UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:		
GENERAL ELECTRIC COMPANY	:	Docket No. 50-70
	:	Operating License
[Vallecitos Nuclear Center - General Electric Test Reactor]	:	No. TR-1 (Show Cause)

Redwood Room,
Holiday Inn - Golden Gateway,
Van Ness at Pine,
San Francisco, California,

Wednesday, 10 June 1981.

The hearing in the above-entitled matter was reconvened, pursuant to recess, at 8:30 a.m.

BEFORE:

HERBERT GROSSMAN, Esq., Chairman
Atomic Safety & Licensing Board Panel
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

GEORGE A. FERGUSON, Ph.D., Member

HARRY FOREMAN, M.D , Ph.D., Member

APPEARANCES:

On behalf of the Nuclear Regulatory Commission Staff:

DANIEL SWANSON, Esq.
RICHARD G. BACHMANN, Esq.
Office of the Executive Legal Director
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Washington, D. C.

-more-

APPEARANCES (continued):

On behalf of the Licensee:

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-and-

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On behalf of the Intervenors Friends of the Earth, et al.:

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I N D E X

WITNESSES:	DIRECT	VOIR DIRE	CROSS	BOARD	REDIRECT	RECROSS
Joseph A. Martore) Christian C. Nelson) John F. Burdoin)				2226 2256 2259	2255	2257
Garrison Kost)) Richard Harding)) Richard Meehan)				2264	2294	2296

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E X H I B I T S

EXHIBIT NO.	FOR IDENTIFICATION	IN EVIDENCE
Licensee No. 42		2301
Licensee No. 43		2301

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P R O C E E D I N G S

(8:30 a.m.)

JUDGE GROSSMAN: The eleventh day of the hearing in the Show Cause proceeding is now in session.

It is my understanding, Mr. Edgar, that Mr. Meehan has not yet arrived, but ought to be arriving at about 9:30. Is that correct?

MR. EDGAR: That's correct.

JUDGE GROSSMAN: Okay. And since he is coming in on one of those all-night coaches, it is my intention of putting him on as soon as you say he is ready so he doesn't have to sit here and wait for other testimony.

MR. EDGAR: And we are going to put Dr. Kost up with him in case we get into the structural interface. It may well be more efficient to do it that way.

JUDGE GROSSMAN: That's fine.

MR. EDGAR: And we think that Mr. Harding will be here, if there are any geological elements of questioning and he could join that panel for that purpose.

JUDGE GROSSMAN: Thank you.

Whereupon,

JOSEPH A. MARTORE,

CHRISTIAN C. NELSON,

and

JOHN F. BURDOIN

resumed the stand and, having been previously duly sworn, were examined and testified further as follows.

JUDGE GROSSMAN: Would the panelists now, the structural panel for NRC, please state your names again so the reporters have you correctly?

WITNESS MARTORE: Joseph A. Martore.

WITNESS NELSON: Christian C. Nelson.

WITNESS BURDOIN: John F. Burdoin, B-u-r-d-o-i-n.

JUDGE GROSSMAN: Thank you.

BOARD EXAMINATION (resumed)

BY JUDGE GROSSMAN:

Q I had almost concluded my questioning yesterday afternoon. I do have one or two more questions.

MR. BACHMANN: Judge Grossman?

BY JUDGE GROSSMAN:

Q Mr. Nelson, we discussed yesterday the possibility of simultaneous design-basis accident and a seismic event which you responded to; but I hadn't asked you whether the NRC had considered the possibility

of a design basis accident occurring first, and then a seismic event occurring. Could you respond to that? Do you understand the question?

A. (Witness Nelson) Yes, sir.

MR. BACHMANN: Judge Grossman, may I clarify something that we were able to discuss last evening?

JUDGE GROSSMAN: Oh, fine. Yes, I would appreciate it.

MR. BACHMANN: Your original question concerned the integrity of the containment structure, in that it was not considered necessary to survive -- for the GETR to survive the seismic event. And then you queried: Well, what would happen if you had a design basis accident, assuming that the containment structure had lost its integrity? And how did we justify not taking this into account when analyzing the seismic event?

We checked it through, and Mr. Nelson has a cogent explanation to give you. However, first I would like to preface that with a reference to Appendix A of Part 50 of 10 CFR.

There is a criterion two in Appendix A to Part 50 of 10 CFR which talks about design bases for protection against natural phenomenon. And then it says: "Structures, systems, and components important to safety

shall be designed to withstand the effects of natural phenomena such as earthquakes." And then it goes on for a few more. And then it says: "The design bases for these structures, systems, and components shall reflect" and part two says, "appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena."

This would appear to require doing what you suggested should be done. However, the introduction to Appendix A says that: "These general design criteria establish minimum requirements for the principal design criteria for water-cooled nuclear power plants."

It is the Staff's position -- and then there is a further discussion and definitions. It is the Staff's position that this particular appendix is not a requirement for a facility such as the GETR. Similar to Part 100, we have used this as a guideline. But from a legal standpoint, it is the Staff's position that we are not required to do the simultaneous situations that would apply in the case of an actual, say, 1000 megawatt power plant.

Now Mr. Nelson has a further substantive explanation as to why we chose not to apply these simultaneous accident conditions.

JUDGE GROSSMAN: Fine. I appreciate your

telling me the legal standpoint, and I understand that this issue involves both legal and technical considerations, and it is very hard to separate them out. But that is fine. I understand that you do have this legal position now, and I will ask Mr. Nelson to also discuss how the evaluation resulted in this type of procedure.

WITNESS NELSON: Yes, sir. The Staff reviewed the justification for not seismically qualifying certain equipment that was designated previously as safety related -- for example, the containment. We considered several factors.

One, the differences between the GETR and nuclear power plants, including the power level or fission product inventory; the seismic scram system at the General Electric Test Reactor; the lack of need for complex systems to mitigate accidents; and the fact that at operating temperature the GETR is subcooled at atmospheric pressure.

The Staff's evaluation also found that the loss of nonseismically qualified equipment, safety-related equipment, within containment did not result in releases which exceeded the Part 100 limits.

Furthermore, based on our review of accident scenarios associated with design-basis events -- and I refer to the Staff's Safety Evaluation Supporting Power

Increase -- we determined that a seismic event would not be a cause for such accidents.

Finally, it is the Staff's opinion that there is no need to postulate or require that it be postulated that two very low likelihood events be considered simultaneously for design purposes.

BY JUDGE GROSSMAN:

Q Well, now that we've had the situation involving Three Mile Island in which the effects of a design, or what may or may not have been a design-basis accident, have been prolonged and the reactor was not in operating condition for quite some time, doesn't it seem that the Staff might consider that -- should have considered that possibility, too, in conjunction, or to be followed by a seismic event?

Do you understand my question? We're back to the first question I raised. Let me rephrase it. Did the Staff take into account the possibility that there might be first a design-basis accident in which there was then need to rely upon the containment; and then subsequently a seismic event which might breach the containment?

A (Witness Nelson) No, we did not.

Q Now is there -- What is the reason why you didn't consider it? You didn't think of it? Or you didn't

think it was important? Or there was a legal basis for not doing it? Or any other possibility? Could you explain to us?

A. Well, I think there are two factors. One, the legal basis, which Mr. Bachmann briefly discussed. The second, what I just tried to present, is the logic behind not requiring the two low likelihood events, the design basis event and the seismic event.

Q. Simultaneously.

A. Well, simultaneously or one right after the other. I treat those both the same.

JUDGE GROSSMAN: Okay, Mr. Bachmann, what takes the place of Part 50 when it comes to a test reactor of this size and used for this purpose?

MR. BACHMANN: I did not mean to imply that Part 50 itself did not apply. What I was explaining was the application of the criteria given in Appendix A to Part 50, in which criterion two seemed to fit the scenario that you were postulating in your question yesterday. Excuse me just for a second.

JUDGE GROSSMAN: Sure.

(Counsel conferring.)

MR. BACHMANN: Basically, when you are dealing with a test reactor of which there are only two licensed in the United States -- one at the National

Bureau of Standards and the GETR -- the NRC does not really have specific regulations to apply to these. We have a lot to do with large power reactors, but the testing facilities are such, I guess, an odd situation that for the most part it is in the technical Staff's judgment as to how they must be constructed and what they must withstand.

As Mr. Nelson mentioned before, there are significant differences, whole orders of magnitude as far as power levels and fission inventories, and pressures and temperatures between these. So to answer your question briefly, it is essentially a matter of Staff judgment using Part 50 primarily as guidelines, and not as specifically legally binding requirements.

JUDGE GROSSMAN: Well, then, doesn't that lead to the position now that it is the Board's judgment as to whether to apply Part 50 or to use it as an analogy?

(Counsel conferring.)

MR. BACHMANN: Let me just set the record straight. Part 50 as a whole does apply.

JUDGE GROSSMAN: I'm sorry. I meant Appendix A to Part 50 and the particular part that you mentioned. I just didn't care to make it that specific. But the question is: At this point in the proceeding, is it not then the Board's responsibility to make that same

determination for itself that the Staff has made for itself, whether to apply those particular sections to this situation?

MR. BACHMANN: In the sense of -- when you say "apply," I would say in the sense of using it as guidelines and requiring the Staff or the Licensee to conform to these prior to a licensing, or in this case an action of putting the reactor back in operation, yes, I would have to say that it would be in the Board's judgment. The Staff gives its opinion, but the Board must judge based on the evidence presented here.

JUDGE GROSSMAN: By the way, just to clarify the record, I didn't suggest that this should have been done yesterday. If I did, I didn't intend to suggest that. I was asking what the Staff's position was with regard to it, and I wasn't suggesting that it do it one way or the other.

I assume when we issue our decision we will suggest one thing or another, but we certainly have not reached any position on that.

BY JUDGE GROSSMAN:

Q Now, Mr. Nelson, did you quantify at all the probability of these events occurring simultaneously, or close together?

A (Witness Nelson) The only quantification

that was done was with respect to the seismic event, which has already been discussed during this proceeding as far as probability of occurrence. We did not quantify the probability of the other design basis events or the simultaneous -- the probability of simultaneous occurrence of both of them.

JUDGE GROSSMAN: Okay. I am finished with my --

MR. EDGAR: Judge Grossman, may I -- I have remained silent --

JUDGE GROSSMAN: Oh, certainly.

MR. EDGAR: -- through practically all of these discussions, and I would maintain that posture for the near term. But I have some strong views on the subject that I will present in my brief. I think there are many factors that are in this record that can be brought to bear on the ultimate judgment, and they need to be integrated, and that can be done in the briefs. So I just want to make it clear that that is why I have hesitated.

end JWB #1

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JUDGE GROSSMAN: I only ask that you bring to the Board's attention whatever position you think would be a foundation for asking questions of the technical people. But as far as argumentation goes, that is certainly unnecessary at this point.

MR. EDGAR: Understood.

JUDGE GROSSMAN: Anything further from the Staff?

MR. BACHMANN: No, sir, not at this time.

JUDGE GROSSMAN: Okay. I have concluded my questioning in this area, and Judge Ferguson has questions now to the people.

JUDGE FERGUSON: Mr. Bachmann, let's start with a question to you.

Did I understand you to say just a moment ago that this reactor and the one located at the Bureau of Standards are unique? Staff considers them unique and there are no other reactors similar to these two?

MR. BACHMANN: Yes, sir, as far as being licensed by the NRC. I understand the Department of Energy has some like this, but they are not licensed by us. These are the only two of that configuration and that power level.

JUDGE FERGUSON: Could you tell us what the power level of the NBS reactor is?

MR. BACHMANN: Well, of course the GETR is 50 megawatts thermal, and the one at National Bureau of

Standards is 10 megawatts thermal, and they have applied for a power increase to 20 megawatts thermal.

JUDGE FERGUSON: And it's the Staff's position there are no similar reactors in that power range that are licensed; is that correct?

MR. BACHMANN: Licensed by the NRC, yes, sir. We have small research reactors of much less power range, for instance, under 1 megawatt thermal. There are several of those, but in this particular power range, those are the only two.

BY JUDGE FERGUSON:

Q Let me turn to you, Mr. Martore, for just a moment, and recall that last Friday, I believe, we had begun to discuss the effects, seismic effects on the structure of the GE Test Reactor, and we sort of postponed a discussion of soil-to-structure coupling. You had indicated that you would be able to tell us very briefly something about that.

My question to you is this, and I would like for you to be as brief as possible:

Would you review very briefly for us what the Staff investigated in its analysis of the Licensee's submission as regards the soil-to-structure coupling?

A (Witness Martore) When you say "investigated," do you mean the type of review that the Staff did of GE's

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work?

Q Did you do any independent investigation of that matter? Did the Staff do any independent investigation?

A The Staff did certain independent analyses to check the output at various steps of GE's work; that is to say, for example, we did our own analysis of the soil springs that were used in the soil structure interaction analysis and interim steps such as that throughout the design and analysis procedure.

Q Are you saying that you essentially reviewed the analysis that the Licensee did?

A Essentially that's the role of the NRC Staff. It's to review, to set the criteria, review the methodology, the analysis, procedures, and then the results at various steps and, of course, the final results and their applicability.

Q What I'm trying to get at, Mr. Martore, is whether or not there was any independent study made by the Staff, other than the review of what the Licensee proposed on this particular point.

A The only independent studies were again calculations at interim steps, but certainly no analysis as in depth as that done by GE.

Q We have had some description of how that fairly detailed study was done that I believe was discussed by Dr.

Kost and others, and I assume based on your statement and your testimony that that was satisfactory; is that correct?

A Yes, sir, that's correct. If I could add one thing. This is similar to the type of review that the NRC Staff does for -- or is common to the review NRC does for other licenses for power reactors and for other similar licenses.

The Staff performs basically an audit review function.

Q Very good.

If that is the case, then let me inquire very briefly into another matter that perhaps you have reviewed in the same way.

We have had some testimony about water levels, the replenishing of water in the event of a seismic event, and there has been testimony as regards the rate at which water will be boiled off or evaporated. Did you review that?

A No, I did not. That was reviewed by our Systems people.

Q Did your Systems people also review the effects of heat on the reactor shield, or was that part of your review?

A The reactor shield? I'm not sure what you mean. The vessel or the concrete core structure?

ar2-5

Q Well, let's call it the concrete core structure.

A That would have been part of my review.

Q Very good.

There was some discussion yesterday about that. Do you recall that discussion?

A Yes, I do.

Q Then I can refer very briefly to some things that were said. There was a discussion about the effects, the radiation effects, on the concrete of the core shield, and I think the testimony indicated that over the life of the reactor, the shield has actually gotten stronger. Is that also your belief?

A Yes, sir.

Q And could you tell us why it is your belief that the shield gets stronger as it is irradiated?

A It is not my belief, or I did not mean to say that it gets stronger as it is irradiated. It is a property of concrete to increase -- its strength increases with time.

Q Yes, I think we understand that, but this is a peculiar situation. Not only is time hardening the concrete and causing it to strengthen, but there are other effects present which may negate that.

Is it your testimony that in spite of those other effects -- and I'm talking about the radiation effects -- the net effect is that the concrete has gotten

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stronger or is stronger now than it was when it was first laid?

A Yes, sir. It is my belief that the net area or the significant part of the area of the concrete that does resist the various loads does get stronger. That is to say that if there were any effects from irradiation, that that would be restricted to a smaller portion of the concrete.

Q Presumably very close to the core; is that correct?

A Yes, sir.

Q All right. Perhaps we'll get back to you, Mr. Martore, but I'd like to ask you a question, Mr. Nelson, regarding your testimony. I was a little perplexed. On page 3 of your testimony, you state in your answer No. 5 that:

> "If the equipment identified in Section A satisfies the seismic design criteria for the GETR site and remains operable to the extent described in Section A, the reactor core and irradiated material in the storage canal will remain submerged in coolant, and adequately cooled during and following the design basis seismic events."

Now did you have any question about the fact

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that the equipment would in fact satisfy the criteria in Section A?

A (Witness Nelson) When Section A was written, it was to verify the identification that had been made of what equipment was safety-related and direct the engineering review to the equipment that required seismic qualification.

Q What I'm asking you is, do you have any question in your mind that the equipment will in fact satisfy the criteria in Section A?

A At this time, no, sir, there's no question.

Q What do you mean by "at this time"?

A This equipment that needed seismic -- or needed to be seismically qualified was identified during the initial phase or shortly after the General Electric Test Reactor was shut down. At that time the proper seismic design criteria had not even been determined, and that's why it's written in this fashion.

Q All right. I'm a little more confused now than I was in the beginning. Is this answer something that you answered a long time ago and it's not your answer now to the question No. 5 that has been asked?

A No, I believe, first of all, it was a review done a while ago, couple of years ago, and updated as necessary.

But, secondly, the only purpose of Section A of

the SER was to identify the equipment that should be seismically qualified and not make a conclusion regarding its seismic qualification, and I believe that's all that statement indicates.

The SER was written in, or this particular portion of the SER was written in four sections, this being the first.

Q In 1980, October 27, 1980; is that correct?

A Yes, sir. But it was -- Section A identified the equipment that must be seismically qualified. Section B discussed in detail the electrical aspects of the review.

Q I think that's clear, yes. But I'm only trying to get your feeling or your answer to the question that was asked in question No. 5 of you by the Staff, presumably. What is your feeling today?

A It says written in the answer, if that equipment identified in Section A satisfies the seismic design criteria, then the fuel will remain, you know, covered and adequately cooled.

Q What, Mr. Nelson, is the Staff doing, based on your understanding, to be sure that that equipment does in fact satisfy the criteria in Section A? What will it do?

A As far as the functional criteria, and that is that valves be operable or flow rates be established and maintained, there are a number of items that are done or

have been done and will be done to assure that the equipment functions as indicated.

One is reviewed from the seismic design basis to assure that it's capable of performing its intended function.

Secondly, we impose limits through technical specifications to ensure that the functioning of the system -- for example, flow rates, operability of electrical valves -- are periodically checked to verify that these equipments continue to operate as designed.

Q And this is done during your normal inspection procedure?

A Yes, sir. The technical specifications will be imposed before the GE Test Reactor resumes operation, assuming that it does, and the compliance with technical specifications and periodic test and maintenance procedures is verified by our Office of Inspection & Enforcement.

Q Yes, I understand.

Okay, following that same line, if I may, Mr. Burdoin, there is a description of the seismic triggers.

A (Witness Burdoin) Yes.

Q And they are in the SER. As I understand those seismic triggers, they are small coils that measure acceleration. I think it says they are three octagonal coils, is that right, that move? Or are accelerated by an

event, a seismic event, and those are sort of electromechanical type devices?

A There are three transducers that are electromagnetic.

Q Excuse me just a moment. Let me finish asking the question.

There is a discussion regarding the point at which the seismic triggers will scram a reactor and that, I think, is .01g; is that correct?

A Yes.

Q What I want to get at is that that trip point is determined presumably by setting on an amplifier; is that also correct?

A Yes.

Q And it can be changed by changing the setting of the amplifier; is that correct?

A Yes, that's the way I understand it.

Q Very good. And I thought we had had testimony earlier that these triggers had been qualified by the manufacturer; is that correct?

A Seismically qualified, yes.

Q Okay. My question to you is -- and it concerns -- relates to my concern about qualifications. Whose statements do we take as regards equipment being qualified? Do you know of the procedure by which these triggers will be

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-- or the level at which these triggers will be operated by seismic event -- how that level is routinely determined?

A Well, as I understand it, these triggers are qualified up to .5g.

Q Right.

A There is different methods of qualifying them. These being small devices, they can put them on a shaker table and shake them.

Q Excuse me, Mr. Burdoin. I don't like to interrupt you, but really what I want to get at is, I am assuming that the triggers have been qualified before installation up to .5g by the manufacturer. They are installed. Somehow the electronic circuitry is designed to trip to .01g, but that set point is determined by an adjustment of an amplifier; is that correct?

A Yes.

Q My question is, what assures us that that setting at which the triggers will operate will always be .01g? Do you understand my question?

A Well, these things are periodically checked and calibrated to determine that the setting is still set at that proper position.

Q Okay. Now how is that done? That is my question.

A I can't give you the exact mechanics of it. It's done periodically -- and when I say periodically, as I

recall, it's checked annually and calibrated annually. The setting, I think, is checked more frequently than that.

Q Do you think that that's a point that we all should be concerned about?

A No, I don't think it's a point that we should be too concerned about. I don't think you're going to find this equipment drifting that much. You will find electronic equipment will drift slightly, but it's not going to drift from say .01g up beyond .5g.

Q And what's the basis of that statement, sir?

A Well, the basis of that statement is that I have been in this business a long time, and I know what drifts in electronic equipment can amount to, and you can expect 5 to 10 percent drift.

Q I see.

If a component in an amplifier in fact fails, that would exceed the normal drift that you are speaking about; is that correct? It would not respond?

A Possibly, yes. Not in every instance of a failure would the drift exceed that, but depending upon certain components.

Q There is a component that you can envision that would fail and cause the drift to be more than that; is that correct, more than .5g?

A I suppose so.

Q Well, let's assume that that one fails, and that's the case that I'm concerned about, and that point seems to indicate to me that it's important to calibrate thes· struments regularly or periodically, to use your word, and I was really concerned about how that was done.

But is it your testimony that you cannot in fact testify to that?

A As to how it's done, no, I can't.

Q Is there anyone on the panel who can?

A I doubt it.

Q Okay. What will be in NRC's licensing and inspection by the licensing and inspection team to be certain that this is done?

A Well, the tech specs require that the calibration be done annually, and as I stated earlier, the checking is done more frequently. Tech spec requirement is just that, a requirement, in that the Licensee has to conform to it. And records are checked periodically in audits by the NRC to determine that these things indeed are done.

If they are found that they are not done, then they are in noncompliance and they are not in accordance with tech specs, and then they are subject to action.

Q I think that's a very general statement, and I can't disagree with it, Mr. Burdoin, but I'm a little uneasy, I guess, at this particular point to feel or to

understand that no one here can tell us in fact how that calibration is done. I am concerned about it. I think it is an important point.

A (Witness Nelson) Excuse me, your Honor. I'd like to just add something. I can't add that specific detail as to actually how the coils are moved annually, but that is what would be required to check the output, whether it is done by shaking or other means. That would be at the annual check.

Periodically, at every reactor shutdown, which is on the order of two to three weeks, they would check the balance of the system beyond the detector, and I know that they have obtained equipment from the manufacturer of these things to do that annual check. I just don't know exactly how they move the coils.

Q I would think, Mr. Nelson, that a certain motion of the coil must give a certain output from the amplifier, and that presumably is related to the acceleration.

All right, let me ask one question. We are going back now to the boiling of the water, the evaporation of the water after a seismic event, and the core has been shut down. There are several statements in the SER that indicate that water must be replenished at a certain rate. I think the SER says that the replenishment rate must be 1.96 or something like that gallons per minute. I could

possibly find that if I thumb through this quickly, but does anyone on the panel have that number?

A Yes, sir. It's 2.44 gallons per minute.

Q Where will I find that in the SER?

A It's in Section 2-A of the October 27th SER. I'll get the page number shortly.

Q Well, I have page A-2 of the October 27 SER, but I don't see that number two point whatever it was you gave us.

A The number is on Section E on page A-5. Also the number is -- there are two components to that number. There are two things which add up. That is the makeup required for the reactor core itself, .8 gallons per minute, which is on page A-2, and the makeup required for the fuel storage canal, which is 1.64 gallons per minute. I'm trying to locate that page right now.

Q That, I believe, is on A-2.

A Yes, sir. But those values must be added together to find the system requirements for the fuel loading system, and that is to be supplied by each of two redundant systems.

Q Correct me if I'm wrong on this, but I thought the Licensee's experts indicated that the fuel flood system was capable of supplying two gallons per minute.

A I'm not aware of that.

JUDGE FERGUSON: Mr. Edgar, do you have anyone --

MR. EDGAR: Mr. Gilliland can answer that right away, I think.

What is the capacity, flow capacity of the fuel flooding system total, and then per tank?

MR. GILLILAND: Flow capacity?

JUDGE FERGUSON: The replenishment capacity which may be equal to the flow capacity.

MR. GILLILAND: Let me state two values. The design flow is in the vicinity of eight to nine gallons per minute.We haven'tmeasured the system because it's not been installed, so we don't actually know what the value is. We believe it will be higher than that.

And the capacity of the reservoir is 100,000 gallons for each of the two systems. There are two 50,000 gallon tanks. There are two 50,000 gallon tanks in each of two locations. So each leg has 100,000 gallons capacity, each leg supplies a design flow rate of that value, although the required value is much lower than that. And we will be reducing the flow, controlling the flow, to meet the design requirement as appropriate.

JUDGE FERGUSON: The replenishment rate is about 9 gallons per minute, did you say?

MR. GILLILAND: The design value, that is pipe sizing and so forth, were based on that requirement, and the flow will be adjusted to meet the demand.

JUDGE FERGUSON: I understand.

MR. GILLILAND: That is, it will be fixed, but once we get the system in place and test it, then we'll be in a position to --

JUDGE FERGUSON: So it will more than adequately satisfy the 2.44 gallons?

MR. GILLILAND: Yes, sir.

JUDGE FERGUSON: Fine.

BY JUDGE FERGUSON:

Q Now that 2.44, let's focus on that for just a brief minute. That, you say, on page A-5 is the maximum evaporation rate from irradiated fuel subsequent to the postulated canal and pool drainage.

Was that a correct reading of what's on page A-5?

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A. (Witness Nelson) Yes, it is.

Q. My question is: When does that maximum -- I guess that flow rate is determined by the rate at which water is evaporated? Is that correct?

A. Yes, it is, sir.

Q. And when is that maximum evaporation understood to occur after shutdown, after scram?

A. The point at which maximum evaporation is required and makeup is required to compensate for that evaporation is the point where the water level reaches the top of the core, or the stop of the stored fuel in the storage canal, which for the fuel stored in the storage canal is approximately 30 hours after shutdown, or about 24 or 25 hours after the seismic event. And for the core, it is approximately 45 hours after the seismic event.

Q. Yes, but I don't think that really answers my question. Perhaps I should ask the question again. My question is: When will the maximum boiloff, or evaporation take place after shutdown?

A. The maximum evaporation would be -- the maximum heat input is immediately after shutdown.

Q. Immediately after shutdown?

A. Yes, sir. And it decays from there. But it is not needed as far as determining the required makeup

rate because there is already sufficient inventory of coolant in the system.

JUDGE FERGUSON: All right. Thank you. I have no further questions.

JUDGE GROSSMAN: Judge Foreman?

JUDGE FOREMAN: I don't have any questions of this panel.

BY JUDGE GROSSMAN:

Q Mr. Martore, one question. You are familiar with the soils under the reactor, are you?

A (Witness Martore) To the extent that they affect the soil/structure interaction analysis, yes, sir.

Q How would you describe the soils?

A The soils are Livermore gravels, I believe. What I looked at was the properties that were given to me by the geotechnical engineers, and then used that to determine the spring constant properties that are used in the analysis. So that I do not get directly involved with the type of soils, but use the properties that are given to me by the experts.

Q I see. And how would you describe Livermore gravels?

A I'm not sure I understand the question.

Q Well, are they soft, hard? Is there any other way of describing them?

A. Excuse me.

(Witnesses conferring.)

MR. BACHMANN: Chairman Grossman, may I make a comment here, please, sir?

JUDGE GROSSMAN: Certainly.

MR. BACHMANN: I don't believe that Mr. Martore's expertise lies in descriptions of soils as such, but merely in their interaction description by means of mathematical engineering models. I might point out, though, that on page five of the stipulation in Section M and N, there is a stipulated -- well, there is a stipulation, for instance, "The base of the GETR foundation mat which is located about 20 feet below grade is underlain by very dense clay, sand, and gravel with occasional layers of very dense sandy and/or gravely clay to a depth of seven feet."

Now if that is the type of qualitative description, all parties have agreed to that.

JUDGE GROSSMAN: That's fine, then. I withdraw the question, Mr. Martore.

Redirect?

MR. BACHMANN: May we have a short, five-minute break to see if we need any redirect?

JUDGE GROSSMAN: Certainly.

MR. BACHMANN: Thank you.

(Recess.)

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: Yes, sir.

REDIRECT EXAMINATION

BY MR. BACHMANN:

Q Yes, sir. Previously Judge Ferguson had asked Mr. Burdoin about the seismic triggers, and I would like to address that in a brief question to him.

Mr. Burdoin, you indicated to Judge Ferguson certain confidence levels you had in the seismic triggers at the GETR reactor. Would you please expand a bit on that? There seemed to have been some question as to reliability.

A (Witness Burdoin: With regard to the confidence that I have in the operation of these devices, Southern Cal Edison has had these devices in operation at some 100 locations for a period of 10 years. In that time, they have never experienced one failure for the device to operate when it was required to operate.

They were using these devices primarily to operate -- to trigger and initiate the recorders. Basically, that is my basis for confidence in them.

Secondly, we have two of these mounted there at GETR, and if one fails to operate the other is available to operate.

The third issue, these are checked quarterly and if there is a failure in the amplifier, it will be picked up at that time.

That's all I have.

FURTHER BOARD EXAMINATION

BY JUDGE FERGUSON:

Q How will it be picked up, Mr. Burdoin?

A (Witness Burdoin) When they make their quarterly check of the system, they will determine that the amplifier is not working.

Q That's a calibration procedure, right?

A Well, no. That's a checking procedure. Calibrations are annually.

Q Well, let's not be confused by semantics. First of all, let me say that I appreciate your additional statement. I hope my concern was clear. They may be very reliable. I was interested in the level at which the device is tripped, and the assurance that one has that that level is in fact what we think it is.

A In the calibration that determines the level at which it trips, they use the calibrated voltage at the input to the amplifier to calibrate the amplifier, and the point at which it will trip at .01g.

(Witnesses conferring.)

Q Did you have something further, Mr. Burdoin?

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A. Well, at the calibration which I mentioned, which is an annual operation, they use this calibrated voltage input to the amplifier to set the end trip set. They also check the operation of the seismic switch itself by blowing on it or moving the device so that it will operate, and then initiate an operation.

At that time, the entire circuit is operating.

Q. Well, I don't want to prolong this. Did you have something to add, Mr. Nelson?

A. (Witness Nelson) Yes, sir. I would just like to try to clarify the sequence and timing of testings to verify reliability of set points in this case, the seismic triggers. Annually they will verify that input motions comparable to a .01g will move this detector or these coils.

Q. What is the driving force for those motions?

A. This is a piece of equipment that the manufacturer supplies.

Q. I see.

A. And more frequently they check that that motion, the output from that motion, is the correct value of signal to scram the reactor. And that is done quarterly and, to a certain extent, after each shutdown two to three weeks.

Q. So the picture is that there is some

mechanical signal generator, so to speak, that will move the coils given amount; and that then is measured in terms of the output signal? Is that correct?

A. Yes, sir.

JUDGE FERGUSON: Thank you, Mr. Nelson.

Mr. Edgar, did you have anything that you wanted to add?

MR. EDGAR: No, sir. I think that is the sum and substance of what Mr. Gilliland had advised me.

JUDGE FERGUSON: I see. Thank you.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: I have no other questions, your Honor.

JUDGE GROSSMAN: Mr. Cady?

MR. CADY: No questions.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: I have one clarifying question.

RECROSS-EXAMINATION

BY MR. EDGAR:

Q. Mr. Martore, earlier on you were asked about soil properties and the input you get from your geotechnical experts. In regard to the structural analysis that GE performed, that analysis performed by Dr. Kost, you were the principal reviewer? Is that correct?

A. (Witness Martore) Of the structural analysis,

yes.

Q And in regard to the soil-bearing capacity values used in that analysis, would your conclusions in regard to the validity of the analysis be in the affirmative if soil-bearing capacity value of a larger value of 30 ksf were used?

A If a larger value than 20 ksf?

Q No, if a value of 30 ksf were used.

A Yes. My understanding is that the type of analysis that were done was a reasonable and adequate analysis. The question was brought up as to the strength of the soils, and I would agree that if a soil strength that was acceptable to the geotechnical experts of the staff was used, that the type of analysis and procedures would be acceptable for the structural review.

MR. EDGAR: Thank you.

JUDGE GROSSMAN: Does that conclude the direct and cross?

WITNESS MARTORE: Your Honor, I had one other clarification, if you require. Judge Ferguson had asked on Friday if we could specify what the vertical accelerations were and the amplification through the structure. I did get that information. I am not sure whether it is still of interest?

JUDGE FERGUSON: Please. Please give it to

us if you have it.

WITNESS MARTORE: As we said on Friday, for the Calaveras event the vertical input acceleration was two-thirds of the .75g. That then is amplified through the structure to a small amount, to .8g as a peak floor acceleration at the highest floor level; and then the spectral accelerations are accordingly amplified.

BOARD EXAMINATION

BY JUDGE FERGUSON:

Q The numbers you have just given us, except for the measured value on the Calaveras, are all calculated numbers?

A (Witness Martore) Yes, sir. The input is a design input which was specified. And then the speak floor acceleration of .8g was calculated analytically.

Q I see.

A In addition, the spectral numbers are also calculated.

Q If I remember correctly, there was a measurement taken on the third floor, was there not, of an acceleration?

A Yes, sir, during a recent event.

Q I see. Did that agree with the .8g that you

just mentioned?

A. No. That would not agree because the input to that specific event was not the same, of the same magnitude or the same frequency content.

Q. I meant proportional. That is, if you scaled up presumably the value, would you get the .8?

A. Okay. You may or may not get the same, because the input to the base would not be the same. The input that our design criteria requires is of significant energy, and that is the Regulatory Guide 1.60 spectra.

So the event that actually shook the reactor probably did not have the same energy content. That is one of the aspects to the amplification. The other is, I was not able to -- and I am not sure GE was able to make the calculation, because there were not -- I am aware of no instruments at the base or at the free field that could give you what the input was at that specific event.

Q. Mr. Martore, I am always trying to associate calculated numbers with instrumental values, but you say in this case there is no relationship, or none was investigated?

A. That's true. At the General Electric Test Reactor, there was an instrument at the upper level, but

I am not aware of an instrument at a lower level which then could be used to make the ratio calculation that you are suggesting.

The other point that I was trying to make is: If we did have that lower level instrumental value and tried to ratio it up, my judgment as an expert would be that the calculated numbers that we are showing would indicate a higher amplification in the calculations because of the increased input energy content of the input that we are requiring in our analysis.

Q So the .8g is a conservative number? Is that correct?

A Yes, sir.

JUDGE FERGUSON: Thank you, Mr. Martore.

BY JUDGE FOREMAN:

Q I have a quick question, sort of a catch-up question not directly related to the subject this morning, and it might better have been addressed to Dr. Vesely, but I think Mr. Nelson might be able to speak to it.

This deals with the statement that Dr. Vesely made that probabilities of occurrence of tectonic events of 10^{-4} were not considered of great concern to the NRC. But when the probability dropped down to 10^{-3}, then attention was directed to these matters. I am not sure I am quoting you correctly, but the gist of

the thinking was this.

My question of you then, is: Have you had occasions where in your site analyses, analysis of sites or other kinds of analyses in which you had to deal with -- in which the probabilities for tectonic events indeed were 10^{-3}?

(Witnesses conferring.)

A. (Witness Nelson) Your Honor, I don't think I have enough information to answer that question for plants in general. Mr. Martore might be able to discuss these aspects.

Q. I really don't want a long answer. I just wanted to know whether that ever really happens, for example.

A. (Witness Martore) The only point that I would make is that the design seismic event that we used in this case, and that is typically used for power reactors, is of a return period on the order of 1000 years, something in that range, which would be 10^{-3}. And if you look at the testimony that we offered and our safety evaluation, I think the indications were that the magnitude events on the Calaveras and Verona were on the order of a return period of 1 in 1000.

Q. One in 1000? Or 1 in 10,000?

A. One in 1000. The magnitudes were on that

order. So that would be 10^{-3}.

Q. I guess I don't understand that.

A. (Witness Nelson) That number can't be directly compared with the 10^{-4} because the 10^{-4} also considered the likelihood of offset underneath the reactor.

JUDGE.FOREMAN: I see.

JUDGE GROSSMAN: Thank you, gentlemen. You are excused.

(Panel excused.)

JUDGE GROSSMAN: I believe now we are up to Mr. Meehan's testimony?

MR. EDGAR: Yes. We would like to call Mr. Meehan and Dr. Kost to the witness stand, and Mr. Harding, if he would join them.

Whereupon,

GARRISON KOST,
RICHARD HARDING,
and
RICHARD MEEHAN

were recalled as witnesses on behalf of the Licensee and, having been previously duly sworn, were examined and testified further as follows:

JUDGE GROSSMAN: Could you please state your names for the reporter, again?

WITNESS KOST: My name is Garrison Kost. I am with Engineering Decision Analysis Company, Palo Alto, California.

WITNESS HARDING: Richard Harding, Earth Sciences Associates, Palo Alto, California.

WITNESS MEEHAN: Richard Meehan, Earth Sciences Associates, Palo Also.

JUDGE GROSSMAN: Judge Foreman?

BOARD EXAMINATION

BY JUDGE FOREMAN:

Q Mr. Meehan, first of all, I want you to know that I am aware that you have been flying all night and I am sorry that it happened. I should say that for my purposes it would have been possible for you to have been more comfortable, and it wouldn't have mattered had you not arrived early this morning; later in the day would have been all right. But in any event, I do appreciate your coming -- we do.

I would like to start our discussion by perhaps putting into context our concerns and why we wanted to have you come back. Your findings, at least to some of us on the Board, were at a minimum very interesting. In a sense, I thought they were pretty startling, personally, and significant, and also I believe important. It is true that we have information from

probabilistic studies that the likelihood of an event under the reactor is very low, but it is useful and I think important to have that backed up by information that is generated partly from data that is gathered empirically and analyzed on a theoretical basis.

And in that sense, I consider at least, and I think our other Board members do, that your testimony is very, very important. We talked about this a great deal among ourselves, and from time to time during the course of this proceeding after you had provided your information at Livermore.

We had asked in various ways -- sometimes directly, sometimes obliquely -- of the different experts on the panel relating to your findings and your conclusions, and admittedly only one of these is a soils engineer, Dr. Pichumani, but a number of the others were experienced geologists who were accustomed to observing faults and were sensitive to fault descriptions and the like, and we never were able -- at least to my mind -- to get a clear understanding that any, perhaps there might have been one, that any of these experienced geologists were aware of the kind of analysis that you have done, and I hope you will speak to that. And except for the one instance of the Banca Sandrol in Nicuaraga, no one had every had occasion to observe the phenomena.

Now I am not surprised that they didn't, because I realize the probability of a fault occurring underneath the building, a large building, over the world could be low, and occurring in very wide areas of the world it wouldn't attract attention necessarily to see if that would be happening.

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And so we felt, particularly I felt, we'd like to have more clarification as to how you came to your findings and your decisions, and in saying this, I hope you recognize that we are laymen, and so that we may not be able to ask directly pertinent searching questions to illustrate your analysis.

So I am asking that you ad lib in providing your information to enlighten us, in addition or even in the place of specific questions that we ask of you.

Now in going on, let me tell you very briefly my understanding of your analyses and of the circumstances that you have described. First of all, the phenomenon of diversion of the thrust from underneath the structure. I think it's clear to me and you have made it quite clear that to a very large extent that's a function of the soil characteristics beneath the structure.

A (Witness Meehan) Yes, that's true.

Q And the mechanism by which the diversion comes about stems from the fact that the weight of the structure on the soil beneath the foundation of the structure produces planes, that in reference to a whole series of other planes beneath the structure are planes of least resistance, and therefore the thrust that develops is diverted along the plane of least resistance.

A Yes.

Q Let me just lay out a few things and then I'd like you to sort of talk on uninterruptedly, and when you are done, I will have other questions for clarification, and maybe also my fellow Board members.

Your analysis to identify these planes of least resistance -- and we didn't get this from you, but we got it from Dr. Pichumani -- involved a construct of a system of wedges. At least he indicated that that was a method of analysis, and I attributed that to you.

Now you refer in your testimony, in Exhibit 22, to a reference -- I believe it's reference No. 72. That reference, at least here, wasn't available to me, so I wasn't able to pursue my concerns and investigations directly from that, and so now I am approaching my questions to you.

Anyway, one of the statements that triggered my curiosity and led me to want to inquire further of you was a statement on page 92 of your testimony. This is Exhibit 22 of General Electric -- Exhibit 1, excuse me, of General Electric, and the statement says:

> "It should be noted that the analysis is to specific conditions of the GETR, and would not apply to lighter or wider findings."

That I found very interesting and, in a sense, curious, whether by specific you mean unique to the GETR and none other, or unique to structures like the GETR, and

so forth.

Well, with that kind of background, please enlighten us in the fashion that you feel will be helpful to us in our understanding, starting anywhere. You needn't directly speak to the query I made in the beginning, unless you choose to.

A Perhaps I could address two questions. One is to attempt to explain in simple terms what the physics of this phenomenon are, in connection with my statement about it not applying to lighter structures; and the other, to talk about the availability or absence of other field case histories that one might use to confirm the theoretical calculations that have been done.

In connection with the question of what was really happening in the weight of the structure and the theoretical influence of those things, I'm casting about in my mind for some sort of a simple analogy, and perhaps this pitcher of water here in front of me might serve to be a nuclear reactor, if you can visualize that, and let us imagine that beneath this tablecloth there are two tables and this happens to be sitting on the crack between two tables, and we don't see the two tables because it's covered by the tablecloth. And let us say that Mr. Harding should raise his knees so that one of the tables rises with respect to the other, so we have a little step here.

My analysis is no more than attempting to look at the physics of that and to ask the question of whether the water pitcher would be willing to cantilever itself such that part of it is hanging in air and the other part is on the higher table or not.

My findings were that it depended on what the table was made of. If the table were made out of what it is made out of, there would be no question, a hard substance, perhaps a rock-like substance that is strong with respect to the weight of this pitcher.

On the other hand, I find it easy to imagine that if in fact what was under this tablecloth were beach sand, and if this were a relatively heavy pitcher -- it happens to be full of water -- that the beach sand would not choose to produce this little stair step, but rather would deform around the pitcher.

My analysis is no more than an attempt to apply some sophomore physics to that problem, and ask the equation which result is produced.

In fact, I think it's also fairly easy to realize that if this were not full of water, but rather empty, that perhaps the sand would produce the cantilever condition.

So it would have to do with the weight of the structure, too, and I simply solved some simple equations that determine what the optimum failure plane would be for

the material that we know exists underneath the GETR, and asked those equations whether or not the optimum failure plane is under the reactor or not.

The answer we got -- I set this up on a little computer, because I wanted to look at a couple of hundred different failure planes and different load combinations, and I was never able to cause the plane to come up under the reactor.

You might think of it as stair steps always that broke off. That's another way to visualize the process. It broke off and the break went around the side of the reactor.

So that, in what I hope is a reasonably clear nutshell, is the process that I attempted to describe.

With respect to the availability of large scale field evidence, I made considerable attempt to find some of that evidence, because I realized we were dealing with theoretical calculations and it would be desirable to back these up with something that's actually happened in the ground, and the kinds of analogies, in the absence of having faults under nuclear reactors or other similar heavy structures, the kinds of analogies that I thought appropriate were such things as perhaps a fault with a heavy boulder lying on the ground. That would do fine. That would be an appropriate analogy. Or, likewise,

perhaps rather than picking a fault, let us pick the toe of the landslide, which for all intents and purposes is a thrust fault, at least in the immediate vicinity of the toe. he ground of the structure doesn't know the difference, basically, and we made some attempt to try to find toes of landslides that may have come up underneath heavy structures or heavy boulders or anything.

We were not too successful. Unfortunately, there are not a large number of documented case histories. The one other case that I think has some application here is there was a large landslide that occurred in Anchorage, Alaska in 1964, as a result of the 1964 earthquake. It was a landslide probably about the size of this hotel, and its toe was a thrust fault-like feature, and it came up under a tank that I think was an oil tank -- possibly it was a water tank -- but apparently a fairly heavy structure, and looking at the photograph of this, it appeared that there was a diversion of the thrust surface around the tank.

I would hardly call it a conclusive experiment, and I had no other information aside from looking at the photograph. It's possible we have that photograph with us.

Q That was the landslide and it came along the surface. It didn't occur beneath the building.

A The landslide toe went underground and then it rose up. The landslide, perhaps in the position of Mr.

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Harding, created a thrust fault-like feature here that to my mind was analogous to the fault condition we have.

I don't want to confuse this by talking about landslides. It has nothing to do with landslide vs. fault.

Q No, I realize that, but I guess I don't picture the thrust that you're talking -- that you're describing in the landslide. That's a thrust that occurred beneath the surface of the earth?

A Yes.

Q It disturbed the soils beneath the earth and thrust below?

A I'm not sure how to go about showing you a picture of that.

Q Okay, I don't need that.

A Oh, yes, there is a figure in my testimony, or in the testimony, on page 15.

A (Witness Harding) It's actually my testimony, I believe, page 15.

A (Witness Meehan) There's a picture of a diagram of the landslide. In the particular case that I had in mind, there was a similar landslide and there happened to be an oil tank sitting on one of those things called a thrusting toe. So I saw a certain analogy there. The thrusting of the toe, it appeared from the photograph, was diverted.

This was my best success in terms of trying to

find an analogy for the case that --

Q And you're saying indeed the thrust was diverted by the oil tank?

A It appears that way from the picture. That's what we felt upon looking at the picture. The tank was not tilted or seemed to be undisturbed. It's an aerial photograph.

Q Was the force created by the landslide of such magnitude that one would expect it to affect an oil tank as heavy as it was? Are they forces comparable to a force generated by an earthquake thrust?

A Yes. In both cases you might consider the force irresistible from the standpoint of the -- the only possibility would be for the thrust to be diverted around the structure. The structure itself would not in either case stop the landslide or the fault.

Q Well, go ahead with your story.

A That is my attempt to summarize the mechanics of the process and to summarize the results of my attempt to find analogous physical cases that might apply here.

Q Does it bother you for me to interrupt?

A Not at all.

Q Because maybe things would go faster and smoother if I did. It helps me think, anyway.

Are there many instances of thrusts occurring

in cities where there are heavy buildings?

A Not that I'm aware of. The San Fernando earthquake was a thrust fault. In fact, in many ways it was comparable to this. It occurred -- much of it occurred in areas that were underlain by soil, probably similar to the kind of soil we have in this situation. It came up under quite a few buildings. They were principally houses, streets, curbs,relatively light buildings.

In all cases the fault was not troubled at all by the existence of a structure. It would simply go right through the structure or lift the structure or break it in half.

This was exactly what I would expect. If I had done a similar analysis using the same equations, my answer would have been that the fault would not have been diverted by the structure, unless the structure were somewhere above 3000 pounds per square foot, which is a quite heavy structure.

Unfortunately, I know of no analogy in San Fernando where the same weight conditions existed. The GETR is a very heavy structure. It's equivalent to perhaps a 30-story building or something like that.

Q Well, I mentioned that because in view of your interest in theory -- incidentally, are you the first to propound this theory? Has it been applied in other places and so forth? That's the sense in which I'm asking.

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A The issue did arise, I believe, in connection with either licensing or licensing studies several years ago. There was an attempt to analyze the burial of a large ring-like reactor structure, and the question was if there were a strike-slip fault and this were buried in soil, rather than rock, would the rigidity of the reactor containment be sufficient to cause the strike-slip fault to migrate around the containment?

It's a tempting analogy. Those studies, by the way, were carried out by Bechtel Corporation and some -- Prof. Duncan, I believe, at the University of California, and I believe they were conducted in support of a possible buried nuclear power plant in the San Joaquin Valley. They were trying to suggest a possible immunity from the effects of deep faulting, provided they built the structure strong enough.

The analogy is more comparable to the Banco Centrale case than it is to the thrust fault case, because there they were depending on the strength of the buried structure to resist and divert the fault, and the physics of that are slightly different.

Q I mentioned city because in view of your interest in theory, and I'm sure you'd be one to look for examples that might illustrate or demonstrate your hypothesis or buttress it. That would be a place to look, wouldn't it,

in various urban areas?

A We don't have many thrust faults in urban areas that I'm aware of. I think San Fernando is probably the best one. We certainly reviewed the literature to find some analogies.

Q Excuse me. Go ahead.

A I didn't understand.

Q I interrupted you asking about whether you'd looked in urban areas, for example. Can you pick up your train of thought?

A We reviewed the literature for both thrust faults and strike-slip faults, but we did not find anything that we considered applicable.

I believe the Staff also made some review, and they certainly urged us to try to find examples, too, but neither group was successful in coming up with anything that fits this case exactly.

Q Do you want to go ahead, or do you want me to ask another question then? Which would be helpful to you?

A I think I've run out of an answer at this time.

Q I see. Okay.

I would, I guess at the risk of making things difficult for myself, I would ask you to be a little more technical in describing your analysis, the wedge analysis and how it works, and then tell us why these analyses -- this

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analysis is specific for the GETR.

A Perhaps I could do that with a reference to one of the figures in my testimony; if I may have about 15 seconds, I'll try to find that.

(Pause.)

Figure 51 on page 91 of my initial testimony. One might imagine this as a simple experiment that could be done in the laboratory. Unfortunately, it is not easily done in the laboratory, for various complicated scale factors.

If you were to visualize this as a block of sand and gravel being squeezed by a vice, applying force F to its two sides, in the absence of there being a structure such as the GETR, the preferred or optimum plane of failure might well be the plane marked 2350.

Q Say that again. Why would it be the preferred plane?

A We might analyze 2000 different planes of orientation and ask the analysis which plane takes the least amount of force F to fail. When we have identified the one that takes the least amount of force, we have identified the plane that actually will fail.

Now having done that, we might -- having identified that most favorable failure plane, most likely failure plane, we might change the ground rules of the

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analysis by applying the weight of the structure, as I've shown here, at the location of the GETR, repeat the same thing, and ask the analysis what now is the most favorable plane, and this is what we've done by computer.

We have simply repeated the analysis for hundreds of planes, and my approach was to try to find one that came up under the reactor, given the properties of the soil, to try to produce an unfavorable result.

This was the best I could do, in terms of playing devil's advocate. The one I have illustrated here is the least favorable case from the standpoint of the GETR that I came up with, and I've shown only a few of the many planes that were analyzed and the numbers that are written next to the planes are the number of thousands of pounds of force F that are required to cause the soil to move along those planes.

The highest force, twenty-three hundred fifty thousand pounds, 2 million pounds plus, is the one that comes up under the GETR.

The lesser force is required to cause movement along any of the other planes shown, and I might have shown a lot more.

Therefore, I conclude from this, this being the least favorable case, that I am unable to find a case where the preferred failure plane is under the reactor.

No matter how I locate the reactor anywhere on that diagram.

That, in a nutshell, is the basis for my conclusion.

Q I guess a couple of things come to mind.

First of all, tell us a little more. Then you didn't use the so-called Rankin wedge analysis to do this?

What I'm asking you is how did you arrive at these numbers? What sort of analyses? I know you fed a program into the computer, but what did you feed into the computer to get out the result? What sort of analysis? What sort of considerations were involved in the analysis other than just the weight of the reactor bearing against the force coming from the earthquake or the thrust?

A The analysis was actually a standard analysis in soil mechanics, because we often wish to know the amount of force F it will cause, that will be necessary for something to move in the ground.

We have run into this in many applications. If we try to push a wall against the soil, and that happens in civil engineering design in some cases.

Q You mean down?

A No, sideways.

Q Okay.

A We need to know what F is required to cause the wall to start moving. Sometimes we bury things in the

ground, we don't want them to move. We want to know how much resistance they have against moving. The problem of the tipping over of the telephone pole that's buried in the ground is a similar problem to this. You need to know what force F is required before the buried part of the pole begins to rotate.

So the analytical technique is one that's been used for about 150 years in soil mechanics. It's a relatively common analysis.

The application of this particular problem is not common, of course.

So I would say the tools are common, the particular problem is uncommon.

What we need to perform the analysis is not only the weight of the structure, but we need information with respect to the soil properties, too. We need to know whether the soil is saturated or unsaturated with groundwater. We need to know whether the load that's being applied, F is being applied very rapidly or very slowly. We need to know what the strength characteristics of the soil are. That's a very important consideration. What we call the friction angle of the soil is. This is a key consideration. Its significance, I think, is evident if you consider these blocks to be sliding blocks, and the friction angle of the soil would be equivalent to coefficient of friction between

blocks. I think you could almost visualize this as a freshman physics problem in mechanics.

Q I guess what puzzles me is why it isn't the friction between the particles of soil, rather than blocks of soil.

A It is the friction between the particles of soil. I used the block analogy, too.

Q It's not just chunks of earth beneath the reactor, it's the individual particles that comprise the material beneath the reactor, their cohesiveness or lack of cohesiveness?

A Both their cohesiveness and their friction. Each is a separate constituent of property. The science of how soil behaves is extremely well developed. There are probably 10 professional journals, and 50,000 professionals in the world who are in this field. It's a very large part of the civil engineering curriculum. The entire technique and science has been in existence for about 50 years now. It is a major and fairly well developed field, the issue of the behavior of soil under various kinds of loading conditions.

There are many textbooks. It's probably 20 to 40 percent of students in any civil engineering graduate school engineering program who specialize in this field.

Q You were laying out the various parameters

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of that influence or analyses that have to be factored into the analyses.

end 4

A. Yes.

Q. And I stopped you at one, the friction between the blocks.

A. I should have said, between the soil particles.

Q. I'm sorry. I wasn't challenging you; I was just trying to understand.

And then are you going on then to lay out more?

A. No. Those are the principal properties concerned.

Q. And in that particular field, knowing those properties one can make calculations that lead to predictions of behavior with a high degree of certainty?

A. It depends on how well you know the underlying parameters. I would say, the degree of certainty in the field of soil mechanics is less than it is in say structural engineering, because we are dealing with natural materials that tend to be more variable as opposed to steel and concrete which we can manufacture to tight specifications and control the properties of. So it is less -- in general, the results of analyses are not as reliable as comparable simple structural calculations.

Q. But they are sufficiently reliable so that

they are useful and can be used, I guess applying conservatisms, for putting buildings in and things like that? I gather that must be so, because people do build buildings and analyze soils and things do stay together. Am I right, then?

A. Yes. The foundations of all major buildings in many cities are on very soft soil, and their success is pretty much dependent on the results of analyses like this. The entire City of Boston, for example, is underlain by 200 feet of soft clay, and without these kinds of analyses it would be very difficult to design buildings.

Q. Just out of curiosity, what underlies San Francisco?

A. San Francisco is underlain in some areas by hard rock; in other areas, by very soft mud.

Q. Well, to get back -- I was making some notes, but I was so intent in what you were saying that I can't read back my writing. It was the first of the parameters that you said, or factored in in soil analyses, and it begins with a "g"-something. Do you recall what it was?

A. Groundwater level. The level of the groundwater.

Q. Groundwater. That's right. Now what is the likelihood of groundwater and groundwater changes in the

GETR area influencing your conclusions? Is the hydrology well-enough known, and is the groundwater -- are the groundwater levels stable over long periods of time so that the changes need not be of concern in their effect on the soil characteristics beneath the GETR

A I performed the analysis for both the existence of groundwater and the absence of groundwater. I get less favorable but still acceptable results for the case of no groundwater. That is a less favorable case.

The case I have shown here I believe is for no groundwater. However, it is highly probable that there will always be groundwater beneath the GETR. In fact, the groundwater is within a foot or two of the base of the foundation. We did have one record from the past, several years ago, when there was a drought, when it dropped as low as I believe 9 feet below the base of the GETR. That is not low enough to put it in the category of the "no groundwater" case. In the no groundwater case the groundwater table would have to drop 30 or 40 feet below the level of the GETR.

I doubt whether in any historical time that such a thing has ever occurred. It may have occurred in ancient geologic time when climatic conditions were different. I don't feel that the groundwater is a -- I

don't feel that I am dependent on a certain set of groundwater conditions to establish in my own mind the adequacy of this analysis.

Q Okay. Then pursuing further into the direction that I felt I was going, you have outlined the parameters that are involved in this soil analysis --

A Yes.

Q -- in order to make calculations with respect to the forces that are involved, the forces generated by the weight of the GETR for example.

How do these interrelate? What sort of equations, or what sort of relationships do you develop in order to come out with numbers relating to the forces that you describe here? Can you give us some idea? In other words, I am asking you to go into a little more technical detail than you have.

A Would it be helpful or appropriate to refer to Reference 72? Is that part of the testimony?

MR. EDGAR: It is Exhibit No. 20 in the Licensee's Exhibits.

JUDGE GROSSMAN: Mr. Meehan, I don't think we want to be unfair to you, but you have been up all night on the plane. If that is already in the exhibits, I don't think we ought to make you repeat it. Is it all found there in that exhibit?

WITNESS MEEHAN: I think perhaps Dr. Foreman said he wanted to get a feel for the kind of calculation, and if he referred to the -- I believe it is Appendix -- it is the appendix to that exhibit, and the equations are written out there in I think fairly straightforward terms. They are really not very difficult to follow, I don't think.

JUDGE GROSSMAN: Okay. That's fine for our purposes.

JUDGE FOREMAN: Well, I am not entirely sure that it is.

BY JUDGE FOREMAN:

Q Is there any way for you to summarize them in a sense to give me some understanding as to those equations, other than just stating the equations as such?

A (Witness Meehan) They would be the comparable kinds of equations that one would use if I were to tilt the table and try to pull these things (indicating) or push them up the hill or down the hill. They would contain resolution of forces. It would be a matter of combining imposed forces and gravitational forces, and solving the equation of equilibrium to find the unknown, which would be the force that would be required to push this thing, or cause the soil to move.

Q Just go through briefly those four forces,

gravitational forces -- what were the others?

A. Weight of the soil, and the strength properties of the soil, the location of the groundwater table, the weight of the reactor. Those would be the inputs.

The output would be the force F shown on Figure 1 required to -- on Figure 51, I'm sorry -- required to cause a movement for any one of the planes. You would have to repeat it again and again for each plane.

Q. Okay. I think that gives me the general idea. In fact, that is exactly what I wanted. I don't really care the constants you put in, or how you weigh them particularly, as you would explicitly in your equations.

Now would you go ahead, then, and speak to why these conditions are specific and GETR and don't apply to other structures?

A. The principal special condition that exists at GETR in my view is the weight of the reactor. The weight of the reactor is 4000 pounds per square foot. The results are dependent on that. If they were 2000 pounds per square foot, the analysis would probably give you an entirely different result. That information I obtained from the structural engineers, and probably

Dr. Kost could comment better than I could on the reliability of that sort of number.

Would you care to comment, Gary?

A. (Witness Kost) I think we know the weight of the building very well. It is an easily calculated number.

A. (Witness Meehan) The other parameters, the groundwater I have previously discussed. The soil properties we obtained from both the results of laboratory tests, the results of field tests, and also we can back-figure the soil properties by looking at the orientation of failure planes that we can observe in the trenches where faults were observed.

So we have basically three kinds of ways of inferring the strength properties of the soil.

Q. To the extent that these conditions are appropriate for the GETR, would this sort of analysis be used for other nuclear power plants, given the soil conditions that approximate those at GETR?

A. I think they well might. As I mentioned previously, I think some attempt has been made to use a similar analysis in connection with buried -- to try to to determine whether buried plants might be immune from faulting under certain circumstances.

I am not -- it probably hasn't been used a

great deal because ordinarily in siting new plants the attempt is made to provide such a level of assurance against the potential for faulting that no special considerations have to be made of faulting.

Q They don't need the assurance that the rupture will not occur beneath the plant? Is that what you're saying?

A They would be required to settle the issue on geologic grounds, thereby eliminating the need for doing any special structural analyses. That has been my experience.

Q So in that sense, this is why -- that is why this is the first time that it has come up in the hearings such as this, because there hasn't been the need, or no one has felt the necessity of making that sort of calculation?

A I believe that's true.

Q And then once again, as I understand it, and I think correctly, that this all comes about from well recognized, long applied methods that are used for soil analysis?

A That's true.

Q And that another competent, or other competent soil engineers such as yourself would come up with the same kind of analysis and consider that appropriate, that

analysis appropriate, and would come up with the same kinds of numbers as you? I am not doubting you at all. I would just like to have this in the record, so to speak.

A. I think that would be the case. I believe the NRC Staff took a rather independent look at this. My understanding is they came up with similar results. In fact, I think they tried some other variations in the analysis that I had not tried.

Q. I thought that what their contribution was was they reviewed what you did, and they talked about a Rankin wedge analysis that I think was attributed to your theory, but apparently it isn't. I may have misread their testimony. And then they applied other parameters. They gave different boundary conditions -- or if they weren't boundary conditions, other numbers and found that the conclusions that you drew would come out the same way. That is my impression.

A. I think that's correct.

Q. Well, as far as I'm concerned, I am satisfied with what you had to say, and I thank you.

JUDGE GROSSMAN: I have no questions.

Judge Ferguson?

BY JUDGE FERGUSON:

Q. Just a brief question, Mr. Meehan. We can conceive of an offset occurring beneath a building or

a structure in two ways. It can occur as an impulse, impulsively; or it can occur over a very long period of time. I would like to consider the impulsive type of appearance as a result of an earthquake, cracking due to a sudden fault caused by an earthquake; and the other one due to creeping motion.

Do you feel that in the simple physics equations that you referred to earlier that time would be a parameter that should be considered?

A. (Witness Meehan) It quite definitely would be a parameter to be considered in a case where there was groundwater present, which I believe is the main case here.

Q. Why would the occurrence or not of the presence of groundwater affect what we're talking about?

A. Because the soil that is saturated with groundwater --

Q. Excuse me. I don't want to interrupt you too often, but I think I can understand that that of course will affect the nature of the soil.

A. Yes.

Q. The yielding property of the soil. I don't want to talk about that. I want to assume that there is a soil of some consistency, and I simply want to ask whether or not the rate of arrival of the offset would

give you different results in the analysis that you described using the simple physics equations that you referred to.

A. In the case of a dry soil, there would be a very slight difference, perhaps not more than a few percent. In the case of the wet soil, the properties of the soil as you just pointed out would be affected by the presence of water, and that would make it sensitive to the rate of loading.

Q. Did you in fact consider those separate cases in your analysis?

A. Yes.

JUDGE FERGUSON: Okay. Thank you. I have nothing further.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: I have one item.

REDIRECT EXAMINATION

BY MR. EDGAR:

Q. Mr. Meehan, one item. Have you done any additional analyses in the soils area in regard to examining soil bearing capacity value at about -- at 30 ksf?

A. (Witness Meehan) Yes, I have done considerable work on that. Initially I attempted to approach this entire problem by looking at it as a bearing capacity

problem, and I achieved similar results to what I obtained by the Rankin wedge approach. I felt that these results were convincing to me. However, the NRC Staff had reservations about certain aspects of that approach. So I abandoned it as a means of dealing with this particular question.

However, bearing capacity is also applicable, as I understand it, to certain elements of the structural analysis. So much of that work that I did was also applicable in many discussions back and forth between ourselves and the Staff with respect to appropriate values of bearing capacity. So I have done a great deal of work.

Q. Have you done any work, and do you believe that 30 ksf is an appropriate value for soil bearing capacity?

A. I personally believe that the bearing capacity is quite a bit lower than 30 ksf. For structural purposes I understand that 30 ksf is a conservative number. I believe that it is definitely a conservative number. I think the bearing capacity is lower than 30 ksf.

(Pause.)

MR. EDGAR: I have no further questions.

JUDGE GROSSMAN: Mr. Cady?

MR. CADY: I have no questions.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: Yes, sir, just to clear up one point on the record.

RECROSS-EXAMINATION

BY MR. BACHMANN:

Q. Mr. Meehan, in answer to one of Judge Foreman's questions, the way it was answered, which I believe was in the negative, indicated that your fault plane analysis did not utilize the concept of a Rankin wedge, and I believe it does. Is that correct?

A. (Witness Meehan) It quite definitely does.

MR. BACHMANN: Thank you. No further questions.

JUDGE GROSSMAN: Thank you, gentlemen. The panel is dismissed and excused. Thank you.

(Panel excused.)

JUDGE GROSSMAN: We have some housekeeping --

JUDGE FOREMAN: Thank you, personally. I hated to do this to you, but I do appreciate it.

JUDGE GROSSMAN: Okay. We do have some housekeeping matters before we conclude. You had a schedule in your stipulation which we adopted, and I assume we are going to adhere to that schedule?

MR. EDGAR: On our part, yes.

MR. SWANSON: The parties did agree to that schedule.

MR. CADY: Yes.

JUDGE GROSSMAN: Okay. The record will be closed June 26th. The Licensee's proposed findings, July 23rd. Intervenor's proposed findings, July 17th. NRC Staff's proposed findings, July 24th. And the Licensee's reply on July 31st.

Is that correct? That is what is listed in the stipulation.

MR. EDGAR: Yes.

MR. SWANSON: That's correct.

MR. CADY: Yes.

MR. SWANSON: And we pointed out that in order to meet those time limits, some sort of express mail service would have to be used to ensure that the succeeding parties had a chance to respond and would in fact have a fair amount of time to do so.

JUDGE GROSSMAN: Okay. That's fine.

Then the next housekeeping matter is Staff's Exhibit No. 7, I believe.

MR. SWANSON: Yes. That was received last Friday. However, at that time I had indicated to the parties that there was a difficulty in reproducing exactly the chart that we have used as Staff Exhibit No. 7

during this proceeding. It was impossible to photocopy it. It was pasted to a solid sheet of cardboard. So as I had indicated to the parties and the Board previously, Dr. Herd and Dr. Brabb redrew lines as accurately as they could to reproduce what in fact was drawn during the hearing, and the reproduction of that copy is what I passed out today as Staff Exhibit No. 7.

Now perhaps the parties would not want to -- I don't know if there is a problem with the parties agreeing to the drawing of lines now, or perhaps we could set a date such as a week from now for the parties to respond as to whether or not they have any problems with it.

MR. EDGAR: I would prefer to do that. I haven't reviewed it. I would ask one question. There is a little legend up in the top left-hand corner which says "approximate distances." Dr. Brabb testified that that included a mathematical absurdity. My question is: Is the absurdity still present?

MR. SWANSON: I believe so.

MR. EDGAR: That is as per the original?

MR. SWANSON: Yes. The only thing that could be slightly different is in the redrawing of lines. There was a fair amount of drawing of lines on the easel, I guess, during the proceeding, and they have

tried to reproduce those lines as accurately as possible.

My concern is that someone might try to take measurements that were not testified to during the hearing, and if there is a slight difference in the lines, that could result in perhaps a different number. So I guess what I would propose is that we set a date, perhaps the time the transcript corrections are due, to indicate whether or not the parties have any objections to the form of this exhibit.

JUDGE GROSSMAN: Do all parties agree?

MR. CADY: Yes, sir.

MR. EDGAR: Yes.

JUDGE GROSSMAN: Okay. Fine. That is what we will do, then.

MR. SWANSON: And then of course the Staff has I believe two other exhibits that we still have to furnish copies of: the photographs of the Exhibit No. 5 series; and reproductions of the colored plates, plates 1 through 11 of Figure 13 of the USGS input into the Staff's Safety Evaluation of May 1980 that we have yet to reproduce. We will do so upon returning.

JUDGE GROSSMAN: Okay. My recollection is we admitted those subject to your producing the requisite copies.

MR. SWANSON: That is correct.

JUDGE GROSSMAN: Are there any other problems with regard to exhibits, first?

MR. EDGAR: Yes. Two housekeeping items. I would like to make an offer of two exhibits which our review of the transcripts indicated we hadn't offered. One is Exhibit No. 42, which is Dr. Kovatch's chart illustrating velocity gradients of the Imperial Valley. The second is Exhibit No. 43, which is a California Division of Mines and Geology memorandum which reflects a trip report of October '77 to T-1. Incidentally, the California Division of Mines and Geology Report of Geology is attached to Staff Exhibit No. 1-A, which is the original SER.

JUDGE GROSSMAN: Mr. Cady?

MR. CADY: Intervenor has no objection to the introduction of those exhibits.

MR. SWANSON: No objection.

JUDGE GROSSMAN: My recollection on Exhibit No. 43 was that the only foundation laid was a somewhat skeptical one with regard to that California report. Isn't that basically correct, that Dr. Brabb seemed to feel that the report was of almost no value?

MR. EDGAR: Well, no.

JUDGE GROSSMAN: Or of less than no value?

MR. EDGAR: I wouldn't leap to that conclusion.

It depends upon the purpose for which one uses the report. Dr. Brabb expressed some skepticism about the people writing the report, I believe. I don't want to go into that and characterize it, but it is there.

Another question is the statement was made in testimony that there was a concensus. Everybody in the trenches agreed that there was an offset of the A-2, and this if it is admitted, if nothing else than for the purpose of the fact that the statement was made that this memorandum along with Dr. Jackson's clearly indicates the opposite.

JUDGE GROSSMAN: Well, since there is no objection, we will admit both exhibits.

(The documents referred to, previously marked as Licensee Exhibit Nos. 42 and 43 for identification, were received in evidence.)

MR. EDGAR: I had another question for Judge Grossman. Do you have a preference or a convention for forms of citations to trial records? Some Boards will say they want it Licensee's Exhibit X, or the witness's name, but do you have a preference as to how you would like to see that in the findings?

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JUDGE GROSSMAN: I can't focus right now on the alternatives. As long as they are descriptive, I don't hold you to any particular form, as long as they identify what you are referring to.

MR. CADY: I believe we still have open the question of Glenn Barlow's testimony. Is the Board going to make a ruling on this at this time? Or is that going to come at a later date?

JUDGE GROSSMAN: I believe we have made our ruling as to this hearing, and we indicated that we would reconsider after the hearing, but I didn't mean at this time. I meant when we are reviewing the briefs or the proposed findings, so that our ruling stands. The testimony is not admitted at this time.

MR. CADY: Is that not admitted as an expert? Is there a possibility it could be admitted on less than expert reliability?

JUDGE GROSSMAN: As I understand it, there may be some factual statements in there that might be admitted. Would you care to respond to that, Mr. Swanson? Or Mr. Edgar, first?

MR. EDGAR: Well, I don't see a distinction conceptually, if it's in the record and admitted, it's there for whatever it's worth.

Either way, it seems to me there is very little

difference. If the Board does not consider Mr. Barlow to be an expert and has excluded the testimony on those grounds, at least for the time being, I don't see how the admission of that on the grounds of some -- on the theory that it is simply a statement of fact is proper.

It seems to me there is some inconsistency, that it's almost mutually exclusive, so that our inclination would be that if the Board let it in, we would be prepared to address it.

I mean the record is there. We have raised the objection, but it would quite frankly not give us pains if the Board admitted it as fact.

JUDGE GROSSMAN: Okay. We certainly don't mean to imply that we would admit any of his opinion as fact, that that's his opinion. That's just in effect back-dooring the opinion. But there may be some matters of fact in there that would be very difficult to ignore. But certainly the parties would have an opportunity to respond. We certainly don't contemplate taking unfair advantage of anyone by not permitting substantive response to something that the parties -- the other parties were not aware might be admitted into the record.

Mr. Swanson?

MR. SWANSON: Yes. I do see a distinction, that being that -- although I am not prepared to argue it

in detail at this point. Boards in the past have drawn distinctions between experts and nonexperts, and the liberties that they may take in interpreting other expert opinion, particularly in statements from other experts, interpreting and relying upon, for example, scientific journals and treatises. Experts have been accorded leeway in relying on other experts and interpreting other expert opinion.

Again, because of the very fact that they are accorded the status of experts, they are allowed to in effect take great liberties with hearsay because of the reliance of Boards upon their ability to make informed judgments.

Now Mr. Barlow, of course, went through his testimony line by line, indicating where he formed conclusions and where he in fact relied on others. I think I would have to go back and study that more carefully, but there were many instances where I believe he took liberties which an expert perhaps would be allowed to take liberties, but where in fact a nonexpert would not be allowed to.

I am thinking here in the instances where he relied upon statements, publications and his interpretations of them, of other geologists.

So I think there is a distinction that needs to be kept in mind, and I think really to respond further, I

would have to get into detail and study his testimony again.

JUDGE GROSSMAN: There's no question but that the Board does have those distinctions in mind. Certainly what would be classified as expert testimony, in which an expert can rely on other opinion, would still not be admitted under the Board's current ruling.

MR. SWANSON: I guess my point is, I'm not sure there would be anything left if we started excluding those things.

JUDGE GROSSMAN: I'm not sure there is, either, but we are just dealing with the possibility, and I guess we will just have to deal with it when it arises. If there is anything that the Board sees that is the exception to expert testimony.

Does that take care of all the housekeeping matters?

MR. CADY: Yes, sir, as far as Intervenors are concerned, it's all taken care of. Thank you.

MR. EDGAR: Nothing here, thank you.

JUDGE GROSSMAN: Mr. Swanson?

MR. SWANSON: Nothing.

JUDGE GROSSMAN: Okay. I guess that concludes the hearing, and the record will be open, as we said, until June 26th for the corrections and the other housekeeping chores.

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Thank you very much, gentlemen. The hearing is concluded.

(Whereupon, at 10:50 a.m., the hearing was concluded.)

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This is to certify that the attached proceedings before the

US NUCLEAR REGULATORY COMMISSION .

in the matter of: GENERAL ELECTRIC COMPANY (VALLECITOS NUCLEAR CENTER)

Date of Proceeding: _____

Docket Number: 50-70 SC

Place of Proceeding: SAN FRANCISCO, CALIFORNIA

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Jane W. Beach

Official Reporter (Typed)

Ann Riley

Official Reporter (Signature)