50-275

NUCLEAR REGULATORY COMMISSION

ORIGINAL

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[redacted]

In the Matter of:

PACIFIC GAS AND ELECTRIC COMPANY

(Diablo Canyon Nuclear Power Plant,

Units 1 and 2)

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C O N T E N T S

Witnesses:	Voir Dire	Direct	Cross	Redirect	Recross
G. Frazier)			472		
H. Seed)					
S. Smith)					
J. Blume)					
R. Edwards)					
N. Newmark)		432	562		
J. Knight)					
P. Kuo)					
R. Rothman)					
J. Brune)		599			
G. Young)	608				

E X H I B I T S

Number	For Identification	In Evidence
Governor Brown's		
R-6	471	
R-7	472	
R-8	473	
R-9	475	

E X H I B I T S (Continued)

Number	For Identification	In Evidence
Joint Intervenor's		
R-10	508	
R-11	525	
R-12	610	
R-13	611	
R-14	611	
R-15	611	

P R O C E E D I N G S

CHAIRMAN SALZMAN: The hearing will reconvene.

We have some preliminary matters. The first one is that since we are starting early this morning, we will break for lunch at noon rather than one o'clock.

I believe the second matter is that Mr. Lanpher has something.

MR. LANPHER: Yes, Mr. Salzman, I would like to offer in evidence Governor Grown's Exhibit R-5. It was a 1973 Newmark, Blume and Khapur article. I have checked with counsel, and there are no objections.

CHAIRMAN SALZMAN: Hearing no objection, the document is admitted as Governor Brown's Exhibit R-5.

(The document previously marked as Governor Brown's Exhibit R-5 was received in evidence.)

MR. LANPHER: This is our only preliminary matter.

CHAIRMAN SALZMAN: Mr. Fleischaker.

MR. FLEISCHAKER: Mr. Chairman, I have a very quick preliminary matter.

We requested on the first day of hearing that Dr. Smith plot the exhibits, I think it is Applicant's Exhibits R-2 and R-2, the location of the data. I believe

he was going to do that. I was wondering if we could get agreement that we would obtain that at the first break.

MR. NORTON: Excuse me. That was not my understanding of the agreement. He was to be able to identify certain of the stations on the graph, and that he can do. But there is not room, obviously, to write the identification of all the stations on the plot itself. So you will have to put a viewgraph up, or something, and show them with a pointer, and say, "This is station such and such."

We don't have a new plot with the name of all the stations.

MR. FLEISCHAKER: Mr. Norton and I can work out at the first recess the best way to have the information.

CHAIRMAN SALZMAN: I think you could do that.

Hearing no further preliminary matters.

MR. NORTON: Mr. Salzman, there was one other that we discussed last night at the end of the day. We talked about the order of rebuttal. We were going to address that this morning the first thing.

CHAIRMAN SALZMAN: As I recall, the request was that you be allowed to rebut the following morning.

MR. NORTON: Yes.

CHAIRMAN SALZMAN: Why don't you state it again.

MR. NORTON: The problem is that there are four areas of inquiry. The way it was established the first day, we would rebut as the first area of inquiry was completed, and so on. The problem with that is, if that area of inquiry ends in the middle of the day, or any time during the day, we will not have time to prepare rebuttal, because the last part of the last part of the case is, of course, Governor Brown's and Dr. Luco and Trifunac, and the intervenors. So we would not have the opportunity to prepare rebuttal until overnight.

What I would suggest is that we do the rebuttal of the first two areas the first full day after those first two areas are completed.

CHAIRMAN SALZMAN: By the first two areas, do you mean Questions 1 through 7?

MR. NORTON: That is the first area, Questions 1 through 4 and 7, and then 5 and 6.

CHAIRMAN SALZMAN: I am not quite sure I am following. Did you say you wanted rebuttal the day following the completion of each of those?

MR. NORTON: It seems to me to make sense not to make any rebuttal until each of these areas is completed. The second area, there is no witness, so there is going to no rebuttal. So we could do it before we start the second area, or between those two areas, or even after those two areas, whatever is convenient. But we would need at least

overnight to prepare any rebuttal.

CHAIRMAN SALZMAN: Mr. Olmstead.

MR. OLMSTEAD: My view of that is that it should depend upon the circumstances as to what the nature of rebuttal is going to be. I don't know exactly what it is going to be at this point. But, I am not sure that it is going to be a problem.

CHAIRMAN SALZMAN: Apparently Mr. Norton thinks it is going to be.

MR. OLMSTEAD: I hear him say that it is a problem, and I guess the problem I have with it is, if in order to give him overnight to prepare rebuttal, it means that this hearing goes on for an additional week, I am not interested.

CHAIRMAN SALZMAN: Mr. Fleischaker.

MR. FLEISCHAKER: I share Mr. Olmstead's view.

In addition, it seems to me to make sense to have rebuttal immediately following the discussion of the issues in each area, because that is when the matter is freshest in our minds.

So, for example, after we finish issues 1, 2, 3, 4 and 7, it would make sense, then, to have rebuttal on the issues in connection with those Board questions. So I think the Applicant ought to present his rebuttal upon completion of the case for each of the areas.

CHAIRMAN SALZMAN: Mr. Lanpher, do you want to

address that?

MR. LANPHER: I would like to ask for a clarification.

First of all, is this rebuttal by PG&E, or is it an opportunity for rebuttal by all the parties?

CHAIRMAN SALZMAN: Rebuttal by PG&E only. That is what the rules provide.

MR. LANPHER: It is my recollection that we held that in abeyance on the first morning.

CHAIRMAN SALZMAN: I don't think that that is quite right. It is rebuttal by PG&E only, sir, otherwise we would be here until the middle of next year.

Mr. Lanpher, I presume that your own witnesses will comment, when you put them on. They will be entitled to comment on the testimony that has gone on before, and that is why they have been here.

MR. FLEISCHAKER: That is the discussion that we had yesterday.

CHAIRMAN SALZMAN: The rebuttal is in response to your criticism.

MR. LANPHER: I thank you for that clarification.

CHAIRMAN SALZMAN: Mr. Olmstead.

MR. OLMSTEAD: I think that while things are fresh immediately, we ought to have the rebuttal immediately following the completion of a subject matter area.

CHAIRMAN SALZMAN: Just one moment.

(Pause.)

CHAIRMAN SALZMAN: Gentlemen, two observations. One of them is that it is a highly technical matter; two, that everybody has been very active. No one wants to delay the hearing any longer than possible, but I think that it would be very difficult for Mr. Norton to immediately start getting up and rebut without some time to talk to his witnesses, and to indicate what he is going to do, otherwise we are likely to be here while he thinks on his feet.

Why don't we, as usual, split the baby, and wait until the first panel of witnesses is finished, then see what time it is, and when it would be appropriate to have rebuttal, and what sort of problems Mr. Norton has, so he can decide the problem in the concrete rather than in the abstract.

If you, gentlemen, will bear with that, we will take it up at that point. But I think that Mr. Norton is entitled to some time to get his ducks in a row.

MR. OLMSTEAD: Mr. Chairman, there was something you said that caused me to clarify.

CHAIRMAN SALZMAN: I should not have said anything.

MR. OLMSTEAD: When we first covered this matter on Monday, the stipulation I thought we had, and the agreement that I thought we had was that each panel of witnesses could assume that the testimony of the six witnesses, namely in our

case the State and the intervenors, would be as filed, therefore, minimizing the need for rebuttal, because they could address that point while they were on the stand. I have proceeded on that assumption.

CHAIRMAN SALZMAN: That is what I had understood they were going to be doing while they were on the stand. They are going to address the preceding testimony.

MR. OLMSTEAD: That is right, and there has been a lot of rebuttal, for instance, to the direct pre-filed testimony of Drs. Trifunac and Luco by this panel already. So the extent that you are talking about the formal procedures that one would follow, the testimony comes in and then you rebut that testimony --

CHAIRMAN SALZMAN: Mr. Olmstead, I think that it is a complicated case, and the person with the burden of proof is entitled to attempt to straighten out what he thinks is a problem. To that extent, I think we are going to allow him this rebuttal.

MR. OLMSTEAD: Very well, sir.

DR. JOHNSON: Mr. Olmstead, you made a characterization that I don't think is quite correct. The testimony of Drs. Trifunac and Luco has been the subject of commentary by these witnesses, but only in response to questions asked them on cross-examination. I don't believe that that could be considered rebuttal. Attorneys from the intervenors and

from the State have asked them questions related to that testimony and they have answered those questions. I don't believe that any one of those witnesses has directly volunteered rebuttal testimony of those witnesses or anyone else.

MR. OLMSTEAD: I understand that, but by opening it up, it is subject to redirect.

CHAIRMAN SALZMAN: I think this is enough. We will make the ruling and decide when we finish this. But at the moment, the ruling is as it stands.

Please, Mr. Brown, begin now.

MR. BROWN: First, I would like to have marked for identification the three documents which were provided to us by Dr. Frazier at the end of the session yesterday.

Governor's Exhibit R-6 is entitled "Visco-elastic parameters of the earth structure at Diablo Canyon."

CHAIRMAN SALZMAN: The reporter will mark that as Governor's R-6 for identification.

XXX (The above entitled document was marked for identification as Governor's Exhibit R-6.)

MR. BROWN: Governor's Exhibit R-7, for identification, is entitled "Prescription of Rupture Incoherence Used in Earthquake Modeling Process."

Governor's Exhibit R-8 is entitled "Source

XXXX

Parameters for Rupture Simulations Along the Hosgri Fault."

CHAIRMAN SALZMAN: They will be so marked.

(The above entitled documents were marked for identification as Governor's Exhibits R-7 and R-8.)

CHAIRMAN SALZMAN: Mr. Brown, please proceed.

Whereupon,

GERALD FRAZIER

H. BOLTON SEED

STEWART SMITH

JOHN BLUME

ROBERT EDWARDS

the witnesses on the stand at time of recess, resumed the stand and, having been previously sworn, testified further as follows:

CROSS-EXAMINATION (resumed)

BY MR. BROWN:

Q Dr. Frazier, there was one data point that was not included if you used the same philosophy as you did in the San Onofree model, which is Joint Intervenor's Exhibit R-9.

CHAIRMAN SALZMAN: You will have to speak more slowly and more distinctly, or we are not going to hear you, sir.

MR. BROWN: Thank you, sir.

WITNESS FRAZIER: Yes.

BY MR. BROWN:

Q Would you please direct your attention to page 9 of your testimony, at lines 12 to 15, would you please read that sentence?

A The sentence reads: "Material attenuation properties which also vary with depth are assigned values based on generic relationships used in all prior and on-going test calculations for past earthquakes."

Q Referring to all prior and on-going test calculations for past earthquakes, Dr. Frazier, do you include the following reports of terra delta, the May 1978 simulation of ground motion at San Onofree, which was marked for identification as Joint Intervenor's Exhibit R-6?

A Yes.

Q Do you include Supplement 1 to that report, which is a Joint Intervenor's Exhibit R-7?

A Yes.

Q Do you include Supplement 2 to that report, which is a Joint Intervenor's Exhibit R-8?

A Yes.

Q Do you include Supplement 3 to that report, Joint Intervenor's Exhibit R-9?

A Yes.

Q Do you include the "Response to Proposed Test for Earthquake Ground Motion Simulations for San Onofree Unit 1,"

dated August 29, 1979, and revised September 5, 1979?

A Yes.

Q Are there any other reports that are included in your statement -- When I say your statement, I am referring to al prior and on-going test calculations for past earthquakes?

A Not that I can think of. I don't believe there is any other.

Q So the answer is no. Am I correct that the answer is no?

MR. NORTON: I object. He said, not that he can think of.

CHAIRMAN SALZMAN: Mr. Brown.

MR. BROWN: That is fine, I withdraw the question.

I would like to mark for identification now the document entitled "Response to Proposed Task 4 Earthquake Ground Motion Simulations for San Onofree, Unit 1, dated August 29, 1979," and revised September 5, 1979. That would be the marking for identification of Governor's Exhibit R-9.

CHAIRMAN SALZMAN: The reporter will mark the document when it is given to her.

(The above entitled document was marked Governor's Exhibit R-9 for identification.)

DR. JOHNSON: Mr. Brown, may I interrupt you one second?

Dr. Frazier, the data displayed on Governor's Exhibit R-6 is supposed to be the same as that displayed in Table 7-2 of your testimony, the graph of the depth dependent parameters?

WITNESS FRAZIER: Yes.

DR. JOHNSON: The sheer velocity in the figure has values that start at -- I may be displaying my ignorance here -- around 2 and go up to approximately 3 with depth, whereas the s wave velocity in the table start at approximately 3 and go up to 8.

It was my understanding that S and sheer waves were identifical?

WITNESS FRAZIER: No, you are not displaying your ignorance. Let me take a moment, I think I see what the confusion is.

(Pause.)

WITNESS FRAZIER: We are referring to Governor's Exhibit R-6?

DR. JOHNSON: That is right.

WITNESS FRAZIER: The first column is now labeled

P-wave velocity, and it should be labeled S-wave velocity. The second column is labeled S-wave, and it should be labeled P-Wave velocity.

DR. JOHNSON: Thank you, sir.

MR. NORTON: Have counsel made the change in the exhibit, and changed the copy of the exhibit given to the reporter? I don't know if anyone was paying attention to that.

CHAIRMAN SALZMAN: I think everyone heard the statement, and will change the exhibit.

BY MR. BROWN:

Q Dr. Frazier, could you turn to page 4-18 of the final report on San Onofree, which is Joint Intervenor's Exhibit R-6?

A What page again, please?

Q IV-18.

A Yes.

Q Would you first read the first paragraph for the record?

A The first paragraph reads, "The effect of the geologic model was examined by computing what the site response would be if the site were located on various geologic structures.

Because of the availability of computed grains functions, we chose structures characteristic of Southern California coast: the San Onofre site, the region southwest of the San Andreas fault near Parkfield, and the Imperial Valley.

These four structures are compared in Figure, IV-11.

Q. Dr. Frazier, which of the four geologic structures to which you just referred in that paragraph is the Hosgri most similar to?

A I do not know. I don't know on what basis I would cite similarity.

Q In terms of shear velocity and Q.

A You are asking me to compare a rock site with earth structures that are not on rock at the surface, and you are asking me which is most similar, so I don't know.

(Pause.)

Q Would you say the average shear velocity in the range of 5 kilometers is closer to the San Onofre or to the Imperial Valley?

(Pause.)

A I want to repeat the question in my answer to make sure that I -- I believe that the shear wave velocity is closer to that of San Onofre than it is to that of Imperial Valley.

DR. JOHNSON: Dr. Frazier, when you say the shear wave velocity, you mean the shear wave velocity displayed on your table, which is Governor's Exhibit R-6?

WITNESS FRAZIER: Yes. And this Figure IV-11 at a depth of about 5 kilometers.

DR. JOHNSON: Fine. Thank you.

MR. BROWN: Are you referring to this exhibit, to the Joint Intervenors' Exhibit R-6?

DR. JOHNSON: I am referring to Governor's Exhibit R-6 which is the table of parameters.

MR. BROWN: Thank you.

BY MR. BROWN: (Resuming)

Q Dr. Frazier, could you now --

MR. OLMSTEAD: Excuse me, Mr. Chairman. Now I am confused. I thought we were referring to Joint Intervenors' R-6, the Table IV-11 on page IV-19.

DR. JOHNSON: Well, since I raised the question,

I think maybe I can explain that problem. Dr. Frazier said this velocity is closest to the velocity of San Onofre or closer to the velocity of San Onofre than it is to the Imperial Valley. San Onofre and Imperial Valley velocities are displayed in Figure IV-11 of Joint Intervenors' Exhibit R-6.

This velocity that he referred to is the velocity referred to in the first column of Governor's Exhibit R-6, which is the way I interpreted his answer.

MR. OLMSTEAD: Thank you.

CHAIRMAN SALZMAN: Dr. Frazier, is that the way -- did Dr. Johnson interpret your answer correctly?

WITNESS FRAZIER: Yes.

CHAIRMAN SALZMAN: Thank you.

BY MR. BROWN: (Resuming)

Q Now, Dr. Frazier, could you please direct your attention to the third paragraph on page IV-18 of the Joint Intervenors' Exhibit R-6, and could you please read that for the record?

A "The pattern of grains functions"-- let me start over again. "The pattern of grains functions amplitudes in Figure IV-12 repeats itself in the response spectra of Figure IV-13. The horizontal responses indicate that at San Onofre and Parkfield structures give comparable high frequency responses, while the Southern California coast

leads to somewhat larger responses, and the Imperial Valley leads to somewhat smaller responses."

Q Dr. Frazier, can you now refer to Figure IV-13 of this same exhibit, and that is at page IV-21.

A Yes.

Q Each of the three earthquake curves falls above the Imperial Valley curve in the frequency range of interest. Therefore, Dr. Frazier, isn't it correct that this figure predicts for a given source mechanism higher peak accelerations at Diablo Canyon than at Imperial Valley due to the effects of geologic structure?

MR. NORTON: Excuse me. May I have a definition from counsel of periods of interest within that question?

CHAIRMAN SALZMAN: Yes. Counsel, please present a definition.

MR. BROWN: A frequency range of interest is what you are referring to.

MR. NORTON: You said your words. Now I need a definition of what frequency is.

(Pause.)

BY MR. BROWN: (Resuming)

Q Dr. Frazier, by frequency range of interest we are referring to the range of 2 to 15 hertz.

MR. NORTON: I guess my problem is is that of interest to who? Of interest to the Examiner --

MR. BROWN: I substituted 2 to 15 hertz.

CHAIRMAN SALZMAN: That is obviously of interest to Mr. Brown.

MR. NORTON: Fine.

MR. OLMSTEAD: Mr. Chairman, staff does have a point of clarification, however. Yesterday when these documents were interested -- marked, we pointed out that this particular document we were in was published prior to the October 1979 earthquake in the Imperial Valley which is the subject of the Board's question. And to the extent that we are getting away from that, the staff objects.

CHAIRMAN SALZMAN: Mr. Brown, would you care to respond?

MR. BROWN: We are simply cross examining the witness on his model and on the data that he provided to us, and the application of those data here.

CHAIRMAN SALZMAN: I am sorry. I cannot understand you.

MR. BROWN: Mr. Salzman, we are just cross examining the witness on his model and the parameters and the application of those parameters here in order to draw judgments on the soundness of the conclusions drawn.

MR. NORTON: Mr. Salzman, just a moment. Obviously this is not the Imperial Valley earthquake of October 15, 1979. This report was done in 1978, and while Mr. Frazier's

model is good, it is not that good. This was an earlier Imperial Valley earthquake, and I think it would help the record if when referring to the Imperial Valley that this one be called Imperial Valley '40. I believe it is the Imperial Valley 1940 earthquake or some other earthquake or whatever.

But this modeling done in 1978 is not the 1979 earthquake, and we are going to have a very confusing record if we do not clarify that.

DR. JOHNSON: Mr. Norton, I think perhaps you have added some confusion here. We are talking about the result of model calculation, and the only relevance to Imperial Valley is the fact that the geological structure for which one of these calculations was made was a geological structure which simulated that of the Imperial Valley, and there is no data for any earthquake in this Figure IV-13 that I am aware of.

MR. NORTON: Okay.

DR. JOHNSON: Maybe I am mistaken, and maybe Dr. Frazier would --

MR. NORTON: Maybe if Dr. Frazier could be asked to clarify what these mean and what they were compared against, because it is my understanding they were indeed checked against real earthquakes at those places -- Parkfield, Imperial Valley, etcetera. And we are going to get very

confusing when we start talking about different Imperial Valleys. The record is going to be hopelessly confusing.

CHAIRMAN SALZMAN: Mr. Olmstead, I do think what Mr. Brown is attempting to do is to check the accuracy and validity of certain calculations used by the witness in evidence. He has done some things which depend on this, and I am certainly prepared to let him continue to determine how valid some of those calculations are.

MR. OLMSTEAD: I apologize for not making my objection clear. My objection is not, as Mr. Norton and Dr. Johnson were characterizing it, that this essentially goes to the basis for the testimony which was available in the hearings below. And to the extent that we are going to go back into how these particular witnesses developed the theoretical basis for their testimony before the Imperial Valley earthquake of 1979, rather than focusing on any changes in their assumptions that occurred as a result of that, I view it as beyond the scope of the Board's question.

CHAIRMAN SALZMAN: Mr. Brown, will you connect this line of questioning for us right now into the matter before us?

MR. BROWN: Yes. I am not sure I even understand what Mr. Olmstead is talking about. We are talking here about the application of a given source mechanism for the

development of each of these curves, and we are simply asking for that given source mechanism what would be the effect at the Diablo site, and then we are going to make some comparisons, and this is going to be the basis of something that goes to the questions that are relevant here.

(Board conferring.)

DR. BUCK: Wasn't this data all available long before this reopened hearing?

MR. BROWN: Pardon me?

DR. BUCK: This data was available, and as far as I know could have been used in the original hearing.

MR. BROWN: I know that we are going to a question here related to Dr. Frazier's models and his testimony here on question 7, and this is part of the cross examination we are using with respect to the tests and the calculations he refers to in his testimony.

DR. BUCK: How long do you propose to continue on this?

MR. BROWN: On this particular line?

DR. BUCK: Yes.

MR. BROWN: I would say no more than five minutes if we get the correct answer, or the answer I should say.

CHAIRMAN SALZMAN: The objection is overruled. You may continue.

MR. BROWN: Thank you.

BY MR. BROWN: (Resuming)

Q Would you like the question reread, Dr. Frazier, or do you recall it?

A I recall it.

Q Would you please answer?

A The answer is no.

DR. JOHNSON: I am sorry. Dr. Frazier's memory is very much better than mine.

(Laughter.)

And just so I will understand where we are without having to have the Reporter read something back, Dr. Frazier, could you say what question you are answering no to?

WITNESS FRAZIER: Roughly the question asked if this figure drew implications that ground motions would be higher at Diablo from an offshore earthquake than in Imperial Valley, and the answer in my opinion is no.

DR. JOHNSON: Right. Thank you very much.

BY MR. BROWN: (Resuming)

Q Now, I would like to pose this question. Is it correct that this figure predicts for a given source mechanism higher peak accelerations at San Onofre than those at Imperial Valley due to the effects of geologic structure?

MR. NORTON: Excuse me, Dr. Frazier. Would you

please listen to the last part of the question. I don't think maybe you heard the last two words of the question.

BY MR. BROWN: (Resuming)

Q Due to the effects of geologic structure.

A San Onofre is the higher of the two -- it is generally the higher of the two.

Q Dr. Frazier, is it true that high frequency responses are controlled primarily by the Q structure?

A They are significantly influenced by Q.

Q And do low Q structures, Dr. Frazier, lead to smaller responses than high Q structures?

A Not necessarily, not in the modeling work.

Q Dr. Frazier, would you please refer to page 418 of the Joint Intervenors' Exhibit R-6, which I think is the one that you have before you? Could you please read the last paragraph on the record?

A The last paragraph reads: "These computations suggest that the magnitude of high frequency responses are controlled primarily by the Q structure. For low Q structures" -- I am sorry -- "Low Q structures lead to smaller responses than do high Q structures."

Q Based on this paragraph, Dr. Frazier, does this mean that increases in Q beta values reduce attenuation and increase acceleration?

A Would you repeat the question, please?

Q Does this mean, based on the paragraph that you just read, that increases in Q beta values reduce attenuation and increase acceleration?

A I don't comprehend the question.

Q The question is if the values of Q are increased, does that mean that attenuation is reduced?

A I am willing to volunteer a question in the line that you are asking.

Q Please do that.

A If I increase --

Q Does that lead to higher accelerations? Your answer? What is your answer, please?

A In some cases, yes.

Q Dr. Frazier, do you still continue to believe what I presume you believed in the last paragraph of IV-18, which you read for the record a moment ago?

A The last paragraph on page IV-18 is in a context and within many contexts increases in Q lead to higher accelerations. There are contexts to where that is not true, or at least I would presume there are contexts where that is not true.

Q Would you please explain your response?

MR. NORTON: I am going to object to that. That is not really a question.

BY MR. BROWN: (Resuming)

Q I would like to know the exceptions to which you just alluded.

A There are two things that are making it difficult for me to answer your question. One is that in this model the Q properties are tied to the shear wave velocities, so if we change Q, there is a question, that is, the dissipation or the quality factors, the question in my mind: are we at the same time changing the shear wave velocities since they are tied in the model, and that is where we started from my testimony. That is where we began this line of questioning.

If I change simultaneously Q and the shear wave velocity, then I get real confused about what the results might yield.

Secondly -- well, that is enough.

Q Dr. Frazier, could you now turn, please, to Figure III-15, which is in the Governor's Exhibit R-9. It is the Task Four response.

CHAIRMAN SALZMAN: At this point, Mr. Brown, I would like to ask a question. A copy of Governor's Exhibit R-9 for identification, which was presented to the Board, is marked "Draft." Is that the one you are referring to?

MR. BROWN: I believe it is.

CHAIRMAN SALZMAN: Is this the most recent response?

MR. BROWN: The copy I had I believe said "Draft" also, Mr. Salzman. It turns out Dr. Brune has one that doesn't say "Draft."

MR. NORTON: May we have the table number we are referring to?

CHAIRMAN SALZMAN: Before we do that, Mr. Olmstead, I would like to know is this the final document or has there been a document that superseded this one? This is a draft report that he is referring to dated August 1979.

MR. OLMSTEAD: You said Mr. Olmstead?

CHAIRMAN SALZMAN: I am sorry. I meant Mr. Brown.

MR. BROWN: To the best of my knowledge there is not a future document on this, to the best of my knowledge.

MR. OLMSTEAD: I might note this is among a series of draft consultant reports that are being submitted to the NRC staff in the San Onofre docket on this subject, and as far as the staff knows, this is the most recent one.

CHAIRMAN SALZMAN: But it is not the final conclusion?

MR. OLMSTEAD: Well, the staff has not yet -- is not yet prepared to say what its position is on modeling studies which is exactly why I have objected to this discussion of all of the San Onofre material.

CHAIRMAN SALZMAN: Well, you did not, however,

object to the evidence introduced by the Applicant which has a great many modeling studies in it, and I gather the idea is to test the accuracy of those models, and the Applicant is relying on them.

MR. OLMSTEAD: Well, to the extent that they are making at the end of Dr. Frazier's testimony -- there are three pages or so of references to this focusing study. They are saying this is another look that comes out one way. I guess I don't have any inherent objection to it.

I do have problems, though, if the staff is going to be asked to comment on all of the reports that are being submited to it in the San Onofre docket.

CHAIRMAN SALZMAN: Well, the staff has not been asked to comment on anything beyond this, and we will cross those comments when we come to them.

Please continue.

BY MR. BROWN: (Resuming)

Q Referring, Dr. Frazier, to this Figure III-15, do you have that before you?

MR. NORTON: Could you give a page number on these figures?

MR. BROWN: It is page 34.

WITNESS FRAZIER: Yes.

BY MR. BROWN: (Resuming)

Q Dr. Frazier, does this figure show the effect

of changing Q on the amplitudes of seismic shear waves?

(Pause.)

A. It shows the effects of changing Q, yes.

Q Could you please tell us what you mean in the caption of this graph where there is a statement from the double Q earth structure? Could you please define that for us?

A I am going to paraphrase, and I also want to qualify my paraphrasing. This report was written some time ago, and I have not reviewed it since it was written. Without stopping to read it, I will tell you what that means.

There were two earth structures studied, or there was an earth structure studied, and the results were obtained and response spectra were calculated. Then the same earth structure tests were done in the same earth structure, and the Q properties of that structure were doubled. Everything else was held the same, and the same type of test calculations were performed. And then the ratio of those two results were calculated in an effort to get some understanding about how Q influences some properties about the computed results.

Q Dr. Frazier, what does this figure show -- I will withdraw that.

Dr. Frazier, what does this figure show about the effect of changing the Q structure on the accelerations

to be expected?

A This figure was not derived from an earthquake simulation, so it would be an extrapolation to deduce how earthquake ground motions would be affected. In general, the figure shows that if you increase Q, holding everything else constant, that ground motion would be expected to increase.

Q Could you now please refer to Supplement 3 document which I believe is the Governor's Exhibit R-8?

CHAIRMAN SALZMAN: Did you say Supplement 2 or Supplement 3?

MR. BROWN: Supplement 3.

CHAIRMAN SALZMAN: It must not be R-8. It must be R-9.

MR. BROWN: I have that as -- oh, no, it is the Joint Intervenors'. I am terribly sorry. It is Joint Intervenors' Exhibit R-9, yes.

CHAIRMAN SALZMAN: What is the green one?

MR. BROWN: I do not have the green one.

BY MR. BROWN: (Resuming)

Q Could you refer, please, Dr. Frazier, to page V-5?

A Yes.

Q This page is a point of reference for you. It is the second page -- the point in your report under the

title "Results and Conclusions." If you want to refresh your recollection for a moment, please do that. And I am particularly interested -- I will point out to you at this point as you go through it briefly, in the second to the last paragraph on page V-5 --

A I have read the second to the last paragraph which I guess is also the second paragraph on that page.

Q Are you familiar with that in the context of this section of your report now?

A Yes.

Q Could you please read for the record the center sentence -- the second sentence actually in the second to the last paragraph or the second paragraph. It begins, "The conclusions are identical" and continues. If you could just read that sentence for the record.

A "The conclusions are identical to those for station 4 except that the deficiencies in the Fourier spectra for the horizontal components at higher frequencies provide further evidence for the need to further constrain the material attenuation parameter for shear waves, Q beta."

Q Now, I am referring, Dr. Frazier, specifically to a part of that sentence that I want you to recall the total context if you can. The part that I am addressing specifically is the word "except" and after that where it states "except that the deficiencies in the Fourier spectra

for the horizontal components at higher frequencies provide further evidence for the need to further constrain the material attenuation parameter for the shear waves, Q beta."

If you could please tell us does that language, particularly that dealing with further constrain, mean that the Q values, your Q values in this model are too low or too high?

A They are probably too low. For clarification of the Board that means they are probably too much dissipation.

Q Dr. Frazier, could you now turn to your testimony --

DR. JOHNSON: I would like to interrupt a minute. The earthquake that you are dealing with in these analyses for San Onofre, how far away from that is the fault from the site?

WITNESS FRAZIER: We are referring here to calculations of the Imperial Valley '79 earthquake and synthetic ground motions were calculated from a distance essentially adjacent to the surface rupture out to a distance of 21 or 22 kilometers.

DR. JOHNSON: Are you sure you are dealing with '79 in this particular document, Supplement 3?

WITNESS FRAZIER: Yes.

DR. JOHNSON: But earlier in the discussions

you were modeling earthquake at San Onofre site with various soil compositions or structural compositions. At the San Onofre site what is the distance of the site to the positive fault that you were discussing?

WITNESS FRAZIER: Okay. The distance from the hypothesized earthquakes of interest for San Onofre are approximately 8 kilometers, but I would like to clear up the earlier -- this morning this is not what we were talking about. We were again talking about modeling earthquakes and other geologies. Those were not results at San Onofre per se, like the Imperial Valley results were calculations we had one earlier to simulate the Imperial Valley 1940 earthquake. That was one of the curves on that plot, for example, or it had to do with that earth structure at Imperial Valley. It was not per se an earth stucture for San Onofre.

DR. JOHNSON: On that Figure IV-18 I think it was. It had four different structures on it, and they were the same earthquake, and the only difference in those spectra was the fact that you had different earth structures.

WITNESS FRAZIER: That is right, and it was at 8 kilometers.

DR. JOHNSON: Okay. Thank you. That's all I have, Mr. Brown.

BY MR. BROWN: (Resuming)

Q Dr. Frazier, would you please look at page VII-10 of your testimony? Do you have it?

A VII-10?

Q Page 10 of your testimony.

A Yes.

Q Could you please direct your attention to line 7. There the term "dip slip" is used. Is it correct that you are using dip slip here to mean dip slip on a vertical fault?

A Yes.

Q Did your model or actually did you model any specific non-vertical dip toward or under the Diablo Canyon nuclear power plant?

A Would you repeat the question?

Q Yes. In the configuration of the model that you did that you are addressing here in your testimony, did you model any specific non-vertical dip toward or under the plant, the Diablo Canyon plant?

A No.

Q Do you, Dr. Frazier, have any geological evidence that a site specific to Diablo Canyon with respect to the possibility of a non-vertical dip?

A I believe that there is testimony by Mr. Hamilton regarding evidence whether or not there is dip.

Q Dr. Frazier, can you now turn to Figure VII-4 of your testimony? We have had some difficulty, and Mr. Norton was cooperative and sent us an additional copy of this page, but unfortunately, the additional copy also was not clear.

We would very much appreciate it if you would clarify for us the legend, particularly where it states "strike slip rupture sequence," which is line A, B, C, and so on through G, and if -- if you could start with that, please.

DR. JOHNSON: Wait a minute. What page are you talking about?

MR. BROWN: This is Figure VII-4 of Dr. Frazier's testimony.

WITNESS FRAZIER: I would like a moment to find out what letters on the various dashed and semi-dashed lines -- I would be very hesitant, and I am going to take a lot of time if I have to do this on the spot. I would like a moment to sit down and put the letters on.

CHAIRMAN SALZMAN: Did you say to make amendations to this page?

WITNESS FRAZIER: No. As I understand the question, I have been asked to identify the various lines shown on Figure VII-4 with regard to whether they are associated with fault A, B, C, D, and so forth. I would

like a minute to be able to look at the dashes and the dots and so forth to label them carefully.

CHAIRMAN SALZMAN: Okay. We will take a break at this point for five minutes.

(Recess.)

parker 4
sp r&t
dsp4-1

CHAIRMAN SALZMAN: Mr. Brown, please go ahead.

BY MR. BROWN:

Q Dr. Fraser, do you have the information that you said you prepared during the break?

A Yes.

Q Could you please give it to us.

A Yes.

I would like to clear up an answer to a question that may have been misleading, if I might at this time.

Q Go ahead.

A I think the answer is correct, but it may be misinterpreted. When you asked me about the dip slip calculations that appeared in my testimony, equal components of dip slip and strike slip, my understanding, I think, was that you were asking me if these calculations in my testimony were performed on a vertical fault plane, and I answered the question that they were indeed performed on a vertical fault plane.

I did not mean to imply anything beyond that. I did not mean to imply that other cases have not been considered; I did not mean to imply that.

Q Yes. Can you please tell us about the other cases that were considered that you just mentioned? Could you describe them?

A Which would you like me to do first? I have two

dsp4-2

things to do now.

Q All right. Let's first get the data that you were going to prepare, and then let's get back to this question.

A Okay. One possible way to transmit this information, I think, would be to use a vu-graph and point to the--with some verbal description, I guess, point to the curves and say that this curve is such and such.

Q If it is all right with the board.

CHAIRMAN SALZMAN: Mr. Brown, are you interested in all these curves, every one?

MR. BROWN: We are really not interested in those that come together. We are interested in the separated ones.

CHAIRMAN SALZMAN: Why don't you identify which curves you want the witness to speak to, and we will ask the witness to do that.

MR. NORTON: Excuse me, Mr. Salzman. I think it would be very difficult for Mr. Brown to describe which curve he wants him to identify. That is his problem, and if Mr. Frazier just simply puts it up on the screen, then he can point with a pointer and say this is curve A, curve B, et cetera.

I think that would be much quicker for everybody.

CHAIRMAN SALZMAN: All right. Mr. Frazier, put it

dsp4-3

on the screen.

(Slide)

CHAIRMAN SALZMAN: Mr. Frazier, I am going to ask you to take the pointer and stand on the other side of the screen.

Pardon me, Dr. Frazier.

WITNESS FRAZIER: On the screen is a reproduction of figure VII-4. In the upper lefthand corner of the figure is the horizontal component for the north 65 east synthetic calculation at high frequencies. The curve that separates out, that is the low curve, is earthquake G.

And similarly at the extreme long periods, the lower curve is also G.

And then working up through this region, I will describe the top curve is A, at long periods. And what I have right in front of me is this one.

(Indicating)

It is earthquake B, as in boy. It is the intermediate curve. Do you want more detail here, or is this okay?

MR. BROWN: That is fine, Dr. Frazier.

WITNESS FRAZIER: Moving to the upper righthand corner, which is the synthetic south, 25 degrees east, the curves are basically overlapping. The only one that is

dsp4-4

different and distinguishable is at long periods the low value is again earthquake G.

The lower lefthand corner are synthetics produced for the vertical components and again both at high and low frequencies. That one that separates out and is low is earthquake G

BY MR. BROWN:

Q Could you please tell us in the south 25 east figure where G is among the congestion there where it becomes congested, where they are separated there, right beyond --

A I am going to have to take a blown up view of that region. Those are so overlapping that it is clearly not easy to read these right here.

Let me look at a blown up view.

MR. NORTON: Excuse me, Mr. Salzman. I would ask as to the relevancy of lines that merge as to which one is which. I cannot in my -- I cannot imagine how that could be significant.

MR. BROWN: We are referring to where they are separated, which is that curve in the open area that can be identified. Dr. Frazier is going to tell us what it is. The unmerged line is what we are trying to identify.

WITNESS FRAZIER: At a period of one second or slight shorter period than one second, I can see earthquake

dsp4-5

G emerging out of the curves by maybe 10 percent.

CHAIRMAN SALZMAN: Below the curve?

WITNESS FRAZIER: Yes, and it is the low value.

(Pause)

At a period of approximately .2 seconds, G is the lower value.

MR. BROWN: That is all we need. Thank you very much.

DR. JOHNSON: Dr. Frazier, the design spectra displayed on those graphs, is that a 2 percent damped version of the design spectra?

WITNESS FRAZIER: Yes.

DR. JOHNSON: Thank you.

CHAIRMAN SALZMAN: Dr. Frazier, is that the end of your presentation?

MR. BROWN: That answers our concerns on the figure, thank you.

CHAIRMAN SALZMAN: You may sit down.

MR. NORTON: Did you also want the next one, VII-5. While we are there, he can do the same thing.

MR. BROWN: I guess while he is there we can get that just to make sure there is no disagreement later.

BY MR. BROWN:

Q Actually, Dr. Frazier, if you would simply tell us where G is on the third figure, if you can do it in there, we need not even put it up.

A You are asking about the vertical component in the lower lefthand of the graph?

Q Just where curve G is.

A For the vertical components?

Q Yes.

A Okay, just a minute.

(Pause)

Yes, G is also the lower value at long periods.

Q Thank you. That is all we need. Thank you very much.

CHAIRMAN SALZMAN: Mr. Brown, before we go any further, quite some time ago you said you would be completing this line of questioning in about five minutes. How much longer do you plan to proceed?

MR. BROWN: That part I was finished with. With the next question in fact we left that. I would say in total, Mr. Salzman, I should be out of this seat in 30 minutes. That is my estimate.

CHAIRMAN SALZMAN: Please proceed, Mr. Brown.

BY MR. BROWN:

Q Dr. Frazier, there was a second point dealing with the dip slip matter that you wanted to clear up, and I asked you if you would please explain it.

Would you now like to do that?

A Yes. I thought that was cleared up, that what I

p4-7

was referring to was in my testimony; that was performed for a vertical fault plane. That is not to mean that other considerations have not been made.

Q If you had other considerations or you made others, would you just identify those for us, please.

A Yes. First of all, I would like to point out that a vertical fault plane in the earthquake model can yield results for dips slightly off from vertical. An example of that is that in modeling the Imperial Valley 1979 earthquake, that earthquake was modeled using a vertical fault plane.

There is some evidence that that fault plane, as many fault planes, may dip a bit off from vertical. There is some evidence that it may dip at about 75 degrees to the east.

And so those test calculations to test the validity of the earthquake modeling procedure have some latitude with regard to dip of the fault.

Secondly, there are random parameters in the model; that is, in the modeling rupture segment, one kilometer segments on a vertical fault plane may just around a little bit away from vertical, and so we have entered into the model modeling procedures, a random dip of individual one kilometer segments with a standard deviation of not to exceed 20 degrees from the gross dip

angle that was specific. So in that case, these random parameters would have some asperity dip angles to them or some random dip angles.

And thirdly, since the time of submission of testimony, I have done additional calculations to ascertain what sensitivity ground motions that Diablo might have from non-vertical dip.

Q Now, do you have those calculations with you, Dr. Frazier?

A Yes, I believe I do.

Q Would you like to provide them to the board and to us?

MR. NORTON: We will have to make copies, of course. It perhaps might be quicker for him to give the results. We will provide you a copy, obviously, if you want.

MR. BROWN: All right. We may have some questions on that. I guess we can -- if the copies could be made promptly, we may have some questions while he is still here. In a few minutes we could bring them out.

MR. NORTON: Do you have any transparencies of those?

WITNESS FRAZIER: Yes, I do.

MR. NORTON: Do you also have a paper copy?

WITNESS FRAZIER: A single paper copy.

sp4-9

MR. NORTON: Why don't we give the paper copy to Mrs. Manning. She can go make copies, and you can put the transparency up, and you can ask questions on the transparency and we will bring the copies back.

MR. BROWN: That is fine with us.

CHAIRMAN SALZMAN: Mr. Brown, do you intend to offer this as an exhibit?

MR. BROWN: Well, give us an opportunuty, please, to see it. Perhaps we will.

CHAIRMAN SALZMAN: My problem is only referring to it. You can mark it as an exhibit for identification. Whether you put it in or not is not the point. My point is it is going to be hard to remember what you are looking at without it.

MR. BROWN: Well, then we will, yes.

CHAIRMAN SALZMAN: All right. The next one would be Governor's Exhibit R-10 for identification. And I would appreciate it if you would describe it or give it a title please.

WITNESS FRAZIER: There are three -- as in figures four and five, there are three components of motion, and consequently there are three vu-graphs or three graphs of results.

CHAIRMAN SALZMAN: Is there a title at the top of it, Dr. Frazier that we can refer to it?

p4-10

WITNESS FRAZIER: You can refer to it as a fault dip study.

CHAIRMAN SALZMAN: Fine.

(The above-mentioned document was marked Governor Brown's Exhibit R-10 for identification.)

CHAIRMAN SALZMAN: One moment, Dr. Frazier.

(Board conferring)

CHAIRMAN SALZMAN: Are you ready, Dr. Frazier?

WITNESS FRAZIER: Yes, I think so.

CHAIRMAN SALZMAN: Are you going to put something up on the vu-graph for us all to see?

Dr. Frazier, how many sheets will you be showing?

WITNESS FRAZIER: I have three graphs.

CHAIRMAN SALZMAN: And they will be reproduced on three pages?

WITNESS FRAZIER: Yes.

CHAIRMAN SALZMAN: All right. The reporter will please make note that Governor's Exhibit R-10 for identification is a three page document.

(Slide)

WITNESS FRAZIER: The first one I am showing here is synthetic ground motions at Diablo Canyon from a rupture offshore model, and it is the component for the south 25 degrees east;shown on the graph is the suitable velocity response spectrum versus period for four configurations of rupture offshore.

dsp4-11

Each of these configurations corresponds to earthquake A. The first configuration -- the first three configurations involve a vertical fault plane with a dip of 90 degrees with varying rates; the first is for a rake of zero degrees which corresponds to strike slip faulting.

The second is for a rake of 90 degrees which corresponds to vertical dip slip faulting, and the third is a rake of 45 degrees which corresponds to equal components of strike slip and dip slip.

All three of these are on a vertical fault plane. And then finally the fourth in the legend is for a dip of 120 degrees, which is 30 degrees from vertical for the orientation of the fault plane in a rake of 45 degrees. That is equal components of strike slip and dip slip.

MR. NORTON: For apoint of clarification, I don't think anybody has ever asked the question about which way it dips, and obviously that is of importance.

BY MR. BROWN:

Q Which way does it dip?

(Laughter)

CHAIRMAN SALZMAN: If you know, Dr. Frazier.

WITNESS FRAZIER: It dips eastward; in this synthetic modeling here we have hypothesized rupture dipping eastward underneath the site.

dsp4-12

DR. JOHNSON: Is the model then in conformance with the 70 degree east dip that Mr. Hamilton suggests is the characteristic of Hosgri offshore from the Diablo Canyon site?

WITNESS FRAZIER: I am sorry, Dr. Johnson. I did not understand.

DR. JOHNSON: As I recall the testimony of Dr. Hamilton, he suggested Hosgri at a depth greater than something like 2000 meters, I think, 2 kilometers as a 70 degree east dip.

WITNESS FRAZIER: Right. There is evidence to that in his testimony, right.

DR. JOHNSON: Does the dip which you have included in your model conform then to that actual configuration of the Hosgri fault?

WITNESS FRAZIER: Not precisely, no.

This is more extreme than what he sees from evidence. This is an effort to bound the effect.

DR. JOHNSON: All right.

WITNESS FRAZIER: And basically the conclusion here is that there is little sensitivity to that sort of dip.

BY MR. BROWN:

Q Dr. Frazier, how much difference is it? What do you mean by "a little"?

dsp4-13

A The various synthetic -- the various results obtained from the earthquake modeling are tightly packed in the area of interest and the frequency range of interest, and there is little separation between the various results. That is what I mean by insensitive to this parameter.

CHAIRMAN SALZMAN: Mr. Frazier, are you using "of interest" in the same sense we used it before?

WITNESS FRAZIER: The results are very tightly packed for frequencies higher than about 3 hertz.

CHAIRMAN SALZMAN: Thank you.

DR. JOHNSON: Dr. Frazier, this is a plot of pseudo-velocity versus period. Is the frequency range of interest in this curve the same as it would be for a plot of acceleration versus period?

WITNESS FRAZIER: Yes.

DR. JOHNSON: Thank you.

BY MR. BROWN:

Q Dr. Frazier, is the top curve on the figure that you have before us now higher than the top curve on your figure VII-4?

Perhaps you should get a copy of that; it is from your testimony on the horizontal component, south 25 east. Could you compare those two for us, please.

A It is a little confusing for me.

Q Would you compare that figure with your figure VII-4?

p4-14

(Pause)

Which of the upper curves is higher of the two figures that you are now comparing?

A It appears to me that the one on the vu-graph is higher at -- yes, is slightly higher.

end 4

Q Dr. Frazier, is this the mean curve?

A Yes.

Q We are finished with this particular graph.

I think we understand this without having to burden you with a question. There is no question on that one, so if you would like to go to the third one, it would be fine.

CHAIRMAN SALZMAN: One moment.

Before you tell the witness to go on, Mr. Brown, I would appreciate it if you would wait until we find out whether we have any questions.

Go ahead, Dr. Frazier.

WITNESS FRAZIER: This is the corresponding hypothesized earthquake off-shore, and it presents four pseudo-velocity responses, the vertical component ground motion compared with the re-analysis spectrum.

DR. JOHNSON: Were these calculations performed for 2 percent damping?

WITNESS FRAZIER: I will need to review that to get the answer. I am not certain they are all 2 percent damping. I am at least 90 percent sure that they are all 2 percent damping, but perhaps I should check for the record.

DR. JOHNSON: Thank you.

WITNESS FRAZIER: The answer is yes.

DR. JOHNSON: Thank you, Dr. Frazier.

BY MR. BROWN:

Q Dr. Frazier, could you go back to the second figure, we have one question.

A That refers to the north 65 east.

Q Could you tell us please for the real earthquake what would be a reasonable standard deviation for response spectrum of about 5 Hertz?

A With regard to what? A reasonable standard deviation with regard to what; I don't understand.

Q The standard deviation for many different earthquakes?

A You mean, if I recorded ground motion for many different earthquakes and plotted response spectrum, and looked at 5 Hertz what would be the scatter in the data?

Q Yes.

A I think that it is a function of distance and magnitude, and many things, soil properties.

Q In close to the earth for Diablo Canyon, distance, for example?

MR. NORTON: It is just one of many variables that Dr. Frazier said he would need to know.

MR. BROWN: I would like to know whether he can answer it with that additional variable.

WITNESS FRAZIER: I don't know if I understand the

3

question. Even if we keep pursuing all the parameters, I have not done such a study.

DR. JOHNSON: Dr. Frazier, I believe in your written testimony you indicated that you were performing calculations of the IV-79 earthquake using this model.

WITNESS FRAZIER: Yes.

DR. JOHNSON: But that those calculations had not been completed. Is that still the situation?

WITNESS FRAZIER: No. Those calculations are contained in, I believe, Joint Intervenor's Exhibit R-9, the title is Supplement 3.

DR. JOHNSON: So those calculations which you indicated had not been completed have now been completed, and they are in that exhibit; is that correct?

WITNESS FRAZIER: Yes.

DR. JOHNSON: Thank you.

BY MR. BROWN:

Q We are finished with the graphs for our purposes.

Dr. Frazier, in your model of Hosgri what would be the effect on ground accelerations and response spectra if the values for Q beta were doubled?

A I have not performed the calculation, but I think the ground motion would certainly increase.

Let me clarify that. I think that it is very important. The results that are obtained from modeling

calculations are a complete package. That is, if for some reason I were to want to double the Q values, or reduce dissipation factors by a factor of two, I would be forced, I believe, since that is contrary to the modeling procedure that we are using, to go back and revalidate the model.

So in that context the ground motion probably would not vary in any significant amount. To recalibrate would make other properties in the model readjust to the strong motion data closer into larger earthquakes that the model has been calibrated against, and then brought back to Diablo where we performed the calculations. It would yield about the same results.

Q Dr. Frazier, would increases in Q values in your Hosgri model increase the distance that high frequencies will travel?

A I think I should answer the question that I think you are asking me. The question I think you are asking me is, would high frequency motion from larger distances increase in significance. The high frequences, I think, don't travel any further, but the significance might be altered.

Q Yes, please answer that.

A Yes, that would be the case.

Q So, is it correct that in your model, Dr. Frazier, a decrease in attenuation, that is an increase in Q, will

extend the distance from the site that energy can contribute to focusing?

A That question, I think, bears on Qs at greater depth, and Qs within a few kilometers of the earth surface probably would have little effect on that. I think that is an issue of Qs down here near the mantle, just above the mojo.

Q Can you tell us please what would be the effect, if you know, at 5 to 10 kilometers?

A We are still talking about focusing?

Q The same question, but taking the depth that you just mentioned going 5 to 10 kilometers.

A I think that if -- I don't know, I think that is a question, as I mentioned earlier, that would involve recalibrating the model. So it is rather difficult to know in calibrating the model. So you see, if we have other things like randomness in the model that also bear on the question.

So if I arbitrarily change Qs in the model, I might be forced to go back and change other things in the model which would give the opposite effect of my guess here. So I don't know the answer. If I did not change anything, it would be an invalid model, and probably the answer to your question would be yes.

Q Thank you.

Dr. Frazier, could you now turn to your Figure 7-4

in your testimony?

A Yes.

Q Do you have that?

A Yes.

Q North 65 east, is the curve separated due to focusing?

A There is a tendency that earthquake G is lower than the other values, and earthquake G is defocused. The answer is that there are effects of focusing in these curves, and you can see it.

Q Is the corresponding curve separated in the figure south 25 east?

A Surprisingly not, the frequency is higher than about one Hertz.

Q Do you know why not?

A In these calculations, the rupture nearest to the site on the Hosgri at the points nearest to the site tend to be the culprit for producing the highest amplitude ground motions. I believe that the focusing or defocusing is not very much at issue at points perpendicular to the site.

Q Dr. Frazier, could you now turn to page 5 of your Supplement 1, which is Figure 6-3 in Joint Intervenor's Exhibit R-7, page 6-5 of Supplement 1.

A Yes.

Q Have you had a chance to briefly look at it?

A Yes I think I am back up to speed on this one.

Q We are jumping between quite a few. We want figure 6-2, and I may have said figure 6-3. I actually would like the southeast site, do you have that?

A Yes.

DR. BUCK: Are you talking about page or figure?

MR. BROWN: We are talking about the figure. We are talking about Figure 6-2, and at the top of the figure it says southeast.

DR. BUCK: Thank you.

BY MR. BROWN:

Q Dr. Frazier, you are comparing curves B and F. Is focusing shown for all three components at the eight kilometer distance from the site?

A For faults, the configurations B and F?

Q The question is, is focusing shown?

A The effects of focusing are shown.

Q Can you please explain for us why it is shown in this southeast component please, but according to your testimony it is shown in the southeast component, and in your Figure 7-4 of your testimony?

A I could speculate, that is all I would know how to do.

Q If you don't know, that is a satisfactory answer.

A I don't know. I think there are many reasons.

Q Dr. Frazier, now can you turn to page 7-11, or page 11 of your prepared testimony? I am specifically looking now at lines 23 through 25 if you would like to briefly look at that paragraph to refresh yourself. We are dealing there with time demand signals.

A Yes.

Q Dr. Frazier, could you please explain why the vertical accelerations do not show higher amplitude motion given that the Diablo Canyon design earthquake is larger than the IV-79 earthquake?

MR. NORTON: Excuse me, but is he restricted to one reason?

MR. BROWN: He can answer it any way he likes.

WITNESS FRAZIER: The question is, why the high vertical --

BY MR. BROWN:

Q Why the vertical accelerations do not show higher amplitude motion given that the Diablo Canyon design earthquake is larger than the IV-79 earthquake.

A Is the question, why they are not higher than the IV-79 earthquake, but you are not telling me higher than what?

Q Yes.

A I think that is laid out fairly clearly in my testimony to Question 4.

DR. JOHNSON: May I ask a question to clarify the question you just asked?

Are the maximum accelerations in each of the three directions indicated by the number on the left side of the platt, for example, the vertical motion of earthquake F at the top, having a maximum acceleration of 0.145G?

WITNESS FRAZIER: Yes.

DR. JOHNSON: Is that the way to interpret that?

WITNESS FRAZIER: Yes.

DR. JOHNSON: Thank you.

CHAIRMAN SALZMAN: Go ahead, Mr. Brown.

MR. NORTON: Excuse me, we have the exhibit, I guess it is Governor's R-10, paper-clipped in a packet of three. I wanted to know that this is what was. They are not marked, however.

CHAIRMAN SALZMAN: Take a moment and pass it around.

Do you mind, Mr. Brown?

MR. BROWN: I wonder if we might take a couple of minutes break at this point because something came up which I would like to clarify.

CHAIRMAN SALZMAN: In a couple of minutes, you are going to give up that chair completely.

MR. BROWN: Apparently what happened is that we had an additional response that we did not expect, and it

1 involved a substantial amount of time when Dr. Frazier went
2 to the new exhibit to explain that.
3 CHAIRMAN SALZMAN: We will take a break for five
4 minutes, and only five minutes.
5 (Whereupon, a short recess was taken.)
6 CHAIRMAN SALZMAN: We are back on the record.
7 Mr. Brown, since we have allowed considerable time
8 for cross-examination, we have a lot of other matters which
9 the Board wishes to get to, I would appreciate your complet-
10 ing this line of questioning in no more than 10 minutes.
11 MR. BROWN: That is fine.
12 BY MR. BROWN:
13 Q Dr. Frazier, would you please direct your atten-
14 tion to page 6-23 of the Supplement 1, which is the Joint
15 Intervenor's Exhibit R-7.
16 MR. NORTON: Excuse me, but Mr. Brown, would you
17 please identify the document first, and the page last.
18 MR. BROWN: Supplement 1, Joint Intervenor's R-7.
19 BY MR. BROWN:
20 Q Do you have that?
21 A Yes.
22 Q Dr. Frazier, would you please look at the second
23 paragraph.
24 A Yes.
25 Q Would you address yourself to that, because I would

like you to read one sentence for the record.

(Pause.)

Q Have you read it?

A Yes.

Q Would you please read for the record the second to the last sentence in that paragraph, which begins "our ability is"?

A Yes. The sentence reads: "The probability --

CHAIRMAN SALZMAN: Just one minute.

BY MR. BROWN:

Q Please continue, Dr. Frazier.

A "The probability is higher for getting large ground acceleration from large magnitude earthquakes since there is greater likelihood of having the rupture focus at the recording station for larger zones of rupture."

Q Dr. Frazier, have you changed your opinion on that statement?

A No.

Q Dr. Frazier, could you now please direct your attention to Figure 6-19 of the same document, it is on page 621?

A Yes.

Q Have you had a chance to look at it?

A I think I am prepared.

Q Could you please explain to us the meaning of

this figure?

A What I see plotted in the figure is pseudo-velocity response spectrum for three hypothesized earthquakes. For one hypothesized earthquake, I senthetized at three distances, 4, 8 and 12 kilometers.

Q Kilometers from what, Dr. Frazier?

A From the surface trace of the zone of rupture.

Q This is thefinal question for us, and it is going to be complicated. I would like you to compare three documents. So why don't I have you put the three in front of you first.

The first is Figure 7-6 of your testimony. Actually, I am going to hand you still a page that has all three of them on it. We did it by Xerox, and perhaps after you have looked at the three figures, you can confirm whether or not this is an authentic representation of the three figures. I think that it will make it easier for everyone to look at a single document.

MR. NORTON: To speed things up, if you pass the document out.

MR. BROWN: Perhaps we should mark that for identification. We will mark that as Governor's Exhibit R-11.

CHAIRMAN SALZMAN: The reporter will mark this latest document R-11 for identification. It is entitled,

XXX

in the upper-right-hand corner, Imperial Valley Earthquake Computation.

(The above entitled document was marked Governor's Exhibit R-11 for identification.)

BY MR. BROWN:

Q Do you have a copy of that now?

A Yes, I have a copy of what was just handed out. I don't know where the various components came from.

Q The figure in the left corner of the page in the vertical is Figure 7-6 of your testimony. If you would like to mark that or confirm it.

MR. NORTON: Excuse me, but looking at 7-6, it is only half of it.

MR. BROWN: Yes, it is the upper-half.

MR. NORTON: Okay.

BY MR. BROWN:

Q Next is the figure 3-8, which is at page 3-15 of Joint Intervenor's R-6.

DR. JOHNSON: What do you mean by next?

MR. BROWN: The one in the upper right.

DR. JOHNSON: Would you identify it again, please, sir?

MR. BROWN: It is page 3-15, and it is shown as Figure 3-8. It is only the three eccelograms in that

figure.

DR. JOHNSON: Which document?

MR. BROWN: It is in the final report, Joint Intervenor's Exhibit R-6.

CHAIRMAN SALZMAN: The document first, and then the page.

MR. BROWN: It Joint Intervenor's R-6, and the page is 3-14. It is figure 3-7.

I am advised by Dr. Brune that it is not the same figure, but it is a better representation. It is the Cal Tech accelogram.

BY MR. BROWN:

Q Dr. Frazier, are you familiar, so that you are comfortable with this particular figure?

CHAIRMAN SALZMAN: I have lost you, Mr. Brown; which is not the same figure?

MR. BROWN: The bottom one.

CHAIRMAN SALZMAN: The bottom one is not Joint Intervenor's R-6, page 3-14?

MR. BROWN: Dr. Brune advises me that it is a better representation. It is the Cal Tech accelogram of the El Centro earthquake, and I would ask Dr. Frazier to confirm that. If so, I would ask that it be accepted for this purpose.

WITNESS FRAZIER: Yes, I assume that that is a

clearer representation of what is on page 3-14 of R-6.

MR. NORTON: Excuse me, I would like to ask one of my witnesses a question or two about this before I am willing to accept it.

CHAIRMAN SALZMAN: Go ahead, Mr. Norton.

(pause.)

MR. NORTON: I think we have to clear the record up a little bit. The second thing discussed by Mr. Brown is in the upper-right-hand corner. What that is is from 3-15, page 3-15 of Joint Intervenor's Exhibit R-6, but what they have done is taken the top line of each of the three diagrams on Figure 3-8, page 3-15, not any one of the boxes which that first glance might cause one to believe.

Similarly, when you go to what is on the bottom, which supposedly is a better representation than on page 3-14 of the same exhibit, again these are the three top lines of each of the three boxes. The boxes, of course, have three lines, and it is confusing at first blush. That is what I was confused about until I talked to Dr. Frazier.

So it is not a representation of any one of the boxes, but only one line out of each box.

MR. BROWN: It is absolutely correct. Our intention was to simplify it.

MR. NORTON: But I was having problems identifying

which one was which.

CHAIRMAN SALZMAN: Does the witness understand which is which?

WITNESS FRAZIER: Yes, I believe I have it figured out.

CHAIRMAN SALZMAN: Mr. Brown, please proceed because this is going to be your last question.

MR. BROWN: I have three questions related to this.

CHAIRMAN SALZMAN: Get them out, please.

BY MR. BROWN:

Q Is it correct, Dr. Frazier, in your figure 7-6 that earthquake F ruptures about 40 kilometers passed the site?

A This is figure 7-6 of my testimony?

Q Yes, sir.

A Does it rupture about 7 kilometers?

Q About 40 kilometers passed the site?

A All I can do is refer to figure 7-3, and that may be approximately correct. I have no issue with the number.

Q That is fine.

Is energy from the southeast end from earthquake F shown on arriving at the site?

MR. NORTON: Where?

MR. BROWN: On this record.

MR. NORTON: Where on the record do you mean?

MR. BROWN: The same figure.

MR. NORTON: That is what I wanted to make sure.

WITNESS FRAZIER: Energy from the southeast extreme, or end of the earthquake F shown in figure 7-6, I believe it is?

BY MR. BROWN:

Q Yes, arriving at the site.

A It is certainly contained in all those wiggles.

Q Is amplitude high compared with similar energy in the 1940 earthquake, which is in the figure on the bottom of that page?

A I don't know how I would relate energy coming from the southeast end of that rupture with the Imperial 1940 earthquake. I don't have a context, I don't think, for comparing whether they are the same. or different. I don't understand.

CHAIRMAN SALZMAN: Mr. Brown, do you have one final question before we proceed?

BY MR. BROWN:

Q Dr. Frazier, please explain the figure in the right corner of the Imperial Valley earthquake computation why there is little energy shown on the right extremity line compared with the real data?

A One of the reasons is that this was taken from a report more than two years ago, and has been redone and is available in Supplement 1 in a revised fashion with an improved earthquake model.

This is a version of the earthquake model that is outdated, and I think that this is the major reason. That is, the model has no randomness on the rupture surface. It incoherent rupture.

Q Is also part of the reason due to the low Q values?

A I presume the Qs used for that rupture are representative of the Imperial Valley -- so low with respect to what?

Q Low compared with what would be needed to make the two records agree with each other?

MR. NORTON: I object.

CHAIRMAN SALZMAN: Objection sustained.

The witness has already said that this is a bad representation, and that there is more recent up-to-date data.

You have consumed the time available.

MR. BROWN: That is fine.

CHAIRMAN SALZMAN: I think we will close that line of questioning.

Would counsel approach the bench, please?

CHAIRMAN SALZMAN: Mr. Olmstead, you are going to waive cross examination of these witnesses?

MR. OLMSTEAD: Yes.

CHAIRMAN SALZMAN: All right. This panel is excused for the time being.

(The witnesses were excused.)

CHAIRMAN SALZMAN: Mr. Olmstead, would you go ahead and proceed? You have a panel.

MR. OLMSTEAD: Yes, Mr. Chairman. The staff is going to call its first panel, a panel comprised of Dr. Nathan Newmark, and we are going to bring him up and his chair, if you will indulge us that -- Dr. Robert Rothman, Dr. Pao-Tsin Kuo, and we would also -- are planning on bringing Mr. James Knight out who has no testimony filed on these issues, but who is responsible for coordinating the staff's presentation of this case and appeared as panel lead in the Board below.

CHAIRMAN SALZMAN: Please ask them to take the stand.

MR. OLMSTEAD: Now that the witnesses are all seated, if they will stand to be sworn.

CHAIRMAN SALZMAN: Mr. Norton, are you ready to proceed?

Mr. Lanpher, are you going to be handling this part?

MR. LANPHER: Yes, I am.

CHAIRMAN SALZMAN: Mr. Fleischaker, are you ready to proceed?

MR. FLEISCHAKER: Yes, sir.

CHAIRMAN SALZMAN: Will the witnesses please raise their right hands?

Whereupon,

NATHAN M. NEWMARK

ROBERT L. ROTHMAN

PAO-TSIN KUO

JAMES P. KNIGHT

were called as witnesses by counsel for the NRC staff and, having been first duly sworn by the Chairman, were examined and testified as follows:

CHAIRMAN SALZMAN: Mr. Olmstead.

DIRECT EXAMINATION

XXXX BY MR. OLMSTEAD:

Q Dr. Newmark, I have in front of me a copy of a document entitled "Testimony of Nathan M. Newmark, Consultant to the U.S. Nuclear Regulatory Commission," and I ask you if this document is your testimony in this proceeding?

A (Witness Newmark) Yes, it is.

Q And do you have any corrections you wish to make to that document?

A Yes. There is one correction. On page 14 there

is a typographical error. Either a sentence was omitted or a reference was confused. I do not have my draft with me, but I have made a correction which clarifies the point at issue.

Q Would you indicate where that correction should be inserted?

A Four lines from the bottom of page 14, the words "more clearly described in" and let me read the corrected version instead of the actual version. "More clearly described in a proposal to the National Science Foundation for detailed analysis of the damage to the building by Sozen, shown in Figure 1 taken from that proposal."

Q Do you have other corrections to your testimony at this time?

A No.

MR. NORTON: Could someone who got that read it back to me? I did not get it.

CHAIRMAN SALZMAN: Will the Reporter please read it back? It will, of course, appear in the transcript.

BY MR. OLMSTEAD: (Resuming)

Q Dr. Newmark, attached to your testimony is a statement of professional qualifications. I ask you if those are your qualifications.

A Yes, they are.

Q And taking your qualifications and your testimony

as corrected, is it true and correct to the best of your knowledge and belief?

A Yes, it is.

MR. OLMSTEAD: Mr. Chairman, I move the testimony of Dr. Nathan M. Newmark be bound into the transcript as if read.

CHAIRMAN SALZMAN: Please do so.

(The document referred to follows:)

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 Nos. 1 and 2)	Docket Nos. 50-275 O.L. 50-323 O.L.

Testimony of Nathan M. Newmark

Consultant to the U.S. Nuclear Regulatory Commission

INTRODUCTION

The purpose of this testimony is to reply to certain questions concerning seismicity, seismic design, and safety to resist the effects of earthquakes, of the Diablo Canyon Nuclear Power Plant Units 1 and 2 raised by the Atomic Safety and Licensing Appeal Board (ASLAB) in its Decision dated June 24, 1980.

In order to present my comments and answers in a consistent manner, this document is divided into two parts. The first part is a brief discussion of fundamental issues in earthquake resistant design, to lay the groundwork and explain the basis of the second part, which consists of answers to specific questions raised by the ASLAB.

My qualifications for this work are described briefly below. I have been a consultant to the NRC and to its predecessor, the Atomic Energy Commission, for nearly 20 years. A summary of my extensive experience and responsibilities is contained in my testimony of 8 November 1978 before the Atomic Safety and Licensing Appeal Board. A list of my degrees, both earned and honorary, and my awards, medals, and honors, is contained in my biographical sketch dated November 1979, attached hereto, with an addendum to June 1980. A list of my published technical papers and books, numbering 243 as of this date, is also attached.

I. FUNDAMENTAL ISSUES IN EARTHQUAKE RESISTANT DESIGN

A. Relation Between Seismic Response Spectra and Seismic Design Coefficients

In order to understand some of the data concerning earthquake damage, the damage, and also the lack of damage, must be considered in relation to the design basis. Nuclear reactor structures are designed with the use of a seismic response spectrum with generally elastic behavior, with allowable stresses not exceeding the yield strength of the material. See, for example, Newmark and Rosenblueth (1971), and Newmark (1970). Other structures, and particularly buildings, including schools, apartment buildings, commercial structures, etc. are generally designed using a seismic coefficient specified by building codes, such as the Uniform Building Code, for the total lateral or shearing force at the base of the building, with some distribution of lateral force over the height of the building, at a level of stress corresponding to the allowable static working stress augmented by a factor of 1/3 when earthquake (or wind) forces act on the building. The net design coefficient at the base of the building is used with about 2/3 of the yield strength. The equivalent coefficient is, therefore, about twice the allowable static coefficient at the yield point of the material. There is an implied requirement of ductility to resist the actual expected earthquake, because the earthquake forces may be several times greater than the static coefficient. Taking into account the spectrum amplification factor, the peak ground

acceleration used for nuclear reactor structures is at least 3 to 4 times that corresponding to the seismic coefficient used for even the most important building when the sites are the same, but nuclear reactors are generally designed for a peak site ground acceleration of 1 1/2 to 2 or more times that used for an ordinary building.

Recently, design recommendations were made for design of structures using a design response spectrum and a ductility factor or spectral reduction factor depending on the framing and material of the building, ranging from about 1 for unreinforced masonry walls to about 8 for ductile steel frames. See ATC-3 (1978). The spectral reduction factors developed give design coefficients generally exceeding those in current building codes.

The design response spectrum is obtained by taking the peak effective ground accelerations, velocities, and displacements expected at the site, and amplifying them by factors such as those given in Newmark and Hall (1978), where these factors are a function of the damping in the structure and its foundation.

As a result of the fact that the effective peak acceleration used for structures as in ATC-3 (1978) are generally only about half of the SSE acceleration levels used for nuclear reactors, and because there is no spectral reduction factor used in nuclear structural design, nuclear reactor structures are designed for seismic forces ranging from 4 to 10 times those corresponding to the Uniform

Building Code or other building codes, for the same seismic environment or site, as explained above.

B. Effect of Eccentricity of Seismic Loading

As discussed in Newmark and Rosenblueth (1971) or Chopra and Newmark (1980), there are two sources of enhanced response of a structure in an earthquake over the response computed by assuming only uniform lateral deformations over the width of a building. If the center of stiffness of the framing of a building departs significantly from its center of mass, there is a real eccentricity giving rise to a torsional or twisting deformation coupled with the uniform lateral deformation.

This torsional response causes one side of the building to deform more than the opposite side, and often causes a progressive failure or collapse. Moreover, as failure occurs, the torsional response increases.

There is also a small torsional response even for symmetrical structures with no real eccentricity, caused by the wave passage of the earthquke motions over the width of the building.

These topics are discussed in ATC-3 (1978) in the commentary on Chapter 4. In general, buildings to resist earthquakes should be symmetric, and real torsional eccentricity should be avoided. Where it cannot be avoided, provision for the increased response must be provided. Most older buildings do not have any provision

even for real torsion in their design. Much of the damage noted in earthquakes is caused by eccentricity of shear walls, or by concentrating the shear resisting element near the center of the structure, enhancing the torsional response due to wave passage effects.

C. Overturning and Compressive Vertical Forces

Because a building must inevitably have a moment at its base (overturning moment) due to the distribution of inertial lateral forces over its height, there is a tendency to cause tilting or tipping, which produces higher compressive forces in the vertical direction near the perimeter of the structure. This topic is discussed in the commentary on Chapters 3 and 4 of ATC-3 (1978), and in Newmark and Rosenblueth (1971), Sect. 15.7.

The increased compression due to the overturning moment must be provided for in the outer and especially the corner vertical members (columns and walls) of the structure. Methods of increasing the vertical compression capability of columns near joints and connections is required to give both increased strength and increased ductility. Many of the failures observed in earthquakes were caused by inadequate or no provision for the increased compressive forces. The Imperial County Services Building is a particularly good example of inadequate provision for both overturning and torsional eccentricity, with ties spaced at about 12 inches or more apart rather than the 2 or 3 inches corresponding to good design practice near the joint.

D. Effects of Discontinuities in Strength or Stiffness

When there are abrupt changes in stiffness or strength over the height of a building there is a concentration of stress at the discontinuity which may give rise to collapse or failure. Such discontinuities have played an important part in many of the observed failures in earthquakes. One of the most common discontinuities is the use of a so-called flexible first story, either intentional or unintentional.

Several examples are discussed herein of failure due to discontinuities or abrupt changes as documented in reports of earthquake damage. For example, the Macuto-Sheraton Hotel near Caracas had its three lower floors supported only on columns, while the upper stories of the ten-story building was of heavy shear wall construction. The columns in the lower stories failed and the building nearly collapsed.

A description of the building is contained in Hanson and Degenkolb (1967), p. 98-99, and a detailed description of the damage in Sozen et al (1968), p. 58-62. A sketch of the framing of the building is shown in Fig. 7.5 from that reference. The column failures were influenced primarily by the discontinuities in strength and stiffness between the lower 3 stories to the upper part of the building, but were contributed to by the effect of accidental torsion and the overturning moment.

A particularly interesting response occurred in the Palace Corvin in Caracas, which is described in Hanson and Degenkolb (1967),

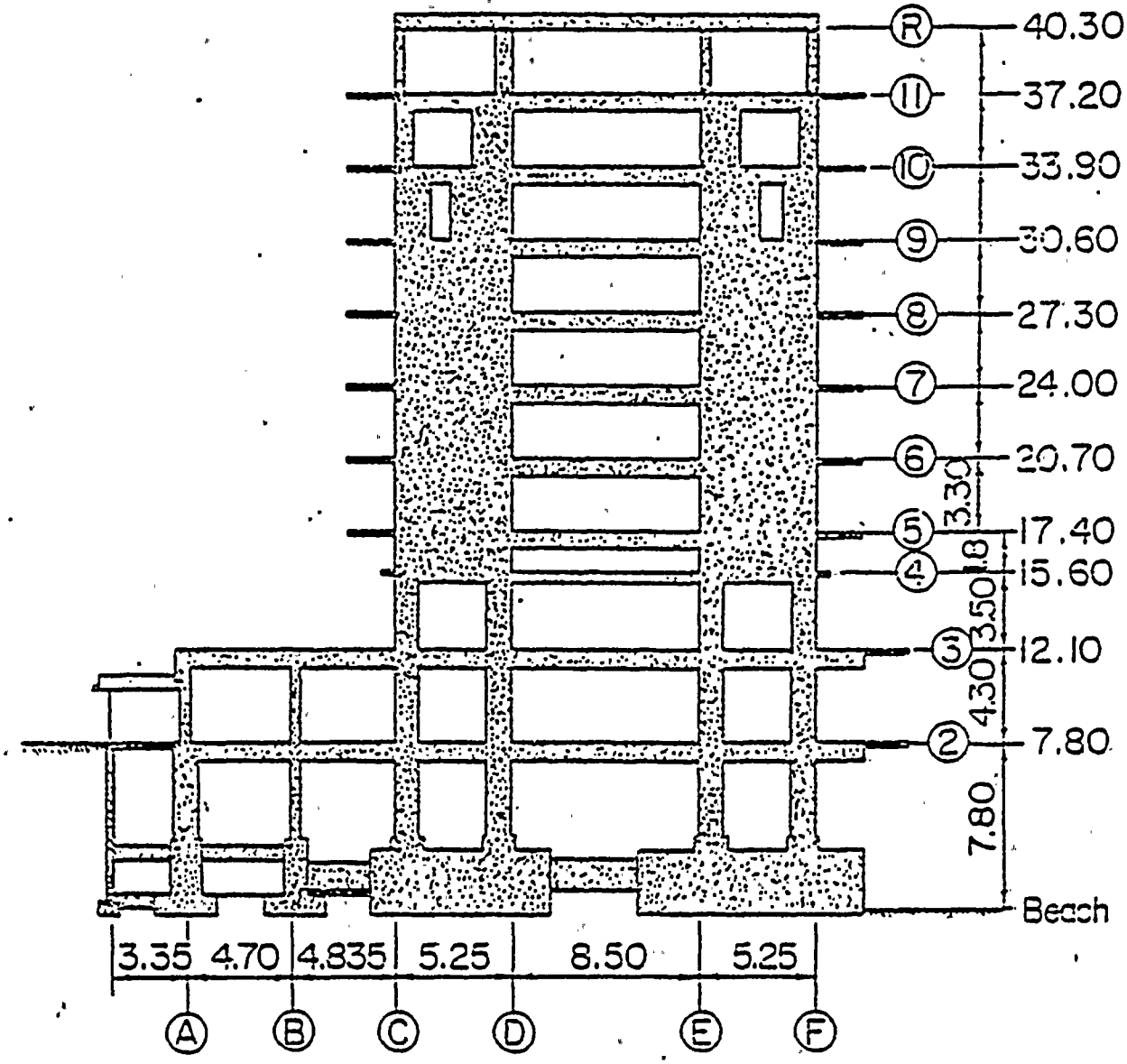


FIG. 7.5 SECTION, THE MACUTO-SHERATON
(East Elevation)

pp. 48-49. This structure consisted of two nearly identical ten-story apartment buildings joined by a common elevator shaft and staircase. The west building had exterior walls continuing to the foundation level, and the east building had the walls removed in the first story to provide for parking. The east building collapsed completely, while the west building had no structural damage. A photograph of the remaining west building, looking across the site of the collapsed eastern half is shown in Fig. 4.11 taken from Sozen et al (1968). This building failure demonstrates clearly the damaging effect of discontinuities in strength and stiffness.

It is examples like this which led the ATC to provide for an increased resistance near discontinuities. See ATC-3 (1978), Sect. 3.7.3.

E. Effects of Piles and Wave Passages

In general, piles do not affect the lateral response of a building due to earthquakes, since they must conform to even soft ground shear deformations because the soil mass is stiffer by a larger margin than the piles. However, large and stiff caissons or piers may affect the lateral response, depending on the design of the pile cap between the piles or piers of the building. Piles do affect the vertical response of a building because of their transfer of the point of support to a level where the soil is generally stiffer than at the surface level or the foundation mat or footing level. The fact that a building is supported on individual footings may affect its response

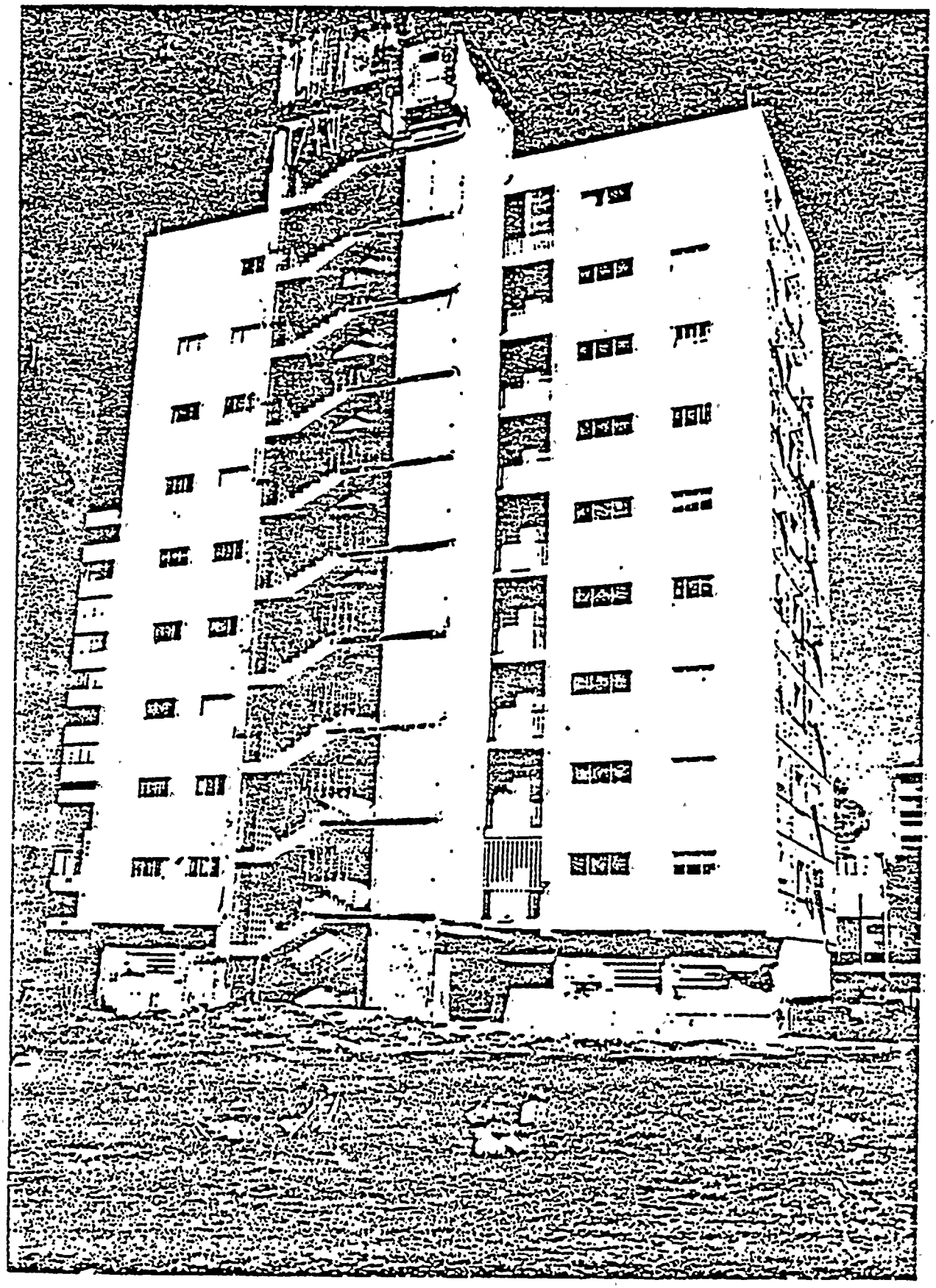


FIG. 4.11 EAST ELEVATION OF THE PALACE CORVIN BUILDING SHOWING THE WEST WING AND THE SERVICE CORE

compared with a building supported on a raft or large foundation, if the individual footings are not well tied together. However, building codes generally provide for heavy ties or braces between the individual footings, whether or not they are supported on piles. When these are present and properly designed, the building responds as if it were supported on a single foundation structure.

Hence, the wave propagation effect in reducing the high frequency response of a building is not affected by pile supports, but rather by the design of the pile cap under the building and the presence or absence of ties connecting the pile caps. However, one should not expect to identify Tau effect reductions in response for poorly designed buildings in which, because of torsional effects or high overturning compressions not provided for or stress concentrations due to discontinuities, there is a major increase in response in the lower floors. Moderately well designed buildings will generally show the wave passage reduction effects. Poorly or inadequately designed buildings will only show failure.

F. Over Registration of Response in Vertical Acceleration

The instruments used to measure acceleration time relationships are themselves responding structures coupled with their supports. When instruments that are mounted on isolated blocks, generally of concrete, resting on or only slightly embedded in the ground, the block and the soil immediately beneath it give a response which is amplified above that of the acceleration of the ground itself in the free field. This

is true also of instruments in buildings if they are not firmly tied with ties of high rigidity to the building structure. This over registration gives a spurious indication of high vertical acceleration for frequencies in excess of 3 to 4 hertz, as demonstrated in Newmark (1974) and in Bolt and Hansen (1977). This over registration may be as much a factor of 2, and may lead to indications that vertical accelerations greater than 1 g exist, when the actual vertical acceleration in the free field is of the order of 0.5 to 0.6 g.

Although there is a slight tendency, similarly, to over record horizontal responses, it is relatively negligible and has not been considered in development of design criteria. The over registration in vertical response, as indicated in the references, is taken into account in the criteria that I developed for the design of buildings and nuclear reactor facilities, in which the vertical acceleration response is taken as 2/3rds of the horizontal acceleration response over the entire range of frequencies, as developed from statistical studies reported in Newmark and Hall (1978), and in contrast with the earlier design requirements of USNRC Regulatory Guide 1.60. This is also taken into account in Hall, Mohraz and Newmark (1976). Occasionally in thrust faults the vertical acceleration response may exceed 2/3rds of the horizontal value but rarely if ever in strikes-slip fault motions.

G. Probability Levels Implied in Design Response Spectra

In general, in all of the design criteria for design response spectra, the SSE earthquake acceleration at which the spectrum is anchored is

taken at the median plus one standard deviation value, and the spectrum is also taken as the median plus one standard deviation value. Similarly, the fragility or strength of structures and equipment is taken at the median plus one standard deviation. When these are combined, the probability of exceeding the design level is at a much lower probability level than the median plus one standard deviation. The techniques for making the combination are described in Cornell and Newmark (1978) and in Ang and Newmark (1977).

Extreme upper limits for free field earthquake acceleration may be very high but are not of significance since the spectrum does not depend on isolated high peaks of acceleration. If one were to take an envelope of all of the values developed for response spectra for various earthquakes one would obtain an unreasonably high degree of conservatism that would make it impossible to design buildings of any sort, and particularly nuclear reactors, without causing failures from other sources such as thermal stresses, and brittle fractures arising from lack of ductility in highly overdesigned sections.

Ductility and energy absorbing capacity are the aims of earthquake resistant design. Consideration of strength alone can often be self defeating.

II. ISSUES RAISED BY APPEAL BOARD

The following discussion is in reply to specific topics raised by ASLAB for the Diablo Canyon facilities.

A. Imperial Valley Earthquake Data

In general, the revised and corrected data for the Imperial Valley Earthquake give results that are not greater than those used in nuclear reactor design as exemplified in the design criteria specified by me for the Diablo Canyon reactor facility. See Newmark (1976). There are some instances in which the uncorrected data are greater, and there are also some instances in which the vertical measurements in the high frequency region are greater than the horizontal reading of acceleration. However, these instances are generally due to over registration in frequencies in excess of 3 to 4 hertz as discussed in Part I F, above and to site conditions in the Imperial Valley which do not exist at Diablo Canyon.

A recent study by Donovan (1980) shows data from 115 stations within 20 kilometers of a fault, plotted to show the relation between peak recorded acceleration and distance from the fault in kilometers. Magnitudes from 3.5 or less up to 7.5 are considered, and the data show no consistent relationship with magnitude. This is an indication of the fact that the high dependence on magnitudes reported in some attenuation relationships is probably a spurious one. Basic physical principles indicate that close to the source of the earthquake the peak acceleration should be dependent only on the local conditions, including

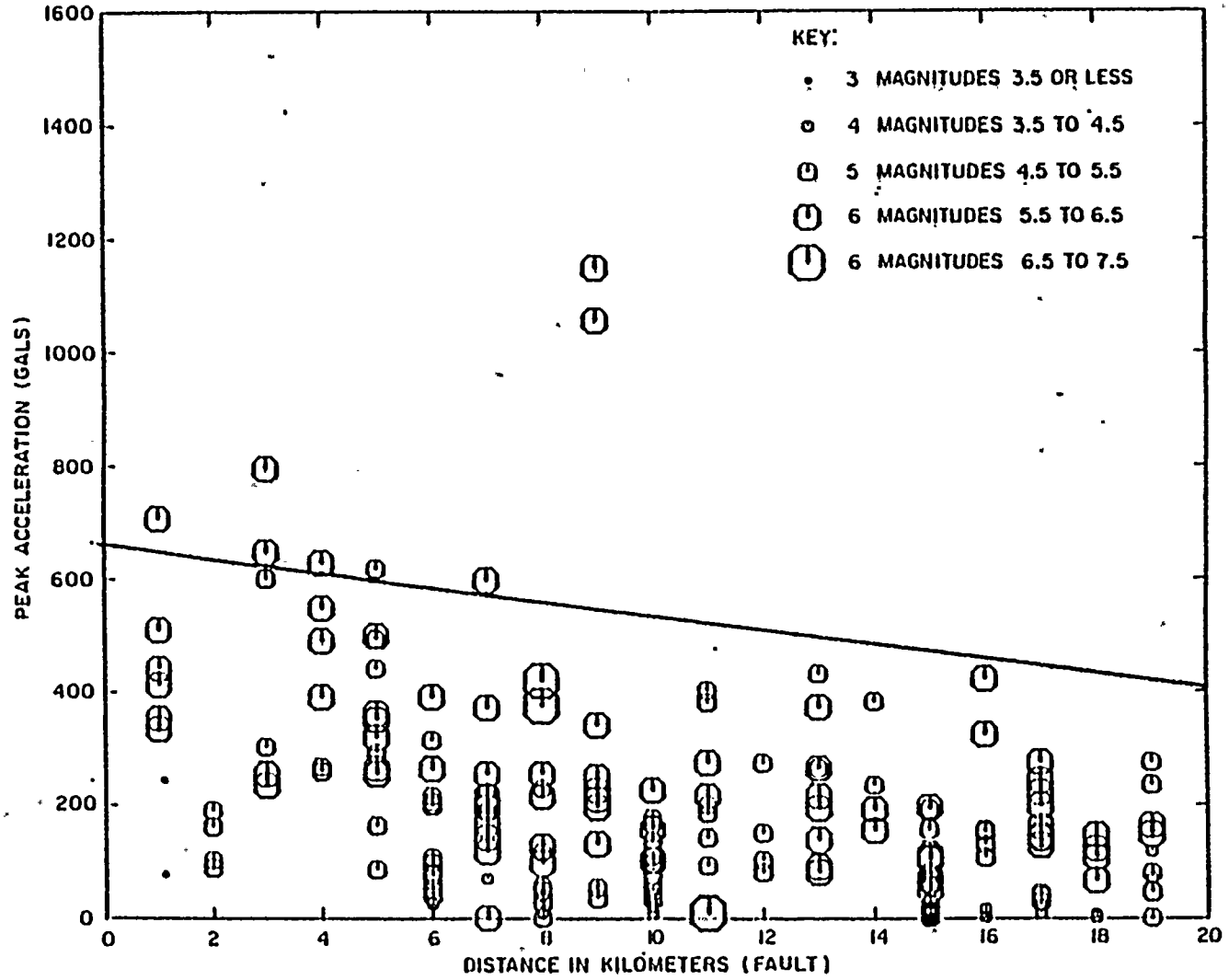
the shear strength of the rock at the focus and is not a function of the magnitude, although at larger distances the acceleration is dependent on magnitude or amount of energy release. A plot of these data is shown in Plate C-1 taken from Donovan (1980). The linear relationship shown on Plate C-1 was drawn to indicate the approximate level of the 84 percentile or median plus one standard deviation value, and indicates a peak acceleration level at about 6 kilometers from the fault, corresponding to the Diablo Canyon situation, of approximately 0.6 g or slightly less.

The Imperial Valley data do not require an increase in the design requirements for nuclear reactors and other structures that I have used since the mid 1960's, and may even justify a less conservative requirement than I specified for Diablo Canyon in Newmark (1976).

B. Vertical Relative to Horizontal Acceleration

The over registration of the vertical relative to the horizontal accelerations measured for various earthquakes in the high frequency region, when taken into account, justifies the use of a vertical response spectrum of approximately 2/3rds the horizontal response spectral values throughout the entire range of frequencies. The actual statistical value of the mean of the vertical acceleration is less than 2/3rds of the horizontal acceleration, as indicated in Hall, Mohraz and Newmrk (1976). The bases of this conclusion is presented in detail in Item I-F. It is noted that this over registration of vertical acceleration occurs only close to the source or epicenter

From Neville Donovan (1980)



NEAR FIELD DATA SUMMARY OF PEAK INSTRUMENTAL ACCELERATIONS

(or close to the fault break) where the frequency content of the acceleration record is high.

C. Wave Passage Effects

The wave passage effect or so-called Tau effect is a real effect. This has been demonstrated by a number of examples, and is discussed in some detail in Newmark (1976). Further studies by others, not yet published, including studies by the TERA Corporation, indicate at least a 20 percent reduction for a number of structures for which free field data and data in buildings are both available. Part of the reduction is due also to lack of coherence in time of the acceleration versus time acceleration data over a moderately large area corresponding to the width of the building. This reduction, of course, exists only at frequencies in excess of 2 hertz and in a near field phenomenon.

As explained in Item I.E. the presence or absence of piles is not relevant to the behavior or response of buildings or to the Tau effect. However, no Tau effect should be expected in buildings that are supported on independent spread footings not well tied together whether or not the footings bear directly on soil or on piles.

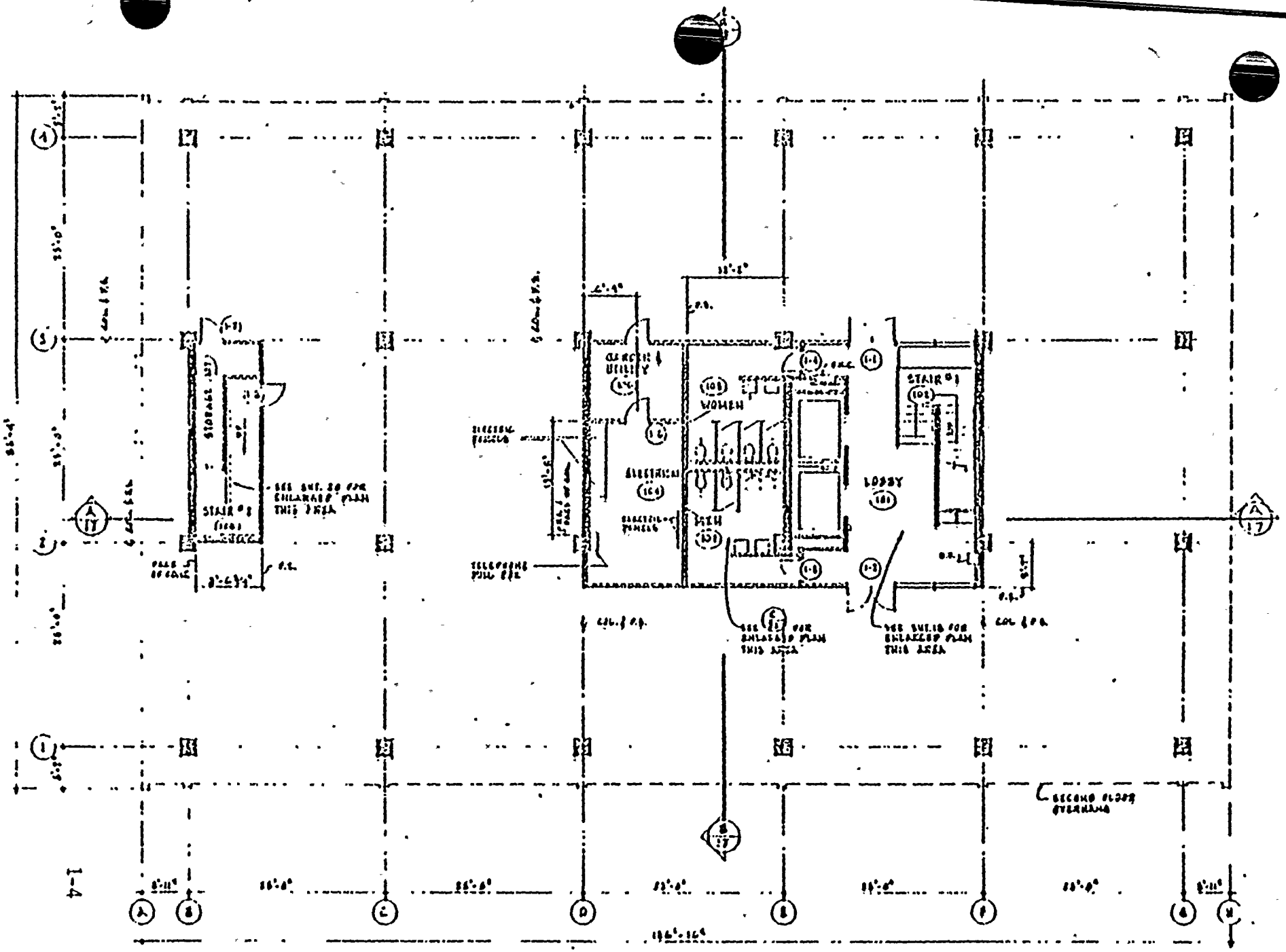
D. Conservatism of Newmark's Spectra

Some of the Imperial earthquake specrta are stated to exceed the Diablo Canyon design value. Only a relatively small number of exceedances are obtained from the corrected Imperial data and the exceedance exists only over very short ranges of frequency, different

for different stations. However, the design spectrum for Diablo Canyon, those in USNRC Regulatory Guide 1.60 and those in Newmark and Hall (1978) are intended to be a median plus one standard deviation value, and are not upper bounds. Hence occasional exceedances over small ranges of frequency should be expected and have no important significance. If conservatism were not used in other aspects of the design calculations, it would be desirable to use an envelope of the response spectra, but in order to obtain a balanced degree of conservatism and to avoid other design difficulties, the mean plus one standard deviation value is the standard that has been used, and is adequately conservative when proper account is taken of all the parameters involved in earthquake resistant design.

E. Imperial County Services Building

The damage to the Imperial County Services Building is due to the fact that the building was inadequately designed. This has been pointed out in a number of reports, and the topics discussed in Items I B, C and D are particulary pertinent. There was a large torsional effect because of real eccentricity in the first story shear wall. This eccentricity is shown in the ground floor plan of Services Building taken from Blaylock-Willis and Associates (1980) in a figure entitled "Services Building - Ground Floor Plan" and more clearly described in the report by Sozen et al (1968), shown in Fig. 1 taken from that report. The center of shear stiffness of the four shear walls in the north south direction in the central bay of the first story really is located west of the center of mass



SERVICES BUILDING - GROUND FLOOR PLAN

SCALE 1/8"=1'-0"

NORTH

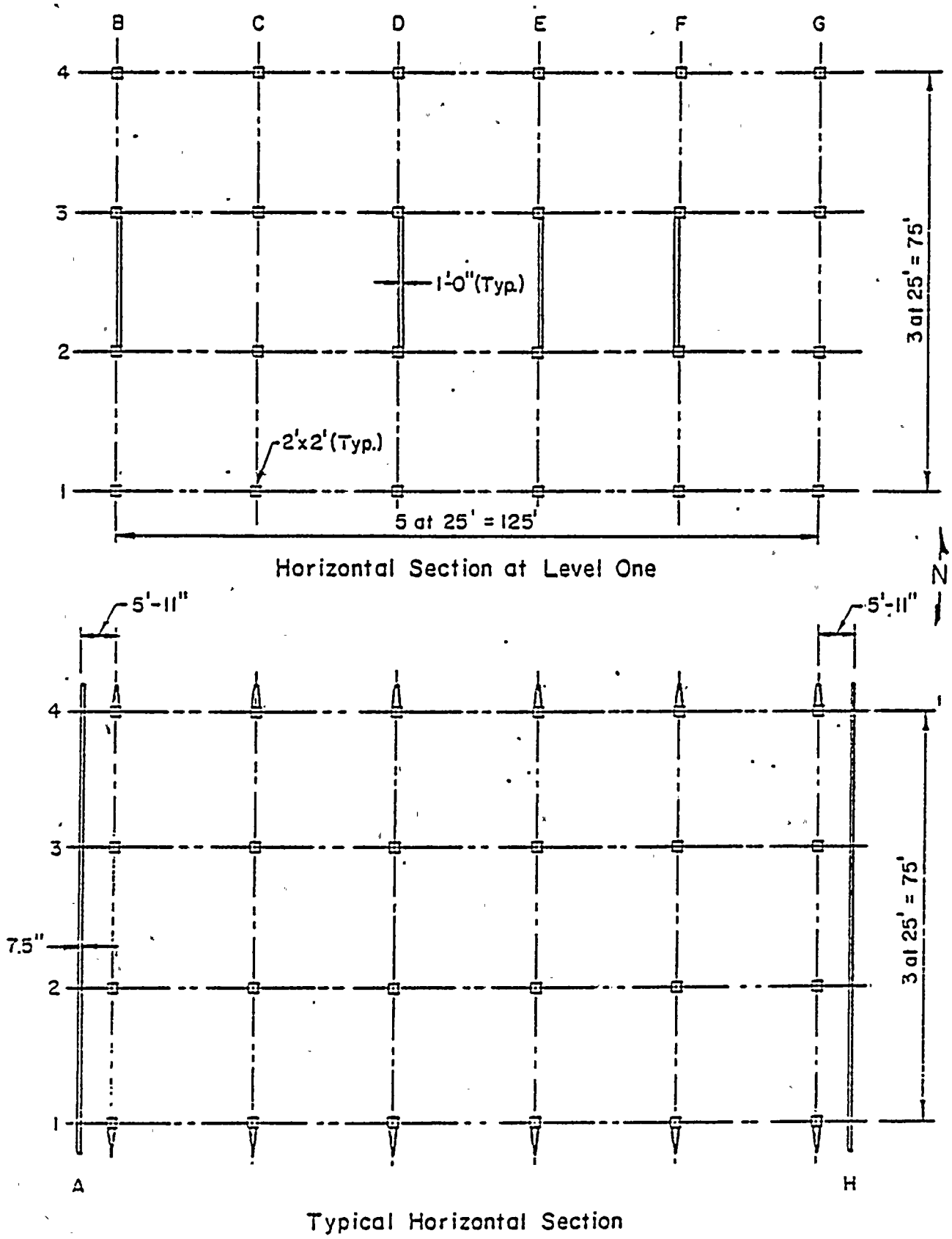


FIG. 1 PLAN DIMENSIONS OF CALIFORNIA IMPERIAL COUNTY SERVICES BUILDING

of the building. This could enhance the response of the eastern perimeter of the building.

The overturning moment was apparently neglected, and provisions for concrete restraint at the joints were inadequate. The ties that were used to confine the concrete were only nominal and had a wide spacing which allowed the steel bars to buckle outward and rupture the concrete. Closely spaced ties or spiral reinforcement containing the steel would have helped to prevent this effect, as discussed in Item I.C.

There were abrupt changes in stiffness between the first story and higher levels in the building which caused stress concentrations in the columns of the first story which exceeded the capacity of these columns. This point of view is supported by a news article in Engineering News Record for 17 July 1980 in an interview with Dr. Paul Jennings of the California Institue of Technology. He is quoted as saying that he feels the use of continuous walls on the first floor rather than beams and columns "would have definitely reduced or eliminated the damage."

"The damage to this building shows that this is a disadvantageous form for earthquake country." Similar comments were made in Brandow and Leeds (1980) in a review of damage in the Imperial earthquake.

In my view these 3 inadequacies in design dicussed above were of primary importance in contributing to the failure of the building

as discussed in Items I.B, C and D.

F. Effect of Pile Foundations

As explained in Item I.E, the piles are not a factor in either the Hollywood Storage Building or the Imperial County Services Building failure. The Hollywood Storage Building, although founded on piles, would have no effect from the piles since the building was properly designed and was not subjected to a strong enough earthquake to cause damage to the building. The Imperial County Services Building was improperly designed and the response of the building failing in torsion and overturning increases as the earthquake vibration continued. It is not appropriate to consider the results of measurements made in the Imperial County Services Building as indicative of the effects of wave propagation or the adequacy of properly designed structures, because higher response accelerations would be developed in the progressive failure of the supporting elements in the first story of the building.

G. El Centro Steam Power Station

The El Centro Steam Power Station was designed for a seismic coefficient of 0.2 g at working stress plus a 1/3 increase, according to a private communication from the designer of Unit 4 of the building. This corresponds to a yield value of the response spectral acceleration of about 0.4 g and therefore to a ground acceleration design value for 5 percent damping of approximately 0.14 g. The actual ground acceleration as reported in Brandow and Leeds (1980) in an

article by Otto W. Steinhardt on "Earthquake Effects at El Centro Power Plant," pages 57 to 60, indicates that the actual ground acceleration was of the order of 0.4 to 0.5 g for measurements near the building. Hence the building was overloaded by a factor of approximately 3 to 4 times. Only slight damage was developed because of good design practices used in general for both Units 3 and 4. Some of the equipment was not properly anchored and suffered slight damage but these units were able to be put on the line within a very short time after the earthquake, Unit 3 being restored to services 5 minutes after the main shock, and Unit 4 being restored to service some 5 hours later after repairs were made to the unit substation which powers the cooling tower fans and circulating water pump valves. This damage was not necessarily seismic induced, according to the reference previously cited.

H. Hard Rock Versus Soft Sediment Site

Energy losses and attenuation of acceleration are greater in soft soil than competent rock when the shearing stresses exceed the strength in the material. Because of this fact one may expect higher accelerations in soft sediment than in rock when the peak effective acceleration is less than aouut .2 g, about the same values for peak effective accelerations about .4 g, lower values when the peak effective accelerations exceed about .6 g. These phenomena have been taken into account in the development of the design spectra recommended by me for Diablo Canyon Newmark 1976.

However, the apparent wave propagation velocity used in determining the Tau effect should be based on the shear wave velocity at a depth of several hundred feet below the surface of the site. The softer near surface layers at the site cause a refraction of the wave, tilting it upwards, but not changing its apparent horizontal velocity. For this reason the Tau effect at the Hollywood Storage Building was taken as corresponding to the apparent wave propagation velocity of 2000 ft per second and that at Diablo Canyon at 4000 ft per second.

It should be noted that the Tau effect is essentially a soil structure interaction effect. In my practice I have never combined the Tau effect with the effect of soil structure interaction. In all cases either of these effects reduces the response and never increases it above the free field indicated values except in instances of progressive failure due to inadequate design.

I. General Comments

Many of the points made in this testimony were developed and accepted by competent engineers at least as early as the latter part of the 1950's. They were emphasized in a number of reports including Hanson and Degenkolb (1967), Blume, Newmark and Corning (1961), Newmark (1969), and Newmark and Hall (1969). Of particular interest is a section entitled "Lessons Learned and Relearned" taken from Hanson and Degenkolb (1967), pages 125 to 128. This points out the influence of nonstructural elements which was not discussed in this testimony, the effect of overturning forces, sudden changes of stiff-

ness and framing, column ties, and connections.

It can be inferred from the discussion in this testimony, and from consideration of earthquake damage and lack of damage in various earthquakes, that the factor of safety for nuclear reactors based on current design procedures is at least 3, and may greatly exceed that value.

In my opinion, based on my extensive experience and observations of the effect of earthquakes and explosions, the design criteria given in Newmark (1976) for Diablo Canyon are conservative and require no change in the light of the Imperial Valley Data.

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1 November 1979

NATHAN M. NEWMARK

Biographical Data

Nathan M. Newmark, Professor of Civil Engineering and in the Center for Advanced Study, Emeritus, at the University of Illinois has been a member of the faculty at the Urbana Campus since 1930. He has been engaged in research, instruction and engineering practice in applied mechanics, structural engineering and structural dynamics for his entire career.

He was born on 22 September 1910 in Plainfield, New Jersey. He attended Rutgers University where he received the B.S. degree in Civil Engineering in June 1930. He received the degree of Master of Science in Civil Engineering from the University of Illinois in June 1932 and the degree of Ph.D. in Engineering from the same institution in June 1934.

In January 1969 Professor Newmark was awarded the 1968 National Medal of Science by President L. B. Johnson. On 21 February 1969 he became the 46th recipient of the Washington Award. On 2 April 1979 he received the John Fritz Medal, awarded annually since 1902 by the five major engineering societies of the United States. In April 1980 he will receive the Gold Medal of the Institution of Structural Engineers of Great Britain, the fourteenth time this medal has been awarded in the past 57 years.

In 1955 Rutgers University conferred the honorary degree of Doctor of Science on him. In 1967 he was awarded the degree of Doctor Honoris Causa by the University of Liege in Belgium on the occasion of the 150th anniversary of the founding of that University, and in 1969 he was awarded the honorary degree of Doctor of Laws by the University of Notre Dame. He was honored in 1972 by a degree from the National Civil Engineering Laboratory of Lisbon, Portugal, and in 1978 by the honorary degree of Doctor of Science by the University of Illinois at Urbana-Champaign.

Dr. Newmark's awards and honors include election to membership in the National Academy of Sciences in April 1966, election as a Fellow of the American Academy of Arts and Sciences in 1962, and election as a Founding Member of the National Academy of Engineering when it was formed in December 1964. He was a member of the Council and of the Executive Committee of NAE until 1968. In August 1970, Dr. Newmark was made a Fellow of the Argentine Academy of Exact, Natural and Physical Sciences, and in June 1975 he was designated as corresponding academician of the Academy of Engineering of the Mexican Institute of Culture.

His other honors include the Vincent Bendix Award for Engineering Research from the American Society of Engineering Education in June 1961, the Norman Medal of the American Society of Civil Engineers in 1958 and the Ernest E. Howard Award of ASCE in the same year. He received also from ASCE the J. James R. Croes Medal in 1945, the Moisseiff Award in 1950, and the Theodore von Karman Medal in 1962. In 1950 he received the Wason Medal of the American Concrete Institute and in 1956 an award from the Concrete Reinforcing Steel Institute in recognition of his contributions to the field of reinforced concrete research. In 1965 Dr. Newmark was awarded the Order of Lincoln of Achievement in the field of technology and engineering by the Lincoln Academy of Illinois.

Dr. Newmark was elected to Honorary Membership in the American Society of Civil Engineers in 1966, and to Honorary Membership in the American Concrete Institute in 1967. In 1969 he was elected an Honorary Fellow of the International Association of Earthquake Engineering, and in 1971 an Honorary Member of the American Society of Mechanical Engineers. He is a Fellow of the ASCE, ASME, the American Association for the Advancement of Science, the American Geophysical Union, and the Institution of Civil Engineers of Great Britain.

In May 1958 the 43-story Latino Americana Tower in Mexico City, for which Dr. Newmark was the seismic consultant, was given a special award by the American Institute of Steel Construction because of its successful resistance to the major earthquake of July 1957. A stainless steel plaque was attached to the building indicating the part in its design that was played by Dr. Newmark.

Professor Newmark is the author of over 236 papers, articles, monographs and books in the fields of structural analysis and design, applied mechanics, numerical methods of stress analysis, and effects of impact, shock, vibration, wave action, blast and earthquakes on structures. He is the co-author of two books on earthquake engineering including "Design of Multistory Reinforced Concrete Buildings for Earthquake Motion" with J. A. Blume and Leo Corning, published by the Portland Cement Association in Chicago in 1961, and "Fundamentals of Earthquake Engineering," with Emilio Rosenblueth, published by Prentice-Hall, Inc. in 1971.

Professor Newmark's chapters in books include Chapter 16, "Current Trends in the Seismic Analysis and Design of High Rise Structures," in Earthquake Engineering, published by Prentice-Hall, Inc. in 1970; Chapter 4, "Seismic Analysis," in "Pressure Vessels and Piping: Design and Analysis," published by the American Society of Mechanical Engineers, in 1972; and others. Dr. Newmark is editor of a series of texts in Civil Engineering and Engineering Mechanics for Prentice-Hall, Inc.

In February 1965 Professor Newmark was selected to give the Fifth Rankine Lecture under the auspices of the Institution of Civil Engineers of Great Britain, in London; and in September 1978 he was selected to give the Terzaghi Lecture by the American Society of Civil Engineers. Both of these lectureships involve the area of soil mechanics and geotechnical engineering.

In June 1968 he was selected as one of the twenty-two engineering educators for the American Society for Engineering Education Hall of Fame.

Dr. Newmark has been active on a number of national committees and boards including: the Commission on Engineering Education, of which he has been a member from its inception in 1962 until 1972; the Commerce Technical Advisory Board of the U. S. Department of Commerce, during 1963-64; the National Science Foundation's Advisory Panel on University Computing Facilities, from 1964-1966; and the National Science Foundation's Advisory Committee for Engineering, from 1966 to 1969.

From 1969 to 1972 Dr. Newmark was Chairman of the Section on Engineering of the National Academy of Sciences, and from 1974 to 1978 he was Chairman of the National Research Council Committee on Natural Hazards. Since 1977 he has been Chairman of the Advisory Committee on Earthquakes to the U. S. Geological Survey.

In 1976 Dr. Newmark was appointed by the President's Science Advisor as Chairman of an Advisory Group on Earthquake Prediction and Hazard Mitigation to prepare plans to augment the earthquake-related research programs of the U. S. Geological Survey and the National Science Foundation. This Advisory Group's report was published in September 1976 and has since served as the basis for earthquake related research by the two agencies.

From 1974 to 1978 Dr. Newmark had the principal technical responsibility for the development of the Applied Technology Council's Recommended Seismic Design Provisions for Buildings, as Chairman of the Task Group Coordinating Committee, the Steering Committee, and Task Group II on Structural Behavior. These recommendations involved the cooperation of over 80 engineers, seismologists, and building code officials, and were published in July 1978.

During World War II, Dr. Newmark was a consultant to the National Defense Research Committee and the Office of Field Service of OSRD. For this service he was awarded the President's Certificate of Merit in 1948. In March 1971, he was awarded the outstanding Civilian Service Medal by the Department of the Army.

He has been a member of numerous boards and committees, including the Scientific Advisory Board of the U. S. Air Force from 1945-49, the "Gaither Committee" in 1957, and various other groups including boards and panels for the Office of the Chief of Engineers, the Air Force Space and Missiles System Organization, the Air Force Weapons Laboratory, the Defense Atomic Support Agency, the Defense Nuclear Agency, the Defense Intelligence Agency, the Office of Secretary of Defense, the Nuclear Regulatory Commission, and other agencies.

He has been a consultant to a great many industrial organizations and agencies, and has been associated with development of seismic design criteria for the San Francisco Bay Area Rapid Transit System, Le Chateau Champlain, a multi-story hotel building for the Canadian Pacific Railways in Montreal, the sewer outfall for the City and County of San Francisco (which crosses the San Andreas Fault under water), and the Liquified Natural Gas Terminal at Point Conception, California, among others.

Other important consulting work includes his activities since 1970 as principal seismic consultant on the Trans-Alaska Oil Pipeline System and the proposed Canadian Gas Arctic Pipeline. Recently he has been engaged in the preparation of seismic design criteria for the Northwest Alaska Gas Pipeline and the Foothills (South Yukon) Gas Pipeline in Canada. Since 1972 he has had an association with the Bechtel Corporation on seismic, structural, and geodynamic problems. Since 1960, Dr. Newmark has been a consultant to the Atomic Energy Commission and its successor, the Nuclear Regulatory Commission, on various aspects of the seismic resistance of nuclear reactor facilities. He has been engaged in development of seismic design criteria for buildings in the United States, Canada, and Mexico, and on nuclear reactor projects in Iran, Israel, Italy, and France. He was engaged by Electricite de France to develop criteria for inelastic design of nuclear reactor power facilities in 1978-79.

Dr. Newmark has been involved in seismic design studies and criteria for a number of major dams and proposed dam projects including Kremasta Dam in Greece, Portage Mountain Dam on the Peace River in Canada, Richard B. Russell Dam in Georgia, Mirpur Dike, a part of the Mangla Dam project, in Pakistan, and others. His Rankine Lecture describes his early original contributions in this field. His Terzaghi Lecture is concerned with design concepts for tunnel linings.

He is a registerd Professional and Structural Engineer in Illinois and a registered Civil Engineer in California. As a Fellow of the Institution of Civil Engineers he is licensed to practice engineering in the United Kingdom.

Professor Newmark's career at the University of Illinois included service as a Research Assistant and Research Associate from 1934 to 1937, Assistant Professor to 1943, and Professor of Civil Engineering since 1943. He served as Head of the Department of Civil Engineering from 1956 to 1973, and as Chairman of the Digital Computer Laboratory from 1947 to 1957.

In September 1973 Dr. Newmark resigned as Head of the Department of Civil Engineering and became Professor of Civil Engineering and Professor in the Center for Advanced Study at the University of Illinois at Urbana-Champaign. He retired and became Professor Emeritus in July 1976. Since that date he has devoted full time to work on national boards and committees and on his consulting practice.

The following was included in a statement prepared by his colleagues in support of his nomination for the Honorary Degree from the University of Illinois in 1978:

"Professor Newmark has made outstanding research contributions in a wide variety of areas of structural engineering and foundation engineering. His papers, books and chapters in books form a list of publications with more than two hundred entries. These, however, are not the sum total of his efforts, for his concern has always extended to the realization of new concepts in the steel and concrete of actual engineering works."

"His influence on engineering education has been extensive. Graduate study in structural engineering today bears his indelible imprint as a result of the large group that he attracted to Illinois to work with him and because of the more than ninety Ph.D.'s for whom Professor Newmark was adviser or co-adviser. His style, combining rigorous analysis with a sophisticated appeal to experience and intuitive leaps, while inimitable, has provided generations of graduate students with a model of engineering creativity at its best."

"The threefold purpose of this University, teaching, research, and public service, rarely finds exemplification in a single career. The engineering profession, the nation and the University of Illinois are the richer for the remarkable exception of Professor Nathan M. Newmark."

The following is the citation for the John Fritz Medal:

"for inspired service in enhancing the welfare of mankind and the practice of engineering. By his unceasing devotion to research, his noteworthy contributions to improving design practices and his leadership in engineering education he has been an inspiration and a source of guidance to the engineering profession."

A list of former John Fritz medalists is appended.

JOHN FRITZ MEDALISTS

1902 John Fritz
1905 Lord Kelvin
1906 George Westinghouse
1907 Alexander Graham Bell
1908 Thomas Alva Edison
1909 Charles Talbot Porter
1910 Alfred Noble
1911 Sir William Henry White
1912 Robert Woolston Hunt
1914 John Edson Sweet
1915 James Douglas
1916 Elihu Thomson
1917 Henry Marion Howe
1918 J. Waldo Smith
1919 George W. Goethals
1920 Orville Wright
1921 Sir Robert A. Hadfield
1922 Charles P. E. Schneider
1923 Guglielmo Marconi
1924 Ambrose Swasey
1925 John F. Stevens
1926 Edward Dean Adams
1927 Elmer Ambrose Sperry
1928 John Joseph Carty
1929 Herbert Hoover
1930 Ralph Modjeski
1931 David Watson Taylor
1932 Michael Idvorsky Pupin
1933 Daniel Cowan Jackling
1934 John Ripley Freeman
1935 Frank Julian Sprague
1936 William Frederick Durand
1937 Arthur Newell Talbot
1938 Paul Dyer Merica
1939 Frank Baldwin Jewett
1940 Clarence Floyd Hirshfeld
1941 Ralph Budd
1942 Everette Lee De Golyer
1943 Willis Rodney Whitney
1944 Charles Franklin Kettering
1945 John Lucian Savage
1946 Zay Jeffries
1947 Lewis Warrington Chubb
1948 Theodore Von Karman
1949 Charles Metcalf Allen
1950 Walter Hull Aldridge
1951 Vannevar Bush
1952 Ervin George Bailey
1953 Benjamin F. Fairless
1954 William E. Wrather
1955 Harry A. Winne
1956 Philip Sporn
1957 Ben Moreell
1958 John R. Suman
1959 Marvin J. Kelly
1960 Gwilym A. Price
1961 Stephen D. Bechtel
1962 Crawford H. Greenewalt
1963 Hugh L. Dryden
1964 Lucius D. Clay
1965 Frederick R. Kappel
1966 Warren K. Lewis
1967 Walker L. Cisler
1968 Igor Ivan Sikorsky
1969 Michael L. Haider
1970 Glenn B. Warren
1971 Patrick E. Haggerty
1972 William Webster
1973 Lyman W. Wilbur
1974 H. I. Romnes
1975 Manson Benedict
1976 Thomas O. Paine
1977 George R. Brown
1978 Robert G. Heitz
1979 Nathan M. Newmark

Addendum: July 1980

NATHAN M. NEWMARK

Biographical Data

On April 15, 1980, Dr. Newmark was awarded the 16th Gold Medal in 57 years by the Institution of Structural Engineers of Great Britain. Only one other American engineer has received this medal.

In June 1980, Dr. Newmark was elected as the 5th honorary member of the Seismological Society of America.

MR. LANPHER: No objection.

MR. NORTON: No objection.

MR. FLEISCHAKER: No objection.

BY MR. OLMSTEAD: (Resuming)

Q Dr. Kuo, I have in front of me a document entitled "Testimony of Pao-Tsin Kuo." I ask you if you prepared this testimony for filing in this proceeding?

A (Witness Kuo) Yes, I did.

Q And do you have any corrections or additions to make to this testimony?

A No, I do not.

Q Attached to this testimony is a statement of your personal qualifications. I ask if those are your qualifications?

A It is.

Q Is this testimony and the attached statement of professional qualifications true and correct to the best of your knowledge and belief?

A It is.

MR. OLMSTEAD: Mr. Chairman, I move the testimony of Pao-Tsin Kuo be bound into the transcript as if read.

CHAIRMAN SALZMAN: Any objections, Mr. Fleischaker?

MR. FLEISCHAKER: No, Mr. Chairman.

CHAIRMAN SALZMAN: Mr. Lanpher?

MR. LANPHER: No, sir.

CHAIRMAN SALZMAN: Mr. Norton, any objection?

MR. NORTON: No objection.

CHAIRMAN SALZMAN: The Reporter will please do so.

(The document referred to follows:)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

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

TESTIMONY OF ROBERT L. ROTHMAN

Q. By whom are you employed, and describe the work you do?

A. I am employed as a seismologist in the Geosciences Branch, Division of Engineering, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission. My work includes the technical review and evaluation of the acceptability of proposed and operational nuclear reactor sites with respect to the seismological aspects of the sites. My work includes the use of my expertise in the areas of seismicity, rupture mechanics, seismic wave propogation, and seismic instrumentation.

Q. Would you describe in general terms the development of your testimony in responding to the Appeal Board's questions.

A. Yes, my testimony in response to the Appeal Board's questions related to seismic matters was developed in coordination with Dr. Pao-Tsin Kuo

and under the general supervision of James P. Knight, Assistant Director for Components and Structures Engineering.

Q. Would you detail your professional qualifications.

A. A copy of my professional qualifications are attached to this testimony. A copy of my professional qualifications was previously submitted in this proceeding as an attachment to the "Joint Affidavit of Robert L. Rothman and Pao-Tsin Kuo" dated May 5, 1980. That affidavit was attached to the May 5, 1980 "NRC Staff Response to Joint Intervenors' Motion to Reopen" submitted in this proceeding. I have not previously testified in this proceeding, however.

Q. Would you describe the scope of your testimony?

A. Yes. My testimony is directed specifically toward the seismological aspects of the questions raised by the Atomic Safety and Licensing Appeal Board (Appeal Board) in the Appendix to Pacific Gas and Electric Company (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-598, Slip Op. (June 24, 1980).

Q. Which questions does your testimony address?

A. My testimony is directed to Appeal Board questions 1, 3, and 7.

Q. Are there any particular caveats you have with respect to use of the seismic data generated by the Imperial Valley Earthquake of October 15, 1979 (IV-79) with respect to nuclear power plant design.

A. The Imperial Valley Earthquake occurred on the Imperial Valley Fault which is a part of the San Andreas System. This area is one of high seismicity and an area where earthquakes of this type might be expected to occur. A number of strong motion seismic instruments were located near to the site of the earthquake prior to its occurrence because it was thought that the area was one where such an earthquake might occur. The large number of seismic recordings at close distance has made this particular earthquake important as a data source, but because of specific geologic conditions within the Imperial Valley the data must be subjected to critical analysis before it is applied.

The particular characteristics at the IV-79 area must be carefully considered before applying the data recorded at IV-79 to the design of nuclear facilities at sites having different characteristics. For example such things as earthquake focal mechanism, seismic wave propagation path characteristics and recording site geology can have a significant effect on the data recorded. Thus, data from IV-79 must be used with caution if transferred to the DCNPP site. In particular the geology at DCNPP is different than that of the Imperial Valley. The

Diablo Canyon site is underlain by a relatively thin section of sedimentary rock overlying the basement which consists of the Franciscan Formation. The Imperial Valley is a sedimentary basin in which over 300 meters of unconsolidated alluvium are underlain by approximately 5.5 kilometers of sedimentary rock. See also discussion below in response to Appeal Board's question No. 3.

Q. Appeal Board Question No. 1 states:

> The October 15, 1979, Imperial Valley Earthquake (IV-79, M_L=6.4-6.9) provided an extensive set of strong motion records in the near field of a rather severe earthquake.33/ The parties should compare the horizontal peak acceleration values recorded for various instrument positions with earlier predictions and compilations of such motion, 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. Those comparisons should (if possible) address whether there is magnitude independence or a saturation effect for ground motion intensity in the near field of earthquakes.34/

33/ Preliminary Summary of the U.S. Geological Survey Stong-Motion Records from the October 15, 1979 Imperial Valley Earthquake by R.L. Porcella and R.B. Mathiesen (October 1979), included in Board Notification, December 17, 1979.

34/ See, for instance, Tr. 8597; 10,105; 5889-90.

A. In response to question No. 1, I have made comparisons between the horizontal peak acceleration values recorded for IV-79 at various instrument positions and Figures 4, 24, 47 and 48 of United States Geological Survey (USGS) Circular 795 (Boore et al., 1978). In

Circular 795 the results of the study by Boore et al. of the relationships between peak accelerations, distance, earthquake magnitude and recording site characteristics are presented. In addition, these results are compared with the results of other studies on the same subjects (Schnabel and Seed, 1973; Donovan, 1973; and Trifunac, 1976). Figures 4, 24, 47 and 48 of Circular 795 contain plots of the predictions and compilations developed in these four studies. As a means of comparing these studies with the data obtained from IV-79, the peak horizontal accelerations from the various instrument positions in the Imperial Valley were plotted on Figures 4, 24, 47 and 48 of Circular 795.

The Appeal Board has indicated, in question No. 1, a range of magnitude M_L values for IV-79 of 6.4-6.9. The USGS magnitudes for this event are M_L = 6.6, m_b = 5.7 and M_s = 6.9. At this point it might be beneficial to discuss this variation in magnitude values.

The differences in these magnitudes is caused by the way in which they are each calculated, specifically, the periods (frequency) of the waves which are used in each measurement. M_L is the original Richter magnitude which was developed for Southern California earthquakes recorded on Wood-Anderson seismometers (free period 0.8 seconds) at distances of 600 kilometers or less. M_s and m_b use signals recorded at teleseismic distances (2000 kilometers or greater). The M_s measures the amplitude of surface waves with periods of 20 seconds and the m_b is a measure of the 1 second body waves. The variations in the magnitude calculations

are due in part to the fact that different size earthquakes generate relatively different amounts of energy in these frequency bands.

As a means of presenting the peak horizontal accelerations recorded at the various locations for IV-79. I have plotted Figure 1. This figure contains the peak horizontal accelerations recorded at ground level plotted as a function of distance. The distances are the normal to the surface expression of the Imperial Fault or its projections. The circular points are from stations in the U.S. owned by either the U.S. Geological Survey or the California Division of Mines and Geology. The squares represent stations in Mexico owned by the University of California at San Diego and the Universidad Nacional Autonoma de Mexico.

There is considerable scatter in the data with a range of from 0.22g to 0.81g for stations within 10 kilometers of the fault. The highest peak horizontal acceleration was recorded at Bonds Corner. However, the Bonds Corner high reading may be, to some extent, due to an anomalous site condition. During a subsequent earthquake, Calexio Valley earthquake of June 8, 1980 (Magnitude 6.2), the Bonds Corner station recorded a high peak horizontal acceleration of 0.14g. This reading was approximately three times larger than any of the other stations in the region at approximately the same epicentral distance (USGS, 1980).

Studies of earthquake ground motion parameters (Schnabel and Seed, 1973; Donovan, 1973; Trifunac, 1976; and Boore et al, 1978), have had

to rely on the extrapolation of far-field data to make predictions for engineering estimates in the near field. This has not proved to be completely satisfactory. For example, when various relationships are compared in the distance range for which there is abundant strong motion instrument data, 30 to 100 kilometers, they are in reasonably good agreement with each other. However, when they are compared at distance of less than 30 kilometers there is considerable divergence among these relationships. This is illustrated by Figure 2a which is a copy of Figure 47 from USGS Circular 795 (Boore et al, 1978) and contains the distance-peak horizontal acceleration relationships for a magnitude 6.6 earthquake as developed from the above mentioned references. The peak horizontal accelerations from IV-79 (small dots) are also plotted in this figure. The IV-79 data generally falls below the curves of these studies and especially so at short distances. The IV-79 data tends to support the theory that the peak horizontal acceleration-distance curve flattens out at short distances. I say tends to support because IV-79 is only one event and I cannot make a definitive statement solely on it.

Figure 2b is a copy of Figure 48 from USGS Circular 795 (Boore et al, 1978). It contains the distance-peak horizontal acceleration relationships for a magnitude 7.6 earthquake as developed from the references and the peak horizontal accelerations from IV-79. The IV-79 data generally falls below the curves. Figure 2c is a copy of Figure 4 from

USGS Circular 795 (Boore et al, 1978) with the peak horizontal accelerations from IV-79 also plotted. The IV-79 data appears to be generally consistent with the plots and there is an indication that at distances of 10 kilometers and less it even falls within the range of the magnitude 5.0-5.7 curves. Figure 2d is a copy of Fiqure 24 from USGS Circular 795 (Boore et al, 1978) with the peak horizontal accelerations from IV-79 plotted on it. The IV-79 data seem to be generally consistent with the Circular 795 data and, in addition, indicate a flattening of the curve at short distances from the fault. This one earthquake has given us data that tends to show that previous predicitons, based on the extrapolations of far-field data, over-estimate the peak accelerations to be expected in the near field. As a consequence, use of the circular 795 figures discussed above to predict peak acceleration at the DCNPP from a Hosgri earthquake could also result in an overly conservative value of peak acceleration.

Q. Have you addressed whether the above described comparisons show that there is magnitude independence or a saturation effect for ground motion intensity in the near field of earthquakes?

A. Yes.

Q. What can you state on this subject?

A. It has been postulated that peak ground acceleration saturates with increasing magnitude in the near field. A comprehensive report on this subject is that of Hanks and Johnson (1976). Their conclusion was that the causative processes, in the source region, responsible for generating peak ground accelerations at distances of approximately 10 kilometers are independent of magnitude for events of magnitude 4.5 or greater. They explain this with a theoretical argument predicated on the basis that high-frequency accelerations reflect isolated bursts of rupturing of localized inhomogeneities which are magnitude independent. Figure 3 is a copy of Hanks and Johnson's figure showing peak accelerations as a function of earthquake magnitude at approximately 10 kilometers. The peak horizontal accelerations of IV-79 for stations less than 11 kilometers has been plotted on the Hanks and Johnson figure. The log of the mean peak horizontal acceleration of IV-79 for stations less than 11 kilometer is 2.6. This value is in agreement with the Hanks and Johnson plot. The Imperial Valley earthquake is, in effect, one additional data point which adds support to the theory that acceleration saturates with magnitude. This means that in the near field the peak ground accelerations for larger earthquakes (magnitude 4.5 and greater) are probably independent of magnitude.

Q. Appeal Board Question No. 3 states:

> We are told that IV-79 data are not relevant to the Diablo Canyon seismic analysis because that plant is a "rock" site, whereas the Imperial Valley data were obtained on soil sites. (Rothman - Kuo Affidavit at p. 3; Blume Affidavit, Para. 8.) What is the significance of this difference in view of the conclusion of the authors

of USGS Circular 795 (based on an analysis of data provided in that document) that, for comparable earthquake magnitude and distance, there are no significant differences between peak horizontal accelerations measured on soil or rock? (USGS Circular 795 at pages 1, 17, and 26.) This question should 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 (Blume Affidavit, Para. 9; Testimony fol. Tr. 6099, p. 33).

A. The key to my discussion in answer to question No. 3 is the fact that the specific geologic conditions in the Imperial Valley are significantly different from those at Diablo Canyon and the high peak accelerations recorded at some of the Imperial Valley stations for IV-79 may be directly attributable to the geology.

The Imperial Valley is a sediment filled basin in which approximately 5.5 kilometers of sedimentary rock are overlain by over 300 meters of unconsolidated alluvial soil. This basin has a very steep vertical velocity gradient with the P-wave velocity increasing from 1.8 km/sec near the surface to 5.6 km/sec at a depth of approximately 5 kilometers. Studies are currently being performed to explain the high-frequency high peak vertical accelerations recorded at some of the strong motion stations during IV-79. Helmberger and Hadley (1979) and Archuleta (1980) attribute these anomalous readings to the geologic setting of the area and to fault breakout from the basement into the sediments. There is a considerable range in the peak horizontal accelerations recorded from IV-79, see Figure 5. Some of these variations may be due to the differences in geology between sites. As noted in the response

to Appeal Board Question 1 the Bonds Corner station has recorded a higher peak acceleration than other stations at approximately the same distance for another earthquake. Boore et al (1979) have reported consistent differences in the amplitude of signals recorded at El Centro Array Station 6 and Station 7. These two stations are approximately two kilometers apart and on opposite sides of the fault. They found, in a study of the aftershocks of IV-79, that the S waves near Station 6 were delayed by about 0.5 seconds with respect to Station 7 and the spectral amplitude in the range 2 to 5 Hz was increased by up to a factor of 10. In a study of a 1977 swarm of earthquakes they also found that the peak accelerations at Station 6 were larger than at Station 7.

U.S.G.S. Circular 795 reports that for comparable earthquake magnitude and distance, there are no significant differences between peak horizontal accelerations measured on soil or rock. Assuming the same propagation path and other conditions being the same, I agree with Circular 795. This is a different situation than that addressed by the Rothman-Kuo affidavit, at page 3.

In the Rothman-Kuo affidavit we should have more clearly emphasized the difference in overall geologic characteristics rather than simply referring to rock and soil distinctions. The point is that the geology at Diablo Canyon is different than that at Imperial Valley. Thus, some of the high accelerations from IV-79 may be due to specific source

characteristics, recording site considerations, and propagation path effects. The distribution of peak accelerations in the Imperial Valley from IV-79 was very complex. A generally accepted explanation has not as yet been found for this complexity. However, explanations such as those discussed above based on the particular geologic setting of the Imperial Valley would tend to indicate that the conditions experienced from IV-79 would not be directly applicable at Diablo Canyon.

The fact that IV-79 occurred in sedimentary basin with particular geology, which is different from the DCNPP site, is significant enough to caution that the data generated by IV-79 must be used with care when applied to another area with different underlying geologic characteristics.

Q. Appeal Board Question No. 7 states:

> Intervenors (Brune Affidavit, p. 5) and the applicant (Frazier Affidavit, para 3) have suggested that the strong motion data obtained from stations along the direction of the Imperial Fault evidence the "focusing" of earthquake motion. Yet, when the acceleration data of two such stations, El Centro Array Numbers 6 and 7, are plotted as a function of distance from the fault (e.g., Blume Affidavit, Figures 1 and 2), the horizontal acceleration values fall well below the regression line mean for the 1 km distance. The vertical acceleration values are also lower than the mean on such a plot.
>
> To the extent possible, the parties should analyze the seismic records for the IV-79 earthquake as they pertain to the focusing phenomenon and relate the results of such analyses to the likelihood that, in the event of an earthquake anywhere along the Hosgri Fault, focusing might result in amplified seismic motion at Diablo Canyon.

A. Focusing is a signal amplitude effect resulting from rupture propagation. Figure 4 is a schematic representation of the focusing phenomena taken from Hugo Benioff's article on the Kern County Earthquake (Benioff, 1955). The focusing effect results from constructive interference of signals whose velocity is close to that of the rupture propagation velocity. The focusing effect probably occurs to some degree in all earthquakes. The strong motion recording data base which is used by the seismological community to establish the distance-acceleration, acceleration-magnitude, and other strong seismic motion relations undoubtedly contains values which are the result of focusing.

The Pacoima Dam record of the San Fernando Earthquake which played a key roll in the development of the DCNPP design spectra displayed large ground motions. These values were, in part, caused by the focusing phenomenon (Heaton and Helmberger, 1979).

We have examined, to the extent possible from available data and studies performed, the peak accelerations and their relationship to the focusing phenomenon. Figure 5 is a map of the section of the Imperial Valley within the U.S. The epicenter of IV-79 and the U.S. strong motion stations are plotted on it (Brady et al, 1980). The rupture of the IV-79 is believed to have initiated at the epicenter (10/15/79) and to have propagated to the northwest. The peak horizontal acceleration recorded at each station is also noted in Figure 5. There is no obvious indication of focusing in this data. The fault propagating to the

northwest should cause larger signals in the U.S. than in Mexico if there is a focusing effect present. Referring to Figure 1, it can be seen that the Mexican stations (squares) fall within the general scatter of the data and there is no obvious indication of focusing affecting the peak horizontal accelerations. If focusing did occur with IV-79 the evidence is hidden within the considerable complexity of this data set. This is not surprising since ground motion at a particular site results from a combination of many factors including, for example, radiation pattern, localized source effects, site effects and focusing. As indicated above, the analysis and interpretation of all these complex ground motion parameters from IV-79 is not available at the present time.

Q. Can the results of the analysis for focusing phenomenon of IV-79 be related to the likelihood that, in the event, of an earthquake anywhere along the Hosgri Fault, focusing might result in amplified seismic motion at Diablo Canyon.

A. Since the examination of IV-79 seismic data thus far has not resulted in a clear indication of the focusing phenomenon it is not possible to apply data from IV-79 to the Hosgri Fault and focusing at Diablo Canyon. However, as discussed above it is my opinion that the focusing phenomenon is necessarily incorporated in the design spectra for the DCNPP.

The spectral approach used by the NRC in its review of seismic design is based upon data from a selected population of earthquakes. We believe the data range is sufficient to reflect the effect of focusing. Thus, the data base underlying the spectra which we use inherently contain the focusing phenomenon.

Q. Is there an explanation as to why the stations 6 and 7 peak accelerations from IV-79 fall below the regression lines in the Blume Affidavit Figures 1 and 2.

A. As noted by the Appeal Board, if focusing were occurring the accelerations at stations 6 and 7 would be expected to be much higher than those predicted by the regression line. However, the fact that the peak accelerations for stations 6 and 7 fall below the regression line cannot be used to address the focusing question. Rather, this demonstrates the inappropriateness of linearly extrapolating the regression to a distance of 1 kilometer from the fault. This is explained in my response to question No. 1 where I discuss the acceleration-distance relationships developed with far field data and the inappropriateness of applying them in the near field. If indeed we had an adequate near field acceleration distance relationship to compare the stations 6 and 7 values to, then I would expect them to be above the line if there were focusing.

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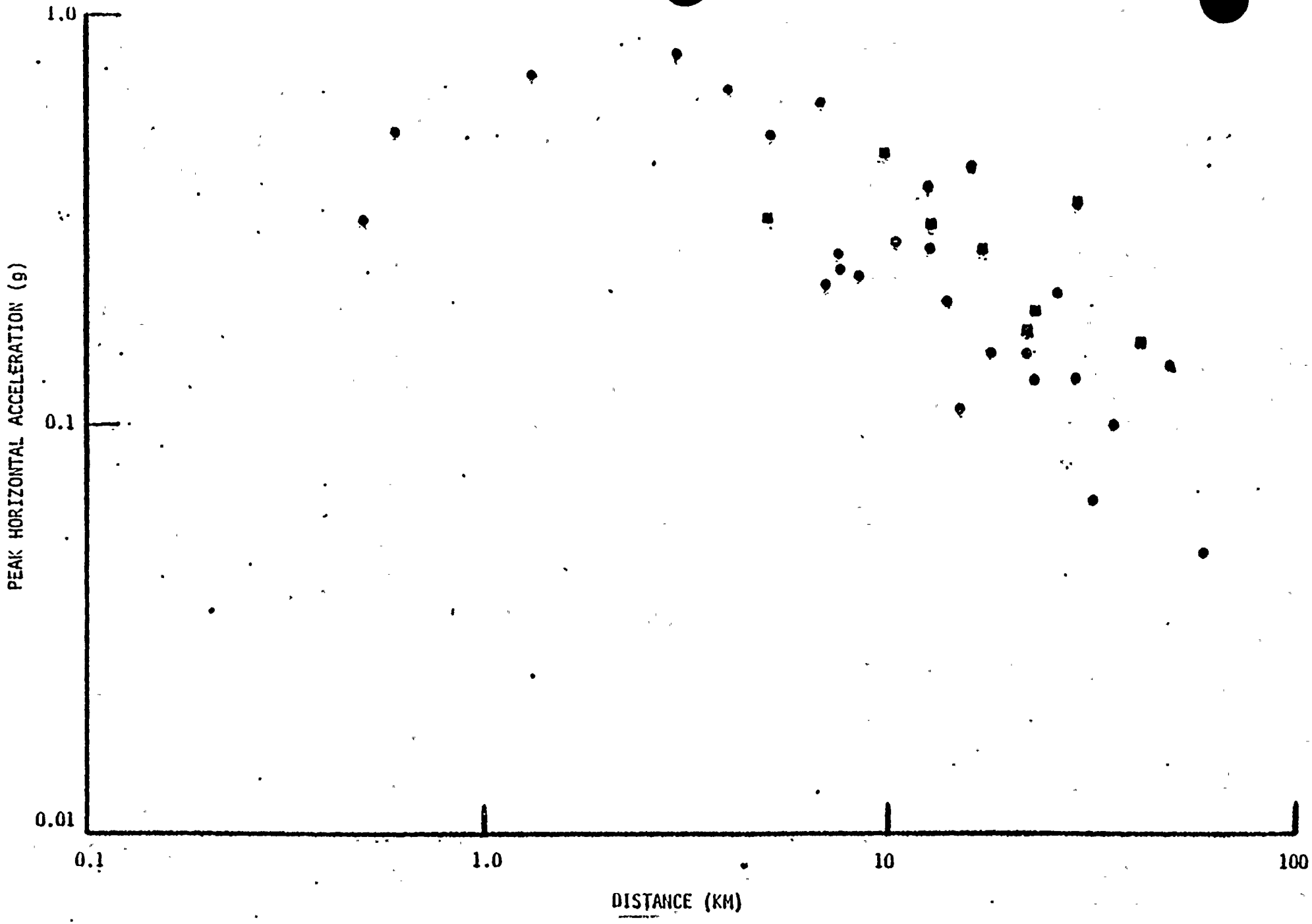


FIGURE 1 PEAK HORIZONTAL ACCELERATIONS AS A FUNCTION OF DISTANCE (BOORE & PORCELLA, 1980)

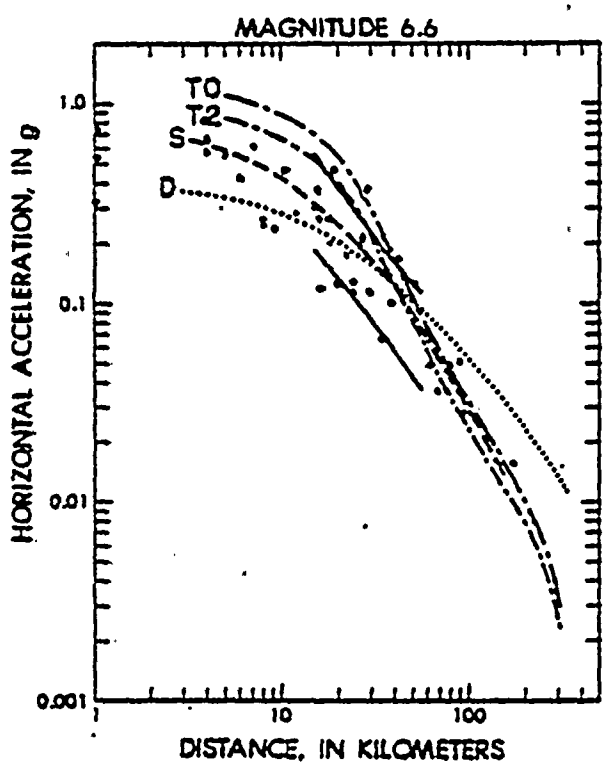


Figure 47. Proposed relations of peak horizontal acceleration to distance from slipped fault for magnitude 6.6 earthquake. Curve labeled S is given by Schnabel and Seed (1973) for rock sites, curve labeled D is given by Donovan (1973) for soil sites, and curves labeled TO and T2 are mean curves given by Trifunac (1976) for soft and hard sites, respectively. Solid lines show 70 percent prediction interval for data set for magnitude class 6.0-6.4 and small structures, from this report.

Figure 2a (Boore et al, 1978)

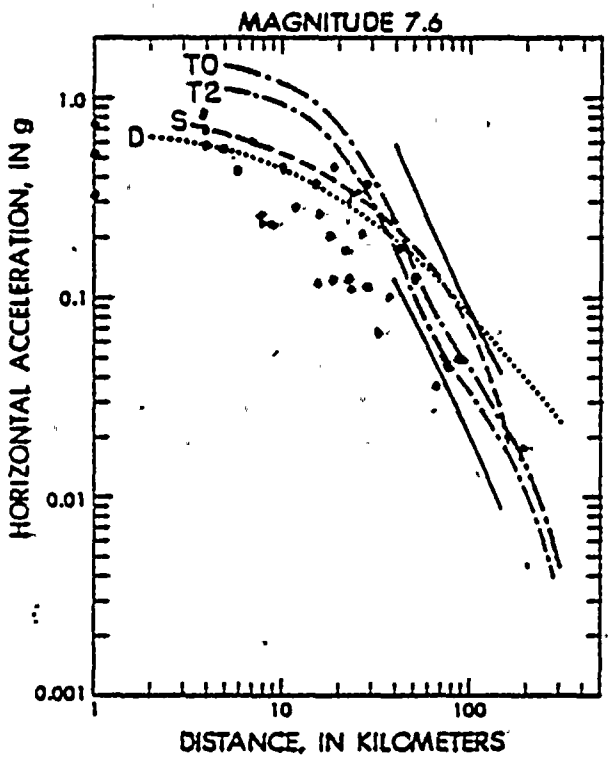


Figure 48. Proposed relations of peak horizontal acceleration to distance from slipped fault for magnitude 7.6 earthquake. Curves labeled S, D, TO and T2 are from sources given in figure 47. Solid lines show 70 percent prediction interval for data set for magnitude class 7.1-7.6 and small structures, from this report.

Figure 2b (Boore et al, 1978)

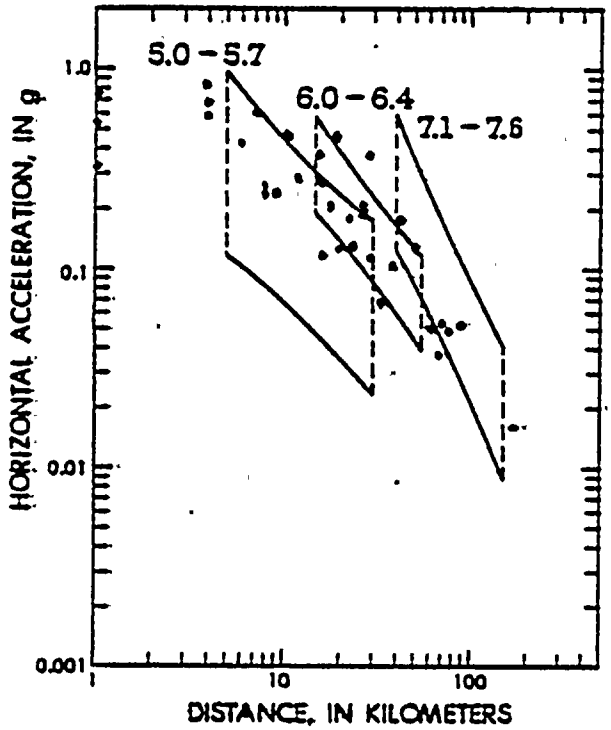


Figure 4. Comparison of 70 percent prediction intervals for peak horizontal acceleration recorded at base of small structures for magnitude classes 5.0-5.7, 6.0-6.4, 7.1-7.6. Curves taken from figures 1-3.

Figure 2c (Boore et al, 1978)

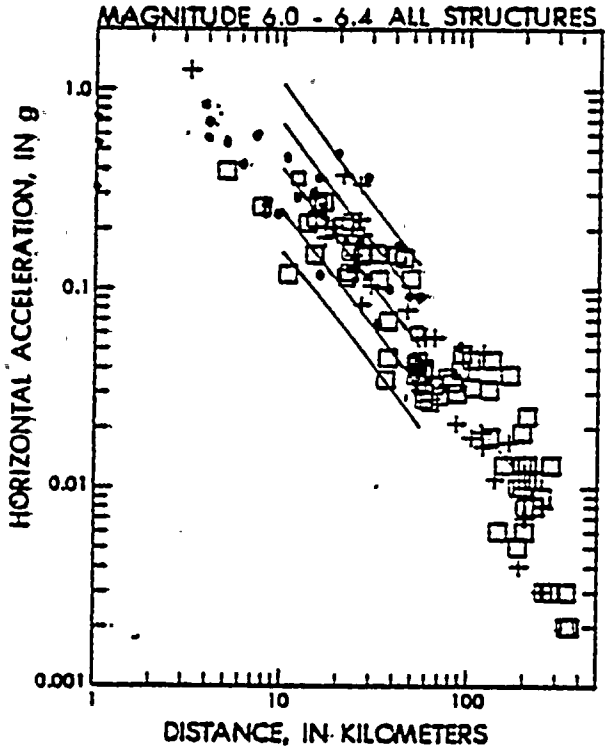


Figure 24. Peak horizontal acceleration versus distance to slipped fault for magnitude range 6.0-6.4 including data from both large and small structures. Symbols and curves same as in Figure 23.

Figure 2d (Boore et al, 1978)

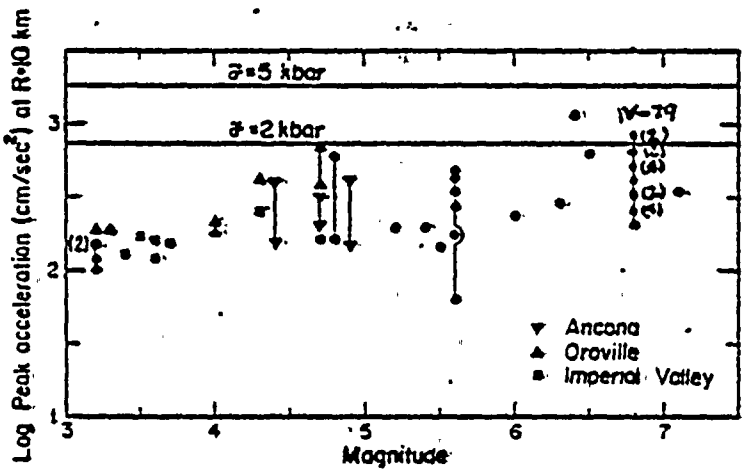
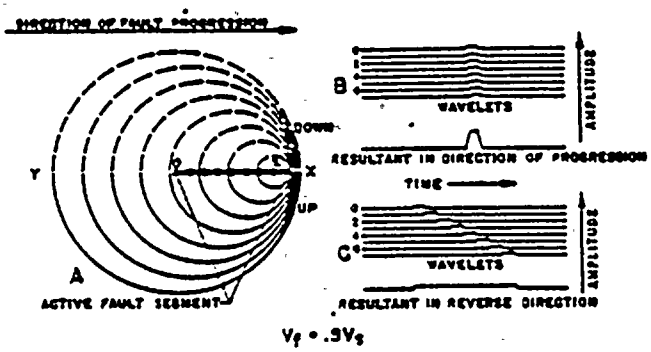


FIG. 1. Peak accelerations at $R \simeq 10$ km as a function of earthquake magnitude. Vertical lines connecting two or more symbols denote multiple observations of the same earthquake. The notation (2) indicates two coincident data points. The horizontal lines represent peak accelerations at $R \simeq 10$ km, as predicted by theoretical considerations discussed in the text.

Figure 3 (Hanks and Johnson, 1976)



EFFECTS OF SLIP PROGRESSION ON WAVE AMPLITUDES AND SHAPES.
H. BENIOFF • JULY, 1963

FIGURE 4.

Figure 4 (Benioff, 1955)

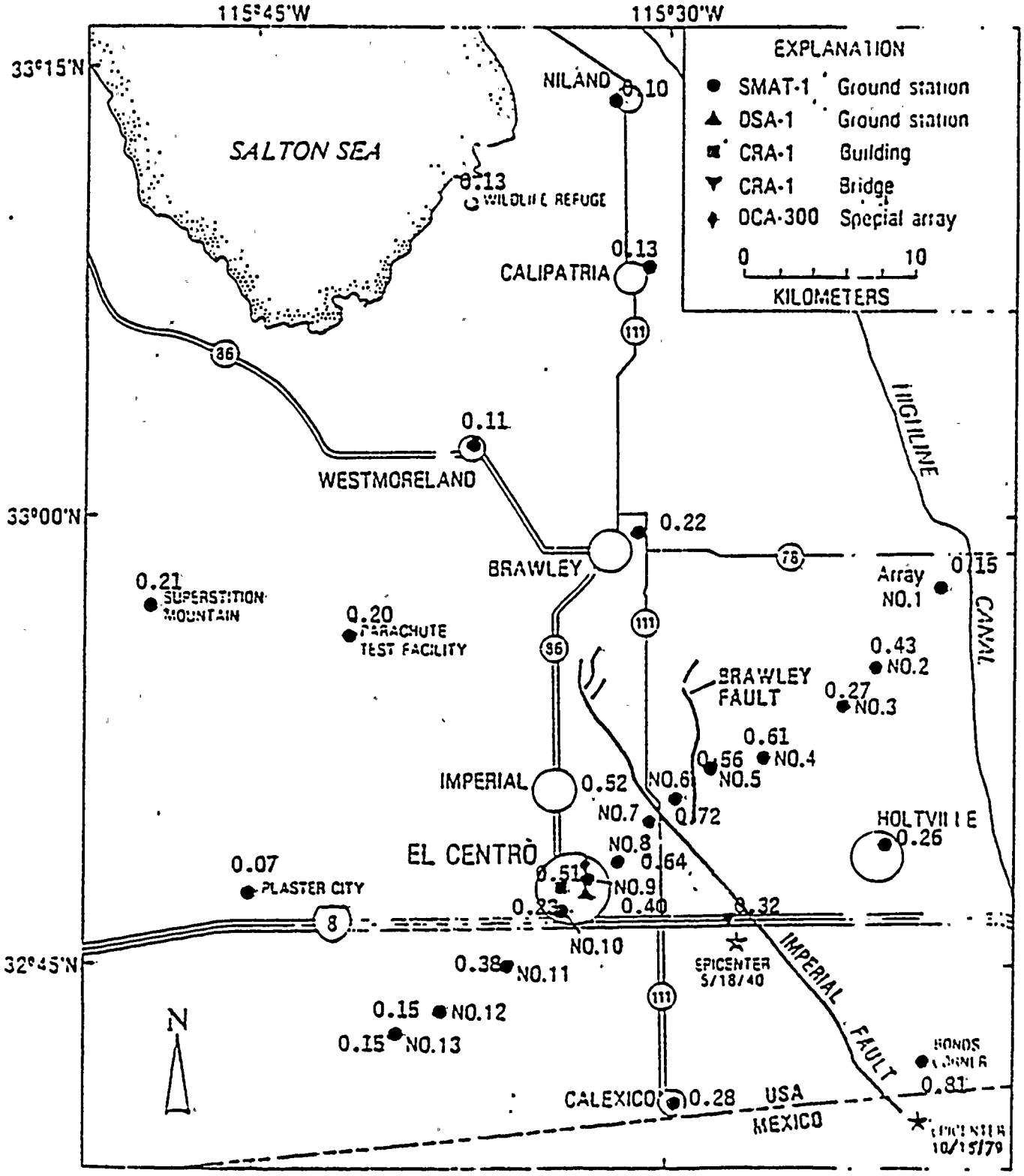


Figure 5 Strong-motion stations in the Imperial Valley, California (from (Brady et al, 1980)

ROBERT L. ROTHMAN
GEOSCIENCES BRANCH
DIVISION OF ENGINEERING
U. S. NUCLEAR REGULATORY COMMISSION

My name is Robert L. Rothman. I presently reside at 8409 Stonewall Drive, Vienna, Virginia 22180 and I am employed as a Seismologist in the Geosciences Branch, Division of Engineering, Office of Nuclear Reactor Regulation, Washington, D. C. 20555.

PROFESSIONAL QUALIFICATIONS

I received a B.S. degree in Geology from Brooklyn College and M.S. and Ph.D. degrees in Geophysics from the Pennsylvania State University.

I have been employed by the NRC since October 1979 as a Seismologist in the evaluation of the suitability of nuclear power plant sites. My areas of expertise include seismicity, rupture mechanics, seismic wave propagation and seismic instrumentation.

From 1975 through 1979, I was employed by the U. S. Air Force Technical Applications Center as a seismologist in the nuclear explosion detection program. I was involved in several projects of this program both as a Technical Project Officer and as a researcher. These projects included the detection of and the discrimination between underground explosions and earthquakes, magnitude and yield relationship studies, seismic network detection and location capability studies, regional and teleseismic wave propagation studies and projects to operate seismic instrument arrays and automatic data processing and communications systems.

From 1965 through 1970 I was employed as a seismologist by the U. S. Coast and Geodetic Survey. In this position I was involved in studies in the areas of engineering seismology, seismicity and earthquake aftershock sequences. This work was performed as part of a program to investigate seismic hazard in the United States.

From 1959 to 1961 and during 1964-1965 I was an Engineering Geologist with the New York State Department of Public Works. In this position, I conducted geophysical field surveys in support of construction projects such as bridges, buildings and highways.

BY MR. OLMSTEAD: (Resuming)

Q Dr. Rothman, I have in front of me a document entitled "Testimony of Dr. Robert L. Rothman." I ask you if this is the testimony you prepared to be filed in this proceeding?

A (Witness Rothman) Yes.

Q And do you have any corrections or additions to make to this testimony?

A Yes, I have one change to make. On page 9, the last line to the answer, strike out "independent of" and replace it with "not linearly dependent on."

Q Okay. Do you have other corrections?

A No, I don't.

Q Okay. Attached to your testimony is a statement of professional qualifications. I ask you if those are your professional qualifications?

A They are.

Q Dr. Rothman, your testimony as just corrected and your statement of professional qualifications as filed in this proceeding, are they true and correct to the best of your knowledge and belief?

A Yes.

MR. OLMSTEAD: Mr. Chairman, I move that the testimony of Dr. Rothman be bound into the transcript as if read.

CHAIRMAN SALZMAN: Any objection, Mr. Fleischaker?

MR. FLEISCHAKER: No objection, Mr. Chairman.

MR. LANPHER: No objection.

MR. NORTON: No objection.

CHAIRMAN SALZMAN: The Reporter will please do so.

(The document referred to follows:)

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 Unit Nos. 1 and 2)	)	Docket Nos. 50-275 O.L. 50-323 O.L.

TESTIMONY OF PAO-TSIN KUO

Q. By whom are you employed, and describe the work you perform.

A. I am employed as a structural engineer in the Structural Engineering Branch, Division of Engineering, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission. My work includes review of commercial nuclear power plants from a structural engineering perspective including the analysis of structural systems, static and dynamic analysis, design, and testing of safety-related structures. My work also includes the review and evaluation of the criteria developed and used for protection of nuclear power plants against the adverse effects associated with natural environmental loads and postulated failures of fluid systems for nuclear facilities.

Q. Would you detail your professional qualifications?

A. A copy of my professional qualifications is attached. I also testified at the Atomic Safety and Licensing Board proceedings, and a copy of my professional qualifications are bound into the transcript following Tr. 8697. I was also a participant in the "Joint Affidavit of Robert T. Rothman and Pao-Tsin Kuo" dated May 5, 1980 attached to the May 5, 1980 "NRC Staff Response to Joint Intervenors Motion to Reopen" submitted in this proceeding. The purpose of that affidavit was to provide our evaluation at that time of the preliminary seismological data from the Imperial Valley Earthquake of October 15, 1978 and its implication on the adequacy of the seismic design criteria for the Diablo Canyon Nuclear Power Plant (DCNPP). That analysis was based on the preliminary data then available from the Imperial Valley Earthquake. It was my view then based on the preliminary data from the Imperial Valley Earthquake, that the data should not cause any concerns about the seismic design criteria used for the Diablo Canyon Nuclear Power Plant (DCNPP). Further analysis of the data has not changed my position. The Imperial Valley Earthquake does not provide a basis for me changing my conclusion that the seismic design criteria used for the reevaluation of DCNPP are adequate for engineering design purposes.

Q. How did you develop your testimony?

A. My testimony in response to the Appeal Board's questions was developed in cooperation and consultation with Dr. Robert Rothman, and under the direct supervision of Mr. James Knight, Assistant Director for Components and Structures Engineering, USNRC.

Q. Would you describe the scope of your testimony?

A. Yes. My testimony is directed specifically toward the structural engineering aspects of the questions raised by the Atomic Safety and Licensing Appeal Board (Appeal Board) in the Appendix to Pacific Gas and Electric Company (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-598, Slip Op. (June 24, 1980).

Q. Which questions raised by the Appeal Board does your testimony address?

A. My testimony is directed toward questions 2, 4, 5, and 6. I also want to point out that Dr. Nathan M. Newmark, who acts as a consultant to the Nuclear Regulatory Commission Staff in structural engineering matters, is submitting separate testimony addressing the same Appeal Board's questions.

Q. Are there any significant difference in conclusions between Dr. Newmark's testimony and your testimony?

A. No. The conclusions arrived at in both testimonies are essentially the same although the bases used to draw the conclusions may be slightly different. My assessment shows that even in light of the IV-79 data the Diablo Canyon seismic design criteria reviewed during the Atomic Safety and Licensing Board hearings are adequate. The data generated from the recent Imperial Valley Earthquake of 1979 do not adversely affect the adequacy of the seismic design criteria used for the DCNPP.

Q. Do you have specific response to the Appeal Board's questions?

A. Yes, I do. They are as follows.

Q. Appeal Board Question 2 states:

> 2. Response spectra have been developed from the near field (1 to 11 km) ground motion records produced by IV-79. The records contain horizontal peak acceleration values in the range of 0.81g to about 0.2g. The applicant calculated a mean peak acceleration of 0.36 for IV-79 at the 5.8 km site-to-fault distance that characterizes the Diablo Canyon site (Applicant's Brief). Despite the fact that the IV-79 peak acceleration values are generally lower than the 1.15g peak acceleration or 0.75g zero-period acceleration used as the design basis for the Diablo Canyon plant (resulting from a postulated 7.5M event on the Hosgri fault), there are instances(although only those from the El Centro Arrays are significant) for which the IV-79 horizontal responses exceed the Newmark Design Response Spectrum for Diablo Canyon. (See Staff brief at p. 9; Brune affidavit, Attachments A and B.) In view of this, the parties should discuss whether the Newmark Spectrum is an appropriate and sufficiently conservative representation of the 7.5M event at Hosgri.35/

35/ In other words, if the various IV-79 near-field response spectra were used to generate a smoothed, average response spectrum for a zero-period acceleration appropriate to that event (in accordance with techniques explained in Blume's testimony fol. Tr. 6099 at page 6 and pages 39 and 40), and if this spectrum were scaled to a 0.75g zero-period acceleration, would the resulting response spectrum be bounded by the Newmark Spectrum for Diablo Canyon?

Q. Before you answer the questions, are there any clarifications you wish to make with respect to the question and footnote 35 to the question.

A. Yes. I did not perform the analysis requested by footnote 35 to question 2. I did not do this analysis because (1) I do not have the data available to complete such an analysis in the time required, and (2) I believe there is an equally convincing way to demonstrate that the Newmark Spectrum for DCNPP is appropriate and sufficiently conservative.

Q. Would you please explain?

A. Attachment 1 is a plot of an envelope of upper and lower bounds of all horizontal response spectra for 5% damping generated from the IV-79 motions recorded within 11 Kilometers of the fault. Plotted in the same graph is also a Newmark horizontal design spectrum for 5% damping used for the Diablo Canyon seismic reanalysis.

It can be seen that for periods in the range of interest (i.e., lower than 0.5 seconds), the Newmark design spectrum is for the most part above the upper bound envelope of the IV-79 data. For a few places where the Newmark design spectrum falls below the upper bound envelope, the differences are minor. Should a smoothed, average response spectrum be generated from the IV-79 data for a mean zero period acceleration scaled up to 0.75g as suggested on p. 22 of the ALAB-598 decision, in my opinion it would be bounded by the Newmark design spectrum for Diablo Canyon over the frequency range of interest (i.e., above 2 Hz for DCNPP). This is because the amplification factors exhibited in the

IV-79 data do not appear to be greater than those used in the Newmark design spectrum. Therefore, the few small exceedances shown in Attachment 1 will not be heavily weighted if a statistical averaging process were applied to the entire IV-79 data set.

Attachment 2 is a plot of the vertical response spectrum at El Centro Array 6 Station and the upper and lower bounds of all the remaining vertical response spectra for 5% damping generated from the IV-79 motions recorded within 11 kilometers of the fault. Plotted in the same graph is also a Newmark vertical design spectrum for 5% damping used for Diablo Canyon seismic reanalysis.

The same type of trends explained above for the horizontal response spectra can also be said for the vertical response spectra. Although it is seen that the vertical spectrum at the El Centro Array 6 station is considerably above the Newmark vertical spectrum, because of the peculiar geological environment at that station as explained in Dr. Rothman's testimony, this spectrum is considered nonrepresentative of the IV-79 data in general. More discussions on the vertical response spectra are given in my response to the Board's Question 4.

Furthermore, I am of the opinion that there are inherent conservatisms (e.g., elastic design, conservative loads and load combinations) in the nuclear design practice which are enough to alleviate any concerns caused by these occasional exceedances over small ranges of frequency.

It is also worth noting that Regulatory Guide 1.60 Design Spectra are not intended to be statistical upper bounds. They are instead design spectra of mean plus one standard deviation values. Therefore, there are a few spectral values in the statistical data used which actually exceed the Regulatory Guide 1.60 Design Spectra.

For the above reasons, my opinion is that, even in light of the IV-79 data, the Newmark design spectra for Diablo Canyon are appropriate and sufficiently conservative.

Q. Appeal Board Question 4 states:

> The magnitudes of vertical and horizontal acceleration values measured at IV-79 are generally comparable. (Mean values calculated at a distance of 5.8 km from the fault are virtually identical.)36/ The response spectra developed for vertical motion within 11 km of the Imperial Fault during IV-79 appear to show generally equivalent values of vertical and horizontal response for periods less than about 0.2 seconds (i.e., frequencies in excess of 5 cps).37/ Finally, 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 Spectrum.38/
>
> Observations made of the IV-79 data and response spectra appear to be consistent with the criteria set forth in NRC Regulatory Guide 1.60. These require that vertical accelerations in the higher frequency range be equal to horizontal accelerations. As the guide states:
>
>> It should be noted that the vertical Design Response Spectra are 2/3 those of the horizontal Design Response Spectra for frequencies less than 0.25; for frequencies higher than 3.5 they are the same, while the ratio varies between 2/3 and 1 for frequencies between 0.25 and 3.5.39/
>
> The references to vertical motion made in the Diablo Canyon record, however, indicate that a 2/3 ratio between vertical and horizontal

motion was apparently utilized at all frequencies.40/ The parties should address this apparent inconsistency and explain it, if possible. Should there be substantive and relevant analyses suggesting that vertical motion records do not reflect the true vertical motion, these should be provided.41/ [footnotes deleted]

Q. Is it correct that Regulatory Guide 1.60 specifies that vertical accelerations in the higher frequency range be equal to horizontal accelerations?

A. Yes. That is correct.

Q. Then would you explain how the staff's position on vertical motion adopted for Diablo Canyon of 2/3rds the horizontal acceleration value is consistent with the established staff position?

A. The position adopted for Diablo Canyon is not inconsistent with the staff position. But the overall staff position was changed after Regulatory Guide 1.60 was issued (and revised in December 1973). After Regulatory Guide 1.60 was issued, the staff had contracted with N.M. Newmark Consulting Engineering Services to perform additional statistical studies of recorded earthquake motions. The final report resulting from this contract was entitled "Statistical Studies of Vertical and Horizontal Earthquake Spectra" and was issued in January 1976 by NRC as Report No. NUREG-003.

One of the conclusions and recommendations of this report was that the response spectra for vertical motions can be taken as 2/3rds of the response spectra for horizontal motions over the entire frequency range for sites in the Western United States. This finding was adopted as the branch position on July 22, 1976. Attachment 3 is a copy of the memorandum by the Branch Chief reflecting the branch position. The memorandum indicates that "we will allow applicants the option of taking the vertical design response spectrum as 2/3rds of the horizontal response spectrum over the entire range of frequencies in the Western United States only. For other locations, the vertical response spectra will be the same as given in Regulatory Guide 1.60".

The basis for the branch position was the extensive study by Newmark involving a large statistical population of the earthquake records available at the time of the study.

Q. Are there any substantive and relevant analyses suggesting that vertical motion records do not reflect the true vertical motion?

A. Yes. With regard to the records of the observed vertical motions, Newmark (1973)[1/] and Bolt and Hansen (1977)[2/] demonstrated in their papers that an upthrow of objects could physically occur during earthquakes even if the vertical ground motions did not attain the value of 1g. This implies that an overregistration by recording instruments is entirely possible, especially if the instruments rest directly on the earth without any anchors.

Q. Have the new data generated by IV-79 altered the NRC Staff conclusion with respect to the Newmark vertical design response spectrum for Diablo Canyon?

A. No. Although the IV-79 data show in some instances comparable vertical and horizontal accelration values and resulted in three vertical response spectra (Stations 6, 7, and El Centro Differential Array) which exceeded the Newmark vedrtical design spectrum, these data do not serve as an adequate basis for altering the previous conclusion that the Newmark design response spectra are adequate.

Q. What is the basis for this Staff conclusion:

A. The basis for the Staff conclusion is as follows:

(1) Geological differences between Imperial Valley and the Diablo Canyon site. This is discussed in detail in Dr. Rothman's response to ALAB Question 3; but in general, the high vertical peak acceleration in Imperial Valley may be due to the high seismic velocity gradient (Archuleta 1980).

(2) Inclusion of IV-79 data in the Newmark Statistical Study will not likely alter the finding of that study significantly. Of the many data recorded from IV-79, only three data points exceed the Newmark design spectrum.

(3) Uncertainties about the representative characteristics of the records as explained in Rothman-Kuo Affidavit, pages 9-10. They are (a) El Centro Differential Array Station and (b) difference between corrected and uncorrected data.

Q. Appeal Board Question 5 states:

Peak horizontal acceleration values measured at the base of the Imperial Valley Services Building during IV-79 exceed those measured in the free field 103 meters away from the building. The motion records are described as showing similar amplitudes but greater low frequency motion in the building than in the free field.42/ No response spectra for the two recording locations have been provided. The acceleration data, however, may be taken to indicate that no reduction in building motion due to the tau effect was realized in this instance.

Based on these observations, intervenors question the validity of the tau concept as well as its use to reduce the higher frequency portions of the Diablo Canyon Design Spectrum. The Staff and the applicant answer that, because the Imperial County Services Building was supported on piles in a deep soil structure, these observations are irrelevant to the use of a tau effect in the seismic reanalysis of Diablo Canyon, which is built on a rock site.43/ Staff witness Newmark, however, used recorded earthquake motions at the Hollywood Storage Building to demonstrate the use of a tau effect analysis.44/ The Hollywood Storage Building itself is built on piles in soil. Thus, the "built-on-piles" rationale appears insufficient to explain why no tau effect was evident at the Imperial Valley Services Building.

One feature distinguishing the two buildings that no party commented upon is that the Hollywood Storage Building has a partial basement and the Services Building does not. Intervenors' witness, Dr. Luco, used this fact to explain in part why he believes the Hollywood building should have a large tau value.45/ Rojahn and Ragsdale's discussion implies that to some extent ground level instrumental responses within the Imperial Valley Services Building may have been influenced by the response (and failure) of the building itself.46/

In any event, 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 should provide additional information on this point and relate their analyses to both geologic and structural conditions prevailing at the Diablo Canyon site.

42/ See "A Preliminary Report on Strong-Motion Records from the Imperial County Services Building by Christopher Rojahn, U.S. Geological Survey and J.D. Ragsdale, California Division of Mines and Geology (undated but issued early January 1980), pp. 7 and 8.

43/ Blume Affidavit, Para. 10; Rothman - Kuo Affidavit, p. 7.

44/ SER Supplement 5, Appendix C.

45/ Tr. 8949.

46/ Rojahn and Ragsdale, pp. 7 and 8. That report also reflects information regarding the Services Building asymetric structure (at pp. 2 and 3) which may explain why it was susceptible to damage (see Newmark Testimony fol. Tr. 8552, Attachment B, pp. 14 and 15).

Q. The Appeal Board's question indicates that the answer given in the Rothman-Kuo affidavit does not sufficiently explain why no Tau effect is evident at the Imperial County Services Building (ICSB). Do you have any more information to add?

A. Yes. I would like to point out that the structural response recorded during the IV-79 earthquake at the Imperial County Services Building is very complex in nature due to its design and structural failure during the earthquake. The dynamic response of the building could have been influenced by a number of factors such as "Tau", torsion, yielding and cracking of structural members, failure of columns, and soil-pile-structure interaction. The fact that no Tau effect was evident at ICSB

can be attributed to the masking influence of any one or a combination of these factors. For example, Dr. Newmark's testimony attributes the lack of ability to identify the Tau effect to the influence of torsion, yielding, and failure of columns. In Rothman-Kuo's affidavit on Page 7, we attributed the apparent lack of the Tau effect to the influence of piles. This was based on our preliminary assessment. We have since examined the situation that occurred at ICSB more closely. It is my opinion that what appears to have happened to the dynamic response recorded at ICSB was a combination of the influences from all these factors. Attachment 4 is a comparison of the response spectra for 5% damping, generated from the motion recorded at the ground floor of the Imperial County Service Building and in the free field (Response Spectra were taken from a preliminary data report by California Division of Mining and Geology.[3/]). In the north-south direction, the response spectra at the ground level is above the free field spectrum for periods lower than about 1.3 seconds, while in the east-west direction, the response spectrum at the ground floor oscillates about the free field response spectrum. The comparisons demonstrate the complex nature of the response characteristics of the Imperial County Service Building while it was undergoing failure.

Q. How do you explain the fact that the dynamic response characteristics are so different for two buildings, i.e., the ICSB and the Hollywood Storage Building, with the apparent similarities between the structural foundations?

A. Although both the Hollywood Storage Building and the Imperial County Services Building were founded on piles, the construction of the pile foundations for the two buildings were quite different. At the Hollywood Storage Building, the tops of the piles were encased in the foundation slab; while at the Imperial County Service Building, the piles were linked together by concrete beams. This difference alone in my opinion was enough to cause the different dynamic response characteristics. Moreover, the Imperial County Service Building has serious stiffness discontinuities between the 1st and 2nd floors and its columns failed during the earthquake. The column failure inevitably increased the eccentricity in the building. It is my opinion that all these factors have contributed to the difference in response characteristics between the two buildings.

Q. What is the conclusion, then, based on your assessment of the IV-79 data as it affects the ICSB?

A. My opinion as expressed on Page 8 of the Rothman-Kuo affidavit is that the records at the ICSB for the IV-79 earthquake can <u>neither</u> validate <u>nor</u> invalidate the use of the "Tau" effect as an engineering equivalent factor at this time. But the absence of a record showing the Tau effect at ICSB does not detract from properly taking account of the Tau effect for the design of buildings.

Q. Appeal Board Question No. 6 states:

> Throughout the Licensing Board hearings, parties stressed the rôle of soil-structure interactions as a mechanism that would reduce the magnitude of structure motion relative to ground motion (e.g., Tr. 8878; 8947-46). Staff and applicant's arguments (in response to intervenors' suggestion of the apparent lack of tau effect during IV-79) point to soil-structure interactions as the reason for building motion exceeding that of the ground (Blume Affidavit, para. 10; Rothman-Kuo Affidavit, p. 7). (a) Describe and explain the circumstances in which soil-structure interactions produce enhanced or reduced structural response. (b) Discuss the relevance and applicability for such interactions to the seismic response assumed for Diablo Canyon.

Q. To what do you attribute the apparent lack of Tau effect in the Imperial County Services Building?

A. In the Rothman-Kuo affidavit referred to in the Appeal Board's question, I initially indicated that "The motions recorded at the Imperial County Services Building foundation, it appears, are the amplified responses from the earthquake motions through the piles." Since that time, as indicated in my response above to question 5, we have examined the situation at ICSB more closely. As I indicated, what appears to have happened to the dynamic response recorded at ICSB was a combination of a number of factors in which the Tau effect was masked.

Q. Describe and explain the circumstances in which soil-structure interactions produce enhanced or reduced structural response.

A. The effect of soil-structure interaction is also a very complex phenomenon. There are many different modeling techniques being used to analyze such phenomenon. A great deal of engineering judgement is involved in each of these techniques. In general, it has been my experience that for structures founded on soft soil and especially with basements, the effect of soil-structure interaction reduces the structural response at the foundation level. On the other hand the response at high elevations in a structure may be enhanced due to the fact that the relatively soft soil allows the structure to rock on its foundation.

Q. Discuss the relevance and applicability for such interactions to the seismic response assumed for Diablo Canyon.

A. Since all major structures for Diablo Canyon are founded on a rock site which is generally recognized as having little or no soil-structure interaction effect, the discussion of such effect does not apply to the seismic response assumed for the design of Diablo Canyon facility.

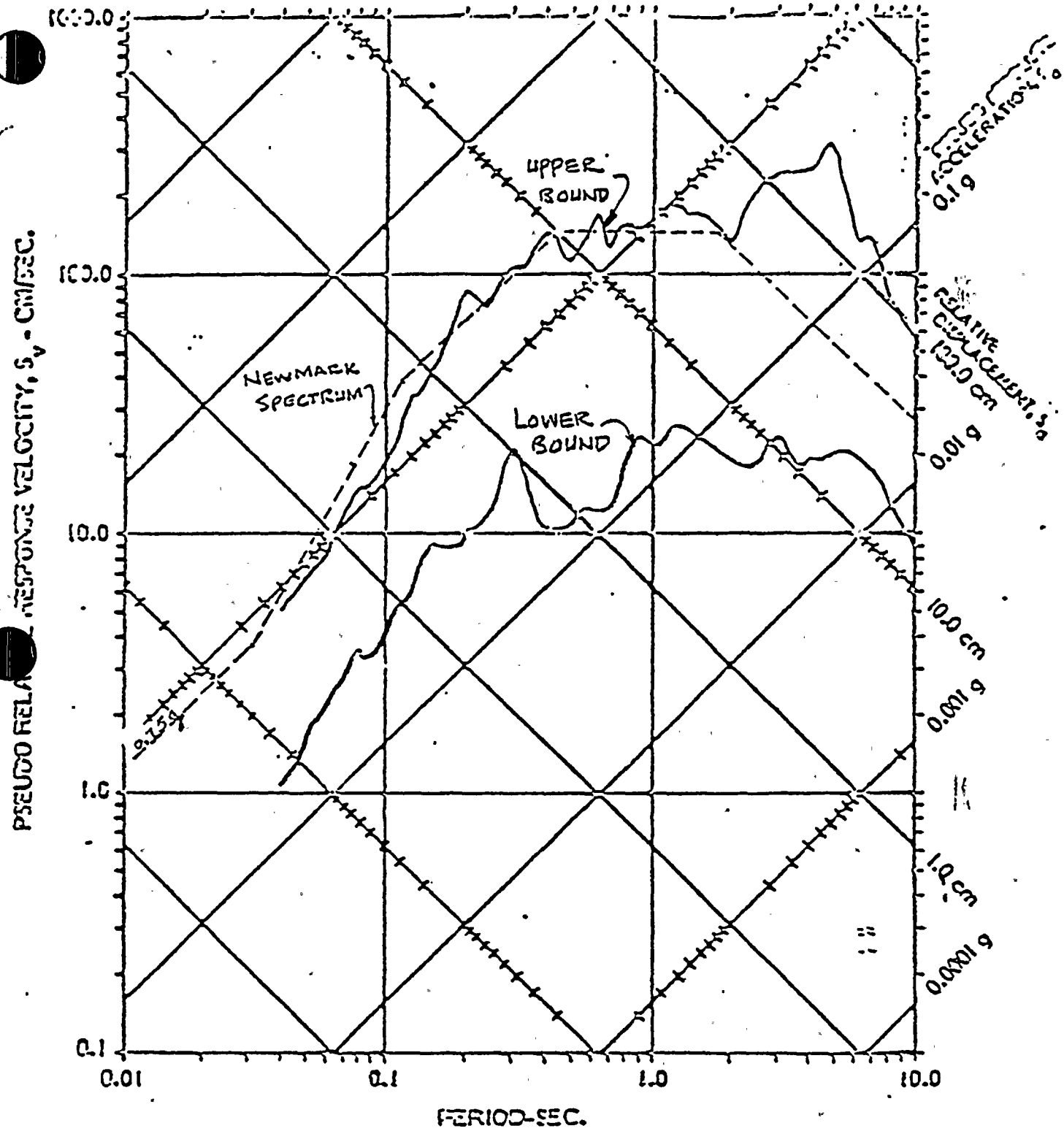
REFERENCES

1. Newmark, N. M., Interpretation of Apparent Upthrow of Objects in Earthquakes, 5th. World Conference on Earthquake Engineering, Rome, Italy.

2. Bolt, B. A. and Hansen, R. A., The Upthrow of Objects in Earthquakes, Bulletin of the Seismological Society of America, Vol. 67, No. 5, October 1977.

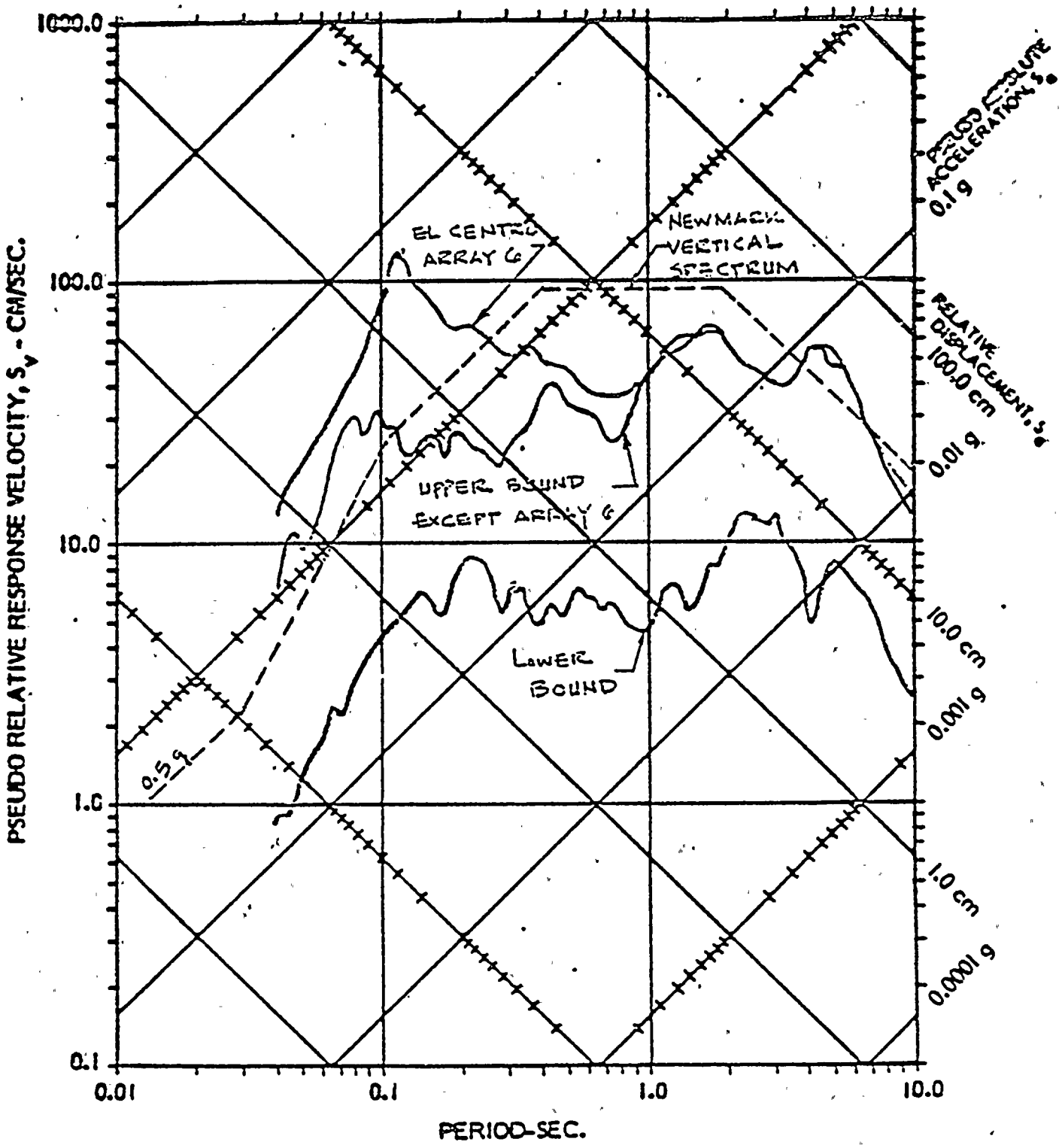
3. Preliminary Data, Partial Film Records and Preliminary Data, Imperial Valley Earthquake of 15 October 1979, Imperial County Services Building, Department of Conservation, Division of Mines and Geology, Sacramento, California.

Attachment 1



IMPERIAL VALLEY EARTHQUAKE 15 OCT 79 - ENVELOPE OF HORIZONTAL RESPONSE SPECTRA (5% DAMPING) OF ELEVEN STATIONS WITHIN ELEVEN KILOMETERS OF THE FAULT TRACE.

Attachment 2



COMPARISON OF NEWMARK VERTICAL SPECTRUM AND VERTICAL SPECTRA DEVELOPED FROM THE IV-79 DATA ALL FOR 5 % OF CRITICAL DAMPING

Attachment 3

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 22 1976

Members, Structural Engineering Branch

RESPONSE SPECTRA IN THE VERTICAL DIRECTION

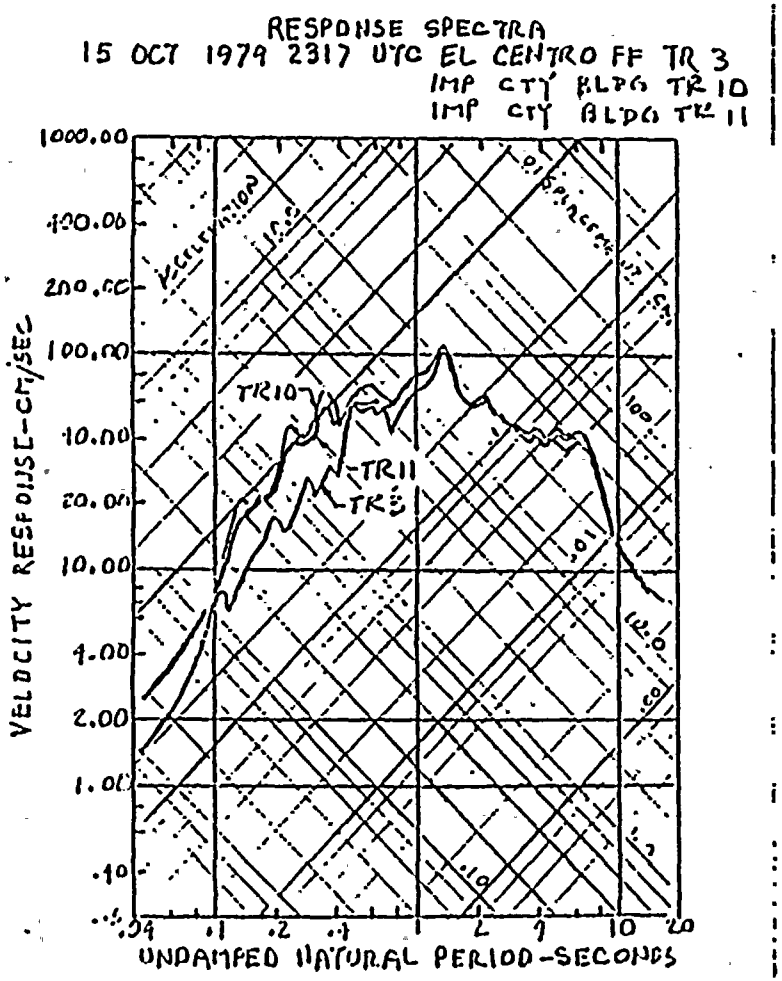
Subsequent to the issuance of Regulatory Guide 1.60, Nathan M. Newmark Consulting Engineering Services performed for us an additional statistical study of ground motions for a number of horizontal and vertical components of strong motion earthquake records to determine the dependence of design response spectra on the earthquake ground acceleration level. The final report on this study entitled "Statistical Studies of Vertical and Horizontal Earthquake Spectra" was issued in January 1976 by NRC as Report No. NUREG 0003.

One of the important conclusions of this report was that the response spectrum for vertical motion can be taken as 2/3 the response spectrum for horizontal motion over the entire range of frequencies in the Western United States. According to Regulatory Guide 1.60, the vertical response spectrum is equal to the horizontal response spectrum between 3.5 cps and 33 cps. To be consistent with the latest available data in NUREG 0003, we will allow applicants the option of taking the vertical design response spectrum as 2/3 the horizontal response spectrum over the entire range of frequencies in the Western United States only. For other locations, the vertical response spectrum will be the same as that given in Regulatory Guide 1.60.

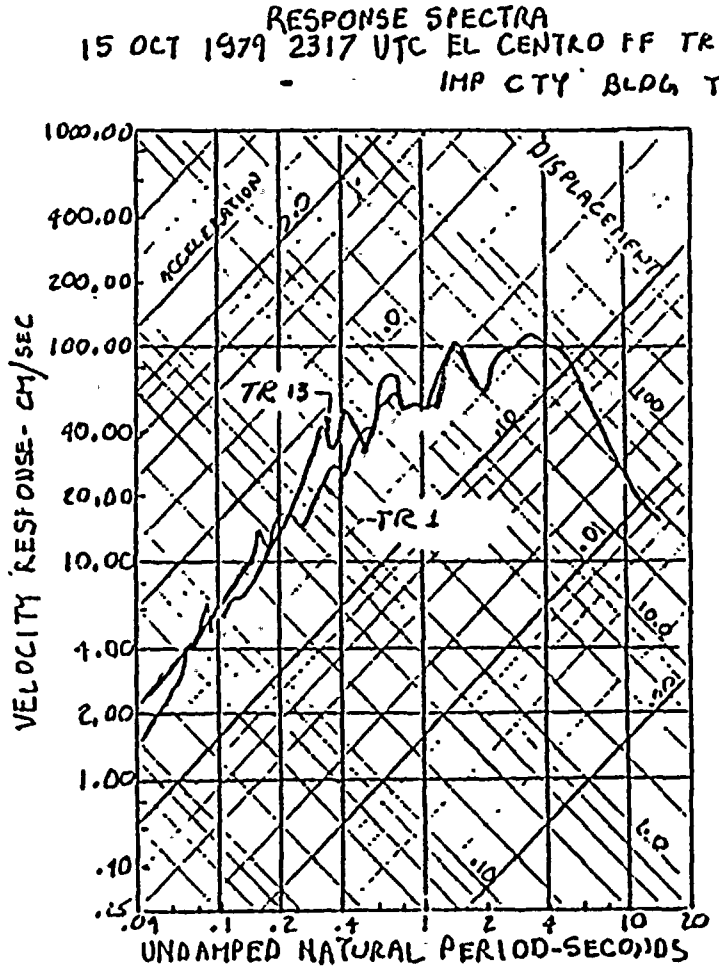
/s/ I. Sihweil

I. Sihweil, Chief
Structural Engineering Branch
Division of Systems Safety

cc: J. Knight



5% Critical Damping



5% Critical Damping

RESPONSE SPECTRA OF IMPERIAL VALLEY EARTHQUAKE AT IMPERIAL COUNTY SERVICE BUILDING (TAKEN FROM A PRELIMINARY DATA REPORT BY CDMG)

Attachment 4

PROFESSIONAL QUALIFICATIONS

PAO-TSIN KUO

U.S. NUCLEAR REGULATORY COMMISSION

STRUCTURAL ENGINEERING BRANCH

DIVISION OF SYSTEMS SAFETY

I am a Structural Engineer responsible for review and evaluation of design criteria for structural systems, static and dynamic analyses, design, and testing of safety-related structures, and the criteria for protection against the adverse effects associated with natural environmental loads and postulated failures of fluid systems for nuclear facilities.

I received an Engineering Diploma in Civil Engineering from Taipei Institute of Technology in 1958, a M.S. degree in Civil Engineering from North Dakota State University in 1966, and a Ph.D. degree in Civil Engineering from Rice University in 1974. I completed my graduate studies all under scholarships and fellowships. My major fields of studies included structural dynamics, engineering mechanics and earthquake engineering in particular. I was elected to be a member of Sigma Xi honor society in 1970. Currently, I am a member of both Earthquake Engineering Research Institute and American Society of Civil Engineers. I am also a registered Professional Engineer in the State of Maryland.

From September 1958 to June 1960, I served as a commissioned lieutenant officer with Chinese Marine Corps. During the last eight months of this period I also served as a field engineer involved in the reconstruction of a reinforced concrete dam destroyed by a record flood.

From July 1960 to June 1961, I was employed by Taiwan Water Conservancy Bureau as a civil engineer involved in embankment line layout.

From July 1961 to March 1965, I joined Keelung Harbor Bureau in Taiwan, China. I served as a field structural engineer responsible for construction

of a number of harbor structures including both steel and reinforced concrete structures.

From April 1965 to September 1965, I was employed by John A. Mackel and Associates in Los Angeles, California as a Designer responsible for analysis and design of highrise commercial buildings.

Immediately after I received my MSCE degree, I was employed as a Senior Design Engineer by Cushing and Nevell Technical Design Corporation on contract to Ebasco Services, Inc. in New York City from July 1966 to August 1967. During this period I was primarily concerned with the structural analysis and design for a commercial nuclear power plant.

From March 1971 to May 1975, I was associated with Bechtel Power Corporation in Gaithersburg, Maryland. Between the years of 1971 to 1973, I served as a Senior Engineer in charge of seismic analyses for a commercial nuclear power plant. I was also responsible for reviewing and approving the seismic qualifications of mechanical and electrical equipment by either analytical means or laboratory testing. During this period I was also engaged in impact analysis for cask drop and aircraft impact and in developing design criteria and methods for pipe whip restraint design.

Between the years of 1973 to 1975, I served as an Engineering Specialist responsible for reviewing and establishing criteria for seismic analyses of structures, performing specialized investigative studies in the seismic analysis area, and advising the Chief Engineer concerning problems related to sesimic analyses and design.

Representing the Gaithersburg Division, I also served as a member of the Bechtel Seismic Task Force Committee during the period from 1972 to 1975. The Committee had the responsibility of establishing the corporate standards related to seismic analyses and design. We co-authored the Bechtel topical report, BC-TOP-4A, entitled "Seismic Analyses of Structures and Equipment

for Nuclear Power Plants" which is widely referenced by the nuclear industry.

In June 1975, I joined the Nuclear Regulatory Commission and have remained with this organization since. During this time, I have participated in the review and evaluation of many construction permits and operating licenses and in the generic review of topical reports, seismic analysis methodology, and structural aspects of suppression pool dynamics. I have also participated in the NRC sponsored confirmatory research activities related to seismic analyses.

I have also served as a member of AISC Nuclear Specification Task Committee III responsible for writing the nuclear specification (ANSI N690).

MR. OLMSTEAD: Mr. Chairman, Mr. Knight also has testimony filed in this proceeding, but it is on a later question, so I propose to defer moving that into the evidence until we reach the question.

CHAIRMAN SALZMAN: As you wish, Mr. Olmstead.

BY MR. OLMSTEAD: (Resuming)

Q Dr. Newmark, you have been present during the course of these proceedings since they began on Monday, is that correct?

A (Witness Newmark) Yes, I have.

Q And have you heard testimony concerning the question of earthquake acceleration levels, ground motion levels involving an amplified envelope, probabilistic levels and questions as to the appropriateness of using amplified envelopes for design response spectra?

A Yes, I have.

Q And do you have a particular viewpoint on the appropriateness of using amplified envelopes in seismic design response spectrums?

A I have great objections to that, and I would like to explain in some detail. I will try to keep this as brief as possible, Mr. Chairman.

Let me outline the way in which I have approached the design of critical facilities of all kinds for a number of years, and in particular, nuclear reactor facilities.

The design of a nuclear reactor facility is essentially composed of a number of aspects governed by criteria which involve decisions as to parameters to use and their interaction. None of these is independent of the others. For example, the earthquake acceleration level or ground motion, more precisely including velocity and displacement, may involve an envelope, an amplified envelope, a mean or some probabilistic level such as a mean plus one standard deviation or other probable level.

If only the ground motion were involved in design with no safety factors or conservatism in the other parameters, it might be appropriate to use an amplified envelope or an envelope spectrum, but the problem is really a probabilistic one, although it is usually stated in deterministic form.

The most important parameters can be stated more or less as follows, omitting some which contribute to additional conservatism. Each of the following has a probability distribution function.

One, the earthquake magnitude and the distance from the site. We do not know precisely what the earthquake magnitude will be for design purposes. We even have difficulty in ascribing a specific magnitude to a past earthquake. There is some uncertainty in the numbers.

Two, the peak ground motion values of acceleration,

velocity, displacement, the transient values of these, and not nearly the acceleration level. Each of these has a probabilistic distribution.

Three, the response spectrum or other measure of the effect on structures and equipment. These might be rather than the response spectrum, the Fourier spectrum, the paraspectral density and the like.

Four, the damping level for energy absorption essentially in the linear or elastic range.

Five, the analytical procedure used which involves developing a model of some sort which is analyzed, but which represents only approximately the real structure and the real equipment at its mounting.

Six, the combinations of loading and/or motions and in particular, the earthquake motions in the various directions, both horizontal and vertical, and other loadings including operating loads, accident loads, and the like.

Seven, the material properties of which the structure is composed or which is involved in the mounting of equipment or in the equipment itself.

Eight, the strength of the structures and the fragility levels of equipment. By that I mean the levels at which they cease to function properly or have some aspects of inadmissible deformations.

And nine, which is essentially closely related to

the preceding one, the ductility levels or energy absorption in the range of permissible non-linear action.

Q Dr. Newmark, have you reviewed copies of the testimony filed in this proceeding by Dr. Luco?

A Yes, I have.

Q On page II-3 of his testimony --

MR. NORTON: Excuse me. If we could ask that when you refer to somebody else's testimony, could you give us a chance to get it out and be looking at it before you ask the question?

CHAIRMAN SALZMAN: Surely. Please, Mr. Olmstead.

(Pause.)

MR. NORTON: I think we need the page. We are all scrambling for the document.

MR. OLMSTEAD: Page II-3.

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dsp7-1

BY MR. OLMSTEAD:

Q Dr. Newmark, do you have a copy of Dr. Luco's testimony?

A Yes, I do.

Q If you would refer to page II-3, at the bottom of the page, there is a paragraph numbered three, which says, "To study whether the Newmark Spectrum is an appropriate and sufficiently conservative representation for the 7.5 magnitude event at Hosgri, I have used the following procedure:" and then there are five numbered paragraphs in small Roman numerals continuing on to page II-4.

Do you agree with those five assumptions?

A I disagree completely with those assumptions, except for one point in the third item in which Dr. Luco states that the value of the median plus standard deviation is approximately 1.5 times the median value.

However, his value of .75g as a mean expected acceleration is not correct; it is not supported by evidence from actual earthquakes, nor by any of the statistical studies that have been made of actual earthquakes.

And it implies essentially an envelope of data rather than a probabilistic distribution at the level which should be used.

I would like to explain the data that I have

dsp7-2 1

1 used in determining the levels for the design or review,
2 rather, of Diablo Canyon and for the design of other
3 nuclear reactors, if I may.
4 Q Please explain, then.
5 A In the development of my concepts from about
6 1965 I have used data from actual earthquakes, analyzed
7 statistically, and have published from time to time papers
8 describing and characterizing the mean and mean plus
9 standard deviation levels of ground motion for use in
10 design.
11 At that time the Atomic Energy Commission, the
12 forerunner of the Nuclear Regulatory Commission was using
13 a design spectrum developed by Dr. George Housner of
14 the California Institute of Technology, which I felt was
15 much too low for the design of nuclear reactors.
16 And I presented evidence to support my contention
17 that those should be increased by 60 to 70 percent, and
18 those were presented in detail in a paper given in Japan
19 at a meeting of the International Atomic Energy Agency in
20 1967 and later adopted more or less informally by the AEC
21 in their review of nuclear reactor design proposals for
22 seismic resistence.
23 There were not very many earthquakes available at
24 that time, but the advantage of the probabilistic
25 interpretation of the records is that there has been only

dsp7-3

slight changes required in light of the additional data that had become available from time to time since that paper was presented.

As a matter of fact, my earlier recommendations were perhaps somewhat conservative or more conservative than I think they needed to be, and further data have permitted in some cases a reduction in that conservatism.

An envelope of data would have required a constant increase, however; in the design -- the development of the criteria for the Diablo Canyon reactor, I took as the basis the strongest earthquake record that was available, assumed that this would represent something that would be conservative for the design.

This was the Pocoima Dam record of the San Fernando earthquake, but I recognized from the data and the records that the peak on which the instrument was mounted was responding at much the same was as a structure. For example, all three components of motion that were measured showed a very high degree of correlation, which is very much different from all other earthquake records except for one or two others on similar peaks.

I arrived at an effective value -- not so much effective value; it was a real -- at a real value for the earthquake if the peak were not there of 0.75g, which is substantially the same values that Dr. David Boore developed

for that record of 0.8g.

And because it was a thrust fault very close to the site and because our experience had indicated even at that time that very close to a fault within a distance that is less than or at most equal to the rupture length of the -- or a measure of the rupture area in any one slip phase of an earthquake, the acceleration level and other parameters describing the earthquake should be independent of the magnitude and depend only on the stress drop and for a thrust fault, a stress drop that would take into account thrust on the surface.

I, therefore, used 0.75 g for the design level. In the further studies that I have made and those that I have made more recently, I have looked at a number of sets of data for various earthquake measures, and I find of course that there is a range of values different; people come up with different results, not greatly different, but different enough to require some rationalization and selection of the proper parameters.

The first of these studies that I know of was one made by Luis Esteba of the University of Mexico following a suggestion by me of ways of plotting the data that would permit better inferences to be drawn, but there were so few data available for his processing that I do not feel that I can rely on those results.

sp7-5

The best set of early data was that of Donovan in 1973, published in one of the proceedings of the International Association for Earthquake Engineering in which he used the hypocentral distance as the parameter against which to make estimates of the acceleration levels for various magnitudes of earthquake.

And he arrived at a value for the mean plus standard deviation relative to the mean which he stated as corresponding to a factor of about two.

But on close examination of the data that factor is less for points close to the source than it is for points several hundred kilometers away, which corresponded to much of plotting.

I used a value of 1.6 as the ratio for the range of zero to 20 kilometers in reviewing his data. There were a number of other sets of data, some of which have been discarded. There was a report which was referred to and sponsored by Dr. Tewart Smith in the preceding presentations here prepared by the TERA Corporation, which uses a relationship between mean plus standard deviation of 1.52 times the mean and develops an equation which is constrained to have a certain exponent on the attenuation factor.

However, the TERA Corporation low horizontal components of motion rather than the maximum which I prefer to use, and which the Geological Survey uses, and therefore

I have corrected upward the values given by the TERA equation by approximately 10 percent to take account of the fact that in general the minimum horizontal recorded motion is about 80 percent of the maximum.

There is another TERA equation which has statistical regressions for all of the coefficients that appear including the attenuation exponent which includes a number of European earthquakes and probably is not suitable for very large distances, but does not give substantially greater values in the range of about 1 or 2 up to 10 or 15 kilometers.

And that has a relationship between mean plus standard deviation to the mean or median of 1.5 and again requires in my opinion an increase of 10 percent.

Then there is a relationship presented in an abstract given in a meeting in Canada by Dr. Donovan this year in March, I believe, and a plot of which is contained in my testimony where Dr. Donovan claims that there is no effect essentially of magnitude on the acceleration level within 20 kilometers.

Let me see. I am looking for a copy of my testimony.

Oh, yes, that equation is marked plate C-1, preceding page 12 of my testimony. And you see there are two points representing the Pocoima Dam record that are

dsp7-7

above 1g acceleration. Those should be reduced in my opinion to about .75 g which would be closer to the other values.

And I have drawn a line; the line that is shown here is not the line that I finally settled on as being an appropriate value of mean plus standard deviation for these data which drops from .6 g at zero distance to .4 g at 20 kilometers.

MR. FLEISCHAKER: Excuse me, Dr. Newmark. Can I ask you to hold on one moment while we get plate C.

(Pause)

We found it. Thank you.

Thank you.

MR. LANPHER: Could you please repeat the previous statement or maybe the reporter could read it back.

CHAIRMAN SALZMAN: Dr. Newmark, can you repeat it?

WITNESS NEWMARK: I can repeat it.

CHAIRMAN SALZMAN: Thank you, Dr. Newmark.

MR. LANPHER: Where you were talking about the Pocoima Dam record, please.

WITNESS NEWMARK: Oh, yes. The Pocoima Dam points are shown on the record at about a little over eight kilometers distant. This is an aritmetic plot of distance, incidentally, and of peak acceleration. The unit is gals,

dsp7-8

which is essentially 1000th of the acceleration of gravity. Those should be dropped to about .75 and about .65 or .6 respectively, rather than being situated where they are on the figure if they are to be representative of other data on essentially level surfaces.

The determination that I have made from these data of a mean plus standard deviation value or of a 15 to 16 percent exceedence level is a striaght line between 600 gals at zero distance to 400 gals at a 20 kilometer distance. Incidentally, the TERA equations and the Donovan equation use the distance from the fault rupture at the surface as a parameter rather than the hypocentral distance.

I started using that after some work that I had done with Dr. A. H. S. Ang, who developed with a student of his at Berkeley where this was first published, as a better basis for distance, rather than the hypocentral distance.

And Dr. Ang and I used that data in our probabilistic studies of the Diablo Canyon reactor in one of the reports that was developed for that project in about 1976. I have data which I have computed for magnitude 6.5, 7, and 7.5 for these four equations.

And it may be worthwhile to mention these to show some indication in the spread of the data amongst these various relationships and the numbers that are

dsp7-9

arrived at for the median plus standard deviation level of acceleration at magnitude 6.5.

I shall read in order the Donovan 1973 estimate, the TERA equation that is recommended for use in the areas of the United States west of the Rockies, the TERA equation which is -- which involves a complete regression analysis, and the Donovan plot which is shown in plate C-1.

At magnitude 6.5 these values are, respectively: 39 percent of gravity; 47 percent, which I have increased arbitrarily to 52 percent of gravity because of the way in which the two horizontal components were used, with which I do not agree; the 47 percent again increased to 52 percent for the other TERA equation; and 54 percent of gravity for -- from plate C-1. These are all at 5.8 kilometers distant from the fault.

At magnitude 7 the numbers are -- and I will just read the final numbers in the same order: 50 percent; 59 percent; 65 percent; and 54 percent.

And for a magnitude 7.5: 65 percent; 66 percent; 78 percent; and 54 percent.

Now, this is not to say that there will be larger values of acceleration recorded for some earthquakes at some stations. I have taken a median plus standard deviation value, and the reasons for that I tried to explain

dsp7-10

earlier.

I think it is an unwarranted degree of conservatism to use envelopes for all of the parameters that enter into earthquake resistant design. Unfortunately, acceleration is not a very stable or good parameter to designate an earthquake.

end 7

I would have preferred to have used from many years ago the peak ground velocity which is a better measure of the energy available to be stored into or absorbed by a structure.

In the paper by Newmark, Blume, and Kapur, which was referred to and entered into evidence earlier today -- I cannot remember the number. Perhaps someone could help me.

CHAIRMAN SALZMAN: Governor's Exhibit R-5.

MR. LANPHER: R-5.

WITNESS NEWMARK: R-5. That was developed as a sort of compromise between two studies made by -- one made by a group working under my direction for the Nuclear Regulatory Commission and Dr. Blume's organization.

We used different approaches, different ways of balancing the records and so forth. My effort was described in a report, I believe number WASH-1255, and an earlier report. I don't recall the numbers, but they are listed in my testimony, I believe, in the references. If not there, then in the earlier testimony in 1976.

Dr. Kuo has volunteered to look up these references for us.

I have used amplification factors for different ranges of frequency. For high frequencies I amplified the acceleration levels of the ground to obtain the spectrum

values or I looked at the statistics for that for intermediate frequencies. Up from about a quarter hertz to 2 hertz I used the maximum ground velocity as a normalizing factor, and below the quarter hertz or four-second period the maximum ground displacement.

That is really of no consequence in the design of structures like nuclear reactors where almost all of the equipment and structures have frequencies above one hertz. The purpose of this, however, was to develop essentially site specific spectra for design, avoiding some of the difficulties in the footnotes that were referred to by Dr. Blume in the paper R-5.

In other words, one would make for the particular site conditions, source conditions and the like, separate estimates of the peak ground acceleration, the peak ground velocity, and the peak ground displacement at the level of probability that one wished to draw the spectrum and come up with the design spectrum.

In making the plot in this way, I found that the standard deviation over the whole range of frequencies from very low to very high was nearly constant and was less in general than for the use of -- than was developed for the use only of the peak ground acceleration as the basic parameter with which to normalize the spectra.

Also, I would use the median plus one standard

deviation acceleration level for the very high frequencies for the median plus one standard deviation spectrum, and the median acceleration level with the median amplification factors for the median spectrum. So that there is essentially a range in values between median and median plus one standard deviation at all frequencies; including the high frequencies in the way in which I used the data. That range is a factor of about 1 1/2 for the very high frequencies and for about between 1.4 and 1.5, with occasional dips down to about 1.3 for the lower frequencies.

By the way, the two references that were referred to earlier, WASH-1255, April 1973, which is entitled "A Study of Vertical and Horizontal Earthquake Spectra;" the next, NUREG-0003, published in 1976, and entitled "Statistical Studies of Vertical and Horizontal Earthquake Spectra." A more recent update with very little change in any of the parameters is published in a report to the Nuclear Regulatory Commission by Dr. W. J. Hall, my associate, and myself, entitled "Development of Criteria for Seismic Review of Selected Nuclear Power Plants, published in May 1978. Report NUREG/CR-0098, which is, I think, so far informally and probably will be formally adopted by the Nuclear Regulatory Commission for review of the older nuclear plants to make certain that they are adequate to resist the seismic motions to which they might be subjected.

I think that covers pretty well my views on the appropriate level of earthquake motions, including all of the motions, not only the accelerations, that should be used in a review of nuclear power plants. But I should point out again and caution that when one uses these median plus one standard deviation spectra, there is an implication that one should use appropriate values having appropriate factors of safety in them for all of the other eight aspects of design which I listed.

And if one were to take only a strength level and design for that without some appropriate conservatism, one would then properly use something like the data suggested by Dr. Luco in his report.

It would be inappropriate to do so if one makes a complete statistical study, even though it may be couched in deterministic language.

CHAIRMAN SALZMAN: Just one moment, please.

(Board conferring.)

CHAIRMAN SALZMAN: Mr. Olmstead, if it won't interrupt your presentation of your witnesses, we did start early this morning, and it would seem to me appropriate to take a break until 1:15 for lunch, unless someone has a problem with that.

MR. OLMSTEAD: I think that is fine.

CHAIRMAN SALZMAN: Gentlemen, the hearing will

be recessed until 1:15.

(Whereupon, at 11:52 a.m., the hearing was recessed for lunch, to be reconvened at 1:15 p.m., the same day.)

AFTERNOON SESSION

1:15p.m.

CHAIRMAN SALZMAN: The hearing will reconvene.

I have a request. At the close of the testimony today, which will be shortly after five, to accommodate people using this hall, I would like the attorneys to please join the Board at the bench to discuss whether it will be necessary to continue this hearing over the weekend and into next week.

I would also appreciate if you would make arrangements to have someone move the material, any material you wish to keep in the building, behind those doors which will be open at 5:00 o'clock for that purpose. You can leave it in that room securely, as securely as anything that can be left in this building.

I would like the attorneys to come and see me at the close of testimony or when we finish today. I would also like to discuss at that time the possible reordering of the order in which we are going to hear the panels. We are going to hear the staff's panel, Dr. Newmark and others, on Questions 5 and 6 first, rather than second. We will discuss this at the close of the hearing.

Are there any other preliminary matters?

Mr. Lanpher?

MR. LANPHER: No.

CHAIRMAN SALZMAN: Are you sure.

MR. LANPHER: If Mr. Brown were here, he was going to raise -- I don't know where he is, and I apologize. He wants to raise the question of moving into evidence certain of the exhibits.

CHAIRMAN SALZMAN: If he wants to do that, we can do it at the opening of the next session.

Are there any other preliminary matters?

(No response.)

CHAIRMAN SALZMAN: Mr. Olmstead, please continue.

Whereupon,

NATHAN M. NEWMARK

ROBERT L. ROTHMAN

PAO-TSIN KUO

JAMES P. KNIGHT.

the witnesses on the stand at time of recess, resumed the stand and testified further as follows:

DIRECT EXAMINATION (resumed)

BY MR. OLMSTEAD:

Q Dr. Newmark, before we recessed for lunch, you had been discussing what you thought were the appropriate parameters to consider when evaluating the design response factor, and had concluded that discussion.

Now, I would like to ask you if you have reviewed

the testimony of Dr. Young in this proceeding?

A (Witness Newmark) Yes, I have.

Q I would like to refer you to Figure 3 on page 10 of that testimony.

A I have located it.

Q In Dr. Young's testimony, he characterizes your procedures, and then plots some data on this chart. I ask you to comment on the significance of the data points falling below the bars indicated on figure 3?

A I am not quite sure what Dr. Young meant by these curves, whether there was a implication that the data points justified the use of a stress drop of 350 bars, which appears to be an upper-bound rather than any standard statistic.

Incidentally, the data points appear to be those from the Imperial earthquake of 1979, and are consistent with the numbers that I quoted and with the values of acceleration that I have used on a statistical basis, all falling below, except for one point, the values that would correspond to platt 7 G at one kilometer distance, and about less .64 six kilometers distance.

The figure itself does not cause many problems, but the implication that the lines on that figure are to be recommended for use in design does not seem to be justified by data, nor does it seem to me to warrant an

extrapolation to a larger magnitude or larger acceleration for magnitude 7.5 earthquake.

In particular, I refer to the report by Dr. H. S. Shaw, San-1011-125, entitled "Correlation of Peak Earthquake Ground Acceleration in the Very Near Field." Apparently these figures come from that report, and I believe that Dr. Young was associated in some way with that report.

On page 1-3, there is a statement by the author.

MR. LANPHER: Could you wait just a moment while we get our copies.

MR. OLMSTEAD: For the record, while we are waiting, that report is the last reference on page 42 of Dr. Young's testimony. It is the reference in Dr. Young's testimony on page 42.

WITNESS NEWMARK: There are three paragraphs, (a), (b) and (c) down the main part of the page, and (c) reads as follows: "The regression equation for peak ground acceleration developed in this study is not recommended for use as a design prediction equation at this time. Additional work is needed before values can be specified for the stress drop and fault dimension. Both are a function of magnitude and are probably also a function of local faulting conditions." In view of the fact that this equation is not recommended by the author, I wonder why

it is stated as being the basis for a value to be selected in place of the values that I recommended for use for the Diablo Canyon facility as affected by the Imperial Valley earthquake.

BY MR. OLMSTEAD:

Q Dr. Newmark, I would like to refer you to page 15 of Dr. Young's testimony, Question 8. The question reads: "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 six kilometers, and having a full depth of 10 kilometers, with the equation 2 using E equals 0.545. The answer is the equation would give a mean peak horizontal ground acceleration of 1.0 G for these conditions." Do you agree with that statement?

A It may well be true for the parameters that were used by Dr. Young, but I question the validity of those for the site considered, and for the Diablo Canyon reactor. 1.0 G for the mean peak would imply something like 1.5 G for the mean plus standard deviation, which is above all of the data that we have available for earthquakes and, therefore, is an amplified upper-bound rather than a mean value.

MR. OLMSTEAD: I believe I have no further questions of the witnesses at this time.

CHAIRMAN SALZMAN: Before I turn the panel over to the next group of questioners, I want to talk to my colleagues for a second.

(Pause.)

CHAIRMAN SALZMAN: Mr. Fleischaker, as counsel for the intervenors, it is your turn.

MR. FLEISCHAKER: I believe the applicant goes first.

MR. NORTON: I don't believe the applicant goes first at all. It is Mr. Fleischaker who goes first, then the Governor, and then myself.

CHAIRMAN SALZMAN: Do you have any objection to going first?

MR. NORTON: Yes.

MR. FLEISCHAKER: I will go.

CROSS-EXAMINATION

BY MR. FLEISCHAKER:

Q Dr. Rothman, I am going to ask you a series of questions now related to the Appeal Board's Question No. 1, and I would like to direct your attention to page 6 of your testimony.

Do you have page 6?

A (Witness Rothman) Yes, I do.

Q Could you read the first three sentences in the second full paragraph on page 6?

XXX

A "There is considerable scatter in the data with a range of from 0.22 G to 0.81 G for stations within 10 kilometers of the fault."

MR. NORTON: Could Dr. Rothman get closer to the microphone, it is very difficult to hear.

THE WITNESS: "The highest horizontal acceleration was recorded at Bond's Corner. However, the Bond's Corner high reading may be to some extent due to an anomalous site condition.

BY MR. FLEISCHAKER:

Q Stop right there. Do you, sir, have any data to indicate that the conditions at Bond's Corner are anomalous with respect to other recording sites at Imperial Valley?

A No, I don't.

Q Do you have any geo-physical data, other than the seismogram from the Galexio Valley earthquake?

A I don't have a seismogram from the Galexio Valley earthquake. I don't have any other geo-physical data either.

Q You do not have any geo-physical data to indicate that the conditions at Bonds Corner are anomalous?

A That is right.

Q I would direct your attention to the last two sentences of that paragraph, and I want you to read

1 those please?

2 A "During a subsequent earthquake, Galexio Valley
3 earthquake of June 8, 1980, magnitude 6.2, the Bond's
4 Corner station recorded a high peak horizontal acceleration
5 of 0.14 G. This reading was approximately three times
6 larger than any of the other stations in the region, and
7 approximately the same epicentral distances referenced in
8 the U.S.G.S. 1980."

9 Q Dr. Rothman, have you conducted any analysis, or
10 have you been able through analysis to exclude the
11 possibility that the peak accelerations at Bond's Corner
12 which are high relative to these other stations that you
13 refer to in your testimony, was due to fault rupture
14 orientation or distance from the recording site, as opposed
15 to anomalous site conditions at the Bond's Corner site?

16 A No, I haven't.

17 The other stations in the Imperial Valley are
18 approximately the same as or fairly close azmuth to the
19 epicenter, but the distances vary.

20 Q I would like to direct your attention to page 8
21 of your testimony, toward the bottom. In the middle of
22 the page, your testimony begins, "This one earthquake has
23 given us data." Could you read us that sentence and the
24 following sentence, sir?

25 A "This one earthquake has given us data that tends

to show that previous predictions based on the extrapolation of far field data over estimate the peak accelerations to be expected in the near field. As a consequence, use of the Circular 795 figures discussed above to predict peak acceleration at the DCNPP for Hosgri earthquake would also result in an overly conservative value of peak acceleration."

Q Is this conclusion, sir, based on your analysis of figure 2A in your testimony, which is attached to the end of your testimony?

A In part it is, yes.

Q Now I would like to direct your attention to page 7 of your pre-filed testimony and ask you to read what you stated about Figure 2A, which begins in the middle of the page with the sentence "this is illustrated by Figure 2A," and I would like to ask you to read that sentence and the two that follow?

A "This is illustrated by Figure 2A, which is a copy of Figure 47 from USGS Circular 795 (Boore, et al. 1978) and contains the distance peak horizontal acceleration relationships for a magnitude 6.6 earthquake as developed from the abovementioned references. The peak horizontal accelerations from IV-79 (small dots are also plotted in this figure).

Q And the following sentence.

A The IV-79 data generally falls below the curve of these studies, especially so at short distances."

Q Let's turn to Figure 2A and examine that figure, please, in light of what you have just stated.

Is it your testimony that the IV-79 data falls generally below the 70 percent prediction of the USGS in the range that is defined here?

A No. I said short distances in the range in which they are defined, meaning distances of 10 kilometers or less.

Q Can we agree that the USGS has not extended their predictions any closer than 10 kilometers here?

A Yes.

CHAIRMAN SALZMAN: Dr. Rothman, put your microphone up, and speak louder.

MR. NORTON: I did not hear the last answer. Can we agree that the USGS has not extended their predictions beyond 10 kilometers in Figure 2A?

MR. FLEISCHAKER: Closer than 10 kilometers to the fault.

WITNESS ROTHMAN: The U.S.G.S. 70 percent confidence level only goes to 10 kilometers from the fault.

CHAIRMAN SALZMAN: It might help if you would clarify the lines on that figure. Which are the USGS lines?

WITNESS ROTHMAN: The two straight line, one of

which is the lowest line on the figure, extends from approximately, I would say, 15 kilometers, to approximately 60 or 70 kilometers. Then there is another straight line, which is difficult to see, and it is overlapped in part by the curve marked "T-2," but it is parallel to the lower line and extends over the same distance range.

BY MR. FLEISCHAKER:

Q Moving on to the Donovan curve, is it your testimony that the points plotted -- the IV-79 points plotted fall generally below the Donovan curve, close distances is what we are concentrating on.

A I would estimate that about one-third of them are at 10 kilometers or less. Maybe one quarter to one-third fall below the Donovan curve.

Q What about the Seed curve?

A I would say an additional five or so.

Q Now let's talk about the Trifunac curve. It would appear that most of these dots fall below the Trifunac, would you agree with that, sir?

A At distances closer than 10 kilometers?

Q Yes.

A Yes.

Q Is it your understanding that the Trifunac correlations were developed using epicentral distances?

A Yes.

Q What is the distance for which the IV-79 data is plotted on this graph?

A These are the distances that were used by Boore and Porcello, I believe, in one of the references that Governor Brown's attorneys introduced into the record yesterday. It is the use, depending on what part of the fault they were on, they used the shortest distance to the fault in the middle range at the northern end. They used the distance to a particular point where they assumed that -- they used the closest distance to the trace of the Imperial Valley fault but at a depth of five kilometers, I believe. At Bond's corner it was the distance to the fault at a depth of three kilometers.

Q Have you determined how the IV-79 data would fit the Trifuna curve if they were plotted at epicentral distances on this plot?

A No, not on this plot. But I have plotted that data versus epicentral distance and we have, since the numbered stations in the array all are epicentral distances on the order of about 24 or 27 kilometers, most of the points plot up at that distance range, have a fairly large range of peak horizontal acceleration, About the only point that those plot near the Trifuna curve is the Bond's Corner station, whose epicentral distance is fairly close to the distance to the fault trace.

TP9 ends

Q So you have done that analysis, and you have plotted the points.

Q So you have done an analysis and concluded, and you have compared them to determine how they fit the Trifunac curve.

A I have not plotted them over the Trifunac curves, I do not believe. I have plotted them and looked at them in relation to what I would project the Trifunac curves to be on that plot.

Q And what have you concluded? Have you concluded they are a good fit or a bad fit to the Trifunac curve?

A I have concluded the Trifunac curve was a bad fit to the IV '79 data.

Q Okay. Let me get back to the conclusion. You stated on page 8 that the use of the Circular 795 figures -- let's get back to the conclusion that you have drawn that use of the Circular 795 figures --

A Is that on page 8?

Q That is correct.

A I see that now, sir.

Q The conclusion at the bottom of that page is what we are discussing, and it is that the use of the Circular 795 figures discussed above to predict the acceleration at the DCNPP from a Hosgri earthquake could result in overly conservative values of peak acceleration. And I will ask you what else did you rely on for that conclusion?

A When you say what else, you mean beside the figures that were discussed?

Q Okay. That conclusion is derived from your analysis of the figures.

A Yes. From a plotting of the data from IV '79 on the four figures that we were instructed to by the --

CHAIRMAN SALZMAN: Would you speak up, please?

WITNESS ROTHMAN: By the plotting of data from IV '79 on the four figures as the Appeal Board instructed.

BY MR. FLEISCHAKER: (Resuming).

Q Okay. Let's go to Figure II-B then. Now, this is the IV '79 data plotted against predictions for a magnitude 7.6 earthquake, and I will ask you what about that figure leads you to your conclusion?

A The fact that these curves, the Trifunac curve at short distances is completely above the highest data points recorded for the IV '79 data. The curve marked S, which is the Schnabel and Seed, at short distances except for one point, envelopes of the data, and the Donovan curve except for, I believe, two or three points, is above the data at short distances.

Q Wouldn't you expect this data to fall above -- excuse me. Strike that.

Would you expect this data to fall generally below these curves, given the fact that the IV '79 earthquake has

been estimated magnitude -- surface wave magnitude 6.5 to 6.9?

MR. NORTON: I object. I am not sure there is any evidence in the record about a surface wave magnitude of 6.5. I think the only numbers I have heard are 6.8 and 6.9 MS. I could be corrected.

(Pause.)

MR. FLEISCHAKER: We have the pre-filed testimony of Dr. Luco which estimates 6.5 to 6.9.

MR. NORTON: Which is not in evidence.

MR. FLEISCHAKER: And we have Dr. Blume's testimony which estimates it as a 6.4 to 6.9, footnote 1, page I-1.

MR. NORTON: That is not MS.

MR. FLEISCHAKER: I think I asked him that question. He indicated it was MS.

MR. NORTON: Absolutely not.

MR. FLEISCHAKER: It seems to me that we are spending a little too much time on this point. We have Dr. Luco's testimony.

CHAIRMAN SALZMAN: Mr. Norton, do you object to his answering the question subject to his finding that?

MR. NORTON: I object to Mr. Fleischaker saying we have evidence that it is 6.5 to 6.9. The only evidence in the record to date is that it is a 6.8 to 6.9 MS, period.

MR. FLEISCHAKER: I have notes from the -- I have

notes from the first day of hearing, and I will be glad to check the transcript, but these notes reflect that when I questioned Dr. Blume about the meaning of that footnote, he indicated that the numbers 6.4 to 6.9 were surface wave magnitude.

MR. NORTON: Well, all I can say is Dr. Blume is sitting right here saying that is not so. Mr. Fleischaker's notes are one thing, and Dr. Blume is here.

CHAIRMAN SALZMAN: Mr. Fleischaker, why don't you ask the question on the assumption that that was Dr. Blume's testimony, and you can tell us where Dr. Blume said it after we have had a break. You have the transcript, don't you, sir?

MR. FLEISCHAKER: I do have the transcript.

CHAIRMAN SALZMAN: All right. Let's assume Dr. Blume so testified subject to confirmation.

MR. FLEISCHAKER: We don't have to -- the record will be confused. We can, I think, reference Dr. Luco's testimony subject to it being introduced into evidence later on in this proceeding.

It is quite clear --

CHAIRMAN SALZMAN: Any way you wish to proceed.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Luco in his prefiled written testimony has estimated the surface wave magnitude of this earthquake

in the range of 6.5 to 6.9 in his prefiled direct testimony. In view of that, would you expect the IV '79 data to fall below the curves depicted in Figure II-B of your testimony?

A For an earthquake which had a possibility of a magnitude of 6.4 surface wave magnitude or 6.9, yes, I would expect it to fall below the curves.

Q Let me direct your attention, sir, to Figure II-C of your prefiled written direct testimony, and I will ask you what is it about this particular figure that supports the conclusion that we are discussing on page 8 of your testimony?

CHAIRMAN SALZMAN: Let me make sure I follow you. The conclusion is these data overestimate the peak acceleration to be expected in the near field, is that the conclusion?

MR. FLEISCHAKER: The conclusion is in the last sentence, "Use of the USGS Circular 795 figures discussed above to predict peak accelerations at the DCNPP from a Hosgri earthquake could also result in an overestimated value for peak acceleration.

CHAIRMAN SALZMAN: Thank you. I understand.

WITNESS ROTHMAN: The magnitudes plotted on this curve, it is not clear whether they are surface wave magnitudes or local magnitudes. However, if we are in the range 6 to 6.4, that they are M_1, and we have a magnitude 6.6 M_1 for

the Imperial Valley earthquake of 1979, and we take the 70 percent confidence levels of that earthquake and extrapolate them linearly into short distances, we will be over the data points in the range of 10 kilometers. They will not be encompassed by the 70 percent confidence levels, but the confidence levels will pass well above those points.

In fact, I imagine they will -- those confidence levels may intersect the 1 kilometer axis at about 1 1/2 g. I cannot tell because there is no -- the scale does not go above 1 g. But the lower limit may actually predict, extending that into 1 kilometer, the peak horizontal acceleration close to 1 1/2 g.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Rothman, has either the USGS or Dr. Luco or Dr. Trifunac or Dr. Seed argued for linear extrapolation?

A No. I don't think they have argued for a linear extrapolation. This is not their curve. This is the USGS curve.

Q Has the USGS argued for linear extrapolation from distances closer than 10 kilometers?

A No, they have not.

Q Let me direct your attention now to Figure II-D. What is it in this figure that leads you to the conclusions expressed on page 8 of your testimony?

A The fact that the data, again from IV '79, at distances less than 10 kilometers would fall below extensions of the 70 percent confidence levels, the mean or the -- I think those are -- I am not sure what the other ones are. They are either 90 or possibly 84 confidence levels.

Q Are you referring here to a linear extrapolation of the lines?

A Yes, I am.

Q And again, we agree that the USGS has specifically stated that they do not intend these lines to be linearly extrapolated.

A - No, I do not remember them saying that. I don't think that they have said it. They should be, but I don't remember them saying that they should not be either.

Q Okay.

MR. NORTON: Excuse me. I would like to go back for a moment. Mr. Fleischaker is examining at page 70, Dr. Blume, on the first day regarding that footnote. I would like -- question: I would like to direct your attention to the footnote on page I-2 of your testimony.

CHAIRMAN SALZMAN: One moment, please.

MR. NORTON: And Dr. Blume indeed --

CHAIRMAN SALZMAN: Mr. Norton, one moment, please. Is it necessary we do that now? We passed beyond that point.

MR. FLEISCHAKER: And I might add that my question was not premised --

CHAIRMAN SALZMAN: He withdrew that point. You can make it in your paper, sir, but he did not choose to rest on his recollection of what Dr. Blume testified.

MR. NORTON: Well, I was trying to correct for Mr. Fleischaker's benefit.

CHAIRMAN SALZMAN: Mr. Fleischaker I think is the best judge of his own benefit, sir.

MR. NORTON: What I am saying is Mr. Fleischaker was correct.

CHAIRMAN SALZMAN: So be it. Maybe I was wrong.

(Laughter.)

MR. FLEISCHAKER: It is hard to keep up with Bruce. He keeps things moving.

One moment, please.

MR. NORTON: I will not ever interrupt to tell Mr. Fleischaker that he is correct again.

(Laughter.)

(Pause.)

WITNESS ROTHMAN: I might add on the analysis of these figures I have been in conversation with some of the authors of these reports, and they are at the current time doing a re-evaluation of the data, new regression lines for the data to encompass the IV '79 data, and they expect

to have those curves flatten out at distances less than 10 kilometers to include the IV '79 data.

MR. FLEISCHAKER: I would like to move to strike that, because I think he is now referring to Dr. David Boore. I requested a subpoena for Dr. David Boore.

WITNESS ROTHMAN: I am not referring to Dr. David Boore. I am referring to Bill Joiner of USGS.

MR. FLEISCHAKER: It is hearsay. I would move to strike it. It would be very difficult to cross examine that statement.

MR. OLMSTEAD: Mr. Salzman, I would like to respond to that.

CHAIRMAN SALZMAN: I was about to ask you.

MR. OLMSTEAD: Mr. Fleischaker is the one that asked him whether he had heard whether anyone at USGS contended whether the data fell below the curve, and in order to give a complete response, he told us what he had heard. So I find it interesting that he is now objecting to his own question.

CHAIRMAN SALZMAN: All right. Mr. Fleischaker, that is true, but I don't think this is a major point, and I think we will accept it for what it is worth. The motion to strike is denied.

MR. FLEISCHAKER: I will move on. Thank you.

BY MR. FLEISCHAKER: (Resuming)

Q I would like to move on to page 9 of your testimony, Dr. Rothman. At the bottom of the page there I want to make sure I got your correction, because we had some discussion, we were looking forward to some discussion on that.

At the bottom of page 9, the sentence that begins -- the last full sentence on the page above question 3, could you now read that as you have amended it?

A "This means that in the near field, the peak ground accelerations for larger earthquakes (magnitude 4.5 and greater) are probably not linearly dependent on magnitude."

Q Okay. Thank you.

DR. BUCK: You did change "independent" to "dependent," is that right?

WITNESS ROTHMAN: It was made in a negative -- excuse me. I said "not linearly dependent."

DR. BUCK: Dependent.

end 10

WITNESS ROTHMAN: Yes.

DR. BUCK: Thank you.

BY MR. FLEISCHAKER: (Resuming)

Q I would like to move on to question Dr. Kuo.

A Yes, sir.

Q I am looking for the figure which sets forth the spectrum. Is that in the back of your testimony?

A That is correct.

Q Okay. Attachment 1 to your testimony depicts an upper bound and a lower bound as compared to the Newmark spectrum. The upper bound curves derived from 11 -- the 11 stations that recorded the IV '79 earthquake, is that correct?

A That is correct.

Q Is the upper bound spectrum there -- is that essentially the Bonds Corner response spectrum?

A I cannot recall, but I would say on the righthand side of the spectrum is basically Bonds Corner spectrum. I am not sure of the spectrum curve on the lefthand side. I would have to check.

Q Could you give us some reference for left and right by indicating the period or second, the vertical line?

A Yes. For periods higher than 1 second, I believe that portion of the spectrum is basically Bonds Corner spectrum. For periods below 1 second I am not so sure. I would have to check. I don't have it with me right now.

DR. JOHNSON: May I interrupt a minute, Mr. Fleischaker?

MR. FLEISCHAKER: Yes, sir.

DR. JOHNSON: Do I understand from your testimony,

Dr. Kuo, that these upper bounds are composites of spectra at various locations?

WITNESS KUO: That is correct, sir.

DR. JOHNSON: Thank you. Excuse me, Mr. Fleischaker.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Kuo, could you do -- would you tell me -- identify for the record the 11 stations that were used to derive the upper bound and lower bound? If that is set up in your testimon, just direct me to the page it is on. I could not find it.

A It is not listed in the testimony.

Q If you would like to make the information available at a later time, that would be sufficient also.

A Yes, I would be happy to.

Q Okay. Now, could you just explain for the record how you derive an upper bound?

A Yes. What I did, I plotted all the response spectrum curve from the stations within 11 kilometers from the fault, and then I drew an envelope of the -- of those response spectra.

Q How did you measure the 11 kilometers?

A The fault distance from the stations.

Q Is that distance normal to the fault?

A That is correct.

MR. FLEISCHAKER: Thank you. I have no further

1 questions.

2 Question 3, Dr. Rothman.

3 BY MR. FLEISCHAKER: (Resuming)

4 Q Dr. Rothman, I would like to direct your attention

5 to page 11 of your testimony.

6 A (Witness Rothman) Yes.

7 Q And I would like you to read the first sentence

8 in the first full paragraph of that page.

9 A Is that the one that begins "USGS Circular 795?"

10 Q Correct.

11 A "USGS Circular 795 reports that for comparable

12 earthquake magnitude and distance there is no significant

13 differences between peak horizontal accelerations measured

14 on soils"-- excuse me --"on soil or rock."

15 Do you want me to continue?

16 Q That is fine. Do you have a copy of 795 available?

17 A I think so.

18 Q I would like to direct your attention to page

19 1 of 795, Joint Intervenors' Exhibit R-1.

20 A Could you tell me what page that is again?

21 Q Page 1.

22 (Pause.)

23 Let me ask you this question. To what, specifically

24 what part of 795 are you referring when you make this

25 statement?

A Page 1, the abstract, the last sentence in the first paragraph.

Q Would you read that sentence, please?

A "In the distance range used in the regression analysis (15-100 KM) the values of peak horizontal acceleration recorded at soil sites in the San Fernando Valley earthquake are not significantly different from the values recorded at rock sites, but values at peak horizontal velocity and displacement are significantly greater at soil sites than at rock sites."

Q There is a difference between that statement and the one that is in your testimony, isn't there?

A I believe I was paraphrasing that.

Q Isn't the difference that USGS is talking about distances of 50 to 100 kilometers?

A I did not mention distance in my statement.

CHAIRMAN SALZMAN: Please speak up.

WITNESS ROTHMAN: I did not mention any distance in my testimony.

BY MR. FLEISCHAKER: (Resuming)

Q Is it fair to conclude that to make it accurate, we would have to qualify the statement in your testimony to indicate that USGS was referring to distances of 50 to 100 kilometers?

A I guess you could do that.

Q . I would like to move on to question 4.

CHAIRMAN SALZMAN: Dr. Rothman, I did not hear the answer.

WITNESS ROTHMAN: I said yes, you could do that.

BY MR. FLEISCHAKER: (Resuming)

Q I am not sure to whom to address this question. The testimony I am referring to is on page 9 of Dr. Kuo's testimony, but apparently he has referred to a report by Dr. Newmark, so I will address this to both of you and ask either of you who feels -- who wants to respond to please respond.

At the top of page 9 you discuss the change in the -- you indicate that the change in the reg guide position -- no. You indicate the reg guide position, Reg Guide 1.60, has been changed -- has been interpreted differently and that you have developed a staff position.

Let me ask this question. What is the engineering rationale for taking vertical design spectrum as two-thirds of the horizontal response spectrum over the entire range of frequencies in the near field? Why is that warranted in the western United States for nuclear power plant design but not warranted in the eastern United States for nuclear power plant design?

MR. OLMSTEAD: Could we have the frequency range we are talking about?

CHAIRMAN SALZMAN: Excuse me. I was interrupted twice. Will you hold on that one moment?

(Board conferring.)

CHAIRMAN SALZMAN: Is that --

MR. FLEISCHAKER: Let me strike that and ask that in a more precise way.

CHAIRMAN SALZMAN: I certainly cannot refuse that.

BY MR. FLEISCHAKER: (Resuming)

Q At page 9 the following sentence is found -- Dr. Kuo this is in your testimony -- "The memorandum indicates that we will allow Applicant the option of taking the vertical design response spectrum as two-thirds of the horizontal response spectrum over the entire range of frequencies in the western United States only. For other locations the vertical response spectra will be the same as given in Regulatory Guide 1.60."

My question is what is the engineering rationale for making that particular distinction for nuclear power plants located in the western United States versus those located in the eastern United States?

A (Witness Kuo) This conclusion basically was taken from Dr. Newmark's report, so Dr. Newmark would like to respond to your question.

Q Thank you.

A (Witness Newmark) I have some comments on vertical

acceleration in my testimony in item F on page 8, and I have some other material that I prepared for other purposes which discusses that same topic. Since the testimony is available, let me summarize the material that supplements it, because that might explain in more detail than the testimony does.

MR. FLEISCHAKER: Excuse me, Dr. Newmark.

I cannot hear him, Mr. Chairman.

CHAIRMAN SALZMAN: It is too noisy?

MR. FLEISCHAKER: Could you move a little closer to the microphone?

WITNESS NEWMARK: Thank you.

Shall I repeat?

MR. FLEISCHAKER: No. I followed you.

MR. NORTON: Excuse me, Mr. Salzman. There is a lot of noise. There are people talking out in the foyer.

CHAIRMAN SALZMAN: Could you be kind enough --

MR. NORTON: If we shut the doors, the temperature goes up 20 degrees.

CHAIRMAN SALZMAN: I suggest the gentleman in the back close the door, and you take your jacket off. You can't please everyone. I notice Mr. Olmstead has a wool suit, a jacket and a vest. Please continue.

MR. NORTON: The NRC is always over-conservative.

(Laughter.)

CHAIRMAN SALZMAN: Dr. Newmark.

WITNESS NEWMARK: Yes, sir. Generally the mean value and the mean plus one standard deviation are the vertical accelerations as related to the horizontal accelerations ranges from about one-third to one times the horizontal accelerations, with a mean plus one standard deviation at about two-thirds.

This -- these data come from the several studies that were recorded -- identified this morning. That does not preclude the fact that occasional values go higher. There are two papers, one of which was written by me and another by Bruce Bolt, and I shall refer to them shortly, which indicate that vertical earthquake recording elements generally over-register the vertical motions in certain frequency ranges, usually above about 3 to 3.5 hertz up to about 10 or 15 hertz because of the way in which they have to be mounted, unless they are embedded or firmly attached by bolts to a heavy foundation.

This is because the instrument itself acts as a system resting on a spring which is the soil or soil and concrete pedastal on which it is mounted. When the frequency of that system is close to the frequency of the vertical motions accelerations which the instrument is set to record, there is an amplification of the actual ground motion. This may be as much as 1.5 to 2 times the

actual ground motion.

The two papers, one by N.M. Newmark entitled "Interpretation of Apparent Upthrow of Objects in Earthquakes," was published in the proceedings of the Fifth World Conference on Earthquake Engineering in Rome, 1974. It was an attempt to explain why certain historic earthquakes showed deformations of light objects that corresponded to vertical motions greater -- critical accelerations greater than 1 g, although damage to buildings and other heavier items was not consistent with that.

And it was a fairly simple matter to show by calculations of the frequencies of the system, the fact that it is a two-mast system not a single mast, that this amplification must take place.

Dr. Bolt, who is director of the Seismographic Research Laboratory at Berkeley; and a student of his, R.A. Hansen, became interested in this topic and studied it again and published a paper entitled "The Upthrow of Objects in Earthquakes," which was published in the bulletin of the Seismological Society of America, Volume 67, No. 5, in October 1977.

This study substantiated my results, and although it has not been used to correct records in general, it has been used by a number of investigators to discount essentially some of the larger vertical recordings that

have been measured.

So from the point of view of actual records and taking into account this over-registration or reading of many of the instruments -- bear in mind that this is only in the higher frequency region -- that I felt that the readings in this range could be discounted.

There are other reasons for discounting the vertical records close in in the Imperial earthquake which were summarized in the previous panel's testimony.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Newmark, have you determined that the recording instruments in the eastern United States are mounted differently from those in the western United States?

A I do not agree with the NRC that you should use the larger values in the eastern United States. I would use two-thirds wherever.

Q That clears that up.

(Laughter.)

Dr. Newmark, does either the USGS or institutions like Cal Tech at Pasadena and the Scripps Institute at UC San Diego, generally those institutes that are concerned with seismology, do they apply a correction for the vertical acceleration in the recording instrument?

A No. They properly do not because to make a correction one would have to measure the frequency of the

soil column and identify precisely the amount of over-registration.

The purpose of these institutions is to report the data as it occurs. Some earthquake engineers do take account of this fact, but only in the sense that I have taken account of it, by neglecting the occasional larger values unless they are substantially larger than can be accounted for by the particular circumstances.

In other words, if I were to see an earthquake acceleration recorded of 2 g and a horizontal of .6, I would feel inclined that this was a real value greater-than the horizontal.

Q Thank you.

Dr. Kuo, I would like to turn to page 9 of your testimony.

MR. OLMSTEAD: Excuse me, Mr. Chairman. Just to clear up the record, the references that Mr. Fleischaker got in response to the earlier question are on pages 20 and 21 of Mr. Newmark's testimony.

CHAIRMAN SALZMAN: Of Dr. Newmark's testimony?

MR. OLMSTEAD: Of Mr. Kuo's testimony. I am sorry.

CHAIRMAN SALZMAN: Thank you.

end 11

parker 12
dsp r&t
dsp

BY MR. FLEISCHAKER:

Q We have already covered that. Let's move on to question seven.

Dr. Rothman, I would like to turn to page 13 of your testimony.

Could you read the second full paragraph there, please.

A (Witness Rothman) "The Pocoiman Dam record of the San Fernando Valley earthquake, which played a key role in the development of the DCMPP design spectra, displayed large ground motions. These values were in part caused by the focusing phenomena."

The reference in parentheses is Heaton and Helmberger, 1979.

Q In your testimony you refer to "these values." What values are you talking about specifically?

A The values of peak horizontal acceleration -- the value of peak horizontal acceleration on the Pocoima Dam record of the San Fernando Valley.

Q So it is your testimony that your reading of Heaton and Helmberger -- strike that.

You conclude as a result of reading Heaton and Helmberger that focusing played a part in causing the peak accelerations recorded at the accelerometer at Pocoima Dam during the San Fernando Valley earthquake of

dspl2-2

1971?

A Yes.

Q Okay.

A (Witness Kuo) I would like to respond to your previous question as to the stations that were included in the attachment one of my testimony.

Q Okay. Fine.

A I can read it to you. Those are stations 7, 6, 8, 5, Bonds Corner Station, El Centro differential array, station 9, station 4, Holtville, and Brawley Airport Station 10, Calexico, and that is all.

MR. FLEISCHAKER: I have no further questions of this panel.

CHAIRMAN SALZMAN: I think at this moment it would be appropriate to take a break for just five minutes. I intend to keep it very short.

(Recess)

CHAIRMAN SALZMAN: I believe, Mr. Lanpher, the ball is in your court.

BY MR.LANPHER:

Q: Dr. Newmark, in response to one of Mr. Fleischaker's questions, I believe you stated that you think that the vertical accelerations are overrecorded unless the recording instrument is firmly attached. I believe that is consistent with what you have stated at the top of page 9 in your prepared testimony.

pl2-3

Is that correct?

A (Witness Newmark) Yes, I believe so.

Q Have you performed any analysis to determine which IV '79 recording instruments meet this criteria, if any?

A I have not done so because the studies that I have been acquainted with were the Imperial Valley earthquake and they had indicated that the situation there is one that would lead to large verticals close to the source in a situation that would be different from Diablo Canyon. I was primarily interested in the applications to Diablo Canyon.

Eventually, I shall go into more detail for other purposes for other problems, but I did not have time to study the implications of Imperial Valley for other than the distances and geology that would be related to the Diablo Canyon situation.

By the way, let me correct one point. What I meant by "firmly attached" is bolted with a considerable amount of initial tension, not just barely bolted in place.

Q Thank you.

Dr. Kuo, I would like you to turn your attention to attachment two of your prefiled testimony.

A (Witness Kuo) Yes, sir.

Q Am I correct that this represents the response

dspl2-4

spectrum for the scatter band for vertical accelerations of your 11 stations?

A That is correct, except station 6, as you see there, which is separate from the rest.

Q Is it correct that again except for station 6 in the frequency of approximately .1 -- well, the period of approximately .1, there is an exceedance of thd Newmark-Hosgri response spectrum?

A Let me try to clarify first. Are you talking about the upper bound?

Q Yes, the upper bound.

A For all the stations except station six?

Q Yes.

A Yes. At periods lower than .1 seconds. Yes, there is some exceedance there.

Q Does that exceedance give you any concern?

A No, I would not think so. Based on the statistical analysis, if you plot off the mean on all the records as instructed by the board, I would not see such an exceedance.

Q Did you plot a mean spectrum of these records and a mean plus sigma spectrum of these records?

A I did not perform that. I did not plot the mean spectrum curve as you suggested, but I believe in the previous testimony, I believe, in Dr. Brune's testimony, figure 2 -- just a minute.

dsp12-5

(Pause)

Figure II-3, I think he plotted the mean spectrum curve for the set of data that I am plotting here.

Q That was for the horizontal acceleration; is that correct?

A That is correct.

Q Then you do not know whether a mean spectrum or a mean plus sigma spectrum of these stations for the vertical accelerations including array six --

CHAIRMAN SALZMAN: Let me interrupt, please. I understand that you are talking about an exhibit prepared by Dr. John Blume; is that correct?

WITNESS KUO: That is correct, sir.

CHAIRMAN SALZMAN: Thank you.

BY MR. LANPHER:

Q Just so I am clear, it is your testimony you have not determined whether a mean spectrum or a mean plus sigma spectrum of the 11 records which you have referenced -- and this time I am including array -- El Centro array number six -- would or would not exceed the Newmark-Hosgri vertical design spectrum?

A No, I did not perform that calculation.

MR. LANPHER: I have no further questions.

CHAIRMAN SALZMAN: All right. Mr. Norton?

MR. NORTON: No questions.

CHAIRMAN SALZMAN: Mr. Olmstead.

MR. OLMSTEAD: I don't believe we are going to ask any further questions on these questions.

CHAIRMAN SALZMAN: That is, I take it, we are talking about questions 1 through 4 and 7.

MR. OLMSTEAD: That is correct.

CHAIRMAN SALZMAN: Dr. Johnson, did you have any further questions?

DR. JOHNSON: No.

CHAIRMAN SALZMAN: Dr. Buck?

DR. BUCK: Hold on just for a minute.

CHAIRMAN SALZMAN: One moment.

DR. BUCK: I would like to have a moment to check to see whether some of the questions I have here have been answered.

(Pause.)

MR. NORTON: Mr. Salzman, could counsel approach the bench for a minute, please?

CHAIRMAN SALZMAN: Yes, certainly.

(Bench conference.)

DR. BUCK: I have no further questions, Mr. Chairman.

CHAIRMAN SALZMAN: Gentlemen, the Board has no further questions of you at this time, and you are excused for the time being.

(The witnesses were excused.)

MR. FLEISCHAKER: Counsel have agreed to stipulate that Dr. Brune and Dr. Young would take the stand at the same time. Dr. Brune appears in this proceeding as a witness both on behalf of the Joint Intervenors and Governor Brown. However, to expedite the proceeding, instead of having Dr. Brune take the stand twice, we have agreed that he will take -- he will appear now and be questioned about the prefiled testimony that he has submitted on behalf of both the Joint Intervenors and Governor Brown.

In addition, I will ask all of the direct questions, permitting Dr. Brune to respond to the testimony given so far in the prefiled direct on questions 1, 2, 3, 4, and 7. I will ask those questions both for the Joint Intervenors and on behalf of Governor Brown, again in order to expedite the proceeding.

CHAIRMAN SALZMAN: I understand all counsel have agreed, Mr. Norton.

MR. NORTON: The one thing I was not sure about is is Mr. Fleischaker going to be cross examining Dr. Young, who is a member of his own panel?

CHAIRMAN SALZMAN: Mr. Fleischaker, I take it you are not going to be cross examining Dr. Young, are you?

MR. FLEISCHAKER: I may cross examine Dr. Young.

I think to say he is a member of my panel is not exactly correct. I will not be cross examining Dr. Green, of course, because I share him as a witness with Governor Brown, but I have no relationship to Dr. George Young.

CHAIRMAN SALZMAN: I see nothing wrong with that, sir. The Board has no objections. That will be fine.

Mr. Fleischaker, will you proceed?

I think before we begin the witnesses ought to raise their right hands.

Whereupon,

GEORGE A. YOUNG

AND

JAMES N. BRUNE

were called as witnesses by counsel for the Joint Intervenors and, having been duly sworn by the Chairman, were examined and testified as follows:

WITNESS BRUNE: I would like to affirm.

CHAIRMAN SALZMAN: That is quite fine.

The Reporter will please note that Dr. Brune will affirm.

MR. FLEISCHAKER: I will ask the introductory questions of Dr. Brune, and Mr. Lanpher will ask the questions of Dr. Young. Then we will get on to the substantive testimony

XXX

DIRECT EXAMINATION

BY MR. FLEISCHAKER:

Q Dr. Brune, you have appeared before in this proceeding. Is that correct?

A Yes.

Q You appeared as a witness on behalf of the Joint Intervenors during the evidentiary hearing before the Atomic Safety and Licensing Board?

A That is correct.

Q I would like to call your attention to documents that I have before us, if you have them before you. The first document is entitled Testimony of James N. Brune on behalf of the Joint Intervenors regarding Appeal Board Questions 1, 4-partial, and 7, dated August 8, 1980.

The second document is entitled Prepared Direct Testimony of James N. Brune on behalf of Governor Edmond G. Brown, Jr., regarding Appeal Board Question 7, dated August 1980.

Were these documents prepared by you, sir?

A Yes, they were.

Q And they have been prefiled as you written direct

1 testimony in this proceeding on behalf of the Joint Inter-
2 venors and Governor Brown?
3 A That is correct.
4 Q Now, sir, do you have any corrections that you
5 wish to make to the first document, that is the testimony
6 submitted on behalf of the Joint Intervenors?
7 A No, I do not.
8 Q Sir, do you have any corrections that you wish to
9 make to the second document, which is your direct testimony
10 prepared on behalf of Governor Edmond G. Brown, Jr.?
11 MR. LANPHER: If I could interrupt just one
12 moment. There is one correction that was made, and I mailed
13 out the correction. It is to page 7. I think everyone has
14 it. The correction has been made in the copy given to the
15 reporter.
16 CHAIRMAN SALZMAN: Why don't you repeat the
17 correction so that I can make sure that Ihave it.
18 MR. LANPHER: It is on page 7.
19 CHAIRMAN SALZMAN: On the stress drop?
20 MR. LANPHER: The eighth line, instead of 100
21 bars, it should read 1000 bars.
22 CHAIRMAN SALZMAN: Thank you, Mr. Lanpher.
23 MR. FLEISCHAKER: Are we ready to proceed, Mr.
24 Chairman.
25 CHAIRMAN SALZMAN: You will have the testimony

bound into the record.

MR. FLEISCHAKER: Yes, I will.

CHAIRMAN SALZMAN: If there is no objection, the reporter will bind the testimony of Dr. James Brune as if read into the transcript at this point.

(Testimony of Dr. James Brune follows:)

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UNITES STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

TESTIMONY OF JAMES N. BRUNE

On Behalf Of

JOINT INTERVENORS

Regarding

APPEAL BOARD QUESTIONS 1, 4 (PARTIAL), AND 7

In The Matter Of

DIABLO CANYON NUCLEAR POWER PLANT, UNITS 1 & 2

Docket Nos. STN 50-275, 50-323 O.L.

AUGUST 8, 1980

TESTIMONY OF JAMES N. BRUNE

On Behalf of Joint Intervenors*

Regarding

APPEAL BOARD QUESTIONS 1, 4 (PARTIAL), AND 7

DIABLO CANYON NUCLEAR POWER PLANT, UNITS 1 & 2

Docket Nos. STN 50-275, 50-323 O.L.

I. INTRODUCTION

My name is James N. Brune. I am Professor of Geophysics at the University of California at San Diego. My educational background includes a Bachelor of Science degree in Geological Engineering from the University of Nevada and a Ph.D. in Seismology from Columbia University. I have carried out a number of studies relating to earthquake source mechanism and strong motion in recent years. Currently I am conducting a study of the strong motion records resulting from the October 15, 1979 Imperial Valley earthquake. My study of the strong motion data resulting from the Imperial Valley earthquake is being funded by a grant from the National Science Foundation. Hence, I am very familiar with current and previous investigations of earthquake source mechanisms and strong motion data. My qualifications,

* Joint Intervenors are: Scenic Shorelines Preservation Conference, Inc., San Luis Obispo Mothers for Peace, Ecology Action Club, Sandra A. Silver, and John J. Forster.

experience, and a list of publications are described in detail in an attachment to the testimony I presented to the Atomic Safety and Licensing Board during the Diablo Canyon seismic hearings in January, 1979. 1/

II. STATEMENT OF ISSUES

The purpose of my testimony today is to address Questions 1 and 7 proposed by the Atomic Safety and Licensing Appeal Board (Appeal Board) in ALAB-598 as follows:

A. (Question 1) "The October 15, 1979, Imperial Valley Earthquake (IV-79, M_L=6.4-6.9) provided an extensive set of strong motion records in the near field of a rather severe earthquake. The parties should compare the horizontal peak acceleration values recorded for various instrument positions with earlier predictions and compilations of such motion, 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. Those comparisons should (if possible) address whether there is magnitude independence or a saturation effect for ground motion intensity in the near field of earthquakes."

B. (Question 7) "Intervenors (Brune Affidavit, p. 5) and the applicant (Frazier Affidavit, Para. 3) have suggested that the strong motion data obtained from stations along the direction of the Imperial Fault evidence the 'focusing' of earthquake motion. Yet, when the acceleration data of two such stations, El Centrol Array Numbers 6 and 7, are plotted as a function of distance from the fault (e.g., Blume Affidavit, Figures 1 and 2), the horizontal acceleration values fall well below the regression line mean for the 1 km distance. The vertical acceleration values are also lower than the mean on such a plot."

(Question 7 contd) "To the extent possible, the parties should analyze the seismic records for the IV-79 earthquake as they pertain to the focussing phenomenon and relate the results of such analyses to the likelihood that, in the event of an earthquake anywhere along the Hosgri Fault, focussing might result in amplified seismic motion at Diablo Canyon."

My testimony today also partially addresses Appeal Board Question 4, (the portion regarding the application of Regulatory Guide 1.60 to Diablo Canyon is not discussed herein) as follows:

C. (Question 4) "The magnitudes of vertical and horizontal acceleration values measured at IV-79 are generally comparable. (Mean values calculated at a distance of 5.8 km from the fault are virtually identical).....Should there be substantive and relevant analyses suggesting that vertical motion records do not reflect the true vertical motion, these should be provided."

III. DISCUSSION OF ISSUES

The Appeal Board in ALAB-598 granted Intervenors' motion to reopen the Diablo Canyon record to address nine questions drafted by the Appeal Board concerning the NRC review of Diablo Canyon Nuclear Power Plant, Units 1 and 2. The Appeal Board questions were in response to Intervenors' motion that new data obtained from the October 15, 1979 Imperial Valley earthquake cast a shadow on the adequacy of the Licensing Board's seismic analysis presented in the September 27, 1979 partial initial decision.

A. Horizontal Acceleration:

In my affidavit of February 29, 1980, I stated that the new data from the Imperial Valley earthquake of 1979 provide the only extensive set of data points for a single earthquake in the distance range relevant for the Diablo Canyon site.[2/]

As noted in my 1980 affidavit, the peak horizontal accelerations for the 1979 Imperial Valley earthquake were in general agreement with the 70% prediction intervals of Boore et al 1978 (USGS Circular 795) for an M=6.4 earthquake. For distances less than 15 km from the slip surface (less than the distances of the Boore curves, where there were few data before the IV-79 data points), the data indicate that acceleration increases with decreasing distance, but with a flattening slope at close distances.

Considering the inherent variability from earthquake to earthquake, it must be considered likely that future earthquakes of this same magnitude will in some cases generate higher accelerations. A magnitude 7.5 earthquake would be expected to generate still higher average accelerations. I indicated in my 1978 testimony before ASLB that about 10 earthquakes of magnitude near 7.5 would have to be recorded at close distances before we could be confident of expected accelerations. Frazier, in his 1980 affidavit (23 April, 1980) agrees that "Near-field data from several earthquakes should be considered to assess the variability in ground motion between earthquakes."

Based on the observations from the IV-79 earthquake, and on elementary physical considerations of such phenomena as focussing by rupture propagation and possible localized anomalously high stress drop, I conclude that there is no reason to assume that the accelerations observed for the IV-79

earthquake represent the maximum likely or conservative values for earthquakes of this magnitude. Rather, the most logical assumption (with low confidence because of the lack of sufficient data) would be that the accelerations for the IV-79 earthquake represent the average expected, and thus other earthquakes of the same magnitude would be expected to, in some cases, generate considerably higher average accelerations and in other cases, considerably lower average accelerations.

B. Horizontal Velocity

The peak horizontal ground velocities recorded for the IV-79 earthquake agree well with the curves of USGS Circular 795. For distances less than 15 km, the new data suggest extrapolations with an average velocity of about 40 cm/sec at a distance of about 7 km, with a corresponding 70% prediction interval velocity of about 75 cm/sec. For example, the Seismic Engineering Data Report for the IV-79 earthquake (Brady et al, 1980)[3/] gives peak (single component) velocities of 67.77 cm/sec at station 5 (4 km), and 77.65 cm/sec at station 4 (7 km) and 108.6 cm/sec at station 6 (1 km). Since this earthquake had a relatively small amount of slip compared to the 1940 El Centro earthquake of nearly the same or slightly smaller magnitude (see next section), it is likely that some earthquakes in this magnitude range will have considerably higher velocities at comparable distances. A magnitude 7.5 earthquake would be likely to have still larger velocities. Thus, a horizontal ground velocity of 61 cm/sec for the Diablo Canyon nuclear plant is

definitely not supported as a conservative value by the present data.

C. Comparison With 1940 Earthquake

The 1940 Imperial Valley earthquake, with nearly the same Richter local magnitude (6.4) as the IV-79 earthquake, had considerably larger displacements (up to 3 meters and greater) and thus a higher average stress drop. The high slip values occurred southeast of the only operating strong motion station. Further, the fault ruptured southeast, away from the strong motion station, focussing the energy in a direction where there were no strong motion recorders (see my ASLB testimony). Thus, the 1940 earthquake probably generated accelerations and velocities to the southeast of the epicenter that were higher than recorded in the IV-79 earthquake. Thus, the IV-79 earthquake is probably not a conservative example in terms of its stress drop, accelerations, and velocities (relative to its Richter local magnitude). This consideration emphasizes the lack of reliability, due to lack of data, in estimating likely near source values of acceleration and velocity.

Several persons have noted that damage was relatively low for the IV-79 earthquake even though recorded accelerations were relatively high (e.g., NRC staff response). Estimates of the Modified Mercalli Intensity in the near-field for the IV-79 are less than for the IV-40 earthquake (see attached comparison, Figure 1). Although this may in part be due to ambiguities in the Modified Mercalli Intensity scale, it is

clear that the damage from the IV-79 earthquake was considerably less than for the IV-40 earthquake, even though for the IV-40 earthquake the direction of rupture was away from the region where most buildings were located. This further supports the conclusion that the IV-79 earthquake is not a conservative example for its Richter magnitude. The fault length and average slip were both larger for the IV-40 earthquake. The surface wave magnitude for IV-40 (7.2 ± 1) is also larger than for IV-79 (6.9) reflecting in part the larger slip in IV-40 (James Lienkamper, USGS, personal communication).

D. Extrapolation to M=7.5

Concerning extrapolations of results for the IV-79 earthquake to higher magnitudes, all statistical correlations available in literature[1] indicate an increase in average peak accelerations, velocities and spectrum of ground motion with magnitude, with decreasing slope for larger magnitude. However, there are so few data available for earthquakes near magnitude 7.5 (only one good data point, from the Gazli earthquake), that there can be little confidence in these extrapolations, and thus large uncertainties exist in the ground motion spectrum and peak acceleration values appropriate for an M=7.5 earthquake. We can only be sure that on the average they will be higher for an M=7.5 than for an

[1] Aside from the correlations referenced in my testimony before ASLB, I have recently been shown results from a study by Ts'ao (1980) which also indicate increasing average peak accelerations with magnitude between M=6.5 and M=7.5.

M=6.5 earthquake.

E. Focussing

In ALAB-598, the Appeal Board stated that, "Intervenors (Brune affidavit, p.5).....have suggested that the strong motion data obtained from stations along the direction of the Imperial fault evidence the 'focussing' of earthquake motions." Actually, I suggested in my 1980 affidavit that focussing may have been operative in three other earthquakes (Santa Barbara, 1978, Gilroy, 1979, and Livermore, 1980).[2] The evidence for the effect of focussing on the observed accelerations in the case of the IV-79 earthquake is not clear to me at this time, and I believe that it is necessary to further analyze the data and the rupture mechanism before the effect of focussing can be assessed. It may turn out that the IV-79 earthquake is better represented as a sequence of multiple events than as a continuous rupture. Thus, it may be that focussing from a more continuous rupture would have led to even higher accelerations.

F. Vertical Accelerations

The magnitudes of vertical and horizontal accelerations near the fault (< 10 km) for IV-79 are generally comparable, but at some stations the vertical values considerably exceed the horizontal. Previous suggestions that

[2] Recently Boore and Porcella[5] (1980) have further documented the evidence for focussing in the Livermore, 1980 earthquake.

the vertical accelerations are less than 2/3 the horizontal appear not to apply very near faults. Even with the data from the IV-79 earthquake, there is not sufficient data to establish the expected average ratio of vertical to horizontal acceleration very near faults. I know of no evidence to suggest that vertical accelerations do not reflect the true vertical motion.

G. High Vertical Accelerations

To my knowledge, the explanations for the high frequency vertical accelerations of 1.74g at station 6 (1 km) and .93g at the El Centro differential array station (5 km) have not been finally established. There are several possible factors which may have led to increased accelerations at these sites, including effects of crustal structure, local amplification, localized high stress drop, and focussing by rupture propagation. Extensive analysis will be required before a final explanation is accepted. It seems probable that whatever the explanation, it represents a combination of phenomena which could only occur relatively close to the fault surface. However, until the final explanation is established there remains the possibility that such accelerations could occur at distances as far as several km from the fault trace and in particular at the Diablo Canyon site.

IV. CONCLUSIONS

The main conclusions of my testimony are as follows:

A. The recorded peak horizontal accelerations for IV-79 are in approximate agreement with the 70% prediction limits of USGS Circular 795 for an M=6.4 earthquake in the common distance range. For distances less than 15 km from the slip surface, the IV-79 data indicate that accelerations increase with decreasing distance, but with a flattening slope at close distances. The IV-79 earthquake is probably not a conservative example in terms of its stress drop, accelerations, velocities, and spectrum, relative to its Richter local magnitude.

B. There are too few data for earthquakes of M=6.5 to M=7.5 to establish the rate of increase of average peak acceleration or spectrum of ground motion going from M=6.5 to M=7.5. We can only be sure that on the average they will be higher for an M=7.5 than for an M=6.5 earthquake.

C. The effects of focussing have not yet been established for the IV-79 earthquake. Further analysis will be required. Focussing could have led to even higher accelerations than were observed in the IV-79 earthquake. There is indirect evidence that for the IV-40 earthquake, higher accelerations might have been generated (to the southeast) than were recorded for IV-79.

D. Data from the IV-79 earthquake indicate that in the near field, values of vertical acceleration can be considerably higher than 2/3 of the values of the horizontal accelerations.

In summary, the IV-79 data discussed in the foregoing and in my affidavit indicates that the Diablo Canyon design accelerations, velocities and displacements of 0.75g, 61 cm/sec and 24 cm, respectively, if assumed to represent true ground motion, are not established as conservative values for the M=7.5 design earthquake, since they were exceeded in the distance range of 3 to 7 km by the Imperial Valley earthquake with a magnitude of only approximately 6.6, the first earthquake of this size for which there were extensive near field recordings. The data also indicate that, in the near field, values of vertical accelerations can be considerably higher than 2/3 of the values of the horizontal accelerations.

We are not in the situation of having an extensive body of data on accelerations to be expected in the near-field (<10 km) of even M=6.5 earthquakes, let alone M=7.5 earthquakes. Methods of extrapolation have not been established as reliable. No reliable estimates of means or standard deviations can be made. Each new well-recorded earthquake can be expected to bring surprises (as did the IV-79 earthquake, with its high vertical accelerations) and thus significantly change our perceptions of what accelerations are probable and possible. In this situation, statements that certain assumed peak accelerations are "conservative" are necessarily cast in doubt, whereas the negative statement, that such accelerations have not been established as conservative, remains true.

LIST OF REFERENCES

1/ Testimony of James N. Brune entitled, "Contention 3 - Ground Motion," dated November 15, 1978, Diablo Canyon O.L. Proceeding Before the Atomic Safety and Licensing Board and hereinafter referred to as "1978 Testimony." The discussion and conclusions presented in my "1978 Testimony" are not repeated herein, but are adopted in their entirety as my current views for this testimony by this reference.

2/ Affidavit of James Neil Brune dated February 29, 1980, Diablo Canyon O.L. Proceeding Before the Atomic Safety and Licensing Appeal Board and hereinafter referred to as "1980 Affidavit." The discussion and conclusions presented in my "1980 Affidavit" are not repeated herein, but are adopted in their entirety as my current views for this testimony by this reference.

3/ Brady, A. G., V. Perez, and P. N. Mork. The Imperial Valley Earthquake, October 15, 1979. Digitization and processing of accelerograph records. United States Geological Survey Open File Report 80-703, (1980).

4/ Ts'ao, H. S. Correlation of peak earthquake ground acceleration in the very near field. SAN/1011-125. El Segundo, CA: Agbabian Assoc., Mar., (1980).

5/ Boore, David M. and Ronald L. Porcella. Peak acceleration from strong-motion records: a postscript. (To appear in Bulletin of the Seismological Society of America, December, (1980) as a letter to the editor.)

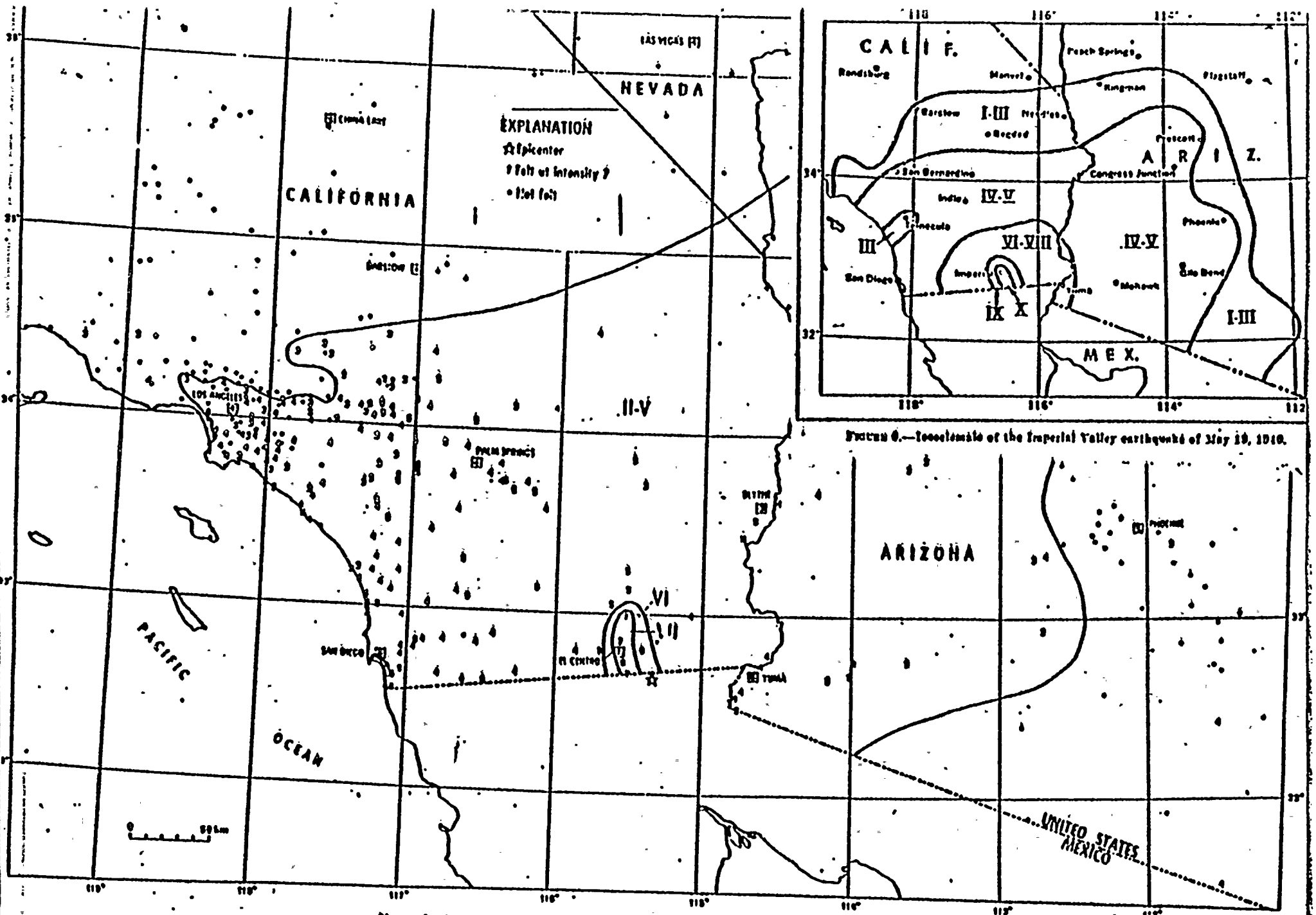

Figure 6.—Isoseismals of the Imperial Valley earthquake of May 19, 1940.

Figure 1.—Isoseismal map for the Imperial Valley earthquake of October 15, 1979.

Reagor and others, (1980)

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 James N. Brune

on Behalf of Governor Edmund G. Brown, Jr.

Regarding

APPEAL BOARD QUESTION 7

August 8, 1980

Testimony of James N. Brune

On Behalf of Governor Edmund G. Brown, Jr.

Regarding Appeal Board Question 7

The purpose of my testimony today is to address Question 7 proponded by the Appeal Board in the Appendix to ALAB 598.[1] I have already expressed certain views relating to this question in my prepared testimony on behalf of Joint Intervenars. There I stated:

> In ALAB-598, the Appeal Board stated that, "Intervenors (Brune affidavit, p. 5) . . . have suggested that the strong motion data obtained from stations along the direction of the Imperial fault evidence the 'focusing' of earthquake motions." Acutually, I suggested in my 1980 affidavit that focussing may have been operative in three other earth-

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[1] Question 7 states:

> "Intervenors (Brune Affidavit, p. 5) and the applicant (Frazier Affidavit, Para. 3) have suggested that the strong motion data obtained from stations along the direction of the Imperial Fault evidence the 'focusing' of earthquake motion. Yet, when the acceleration data of two such stations, El Centro Array Numbers 6 and 7, are plotted as a function of distance from the fault (e.g., Blume Affidavit, Figures 1 and 2), the horizontal acceleration values fall well below the regression line mean for the 1 km distance. The vertical acceleration values are also lower than the mean on such a plot. To the extent possible, the parties should analyze the seismic records for the IV-79 earthquake as they pertain to the focussing phenomenon and relate the results of such analyses to the likelihood that, in the event of an earthquake anywhere along the Hosgri Fault, focussing might result in amplified seismic motion at Diablo Canyon."

quakes (Santa Barbara, 1978, Gilroy, 1979, and Livermore, 1980). The Evidence for the effect of focussing on the observed accelerations in the case of the IV-79 earthquake is not clear to me at this time, and I believe that it is necessary to further analyze the data and the rupture mechanism before the effect of focussing can be assessed. It may turn out that the IV-79 earthquake is better represented as a sequence of multiple events than as a continuous rupture. Thus, it may be that focussing from a more continuous rupture would have led to even higher accelerations.

My purpose in this additional testimony is to express further views on this subject.[2]

INTRODUCTION

In Question 7 appended to the NRC Atomic Safety and Licensing Appeal Board decision of June 27, 1980, ALAB-598, the Appeal Board said that the parties should "analyze the seismic records for the IV-79 earthquake as they pertain to the focussing phenomenon and relate the results of such analyses to the likelihood that, in the event of an earthquake anywhere along the Hosgri Fault, focussing might result in amplified seismic motion at Diablo Canyon." I concur with the Board that this analysis is important to understanding the seismic hazard at Diablo Canyon.

IMPORTANCE AND RELEVANCE OF COMPUTER MODELLING

I believe that it is important that one aspect of the analyses for carrying out the boards directive be use of computer modelling of fault

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2 A statement of my professional qualifications and publications has previously been submitted as Attachment A to my ASLB testimony dated November 15, 1978.

rupture to simulate strong motion. Without this modelling, we will not be able to make full use of important new data from the Imperial Valley earthquake. Modelling, along with new information provided by the Imperial Valley earthquake, will provide improved understanding of the strong motion, especially the effects of focussing by rupture propagation and localized concentrations of high stress drop, which might occur at the Diablo Canyon Nuclear Plant from a rupture on the Hosgri Fault. This modelling can significantly reduce our uncertainties about the expected ground motion at Diablo Canyon. It will provide a range of realistic models of ground motion records from which to predict expected response spectra parameters.

In previous testimony (prior to the existence of the Imperial Valley data), I indicated that computer modelling would be important in estimating the strong motion to be expected at Diablo Canyon (ACRS testimony, 1977, p.4). The main reason for this was that because of the lack of data it is not possible to establish empirically the average peak acceleration at close distances (<10 km) for large earthquakes (M>7), nor to establish the standard deviation of peak accelerations from this mean. There was only one data point for an M>7 event at close distances (< 10 km) (Gazli earthquake). Since new data can only be accumulated with time,[3] as important future earthquakes are recorded on strong motion instruments, numerical modelling represents the best and most timely way to reduce existing uncertainties in the expected

[3] I indicated in my NRC testimony that about 10 earthquakes of magnitude near 7.5 would have to be recorded at close distances before we could be confident of the expected accelerations.

ground motion at Diablo Canyon. Modelling provides a method of assessing the importance of phenomena such as focussing of energy due to rupture propagation and anomalously high stress drop.

The existence of the Imperial Valley earthquake data will further decrease the uncertainty and non-uniqueness in the modelling process and thus increase the value of modelling at Diablo Canyon since this earthquake is the first with multi-station near-fault strong motion observations. Once the data from the Imperial Valley earthquake are modelled, including the effects of parameters such as focussing and local concentrations of high stress drop, we will be able to better assess their importance for Diablo Canyon.

Computer modelling capabilities have improved in recent years. Computer modelling is in the process of being developed for the San Onofre Nuclear Plant (Del Mar Technical Associates, 1978, 1979). In the case of San Onofre and Diablo Canyon the distance of the postulated design earthquake from the nucelar plant is very small (5 km for Diablo Canyon), and thus in the range where, due to the lack of empirical data, modelling is most important.

FEASIBILITY

In my previous testimony before the ACRS and NRC, I indicated that useful numerical modeling techniques were available to aid in estimating the expected ground motion at Diablo Canyon. The capability for doing site specific calculations similar to those proposed here has been developed by my colleagues at UCSD (Apsel and Luco, 1978).and I have been involved, along with other colleagues and students, in using their computer program (PROSE) and its results to interpret strong

motion records from several earthquakes, including earthquakes in 1977 near Acapulco, in 1977 along the Imperial fault, and in 1978 along the Cerro Prieto fault. At the present time I am working on a modelling study of the Imperial Valley earthquake of October 15, 1979. The above studies are briefly described here.

Hartzell, et al (1979) used the PROSE program to model the strong motion records from the October 1977 Acapulco earthquake. In another study (Nava and Brune, 1980) the PROSE program was used to model strong motion records of the double-event Mesa de Andrade earthquake of magnitude 5.3. In an unpublished study, Adair, et al (1979) found, using the PROSE program, that earthquakes recorded at Imperial Valley College from a 1978 earthquake swarm along the Imperial fault could be closely matched by a simple concentrated stress drop. In another study underway, (Munguia, et al, 1980), we are comparing strong motion records from the Victoria earthquake swarm of March 1978 (records shown in Appendix II of my ASLB testimony). I am presently involved in a modelling study of strong motion records from the Imperial Valley earthquake of October 15, 1979 using results from the PROSE program.

The basic difference between the modelling studies referred to above and the modelling which I am recommending for the Diablo Canyon site is one of scale. With the limited funding available at my institution, it is not possible to make the multiple computer runs with variations in parameters that would be required for the Diablo Canyon study. To estimate the effects of uncertainties in the parameters for the Diablo Canyon modelling, reasonable variations in model parameters will indicate worst-case or conservative conclusions.

GEOLOGIC PARAMETERS FOR MODELING

The numerical modeling would include effects of rupture on all faults considered capable. In particular, the orientations and locations of fault ruptures should be varied to take into account possible effects of focussing, i.e., whether fault rupture could proceed toward the plant, thus focussing energy in that direction. A conservative approach in this case would be to choose fault orientations as close to the direction toward the plant as allowed by the data.

It is also important to consider the effect of possible rupture on the several splay or branch faults of the Hosgri indicated on various maps (see Geologic Map References). These maps show splay or branch faults which point in a more easterly direction than the overall fault zone. Especially important would be splays or branches which strike toward the Diablo Canyon site. The most general model should include both a rupture on the main fault and superimposed effects of rupture on branch faults.

The calculations should also consider the possible range of fault orientations and mechanism, in particular the type of motion (normal, thrust or strike slip), and the possibility that the faults may dip under the plant.

The layered geologic model used in the numerical modeling should be chosen to be as representative as possible of the site-specific geologic structure at Diablo Canyon, based on appropriate geologic mapping, and refraction and reflection profiling. The effects of reasonable variations in structure, given the existing uncertainties, should be taken into account.

STRESS DROP

The main physical parameter necessary as an anchor value for the numerical modeling is stress drop. The 1979 earthquake is the first earthquake for which we will be able, after modeling studies are done, to determine the stress drop with some certainty, and this will aid in predicting the stress drop which might occur along the Hosgri fault. In my NRC testimony, I indicated that most earthquakes have stress drops less than 100 bars, but there was evidence that in some circumstances stress drops of over 100 bars could occur over volumes at least a few km in dimension relatively near the surface.

A reasonable initial model for an earthquake on the Hosgri fault would be a model with a uniform stress drop of 100 bars (over the entire fault rupture), and superimposed local stress drops of about 500 bars for local stress concentrations of about 5 km in radius, located at several points along the main fault branch and on splay or branch faults which are judged capable. Refined estimates for these values could be made when the initial results of the modeling are obtained (by comparison with existing strong motion records from the Imperial Valley earthquake and with other strong motion records considered important). It should be emphasized that it is not necessary to arrive at a final choice on faulting parameters before important and useful reduction of the uncertainties in the strong motion to be expected at Diablo Canyon are achieved. Initial results from the modeling will be of great benefit in this respect, since the information from empirical data is so limited.

CONCLUSION

I believe that it is important that one aspect of the analysis of the seismic records for the IV-79 earthquake as they pertain to the focussing phemonemon and the possibility of amplified seismic motion at Diablo Canyon, suggested in Question 7 of the appendix to ALAB-598, be use of computer modeling. Such modeling is presently feasible and represents the best and most timely way to reduce the uncertainties in the expected ground motion at Diablo Canyon for an M=7.5 earthquake on the Hosgri fault, particularly as these uncertainties relate to the possibility of focussing and localized stress drop.

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MR. FLEISCHAKER: I might note at this time, Mr. Chairman, that Dr. Brune's qualifications are set forth in a separate item attached to the testimony, and they were submitted at the evidentiary hearing before the Licensing Board.

CHAIRMAN SALZMAN: I know that, and no one is questioning Dr. Brune's qualifications.

MR. FLEISCHAKER: This is all I have at this point.

MR. LANPHER: May I go ahead?

CHAIRMAN SALZMAN: Yes. Do you want to go to Dr. Young's testimony?

MR. LANPHER: Yes.

BY MR. LANPHER:

Q Dr. Young, do you have before you a document entitled Prepared Direct Testimony of George A. Young on behalf of Governor Edmond G. Brown, Jr., regarding Appeal Board Questions 1-6?

A Yes, I do.

Q Do you also have a loose page numbered 43?

A Yes, sir.

Q Is that a correction to the page 43 which was pre-filed?

A Yes, sir. Two references have been added.

Q Which references have been added?

A The last two references on the page. The first is Trifunac MD-1972-A, and the second is by the same author, 1972-B.

Q There is a statement of your qualifications attached to your testimony, Dr. Young?

A No, it is not.

MR. LANPHER: They were attached to the copies of the testimony that were submitted.

CHAIRMAN SALZMAN: It is attached to my copy, if it will help.

BY MR. LANPHER:

Q Is that a statement of your qualifications?

A Yes.

Q Do you have any other corrections to your testimony for the one noted with regard to page 43?

A Yes sir. On page 6, the references that have been cited on page 43 are also corrected in the text on the fifth line from the bottom. The citation was originally Trifunac 1972, 1976. Those should be changed to Trifunac (1972-A, 1972-B).

CHAIRMAN SALZMAN: Are you dropping the 1976 reference.

WITNESS YOUNG: Yes, it could be dropped.

CHAIRMAN SALZMAN: The question is whether you are dropping it?

WITNESS YOUNG: I left it in the reference. My thought was that it would not hurt anything, but it is not referred to in the text.

CHAIRMAN SALZMAN: That makes it clear, then.

WITNESS YOUNG: Should we drop it on page 42, then?

CHAIRMAN SALZMAN: It does not make any difference. You just told us what we wanted to know.

WITNESS YOUNG: I prefer leaving it. It is a correction that does not have to be made and does not cause any trouble.

DR. JOHNSON: There is a reference to it above, about the fourth line.

WITNESS YOUNG: Then you are correct, I should leave it in.

BY MR. LANPHER:

Q Dr. Young, do you have any other additions or corrections that you would like to make?

A No, sir.

MR. LANPHER: We would ask that Dr. Young's prefiled testimony be incorporated in the transcript as if read.

CHAIRMAN SALZMAN: Any objection?

MR. OLMSTEAD: Mr. Chairman.

CHAIRMAN SALZMAN: Mr. Olmstead?

MR. OLMSTEAD: Mr. Chairman, there is a question 10 on page 22 of his testimony to which we would pose an objection.

CHAIRMAN SALZMAN: What is your objection?

MR. OLMSTEAD: We object to the question as not being responsive to the Board's question, and as irrelevant to the issues related to the Imperial Valley earthquake 1979.

CHAIRMAN SALZMAN: How far does this response go?

MR. OLMSTEAD: It starts on page 22.

CHAIRMAN SALZMAN: It goes how far?

MR. OLMSTEAD: It runs over to page 25.

CHAIRMAN SALZMAN: Including the diagram on page 24?

MR. OLMSTEAD: I think the diagram is only for that question, yes.

CHAIRMAN SALZMAN: Mr. Lanpher?

MR. NORTON: If he is going to respond to the objection, I would assume that you would want all of the objections first before the response.

CHAIRMAN SALZMAN: All right.

MR. NORTON: We would join in the objection. Mr. Olmstead may not have been at the hearing several years ago, but I am sure he is familiar with the transcript. Effective acceleration was litigated extensively, ad nauseam, days and days. It was not a concept subject for rehearing. The

concept subject to rehearing was Imperial Valley 1979.

We join in the objection. To relitigate the concept of effective acceleration in this setting is a waste of time. It already has been litigated.

CHAIRMAN SALZMAN: Are you joining in the objection?

MR. NORTON: Absolutely.

CHAIRMAN SALZMAN: Mr. Lanpher.

MR. LANPHER: Appeal Board Question 2 asked the parties to address whether the Newmark spectrum is an appropriate and sufficiently conservative representation of 7.5 magnitude event at Hosgri. I believe the question of the effective acceleration, especially in the context as address by Dr. Young in the testimony, is completely responsive to the Appeal Board's question.

CHAIRMAN SALZMAN: We will take one moment, please.

MR. NORTON: Excuse me, Mr. Salzman. I would like to comment on Mr.Lanpher's statement on Question 2.

Question 2 has to do in light of Imperial Valley 1979 very explicitly, and not generally into the whole world, but in light of Imperial Valley 1979, which does not involve effective acceleration.

CHAIRMAN SALZMAN: Let us consult on the answer right now.

(Pause.)

CHAIRMAN SALZMAN: Mr. Lanpher, the Board has considered the objection in light of your confirmation that the answer offered in response to Question 2. The Board does not find the answer is responsive to Question 2, and the motion to strike this answer is granted. The reporter will note that in the record, without specifically striking that portion of the document.

MR. NORTON: Mr. Salzman, I assume that we are striking figure 8, which is reference in the text that is being struck. I suppose we ought to ask if figure 8 is referenced any place else in the testimony, I don't believe it is.

CHAIRMAN SALZMAN: Mr. Lanpher, can you answer that, or can you ask your witness?

MR. LANPHER: Let me ask Dr. Young.

BY MR. LANPHER:

Q Dr. Young, is that correct?

A (Witness Young) As I recall, that is correct.

CHAIRMAN SALZMAN: Then figure 8 will be stricken, too.

Mr. Olmstead, do you have any further objection?

MR. OLMSTEAD: I did have one question that I wanted to ask on voir dire, but I don't know whether the applicant is going to do that yet, or not. I would assume that the applicant would go first.

10

1 MR. NORTON: Please go ahead, Mr. Olmstead.

2 MR. OLMSTEAD: Are you going to do voir dire?

3 MR. NORTON: I have no questions on voir dire.

4 MR. OLMSTEAD: I have a question on the qualifica-

5 tions of Dr. Young.

6 MR. NORTON: No.

7 CHAIRMAN SALZMAN: Do you have a question?

8 MR. OLMSTEAD: I have one question.

XXXX 9 VOIR DIRE

10 BY MR. OLMSTEAD:

11 Q Dr. Young, on the first page of your qualifications

12 and your experience, it says that your engineering career has

13 included teaching, research and consulting in the fields of

14 structure mechanics and hydraulics.

15 I was wondering if you would outline for us

16 experience you have had where you were retained as a con-

17 sultant on a major project to develop a seismic design

18 criteria for a building or structure the size of the ones

19 that we are considering here?

20 A I am afraid I missed the very first part of your

21 question.

22 CHAIRMAN SALZMAN: Please restate it, Mr. Olmstead.

23 BY MR. OLMSTEAD:

24 Q Essentially, I am asking you to tell us any

25 experience that you have had that might be included within

the statement I read in which you were retained as a consultant or as the principal engineer in a major project to develop a major seismic design criteria for the building or structure, the building or structure being the size of the buildings or structures that we are considering at Diablo Canyon.

A In other words, you are not associating soil mechanics, hydraulics, and so forth, which were in the general opening sentence that you referred to. You are referring now relative to seismic criteria for a major project. Is that correct?

Q Yes. A structural engineering consultant in a project of that type.

A My activities in this area have been primarily in the capacity of reviewing criteria, and in studies for the development of criteria. In those capacities, I could give you examples, but I have no specific example of a completely new project where I have had the responsibility of providing the overall criteria for the design of the plant.

MR. OLMSTEAD: Thank you very much.

CHAIRMAN SALZMAN: Are there any further questions?

MR. OLMSTEAD: No.

(Written testimony of Dr. George Young follows:)

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

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 118, 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 118 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

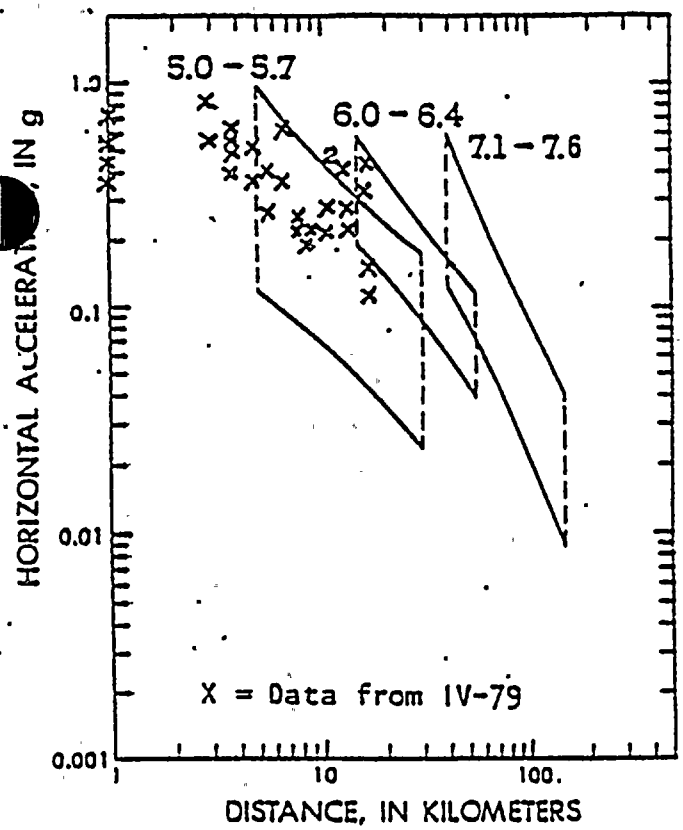


Figure 4. Comparison of 70 percent prediction intervals for peak horizontal acceleration recorded at base of small structures for magnitude classes 5.0-5.7, 6.0-6.4, 7.1-7.6.

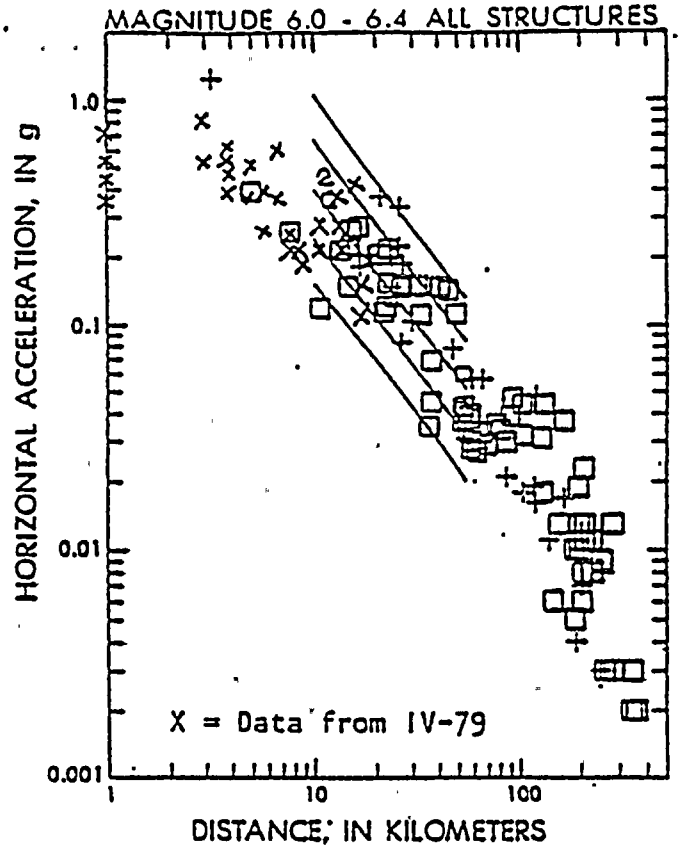


Figure 24. Peak horizontal acceleration versus distance to slipped fault for magnitude range 6.0-6.4 including data from both large and small structures.

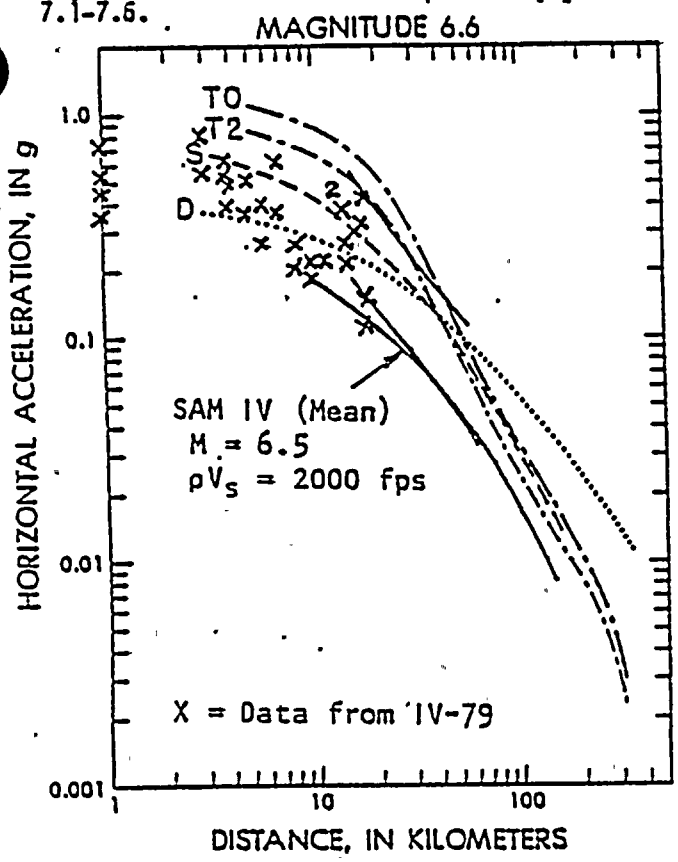


Figure 47. Proposed relations of peak horizontal acceleration to distance from slipped fault for magnitude 6.6 earthquake.

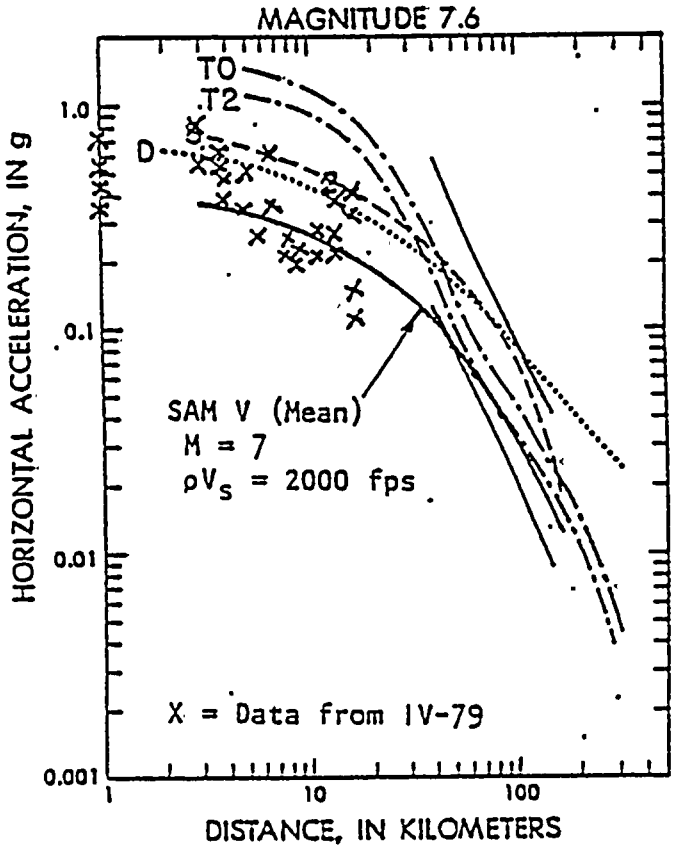


Figure 48. Proposed relations of peak horizontal acceleration to distance from slipped fault for magnitude 7.6 earthquake.

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 (TO; 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 below the mean of 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 (TO; 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 (TO; 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

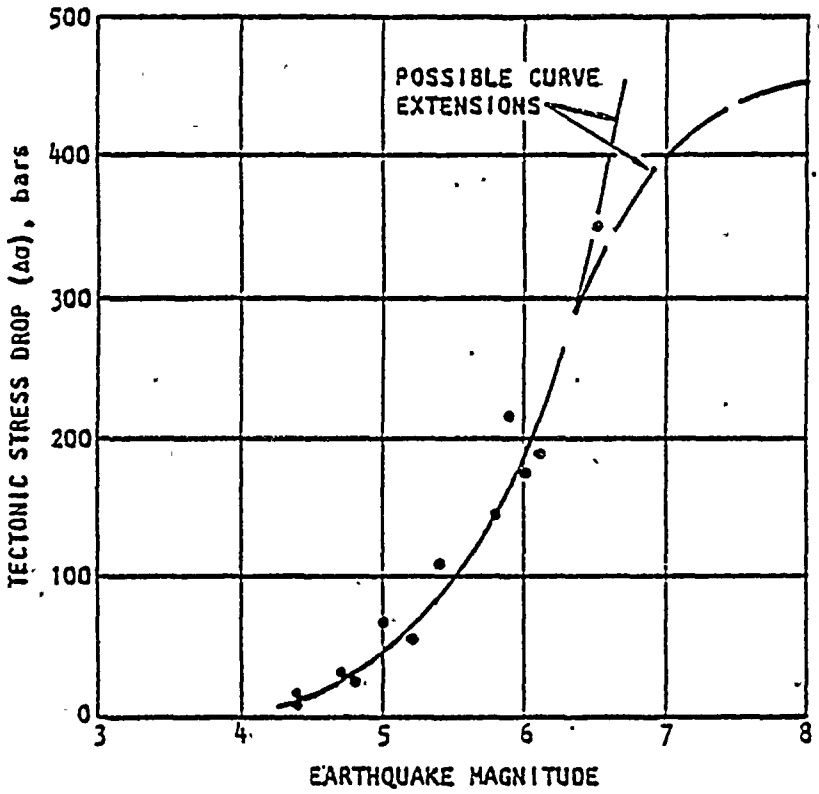
R = Hypocentral distance in km

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

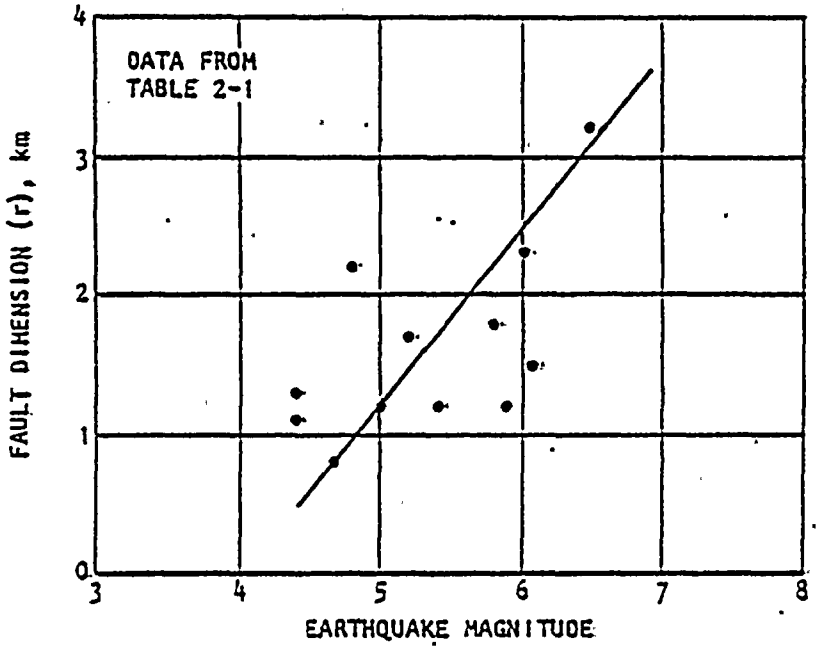
r = Radius of equivalent circular dislocation (fault dimension) in km

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 2 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

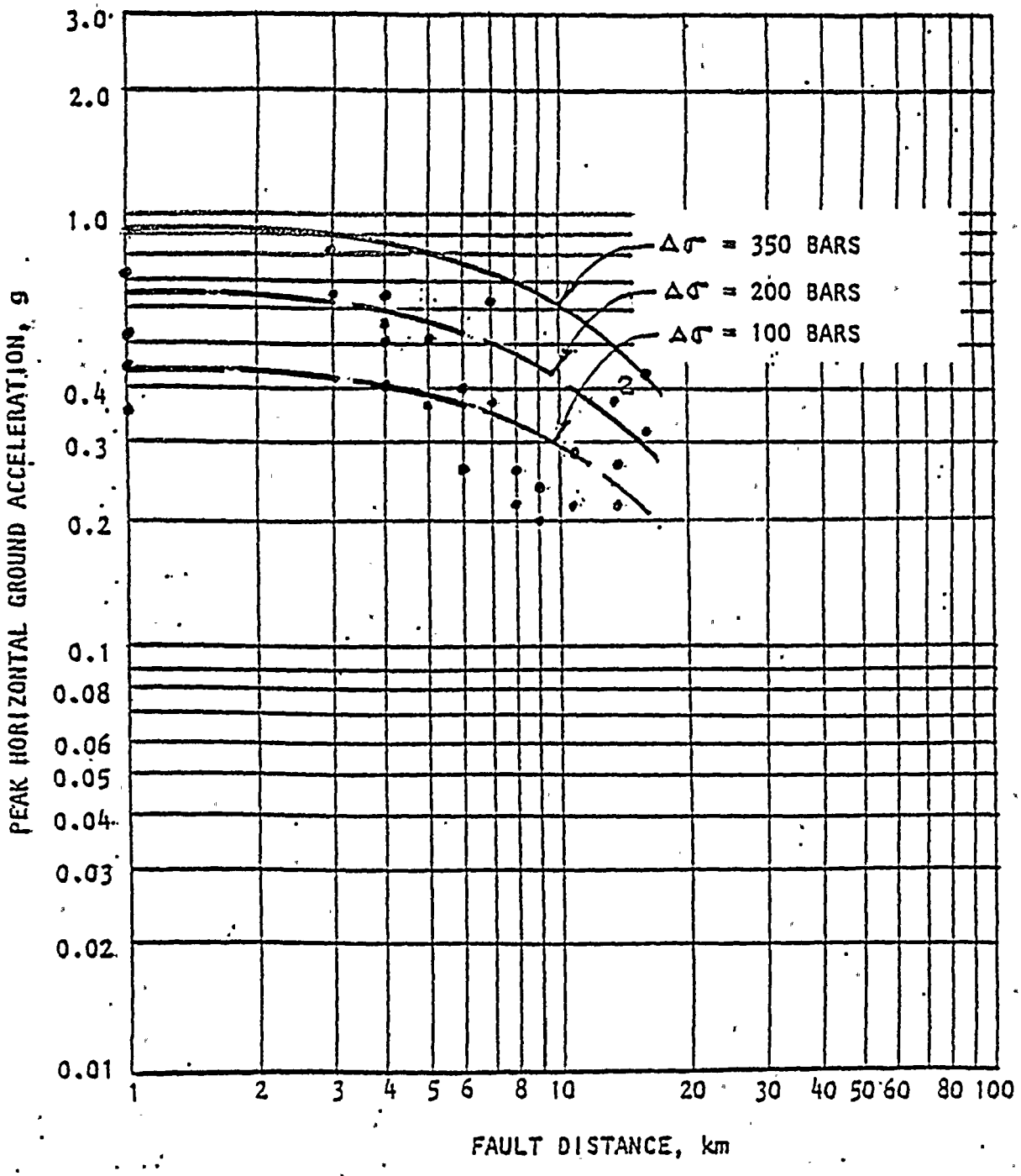


FIGURE 3. COMPARISON OF EQUATION 1 WITH PEAK HORIZONTAL GROUND ACCELERATIONS RECORDED AT BOND'S CORNER AND EL CENTRO ARRAY STATIONS FOR IV-79 EVENT

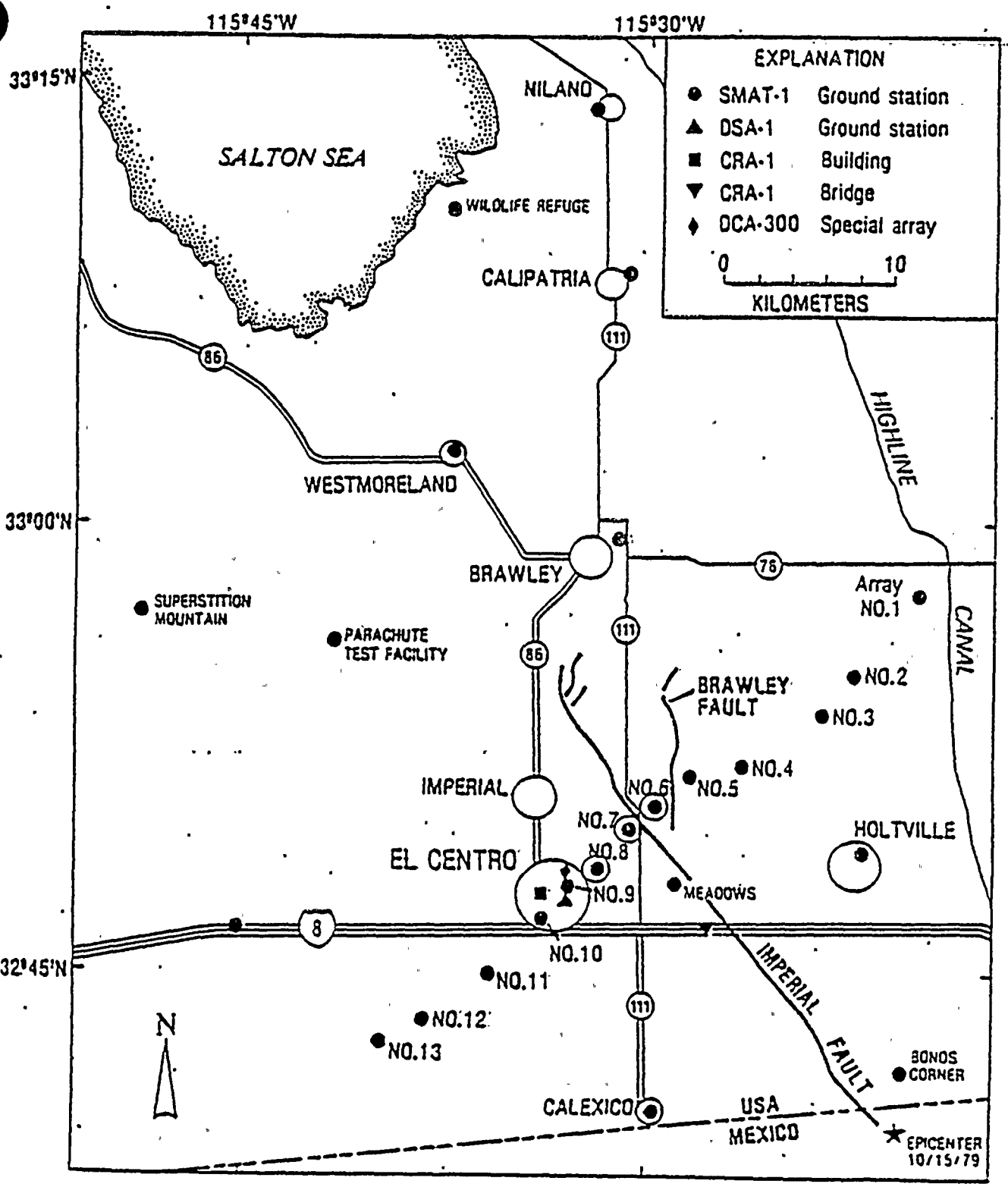


FIGURE 4. MAP SHOWING LOCATION OF STRONG MOTION RECORDERS AND FAULT OF OCTOBER 15, 1979 IMPERIAL COUNTY, CALIFORNIA, EARTHQUAKE (From EERI, 1979)

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:

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

Here

$\ln a'$ = 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,

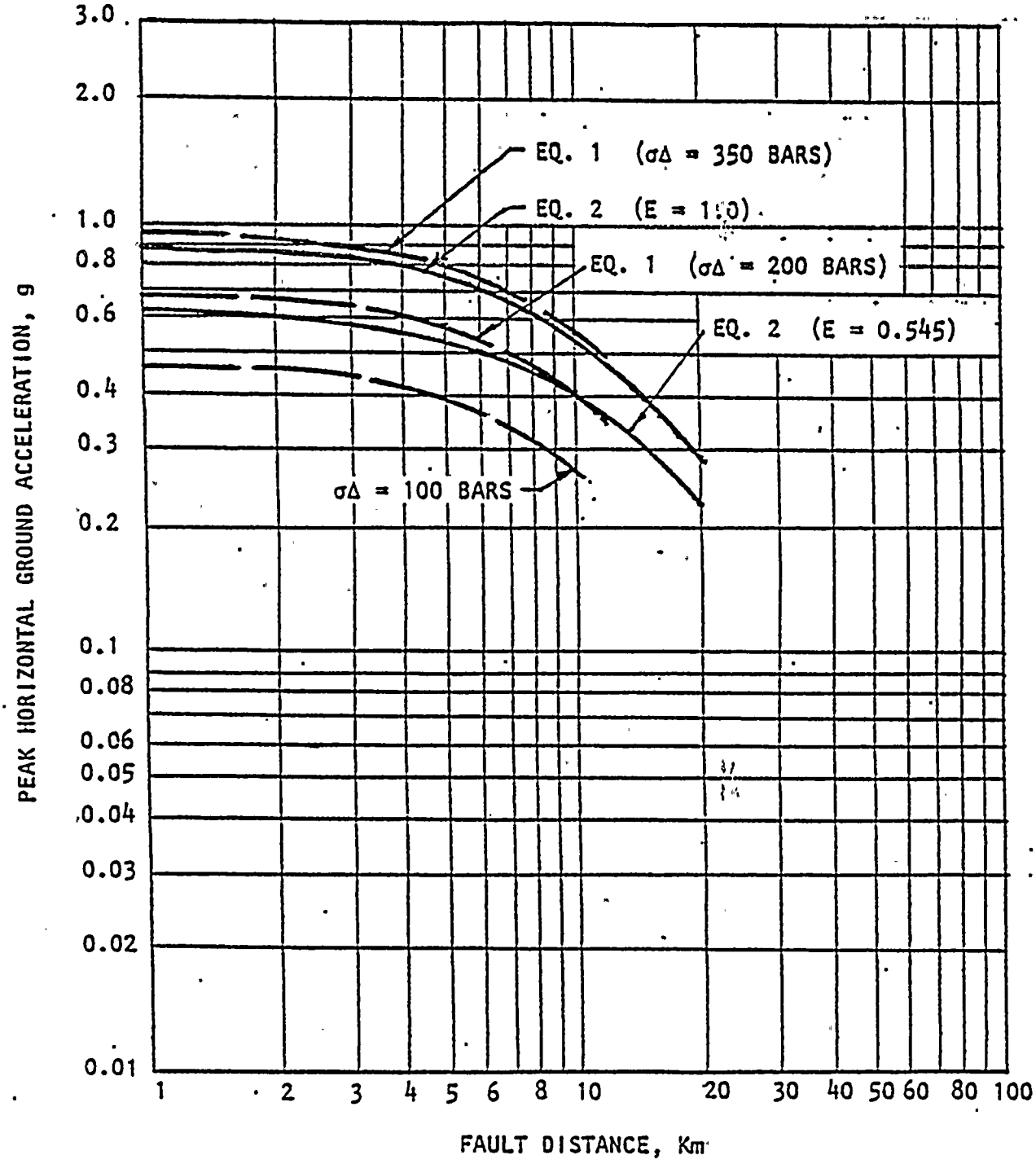


FIGURE 5 - COMPARISON OF EQUATIONS 1 AND 2 FOR 6.5 MAGNITUDE AND FOCAL DEPTH OF 10 Km

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 controlled by peak ground 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.

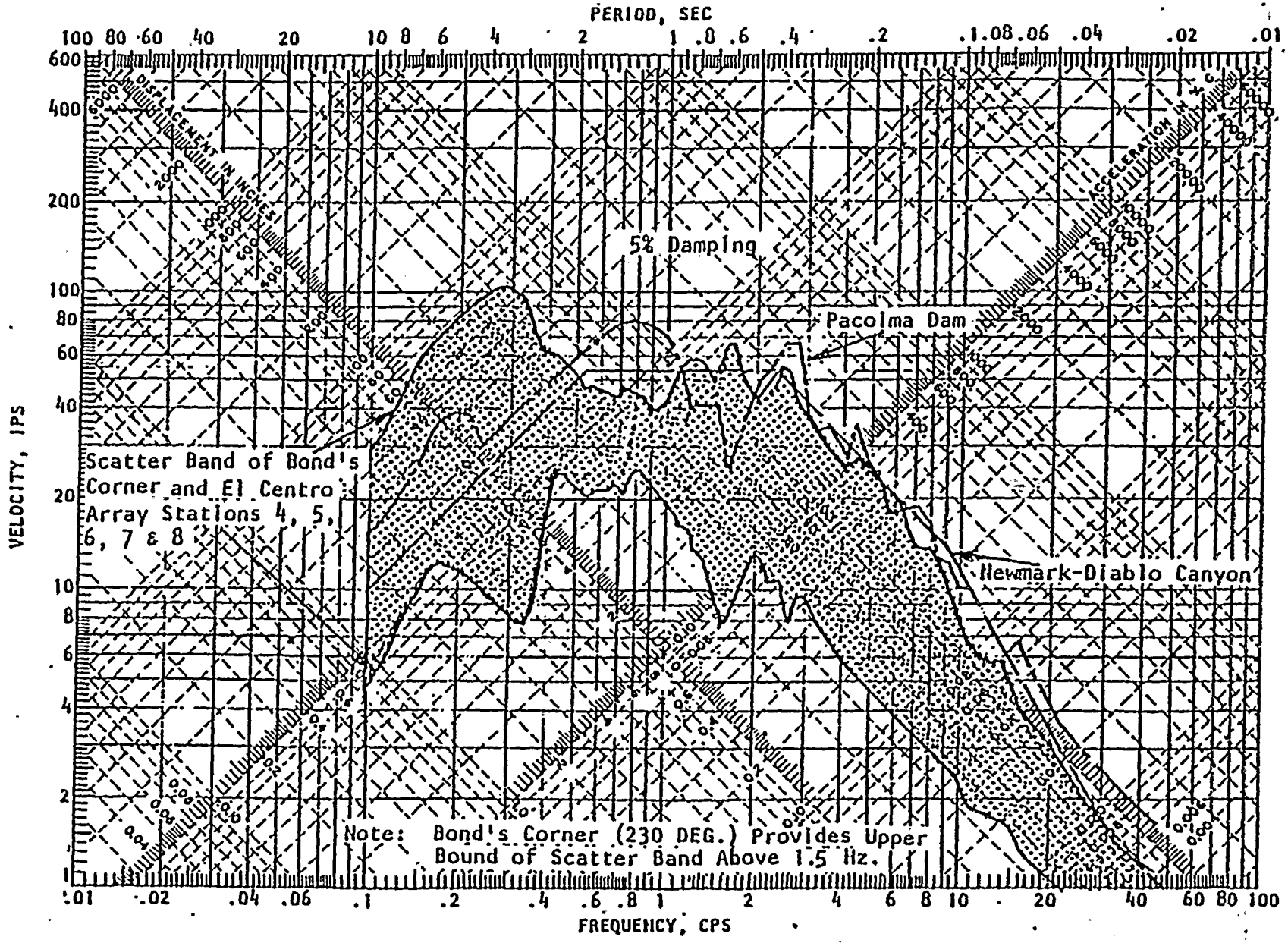


FIGURE 6 - COMPARISON OF NEWMARK-DIABLO CANYON HORIZONTAL RESPONSE SPECTRA WITH IV-79 RESPONSE SPECTRA SCATTER BAND FOR SIX STATIONS RECORDING PEAK HORIZONTAL GROUND ACCELERATION ≥ 0.5 G

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 Fernando 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

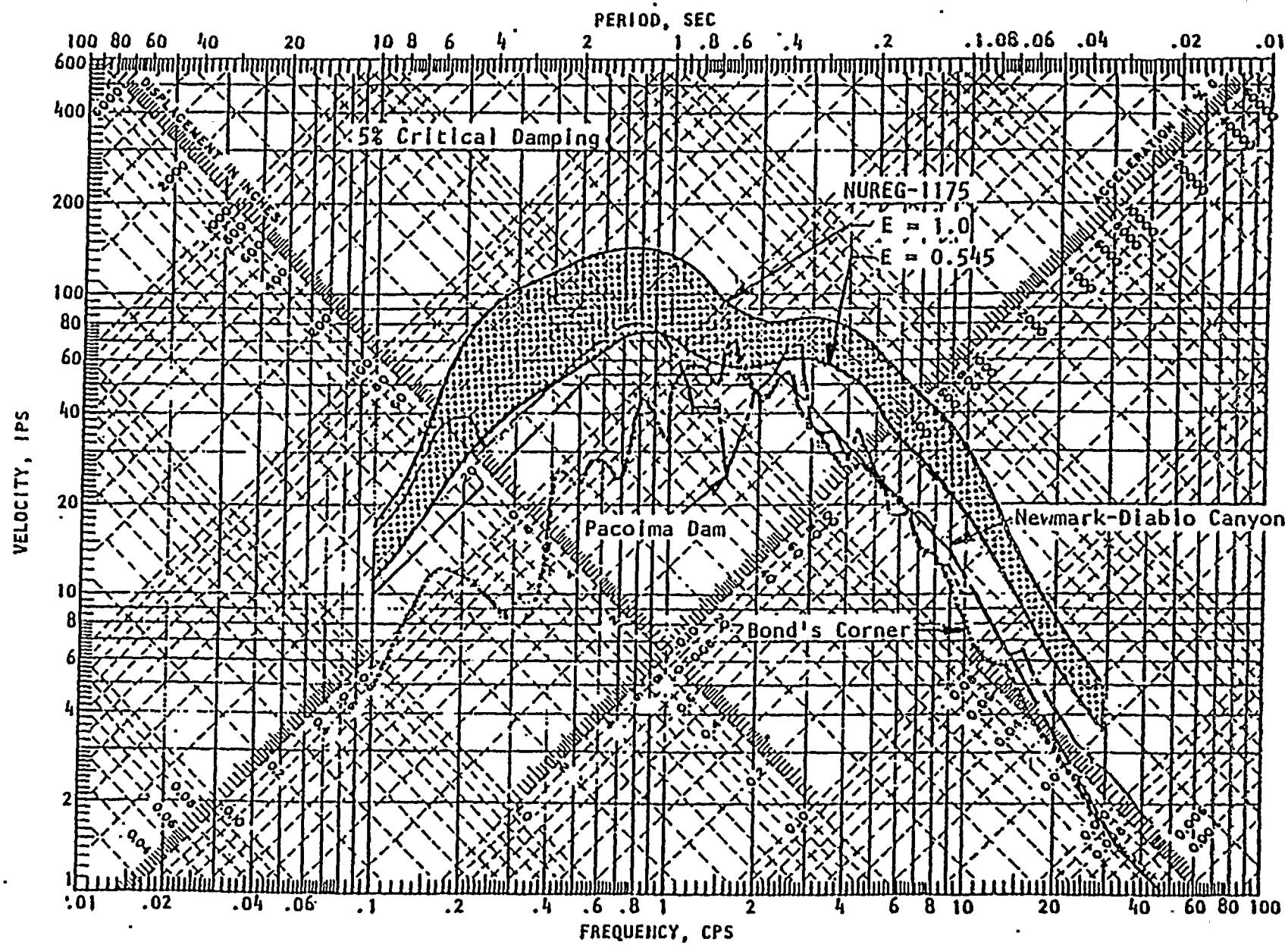


FIGURE 7 - COMPARISON OF NU/REG-1175 RESPONSE SPECTRA FOR 7.5 MAGNITUDE EARTHQUAKE, EPICENTRAL DISTANCE OF 6 KM WITH NEWMARK-DIABLO CANYON, PACOIMA DAM AND BOND'S CORNER SPECTRA

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.

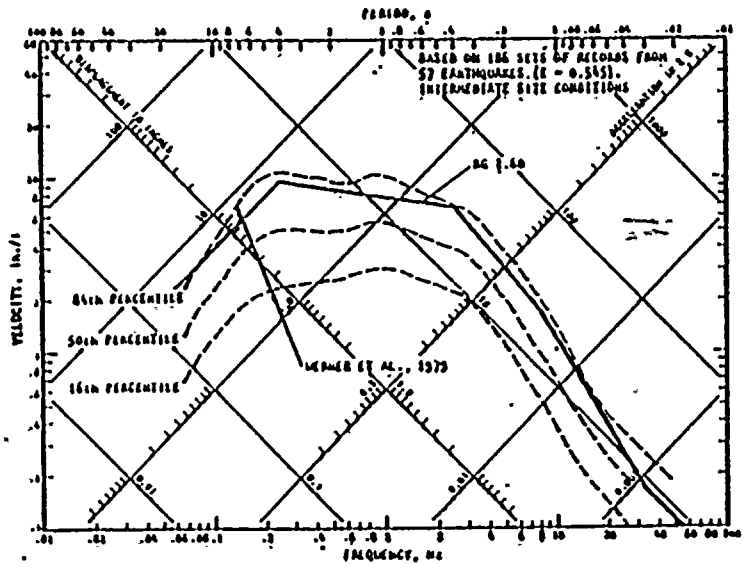
I conclude that an appropriate and conservative representation of the 7.5 event on the Rosgri fault would be a response spectrum that falls within the limits of the two NUREG/CR-1175 spectra given in Figure 7.

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?

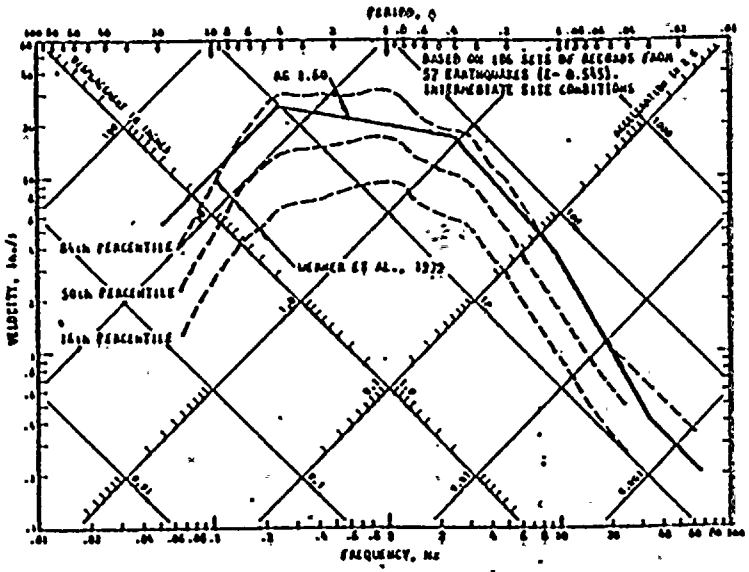
A 10 The effective acceleration as used by Newmark is actually the mean peak acceleration of the normalized sample of records used to develop spectral amplification factors in the 2.5 to 10 Hz range for the Newmark and Regulatory Guide 1.60 spectra. In order to understand why the effective acceleration 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 ($M+\sigma$) 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.

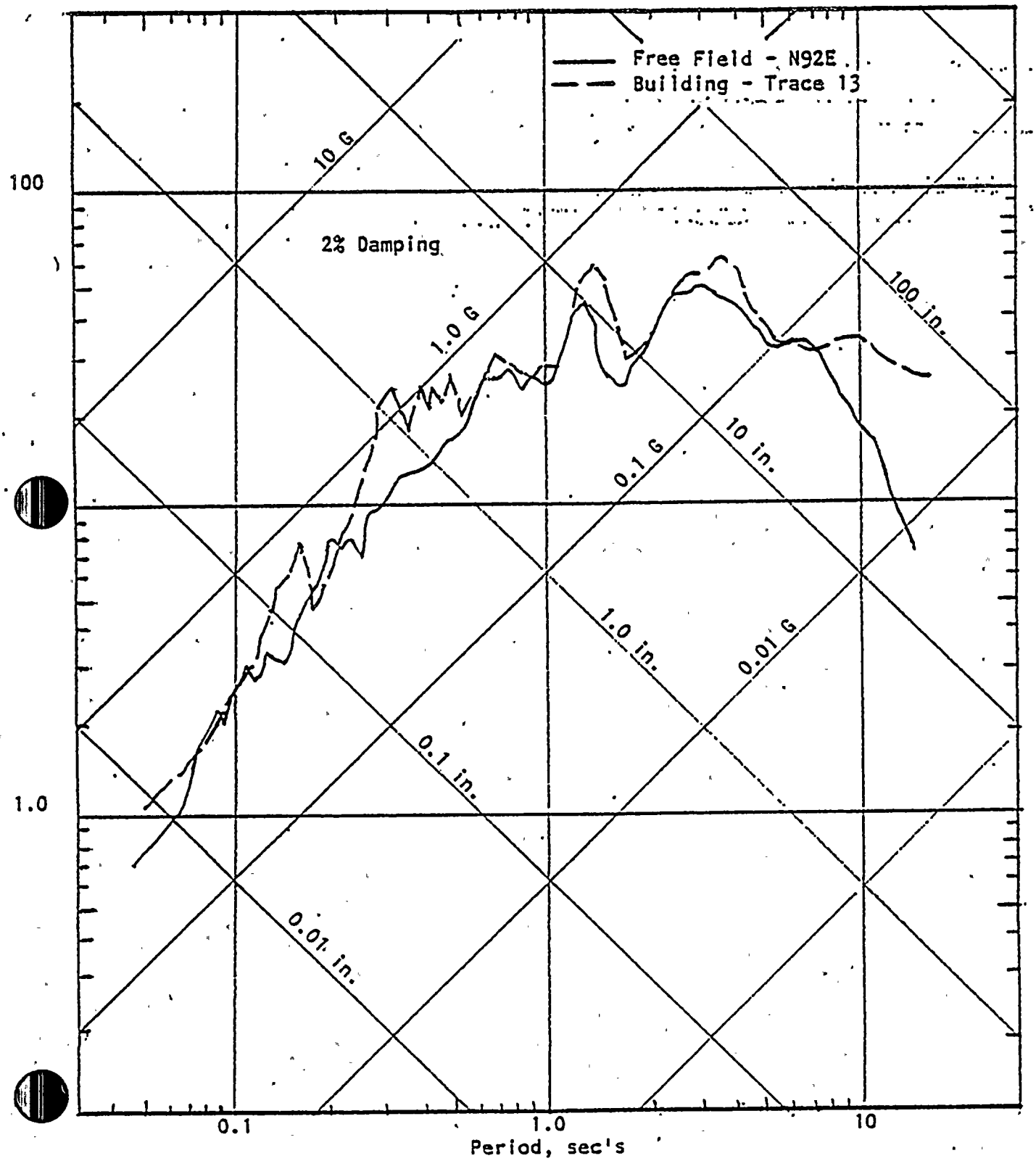


FIGURE 9. COMPARISON OF FREE FIELD AND IMPERIAL COUNTY SERVICES BUILDING FOUNDATION E-W RESPONSE EVENT IV-79

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.

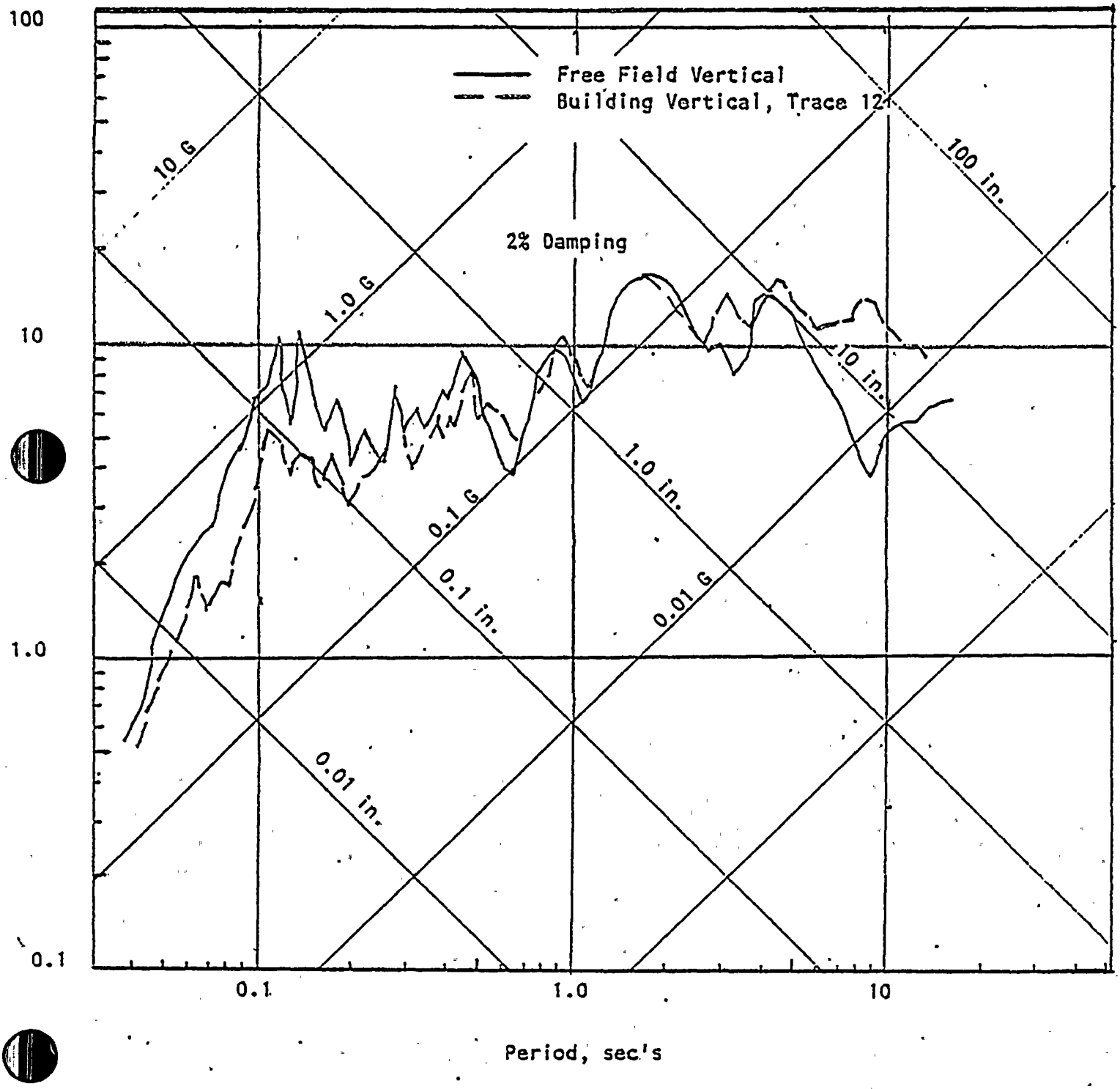


FIGURE 10. COMPARISON OF FREE FIELD AND IMPERIAL COUNTY SERVICES BUILDING FOUNDATION VERTICAL RESPONSE EVENT IV-79

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

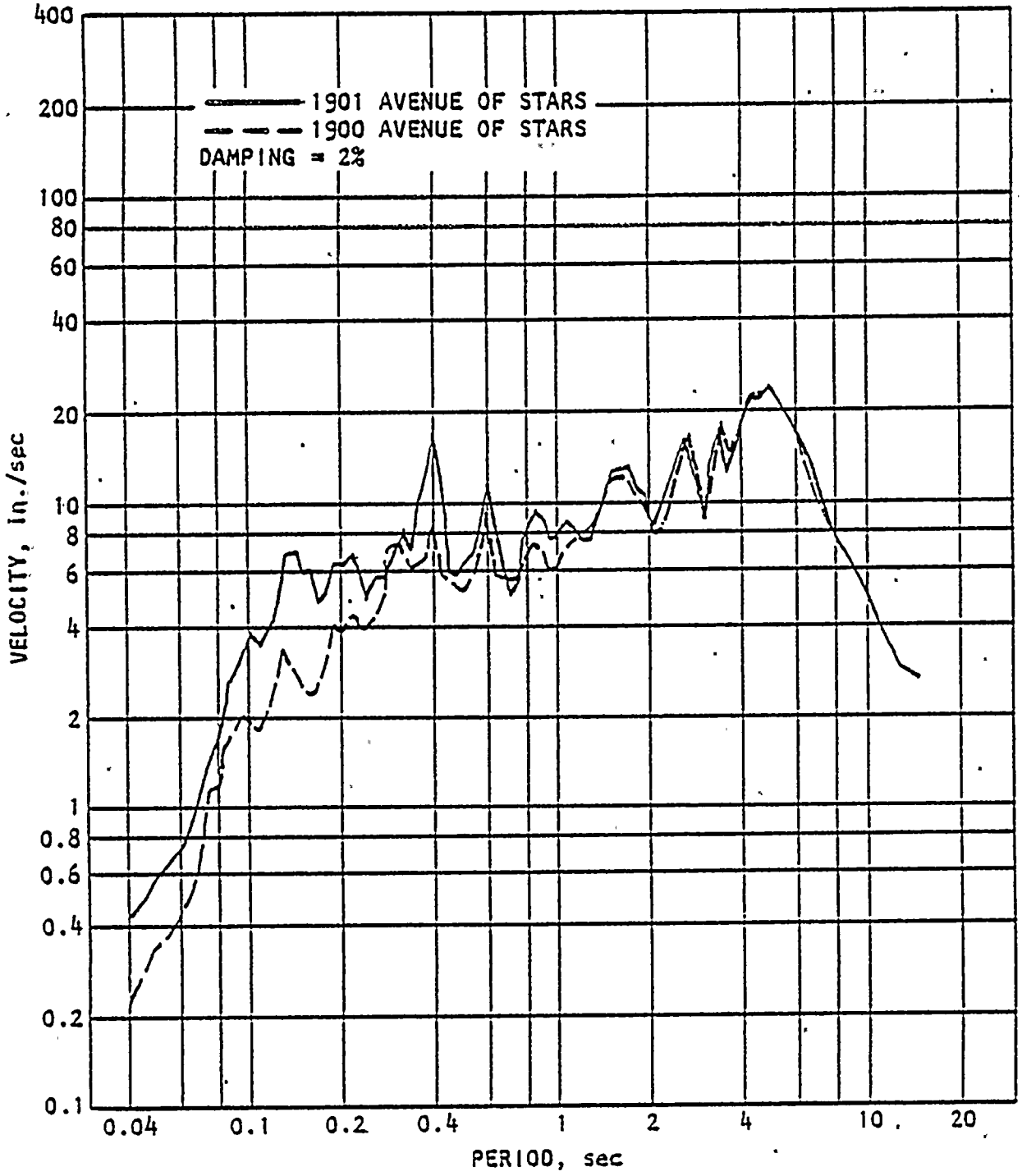


FIGURE 11. S44W RESPONSE SPECTRA FOR 1900 AND 1901 AVENUE OF STARS, 1971 SAN FERNANDO EARTHQUAKE

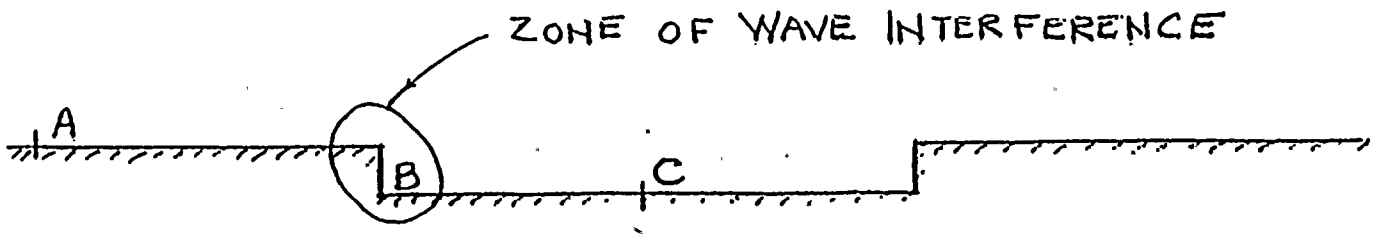


FIGURE 12. VERTICAL SECTION SHOWING ZONE OF WAVE INTERFERENCE

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 3600 to 5900 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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CHAIRMAN SALZMAN: We are ready to proceed with the questions, Mr. Fleischaker.

MR. FLEISCHAKER: Thank you, Mr. Chairman.

I have passed out to counsel, to all parties, and provided the reporter with three copies, and also the board with copies of documents that have been marked as Joint Intervenor's Exhibit R-12, R-13, R-14 and R-15. These will be utilized by Dr. Brune in his opening statement.

Joint Intervenor's Exhibit R-12 is taken from Dr. Trifunac's testimony, and is a map that is contained in his testimony. It is entitled "Figure I.1.

(The above entitled document was marked for identification as Joint Intervenor's Exhibit R-12.)

DR. JOHNSON: Mr. Fleischaker, I see that there are changes made to the first of these figures. I think that it would be well to indicate that these are modifications.

MR. FLEISCHAKER: You are quite right, there are changes to both of these. Dr. Brune will explain the modifications.

DR. JOHNSON: Maybe you should refer to them as modified versions of the figures.

MR. FLEISCHAKER: I believe you are right. It would be better for purposes of the record.

Joint Intervenor's Exhibit R-12 is a copy of a

XXX

modified Trifunac map, which is denoted in his testimony as Figure I.1.

Joint Intervenor's Exhibit R-13 is Dr. Seed's Figure I-2 of his prepared testimony, but it has been modified.

(The above entitled document was marked for identification as Joint Intervenor's Exhibit R-13)

MR. FLEISCHAKER: Joint Intervenor's Exhibit R-14 is the Blume SAM 4 and SAM 5 curves that Dr. Brune has done.

(The above entitled document was marked for identification as Joint Intervenor's Exhibit R-14)

MR. FLEISCHAKER: Joint Intervenor's Exhibit R-15 is a plot of the Trifunac curve that Dr. Brune has done.

(The above entitled document was marked for identification as Joint Intervenor's Exhibit R-15)

CHAIRMAN SALZMAN: This is Dr. James Brune, to distinguish from Dr. John Blume.

MR. NORTON: Mr. Salzman, I have a real problem with R-13. I do not have a problem with R-14 or R-12, but R-13 is now something different than what it says on its face that it is. This gives me a great deal of problem. There is nothing to indicate. If you look at it, it is clearly

not what it says it is, and that bothers me.

I think that they could Xerox them again, and put a copy over what it says it is, because it is not what it says it is.

CHAIRMAN SALZMAN: I think that it would be satisfactory if you took a pencil and drew a line through.

MR. FLEISCHAKER: I would be satisfied with that. Dr. James Brune can explain precisely what it is.

MR. NORTON: But when it gets into the record everyone will get confused.

CHAIRMAN SALZMAN: We will draw a pencil line through the descriptive information on the graph.

MR. FLEISCHAKER: Thank you, Mr. Chairman.

DIRECT EXAMINATION (Resumed)

BY MR. FLEISCHAKER:

Q Dr. Brune, have you reviewed the pre-filed testimony in this proceeding relative to the questions 1, 2, 3, 4 and 7?

A Yes, I have.

Q Have you been here throughout the proceeding and listened to the testimony of the applicant's panel, and of the NRC staff's panel?

A Yes, I have.

Q I have a few questions for you in the beginning.

Dr. Blume, in his testimony at page 1-2, in the

footnote regarding the significance of the recorded peak acceleration measured during the IV-79 earthquake, stated that his analysis assumed that the Imperial fault was considered a vertical plane of energy release.

Do you have information suggesting that that assumption may be inappropriate?

A I have information indicating that it would not be a plane of energy release.

Q Could you describe this information please?

A Yes.

I have been working with graduate student, Allen Olson, to determine the nature of energy release during the Imperial Valley 1979 earthquake.

Q Dr. Brune, you are going to have to slow down.

A The main conclusions important to the Appeal Board Question 1 are: (1) The Imperial Valley 1979 earthquake can be approximated by concentrated stress release at a depth of about six to 10 kilometers beneath the point of maximum fault displacement observed at the surface.

This is indicated in Intervenor's Exhibit R-12 as a colored in square area on Dr. Trifunac's curve beneath the point of maximum displacement on the surface, and labeled "concentrated energy release" by, a modification of Dr. Trifunac's curve.

There was some additional rupture propagating

upward toward Imperial Valley stations 6 and 7, and in addition smaller energy releases occurring somewhat earlier and near the epicenter.

This mechanism may explain the lack of focusing observed in the Imperial Valley 1979 earthquake. The actual surface rupture to the northwest in the neighborhood of stations 6 and 7 appears to have released relatively little seismic energy.

We can plot peak acceleration as a function of distance from the point of concentrated energy release as suggested by Dr. Seed. I have taken this curve out of Dr. Trifunac's testimony and simply plotted the points according to their epicentral distance from the point of maximum displacement on the surface.

As you can see in that curve --

DR. JOHNSON: Just a moment, Dr. Brune, I am confused. Yo have gone to Joint Intervenor's Exhibit R-13?

WITNESS BRUNE: Yes, I am sorry.

DR. JOHNSON: Thank you.

WITNESS BRUNE: You can see that several points fall above the curve. The same is true if we use the curves of Blume, which is Joint Intervenor's R-14.

If we use the curves of Trifunac, Joint Intervenor's R-15, the fit appears to be better. Thus the Trifunac curve better represents the data from the IV-79 earthquake

given the concentrated source I have described, in particular the fact that the Bond's Corner station has the highest horizontal acceleration and highest response spectrum, it is understandable since it is the closest station to the zone of concentrated energy release.

Q Dr. Brune, have you read the testimony of the Applicant, in which plots and correlations are made using distance to the fault as a parameter -- normal distance to the fault?

A Yes, I have

Q What is your opinion as to how this affects the analysis of the data?

A I think that using the distance normal to the fault may be seriously biasing the data. At the present time, there is no basis for assuming that the portion of the fault northeast of the zone of concentrated energy release was very important in the generation of strong motion. What may have been primarily sympathetic slips triggered off by the main energy release, this section of the fault is well known to exhibit spontaneous grave slips as well as sympathetic slips.

There was actually a small amount of slip triggered off along the fault, as much as 20 kilometers away, during the Imperial Valley 1979 earthquake.

I don't believe one should propose averaging in

the data from the Mexican stations in this region as if they were close to the energy release fault.

Similarly very small slips were triggered off along the San Andrea fault, more than 20 kilometers north of Brawley. Again, I don't believe we should average the data from this region as if it were close to the center of energy release.

A slip observed on the Brawley fault itself may have been sympathetic slip.

Clearly treating the station in the Clear Valley Array as if they were close to the main energy release is seriously biasing the acceleration versus distance data downward if the mechanism I propose is correct.

A more meaningful way to plot the data at this time would be to plot as a function of distance from the likely center of maximum energy release, as I have done in the previous intervenor figures.

Plus, I would conclude just the opposite of Dr. Blume, namely, that the Bond's Corner record rather than being too conservative is the most obvious record to use if one wants to estimate the ground motion at Diablo Canyon for a magnitude 6.2 earthquake, and energy release at the closest place on the fault.

Q Dr. Brune, in your statement I think you referred to the fault northeast of the zone of concentrated energy release.

A I am sorry. I meant that to be northwest.

Q Okay. Thank you.

A It was my --

Q Dr. Brune, the NRC staff and PG&E have prefiled testimony discussing the dependence on magnitude of peak ground accelerations in the near field. Could you please provide your view as to that subject?

A Yes. As I indicated in my testimony, the available evidence indicated that the probability of getting high peak accelerations, as well as average accelerations, clearly increased with increasing magnitude. However, there were so few data available for earthquakes near magnitude 7.5 that large uncertainties exist in estimates of peak acceleration expected for earthquakes of this magnitude.

Dr. Blume has referred to the paper by Hanks and Johnson in the Seismological Society of America in 1976 stating that they showed that magnitude is a very weak parameter relative to peak acceleration. I believe that the argument and data presented by the Hanks and Johnson paper have not been placed in the proper context.

Hanks and Johnson do not claim that they have enough data for earthquakes of magnitude near 7.5 to

establish a reliable estimate of peak accelerations for this magnitude. To focus on this one speculative paper and ignore the results of many other investigators referred to in my testimony who do not speculate but actually do a correlation with magnitude as a parameter, and find a clear magnitude dependence is not justified.

Q Dr. Brune, Dr. John Blume stated that the local magnitude measurement of 6.6 was to be preferred over the others set forth in the testimony because it was obtained on a Wood-Anderson instrument and was recorded by a trustworthy source, I believe it was Pasadena, and there may be some disagreement that that is Cal Tech.

Do you have an opinion on that matter?

A Yes, I do. The equivalent local magnitude was determined from strong motion records in Mexico in a study done by myself using the technique developed by Kanamore and Jennings and a value of 6.3 was obtained. As referred to earlier, Dr. Luco reports in his testimony that Kanamore at Cal Tech obtained a value of 6.2 using the strong motion stations north of the border. Thus, the strong motion data suggests a local magnitude less than the preliminary value reported by Cal Tech of 6.6.

It is particularly important to have stations at as many azimuths as possible in determining magnitude. Therefore, the Mexican results are important since the

Cal Tech stations only represent a limited azimuth sample to the north.

Q Dr. Brune, have you studied the testimony of Mr. Edwards as it relates to focusing, as described in your previous testimony regarding this phenomenon before the Licensing Board?

A Yes, I have.

Q Do you agree that he properly relied on the statement contained in your letter to the ACRS and attached to your original testimony submitted in the evidentiary hearings before the Licensing Board, to reach the conclusion stated in the last sentence of his prefiled testimony at VII-4?

A No. Mr. Edwards states that "The rupture focusing phenomenon is not relevant to the Diablo Canyon site in light of the fact that the portion of the Hosgri fault face which may be lined up with the Diablo Canyon site, plus or minus five degrees, is so far from the site (nearest approach is approximately 27 kilometers) that any amplification by high frequency focusing would be eliminated through material damping of high frequency radiation. Brune, ASLB testimony."

I feel that Mr. Edwards misrepresents the position given in my testimony, and I welcome the chance to clear this up. In my ASLB testimony I in fact concluded that focusing was relevant to the Diablo Canyon site, and might,

1 along with other factors, lead to ground accelerations higher
2 than the 1.5 g postulated in USGS Circular 672 for a magnitude
3 7.5 earthquake. That was on page I-8.
4 My conclusion four was that, "Focusing of energy
5 or directivity associated with fault propagation can lead
6 to accelerations and velocities amplified by more than a
7 factor of two in a sector of about plus or minus 5 degrees."
8 And I add the emphasis of the word "about" from the direction
9 of fault propagation. Diablo Canyon could be in the sector of
10 focusing."
11 That is on page III-2. I referred to the study
12 of Boore and Joiner which indicates that when incoherence
13 is introduced into the rupture proposition, the focusing or
14 directivity effects are as strong or stronger than for the
15 corresponding smooth idealized rupture.
16 Q Dr. Brune, you are going to have to slow down a
17 little bit.
18 A Thank you. I noted that the Hosgri fault is
19 curved northwest of the Diablo Canyon site and might be
20 much closer than 5 kilometers to the projection of the
21 trend from the fault northwest of the site.
22 I quote, "Energy could be focused nearly directly
23 at the Diablo Canyon site. A calculation should be made
24 to estimate the effect of focusing in this case." Page III-13.
25 Concerning the initial idealized model of focusing,

I stated: "However, since this idealized theoretical model does not closely represent the real situation, we must do other calculations to verify the possible effects of focusing. In particular, if the rupture propagation is not perfectly coherent, we may expect the beam of focusing -- focused energy to be wider but less intense." That is on page I-5.

I went on to describe the focusing phenomena from another point of view -- constructive interference of bursts of energy release. I then refer to a study of Dr. Steve Hartsell which showed that constructive interference, focusing during the 1940 Imperial Valley earthquake, could have led to accelerations twice as high as in the unfocused direction for the El Centro station which is 5 kilometers from the Imperial fault."

Clearly Mr. Edwards is not following the essence of my testimony when he concludes that Diablo Canyon cannot be in the zone of focusing. Computer modeling which clearly shows the effect of focusing has been carried out by TERA Delta for the San Onofre Nuclear Power Plant which is 8 kilometers from the postulated fault, about 2 kilometers further than Diablo Canyon.

These modeling results clearly show the effects of focusing as stated by Dr. Frazier earlier this morning. Dr. Frazier clearly describes the phenomena of focusing on

page VII-2 of his Diablo Canyon testimony, saying that it can be understood in terms of time compression of signals. The mechanism which he describes is not limited to plus or minus 5 degrees and corresponds to the interference of bursts of energy release described in my testimony. Thus, it is clear that in the real earth the effects of focusing are not limited to plus or minus 5 degrees, as implied by Mr. Edwards' conclusion.

In addition, Mr. Edwards has apparently relied on a greatly oversimplified and inaccurate representation of the actual fault pattern. In my testimony before the ASLB I was referring to various maps of offshore faulting in the Hosgri fault zone which show numerous branches and segments which leave considerable uncertainty as to a precise direction of the fault at any given point. Thus, the fault might locally strike more in the direction of Diablo Canyon than a single line drawn through these various branches and segments.

In this situation the narrow limitation of focusing to plus or minus 5 degrees from some imagined straight line through the various segments is not an accurate characterization of the true situation.

Among the maps which I have previously referred to in my discussion of focusing was the Applicant's map, Plate 2-N in the Appendix 2.5E of the FSAR, which shows sections of the fault northwest of the Diablo Canyon site which

could focus energy more directly toward the site, as well as a branch fault which branches off the main fault and strikes nearly directly at the Diablo Canyon site, coming at least as close as 5.8 kilometers.

Unfortunately, the record has become confused by Mr. Norton's cross examination of me regarding the phenomenon of focusing relative to an idealized diagrammatic representation of the Hosgri fault similar to that used by Dr. Frazier in his Appeal Board testimony, and not an actual geologic map, for example, the Applicant's own map which clearly shows the type of complications occurring in the real earth.

In addition, it should be noted that the official USGS map of the region by Buchanan and Banks shows a branch of the Hosgri fault of Holocene Age which is only about 3.8 kilometers from the site rather than the 5.8 kilometers assumed by Mr. Edwards. This could make the effects of focusing even more important at Diablo Canyon.

Thus, from a geologic point of view also, I conclude that Mr. Edwards' conclusion that focusing is not relevant to the Diablo Canyon site is not warranted.

Q Dr. Brune, have you reviewed Dr. Frazier's prefiled testimony as it relates to focusing which might have occurred during --

MR. NORTON: Excuse me, Mr. Fleischaker. I want to make an objection to the last response before you ask the

next one, so rather than have you get it all out, I just interrupted.

Mr. Salzman, I move to strike certain portions of that last statement. Dr. Brune was very, very careful at the last hearing to quantify and qualify his area of expertise. He took great pains to point out that he is not a geologist, and he was not a structural engineer, and he refused to answer any questions of any kind asked by either his counsel or by myself in those areas. I am sure he will agree with me.

He is now giving geologic testimony about faults and geologic maps. He is talking about branch faults. He said, and I quote, "a branch fault which branches off the Hosgri fault." He is talking about the USGS map showing a branch of the fault.

I submit that Dr. Brune does not have the expertise to make those kinds of statements, or else he has suddenly acquired it since he said he did not have it.

CHAIRMAN SALZMAN: Mr. Fleischaker.

MR. FLEISCHAKER: Well, I think that this matter could be more properly explored by Mr. Norton on cross examination. I cannot speak for Dr. Brune, and I don't agree with Mr. Norton's characterization of his expertise.

It appears to me that Dr. Brune is an expert in modeling of fault rupture, and in that connection he certainly

has an expertise in geological matters. He is not a geologist, but he has acquired through his studies and his experience as a seismologist and geophysicist certainly a deep working knowledge of geology in order to be able to make the kinds of computations that he has.

It seems to me that this matter is more appropriately pursued by Mr. Norton on cross examination, and to the extent that he can discredit or discount Dr. Brune's testimony, then he should do so then.

CHAIRMAN SALZMAN: One moment, Mr. Fleischaker.

Mr. Olmstead, did you wish to be heard?

MR. OLMSTEAD: Not on this one.

CHAIRMAN SALZMAN: Mr. Lanpher, do you pass also?

MR. LANPHER: Yes.

CHAIRMAN SALZMAN: One moment, please.

(Board conferring.)

CHAIRMAN SALZMAN: Mr. Norton.

MR. NORTON: Yes?

CHAIRMAN SALZMAN: I think the fairest characterization of all this is that your question is really the weight of the gentlemen's testimony. One way or the other I think the record will show whether he has the qualifications or has done what he says he has or has not done in the past, and that you will be able to indicate this fairly, and we will take the testimony for what it is worth and subject

to your cross examination, certain cross examination, I assume, and we will let it stand.

Please continue.

MR. FLEISCHAKER: Thank you, Mr. Chairman.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Brune, have you reviewed Dr. Frazier's prefiled testimony as it related to focusing which might have occured during the IV '79 earthquake?

A Yes.

Q Do you agree with his conclusion that "Recordings of the 1979 Imperial Valley earthquake provide further evidence on the limited effects that rupture focusing has on increasing peak acclerations?"

A Yes. I believe this statement is misleading. Dr. Frazier and I both agree in our testimony that there is no strong evidence for focusing in the peak accelerations recorded for the Imperial Valley 1979 earthquake. However, Dr. Frazier implies that this is evidence against the focusing of high frequency energy in general, based on what I believe is an erroneous assumption, namely that the energy release in the Imperial Valley 1979 earthquake occurred along the more or less continuous rupture from the epicenter northwestward beyond the stations in the Imperial Valley array.

The velocity and displacement records for the

Imperial Valley 1979 earthquake, especially those from Mexico, strongly suggest that this is not correct. As I indicated in my Appeal Board testimony, the earthquake may be better represented as a sequence of multiple events rather than a continuous rupture. Thus, it may be that focusing from a more continuous rupture would have led to even higher accelerations.

The sharp velocity and displacement pulses recorded south of the U.S.-Mexico international border clearly suggest that the earthquake cannot be represented by the continuous, uniform rupture to the northwest.

As I have described earlier relating to question 1, the studies that Mr. Alan Olson and I have been carrying out indicate that the earthquake can better be approximated as a concentrated energy release at a depth of about 6 to 10 kilometers beneath the point on the fault with maximum displacement, combined with some small energy release -- earlier energy release and subsequent energy release along a rupture propagating northwestward, but not necessarily with high energy release extending to the Imperial Valley array.

As I mentioned before, this would explain the lack of evidence for focusing.

Q Dr. Brune, have you studied the testimony of Dr. Frazier as it relates to focusing as described in your previous testimony before the Licensing Board?

A Yes, I have.

Q Do you have an opinion on his testimony that "Focusing of high frequency ground motions from a large earthquake on the Hosgri fault is not expected to result in unusually high accelerations at the Diablo Canyon site?" And also states that "Furthermore, the Diablo Canyon site is not positioned for significant focusing from rupture along the Hosgri."

A Yes. Dr. Frazier's conclusion is not supported by his testimony results nor the developmental studies for the computer model. He has developed in association with TERA Corporation and Delmar Technical Associates in Supplement 1 for the San Onofre study that is Joint Intervenors' Exhibit R-7, page VI-1, it is stated that for the San Onofre site, which is 8 kilometers from the postulated fault, focusing is clearly included in Dr. Frazier's model.

If focusing occurs so obviously for the San Onofre site at a distance of 8 kilometers from the fault, it certainly occurs for the Diablo -- it certainly could occur

for the Diablo Canyon site at a distance of only 5.8 kilometers.

The obvious effects of focusing are obscured in Dr. Frazier's testimony by his particular choice of fault configurations which differ from the configurations presented in the San Onofre report. That is, he did not show an example corresponding to configuration G and D, San Onofre report. Even so -- excuse me -- the effect of focusing can be clearly seen in Figure VII-5 in which the response spectra for configuration G, the focus is clearly less than for the other curves which have the effect of focusing in them, as was stated by Dr. Frazier this morning.

Dr. Frazier has chosen -- if Dr. Frazier had chosen a unilateral fault, as was done in the San Onofre study, the effect of focusing would have been clearer, since curve G would have been lower.

There are other limitations in Dr. Frazier's presentation which have obscured the effect of focusing. The time functioning for fault slip has been forced to be the same at all points on the fault, whereas for an actual earthquake starting near the site and rupturing away from it, fault slip near the initiation would not develop to the final slip values until some distance down the fault.

Thus, the curve G or a corresponding unilateral fault initiating near the site and rupturing away would have

an even lower response spectra.

Similar conclusions obtained relative to the peak acceleration listed in Table VII-1 and Table VII-2 of Dr. Frazier's testimony. The peak accelerations for configuration G are low because of the focusing, and the effect would have been more obvious if the configurations mentioned above had been presented.

Another limitation of Dr. Frazier's results stems from the fact that the attentuation parameters in his model attenuate high frequency energy too quickly, thus preventing energy from farther distant parts of the fault from arriving at the station. This artificially limits the effect of focusing.

This limitation of Dr. Frazier's computer results has been mentioned in Supplement 3 to the San Onofre study showing Intervenors' Exhibit R-9, page V-5.

Thus, I feel that the proper conclusion to draw from Dr. Frazier's testimony results is not that focusing is not significant, but rather that focusing is very significant, and the other parameters in the model such as dynamic stress drop, rupture velocity, attenuation, fault consideration and randomness have been chosen in such a way that the effects of focusing are not as obvious as they were in the San Onofre study, Supplement 1, Joint Intervenors' Exhibit R-7.

Q Dr. Brune, have you studied the testimony presented by Dr. Frazier relative to the computer modeling of strong motion at the Diablo Canyon site?

A Yes, I have studied his testimony and the related publications of Delmar Technical Associates, Joint Intervenors' Exhibits R-6 through 9 and Governor Brown's Exhibit R-9, which explained the computer program developed by them.

Q What are the conclusions of your study related to the recommendations for computer modeling given in your testimony?

A As I stated in my testimony on behalf of Governor Brown, I feel that computer modeling is important to use in conjunction with the Imperial Valley 1979 data and other data to reduce the uncertainties about the expected ground motion at Diablo Canyon Nuclear Power Plant from a magnitude 7.5 earthquake on the Hosgri fault.

I further stated that to "estimate the effects of uncertainties in the parameters for the Diablo Canyon modeling, reasonable variations in model parameters will indicate worst case or conservative conclusions."

The computer modeling results presented in the testimony of Dr. Frazier have confirmed and strengthened my previous estimation of the feasibility and importance of computer modeling to understand strong ground motion at

Diablo Canyon from a postulated magnitude 7.5 earthquake on Hosgri fault. I believe that is now clearly on the record that such computer modeling is feasible and should be carried out. Unfortunately, the results presented in Dr. Frazier's testimony do not represent the results for reasonable variations in model parameters which will indicate conservative conclusions as recommended in my testimony.

On the contrary, Dr. Frazier's results represent only one set of the parameters important to the results and not reasonable variations in these. In fact, in nearly all the cases where I have been able to make a determination, the parameters appear not to be conservative.

When the response spectra and peak accelerations given by Dr. Frazier in his testimony are corrected by amounts estimated from previous documentation of the TERA Delta computation procedures to correspond to conservative values, they clearly exceed the Newmark design spectra for Diablo Canyon, and thus indicate that the Newmark design spectra for Diablo Canyon are not conservative.

First, the mean spectra and accelerations presented by Dr. Frazier are actually quite close to the Newmark spectra. For the examples which Dr. Frazier had in his testimony originally filed, they were less than a factor of two different. And as we saw this morning, when a small

amount of dip was introduced underneath the plant, the response spectra, the means without any standard deviation were almost touching the Newmark curves. When a realistic standard deviation is added to these curves, they will exceed the Newmark spectra.

Second, the effects of a geologic structure, mainly Q, the effect of geologic structure, mainly Q, has been indicated by the Delta parameter studies, Supplement 1, Figure IV-13, to result in approximately 80 percent higher response spectra at San Onofre than in the Imperial Valley for the same source.

The Diablo Canyon structure is similar to the San Onofre structure with higher rigidities and thus lower attenuation at shallower depths. Thus, the TERA Delta parameter study, along with the information provided by Dr. Frazier concerning his Diablo Canyon correlations this morning, indicate that for the same source mechanism as occurred for the Imperial Valley 1979 earthquake, if it had occurred at the -- in the Diablo Canyon structure, the response spectra would have been considerably higher.

Third, the effective value for dynamic stress drop --

MR. NORTON: Excuse me, Mr. Salzman. I am having a slight problem. The direct examination up to this point in time has been submitted written testimony, and that is it, and then there has been cross examination by questions.

Dr. Brune is reading obviously rebuttal testimony. I cannot write as fast. I cannot take notes as fast as he is reading.

Is it possible that copies can be made available of what he is reading? There is just no way to keep up with somebody when they are reading that rapidly.

CHAIRMAN SALZMAN: Ask that of Mr. Fleischaker.

MR. FLEISCHAKER: Well, there are three problems. The first is that we just cannot make copies of what Dr. Brune has there because he is not giving the precise testimony for the record of the thing that he has written there.

Secondly, this document contains numerous interlineations, changes, and my comments on it, so it is an attorney work product.

MR. NORTON: Okay. You can stop there.

MR. FLEISCHAKER: Third, we would have to type it, and fourth, if we were going to do that, I would like to have the same --

CHAIRMAN SALZMAN: Wait.

MR. NORTON: I withdraw the request on that basis, but we would like to see the transcript before we have to complete our cross examination, because we just cannot keep up. We cannot keep notes as fast as he is reading. He is reading quite rapidly. There is no way to

take notes that quickly.

MR. FLEISCHAKER: We will have that same problem.

CHAIRMAN SALZMAN: I think everybody will have that sort of problem, but you are going to have this transcript tomorrow morning, and it is already ten minutes after 4:00, so let's keep up. And Dr. Brune, a little slower, please.

MR. NORTON: Thank you.

MR. OLMSTEAD: Mr. Chairman, while we are here, though, I might say that I have no objection to the question that was asked, but I am starting to have an objection to the response that is being given to the unasked questions, so I would like another question.

CHAIRMAN SALZMAN: I don't follow you. You want -- your point is that the witness is not answering the question that was asked.

MR. OLMSTEAD: Right. I mean, when he started off I had no problem, but as he got into the question of design response spectra and what is conservative and what is not conservative, he is not a structural engineer, and I would have objection to expert testimony in that area if there were a question to object to. But the question that was asked was a geological question to which I have no objection.

MR. NORTON: Could we have that question and answer, please? That is why I interrupted. He was going so rapidly that I frankly just got lost.

CHAIRMAN SALZMAN: If the answer is to be read, it will take the rest of the afternoon. You may go back, please, if you can, Mr. Reporter, to the question asked by Mr. Fleischaker and repeat Mr. Fleischaker's question, unless Mr. Fleischaker has it written and can restate his question quickly.

MR. FLEISCHAKER: I can restate the question and will do so to save us time.

What do you propose Dr. Brune to do, start from the beginning of his response?

CHAIRMAN SALZMAN: I would like you to restate the question that you asked Dr. Brune.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Brune, have you studied the testimony presented by Dr. Frazier --

CHAIRMAN SALZMAN: I would like you to state the question slowly so that everyone hears it, too, sir.

BY MR. FLEISCHAKER: (Resuming)

Q Dr. Brune, have you studied the testimony presented by Dr. Frazier related to computer modeling of strong motion at Diablo Canyon, and what are your conclusions related to the recommendations for computer modeling given

in your testimony?

CHAIRMAN SALZMAN: That being so, I suggest that if you have an objection to something the witness is saying, I suggest you make that objection when he says it, Mr. Olmstead, and we will allow Dr. Brune to continue from this point, a little more slowly, sir.

WITNESS BRUNE: Third -- excuse me.

BY MR. FLEISCHAKER: (Resuming)

Q You completed point two of your critique.

CHAIRMAN SALZMAN: I heard Dr. Brune say third. Please go ahead, sir.

WITNESS BRUNE: Third, the effective value for dynamic stress drop in the TERA Delta model I believe is only approximately 40 to 50 bars based on a dynamic source study comparison by Dr. Steve Day at Systems Science and Software. I do not -- this is a conservative value. A conservative value should be 100 bars, and in addition, the possibility of localized stress drops of up to 500 bars should be considered as indicated in my testimony.

The parameter studies by TERA Delta have shown that in the frequency range 2 to 10 hertz, the response spectra are essentially linear with respect to dynamic stress drop. If we multiply the spectra in this frequency range by a factor of two to go from 50 to 100 bars, the calculated response spectra will exceed the Newmark design

spectra at certain places.

Fourth, the low Q values --

MR. OLMSTEAD: Okay, Mr. Chairman, now that we are here, it is that portion of the response to and that portion right here that I start to object to, not to what his representation of the model is, but when he starts characterizing the Newmark design spectra, because I do not think he is qualified to characterize the Newmark design spectra.

CHAIRMAN SALZMAN: Mr. Fleischaker.

MR. FLEISCHAKER: The Newmark spectra represents --

MR. NORTON: Excuse me, Mr. Salzman. I think I get a chance to make an objection, too.

CHAIRMAN SALZMAN: I did not realize you were objecting. Usually you state it loudly and clearly.

MR. NORTON: I was not as quick as usual. Again, Dr. Brune has stated very clearly in this record in this proceeding that he has absolutely no expertise in the area of structural engineering, and for Mr. Fleischaker to define what Mr. Newmark's design spectra is all about does not do us any good. Dr. Brune -- and I think he should be voir dired on this question.

He has stated he has no expertise in this area. He should not be talking about --

CHAIRMAN SALZMAN: That is in the record, is it

not?

MR. NORTON: It most certainly is, and so he should not be allowed to testify about something he admits he has no knowledge about.

CHAIRMAN SALZMAN: Stop. Mr. Fleischaker, will you respond to both Mr. Olmstead and to Mr. Norton's objections, please?

MR. FLEISCHAKER: Well, Mr. Norton's objection is curious, because if we examine Dr. Frazier's testimony, what we find throughout is a comparison of the response spectra, the free field response spectra generated by this computer model, a comparison to the Newmark spectra. And Dr. Frazier also is not a structural engineer.

CHAIRMAN SALZMAN: The obvious answer to that is the time to object to that was when it was testified.

MR. FLEISCHAKER: Still, the point is --

MR. NORTON: Excuse me. Dr. Frazier is a Ph.D. structural engineer.

CHAIRMAN SALZMAN: Mr. Norton, please do not interrupt. Mr. Fleischaker is speaking. I reserve myself that prerogative.

Mr. Fleischaker, complete your answer.

MR. FLEISCHAKER: Dr. Brune's -- the computer model that we are talking about predicts amplitudes of strong ground motion at the Diablo Canyon site. In order

to make a judgment as to whether the Newmark design spectra are conservative, you have to have a model of the strong ground motion expected in the free field at Diablo Canyon, and that is what this subject is all about.

There is a necessary relationship between the result from the computer model, and you need the result from the computer model in order to determine whether the Newmark spectra are reasonable and conservative.

CHAIRMAN SALZMAN: Mr. Fleischaker, Mr. Norton objected also on the ground that the witness had no experience as a structural engineer, and I would like you to tell me whether the statements that Mr. Norton has made on the record, because I was not presiding at the hearing below.

MR. FLEISCHAKER: I cannot answer that question, but I don't think that Dr. Brune is a structural engineer.

CHAIRMAN SALZMAN: One moment, please.

MR. NORTON: Excuse me, Mr. Salzman.

CHAIRMAN SALZMAN: One moment, please.

(Board conferring.)

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(Board conferring)

MR. FLEISCHAKER: If I might continue: one other thing, I would like to direct the board's attention to one thing here.

CHAIRMAN SALZMAN: Yes, sir.

MR. FLEISCHAKER: Let me see if I can state this more precisely.

The purpose of this hearing is to determine what the amplitude of strong ground motion in the -- at the Diablo Canyon site will be, given a 7.5 magnitude earthquake.

The applicant has presented a computer model that apparently gives us some answer. Dr. Brune has examined that model to determine the validity of the computer's output.

If you look at his testimony here, he simply compares the calculated response spectra with the Newmark spectra. He says the line -- the line on which we got the objection was the calculated response spectra will exceed the Newmark design spectra.

CHAIRMAN SALZMAN: Mr. Norton wishes to be heard.

MR. NORTON: I am quoting Mr. Fleischaker from page 7996 of the record below. "But more broadly" -- starting on line 11 -- "But more broadly on an different kind of objection is that the kinds of information that

dsp16-2

Mr. Norton is seeking to obtain or the kinds of testimony thathe is seeking to elicit is beyond the scope of this witness's expertise.

"Dr. Brune is a seismologist, and I think that before he said he was not a structural engineer, and he was not prepared to talk about appropriate numbers that should be utilized at zero period."

And it goes on and on and on.

For Mr. Fleischaker to argue that he somehow now should be talking about it, I think is -- I think it just isn't.

CHAIRMAN SALZMAN: Mr. Olmstead?

MR. OLMSTEAD: Yes, I think it is difficult for me to get the precise words because I have just been hearing this testimony and I must admit that I did not jump on it as soon as I probably should have. But when I began to rezlie that what we were doing was starting to characterize the Newmark design response spectrum as conservative or not conservative after Dr. Newmark went to great pains this morning to talk about all of the various factors that went into developing a design response spectrum, I don't see how someone who is not a qualified structural engineer can start to make those characterizations, and I think Dr. Frazier has made it clear in his testimony that he could not compute the number -- namely, one standard

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deviation -- because the procedures in his model would not permit this.

So how one could look at a chart with a design response spectrum on it and say, "Well, because it is so close to a line, it is not conservative," is beyond me.

CHAIRMAN SALZMAN: One moment.

MR. FLEISCHAKER: I think we have gone -- may I please respond to that?

CHAIRMAN SALZMAN: Please.

MR. FLEISCHAKER: The beginning point of these hearings, the beginning point of seismic design is to characterize the amplitudes of strong ground motion at the site.

TERA Delta -- excuse me -- Dr. Frazier has presented a model and he believes that the results from that model properly characterize the amplitudes of strong ground motion.

Three, Dr. Brune has examined that model and he concludes that Dr. Frazier's model underestimates the character of strong ground motion at the site.

Four, he then takes what he believes to be a proper characterization if the model had the appropriately conservative parameters; thoseconservative parameters relating to the characteristics of the fault, the geologic structure.

dspl6-4

And he compares the characteristics of strong ground motion to the Newmark spectrum. Period.

CHAIRMAN SALZMAN: One moment.

MR. FLEISCHAKER: That falls clearly within his expertise.

CHAIRMAN SALZMAN: Mr. Norton, one last word from you.

MR. NORTON: All right. The problem is that I agree with Mr. Fleischaker through the first several of his points, that the ground motion, that that is definitely inthe area of Dr. Brune's expertise. But it is amply clear on this record, both below and presently, once you take a free field ground motion, this is a whole new ball game, a whole new science to get into design spectra, one of which Dr. Brune has never pretended to know anything about.

And he should not be testifying. He is comparing free field ground motion with response spectra, and saying, "Therefore the design response spectra is not conservative." And he is not qualified to do that.

First of all, it is improper, and secondly, he is not qualified.

CHAIRMAN SALZMAN: One moment.

MR. FLEISCHAKER: I cannot find anything here where he has characterized the design spectra. He has

dsp16-5

simply compared the amplitudes of strong ground motion with a spectral shape.

CHAIRMAN SALZMAN: I think I understand everyone's position. Will you wait one moment, please.

(Board conferring)

CHAIRMAN SALZMAN: Back on the record. I understanding, notwithstanding the magnitude of the problem we were just addressing, the parties have a stipulation, an agreement which I would like Mr. Fleischaker to state, please.

MR. FLEISCHAKER: The agreement that has been reached by counsel is that Dr. Brune in his testimony will be able to compare the Newmark design spectra with the amplitudes of strong ground motion which he would predict or expect to occur at the site.

However, he will not characterize the Newmark spectrum as conservative or non-conservative at all.

MR. NORTON: And I think it was further stipulated, Mr. Fleischaker, that in those portions of his testimony where he has already done so, that comparison or the qualitative comparison that it is conservative or shows it to be nonconservative would be stricken.

MR. FLEISCHAKER: I agree. I think it has been done once, but we will agree with that.

One further clarification, however: in his

dspl6-6

testimony, Dr. Brune has referred to the parameters in the computer model as conservative or nonconservative. And I believe those fall clearly within his area of expertise.

CHAIRMAN SALZMAN: I see Mr. Norton nodding in agreement. Mr. Olmstead, are you in agreement also?

MR. OLMSTEAD: I am in agreement with striking the references to the Newmark spectrum as nonconservative, whether they are or they are not.

CHAIRMAN SALZMAN: Wha about the rest of the stipulatiom, is that satisfactory to you, sir?

MR. OLMSTEAD: I am not sure that I fully understood. I think I agree with it generally, although I just wanted to be clear that we are comparing free field data to a structural engineer's response spectrum which includes a lot of other things besides free field. With that caveat, I agree.

CHAIRMAN SALZMAN: I am not sure what that caveat implies here. Mr. Fleischaker, it is correct Dr. James Brune is not a structural engineer?

BY MR. FLEISCHAKER:

Q Dr. Brune, are you a structural engineer?

A No, I am not a structural engineer.

CHAIRMAN SALZMAN: All right. With that, is that clear enough now?

dsp16-7

MR. OLMSTEAD: Yes.

MR. FLEISCHAKER: Thank you. Shall we continue?

CHAIRMAN SALZMAN: In that case, all the learning that was pumped into me in the last five minutes has been wasted.

Please continue, Mr. Flesichaker.

BY MR. FLEISCHAKER:

Q Where were we, Dr. Brune?

A I was beginning the fourth. I had just finished the third.

Q You will be careful when you characterize the Newmark spectra.

A Yes, I will be very careful about that.

Q Please continue.

A Fourth, the low Q values assumed in the TERA Delta model have excessively attenuated high frequency energy traveling large distances and thus artificially reduced the effectiveness of focusing.

Fifth, the TERA Delta model does not adequate predict the accelerations actually observed in the Imperial Valley 1979 earthquake at stations a few kilometers from the fault, being consistently a factor of two too low; for example, Bonds Corner and station 8.

And I refer to supplement III of Joint Intervenors' Exhibit R-9. This indicates that the dynamic

dsp16-8

stress drop or some other parameter should be changed to increase the peak acceleration by about a factor of two in order to fit the M equals 6.2 to 6.6 Imperial Valley earthquake.

Then appropriate changes in parameters to correspond to a magnitude 7.5 earthquake should be made and the calculation be done for Diablo Canyon.

Sixth, the result of the computer modeling presented by Dr. Frazier do not constitute an adequate study of the effects of varying the geological parameters as suggested in my testimony. No variation of the position and direction of the fault as been considered to determine the effects of the differences corresponding to the different geologic maps of the area; for example, the faults presented on applicant's map presented in the FSAR does not coincide exactly with the USGS MS 910 map of Buchanan and Banks.

If the Buchanan and Banks map had been used where the fault is only 3.8 kilometers offshore from the site, the calculated accelerations would have been higher. Furthermore, no consideration has been given to the effect of rupture on a splay fault as shown on the applicant's map, FSAR map plate, 11N, Appendix 2.5E, which points directly at the plant and thus could lead to a maximum of focused energy toward Diablo Canyon Nuclear Power Plant.

In conclusion, the results of the computer modeling presented in Dr. Frazier's testimony support the feasibility and importance of doing a parameter study such as that recommended in my testimony but by themselves do not constitute such a study, but rather one specific calculation in which several important parameters have been given values which are not conservative.

If these parameters had been assigned conservative values, the Newmark spectra would have been substantially exceeded, based on the sensitivity studies presented in the --

MR. OLMSTEAD: Mr.Chairman, the witness has testified here that the Newmark spectra would be exceeded, but that would be uncorrected data which would exceed the spectra and necessarily would not be subject to comparison.

CHAIRMAN SALZMAN: Yes, that is true. But it is also something you could discuss on cross examination of the witness.

Please continue, Mr. Fleischaker.

BY MR. FLEISCHAKER:

Q Dr. Brune, have you completed your answer to that question?

A I think I ended with the words, "In previous TERA Delta reports."

Let me read the last sentence just to make it

sp16-10

clear because I may have forgotten. If these parameters had been assigned conservative values, the Newmark spectra would have been substantially exceeded, based on the sensitivity studies presented in previous TERA Delta reports.

That concludes my statement on that question.

Q Dr. Brune, have you studied the calculations -- and I will refer counsel and the board to page VII-10 of Dr. Frazier's testimony -- as they relate to estimating the increase in peak ground accelerations with magnitude?

A Yes, I have.

I conclude -- Dr. Frazier states on VII-10, "In addition, ground motions were calculated for an even larger magnitude earthquake having a rupture of 120 kilometers nearly 50 percent longer than has been postulated for the Hosgri Fault.

"The results show very little difference in peak ground accelration for the longer length of rupture."

Dr. Frazier further states in his conclusion three, "The computer levels of ground motion" --

MR. NORTON: Excuse me. I am having a problem finding this. He is supposedly quoting Dr. Frazier, but I cannot find where he is quoting.

CHAIRMAN SALZMAN: Mr. Fleischaker, will you show us where on page VII-10 of Mr. Frazier's testimony that that appears?

MR. FLEISCHAKER: This is probably my fault. I probably misprinted the number here. Let me ask Dr. Brune.

MR. NORTON: Part of it is there.

MR. OLMSTEAD: Line 23 is where he is quoting from it.

MR. NORTON: Part of it.

WITNESS BRUNE: Yes, the quote starts, "In addition," and that is on line 23.

CHAIRMAN SALZMAN: Of page VII-10.

WITNESS BRUNE: VII-10, yes.

dsp17-2

"Ground motions were calculated for an even larger magnitude earthquake having a rupture of 120 kilometers, nearly 50 percent longer than has been postulated for the Hosgri fault."

I probably forgot to put the end quote in there.

MR. NORTON: That is what happened.

WITNESS BRUNE: "The results show little difference in peak ground acceleration for the longer length of rupture."

Dr. Frazier further states in his conclusion three, and I quote again -- that is on page VII-13, "The computed levels of ground motion are relatively independent of the length of rupture, and consequently peak accelrations at Diablo Canyon should be basically insensitive to increases in magnitude for magnitudes greater than about 6.5."

I do not believe that the calculations done by Dr. Frazier support this conclusion. The model he has used does not appropriately allow for a change in slip function with magnitude, in particular an increase in dynamic stress drop with a magnitude corresponding to the well documented increase in fault slip with magnitude.

Furthermore, the high attentuation used in the earth model for the calculations prevents high frequency energy from distant parts of the fault from arriving at the

dspl7-3

station and thus artificially decreases constructive interference for larger magnitude earthquakes.

Thus, the TERA Delta model has been constrained to give little increase in peak ground acceleration with magnitude by fixing certain parameters in the model and thus cannot without changing these parameters be used to predict real variations in peak ground accelerations with magnitude in the range 6.5 to 7.5.

BY MR. FLEISCHAKER:

Q Dr. Brune, you mentioned in your testimony that the possibility of anomalously high stress drop should be taken into account in modeling the strong motion at the Diablo Canyonsite.

In your opinion, do the computational results presented by Dr. Frazier take this possibility into account?

A No, I do not believe they do.

The Delta computer model used by Dr. Frazier corresponds to approximately constant displacement or stress drop over the fault surface with superimposed randomness in directions of faulting.

Dynamic computer modeling of the fault by Dr. Steve Day of SCCC shows that the --

MR. NORTON: Excuse me.

CHAIRMAN SALZMAN: Mr. Norton.

dspl7-4

MR. NORTON: My understanding is that they withdrew Dr. Day's testimony and have no intention of putting Mr. Day on the stand, which means we cannot cross examine him.

CHAIRMAN SALZMAN: That is correct.

MR. NORTON: I don't think that is fair to have Dr. Brune read his testimony.

CHAIRMAN SALZMAN: Dr. Day's testimony has been withdrawn, Mr. Fleischaker.

MR. FLEISCHAKER: It is an old rule that an expert witness has the right to rely on the opinions of other experts.

CHAIRMAN SALZMAN: You cannot rely on testimony that has been withdrawn.

MR. FLEISCHAKER: This was not the testimony. This was a study that he did.

His testimony, as I recall, recommended that a certain kind of computer modeling be done. What we are talking about here is an entirely different document which was a critique that Dr. Day had done several months ago and unrelated to this hearing of the TERA Delta report.

MR. NORTON: Is Dr. Day still here?

CHAIRMAN SALZMAN: I do not know.

MR. NORTON: They sent him home?

MR. LANPHER: Dr. Day is not here.

dspl7-5

MR. NORTON: Well, I don't know which specific study he is talking to,but Dr. Day's testimony certainly referenced the studies that he was doing and that should be done, et cetera, et cetera. I do not -- I think it is totally improper for them to tell us yesterday -- I think they told us -- it might have been the day before that they were going to withdraw his testimony.

They were not going to have him as a witness, and now they are relying on him.

MR. FLEISCHAKER: May I reply to that?

CHAIRMAN SALZMAN: Yes, Mr. Fleischaker.

MR. FLEISCHAKER: I think if you read Dr. Day's testimony you will see the principal reason that it was withdrawn was because it was a recommendation about a general type of modeling that should be done.

CHAIRMAN SALZMAN: Mr. Fleischaker,I do not know why it is withdrawn. You cannot tell from reading testimony why it was withdrawn, sir.

MR. FLEISCHAKER: I don't think that is relevant here. The point is the testimony that was given, the testimony that was prefiled was not at all about the same subject of the paper that Dr. Brune was -- is referring to. That paper was generated for entirely different purposes, for purposes unrelated to this hearing, and I think there is a well established rule of evidence that an expert

witness has the right to rely on the expert opinions of other experts.

CHAIRMAN SALZMAN: All right, Mr. Fleischaker, just one moment.

Mr. Olmstead, did you have an objection?

MR. OLMSTEAD: Well, I do have a comment on that, and I guess it is an objection. The rules that Mr. Fleischaker is referring to has an important qualification, and that is that expert upon whom one is relying is available and present for cross examination within the jurisdiction of the body that is asking for that testimony unless it is a learned treatise that other people are willing to say is relied upon by experts in the field.

My understanding of this particular so-called learned treatise is that it does not yet have that status because it has just been prepared.

CHAIRMAN SALZMAN: What?

MR. OLMSTEAD: Just been prepared.

MR. NORTON: Excuse me, Mr. Salzman. I would like to respond to Mr. Olmstead. I think he is wrong. I do not believe that an expert can only rely on a witness if that expert is available forsubpoena. But he cannot on ahearsay basis say, "Well, somebody is doing some work and Iknow this and I know that."

If they have a paper that has been published and

it is recognized by people within that community, sure, they can cite it and they can quote it and everybody here can look at it and our experts can look at it.

But what do I do when an expert witness says, "Well, gee, the witness was here a couple of days ago, but we sent him home. He did something that I know about and this is what it says."

CHAIRMAN SALZMAN: I understand your objection.

CHAIRMAN FLEISCHAKER: Might it be helpful to have Dr. Brune describe that paper? He may even have it here.

MR. NORTON: Absolutely not.

CHAIRMAN SALZMAN: Wait. We will make a ruling. Just one moment.

Mr. Olmstead?

MR. OLMSTEAD: I would like to respond. I think Mr.Norton did not understand what I was trying to say because I did not disagree with what I said at all. Essentially I was referring to Rule 803 on hearsay, item 18, learned treatises, which reads: "To the extent called to the attention of an expert witness upon cross examination"-- which this is not -- "or relied upon by him in direct examination, statements contained in published treatises, periodicals or pamphlets," established as reliable authority by the testimony or admission of the witness

dsp17-8

or by other expert testimony or by judicial notice" -- or in our case, official notice, then it is excepted from the hearsay rule.

CHAIRMAN SALZMAN: You are reading from the Rules of Evidence?

MR. OLMSTEAD: Yes, Federal Rules of Evidence.

CHAIRMAN SALZMAN: I am aware of those. Mr. Fleischaker, is this material to which your witness is referring published?

BY MR. FLEISCHAKER:

Q Dr. Brune, do you know whether it is published?

A Yes, it is a publication of the SCCC Corporation, and it is part of a study that was done for the NRC, and I believe it is a public document and perhaps Dr. Luco is about to get it.

He seems to be --

MR. NORTON: If we have the document here --

WITNESS BRUNE: I have the document myself if you will give me some time; I am not absolutely sure it is here. It may be in my motel room.

CHAIRMAN SALZMAN: One moment.

(Board conferring)

CHAIRMAN SALZMAN: All right, Mr. Fleischaker. If the document is published, we can look at it and it will say what it says it says.

dspl7- 9

MR. NORTON: Mr. Salzman. I withdraw my objection. We have a copy of the document, and we will now allow him to testify about it, but when he just started going into it, I did not have any idea what he is talking about.

CHAIRMAN SALZMAN: I understand. We are a little rushed for time. The witness may refer to the document.

Please continue, sir.

WITNESS BRUNE: I should have referred to it more indicating that it was not just hearsay evidence. However, I will state that just to be perfectly clear here, that the conclusion stated in that publication is based on a comparison of the Delta model with the Parkfield modeling parameter -- excuse me -- is based on a comparison of Dr. Steve Day's results with the Parkfield time function and not with the Diablo Canyon time function.

And therefore I believe there still remains a basis for an objection because I have -- I have relied --

MR. FLEISCHAKER: Why don't you let me decide rather than let Mr. Norton decide what is the basis for the objection.

(Laughter)

CHAIRMAN SALZMAN: The transmogrification here is enormous.

MR. FLEISCHAKER: Dr, Brune is learning.

(Laughter)

dsp17-10

BY MR. FLEISCHAKER:

Q Having planted that seed, Dr. Brune, could you continue with your testimony.

A I would like to add one statement which will be accurate in this respect: and that is Dr. Steve Day has done a study for the NRC comparing the time function for a dynamic model reported in this document. In comparing that time function with the TERA Delta time function for Parkfield and concluding in the interim report that that corresponds to a stress drop of about 30 bars, that should be the correct conclusion.

These values of stress drop are not conservative based on available estimates of stress drop for the average stress drop over a fault surface.

As I noted in my testimony, a conservative value for average stress drop over the fault surface would be about 100 bars.

Furthermore, the Delta computer model does not take into account the possibility of concentrations of 500 bar stress drops recommended in my testimony. These concentrations of high stress drop cold lead to considerably higher accelerations than shown in the results presented in Dr. Frazier's testimony.

In particular, he does not consider the possibility of a 500 bar stress drop over a five kilometer zone near the

sp17-11

plant or on the branch fault shown in the applicant's map plate 2N, Appendix 2e, FSAR, of the Hosgri Fault zone.

MR. NORTON: Same objection as before for the record.

I assume that the ruling is the same as to the branch fault and the lack of qualifications of this expert to so testify.

MR. FLEISCHAKER: I think that remains to be established. I think Mr. Brune has some qualifications of which I was not advised and Mr. Norton can inquire into that on cross examination.

MR. NORTON: Mr. Salzman, I am just making my objection for the record.

CHAIRMAN SALZMAN: What qualifications?

BY MR. FLEISCHAKER:

Q Dr. Brune, do you have any qualifications in geological science?

A I have a degree in geological engineering. I believe that in the previous testimony I disqualified myself not from reading geologic maps and drawing the obvious implications from that, but in matters relating to determining the overall geologic history of an area and the tectonic history when I had not studied. Actual reading of geologic maps is within my expertise.

Q Thank you. Would you please continue.

sp17-12

CHAIRMAN SALZMAN: We will let the witness answer. Please continue.

WITNESS BRUNE: Just a minute. I am trying to remember where I left off.

Thus, I conclude that modeling results presented by Dr. Frazier do not correspond to a conservative value of stress drop.

It is clear from the parametric studies of the effect of stress drop in the Delta model, San Onofre Report Supplement I, Joint Intervenors' Exhibit R-7, that the peak accelerations and high frequency response spectra vary linearally with effective stress drop.

Thus if the values of stress drop suggested in my testimony were used in that calculation, the Newmark design values and response spectra would be exceeded.

BY MR. FLEISCHAKER:

Q I have one final question.

Dr. Brune, there was this afternoon testimony introduced on behalf of the staff that the high accelerations recorded during the IV '79 earthquake were perhaps due to anomalous site conditions at the recording -- at the site of the recording instruments.

Specfic reference to Bonds Corner was made. Do you have any information indicating that these high peak accelerations were not anomalous?

dspl7-13

A Yes. The recent Victoria,Mexico earthquake of January 9, 1980, magnitude 6.2 in nearly the same tectonic environment as the Imperial Valley '79 earthquake recorded peak horizontal accelerations at a station approximately 11 kilometers from the epicenter of 0.5 g on one horizontal component and 0.92 g on the other horizontal component and vertical accelerations of over 1 g.

Clipping the dynamic range of the kineme-tric 1 g instrument several times, this tends to confirm that the level of horizontal acceleration recorded for Imperial Valley 1979,for example, at Bonds Corner and the high vertical accelerations over 1 g are not unusual for a magnitude 6.2 earthquake in this tectonic environment.

Unfortunately, parts of the record are unreliable or missing. Even higher accelerations may have occurred. At the present time an accurate epicenter is not available. There was no surface fault slip observed.

Q I am sorry. I have one last question.

Dr. Brune, in your prefiled testimony you mentioned focusing, possibly focusing occurred in the 1978 Santa Barabara earthquake and the 1980 Livermore earthquake.

Do you have any additional data related to those two events?

dspl7-14

A Well, I looked at the publications that are referenced in my testimony, and I believe that the only additional thing I could mention is that the focusing did occur at high frequencies for Santa Barabara earthquake and is inferred to have occurred at high frequencies based on the intensity four the Livermore earthquake.

MR. FLEISCHAKER: We have no further questions. Thank you, Mr. Chairman.

CHAIRMAN SALZMAN: All right. Now, who is next? We are going to run until 5:30. We have to be out of the building by 5:30. Perhaps it might be wise if we take a break now, and I would like counsel to come to the bench and someone to make arrangements to move all of the furniture.

Yes, we are going to quit for the night. We are going to resume again tomorrow morning at 8:00 a.m.

(Thereupon, at 5:03 p.m., the hearing in the above-entitled matter was recessed to reconvene at 8:00 a.m., October 23, 1980.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

Appeals Board

in the matter of:

Date of Proceeding: 10-22-80

Docket Number: 50-275 50-323

Place of Proceeding: San Luis Obispo, California

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Patricia A. Minson

Official Reporter (Typed)

Patricia A. Minson

Official Reporter (Signature)

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David S. Parker

Official Reporter (Typed)

Official Reporter (Signature)