NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

PACIFIC GAS & ELECTRIC COMPANY

(Diablo Canyon Units 1 and 2)

Docket Nos. 50-275
50-323

Place -

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UNITED STATES OF AMERICA

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(Diablo Canyon Units 1 and 2)

Docket Nos. 50-275
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Cavalier Room,
San Luis Bay Inn,
Avila Beach, California.

Tuesday, January 9, 1979.

Hearing in the above-entitled matter was reconvened, pursuant to adjournment, at 8:30 a.m.

BEFORE:

ELIZABETH BOWERS, Esq., Chairman,
Atomic Safety and Licensing Board.

DR. WILLIAM E. MARTIN, Member.

GLENN O. BRIGHT, Member.

APPEARANCES:

On behalf of Applicant, Pacific Gas & Electric Company:

BRUCE NORTON, Esq., 3216 No. Third Street,
Phoenix, Arizona 85012.

MALCOLM H. FURBUSH, Esq., and PHILIP CRANE, Esq.,
Legal Department, Pacific Gas and Electric
Company, 77 Beale Street, San Francisco,
California 94106.

APPEARANCES: (Continued)

On behalf of Joint Intervenors:

DAVID S. FLEISCHAKER, Esq., Suite 602,
1025 15th Street N.W., Washington, D.C.

On behalf of the NRC Regulatory Staff:

JAMES R. TOURTELLOTTE, Esq., EDWARD KETCHEN, Esq.,
and MARC STAENBERG, Esq., Office of Executive
Legal Director, U. S. Nuclear Regulatory
Commission, Washington, D. C. 20555.

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Witness	Direct	V/D	Cross	Redirect	Recross	Board
Richard B. Hubbard			7895	7917 7919	7917	
James N. Brune	7920		7941	8129	8139	

EXHIBITS:		IDENT.	REC.
Joint Intervenors' 65	Richard B. Hubbard Testimony, Contentions 4, 5, 6 and 7		7895
Joint Intervenors' 66	James N. Brune Testimony, Contention 3	7920	7940
Applicant's 36	Applicant's Freehand Drawing	7942	8114
Applicant's 37	Map by California Division of Mines and Geology	8095	8114

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WRB/agbl

PROCEEDINGS

MRS. BOWERS: We'd like to begin.

Whereupon,

RICHARD B. HUBBARD

resumed the stand on behalf of the Applicants, and, having been previously duly sworn, was examined and testified as follows;

MRS. BOWERS: Mr. Fleischaker, do I understand correctly Mr. Kristovich will not be here this morning?

MR. FLEISCHAKER: That's correct.

MRS. BOWERS: Well at the close of business yesterday, we had the position of the parties on the prepared testimony of Richard B. Hubbard relating to Contentions 5, 6 and 7, Seismic Re-analysis of Structures, Systems and Components.

We went through this document during the evening break, and would now like to give you our ruling on what we think is appropriate to come into the record.

Number one, the introduction. There was no position of the parties on that and there was no objection by the parties on Number Two, the statement of contentions.

Number Three, and our opinion is sort of an historical recitation of the issues, except on page 7-4. And in the middle of the paragraph that begins there, there's a sentence:

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"Revision Three of Regulatory Guide 1.29 appears applicable to Diablo Canyon as the implementation portion of the Guide states that --"

And quoting part of the Guide. We feel that's a legal opinion and that sentence would be deleted.

Now 3.2, the parties have reminded the Board that this really is based on a contention that was not admitted for several reasons, a couple of years or so ago. And we also think that, as talented and as qualified as Mr. Hubbard is in many areas, that he does not have the -- that, in addition, he does not have the expertise to be sponsoring the testimony in that section, so it's out.

That's also true of 3.3, Use of Actual Material Strengths, we feel there isn't an expertise to sponsor that section.

Now, over in 3.4, we're dealing here with requalification program inadequate, but the focus has been on electrical equipment, and so we think that's it's appropriate to have this section in except for three sentences.

The last sentence in the second paragraph is where this witness has given the Board what we consider essentially legal instructions: "The Board should determine..." so and so.

And then the last two sentences in the last paragraph, we feel this also is a legal opinion and in part

WRB/ab3

giving the Board instructions. So those sentences would be deleted.

Now paragraph 3.5, Load Response Combinations Not in Accord with Regulatory Guide 1.92, we also think that the witness does not have the expertise to sponsor this, except for one small part that we feel is more of an historical recitation.

If you'll go to page 7-10, the paragraph that begins:

> "At the request of the Staff, a study was performed by the Applicant to evaluate the differences in the piping system responses when the two different analytical approaches discussed above were used. The responses at some locations on the systems increased; at other locations decreased. (See Attachment B.)"

Now, we'll talk later about Attachment B, but we feel it has been adequately identified, not only in the footnote here, but in the page that lists the attachments, that there has been sufficient foundation for it to be considered.

But the next sentence: "Because of the sensitivity of the results in the analysis method..." et cetera, that is out. We feel it's beyond the expertise, and it's stating instructions really, legal instructions to the Board.

WRB/agb4

3.6: "Design in Excess of Yield," the first part of it down to the end of the quote, we feel is essentially reciting history and that will be left in. But the last paragraph, beginning with:

"The FSAR amendment does not include a list of structures, systems..." et cetera.

We feel that that is not only beyond the expertise, but it's also really giving legal instructions to the Board. You'll notice the sentence that follows it is particularly sharp in instructions to the Board.

Now, when it comes to IV, Conclusions, we really feel that this should have been entitled Summary, because in this there are very brief statements concerning the various sections that have gone before, but because of their briefness, they really do not give enough information, we feel, to give the whole picture and could be misleading.

So we would delete the Conclusions, which we call the Summary, because we think the same information is covered earlier. There's nothing new here. But because of the rather shorthand approach to try to get the thing pulled together in one brief paragraph, we think the way it is presented is incomplete and could be misleading.

Now, Attachment A, we agree with the Staff and the Applicant's support that no foundation has been laid for this document, and it will not be accepted.

WRB/agb5

Attachment B, the parties felt no foundation, but we feel, as we said, that there is an adequate description of the document of Attachment B in the listing of attachments as well as the footnote.

When it comes to Attachment C which is a memo for E.G. Case from Hanauer, we feel that there's no foundation here and so therefore it's not competent.

Attachment D, we feel is not relevant. We haven't had any information that would focus this on Diablo. It was a general document.

Well that's the position of the Board. Now it has not been easy to consider this testimony because, as I told you when we began yesterday, the Board recognizes the difficulty that Intervenors have, the lack of resources, in order to obtain witnesses to sponsor their position. And we really have tried awfully hard here to see if part or parts of the testimony could come in.

But we also recognize our responsibility that we cannot allow testimony to be sponsored by someone who, although extremely talented in many ways, does not have the expertise in the particular narrow fields that are covered by the proposed testimony.

Mr. Fleischaker, yesterday what we did was separate the two, as you may know, and went through Contention 4 proposed testimony, and then Mr. Hubbard spoke briefly about

WRB/agb6

those parts that remained in.

Now would you like for him to do that here? How do you want to proceed, are you prepared to proceed on this?

MR. FLEISCHAKER: Yes, Ma'am.

We don't think that there's any reason to summarize the testimony that is remaining in evidence. And so I take it that at this time it would be appropriate for Mr. Hubbard to stand cross-examination on the remaining testimony.

Well we have to offer it into evidence, I guess.

MRS. BOWERS: It hasn't been offered yet. Both documents were marked Joint Intervenors' 65.

MR. FLEISCHAKER: Correct, so we are finished, I guess, with -- my understanding is that after the Board ruled, it would be appropriate to offer the document, Exhibit Number 65, into evidence and then Mr. Hubbard would stand cross-examination on the basis of that which was remaining in evidence, is that correct?

MRS. BOWERS: Well that's one way to proceed.

Let me check with the parties. Mr. Norton?

MR. NORTON: Mr. Fleischaker can offer it into evidence any time he wants.

MRS. BOWERS: You've heard the Board's position on this matter as to what part remains in and what's out, so let's check with the Staff.

WRB/agb7

Mr. Tourtellotte? Joint Intervenors' Number 65 is being offered in evidence.

MR. TOURTELLOTTE: No objection.

MRS. BOWERS: Well Joint Intervenors' 65 --

MR. NORTON: Excuse me, Mrs. Bowers, I didn't know if you were asking for objections. We object to it going into evidence on the same basis on which we made the motion to strike. We understand you've already ruled on that, but we are not waiving those objections as it's been offered into evidence.

I thought the question was whether we agreed that he could offer it into evidence at this time. And I said he could offer it any time he wants, I didn't realize the offer had been made.

But we object to Exhibit 65 going into evidence for the reasons stated in the motions to strike made by Mr. Tourtellotte and myself.

MRS. BOWERS: Well your objections are overruled to the extent that we have admitted the portions of the documents.

MR. FLEISCHAKER: And for the same purpose, I would also like to note for the record our objections to the Board's ruling understanding that that which has not been stricken will be admitted into evidence as I understand the Board's ruling.

WRB/agb8

MRS. BOWERS: That's right.

Now do you want to proceed with any cross-examination?

MR. NORTON: If you'll give me just a moment to reorganize after the striking.

(Whereupon, the document previously marked for identification as Joint Intervenors' Exhibit 65 was received in evidence as modified by the Board's ruling.)

CROSS-EXAMINATION (Continued)

BY MR. NORTON:

Q Mr. Hubbard, turning to Page 7-8, Requalification Program Inadequate, the heading, 3.4, the IEEE Standard 344-1975, I take it it's your testimony that that Standard test has a component of aging in it for electrical equipment, is that correct?

A Yes.

Q Now, do you know if the standards which preceded that one, whatever numbers and years they may have been, but preceded IEEE 344-1975, had a component for aging or a requirement for aging testing?

A I believe it was 1971 and, to the best of my

WRB/agb9

recollection, it had no component of aging.

Q All right.

Do you know whether any other nuclear power plants which have received construction permits prior to 1975 had a requirement for aging in their electrical equipment testing or analysis?

A I don't know the answer to that.

Q All right.

Now Mr. Hubbard, the thrust of your argument here and others that you've made in your testimony seems to be that, as regulations or Reg. Guides or codes or standards or whatever it is we're talking about are updated, one has the duty to do whatever that new update requires in terms of an analysis or a design or whatever the subject matter is. Is that your basic premise?

A No.

Q All right. Then explain your basic premise as to -- as a new standard or a new code comes out or whatever, as to how it applies to something that has been built before that code came out, in terms of a new requirement under that code.

A Well I think the part having to do with backfitting would be covered by 50.109 of the regulations. I mean, an actual decision of whether to do backfitting. Now that is separate from my feelings on aging, that IEEE Standard 323

WRB/agb10

was written in 1974, or it was issued in 1974 and that was one of the family of standards of which the -- well, 323 described qualification in general, environmental qualification, and one aspect of environmental qualification is seismic qualification which was then later updated in this 1975 version. So the requirements for aging in an IEEE standard, to the best of my knowledge, date back to 1974, that's the first time the IEEE had specifically addressed it in this more generic sense.

So there has always been a possible requirement of aging. We talk about components in the reactor lasting for the life of the reactor, whether that's 30 years, 40 years, or 50 years. But the difference is that in 1974 when the IEEE wrote their standard, they had now specifically said something about aging.

So my position is, if you're going to do qualification testing to say that something that is to be installed in the plant will be able to withstand an earthquake for the design life of the plant, well then, aging should be part of that consideration, either through testing to do the aging or some analytical technique to say that it was specifically considered.

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Q Could you tell us what the technique is?

A For aging?

Q Yes, how you test it.

A Well, you can age things a number of ways. For electrical equipment one way you age things is to take them to an elevated temperature for some time. Shaking itself is one way to age something. Duty cycle is another way to age.

1.200

In other words, something has a certain number of operations. These were the examples of how you can age something, and then run tests later on.

Q Well, I guess what I'm trying to get at, Mr. Hubbard, is every time, you know, we make advances in codes and regulations and so on and so forth to find out how we do things or think we find out how to do things that we didn't know how to do before, and so on, does that mean that everything that went before it is unsafe, I mean, that it didn't have that component, that all of the electrical equipment and all the power plants, whether they be nuclear or coal-fired or what, are somehow unsafe because they didn't have this component of analysis prior to 1974, that everything that's out there is unsafe?

That's what I'm driving at. I don't understand the thrust.

A I really don't feel you can make that argument that they're all unsafe, no.

wb2

My experience at General Electric was that we found there were aging problems, particularly with electrical equipment. We found things like coils of relays that over a ten year period would dry and become embrittled. Certain paints, or like on relay contacts; through aging times the relay contacts would stick. And so when you took the power off the relays, the relays stayed in. Things like neutron sensors that had, oh, various plating processes, that those plating processes would start to deteriorate or flake due to aging.

So that we did have a considerable experience with the aging phenomenon causing deterioration in performance of components.

Q All right.

How did you discover this?

A Well, we discovered it, rather than through qualification testing, we discovered it after the plants were operating.

Q How did you discover it? I didn't ask when, I asked how.

A Through various ways. Would you like me to describe those?

Q Well, isn't it a fact that there is periodic testing of equipment to see that it works, to see that it is functional? Inspection of equipment, electrical equipment, to

wb3

see that it is indeed functional and operable? For example, a battery, if one is relying on a battery wouldn't one check it now and then to make sure that, say, all the lead hasn't dropped out of the bottom of the battery? Isn't that sort of a periodic checking and testing done of electrical equipment?

A There's a lot of periodic testing and in-service inspection, yes.

Q And wouldn't that indeed uncover, if you had aging, or you know, some of the aging you were just describing?

A Well, I don't believe so in all cases. Like take the neutron sensors, that's not in an area where you can get at them real easily to do that during continuous operation of the plant. So if the plating would deteriorate and then you would have a shaking phenomenon, you might not know that. It would continue to act like it was operating fine. But you would have a lot less adherence of the plating to the sensor.

The relays I mentioned, that, you know, that happened in Monticello. Actually they turned off the power and the relays stayed in.

So some of them you would obviously find during in-service inspection, and others might be difficult to find.

Q Well, are you aware of any situation where a seismic event has occurred and there has been a failure of electrical equipment due to aging as a result, you know, at

B/wb4

the time of the seismic event?

A I'm not aware of any.

Q Any time that it ever happened anyplace in the world at a nuclear power plant, anyplace, anytime?

A I'm not aware of any.

Q Fine.

Turning to page 7-11, I take it that your thrust there is that there are instances where design is in excess of yield; is that correct? And that this is an unsafe condition?

A That's a two-part question, then?

Q Yes, it is.

A Yes, there are designs in excess of yield. And as far as, Is it unsafe? my answer to that would be I don't really know. Because I don't really know what the deformations will be. The two sentences, one addressed buildings and structures and the other addressed equipment, and there's really not a lot of information given about equipment, about how much deformation will occur.

Q Well, excuse me, Mr. Hubbard. Is it your position that the regulations do not allow design in excess of yield?

A No.

Q In fact the regulations do allow it, do they not?

A That's correct, I believe.

RB/wb5

Q Fine.

And did you ask in interrogatories or on cross-examination of the witnesses that were here for structures, components and systems where deformation would occur and to what extent?

A I believe so.

Q All right. So now you know.

A I have more of a general knowledge than I had then, but not specific knowledge on a piece-by-piece basis. I heard general criteria.

Q Did you not ask the witnesses? For example, I remember some rather extensive cross-examination of Mr. Ghio about the clearances, the tolerances in the turbine pedestal. Do you remember you cross-examined about that? Did you not have the opportunity to ask all those questions that you wanted and find out where the design in excess of yield occurred? I remember the discussion about the intake structure, the questions. Is there any area that you did not inquire about that was overlooked?

A That's a two-part question again. I believe the first part had to do with structures. That's what Mr. Ghio talked about.

Q That's correct.

A And Mr. Hoch very early in his testimony said that in structures there were three places where you might have

RB/wb6

where you might go into the inelastic region. And Mr. Ghio talked more about that. So on structures I think it is pretty well determined on the record where inelastic behavior might occur.

Q All right.

And you do not have the expertise, do you, to make a judgment as to whether in those three instances that is somehow a safety problem? --or, to put it another way, you do not have the expertise to contradict the witnesses who said it was not a safety problem?

A That is correct.

Q All right.

Now what other areas are you concerned about that you didn't have an opportunity to ask about on cross-examination?

A The second part that includes the quote, it talks about possible initiation of safety features and momentary interruption or non-activation of safety functions. And that has never really been defined about what initiation of safety features might occur. I mean, does that mean relays might pick up--

Q Excuse me. Safety. Okay, initiation of safety features and momentary interruption or non-activation of safety functions?

A Yes. It's just a statement there that says that's

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the criteria. And I think there should be more fleshing of that out, like what safety functions might be initiated.

Q Did you ask those questions in interrogatories or in cross-examination?

MR. FLEISCHAKER: Excuse me. We don't have our copy of the interrogatories here, unfortunately. But, having participated in writing them, I think Mr. Norton is aware that we did ask those questions in interrogatories about yield and deformation. Not the specific question about safety functions, but there was a question about yielding and deformation. And I believe we got a very general answer back. But I don't have my interrogatories with me.

MR. NORTON: Well are you testifying as to--

MR. FLEISCHAKER: No. If you had the interrogatories it might be useful.

MR. NORTON: I'm asking Mr. Hubbard questions which I thought was the purpose of cross-examination.

BY MR. NORTON:

Q Well, Mr. Hubbard, there were panels here that covered each and every aspect of the facility as you go through it, structures, systems and components, mechanical equipment, electrical equipment. Did you just not ask the questions; or were the questions asked and answer not given, or what? I'm somewhat confused.

A Well I didn't ask any questions. The attorneys

WRB/wb8

asked the questions.

Q But I sat here and heard you ask them first and then the attorney asked them.

A I think it can be safely said that there were a number of questions that I might have wanted asked that the attorneys didn't ask.

Q Now the quote you're talking about here is not the Hosgri analysis, is it; it's the DDE, the original design, double design earthquake?

A That's correct.

Q All right.

Do you have the FSAR there with you?

A No, I do not.

Q Do you have the Hosgri Report, Volume 1, with you by chance?

A Yes, I do.

Q Okay.

A No, I'm sorry; I didn't bring that in today. Or maybe it over by Mr. Fleischaker. I think we didn't bring that in.

MR. FLEISCHAKER: I think we have it in the car. If you need it we can get it out of the car.

MRS. BOWERS: Is there an extra copy? Does the Staff happen to have an extra copy that could be loaned?

MR. FLEISCHAKER: It'll take us five minutes. If

WRB/wb9

Mr. Norton wants to pursue this I'll just run out to the car and bring the whole box in.

MR. NORTON: We have an extra copy.

(Document handed to the witness)

BY MR. NORTON:

Q You've been handed the copy, page 2-20 of the Hosgri Report, Volume 1. Have you reviewed that page?

A I believe that is the page where I took the quote.

Q And what does it say?

Now the fact that the DDE is no longer controlling but the same -- the Hosgri analysis has taken place for a much larger earthquake, a .75g effective acceleration as opposed to the DDE which was .4g, how does this have significance now that all of the equipment has been analyzed under the Hosgri and all the structures and all the components and all the systems?

A Well I believe during the testimony that we've heard for the last couple of weeks the applicant said that part of the criteria was to allow components to go beyond yield. You know, we talked about the 2.4 and the 3.6 factors and--

Q Are you talking about the Hosgri analysis or the DDE analysis? Because your testimony here deals with the DDE condition, not the Hosgri analysis.

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MR. FLEISCHAKER: Mrs. Bowers, I would just like to object because on several occasions Mr. Hubbard has started to answer, and Mr. Norton has objected or has interrupted him, and so I would like to object to Mr. Norton's interruption of Mr. Hubbard before he completes his answer.

BY MR. NORTON:

Q I'm sorry, Mr. Hubbard, I did not intend to interrupt you in any way. You know me well enough to know that if you want to keep talking, you just keep talking, okay?

MRS. BOWERS: Let's don't have two people talking at once.

THE WITNESS: I'm sometimes guilty of that myself.

The quote says that I have in the testimony for the DDE condition, and I had assumed that that same criteria applied for the Hosgri condition.

BY MR. NORTON:

Q You had assumed that?

A Yes, sir.

Q And what did you base that assumption on?

A I based that assumption that in the Hosgri, the amendment later on says that the design is allowed beyond yield. So I would assume if it was an acceptable criteria for the DDE, it would be equally acceptable for the Hosgri.

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WEL/wel 1

Q Could you tell the Board the relationship between initiation of safety features and yield? What is your understanding as to the relationship between something designed perhaps in excess of yield and initiation of safety features?

Do you understand that relationship?

A Not in all cases, I don't. The sentence up above said some material deformations and some abnormal actions, including possible initiation of safety features.

What came to my mind was something like a pressure transmitter. That is a force-balance relationship that if you start to wiggle that, like you would during an earthquake, I could picture that that might get a momentary signal that would say you were getting more pressure, or something of that sort.

When I read that, I thought, well, maybe those are the sort of things that might be meant. Like you'd get a momentary deformation of something like a needle. That's more movement than deformation.

But the sentence itself that says there are some material deformations and some abnormal actions, well, abnormal actions I was thinking would be like pressure transmitters, something of that sort, including initiation of safety features.

Q My point is: Do you believe that because there

wel 2

is some material deformations, it's that which initiates the safety features?

A Not necessarily, no.

Q Do you understand how that could or could not occur? Do you have the expertise to make that judgment?

A I think if I looked at the specific thing and found out what type of material is deforming, I could see if that might impact on the safety function, yes.

But I do not have the knowledge of what material deformations you all had in mind when you wrote this.

Q Well, how about quoting the criteria immediately above the part you chose to quote, number 3?

Would you read that please?

A Yes. Part 3 says:

"No device shall fail to initiate and maintain its safety function nor prevent other safety devices from performing their safety functions."

And that's really not in conflict with the next sentence, because the next sentence says that some safety functions may get initiated when they shouldn't have been. In other words, like you might shut down the reactor when you really didn't need to, or you might have an interruption of non-safety functions.

So those sentences are not in conflict.

Q So in final conclusion you have just assumed that

wel 3

this criterion for the DDE applied to the Hosgri event, but you don't know, is that correct?

A That's correct.

Q And even if you did know that that were the case, or if it were the case, you are not aware of any specifics. You just say, well, this is a possibility?

A Yes, sir.

MR. NORTON: I have nothing further.

MRS. BOWERS: Mr. Tourtellotte?

BY MR. TOURTELLOTTE:

Q Mr. Hubbard, when you were with General Electric did you get into the seismic qualifications of semi-conductors and vital instruments?

A I participated in reviews we had of that, yes.

Q How was that done?

A We were getting a lot of semi-conductors from Taiwan, and at one time we got -- well, we did shaking of those in instruments, but we could not determine at that time what sort of aging we were inducing through the shaking. So the semi-conductors was one that concerned us, that we could do functional testing later on to see that the device worked.

But we didn't know how much of the life we had taken out of the device of these little packages of semi-conductors. So that was a matter of concern, and we really,

wel 4

while I was there, never came up with an answer for that.

Q My question is: How did you perform the tests?

A We had a shaker table where we could do multi-access, multi-frequency testing, and in general the electronic boards were part of drawers or control panels that were put on that table and shaken. And then afterwards we would examine -- well, during the test we would examine that the function was continuing to operate and then after the test we would repair whatever damage had taken place, and then re-test to see that the function was continuing to be performed.

Q How big are semi-conductors?

A Some of them are very small, up to the larger size -- well, you know, when you talk about chips. I mean when we start off, we're talking about one transistor, one diode, which is very small, and you're talking now of --

Q The surface area would be like perhaps the surface area of your fingernail, something like that?

A For some of the very small semi-conductors, yes. And then we'd have larger chips which might be, oh, the size of a penny or so.

Q So how many g's did you put on those things in testing?

A I do not really recall.

Q You don't know whether the g forces were small or

wel 5

great?

A As I recall, we tested some of them up to as high as like 25 g, because they would be high up in the control panels, and some of the control panels were not -- well, they were very flexible, so there'd be a lot of acceleration in g levels as you'd go up in height in the panels.

So that I recall some of them had a quite high g level. I recall 25g or so.

Q Actually, it's true, is it not, that in order to test something that small you really have to have a high g level to get some kind of an accurate reading on the test?

A I don't really know if that's the case or not.

Q On page 5,6,7-8 you start out, at the bottom,

"Because of the uncertainties introduced by qualification testing, qualification testing is not normally accomplished on equipment that is to be utilized for safety functions in a plant."

What do you mean by that?

A This is what we talked about yesterday. My experience at General Electric was that occasionally we would take production units off the production line and then run qualification tests like this on them.

We would have a rather unique looking control panel for a particular utility, and rather than do analyses

wel 6

of the seismic response, we'd put it on the shaker table and shake it.

As a result of that, you might get a few cracked welds and a few instruments come flying out and broken windows, and one thing and another.

Then we would repair that, re-test it to see that it was functionally operating, and ship it to the customer to be good for 40 years. And it was a little hard to verify that we hadn't, you know, done a lot more aging to that particular equipment.

So my recommendation was at GE that we not shake equipment that we were eventually going to send to a customer. However, we did do that.

It just adds uncertainty into what you've really done. I mean you can get that back and re-test, and it looks like everything is operating. But there still is a considerable amount of uncertainty, in my opinion.

Q Actually, there's uncertainty either way, isn't there? If you don't -- are you saying that you shouldn't test equipment that's to go into the plant for safety functions?

A No, I'm not saying that, Mr. Tourtellotte. My feeling is that as part of your design verification, design qualification program, that at that time you do a prototype and first production units. And prior to starting shipping

things to customers, my feeling is that those sorts of tests ought to be done on prototypes so that the equipment that is shipped to the customer does not have this aging phenomenon, or has not been subjected to this phenomenon.

Q Do you know of any specific instances in Diablo where the semi-conductors have been tested and then installed in the plant?

A If I had the Applicant's testimony I think I could find some. They sent a number of pieces of electrical equipment to Wyle Labs to be tested, and we could go through the list. I mean it was in the testimony, the list of panels that were put on the shaker table, as I recall.

Q What you're saying is that those pieces of equipment shouldn't have ever been tested in the first place?

A We're talking about a facility that is costing billions of dollars, and we're talking about putting back into the plant devices that cost at the most tens of thousands of dollars in many cases.

So my recommendation would be if you're going to do environmental testing like seismic testing, buy another one, or take a representative sample and do the shaking on that one, rather than on the one you're going to reinstall in the plant.

Q But I don't understand that. No two units are

wel 8

built exactly alike, are they?

A You would like to have them built alike. That's what you do, like when you qualify weld processes and qualify plating processes and soldering processes, the purpose of that is so that your production is repeatable.

I'd have to agree with you that, depending on the level of control you have, it may or may not be repeatable. But that is also a problem with any qualification testing, where you test one and say that's indicative of a number of units. If you don't have tight process control, it's only indicative of that one particular unit.

Q But in fact it's really quite difficult, very difficult, to reproduce two of anything that are exactly alike, isn't it?

A I hope not. That sounds like a smart answer, so I apologize. But what I mean by that is that a lot of qualification testing for components for nuclear power plants is based on testing one unit, and then saying the other 10 or 100 have the same properties. And that is based on the fact that you have tight control of the processes and the procedures by which they are built.

So when I say, I hope not, what I mean is that I hope the controls are such that the one that is tested is, indeed, indicative of the other units.

Q But it is possible, isn't it, that if you have

wel 9

two units that are tested, or two units, one that is tested, say "A", and "B", one which is not tested, that "B" will have a defect in welding that "A" doesn't have and, therefore, would not show up on the testing; isn't that correct?

A That's correct. And that's why the validity of your testing program is somewhat dependent upon the number of units you test.

My experience in the nuclear program was it's hard enough to get people to test one of something, let alone -- I mean because of the expense -- let alone testing 5 or 10, or repeating the test once a year or once every two years, to see that they are still valid, when it comes to environmental qualifications.

So I don't think you and I are in disagreement.

Q But it is true that there will be uncertainties either way, isn't that true? There is uncertainty if you reinstall the unit that's tested, and there's uncertainty if you don't reinstall the unit that's tested; isn't that true?

A They are different types of uncertainties, yes.

MR. TOURTELLOTTE: No more questions.

MRS. BOWERS: The Board has no questions at this time. Mr. Fleischaker, do you have redirect?

MR. FLEISCHAKER: Yes, I have some questions, thank you.

wel 10

REDIRECT EXAMINATION

BY MR. FLEISCHAKER:

Q Mr. Hubbard, during the time you worked for General Electric or at any time since have you become aware of any nuclear power plant that's been subjected to strong ground motion?

A By "strong ground motion" I assume you mean a fault within -- like we're talking here -- 6 kilometers or 10 kilometers? I'm not aware of any.

Q Let me be more specific:

Are you aware of any operating plant that's been subjected to accelerations -- any operating facility -- strike that. Are you aware of any facility, while operating, that has been subjected to accelerations in excess of .15g?

A I'm not aware of any.

MR. FLEISCHAKER: No further questions.

MRS. BOWERS: Mr. Norton?

RECROSS EXAMINATION

BY MR. NORTON:

Q Just because you are not aware does not mean there haven't been some, does it, Mr. Hubbard?

A Well, I've followed that with some interest, and like for example the Japanese plants, to get some idea, you know, how far off some of the earthquakes might have been from the Japanese plants.

Q Is it your testimony that the Japanese plants have not received in excess of .15g?

A I thought he said 1.15.

Q Oh, no, he said .15g.

MR. FLEISCHAKER: Can I get that cleared up?

MR. NORTON: Excuse me, I thought I was going to recross.

BY MR. NORTON:

Q Is it your testimony that no plants have received in excess of .15g, or was it your testimony that it was 1.15g?

A I thought I heard 1.15g.

Q Well, I believe you said .15g, so I'll ask that question:

Are you aware of any facilities that have received in excess of .15g?

A No, I am not.

Q By that answer are you saying that you don't believe there are any facilities -- any nuclear facilities at anyplace in the world that have received .15g? 15 percent of gravity?

A I think there's a possibility that some may have received that, like San Onofre.

I don't know. When we're talking about at the .15g level, I don't know.

Q .15, 15 percent of gravity, you don't know?

A That's correct. I would assume that some have.

MR. NORTON: Nothing further.

MRS. BOWERS: Mr. Tourtellotte?

MR. TOURTELLOTTE: No questions.

MRS. BOWERS: The Board has no further questions.

MR. FLEISCHAKER: I'd like to clarify that, because I don't think it's clear on the record. I'd like to restate my question to Mr. Hubbard.

FURTHER REDIRECT EXAMINATION

BY MR. FLEISCHAKER:

Q Are you aware of any facility, while operating, that's been subjected to accelerations in excess of .15g?

A I'm not aware of any that have or have not. I'm not aware of any studies that would say that.

MR. FLEISCHAKER: No further questions.

MRS. BOWERS: Are you suggesting that Mr. Hubbard move from one side of the room to the other?

MR. FLEISCHAKER: Yes. If there are no further questions, we'd ask that Mr. Hubbard be dismissed.

MRS. BOWERS: Mr. Hubbard will be dismissed.

(Witness excused.)

MRS. BOWERS: Are you ready to proceed with Dr. Brune?

MR. FLEISCHAKER: Yes.

Whereupon,

JAMES N. BRUNE

was called as a witness on behalf of Joint Intervenors, and, having affirmed that he would speak the truth, was examined and testified as follows:

MR. FLEISCHAKER: Mrs. Bowers, may I have one moment? I'm looking for a third copy of the testimony to give to the Reporter.

(Pause.)

I'd like to have the record reflect that we are handing to the Reporter three copies of a document entitled, "Testimony of James N. Brune on Behalf of Intervenors Regarding Contention 3, Ground Motion," and I'd like to have this marked as Intervenors' Exhibit Number 66.

(The document referred to was marked for identification as Joint Intervenors' Exhibit 66.)

DIRECT EXAMINATION

BY MR. FLEISCHAKER:

Q Would you state your name for the record, please?

A James N. Brune.

Q Dr. Brune, do you have before you Joint Intervenors' Number 66, which is entitled, "Testimony of James N. Brune, on Behalf of Intervenors Regarding Contention 3, Ground Motion?"

A Yes.

Q Could you please describe briefly what that document contains? I'm not asking for a summary of your testimony, just a description of the document, the main body of the text and the attachments and appendices.

A I see. Right.

This is a summary of my knowledge about the status of our knowledge about strong ground motion very near large faults, and some of the factors which lead to the present state of uncertainty in this zone near the fault, and includes a statement to the NRC, this Commission, plus an appendix which I submitted to the ACRS describing this problem. Also a letter that I submitted earlier to the NRC concerning one of the effects involved in our uncertainty, namely the effect of rupture propagation.

There's also another appendix relating to some recent evidence from new earthquakes in Mexico.

Q So we can understand, the first piece of the document is your testimony in this proceeding. The document marked Attachment A is your bibliography, which contains your professional -- a statement of your professional experience, your training and a bibliography. And then there is an Appendix 1, which is a statement to the ACRS by James N. Brune, dated June 23, 1977.

MRS. BOWERS: You're calling the appendices. It's

wel 15

attachment, isn't it?

MR. FLEISCHAKER: Let's call that attachment, yes. I'm sorry. It's not marked, but just for purposes of the record, let's call the statement to the ACRS Attachment B, and the letter to the Executive Director, Advisory Commission on Reactor Safeguards -- that's it. Those are the two things that I see here. Is that correct? Do you have the main body, the attachment which is your bibliography, and attachment B, which is your statement to the ACRS?

THE WITNESS: Yes. Those are in there. I'm not sure about your designation of what the titles of them are.

BY MR. FLEISCHAKER:

Q Now, with respect to the document that's been marked as Joint Intervenors' Exhibit Number 66, do you have any corrections that you'd like to make to this document?

A No, I don't.

Q What we designated as Attachment A, the bibliography of James Neil Brune, could you give a brief summary of that document, which contains a statement of your professional experience and your education?

A The statement indicates my academic association with Columbia University, California Institute of Technology, and presently with University of California at San Diego.

It lists some honors I've received, professional

memberships, scholarships and fellowships, committees, and then there's a list of papers I've written.

Q Can I ask you how long you've been involved in the study of strong ground motion?

A Approximately since about 1965-66 when I first came to Cal Tech, I started working on local earthquakes and strong ground motions. So that would be 13 years.

Q As I understand your statement, that also is the amount of time in which you've been studying the characteristics of near source?

A Yes.

Q Could you please give a brief summary of the statement that is the main body of your testimony?

A The testimony begins with a summary of my ACRS statement, from which I will read a couple of paragraphs. The points in that testimony are summarized as follows:

1. For large earthquakes (magnitude greater than 7) at close distances (less than 10 km), peak accelerations and velocities could be a factor of 2 greater than postulated in USGS Circular 672. Uncertainty stems from both the lack of a sufficient data base and lack of knowledge about parameters necessary for theoretical modeling.

2. Theoretical and numerical calculations suggest that accelerations and velocities of 2g and

200 cm/sec, respectively, are possible, but calculations directly applicable to Diablo Canyon were not available.

3. Important improvements in data base and theoretical understanding can be expected in the next few years.

4. Focusing of energy (or directivity) associated with fault propagation can lead to accelerations and velocities amplied by more than a factor of 2 in a sector of about ±5° from the direction of fault propagation. Diablo Canyon could be in the sector of focusing.

I describe an alternate way of looking at this in terms of interference of wave packets.

6. Accelerations and velocities are proportional to the stress drop on the fault plane. Although stress drops averaged over the fault are typically less than 100 bars, there is evidence that in certain circumstances stress drops can be as high as a kilobar. The probability of such high stress drops occurring over large volumes at shallow depth is not known, and thus the possibility exists that such high stress drops could lead to unexpectedly large accelerations and velocities.

My statement before the ACRS concluded that the

design earthquake gives a reasonable estimate of the probable ground accelerations and velocities expected at Diablo Canyon for a magnitude 7.5 earthquake on the Hosgri fault, but that it does not represent the maximum possible. The occurrence of focusing by rupture propagation or constructive interference, along with other factors, could lead to values as much as a factor of 2 higher.

In the next sentence I describe some additions to the data base, including the records from the recent Gazli, Russia earthquake.

These accelerograms represent the first near source instrumental acceleration data available for an earthquake of magnitude greater than 7.

The maximum recorded amplitude was 1.3g on the vertical component. The horizontal accelerations were about .75g on the east-west component and .67g on the north-south component.

The horizontal components of this record are roughly typical of what we might have expected for a complex multiple event earthquake of this magnitude. However, the vertical acceleration is unusual since it is considerably higher than the horizontal accelerations, in contrast to most other known strong motion records.

I mentioned a couple of other recent records where the same thing is true.

It is to be expected that in the next few years a number of detailed studies will be made of this record. Such studies will include theoretical and numerical modeling, determination of earthquake mechanism and source parameters, and study of special propagation and attenuation characteristics of the site. Only further study and the collection of more data will allow us to judge with confidence whether it is typical or not.

I then proceed to describe some other new records that are perhaps surprising, including one on April 6, 1977 a magnitude 5.5 shallow earthquake in Iran that generated peak accelerations of .95g and 1.08g, horizontal and vertical components respectively.

I then describe some important new accelerograms recorded during the Victoria, Baja California, Mexico earthquake swarm of March, 1978. Peak horizontal accelerations of .6 g were recorded at the Victoria station for an event of magnitude 4.9 at a hypocentral distance of about 15 kilometers. These events all occurred and were recorded in the deep sedimentary basin of the Imperial Valley in a setting essentially the same as that of the 1940 Imperial Valley earthquake.

At least three of these small events generated accelerations greater than recorded in the 1940 El Centro earthquake. This illustrates the difficulty of using a

small data base to infer maximum likely accelerations for a given area.

Then I consider some extrapolations people have made. Because of the lack of near source data and the necessity to estimate accelerations there, a number of people have extrapolated data from larger distances and smaller magnitudes. The earlier extrapolating gave lower near source accelerations than the more recent ones. For example, at distances of 10 kilometers for a magnitude 7.6 earthquake, the curves of Donovan indicate accelerations of about .45g at 10 kilometers, whereas the curves presented by Trifunac and Brady indicate that near the fault for a magnitude 7.5 earthquake the average peak accelerations could be 1.75g and the average plus one standard deviation could be about 2.5g.

Trifunac gives about 1.7g for the average acceleration near the fault for a magnitude 7.5 earthquake and about 4.0g for the acceleration with 90 Percent probability of not being exceeded.

These are for right close to the fault.

The values at an epicentral distance of 10 kilometers are 1.1g and 2.45g, respectively. That is for the average acceleration and the 90 percent probability acceleration.

Ambraseys presents average curves for peak

wel 21

acceleration versus magnitude for various distance ranges. His curve for R less than 10 kilometers, distance less than 10 kilometers, indicates accelerations of over 1g for magnitudes greater than 6 could occur. He demonstrates that the earlier curves of Donovan and Esteva systematically underestimate the observed European data.

Ambraseys also makes the observation that the upper limit on observed accelerations may be independent of magnitude, even though the average values clearly increase with magnitude.

Ambraseys concludes that accelerations in the focal volume may well reach and exceed values of 100 percent g, and that in the future accelerations greater than 1 g will probably be recorded for even low magnitudes.

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I go on to describe some of the calculations which support the statement made in my ACRS testimony about the focusing of energy in a sector about -- excuse me, about five degrees off of the direction of rupture.

The concept of focusing or directivity is important in strong motion seismology not only because of the fact that it can lead to anomolously high ground velocity and acceleration in the focusing direction, but because it introduces a large range of scatter in the data, in addition to the effect of the radiation pattern, thus making it particularly difficult to estimate the mean and standard deviation of expected velocities and accelerations from a limited sample of data. For this reason we will probably need ten or more recordings of strong ground motion near large earthquakes before we can have much confidence in estimating the expected accelerations and velocities.

It should be noted that the Hosgri fault is curved northwest of the Diablo Canyon site. Thus, although the site is about five kilometers from the fault at its nearest point, it is much closer to the projection of the fault using the trend northwest of the site. Energy released about 20 kilometers up the fault could be focused nearly directly at the Diablo Canyon site. A calculation should be made to estimate the effect of focusing in this case.

In summary of the section on Directivity,

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directivity is a verified phenomenon in earthquake ruptures. Its effects are understood in a general way, although the details of how effective it can be in leading to high accelerations and velocities are not yet understood. As noted by Bakun, et al, in a recent paper:

> "It would be imprudent to neglect the Effects of rupture propagation in the estimation of strong ground motion."

Then I have a section on the Possibility of High Stress Drops.

For other fault parameters constant, accelerations and velocities are proportional to stress drop. The average stress drop for large earthquakes is about 30 bars, with a range up to a little over 100 bars.

Although most small earthquakes have stress drops of less than 100 bars, there is evidence from spectrum studies that in some circumstances stress drops can be as high as a kilobar, with proportionally higher near source accelerations and velocities.

The stress drop along a major fault during a large earthquake is probably quite variable, and thus even though the average stress drop is usually less than 100 bars, locally the stress drop could be considerably higher.

Aki inferred a local stress drop of 370 bars and associated near source accelerations of 1.5g for the

mpb3

1857 California earthquake, based on variations of observed fault slip and a barrier theory of faulting.

Whether or not large stress drops can occur at shallow depths, less than a few kilometers, is not known. Some of the studies which suggest that they can are summarized in my testimony.

I conclude that large stress drops over relatively large volumes near the surface may cause anomalously high accelerations and velocities in some instances, greater than 2g accelerations and greater than 200 centimeters per second velocities. The probabilities of occurrence for high stress drops is not known.

Fault breakout.

Archuleta and Frazier showed that, for a rupture initiating at depth and reaching the free surface, fault breakout almost doubled the particle velocities along the fault. For a 100 bar stress drop the near fault velocities exceeded 400 centimeters per second. If such high surface particle velocities occurred in a layered medium so that energy were more confined to the surface than in their half space model, very high particle velocities could be generated five kilometers from the fault trace.

A study should be carried out investigating this effect for the situation at Diablo Canyon.

AI then have a section where I outline some of the

arguments against high velocity and acceleration.

I have discussed above a number of points which suggest that near large earthquakes accelerations as high as 1g and velocities as high as 100 centimeters per second may be common, and accelerations as high as 2g and velocities as high as 200 centimeters per second occasional.

I discuss some of the arguments which might be cited as a possibility against such high velocities and accelerations.

The fact that the data base is so small can equally well be used to argue that the above conclusion, that high velocities and accelerations can occur is not proven, especially since no accelerations as high as 2g nor velocities as high as 200 centimeters per second have ever been recorded. Also, a number of physical phenomenon may limit the velocities and accelerations observed, for example, scattering, inhomogeneities in the rocks, incoherency in the fault rupture, low Q and high non-linear attenuation.

The fact that stress drops averaged over the fault plane are commonly about 30 bars and thus less than thought necessary for generating large accelerations and velocities suggests that in most cases such large velocities and accelerations would not be expected.

Building damage observed near large earthquakes has usually not been as great as engineers would have expected

mpb5

for such large accelerations and velocities.

Finally, it can be reasonably argued that the very high values of accelerations and velocities require such a coincidence of deviations of variables away from their average values as to be very unlikely for any given earthquake.

All of the above arguments carry some weight, but in most cases -- I probably should have said in no cases that I know of -- have they not been verified -- they have not been verified as arguments against the possibility of high accelerations and velocities.

They do not, in my opinion, outweigh the contrary arguments and evidence presented earlier. They are especially weak if the burden of proof is assumed to lie with the contention that high velocities and accelerations are not expected.

In other words, to accept these arguments without verification would be to abandon conservatism in the process and thus to accept greater risks. The situation is such that in the face of the strong evidence of high accelerations and velocities can occur, but with a data base too limited to be sure what the probabilities are, we can only conclude that the higher the design levels, the less the risk will be.

Expectations for the Near Future.

It is evident from my testimony that our

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understanding of the nature of strong ground motion near large earthquakes is still in an uncertain stage. New recordings are often surprising. Deployment of large numbers of accelerographs near active faults began only a few years ago and the data base is as yet very limited.

We may expect marked changes in our ideas once strong motion from several large earthquakes has been observed on a number of instruments in the near field. Also, our ability to do theoretical and numerical modeling is advancing rapidly and may lead to important insights in the near future.

Conclusions:

The main conclusion of my testimony is that, based on our present limited data base for near source -- that is epicentral distance less than ten kilometers -- ground motion for large earthquakes -- magnitude less than seven -- and based on our present limited understanding of the seismic wave generation and transmission, the ground motion postulated in USGS Circular 672 for a magnitude 7.5 earthquake -- that is, peak accelerations of 1.15g and peak velocities of 135 centimeters per second -- has not been shown to be conservative.

Under reasonable conditions, maximum accelerations and velocities could exceed 2g and 200 centimeters per second, respectively. Circular 672 notes that the tabulated

mpb7

values are not the maximum possible. Average accelerations may be about 1g with the average plus one standard deviation about 2g.

Although there may be factors operating to make such large accelerations and velocities less likely, such limiting factors are not established by our present data base and theoretical understanding. Near source recordings of earthquake strong motion are still very limited, but nevertheless, accelerations greater than 1g have been recorded three times and velocities greater than 100 centimeters per second once.

I conclude that the present data and physical understanding of seismic wave generation support the higher acceleration versus distance curves such as those of Trifunac and Brady and Ambraseys. A near certain conclusion is that if the burden of proof is assumed to lie with the thesis that very close to large earthquakes accelerations of greater than 1g are not common, then the thesis has not been proven.

That ends my summary.

Q During the course of reading the conclusions, I noted that in the third line I think you misstated. You said:

"...motion for large earthquakes magnitude less than seven..."

I think you meant greater than seven.

mpb8

A Greater than seven.

Q That's the way your text reads.

I have a couple of questions that I'd like to ask you.

During the course of your summary and in your testimony here you speak several times of a phenomena which you call focusing.

Could you, in layman's terms, or in terms that might be readily accessible to someone who hasn't had intensive training, explain what the phenomena of focusing is all about?

A Yes.

If you have a finite fault, a long fault, then you can represent the energy radiated from that fault as occurring at different parts of the fault. Now, if the energy from the different parts of the fault were released at random and not in phase, then they would constructively and destructively interfere. And the net result at any given station near the fault would be a superposition of these randomly interfering bursts of energy.

However, if the energy is released in a coherent way then, for example, as the rupture propagates down the fault, if it propagates with a velocity somewhat near the velocity of the waves that are generated, then each successive section of the fault will release energy which will be right

mpb9

in phase, that is, lie right on top of the energy from the previous section of the fault which is traveling down the fault. And therefore they will add up.

Each little subsequent section of the fault will release some energy which adds on to the energy traveling in that same direction with the same velocity from previous parts of the fault, and therefore energy will continuously add up.

And in that sort of a situation the energy is focused in the direction of rupture propagation.

Q You also mentioned in your summary here a phenomenon which you called constructive interference of wave packets from discrete bursts of energy released on a fault.

Is that a phenomenon different from or the same as the focusing phenomenon that you've just described?

3.150

A It's a different way of looking at the same thing, essentially. Which way of looking at it -- there is somewhat of a difference, but which way of looking at it is more appropriate for earthquakes depends on knowing more about earthquakes than we do right now.

That is, at the present time we don't know whether it's, for example, a better approximation to model an earthquake as a smooth propagating fault or to model it as a series of sort of discrete bursts of energy. But

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basically the physics is the same.

Q Again, I think we've had some discussion about this, but at this point I'd like to get your description of a term that you use in your testimony called "stress drop", and, again, in language that might be accessible to someone who doesn't have intensive training, explain what "stress drop" is and what the term "bar" is, what that represents as a measurement.

A Stress drop is a term that refers to the change, the deformation -- it relates to the deformation that occurs in the earthquake in terms of the amount of slip and the rigidity of the rock. A certain amount of stress will deform rock of low rigidity a lot more than rock of high rigidity.

So in a rock of a certain type and a fault of a certain size, the higher the stress drop, the higher the slip on the fault.

In other words, if we had a circular fault in a given type of rock, and slip of one meter occurred on that averaged over the fault, then we would say that the stress drop is a certain amount. If the slip had been two meters, we would say that the stress drop is twice as much.

So in an elastic medium, the deformation is related to the stresses involved, and that's why we use the term "stress". It's stress by the rigidity of the rock is

mpb11

related to the deformation of the rock. So essentially stress drop refers to how much deformation has occurred in the rock.

Q Is there in your testimony anywhere in any of the attachments an equation -- or is that described by an equation, this term "stress drop"?

A No, it's not in my testimony.

Q Can it be described --

A Well, yes. The standard elasticity law relates the stress drop to the rigidity of the rock times the displacement that occurs with some appropriate constants, depending on the geometry and the shape of the fault or something like that.

But basically it's stress is equal to the rigidity times the displacement or the strain. It's really the displacement over a given distance.

Q You use the term in here "bar". What is that?

A Okay.

A bar is essentially one atmosphere of stress. In other words, the force per unit area that is exerted by the pressure of the atmosphere on the surface of the earth. And this is just used as a unit in seismology to measure stresses relative to.

MR. FLEISCHAKER: I believe that ends our summary at this point.

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I'd like to offer into evidence Joint Intervenors Exhibit which has been marked as number 66.

MRS. BOWERS: Mr. Norton?

MR. NORTON: No objection.

MRS. BOWERS: Mr. Tourtellotte?

MR. TOURTELLOTTE: No objection.

MRS. BOWERS: Well, Joint Intervenors' Exhibit number 66 is received in evidence.

(Whereupon, the document previously marked as Intervenors' Exhibit 66 was received in evidence.)

MRS. BOWERS: We'd like to have a brief break. We'll take ten minutes.

MR. FLEISCHAKER: Thank you.

(Recess.)

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MRS. BOWERS: We'd like to begin.

CROSS-EXAMINATION

BY MR. NORTON:

Q Dr. Brune, I want to ask some questions, basically just background questions about the focusing, and I want to draw a couple of exhibits which I'm sure Intervenors' counsel will like, to see that I understand what you're talking about when you talk about focusing.

(At the viewgraph.)

The first fault I'm going to try to draw would be a plane view, a surface view of a fault. And if I can draw a fault like this, and have this triangle represent a strong motion instrument recording station, and put an X at where the rupture started on this hypothetical earthquake and a squiggly line showing the rupturing occurring along with an arrow showing the direction of that rupture.

Now, is that the kind of phenomenon you're talking about, where you would expect focusing, a rupture occurring along, propagating toward the instrument?

A That's correct.

Q All right.

Now, the problem I have with that is that it seems to me that that is a paper phenomenon. In other words, if there's isn't an instrument there, you don't have focusing. Or if it ruptures in the other way and there's no instrument

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in the other direction you don't have focusing. But obviously that's not true, because focusing, I assume, is a real phenomenon, is that correct?

A That's correct.

Q All right.

So whether I've got the instrument there or not, focusing can occur.

A Yes.

Q It's a physical phenomenon.

A It's a physical phenomenon.

MR. FLEISCHAKER: I was just wondering what we're going to do with this piece of paper?

MR. NORTON: It's marked as Applicant's Exhibit Number 36.

(Whereupon, the document previously referred to as Applicant's Exhibit 36 was marked for identification.)

MRS. BOWERS: Up at the top.

MR. NORTON: At the top, in red, and we're going to offer it in evidence.

MR. FLEISCHAKER: Do you want to sign it?

MR. NORTON: I don't care. The record is pretty clear as to who was making it.

MR. FLEISCHAKER: Okay.

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BY MR. NORTON:

Q You talked about coherency in terms of rupture, the coherency of the rupture in connection with focusing. Now if I understand that correctly, it's the amount or the degree of coherency that is directly related to the amount of focusing, is that correct?

A That's one of the factors, yes.

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Q In other words, if you have a very coherent rupture, you would have more focusing than if you had a very incoherent rupture?

MR. FLEISCHAKER: I have an objection, only on the basis of foundation. I think we should have some explanation of what coherency is before we proceed.

MR. BRIGHT: I would appreciate knowing.

MR. NORTON: That's what I'm attempting to do. Okay.

BY MR. NORTON:

Q And if you had less coherency, you would probably have less focusing, is that correct?

A There's a little bit of uncertainty introduced there about how you normalize what you assume constant in the two cases.

For eaample, there's a recent paper by Boore and Joiner where they conclude that the introduction of coherency leads to higher accelerations in the direction, but

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the reason for this is --

Q I think you misspoke, the introduction of incoherency?

A Yes.

Q You said "coherency."

A The introduction of incoherency leads to higher accelerations in the focus direction, but that's because of the way they normalize things. So if we're going to get this exactly straight, we're going to have to be careful, you know, what we assume is constant.

But in a general way, what you're saying is right, that is, given the same amount of energy and the same energy release and stress drop as a constant then, given that amount of thing, then if you make it more incoherent, the accelerations will be less in the focus direction.

Q Okay. Let's talk about coherency. Could you define coherency in this concept?

A Well, it's a parameter to quantify how much the energy radiating from the different parts of the fault is describable by a smooth mathematical function or is, say, how close it is to the wave velocity of the waves it generates and things like that.

Q Okay.

In other words, if you have a rupture propagation which is halting, lurching, going fast, slowing down, in other

RB/ago5

words, that's less coherent than one which is just kind of moving at the same rate right down the fault?

A That's correct.

Q Okay.

Now, obviously parfect coherency we could assign a value of like 100, okay, 100 percent coherent. Perfectly incoherent -- which I presume you could never get, and then zero percent would be perfectly incoherent, which I guess by definition you couldn't get because you wouldn't have a rupture if it were zero percent incoherent. Okay?

So, would you agree with that, I mean, the two extremes are zero and 100 percent, in terms of coherency, you would never achieve, it's obviously something in between.

A In nature, yes.

Q Okay.

And we're talking about the real world here for the moment.

So how do you know whether any fault or any portion of a fault or anything -- what percent of coherency you're going to get.

A The only way we can tell is to get some more strong motion records and see, for big earthquakes, get enough data in the near field to measure the records and see how coherent the rupture is, which is a process where --

Q How do you measure coherency?

WRB/agb6

A By looking at the shape of the wave form that's recorded on the strong motion instrument.

Q Okay.

A The ideal experiment, of course, is to have a large number of stations, so that you can interpret the various wave forms in terms of what's going on in the fault and then, by looking at the shape of the wave, you can tell what the coherency on the fault was. We have not been able to do this yet because we don't have enough data.

Q All right.

Now the first plane view here that I've written, let's label that, if we can, A. And then let me do another one, which would be a cross-section, where the line I'm drawing represents the surface of the Earth. And let's say we have down here, oh, 20 kilometers underneath the surface of the Earth we have a rupture that's the -- shall we call that the, what is it, the epicenter of the earthquake?

A Hypocenter.

Q The hypocenter, excuse me. The epicenter would be up here, right?

A Yes.

Q Okay.

Now when that ruptures, it can rupture in more than one direction, it's three-dimensional, isn't it?

A Yes -- well, it could be sort of unilaterial, but

WRB/agb7

it probably starts out more or less three-dimensional.

You've got to be careful here. At the instant of rupture, there probably have to be three -- not three-directional, but it has to move initially in a plane, but then what happens after that you can't tell, it could spread out more or less in one direction or it could go both directions.

Q Okay. You're telling me, then, that it could rupture parallel, in a sense, without rupturing vertically, parallel to the surface?

A In physical reality, it couldn't rupture the fault plane, it couldn't be a narrow line.

Q Okay.

A Not in that sense. But the shape of the area that's ruptured that you would draw after that could be variable.

In other words, right after that as the rupture propagates out, you might draw a little circle around there in one case, for example, or you might draw various shapes.

Q All right.

For example, it could rupture toward the surface, as I'm drawing here, and then go this way, could it not?

A I wouldn't like to -- when you say it ruptured, I need to know what the rupture surface is you're talking about.

In other words, at the initial point there is no

WRB/agb8

rupture at all. A short time after that, there is some line you have to draw around there which says what part of the fault has ruptured. You can't draw a line like that, you've got to draw -- the line is sort of normal to the area that's ruptured. The rupture spreads out like a crack.

Q All right.

A And in that thing, it would be a two-dimensional thing you would have to draw.

Q Okay.

What I'm trying to get at though -- we'll label this B -- what I'm trying to get at is, not only do you have horizontal focusing, the phenomenon, you have vertical focusing, on occasion, do you not?

A It could be in any direction. It could be in the -- it's in the direction of rupture.

Q It's in the direction of the rupture. So if you have a rupture which starts 20 kilometers down in the earth's surface and moves up toward the surface, you could have a vertical focusing.

A That's correct, yes.

Q All right.

So you have the horizontal and the vertical focusing, and anything in between, correct?

A Correct.

Q But it's always five degrees, plus or minus, in the

RB/agb9

direction of the propagation.

A Well the five degrees refers to an idealized model.

If you have a rupture front that's complicated, as you're suggesting, that moves first in one direction and then in another, then you might -- the concept of the five degrees is introduced for an ideal model which is propagating more or less in one direction. If you've introduced the rupture that moves variably, then you can't -- the five degrees can't be applied necessarily. You'd have to do that model and see what happened.

Q Okay.

What are the factors that bear on coherency?

A In this context, it's basically the way in which the fault rupture expands around from that point you drew.

Q Well, but doesn't it also have to do with the characteristics of the earth, of the fault along the rupture plane?

A Yes, it has to do with the wave velocities, the velocities of the waves that are generated by the earthquake also. It's a combination of the way in which the fault ruptures and the way in which the waves propagate once they've been released.

Q All right.

Let me ask you this: isn't it true that for every

WRB/agb10

earthquake there has ever been, the phenomana of focusing has existed in that earthquake?

A Well as I said, in the case of a complex model -- it depends on whether you're referring to the simple model or not. I would say the physics which leads to the concept of parameterizing the thing as focusing, yes, that occurs.

Q Okay.

What I'm getting at, if that focusing, whether it be at zero percent or 100 percent, both of which would be impossible, like coherency of zero to 100 percent occurs in every earthquake, the question is how much focusing occurs in any given earthquake. But the phenomenon, the physical phenomenon that you are describing has to occur to one degree or another in every earthquake, does it not?

A Yes. Right. But also it's not just coherency, it's also the direction in which it ruptures and things like that.

Q But it doesn't make any difference in which direction it ruptures, you still have focusing, it just isn't -- there isn't an instrument there to measure it but it's there.

A Yes, to a certain extent, right.

Q Well, it's a phenomenon or it isn't a phenomenon. If it is a phenomenon and it's there, it's there.

A But on the limit of your scale, if you're saying it's near zero percent, yes, it's there but it's very small,

WRB/agb11

and so --

Q But it's focusing?

A But for a particular case you might say, for practical purposes, it isn't significant in that case, depending on what you -- if the thing is essentially completely incoherent but there's a slight amount of coherency, okay, then there's a slight amount of focusing, and the question is is that practical or not.

Q But my point is that it's a phenomenon that exists in every earthquake that has ever occurred. It's a physical phenomanon, just as much as there is a wave produced from every earthquake that ever existed, isn't that true?

A That's correct.

Q All right.

1Dflws

4.170

Dr. Brune, then while your theory of how much of acceleration or velocity is attributable to focusing or directivity is relatively new, the phenomanon itself is as old as the earth, isn't that correct?

A I'm not sure what you mean by "my theory."

Q Well --

A Most of the things I've quoted were other people's studies in the testimony.

Q Okay. I didn't mean to ascribe -- don't get me wrong, I'm not arguing with you that it doesn't exist, but what

WRB/agb12

I'm pointing out is that it has only been in the last year or two or three or four or whatever that numbers have been ascribed to focusing. And while that's true, that this is, as you plainly state in your paper a recently evolving -- and I use the word "theory" but you can use any word you like, the phenomena has existed since the earth has existed, isn't that correct?

A Well, the first part about whether it's a recently evolving idea, I think, to put it in the right context is it's something that everybody essentially who thought about it knew existed. But the level of the science, and the level of knowledge about earthquakes and so forth have not proceeded to the level at which it was -- well, where it was introduced in hearings like this.

The implication, I don't think it is correct to imply that it's sort of a new theory that has just come around. In fact it, you know, it has existed since the beginning when people started writing down mathematical equations about faulting and so forth.

Q Dr. Brune, I'm not trying to imply that.

A Okay, well that's the first part of your statement.

Q It hasn't received attention, it hasn't been called focusing and it hasn't received the attention up until the last however many years it's been, I'll say few years where it has received a great deal of attention.

WRB/agb13

A. Well I think you're referring to the case of seismology. In acoustics, it's been known and referred to lots of times, but in seismology we haven't had the near source records to interpret it or there haven't been that many studies made in the far field, if you want to go to the far field.

But you know, back in 1952 Benioff used the concept for the Tehachapi earthquake. So in case of the strong motion, the reason it hasn't been applied is because there hasn't been enough data to apply it to.

Q But the phenomenon has always been there. I mean, there's no more focusing occurring in earthquakes today than there was 100 years ago or 1000 years ago?

A That's correct, the same physics applies to earthquakes in the past as now.

Q All right.

Now another term I'd like to talk about and get a basic understanding about before we proceed into your testimony is intensity. How is that used, how is the term "intensity" used by seismologists?

A Intensity is a qualitative scale of the amount of damage that is done by earthquakes. That is, whether something is knocked over, whether a certain type of construction is damaged or not and so forth.

Q All right.

WRB/agb14

And can you relate accelerations to intensity?

A There could be a general relation -- a number of people have tried very general relations, but there isn't a one-to-one correspondence between acceleration and intensity, no.

Q Okay. What's the general relationship? I appreciate it isn't exactly linear.

A Well the general relationship is the higher the intensity, the higher the acceleration. That is, higher accelerations tend to generate higher intensities.

Q All right.

What kind of intensity would you associate with, for example, 400 percent of gravity?

A I don't know.

Q Let's take a city like San Francisco or Los Angeles, whichever you like, a major city here in California. What intensity would you expect in those cities if an earthquake occurred that produced 400 percent of gravity?

A IT would depend on what the frequency content is and what the character of the wave form itself is. Then in order to -- well, in order to assign intensity, you usually discuss building design and how much damage there is done to buildings. At most levels of intensities, that's one of the factors. So you'd have to have some way of, say, relating the amount of damage in the building to the acceleration.

WRB/agb15

Q Well let me ask you this: what are buildings -- if you have 400 percent of gravity, would you expect buildings in Los Angeles and San Francisco to withstand those, those kind of g forces?

A At low frequencies, no, but it depends on what frequency is involved. At very high frequencies, they can easily stand them.

Q Well what frequencies would you associate with 400 percent gravity, what would you expect in terms of frequency range for 400 percent gravity?

A I would expect probably quite high frequencies, but I'm not exactly sure. In other words, probably up around greater than 10 Hz.

Q And it's your testimony that, for example, the Los Angeles Coliseum could withstand 400 percent gravity at 10 Hz?

A No. I'm not a structural engineer.

Q You don't know what would happen to it?

A No.

Q Okay.

What's the largest maximum free field ground acceleration ever recorded in the world?

A The largest in my knowledge is the Gazli earthquake 1.3g.

Q Dr. Brune, could you list the records which you

WRB/agb16

feel represent focusing?

A I could list some records which may represent focusing, and I think with some probability probably do. But again, as I said before, there have not been enough records taken in the near field of, say, a large earthquake to completely outline the rupture pattern and the wave pattern so that you could figure out exactly what was going on. So it's more in the line of guessing, like you say in the case of the San Fernando earthquake, very likely the velocity pulse in the beginning of the record was due to focusing. Most people who studied it agree that that was -- well not all, but most people think that it was due to focusing. So I would say that I more or less agree in that case.

Q That's the Pacoima record?

A The Pacoima record.

And also people have suggested that the Bear Valley earthquake, which had a fairly high acceleration for a low g, may have been the result of focusing since it was on the fault plane.

Q Well let me ask you this: isn't it true that every record that was ever taken where a fault was propagating at the record for any period of time, is a measurement of focusing?

In other words, if you've got a strong motion instrument and you've got a fault rupturing, propagating in

WRB/agb17

the direction of that instrument for however brief or however long a period of time, you have a record of focusing whether you know it or not.

A Yes, it's a record of the phenomenon of focusing in a sense, but it doesn't tell you how effective focusing can be in generating large ground motion because, in order to know that, you have to have a large sample of events and know -- and record data for ruptures going in various directions for various types of faults.

Q But it does measure the phenomenon?

A Yes, but it is not very helpful to you if you don't know which direction the rupture went. You can say, yes, that's the result, focusing was somehow involved in that earthquake but I don't know which way the rupture went, so you don't know how much of what you see is due to -- in other words, you don't know how focusing affected that particular record unless you know what the rupture was.

Q Well let me say this, this may be a pretty naive question and expose my ignorance, but it seems to me that if you know the hypocenter of the earthquake and you certainly know where your instrument is, then you know the direction of the rupture, don't you?

A Well not necessarily. As you pointed out in your diagram, the actual wave front may be quite complicated. If you know the hypocenter accurately and you know that the fault

WRB/ab18

ruptured in a nice smooth way, for example, which you usually don't know and as I said before, we don't have enough data to know whether it was -- whether maybe the fault initially ruptured the other way and then turned around and came back or -- there's a lot of things we don't know about it.

Q But if the hypocenter is 20 kilometers south of my station, and it somehow gets by my station, it had to come at my station at some time.

A There's a component of the direction of rupture which is toward the station, yes.

Q That's correct.

A Yes.

Q So that record has to reflect whatever focusing occurred.

A Not whatever, it reflects the focusing that occurred for that particular rupture that occurred to that site. If the rupture variated -- moved slightly differently it would be different.

Q That's correct. But it does record whatever focusing there was to record at that site.

A Yes, it reduces to a tautology saying whatever focusing occurred occurred and I agree.

Q That's correct.

A Okay.

Q. So all records we have then where there was

WRB/agb19

propagation in the direction of the instrument are records of focusing?

A That's not what I would say, records of focusing. I would rather say that somewhere in the energy that is arriving at the station, the effectsof focusing are involved in that data to a certain extent but you don't know how much because you don't know how the rupture occurred.

Q. Well Dr. Brune, that's I guess one of the things that bothers me about your testimony. You seem to call it only focusing if it's a high g but it's a focusing phenomenon no matter what the g level is.

A. Well I didn't use the term "defocusing" in my testimony, but that's a term that is introduced, for example, in the direction that if the rupture occurs in such a way that you get destructive interference, you could call it defocusing.

Q Okay.

A So in that sort of generic terminology, you might say defocusing is one subset of focusing. So that in some directions, for example, a seismograph might record lower accelerations than normal because of defocusing, in other words, the rupture happened to go in such a way that it destructively interfered.

Q Well what's normal? What do you mean "lower accelerations than normal," what's normal?

JRB/agb20

A Well say then the average. If you had a whole bunch of stations, if we had had, as I said, if we had had a situation where there was a rupture and a large number of stations around it, then you could measure the acceleration at a large number of points.

And then you would say Okay, at most of the -- the average accelerations are so-and-so. In one certain direction, the accelerations are very high, say, the direction of focusing. In another direction, they're very low. You could say it defocused in that direction, that's what other people have said.

Q And that's another way of saying that if you put 10 strong motion instruments out there you probably are going to get 10 different recordings.

A Yes, the effect of focusing is a phenomenon which is directional, so at different directions you get different accelerations.

Q Okay. And so what you do is you add up the 10 instruments and divide by 10 and you say Well, this is normal for this earthquake and anything higher than that is focusing and anything lower than that is defocusing?

A It depends on exactly what the fault mechanism is you'd be working with, but that's one way to do it.

In other words, let's take a simple case of a nice unilateral rupture, and then you have a large number of

3/agb21

strong motion seismographs around it and you record a large number of accelerations. And you notice that in the direction in which the rupture occurred, there's very, very high accelerations and in the opposite direction there's very low accelerations, and off in other azimuths there are in-between accelerations.

Okay. If you wanted to use the word "normal," as you introduced it, I would say well one way to do that would be to, say, just to average all the accelerations and say Okay, the accelerations in the direction of focusing are higher than the average of the accelerations, and the opposite direction in the defocused direction are lower.

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Q Will you turn to page 3-8 of your testmony?
A Okay. Yes.
Q All right.
You say-- When did you prepare this testimony?
A It was just around the first week of November.
Q It was in November?
A Yes.
Q Okay.
You say at the very bottom of that page,
"Except for the study of Ambraseys, none of the above studies included the results of the Gazli earthquake described above. Since this is the only near source record we have of such a large earthquake, a reasonable assumption (with very low confidence level) might be that this record represents the average value of acceleration, and we can estimate probability and confidence limits by assuming the same variation in data for this distance and magnitude range as found by Trifunac."
Do you believe that it's a reasonable assumption to take one piece of data and have that representing the average value of acceleration? Do you feel really that that's a reasonable assumption, Dr. Brune?
A Well that's why I qualified it with "very low

WRB/wb2

confidence level" and "might be." The implication is that--

Q. Would you base any decision on that? I mean would you call it a reasonable assumption and go so far as to base any kind of important decision on it?

A No, the whole subject of my-- in fact the whole emphasis.... You have to take this in context. The whole emphasis of my testimony is that since we don't have any records available that we can't be sure what the ground motions will be in the near field of large earthquakes.

Q I guess I would feel a lot more comfortable if your sentence said "Since this is the only near source record we have of such a large earthquake, an assumption with a very low confidence level might be* * *" I have real problems with "reasonable," when you've got one data point.

MR. FLEISCHAKER: Objection. I don't think that's a question. Objection to the form.

BY MR. NORTON:

Q Would you agree to remove the word "reasonable" in front of "assumption?" I guess that's my question. As I read it, as a layman, the word "reasonable" when we're talking about one data point in the whole world as an average, it just defies my understanding of the word "reasonable."

A Well I think the question is, given in the context of not having any data points versus having one, the question is, is the confidence level any higher with one data

WRB/wb3

point than with none. So I feel-- The reason I qualified that section so much is that I -- is basically to emphasize the point that I'm making in my testimony and which you're making now, that we really can't have any confidence of our present estimates of accelerations in the near field of large earthquakes for this very reason.

Q Well let's go back to the word "only" in that sentence. What was the magnitude of the Gazli earthquake?

A The MS value?

Q Yes.

A It's about -- I believe it was 7.2, I think. Let me just look and see.

Q Something above 7 and something less than 7.5?

A Right.

Q What was the distance of the instrument from the fault?

A The Russian interpretation of the distance-- The hypocenter or the fault itself?

Q Both.

A Both.

The hypocenter was, I believe that it was about 20 kilometers to the hypocentral distance. And I think it was something like 10 kilometers, or that distance, to the fault rupture.

Q Okay.

And that was a thrust fault?

WRB/wb 4

A Well it had a large amount of dip-slip motion on it.

Q It had a large amount of thrust?

A Yes. Dip-slip.

Q Okay.

And you say that's the only one. How about the Tabazrecord? Do you know what the parameters of the Tabaz earthquake of September 16, 1978, are?

A That's the recent Iran earthquake?

Q Yes.

A Yes. Well, I--

Q That was a couple of months before you wrote your testimony.

A Right. Well, as I mentioned in there I had a-- No, I don't know what the final fault plane solution, direction of rupture--

Q You haven't investigated to find out the magnitude of that earthquake or the acceleration of that earthquake? When you've only got one piece of data here you haven't found out the other piece ofdata?

A Well I looked at the xerox copy that I had and tried to estimate what the accelerations are, and I concluded that I couldn't be very sure from the data I had.

Q Have you read the preliminary report on the Tabaz

WRB/wb5

earthquake, the Tabaz, Iran, earthquake of September 16th, 1978 by Robert Sharp and Nicholas Orsini, U.S. Geological Survey, Menlo Park, California?

A No, I haven't.

Q Have you been in contact with Dr. Bruce Bolt who supplied that information?

A The information in the report?

Q No the information regarding-- A separate report, information regarding magnitude of the earthquake, g levels measured, location of the hypocentral--

A No, I haven't.

MR. FLEISCHAKER: Excuse me; I'm going to object to that question on the basis that I don't know-- My recollection is that Dr. Bolt provided some information to the record which he said was preliminary, and I'm not sure if that's what Mr. Norton is referring to. Or is he referring to some other report that was submitted to the U.S.G.S. or submitted to the University for press, or what?

MRS. BOWERS: Could you clarify?

MR. NORTON: What am I supposed to clarify? I don't understand. I asked him if he were aware of these things. And I don't understand. He said he isn't. I don't understand what the objection is.

MR. FLEISCHAKER: The objection is the use of the word "report." I don't understand what he's talking about.

WRB/wb6

MR. NORTON: All I have is the title to the report. It's a USGS report. That's all I have.

DR. MARTIN: Is that Bolt's report?

MR. NORTON: No. Bolt's was a letter, I said, a letter to Dr. Smith. And I think he testified about that in his testimony. And I asked him if he was aware of the information or had been in contact with Dr. Bolt.

MR. FLEISCHAKER: Okay. I just wanted to make that clear on the record.

DR. MARTIN: I'm still not clear. This was a letter that Dr. Bolt wrote to Dr. Smith, and you're asking Dr. Brune if he knows about that letter?

MR. NORTON: No; if he knows about the information on the earthquake. It's obvious that somebody has the information if they're writing about it in letters back and forth to each other.

This letter was in November, and I'm just asking him if he has that information about that earthquake.

DR. MARTIN: Well the only place we know the information occurs is in a personal letter?

MR. NORTON: No. Here's a USGS report about it.

DR. MARTIN; That has the same information as the letter?

MR. NORTON: Yes. And I'm just trying to find out if he's aware of that information.

WRB/wb7

MR. FLEISCHAKER: Before we proceed any further on this line of cross-examination I think Dr. Brune should be given an opportunity to see what that information is. And I also think it would be useful for purposes of the record to see what that information is, whether it's preliminary or, you know, what the basis for the numbers are that are in the USGS report or in the letter from Bolt to Smith.

DR. MARTIN: The question about the USGS report was asked and answered.

MRS. BOWERS: But Dr. Brune referred to a xerox document that he said he had no confidence in.

THE WITNESS: No. That was a xerox copy of the record of one of the strong motion accelerograms.

MR. FLEISCHAKER: I'm not quite sure where we are at this point. I think Mr. Norton has just cross-examined this witness on the basis of two documents, and I'd like to have the opportunity to see them.

MR. NORTON: But I haven't cross-examined on the basis of any documents. I asked him if he were aware of the existence of the documents or the informaton contained in the documents, and he said No.

I don't understand what the problem is.

MR. FLEISCHAKER: Well I may wish to ask some questions about those documents on redirect, and I think since Mr. Norton has got them there I ought to have the

WRB/wb8

opportunity to look at those.

MRS. BOWERS: But he says he's not familiar with them.

MR. FLEISCHAKER: But the implication is that those documents contain some sort of definitive description of what that earthquake was all about. And I'm not sure whether that's the case or not.

MR. NORTON: There's no implication whatsoever about what those documents contain. I asked him if he was familiar with the information they contained and he said No.

MR. FLEISCHAKER: Okay. So all we're asking him is whether he has seen the documents?

MR. NORTON: I think the record is very clear as to what I asked him and what he answered.

MR. FLEISCHAKER: Well it's not clear in my mind.

MRS. BOWERS: Well he said he was not familiar with the information. I would assume that meant he hadn't seen the documents.

MR. FLEISCHAKER: Okay.

BY MR. NORTON:

Q In your testimony on page 3-6, at the end of the first paragraph you have a bracket "I have received unconfirmed reports that the recent Iran earthquake produced accelerations of 0.8g at a near source station." Close bracket.

mm8/wb9

I guess what I'm asking is why you didn't follow up and get the information on this earthquake if you were relying on data source in the world. This appears to be a second, which doubles your data base.

A Okay. Well, I talked to some people about that record and tried to figure out, on their basis, how confident they were of the acceleration itself. And everybody I talked to said, Well I've looked at the record but it's a very poor copy, and I'm not sure what the real acceleration on the record is, I think it's about .8g, but we can't get the original, and I'm not sure exactly what the true acceleration is.

Q Did you ask Dr. Frazier about it?

A Yes.

Q And Dr. Frazier told you he didn't have any data?

A Well he said that he had seen-- As I recall, at the time he had a similar record, and that he thought the -- he was convinced that the peak acceleration on the horizontal was .8g and on the vertical he wasn't sure but it probably was something of the same.

That's my recollection of the conversation.

Q When was that?

A I'm not sure. It was fairly recently, like within the last couple of week, I think. But I'm not absolutoly sure what the data of the conversation was.

WRB/wb10

But, anyway, to finish answering your question, Why didn't I follow up on this? Well, the reason is, any time you have a new data point like that, as I indicated before, in order to understand the significance of that data point you really have to eventually get the fault plane solution, the direction of rupture, the depth, and all this kind of information on any earthquake. That's usually a couple of years later.

For example, in my ACRS testimony, the Gazli earthquake had just occurred, and it had 1.3g acceleration. And in my testimony you'll see that even though I used that data -- and maybe you might say I should have called everybody right away and really got all that information because we had zero data and now we had one data point, but the fact is I wouldn't trust any final interpretation on any of these data points until a couple of years afterwards when all the-- For example, in the case of the Pacoima Dam, it is now many years after the earthquake and still a recent SSA Bulletin article comes out with a completely new interpretation of the faulting.

So one of the reasons I didn't call everybody up and find out what all the information was on this recent earthquake is because I don't believe that that would have been a final -- would have provided the kind of information you need to finally evaluate the result anyway.

Q Well but you used the Gazli earthquake which you

WRB/wb11

knew very little about before the ACRS to support your testimony. And here you have not used the Tabaz earthquake which is in the same status that the Gazli earthquake was at the time of your ACRS testimony; is that correct?

A I don't think that's-- "Same status" implies identical status.

Q Well I don't mean identical in every way. But basically it's virgin data that hasn't been looked at over and over and over, and looked at in many different ways.

A Well the fault plane solution has not been determined.

Q Has the Gazli fault plane solution been determined?

A At the time of my ACRS testimony?

Q Yes.

A No.

Q So there's no difference there, then?

A Well there's a gradation, obviously, in terms of time.

Q Well would it surprise you, or would you have any basis to contradict the fact that the Tabaz earthquake was a 7.7 MS?

A No, I haverno reason to contradict that.

Q All right.

And that the hypocentral distance was no greater than the Gazli earthquake from the instrument to the--

WRB/wb12

A No.

Q And that the earthquake ruptured in the direction of the instrument?

A No. As I say, I don't know any of these facts about that Tabaz.

Q Well if you assume that it's "as valuable a piece of data" as the Gazli data, wouldn't it significantly change your numbers in your testimony if the maximum acceleration were .8g?

MR. FLEISCHAKER: Excuse me. I'd like to object to this line of questioning. Because I think before we ask questions about the magnitude of the earthquake, the hypocentral distance and the direction of rupture, that an adequate foundation ought to be laid for the types of questions that are being asked.

I recall Dr. Bolt testifyingabout this earthquake and giving some figures. But my fuzzy recollection is that he said these were preliminary determinations.

So at this point I'm going to object to those questions, all of those questions, and request that they be stricken and the answers be stricken, on the basis that an adequate foundation hasn't been laid for those numbers in the record.

MRS.BOWERS: Do you want to repond, Mr. Norton?

MR. NORTON: I believe there was testimony from

MRB/wb13

our panel of seismologists about the Tabaz, Iran, earthquake as to magnitude and g levels. I don't think there is any doubt about it. There was testimony in the record. It's now in evidence in this case. So there certainly is a sufficient foundation for that hypothetical.

MRS. BOWERS: Does the Staff have a position?

MR. TOURTELLOTTE: No.

MRS. BOWERS: Can you readily identify the transcript?

MR. NORTON: It was the seismology panel which was on for about three, four or five days. We'd have to dig it out. But they definitely-- I remember Dr. Bolt and Dr. Frazier and Dr. Blume talking about the Tabaz, Iran, earthquake of September '78, the magnitude 7.7, the .8g.

MR. FLEISCHAKER: I also recall that they discussed that earthquake. But what I don't recall is what the source of their information was, nor the certainty they attached to the information that they gave to the record.

MR. NORTON: Well, counsel had all the opportunity in the world to cross-examine on that. But those facts are in evidence. And counsel is saying, Gee I don't know about those facts. He had his opportunity to cross-examine at that time, the time they went into evidence.

MR. FLEISCHAKER: That is not the point. The point is that if Mr. Norton wants to question this witness

WRB/wb14

about specific facts relating to a specific earthquake he should lay an adequate foundation for those questions. And if he had the information in the record, then it was incumbent upon him to go back into the record and determine the information and the basis of the information. Then he could ask this witness the questions.

He's got Mr. Frazier sitting right next to him. Mr. Frazier can advise him as to the basis for the information that he is laying out here, 7.7 magnitude earth quake, what's the basis for that measurement, hypocentral distance of 'x' kilometers, what's the basis, what's the basis for that, rupture propagation in a certain direction, what's the basis for that?

MR. NORTON: Mrs. Bowers, that's just -- I've never heard of such a thing. When something is in evidence and was not objected to when it came into evidence, you can't later when somebody wants to use that evidence to pose a hypothetical state that there's no foundation for that evidence. The foundation is, in fact, that it is in fact in evidence.

MR. TOURTELLOTTE: Mrs. Bowers.

MRS. BOWERS: Mr. Tourtellotte.

MR. TOURTELLOTTE: Maybe it would be well for the Board to inquire as to whether the questioning is going on in this direction. If it isn't, then maybe rather than ruling

WRB/wb15

right now that could be checked into during the noon hour. Just as a possibility. I don't know whether Mr. Norton has anything further on that or not.

MRS. BOWERS: Well we recall, of course, generally the testimony, but do not have the exact figures in mind.

MR. FLEISCHAKER: What I'm objecting to is an implication that might be drawn that there is certain information regarding this earthquake that is -- well, the objection is there. I just want to know what the basis for these questions is, what the foundation is and where this information is coming from.

MRS. BOWERS: Mr. Norton, we think you have an obligation to identify in the record the source of your information.

MR. NORTON: All right.

MR. FLEISCHAKER: Fine. Thank you.

BY MR. NORTON:

Q Well, Dr. Brune, you would certainly, however, have to change your testiony at the bottom of page 3-8 as the only near source record we have of such an large earthquake, would you not? You are aware that there is indeed a record of another large earthquake, near source?

A Yes. I mean, if all the information which you submitted is correct, then it logically follows, yes. And on the basis of, you know, phone contacts, and so forth, that

seems more or less correct.

WRB/wb16

Could I add one explanatory comment?

You asked why I didn't follow up on this earthquake. Well, one of the reasons is that there was another earthquake and I had to fly down to Mexico. It was a short time, and I really didn't have time to follow up on it, with my other duties.

Q How many strong motion records have there been taken in the whole world to date?

A I'm not aware of the exact number.

Q Is it a large number?

A Well it's hundreds. Over a hundred.

Q Over a hundred?

A Hundreds. Yes. It might even be a thousand; I don'tknow.

Q How many had accelerations in excess of 1.15g?

A To my knowledge, only two.

Q And those two are?

A The Pacoima Dam record and the Gazli earthquake record.

Q How many showed focusing? Let me say that another way:

How many recorded focusing?

A Well I wouldn't like to phrase the question, recorded focusing in the way that you initially introduced it.

WRB/wb17

Do you mean they recorded energy from an earthquake which had fccusing in it, or do you mean they were in the direction of focusing, of maximum energy focusing?

Q Well, first of all, to understand your distinction, first of all it it possible to distinguish between the two in the real world?

A In the real world? Sure. As I said, once we get enough stations surrounding an earthquake where we can understand the direction, the actual mechanism of rupture, and so forth--

Q Excuse me; we're talking about records that have existed in the world. We're not talking about records that may exist in the future; we're talking about what we're living with now.

Is it possible to distinguish the two?

A In some cases it's possible, yes.

Q In which cases?

A Well, for example, in the 1952 earthquake Benioff the direction of rupture from the asymmetry of the surface waves. And a lot of this has been done for various earthquakes. But in terms of interpretation of the strong motion records -- and that's probably what the main implication is, is there a strong motion record that somebody has inferred focusing for. And I would say that, as I mentioned before, aside from the suggestion from the Bear Valley earthquake, the Pacoima Dam

WRB/wbl.8

record is the one that is most common, probably: there has been more study on it. which indicates the velocity pulse at the beginning of the record was the result of focusing.

Q Let's talk a little bit about the difference between velocity and acceleration; not necessarily the definitions of those words, because we've heard that before. But I have a little bit of difficulty in understanding how a record can have velocity focused on it but not acceleration.

A Well in the case of the San Fernando, the Pacoima Dam record, some interpretations have indicated that the initial pulse of the record, which leads -- when you do the integration of acceleration to get velocity it gives a very large pulse of velocity. And people refer to that in an approximate way of saying the velocity pulse on the beginning of the Pacoima Dam record. And what they mean is, if you integrate the acceleration and get velocity you find there's a big pulse, on the beginning, of velocity, and that's not at the same time on the record that the peak accelerations occur which are later in the record. And so people have said, for example, that the big velocity pulse at Pacoima Dam was the result of focusing.

Q Well, just a moment.

Velocity is derived-- Velocity doesn't arrive on a record without a wave, does it? I mean, velocity isn't something that a recorder picks up without picking up a wave?

WRB/wb19

A Velocity is the rate at which the ground moves.

Q All right. And that's the waves; correct; that are emanating from the earthquake?

A The waves cause the ground to move at a certain velocity or acceleration.

Q So velocity you can't measure without having the waves. If the velocity is focused, how can it be that the waves aren't being focused?

A Well I wouldn't say the velocity is focused; I would say the waves are focused and led to the large velocity pulse observed. I mean, that's what the interpretation has been.

Q Okay.

So the Pacoima Dam record was focused?

A As I said before, the large pulse at the beginning of the record, which showed a large pulse of velocity and which people have referred to as the velocity pulse, has been inferred by various people to be a result of focusing.

Q Of waves?

A Yes. From the deeper part of the fault. And that's distinct from the later part of the record where the high accelerations come.

Q Okay. But, in other words, that fault as it ruptured propagated toward the instrument, and whatever focusing occurred was measured on that instrument during

WRB/wb20

that portion of the rupture?

A Yes. But you dont exactly what the angle between the direction of rupture and the fault is. And the focusing effect is dependent on the frequency content.

In other words, the actual focusing of energy for different frequencies is different. And so unless you had an exact solution to know exactly how the rupture occurred you don't know whether the frequencies that made up the velocity pulse might have been focused, and the ones that make up the acceleration, not. You don't know the exact details of the rupture.

And also the attenuation may have removed some of the high frequencies from the velocity pulse.

Q You referred, didn't you, to the recent Mexico earthquake?

A Yes.

Q What was the magnitude of that earthquake?

A 7.9.

Q And how would you describe the intensity?

A I would say it was quite low.

Q Very little damage?

A Very little damage, yes.

Q What was the measured acceleration at Oaxaca?

A As I understand, it was about .2g. But I've not seen the record, the original record. That's quite a large

distance from the epicenter.

WRB/wb21

Q Turning to page 3-7, starting -- the sentence the third line from the top,

"Trifunac gives about 1.7g for the average acceleration near the fault for a Magnitude 7.5 earthquake and about 4.0g for the acceleration with 90 percent probability of not being exceeded."

Let me see if I understand my statistics very well.

Are you there?

A Yes.

Q Okay.

Does that mean that if you have ten 7.5 magnitude earthquakes one out of ten of those earthquakes is going to result in an acceleration in excess of 400 percent of gravity?

A That's on the fault. That's the interpolation. That would not necessarily mean 4g at the surface.

But what he's saying in that thing is that's right on the fault itself. The numbers for, say, 10 kilometers away are given in the next sentence.

Q All right.

So at 10 kilometers away you'd have 245 percent of gravity. Now that's a 90 percent probability of not being exceeded, that 2.45g?

A That's right.

WRB/wb22

Q So that means within 10 kilometers of the fault for every ten earthquakes you're going to have 245 percent of gravity within 10 kilometers of the fault?

A If you accept those-- I'm quoting his extrapolations.

Q I understand that.

A And you're saying, What's the implication if those extrapolations aren't correct?

Q No; I'm asking you if I understood the statistics correctly?

A Oh, yes.

Q Okay.

Now you go on and you say, "Boore...."

Excuse me just a moment.

2A fls

(Pause)

2A
WRB/agbl

You say "Boore et. al. do not extend their curves for magnitude 7.5 earthquakes to short distances for lack of data but the slope of their curves projected toward short distances suggest accelerations of greater than 2g are possible at distances of 10 kilometers."

5.190

I believe in your deposition we discussed the acceleration and distance relationship. Do you recall that?

A No.

Q We talked about the near field and whether there would be any distinction between the faults and two kilometers from the fault or five kilometers from the fault, do you recall that?

A Yes, I recall that.

Q And do you recall what your position was on that?

A I wouldn't try to summarize it, but I could give my position now or we could go back and read it.

Q Okay. Why don't you give us your position now.

fls WRB
3WEL/wel 1

A Okay. Would you repeat the question?

Q We're talking about the relationship between acceleration and distance from the fault?

A Yes.

Q From zero to, say 5 kilometers.

A Yes.

Q What is the relationship between acceleration and distance? Would you expect to get a difference in acceleration in that 5 kilometers?

A Well, I think that the same thing is true, that we don't have enough data to say what that is, either. I mean we can hardly -- if we can't tell what the average accelerations are, we could hardly start talking about what the slope of the acceleration curve is.

Q But didn't you say you had an opinion as to --

A Well, I think there will be attenuation of high frequency energy as it goes away from the fault, and therefore that there will be a decrease in acceleration with distance away from the fault.

Q Linearly?

A No. Again, I can't imagine that we have enough knowledge -- we don't have enough knowledge, in my opinion, or enough data, to say whether it's linear or not.

Q Let me ask you this:

Do you really believe that for one out of every

10 7.5 magnitude earthquakes that occur that within 10.5 km of the fault you're going to have 245 percent gravity occurring?

A "Really believe," with the emphasis that you put on it, sort of . . . I'm not sure what you mean by that emphasis.

I have no reason to doubt the extrapolation that he made in terms of fitting the data, and so forth. And the data are too limited, and I understand the physics is too limited, to say what the probabilities are.

Everything seems to suggest the fact that we have a couple of accelerations around 1g, and we've only got so much limited data, that eventually there'll be something -- a factor of 2 -- our knowledge of the subject is such that a factor of 2 is not an unreasonable amount of variation. So they could be over 2g.

Q Well, I know you said that you didn't have any expertise in whether buildings would stand or fall, but weren't you very active in and involved with the La Jolla -- about an apartment building being built, and the schools, the standards to which they are being built, for earthquake? Weren't you personally involved in that?

A I don't remember the exact details, but . . . what was the first part of the question again? You know that I -- about building damage.

Q You stated, when I asked you about the L.A.

wel 3

Coliseum withstanding 400 percent of gravity, you said, well you didn't know whether it would or not, because you didn't have any expertise.

A Well, I also said it depended on the frequency. I said that there's no doubt in my mind that at very high frequencies like 50 cycles it'll stand it.

But, as I say, if you're trying to get me to in exact details tell how a building would stand a certain amount of acceleration, that's when I said that that's outside of my expertise.

But I'm willing to tell you everything I know about the response of the buildings and how that implies on acceleration, which I think is what you're . . .

Q Well, I guess what bothers me is that, as I understand the building codes up and down the State of California -- and I understand the San Diego area where you live is lower than, say, Los Angeles, which is probably a little bit higher than San Francisco -- they're calling for 10 percent to 20 percent gravity -- the best ones -- for hospitals, schools, auditoriums, buildings where thousands, tens of thousands, and even up to 100 thousand people congregate at one time. And when I see numbers like 245 percent of gravity as being predicted for one out of every ten 7.5 magnitude earthquakes, I'm very surprised.

So my question to you is: If you really believe

these numbers, would it be your opinion that these codes, these recent earthquake codes for Los Angeles and San Francisco, and so on, are nowhere near what's necessary to protect the buildings?

MR. FLEISCHAKER: Objection. I'm going to move to strike that whole speech on codes and thousands of people, and the figures there. There's just no basis for that in the record.

MR. NORTON: Well, we can go through the basis and lay the foundation. I think the objection is properly taken. And I will do that.

BY MR. NORTON:

Q You are aware of the building codes of Los Angeles, are you not, as to the g values specified?

A Yes. I think I can clear you up on my understanding of the topic you're aiming at, and that is, as I mentioned in my testimony, one of the arguments against the high accelerations is the fact that the building damage that's been observed has not been as high as the engineers would have predicted for such large accelerations. That's the point you're getting at.

Again, that's -- that's not the point?

Q No, but go ahead.

A Okay.

Q Your testimony is interesting, anyway.

A. As I said, I'm not an expert in structural response. So whether or not a building should be damaged at a certain acceleration or not, I don't know.

But I do know the history of the engineers attempting to say what the peak ground motion should be on the basis of this. That is, I know that in the past there was a time, as mentioned in Dr. Newmark's testimony, when the engineers argued because the building damage was so low that the accelerations couldn't be over .5g for many years, until there was a record that was recorded of .5g.

So there's a long history of the argument that the building damage is not what you'd expect for these large accelerations and, therefore, they don't occur.

This is essentially what I would say is using a building as an accelerometer, and I think that's an important point that it's very important to society to get straightened out, as to what that is. As I understand it, that's the reason for the introduction of the concept of effective acceleration and so forth.

What I see as the final answer, the satisfactory answer, that we need to come to is when we put in an accelerogram of a certain acceleration and certain type, and so forth, that we do accurately predict the damage to the building. And then when that situation arises, then I would say, okay, at that time it's all right to use building

wel 6

damage as a measure of ground acceleration. But up until that time, I would say that I would put much more faith in the actual accelerograms to estimate what the ground motion is, rather than estimating the acceleration from the building damage.

Q Okay. And you would use the accelerograms in lieu of some mathematical extrapolations too, wouldn't you?

A Yes, right. Well, not in lieu of. I'd say in preference to.

Q Yes.

A Yes. I think we need to get more acceleration data.

Q Well, then, what acceleration would you recommend for design of buildings that I've described, hospitals, schools, auditoriums, that have large collections of people continually?

A I have not thought about the building design problem.

Q Well, now, weren't you very involved in La Jolla in just that question?

A To a certain extent. I was working with a fellow professor there, Gilbert Hagemeyer, who was the engineer, and --

Q Regarding schools, apartment buildings?

A Yes, he's the one -- I was sort of the seismologist and he was sort of the engineer, in talking. So the

wel 7

combination of what we were discussing there -- but I'm willing to say that for -- you're asking me as a citizen, now, to sort of take into account all the --

Q No, I'm asking you as one who used a statement, relied on a statement, that one out of every ten 7.5 magnitude earthquakes would produce free field accelerations of 245 percent of gravity.

A I quoted that as one of the pieces of information that's in the literature about what accelerations might be expected in the near field.

My main point in my testimony is not that that's a valid number for extrapolation, but that we don't know what the true accelerations to be expected are.

I'm not taking Trifunac's number and saying, okay, that's what I think we ought to design buildings for, that that's the appropriate number.

I'm simply citing that as one of the studies, and I prefaced that whole section by saying we don't have enough data, and all these authors, whether they come up with low values or high values, have always prefaced their studies by saying we don't have enough data to know what the true accelerations are.

ake 4

MR. NORTON: While I've been cross-examining, some people have gone to the transcript for the previous objection made by Mr. Fleischaker. The transcript is from

wel 8

December 15, 1978. It starts at page 5845. We are talking about Mr. Bolt, who says:

"May I add something?"

And he then goes on for three or four pages.

(Laughter.)

So we'll move over to where the appropriate data is, 5847, at the top.

"The Pacoima record and this acceleration of 1.2g was a very important pivot point in their argument. Since that time we have had one other record which bears I think more importantly on the assessments. That was on September 16th in Iran, a record obtained in the City of..." --

and I think we have a typo here -- it should be Tabas --

"...Tabas which was five miles from the end of the fault rupture.

The fault rupture, again according to the U.S. Geological Survey people just published in the Newsletter of the Earthquake Engineering Research Institute, was thrust-type faulting, so this is, according to the testimony that we have given in this submission, likely to be on the high side. And the magnitude, the M_s magnitude for this earthquake is variously given as 7.7, 7.8. We got 7.8 at Berkeley on our calculation.

wel 9

So this would be the highest acceleration -- I'm sorry, this would be the closest acceleration ever obtained on an instrument near to a great earthquake, 7.7, 7.8 magnitude, and the peak acceleration was about .8g, in flat contradiction to the extrapolation that was carried on in this particular circular..."

and we were referring to Circular 672 --

"...which reinforces my view that the basis of that particular argument is on very -- shall I say shaky ground?

(Laughter.)"

So that's where the data for our numbers came.

Could we have a ruling on the objection?

MRS. BOWERS: We can proceed with the questions now that you've --

MR. NORTON: I think Mr. Fleischaker made a motion to strike my questions and answers.

MRS. BOWERS: Well, the motion is denied to strike. We now have specific information.

BY MR. NORTON:

Q You still haven't answered my question, which is: what you would recommend for the types of buildings that I have described.

Are you not going to answer that question?

A I'd like to have some time to think about it.

WEL/mpbl

As I say, it's -- I'm not sure exactly in what context you're putting it in.

MRS. BOWERS: On the basis of the present information if we have a sensitive building very near an active fault which could have a magnitude 7.5 earthquake, is that what you're --

BY MR. NORTON:

Q You have a lot of buildings very near faults in Los Angeles and San Francisco. San Francisco is loaded with them. The San Andreas goes right up through the whole Bay area, does it not? You have a tremendous number of buildings within ten kilometers of the Hayward, Calaveras, and the San Andreas. You know, that's what I'm talking about.

MR. FLEISCHAKER: I'm going to object to this line of questioning on the basis of relevance.

We're not talking about general structures like hospitals and schools, and even those kinds of sensitive structures. We're talking about a particular structure, the Diablo Canyon.

That structure has a frequency range which is quite different from schools and hospitals generally. It also has equipment, valves in it, that is quite different from the kinds of equipment that is in schools and hospitals, so that the number that might be appropriate for a general

WEL/mpb2

building code aren't relevant to the discussion before this Board.

The discussion before this Board is what are the appropriate numbers for the Diablo Canyon Nuclear Power Plant assuming a 7.5 magnitude earthquake on the Hosgri fault.

MR. NORTON: I'm not going to respond to that in very great detail, except that Mr. Fleischaker doesn't know what he's talking about. In some instances he says we're interested in entirely different frequency ranges. He's just absolutely wrong.

But we certainly have the right to go to the numbers used in this man's testimony and ask him how he would apply those numbers to the real world. And the real world isn't limited to just Diablo Canyon and earthquake engineering. There's been all kinds of testimony about different kinds of buildings, what kinds of buildings have withstood earthquakes of great magnitude. There was testimony about San Francisco and all the buildings there. There was testimony about Lachupada Steel Plant, I forget all the places that Dr. Blume has testified about. There has been testimony by this witness about a 7.8 or 7.9 magnitude earthquake in Mexico with very little damage.

He's here to talk about earthquake engineering or earthquakes and seismology, and limit it to one little spot on the face of the earth, that's a little bit broader

WEL/mpb3

subject matter than that.

MR. FLEISCHAKER: Well, let's get two things separated here.

The first thing that we were talking about was the relevance of the numbers that might be contained in building codes which are used for design of schools and hospitals.

My objection stands on the basis that his questions were directed to soliciting that kind of information from this witness is irrelevant for this discussion.

But more broadly, or a different kind of objection is that the kinds of information that Mr. Norton is seeking to obtain, or the kinds of testimony that he is seeking to elicit is beyond the scope of this witness' expertise.

Dr. Brune is a seismologist, and I think before he said he wasn't a structural engineer and he wasn't prepared to talk about the appropriate numbers that should be utilized as the zero period limit for the design response spectra for the Diablo Canyon Nuclear Power Plant, or the zero period limit for any response spectra for any facility. That's the kinds of things that Dr. Trifunac and Dr. Luco talk about. That's the kinds of things that Dr. Blume is imminently qualified to talk about. That's the kind of thing that Dr. Newmark is qualified to talk about.

wel 1

MR. NORTON: Mrs. Bowers --

MR. FLEISCHAKER: So I'm going to object to that line of questioning.

MR. NORTON: One thing. And that is that this witness just testified that seisologists should set the standards. He just testified to that. And now Mr. Fleischaker is saying he isn't qualified.

Well, I don't quite understand that.

THE WITNESS: If I said that the seismologist -- I hope I can have that quote corrected, if that's exactly what I said. That seismologists should set the standards? I don't recall that. And I don't know what "the" standards are.

MR. NORTON: We were talking about the building codes, we were talking about the numbers for g's, and you were in your discussion about the buildings being accelerometers and the strong motion records.

THE WITNESS: I did not say that the seismologists should set the standards. What I said is that in our present status as far as me as a scientist answering what the true ground accelerations are, I would trust the evidence from the accelerometers before I would trust the evidence from buildings.

MR.NORTON: I know you said that. But I think --

THE WITNESS: And so if the question is what the

true ground acceleration is, not what the building design level would be, or, as I said, some structural engineering ~~question,~~ the standards --

MR. FLEISCHAKER: Let me interrupt you. I have two objections pending before the Board.

The first objection goes to the line of questioning. The question that was pending before this witness had to do with what standards he would set for general building design codes having to do with hospitals, and I object to that on the basis of relevance.

The second objection had to do with pursuing this whole line, trying to get this witness to testify about the design levels that he would specify for the Diablo Canyon nuclear power plant.

I believe he's testified before that he is not an engineer, he is not a structural engineer. He's a seismologist.

MRS. BOWERS: Does the Staff have a position on this?

MR. TOURTELLOTTE: Yes. I think the matter can be resolved if you consider the focus of the question. The focus of the question -- no pun intended -- is not on what this witness would do relative just to hospitals and other buildings. The real import of the question is how does this witness apply his science in the real world. The questio

wel 3

is what application does he make of the figures that he comes up with.

Now, that doesn't necessarily mean that this witness would go so far as to make an application that a structural engineer would make. On the other hand, I think the testimony throughout the proceedings have clearly indicated that there is a relationship between seismologists and the structural engineers, and that seismologists do have some kind of input into the basic data used by structural engineers.

And it seems to me that that is the focus of the question. The question is what kind of input would this witness made as a seismologist in the real world, given the substance of this testimony.

MRS. BOWERS: Mr. Tourtellotte, the basis for the -- there are two objections, one relevancy and beyond the expertise. Now, are you saying that you think there could be relevancy and it's within the witness' expertise?

MR. TOURTELLOTTE: I guess I'm answering both of those, because the relevancy is that this witness, as a seismologist, has the basic information, part of the data base that the structural engineer uses to come up with his design.

Now, the structural engineer may do something else once he gets a 1g or a 1.5g or 2g, or 2.45g, the

structural engineer may do something else.

The question is, what value is it that this witness is going to give the structural engineer for the design of any plant, it doesn't really make any difference whether it's hospitals, or anything else. That's the first place.

The second place is it is within his expertise, because I think way back when we got into the business of seismology and structural engineering there was a clear indication on the part of the witnesses, which was not contradicted by anybody, that seismologists at times worked over into and overlapped -- the word was "overlapped" I think -- with the structural engineers, and structural engineers overlapped with seismologists.

There isn't a clear-cut line between the two, and there is an area of expertise which the seismologist has that makes a considerable input into the structural engineer's analysis.

MB fls

ADELON
c8 mpbl

MRS. BOWERS: Well, the fact that they talk to each other and the seismologists give information to the structural engineers, does that in any way, then, give seismologists expertise in design of buildings?

MR. TOURTELLOTTE: No, not in the design of the building.

But the question obviously in an ordinary -- again, we're talking about the real world. A structural engineer is going to say I've got a building to build and my building is going to be in Los Angeles, it's within X number of miles of this fault, and I don't know what the capabilities of the fault are, I don't know what values might be assigned; but I'd like for you to do me a study that would show what kind of accelerations I might expect at this place so that I can figure out what the design of the building will be.

Well, in effect he's asking for some sort of a parameter from the seismologist which would tell him how to design the building, and to an extent he makes a contribution to that design. That doesn't say that he's designing the building, but his basic information is put into the design by the structural engineer.

MR. FLEISCHAKER: I agree with Mr. Tourtellotte.

And if I can -- just to make sure we understand the focus of my objection:

mpb2

There's no question but this witness and any other seismologist has useful information to give a structural engineer. And that information is his estimate as to the parameters of ground motion that can be expected at the site, with the velocity of the acceleration, the velocity, whatever.

The basis of my objection, though, is that in these questions he is requesting this witness to select the zero period limit. He is expecting him, or requesting him to designate the acceleration values to be used in the design that scales the design response spectra. And that's the nature of the objection. Not that he gives information to engineers regarding ground motion parameters; but that he should do the selecting of the number that scales the design response spectra. That, I think, is an improper line of questioning.

So I agree generally with what Mr. Tourtellott's been saying.

The objection stands.

MRS. BOWERS: Mr. Norton, you were talking also about some of the codes that relate to schools and hospitals.

MR. NORTON: Yes.

MRS. BOWERS: And you referred to the numbers of those codes.

MR. NORTON: Yes.

mpb3

And Dr. Brune, I think, assented that those numbers were correct. I started to lay the foundation and he kind of went ahead and answered a portion of the question without really answering whether he agreed with those numbers. But I got from his answer that he did agree with those numbers.

MRS. BOWERS: But do those code numbers -- I need a little education.

MR. FLEISCHAKER: I see Dr. Brune shaking his head --

MR. NORTON: Yes, we were talking about the Los Angeles Building code, for example, .1 to .2g for hospitals and so on, and I gathered that he agreed with those numbers. Maybe he didn't.

THE WITNESS: No. Agreed with them? You mean agreed that those were the numbers or that those should be the design numbers?

MR. NORTON: That those were the numbers of the code.

THE WITNESS: No, I don't know exactly what the numbers are.

BY MR. NORTON:

Q But they're in that range?

A Yes.

MRS. BOWERS: The Board would like to consider this matter. We have objections pending.

mpb4

7.040

(The Board conferring.)

MRS. BOWERS: Well, we're going to overrule the objection with the understanding that this witness has testified as to his role when he was dealing with an associate who was a structural engineer and how it was a combination of the two disciplines that got him involved with code matters.

So we think, while there's relevancy, that perhaps it has limited value.

So why don't you proceed?

MR. NORTON: All right.

BY MR. NORTON:

Q Let me ask this:

The schools and the apartment buildings that you were interested in in La Jolla, were they within ten kilometers of a fault?

A Yes, some of them were, yes.

Q All right.

And was that fault capable of a 7.5 magnitude earthquake?

A I don't know that, no.

Q Well, do you have any idea of what the magnitude was that it was capable of?

A I think that it's really not known. That's one of the problems. In some studies it said that I believe it

mpb5

was a 6.75 or 7 earthquake. It's possible in that area. And I think that in the realm of possibility, it's possible that there could be a 7 earthquake there.

Q Okay.

And as far as this distinction between a 7 and 7.5, it isn't that critical, is it?

A I'm not sure what you mean by "that critical".

Q Well, the idea of accelerations in the near field, the distinction between a 7 and 7.5 isn't really that critical, is it?

In other words, if you've got a facility within 10 kilometers of a fault, and there's a 7 or 7.5, it doesn't really make much difference whether it's a 7 or 7.5 in terms of the acceleration that facility is going to see for the near field, does it?

A It depends on what you mean by "much difference". In the terms you use there's a probabilistic sort of increase in the probability of high accelerations as you increase the magnitude.

Q Right.

But it's not a significant consideration, the significance between 7 and 7.5 in that circumstance, is it?

I believe we discussed this in the deposition.

A Yes.

Well, I wouldn't say that it's not significant;

mpb6

but I would say that you can't draw -- that we don't know a nice relationship to draw to say that the acceleration at 7.5 is a certain value, whereas that at 7 is a certain value.

Q All right.

Well, let me ask you this:

What was the acceleration that you suggested be used in the codes for those schools and that apartment building within ten kilometers of that fault?

A I don't recall.

Q Was it higher than .5g?

A I don't recollect.

Q You have no memory of that at all?

A No, I don't remember the number.

Q Was it accepted?

A I don't remember that either.

Accepted by what? By the....

Q Whatever you proposed. Was it accepted by the people that --

A No, I'm sorry, I have forgotten about that and the details of it. And also, as I say, I was involved with another person and I don't remember. Most of my input was -- well, I don't remember exactly what the details were.

Q All right. Let's move on.

Page 3-13 of your testimony, the last paragraph:

"It should be noted that the Hosgri fault

mpb 7

is curved northwest of the Diablo Canyon site."

Where did you note that from?

A From a couple of the maps that I've had.

Q What maps?

A I would have to look them up in order to get them.

Q You can't tell us whether it was an Applicant map, whether it was a Dr. Silver map, or anything more about it than it was a map?

A Well, other than I looked at a couple of maps and looked at the -- I think I looked at both of them, but I can't remember exactly. You know, I couldn't swear that I....

Q Well, your next sentence is the one I really want to talk about anyway.

You say:

"Thus, although the site is about five kilometers from the fault at its nearest point, it is much closer to the projection of the fault using the trend northwest of the site."

The first time I read that sentence I said, Gee, he's got the plant closer than five kilometers from the fault. But then I read a little bit more carefully and I don't get that meaning of it.

But the problem is the more carefully I read it the less I understand it. I just don't understand what you mean "it is much closer to the projection of the fault using

mpb8

the trend northwest of the site."

Are you saying that you find a point on the fault, that someplace on that fault it's pointing at --

A Yes.

Q -- the facility that, and then you put a ruler somehow and run that imaginary, now, fault, that you can run it through the site somehow?

A Yes, right. As I said, it's closer to the projection using the trend northwest of the site.

Q Oh, but that projection still doesn't go through the site?

A I think there's some latitude in how you draw that. It's possible you could draw it so it went through the site.

But my estimation of what it was, no, there was just somewhere it was closer, but not through the site.

Q All right.

Well, how long a stretch of the site is it that you're projecting from to send waves to the site? How long is that piece of fault? Is it a kilometer, is it 100 kilometers, what is it?

A No. On the map, as I recall, the number I -- the area I looked at was just a few kilometers long, but it all depended on making the statement -- I was aware of the controversy about whether the Hosgri fault in fact connects up with

mpb9

the San Simeon fault, and so the question is exactly where does the fault go and where do you draw the tangent to it. And that's why I said the statement at the end, that a calculation should be made to see what the effect is.

I could not, from my own mind, from the various testimony from geologists that I'd heard and so on, decide for sure where the fault went up in that direction. So I suppose part of my implication in saying a calculation should be made was not only just not trying to imply that I knew exactly where the fault was, but, rather, saying that if someone does know exactly where the fault goes, that-- and if this can be established, or the boundaries can be established within reason, then a calculation should be made for a rupture going along that particular section of the fault and see if this effect occurs.

I don't know whether it does or not.

Q Well, how would you suggest that one go out and specifically do what you're suggesting be done?

A Well, I would take the various reasonable possibilities for where the fault goes, and then put a -- do a number of models of dislocation propagating along the fault in that direction, similar to what Boore has done for the San Francisco earthquake, or various other people, and try a whole bunch of different combinations of rupture along the various possibilities for the fault, and see if in those

mpb10

in any case there was more focusing than we expect.

Q Well, let's talk a little bit about focusing.

You know, we talked about focusing, but we really didn't talk about how long focusing lasts. We talked about the coherency of the rupture as kind of the controling factor as to how much focusing you get.

What we didn't talk about -- you know, let's assume we have a nice fault rupture that goes in a straight line, and then, boom, goes off at a 45 degree angle, so that we can talk about a straight, you know -- let's say we've got focusing that occurs before the fault turns away, so that we've got, you know, a nice straight line that we're talking about.

How far out from the direction of that line is focusing going to remain intact?

Do you see what I mean?

A Yes.

Q Let me see if I can make it a very discrete -- let's say you have two waves that focus, that you have just enough velocity. The velocity of the propagating rupture and the velocity of the propagating waves are the same for just two waves, so that you have a double wave, okay? So you've got, instead of one wave, you've got two waves traveling straight out from the end of that fault. That just happens to be the way it works out.

mpb11

How long are those two waves going to stay together and have a focusing effect? Is anything going to interfere with them?

A I don't know the answer to that question. I think what needs to be done is to take a realistic model of velocity layering in the earth or velocity structure, put in reasonable models of dislocation, and see in any given case how much it occurs.

Q That's never been done?

A It may have been done for a few cases, but to follow the line of reasoning, I'm not aware that it's been done for the case of the Hosgri fault. In other words, actually someone has gone along, decided what the possible variations of the fault are, what's the possible range of dislocation models and types, and then gone and done the series of calculations to see what the effect is, so that --

Q Okay.

Well, there's lots of things that interfere with focusing, aren't there? You have to have coherency, and coherency is very easy to get in a laboratory, isn't it, with a model? You can get coherency there almost 100 percent, can't you?

A Yes.

Q But in the real world, you know, the real rocks that exist out there, it's pretty difficult to get anywhere

mpb12

near 100 percent coherency, isn't it?

A It's hard to say. I'd say it depends on --

Q All right.

But let's say this:

You would say this, wouldn't you: that even if you could achieve close to 100 percent coherency for any moment in time, any brief moment in time, the longer out you go in time, that coherency is going to fall apart, isn't it. I mean, as you start traveling over distance, the more distance you travel, the less coherency you're going to have, isn't that correct?

A To a certain extent. It depends on the wave lengths and the velocities, variation in the structure, and so on. But in general, yes.

Q But it's the real world, and those things aren't going to mesh together very well for any length of time in the real world, are they?

A Those are qualitative statements. By "any length of time" or "in the real world". I would just say that as far as I know there have been, as I said -- I say what I said in my testimony, that the phenomena has been demonstrated to exist in ruptures. And we don't know exactly how effective it is in the real world.

There's two ways to reduce the uncertainty: one is to get a lot more data, and the other one is to do more

numerical calculations and see.

Q Well, theoretically if you had a building built on a fault and the fault, say, had -- well, let's take the 1906 earthquake. Let's take the 400 kilometer -- no, it was more than that. The San Andreas is -- what -- 700 kilometers long, something like that? And you had about a 200 kilometer rupture along that fault. If you got focusing for the entire 200 kilometers and you get to the end of that 200 kilometers where the building was, you could send it to Venus, couldn't you? I mean, it would just blow it right away, wouldn't it?

If you had that kind of focusing for 200 kilometers it would just -- it would be an incredible explosion, wouldn't it, an incredible amount of energy?

A I wouldn't use any of those adjectives that you used.

But I would say that we really don't know yet for a propagating dislocation and a given stress drop in certain and realistic layering situations what the effective amount of focusing is.

Q Well, but you don't really believe that you could have focusing and coherency of a rupture for 200 kilometers, do you, Dr. Brune?

A It depends on which wave lengths you're talking about. I don't think it's likely -- it's not going to happen

mpb14

at very high frequencies. But --

Q Okay.

Let's talk about frequencies.

MR. FLEISCHAKER: Excuse me.

I'm going to object because Mr. Norton is not permitting Dr. Brune to complete his answers. I know that when an expert begins an answer you want to jump in with a question, because that happens to me. But I would appreciate it if Mr. Norton would permit Dr. Brune to complete his answers. And I'm going to object on the basis of that.

BY MR. NORTON:

Q Go ahead and finish, Dr. Brune. I'm sorry.

A I'm trying to recall exactly the context.

Q We were talking about propagating -- a rupture having coherency for 200 kilometers, and you said, Well, it depends on what kind of frequencies you're talking about. I interrupted and said, Okay, let's talk about frequencies.

A What I was going to say was that the Boore and Joyner study which introduced coherency on the fault as it propagated along still concluded, as I quoted in my testimony, but in this case the accelerations were even higher in the case of incoherency.

Now this is partly, I think, because of the way they normalized the results. But that just shows that the effect of incoherency propagating along does not get rid of

mpb15

the fact that there is more energy focused in the direction of rupture propagation.

Q All right.

Let's talk about frequencies.

Focusing waves are -- frequency is a component of a wave, is it not? I don't know if that's the right word. Waves are measured in terms of frequency.

A Yes.

Q All right.

Now what frequency is of interest to buildings? Do you have any idea, for example, what frequency Diablo Canyon buildings are concerned with?

A Again, that's sort of outside my area of expertise. But as I recall, there is quite a range of frequencies for different components, depending on whether it's pipes or the main building, or so on.

Q But generally it's high frequencies. It's not what we would term low frequencies, is that correct?

A No, I wouldn't --

Q Well, how do you define a low frequency?

A You would define it in each given context, according to -- I mean, if the building has a certain period, then what you call low frequency or high frequency might shift, depending upon what the context is.

Q Well, we've been listening to seismologists and

mpb16

structural engineers for weeks now, and they've used the terms high and low frequencies rather easily without any problem. And we've never had a problem with definition, I don't think, up to this point in time.

Generally frequencies below five hertz have been termed as low frequencies and frequencies above five hertz and up have been termed as high frequencies.

Do you have a problem with that basic definition?

A Yes.

I think that's the way to approach it rather than low and high frequencies. Simply tell me the frequencies you're interested in.

Q Okay.

Well, but the testimony, the record to this point in time talks about low frequencies and high frequencies, and it's generally been low frequencies of one hertz, .1 hertz, et cetera, okay?

MRS. BOWERS: Mr. Norton, are you beginning on what is a rather long interrogation on a particular point? Perhaps we should break for lunch.

MR. NORTON: Well, this particular point I'd like to finish. It's not a long one, it's fairly short.

BY MR. NORTON:

Q Isn't it true, Dr. Brune, that the phenomena of focusing is one which affects low frequency waves much more

mpb17

than high frequency waves?

A I believe that's true. I almost certain that in most contexts that's true. There's a little bit of uncertainty in my mind about the interpretation of this Boore and Joyner paper where they introduce incoherency in a couple of different ways.

One is they introduce it by the variable velocity and another one by a variable amount of dislocation. But basically I think that's correct.

And in the case of a, say, a uniformly propagating rupture on which you introduce a variable amount of slip, say, or a variable amount of rupture, then that's certainly true. As you go to the higher frequencies, that introduces incoherency in those.

So the effect of focusing would become less.

Q In other words, at one hertz you're apt to have much more focusing at one hertz or lower than you are for example at ten hertz?

A I think that's correct, yes.

Q All right.

MR. NORTON: We can take the lunch break now, if you want.

MRS. BOWERS: Fine.

We'll resume at one o'clock.

(Whereupon, at 12:00 noon, the hearing in the above-entitled matter was recessed, to reconvene at 1:00 p.m., this same day.)

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AFTERNOON SESSION

(1:00 p.m.)

MRS. BOWERS: Are we ready to resume?

C9

Whereupon,

JAMES N. BRUNE

was called as a witness on behalf of Joint Intervenors, and, having affirmed that he would speak the truth, was examined and testified further as follows:

CROSS-EXAMINATION (Continued)

BY MR. NORTON:

Q Dr. Brune, I asked you to get out the maps on which you relied in arriving at the statement in your testimony, and I'll have to find it here, that we were discussing earlier today on 3-13 regarding the projection of the fault, the bend in the fault and so on. Do you have those maps?

A What I have is, I looked at several maps, what I have is a tracing I made off of one of the maps, and unfortunately I didn't label which one it was but I can find out later.

The other one is a Xerox copy of the fault map from the California Division of Mines and Geology.

Q Now this tracing that I'm looking at, you have no idea where that came from?

A I don't remember which one of the maps I had, and when I traced that one off, it was among the group of maps

WRB/agp 2

that had been sent to me about faulting.

Q My problem is what I have here is a tracing with no key as to distance, I have no way of checking the map and no way of verifying what your testimony says.

There is no way you can supply that information to us?

A Well as I said, what I did, I took that and traced the map and I don't remember which map. I looked at the other map you have and I looked at some others. The one that I drew, I drew a tangient on it and it pointed almost at the fault. And I looked at another one, the one that you have in your hand now, the California Division of Mines, and when I drew the tangient on that it did not.

Q Yes, as I look at this California Division of Mines and Geology map I don't see any band that would project toward Diablo Canyon at all.

A Well there's two traces on the upper end of the Hosgri Fault there.

Q Well they're far more than 20 kilometers away.

A Well the one end -- the precise distance at which you say the focusing stops I don't know exactly.

Q But the band where the focusing would have to start or stop, in other words, where the projection would start is far more than 20 kilometers on this map, far more.

A May I look at it?

WRB/agb3

Q Sure. But I really wish you would give some thought as to how we identify -- this is just a sketch in your hand in pencil, there's nothing on it to indicate where it's from or what the basis for it is.

MRS. BOWERS: But he's testified he simply doesn't know.

MR. NORTON: Mrs. Bowers, he's got testimony in his testimony that, indeed, it's 20 kilometers. And there's no way to pursue that.

THE WITNESS: Well I think I can explain that, and that is that the distance, 20 kilometers, is not a precise number like you can put your finger right on that point and say that's where it is. What needs to be done is what I mentioned in the testimony, that is, you need to take the actual shape of the fault and do the calculation on it, and then try the various -- if you can eliminate everybody else's interpretation you could probably just do it with one, but I would think you would want to take various geologists' interpretation and try those.

BY MR. NORTON:

Q But you have a statement in your testimony that says:

"Energy released about 20 kilometers up the fault could be focused nearly directly at the Diablo Canyon site." Period. Now that's a

WRB/agb4

statement of fact. Am I now to understand that that's just one of many possible possibilities?

A Yes. The "could" implies that until you've done the calculation, you don't know whether it will or not that's the whole purpose of doing the calculation.

MR. FLEISCHAKER: Excuse me, may I have those, please?

MR. NORTON: Surely.

(Handing to Mr. Fleischaker.)

MR. NORTON: Mrs. Bowers, I would like to take a moment and see if we can find which map that tracing comes from. There aren't that many maps, and I think we have most of them in the prepared testimony and perhaps by overlay process we can find out which one it comes from and then show that map to Dr. Brune and he could tell us whether or not that's the map.

MRS. BOWERS: Well let's take a few minutes and do that.

(Pause.)

THE WITNESS: Figure 30 shows where Hoskins and Griffiths pointed the fault, and the curve that they've drawn, it could be, the tangient would be even on the other side of the -- as I said, I didn't just look at that one map, you happened to pick one that is one that I Xeroxed but I looked at the other one, if we look at that one, we'll

WRB/agb5

see that it's certainly true, Figure 30.

BY MR. NORTON:

Q Well, but which is the map you did your tracing from, can you determine that by looking at both maps?

A I don't think we can, because it was on a bigger scale, it wasn't a reduced map like this. As I recall, it was a bigger scale map.

Q Well, would you look at Figure 44 in the testimony?

A Yes, I'm looking at it.

MRS. BOWERS: We're going to have to have a brief recess, long enough for me to make a telephone call.

(Brief recess.)

MRS. BOWERS: Will you proceed?

BY MR. NORTON:

Q Have you found the map from which you made the tracing?

A No, I haven't.

Q You have not been able to identify it?

A No.

Q Well Dr. Brune, looking at Figure 44 of the direct testimony of Hamilton and Jahns, do you have that in front of you?

If it's Figure 44 in the bound testimony, that's whose testimony it is.

A Yes.

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Q All right.

Now as I look at that figure, the only band I see is in excess of 20 miles away from the site. Can you verify that with a piece of paper using the scale?

Is that correct?

Could you use a piece of paper instead of your fingers, I think sometimes it works a little better.

A Yes.

Q It is in excess of 20 miles?

A It looks about 20 miles.

Q Okay. And 20 miles translates to what, approximately 32 or 33 kilometers?

A More than that.

Q More than 33 kilometers?

A Yes, that's about right.

Q Okay.

Now Dr. Brune, in your deposition, I believe we discussed what was the near field, and you said it's generally accepted as the smallest dimension of the fault in question, whether you're talking about fault length or fault depth. And you were talking about most faults in California are assumed to be 15 to 20 kilometers in depth and that, therefore, the near field would be 20 kilometers.

That's my memory of your deposition. I don't have it open, but generally that was the discussion. Is that a

WRB/agb7

correct --

A Something of that order, yes.

Q Would that be a correct definition of near field, then, generally around 20 kilometers?

A I would say, depending on the context, yes, that would be a reasonable number.

There's not a sharp transition between near field and far field.

Q I understand, you just have to arbitrarily give it a label someplace, and that's generally what one means by near field though is something within 20 kilometers in California, is that correct?

A That's correct.

Q And in your testimony, when you use the term "near field," you are certainly not talking about anything other than that are you, Dr. Brune?

A In my testimony in talking about near field?

Q Yes, when you use the term "near field," you don't mean something greater than 20 kilometers, do you?

A No.

Q All right.

A Well -- I don't believe I've testified about near field yet. But you're asking me what I would use? I think in this context it would probably be correct, yes.

Q Okay.

WRB/agb8

So then the Diablo Canyon site would not be within the near field of any focusing phenomena from the Hosgri, is that correct?

A Yes, in that definition, yes.

Q Now one last thing, you were talking about some sort of a study that should be done on the bottom of Page 3-13 you say:

"A calculation should be made to estimate the effect of focusing in this case."

Can you tell me anyplace where such a study, calculation has been done?

A No, not that I know of.

Q Going to Page 3-11 of your testimony, at the top of the page, you're talking about stress drop, velocity, acceleration, and you talk about Kostrov model and you say:

"Figure 1 shows the particle velocity and acceleration observed at the surface along the projected strike of the fault for a buried vertical circular fault (center at seven kilometers depth) expanding like a Kostrov model (propagating stress drop) to a radius of five kilometers and stopping. The epicentral distance is six kilometers."

And then you start talking about velocities of 1.8g accelerations, velocities of about 1.8g. And you say:

WRB/agb9

"This result dramatically illustrates the effect of focusing."

Is this in any way a real world model? That perhaps awkwardly phrased, how about does this model in any way represent what happens in the real world?

A Well it represents it in the sense that you could have a rupture starting at a point and rupturing out to that kind of a distance. In other words, it's conceivable that you could have a rupture like that in the earth. The way that it does not represent reality, perhaps, is the fact that the model is a half-space rather than a layered space.

Q Well let's talk about some terms that haven't been introduced, I don't think, yet. Let's talk about a crack tip, what's a crack tip?

A If the rupture propagates along in such a way that the rupture, you can specify along a certain plane that at a certain point a rupture has occurred, then shortly after that or shortly in front of that the rupture has not occurred, so you can draw a nice even line at the point between where rupture has occurred and where it hasn't occurred. Then you probably would use the term "crack tip" to represent the edge of the crack traveling along.

Q And what do you measure at the crack tip, commonly? Is it stress?

WRB/agb10

A You mean on strong motion seismographs or, what kind of measurement are you referring to?

Q When you're talking about a crack tip in terms of the Kostrov model, what level of stress is the Kostrov model assumed to exist at the crack tip?

A Oh, there is a singularity in the stress at the crack tip.

Q In other words, it's an infinite stress at the crack tip?

A Yes.

Q That's what the model assumes.

Now could you tell me where in the world I could go to observe infinite stress at a crack tip?

A No, in the real world, there would be some filtering at high frequencies because the stress couldn't achieve that value.

Q Well isn't it a fact that the maximum acceleration and velocity depend on the stress drop at the crack tip?

A That is correct, yes.

Q Well so what is the use of this model for purposes of this hearing, what's the advantage?

A It has been filtered to 12.5 Hz. which means that, to a certain extent, the singularity -- and you are not on the singularity -- so the purpose of it is to.... Once you get right away from the crack tip, you can use the model to get

WRB/agb11

a rough idea of the type of energy that is radiated from the fault.

Q Well how about stopping? How is that introduced in the model, is that a real phenomenon?

A Well again a fault could stop in that manner, that is, the stress -- the rupture front could stop and heal this way back. That's not the only way, there's lots of different ways that it can stop.

Q Can this model be demonstrated in the real world?

A You mean could a laboratory model be made of this?

Q Could this occur in the real world as you have it here?

A Exactly?

Q Infinite stress?

A No.

Q Let me ask you this:

We've talked about focusing and you say we need more data, we need more data. How, if you were going to collect the data, would you do it?

You know, you're given a reasonably large sum of money to go out and collect that data at a point, at some place. Unfortunately, you may have to wait a lot of years to get your 7.5 magnitude earthquake. But let's assume that someone has the ability to tell you there's going to be a 7.5 magnitude earthquake on Fault X, and we want you to go out and

WRB/agb 12 capture focusing for us. How would you do that?

A Well basically I would put a dense array of strong motion and other types of instruments around the fault, so I could measure the radiation at a large number of different places.

Q How many? When you say "a dense array," are you talking about 100 strong motion instruments or five?

A It's one of these things that you would try to get as many as you can, but practical reality would limit the number that you could put down there.

At the present time, we typically deal with maybe one or two or three, in some cases, right close to a fault. So what we would really like to have is, say, maybe an order of magnitude increase, like a factor of 10, so it would be 20 or 30 instruments around the -- covering various parts of the fault.

Q Is there any place in the world where there are 20 or 30 strong motion instruments around a fault? You know, where you could get that result?

A For a large earthquake in Southern California there are, but for small earthquakes I don't know of any. It could happen in soma cases, like we have some earthquakes right now down in Mexico, a dense array -- well, we have seven stations, and there might be other places in the world where it exists such that an earthquake could occur there. But if the earthquake

WRB/agb13

is large enough like all of Southern California, then of course there would be enough data to do that.

Q The Parkfield earthquake, wasn't that, except perhaps for the total number of instruments, wasn't that pretty much what you're suggesting?

A No, because that was just a limited array of one part of the fault down in one end which went perpendicular to the fault. Almost all the rupture occurred up in the other direction.

To really be certain about the mechanism, you would need an array of stations that covered the fault up and down the fault, both directions of rupture propagation, some near the fault, some far away.

Q Didn't the rupture propagate right at the instrument that was located within 200 meters of the fault, within, you know, a couple of football fields of the fault, didn't it rupture right at it and right on by it?

A Well it's not clear exactly where the rupture went at the time of the earthquake. There's different people who have studied, yet some of them say it stopped about 20 kilometers up, other models have had it going by. Thre's a lot of different models and we don't know. For this very reason, we don't have enough data to tell.

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Q How about surface breakage? Wasn't there surface breakage?

A There was surface breakage, yes.

Q Did that indicate where it went?

A Well, the surface breakage right near the fault, though, occurred after the earthquake, and it's not clear whether the actual rupture at the time of the earthquake occurred at the site or not -- right at the site or not.

Q At a minimum would you say it ruptured toward that instrument within 20 kilometers, or up to 20 kilometers, at a minimum?

A Well . . .

Q In other words, it may have ruptured a lot closer than that, but at a minimum it came within 20 kilometers?

A I think that's correct. I'm not sure about the exact number, but --

Q What was the magnitude of that earthquake?

A I believe it was 5.5.

Q Are you sure it wasn't 6.3?

A The Parkfield earthquake?

Q Yes.

A I'm not sure about what the surface wave magnitude and the local earthquake magnitudes were, but --

Q I'm talking M/S 6.3.

A It could have been that. I forget what the exact

wel 2

numbers were.

Q And what was the acceleration?

A Acceleration was .5g on one component, near the fault, roughly .5g.

Q Let's talk about the Imperial Valley earthquake. The instrument was at El Centro, was it not?

A Right.

Q How many kilometers off the fault was the instrument?

MR. FLEISCHAKER: Objection. Well, I'm a little bit late in this, but I'm going to raise this anyway.

There's a figure in the testimony now that Mr. Norton has. I assume he has a basis for the figure 6.3. I don't want to quarrel about it if he has a basis for it, but it would save a lot of trouble just to get it into the record.

MRS. BOWERS: Are you going back, now, to --

MR. FLEISCHAKER: Yes, I'm going back to the 6.3 for the surface wave magnitude, as a measure of the M/S of the Parkfield earthquake, and I think Dr. Brune indicated he wasn't sure, but it could be 6.3.

If Mr. Norton has a basis for that, it would clarify the record and make it a figure we all could rely on when we write our findings, which is what I'm talking about.

MR. NORTON: Do you want me to testify that it

6.3?

MR. FLEISCHAKER: Well, that's what you did.

MR. NORTON: No, I asked the question, could it have been a 6.3, and he said yes.

MR. FLEISCHAKER: He said it could have been.

MRS. BOWERS: Well, there's not a dispute, isn't that correct?

MR.NORTON: There's no dispute that I'm aware of.

MRS. BOWERS: The witness agreed that it could be of that magnitude.

Mr. Norton, if you can quickly put your hands on a document that --

MR. NORTON: I can quickly put my hands on some experts who gave me the number, but they've got to dig out the document that the number is in.

MR. FLEISCHAKER: What I'm looking to is writing the findings of fact. I'm perfectly happy to rely on 6.3, if that's what it was. But I think that for purposes of the record it would be useful to have the basis for the estimate, and then everybody can rely on it without any problem.

MR. NORTON: Well, we will certainly provide that in rebuttal, if not before.

MRS. BOWERS: Fine. Thank you.

BY MR. NORTON:

Q Now, turning to the Imperial Valley earthquake, I asked you about the record -- was it at El Centro?

A Yes.

Q And how many kilometers was that record from the nearest point to the fault?

A You mean the fault that ruptured during the earthquake, or the fault traces mapped on the ground?

Q The fault that ruptured during the earthquake.

A I've forgotten exactly.

Q Does five kilometers sound about right?

A I think it was farther than that, Trifunac's and my interpretation of where the rupture started -- I'm not sure.

Q No, I'm talking about the -- not where it started rupturing, but from the fault from where it ruptured.

A Well the problem is that in a study that we did the slip on the fault to the north we interpreted as possibly occurring in an aftershock, that occurred after the earthquake. So that if that interpretation is accepted, then during the time of the earthquake which caused the strong shaking, the rupture started farther to the south, and in that --

Q But the instrument -- what I'm trying to do is analogize this to Diablo Canyon. The Hosgri fault sits out there, okay?

A Yes.

Q Some 5, 6 kilometers off the coast.

Okay. So the instruments at Diablo Canyon are some 5 or 6 kilometers off the fault.

A Yes.

Q That's independent of where any rupture or propagation of rupture occurs. That's where the fault, the Hosgri --

A Okay.

Q -- fault is.

A Sure, yeah.

Q Okay. And that's what I'm trying to do.

A The rupture on the earthquake, if you take our interpretation, then the rupture that occurred during the earthquake did not occur there.

Q I understand that. But the instrument was approximately five kilometers from the fault that was involved --

A Yes.

Q -- in the Imperial Valley earthquake. Isn't that correct?

A I don't remember the exact number, but that seems like it's close, yes.

Q All right. Now, that earthquake in 1940 was what magnitude?

A Well --

Q Surface wave magnitude. What was it?

A Well, the number that Hanks and Kanamori recently listed was 6.7, in their paper.

Q Surface or local?

A Surface wave.

Q Have you ever heard the term 7.1 surface wave magnitude for that earthquake?

A Yes. The listed value in Gutenberg and Richter, as I understand it, is 6.7. The value that's given in Richter's book I believe is 7.1. I'm not sure about whether it's 7.1 or 7.2.

I'm not sure about what the explanation for the discrepancy is.

Q So anyway, it's someplace between 6.6 and 7, 7.1 -- someplace in that area?

A Well, the --

Q Is that correct?

A I think the measured value, based on the surface waves themselves, is 6.7.

Q Okay.

A Okay.

Q All right. And do you know what the acceleration measured at that site was five kilometers from the fault?

A It was about .3g, in that order of magnitude.

Q 30 percent of gravity?

A Yes. Again, that's not the fault that ruptured during the event, though. That's just the projection of the fault by the station.

Q Well, it's the same fault that ruptured during the event. What you're saying it didn't necessarily rupture all the way down to where the instrument was?

A That's right.

Q But it is the same fault?

A It's the same fault, yes. But it could have been a completely different answer if the rupture had gone by the instrument. You don't know.

Q How close would you say the instrument was to the rupture, the epicenter?

A I've forgotten exactly what we got in that.

Q A long ways away?

A No, not a -- well, I would say probably something like 10 to 20 kilometers, something of that order. 10.

Q Can you translate that to miles, how far it is in miles?

A Well, something like 5, or . . . something of that order. It may be 10 miles. I'm not sure. I don't remember the exact numbers.

Q Okay. Certainly closer than plus 20 miles?

A I wouldn't say "certainly." But I think so.

That's my recollection of the map.

Q Well, let's refer to your paper.

A Okay, let's get the paper out.

Q Tectonic Stress and the Spectra of Seismic Shear Waves from Earthquakes, James N. Brune, Volume 75 Number 26, September 10, 1970, page 4999. There it lists maximum velocities observed near earthquake in Table 1. Parkfield Station 2 -- excuse me -- El Centro.

It's got 7 miles southeast, and in front of 7 it has a . . . a squiggle.

A Yes. Approximately sign.

Q This is approximate, okay?

A Yes.

Q So the distance was, then, the epicentral distance was approximately 7 miles from the station, is that correct, the recording station?

A Yes.

Q All right. And that is certainly a lot closer than 20-plus miles, is it not?

A Yes.

Q And the recording was a .33g?

A Yes.

Q And the magnitude was approximately 6.7 MS?

A Right.

Q Or the magnitude may have been as high as 7.1 MS.

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There is some dispute about that, is that correct?

A I don't think there's a dispute about it. There's a difference in the literature, let's put it that way.

Q Well, as a matter of fact, your paper shows the magnitude as 6.7, 7.0.

A Okay.

Q Okay?

A Yes.

Q This table I just referred to.

A Yes, but that -- since the time that Kanamori and Hanks have done their study, they looked back into the way that Gutenberg and Richter actually calculated the magnitude on that earthquake, and looked back to the original notes.

And so I think that uncertainty to a certain extent is eliminated, and I would take their value as the correct value.

Q Page 3-16 of your testimony, under the heading, "Fault Breakout," you quote Archuleta and Frazier.

Is the Frazier that is quoted the person who is sitting next to me?

A Yes.

Q Could you tell me -- well, in the second sentence it says:

"For a 100 bar stress drop the near fault

wel 10

fault velocities 400 centimeters per second."

What equation was that derived from?

A That wasn't an equation. I looked at the graphs and looked at the table of numbers at the top of each graph and estimated the velocity on that.

Q How about an earthquake? What earthquake would that be?

A You mean what magnitude would that correspond to?

Q Yes.

A I don't know. I'd have to sit down and calculate the moment and try to make an estimate.

Q What would happen if you reduced the grid size by a factor of 2?

A I don't know.

MR. FLEISCHAKER: Objection. Foundation. There has been no foundation laid for the term grid size.

MR. NORTON: Dr. Brune, do you understand what I mean when I say what would happen if you reduced the grid size by a factor of 2?

MR. FLEISCHAKER: That's not the point. The point is that the record doesn't understand, and I'd like to have the record show what he means by grid size.

I have an objection.

MRS. BOWERS: Well, this member of the Board doesn't understand it. Would you please ask for a definition?

BY MR. NORTON:

Q Could you define grid size?

A Well, I'd rather that the Frazier sitting next to you who wrote the paper defined it, but I'll try.

Grid size is basically the term used to represent the distance between points, and the numerical approximation of the propagation of waves in the faulting.

So that if everything is done right, then the more you reduce the grid size the closer you will get to the correct answer, supposedly.

That's it, in general. There could be some exceptions to that, but . . .

Q But isn't it a fact that if you reduce the grid size by a factor of 2 you'd double the close-in velocities, and you keep doing that?

A Well, not at the distance at which this particular grid was computed. But if you follow it in, that is, if you follow each grid in, then if the numerics approximates the Kostrov solution for that kind of a propagating fault, then you have a singularity in velocity at the crack tip, so that it will go to infinity.

Q That's correct, keep doubling the velocity?

A Yes, that's --

Q That's not the real world, is it?

A Well, but this is done at a finite distance

away, so it's not clear how -- a grid of points sort of spaced like that is not the real world, that's true. But I presume the authors thought that it came somewhat close to it, or they wouldn't have done the calculation.

In other words, it's one of the available approximations we have toward trying to find out what's going on. I'm not saying it's the only one.

Q Could you carry out such a study for Diablo Canyon?

A Could I carry out such a study?

Q Yes. Or, in your opinion, could Dr. Frazier?

A Yes, I think he could, given time and money. I think we could find out --

(Laughter.)

MR. FLEISCHAKER: Who's paying who? Is this a study by Brune and Frazier?

(Laughter.)

MR. NORTON: Well, the rebuttal will take care of that. There's certainly not going to be.

(Laughter.)

BY MR. NORTON:

Q Now, going to page 3-17, the last paragraph, where you state, "Finally..." you're talking about the probabilities, I take it, in that sentence, of these various things coming together at the same time, is that correct?

A Yes.

Q All right. You're talking about very high values of accelerations and velocities require such a coincidence of deviations of variables away from their average values as to be very unlikely for any given earthquake.

Now, what are those variables? Let's list all the variables.

We know there's coherence.

A Well, the two main ones that I talked about in this testimony are the fault rupture propagation of focusing and the stress drop.

Well, I listed up above there at the top of the page on 3-17, for example, scattering, inhomogeneities in the rocks, incoherency in the fault rupture, low Q and high non-linear attenuation, among other things.

Q What are --

A Stress drops, and so forth.

Q But I would like all of them.

You listed scattering, inhomogeneities -- I can never pronounce that word -- in the rocks, incoherency in the fault rupture, low Q and high non-linear attenuation and stress drop.

Now, what other variables?

A I'm not sure I could get the list complete. There's a certain lack of knowledge about exactly how

faulting occurs,so --

Q Would we call that a variable, lack of knowledge?

A Okay. Things like, you know, stress concentration around the crack tip, and rupture velocities, standard deviation in the rupture velocities, other measures of complexity of the rupturing.

Q All right. So you've got all of these variables, all of which have varying degrees of probability of occurring at any given dimension, any given level, if you will, at any point in time.

Then you combine all of those probabilities, and then that gives you a probability of whether or not focusing resulting in higher than average accelerations -- focusing would occur in any event -- but focusing resulting in higher than average accelerations would occur. Is that correct?

A Well, if you're going to throw in all those other variables, then it's not just focusing, it's the whole suite of them, which is what you're saying, the combination of all of them would occur such that the acceleration was high.

Q Yes, higher than average acceleration.

A Right.

Q Okay. Now, given all of those variables what is the probability that you can predict that that would be site specific, that you could take an area such as Diablo Canyon and stake it out as to its square footage, or square

acreage -- and in terms of the structures there you're really talking about square footage, probably, as opposed to square acreage -- what is the probability of getting that at that site?

A We don't know. I stated in a couple places in here that we don't know the probabilities on accelerations. That's --

Q You don't know the probabilities on accelerations occurring anyplace, do you?

A Well, once you get -- the point is once you get a little ways away from the fault, like maybe 20 kilometers, then you start to have enough data that you can, for example, establish a mean curve, and you can establish a standard deviation. And purely from the data, rather than trying to predict it from theory, you can -- in scientific terms if you can say what the average is in the standard deviation, although you can't predict at any given point, you're said to be able to sort of estimate the probability.

So what you'd have to do to satisfy this situation here is get anough data in close to a fault so that you could establish a mean and a standard deviation, and then you would say, yes, I know the probability.

Q Dr. Brune, let me try again. I'm trying to find out:

Isn't it true that at this point in time, given

a 6.5 or a 7.5 magnitude earthquake anyplace in the world, you don't know what the probability is that you're going to get a g value in excess of 1?

A In close to the fault, that's correct. That's the essence of my testimony.

Q And you don't have any idea what that probability is?

A I don't have any specific idea, no.

Q That's right. But it's possible, is that what your testimony is?

A Well, yes, it's possible. But if you believe the various that I've cited in here, there are reasonable -- it's not just a far out possibility that could occur, but in fact some people have extrapolated their curves back and actually got those values.

Q A couple of times?

A What do you mean, a couple of times?

Q A few times, they've extrapolated back and got --

A Oh, a few people, you mean? Out of the suites of different people that do it? Some of them got it, and some of them didn't.

Q Yeah, that's true. But in addition to that, even those that got it have only got it for a couple of instances -- values in excess of 1g?

A The curves -- no, the curves are a prediction of

wel 17

the average value -- like Trifunac's curves are a prediction of what the average value in the standard deviation would be.

Q No, I'm talking about actual earthquakes.

A Oh, the actual data?

Q Yes.

A Oh, yeah. No, we don't. We've got just a few values. Maybe one or two earthquakes, at this stage, of that large a magnitude at that close a distance to the fault.

Q And some of those two are below 1g, aren't they?

A Yeah, right. Well, I don't know about -- we have at least at one station, we know that if we accept that record as right, then the acceleration was .8g at that one station.

Q All right.

My point is: Given the possibility of it occurring anyplace along the fault, what is the probability of predicting it for any site specific, like Diablo Canyon?

A I'm not sure I -- you mean what is the probability of predicting it, or can we predict the probability? The answer is no, we don't have enough data to say what the probability is.

Q All right. You know the averages and standard deviations for distances greater than 20 kilometers, is that correct?

A Yes. Well, there are various people who have

reduced the data and come up with curves, like Boore, et al for the USGS, and Trifunac, and others.

I've listed a number of people who have done the extrapolations.

Q Okay. Well, therefore, how likely is the Hosgri bend which is 20 miles, according to the map, to produce greater than 1g acceleration at the Hosgri site?

MR. FLEISCHAKER: Objection.

MRS. BOWERS: Number one, you meant at the Diablo site, didn't you, Mr. Norton?

MR. NORTON: Well, let me rephrase the question, and he can restate his objection. I interpolated a couple of words, I believe.

BY MR. NORTON:

Q How likely, or what is the probability, of this bend in the Hosgri on Exhibit 44, which is over 20 miles away, which is far more than 20 kilometers, to produce accelerations at the Diablo site in excess of 1g?

MR. FLEISCHAKER: I'm going to . . . well, I'll let the question stand.

THE WITNESS: Well, as I mentioned in the testimony earlier, that particular map that you've drawn is not the only thing that I looked at. If, like on this other map in Figure 30, that is more like what the correct -- figure 30 in this book --

BY MR. NORTON:

Q Excuse me. We're using Figure 44, the bend shown in that map, which is in excess of 20 miles away --

A Okay.

Q And I'm asking you to assume --

A Assume that map is correct,okay.

Q Assume that map is correct. What is the probability of a rupture occurring north of that bend, propagating in a south direction, producing accelerations greater than 1g at the site?

A I don't know what the exact probabilities are, but I think it would probably be low.

MR. NORTON: Mrs. Bowers, I would like to take a couple of minutes to get my notes together and review my cross, and hopefully complete it.

MRS. BOWERS: Do you just want a couple of minutes, or do you really want a ten-minute break?

MR. NORTON: Well, I'm not sure. What time is it?

MR. TOURTELLOTTE: 2:00.

MR. NORTON: I don't think it's necessary to take a ten-minute break this early.

MR. FLEISCHAKER: Mrs. Bowers, if we took a break now, I could also have an opportunity to review my notes for redirect and it wouldn't necessitate another

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break.

Well, let me ask Staff: Do you have much cross?

MR. TOURTELLOTTE: About an hour.

(Laughter.)

MR. FLEISCHAKER: Is that right, Jim?

MR. TOURTELLOTTE: Yep.

MR. FLEISCHAKER: Okay. Well, forget it.

MRS. BOWERS: So you don't want a ten-minute break? All right.

(Pause.)

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MRS. BOWERS: Are we ready?

MR. NORTON: Mrs. Bowers, I have no more cross-examination at this time.

MRS. BOWERS: Mr. Tourtellotte?

BY MR. TOURTELLOTTE:

Q Dr. Brune, you're a professor of geophysics, is that right?

A Yes.

Q And where is that?

A At the University of California at San Diego, the Institute of Geophysics and Planetary, Scripps Institution of Oceanography.

Q You must do a lot of consulting work in connection with that, is that correct?

A I am not sure what you mean by "a lot", but....

Q Well, do you do consulting work?

A I am not involved in any consulting right now.

Q Have you done any work in earthquake building?

A Earthquake building?

Q Yes.

Have you done any consulting work relative to building for earthquakes?

A I don't recollect any, no.

Q You stated in response to some questions that were asked by Mr. Norton, you stated roughly that there was

mpb2

a 95 percent confidence that 2gs are possible at ten kilometers. Do you recall that?

A No.

My recollection is that we were discussing Trifunac's extrapolated curve at that time.

Q I see.

A That's not my curve.

Q Well, maybe I don't understand. Why are you presenting that curve?

A I presented a number of different curves, including those that show lower values, and some that show higher values, to show that the extrapolations in this distance range are not consistent because there's not enough data, so that we don't know what the true values are. And this is stated in Trifunac's paper too, that they are based on very little data.

Q Well, the idea of quantifying focusing, then, is a very recent development in geophysics?

A I'd say it's a recent development that focusing has been used for strong motion, but it's quite a bit longer than it's been used in more distant ways.

Q You stated during your testimony that acceleration could be increased by a factor of two by reason of focusing, is that correct?

A Yes, I said more than a factor of two.

mpb3

Q More than a factor of two.

Well, would the reverse be true?

A You mean reverse direction on the fault, or what do you mean by "reverse"? Do you mean focus?

Q Okay.

It would be reduced by a factor of two? Would there be a reduction by a factor of two --

A Yes.

Q -- because of focusing?

A Yes.

I think we should go back to the answer I gave to Mr. Norton, that if we had a series of seismographs around a fault and if we then took the average acceleration of all of them, then in the direction of rupture propagation there would be increased amplitudes in the defocus direction, the direction away from rupture propagation there would be lower acceleration.

Q I get from reading your testimony that you have quite a few qualifiers in here and your testimony indicates to me generally that you believe that all of this is possible, that is that focusing and the effects of focusing, such as leading to an increased acceleration by a factor of two is a possibility.

A Well, I'm sure that it does occur in nature.

Q But you don't state with any degree of certainty

mpb4

that that's absolutely what happens, that is that you could increase the g factor by a factor of two.

A Well, that's certainly true that you could increase it. What I'm not certain about is when you put it in the context of, you know, the real earth, like Diablo Canyon and so forth, with all the variables, that that would be true.

Q So, you don't really have a strong degree of certainty that that indeed is what would happen?

A Well, I feel very strongly that that could happen or would happen in some cases, as I said, but there's a couple of places where I put the phrase in 'I don't know what the probabilities are'.

Q One of the things that caused me to wonder about your testimony was a response you made about one piece of testimony, and I believe it was on page 3-8, and I may be wrong, where it says:

"Depending on the coherency of the energy, this could lead to accelerations about two times those observed at Pacoima Dam, i.e., greater than 2g."

And I believe that you said something to the effect that the reason that you used the words "could lead" is that there wasn't that degree of certainty in the real world.

A Yes, it wasn't in that -- that wasn't the one it

mpb5

was. But I'd have to look a little bit to find out what section.

Q Well, I guess that generally sets the stage, because I also have a difficult time finding exactly which one it was, and I didn't make a note of it at the time.

But I would invite your attention to page 3-3. In the next to the last line and the last line, talking about focusing, and it's almost a duplicate of the other statement. It says:

"The occurrence of focusing by rupture propagation, or constructive interference, along with other factors, could lead to values of as much as a factor of two higher."

This is another instance where you're saying -- those are qualifying words, to say that it could happen. It's not necessarily true that it will happen, but it could happen.

A Yes, that's correct.

Q I invite your attention to page 3-4. In about the sixth line down in the second paragraph, it says:

"If the faulting can be represented by a rupture propagating somewhat erratically along a fault, then the Karakyr Point station was probably not in the direction of focusing or directivity maximum..."

mpb6

I am interested in the subjunctive clause there, that:

"If the faulting can be represented by
a rupture propagating somewhat erratically
along a fault..."

Is it also possible that that was not the case?

A Yes.

As I think I've explained quite a number of times, we really don't know that much about how to model faults to know exactly what to put into them.

Q Further on down at the bottom of the page in the last paragraph, it starts:

"The horizontal components of this record
are roughly typical of what we might have expected
for a complex multiple event earthquake of this
magnitude."

When you say "we might have", is that also a reflection of something that might have been, but it might have been something else?

A In "might" there, that means we've given various people's projections, like Trifunac's and so forth. If you haven't had the data points and you've taken their projections, which are done without that, and looked at them and set, you know, what range of accelerations might you have sort of guessed back in that range, then that's the context

mpb7

in which that means that "might have". That is, before the earthquake had occurred, just based on their projections, it's somewhere in that range, I would guess.

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MR. NORTON: Excuse me.

I would like to have that question and that answer read back, please, by the Reporter.

(Whereupon, the Reporter read from the record as requested.)

MR. NORTON: Thank you.

BY MR. TOURTELLOTTE:

Q On the sixth line down at the top of page 3-5--

MRS. BOWERS: Excuse me. Just a minute.

DR. MARTIN: Before we go on, I wonder if I could get a translation of that answer.

(Laughter.)

DR. MARTIN: I just couldn't follow it.

THE WITNESS: Okay.

It means that -- the "might" means that given the situation without that data point ahead of time, based on the various evidence we have, then we would have expected that kind of an acceleration might occur. And the "might have" means that posing the situation before we had that data point if someone tried to say what sorts of accelerations might you expect for that sort of an earthquake, that's what you might have guessed, something in that -- it would not have

been expected to get that kind of an acceleration.

MR. NORTON: Well, I would like to have that answer read back because I think he just totally reversed that answer with that last statement.

THE WITNESS: Okay.

When I used the word "might" I am posing a situation that without that data point what might we have expected for a complex multiple event earthquake of this magnitude.

DR. MARTIN: Excuse me.

Does this supply some sort of extrapolation from the data that were available where you say you might have predicted the data point?

THE WITNESS: No, I mean that given what we knew before and what the extrapolations say that the average should be, and the standard deviation should be in that range for some of the predictions, like the Trifunac prediction, that value falls within one standard deviation. And so it's a reasonable value to have expected.

DR. MARTIN: All right.

So it is statistical.

THE WITNESS: Statistical, yes.

DR. MARTIN: All right.

MRS. BOWERS: Do you want to proceed, Mr. Tourtellotte?

MR. TOURTELLOTTE: Yes.

mpb9

BY MR. TOURTELLOTTE:

Q On the sixth line down from the top of page 3-5, you make the statement that:

"Karakyr Point may have been near a node in the S wave radiation pattern but near an anti-node in the P wave radiation pattern."

That's just supposition, isn't it? It could have been something else?

A No. Well, it's not just supposition. It's a reasonable explanation for the fact that the vertical component was higher than the horizontal.

In other words, the fact that the vertical component is higher than the horizontal, which is unusual for most earthquakes, suggests but doesn't prove that that's the case.

Q It could be something else?

A Yes. That's the only sort of explanation of it that occurred that I feel confident of. And I've talked to a number of other people, and that's the only one they've come up with.

Q The next sentence says:

"Also contributing to the high vertical accelerations could be the relatively low attenuation of P waves which makes up the predominent energy of the vertical acceleration."

mpb10

You use the term "could be" there, and I'm asking you once again: is it possible that it's something else?

A That's correct. The context of this is that the vertical acceleration is observed to be higher than the horizontal, whereas most of the engineers up to the time of this earthquake had been predicting that that wouldn't be the case. So in the context of suddenly finding an earthquake which gives accelerations which are not in agreement with the ideas and curves that existed previously, the context of this is to present two possible explanations of that.

However, I'm not aware of any explanation of why that is true. That has been proven in the literature or is accepted. It's still a possible explanation of that.

Q Continuing on with the next paragraph, where it says:

"If the radiation pattern explanation is taken we may assume that if records had been available from the directions of the S wave radiation maximum, the horizontal accelerations would have been considerably greater."

That sentence starts off with again a subjunctive clause, "If the radiation pattern explanation is taken..."

Is it possible that there is some other explanation that would make an equal contribution?

A Yes, as I said before, that's only one of the

mpb11

possible explanations for that record.

Q And the last paragraph of that section, right above "Other Accelerograms", the last sentence says:

"Only further study and the collection of more data will allow us to judge with confidence whether it is typical or not."

So what you're really saying there is you don't know whether this has any applicability or not right now.

A Well, it certainly has applicability as a data point. What we need is more data. And before we had zero; now we have one.

So it's important to have more data. But before you can tell whether any one data point is close to the average or not, you need enough to determine what the average is.

Q On page 3-6, you're talking about extrapolations at the bottom of the page. And the last sentence reads:

"For example, at distances of ten kilometers for an M equals 7.6 earthquake the curves of Donovan indicate accelerations of about .45g at ten kilometers, where the curves presented by Trifunac and Brady indicate that near the fault for an M equals 7.5 earthquake the average peak accelerations could be 1.75g and

mpb12

that the average plus one standard deviation could be about 2.5g."

Again, the term -- or the use of the words "could be". Does that just indicate what's possible here?

A Well, that indicates the fact that in his paper he also observed the fact that there's not enough data in that range to be sure of the extrapolation, so he qualified his curve, and I am voicing that qualification.

We don't know if that's true. That would be true of any curve, Donovan's curve or anyone else's.

Q You don't know of any earthquake where there has ever been recorded a ground motion of 2.5g, do you?

A No, I don't.

Q Further on in that paragraph you state that:

"Boor, et al, do not extend their curves for M equals 7.5 earthquakes to short distances because of lack of data, but the slope of their curves, projected toward short distances, suggests accelerations of greater than 2g are possible at distances of ten kilometers."

Now isn't it true that a person who makes a curve usually stops their curve because they don't feel that they have enough information to draw that curve any further?

A That's correct.

mpb13

Q And so drawing -- extrapolating a curve which the author himself refused to draw because of the lack of data does not really give reliable information, does it?

A Well, there is some information hidden in there in the fact that you wouldn't expect a curve to make a sharp corner, so that there's some distance beyond the end of the curve that you can trust it.

But basically I agree that I don't think the projection is reliable.

and MADELON WRBLOOM flws (2C)

2C
WRB/agbl
MADELON

Q And the last sentence of that same paragraph says:

"For 95 percent confidence intervals their projected curve suggests accelerations near 2g are possible for distances of 10 kilometers."

There is nothing there that would suggest that there's a reasonable degree of certainty that that's the kind of ground acceleration you're going to get, is there?

A There is no data in that distance range.

Q Further on down on that page --

A I should say not that there's no data, but there's not enough data to be sure about the curve.

Q Further on down on that page, the last paragraph.... Well, let's move on.

On Page 3-8, the first full sentence says:

"Ambraseys concludes that accelerations in the focal volume may well reach and exceed values of 100 percent g, and that in the future, accelerations greater than 1g will probably be recorded for even low magnitudes."

Is the use of the word "may well reach," does that indicate a degree of uncertainty about whether they will or they won't?

A I would say they do. I think that's what he's referring to. I don't believe he places a lot of -- is not

WRB/agb2

sure exactly what the probabilities are going to be and that's why the qualifications.

Q Down in the next to the last paragraph on that page, the last full sentence in that paragraph says:

"Depending on the coherency of the energy, this could lead to accelerations about two times those observed at Pacoima Dam, i.e., greater than 2g."

I apologize, it's the second from the last sentence.

But again here we have the words:

"...could lead to accelerations about two times....," and that is to indicate a degree of uncertainty about whether they would or would not, is that correct?

A Yes. Perhaps that's -- you don't need two qualifying things in that sentence. It probably would have been adequate to say depending on the coherency of energy, because for a given type of coherency you could say they would have definitely but we don't know what -- there is uncertainty about how coherent the energy would have been.

Q On Page 3-9, the sixth line down states that:

"Thus, assuming the horizontal accelerations in the Gazli earthquake represent the mean, one would estimate 90 percent confidence level

WRB/agb3

accelerations of about 0.75g times 2.3 equals 1.73g."

Is there sufficient cause to believe that the horizontal accelerations in the Gazli could represent the mean?

A Well they could represent the mean, that's for sure, but we do not know that they do represent the mean.

Q There's another intervening sentence, and then the next sentence is in parentheses. It says:

"(As noted earlier, if radiation pattern is the explanation forrthe high vertical acceleration at Karakyr Point, then the horizontal accelerations were probably higher at other azimuths, and thus the estimated 90 percent confidence level horizontal accelerations would be even higher.)"

Isn't it possible that there's some other explanation than the fact that radiation patterns -- a radiation pattern is the explanation for higher vertical acceleration at Karakyr Point?

A That's the reason for saying "if."

Q The next paragraph says:

"In summary, the above extrapolations, although based on very limited data and thus of low confidence, indicate that for magnitude 7.5

WRB/agb4

earthquakes as distances of five to ten kilo-
meter accelerations higher than 2g are
occasionally expected, and accelerations of
about 1g are commonly expected."

What do you mean by the term "occasionally," how often would you expect that?

A Well that's referring to the curves of the type of, for example, Trifunac's where the average acceleration -- Let's go back to the one it's referring to.

At 10 kilometers, the average acceleration is 1.1g and the 90 percent confidence level is 2.45g, so that gives you the probability for one of those curves. And my statement simply means that we don't know what the true answer is, so any of those extrapolations could be right and it could be something in that range.

Q Well is "occasionally" one out of 100 or one out of 1000, one every 10 years, one every 100 years?

A In that particular thing, on Trifunac's curve by itself, it just means one out of 10, 90 percent confidence level means one in 10.

Q On Page 3-10, the last sentence in the first paragraph says:

"For propagating ruptures, the particle
velocities in the direction of rupture propaga-
tion can be more than twice as high."

WRB/agb5

That's not to say that they would reasonably be expected to be more than twice as high but only that, again, that it's possible?

A I would say that -- no, I would say in this case, it's reasonable to expect them to be. But there's not enough known about actual faulting and so forth to be sure that, in any given case, that would happen. But it's certainly reasonable to expect them to be that high, yes.

Q It would be reasonable to expect them, if you could demonstrate that this formula applied, is that what you're saying?

A Yes -- well, if there was a smooth....Yes, if the rupture was of the type, the simple type on which that formula is based that it would happen. But it the earthquake is not of -- it could be of a different type.

Q But you don't really know whether even a rupture in the real world would occur in accordance with this formula?

A You know that it could occur, but you don't know that it would occur in any given instance.

Q And you don't know whether one ever has occurred?

A Well I'm getting a little bit confused about what you mean by "this formula." In other words, has it ever occurred that the acceleration in one direction has been a factor of two higher than in some other direction, the answer is yes.

WRB/agb6

But if you mean do I know that there has ever been a rupture in nature that has been, say, if we could accept this statement of how close to an idealized rupture, no, then I don't know that.

Q The next paragraph, the last sentence says:

"The curves suggest..." -- I'm sorry, we're talking about, I guess, the Trifunac and Brady, Trifunac and Boore, et al. extrapolations. It says:

"The curves suggest that velocities in excess of 100 centimeters per second may be expected close to magnitude 7.5 earthquakes."

The term "may be," is that a qualifier to demonstrate that that is considered to be a possibility?

A It's a qualifier taken to mean that even though the extrapolations and data that we have now indicate that it's not reliable enough to know that that's the true values.

Q And then the next sentence in the next paragraph says:

"In view of the above considerations, it seems probable that given more records from large earthquakes, velocities as high as about 200 centimeters per second may be recorded."

I take it from what you said about 100 centimeters per second that the same or equal answer would apply to that statement?

WRB/agb7

A Except that that also includes the probability of variation. That is, the previous sentence says that 100 centimeters per second may be expected, and then the next statement says that if that is expected then occasionally we know there's going to be a large variation and they could vary up to 200 centimeters per second. So the second statement includes a statement of probable variation in the velocities.

Q Okay.

I invite your attention on down to the next paragraph, the third complete sentence I believe, it's right after the brackets. It says:

> "Directivity was probably very important in generating the high velocities observed for the Parkfield and San Fernando earthquakes."

Do we know that directivity was responsible for that?

A No, the probability means that since a number of people have studied these earthquakes and there is some consistency in their interpretations of the data, that probably means that it's probable because their interpretations have this feature in it, that that feature existed in the real earth.

Q On Page 3-11, the first sentence in the second paragraph says:

WRB/agb8

"Hartzell and Archuleta have recently made numerous observations of particle velocities at various azimuths around propagating spontaneous ruptures in foam rubber and found that near the fault in the direction of rupture propagation, the particle velocities may be more than a factor of three higher than velocities near the fault but away from the direction of rupture propagation."

The words that I want you to look at appear in the third line above the end of the sentence where it says, "may be more." Are these words to qualify that statement again as to indicating it is possible but we don't know whether it really would happen or not?

A Well in that particular case, the "may be" refers to whether or not the results in that model are applicable to the earth. But there were factors of three amplification in the model, so the quote "may be" refers to applying that result to the real earth.

Q Page 3-13, the first sentence of the first complete paragraph says:

"The phenomenon of focusing or directivity apparently played important role in the large velocity pulse observed on the Pacoima Dam record of the San Fernando earthquake."

WRB/agb9

Citing Heaton at reference 21.

What other items played an important role in the large velocity pulse recorded at Pacoima?

A Well the size of the stress drop and the various other parameters of the earthquake.

Q So you really can't quantify, can you, what focusing or directivity had to do with the record at those site?

A Well the model itself had directivity in it and the question is is that a unique model, and there are some studies which have modeled the source somewhat differently so that directivity wouldn't have played the same -- wouldn't have been as effective in their models. So depending on whose model you use, there is uncertainty in that.

Q Okay. So you're talking about, in that sentence, you're talking about the conclusion that strong -- by Heaton in a model which he established for the Pacoima Dam and the San Fernando events?

A That's correct.

Q -- rather than the actual records themselves?

A That's correct. Insofar as the model is applicable to the records, the statement is true.

Q And the model may or may not be the real world situation?

A We don't know exactly how close it is. There have

WRB/agb10

been different studies by different people.

Q The first sentence in the next paragraph says:

"Directivity may have worked in the reverse direction for accelerations observed on the Pacoima Dam record."

Again, it's also possible that it didn't, isn't that true?

A That's correct.

Q The last sentence in that paragraph says:

"Thus, points farther to the south may have been more in the direction of focusing for the shallow sector of the fault and, thus, may have experienced higher accelerations."

There where you say "may have been more" and "may have experienced," again reflects a degree of uncertainty about what in fact happened, is that correct?

A Correct.

end2C

2D fls 2C WRB/wbl

Q In your last paragraph on that page, the last two sentences, the first sentence says-- I'm sorry; the next to the last sentence says that,

"Energy released about 20 Km from the fault could be focused nearly directly at the Diablo Canyon site."

It's also possible that it won't be focused?

A That's correct.

Q And we don't even have a reasonable degree of certainty about whether that phenomenon would occur or would not occur; isn't that right?

A Even the phenomenon of focusing itself? We don't know for any given earthquake on the Hosgri fault whether or not it would focus energy toward the Diablo Canyon or not. But we do know that the phenomenon of focussing will occur.

Q But we don't know that it would occur, say, to the extent that Trifunac said it might occur; correct?

A Not for any given earthquake, no.

Q We all agree that focusing is actually a part of all earthquakes to a greater or lesser extent; isn't that correct?

A Yes. It occurs in all earthquakes. That does not mean that energy is focused at every record. There may not be any records. It could be that there are not any records

which have been in the maximum direction of focusing.

WRB/wb2

Q On page 3-16, under Fault Breakout, the third sentence says,

"If such high surface particle velocities occurred in a layered medium so that energy were more confined to the surface than in their half space model, very high particle velocities could be generated five kilometers from the fault."

I take it the introductory portion of that sentence also indicates a degree of uncertainty about what might happen?

A That's correct.

Q The last sentence in the first paragraph on page 3-18 states,

"The situation is such that in the face of the strong evidence the high accelerations and velocities can occur, but with a data base too limited to be sure what the probabilities are, we can only conclude that the higher the design levels, the less the risk will be."

What do you mean, the higher the design levels? What design levels? Are you talking about structural engineering?

A Yes. In other words, the higher you build your safety margin on acceleration the safer it will be. If you

WRB/wb3

design for 2g it will be safer than 1g, and 1g will be safer than a half g.

Q But you're not a structural engineer, are you?

A That sentence does not-- I don't think it implies knowledge about structural engineering; it's saying that if the structural engineer has to design his building to be safe at 1g it certainly will be safer than if it is designed at a half g.

Q Well do you know how the various accelerations affect buildings?

A I think that's outside my area of expertise, if I'm clear about what question you're asking.

In other words, could I calculate the response of a building to a certain acceleration; is that the question?

Q That's true.

A No; that's outside my area of expertise.

Q Well you don't know, for instance, whether if a building were too stiff for a given acceleration that it might be worse than if it were designed in a more elastic mode, would you?

A Well, as I said, if there were some design characteristic that made it less safe at the higher design then I would say from the point of view I'm talking about, which is only the input ground motion at the base of it, then in your case you would say it would be worse to design

WRB/wb4

to design it for the higher thing. And I'm not saying anything about that. All I'm saying is, if it's designed and is in fact safe for 1g then that's better -- you have more safety than if it is in fact designed and safe for half g in a situation close to an active fault like this.

Q Well doesn't that depend on the stiffness of the structure you're talking about?

A I include everything that goes into the engineering design in my statement of, Is it safe or not? So I'm avoiding -- in other words, I'm not trying to get into any engineering design. When I say "safe" I mean you take all that into account, anything which is beyond my expertise, in saying it's safe.

Q You're telling me that you can make a judgment that a building should have -- that a building should be designed to withstand more g's, but you don't know anything about stiffness of structures. It is possible that a structure might be stiffened, or even part of a structure might be stiffened by making it respond to a higher g level; or do you know that?

A Well I don't know that.

Q Okay.

A I'm still saying the safety of the building.

Q Page 3-19. You state in your first sentence, the conclusion says,

WRB/wb5

"The main conclusion of my testimony is that based on our present limited data base for near source (epicentral distance less than ten kilometers) ground motion for large earthquakes (magnitude greater than 7), and based on our present limited understanding of the seismic wave generation and transmission, the ground motion postulated in USGS Circular 672 for a magnitude 7.5 earthquake (peak accelerations 1.15g, peak velocity 135 cm/sec) has not been shown to be conservative."

You're saying that you don't have very much information, and anything is possible. But the USGS Circular has not been shown to be conservative; is that what you're saying?

A You said three things. I didn't say anything is possible anywhere in my statement. But I did say that we don't have very much data. And I did say that the data are -- and the other evidence presented in my testimony, indicates that we have not shown that these values are conservative.

12.340

Q Have you ever used 672 for any purpose other than making this testimony? Have you ever used--

A I used it in the sense of comparing the values with what I had in models and various theoretical calculations and papers I've written, sand so forth. But not in building design, cases involving building design.

WRB/wb6

Q Do you know what USGS Circular 672 was promulgated for?

A Yes.

Q What?

A The Alaska pipeline.

Q I mean, it wasn't for the Alaska pipeline, to put through the pipeline, was it?

A Oh, I see what you mean. Well, it was in a paper which was design values for the Alaska pipeline, and in that they tried to estimate the values of peak ground accelerations and velocities for various sizes of earthquakes. But, as I recall-- Yes, the results are not dependent on it being for the pipeline.

Q But it was used as a guide for engineers; isn't that correct?

A Yes. Right. Or anyone else who was interested in knowing what the accelerations and velocities are.

Q When you got your information from Circular 672, you got that information frm Table 2, didn't you?

A Yes.

Q Did you read the whole circular?

A Yes, I read it at one time. I don't remember all of it in detail.

Q Actually, that circular to a large extent is written also for engineers, isn't it?

WRB/wb7

A I don't know whether to a large extent. I would say that's the primary purpose. But I don't know exactly what it was written for.

Q Well, the ground motion values that are in Table 2 are subject to several conditions, aren't they?

A Yes.

Q And wouldn't those conditions to some extent have a bearing upon their conservatism?

A That's one of the things that would apply to their conservatism, yes.

Q Well do you know what those values -- what those conditions are?

A Being close to the fault is one of them. And there are several conditions listed, but one of the conditions is the statement that they are not the maximum possible; which means that -- I don't take the word "conservative" to be exactly quantitative. So that if they say that the values they have listed there are not the maximum possible, then I believe their statement means that there's room for the possibility that they're not conservative until I know what that means.

Q When did you write this piece of testimony?

A Around the-- That particular part was written around the first week in November.

Q When did you read USGS Circular 672?

WRB/wb8

A The values in the table I read right near the same time. But as far as reading the text of it, that was some considerable time earlier, about the time of my ACRS testimony. And I may have read parts of it after that, but I don't recollect exactly.

Q Which ACRS testimony? When was that?

A June 23rd, 1977.

Q So roughly a year and five months before you read the whole article, the whole circular; right?

A Well, again, I don't remember for sure that I did. But I think so.

Q And you did not review what the written text of that circular was at the time that you actually made this statement that those figures have not been shown to be conservative?

A That's right. I didn't review the whole written text.

End 2D

WEL fls

fls WRB
6WEL/wel 1

Q During your cross-examination with Mr. Norton, you gave one answer which indicated that everything available seemed to indicate that the plus 7 magnitude earthquake you'd get something near 1g, but with more information you might get something closer to 2g, is that correct? Do you recall that?

A Not exactly in those words, no. I don't recall.

Q Do you disagree with it?

A State it again.

Q Well, understand, I'm not a court reporter and I didn't take it down verbatim, but I thought what you said was that everything available seems to indicate something near 1g, but with more information we might get 2g's.

A The first part is correct. I think that the evidence suggests that somewhere around 1g is a good value.

As far as the second part, that we could get 2g, I'm not sure whether that referred to the possible excursions from the mean. . . I don't know the context in which that's quoted, but I can tell you what I feel, what I think, and that is I do feel that you could have values as high as 2g.

Q Also, with more information we could have values less than 1g, couldn't we?

A Oh, we definitely will. There will be a variation of data around the mean.

Q And it's also possible that with more information we won't get values of 2g at all?

A Are you saying it's possible we may never? That's possible, yes.

MR. TOURTELLOTTE: I don't have any more questions at this time.

I do have a motion to strike a couple of things.

I'd like to move to strike, starting on page 3-18, the fourth line down that says:

"They are especially weak if the burden of proof is assumed to lie with the contention that high velocities and accelerations are not to be expected."

That is a legal conclusion which I don't believe this witness can make.

The other item I would ask be stricken is on page 3-19, the last sentence on that page, which also refers to the burden of proof.

DR. MARTIN: I'm sorry. I didn't get the second one.

MR. TOURTELLOTTE: The page is 3-19. The last sentence says, in the last paragraph on that page:

"A near certain conclusion is that if the burden of proof is assumed to lie with the thesis that very close to large earthquakes

of greater than 1g are not common, then the thesis has not been proven."

MRS. BOWERS: Mr. Norton, before I go to Mr. Fleischaker, would you like to express the Applicant's position on this motion?

MR. NORTON: No.

MRS. BOWERS: Mr. Fleischaker?

MR. FLEISCHAKER: Can I take Mr. Brune on voir dire for a moment?

MRS. BOWERS: I didn't hear that.

MR. FLEISCHAKER: Can I take Mr. Brune on voir dire for a moment?

MRS. BOWERS: Well, --

MR. NORTON: We'd object to that procedure, Mrs. Bowers. I don't understand voir dire of one's own witness. I don't understand that term at all.

Was it Saturday or Monday -- I guess it was yesterday -- I didn't understand it yesterday and I don't understand it today, how one voir dire's their own witness.

MR. FLEISCHAKER: I can certainly make an argument without taking him on voir dire, and I'd be happy to do that. So let me make the argument.

First of all, as I recall, I think two days ago when Mr. Kristovich requested that written testimony be struck the Board ruled that it was too late, and that if the evidence

was admitted and there wasn't a specific reservation raised at the time the testimony was admitted, then the party who sought later to strike the evidence was out of luck.

I think that that same rationale applies here.

But even if it doesn't, it's clear -- it appears to me that there is more than one kind of burden of proof. Although lawyers tend to think that only lawyers think in terms of burden of proof, I think that maybe scientists do too.

And it seems to me from reading the evidence that the burden of proof goes to scientific evidence that we're talking about, and that Dr. Brune is not necessarily talking about the burden of proof in a legal sense as lawyers think about it, and as the regulations applicable to this proceeding would require.

The testimony to me here is perfectly consistent with the construction that the burden of proof he's talking about is in a scientific sense.

MR. TOURTELLOTTE: If that's the explanation, and if everybody agrees, then I don't have any objection to it remaining in.

MRS. BOWERS: Mr. Norton?

MR. NORTON: My position is the same as it was before.

MRS. BOWERS: Well, the Board feels comfortable

:el 5

that it was used in a scientific sense.

MR. NORTON: Mrs. Bowers, I think the simple solution to it is to stick in the word, "scientific," the burden of scientific proof, so that it's clear that we're not talking about a legal burden of proof. That's what Mr. Fleischaker has just suggested.

If the word "scientific" were inserted after "burden of" in each clause, that would take care of it.

MRS. BOWERS: Let's check with the witness to try to shortcut this a little bit.

Dr. Brune, would you have any objection, in the sentence that's been identified on page 3-18, beginning the fourth line from the top, "They are especially weak if the burden of proof is assumed..." et cetera, and then the last sentence on page 3-19, to insert the word "scientific" in front of proof?

You see, in this case the Applicant has the burden of proof as a matter of law and regulation, and we're just trying to make sure that you're not getting that factor into your testimony.

THE WITNESS: Well, I'd certainly be easy with putting "scientific" in there. That agrees with the thinking I had.

MRS. BOWERS: And I assume, Mr. Tourtellotte, that your motion to strike is withdrawn, is that correct?

MR. TOURTELLOTTE: I assume that we're going to put the word in both places?

MRS. BOWERS: Yes.

MR. TOURTELLOTTE: Yes, I would withdraw that motion, now that it's clear.

MR. NORTON: Mrs. Bowers, before the Board goes on with its questions, Mr. Tourtellotte's cross-examination has raised a few questions that I have for cross-examination. I could take those now and get them out of the way, and then not have any more, and then the Board could ask its questions and then Mr. Fleischaker could do his redirect, if that's permissible and acceptable to the other parties.

MRS. BOWERS: Let's check with Mr. Fleischaker.

MR. FLEISCHAKER: I have no objection to proceeding in that manner.

MRS. BOWERS: Do you want to go ahead, Mr. Norton?

BY MR. NORTON:

Q While Mr. Williamson is setting up the Vugraph, when we talked before about near source you said you hadn't defined it in your testimony, but indeed you have in the first sentence of the conclusion where you say:

"Near source epicentral distance less than 10 kilometers."

A That's not defining it in a generic way. That

says for the purpose of that sentence that's what I'm using it as.

Q Okay. But generically, then, you can stretch it out to 20 kilometers or less, okay? We established that earlier, didn't we?

A In certain cases, yes.

Q All right.

Well, let's put it another way. You can't stretch it out further than that. Then we start losing the meaning of what we're talking about.

A Well, for the Alaska earthquake, with a very large area, hundreds of kilometers, you could stretch it out further than that.

Q But that's an unusual situation.

A I don't know whether that's unusual. I wouldn't say that. I'd go back to what I said before, that the definition of near field depends on what type of earthquake you're talking about.

Q All right. Well, let's talk about the Hosgri fault. When we're talking about near field in the Hosgri fault what distances are we talking about?

A As I said before, it's not a precisely defined term.

Q All right, but what is the range?

A Something like, I would say 10 to 20 kilometers.

Q All right. Excuse me, while I get up and move to another mike.

(Pause.)

Dr. Brune, I want to make sure I understand this: When you talk about focusing occurring, what you're really talking about -- we keep using the term focusing, but we're really talking about higher accelerations than normal as the result of focusing. So when you use the phrase like, well, focusing occurred here, what you meant was accelerations were recorded which were higher than normal as a result of focusing, isn't that correct?

A I'm not sure of the exact content, but that could be, yes.

Q -- as opposed to -- because focusing always occurs, we agreed on that earlier. But what you're interested in is whether or not it results in higher accelerations.

Is that a fair statement?

A I think that's -- I'm interested in both, whether it's low or high. From a scientific point of view, I'm interested in whether the result of the rupture propagation creates high or low accelerations and how it's distributed.

Q Okay.

A But in terms of trying to estimate what kinds of accelerations, how high accelerations can be, yes, in that context that's what you'd be referring to.

wel 9

Q All right. Would you agree with this sentence, then?

"In order for higher accelerations to occur at a site as a result of focusing you must get a rupture propagating at the site."

Isn't that correct?

A Part of the rupture must be propagating toward the site.

Q All right. In order for the high acceleration as a result of focusing to occur, there has to be rupture, at least part of it, propagating directly at the instrument or within your five degree --

A Well, five degrees is not a precise number. It depends on how incoherent it is. It could be wider for that for less coherency. That's one of the points of my saying that we need to do a calculation, is to put incoherency in and see just exactly how high that is. I don't know how high it is.

Q But propagating at the site within some degree of freedom?

A Correct.

Q Okay.

Now, you testified in response to Mr. Tourtellotte's question -- and, again, I'm not a court reporter but I tried to get it all down, and this is a very close paraphrase, if

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not exact.

You said:

"We don't know for any given earthquake which could occur on the Hosgri fault whether it would result in focusing at Diablo Canyon or not."

Do you recall that statement?

A Yes.

Q Well, let's look at the three maps that I could find in the record that portray the Hosgri fault.

The first one is the one you referred to, the Hoskins and Griffiths figure 30 from the Johns Hamilton testimony.

Now, are you aware when that map was drawn?

A Yes, I can --

Q You can see it right on the bottom there, yes.

A Yes, I was going to say that. 1971.

Q All right.

And are you aware of the history of the collection of data regarding the Hosgri fault, the kinds of data that have been collected, and when all that data was collected?

A I'd say that's outside of my area of expertise. However, I have at one time or another read certain sections of that -- the reports that were given there.

wel 11

Q All right.

Well, I want to inform you -- and I trust that my recitation of the evidence is accurate, and if it's not I'm sure Mr. Fleischaker will grab the microphone away from me -- the testimony has been that it was in 1971 that the fault, that this paper was published, that people other than Hoskins and Griffiths, who obtained this data, that there was a fault out there in their work for an oil company. And it was unpublished until 1971.

It was after that time that a tremendous amount of data has been collected regarding the location of that fault, and that as a result of that collection of data new mapping efforts have, of course, taken place.

Now, as a seismologist, my question to you as a seismologist is:

Wouldn't you want to rely on maps after the data were collected, as opposed to this map which was before probably 95 percent or 99 percent of the data were collected?

A Yes, in general that's true. However, I think I ought to explain why I didn't pick out any one map and say that was it.

Partly because in looking at the maps at the surface, and reading various people's testimony -- for example, Eli Silvers, about where exactly what fault connects with what.

wel 12

I had operated under the assumption that we did not know where -- exactly where the rupture would occur on the fault.

Q Okay. Let's take two of the recent maps that were collected after the data and look at them.

(Slide.)

Let's take first the California Division of Mines and Geology, a map which Joint Intervenors were kind enough to provide as representative of the Hosgri fault.

Now, can you see where the Hosgri fault is on that map?

MR. FLEISCHAKER: What was the label you gave that?

MR. NORTON: Joint Intervenors 35, California Division of Mines and Geology.

BY MR. NORTON:

Q Can you see the Hosgri fault on there?

A Yes.

Q All right.

Now, do you know where Diablo Canyon is on that map? I appreciate it isn't drawn on there, but are you familiar enough --

A Yes.

Q Can you take the pointer which is on the other side of the Vugraph there and point to it?

(The witness complying.)

WEL7
mpb1

Q All right.

MR. NORTON: Let me mark what was Joint Intervenors' 35. This is a xerox of Joint Intervenors' 35. We'll mark it now Applicant's 36.

MRS. BOWERS: No, 37.

MR. NORTON: 37, excuse me.

(Whereupon, the document referred to was marked as Applicant's Exhibit 37 for identification.)

BY MR. NORTON:

Q I've marked this as Applicant's 37 for identification.

You can tell me now, is that right there where the site is, where you indicated?

(Indicating.)

A More or less.

Q All right.

Right in there where I've just put that dot.

Now I want you to assume this earthquake, and I will take my pen and see if I can do this, an earthquake with its epicenter right here by the "T", where it says "Fault", right at the base of the "T", and propagating southward for let's say ten kilometers.

Now isn't it true, Dr. Brune, that given that

mpb2

earthquake, that you could say that it would not result in focusing at the Diablo Canyon site?

A Yes. Well, it would not result in increased acceleration due to the phenomena of focusing.

Q All right, sir.

When you said the statement "We don't know for any given earthquake which could occur on the Hosgri fault whether it would result in focusing at Diablo Canyon or not," you didn't really mean that, did you?

A Well, I meant it in the sense that if we just had an epicenter and you specified the epicenter and not the direction of rupture on the fault, that we wouldn't know. If you specified direction of rupture, then it's --

Q All right.

Then let's take some epicenters. I'll write the number one by the "T", the earthquake I just described. I will write a number 2, I will write a number 3, and I will write a number 4.

Now, could you tell me for any one of those earthquakes whether focusing would occur at Diablo Canyon site given those epicenters and given rupture in either direction, north or south? Isn't it a fact, Dr. Brune, that you would not get focusing resulting in higher accelerations at the site with the epicenter at any one of those places?

A Well, I think that for number four you could be

WEL/mpb3

somewhat in the zone of focusing depending on how broad it is, and how incoherent it is.

But basically that's correct. In the statement that I made in the text I was not assuming that we knew where the Hosgri fault ended going up in that direction. So-- or exactly where it was, so that --

Q Now can you scale off how far away number four is on this map? And I think if I -- yes, there's the scale right there.

Can you tell us? Do you have something to measure with here where we can scale that off as to how many kilometers number four is away?

Well, let's put it this way: It's certainly more than ten kilometers, isn't it?

A Yes.

Q In fact, it's probably more like 20, 25 kilometers, isn't it?

A (Nodding.)

Q Can you answer audibly?

A Oh, yes.

Q So, let's go to your conclusions now. And this says:

"The main conclusion of my testimony is that, based on our present limited data base for near source (epicentral distance less than ten

WEL/mpb4

kilometers) ground motion for large earthquakes (magnitude greater than seven), and based on our present limited understanding of the seismic wave generation and transmission, the ground motion postulated in USGS Circular 672 for a magnitude 7.5 earthquake (peak accelerations 1.15g, peak velocities 135 centimeters per second) has not been shown to be conservative."

How does that statement apply to Diablo Canyon?

A It applies in the sense of giving the data that we have. Near large earthquakes the uncertainty and stress drop, which could be very large, in some cases very small. The uncertainty in direction of propagation of rupture, the effect of layering, the effect of fault break out, all of the things that preceded here; then all those collectively are taken into account.

May I finish?

Q Sure.

A That that data and that knowledge indicates that we cannot be sure that the circular is conservative.

Q But you, taking this map, you can't get focusing within ten kilometers of the site.

A That statement does not mention the word "focusing". So one of the many parameters of the fault.

wel 1

Q Focusing doesn't apply.

A Could I go back and say that I don't agree with your statement that with this map you can't get focusing.

First of all, the conclusion, as I said, is based on the fact that there is some doubt about the interpretation of the continuity of the Hosgri fault and exactly where it goes. It's --

Q Well, now, wait a minute. You're not a geologist. You're not here to testify that this map is wrong, are you?

MR. FLEISCHAKER: Objection. First of all, counsel is arguing with the witness. He's interrupting the witness, and he's misconstruing the testimony.

This witness' testimony was that he looked at several maps, and on the basis of those observations, and in one map in particular he made a tracing, and that tracing led him to this conclusion. And that conclusion is stated on page 3-13 of his testimony:

"Energy released about 20 km up the fault could be focused nearly directly at the Diablo Canyon site."

Now what this counsel is doing, he's taking one map out of many which, for all we know, could be a cartoon, and he's plotted some hypothetical points on there, and I think that as a result he's misconstruing the testimony.

He's interrupting the witness. The objection is

that you are interrupting the witness and misconstruing the testimony.

MRS. BOWERS: Mr. Norton,do you want to respond?

MR. NORTON: I don't believe I interrupted the witness, and I don't believe I'm misconstruing the testimony.

I was asking the witness if he were a geologist who could testify that this map was wrong.

MR. FLEISCHAKER: Furthermore, his questions were argumentative.

MRS. BOWERS: Does the Staff have a position on this?

MR. TOURTELLOTTE: No.

MRS. BOWERS: Well, Mr. Fleischaker, this is a map that was introduced by the Joint Intervenors.

MR. FLEISCHAKER: We didn't introduce --

MR. NORTON: Our cartoon.

MR. FLEISCHAKER: We didn't introduce that map -- I don't recall why we introduced that map, but I think that's part of Hall's work, and the point of his work, I think, is to indicate that there might be continuity between the San Simeon, the Hosgri, and the focus of that work is on geologic offsets.

But that doesn't matter, because if you use -- if you take the Applicant's own work and you take a look at it closely, these plates that are in his own work, and you start

wel 3

drawing lines, you'll see that it is exactly -- that the lines demonstrate the point that Dr. Brune is trying to make here.

And we can sit here and we can play, we can put this map up, we can put this map up, we can put this map up, all afternoon. And if we continue in this vein, I have no other choice but to take these maps -- the Applicant's own maps, by the way, that are in evidence as part of the FSAR -- and demonstrate that within 20 kilometers you can find the fault as he has mapped it, the Applicant has mapped it, and if you take and project a line along that fault toward Diablo Canyon site, it runs right into the site, and that is within 20 kilometers, and that would demonstrate the sentence that is at the bottom of this witness' testimony,

> "Energy released about 20 kilometers up the fault could be focused nearly directly at the Diablo Canyon site."

And I'm referring specifically to plate 1 of Appendix --

MR. NORTON: Mrs. Bowers, this is getting ridiculous. This isn't an objection. This is a closing argument.

MRS. BOWERS: The Board will consider this matter.

(Pause.)

We think it is appropriate to use this map and, as I mentioned earlier, it was originally introduced by the Joint Intervenors.

wel 4

Now, another map could be introduced, Mr. Fleischaker. Do you feel this is not representative or correct?

MR. FLEISCHAKER: Yes, ma'am, it's in evidence.

All I'm pointing out is that, you know, we can do this all afternoon. There are other maps that the Applicant has drawn that are in the FSAR and in evidence, and if you take these maps we can play the same game and come up with different results.

In fact, you can come up with results that directly confirm the testimony that this witness has given. And that's all I'm saying. So on redirect we'll have to play this game all over again.

MR. TOURTELLOTTE: Well, let's go.

MRS. BOWERS: Well, we permitted Mr. Norton to go out of turn, really, so you have an opportunity on redirect.

MR. FLEISCHAKER: I appreciate that, but the initial objection to the point that he was arguing with the witness and was interrupting him.

MRS. BOWERS: Well, --

MR. FLEISCHAKER: I'll withdraw the objection.

BY MR. NORTON:

Q Dr. Brune, I have a question now. Who wrote the testimony, you or Mr. Fleischaker? That last sentence?

A I wrote the testimony.

wel 5

Q Did Mr. Fleischaker have any input to it?

A No.

Q My question to you before the objection was:

You are not a geologist who is here to say that one map is good and another map is not good, are you?

A Well, let me explain the context of my thinking.

As I said, since I read the testimony of some geologists which said that the Hosgri fault may be continuous and it may not be known exactly where the fault goes up in that direction, I assumed that one of the possibilities is to make a continuous fault at depth, even though the surface break is not outlined as continuous. But one possibility is to make a continuous break at depth, or a break that tilts, dips at a certain angle, so that -- So I think you're correct, if we accept this as the only possible interpretation of faulting, I can proceed and answer that I don't think that focusing would be very effective in this particular case for this fault.

Q Okay. But the part where there's some dispute about is to whether there's a connection or not. Do you know where that is that that question arises, physically?

A Well, I know what my interpretation of what it was, yes.

Q Could you tell me that?

A The question as I remember it was whether there

wel 6

was a connection between the San Simeon fault and the Hosgri fault up in this direction, and uncertainty about magnetic anomalies and various interpretations.

This region is exactly where the fault went.

Q As a matter of fact, that is in the area of San Simeon Point, is it not?

A Yes.

Q All right. And how many miles away is that from the site? Please scale it off.

A I think the point you're making is that's too far by itself to be effective in this, and I'll accept that. But there is still the uncertainty about where the fault is and where it connects. And all I said in the testimony is that a calculation should be made to see how effective it is. I did not say that it would be effective.

MR. NORTON: I have nothing further.

MR. TOURTELLOTTE: Mrs. Bowers, a moment ago I thought I had a third motion to strike, and I do.

I'd like to strike the last sentence of the first paragraph on page 3-18, the one that reads:

"The situation is such that in the face of the strong evidence that high accelerations and velocities can occur, but with a data base too limited to be sure what the probabilities are, we can only conclude that the higher the

design levels, the less the risk will be."

I think the examination of the witness on that topic indicated that he was talking about building design, and he is not a structural engineer, and he cannot make that kind of a judgment.

We have had other testimony in the proceeding which indicates that not only are we concerned about just the accelerations, but we're concerned about such things as stiffness and ductility of the structure and their components.

And to make this kind of a statement would be misleading. It could be cited by the Intervenors in an evidentiary way that would mislead the reviewers as well.

Moreover, if there was any possibility of connection between this witness and making a statement like that, it was wiped out when he indicated at the beginning of my direct that he really hadn't participated as a consultant in building for earthquakes.

Now, I also know that previously we have had -- in my previous motions Mr. Fleischaker mentioned the event that occurred the other day, but it really isn't in parallel at all, because what we have here is testimony which says one thing, and upon exploration by cross-examination indicated that it was actually not within the competency of this witness to testify about it.

So this is, in effect, the first that we have

wel 8

known of it.

It's impossible to read the statement itself and know for certain whether he's talking about structural design or whether he's talking about some other design that's known to seismologists.

Consequently, this is the first opportunity we have had, and it's my understanding from ALAB-179 that we have the right to make that motion to strike at this time.

DR. MARTIN: I recall some of the questions and answers with respect to this statement. One answer was to the effect that Dr. Brune assumed that if the building was built to withstand 1g,it would be safer than if it were built to withstand .5g.

Are you refuting that kind of statement?

MR. TOURTELLOTTE: Well, I'm not here to refute it one way or the other. I am saying that this witness can't make that kind of a statement.

Sure, it sounds good. It really sounds good to me to say 1g or half a g, but let's change the values a little bit. Let's talk about 5 g's or 2 and a half g's.

Are we making that structure so stiff if we change the design, are we making the structure so stiff that it loses ductility and the result is the opposite of what a layman might think?

I don't know. I don't know what the answer is.

wel 9

But I know this witness can't make the statement with any degree of competency about whether a design that's one-half g is better than a quarter g, or that 2 g's is better than 1g. He simply doesn't have --

DR. MARTIN: The objection really goes to the witness' expertise, not to what he's saying.

MR. TOURTELLOTTE: No, in fact, you know, we might look at any number of witnesses who might come up and what they have to say might be accurate, but the problem is we don't really know whether they're accurate or not, if they don't have the expertise to back that statement up.

So I guess to answer your question, no, I don't necessarily argue with that, but on the other hand I don't know whether it's true or not. I've learned an awful lot about structural engineering, and there's still a lot that I don't know about it.

So I'm not willing to pass on structures and components, about increasing design or decreasing design.

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WEL7

DR. MARTIN: Okay. I just wanted to be clear on the basis of your motion.

MRS. BOWERS: Before we go on with the motion, I'd like those of you in the audience to refrain from expressing either approval or disapproval of what's happening in this proceeding.

Now we've got the motion.

Mr. Norton, do you have a position on the motion dealing with that last sentence, the top paragraph on page 3-18?

MR. NORTON: Well, I would just like to reiterate what Mr. Tourtellotte has said. It's not the question of whether the statement is correct or incorrect, as in the case of Mr. Hubbard, it's a question of whether the witness is competent to be testifying under oath and giving opinion testimony in an area outside his area of expertise. And I don't think we can sit around and decide whether or not the statement is correct as a basis of whether it should be allowed in or not.

I think the test is whether or not it's within the witness's area of expertise. If it's not, then it should not be allowed in. And I think we followed that fairly closely throughout this proceeding from the very beginning. With our witnesses Mr. Fleischaker insisted on that, and was sustained on a few occasions, and so on.

mpb2

So the question to me is whether or not it's within his area of expertise. I think he has fairly clearly stated that it is not. And I don't make a judgment other than that.

I think on that basis it should be struck.

MRS. BOWERS: Mr. Fleischaker?

MR. FLEISCHAKER: Well, I disagree for this reason:

There are really two things that are floating around in the argument here. One of them is whether this falls within his area of expertise, and the other one, where it is probably misleading. Let me deal with the last one because I think it's the easiest to deal with first.

I think that on the basis of the cross-examination that it's perfectly clear what Dr. Brune is talking about here. He indicated that he's not trying to designate a zero period limit, he's not trying to, you know, specify a particular acceleration or response spectra to apply to a building.

Rather, what he was saying is that it may be that when you consider all of the factors involved, you wouldn't go to a higher acceleration level given to do with the site characteristics or with the particular frequency response of the building, or whatever.

So that I think that his testimony made it perfectly clear that this statement is a broad statement. It is a

mpb3

more general statement along the nature that Dr. Martin has indicated. And I think that it falls within his area of expertise, and I think it is consistent for this Board to so rule.

I recall that at the beginning of the proceeding I made two objections. One of them was sustained and one of them was overruled with respect to the expertise of Dr. Bolt and that panel. The first objection I made was some discussion about the response of the Diablo Canyon structure, and I think the Board sustained me on that one, saying this wasn't the panel to deal with that specific question. But then I made a more general objection having to do with the scope of seismology. And I think that -- and the Board at that time ruled, and I think I agree, that seismologists not only make determinations about ground motion paramaters, but through their knowledge of intensities and the effect on structures generally, they have the ability and it is within their expertise to discuss damage to structures generally.

And I believe that that is the nature of this statement here. What we're talking about, this is a general statement having to do with damage to structures generally. And that falls within the scope of the expertise of a seismologist.

I believe that was the nature of the Board's prior

mpb4

ruling, and I believe that ruling is applicable in this case.

MRS. BOWERS: Mr. Fleischaker, it's not raising the question, it's based on a conclusion. We can only conclude that the higher the design levels, the less the risk will be, rather than just raising the question.

MR. FLEISCHAKER: Well, that goes to the point that Mr. Norton was making, which was whether the statement was right or not.

I'm saying that the Board may not agree with Dr. Brune's conclusion. The question is is it within his area of expertise to make that conclusion, a general statement about ground motion and general levels of design. And I think it's consistent with arguments that have been made in the past by Mr. Tourtellotte when he was talking about seismological panels, it was consistent with Mr. Norton's statement when he was seeking to -- when he was responding to the arguments I made about Dr. Bolt and that panel.

The point is that it is within the area of expertise of a seismologist to make general observations about the level of damage and building response. It is not -- and I think this Board's ruling is that they do not, however, decide and determine particular characteristics of response spectra. That's a structural engineer's job.

I think this is a more general statement and falls within the expertise of a seismologist. Dr. Brune is a

mpb5

seismologist, and so I think --

MR. NORTON: Excuse me, Mrs. Bowers.

I find that incredible, because I tried to get Dr. Brune to tell us what would happen with 4gs or with 243 percent of gravity and so on and so forth and he couldn't answer. He refused to answer any of those questions, saying that was not his area of expertise. And yet this conclusion is going right to those questions he refused to answer because it was outside of his area of expertise.

I don't understand the argument.

MR. FLEISCHAKER: The argument that I made then -- and I used the word very specifically -- was would you designate -- he was requesting in that line of argument for Dr. Brune to designate a particular acceleration as the zero period limit for a bunch of buildings, and I was saying that it was without his area of expertise to designate a specific zero period limit for a collection of buildings or for Diablo Canyon in particular.

But it is not without his area of expertise to make general observations about the correlation of ground motion parameters and damage to structures.

MRS. BOWERS: I think we have the positions of the parties. So the Board will consider it.

(The Board conferring.)

MRS. BOWERS: Well, the Board has considered this

mpb6

matter, and the motion to strike will be granted, since we do think this is a conclusion on the part of this witness dealing with structural design.

MR. NORTON: Mrs. Bowers, I have two minor house-keeping chores.

I'd like to move Applicant's Exhibits 36 and 37 into evidence at this time.

Applicant's Exhibit 36 doesn't have a title. I guess we can call it Applicant's drawing, Applicant's free-hand drawing.

And Applicant's Exhibit 37 would be Revised Joint Intervenors' 35 -- or Annotated Joint Intervenors' 35, I think would be a better title for it.

MRS. BOWERS: Mr. Fleischaker, Applicant's Exhibit number 36 and Applicant's Exhibit number 37, which is the annotated version of Joint Intervenors' 35, are now being offered into evidence.

Do you recall the first one?

MR. FLEISCHAKER: Yes, 36 was the cartoon, I think, with the propagating -- I have no objection.

MRS. BOWERS: Mr. Tourtellotte?

MR. TOURTELLOTTE: No objection.

MRS. BOWERS: Well, Applicant's Exhibit number 36 and Applicant's Exhibit number 37 are admitted into evidence.

mpb1

(Whereupon, the documents previously marked as Applicant's Exhibit 36 and Applicant's Exhibit 37 were received in evidence.)

MRS. BOWERS: Now we have yet to get to the Board's questions for this witness, and I understand that he has commitments where he needs to take a flight -- at what time?

MR. FLEISCHAKER: I think the flight was 5:30.

THE WITNESS: 5:30 or 5:45, I'm not certain.

MRS. BOWERS: Well, rather than taking a recess, we would like to proceed, since we did have a recess not long ago, because you, of course, need time to get to the airport.

EXAMINATION BY THE BOARD

BY MR. BRIGHT:

Q Well, Dr. Brune, I'll give you the same intelligence that I've given the Applicant's geologists, seismologists, et cetera:

I am not a geologist or a seismologist, and principally what I am asking about would amount to either clarification to me or definitions of things that I'm sure are quite familiar to you.

The item "particle velocity" comes up fairly often. What is the particle?

mpb2

A That could be read in this testimony as a point in the medium, the velocity of a point in the medium.

Q It would just be a massless thing?

A You could think of it as a local atom, the velocity of that atom as it moves around.

Q Fine. That's what I thought. Good.

On your focusing, from something you said I got the idea that this was much of what in physics we think of as reinforcement of -- in light or sound, this sort of thing. And the phase relationship between whatever the -- well, in this case it would be the leading edge of the earthquake crack and the speed of propagation of whichever energy wave you're talking about through the medium would be controling.

A Yes, sir, that's correct.

Q Is this what you meant by coherence, or was coherence strictly on the fault?

A Well, coherence, lack of coherence could mean that the source is not moving as a smooth steady source. Or it could be any number of things that introduce phase distortions in the energy so that they don't arrive at the same point in phase with one another.

So it could be incoherence introduced by the fact that the fault itself is moving incoherently and therefore the waves generated by it are incoherent. It could be the medium, the velocities in the medium will distort the

mpb3

wave fronts as they propagate around so that they do not arrive at a particular site coherently.

I think that's the main sources of incoherency. It would either be the structure or the source.

Q Well, then, let me ask you:for a particular material in the earth, rock, whatever, associated with that would be a particular velocity of propagation of the energy wave from the fault, from the earthquake, from the hypocenter.

A Correct.

Q What do we know about the crack propagation speed along the fault?

A Very little is known about that.

Q Is there any known relationship between what I guess we would consider a fairly well known velocity of the energy wave and the velocity of crack propagation in a given medium?

A There are numerous theoretical studies with different types of assumptions which result in estimations of different velocities. So the ratio of the rupture velocity to shear velocity is a critical velocity.

If the rupture velocity is exactly equal to the shear velocity, then you have perfect interference of the shear wave energy, and you get the highest accelerations. Some studies seem to indicate that cracks would be stable at the shear velocity or even higher at the P wave velocity.

mpb4

Others say that it should be lower than the S wave velocity.

So the situation in the theoretical field of understanding these is such that we can't be sure. Most models that are done, you assume that the rupture velocity is slightly less than the shear wave velocity. Part of this is based on some evidence of rupture in the field that seems to suggest this is true. But, again, the data are not good enough for us to be confident that that's correct.

Q All right.

The question of velocities and accelerations came up on -- I think in regard to a particularly high velocity that was obtained at Pacoima Dam.

Let me ask -- I think I've asked it before, but let me ask it once more:

The primary information that you get from the accelerometers is acceleration.

A That's correct.

Q And from this particular trace, whatever you want to call it, you obtain velocity by integration.

A Integration, correct.

Q Integration of this particular signal. Okay.

So you don't have machines that are particularly set up to actually perform the integration and play it out for you at the time it's going on?

A There are such instruments, but there are none

mpb5

that operate as strong motion instruments. In other words, there are none that will stay on scale in intense shaking. But in other cases we measure velocity all the time.

Q Okay.

Now I had a little problem in understanding page 3-7, and a little before that, I think, where you're talking about extrapolations.

Now these are taking small or smaller than your major earthquakes and from instruments that are some distance away, and trying to move that back to the hypocenter, or wherever you want to, and then taking that kind of curve and determining, say, the ten kilometer values --

A That's correct.

Q -- in each respect.

Then, I guess I need a lesson in standard deviations and confidence limits.

I guess it was Trifunac and Brady say that:

"...for a 7.5 earthquake the average peak accelerations could be 1.75g and that the average plus one standard deviation could be about 2.5g."

Now does that mean that you have a range from 1g to 2.5g?

A No. It means that 1g is the mean, right back on the fault itself. And one standard deviation, which is about two-thirds of the population, would fall within 2.5g. But

mpb6

in statistics when we formulate a statistical problem like that, you say the probability of an observation falling outside of some limit from the mean. So, for example -- statistics per se, of course, doesn't always apply to the real earth, but in a statistical distribution there is a finite probability of a very, very large value way up there. But the probability is so low that you say you can ignore it.

So that what that curve means there is if those curves are correct, extrapolating back to the origin, then you would expect the average value to be 1.75, and two-thirds of the value would fall within plus or minus -- well, one standard deviation, which on the upper end would mean 2.5g.

Q And the standard deviation is different on the -- well, I understood the standard deviation to be a plus or minus.

A Yes, there would be some below that too.

Q Yes, and that's what I was asking you.

A Yes. The same thing says that two-thirds of the values would fall within one standard deviation. There could be part of them above and part of them below. There would be some values below that. So there would be some much lower than 1.75g.

Q And would the lower be the same as the upper standard deviation?

A You mean the amount of standard deviation from the

mpb7

mean be the same --

Q Yes.

A -- in the upper and lower direction?

Q Yes.

A I believe it would in that sort of analysis.

Q Okay.

So that if the average peak acceleration, if it could be 1.75g, then you would then have a range --

A That's correct.

Q -- because you have .75 as your upper limit, .75 would be your lower limit, and it would be one, one to 2.5g?

A Well, 2.5g --

Q Within the one standard deviation.

A 1.75 to 2.5g, that means on the upper end that's .75g. The curve for one standard deviation is .75 above, and that means the one for the lower one would be .75 below, below 1.75, in other words, one, right.

Q Fine.

You had quite a conversation with Mr. Norton about what this -- well, the next sentence:

"Trifunac gives about 1.7g for the average acceleration near the fault for an M equals 7.5 earthquake and about 4.0g for the acceleration with 90 percent probability of not being exceeded."

mpb8

Now, my feeling when I first read this was that this was trying to figure what an upper limit would be, and not necessarily that this tells you that you're going to get one of these for every ten earthquakes that came along.

A Well, I think 90 percent confidence means that if you had a lot of samples then 90 percent of the time the values would fall within that value, yes, within that amount of deviation from the mean.

Q But isn't this kind of a standard way of determining what an upper limit in, say, the real world is, 90 percent probability of not being exceeded is the wording?

A Yes.

Well, strictly speaking, I'm not sure what the -- you mean when I say that a phenomana which has only a probability of one in ten of occurring is an upper limit? There are some circumstances where that kind of reliability would be acceptable, but I think there are other cases where it wouldn't be.

In some cases you want to be 99 percent certain that a certain event will not occur.

Q Oh, well certainly.

A But that's what -- I think your interpretation of what it means is correct. It means that 90 percent of the time the values will not exceed that.

Q All right.

mpb9

And that, then, also goes for the values that are given in the next sentence which talks about an epicentral distance of ten kilometers.

A Correct.

Q Then, on 3-19, there, at the last sentence in our first paragraph, you say:

"Average accelerations may be about 1g with the average plus one standard deviation about 2g."

Well, now, if that is so, then it would appear to me that you have a range of from zero to 2g. It says average is one g, one standard deviation is 2g. What is it on the lower end?

Do you see what I mean?

A I think there is somewhat of a logical inconsistency. But I think the "about" -- I'm trying to sort of summarize a whole bunch of curves that people have made, none of which I feel are accurate. And so in that I am making a qualified statement.

Q Oh, these curves are based on empirical --

A That's correct.

Q -- data.

All right. Thank you.

BY DR. MARTIN:

Q I have one question.

mpb10

I am interested in your argument that the possibility of 2g acceleration from near a 7.5 magnitude earthquake hasn't been disproved. What, in your opinion, would constitute proof-positive that 2g could be expected in the near field from a 7.5 earthquake?

A Well, I made a rough attempt to state that when I said that I think that at least ten observations in the near field would be needed. I'm not trying to predict that at the end of having ten observations I would be then ready to say what it is.

Q You mean ten measurements, ten actual measurements?

A At least ten actual -- what I said was at least ten actual strong motion measurements in the near field of large earthquakes, that close to large earthquakes.

Q And those data, then, would constitute proof-positive that it would be or would not be expected?

A Well, it depends on what you've got. It's not a simple logical -- if you --

Q Well, if you got no measurements of 2g, would you then conclude that it's not to be expected?

A No. You would just change the probabilities. But on the other hand, if you got 2g, then you would know that it's possible. So the argument is not a linear one depending on which way you go.

Q Is there any statistical basis for using actual

mpbl1

measurements to indicate an expectation of such high accelerations?

A All of the extrapolations of Trifunac and Brady and Ambraseys and those people, that's what they did. They used empirical data and extrapolated back and came up with those conclusions. But since the data are so few, there's very low reliability in trusting them in that range.

Q Well, I see you have cited in your testimony, reference 10, a paper by Hanks and Johnson, 1976.

A Which page of my testimony is that on?

Q 3-21. It's in the list. I don't know where you cited it.

A Okay.

Yes, I cite it on page 3-8.

end MADELON WRBLOOM flws (2e)

2E
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C14

Q I can't call this a conclusion of their's because it doesn't appear in that section of the paper, but there's a sentence to the effect that:

"also there is considerable scatter in observed peak accelerations at any magnitude level in Figure 1. The peak accelerations that are about 10 kilometers --" which I assume to be range -- "of about 10 kilometers considered in this study are essentially independent of magnitude for M greater than approximately 4.5."

Do you recall that --

A Yes, that's similar to the conclusion that Ambraseys wrote.

Q Do you agree with that?

A I agree that, as I said, that the upper limit may be independent of magnitude. Again, we don't have enough data to be sure. But the average probable acceleration clearly increases with magnitude, as Hanks and Johnson say.

In other words -- Are you clear on that?

Q Yes. But the data I'm looking at tell me that the highest accelerations were not associated with the highest magnitudes.

He's got an earthquake listed at 6.4 magnitude giving an acceleration of 1150 centimeters per second squared He's got a 7.1, and it was only 342.

WRB/agb2

A The larger earthquake was only one -- I believe it was only one data point. And then when they went in after the earthquake, they put a lot of records down, so that point is not taken at the same site in the same position relative to the faults as the other data were, there's an average with a sort of ridge.

Q All right.

Then would you suspect that these data that are higher or lower than you might expect on some kind of regression line would be indicative of focusing and directivity?

A Well no, with so little known about the situation I would not say that that's it. I would just say that, given that we have scatter, if we plot a curve versus magnitude there's a range. On any given event, you can fall above or below that.

So, two successive -- you might get a larger -- for example, you could sometimes get larger earthquakes with less acceleration and you could sometimes get closer earthquakes with less acceleration than further ones.

Q That's exactly my problem, trying to obtain any useful statistical information out of the small number of data points exhibiting a great deal of scatter.

A Are you referring to that particular study or --

Q This particular study plus three data points that were provided later on, later than this study.

WRB/agb3

Well, without going into the average acceleration, I note that we have a coefficient of variation of about 80 percent which, if you apply it to the formal interpretation of probability curves, says that you should have a definite number of such earthquakes where the measurements have negative acceleration. In other words, it's obviously a skewed distribution.

A Obviously.

Q And I see no effort to treat it other than as a normal distribution. In other words, make any translations such as log normal treatment.

A Well, yes, I agree that --

Q But the mediansofthe things he gives are like 0.3g for all the records he has for magnitudes greater than 5.5 or equal to aor greater than 5.5.

Well that's my problem. In these statistics, I can see no indication of a reasonable basis for assuming accelerations so large as 2g.

A Well the way I look at it is, at the present time, we only have two recordings, one sure recording that close to a large earthquake and perhaps this recent one from Iran with 0.8g.

And given those two, since one of them was over 1g, I would not say that -- certainly the upper limit is not 1g, it's somewhere above there, and given the kinds of standard

WRB/agb4

deviations that we see at other distances, it's reasonable to say that it's probably about 2g, that the range could be that far up.

Q All right.

But based on this little bit of data, do you know of any statistical procedure for estimating the number of such data points required to make statistical inferences at a given level of probability?

A No, I'm not that aware of statistics. As I said in my testimony --

Q So really -- Would you agree that your testimony relies largely on theoretical arguments, yours and other people's?

A Well part of my testimony is that we don't know what the accelerations are, and I think that that relies on the fact -- my understanding of the data at larger distances and smaller magnitudes, the variations -- in other words, completely unobserved data to project in and say what's likely to be the variation in range in closer and then, given that situation, then say how much data you think you would need. I might form an idea as to that, and then you tell me you only have two points or something, then my conclusion would be from that that we don't know, which is what my conclusion is.

Q You're conclusion is that we don't know?

A Yes.

WRB/agb5

Q And we're not likely to know without a good deal more pertinent data?

A Yes. There's a possibility that we could get it in a relatively short time because we have deployed a large number of instruments recently.

Q You are now at the point of waiting for a big earthquake to occur near your instruments?

A That's correct.

Q Okay. Thank you.

MRS. BOWERS: The Board has no further questions. Mr. Fleischaker?

MR. FLEISCHAKER: Could I have about two or three minutes? I want to take this map up to Dr. Brune.

MRS. BOWERS: We've had a request for a few minutes.

THE WITNESS: I'd like a break, too, for probably the same reason.

(Laughter.)

MRS. BOWERS: Well we'll have a brief recess.

(Recess.)

MRS. BOWERS: Are you ready, Mr. Fleischaker?

MR. FLESICHAKER: Yes.

REDIRECT EXAMINATION

BY MR. FLEISCHAKER:

Q Dr. Brune, the first thing I would like to take up

WRB/agb6

on redirect is the question of the tracing that you made and the map that you took the tracing from. Have you been able to identify the map that you took the tracing from, from which you drew the following conclusion which appears in your testimony at 3-13:

"Energy released about 20 kilometers up the fault could be focused nearly directly at the Diablo Canyon site."

Can you identify --

MR. NORTON: Excuse me, I'm going to object to that, it's an extremely leading question and it's also contrary to the testimony. This witness testified he did not draw that conclusion from the map that the tracing was drawn from, he drew it from several maps.

BY MR. FLEISCHAKER:

Q With that correction. Can you identify the map from which you apparently took the tracing?

A Yes.

Q Okay, for the record, could you state what that map is?

A Well it says: Map Showing Bathymetry and Major Offshore Geologic Features in the Region Between Point Arguello and Cape San Martin, Appendix 2.5(e), Plate One. It says ESA 1310, July 11, 1975, and it's the map you handed me, I don't know which it is.

WRB/agb7

Q Okay. That's a 1975 map that I took out of the FSAR and handed to you.

MR. NORTON: Is that a question?

MR. FLEISCHAKER: I'm identifying it for the record, do you have any objection?

BY MR. FLEISCHAKER:

Q I'd like to move quickly to the Tabaz earthquake, what information did you have on the Tabaz earthquake prior to writing this testimony?

A The only information I had was essentially what's presented there, that I talked with some people over the phone and they gave me that -- they were having difficulty following the trace, but it was apparently about 0.8g peak acceleration, and they weren't sure what the vertical acceleration was.

Q Did you have any copies of the record?

A Yes, I had a very poor Xerox copy, which I still have.

Q And did you try to make some calculations regarding the peak accelerations from that?

A NO, I just looked at the record.

Q What additional information would be useful regarding that earthquake in helping you formulate some conclusions about -- formulating conclusions that relate to those that are stated on Page 3-2 of your testimony?

A I'd need to -- well, I would like to know the

WRB/agb8

hypocentral points, the direction of rupture propagation, depth, source mechanism, complexity of the source, whether or not there are multiple fault segments, all the information about the source itself, hopefully similar to San Fernando or better.

Q Now the information that is currently in the record that was read to you today by the Applicant's attorney, assuming that information is true and assuming that the peak acceleration for that record is 0.8g, does that change -- how does that change, if at all, the conclusions that you've drawn on Page 3-2 and 3-3 of your testimony?

A I don't think it changes them at all. It means two data points, and if we presume it becomes reliable, then I would still say that that's not enough data points to be sure what the average standard deviation is.

But I wouldn't say it has zero effect. Every time we get a new data point I feel somewhat more confident of the results.

Q How many strong ground motion records do we have within 10 kilometers of earthquakes magnitude equal to or greater than 7?

MR. NORTON: May I have that question repeated? I'm not sure I heard right, within two kilometers?

MR. FLEISCHAKER: Within 10 kilometers.

MR. NORTON: I think the question said two, that's

WRB/agb9

why I asked to have it repeated.

MR. FLEISCHAKER: Do you want to repeat, or shall I restate the question?

BY MR. FLEISCHAKER:

Q Restating the question: Do you have any estimate as to how many records of strong ground motion we have within 10 kilometers of earthquakes magnitude equal to or greater than 7?

A Well I think we only have a couple that I know of. If we accept the Tabaz earthquake, which I think probably is one, then depending on the discussion we had before about a few other ones as to, well, we don't know where exactly the rupture was and so forth, we might be within 10 kilometers, but basically it's very few.

Q When you say very few, could you be more definitive, 10, 20?

A Well no, it's around -- well, for magnitude 7.5, there's only one or for greater than magnitude 7.5 there's only two and if you say greater than 7, right offhand I don't know of any others. But my memory of magnitudes and all this stuff is getting a little bit fuzzy, so I'm not sure.

Q Let me try your memory. How about if we go to 6.5?

A 6.5? Well I hesitate to try to recollect this off the top of my head when there's a table -- I mean, we could go

WRB/agb10

look it up in Boore's paper or something and see how many data points they had. But I can make a rough guess, if you want.

Q Boore's paper, is that 672?

A No, that's the more recent USGS paper.

Q The Open File?

A Yes, where they give a lot of statistical values from papers.

Q All right. Well rather than have you guess, we'll explore that with the USGS people when they get here.

In your testimony, you mentioned the recent earthquake down the bay near Mexico which was estimated to be a magnitude 7.1 and the acceleration at Oaxaca approximated 0.2g.

A 7.8 was the magnitude, or 7.9, actually.

Q I'm sorry, 7.9.

And I believe that the estimation of acceleration that you stated in your testimony earlier was 0.2g.

A That was at quite a distance from the fault, though.

Q Do you have an estimation as to the distance?

A I believe it was around 150 to 200 kilometers, though I don't remember exactly. It depends -- 100, I don't know.

Again, it's kind of hard to tell at this time, since we don't know where the epicenter is yet. We know where

WRB/agb11 Oaxaca is, but we don't know where the rupture broke, and there is not -- we have instruments down in the area right now trying to locate the aftershocks, and there's some uncertainty as to where the epicenter is.

Q At Page 3-11 of your testimony, you discuss the Kostrov model propagating stress drop, and on cross-examination you discussed that there were certain assumptions not found in nature.

A Excuse me, I haven't got the page yet.

Q Page 3-11.

A Okay.

Q There were certain assumptions not found in nature, in particular having to do with the magnitude approaching infinity as you got to the crack tip. Why are the conclusions therefore that you've stated here o this paragraph 3-11 applicable to the real world?

A Well the filtering has been done, as it says, to a corner frequency of 12.5 Hz. which is a reasonable number for the type of frequencies you see in strong motions.

And it is a reasonable model in the sense that it's a stress drop model, it's not an artificially forced model. I wouldn't claim that the Kostrov model is a reliable model for any particular type of faulting, it's one possible physical model.

So I believe that that kind of a rupture could

WRB/agbl2

occur in the earth and you could get that kind of coherency out to roughly that frequency. But I think that might be an extreme case, so I'm not trying to say that that's a -- that that should be the level of our computations at the present time for trying to predict strong ground motion, I think we should do things more realistic.

end2E

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2F,fls 2E

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Q So what you're saying is it's not applicable to the real world?

A It's applicable in a general way, the physics is.

Q You've got to watch out for these redirect questions.

(Laughter)

Why didn't you tell me about that?

(Laughter)

I have one more question: In your testimony you recommended that certain kinds of studies be conducted regarding propagating fault models in order to estimate the kinds of accelerations that one might see at the site. Could you describe generally the kind of model that you're talking about?

A Well I think that what I'd like to see is a propagating fault dislocation model in a layered half space similar, roughly similar to the geology at Diablo Canyon, and try different combinations of faults and different combinations of slip time functions on the fault, propagating in various directions, and then from the predicted accelerations try to get an estimate of what the probable accelerations are at Diablo Canyon. That's one of the things I suggested.

I believe I also suggested that some calculations be done on the fault breakout to see that-- You know, in a reasonable layered structure at Diablo Canyon, if you had a

WRB/wb2

fault starting at the bottom and going up to the top, and if the kind of velocities that were in the finite element model of Archuleta and Frazier, if that occurred what sorts of velocities you would generate at Diablo Canyon. I think that would be a very helpful calculation.

Q Is it possible to do those kinds of calculations given the techniques that we have today?

A Yes.

Q Do you believe that you can have some confidence in the results from those calculations?

A You can have some confidence. But, again, I'd have to know, you know, what kind of answers came out and how much variability there was, and so forth. I can't assume that I know the answers and then say what I would conclude after I got the answers; I'd have to wait until I got the answers before I'd conclude how certain sure I'd be of it.

Q Are you aware of anywhere that these kind of models have been run, anything similar to this?

A Well, yes. Things similar to that for which the technology is essentially available I think are being done by students and by some companies. So it's a technology that's available. It would take some time and money to do the various combinations of things that are necessary to explore enough of the variables to get a confidence about what the accelerations would be. But it can be done.

MRB/wb3

MR. FLEISCHAKER: I have no further questions.

MRS. BOWERS: Mr. Norton.

RECROSS-EXAMINATION

BY MR. NORTON:

Q I have primarily questions raised by the Board.

Let me first ask about the map Mr. Fleischaker gave you. Even using that map that you identified, it's not your testimony that there is a very high probability-- Let me rephrase that.

It's not your testimony, is it, it's really your feeling that the site would be influenced very much by focusing based on the maps of the fault?

A Well I think it could be, depending exactly on where the fault is. But, no, I'm not testifying in the positive sense. What I'm saying is, we should do the calculation and find out.

Q Well let's talk a little bit about that.

If you look at all the maps-- All the maps I've seen, including the one that Mr. Fleischaker gave you and the ones, 30 of Jahns' testimony and 44 of Jahns' testimony, all the maps I've seen, that if you look at the site, the site is approximately -- the fault trend is a northwest trend fault; okay? And if you look at the site, the site is approximately two-thirds of the way up the fault on the north axis; okay?

Do you understand what I'm saying? If you look at

RB/wb4

the fault in terms of a north-south plane, the site is approximately two-thirds of the way up the fault to the north end. Is that a generally fair approximation of your remembrance of the maps, give or take 10 percent: I don't care. But it's in that ballpark?

A I don't have anything to argue against that.

Q All right.

Now, also looking at all those maps, I don't see any way focusing can occur from the south. I don't see any way that that fault plane ever goes at the site where it could occur, where focusing, meaningful focusing could occur within ten kilometers or twenty kilometers of the site. Would you agree with that, looking at all the maps?

A Yes.

There are several phrases in there, like "meaningful" and so forth. But generally I agree with that statement.

Q The curves, if any, that you see are to the north; is that correct?

A That's right.

Q Okay.

Now I guess this is just the basic question. It is specifically applicable to the Hosgri, but I guess it would be applicable to any fault in the world:

The direction of rupture, it's a fifty/fifty

WRB/wb5

proposition as to whether it's going to rupture to the north or the south; isn't that correct?

A As far as I know, yes.

Q So any ruptures that we have occurring, half of them are going to go to the north where we aren't going to have any meaningful focusing; correct? --just as a given, on the whole fault?

A I accept the general logic of what you're saying.

Q Okay.

And then half of those, in fact more than half of the faults, the ruptures that occur are going to occur south of the vicinity, so it doesn't make any difference in which direction it ruptures; isn't that true?

A Well I know don't that it's true that half of the faults are going to occur there. But, not knowing any-- I would say that not knowing any of the physics involved, and not knowing what's going on, they could equally well occur north or south.

Q Right.

You're given a fault that has a length, and if you take the midpoint you can assume that half are going to fall north and half are going to fall south; is that correct?

A Well if you don't know anything else about it. There are some cases where there's seems to be a preference for certain directions of rupture. But they're not, you know,

WRB/wb6

established. So, like I say, not knowing anything else about it, you would say there's no preference for starting north or south.

Q So as a general basis we've already eliminated three-quarters of the earthquakes that appear, or that could occur on the fault as having any focusing effect at all on the fault, or on the site, just as a general premise, right off the top, three out of four, because of the location of the site and the direction of the fault, and the--

A That's correct, if there's a random probability of their occurring anywhere on the fault.

Q All right.

So, then, one out of four magnitude 7.5 earthquakes, or 6.5 or 7 earthquakes would be your area of concern; is that correct?

A I think that's a reasonable way to estimate the probabilities.

Q And then the epicenter of those earthquakes would have to be in some very specific spots to have any focusing effect on the site at all; isn't that correct?

A Yes. It would require special conditions in order to get strong focusing.

Q Okay.

A And there's lots of other situations where you might not get it.

WRB/wb7

Q All right.

Now can you assign any level of probability of that occurring at the site whatsoever, any level of probability above "it's possible?"

A It's possible, and it's plausible. But the actual probability of it occurring, no, I wouldn't try to assign that.

Q And whatever that probability is that you can't arrive at, other than "it's possible," would have to be added on to the probability of getting a 7, 7.5 magnitude earthquake in the first place, wouldn't it?

A Yes. The probability of focusing would be one of the many probabilities you would add on.

Q As a matter of fact you don't add it on, do you, you multiply?

A You multiply, yes.

Q So we're talking about probabilities that get so far out that there's no way to ascribe a number to them, is there?

A I wouldn't say there's no way to ascribe a number to them. I would say I have not studied the-- I don't know what the probability of a 7.5 is on the Hosgri fault. I haven't dealt with that particular problem.

Q All right.

And if we take the bottom line question, you

RB/wb8

cannot state here under oath today that it is probable that such an occurrence will occur at the Diablo Canyon site?

A Well there is a probability, but I don't know what the probability is.

Q But I said "probable."

A Okay. Then you have to quantify it.

Q Well you used "probable" in your testimony any number of times, so you quantify it for me.

A Okay, I would say that we don't know what the probability is. But I would agree that the probabilities are low for any given earthquake that it would be situated exactly so as to cause focusing at--

Q And wouldn't you go so far as to say it would be exceedingly low that a large magnitude earthquake would--

A No, I wouldn't add double uncertainties under low and exceedingly low, and so forth, like that.

Q Well that's a double uncertainty?

A Well I don't know what you mean by "exceedingly."

Q Very.

A I still don't know. I have difficulty knowing for sure if you don't say-- Well, we have the same probability, and you're right that I don't know what the probabilities are. So you can use that uncertainty to argue various different directions.

Q All right.

WRB/wb9

How about this as the bottom line: You are not prepared to testify under oath today that it is any more than possible?

A I have the same problem with "possible," that, you know, I would have to define it in my own terms, or know what you mean before I could say that.

MR. NORTON: No further questions.

MRS. BOWERS: Mr. Tourtellotte?

MR. TOURTELLOTTE: No.

MRS. BOWERS: Well the Board has no further questions.

Mr. Fleischaker?

MR. FLEISCHAKER: No. So we're off to the airport. No, I have no further questions.

MRS. BOWERS: Dr. Brune, of course, interrupted travel, and some of the other witnesses interrupted other commitments. And we certainly appreciate it when these accommodations are made so that we can continue going.

THE WITNESS: I'm glad to do it.

MR. NORTON: The Applicant joins in that appreciation.

(Witness excused)

MRS. BOWERS: All right. We'll recess until eight-thirty in the morning.

(Whereupon, at 4:55 p.m., the hearing in the above-entitled matter was recessed, to reconvene at 8:30 a.m., the following day.)