation 2 would give a mean peak horizontal ground acceleration of 1.0 g for these conditions.

Q 9 Item 2 of the Appendix of ALAB-598 requests the parties to discuss whether the Newmark Spectrum is an appropriate and sufficiently conservative representation of the 7.5 M event on the Hosgri fault in view of the fact that response spectra resulting from the IV-79 event for the El Centro array exceeded the Newmark Design Response Spectrum even though the IV-79 peak accelerations are generally lower than the accelerations used as a design basis for the Diablo Canyon plant. Have you compared the IV-79 response spectra in the near field with the Newmark Spectrum? If so, will you summarize your results and state your conclusion on whether you consider the Newmark

Spectrum to be an appropriate and sufficiently conservative representation of 7.5 M event on the Hosgri fault for the Diablo Canyon site?

A 9 Yes, I have compared the response spectra for the two horizontal components of recorded motion for Bond's Corner, Calexico, Holtsville, and the stations in the El Centro array within 15 km of the fault. In my opinion it is important to develop mean and mean plus one standard deviation spectra from the near field data from this earthquake as suggested in Footnote 35 of ALAB-598, but I would recommend that the spectra not be normalized to peak horizontal ground acceleration before statistical processing. These procedures distort the response spectra in the higher frequencies and have led to the development of an "effective peak acceleration" term to compensate for the distortion. As discussed below, I have strong reservations about the use of the effective acceleration concept. Instead, a response spectra regression equation should be developed from the data using the procedures demonstrated in NUREG/CR-1175. In this procedure regression coefficients were developed for 32 individual frequencies between 0.067 and 25 Hz with no normalization and spectral distortions. Their regression equation is expressed in terms of response velocity as a function of magnitude, epicentral distance, fault condition (i.e., E = 1.0, 0.545, and 0), and site subsurface conditions (i.e., rock, intermediate, and deep soils). However, great care would have to be exercised when drawing conclusions for the Diablo Canyon site based on data from only the IV-79 event regardless of how the smooth spectra is computed since the Diablo Canyon site is not a deep soil site and a larger magnitude earthquake has been postulated for the Hosgri fault than associated

with the IV-79 event. Therefore, it would be better if the spectral data from the IV-79 event were added to the data base used in NUREG/CR-1175 as the 58th earthquake.

Since the above regression analysis could not be performed in the time available, I have proceeded as follows. First, I have constructed the scatter band for the IV-79 spectra (5% damping) for the two horizontal components of those stations that recorded a peak horizontal ground acceleration of 0.50 g, or greater. This was done to provide a sample of the strongest IV-79 records since no attempt should be made to scale these spectra or the scatter bands to higher peak ground accelerations, such as 0.75 or 1.0 g, unless combined with more data. Second, since the Newmark spectra for the Diablo Canyon site were based on the strongest free-field spectrum recorded during the 1971 San Fernando earthquake (Pacoima Dam), I have next provided a comparison of the strongest horizontal response spectrum recorded during the IV-79 event (Bond's Corner) with the strongest 1971 San Fernando earthquake horizontal response spectrum (Pacoima Dam), and the Newmark free-field spectrum for Diablo Canyon. Third, since ($M+\sigma$) amplification factors were used in the development of the Newmark free-field Diablo Canyon spectra, I have provided a comparison between ($M+\sigma$) spectra developed by the procedures given in NUREG/CR-1175 with the Newmark free-field Diablo Canyon spectrum, the strongest IV-79 horizontal response spectrum, and the Pacoima Dam spectrum. My conclusions are based on these three comparisons.

The scatter bands for the two horizontal components of response spectra for the six stations recording a peak horizontal ground acceleration of 0.50 g, or greater, during the IV-79 event are given in Figure 6. Also shown in Figure 6 for comparison are the Newmark spectrum for Diablo Canyon, the strongest Pacoima Dam spectrum, and the strongest IV-79 spectrum (Bond's Corner) for frequencies above 1 Hz. The twelve spectra used to construct the IV-79 scatter bands were recorded at Bond's Corner, and at El Centro Array Stations 4, 5, 6, 7, and 8. These stations have fault distances of 1 to 7 km. The Bond's Corner spectra are particularly significant since this station has an epicentral distance of 6 km (fault distance of 3 km) which is the epicentral distance postulated for the Diablo Canyon/Hosgri fault magnitude 7.5 earthquake.

It is extremely important to note in Figure 6 that for frequencies between 1 and 15 Hz the Newmark Diablo Canyon, Pacoima Dam, and Bond's Corner spectra are all comparable. Based on theories postulated by Seed et al. (1976), the response for a deep soil site (Bond's Corner) in this frequency range should have been less than the response for a rock site (Pacoima Dam) for earthquakes of the same magnitude. This indicates that the Newmark Diablo Canyon response spectrum is not conservative since it has essentially been equalled on a deep soil site for a magnitude 6.5 earthquake in the frequency range determined by acceleration.

It is of interest to note in Figure 6 that the Bond's Corner spectrum demonstrates low response in the 1 to 10 sec period range when compared with the Pacoima Dam spectrum or with spectra for the El Centro array stations.

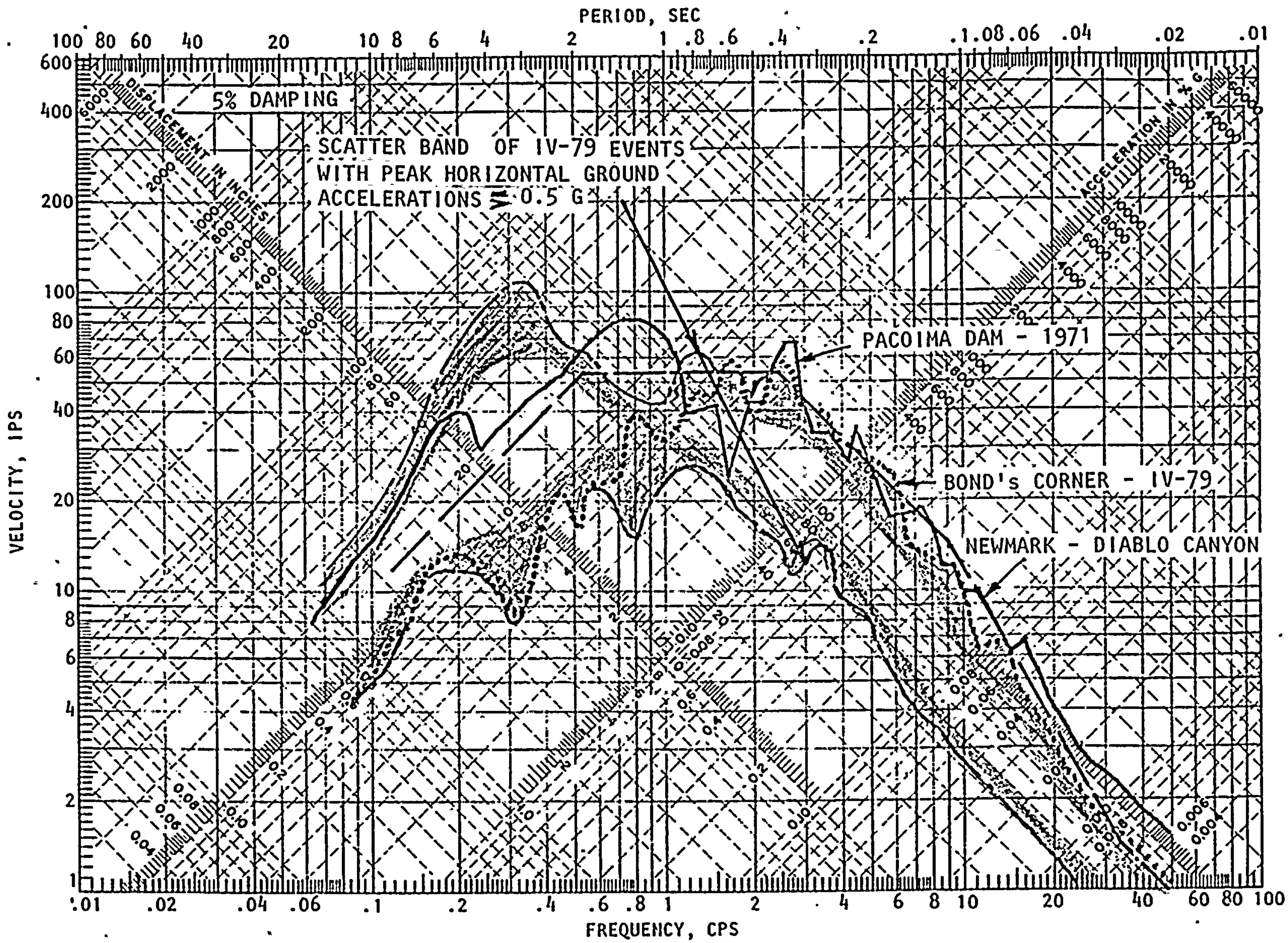


FIGURE 6 - COMPARISON OF PACOIMA DAM 1971, BOND'S CORNER (IV-79) AND NEWMARK - DIABLO CANYON HORIZONTAL RESPONSE SPECTRA WITH IV-79 RESPONSE SPECTRA SCATTER BAND

Response spectra for Calexico and Holtsville (these stations were not used to develop the scatter bands) which have epicentral distances of 15 and 19 km, respectively, show strong 3 to 4 sec period surface wave response developing. Maximum surface wave response, however, develops at the El Centro array stations which have epicentral distances of 26 to 28 km. This is accompanied with lower spectral response in the higher frequencies.

Figure 7 provides a comparison of the Newmark Diablo Canyon, Pacoima Dam, and Bond's Corner spectra with spectra developed from the spectrum regression equation given in NUREG/CR-1175, for a rock site, assuming a magnitude 7.5 earthquake with an epicentral distance of 6 km and a focal depth of 10 km. The spectra are for $E = 1.0$ and $E = 0.545$. The spectrum for $E = 1$ represents the $(M+\sigma)$ spectrum based on the 1971 San Fernandc data while the spectrum for $E = 0.545$ represents the $(M+\sigma)$ spectrum based on the data from 57 earthquakes which include the 1971 San Fernando earthquake. It is particularly important to note that both spectra developed from the NUREG/CR-1175 procedures converge to the $(M+\sigma)$ peak horizontal ground acceleration while the Newmark Diablo Canyon spectrum converges to a value of 0.75 g which is less than the mean peak horizontal ground acceleration for $E = 0.545$. The 0.75 g value is the so-called "effective peak ground acceleration" which I consider to have no rational basis and to be necessary only because of the distortion created in the spectra by the normalization procedure used to develop the Regulatory Guide 1.60 and the Newmark (1973) spectra amplification factors. It should also be noted that significantly greater response is indicated for the NUREG/CR-1175 spectra in the regions

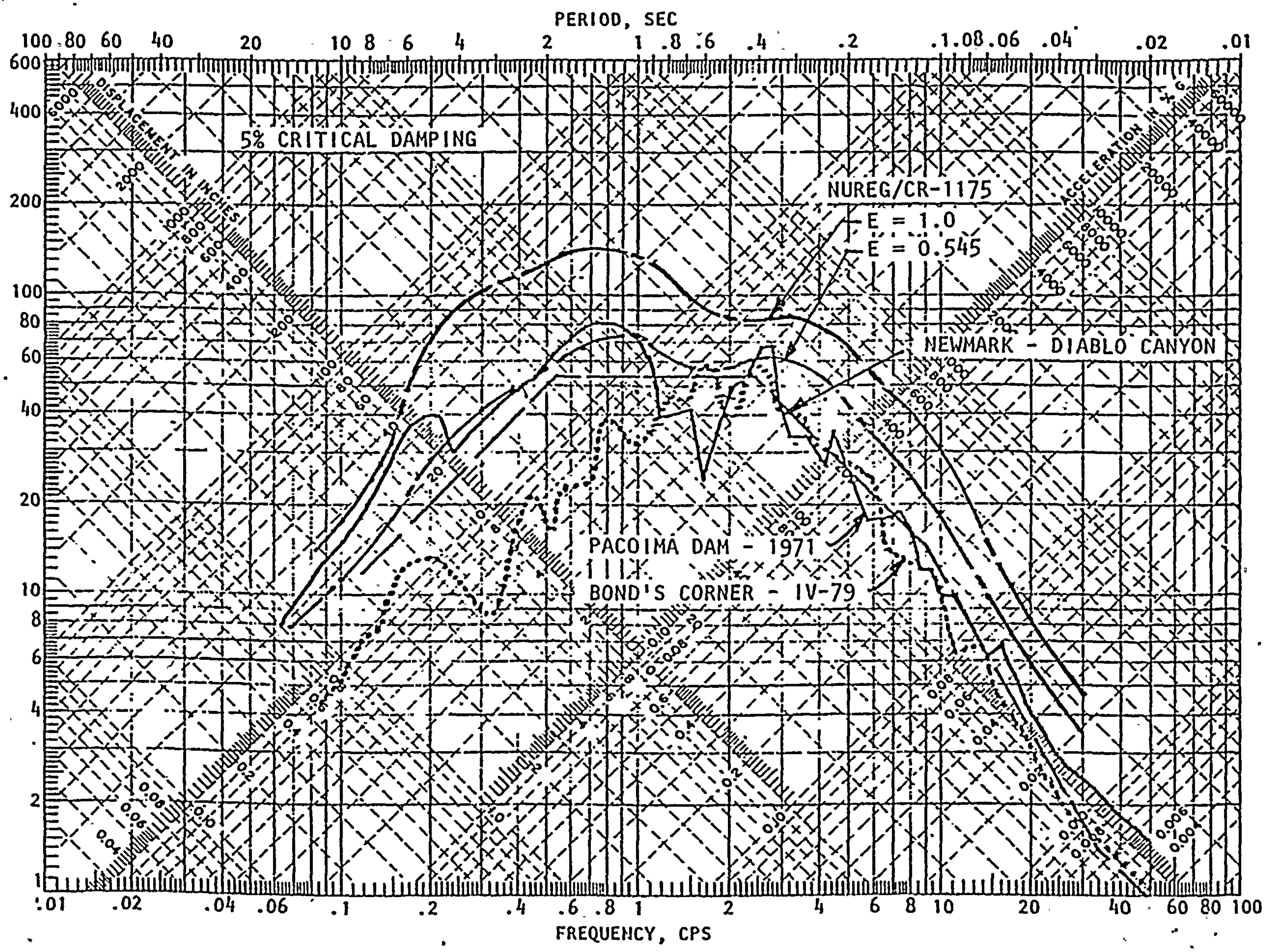


FIGURE 7 - COMPARISON OF NUREG-1175 RESPONSE SPECTRA FOR 7.5 MAGNITUDE EARTHQUAKE, EPICENTRAL DISTANCE OF 6 Km, WITH NEWMARK - DIABLO CANYON, PACOIMA DAM AND BOND'S CORNER SPECTRA

controlled by peak velocity and peak displacement than indicated by the Newmark Diablo Canyon spectrum. It should be further noted that Dr. Newmark has used a peak velocity and a peak displacement to scale the Diablo Canyon magnitude 7.5 spectrum that are both lower than the respective peak values indicated by the Pacoima Dam acceleration record which was a magnitude 6.5 earthquake.

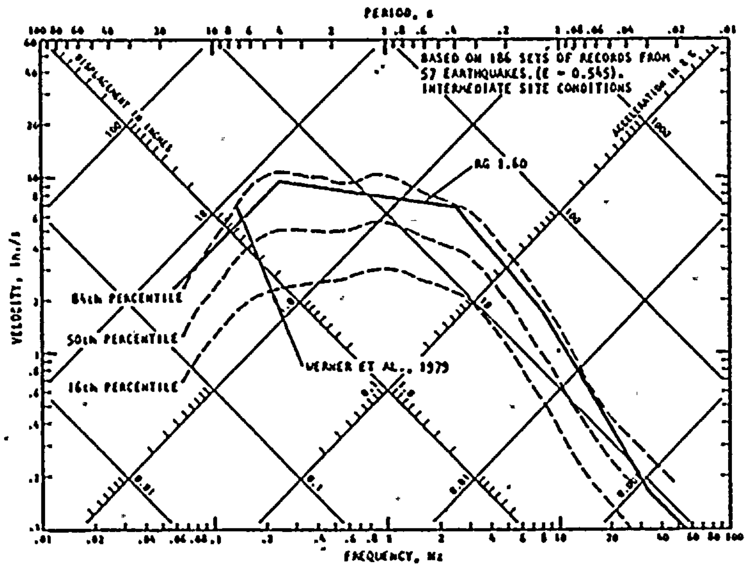
I conclude that an appropriate and conservative representation of the 7.5 event on the Hosgri fault would be a response spectrum that falls within the limits of the two NUREG/CR-1175 spectra given in Figure 7.

Q 10 You have indicated that there is no rational basis for the term "effective peak acceleration" but that it is a term that has resulted from the distortion that exists in normalized spectra. Could you explain the basis for this statement?

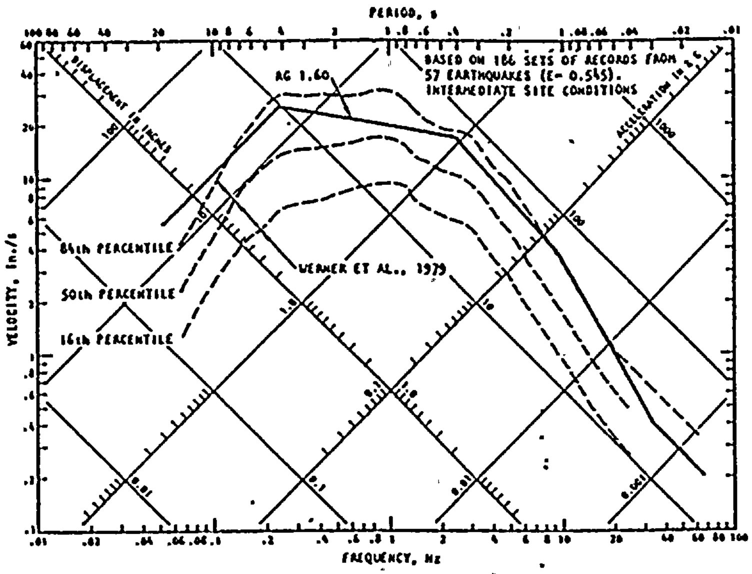
A 10 The effective acceleration as used by Newmark is actually the mean peak acceleration of the normalized sample of records used to develop spectral amplification factors in the 2.5 to 10 Hz range for the Newmark and Regulatory Guide 1.60 spectra. In order to understand why the effective acceleration is a mean peak acceleration, it is necessary to consider how the response spectra were processed in the studies which led to these amplification factors. For example, in the Newmark (1973) studies, the response spectra were *normalized to the instrumental peak accelerations* before statistical processing when computing the mean plus one standard deviation (M+σ) amplification factors for the frequency region controlled by peak acceleration (i.e., frequencies above about 2.5 Hz). This forced all response spectra to converge to the

same normalized peak acceleration of 1 g. Since the normalized response acceleration was 1 g for all records, the standard deviation for the sample was effectively made zero at the higher frequencies by this process. *The 1 g was therefore a mean peak acceleration for the normalized sample, and the (M+σ) amplification factors at 2.5 and at 9 Hz for Regulatory Guide 1.60 spectra are expressed in terms of the mean peak acceleration for the normalized sample.* There is, therefore, a distortion in the normalized spectra in that (M+σ) response is obtained between 2.5 and 9 Hz, but the spectra converge to the mean peak acceleration of the sample at the higher frequencies but should converge to the (M+σ) peak acceleration. If design response spectra are developed using these amplification factors and a mean peak ground acceleration for the site resulting from the design earthquakes, the resulting spectra should be satisfactory within the 2.5 to 9 Hz range but will be unconservative at higher frequencies as the spectra will converge to the mean rather than the (M+σ) peak acceleration for the site. In contrast, if a (M+σ) peak ground acceleration is used with the (M+σ) amplification factors, the resulting design response spectra will be satisfactory in the higher frequencies but will be overly conservative at frequencies below 9 Hz.

The distortion that exists in Regulatory Guide 1.60 spectra is demonstrated in Figure 8 which has been taken from NUREG/CR-1175 for magnitude 6.5 and 8 earthquakes having an epicentral distance of 50 miles. The Regulatory Guide 1.60 spectra given in this figure were scaled using the mean peak horizontal ground acceleration resulting from the NUREG/CR-1175 spectral regression equation. It will be noted that the Regulatory Guide 1.60 (M+σ)



(a) Horizontal response, magnitude = 6.5



(b) Horizontal response, magnitude = 8.0

FIGURE 8. COMPARISON OF STATISTICALLY DERIVED SPECTRA BY WERNER, TS'AO, AND ROTHMAN (1979) WITH REGULATORY GUIDE 1.60 SPECTRA SCALED TO MEAN PEAK GROUND ACCELERATION OF SAMPLE — 5% OF CRITICAL DAMPING

spectrum is converging to the *mean* acceleration at the higher frequencies but the (M+σ) NUREG/CR-1175 spectrum converges to the (M+σ) peak ground acceleration. I estimate the (M+σ) peak ground acceleration for the NUREG/CR-1175 spectrum for E = 0.545 in Figure 7 to be 1.77 g as compared to the 1.0 g mean peak ground acceleration and the 0.75 g effective acceleration.

Q 11 Item 3 of the Appendix of ALAB-598 raises the question whether there is a significant difference in peak ground acceleration for soil and rock sites, assuming other variables (i.e., magnitude, source distance, stress drop, etc.) are the same. Reference is made to the Rothman-Kuo Affidavit and the Blume Affidavit which indicate that the IV-79 data are not relevant to the Diablo Canyon seismic analysis because the plant is a rock site, whereas the Imperial Valley data were obtained on soil sites. The question is to be considered in light of statements by Applicant's witness Blume to the effect that acceleration, rather than velocity or displacement, is the critical parameter in the design of Diablo Canyon. Have you studied this question? If so, would you give your conclusion as well as the basis upon which your conclusion is based.

A 11 I have studied this question over the past two years. I have also reviewed USGS Circular 795 and the Affidavit by Rothman and Kuo and the Affidavit by Blume. The results of my previous studies, which have been published in Department of Energy Topical Reports, are essentially the same as the statements in USGS Circular 795. The regression analyses reported in

NUREG/CR-1175, which is the most extensive statistical analysis of earthquake strong motion data that I know of, also led the authors Werner, Ts'ao, and Rothman to the same conclusion (i.e., peak ground acceleration is not a function of site subsurface conditions). As a result, their regression equation for peak ground acceleration proved to be independent of site subsurface conditions but their regression equations for peak ground velocity and peak ground displacement were found to be a function of site subsurface conditions.

It would appear that subsurface conditions modify the frequencies of ground motion that are amplified, but cause little change in peak ground acceleration. Therefore, the long period amplified motion recorded for the IV-79 event (deep soil sites) are not typical of the amplified frequencies that would occur on a rock site, but the response recorded at Bond's Corner (deep soil site) at frequencies between 1 and 15 Hz which are dependent upon the peak ground acceleration are equivalent to those monitored at Pacoima Dam (rock site). This suggests that the Bond's Corner response would have been greater had it been a rock site. I consider the IV-79 near field data to be as important as the data collected from the 1971 San Fernando earthquake. This is particularly true for the design of nuclear power plant facilities in light of Dr. Blume's statements relative to the importance of the acceleration amplified region of the response spectra.

Q 12 Item 4 of the Appendix to ALAB-598 indicates that Regulatory Guide 1.60 vertical response spectra should be equal to the horizontal response spectra

at frequencies greater than 2.5 Hz, and that a vertical response equal to two-thirds of the horizontal response can only be used at frequencies less than 3.5 Hz. Item 4 then notes that vertical response spectra recommended for Diablo Canyon is two-thirds of the recommended horizontal response spectra at all frequencies. It also points out that response spectra developed for vertical motion within 11 km of the Imperial fault during the IV-79 event appear to show generally equivalent values of vertical and horizontal response for periods less than about 0.2 sec (i.e., frequencies greater than 5 Hz). It further indicates that in some instances the higher frequency portions of the IV-79 response spectra for vertical motion exceed comparable portions of the Diablo Canyon design response spectra. The parties are requested to address the apparent inconsistency in the Diablo Canyon design response spectrum (for vertical motion) relative to Regulatory Guide 1.60 spectra recommendations and explain it if possible. It also requests that if there are substantive and relevant analyses suggesting that vertical motion records do not reflect the true vertical motion, these analyses should be provided. Have you studied this issue? If so, will you give us your conclusions and recommendations?

A 12 Yes, I have studied this problem in the past based on data collected prior to the IV-79 event. I have also examined the vertical and horizontal response spectra that have been computed and released by the U.S. Geological Survey for the near field stations recording strong motion during the IV-79 event.

Historically, it should be noted that prior to the issuance of Regulatory Guide 1.60, it was customary to use vertical design response

spectra that were two-thirds of the horizontal design response spectra at all frequencies. During the past 5 years I have directed statistical studies of vertical response spectra scaling procedures under a Department of Energy study contract which has led to three reports (SAN/1011-113R, -114, and -125). I am also quite familiar with the NUREG/CR-1175 regression equations for horizontal and vertical ground motion and response spectra. All of these studies resulted in regression equations, or response spectra, which indicate that a design criteria providing vertical response equal to two-thirds of the horizontal response would be adequate. However, except for SAN/1011-125, these studies all utilized very little near field data. Therefore, I am certain that the two-thirds criterion is a reasonable assumption based on regression analyses of past data for stations 20 km or more from the fault.

The data collected in the near field during the IV-79 event is significantly different than the general trend of the data available prior to this event. Examination of the IV-79 vertical and horizontal response spectra for stations having a fault distance not greater than the focal depth indicate a general pattern in which the vertical response is equal to or greater than the horizontal response at frequencies greater than about 5 Hz. At lower frequencies the vertical response is in general less than two-thirds of the horizontal response.

Because of the relatively few near field strong motion earthquake records, and because of the importance of vertical ground motions to the design of nuclear power plant piping and equipment, I feel this problem requires additional study. Although I have been a strong advocate of the

two-thirds criterion in the past, I now have serious reservations to applying this criterion to sites that have fault distances less than the potential focal depth of the design earthquake.

Relative to the credibility of vertical strong motion acceleration records, I personally have no basis for applying a lower credibility rating to recorded vertical motions than to recorded horizontal motions. I think if there was concern that a great number of vertical ground motion records are in error, there would have been reservations expressed by those who have processed most of the records at the California Institute of Technology and the U.S. Geological Survey. I know of no such reservations having been expressed.

Q 13 Item 5 of the Appendix to ALAB-598 points out the similarity of the Hollywood Storage Building and the Imperial Valley Services Building in that both buildings are on piles but records monitored at the latter site did not exhibit the tau effect which Dr. Newmark indicates was evident in the records monitored at the Hollywood Storage Building site during the 1971 San Fernando earthquake. Item 5 states that given the apparent similarities between the structural foundations of the two buildings, the explanations provided thus far for a seeming lack of a tau effect at the Imperial Valley Services Building are inadequate. The parties were asked to provide additional information on this point and relate their analyses to both geological and structural conditions prevailing at the Diablo Canyon site. Have you studied this issue? If so, would you summarize your results and state your conclusions.

A 13 Yes, I have studied this problem relative to records compiled for both the 1971 San Fernando earthquake and during the IV-79 event. Let us start with the records computed for the IV-79 event.

I have examined the horizontal (E-W) and vertical response spectra for the base of the Imperial Valley Services Building and for the free field that were recently published in Preliminary Report 26 of the California Division of Mines and Geology. I would like to point out the differences in these spectra which I think are due to soil/structure interaction. Later I will translate this into tau effects. I have compared the E-W response spectra for the base of the building (Trace 13) with the free-field spectrum (N92E) in Figure 9. Looking first at response at frequencies greater than 1 Hz it will be noted that the building base response is greater than the free-field response at periods of about 1.5 and 3 sec, although peaks appear on both spectra at these frequencies. I think study will reveal that these peaks are due to surface wave motion. Therefore, even if the structure were rigid, greater horizontal response would be recorded at the upper floors at these frequencies than at the base and this did occur. Since the building base accelerometer was near a shear wall, this response was picked up in the base record. The enhancement in response here is then a structure effect. The building base record in the 2 to 5 Hz range and at 7 Hz is significantly stronger than the free-field response. These in my opinion are building response effects. However, the response at 7 Hz is probably not a normal structural mode response.

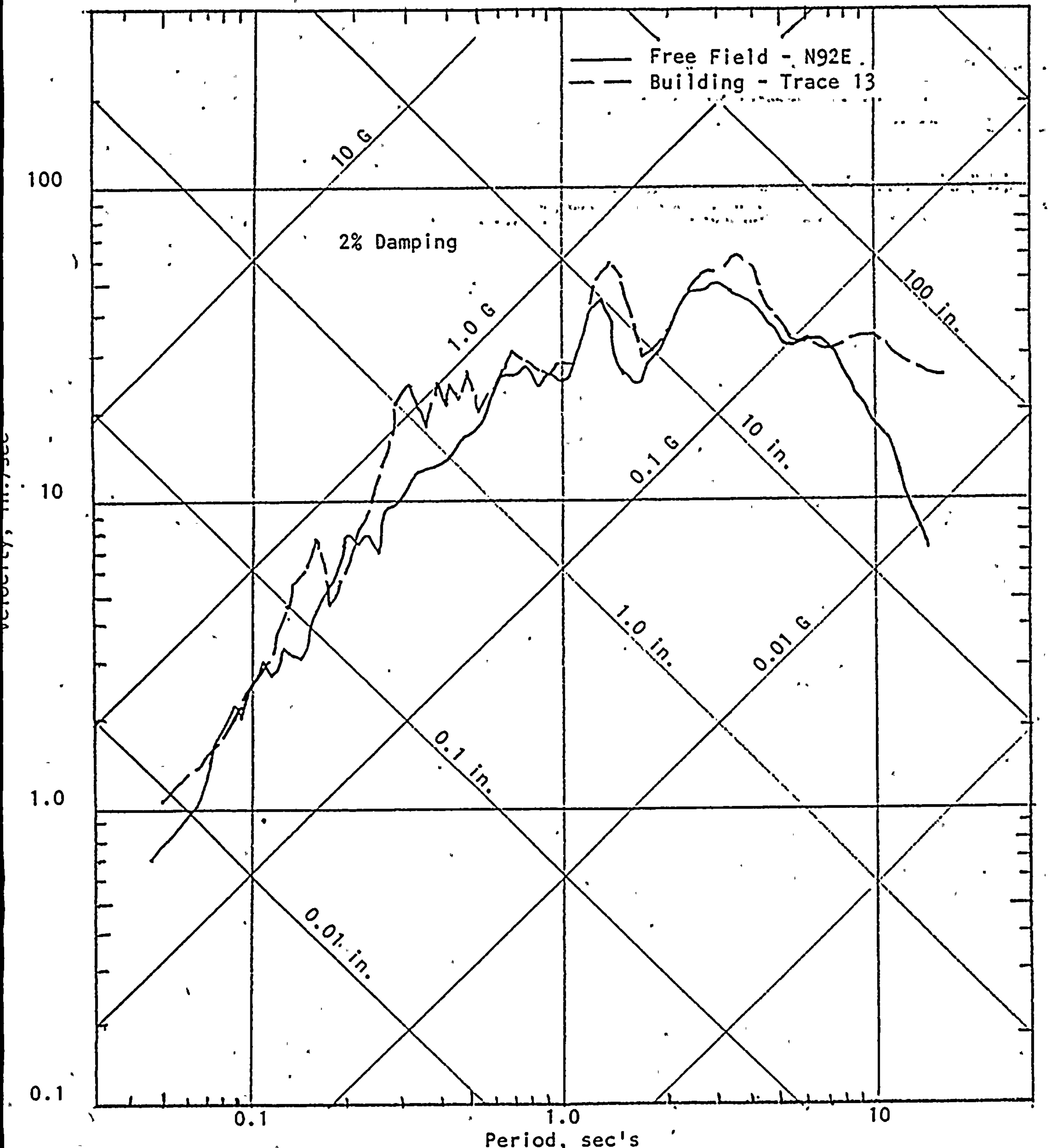


FIGURE 9. COMPARISON OF FREE FIELD AND IMPERIAL COUNTY SERVICES BUILDING FOUNDATION E-W RESPONSE EVENT IV-79

I have provided the vertical response spectra for the free field and the base of the structure in Figure 10. It will be noted that the same long period motions which I attributed to surface waves in Figure 9 also appear at periods of about 1.5 and 4 sec but there is little amplification in the building response at these frequencies. This is consistent with my interpretation that these are surface wave motions. The divergence in the spectra at periods above 6 sec I would surmise is due either to a processing error, or an error in the response spectra routine, probably the latter and is of no consequence. The suppression of the vertical response in the building base record at frequencies above 4 Hz I would attribute to building effects. In my opinion it has resulted from the pile foundation as well as from shear wall restraint. I would consider the piles to be effective in reducing the intensity of the vertically propagating P-waves since they would reduce the normal enhancement of the motion due to wave reflection at the surface. However, I would like to note that I consider the pile foundation to have no effect on the horizontal building motion record. The piles do not, in my opinion, create an "upper story" response.

At this point we need to consider the tau effect that has been postulated by Dr. Newmark for the Hollywood Storage Building based on the 1971 San Fernando earthquake records monitored in the basement and in the free field for this site. I am in strong disagreement with Dr. Newmark in his interpretation of the causes of the reduced response in the basement of the Hollywood Storage Building as compared to the response measured in the free field, and with his logic in justifying the use of a tau factor to reduce the Diablo Canyon free-field response spectra for reasons which I will explain.

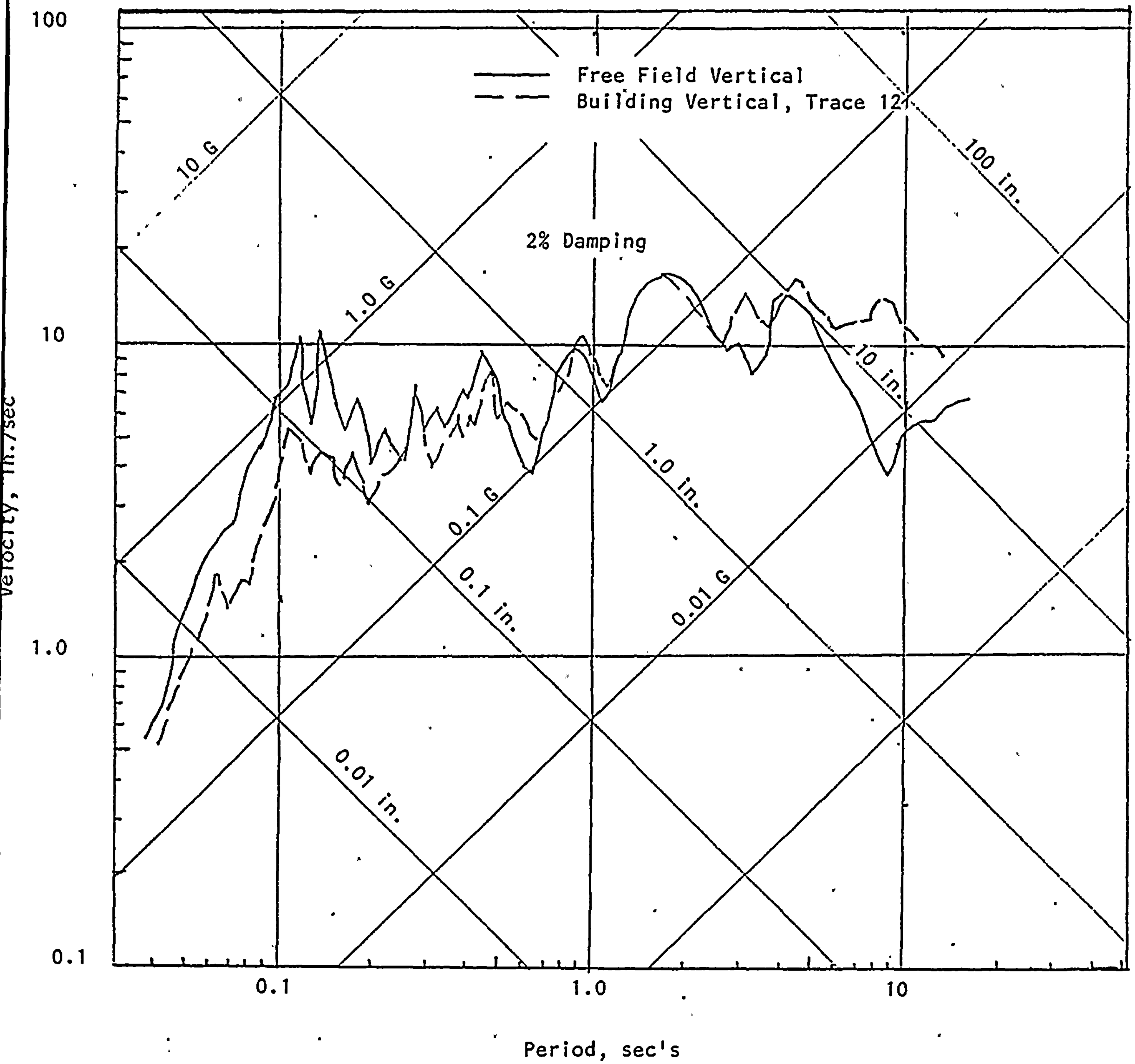


FIGURE 10. COMPARISON OF FREE FIELD AND IMPERIAL COUNTY SERVICES BUILDING FOUNDATION VERTICAL RESPONSE EVENT IV-79

First, I do not accept the tau factor explanation because the Scanlon (1976) derivation is based on the time of travel of *surface waves* across the width of the structure, but the response at this site at periods less than 0.4 sec (i.e., frequencies of 2.5 Hz and greater) was produced by *body waves* which were essentially propagating vertically. Therefore, the time of envelopment is zero and tau is zero. It should also be noted that the E-W axis of this building is normal to a radial line extended from the epicenter of the 1971 San Fernando earthquake. Therefore, the SH wave which produces the E-W body wave motion in this frequency range should reach both the east and west ends of the building simultaneously, and tau would again be zero. The dominant Rayleigh wave motions which would envelop the building horizontally have periods in excess of 1.5 sec at this site but no modification in response is indicated in the records for these periods. I am of the opinion, therefore, that there was no tau effect exhibited by the Hollywood Storage Building records during the 1971 San Fernando earthquake since the time of travel of the body waves across the building was zero and the wave lengths of the surface waves were too long to affect building response. The same arguments apply to the Imperial Valley Services Building. The response motions at the higher frequencies were body waves with zero time of envelopment. Therefore there was no tau effect. Fortunately, in this case it is supported by the strong motion records.

Second, important criteria conclusions for nuclear power plant facilities should never be based on the comparison of only two records, but should be based on an examination of a statistically significant number of

pairs of records. For example, Figure 11 provides a comparison of 2% damped response spectra for the 1900 and 1901 Avenue of Stars buildings that were derived from the motions recorded at these two stations during the 1971 San Fernando earthquake. Similar to the Hollywood Storage Building site, there is a significant difference in the response for these two records for periods less than 0.4 sec (2.5 Hz), but *the motions were recorded in the basements of both buildings which are separated only by the width of the street.* The difference obviously cannot be explained by a tau factor. There are other examples from records in the immediate vicinity of the Hollywood Storage Building. Bernreuter and Wight (1977), for example, in their report entitled, "Analysis of Diablo Canyon Response Spectra" have already pointed out that response spectra for the building at 6430 Sunset Boulevard are in almost complete agreement with the Hollywood Storage parking lot spectra but spectra from the building at 6464 Sunset Boulevard are much like those recorded in the Hollywood Storage Building, yet both recorders are in the basement of the respective buildings.

There are obviously several factors that can cause a difference in the motions recorded from the same earthquake by two closely located accelerographs. I am of the opinion that the major cause of the difference in the motions at the Hollywood Storage Building site was the fact that one instrument was located in the basement near the corner walls, while the other was located on the ground surface more than 100 ft from the building. If we accept the fact that vertically propagating body waves are amplified at the free surface, then referring to Figure 12, amplified response should be anticipated at A

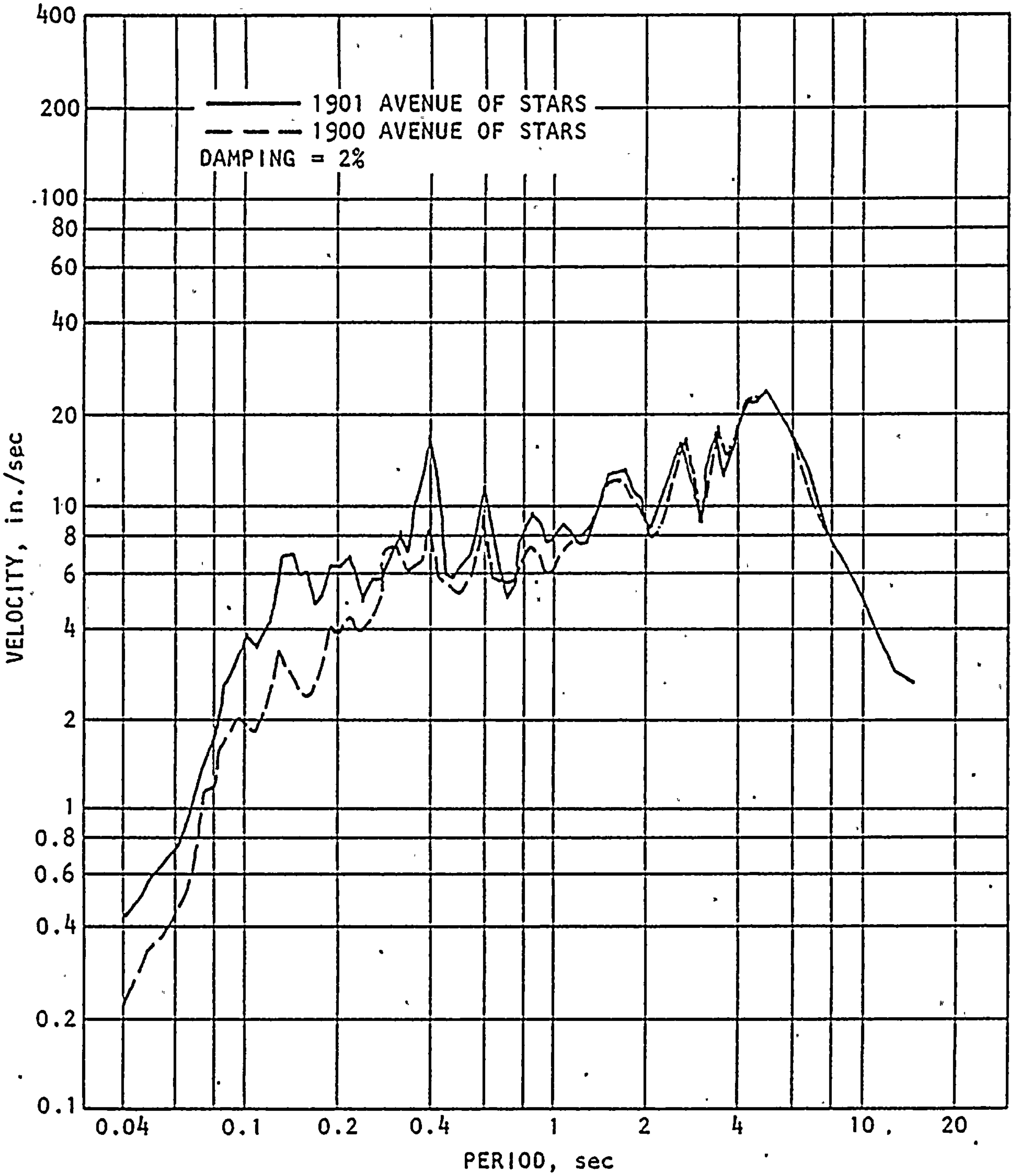


FIGURE 11. S44W RESPONSE SPECTRA FOR 1900 AND 1901 AVENUE OF STARS, 1971 SAN FERNANDO EARTHQUAKE

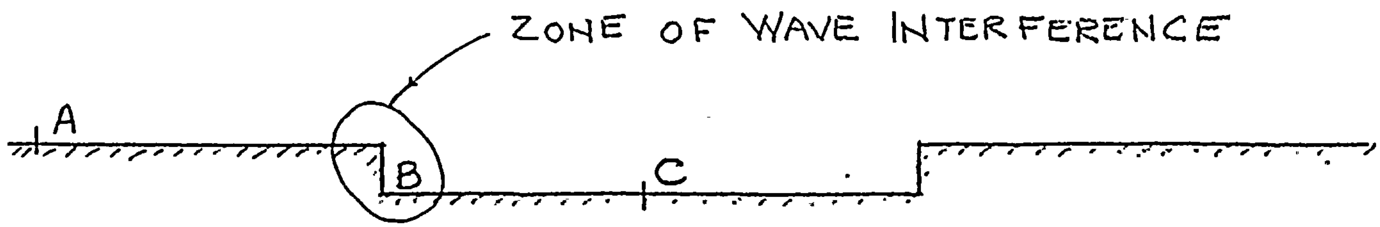


FIGURE 12. VERTICAL SECTION SHOWING ZONE OF WAVE INTERFERENCE

and C, when the basement depth is shallow and wide, but the wave front should be smeared at B and lower peak motion should be recorded. In my opinion this is a more logical explanation of the difference in response of the two records, but this conclusion should not be based on a single set of records.

Third, about 70% of the so-called free-field strong motion records that we have were recorded in the basements or on the ground floor of multi-story buildings. If there is a tau effect in the Hollywood Storage Building records then it must exist to different degrees in 70% of our records. On this basis, regression analyses which have established peak ground motion attenuation and response spectra relationships would be too low for free-field values and should more nearly approximate the motions that apply to the base of large buildings. The free-field spectra given in Figure 7 would therefore be more applicable to the base of large structures, and the free-field response should be something greater. On this basis, the tau factor correction should be applied to *increase* the free-field response and not to *decrease* the response spectra for the containment structure, turbine building, etc. Frankly, I do not consider that there is a tau effect in the Hollywood Storage Building basement record. Therefore I consider the NUREG/CR-1175 spectra in Figure 7 to be free-field spectra and I cannot recommend the tau factor reductions given by Dr. Newmark.

Fourth, the so-called tau factor reduction applied by Dr. Newmark to the Diablo Canyon free-field ground motions is in reality a soil/structure (i.e., rock/structure) interaction effect. *Therefore the same free-field*

spectra should apply to all Category I facilities. If there are reductions in the response of the larger structures due to soil/structure interaction, this should be demonstrated by good finite element soil/structure interaction analyses in which the finite element models have a sufficiently fine mesh to transmit the frequencies in question.

Q 14 Item 6 of the Appendix of ALAB-598 requests the following: (a) Describe and explain the circumstances in which soil/structure interaction produces an enhanced or reduced structural response. (b) Discuss the relevance and applicability for such interaction to the response assumed for Diablo Canyon. Could you provide comments relative to these questions?

A 14 It is difficult to provide the generalized response requested in 6a since soil/structure interaction is a complex problem and is affected by many variables. Important variables are the relative stiffness of the structure and supporting soil, the geometry and mass distribution of the structure and the depth of embedment of the structure in the soil, the dynamic properties of the supporting soil (or rock), and the frequency content and wave characteristics of the input motion. The problem is therefore complex. Reliable soil/structure interaction analyses are also difficult to perform. Within practical limits of this testimony, I can provide only some general statements and guidance.

The relative stiffness of the structure and the supporting foundation is an important consideration since frequently the structure is assumed to have a rigid base in soil/structure interaction analyses. However, I

have usually found the structure to be relatively flexible and not to behave as though it has a rigid base. This is one of several reasons why I prefer a finite element soil/structure interaction model to a rigid base-spring-dashpot model.

The dynamic properties of the supporting soil and rock are extremely important since these properties are an important factor in determining the rocking mode response. If the foundation is rock with a high modulus, the Standard Review Plan (USNRC, 1975) will permit an analysis in which rock/structure interaction effects are neglected, apparently on the assumption that the foundation is rigid and foundation deformations will contribute little to the response of the structure. This assumption was apparently used in the initial design analysis for Diablo Canyon.

The geometry and mass distribution of the structure are also important considerations since they influence the rocking and torsional response of the structure. The depth of embedment is an important variable for two reasons. First, if the structure is deeply embedded, the rocking and torsional response of the structure can be significantly reduced and second, if the structure does not extend over too large an area and is deeply embedded, the higher frequency body wave motions may be reduced since the structure will respond primarily to base motions which have not been enhanced by the amplification that occurs at the ground surface. However if the base width of the structure in both horizontal directions is quite large compared to the depth of embedment, this may not occur. This problem is

too complex to generalize. Unfortunately we have few cases where there are both free field and structure base motions that can be compared, such as for the Imperial Valley County Services Building.

Relative to the Diablo Canyon structures, I do not consider these structures deeply embedded nor do I consider them to be sufficiently stiff to permit one to assume that the structures have a rigid base. Since the foundation material is rock with a shear wave velocity of 5000 fps, I would not expect significant soil/structure interaction effects. Therefore, I would not expect the free-field response spectra to be greatly modified by the structure. I would recommend that the reduction in response, if any, be determined by a finite element soil/structure interaction analysis that has a mesh sufficiently fine to transmit frequencies up to 20 Hz.

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GEORGE A. YOUNG

EDUCATION

Ph.D. in Civil Engineering, University of Illinois, 1956
M.S. in Civil Engineering, University of Illinois, 1950
B.S. in Civil Engineering, University of Illinois, 1942

REGISTRATION

Civil Engineer, California (C27511)

PROFESSIONAL EXPERIENCE
(38 years experience)

BACKGROUND

George A. Young, Engineering Consultant, Rolling Hills Estates, California, 1980-
Technical Director, Agbabian Associates, El Segundo, California, 1968-1980
Head of Department of Civil Engineering, Michigan Technological University, Houghton, Michigan, 1963-1968
Professor of Civil Engineering, University of New Mexico, Albuquerque, 1962-1963
Chief of Civil Engineering Consultants, Air Force Ballistic Missile Division, Inglewood, California, and Scientific Advisor, Structural Dynamics Division, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, 1959-1962
Instructor and Associate Professor in Civil Engineering, University of Illinois, 1948-1959
Design Engineer, Harza Engineering Company, Chicago, 1946-1948
Lieutenant, Civil Engineering Corps, USNR, 1942-1946
Member of American Society of Civil Engineers, Earthquake Engineering Research Institute
Member of Tau Beta Pi, Chi Epsilon, Sigma Xi

EXPERIENCE

Dr. Young's engineering career has included teaching, research, and consulting in the fields of structures, soil mechanics, and hydraulics. His earlier special interests were protective structures, large dams, and construction techniques, including the use of nuclear explosives for excavation purposes. Prior to opening his present firm, Dr. Young served as Technical Director of Agbabian Associates where he provided general direction for all projects undertaken by the company. In addition, he was responsible for reviewing procedures for design and analysis, for coordinating design methodology with regulatory codes, guides, and criteria, and for monitoring state-of-the-art advances in basic science and engineering to identify means of improving design and analysis techniques and also had program and project management responsibilities.

Dr. Young has engaged in the design and assessment of near-surface and deep-underground hardened facilities, and in the assessment and correction of seismic hazards for structures and equipment. He was project manager for the hardness assessment of an existing underground military command center and for the development of concepts for hardness upgrading. He was also project manager for concept development and feasibility demonstration for a large-scale, self-contained, deep underground communications center. He served as project manager for an analysis of the earthquake resistance of an electrical power transmission, substation, and converter station network and for a seismic safety criteria study supporting the breeder reactor development program. He was the project manager for the seismic safety analysis of elements of the emergency cooling water system for a nuclear power generating plant, and for the seismic risk analysis of naval dockside facilities.

As a design engineer for Harza Engineering Company, he specialized in the design of large hydraulic structures, dams, and power plants, conducting site investigations in Iraq and El Salvador. As Chief of Civil Engineering Consultants for the Air Force Ballistic Systems Division, he provided review and guidance to the design of missile facilities for the Atlas, Titan, and Minuteman. As Scientific Advisor of the Air Force Weapons Laboratory, he worked on special problems in structural dynamics as applied to nuclear weapons effects. Under a research contract with Sandia Corporation, while on the staff of Michigan Technological University, he worked on studies involving construction of rock-fill dams with nuclear explosives.

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